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2nd Interim Research Project Report

Integrated systems for the production of organic greenhouse vegetables

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PREAMBLE

The present Second Interim Research Project Report for 2007/2008 fulfils part of our contractual obligations under the multiparty collaborative research and development agreement on 'Integrated Systems for the Production of Organic Greenhouse Vegetables' signed by the parties on August 25, 2006; September 8, 2006, and September 18, 2006.

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To make the second Interim Research Report easier to reproduce and distribute, the number of color graphs and photos has been kept to a minimum.

The professional and technical contribution of a large number of colleagues within AAFC is acknowledged; more focused credit for their contributions will be given when the results of the research are published.

A. P. Papadopoulos Ph.D., Project Leader

Integrated systems for the production of organic greenhouse vegetables, 2007.

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EXECUTIVE SUMMARY

The main objectives of this project have been to identify commercially available organic media, formulate new organic media, and evaluate both as substrates for the production of greenhouse vegetables, and to develop appropriate nutrient feedings based on commercially available organic liquid fertilizers. In year 2006, the project consolidated the technology packages for composting media and strengthening the reliability and sustainability of such media as the main source of nutrients for long season organic greenhouse vegetable production. This report summarizes findings of similar experiments conducted on Tomato (Lycopersicon esculentum Mill. cv. Macarena) in the Spring, and on Cucumber (Cucumis sativus L. Cultivar 'Addison') in the Fall of 2007. Four liquid feeds: Inorganic (IF1), Agrowchem (OF2), Pure Blend (OF3), and Agrogreen (OF4), and four media: Rockwool (M1), Coir (OM2), Organic mix-1 (OM3: Peat+20 L soy meal) and Organic mix-2 (OM4: Peat+40 L soy meal) were tested.

Crop performance results: Year 2007 results demonstrated again the effectiveness of the in-house formulated organic media (Peat-based+ Soymeal) for organic tomato and cucumber production. The pH and EC values in OM3 and OM4 were between 5.6- 6.1, 2.5-3.0 mS cm^{-1} and 5.8-5.9, 1.8-2.0 mS cm^{-1} for tomato and cucumber, respectively; well within recommended ranges. Furthermore, the nutritional status of plants grown on the organic media OM3 and OM4 resembled close the nutritional status of plants grown on rockwool (M1) and Coco (OM2), as evidenced by leaf tissue analysis results on N, K, Ca, Fe, Cu, Zn and B.

Tomato productivity (Spring 2007): Organic liquid feed × media interactions had a significant impact on marketable yield. The highest seasonal marketable yields achieved with the best combinations or organic liquid feeds with organic media were 23.6 and 21.2 Kg m^{-2} for the combinations OF3 x OM3 and OF2 x OM4, respectively; these yields represented 92.2 and 82.3 of the rockwool (inorganic control), or 95.2 and 85.5 % of the coco peat (organic control, but with an inorganic feed) marketable yields; the best marketable yield achieved this year with organic means (i.e. 92.2 of the rockwool control) represents a significant improvement over the corresponding figure in 2006 (i.e. only 75%). Also, in terms of early marketable yield, there was hardly any difference between several organic methods (e.g. OF2 ×OM4, OF3 × OM3 and OF4 × OM4) and the rockwool control (10.4, 11.0, 10.5, and 11.7 Kg m^{-2}, respectively).

Cucumber productivity (Fall 2007): Organic liquid feed × media interactions had a significant impact on marketable yield. The highest seasonal marketable yields achieved with the best combinations or organic liquid feeds with organic media were 22.1 and 20.2 cucumbers m^{-2} for the combinations OF3 × OM3 and OF2 × OM3, respectively; these yields represented 80.1 and 72.8 of the rockwool (inorganic control), or 100 and 90.9 % of the coco peat (organic control, but with an inorganic feed) marketable yields.

Work at PARC (Agassiz): Two trials were also conducted to compare two organic liquid feeds with the standard hydroponic feed and to study the development of biofilms under recirculation conditions. Plants grown in sawdust and fed with organic liquid feeds showed reduced production compared to the standard hydroponic feed. Recirculation reduced yield in both standard and organic treatments, but had a greater effect in the organic treatments. Biofilm development was observed in irrigation lines in all treatments in both trials. Chlorine dioxide significantly reduced the build-up of biofilm in irrigation lines of organic treatments and it was effective in improving dripper volumes with organic feeds. Organic feed Technaflora combined with 20% compost in the sawdust bag resulted in the best post-harvest quality in greenhouse tomatoes

Economic Analysis: An economic analysis on the production of organic greenhouse tomatoes has been included.

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Introduction

Given the past growth of the greenhouse industry and the anticipated new growth of the sector in the next few years, the search for new greenhouse technologies is a high priority for growers who hope to be able to diversify their operations in the face of increasing difficulties in the marketing of the common greenhouse vegetables. At the same time, the market share of organic produce is significant and keeps on growing. The development of methods for the production of organic greenhouse crops has taken a new urgency in the minds of many growers.

The main objectives of this project have been to identify commercially available organic media, formulate new organic media, and evaluate both as substrates for the production of greenhouse vegetables, and to develop appropriate nutrient feedings based on commercially available organic liquid fertilizers. Ultimately, the goal is to develop complete (integrated) methods for the organic production of vegetables in greenhouses, to assess the commercial feasibility of organically grown greenhouse vegetables and to provide appropriate detailed recommendations to the greenhouse industry. In year 2006, the project consolidated the technology packages for composting media and strengthened the reliability and sustainability of those media as the main source of nutrients for long season organic greenhouse vegetable production.

To achieve the goals of this project and further to confirm the results of the 2006 experimental findings, large replicated experiments were conducted during 2007 to compare the growth and productivity of tomato and cucumber on organic media of varying composition, and with the use of commercially available liquid organic fertilizers. This report summarizes the findings of experiments conducted during Spring of 2007 on tomato and Fall 2007 on cucumber.

PART A. Research Work at GPCRC (Harrow)

1. Spring 2007 Tomato crop

1.2. Materials and methods

1.2.1. General crop information

Seed of Tomato (Lycopersicon esculentum Mill. cultivar Macarena) was sown on Nov. 24, 2006 directly in kiemplug/288 cell trays. On December 5th the seedlings were transplanted in 4 inch peat pots filled with an organic medium (OM3) as well as in 2.6×3.9×3.9" (7.5x10x10cm^3) rockwool blocks. For the first week, seedlings were watered every other day with tap water. Transplants in rockwool blocks were fed with a standard transplant nutrition solution, whereas, transplants in fibre pots were fed with organic liquid feed (Pure Blend diluted 400 times with tap water). Final planting in the greenhouse (245 m^{-2}) was on Jan. 5, 2007(Figure 1). Plants were fertigated using 4 L h^{-1} emitters. The frequency and amount of irrigation was adjusted based on plant growth and season. Fertigation was controlled by time clocks. The pH, EC, and volume of fertigation and leachate solution were measured and recorded on a daily basis. Cultural practices resembled those of commercial production.

Greenhouse environment was controlled with an Argus Control ® System. Greenhouse day/night temperature was set at 20/17^{o}C and ventilation temperature was set at 2^{o}C above the heating temperature set point. Relative humidity was maintained at 60±10% using ventilation and misting. Greenhouse climate conditions (temperature and relative humidity) throughout the growing season are presented in Figure 2.

Fruit harvest was from March15 to August 3, 2007. The crop was terminated on August 6, 2007.

1.2.2. Organic media and organic liquid feeds

Four media were used: Rockwool (M1), coir (OM2), organic mix-1 (OM3: Peat+20 L soy meal) and organic mix-2 (OM4: Peat+40 L soy meal). Organic mix-1 (OM3) was prepared by blending 0.66 m^3 (6 bags) of peat moss with 0.33 m^3, (3 bags) of vermiculite, 3 kg of limestone (pulverized FF calcitic 40% Ca), 3 kg of ground limestone (dolomitic, 21% Ca + 12% Mg), 600 grams of potassium sulphate, and 20 L of soymeal. OM4 was the same as OM3 except for the soymeal content, which was doubled to 40 L (Table 1)

Four liquid feeds were tested. One of the organic liquid feeds was Agrowchem (OF2), which was a blend of Nitro Organo (5-0-0), Liquid Bone Meal (0-2-0), Spurt (2-0-1), Agro Kelp (0-0-5) and Bat Guano (0-4-0) (all products of Agrowchem Inc., Kingston, Ontario). Nitro Organo is manufactured as a liquid organic nitrogen source. Liquid Bone Meal is derived from bone meal and organic acid. Spurt is derived from sea weed extract (kelp) and amino acids (protein hydrolysate and potassium hydroxide). Agro Kelp contains a combination of seaweed extracts (kelp). Bat Guano contains liquid form of phosphorus derived from fruit eating bats. The second organic liquid feed used was Pure Blend (OF3;3-1.5-4) (American Agritech, Tempo, AZ, USA), which is derived from fish meal, composted sea bird guano, sea kelp, rock phosphate, potassium carbonate, magnesium carbonate, calcium carbonate, and other ingredients (raw sugarcane, humic acid, silica clay extract and amino acids). The third organic liquid feed used was Agrogreen (LF3) (3.7-0.71-1.3) (Agrogreen Canada Inc., Fonthill, Ontario), which is derived from natural botanical extracts (Table 2). The first one was an inorganic control (IF1), i.e. a standard nutrient solution for a rockwool-grown spring Tomato crop (Table 3).

1.2.3. Experimental design

The experiment was laid out as a split-plot design. The main plot consisted of 4 liquid feeds: Inorganic (IF1), Agrowchem (OF2), Pure Blend (OF3), and Agrogreen (OF4); and, each main plot was split into 4 sub-plots to accommodate 4 media: Rockwool (M1), coir (OM2), organic mix-1 (OM3) and organic mix-2 (OM4). There were 16 treatment combinations replicated four times; this comprised a 64-plot experiment. Each plot consisted of 5 plants grown individually in 20 L plastic pots for the treatments OM3 and OM4 or on two slabs for M1 and OM2.

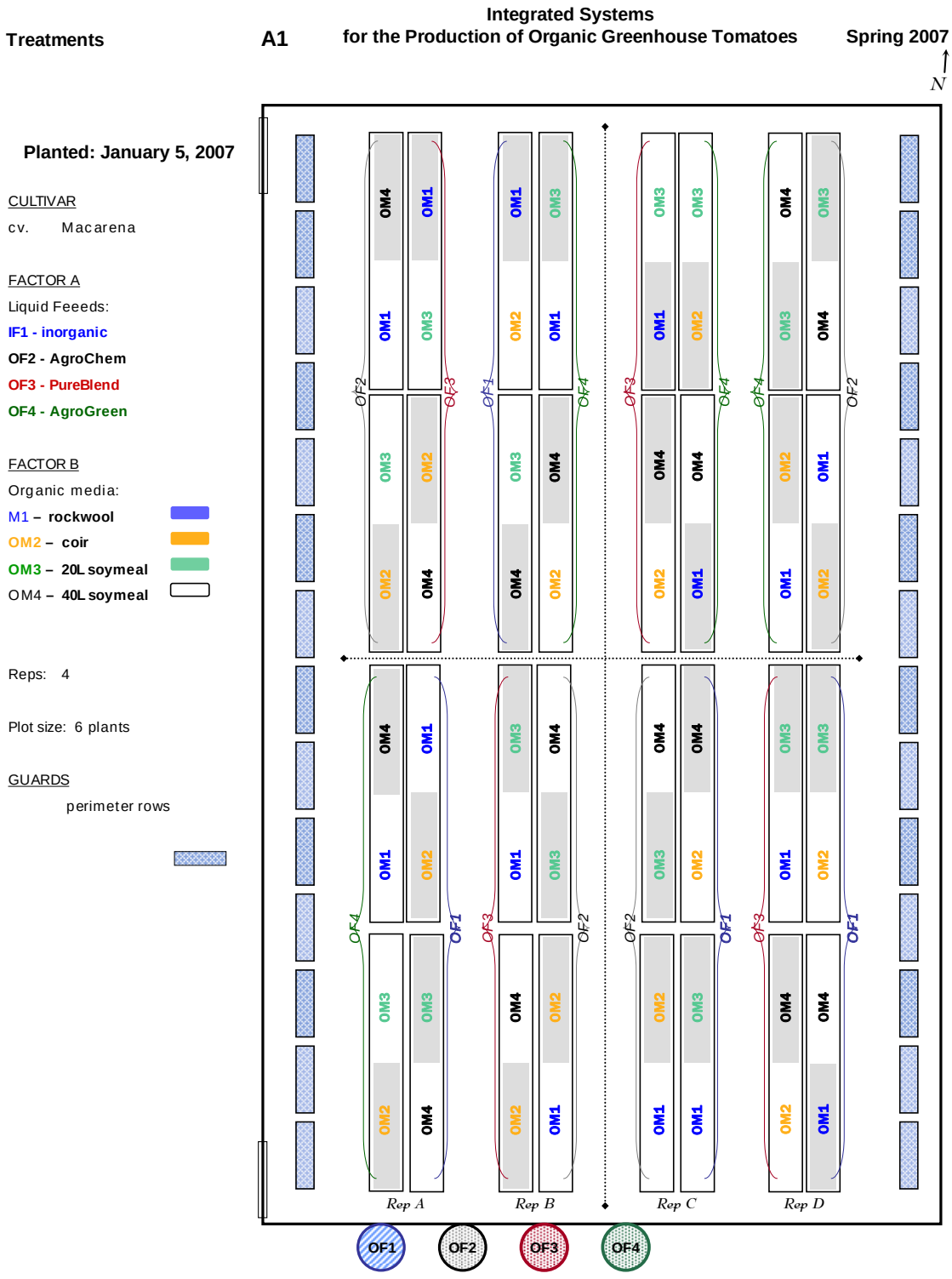


Figure 1. Split plot experimental design of organic tomato production. Spring 2007.

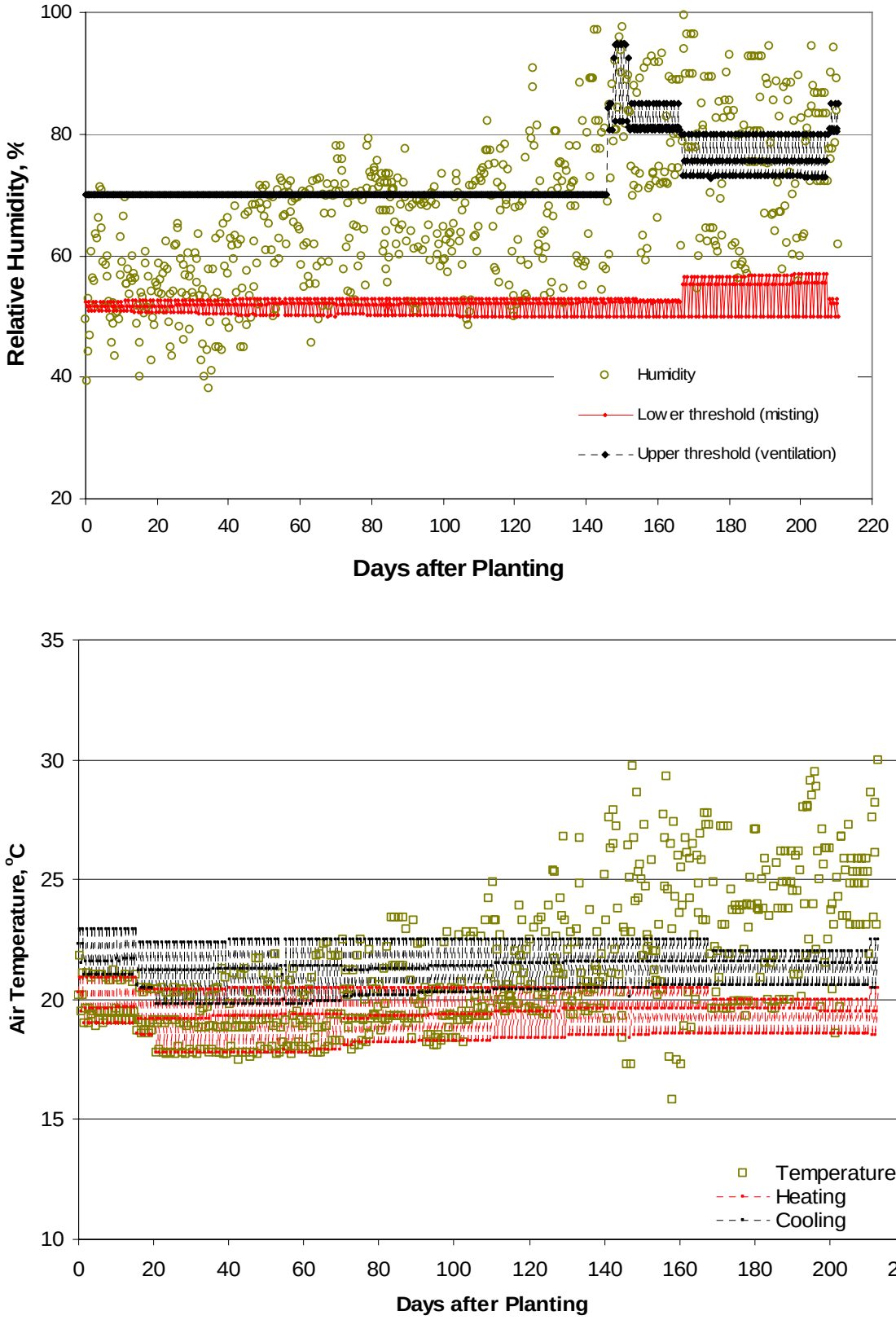


Figure 2. Temperature and relative humidity conditions in the greenhouse, Spring 2007.

Table 1. Media used as substrates in the Tomato Spring 2007 experiment.

Substrates	Code	Ingredients
Rockwool	M1	
Coco coir	OM2	
Organic mix-1	OM3	6 bags (0.11 cubic metres, each) of peat moss 3 bags (0.11 cubic metres, each) of vermiculite 3 kg of limestone (pulverized FF calcitic 40% Ca) 3 kg of ground limestone (dolomitic, 21% Ca + 12% Mg) 600 grams of potassium sulphate 20 L of Soymeal
Organic mix-2	OM4	6 bags (0.11 cubic metres, each) of peat moss 3 bags (0.11 cubic metres, each) of vermiculite 3 kg of limestone (pulverized FF calcitic 40% Ca) 3 kg of ground limestone (dolomitic, 21% Ca + 12% Mg) 600 grams of potassium sulphate 40 L of Soymeal

Table 2. Organic liquid feeds, Spring 2007, Tomato experiment.

Liquid feed treatment	Supplier	Fertilizer	(N P K)	Dilution
*IF1 (Inorganic)	Standard Tomato fertigation schedule for rockwool grown crops			
OF2	Agrowchem Inc.	Nitro Organo	5-0-0	1:800
		Liquid bone meal	0-2-0	1:400
		Spurt	2-0-1	1:400
		Agrokelp	0-0-5	1:400
		Bat Guano**	0-4-0	1:400
OF3	American Agritech	Pure Blend	3-1.5-4	1:300
OF4	Agrogreen Canada Inc.	Agrogreen	3.7-0.71-1.3	1:300

*IF 1 (Inorganic) - Standard Spring Tomato crop fertigation schedule for rockwool grown crops

** Liquid feed Bat Guano added from June 1, 2007.

Table 3. Standard nutrient solution for Tomato spring crop (Papadopoulos, 1994).

Weeks from Planting	$N\text{-}N0_3$	$N\text{-}NH_4$	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B	Mo
Wetting of Slabs	189	13	46	250	247	50	0.7	0.2	0.04	0.01	0.13	0
1	225	13	46	370	247	36	0.7	0.2	0.04	0.01	0.13	0.006
2-5	272	16	55	444	296	70	0.7	0.2	0.04	0.01	0.13	0.006
6	238	16	55	422	247	70	0.7	0.2	0.04	0.01	0.13	0.006
7-9	230	18	50	422	217	75	0.7	0.2	0.04	0.01	0.13	0.006
10-11	208	17	46	367	190	75	0.7	0.2	0.04	0.01	0.13	0.006
12-15	217	17	46	390	190	75	0.7	0.2	0.04	0.01	0.13	0.006
16-17	250	16	46	390	171	75	0.7	0.2	0.04	0.01	0.13	0.006
18-20	290	16	46	350	171	75	0.7	0.2	0.04	0.01	0.13	0.006
21-23	278	16	46	312	171	75	0.7	0.2	0.04	0.01	0.13	0.006
24-25	240	16	46	272	171	36	0.7	0.2	0.04	0.01	0.13	0.006
26	240	16	46	232	171	36	0.7	0.2	0.04	0.01	0.13	0.006
27	237	12	46	212	171	36	0.7	0.2	0.04	0.01	0.13	0.006
28-End	218	8	46	212	152	36	0.7	0.2	0.04	0.01	0.13	0.006

1.2.4. Liquid feed and media nutrient content, pH and EC

Media samples were collected on January 05, 2007 (at planting time), on April 4, 2007 (90 DAP) and July 25, 2007 (202 DAP) and submitted to Stratford Agri Analysis to monitor the nutritional status.

1.2.5. Nutrient solution and leachate measurement

Nutrient solution and leachate volume, EC and pH were recorded daily, for each of the liquid feed treatments.

1.2.6. Leaf tissue analysis

Leaf samples were collected on March 16, (71 DAP) and July 18, (195 DAP) and submitted to Stratford Agri Analysis to monitor the nutritional status of the plants.

1.2.7. Growth measurements

Plant height, main stem leaf number, stem diameter, leaf area of the 5^{th} and 10^{th} leaf from the top and chlorophyll readings using a SPAD 502 chlorophyll meter (Minolta, Osaka, Japan) for the same leaves of each plant were measured and recorded on Feb 2, 2007 (30 DAP); Mar 14 (70 DAP) and July 04 (180 DAP).

1.2.8. Days-to-flower

The rate of plant development was estimated by the number of days from transplant to the appearance of the first flower. Days-to-flower data were collected on the first five clusters of all plants.

1.2.9. Fruit yield

Fruit from each plot (five plants /plot) was harvested twice a week and graded individually to marketable: grade #1 (extra large, large, small and commercial), grade #2, and unmarketable (BER, Cat Faced, Cracked, Hollow and other) according to commercial grading standards (Ontario Ministry of Agriculture, Food and Rural Affairs, Regulation 378/90). Thirty eight harvests were performed from March 15 to August 03, 2007.

1.2.10. Fruit quality

Tomato fruit quality parameters were assessed during the end-season crop stage (August 07, 2007). Fresh fruit harvested from organic liquid feed and media plots was compared with conventionally grown tomatoes (i.e.-on rockwool with inorganic fertilizer). A team of eight taste panellists evaluated appearance (colour, size, shape, freedom from physiological disorders and decay), firmness, texture, flavour, fruitiness, shape, cracking, gold specks, and puffiness using a 1-10 scale, 10 being the best. On completion of evaluation, panellists indicated their overall preference for organic or inorganic fruit, in a blind test.

1.2.11. Fruit soluble solids (TSS), pH and fruit firmness

At 159 days after planting, various fruit quality attributes, namely: fruit soluble solids content, pH, were determined. The homogenized fruit juice was used to determine pH, (Hanna pHep®4 meters;Hanna Instruments, Laval, Quebec, Canada), and its soluble solids content was determined by a portable digital refractometer (model PR-101, Atago Co., Tokyo, Japan).Fruit firmness was measured at 159 days after planting with an Instron Model 4411 Texture Machine (Instron Canada, Burlington, ON, Canada) using a constant area compression test of a pericarp disk (10 mm in diameter) sampled on the equator of tomato fruit at the pink stage.

1.2.12. Statistical analysis

The data were analysed using the General Linear Model (GLM) (SAS Institute, Cary, NC, USA). Significance of main factors and interactions were tested with an F-test at the 0.95 level of confidence.

1.3. Results and discussion

1.3.1. Substrate nutrient content, pH and EC

The nutrient content, pH and EC of the media at planting time and of liquid feed and media at mid- and late-season are presented in Tables 4.1, 4.2 and 4.3.

The pH values in OM3 (Peat+20 L soymeal) and OM4 (Peat + 40 L soymeal) were between 5.6- 6.1, well within recommended ranges for greenhouse tomato production at all sampling times (Tables 4.1, 4.2 and 4.3). However, at mid-season, the organic control OM2 (coir) had a high pH value of 6.8 (Table 4.2) which is outside the recommended pH range (5.5-6.5). In general our in-house blends of organic media had pH values within the acceptable limits for organic greenhouse tomato production throughout the growing season. Electrical conductivity (EC) of the organic media OM3 and OM4 at planting was within the accepted range (2.5- 3.0; Table 4.1). Organic medium OM3 had EC values (2.2- 2.9) close to the recommended level for the entire cropping season, whereas, OM4 had an ideal EC value of 2.2 at planting time (Table 4.1) but, at mid- and late-season the EC values were slightly higher (3.5 - 3.9; Tables 4.2 and 4.3).

At planting, all the N content in OM3 was in the nitrate (NO_3^{-3}) form; while, OM4 had equal amounts of NO_3^- and ammonia ($NH4^+$) Nitrogen (Table 4.1). At mid- and late season, sampling of OM3 had an optimum level of N. At mid-season OM4 had an optimum level of N (Table 4.2), but in late season N was high (Table 4.3). Our in-house organic media (OM3 and OM4) and our composting process achieved rich supplies of nitrogen for a long season organic tomato crop.

The phosphorus level in OM3 and OM4 at planting time was very high (Table 4.1). At mid- and late season sampling time (Table 4.2 and 4.3) the P level was in proportion to the rate of soymeal incorporated in the media. Even though P did not appear to be in deficiency, extensive P deficiency symptoms appeared from mid-season onwards. Organic medium OM3 at planting had a high level of Potassium (Table 4.1), but later in the season the K level was just adequate (Table 4.2 and 4.3). However, OM4 had optimum level of K for the entire growing season. Ca, Mg and Fe levels in OM3 and OM4 were always available at optimal levels at all dates.

Table 4.1. Organic media nutrient content (ppm), pH and EC ($mScm^{-1}$) – Planting time, January 05, 2007, Tomato experiment.

Organic Media[1]	$N\text{-}NO_3$	$N\text{-}NH_4$	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B	Mo	Na	pH	EC
OM 3	112±2.4[2]	4±0.4	46±1.3	247±3.5	115±4.2	113±2.6	1.8±0.2	0.4±0.0	0.02±0.0	0.03±0.0	0.11±0.0	0.01±0.0	30±0.8	5.8±0.0	2.2±0.04
OM 4	130±3.2	143±4.8	84±1.3	283±3.6	89±2.3	87±1.8	3.3±0.4	0.5±0.0	0.03±0.0	0.05±0.0	0.23±0.0	0.01±0.0	30±0.5	5.6±0.0	2.6±0.05

[1] OM3= Organic mix-1(20 L Soymeal added), OM4= Organic mix-2 (40 L Soymeal added)
[2] Data presented are the means of three observations ± SE.

Table 4.2. Liquid feed and organic media treatment nutrient content (ppm), pH and EC (mS cm^{-1}) Mid-season analysis – April 04, 2007, Tomato experiment.

Treatments	$N\text{-}NO_3$	$N\text{-}NH_4$	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B	Mo	Na	pH	EC
Liquid Feed[1]															
IF 1	207	3	43 ab[3]	315	300 a	272	0.7	0.23 b	0.08 a	0.18	0.22	0.04	185	6.0	4.4 a
OF 2	59	7	18 c	67	58 c	40	1.4	0.16 b	0.05 cb	0.07	0.10	0.02	222	6.7	1.7 c
OF 3	156	4	38 b	133	153 b	143	1.3	0.25 b	0.02 c	0.22	0.41	0.02	90	5.8	2.5 b
OF 4	59	6	54 a	64	97 c	83	1.4	0.38 a	0.06 ab	0.91	0.11	0.02	134	6.1	1.7 c
Media[2]															
M 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OM 2	49 c	1 c	10 c	77 c	53 c	39 c	0.4 c	0.05 c	0.08 a	0.30 b	0.20 b	0.01 b	100 b	6.8 a	1.1 c
OM 3	112 b	5 b	32 b	135 b	175 b	160 b	1.1 b	0.20 b	0.04 b	0.24 b	0.16 b	0.03 a	192 a	6.1 b	2.9 b
OM 4	200 a	8 a	73 a	222 a	229 a	205 a	2.2 a	0.51 a	0.05 b	0.49 a	0.27 a	0.04 a	181 a	5.6 c	3.5 a
F-test[4]															
Liquid Feed (LF)	0.999	1.000	**	0.999	**	0.996	0.999	**	**	1.000	0.999	1.000	0.996	1.000	**
Media (M)	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
LF x M	**	**	**	0.3007	0.0324	**	0.3564	*	**	0.7591	0.400	**	**	**	*

1 IF1= Inorganic, OF2 = Agrowchem, OF3 =Pure Blend and OF4 = Agrogreen
2 M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)
3 Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test
4 *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

Table 4.3. Liquid feed and organic media treatment nutrient content (ppm), pH and EC ($mScm^{-1}$) Late-season analysis – July 25, 2007, Tomato experiment.

Treatments	$N\text{-}NO_3$	$N\text{-}NH_4$	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B	Mo	Na	pH	EC
Liquid Feed[1]															
IF 1	551 a[3]	7 b	108 a	434 a	534 a	457 a	3	0.70 a	0.04 bc	0.27 b	0.49 b	0.05 a	216 b	5.1 c	6.5 a
OF 2	42 c	13 a	29 b	57 c	57 c	30 c	2	0.17 b	0.07 ab	0.06 b	0.14 b	0.04 ab	325 a	7.6 a	1.8 c
OF 3	255 b	5 c	38 b	123 b	221 b	180 b	2	0.33 b	0.02 c	0.13 b	1.25 a	0.03 ab	88 c	5.1 c	3.1 b
OF 4	84 c	6 cb	123 a	43 c	79 c	64 c	3	0.71 a	0.10 a	1.74 a	0.11 c	0.02 b	215 b	5.8 b	1.7 c
Media[2]															
M 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OM 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OM 3	177 b	7	63 b	142 b	180 b	141 b	2 b	0.38 b	0.06	0.63	0.45 b	0.03	193.0	6.0	2.7
OM 4	289 a	9	86 a	187 a	229 a	225 a	3 a	0.56 a	0.05	0.47	0.56 a	0.03	229.2	5.8	3.9
F-test[4]															
Liquid Feed (LF)	**	**	**	**	**	**	0.5070	**	**	**	**	*	**	**	**
Media (M)	**	0.0774	**	**	**	**	*	**	0.4514	0.3049	**	0.7446	*	*	**
LF x M	**	0.0911	**	*	**	**	*	**	0.3306	0.1533	0.1892	0.7505	0.2849	0.7653	**

1 IF1= Inorganic, OF2 = Agrowchem, OF3 =Pure Blend and OF4 = Agrogreen
2 M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)
3 Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test
4 *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

1.3.2. Fertigation and leachate solution pH and EC

The fertigation and leachate solution pH and EC values over the entire cropping season, as affected by the organic feed treatments, are depicted on Figure 3 and 4, by week.

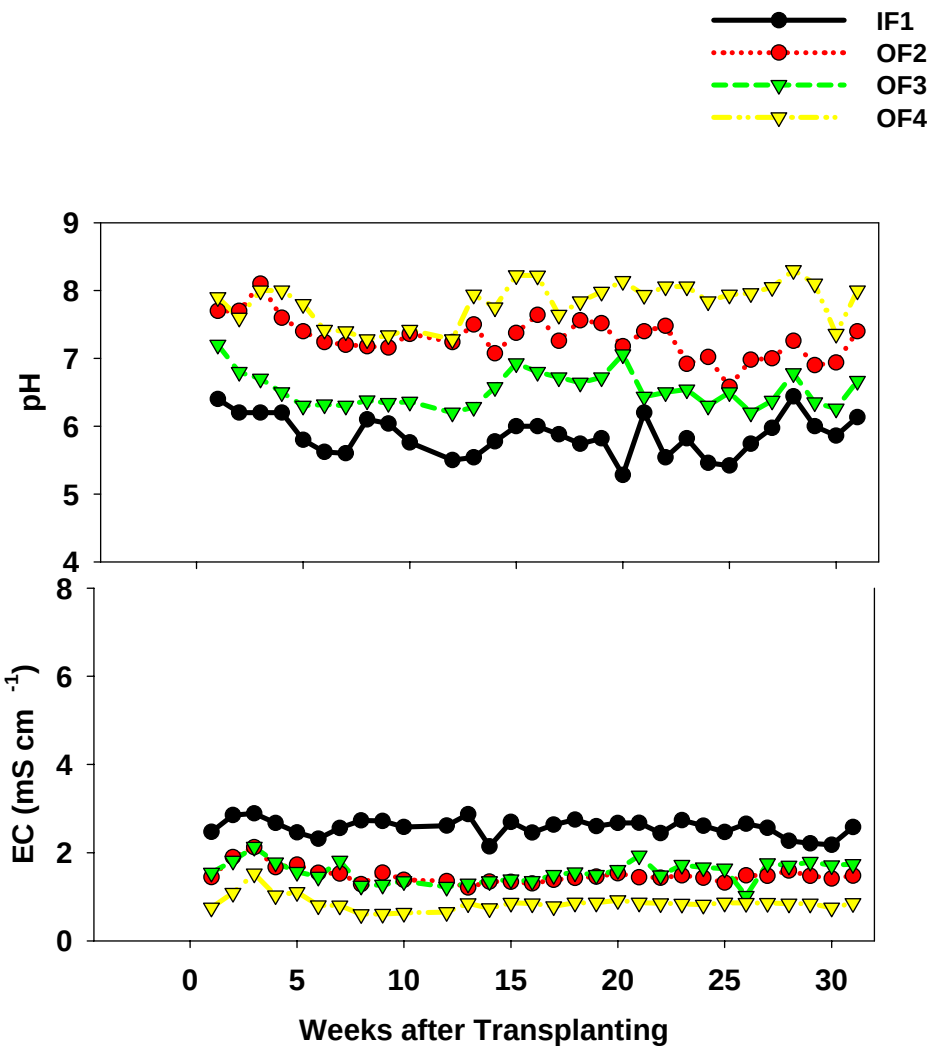


Figure 3. Fertigation solution pH and EC of the four liquid feed treatments during the Spring 2007 Tomato crop. (January 05 - August 03, 2007).

The seasonal weekly fertigation pH values for all organic liquid feeds OF2, OF3 and OF4 were higher (6.5-7.8) compared to the inorganic control IF1 (5.3-6.4). All the organic liquid feeds had low EC values compared to the inorganic liquid feed (IF1) throughout the cropping season (Figure 3).

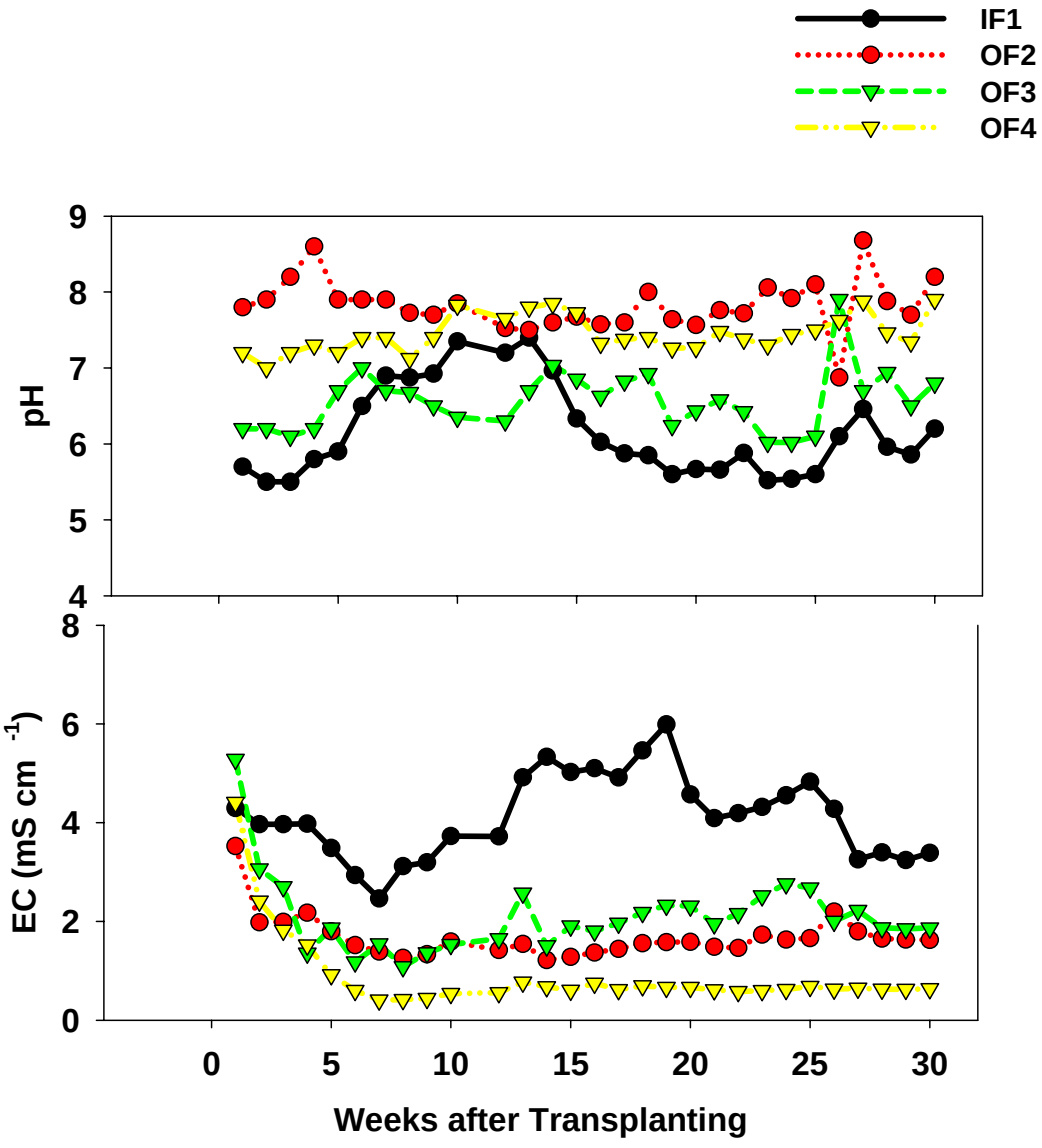


Figure 4. Leachate pH and EC as affected by the liquid feed treatments during the Spring 2007 Tomato crop. (January 05- August 03, 2007).

Throughout the experiment, the leachate pH seasonal mean values were higher (6.2-7.8) than normal (5.5-6.5) for tomato production. Media receiving OF2 and OF4 had high pH values (7.5-7.8) throughout the season. However, media receiving OF3 followed closely the trend of leachate pH of the inorganic control IF1 (Figure 4).

The EC values of leachate solutions for the media receiving organic liquid feeds OF2, OF3 and OF4 were high at the beginning of the season (Figure 4), but later in the season they decreased to 1-2.1 mS/cm, which was closer to the optimal range (2.5) for tomato greenhouse production. The inorganic liquid feed (IF1) had high EC values (4.1-5.9). In general all the three organic liquid feeds tested in this experiment showed promise for organic greenhouse vegetable production.

1.3.3. Nutritional status

The nutritional status of plants as affected by the liquid feed treatments (IF1, OF2, OF3 and OF4) and the media treatments (M1, OM2, OM3 and OM4) at mid-(71 DAP) and late-season (195 DAP) is shown in Tables 5 and 6.

At mid-season (71 DAP), the N concentration in leaf tissue was at deficiency level when the OF2 organic liquid feed was used in combination with the M1 and OM2 media (Table 5); whereas, with the OM3 and OM4 media, the N level was within the recommended range (4.0-5.5%; Table 5). Also, media receiving OF2 had low level of P and showed severe incidence of phosphorus deficiency symptoms at mid-season. The media receiving the organic liquid feeds OF3 and OF4 had all the nutrients (except K) at nearly optimal level. All the liquid feed and media treatments showed low level of micronutrient elements (Zn and B; Table 5). Liquid feed OF3 and IF1 application resulted in most nutrients being in sufficient supply.

Table 6 lists the liquid feed and media treatment means and the analysis of variance (ANOVA) results on the nutrient content of plant tissue, at late-season (195 DAP). Liquid feeds had significant effects on the nutritional content of leaf tissue. Plants receiving liquid feed OF4 had generally lower N concentration compared to OF2, OF3 and IF1. However, the levels were within the recommended range (4.0-5.5%; Table 6). Phosphorus level with liquid feed OF4 was high, but it was just sufficient with the rest of the liquid feeds (OF3, OF2 and

IF1). Tissue level of K was low in liquid feeds OF2 and OF3, compared to IF1. Calcium in tissue was sufficient with OF3, OF2 and IF1. Micronutrient levels in all liquid feeds were within the level of sufficiency to high range, except for Boron.

At 195 DAP, our in-house blend media OM3 and OM4 closely resembled the conventional rockwool (M1) and Coco (OM2) in terms of tissue N, K, Ca, Fe, Cu, Zn and B content (Table 6). However, significant differences in Phosphorus concentration were observed due to the media treatments. In general, plants grown in media OM3, OM4 and M1 had marginally lower micronutrient content than plants grown on OM2.

Table 5. Nutrient content of Tomato leaves as affected by liquid feed and media treatments, March 16, 2007 (at mid-season).

Nutrient Content		Liquid feeds[1]															
(Adequancy range[3])		IF1				OF2				OF3				OF4			
		Media[2]															
		OM1	OM2	OM3	OM4	OM1	OM2	OM3	OM4	OM1	OM2	OM3	OM4	OM1	OM2	OM3	OM4
N (4.0-5.5)	%	5.64^{S}	5.41^{S}	5.78^{S}	5.85^{S}	**3.00^{D}**	**3.50^{D}**	4.77^{S}	5.37^{S}	5.42^{S}	5.28^{S}	5.88^{S}	5.60^{S}	5.69^{S}	6.29^{H}	5.51^{S}	5.39^{S}
P (0.3-0.65)	%	0.53^{S}	0.56^{S}	0.57^{S}	0.67^{S}	**0.09^{D}**	**0.11^{D}**	**0.18^{D}**	**0.28^{D}**	0.61^{S}	0.60^{S}	0.55^{S}	0.62^{S}	0.91^{H}	0.80^{H}	0.72^{H}	0.69^{H}
K (3.5-5.0)	%	3.98^{S}	4.09^{S}	3.98^{S}	3.88^{S}	**3.21^{D}**	**3.35^{D}**	3.50^{L}	3.42^{L}	**1.88^{D}**	**2.25^{D}**	**2.65^{D}**	**3.34^{L}**	**2.74^{D}**	**3.01^{D}**	**2.64^{D}**	**2.66^{D}**
Ca (1.6-3.2)	%	2.53^{S}	3.15^{S}	2.70^{S}	2.70^{S}	**1.94^{L}**	**1.86^{L}**	**1.88^{L}**	**1.90^{L}**	3.32^{S}	3.67^{H}	2.46^{S}	2.17^{S}	2.15^{S}	2.01^{S}	1.78^{L}	1.69^{L}
Mg (0.36-0.5)	%	0.80^{H}	0.84^{H}	0.83^{H}	0.73^{H}	0.46^{S}	0.52^{S}	0.65^{H}	0.71^{H}	0.88^{H}	0.98^{H}	0.86^{H}	0.69^{H}	0.73^{H}	0.74^{H}	0.69^{H}	0.74^{H}
Fe (85-100)	ppm	103^{H}	092^{S}	84^{L}	101^{S}	92^{S}	87^{S}	84^{L}	102^{S}	89^{S}	115^{H}	114^{H}	124^{H}	**55^{D}**	**56^{D}**	99^{S}	111^{H}
Mn (55-165)	ppm	87^{L}	113^{S}	96^{S}	155^{S}	**37^{D}**	**59^{L}**	120^{S}	140^{S}	62^{L}	80^{S}	92^{S}	190^{H}	243^{H}	260^{H}	154^{S}	146^{S}
Cu (5-10)	ppm	20^{H}	22^{H}	17^{H}	19^{H}	9^{S}	9^{S}	12^{H}	11^{H}	18^{H}	21^{H}	12^{H}	13^{H}	21^{H}	18^{H}	18^{H}	18^{H}
Zn (30-50)	ppm	**17^{D}**	**22^{D}**	**25^{D}**	**24^{D}**	**14^{D}**	**18^{D}**	**19^{D}**	**29^{D}**	**22^{D}**	**23^{D}**	**28^{D}**	**30^{L}**	51^{S}	52^{S}	47^{S}	58^{H}
B (55-75)	ppm	**36^{D}**	**44^{D}**	**35^{D}**	**37^{D}**	**31^{D}**	**38^{D}**	**48^{D}**	61^{S}	67^{S}	65^{S}	**52^{L}**	**47^{L}**	**17^{D}**	**26^{D}**	**26^{D}**	**35^{D}**

[1] IF1= Inorganic, OF2 = Agrowchem, OF3 =Pure Blend and OF4 = Agrogreen
[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)
[3] Results Key (H= High, S= Sufficient, L= Low and D= Deficient).

Table 6. Nutrient content of Tomato leaves as affected by liquid feed and media treatments, July 18, 2007 (End-Season).

Treatments	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm
Adequancy range	**(4.0-5.5)**	**(0.3-0.7)**	**(3.5-5.0)**	**(1.6-3.2)**	**(0.4-0.5)**	**(85-110)**	**(55-165)**	**(5-10)**	**(30-50)**	**(55-75)**
Liquid Feed[1]										
IF 1	6.21 a[3] (H)[4]	0.61c (S)	3.99a (S)	2.75a (S)	0.62b (H)	116.0(H)	84.3c (S)	13.0ab (H)	27.4c (L)	**41.3c (D)**
OF 2	5.74 b (H)	0.61c (S)	3.05b (L)	2.10b (S)	0.64b (H)	114.1 (H)	111.6b (S)	11.1b (S)	27.1c (L)	50.9b (L)
OF 3	6.15 a (H)	0.66b (S)	3.01b (L)	2.73a (S)	0.92a (H)	122.1 (H)	100.6b (S)	13.5ab (H)	32.3b (S)	61.2a (S)
OF 4	5.16c (S)	0.86a (H)	**2.44c (D)**	1.59c (L)	0.65b (H)	109.5 (H)	351.0a (H)	16.9a (H)	39.6a (S)	**14.9d (D)**
Organic Media[2]										
M 1	5.75 (H)	0.70ab (S)	3.17 (L)	2.34ab (S)	0.66b (H)	114.8 (H)	194.8a (H)	13.2 (H)	29.8b (L)	39.6b (**D)**
OM 2	5.79 (H)	0.73a (H)	3.02 (L)	2.47a (S)	0.69b (H)	113.6 (H)	188.7a (H)	14.1 (H)	32.9a (S)	42.9a (**D)**
OM 3	5.80 (H)	0.68b (S)	3.15 (L)	2.17c (S)	0.75a (H)	113.3 (H)	121.7c (H)	14.5 (H)	32.7a (S)	42.3ab (**D)**
OM 4	5.91 (H)	0.63c (S)	3.16 (L)	2.20bc (S)	0.73a (H)	120.0 (H)	142.3b (H)	12.6 (H)	30.9ab (S)	43.5a (**D)**
F-test[5]										
Liquid Feed (LF)	**<0.0001	**<0.0001	**<0.0001	**<0.0001	**<0.0001	0.0826	**<0.0001	*0.0234	**<0.0001	**<0.0001
Media (M)	0.3495	**<0.0001	0.4067	**0.0004	**<0.0001	0.3475	**<0.0001	0.7233	0.0836	*0.0313
LF x M	*0.0145	0.1341	0.1021	0.0971	**<0.0001	*0.0475	**<0.0001	0.4136	**<0.0001	**<0.0001

1 IF1= Inorganic, OF2 = Agrowchem, OF3 =Pure Blend and OF4 = Agrogreen
2 M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)
3 Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test
4 Results Key in brackets (H= High, S= Sufficient, L= Low and D= Deficient).
5 *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively

1.3.4. Growth measurements

Tables 7, 8 and 9 show averages of plant height, height from the 10th leaf to the top of the plant, leaf number, stem diameter, chlorophyll content, and leaf area at 30, 70, and 180 DAP.

1.3.4.1. Plant height

Analysis of variance for plant height and height from the 10th leaf to the top of the plant showed no significant differences due to liquid feed or media treatments at 30 DAP (Table 7). However, a significant effect of organic media on plant height occurred at 70 DAP with maximal height of 150 and 161 cm for OM3 and OM4, respectively (Table 8). At 180 DAP, plant height showed significant differences due to liquid feed (Table 9); it was the greatest (371 cm) with OF4 and the least with OF2 (264 cm). Although there was no significant difference in plant height due to OM4 and OM3, plants grown on either OM4 or OM3 were taller than those grown on M1 or OM2. At 180 DAP, there was a significant difference (P<0.0076) in stem extension (10th leaf to top of the plant) due to liquid feed; this parameter was maximized with organic liquid feed OF4 (86.7 cm; Table 9).

1.3.4.2. Leaf number

Leaf number below the first cluster, recorded at 30 DAP showed no significant effect due to liquid feed (P=0.7545) or media (P=0.6948) (Table 7). At 30, 70 and 180 DAP, plant leaf number showed significant differences due to liquid feed; it was significantly higher with liquid feeds OF3 and IF1, compared to OF2 and OF4 at all sampling dates (Table 7, 8 and 9). Furthermore, there was a significant effect of media on leaf number at 70 DAP. Organic media OM3 and OM4 resulted in the highest leaf number (17.2 and 17.4 respectively,) which was 1.3 leaves higher than for standard rock wool media (M1).

1.3.4.3. Stem diameter

At 30 and 180 DAP the liquid feed effect on stem diameter was not significant. However, at 70 DAP stem diameter showed significant differences due liquid feed (Table 8); it was greatest (9.7 mm) with OF3 and smallest with OF2 (7.8 mm). Stem diameter recorded at 30, 70, and 180 DAP showed significant differences due to media treatments P<0.001, P=.0234,

and *P*=0.0299, respectively (Table 7, 8 and 9); plants grown in organic media OM3 and OM4 resulted in progressively smaller stem diameter 10.5-11.3 mm, 8.7-9.7 mm and 8.0-8.3 mm for 30, 70 and 180 DAP, respectively.

1.3.4.4. Leaf Chlorophyll

At 30 DAP, liquid feed and media did not significantly affect chlorophyll content (Table 7). However, leaf chlorophyll measurements at 70 DAP showed significant differences due to liquid feed and media treatments. The chlorophyll content was highest with liquid feeds OF3 and OF2 (56.0 and 41.2); but it was greatest (56.3) with organic medium OM3 (Table 8). At 180 DAP, only liquid feed had a significant effect on chlorophyll content, *P*=0.0027; chlorophyll content decreased in the order: OF2 (53.2), OF3 (51.6) and OF4 (47.5) (Table 9).

1.3.4.5. Leaf area 5th, 10th and 15th leaf

Leaf area measurements on 5th leaf at 30 DAP revealed no significant differences due to liquid feed and media treatments; however for the 10th leaf, leaf area measurement showed significant differences due to both liquid feed and media; the maximum leaf area was achieved with liquid feed: IF1 and OF3 (1358 cm^2 and 1289 cm^2); and media OM3 and OM4 (1340 cm^2 and 1281 cm^2), respectively (Table 7). At 70 DAP, leaf area was affected significantly by the media treatments. Plants grown in media OM3 and OM4 resulted in the highest leaf area, ranging over 1159-1169 cm^2, 1406-1695 cm^2, and 1998- 2067 cm^2, for the 5th, 10th and 15th leaf, respectively (Table 8). A similar trend was observed at 180 DAP (Table 9).

Table 7. Plant height, leaf number, stem diameter, chlorophyll content, and leaf area as affected by liquid feed and organic media treatments- Spring 2007, Tomato experiment. (30 DAP).

Treatments	Plant height (cm)	Stem extension 10^{th} Leaf to Top of plant (cm)	Leaf. No (no plant^{-1})	Leaf. No (Up to first cluster)	Stem diameter (mm)
Liquid Feed[1]					
IF 1	122.1 ± 2.3	73.3 ± 1.4	16.7 ± 0.2 a[3]	8.1 ± 0.1	11.3 ± 0.2
OF 2	114.0 ± 2.1	74.9 ± 2.3	15.4 ± 0.3 b	8.1 ± 0.2	9.8 ± 0.3
OF3	126.1 ± 2.9	79.2 ± 1.8	16.6 ± 0.3 a	7.9 ± 0.1	10.4 ± 0.3
OF4	116.8 ± 2.4	77.0 ± 2.1	15.6 ± 0.3 b	7.9 ± 0.1	9.7 ± 0.4
Media[2]					
M 1	120.2 ± 2.9	79.4 ± 1.5	15.9 ± 0.3	7.9 ± 0.1	9.5 ± 0.4 c
OM 2	122.4 ± 3.5	77.5 ± 1.9	16.1 ± 0.4	8.1 ± 0.1	9.9 ± 0.4 c
OM 3	118.8 ± 1.9	72.4 ± 1.9	16.0 ± 0.3	8.1 ± 0.2	10.5 ± 0.2 b
OM 4	117.6 ± 2.1	75.1 ± 2.2	16.3 ±0.3	8.1 ± 0.1	11.3 ± 0.3 a
F-test[4]					
Liquid Feed(LF)	0.0543	0.1381	0.0078**	0.7545	0.0613
Media (M)	0.4154	0.0521	0.6015	0.6948	<0.0001**
LF X M	0.2933	0.3105	0.0445*	0.6834	0.6918

Treatments	Chlorophyll Content	Leaf Area (cm^{-2}) (5^{th} Leaf)	Leaf Area (cm^{-2}) (10^{th} Leaf)
Liquid Feed[1]			
IF 1	32.1 ± 0.6	915 ± 49	1358 ± 68 a[3]
OF 2	32.6 ± 0.5	882 ± 51	1087 ± 82 b
OF3	30.7 ± 0.5	1042 ± 75	1289 ± 76 a
OF4	30.9 ± 0.6	830 ± 68	1082 ± 65 b
Media[2]			
M 1	32.4 ± 0.5	1005 ± 46	1087 ± 88 c
OM 2	31.6 ± 0.6	948 ± 102	1108 ± 166 bc
OM 3	31.1 ± 0.7	841 ± 84	1340 ± 68 a
OM 4	31.2 ± 0.5	874 ± 68	1281 ± 63 ab
F-test[4]			
Liquid Feed(LF)	0.1459	0.0603	0.0028**
Media (M)	0.0975	0.1712	0.0092**
LF X M	0.0420*	0.0293*	0.0728

[1] IF1= Inorganic, OF2 = Agrowchem OF3 =Pure Blend and OF4 = Agrogreen

[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)

[3] Data presented are means ± SE; Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test

[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

Table 8. Plant height, leaf number, stem diameter, Chlorophyll content, and leaf area as affected by liquid feed and organic media treatments - Spring 2007, Tomato experiment.(70 DAP).

Treatments	Plant height (cm)	Stem extension 10^{th} Leaf to Top of plant (cm)	Leaf. No (no plant^{-1})	Stem diameter (mm)	Chlorophyll Content
Liquid Feed[1]					
IF 1	136.4 ± 2.3	87.5 ± 1.8	17.9 ± 0.3 a	9.8 ± 0.3 a	37.1 ± 1.0 b
OF 2	133.1 ± 14.0	90.3 ± 1.9	15.4 ± 0.5 b	7.8 ± 0.4 b	41.2 ± 0.6 a
OF3	136.3 ± 3.5	86.6 ± 1.3	17.7 ± 0.3 a	9.7 ± 0.5 a	56.0 ± 19 b
OF4	128.1 ± 13.1	90.1 ± 2.5	15.7 ± 0.3 b	8.1±0.3 b	26.0 ± 3.4 c
Media[2]					
M 1	112.4 ± 5.4b[3]	86.8 ± 2.3	16.1 ± 0.6 b	8.2 ± 0.4 b	32.0 ± 3.1 b
OM 2	110.0 ± 6.8b	88.4 ± 1.7	15.6 ± 0.7 b	8.7 ± 0.5 ab	32.9 ± 3.0 c
OM 3	150.1 ± 7.7a	90.0 ± 1.8	17.2 ± 0.3 a	8.8 ± 0.4 ab	56.3 ± 19 a
OM 4	161.4 ± 10.8a	89.3 ± 1.8	17.4 ±0.3 a	9.7 ± 0.4 a	39.1 ± 0.8 a
F-test[4]					
Liquid Feed(LF)	0.8632	0.3633	<0.0001**	<0.0001**	<0.0001**
Media (M)	<0.0001**	0.6122	0.0004**	0.0234*	0.0003**
LF X M	0.1272	0.0854	0.0128*	0.2959	<0.0001**

Treatments	Leaf Area (cm^{-2}) (5^{th} Leaf)	Leaf Area (cm^{-2}) (10^{th} Leaf)	Leaf Area (cm^{-2}) (15^{th} Leaf)
Liquid Feed[1]			
IF 1	1060 ± 61	1554 ± 130	1842 ± 82
OF 2	906 ± 61	1270 ± 100	1370 ± 226
OF3	1142 ± 64	1591 ± 91	2101 ± 107
OF4	932 ± 89	1329 ± 76	1422 ± 242
Media[2]			
M 1	868 ± 55 b[3]	1301 ± 125 b	1321 ± 213 b
OM 2	844 ± 53 b	1342 ± 85 b	1349 ± 223 b
OM 3	1159 ± 66 a	1695 ± 87 a	1998 ± 125 a
OM 4	1169 ± 73 a	1406 ± 97 b	2067 ± 100 a
F-test[4]			
Liquid Feed(LF)	0.0855	0.1533	0.0625
Media (M)	<0.0001**	0.0085**	0.0001**
LF X M	0.4572	0.0592	0.0809

[1] IF1= Inorganic, OF2 = Agrowchem OF3 =Pure Blend and OF4 = Agrogreen

[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)

[3] Data presented are means ± SE; Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test

[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

Table 9. Plant height, leaf number, stem diameter, Chlorophyll content, and leaf area as affected by liquid feed and organic media treatments -Spring 2007, Tomato experiment. (180 DAP)

Treatments	Plant height (cm)	Stem extension 10^{th} Leaf to Top of plant (cm)	Leaf. No (no plant^{-1})	Stem diameter (mm)	Chloro phyll Content
Liquid Feed[1]					
IF 1	347.1 ± 5.4 a[3]	76.6 ± 1.6 b	44.5 ± 1.0 a	8.5 ± 0.6	52.9 ± 1.1 a
OF 2	264.1 ± 8.9 a	78.6 ± 2.0 b	31.8 ± 1.4 b	8.9 ± 0.4	53.2 ± 0.9 a
OF3	349.6 ± 7.3 a	72.4 ± 1.3 b	44.6 ± 0.8 a	8.1 ± 0.4	51.6 ± 0.8 a
OF4	371.9 ± 11.2 b	86.7 ± 1.7 a	43.3 ± 1.7 b	8.5 ± 0.4	47.5 ± 0.5 b
Media[2]					
M 1	327.2 ± 17	77.7 ± 2.0	40.9 ± 2.4	8.2 ± 0.2 b	51.1 ± 0.9
OM 2	322.3 ± 15	79.0 ± 2.4	39.7 ± 2.0	9.6 ± 0.5 a	49.7 ± 0.9
OM 3	334.1 ± 11	79.1 ± 1.9	41.5 ± 1.2	8.3 ± 0.5 b	56.3 ± 1.1
OM 4	349.1 ± 9.1	78.6 ± 2.2	41.9 ± 1.6	8.0 ± 0.4 b	52.7 ± 1.1
F-test[4]					
Liquid Feed(LF)	<0.0001**	0.0076**	<0.0001**	0.7789	0.0027**
Media (M)	0.0977	0.9202	0.6591	0.0299*	0.0668
LF X M	0.1059	0.8675	0.7583	0.5758	0.1322

Treatments	Leaf Area (cm^{-2}) (5^{th} Leaf)	Leaf Area (cm^{-2}) (10^{th} Leaf)	Leaf Area (cm^{-2}) (15^{th} Leaf)
Liquid Feed[1]			
IF 1	789 ± 55	1130 ± 68	1165 ± 75 a
OF2	699 ± 32	950 ± 45	946 ± 46 b
OF3	738 ± 42	1094 ± 75	1226 ± 55 a
OF4	739 ± 41	872 ± 53	1105 ± 76 a
Media[2]			
M 1	750 ±41 b[3]	930 ± 63 b	933 ± 66 b
OM 2	818 ± 51 b	1126 ± 87 a	1139 ± 48 a
OM 3	747 ± 40 a	1009 ± 45 ab	1228 ± 63 a
OM 4	651 ± 32 a	980 ± 54 b	1152 ±73 a
F-test[4]			
Liquid Feed (LF)	0.5729	0.0686	0.0053**
Media (M)	0.0398*	0.0456*	0.0021**
LF X M	0.1508	0.0073**	0.0678

[1] IF1= Inorganic, OF2 = Agrowchem OF3 =Pure Blend and OF4 = Agrogreen

[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)

[3] Data presented are means ± SE; Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test

[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

1.3.5. Days-to-flower for clusters 1-5:

Table 10 lists means by liquid feed and media of the number of days from planting to the opening of the first flower in each of the first five clusters. There was no significant effect due to liquid feeds, but, media had significant effects on clusters 1-3. In media M1 and OM2 plants set flowers on the first three clusters sooner than the plants grown on OM3 and OM4, this trend was not repeated in cluster 4 and 5.

Table 10. Days from planting to first flower as affected by the liquid feed and media treatments- Spring 2007.

Treatments	Days from planting the opening of the first flower				
	Cluster-1	Cluster-2	Cluster-3	Cluster-4	Cluster-5
Liquid Feed[1]					
IF 1	21±0.9	29±0.6	37±0.5	45±0.7	48±0.2
OF 2	20±0.9	29±0.8	36±0.5	45±0.6	48±0.2
OF3	20±0.5	29±0.4	36±0.4	42±0.8	48±0.2
OF4	20±0.9	29±0.7	36±0.4	45±0.6	48±0.2
Media[2]					
M 1	18±0.3 b[3]	28±0.4 b	36±0.4 b	43±0.8	48±0.2
OM 2	19±0.3 b	29±0.6 b	36±0.4 b	44±0.8	49±0.2
OM 3	23±1.0 a	31±0.5 a	37±0.4 a	45±0.7	49±0.2
OM 4	22±0.8 a	31±0.6 a	38±0.5 a	46±0.6	49±0.2
F-test[4]					
Liquid Feed(LF)	0.7697	0.7004	0.2932	0.0629	0.1905
Media (M)	<0.0001**	<0.0001**	0.0003**	0.0923	0.5591
LF X M	0.8043	0.6922	0.3010	0.4083	0.6558

[1] IF1= Inorganic, OF2 = Agrowchem OF3 =Pure Blend and OF4 = Agrogreen

[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)

[3] Data presented are means ± SE; Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test

[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

1.3.6. Fruit yield

Effect of organic liquid feed and media treatments on plant yield was derived from the records of number and weight of marketable and unmarketable fruit. Statistical analysis of tomato fruit yield and yield parameters, as affected by organic liquid feeds and media and their interactions are presented in Tables 11-22.

1.3.6.1. Effects of the organic liquid feeds

Average yield of marketable, unmarketable and total fruit for the entire season (38 harvests-216 days) is presented in Tables 11 and 12. The effect of liquid feed on marketable fruit (weight and number) was significant. Liquid feeds OF3, OF4 and OF2 resulted in marketable yield of 22.5, 17.1, and 15.7 kg m^{-2}, respectively; which, was -8%, -30% and -36% with respect to the inorganic control (IF1). Furthermore, liquid feeds IF1, OF3, OF4 and OF2 recorded progressively decreasing numbers of marketable fruit (140.7, 123.3, 99.7, and 98.2 no m^{-2}, respectively; Table 12). In contrast organic liquid feed OF2 produced a significantly lower number of unmarketable fruit number and weight compared to all other liquid feeds. Furthermore, there were significant liquid feed × media interactions for marketable, unmarketable, and total fruit yield (both number and weight; Tables 13 and 14).

Effects of liquid feed on grade distribution of marketable and unmarketable fruit (number and weight) are shown on Table 15 and Table 16. The percentage of Extra-large, Large, Small, commercial and No2 within the weight based marketable yield and across all liquid feeds ranged over 41.1-52.2%, 10.2-48.1%, 1.3-3.8% 2.4-2.9 % , and 2.9-4.4 %, respectively. Liquid feeds OF3 and IF1 increased the number and weight of extra-large fruit significantly with respect to OF4 and OF2 (Table 15). However, there was no significant difference between OF2, OF3 and OF4 with respect to the number and weight of large grade fruit. Organic liquid feed OF2 recorded significantly higher number and weight of small grade fruit compared to IF1, OF3 and OF4. There was no significant difference in the grade distribution of commercial and Marketable (No2) grade fruits.

Liquid feeds had no significant effect on unmarketable yield components (Blossom-End Rot, Cat-Faced and blotchy), except for feed OF3 resulting in maximal number and weight of hollow fruit (Table 16).

The effects of liquid feed on early and late harvest yield (both number and weight) are shown in Tables 17 and 18. Early in the season (Mar15-May 31; 20harvests), liquid feed IF1 significantly increased the number and weight of fruit yield (marketable and total) (Tables 17 and 18), compared to OF3, OF2 and OF4. Liquid feed OF3 resulted in maximal unmarketable fruit (number and weight) during the early harvest. Similar trend was observed in late season harvest (Jun.1- Aug.3; 18 harvests). There were significant liquid feed X media interactions for early and late marketable as well as for total fruit yield (Tables 19 and 20).

The effect of liquid feed on the seasonal average size of marketable fruit was significant (P=0.0039) (Table 21). Liquid feed OF3 resulted in higher average fruit weight (182 g /fruit) compared to IF1 (173.1 g /fruit), OF4 (169.7 g /fruit), and OF2 (158.4 g /fruit). However, there was no significant difference in late season average fruit weight. There were significant liquid feed X media interactions for seasonal average size of marketable fruit (Table 22).

1.3.6.2. Effect of organic media

The effect of organic media on marketable fruit (weight: P<0.0001 and number: P<0.0001) was significant. Organic media OM4, OM3 and OM2 recorded marketable yields (22.7, 20.7, and 18.0 kg m^{-2}), which were +19%, +10% and -4% with respect to rockwool (M1), respectively; Also, OM3 and OM4 recorded the highest total yields (Tables 11 and 12). Furthermore, OM4, OM3, M1 and OM2 recorded progressively decreasing numbers of marketable fruit (127.6, 118.3, 109.0, and 106.8 no m^{-2}, respectively; Table 12). The organic media effect on unmarketable yield (weight: P=0.2628 and number: P=0.1410) was not significant.

Effects of organic media on grade distribution of fruit (number and weight) are shown on Tables 15 and 16. The percentage of Extra-large, Large, Small, commercial and No2 within the weight based marketable yield and across media ranged over 43.3-48.2 %, 44.4-47.2 %, 1.3-2.8 % 2.1-2.9 %, and 3.1-4.3 %, respectively.

The number and weight of extra-large and large fruit from plants growing on organic media OM4 and OM3 were significantly higher than those on M1 and OM2. Accordingly, media M1 and OM2 recorded significantly higher number and weight of small grade fruit. However, the media effect on commercial, number 2, and unmarketable fruit grade distribution (Blossom-End Rot, Cat-Faced and blotchy) was not significant (Table 16).

The effects of media on early and late harvest yield (both number and weight) are shown in Tables 17 and 18. Early in the season (Mar 15- May 31; 20 harvests), OM4 and OM3 recorded significantly higher marketable fruit yield (Table 16) compared to M1 and OM2. A similar trend was observed in late season (June1- August3; 18 harvests).

Media effects on seasonal average size of marketable fruit were significant (P=0.0356) (Table 21). The seasonal average fruit weight with the in-house blend organic media OM4, OM3 ranged over 174.3-174.4 g, which was 6 g higher than with rockwool (M1)(Table 21). However, there was no significant difference in late season average marketable fruit size.

Interactive effects

Organic liquid feed × media interactions had a significant impact on marketable yield. The highest seasonal marketable yields achieved with the best combinations of organic liquid feeds with organic media were 23.6 and 21.2 Kg m^{-2} for the combinations OF3 × OM3 and OF2 × OM4, respectively; these yields represented 92.2 and 82.3 of the rockwool (inorganic control), or 95.2 and 85.5 % of the coco peat (organic control, but with an inorganic feed) marketable yields; the best marketable yield achieved this year with organic means (i.e. 92.2 of the rockwool control) represents a significant improvement over the corresponding figure in 2006 (i.e. only 75%). Also, in terms of early marketable yield, there was hardly any difference between several organic methods (e.g. OF2 × OM4, OF3 × OM3 and OF4 × OM4) and the rockwool control (10.4, 11.0, 10.5, and 11.7 Kg m^{-2} , respectively).

Table 11. Tomato yield (kg m^{-2}) as affected by the organic liquid feed and media treatments, Spring 2007.

Treatments	Marketable (kg m^{-2})	Unmarketable (kg m^{-2})	Total Yield (kg m^{-2})
Liquid Feed[1]			
IF 1	24.31 ± 0.52 a[3]	2.18 ± 0.21 b	26.49 ± 0.61 a
OF 2	15.74 ± 1.01 b	0.79 ± 0.11 c	16.53 ± 1.06 c
OF3	22.50 ± 0.79 a	4.25 ± 0.34 a	26.75 ± 0.72 a
OF4	17.11 ± 1.10 b	2.38 ± 0.29 b	19.49 ± 1.27 b
LSD (P=0.05)	1.93	0.56	1.81
Media[2]			
M 1	18.71 ± 1.52 c	2.49 ± 0.42	21.20 ± 1.84 b
OM 2	17.97 ± 1.38 c	2.55 ± 0.55	20.52 ± 1.75 b
OM 3	20.67 ± 0.90 b	2.47 ± 0.31	23.14 ± 1.06 a
OM 4	22.31 ± 0.86 a	2.09 ± 0.27	24.40 ± 0.82 a
LSD (P=0.05)	1.42	0.52	1.37
F-test[4]			
Liquid feed(LF)	<0.0001**	<0.0001**	<0.0001**
Media(M)	<0.0001**	0.2628	<0.0001**
LF x OM	<0.0001**	<0.0001**	<0.0001**

[1] IF1= Inorganic, OF2 = Agrowchem, OF3 =Pure Blend and OF4 = Agrogreen
[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)
[3] Data presented are means ± SE; Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test
[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

Table 12. Tomato yield (no m^{-2}) as affected by the liquid feed and organic media treatments, Spring 2007.

Treatments	Marketable (no m^{-2})	Unmarketable (no m^{-2})	Total Fruit yield (no m^{-2})
Liquid Feed[1]			
IF 1	140.68 ± 2.9 a[3]	13.01 ± 1.1 b	153.69 ± 3.1 a
OF 2	98.20 ± 4.5 c	5.10 ± 0.6 c	103.30 ± 4.7 c
OF 3	123.31 ± 3.2 b	24.87 ± 1.9 a	148.18 ± 2.4 a
OF 4	99.74 ± 4.4 c	14.80 ± 1.7 b	114.54 ± 5.3 b
LSD (P=0.05)	7.25	3.50	7.31
Media[2]			
M 1	109.07 ± 6.4 c	14.59 ± 2.2	123.66 ± 7.9 b
OM 2	106.81 ± 6.7 c	15.75 ± 3.2	122.56 ± 8.5 b
OM 3	118.38 ± 4.5 b	14.98 ± 1.8	133.36 ± 5.1 a
OM 4	127.68 ± 4.1 a	12.45 ± 1.6	140.13 ± 3.91 a
LSD (P=0.05)	7.36	2.92	6.89
F-test[4]			
Liquidfeed(LF)	<0.0001**	<0.0001**	<0.0001**
Media(M)	<0.0001**	0.1410	<0.0001**
LF x OM	0.0008 **	<0.0001**	<0.0001**

[1] IF1= Inorganic, OF2 = Agrowchem, OF3 =Pure Blend and OF4 = Agrogreen
[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added), and OM4= Organic mix-2 (40 L Soymeal added)
[3] Data presented are means ± SE; Means within organic liquid feed and media that are followed by different letters are significantly different (P < 0.05) according to Duncan's multiple range test
[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

Table 13. Interactive effects of organic liquid feed and media treatments on marketable, unmarketable and total yield of Tomato yield (no m^{-2}), Spring 2007.

Liquid Feed[1]	Media[2]	Marketable (no m^{-2})	Unmarketable (no m^{-2})	Total Yield (no m^{-2})
IF 1	**M 1**	140.9 ab[3]	16.6 cde	157.5 a
	OM 2	144.0 a	14.6 cde	158.6 a
	OM 3	137.3 abc	9.9 efg	147.3 ab
	OM 4	140.5 ab	10.8 efg	151.3 a
OF 2	**M 1**	87.6 g	4.5 gh	92.1 de
	OM 2	83.4 g	3.0 h	86.4 e
	OM 3	98.2 gf	7.9 fgh	106.1 d
	OM 4	123.6 cde	5.0 gh	128.6 c
OF3	**M 1**	122.9 cde	25.3 b	148.2 ab
	OM 2	114.8 de	35.3 a	150.0 a
	OM 3	126.7 bcde	20.8 bc	147.6 ab
	OM 4	128.9 abcd	18.1 cd	147.0 ab
OF4	**M 1**	84.9 g	12.0 def	96.9 de
	OM 2	85.1 g	10.1 efg	95.3 de
	OM 3	111.3 ef	21.3 bc	132.5 c
	OM 4	117.7 de	15.8 cde	133.5 bc

[1] IF1= Inorganic, OF2 = Agrowchem, OF3 =Pure Blend and OF4 = Agrogreen
[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)
[3] Means within each column are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test

Table 14. Interactive effects of organic liquid feed and media treatments on marketable, unmarketable and total yield of Tomato yield (kg m^{-2}), Spring 2007.

Liquid Feed[1]	Media[2]	Marketable (kg m^{-2})	Unmarketable (kg m^{-2})	Total Yield (kg m^{-2})
IF 1	M 1	25.6 a[3]	3.1 cd	28.7 a
	OM 2	24.8 ab	2.4 def	27.2 abc
	OM 3	22.8 abcd	1.5 fgh	24.2 bcd
	OM 4	24.0 abc	1.8 fgh	25.8 abc
OF 2	M 1	13.2 f	0.6 gh	13.8 e
	OM 2	12.2 f	0.4 h	12.6 e
	OM 3	16.4 e	1.3 fgh	17.7 e
	OM 4	21.2 cd	0.9 gh	22.1 e
OF3	M 1	23.1 abcd	4.5 b	27.5 ab
	OM 2	21.0 cd	5.9 a	26.9 abc
	OM 3	23.6 abc	3.7 bc	27.3 abc
	OM 4	22.4 abcd	3.0 cd	25.3 bcd
OF4	M 1	12.9 f	1.8 efg	14.7 fg
	OM 2	13.9 ef	1.5 efg	15.4 gf
	OM 3	20.0 d	3.5 bcd	23.4 de
	OM 4	21.6 bcd	2.8 cde	24.4 bcde

[1] IF1= Inorganic, OF2 = Agrowchem, OF3 =Pure Blend and OF4 = Agrogreen
[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)
[3] Means followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test

Table 15. Marketable yield components as affected by the organic liquid feed and media treatments -Spring 2007, tomato experiment.

Treatments	Marketable (No.1)								Marketable (No.2)	
	Extra Large		Large		Small		Commercial			
	(no m^{-2})	(kg m^{-2})	(no m^{-2})	(kg m^{-2})	(no m^{-2})	(kg m^{-2})	(no m^{-2})	(kg m^{-2})	(no m^{-2})	(kg m^{-2})
Liquid Feed[1]										
I F 1	48.6 ± 2.8a[3]	10.7 ± 0.6 a	79.7 ± 4.0 a	11.6 ± 0.5 a	5.2 ± 0.6b	0.4 ± 0.1b	1.6 ± 0.3	0.6 ± 0.1	5.6 ± 0.6	1.0 ± 0.1
OF 2	28.3 ± 2.8b	6.5 ± 0.7 b	54.7 ± 2.7 b	7.6 ± 0.4 c	9.7 ± 1.0a	0.6 ± 0.1a	1.3 ± 0.2	0.4 ± 0.1	4.2 ± 0.3	0.7 ± 0.1
OF 3	51.8 ± 3.3a	11.8 ± 0.8a	61.2 ± 2.7 b	9.1 ± 0.4 b	4.3 ± 0.4b	0.3 ± 0.0b	1.5± 0.4	0.6 ± 0.1	4.4 ± 0.6	0.8 ± 0.1
OF 4	33.4 ± 0.5b	7.7 ± 0.1 b	57.2 ± 2.4 b	8.0 ± 0.3 c	5.1 ± 0.6b	0.4 ± 0.1b	1.4 ± 0.3	0.5 ± 0.1	2.8 ± 0.2	0.5 ± 0.0
LSD (P=0.05)	7.8	1.8	7.3	0.9	1.4	0.1	1.0	0.4	2.2	0.3
Media[2]										
M 1	37.7 ± 4.8bc	8.5 ± 1.1bc	58.4 ± 2.9 b	8.5 ± 0.5 b	7.2 ± 1.2a	0.5 ± 0.1a	1.2± 0.4	0.4 ± 0.2	4.6 ± 0.7	0.8 ± 0.1
OM 2	34.5 ± 3.9c	7.8 ± 0.9c	59.8 ± 4.3 b	8.5 ± 0.6 b	6.9 ± 1.0a	0.5 ± 0.1a	1.5 ± 0.3	0.5 ± 0.1	4.1 ± 0.5	0.7 ± 0.1
OM 3	42.3 ± 3.7ab	9.7 ± 0.9ab	64.5 ± 4.3 ab	9.2 ± 0.6 ab	5.2 ± 0.6b	0.4 ± 0.1ab	1.7 ± 0.3	0.6 ± 0.1	4.7 ± 0.6	0.8 ± 0.1
OM 4	47.7 ± 3.5a	10.8 ± 0.8a	70.1 ± 3.3 a	10.1 ± 0.5 a	5.0 ± 0.4b	0.3 ± 0.0b	1.3 ± 0.3	0.5 ± 0.1	3.6 ± 0.4	0.7 ± 0.1
LSD (P=0.05)	6.5	1.5	8.4	1.1	1.5	0.1	0.8	0.3	1.1	0.2
F-test[4]										
Liquid feed (LF)	0.0002**	0.0003**	<0.0001**	<0.0001**	<0.0001**	0.0021**	0.8991	0.8543	0.1075	0.0687
Media (M)	0.0016**	0.0021**	0.0224*	0.0127*	0.0047**	0.0402*	0.6308	0.6441	0.2136	0.4781
LF x OM	0.0007**	0.0006**	0.4121	0.3429	0.0003	0.0435*	0.3308	0.2370	0.5077	0.1754

[1] IF1= Inorganic, OF2 = Agrowchem, OF3 =Pure Blend and OF4 = Agrogreen

[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)

[3] Data presented are means ± SE; Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test

[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

Table 16. Unmarketable yield components as affected by organic liquid feed and media treatments-Spring 2007, tomato experiment.

Treatments	Blossom-End Rot		Cat -Faced		Hollow		Blotchy	
	(no m^{-2})	(kg m^{-2})	(no m^{-2})	(kg m^{-2})	(no m^{-2})	(kg m^{-2})	(no m^{-2})	(kg m^{-2})
Liquid Feed[1]								
I F 1	0.31 ± 0.2	0.03 ± 0.0	0.28 ± 0.1	0.10 ± 0.0	11.7 ± 1.1 b[3]	2.00 ± 0.2 b	0.00 ± 0.0	0.00 ± 0.0
OF 2	0.25 ± 0.1	0.04± 0.0	0.28± 0.1	0.07 ± 0.0	3.45 ± 0.6 c	0.60 ± 0.1 c	0.00 ± 0.0	0.00 ± 0.0
OF 3	0.03 ± 0.0	0.01 ± 0.0	0.41 ± 0.1	0.14 ± 0.0	23.3 ± 1.9 a	3.90 ± 0.3 a	0.00 ± 0.0	0.00 ± 0.0
OF 4	0.28 ± 0.1	0.05± 0.0	0.34 ± 0.1	0.12 ± 0.1	12.9 ± 1.5 b	2.00 ± 0.3 b	0.1 ± 0.1	0.04 ± 0.03
LSD (P=0.05)	0.4	0.1	0.3	0.1	3.4	0.6	0.2	0.1
Media[2]								
M 1	0.09 ± 0.1	0.02± 0.0	0.38 ± 0.1	0.12 ± 0.0	12.9 ± 2.3	2.2 ± 0.4	0.0 ± 0.0	0.0 ± 0.0
OM 2	0.31 ± 0.1	0.06 ± 0.0	0.25± 0.1	0.07 ± 0.0	14.2 ± 3.2	2.3 ± 0.5	0.0 ± 0.0	0.0 ± 0.0
OM 3	0.06 ± 0.0	0.01 ± 0.0	0.19 ± 0.1	0.07 ± 0.0	13.6 ± 1.7	2.2 ± 0.3	0.0 ± 0.0	0.0 ± 0.0
OM 4	0.41 ± 0.2	0.04 ± 0.0	0.50 ± 0.1	0.17 ± 0.1	10.7 ± 1.5	1.7 ± 0.2	0.1 ± 0.1	0.0 ± 0.0
LSD (P=0.05)	0.4	0.0	0.3	0.1	2.6	0.5	0.1	0.0
F-test[4]								
Liquid feed (LF)	0.4313	0.3831	0.8175	0.6751	<0.0001**	<0.0001**	0.4363	0.4363
Media (M)	0.1999	0.1911	0.1876	0.2081	0.0506	0.0710	0.4040	0.4040
LF x OM	0.8122	0.9488	0.4626	0.4062	<0.0001**	<0.0001**	0.4577	0.4577

[1] IF1= Inorganic, OF2 = Agrowchem, OF3 =Pure Blend and OF4 = Agrogreen

[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)

[3] Data presented are means ± SE; Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test

[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

Table 17. Early (March 15- May 31) and late (June 01- August 03) tomato yield (no m^{-2}), as affected by the liquid feed and organic media treatments, Spring 2007.

Treatments	Marketable (no m^{-2})		Unmarketable (no m^{-2})		Total Fruit yield (no m^{-2})	
	Early	Late	Early	Late	Early	Late
	Mar-May	Jun-Aug	Mar-May	Jun-Aug	Mar-May	Jun-Aug
Liquid Feed [1]						
IF 1	64.9±1.8 a[3]	75.7±1.7 a	6.5±0.7 b	6.5±0.8c	71.4±1.7 a	82.3±2.0 a
OF 2	46.8±2.1 c	51.4±2.9 c	2.7±0.7 c	2.4±0.5d	49.6±0.8 c	53.7±2.9 c
OF 3	54.2±1.7 b	69.2±1.8 b	12.7±1.3 a	12.2±1.1a	66.8±1.3 b	81.3±1.9 a
OF 4	46.1±1.9 c	53.6±3.1 c	5.3±0.8 b	9.5±1.1b	51.4±2.2 c	63.1±3.6 b
LSD (P=0.05)	4.0	6.2	1.8	2.6	4.5	6.2
Media [2]						
M 1	51.2±2.4 bc	57.9±4.3 c	7.2±1.4	7.4±1.3	58.4±3.4 bc	65.3±4.7 c
OM 2	48.3±3.4 c	58.5±3.8 c	7.1±1.8	8.7±1.6	55.4±4.0 c	67.2±4.8 bc
OM 3	54.2±2.1 b	64.2±3.1 b	7.4±1.0	7.6±1.1	61.3±2.3 ab	71.7±3.3 ab
OM 4	58.3±2.2 a	69.3±1.9 a	5.5±0.7	6.9±1.2	63.9±1.7 a	76.3±2.5 a
LSD (P=0.05)	4.0	4.9	1.8	2.1	3.6	5.3
F-test[4]						
Liquid feed (LF)	<0.0001**	<0.0001**	<0.0001**	<0.0001**	<0.0001**	<0.0001**
Media (M)	<0.0001**	<0.0001**	0.1485	0.4305	0.0002**	0.0008**
LF x OM	0.0039**	0.0018**	<0.0001**	0.0014**	<0.0001**	0.0002**

[1] IF1= Inorganic, OF2 = Agrowchem, OF3 =Pure Blend and OF4 = Agrogreen

[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)

[3] Data presented are means ± SE; Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test

[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

Table 18. Early (March 15- May 31) and late (June 01- August 03) tomato yield (kg m^{-2}), as affected by the liquid feed and organic media treatments, Spring 2007.

Treatments	Marketable (kg m^{-2})		Unmarketable (kg m^{-2})		Total Fruit yield (kg m^{-2})	
	Early	Late	Early	Late	Early	Late
	Mar-May	Jun-Aug	Mar-May	Jun-Aug	Mar-May	Jun-Aug
Liquid Feed [1]						
IF 1	11.3±0.3 a[3]	13.0±0.3 a	1.2±0.6 b	1.0±0.1c	12.4±0.3 a	14.1±0.3 a
OF 2	7.4±0.6 b	8.4±0.5 c	0.4±0.1 c	0.4±0.1d	7.7±0.6 c	8.8±0.5 c
OF 3	10.6±0.4 a	11.9±0.4 b	2.3±0.2 a	1.9±0.2a	12.9±0.4 a	13.9±0.4 a
OF 4	8.4±0.6 b	8.8±0.6 c	0.9±0.2 b	1.5±0.2b	9.3±0.7 b	10.2±0.7 b
LSD (P=0.05)	1.1	1.0	0.3	0.4	1.0	0.9
Media [2]						
M 1	8.8±0.7 c	9.9±0.9 bc	1.3±0.3	1.2±0.2	10.1±0.9 b	11.1±0.9 b
OM 2	8.2±0.7 c	9.7±1.6 c	1.2±0.3	1.4±0.3	9.4±0.9 c	11.1±0.9 b
OM 3	9.9±0.4 b	10.8±1.1 ab	1.3±0.2	1.2±0.2	11.1±0.5 a	12.0±0.6 ab
OM 4	10.6±2.2 a	11.7±0.5 a	1.1±0.1	1.0±0.2	11.7±0.4 a	12.7±0.5 a
LSD (P=0.05)	0.8	0.9	0.3	0.3	0.7	0.9
F-test[4]						
Liquid feed (LF)	<0.0001**	<0.0001**	<0.0001**	<0.0001**	<0.0001**	<0.0001**
Media (M)	<0.0001**	0.0005**	0.5884	0.2479	<0.0001**	0.0027**
LF x OM	<0.0001**	0.0003**	<0.0001**	0.0006**	<0.0001**	<0.0001**

[1] IF1= Inorganic, OF2 = Agrowchem, OF3 =Pure Blend and OF4 = Agrogreen

[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)

[3] Data presented are means ± SE; Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test

[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

Table 19. Interactive effects of organic liquid feed and media treatments on marketable and total yield of Tomato yield (no m^{-2}), Spring 2007.

Interaction		Marketable Yield (no m^{-2})			Total Yield (no m^{-2})		
LiquidFeed[1]	Media[2]	Early[†]	Late[††]	All[†††]	Early	Late	All
IF 1	M 1	63.0 ab[3]	77.9 a	140.9 ab	70.9 ab	86.6 a	157.5 a
	OM 2	68.8 a	75.3 ab	144.0 a	74.9 a	83.8 a	158.6 a
	OM 3	63.6 ab	73.7 abc	137.3 abc	69.8 abc	77.5 ab	147.3 ab
	OM 4	64.4 ab	76.1 ab	140.5 ab	70.3 ab	81.1 a	151.3 a
OF 2	M 1	40.1 gh	47.5 d	87.6 g	42.8 c	49.4 c	92.1 de
	OM 2	40.0 gh	43.4 d	83.4 g	41.4 c	45.0 c	86.4 e
	OM 3	49.1 def	49.1 d	98.2 gf	52.3 c	53.8 c	106.1 d
	OM 4	58.1 bc	65.5 bc	123.6 cde	61.9 b	66.8 b	128.6 c
OF3	M 1	56.0 bcd	66.9 abc	122.9 cde	71.1 ab	77.0 ab	148.2 ab
	OM 2	47.0 efg	67.8 abc	114.8 de	64.5 bcd	85.5 a	150.0 a
	OM 3	55.6 bcde	71.1 abc	126.7 bcde	67.3 abc	80.3 a	147.6 ab
	OM 4	58.0 bc	70.9 abc	128.9 abcd	64.5 bcd	82.5 a	147.0 ab
OF4	M 1	45.8 fgh	39.1 d	84.9 g	48.8 c	48.1 c	96.9 de
	OM 2	37.4 h	47.8 d	85.1 g	40.8 c	54.5 c	95.3 de
	OM 3	48.5 defg	62.8 c	111.3 ef	57.3 ab	75.3 ab	132.5 c
	OM 4	52.9 cdef	64.8 bc	117.7 de	58.9 ab	74.7 ab	133.5 bc

[1] IF1= Inorganic, OF2 = Agrowchem, OF3 =Pure Blend and OF4 = Agrogreen
[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)
[3] Means within each column are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test
† Early -20 Harvests -Up to 141 DAP
†† Late -18 Harvests -142-211 DAP
††† All-38 Harvests1 - 211 DAP

Table 20. Interactive effects of organic liquid feed and media treatments on marketable and total yield of Tomato yield (kg m^{-2}), Spring 2007.

Interaction		Marketable Yield (kg m^{-2})			Total Yield (kg m^{-2})		
LiquidFeed [1]	Media[2]	Early[†]	Late[††]	All[†††]	Early	Late	All
IF 1	M 1	11.7 a[3]	13.9 a	25.6 a	13.3 ab	15.4 a	28.7 a
	OM 2	12.0 a	12.7 abc	24.8 ab	13.1 ab	14.1 c	27.2 abc
	OM 3	10.4 ab	12.3 abc	22.8 abcd	11.4 c	12.9 bcd	24.2 bcd
	OM 4	10.9 ab	13.1 ab	24.0 abc	12.0 bc	13.8 abc	25.8 abc
OF 2	M 1	5.4 ef	7.8 ef	13.2 f	5.7 f	8.1 e	13.8 e
	OM 2	5.2 f	6.9 ef	12.2 f	5.4 f	7.2 e	12.6 e
	OM 3	8.3 cd	8.1 e	16.4 e	8.8 d	8.8 e	17.7 e
	OM 4	10.4 ab	10.9 cd	21.2 cd	11.0 c	11.1 d	22.1 d
OF3	M 1	11.1 ab	12.0 abcd	23.1 abcd	13.9 a	13.6 abc	27.5 abc
	OM 2	9.4 bc	11.6 bcd	21.0 cd	12.5 abc	14.4 ab	26.9 ab
	OM 3	11.0 ab	12.6 abc	23.6 abc	13.1 ab	14.2 abc	27.3 abc
	OM 4	10.8 ab	11.6 bcd	22.4 abcd	12.1 bc	13.2 bc	25.3 bc
OF4	M 1	7.0 de	6.0 f	12.9 f	7.4 e	7.3 e	14.7 e
	OM 2	6.2 ef	7.8 ef	13.9 ef	6.7 ef	8.8 e	15.4 e
	OM 3	9.8 bc	10.2 d	20.0 d	11.2 c	12.2 cd	23.4 cd
	OM 4	10.5 ab	11.1 bcd	21.6 bcd	11.8 bc	12.6 bcd	24.4 bcd

[1] IF1= Inorganic, OF2 = Agrowchem, OF3 =Pure Blend and OF4 = Agrogreen
[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)
[3] Means within each column are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test
[†] Early-20 Harvests -Up to 141 DAP
[††] Late-18 Harvests -142-211 DAP
[†††] All-38 Harvests -1-211 DAP

Table 21. Average weight of marketable fruit (g /fruit) as affected by the organic liquid feed and media treatments. Tomato experiment, Spring 2007.

Treatments	Marketable fruit weight (g/fruit)		
	Early	Late	Seasonal
Liquid Feed[1]			
IF 1	174.1 ± 3.7 b[3]	172.4 ± 2.7	173.1 ± 2.8 ab
OF 2	153.0 ± 6.2 c	163.6 ± 1.8	158.4 ± 3.3 c
OF 3	194.5 ± 4.3 a	172.3 ± 3.4	182.0 ± 3.5 a
OF 4	179.4 ± 6.3 b	162.6 ± 3.7	169.7 ± 4.1 b
LSD (P=0.05)	14.3	12.1	10.2
Media[2]			
M 1	167.9 ± 7.4 b	168.9 ± 3.6	168.2 ± 4.8 ab
OM 2	167.7 ± 7.2 b	166.4 ± 3.3	166.2 ± 4.2 b
OM 3	183.0 ± 5.3 a	167.9 ± 2.8	174.4 ± 3.4 a
OM 4	182.4 ± 4.5 a	167.7 ± 3.1	174.3 ± 3.3 a
LSD (P=0.05)	8.5	5.3	6.8
F-test[4]			
Liquid Feed(LF)	0.0008**	0.1893	0.0039**
Media (M)	0.0003**	0.9202	0.0356**
LF X M	<0.0001**	0.1529	<0.0001**

[1] IF1= Inorganic OF2 = Agrowchem, OF3 =Pure Blend and OF4 = Agrogreen

[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)

[3] Data presented are means ± SE; Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test

[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

Table 22. Interactive effects of organic liquid feed and media treatments on average weight of marketable fruit (g /fruit). Tomato experiment, Spring 2007.

Liquid Feed[1]	Media[2]	Marketable fruit average weight (g/fruit)	
		Early[†]	All[††]
IF 1	**M 1**	186.3 abc3	182.2 ab
	OM 2	175.4 c	172.3 abc
	OM 3	164.4 cd	166.2 bcd
	OM 4	170.4 cd	171.7 abc
OF 2	**M 1**	133.8 e	149.8 ef
	OM 2	130.2 e	145.4 f
	OM 3	170.2 cd	166.7 bcd
	OM 4	177.9 bc	171.6 abc
OF3	**M 1**	198.2 ab	187.6 a
	OM 2	199.7 a	183.3 ab
	OM 3	196.7 ab	185.5 a
	OM 4	183.4 abc	171.6 abc
OF4	**M 1**	153.3 d	153.1 def
	OM 2	165.6 cd	163.8 cde
	OM 3	200.8 a	179.3 abc
	OM 4	197.9 ab	182.5 ab

[1] IF1= Inorganic, OF2 = Agrowchem, OF3 =Pure Blend and OF4 = Agrogreen
[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)
[3] Means within each column are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test
[†] Early -20 Harvests - Up to 141 DAP
[††] All -38 Harvests - 1- 211 DAP

1.3.7. Fruit Quality

Fruit quality was determined by appearance (colour, size, shape, level of physiological disorder and decay), firmness, texture, flavour, fruitiness, colour, fruit shape, fruit cracking, gold specks, and puffiness, using expert evaluation with a 1-10 scale. Table 23 shows the average scores of a taste panel rating of fresh tomato fruit. With respect to inorganically-grown fruit, organically grown tomato fruit was better in such quality ratings as watery fruit, texture, and flavour. Overall quality rating for organic fruit was slightly higher than for inorganic fruit (Table 23). Also, the overall preference of the panellist's choice was 50.0% for the organic versus 37.5% for the inorganic-grown fruit; undecided vote was 12.5%.

Table 23. Tomato fruit quality attributes of organic and inorganically grown tomatoes as determined by a taste panel-Spring 2007.

Fruit quality parameters[1]	Organic	Inorganic
Watery Fruit	4.50 ± 0.4[2]	4.60 ± 0.7
Firmness	7.00 ± 0.3	6.38 ± 0.8
Texture	7.13 ± 0.5	6.88 ± 0.6
Flavour	6.25 ± 0.6	6.25 ± 0.6
Fruit Colour	6.63 ± 0.6	6.88 ± 0.7
Fruit Shape	7.38 ± 0.5	7.63 ± 0.7
Fruit Cracking	9.00 ± 0.5	8.63 ± 0.9
Gold Specks	6.25 ± 0.7	5.75 ± 0.8
Puffiness	7.50 ± 0.5	6.38 ± 0.8
Overall quality rating	6.76 ± 0.4	6.58 ± 0.3
Consumer choice	**50.0%**	**37.5%**
	Undecided : 12.5%*	

[1] All ratings by an 8 member panel were based on 1-10 scale with 10 being the best.
[2] Data presented are the means ± SE.
* One panellist decision was undecided.

1.3.8. Fruit Total soluble solids (TSS), pH, Firmness and Compression

Liquid feed and organic media did not significantly affect the studied tomato fruit quality parameters (TSS, pH, Firmness, and Compression), according to the ANOVA analysis. There were no significant liquid fertilizer and media interactions for fruit quality attributes (Table 24).

Table 24. Tomato fruit quality attributes of organic and inorganically grown tomatoes Spring 2007.

Treatments	TSS (^{o} Brix)	pH	Firmness (N/mm)	Compression (N/mm)
Liquid Feed[1]				
IF 1	4.81	3.99	1.67	3.32
OF 2	3.78	4.01	1.48	3.73
OF 3	4.04	3.99	1.79	3.07
OF 4	3.90	3.96	1.76	3.43
LSD (P=0.05)	1.38	0.14	0.44	1.84
Media[2]				
M 1	3.84	3.99	1.67	3.26
OM 2	4.04	3.98	1.60	3.09
OM 3	4.39	4.00	1.71	3.49
OM 4	4.26	3.99	1.73	3.70
LSD (P=0.05)	0.99	0.04	0.36	4.41
F-test[3]				
Liquid Feed(LF)	0.1218	0.7520	0.2676	0.7732
Media (M)	0.6243	0.7555	0.8670	0.7852
LF X M	0.4996	0.3758	0.3621	0.8649

[1] IF1= Inorganic, OF2 = Agrowchem OF3 =Pure Blend and OF4 = Agrogreen
[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)
[3] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

1.4. Conclusions

Results from this experiment confirmed the effectiveness of the in-house formulated organic media (peat-based+ Soymeal) for organic tomato production. The pH and EC values in OM3 (Peat+ 20L Soymeal) and OM4 (Peat + 40L Soymeal) were between 5.6- 6.1, 2.5-3.0, respectively; well within recommended ranges for greenhouse tomato production. During mid- and late season, organic media OM3 and OM4 had optimum levels of Nitrogen. Our in-house formulated organic media (Peat + 20 or 40 L soymeal) and our composting process achieved rich supplies of nitrogen for a long season tomato crop. Furthermore, the organic media OM3 and OM4 resembled closely the conventional rockwool (M1) and Coco (OM2) in terms of tissue N, K, Ca, Fe, Cu, Zn and B content. In general, plants grown in media OM3, OM4 and M1 had marginally lower micronutrient content than plants grown on OM2.

Adding of soymeal in the medium significantly affected plant height (P <0.0001). Plant height at 70 DAP was significantly greater in organic media OM3 and OM4 (150-161 cm), as compared to control treatments OM2 and M1 (110 - 112 cm); this difference was also present at 180 DAP (334-349 vs. 322-327 cm, respectively).

On the average, liquid feeds OF3, OF4 and OF2 recorded marketable yields of 22.5, 17.1,and 15.7 kg m^{-2}, respectively; which, was -8%, -36%, and -30% with respect to the inorganic control (IF1). Also, on the average, the organic media OM4, OM3 and OM2 recorded marketable yields 22.5, 20.6, and 17.9 kg m^{-2}, which were +19%, +10% and -4% with respect to rockwool (M1). Accordingly, liquid feed OF3 resulted in significantly higher average fruit size compared to feeds OF4 and OF2. Furthermore, the seasonal average fruit weight with the in-house blend organic media OM3, OM4, ranged over 174.3-174.4 g, which was 6 g higher than with rockwool (M1).

Organic liquid feed × media interactions had a significant impact on marketable yield. The highest seasonal marketable yields achieved with the best combinations or organic liquid feeds with organic media were 23.6 and 21.2 Kg m^{-2} for the combinations OF3 x OM3 and OF2 x OM4, respectively; these yields represented 92.2 and 82.3 of the rockwool (inorganic control), or 95.2 and 85.5 % of the coco peat (organic control, but with an inorganic feed) marketable yields; the best marketable yield achieved this year with organic means (i.e. 92.2 of the rockwool control) represents a significant improvement over the corresponding figure in 2006 (i.e. only 75%).

Also, in terms of early marketable yield, there was hardly any difference between several organic methods (e.g. OF2 x OM4, OF3 x OM3 and OF4 x OM4) and the rockwool control (10.4, 11.0, 10.5, and 11.7 Kg m^{-2}, respectively).

From the results of our two season study (spring 2006 and spring 2007), it can be concluded that the most promising combination of media and feeds for organic tomato production were the combinations of organic mix OM4 (Peat+ Soymeal 40 L) with liquid feeds: OF3 (Pure Blend), OF4 (Agrogreen), and OF2 (Agrowchem).

2. Fall 2007 – Cucumber crop

2.1. Introduction

In 2006 we used substrates comprised of peat moss in combination with varying rates of soymeal (compost) along with organic liquid feeds in the production of greenhouse tomatoes and cucumber with reasonable success. We found that, our in-house blend of organic growing media with commercially available liquid feeds supplied sufficient nutrients to a long season tomato crop (8 month-Spring 2006) as well to a short season cucumber crop (4 month-Fall 2006). However, the Fall 2006 season cucumber experimental results were treated as inconclusive because of a heavy powdery mildew infestation of the crop, which resulted in reduced fruit production rates across all treatments. In accordance with the research plan, a second experiment on cucumber was conducted during Fall 2007.

Objectives of this study were:

- To identify commercially available organic media, formulate new organic media, and evaluate both as substrates for the production of cucumber and to develop appropriate nutrient feedings based on commercially available organic liquid fertilizers.
- To develop complete (integrated) methods for the organic production of cucumber production and to provide appropriate detailed recommendations to the greenhouse industry.
- To assess the commercial feasibility of organically grown greenhouse vegetables.

2.2. Materials and methods

2.2.1. General crop information

Greenhouse cucumber seed (*Cucumis sativus* L. Cultivar 'Addison') was sown in 2.6×3.9×3.9" rockwool blocks, and in 4×4×4" fibre pots filled with 800 ml peat moss mix on July 27, 2007. For the first week after seeding, both the rockwool blocks and the fibre pots were watered daily with tap water. Subsequently, transplants in rockwool blocks were fed with a standard transplant nutrition solution while the transplants in fibre pots were fed with organic liquid feed (Pure Blend diluted 400 times with tap water). Final planting in the greenhouse was done on August 15, 2007 according to the experimental plan (Figure 1).

Crops were raised on organic media filled plastic pots (20 L Capacity) or on rockwool (50 x 20 x 10 cm^3) and coco peat slabs (33 x 22 x 5 cm^3) arranged on raised troughs. Cultural practices resembled those of commercial production. Plants were fertigated 4-5 times daily using 4 L h^{-1} emitters. The frequency and volume of fertigation was adjusted according to plant growth and season. Fertigation was controlled by time clocks. The EC, pH and volume of fertigation and leachate solution were measured on a daily basis.

Greenhouse environment control was with an Argus Control ® System. Greenhouse day/night temperature was set at 22/20^oC and ventilation temperature was set at 2^oC above the heating temperature set point. Relative humidity was maintained at 75±10% using ventilation and misting throughout the growing season. Greenhouse climate conditions (temperature and humidity) throughout the cropping season are presented in Figure 2.

Biological agents were introduced for the control of thrips and whitefly immediately after planting. To control aphids, lady bug biological agents were introduced on October1, 2007. Powdery mildew was found during the mid-season growth stage. Mildew infested lower leaves were removed from affected plants, to manage the disease. In addition severe incidence of stem blight (Oct 25-Nov10) resulted in loss of 7% plants which had a significant impact on fruit yield in late season.

Fruit harvest was from September 09 to December 13, 2007. The crop was terminated on December 14, 2007.

2.2.2. Organic media and organic liquid feeds

Three organic media and rockwool were tested. One of them was coir (Vgrove Inc., St. Catharine, Ontario), a coarse fibre extracted from the fibrous outer shell of coconut and widely used in greenhouse vegetable production. In this trial coir was considered as an organic control treatment (OM2), while rockwool (M1) was used as an inorganic control. Organic mix-1 (OM3) was prepared by blending 0.66 m^3 (6 bags) of peat moss with 0.33 m^3, (3 bags) of vermiculite, 3 kg of limestone (pulverized FF calcitic 40% Ca), 3 kg of ground limestone (dolomitic, 21% Ca + 12% Mg), 600 grams of potassium sulphate, and 20 L of soymeal. OM4 was the same as OM3 except for the soymeal content, which was doubled to 40 L (Table 1).

Two organic liquid feeds were tested (Table 2). One of the organic feeds (OF2) used was the Agrowchem (Higrocorp-I), which was a blend of Nitro Organo (5-0-0), Liquid Bone Meal (0-2-0), Spurt (2-0-1), Agro Kelp (0-0-5) and Bat Guano (0-4-0) (all products of Agrowchem Inc., Kingston, Ontario). Nitro Organo is manufactured as a liquid organic nitrogen source. Liquid Bone Meal is derived from bone meal and organic acid. Spurt is derived from sea weed extract (kelp) and amino acids (protein hydrolysate and potassium hydroxide). Agro Kelp contains a combination of seaweed extracts (kelp). Liquid feed OF4 was Agrowchem (Higrocorp-II) at half the strength of OF2. The other organic liquid feed used was Pure Blend (OF3; 3-1.5-4) (American Agri-tech, Tempo, AZ, USA), which is derived from fish meal, composted sea bird guano, sea kelp, rock phosphate, potassium carbonate, magnesium carbonate, calcium carbonate, and other ingredients (raw sugarcane, humic acid, silica clay extract and amino acids). A standard nutrient solution schedule for cucumber was used as inorganic control (IF1; Table 3).

2.2.3. Experimental design

The experiment was laid out as a split-plot design. The main plot consisted of 4 liquid feeds: Inorganic (IF1), Agrowchem (OF2), Pure Blend (OF3) and Agrowchem (OF4). Each main plot was split into 4 sub-plots to accommodate 4 media: rockwool (M1), coir (OM2), organic mix-1 (OM3) and organic mix-2 (OM4) (Table 1, 2). Both the liquid feeds and the substrates were randomly assigned to the main plots and sub-plots. There were 16 treatment combinations and each was replicated in 4 blocks; this comprised a 64-plot experiment. Each plot consisted of 3 plants grown individually in 20 L plastic pots for the treatments OM3 and OM4 or on rockwool or coir slabs for M1 and OM2, respectively.

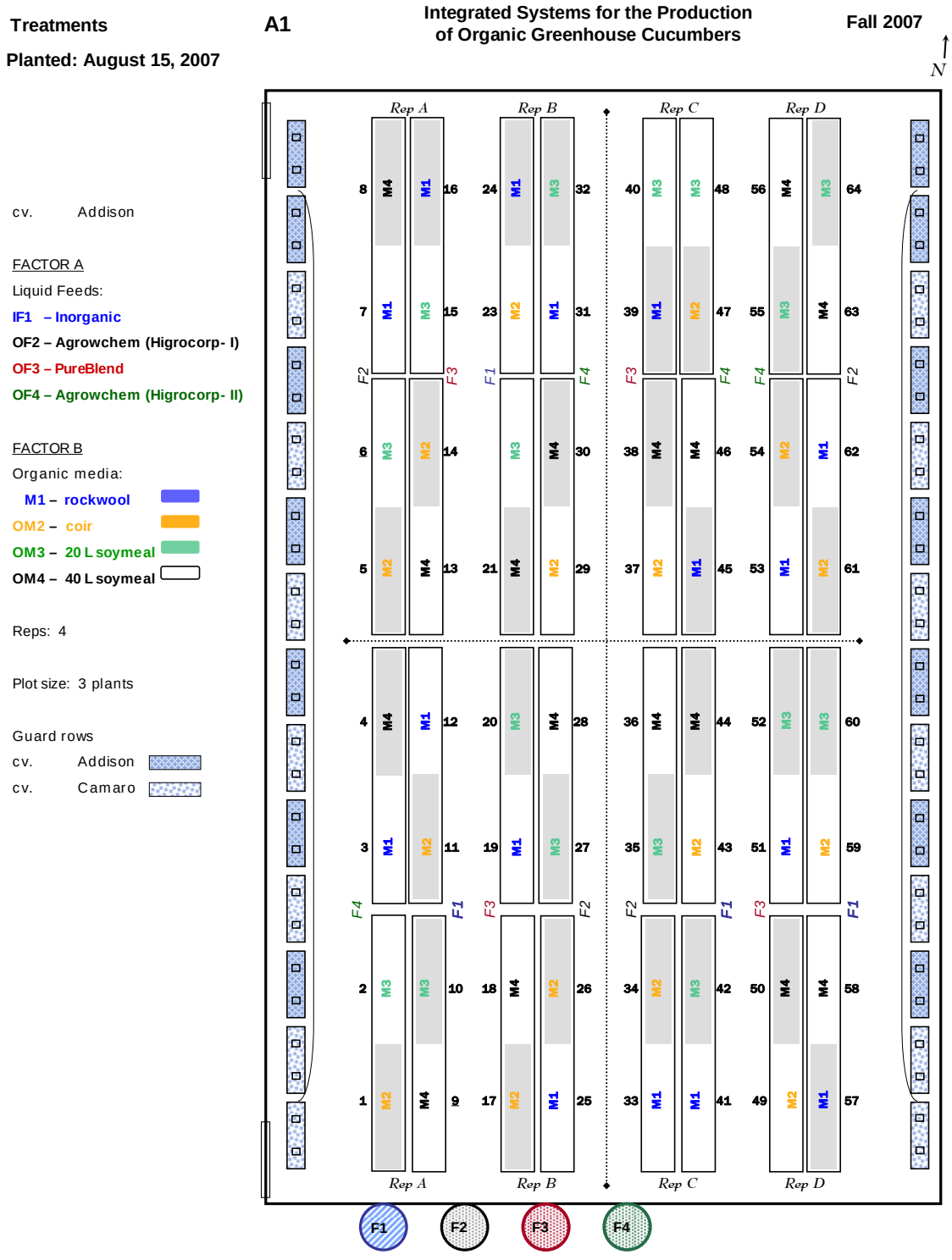
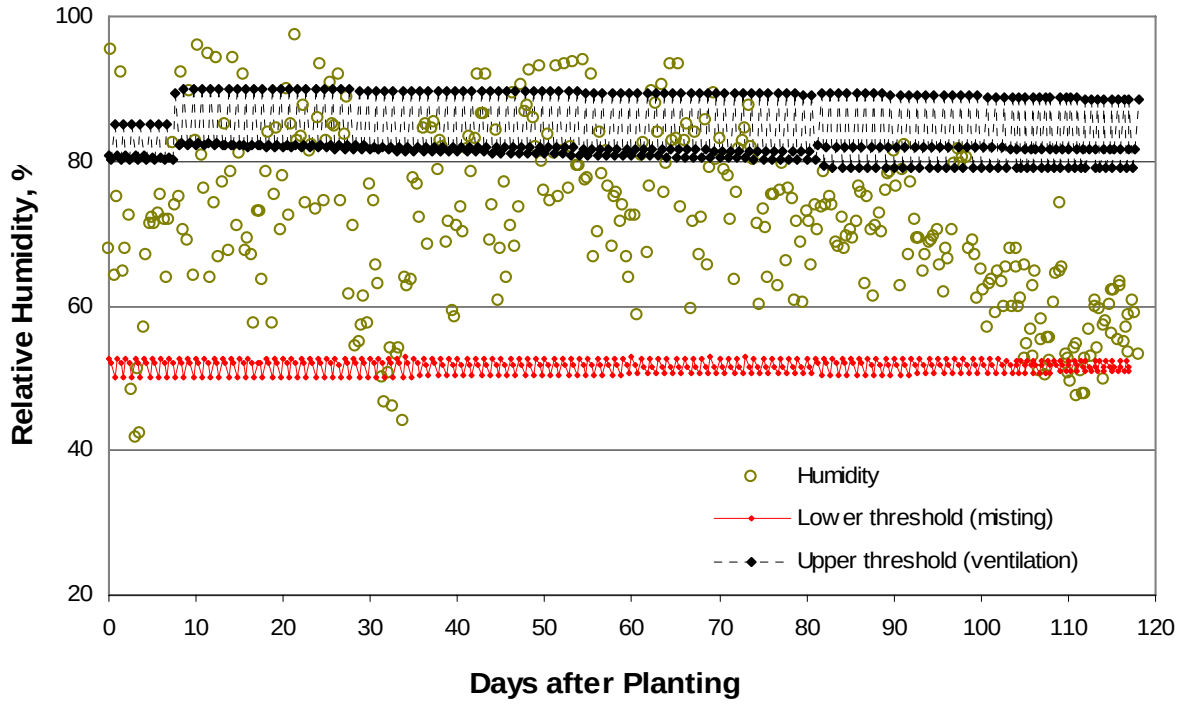


Figure 1. Split-plot experimental design of organic cucumber production. Fall 2007.



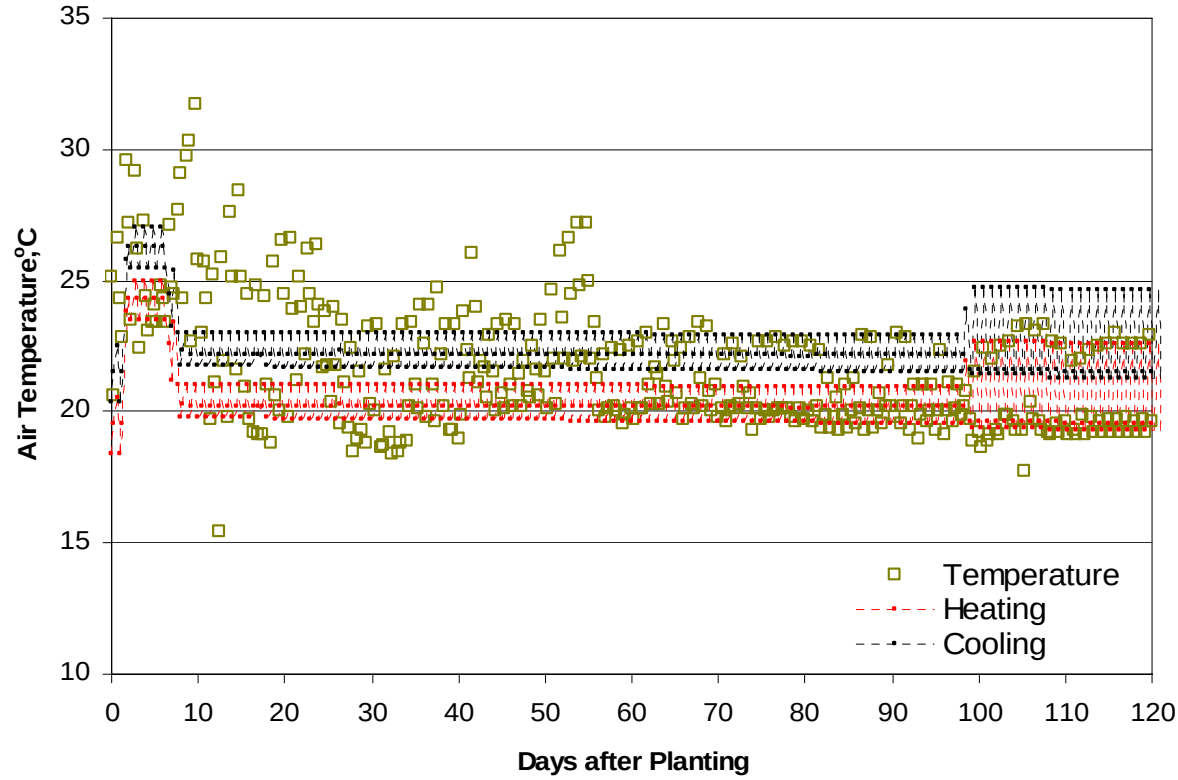


Figure 2. Temperature and relative humidity conditions in the greenhouse, Fall 2007.

Table 1. Media used as substrates in the Cucumber Fall 2007 experiment.

Substrates	Code	Ingredients
Rockwool	M1	
Coco coir	OM2	
Organic mix-1	OM3	6 bags (0.11 cubic metres, each) of peat moss 3 bags (0.11 cubic metres, each) of vermiculite 3 kg of limestone (pulverized FF calcitic 40% Ca) 3 kg of ground limestone (dolomitic, 21% Ca + 12% Mg) 600 grams of potassium sulphate 20 L of Soymeal
Organic mix-2	OM4	6 bags (0.11 cubic metres, each) of peat moss 3 bags (0.11 cubic metres, each) of vermiculite 3 kg of limestone (pulverized FF calcitic 40% Ca) 3 kg of ground limestone (dolomitic, 21% Ca + 12% Mg) 600 grams of potassium sulphate 40 L of Soymeal

Table 2. Organic liquid feeds, Fall 2007, Cucumber experiment.

Liquid feed treatment	Supplier	Fertilizer	(N P K)	Dilution
*IF1 (Inorganic)	Standard cucumber fertigation schedule for rockwool grown crops			
OF2	Agrowchem Inc.	Nitro Organo	5-0-0	1:400
		Liquid bone meal	0-2-0	1:400
		Spurt	2-0-1	1:400
		Agrokelp	0-0-5	1:400
		Bat Guano	0-4-0	1:400
OF3	American Agritech	Pure Blend	3-1.5-4	1:300
OF4	Agrowchem Inc.	Nitro Organo	5-0-0	1:800
		Liquid bone meal	0-2-0	1:800
		Spurt	2-0-1	1:800
		Agrokelp	0-0-5	1:800
		Bat Guano	0-4-0	1:800

* IF 1 (Inorganic) - Standard Fall cucumber crop fertigation schedule for rockwool grown crops

Inorganic liquid feed nutrient solution (IF1) was the standard Fall cucumber crop fertigation schedule for rockwool-grown crops (Papadopoulos, 1994; Table 3).

Table 3. Standard nutrient solution for cucumber crop (Papadopoulos, 1994).

Days after planting	$N\text{-}N0_3$	$N\text{-}NH_4$	P	K	Ca	Mg	Fe	Mn	S
Transplant solution	220	12	63	351	182	48	2.5	0.78	400
1	201	11	39	231	209	33	1.4	0.4	400
2-7	176	8	29	228	152	25	1.4	0.4	400
8-11	195	9	32	250	225	27	1.4	0.4	400
12-14	210	10	37	284	225	33	1.4	0.4	400
15-21	244	12	44	350	225	35	1.4	0.4	400
22-End	226	18	37	323	158	30	1.4	0.4	400

2.2.4. Substrate nutrient content, pH and EC

Media samples were collected on August 15, 2007 (at planting), October 22, 2007 (70 DAP; mid-season) and 14 December 2007 (122 DAP; end of the crop) and submitted to Stratford Agri Analysis to monitor their nutritional status.

2.2.5. Leachate measurement

Nutrient solution and leachate volume, EC and pH were recorded daily, for each of the liquid feed treatments.

2.2.6. Leaf tissue analysis

Leaf tissue samples were collected on October 18, 2007 (64 DAP; mid-season), and submitted to Stratford Agri Analysis to monitor the nutritional status of the plants.

2.2.7. Visual ratings

Visual rating was performed twice during the season. Plants were rated on a 1-5 scale (5=excellent; 4=great; 3=average; 2=fair; 1=poor) for characteristics of Visual Growth Score, Nutrient Deficiency, Leaf-Characters and Fruiting. Nutrient deficiency was measured as the extent of symptoms on leaf with a score of 5 as having no deficiency. Leaf characters were measured as the

degree of colour and size with a score of 5 as having dark green with normal size. Fruiting with a score of 5 was considered normal fruiting.

2.2.8. Growth measurements

Growth measurements were performed on October 10, and November 09, 2007; 57 and 87 Days after planting (DAP), respectively. On each sampling occasion, single plant measurement of plant height, leaf number (longer than 10 cm in length), stem diameter, leaf area and chlorophyll readings using the SPAD 502 chlorophyll meter(Minolta, Osaka, Japan), of the 5^{th} and 10^{th} leaf from the top of each plant were measured and recorded. Stem extension and number of leaves on November 09, 2007 was measured with reference to a stem clip placed at the top of each plant on October 10.

2.2.9. Fruit yield

Fruit from each plot (three plants /plot) was harvested everyday and graded individually to marketable: Grade #1 (extra large, large, medium and small) and grade #2 and unmarketable according to commercial grading standards (Ontario Ministry of Agriculture, Food and Rural Affairs, Regulation 378/90). Sixty nine harvests were performed from September 09 to December 14, 2007.

2.2.10. Statistical analysis

The data were analysed using the General Linear Model (GLM) (SAS Institute, Cary, NC, USA). Significance of main factors and interactions were tested with an F-test at the 0.95 level of confidence.

2.3. Results and discussion

2.3.1. Liquid feed and media nutrient content, pH and EC

The pH, EC and nutrient status in media at planting time, and in liquid feeds and media at mid- and late-season are shown in Tables 4, 5 and 6.

Table 4 shows pH and EC values of organic media at planting time. Organic media OM3 and OM4 had pH and EC values in the ranges of 5.8-5.9 and 1.86-2.07, respectively (Table 4). At planting time, the N in OM3 (20 kg soymeal) was all in the nitrate form, whereas in OM4 (40 kg soymeal) 58 % was as NO_3^- , and 42 % was as NH_4^+ (Table 4). Initial levels of P, K and Fe were higher in OM4, compared to OM3.

Statistical analysis of pH, EC and nutrient status, as affected by liquid feed and organic media at mid-season showed significant differences (Table 5). All the organic liquid feeds OF2, OF3 and OF4 had pH values in the range of 5.9-6.3, which was close to those of the inorganic liquid feed IF1 (6.4). However, organic liquid feeds OF2, OF3 and OF4 had low EC values (1.0-1.2 mS cm^{-1}), compared to IF1 (2.5 mS cm^{-1}). Organic liquid feed OF3 had higher content of N-NO_3^-, K, Ca, Mg and Fe, as compared to OF2 and OF4 (Table 5).

In late-season (122 DAP), organic liquid feed OF3 and the inorganic liquid feed IF1 had about the same pH, EC and nutrient status. Similarly there was little difference in terms of pH, EC and nutrient content between OF2, OF4 (Table 6).

Table 4. Organic media nutrient content (ppm), pH and EC (mS cm^{-1}), August 15, 2007(At planting), experiment with Cucumbers.

Treatments	$N\text{-}NO_3$	$N\text{-}NH_4$	P	K	Ca	Mg	Fe	Mn	Cu	Zn	Bo	Mo	Na	pH	EC
Media[1]															
M 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OM 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OM 3	132 [3]	5	30	180	105	97	1.0	0.3	0.0	0.0	0.1	0.0	21	5.9	1.86
OM 4	83	63	63	224	87	73	3.5	0.7	0.0	0.1	0.2	0.0	21	5.8	2.07

[1] IF1-Inorganic, OF2 = Agrowchem I , OF3 =Pure Blend and OF4 = Agrowchem II.
[2] M1-Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added).
[3] Means of three observations

Table 5. Liquid feed and organic media nutrient content (ppm), pH and EC (mS cm^{-1}), October 22, 2007(Mid-season), experiment with Cucumbers.

Treatments	$N\text{-}NO_3$	$N\text{-}NH_4$	P	K	Ca	Mg	Fe	Mn	Cu	Zn	Bo	Mo	Na	pH	EC
Liquid Feed[1]															
IF 1	90.4	2.9	13.6	256.7	160.9	124.7	1.1	0.20	0.10	0.11	0.22	0.03	79	6.4	2.50
OF 2	37.3	5.5	84.0	52.9	52.6	40.1	1.4	0.30	0.03	0.06	0.10	0.01	130	6.3	1.21
OF 3	56.3	5.5	12.9	65.2	74.9	59.7	4.4	0.16	0.03	0.24	0.50	0.02	48	5.9	1.08
OF 4	29.8	7.9	28.2	46.9	50.8	39.2	1.2	0.21	0.03	0.07	0.09	0.01	65	6.1	1.01
Media[2]															
M 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OM 2	5.0	2.6	16.2	52.4	15.3	9.4	0.8	0.03	0.06	0.09	0.17	0.01	47	6.6	0.48
OM 3	87.2	5.9	31.0	120.4	128.3	102.8	2.5	0.19	0.03	0.12	0.22	0.02	97	6.0	1.96
OM 4	68.1	7.9	56.9	143.6	110.9	85.6	2.7	0.40	0.03	0.16	0.29	0.02	97	5.9	1.91
F-test[3]															
Liquid Feed (LF)	**	**	**	**	**	**	**	**	**	**	0.1360	**	**	**	**
Media (M)	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
LF X M	**	0.7678	**	**	**	**	**	0.3053	**	**	0.2194	**	**	**	0.6259

[1] IF1-Inorganic, OF2 = Agrowchem I, OF3 =Pure Blend, and OF4 = Agrowchem II.
[2] M1-Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added).
[3] *, ** indicate significance of the F-test at the 5 and 1% level, respectively.

Table 6. Liquid feed and organic media nutrient content (ppm), pH and EC (mS cm^{-1}), Dec 14, 2007(Late-season analysis), experiment with Cucumbers.

Treatments	$N\text{-}NO_3$	$N\text{-}NH_4$	P	K	Ca	Mg	Fe	Mn	Cu	Zn	Bo	Mo	Na	pH	EC
Liquid Feed[1]															
IF 1	121.5	5.6	45.6	202.1	94.2	72.6	1.7	0.33	0.02	0.10	0.29	0.03	85	5.8	2.00
OF 2	75.4	4.0	27.3	122.9	56.7	43.9	1.2	0.23	0.02	0.08	0.22	0.02	56	4.4	1.23
OF 3	115.6	4.0	29.4	179.9	84.6	65.2	1.1	0.22	0.02	0.09	0.26	0.03	53	5.2	1.69
OF 4	92.1	5.4	34.3	143.5	68.6	52.3	1.5	0.28	0.02	0.08	0.23	0.03	78	5.3	1.50
Media[2]															
M 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OM 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OM 3	97.5	4.9	36.0	141.3	72.5	56.1	1.5	0.29	0.02	0.09	0.29	0.03	72	5.1	1.55
OM 4	104.8	4.6	32.3	183.0	79.6	61.1	1.3	0.24	0.02	0.08	0.21	0.03	64	5.3	1.66
F-test[3]															
Liquid Feed (LF)	0.5015	0.3208	0.2204	0.5438	0.4970	0.5448	0.2187	0.1861	0.4704	0.7931	0.8780	0.4942	0.2936	0.5682	0.3994
Media (M)	0.7610	0.7488	0.5715	0.3275	0.7014	0.7479	0.3008	0.1880	0.7263	0.5945	0.2671	0.6757	0.5676	0.7897	0.7353
LF X M	0.2665	0.8353	*	0.1968	0.2781	0.2037	0.3735	0.1825	0.3679	0.0882	0.0401	0.2341	0.0034	0.5288	04776

[1] IF1-Inorganic, OF2 = Agrowchem (Higrocorp-I), OF3 =Pure Blend and OF4 = Agrowchem (Higrocorp-II).
[2] M1-Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added).
[3] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

2.3.2. Nutrient solution and leachate pH and EC

The organic liquid feeds and media solution (i.e. fertigation and leachate) pH and EC weekly mean values for the entire crop season are depicted in Figures 3, and 4. The seasonal pH value of liquid feeds OF1 and OF3 had similar trends (Figure 3); in contrast, OF2 and OF4 had relatively higher pH values towards the 13-18th week. The EC of organic liquid feeds OF2, OF3 and OF4 was low, when compared to the EC of the Inorganic liquid feed IF1 (Figure 3).

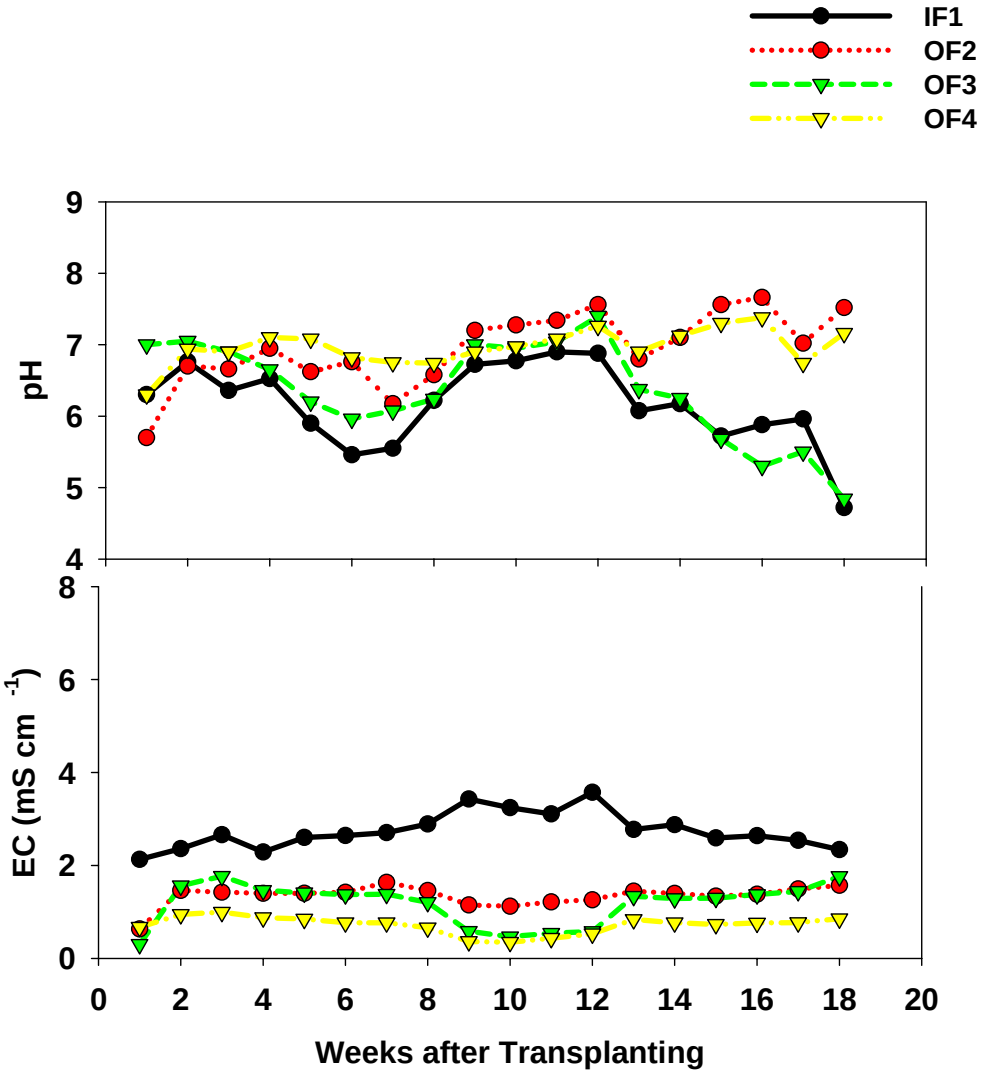


Figure 3. Variation in the fertigation solution pH and EC during the Fall 2007 Cucumber crop.

The seasonal leachate pH value for all the liquid feeds (IF1, OF2, OF3 and OF4) was similar (6.2 -7.0) for most of the growing season (week 4-16). The EC of the inorganic liquid feed IF1 was high (2.8- 4.8 $mScm^{-1}$), while the leachate EC of OF2, OF3 and especially of OF4, was rather low (Figure 4).

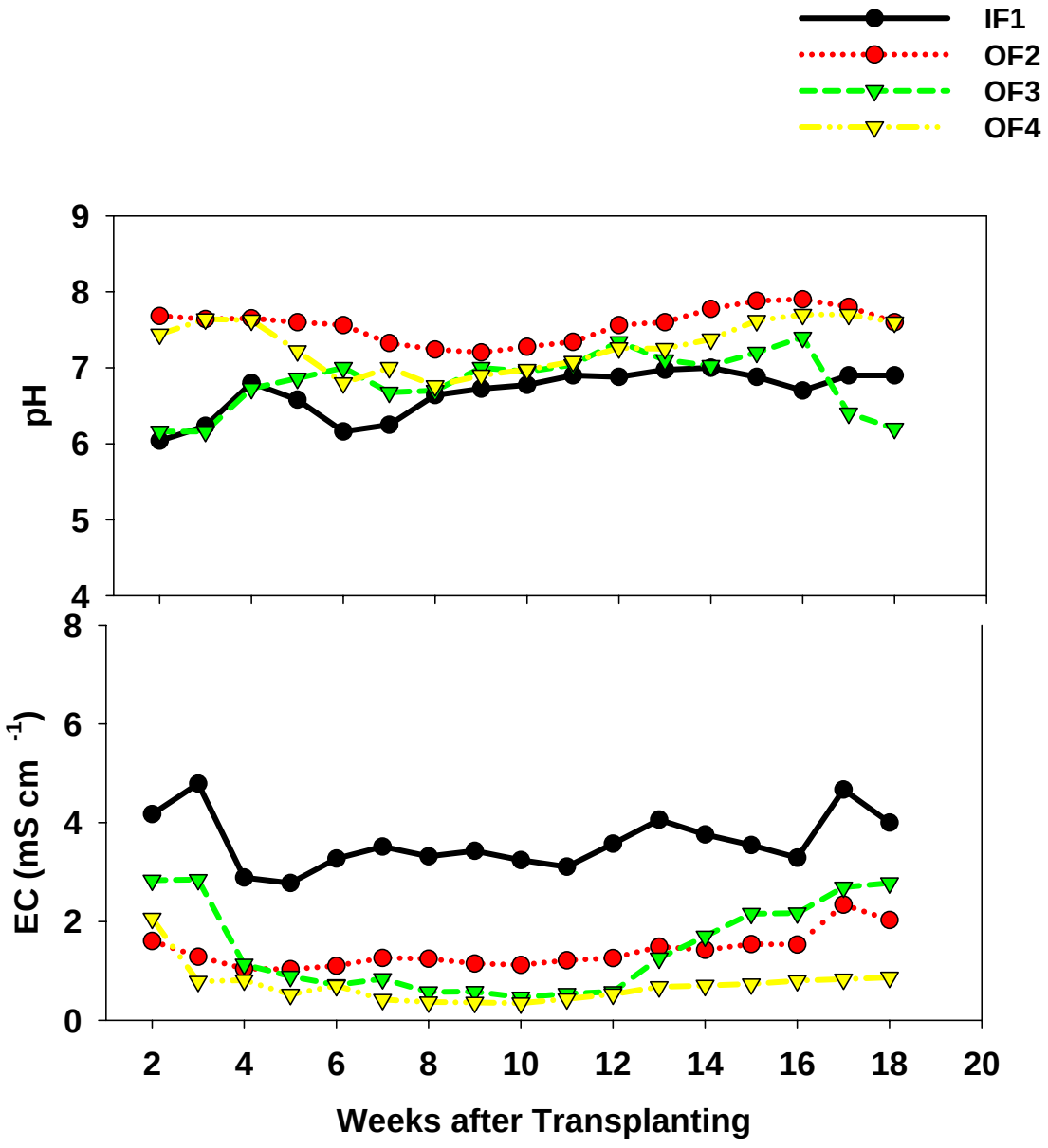


Figure 4. Leachate pH and EC as affected by the liquid feed treatments during Fall 2007, Cucumber crop.

2.3.3. Nutritional status

Table 7 shows results of leaf tissue analysis for macro and micro nutrients at mid-season (65 DAP).

Nitrogen concentration in leaf tissue when plants were grown on organic media and fed with IF1, OF2 and OF3 was within the recommended levels for cucumber production (N=4.00-6.00 %); however, when liquid feed OF4 was used it was deficient. Phosphorus was sufficient at all treatment combinations. Potassium was deficient in most liquid feed and media combinations, even with standard inorganic liquid feed application (Table 7). Liquid feeds IF1, OF2 and all media combinations resulted in Ca deficiency. Magnesium and micronutrients (Fe, Mn, Cu and Zn) were sufficient at all combinations of organic liquid feed and media. Boron was deficient at all IF1, OF2 and OF4 liquid feed and media combinations. Interestingly, when OF3 was used B was in sufficient supply.

The results of the tissue sample analysis showed that K and Ca were occasionally in deficiency; N and P were always in sufficiency.

Table 7. Nutrient content of Cucumber leaves as affected by liquid feed and media treatments, October 18, 2007(Mid-season).

Nutrient Content	Liquid feeds[1]															
(Adequancy range[3])	IF1				OF2				OF3				OF4			
	Media[2]															
	OM1	OM2	OM3	OM4	OM1	OM2	OM3	OM4	OM1	OM2	OM3	OM4	OM1	OM2	OM3	OM4
N (4.0-6.0) %	5.47^{S}	5.29^{S}	5.50^{S}	5.55^{S}	5.53^{S}	5.05^{S}	4.69^{S}	4.96^{S}	4.98^{S}	4.93^{S}	4.60^{S}	5.05^{S}	**3.36^{D}**	**3.53^{D}**	**3.32^{D}**	**3.49^{D}**
P (0.6-1.0) %	0.80^{S}	0.77^{S}	0.91^{S}	0.83^{S}	1.17^{H}	1.01^{S}	1.12^{H}	0.97^{S}	0.60^{S}	0.59^{L}	0.55^{L}	0.61^{S}	0.70^{S}	0.73^{S}	0.74^{S}	0.80^{S}
K (3.5-4.0) %	**2.91^{D}**	**3.08^{D}**	3.66^{S}	3.43^{L}	**2.35^{D}**	**2.40^{D}**	**2.43^{D}**	**2.53^{D}**	**2.19^{D}**	**2.28^{D}**	**2.03^{D}**	**2.40^{D}**	**1.54^{D}**	**1.94^{D}**	**1.97^{D}**	**2.20^{D}**
Ca (2.4-3.2) %	**2.08^{D}**	**2.26^{D}**	**2.17^{D}**	**2.24^{D}**	**1.79^{D}**	**1.96^{D}**	**1.77^{D}**	**1.84^{D}**	2.72^{S}	2.74^{S}	2.42^{S}	2.00^{S}	3.45^{H}	3.25^{S}	3.02^{S}	2.67^{S}
Mg (0.36-0.5) %	0.69^{H}	0.74^{H}	0.74^{H}	0.84^{H}	0.48^{S}	0.48^{S}	0.58^{H}	0.57^{H}	0.99^{H}	0.92^{H}	0.82^{H}	0.83^{H}	0.73^{H}	0.66^{H}	0.96^{H}	0.93^{H}
Fe (85-100) ppm	145^{H}	98^{S}	101^{S}	113^{H}	164^{H}	106^{H}	110^{H}	106^{H}	189^{H}	125^{H}	115^{H}	114^{H}	101^{S}	81^{L}	81^{L}	88^{S}
Mn (55-165) ppm	102^{S}	57^{L}	**44^{D}**	66^{S}	162^{S}	134^{S}	145^{S}	138^{S}	73^{S}	69^{S}	85^{S}	85^{S}	259^{H}	178^{H}	190^{H}	176^{H}
Cu (7-12) ppm	12^{S}	12^{S}	14^{H}	12^{S}	14^{H}	10^{S}	11^{S}	9^{S}	12^{S}	11^{S}	8^{S}	8^{S}	9^{S}	10^{S}	9^{S}	10^{S}
Zn (40-60) ppm	40^{S}	**32^{D}**	48^{S}	50^{S}	39^{L}	48^{S}	42^{S}	45^{S}	51^{S}	56^{S}	70^{H}	64^{H}	75^{H}	67^{H}	56^{S}	62^{H}
B (55-75) ppm	**34^{D}**	**35^{D}**	**37^{D}**	**36^{D}**	**32^{D}**	**40^{D}**	**32^{D}**	**34^{D}**	**76^{H}**	**90^{H}**	**82^{H}**	**75^{S}**	**30^{D}**	**39^{D}**	**37^{D}**	**40^{D}**

[1] IF1-Inorganic, OF2 = Agrowchem I, OF3 =Pure Blend and OF4 = Agrowchem II.
[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)
[3] Results Key (H= High, S= Sufficient, L= Low and D= Deficient).

2.3.4. Growth and development

2.3.4.1. Visual growth score

Tables, 8, and 9 show visual ratings of Growth Vigour Score, Nutrient Deficiency, Leaf-Characters and Fruiting at 30 and 87 DAP.

Early in the season (30 DAP), the effects of liquid feed and media on visual ratings (Growth Vigour Score, Nutrient Deficiency, Leaf-Characters and Fruiting significant) were significant ($P<0.0001$). Liquid feeds IF1 and OF3 received higher ratings (score of 3.9- 4.1) for most of the characters (Table 8). Organic media OM3 and OM4 also received high ratings (score of 3.9-4.4) which were significantly higher than those of the controls (M1-rockwool; OM2-coco coir). Medium OM2 received low ratings (2.4-2.8) for growth vigour. Similar trends were observed at late-season (87DAP). Finally, the fruit abortion percentage was highest with the organic liquid feed OF4 and organic media OM4 treatments (26.5 % and 25.1%, respectively).

Table 8. Effect of organic liquid feed and media treatments on visual ratings. Cucumber experiment, September 13, 2007.

Treatments	Visual Growth Score	Nutrient Deficiency	Leaf Characters	Fruiting
Liquid Feed[1]				
IF 1	3.9 ± 0.9 a[3]	4.3 ± 0.1 a	4.1 ± 0.1 a	4.1 ± 0.1 a
OF 2	3.0 ± 0.3 b	3.3 ± 0.4 b	3.2 ± 0.3 b	3.1 ± 0.3 b
OF3	3.8 ± 0.1 a	4.1 ± 0.1 a	4.0 ± 0.0 a	4.0 ± 0.0 a
OF4	2.5 ± 0.3 c	2.6 ± 0.4 c	3.0 ± 0.3 b	3.0 ± 0.3 b
Media[2]				
M 1	3.1 ± 0.3 b	3.2 ± 0.3 b	3.4 ± 0.2 b	3.4 ± 0.5 b
OM 2	2.4 ± 0.3 c	2.6 ± 0.4 c	2.8 ± 0.3 c	2.7 ± 0.4 c
OM 3	3.9 ± 0.2 a	4.1 ± 3.3 a	4.1 ± 0.9 a	4.1 ± 0.4 a
OM 4	3.8 ± 13 a	4.4 ± 1.8 a	3.9 ±0.9 a	3.9 ± 0.4 a
F-test[4]				
Liquid Feed(LF)	<0.0001**	<0.0001**	<0.0001**	<0.0001**
Media (M)	<0.0001**	<0.0001**	<0.0001**	<0.0001**
LF X M	<0.0001**	<0.0001**	<0.0001**	<0.0001**

[1] IF1= Inorganic, OF2 = Agrowchem-I OF3 =Pure Blend and OF4 = Agrowchem-II

[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added).

[3] Data presented are means ± SE; Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test.

[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

[5] Plants were rated on a 1-5 scale (5=excellent; 4=great; 3=average; 2=fair; 1=poor) for characteristics of Visual Growth, Nutrient deficiency, Leaf-Characters and Fruiting. Nutrient deficiency was measured as the extent of symptoms on leaf with a score of 5 as having no deficiency. Leaf characters were measured as the degree of colour and size with a score of 5 as dark green leaves with normal size. Fruiting was rated with a score of 5 when fruiting was normal.

Table 9. Effect of organic liquid feed and media treatments on visual ratings. Cucumber experiment, November 8, 2007

Treatments	Visual Growth Score[5]	Leaf Characters[5]	Total fruit[6] no	Aborted no	Fruit abortion (%)
Liquid Feed[1]					
IF 1	3.0 ± 0.2 a[3]	2.9 ± 0.3 a	19.7 ± 0.4 a	2.9 ± 0.5	(14.8)
OF 2	2.9 ± 0.2 a	2.7 ± 0.2 a	15.7 ± 0.9 b	2.5 ± 0.4	(19.6)
OF3	3.3 ± 0.2 a	3.1 ± 0.2 a	16.3 ± 0.3 b	3.7 ± 0.7	(22.3)
OF4	2.3 ± 0.2 b	1.8 ± 0.2 b	11.3 ± 0.6 c	3.1 ± 0.5	(26.5)
Media[2]					
M 1	2.7 ± 0.2 b	2.6 ± 0.3 ab	15.6 ± 1.0 ab	3.1 ± 0.5 ab	(20.3)
OM 2	2.8 ± 0.2 b	2.5 ± 0.3 b	15.1 ± 0.9 b	2.3 ± 0.5 b	(15.8)
OM 3	2.8 ± 0.2 b	2.4 ± 0.2 b	15.2 ± 1.2 b	2.6 ± 0.5 b	(22.0)
OM 4	3.3 ± 0.2 a	3.1 ±0.2 a	17.1 ± 0.4 c	4.3 ± 0.6 a	(25.1)
F-test[4]					
Liquid Feed(LF)	0.0214*	<0.0001**	0.0001**	0.4305	
Media (M)	0.0078**	0.256*	0.0962	0.0324*	
LF X M	0.0002**	0.0012**	0.6626	0.0741	

[1] IF1= Inorganic, OF2 = Agrowchem-I OF3 =Pure Blend and OF4 = Agrowchem-II

[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added).

[3] Data presented are means ± SE; Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test.

[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

[5] Plants were rated on a 1-5 scale (5=excellent; 4=great; 3=average; 2=fair; 1=poor) for characteristics of Visual Growth, Nutrient deficiency, Leaf-characters and Fruiting. Nutrient deficiency was measured as the extent of symptoms on leaf with a score of 5 as having no deficiency. Leaf characters were measured as the degree of colour and size with a score of 5 as dark green with normal size. Fruiting was rated with a score of 5 where fruiting normal.

[6] Fruiting data was collected on November 8 from the clip mark (effective fruiting region) to top of the leaf.

2.3.4.2. Growth measurements

Statistical analysis of plant growth measurements, as affected by liquid feed and media is presented in Tables 10-13.

Measurements at 57 DAP showed significant differences in plant height (P<0.0001), leaf number (P<0.0001), stem diameter (P=0.0230), and chlorophyll content (P=0.0044) due to liquid feed and media treatment combinations. Maximal plant height was observed with organic liquid feed OF3 (540.2 cm) and followed by OF2 (506.3 cm); while, minimal plant height was observed with liquid feed OF4 (443.5 cm). Plant height was significantly greater in organic media OM3 and OM4 (565.2 and 549.6 cm), compared to OM2 and M1 (469.8 and 522.6 cm), respectively (Table 10). Differences in stem extension from the 10^{th} leaf to top of the plant were not significant due to organic liquid feed and media.

At 57 DAP, leaf number was maximum with OF3 (48.0) and minimal with OF4 (40.4). The total number of leaves was also greater with OM4 (50.1) than with OM3 (48.8), OM2 (42.9) or M1 (45.3) (Table 10). Differences in stem diameter resulting from the liquid feed treatments were significant *(P=0.0230)*; plants grown with liquid feed OF3 or IF1 resulted in higher values (5.5-6.7 mm); while, media treatments had no effect on stem diameter. Statistical analysis of chlorophyll content showed significant effects of liquid feed and media treatments. Chlorophyll content in the plants grown with organic liquid feed OF2 resulted in higher values (35.3) which were comparable to those plants grown with the inorganic feed IF1 (35.3), while the minimal value was observed with OF4 (Table 11). Leaf area of the 5^{th} and 10^{th} leaf (Table 11) was affected significantly by liquid feed, but not by media. Maximum Leaf area of the 5^{th} leaf resulted with liquid feed OF2 or OF3 (591 and 549 cm^2, respectively). Leaf area of the 5^{th} leaf was lowest with liquid feed OF4 (469 cm^2).

At 87 DAP, plant growth measurements were affected significantly by organic liquid feeds and media. Maximum plant height was with IF1 (235.2 cm) followed by OF2 (202.3 cm) and OF3 (196.9 cm); while, minimal plant height was with liquid feed OF4 (138.8 cm) (Table 12). Leaf number was affected significantly by liquid feeds and media. Liquid feed OF3 resulted in maximal number of leaves (16.7) followed by OF2 (14.6); while, minimal leaf number was recorded with liquid feed OF4. Statistical analysis showed significant effects of organic media on leaf number (P=0.0228). The maximal leaf number was observed with organic media OM4

(17.4) which was 1.9 leaves higher than with the organic control OM2. Differences in stem diameter were not statistically significant (Table 12). Chlorophyll measurements on 87 DAP showed significant differences due to liquid feeds ($p<0.0001$). The chlorophyll content with the organic liquid feeds (OF2, OF3, and OF4) ranged over 32.1-32.4, which was 3.5 lower than with the inorganic control (IF1). Effects of media on chlorophyll content were not significant ($P=0.2134$) (Table 13).

Statistical analysis of leaf area of the 5^{th} and 10^{th} leaf at 87 DAP (Table 13) showed significant effects due to organic media. Maximal leaf area of the 5^{th} leaf was found with media OM3 and OM4 (494 and 459 cm^2), which was 13 % and 5 % higher than with the rockwool control (M1), respectively; similar trend was observed with respect to the 10^{th} leaf area (Table 13).

Table 10. Plant height, Leaf number and Stem diameter of cucumber as affected by the liquid feed and organic media treatments, October 10, 2007(57 DAP).

Treatments	Plant height (cm)	Stem extension 10th Leaf to Top of plant (cm)	Leaf. No (no plant^{-1})	Stem diameter (mm)
Liquid Feed[1]				
IF 1	616.7 ± 7.7 a[3]	116.4 ± 7.7	52.9 ± 0.9 a[4]	6.7 ± 0.4 a
OF 2	506.3 ± 22 c	110.7 ± 2.7	45.6 ± 1.6 c	5.5 ± 0.3 ab
OF3	540.2 ± 9.8 b	107.6 ± 2.3	48.0 ± 0.9 b	5.7 ± 0.4 a
OF4	443.5 ± 15 d	110.4 ± 2.8	40.4 ± 1.3 d	4.4 ± 0.4 b
Media[2]				
M 1	522.6 ± 22 b	115.7 ± 22	45.3 ± 1.7 b	5.1 ± 0.5
OM 2	469.8 ± 27 c	110.1 ± 2.7	42.9 ± 2.1 b	5.3 ± 0.5
OM 3	565.2 ± 13 a	111.1 ± 3.3	48.8 ± 0.9 a	6.1 ± 0.4
OM 4	549.6 ± 13 ab	108.1 ± 1.8	50.1 ±0.9 a	5.7 ± 0.4
F-test[4]				
Liquid Feed(LF)	<0.0001**	0.1103	<0.0001**	0.0230*
Media (M)	<0.0001**	0.2100	<0.0001**	0.1819
LF X M	0.0007**	0.7971	0.0004**	0.5407

[1] IF1= Inorganic, OF2 = Agrowchem-I OF3 =Pure Blend and OF4 = Agrowchem-II
[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added).
[3] Data presented are means ± SE; Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test
[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

Table 11. Chlorophyll content and Leaf area of cucumber as affected by the liquid feed and organic media treatments, October 10, 2007 (57 DAP).

Treatments	Chlorophyll content	Leaf Area (5^{th} Leaf) (cm^2)	Leaf Area (10^{th} Leaf) (cm^2)
Liquid Feed[1]			
IF 1	35.3 ± 0.7 a[3]	573 ± 22 a	869 ± 31 a
OF 2	35.3 ± 0.8 a	591 ± 26 a	641 ± 31 c
OF3	48.0 ± 0.9 a	549 ± 18 a	697 ± 30 b
OF4	40.4 ± 1.3 b	469 ± 28 b	505 ± 31 d
Media[2]			
M 1	33.3 ± 0.9 ab	553± 27	661 ± 53
OM 2	35.0 ± 1.0 a	524 ± 25	656 ± 49
OM 3	32.6 ± 0.6 b	545 ± 24	708 ± 34
OM 4	34.9 ± 0.7 a	553 ± 23	687 ± 41
F-test[4]			
Liquid Feed (LF)	0.0044**	0.0014**	<0.0001**
Media (M)	0.0209*	0.7958	0.4945
LF X M	0.3860	0.0625	0.0130*

[1] IF1= Inorganic, OF2 = Agrowchem-I, OF3 =Pure Blend, and OF4 = Agrowchem-II
[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added), and OM4= Organic mix-2 (40 L Soymeal added).
[3] Data presented are means ± SE; Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test.
[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

Table 12. Plant height, Leaf number and Stem diameter of cucumber as affected by the liquid feed and organic media treatments, November 10, 2007 (87 DAP)..

Treatments	Plant height[@] (cm)	Leaf. No[@@] (no plant^{-1})	Stem diameter (mm)
Liquid Feed[1]			
IF 1	235.2 ± 5.3 a[3]	20.3 ± 0.3 a[4]	7.3 ± 0.2
OF 2	202.3 ± 3.2 b	14.6 ± 1.3 c	7.2 ± 0.2
OF3	196.9 ± 3.7 b	16.7 ± 0.3 b	7.6 ± 0.2
OF4	138.8 ± 10 c	11.4 ± 0.7 d	6.8 ± 0.2
Media2			
M 1	184.0 ± 12	15.6 ± 1.0 ab	7.3 ± 0.2
OM 2	188.9 ± 12	15.5 ± 0.9 ab	7.1 ± 0.2
OM 3	196.9 ± 10	14.4 ± 1.5 b	7.2 ± 0.2
OM 4	203.3 ± 9	17.4 ± 0.7 a	7.4 ± 0.2
F-test[4]			
Liquid Feed(LF)	<0.0001**	<0.0001**	0.0513
Media (M)	0.1453	0.0228*	0.3616
LF X M	0.5777	0.0280*	0.0064**

[1] IF1= Inorganic, OF2 = Agrowchem-I, OF3 =Pure Blend and OF4 = Agrowchem-II
[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added), and OM4= Organic mix-2 (40 L Soymeal added).
[3] Data presented are means ± SE; Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test
[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.
@ : Stem extension was measured on Nov.10, 2007 from stem clip placed on Oct.10, 2007 to the top of the plant.
@@: Leaf number was counted on Nov.10, 2007 from stem clip placed on Oct.10, 2007 to the top of the plant.

Table 13. Chlorophyll content and Leaf area of cucumber as affected by the liquid feed and organic media treatments, November 10, 2007(87 DAP).

Treatments	Chlorophyll Content	Leaf Area (5^{th} Leaf) (cm^2)	Leaf Area (10^{th} Leaf) (cm^2)
Liquid Feed[1]			
IF 1	35.8 ± 0.6 a[3]	422 ± 15	530 ± 24 b
OF 2	32.4 ± 0.5 b	458 ± 18	586± 18 ab
OF3	32.1 ± 0.5 b	470 ± 13	626 ± 25 a
OF4	32.1 ± 0.6 b	473 ± 13	541 ± 25 b
Media[2]			
M 1	32.3 ± 0.6	437 ± 17 b	559 ± 32 ab
OM 2	32.9 ± 0.6	433 ± 18 b	586 ± 21 a
OM 3	33.9 ± 0.9	494 ± 14 a	524 ± 20 b
OM 4	33.3 ± 0.5	459 ± 21 ab	614 ± 20 a
F-test[4]			
Liquid Feed (LF)	<0.0001**	0.1471	0.0316*
Media (M)	0.2134	0.0148*	0.0316*
LF X M	0.1091	0.0009**	0.1171

[1] IF1= Inorganic, OF2 = Agrowchem-I, OF3 =Pure Blend, and OF4 = Agrowchem-II
[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added), and OM4= Organic mix-2 (40 L Soymeal added).
[3] Data presented are means ± SE; Means within organic liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test.
[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

2.3.5. Harvested yields

Effects of organic liquid feeds and media treatments on fruit yield were calculated from the record of number and weight of marketable and unmarketable fruit. Statistical analysis of cucumber fruit yield and yield components, as affected by organic liquid feeds and media and their interactions are presented in Tables 14-21.

2.3.5.1. Effect of organic liquid feed

Liquid fertilizer had significant effects on marketable, unmarketable and total yield (number) (P<0.0001; P<0.0089; P<0.0001, respectively) (Table 14). Liquid feeds OF3, OF2 and OF4 recorded progressively decreasing numbers of marketable (20.9, 16.6, and 12.2 no m^{-2}), unmarketable fruit (4.5, 2.8, and 2.5 no m^{-2}); and total fruit (25.4, 19.4, and 14.7 no m^{-2}), respectively. Specifically, OF3 and IF1 resulted in significantly higher unmarketable fruit number compared to OF2 and OF4. The Effects of liquid feeds on marketable, unmarketable and total yield (weight) were also significant (P<0.0001; P<0.0067; P<0.0001, respectively) (Table 15). Liquid feeds OF3, OF2 and OF4 resulted in marketable yield of 5.7, 4.6 and 3.4 kg m^{-2}, respectively, which translates to 0%, -19% and -40% with respect to the inorganic control (IF1).

Effects of liquid feed on grade distribution are shown in Table 18. The percentage of medium, small, No2 and unmarketable fruit within the weight based marketable yield and across all liquid feeds ranged over 12.2-19.7%, 36.2-42.9%, 22.6-31 % and 14.6-18.8%, respectively. Liquid feeds IF1 and OF3 significantly increased the number and weight of medium fruit with respect to OF2 and OF4 (Table 18). The production of Extra-large fruit was not observed in this experiment. Furthermore, there was no significant difference due to the treatments in large size fruit number and weight (P=0.7047; P=0.8063). Liquid feeds IF1 and OF3 resulted in significantly increased number and weight of small fruit compared to OF2 and OF4. A similar trend was noticed with respect to Marketable No.2 and unmarketable fruit (number and weight) (Table 18).

The effects of liquid feed on early and late yield are shown in Tables 19, 20. Early in the season (27-57 DAP; 30 harvests), IF1 and OF3 significantly increased both number and weight of marketable fruit, compared to OF2 and OF4. Liquid feed OF4 resulted in the lowest number of marketable fruit and weight (Table19, 20).

During the late season (58-122 DAP; 39 harvests), the marketable yield in all plots was very low due to low lighting conditions causing fruit abortion. In addition severe incidence of stem blight (Oct 25-Nov10) resulted in loss of 7% plants which had significant impact on fruit yield. Liquid feeds IF1, OF2 and OF2 resulted in significantly higher marketable fruit (number and weight) compared to liquid feed OF4. However, effects of liquid feed on the unmarketable fruit number and weight were not significant in late season, (Tables 19 and 20). However, early in the season, OF3 and IF1 had resulted in significantly higher unmarketable fruit number and weight compared to OF2 and OF4.

Effect of liquid feed on the average size of marketable fruit was significant (P=0.0023; Table 21). The average fruit weight with all organic liquid feeds OF3, OF2 and OF4 ranged over 272-278 g, which was 16.3 g higher than with the inorganic control (IF1).

2.3.5.2. Effect of organic media

Organic media had significant effects on marketable, unmarketable and total yield (number: P=0.0002, P<0.0001, P<0.0001, weight: P<0.0001, P<0.0001, P<0.0001, respectively) (Table 14-15). Seasonal marketable fruit yield for organic media OM3 and OM4 (number: 19.1 and 18.7 cucumbers m^{-2} ; weight: 5.1 kg m^{-2}) was significantly greater than the seasonal marketable yield for coco coir medium OM2 (number: 15.1 cucumber m^{-2}; weight: 4.1 kg m^{-2}). Furthermore, seasonal marketable fruit yield of the in-house blends of organic media OM3 and OM4 were similar to the corresponding yields produced on rockwool media (M1; 19 cucumbers m^{-2} ; weight: 5.2 kg m^{-2}) (Table 15).

Organic media effects on grade distribution are shown on Table 18. The percentage contribution of medium, small, No2 and unmarketable fruit within the weight based marketable yield and across all media ranged over 12.2-25.0%, 31.9-47.8%, 20.7-30.9%, and 10.0-24.8%, respectively. Medium OM2 (coir-organic control) resulted in significantly increased number and weight of medium fruit with respect to OM3 and OM4 (Table 18), In contrast, small fruit

number and weight with organic media OM3 and OM4 were comparable to those of the organic control (OM2). There was no significant difference due to treatments in large size fruit number and weight (*P*=0.8215; *P*=0.7598). Organic media OM3 and OM4 resulted in significantly increased number and weight of marketable No.2 and unmarketable fruit, compared to M1 and OM2 (Table 18).

The effects of Organic media on early and late yield are shown on Tables 19 and 20. Early in the season (27-57 DAP; 30 harvests), organic media OM3 and OM4 resulted in significantly higher marketable fruit numbers (11.7 and 10.7 no m^{-2}, respectively); which translated to +42 % and +30 % with respect to the coir medium (OM2). A similar trend was observed in marketable fruit weight. However, in late-season (58-122 DAP; 39 harvests), marketable fruit yield (number and weight) was not significantly affected by the media treatments. Furthermore, the yield levels were low in late-season due to high fruit abortion and stem blight disease incidence and the effects of media on the number and weight of marketable fruit became less evident.

The effect of organic media on average marketable fruit size was not significant (*P*=0.0185) (Table 16). The average fruit weight with all organic media (OM4, OM3 and OM2) ranged over 268-270 g, which was 8-12 g lower than with rockwool (M1) (Table21).

2.3.5.3. Interactive effects

Statistical analysis showed that, liquid feed × media interactions were highly significant for marketable, unmarketable and total yield (number and weight), which are presented in Tables 16 and 17. The highest seasonal marketable yields achieved with the best combinations or organic liquid feeds with organic media were 22.1 and 20.2 cucumbers m^{-2} for the combinations OF3 × OM3 and OF2 × OM3, respectively; these yields represented 80.1 and 72.8 of the rockwool (inorganic control), or 100 and 90.9 % of the coco peat (organic control, but with an inorganic feed) marketable yields. The interactive effects of liquid feed and media on average fruit weight were also highly significant (*P*=0.0007; Table 22).

Table 14. Cucumber yield (fruit no m^{-2}) as affected by liquid feed and organic media, Fall 2007

Treatments	Marketable yield (no m^{-2})	Unmarketable yield (no m^{-2})	Total fruit number (no m^{-2})
Liquid Feed[1]			
IF 1	22.0 ± 1.0 a[3]	5.0 ± 0.9 a	27.0 ± 1.0 a
OF 2	16.6 ± 1.2 b	2.8 ± 0.4 b	19.4 ± 1.3 b
OF 3	20.9 ± 0.7 a	4.5 ± 0.6 a	25.4 ± 1.1 a
OF 4	12.2 ± 0.6 c	2.5 ± 0.4 b	14.7 ± 0.9 c
Media[2]			
M 1	19.0 ± 1.7 a	2.1 ± 0.4 c	21.0 ± 1.8 c
OM 2	15.1 ± 1.5 b	2.1 ± 0.3 c	17.2 ± 1.5 d
OM 3	19.0 ± 1.0 a	6.2 ± 0.6 a	25.2 ± 1.3 a
OM 4	18.7 ± 1.0 a	4.4 ± 0.6 b	23.1 ± 1.2 b
F-test[4]			
Liquid Feed (LF)	<0.0001**	0.0089**	<0.0001**
Media (M)	0.0002 **	<0.0001**	<0.0001**
LF X M	0.0003 **	0.0009**	0.0285**

[1] IF1= Inorganic, OF2 = Agrowchem-I, OF3 = Pure Blend, and OF4 = Agrowchem II.
[2] M1=Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L soymeal added), and OM4= Organic mix-2 (40 L soy meal added).
[3] Means within liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test.
[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 significance level, respectively.

Table 15.Cucumber yield (kg m^{-2}) as affected by liquid feed and organic media, Fall 2007.

Treatments	Marketable Yield (kg m^{-2})	Unmarketable Yield (kg m^{-2})	Total Yield (kg m^{-2})
Liquid Feed[1]			
IF 1	5.7 ± 0.4 a[3]	1.0 ± 0.2 a	6.7 ± 0.3 a
OF 2	4.6 ± 0.3 b	0.6 ± 0.1 b	5.1 ± 0.4 b
OF 3	5.7 ± 0.2 a	0.9 ± 0.1 a	6.6 ± 0.3 a
OF 4	3.4 ± 0.2 c	0.5 ± 0.1 b	3.9 ± 0.3 c
Media[2]			
M 1	5.2 ± 0.5 a	0.4 ± 0.1 c	5.6 ± 0.5 b
OM 2	4.1 ± 0.4 b	0.4 ± 0.0 c	4.4 ± 0.4 c
OM 3	5.1 ± 0.3 a	1.3 ± 0.1 a	6.4 ± 0.3 a
OM 4	5.1 ± 0.3 a	0.9 ± 0.1 b	5.9 ± 0.3 ab
F-test[4]			
Liquid Feed(LF)	<0.0001**	0.0067 **	<0.0001**
Media (M)	0.0001**	<0.0001**	<0.0001**
LF X M	<0.0001**	<0.0017 **	0.0005 **

[1] IF1= Inorganic, OF2 = Agrowchem-I, OF3 = Pure Blend and OF4 = Agrowchem II.
[2] M1=Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added).
[3] Means within liquid feed and media that are followed by different letters are significantly different (P < 0.05) according to Duncan's multiple range test.
[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 significance level, respectively.

Table 16. Interactive effects of liquid feed and media treatments on marketable, unmarketable and total yield of Cucumber (no m^{-2}), Fall 2007.

Liquid Feed[1]	Media[2]	Marketable (no m^{-2})	Unmarketable (no m^{-2})	Total Yield (no m^{-2})
IF 1	M 1	27.6 a[3]	1.8 fg	29.3 a
	OM 2	22.1 b	2.5 g	24.6 bcde
	OM 3	19.8 bc	9.1 a	28.9 ab
	OM 4	18.7 bcd	6.8 bc	25.4 abcd
OF 2	M 1	16.6 cde	1.5 g	18.0 g
	OM 2	10.0 f	2.9 efg	12.9 h
	OM 3	20.1 bc	4.0 efd	24.1 cde
	OM 4	19.6 bcd	2.9 efg	22.5 cde
OF3	M 1	21.3 bc	3.3 efg	24.5 def
	OM 2	18.7 bcd	1.8 fg	20.5 efg
	OM 3	22.1 b	7.2 ab	29.3 a
	OM 4	21.7 b	5.6 bcd	27.2 abc
OF4	M 1	10.4 f	1.9 fg	12.3 h
	OM 2	9.5 f	1.2 g	10.7 h
	OM 3	13.8 ef	4.7 cde	18.5 fg
	OM 4	15.0 de	2.4 fg	17.4 g

[1] IF1= Inorganic, OF2 = Agrowchem-I, OF3 =Pure Blend, and OF4 = Agrowchem-II
[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added), and OM4= Organic mix-2 (40 L Soymeal added)
[3] Means within each column that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test

Table 17. Interactive effects of liquid feed and media treatments on marketable, unmarketable and total yield of Cucumber (kg m^{-2}), Fall 2007.

Liquid Feed[1]	Media[2]	Marketable ($kg\ m^{-2}$)	Unmarketable ($kg\ m^{-2}$)	Total Yield ($kg\ m^{-2}$)
IF 1	M 1	7.4 a[3]	0.3 f	7.7 a
	OM 2	5.8 bc	0.4 f	6.2 bcd
	OM 3	4.9 bcde	1.8 a	6.7 abcd
	OM 4	4.8 bcde	1.4 abc	6.2 cde
OF 2	M 1	4.6 cde	0.3 f	4.9 gf
	OM 2	2.6 g	0.5 ef	3.12 h
	OM 3	5.5 bcd	0.9 de	6.4 efg
	OM 4	5.4 bcde	0.6 ef	6.0 g
OF3	M 1	6.0 b	0.6 ef	6.6 abcd
	OM 2	5.2 bcd	0.4 f	5.6 defg
	OM 3	5.9 b	1.5 ab	7.4 ab
	OM 4	5.7 bc	1.1 bcd	6.9 abc
OF4	M 1	2.9 fg	0.3 f	3.2 h
	OM 2	2.5 g	0.2 f	2.7 h
	OM 3	4.0 ef	1.0 cd	5.0 efg
	OM 4	4.3d e	0.4 ef	4.7 g

[1] IF1= Inorganic, OF2 = Agrowchem-I, OF3 =Pure Blend, and OF4 = Agrowchem-II
[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added), and OM4= Organic mix-2 (40 L Soymeal added)
[3] Means within each column that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test

Table 18. Marketable and unmarketable yield components of Cucumber as affected by liquid feed and organic media, Fall 2007.

Treatments	Marketable (No. 1)						Marketable (No. 2)		Unmarketable	
	Large		Medium		Small					
	(no m^{-2})	(kg m^{-2})	(no m^{-2})	(kg m^{-2})	(no m^{-2})	(kg m^{-2})	(no m^{-2})	(kg m^{-2})	(no m^{-2})	(kg m^{-2})
Liquid Feed[1]										
IF 1	0.10 ± 0.1 [3]	0.04 ± 0.0	5.20 ± 0.7 a	1.50 ± 0.2 a	10.61 ± 0.9 a	2.78 ± 0.2 a	6.12 ± 0.5 ab	1.41 ± 0.1 ab	5.01 ± 0.9 a	0.95 ± 0.2 a
OF 2	0.03 ± 0.0	0.01 ± 0.0	3.35 ± 0.3 b	1.05 ± 0.1 b	8.33 ± 0.8 c	2.28 ± 0.2 b	4.86 ± 0.7 b	1.20 ± 0.2 b	2.84 ± 0.4 b	0.55 ± 0.1 b
OF 3	0.08 ± 0.0	0.04 ± 0.0	5.00 ± 0.4 a	1.54 ± 0.1 a	9.18 ± 0.6 b	2.47 ± 0.2 b	6.68 ± 0.8 a	1.66 ± 0.2 a	4.45 ± 0.6 a	0.09 ± 0.1 a
OF 4	0.05 ± 0.1	0.03 ± 0.0	1.80 ± 0.2 c	0.62 ± 0.1 b	5.78 ± 0.4 d	1.61 ± 0.1 c	4.56 ± 0.5 b	1.16 ± 0.1 b	2.53 ± 0.4 b	0.49 ± 0.1 b
Media[2]										
M 1	0.10 ± 0.1	0.05 ± 0.0	4.83 ± 0.7 a	1.49 ± 0.2 a	10.05 ± 1.0 a	2.77 ± 0.3 a	3.96 ± 0.4 b	0.92 ± 0.1 b	2.10 ± 0.4 c	0.37 ± 0.1 c
OM 2	0.05 ± 0.0	0.02 ± 0.0	4.30 ± 0.6 a	1.31 ± 0.2 a	7.19 ± 0.9 b	1.90 ± 0.2 b	3.55 ± 0.4 b	0.83 ± 0.1 b	2.08 ± 0.3 c	0.35 ± 0.0 c
OM 3	0.05 ± 0.4	0.02 ± 0.0	3.31 ± 0.3 b	1.03 ± 0.1 b	8.03 ± 0.5 b	2.15 ± 0.1 b	7.57 ± 0.4 a	1.86 ± 0.1 a	6.24 ± 0.6 a	1.30 ± 0.1 a
OM 4	0.05 ± 0.1	0.03± 0.0	2.90 ± 0.4 b	0.89 ± 0.1 b	8.63 ± 0.6 b	2.32 ± 0.2 b	7.14 ± 0.5 a	1.82 ± 0.1 a	4.41 ± 0.6 b	0.88 ± 0.1 b
F-test[4]										
Liquid Feed(LF)	0.7047	0.8063	0.0003**	0.0005**	<0.0001**	<0.0001**	0.0247*	0.0455*	0.0088**	0.0067**
Media (M)	0.8215	0.7598	0.002**	0.0002**	0.0057**	0.0019**	<0.0001**	<0.0001**	<0.0001**	<0.0001**
LF X M	0.4209	0.3156	<0.0001**	<0.0001**	0.0028**	0.0017**	0.4522	0.4037	0.0009**	0.0017**

[1] IF1= Inorganic, OF2 = Agrowchem-I, OF3 = Pure Blend and OF4 = Agrowchem II.
[2] M1=Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added).
[3] Means within liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test.
[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 significance level, respectively.

Table 19. Early (Sep 10 - Oct 10) and late season (Oct 11- Dec 14) cucumber yield (no m^{-2}), as affected by the liquid feed and organic media treatments- Fall 2007.

Treatments	Marketable yield (no m^{-2})		Unmarketable yield (no m^{-2})	
	Early	Late	Early	Late
Liquid Feed[1]				
IF 1	13.2 ± 0.5 a[3]	8.4 ± 0.6 a	3.5 ± 0.2 a	1.5 ± 0.2
OF 2	9.6 ± 0.5 b	7.0 ± 0.5 ab	1.9 ± 0.1 bc	0.9 ± 0.2
OF 3	12.0 ± 0.5 a	8.3 ± 0.3 a	3.3 ± 0.1 ab	1.0 ± 0.2
OF 4	6.6 ± 0.4 c	5.6 ± 0.2 b	1.5 ± 0.1 c	1.0 ± 0.2
Media[2]				
M 1	10.8 ± 0.8 a	7.7 ± 0.5	0.8 ± 0.2 c	1.3 ± 0.2
OM 2	8.2 ± 0.7 b	6.9 ± 0.6	1.1 ± 0.1 c	1.0 ± 0.2
OM 3	11.7 ± 0.5 a	7.3 ± 0.6	5.0 ± 0.1 a	1.2 ± 0.2
OM 4	10.7 ± 0.6 a	7.3 ± 0.5	3.3 ± 0.1 b	1.0 ± 0.2
F-test[4]				
Liquid Feed (LF)	<0.0001**	0.0110*	0.0224**	0.2661
Media (M)	<0.0001**	0.5717	<0.0001**	0.6990
LF X M	<0.0001**	0.2785	0.0003**	0.4307

[1] IF1= Inorganic, OF2 = Agrowchem I, OF3 = Pure Blend, and OF4 = Agrowchem II

[2] M1=Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added), and OM4=Organic mix-2 (40 L Soymeal added).

[3] Means within liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test.

[4] *, ** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

Table 20. Early (Sep 10 - Oct 10) and late season (Oct 11- Dec 14) cucumber yield (kg m^{-2}), as affected by the liquid feed and organic media treatments- Fall 2007.

Treatments	Marketable yield (kg m^{-2})		Unmarketable yield (kg m^{-2})	
	Early	Late	Early	Late
Liquid Feed[1]				
IF 1	3.6 ± 0.2 a[3]	2.0 ± 0.2a	0.7± 0.0 a	0.2 ± 0.0
OF 2	2.8 ± 0.2 b	1.7 ± 0.1ab	0.4 ± 0.2 b	0.1 ± 0.0
OF 3	3.4 ± 0.1 a	2.2 ± 0.1a	0.7 ± 0.0 a	0.2 ± 0.0
OF 4	2.0 ± 0.2 c	1.5 ± 0.1b	2.0 ± 0.0 b	0.2 ± 0.1
Media[2]				
M 1	3.2 ± 0.3 a	1.9 ± 0.1	0.2 ± 0.0 c	0.2 ± 0.0
OM 2	2.3 ± 0.3 b	1.7 ± 0.1	0.2 ± 0.0 c	0.1 ± 0.0
OM 3	3.2 ± 0.2 a	1.8 ± 0.1	1.1 ± 0.0 a	0.2 ± 0.1
OM 4	3.0 ± 0.2 a	1.9 ± 0.1	0.7 ± 0.0 b	0.2 ± 0.0
F-test[4]				
Liquid Feed(LF)	<0.0001**	0.0193*	0.0177*	0.3456
Media (M)	<0.0001**	0.6116	<0.0001**	0.6937
LF X M	<0.0001**	0.2636	0.0004**	0.2999

[1] IF1= Inorganic, OF2 = Agrowchem-I, OF3 = Pure Blend, and OF4 = Agrowchem-II.
[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added).
[3] Means within liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test.
[4] *,** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

Table 21. Seasonal average marketable fruit size (g / fruit) as affected by the organic liquid feed and media treatments- Fall 2007, Cucumber experiment.

Treatments	Marketable fruit size (g / fruit)
Liquid Feed[1]	
IF 1	258.5 ± 2.9 b[3]
OF 2	273.2 ± 2.5 a
OF 3	272.9 ± 2.9 a
OF 4	278.6 ± 3.3 a
Media[2]	
M 1	276.8 ± 2.1 a
OM 2	268.0 ± 3.1 b
OM 3	268. 0 ± 4.1 b
OM 4	270.4 ± 3.8 b
F-test[4]	
Liquid Feed(LF)	<0.0023**
Media (M)	<0.0185**
LF X M	<0.0007**

[1] IF1= Inorganic, OF2 = Agrowchem-I . OF3 = Pure Blend and OF4 = Agrowchem-II

[2] M1=Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added).

[3] Means within liquid feed and media that are followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test.

[4] *,** indicate significance of the F-test at the 0.05 and 0.01 level, respectively.

Table 22. Interactive effects of the organic liquid feed and media treatments on average weight of marketable fruit (g /fruit), Cucumber, Fall2007.

Liquid Feed[1]	Media[2]	Average weight of marketable fruit[3] (g /fruit)
IF 1	M 1	270.0 bcde
	OM 2	262.9 ef
	OM 3	245.6 g
	OM 4	255.4 fg
OF 2	M 1	277.5 abcde
	OM 2	263.8 def
	OM 3	274.3 abcde
	OM 4	277.3 def
OF3	M 1	281.1 ab
	OM 2	279.4 abc
	OM 3	267.2 bcdef
	OM 4	263.8 def
OF 4	M 1	278.5 abcd
	OM 2	266.0 cdef
	OM 3	284.8 a
	OM 4	285.1 a

[1] IF1= Inorganic, OF2 = Agrowchem-I, OF3 =Pure Blend and OF4 = Agrowchem-II
[2] M1= Rockwool, OM2= Coco Coir, OM3= Organic mix-1(20 L Soymeal added) and OM4= Organic mix-2 (40 L Soymeal added)
[3] Means followed by different letters are significantly different ($P < 0.05$) according to Duncan's multiple range test

2.4. Conclusions

Results of this experiment confirmed the effectiveness of the new in-house formulated organic media (peat-based + soymeal) for organic cucumber production. The organic media OM3 and OM4 at planting time had pH and EC values ranging from 5.8-5.9 and 1.8-2.0 $mScm^{-1}$ which are acceptable for cucumber production. Nitrogen concentration in leaf tissue when plants were grown on organic media and fed with liquid feeds IF1, OF2 and OF3 were within the recommended levels for cucumber production. The liquid feed OF4 (Half strength of OF2) resulted in N deficiency.

Plants grown on organic media OM3 and OM4 received excellent visual growth ratings (score of 3.9-4.4) which was significantly higher than for plants grown on rockwool (M1) and Coco coir (OM2). Plant height at 57 DAP was significantly greater in organic media OM3 and OM4 (565.2-549.6 cm), compared to control treatments OM2 and M1 (469.8 - 522.6 cm). Leaf number increased with the increase of the content of soymeal in the medium; At 57 DAP, the total number of leaves was greater with OM4 (50.1) than with OM3 (48.8).

Liquid feeds OF3, OF2 and OF4 resulted in progressively decreasing numbers of fruit number: (25.4, 19.4, and 14.7 no m^{-2}); and, weight: (6.6, 5.1, and 3.9 kg m^{-2}), respectively. Organic medium OM3 resulted in significantly higher fruit number (25.2 no m^2) compared to OM4 (23.3 no m^2), M1 (21.0 no m^2) and OM2 (17.2 no m^2). The weight of marketable fruit consistently increased with the increase in the medium soymeal content. Media OM4 (Peat +40 L soymeal) and OM3 (Peat +20 L symeal) resulted in maximum fruit yield (6.4 kg m^{-2}, 5.9 m^{-2}, respectively). The average fruit weight with all organic liquid feeds (OF3, OF2 and OF4) ranged over 272-278 g, which was 16.3 g higher than the inorganic control (IF1), whereas for the media OM3, OM2 and OM2 it ranged over 268-270 g, which was 8 g higher than on rockwool (M1).

Organic liquid feed × media interactions had a significant impact on marketable yield. The highest seasonal marketable yields achieved with the best combinations or organic liquid feeds with organic media were 22.1 and 20.2 cucumbers m^{-2} for the combinations OF3 x OM3 and OF2 x OM3, respectively; these yields represented 80.1 and 72.8 of the rockwool

(inorganic control), or 100 and 90.9 % of the coco peat (organic control, but with an inorganic feed) marketable yields.

Results of these experiments showed once again the effectiveness of the in-house formulated organic media (peat-based + soy meal 20 or 40 L) for organic cucumber production. The most promising options for cucumber production were the combination of organic mix OM4 (Peat+ 40 L soymeal) with liquid feed OF3 (Pure Blend) or OF2 (Agrochem).

PART B. Research work at PARC (Agassiz, BC)

3. Plant physiology and crop productivity research.

3.1. Introduction and Objective:

Compare growth, production and quality of conventional and organic tomatoes in open and recirculating systems

Two consecutive crops were established. The first tested the effects of several organic liquid feeds on organic crop production and quality. The efficacy of chlorine dioxide in preventing dripper plugging and biofilm formation in irrigation lines was also studied. The second trial focussed on recirculation, with a few changes to the organic liquid feeds.

3.2. Crop 1

3.2.1. Setup

Crop: tomato, cultivar Rapsodie

Seeded: January 22, 2007

Transplanted: February 28 into 11L pots of yellow cedar sawdust (1 plant per pot)

Irrigation: two drippers per plant (capillary type, 0.076" diameter)

Feed treatments:

1. Standard hydroponic tomato feed (Table 1)
2. Organic Feed 1: Fishplus 3-3-1 and Pacific Natural 2-3-0.3 (both OMRI-certified) (Table 2)
3. Organic Feed 2: MetaNaturals 3-3-3 (OMRI-certified) (Table 3)

Harvest period: May 18 – June 27

Table 1. Standard tomato feed*

Feed	Kg/1000 L	N	P	K	Ca	Mg
Potassium Nitrate	0.55	72	0	210	0	0
Monopotassium Phosphate	0.18	0	41	49	0	0
Potassium Sulphate	0.04	0	0	10	0	0
Calcium Nitrate	0.67	104	0	0	104	0
Magnesium Sulphate	0.27	0	0	0	0	27
TOTAL	1.70	175	41	270	104	27

*Also contains micronutrient mix

Table 2. Organic feed 1

Feed	Kg/1000 L	N	P	K	Ca	Mg
Fishplus Grow	3.80	114	17	32	0	0
Pacific Natural	3.85	79	52	9	0	0
CalPril Ca 36%	0.28	0	0	0	99	0
DoloPril Ca 20%, Mg 11%	0.22	0	0	0	44	24
Potassium Sulphate*	0.62	0	0	255	0	0
Food Grade Citric acid	0.60	0	0	0	0	0
TOTAL	8.76	193	69	296	143	24

*Great Salt Lake Minerals

Table 3. Organic feed 2

Feed	Kg/1000 L	N	P	K	Ca	Mg
MetaNatuals Grow*	6.40	192	84	160	0	38
MetaNaturals Calcium 6%	2.40	0	0	0	144	0
Potassium Sulphate**	0.33	0	0	135	0	0
TOTAL	9.13	192	84	295	144	38

* with 0.6% Mg ; ** Great Salt Lake Minerals

Experimental design: There were three fertilizer treatments (hydroponic, organic 1 and organic 2). In a fourth treatment, some of the Organic 2 fertilizer stream was routed through a chlorine dioxide (ClO_2) system to supply 2 ppm mixed oxidants before going out to the plants. Mixed oxidants were dosed at each feed. A randomized complete block design with 3 blocks and 9 plants of each treatment per block was used.

Biofilm accumulation in the irrigation lines was monitored by observing the change in weight over time of removable segments of irrigation line. Each segment was about 45cm in length. There were 6 segments for each treatment, distributed evenly throughout the greenhouse.

3.2.2. Results

All organic treatments reduced total fruit weight per plant (Table 4) although total fruit number was not different. Organic treatments produced somewhat smaller fruit overall. Chlorine dioxide (Organic 2/ClO_2) did not affect total fruit weight, number, or size compared to the untreated control (Organic 2).

Table 4. Effect of fertilizer treatments on tomato fruit yield, number, and size grade-out.

Treatment	Fruit weight (kg)						Fruit number					
	Total	**MXL**	**XL**	**L**	**M**	**S**	**Total**	**MXL**	**XL**	**L**	**M**	**S**
Standard	4.5a	1.5a	2.6a	0.3b	0.06b	0.01b	18.4	4.6a	11.6a	1.6c	0.5b	0.2c
Organic 1	3.4b	0.4b	2.3ab	0.5a	0.12ab	0.06a	18.3	1.4b	10.8ab	3.9b	1.3a	1.0ab
Organic 2	3.3bc	0.5b	2.1bc	0.6a	0.13a	0.04ab	17.4	1.6b	9.7b	4.1ab	1.4a	0.6bc
Organic 2/ ClO_2	3.0c	0.2b	1.8c	0.7a	0.17a	0.07a	18.1	0.7b	9.1b	5.3a	1.9a	1.2a
Signif.	***	***	**	**	**	**	ns	***	*	***	**	**

All values are expressed per plant

Values with the same letter in each column are not significantly different at P=0.05 using Duncan's multiple range test

ns, *,**,*** - Not significant, or significant at P=0.05, 0.01 or 0.001, respectively

In terms of cumulative build-up of biofilm in irrigation lines over time, the Organic 2 treatment appeared to be the greatest (Figure 1). The chlorine dioxide treatment seems to have reduced biofilm accumulation compared to the control treatment (Organic 2). This is confirmed by examining the increase in dry weight of the sections of line at different dates (Table 6). Although no differences were apparent among treatments on the first two sampling dates, by the third, the Organic 2 treatment showed significantly higher build-up than the other treatments, including Organic 2 plus chlorine dioxide. However, when comparing the incidence of dripper plugging, results were not consistent. On one sampling date, all organic treatments showed more plugging than the standard feed, and chlorine dioxide improved dripper volume output (Organic 2 plus chlorine dioxide compared to Organic 2) (Table 7). However, on the second sampling date, only the Organic 2 and Organic 2 plus chlorine dioxide treatments showed reduced dripper volumes.

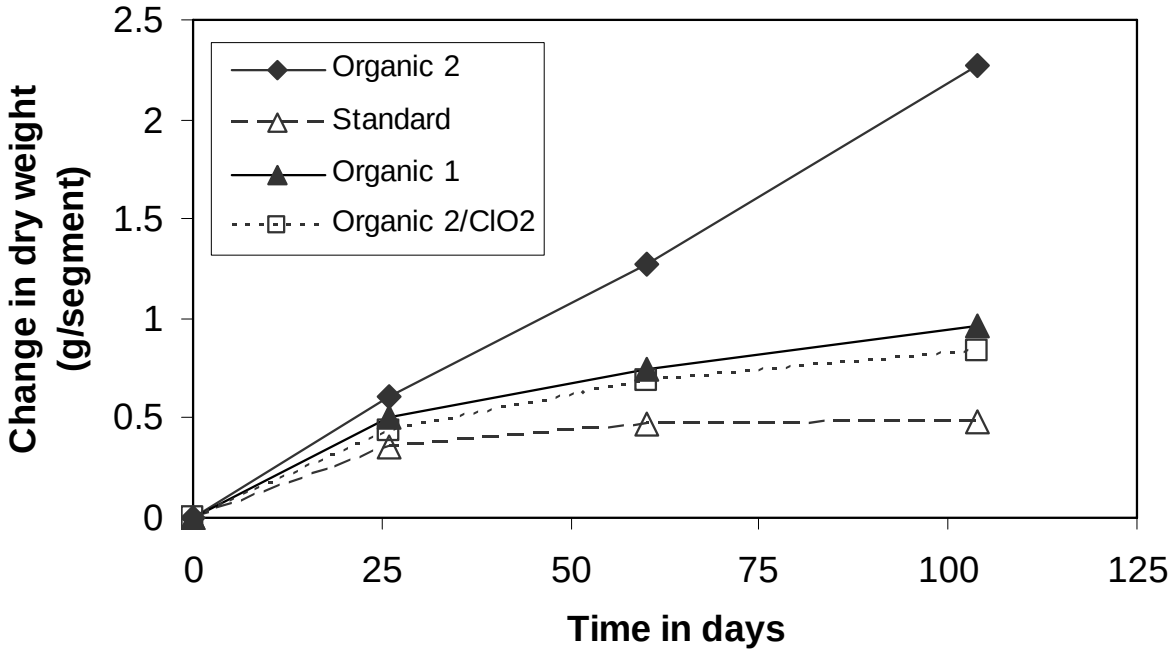


Figure 1. Cumulative weight change (biofilm accumulation) over time in segments of irrigation line for each fertilizer treatment.

Table 5. Change in weight (biofilm accumulation) of irrigation line segments at three different times in the trial.

Treatment	Interval (days)		
	0-26	**27-60**	**61-104**
Standard	0.35	0.12	0.01b
Organic 1	0.44	0.26	0.05b
Organic 2	0.61	0.66	0.99a
Organic 2/ClO2	0.51	0.24	0.21b
Significance	ns	ns	**

Values with the same letter in each column are not significantly different at P=0.05 using Duncan's multiple range test
ns, ** - Not significant, or significant at P=0.01 respectively

Table 6. Dripper volume per bag (2 drippers) measured over 1 minute, on two dates.

Treatment	Dripper volume per bag (ml)	
	Day 132	**Day 164**
Standard	335a	373a
Organic 1	145c	414a
Organic 2	141c	232b
Organic 2/ClO2	216b	236b
Significance	***	***

Values with the same letter within each column are not significantly different at P=0.05 using Duncan's multiple range test*** - Significant at P=0.001

3.3. Crop 2

A short-term trial comparing Fishplus, Pacific Natural, Technaflora and a standard hydroponic feed in tomato and cucumbers showed that newly-acquired Technaflora (TF) products gave growth nearly equal to that of the standard feed when grown on benchs to a height of about 60 cm. Technaflora is a local company and does not use fish products in their organic formulations. Since the absence of fish products may render the drippers less prone to plugging, it was decided to conduct this trial with Technaflora organic products. This trial was also designed to compare drain-to-waste and recirculation growing systems.

3.3.1. Setup

Crop: tomato, cultivar Rapsodie

Seeded: June 4, 2007

Transplanted: July 12 into 11L pots of yellow cedar sawdust (1 plant per pot)

Irrigation: two drippers per plant (button type, 4 L/h)

Feed treatments:

1. Standard tomato feed in yellow cedar, drain to waste
2. Standard tomato feed in yellow cedar, leachate recirculated
3. Organic feed (TF) in yellow cedar, drain to waste
4. Organic feed (TF) in yellow cedar, leachate recirculated
5. Organic feed (TF) in 80% yellow cedar + 20% compost, drain to waste
6. Organic feed (TF) in 80% yellow cedar + 20% compost, leachate recirculated

The compost was produced in the Agassiz compost facility.

Harvest period: September 10 – December 3

Experimental design: Each row of 18 plants was assigned a feed treatment (standard, organic TF, or organic TF plus compost). With 6 rows in total (minus the guards) this gave 2 rows per feed treatment. Within each row, half the plants (9 chosen at random) were provided fresh nutrient feed and were allowed to drain to waste. The leachate from the other half was captured and recirculated only to those recirculation treatment plants in that particular row. Feed composition: see Tables 1 and 2. All Technaflora products are OMRI-certified.

Biofilm accumulation: There were 4 segments for each treatment, distributed evenly throughout the greenhouse.

Table 7. Standard tomato feed*

Feed	Kg/1000 L	N	P	K	Ca	Mg
Potassium Nitrate	0.55	72	0	210	0	0
Monopotassium Phosphate	0.18	0	41	49	0	0
Potassium Sulphate	0.04	0	0	10	0	0
Calcium Nitrate	0.67	104	0	0	104	0
Magnesium Sulphate	0.27	0	0	0	0	27
TOTAL	1.70	175	41	270	104	27

*Also contains micronutrient mix

Table 8. Organic feed

Feed	Kg/1000 L	N	P	K	Ca	Mg
Grow 6-4-4	2.95	177	51.92	68.44	0	0
Bloom 2-6-6	0.20	4	5.28	9.96	0.022	0
Thrive Alive 1-1-1	1.05	10.5	4.62	8.72	0	0
CalPril Ca 36%	0.28	0	0	0.00	99	0
DoloPril Ca 20%,Mg 11%	0.23	0	0	0.00	45	24.75
Potassium Sulphate*	0.50	0	0	207.50	0	0
Food Grade Citric acid	0.50	0	0	0	0	0
TOTAL	5.20	191.5	61.82	294.62	144.02	24.75

*Great Salt Lake Minerals

3.3.2. Results

In the drain-to-waste systems, organic fertilizer treatments yielded less in terms of total fruit weight and had somewhat smaller fruit than the standard fertilizer treatments (Table 9). However, the organic treatments with compost showed no yield reduction. Total fruit number was also not affected by organic treatments although there tended to be somewhat fewer large fruit. Recirculation had no effect on yield in terms of total fruit weight in the standard fertilizer treatment, but did reduce the total number of fruit. Recirculation reduced yield proportionally more in both organic treatments than in the standard feed, when measured as total fruit weight and total fruit number. Overall, all plants growing in recirculation eventually showed signs of poor growth and mineral deficiencies, despite measurement of adequate mineral status in each recirculated solution. The cause of this problem could not be determined, but may be related to some component of the sawdust.

Table 9. Effect of fertilizer and recirculation treatments on tomato fruit yield, number, and grade-out.

Treatment	Fruit weight (kg)						Fruit number					
	Total	**MXL**	**XL**	**L**	**M**	**S**	**Total**	**MXL**	**XL**	**L**	**M**	**S**
Standard/ Drain	5.0ab	0.6ab	2.9b	1.2ab	0.3a	0.07ab	27.4a	1.6ab	12.7b	8.5ab	3.6a	0.9ab
Organic/ Drain	4.1c	0.2c	2.2cd	1.3a	0.3a	0.09a	24.9ab	0.7c	10.3c	9.4a	3.2a	1.3a
Organic/ Compost/ Drain	5.2a	0.8a	3.4a	0.8c	0.2b	0.04ab	25.1ab	2.4a	14.9a	5.6c	1.6b	0.6ab
Standard/ Recirc	4.7b	0.7a	2.7bc	0.9bc	0.3a	0.08a	24.6b	2.1a	11.5bc	6.9bc	3.0a	1.1a
Organic/ Recirc	3.3d	0.1c	1.9d	1.0bc	0.3a	0.06ab	19.4c	0.2c	8.1d	7.3bc	3.1a	0.8ab
Organic/ Compost/ Recirc	3.7cd	0.3bc	2.4c	0.9c	0.1b	0.02b	19.4c	1.0bc	10.4c	6.3c	1.4b	0.2b
Signif.	***	***	***	***	***	*	***	***	***	***	***	*

All values are expressed per plant

Values with the same letter in each column are not significantly different at P=0.05 using Duncan's multiple range test

*,*** - Significant at P=0.05 or 0.001, respectively

Compared to the data for Trial 1, the accumulation of biofilm in the irrigation lines appeared to be less in Trial 2 (compare Figures 1 and 2). As in Trial 1, some organic treatment seemed to show heavier biofilm accumulations in the irrigation lines than the standard fertilizer treatment (Figure 2). However, analysis of the gain in weight at two different measurement times showed only one treatment, the organic drain-to-waste treatment, with significantly higher biofilm (Table 10), and this was only at one measurement time. When comparing dripper volumes (Table 11), all treatments were remarkably similar (despite being statistically different from each other), again attesting to the clean lines overall.

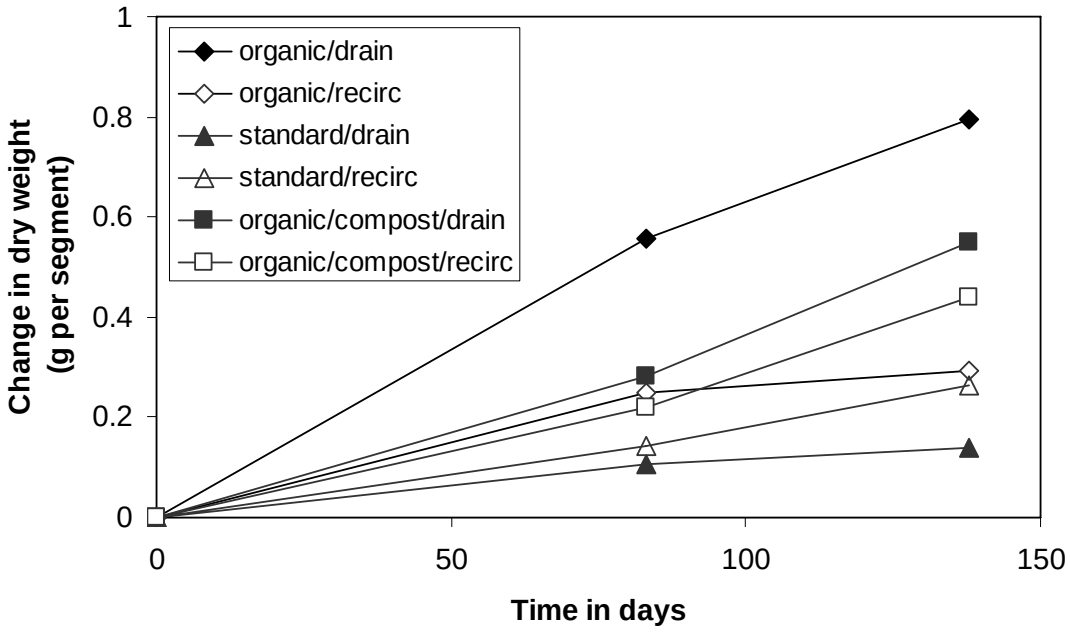


Figure 2. Cumulative weight change (biofilm accumulation) over time in segments of irrigation line for each fertilizer treatment.

Table 10. Change in weight (biofilm accumulation) of irrigation line segments at two different times in the trial.

Treatment	Interval (days)	
	0-83	**84-138**
Standard/drain	0.11b	0.04
Organic/drain	0.56 a	0.24
Organic/compost/drain	0.28 b	0.27
Standard/recirc	0.14 b	0.12
Organic/recirc	0.25 b	0.05
Organic/compost/recirc	0.22 b	0.22
Significance	*	ns

Values with the same letter in each column are not significantly different at P=0.05 using Duncan's multiple range test
ns, * - Not significant, or significant at P=0.05 respectively

Table 11. Volume of dripper output per bag (2 drippers) measured over 1 minute, averaged over 6 dates.

Treatment	Dripper volume per bag (ml)
Standard/drain	135a
Organic/drain	134ab
Organic/compost/drain	132abc
Standard/recirc	130c
Organic/recirc	132bc
Organic/compost/recirc	132abc
Significance	**

Values with the same letter are not significantly different at P=0.05 using Duncan's multiple range test ** - Significant at P=0.01

3.4. Conclusions

In both trials, plants grown in sawdust and fed with organic liquid feeds showed reduced production compared to the standard hydroponic feed. On a fruit weight basis, this varied from 25-33% in Trial 1 and from 18% (drain-to-waste treatments) – 25% (recirculation treatments) in Trial 2. The data also shows that recirculation reduced yield in both standard and organic treatments, but had a greater effect in the organic treatments. The treatment with the sawdust/compost mixture plus organic liquid feed did not show significant yield differences compared with the standard feed in drain-to-waste treatments, but yield was still 20% less in recirculation.

Biofilm development was observed in irrigation lines in all treatments in both trials. There were often no differences between the standard and organic treatments, but occasionally organic treatments showed enhanced biofilm accumulation. Chlorine dioxide significantly reduced the build-up of biofilm in irrigation lines of organic treatments. Similarly, organic and standard fertilizer treatments often did not show differences in the incidence of dripper plugging. Chlorine dioxide was effective in improving dripper volume output with organic feeds, but results were not always consistent. Recirculation of organic liquid feeds did not negatively affect dripper volume output.

4. Post-harvest physiology studies.

Summary. An experiment was run in a greenhouse section with six (6) treatments. With liquid organic feed (Technaflora), there were four (4) treatments: with or without 20% compost in each sawdust bag, and each was delivered with drain-to-waste or re-circulated. There were two (2) with standard hydroponic feed for comparison purpose, either drain-to-waste or re-circulated. Clusters of tomatoes were harvested on November 13, 2007. Fruit were sorted into 4 groups according to the degree of fruit coloration. They were stored at 10C for 27 days. Each fruit was observed for injury index with a score of 0 to 5 (0 for no defect or decay; 5 for most severely injured or decay) three times a week. The sum of injury index was average for these six treatments. The best quality (lowest injury index) of stored tomatoes was obtained from Technaflora Recirculated plus Compost (treatment 3) and Technaflora Straight plus Compost (treatment 4). When compost was not used, there was little difference between organic feed and hydroponic feed, although these four treatments had poor quality (higher injury index) than those organic feed combined with compost. In short, organic feed Technaflora combined with 20% compost in the sawdust bag resulted in the best post-harvest quality in greenhouse tomatoes.

Treatments.

1. Technaflora Straight (liquid organic feed, drain-to-waste)

2. Technaflora Recirculated (liquid organic feed, recirculated)

3. Technaflora Straight plus Compost (liquid organic feed, drain-to-waste, plus 20% compost in the sawdust bag)

4. Technaflora Recirculated plus Compost (liquid organic feed, recirculated, plus 20% compost in the sawdust bag)

5. Standard Feed Straight (hydroponic control, drain-to-waste)

6. Standard Feed Recirculated (hydroponic control, recirculated)

Results:

Cumulated injury index was the sum of 12 recorded injury indices during 27-day storage at 10C. Score: 0 (no defect or injury or decay) to 5 (severe injury or decay).

Trts	Organic feed	20% compost	Drain-to-Waste	Cumulated injury index	N=
1	Technaflora	No compost	Drained	16.9 (4.46)	N=16
2	Technaflora	No compost	Recirculated	11.1 (7.06)	N= 7
3	Technaflora	20% compost	Straight	6.1 (4.98)	N=15
4	Technaflora	20% compost	Recirculated	4.6 (5.68)	N=16
5	Hydroponic feed	No compost	Drained	14.7 (5.52)	N=16
6	Hydroponic feed	No compost	Recirculated	14.4 (4.13)	N=16

Fig. 1. The cumulated injury index of organically grown tomatoes after 27-day storage at 10C.

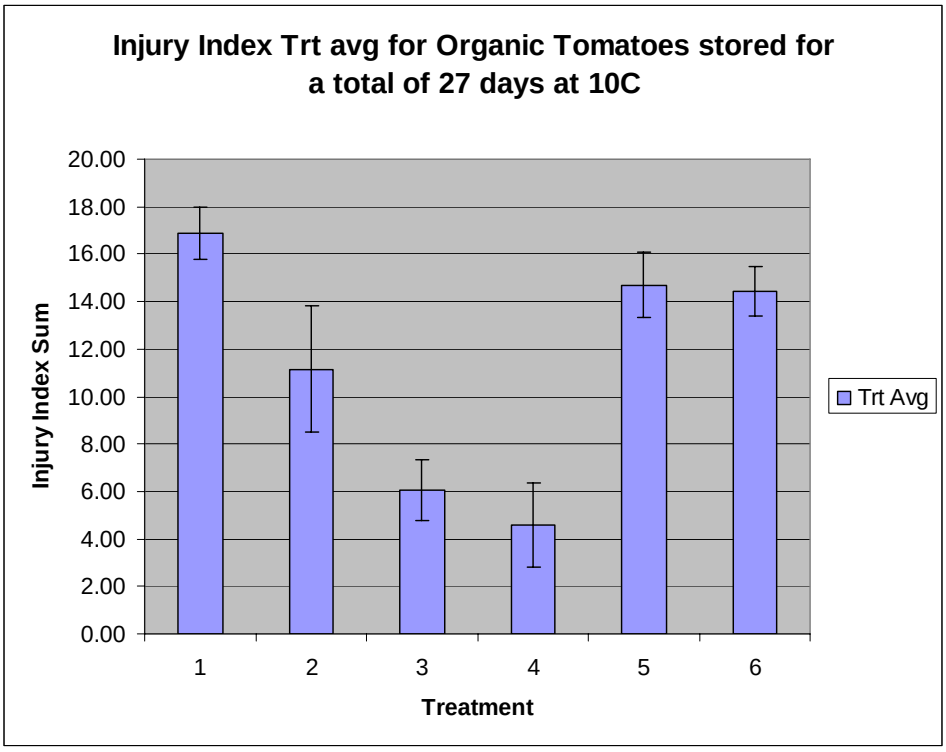
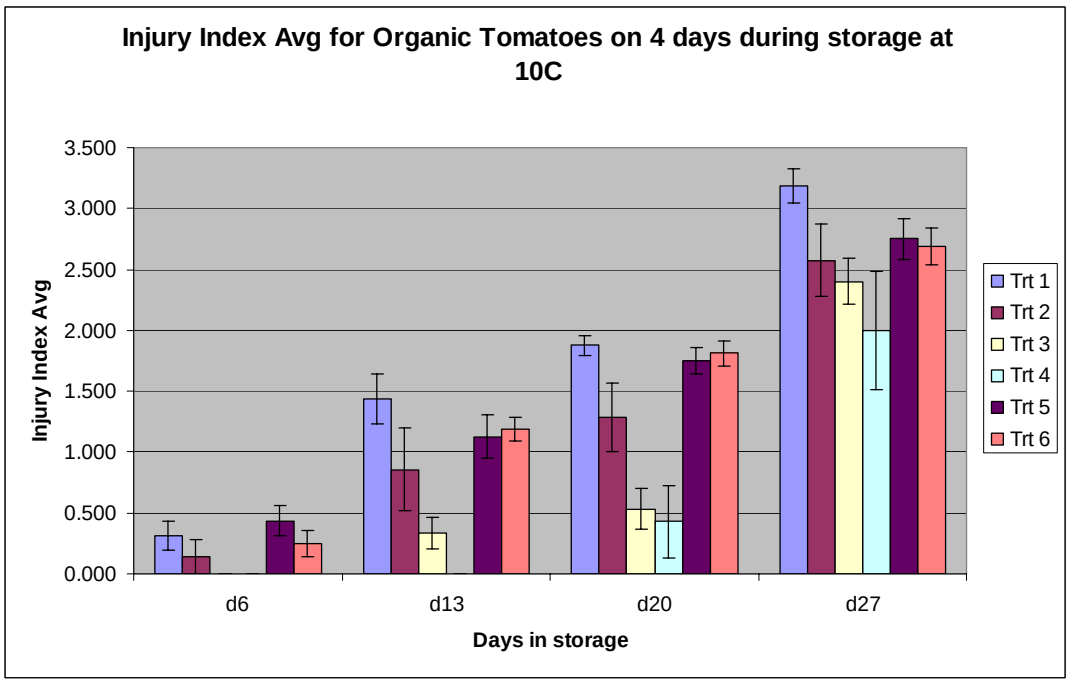


Fig. 2. Injury index of organically grown tomatoes that were recorded on 4 occasions during a 27-day storage at 10C.



PART C. Economic Analysis (Xiuming Hao; Harrow, ON.)

5.1.Economic Analysis - Organic Greenhouse Tomato Production

This economical analysis was performed based on the results from the organic tomato experiments conducted at the GPCRC from Jan. to Aug. 2006 and from Jan. to Aug. 2007. Since we don't have the complete dataset for one full year, the data have been extrapolated for a full year. It is expected the crop performance and economical feasibility of the organic production system would improve with further experimentation as shown by the progress made in 2007. Therefore, the results from this economical analysis are still preliminary. Nonetheless, the economic analysis could provide important information in identifying key factors determining the economical feasibility and potential area of development for further improving the organic production system.

5.2. Conditions and Assumptions for Economic Analysis

The economical feasibility of a certain production system is affected by many factors such as the cost of materials, energy, fertilizers, and fruit yield. Those factors could change very fast. Therefore, the explanation of the economic analysis results can not be separated from the conditions or assumptions used in the analysis (i.e. the validity or scope of the application of the economical analysis is limited to the specific conditions used in the analysis). Because the fixed costs (greenhouse construction, interest on mortgage and marketing) are the same for both organic and conventional systems, they were not included in the analysis.

A. The following is a list of main conditions and assumptions used in the economical analysis for both 2006 and 2007:

1). The organic fertilizer and water consumption data as in Table 1 was used for estimating water and organic fertilizer costs. The data from Jan. to Jul. were actual water and fertilizer consumption in the organic tomato experiments. The data for Aug.-Dec. were extrapolated from the actual data from Jan. to Jul. (Table 1). Two liquid organic fertilizer feeds were used in the 2006 experiment: Pure Blend and AgrowChem while three organic fertilizer feeds (AgrowChem, Pure Blend and Agrogreen) were used in 2007.

2). The costs and yield data for the conventional production system are extracted from the commercial greenhouse tomato production in Ontario and are based on current production and market conditions for a rockwool production system. The energy cost was calculated by assuming the price of natural gas as $9 per GJ.

3). All the costs for organic production systems except for growth media, pots, and organic fertilizers, were assumed to be the same as the conventional system.

4). For beefsteak tomatoes, fruit yield of 55 kg/m2 was assumed/used in the analysis for the conventional rockwool system.

B. Since 2006 was the first year for developing organic cultivation system and the fruit yield was expected to improve with further experimentation, the focus of economical analysis in 2006 was to identify the key area of development for increasing the economical feasibility of the organic system. The analysis was simplified through the use of following additional assumptions:

1) We assumed that the cost for organic fertilizers could decrease with a large volume purchase in the future. Therefore, we used the lowest cost ($33.2/m2/year) in our analysis (Table 2).
2) Since the cost of organic growth media is difficult to determine, an organic Pro-Mix was used in the analysis (about $3.9 per plant; 20 L pot, based on $15.65 for 2.8 cubic foot loose organic Pro-Mix, Table 2). The actual cost of the growth media should be less than it with fast adoption of organic production systems.
3) In the experiment conducted at the GPCRC in 2006, the plants in the organic system achieved 75% of the marketable yield as in the conventional production. With further improvement of the organic production system, its yield could become the same as conventional system. Therefore, two fruit yield scenarios (75% and 100% of the conventional) were tested in the analysis for 2006.

C. In the economical analysis for 2007, actual costs for organic fertilizers and growth media (Table 3) were used in the analysis. Since it was difficult to estimate the cost of labour for preparing the organic media, it was not included the cost for organic media. It is expected the discount in the price of organic materials with a large volume of purchase in commercial production should be sufficient to compensate the labour cost for preparing the media. Four cases (scenarios) were analyzed in the economical analysis for 2007:

- Case 1 – Based on the actual achieved marketable yield as the percentage of conventional rockwool and actual costs of organic fertilizers and growth media as used in 2007 experiment.
- Case 2 – Assumed the organic production system achieved the same yield as the conventional rockwool (100%).
- Case 3 – Assumed the cost of organic fertilizers was further reduced by 50% through further improvement in nutrient recycling etc. from the cost in 2007 while fruit yield stayed the same as case 1 (actual achieved marketable yield as the percentage of conventional rockwool).
- Case 4 - Assumed the organic production system achieved the same yield as the conventional rockwool and the cost of organic fertilizers was further reduced by 50% from the cost in 2007.

5.3.Results and Discussion

5.3.1. Economical Analysis for 2006

1) The largest cost in organic production (35%) was the liquid organic fertilizer feeds (Table2). It was even higher than the energy cost. Therefore, one of the main focuses in developing organic production system should be to reduce the cost of liquid organic fertilizers - finding more economical alternatives, reducing the amount used through recycling, or eliminating the use of liquid organic feed by using side dressing etc. The cost of organic growth media with the use of organic Pro-Mix was also quite higher (about 11%, Table 2). Therefore, research is also needed to find economical organic growth media.
2) The average production cost for the conventional system was $0.98/kg (at 55 kg/m2) (Table 2). At 75% of the conventional yield, the cost for organic tomato production was at $2.26/kg. If the cost for growth media was removed (down to 0), the cost for organic production would be $2.1/kg. Increasing the yield to 100% of the conventional, the average cost would be $1.7/kg when including the cost of organic growth media. Therefore, increasing the fruit yield is also going to significantly reduce the cost for organic production which, in turn, will improve its economical feasibility.

5.3.2. Economical Analysis for 2007

With the further experimentation in 2007, all three key areas of organic production identified in the 2006 economical analysis were improved. First, the usage of organic fertilizers was reduced by 20% through nutrient recycling (Table 1). Second, the fruit yield was increased to about 80-90% of the fruit yield of the conventional inorganic system (Table 4). Third, the cost of 'home-made' organic media (without including labour for preparation) was about 60% of the organic Pro-Mix in 2006, reducing the cost by about 40%.

1) The organic system with AgrowChem and OM4 had the lowest overall production cost while the system with Agrogreen and OM4 had the highest production cost in the 6 treatments with the best yield (Table 3). The cost of organic fertilizers with AgrowChem and OM4 was about 25% of the total production cost, which was similar to the energy cost. For Pure Blend and Agrogreen, the cost of organic fertilizers was the largest cost component in the crop production. Therefore, the organic fertilizers were still among the three largest cost components (energy, labour and organic fertilizers), further reduction in the usage of organic fertilizers may be needed (Table 3).
2) The total cost per kg of tomato with the conventional system was $0.97/kg while it was $1.67 for AgrowChem with OM4 (Table 4) with actual situation achieved in 2007 experiment (Case 1). The cost was reduced by $0.59/kg in comparison to 2006 ($2.26/kg). This represented a major improvement over 2006 experiment. However, the cost per kg of tomato with the organic system was still about 70% higher than that of the conventional system (Table 4). Increasing the yield to 100% of the conventional (Case 2), the cost would be reduced by about 30%. Reducing the usage of organic fertilizers by 50% (Case 3), the cost could also be reduced by 20%. Increasing the yield to 100% of the conventional and reducing the usage of organic fertilizers further by 50% (Case 4), the cost would be reduced by about 50%. (Case 3), Therefore, increasing the fruit yield and reducing the amount of organic fertilizers are still the key for further improving the economical feasibility of organic greenhouse tomato production. In summary, with the organic system that we have developed or achieved so far, the cost of organic

greenhouse tomatoes is about 70% higher than the conventional system. The cost for organic greenhouse tomato production was significantly reduced through the experimentation in 2007.

Table 1. Water and organic liquid fertilizer usage (ml m-2) in organic greenhouse tomato production, based on the spring experiments conducted at the GPCRC in 2006* and 2007**

	2006			2007			
				Organic fertilizers			
Month	Water usage	Pure blend	AgroChem	AgroChem_A	AgroChem_B	Pure blend	Agrogreen
1	801	83	62	50	25	67	66
2	1775	166	125	101	50	134	133
3	2694	278	216	175	87	225	227
4	4545	426	337	272	136	344	351
5	5118	529	313	253	126	428	378
6	5360	536	385	312	155	433	421
7	4933	510	343	278	138	412	387
Month 1-7	**25226**	**2527**	**1781**	**1440**	**718**	**2043**	**1963**
8	5098	510	343	278	138	412	387
9	4545	426	337	272	136	344	351
10	2694	278	216	175	87	225	227
11	1656	166	125	101	50	134	133
12	801	83	62	50	25	67	66
Whole year	**40020**	**3990**	**2865**	**2315**	**1155**	**3226**	**3128**

* For 2006, the cost of Pure Blend Pro-Grow was \$33.2/m^2/year (calculated at \$8.3/L), the cost of AgrowChem was \$38.3/m^2/year (calculated at \$12.75/L).

** For 2007, the cost of AgrowChem was \$14.2/m^2/year (calculated at \$2.5/L for Agro Kelp, \$1.5/L for Liquid Bone Meal, \$2.5/L for Spurt, \$1.35/L for Bat Guano (AgrowChem_A); \$1.5/L for Nitro Organo (AgrowChem_B)), the cost of Pure Blend Pro-Grow was \$19.1/m^2/year (calculated at \$8.3/L), and the cost of Agrogreen was \$22.3/m^2/year (calculated at \$10/L).

Table 2. The cost components for conventional rockwool and organic greenhouse tomato productions based on the tomato experiment in 2006

Cost component		Conventional with Rockwool			Organic (with Organic Pro-Mix)		
		Per Acre	Per M2	% over total cost	Per Acre	Per M2	% over total cost
Heating		80000	19.8	36.7	80000	19.8	21.2
Labour		60000	14.8	27.5	60000	14.8	15.9
Growing	**Rockwool Slab/OM**	**11750**	**2.9**	**5.4**	**41826***	**10.3**	**11.1**
	Blocks	2970	0.7	1.4	2970	0.7	0.8
	Plugs	720	0.2	0.3	720	0.2	0.2
	Seeds	4080	1.0	1.9	4080	1.0	1.1
	Vermiculite/pots	16	0.0	0.0	8580**	2.1	2.3
	Fertilizers	**10000**	**2.5**	**4.6**	**132800*****	**32.8**	**35.2**
	Biological Control	10000	2.5	4.6	10000	2.5	2.6
	Chemical Control	4000	1.0	1.8	4000	1.0	1.1
	CO2	7500	1.9	3.4	5500	1.4	1.5
	Total Growing	51036	12.6	23.4	210475.6	52.0	55.7
Others ****		27200	6.7	12.5	27200	6.7	7.2
Total		218236	53.9	100	377676	93.3	100

*Calculated based on organic Pro-Mix loose at $15.65 for 2.8 cubit foot (20 L for each pot or plant) and at 2.65 plants m^{-2}.
** Pot cost at $0.84 each (per plant).
*** Liquid organic fertilizers/feeding, calculated based on water and fertilizer usage data in Table 1.
**** Other operating costs – includes utility, repairs, property tax and local trucking.

Table 3. The cost components for conventional rockwool and organic greenhouse tomato productions based on the tomato experiment in 2007 ($ m-2 and % - percentage as of the total cost).

Fertilizer type		Inorganic		OF2		OF3						OF4			
Growth media		Rockwool		OM4		OM2		OM3		OM4		OM3		OM4	
		$ m^{-2}	%	$ m^{-2}	%	$ m^{-2}	%	$ m^{-2}	%	$ m^{-2}	%	$ m^{-2}	%	$ m^{-2}	%
Heating		19.8	37.0	19.8	25.6	19.8	24.8	19.8	23.7	19.8	23.5	19.8	22.4	19.8	22.3
Labour		14.8	27.8	14.8	19.2	14.8	18.6	14.8	17.7	14.8	17.7	14.8	16.8	14.8	16.7
Growing	Rockwool/OM*	**2.4**	**4.5**	**6.4**	**8.3**	**2.0**	**2.6**	**6.0**	**7.2**	**6.4**	**7.6**	**6.0**	**6.8**	**6.4**	**7.2**
	Blocks	0.7	1.4	0.7	1.0	0.7	0.9	0.7	0.9	0.7	0.9	0.7	0.8	0.7	0.8
	Plugs	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Seeds	1.0	1.9	1.0	1.3	1.0	1.3	1.0	1.2	1.0	1.2	1.0	1.1	1.0	1.1
	Vermiculite or pot**	0.0	0.0	2.2	2.9	2.2	2.8	2.2	2.7	2.2	2.6	2.2	2.5	2.2	2.5
	Fertilizers***	**2.5**	**4.6**	**19.9**	**25.8**	**26.8**	**33.7**	**26.8**	**32.0**	**26.8**	**31.9**	**31.4**	**35.6**	**31.4**	**35.4**
	Biological Control	2.5	4.6	2.5	3.2	2.5	3.1	2.5	3.0	2.5	2.9	2.5	2.8	2.5	2.8
	Chemical Control	1.0	1.9	1.0	1.3	1.0	1.2	1.0	1.2	1.0	1.2	1.0	1.1	1.0	1.1
	CO2	1.9	3.5	1.9	2.4	1.9	2.3	1.9	2.2	1.9	2.2	1.9	2.1	1.9	2.1
	Sub-Total	12.1	22.6	35.8	46.4	38.3	48.1	42.2	50.6	42.6	50.8	46.8	53.1	47.2	53.3
Others – Operating**		6.7	12.6	6.7	8.7	6.7	8.4	6.7	8.0	**6.7**	**8.0**	6.7	7.6	6.7	7.6
Production - Total		**53.4**	**100.0**	**77.1**	**100.0**	**79.6**	**100.0**	**83.6**	**100.0**	**83.9**	**100.0**	**88.1**	**100.0**	**88.5**	**100.0**

* For growth media, the cost was $0.9/plant for rockwool stubby, $0.75/plant for OM2-Coco Stubby, $2.277/plant for OM3, and $2.424/plant for OM4; the total growth media cost was calculated based on 2.65 plants m^{-2} , and the labour cost for preparing the organic media was not included in the calculation.

** Pot cost was calculated at $0.8 each (per plant).

*** Liquid organic fertilizers/feeding cost were calculated based on fertilizer usage data in Table 1.

**** Other operating costs – includes utility, repairs, property tax and local trucking.

Table 4. Economical analysis for conventional rockwool and organic greenhouse tomato productions based on the tomato experiment in 2007*

Fertilizer	Growth media	Case 1				Case 2		Case 3				Case 4	
		$ m-2	MY(%)	$ kg^{-1}	%	$ kg^{-1}	%	$ kg^{-1}	MY (%)	$ kg^{-1}	%	$ kg^{-1}	%
IF1	M1	53.40	100.0	0.97	1.00	0.97	1.00	53.40	100.0	0.97	1.00	0.97	1.00
OF2	OM4	77.07	82.81	1.69	1.74	1.40	1.44	67.12	82.81	1.47	1.52	1.22	1.26
OF3	OM2	79.57	82.03	1.76	1.82	1.45	1.49	66.19	82.03	1.47	1.51	1.20	1.24
	OM3	83.56	92.19	1.65	1.70	1.52	1.56	70.17	92.19	1.38	1.43	1.28	1.31
	OM4	83.95	87.50	1.74	1.80	1.53	1.57	70.56	87.50	1.47	1.51	1.28	1.32
OF4	OM3	88.13	78.13	2.05	2.11	1.60	1.65	72.46	78.13	1.69	1.74	1.32	1.36
	OM4	88.52	84.38	1.91	1.96	1.61	1.66	72.86	84.38	1.57	1.62	1.32	1.36

* Economical analysis was only conducted for some of the best treatments in 2007 experiment, $ m^{-2} – total production cost, $ kg^{-1}- production cost per kg of tomato, MY (%) – marketable yield as percentage of the conventional rockwool (IF1 & M1, Table 20), % - production cost per kg of tomato as percentage of the conventional rockwool (IF1 & M1).

- Case 1 – Based on the actual achieved marketable yield as the percentage of conventional rockwool (MY (%)) in 2007 experiment; the total marketable yield of conventional rockwool (IF1 & M1) was assumed to be 55 kg m^{-2}; the total production cost was based on Table 3.
- Case 2 – Assumed the organic production system achieved the same yield as the conventional rockwool (IF1 & M1, 100%); other assumptions were the same as in case 1.
- Case 3 – Assumed the cost of organic fertilizers was reduced by 50% through further improvement in nutrient recycling etc. from the cost in 2007 while fruit yield stayed the same as case 1 (actual achieved marketable yield as the percentage of conventional rockwool (MY (%)); other assumptions were the same as in case 1.
- Case 4 - Assumed the organic production system achieved the same yield as the conventional rockwool (IF1 & M1, 100%) and cost of organic fertilizers was reduced by 50%; other assumptions were the same as in case 1.