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Effect of substrate and cultivar on growth characteristic of strawberry in soilless culture system

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The investigation was carried out for evaluation effect of substrate and cultivar on growth characteristic of strawberry in soilless culture system. Experimental treatment consisted of three strawberry cultivars (Camarosa, Mrak and Selva) and six growing media (rice hull, sycamore pruning waste, cocopeat + perlite (50:50), vermicomposts + perlite + coco peat (5:45:50), (15:40:45) and (25:35:40). Measured factors were dry and fresh weight of root and shoot, runner number, petiole length, leaf area, total biomass and root/shoot ratio. Measured physical and chemical characteristics of different substrate consisted of pH, EC, porosity, bulk density, particle density, % organic material and % inorganic material. Results show that these cultivars responded differently to different substrates under this investigation. Furthermore, these substrates had significant effects on cultivars. Camarosa cultivar had the highest of leaf area, length of petiole, runner number and total biomass. Mrak cultivar was the highest of yield. Adding vermicompost to substrates was effected in most of traits.

Key words: Substrate, vermicompost, strawberry, growth characteristics, cultivar.

INTRODUCTION

The soil acts as a reservoir to retain nutrients and water, and also provides physical support for the root system. Soilless culture is an artificial means of providing plants with support and a reservoir for nutrients and water. Characteristics of substrates include holding water and nutrient, providing good aeration to root system, light weight, free of pathogenic organisms and substances that are toxic to plants (Johnson et al., 2010). The use of different organic and inorganic substrates allows the plants better nutrient uptake, sufficient growth and development to optimize water and oxygen holding (Verdonck et al., 1982; Albaho et al., 2009).

Among growth medium, peat has been the most widely used. Many studies were carried out for search of new peat substitute. Reasons for the search of a peat substitute include high price, especially in countries without peat moss resources and environmental constraints (Abad et al., 2001). One of the substrates which can be used as a replacement for peat is composted pruning waste. Advantages of using of compost included reduction of volume of waste and high potential for using as substrate (Ribero et al., 2000; Zoes et al., 2001; Benito et al., 2006). Pathogens present or trace metals in composts can have hazardous effects. Analysis of materials studied demonstrated that composting of pruning waste whose organic components are free of contaminated waste, leads to a high quality organic amendment (Benito et al., 2006).

In addition, coconut coir is an inexpensive soilless media with suitable water and air retention capacity (Abad et al., 2002; Cantliffe et al., 2007a). Rice hulls are also easily available. In many studies, rice hulls were used as substitutes for organic and inorganic substrate (Tsakaldimi, 2006). Subler et al. (1998) reported that adding vermicompost to substrate significantly increased weights of tomato seedlings in 10 and 20% pig manure vermicompost. Melgar- Ramirez and Pascual-Alex (2010) also reported that the EC, pH, bulk density and water-soluble elements related to substrates increased with increasing amounts of vermicompost in the substrate, whereas significantly decreased the total porosity, easily available water and total water holding capacity. The growth of tomato seedlings in 10% vermicompost (from

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Table 1. Nutrient solution formula.

Micronutrient	Concentration (ppm)	Macronutrient	Concentration (ppm)
Fe	1.12	NH4	9
Mn	0.55	Ca	110
Zn	0.26	Mg	24
B	0.22	NO3	62
Cu	0.048	SO4	198
Mo	0.048	H2PO4	121.25
		K	204.75

Table 2. Substrate analyses at the beginning and end of strawberry cultivation.

Substrate	pH		EC	
	Before	After	Before	After
Rice hull	7.10	7.22	0.83	0.11
Sycamore pruning waste	7.46	7.55	0.65	0.55
50% coco peat: 50% perlite	7.22	7.46	1.32	0.84
5% vermicomposts: 45% perlite: 50% cocopeat	7.15	7.22	1.95	1.5
15 % vermicomposts: 40% perlite: 45% cocopeat	7.12	7.29	2.43	1.98
25% vermicomposts: 35% perlite: 40% cocopeat	7.52	7.66	2.73	2.22

pig waste) substrate significantly increases compared with those of plants grown in 100% Metro-Mix 360, 100% peat/perlite mixture or 100% coir/perlite mixture (Atiyeh et al., 2000 b). Zaller (2007) used percentage of vermicompost in substrate as substitute for peat and the results of his experiment showed that biomass allocation (root: shoot ratio), morphological and chemical fruit parameters were significantly affected in seedling substrate. However, it was not affected on yield and marketable of tomato. Zaller (2007) suggested vermicompost as an environmentally friendly potting media.

The aim of this study was to evaluate the effect of substrate and cultivar on growth characteristics of strawberry in soilless system.

MATERIALS AND METHODS

The investigation was conducted on the 6th of July 2010 to 2nd of February, 2011, at the experimental greenhouse of the Agricultural Faculty, Ferdowsi University of Mashhad (latitude 36° 16′ N, longitude 59°36′ E and 985 m elevation), Iran. The experiment was arranged in factorial experiment based on randomized complete design with four replications. Experimental treatment consisted of three strawberry cultivar (Camarosa, Mrak and Selva) and six growing media:

M1 = rice hull
M2 = sycamore pruning waste
M3 = 50% cocopeat + 50% perlite
M4 = 5% vermicompost + 45% perlite + 50% coco peat
M5 = 15 % vermicompost + 40% perlite + 45% coco peat
M6 = 25% vermicompost + 35% perlite + 40% coco peat

Day/ night temperature was kept at 22/17°C. Growth media were prepared based on volume (the volume of pot was 2000 cm^3). One plant was planted in each pot cultivars root were put in fungicides (mancozeb and captan) before planting. The hydroponic system was open and we used pot and pipe. Nutrient solution formula was prepared according to Kerej et al.'s (1999) instruction (Table 1). Nutrient solutions were used based on 100-250 ml $plant^{-1}$ day^{-1} depending on growth stage.

The pH and EC of nutrient solution were adjusted to 5.7 and 0.9 to 1.4 dS m^{-1}, respectively. Measured properties were dry and fresh weight of root and shoot, runner number, petiole length, leaf area, total biomass and root / shoot ratio. Leaf area was measured by area meter (L1- COR L1 – 3100C). Physical and chemical characteristics of different substrates were measured before planting (Verdonck and Gabriels, 1992). pH and EC was measured from watery extraction (1:10) at the beginning and the end of cultivation (Table 2). Data were analyzed using SAS 9.1 and means were compared by LSD test at 5% level of confidence.

RESULTS AND DISCUSSION

Analysis of variance of growth traits was significant in most cases ($P<0.05$) (Tables 3 to 6). Data of the effects of cultivars on growth characteristics showed that Camarosa was the best cultivar in leaf area, petiole length, number of runner and total biomass, whereas the highest dry and fresh weight of shoot, fresh weight of root, and yield were related to Mrak. Crown number and leaf number of Mrak cultivar have no significance with Camarosa cultivar and were the highest. The highest of root/ shoot ratio was obtained in Selva. There was no significant difference at $P<0.05$ in dry weight of root property (Table 3). In this investigation, three cultivars of

Table 3. Effect of cultivar on growth characteristics in soilless culture system.

Treatment	Leaf area (cm^2)	Petiole length (cm)	Number of runner	Root /shoot	Dry weight of shoot (g)	Fresh weight of shoot (g)	Dry weight of root (g)	Fresh weight of root (g)	Total biomass (g)	Yield (g)	Leaf number	Crown number
Camarosa	54.30^{a}	13.18^{a}	2.16^{a}	0.75^{c}	10.42^{b}	33.74^{b}	8.22^{a}	26.28^{b}	20.50^{a}	191.7^{b}	32.72^{a}	4.94^{a}
Mrak	48.77^{b}	12.63^{b}	1.16^{b}	0.90^{b}	11.60^{a}	38.90^{a}	8.90^{a}	34.63^{a}	18.64^{b}	213.9^{a}	35.28^{a}	4.61^{a}
Selva	46.96^{c}	11.51^{c}	0.27^{c}	0.99^{a}	8.08^{c}	27.70^{c}	8.46^{a}	27.65^{b}	16.54^{c}	170.4^{c}	21.61^{b}	3^{b}
Significance	**	**	**	**	**	**	n.s.	**	**	**	**	**

Different letters in columns indicate significant difference between treatments at 5% level. NS, Non-significant; *,**significant at P = 0.05 or 0.01, respectively.

Table 4. Effect of substrate on growth characteristics in soilless culture system.

Treatment	Leaf area (cm^2)	Petiole length (cm)	Number of runner	Root /shoot	Dry weight of shoot (g)	Fresh weight of shoot (g)	Dry weight of root (g)	Fresh weight of root (g)	Total biomass (g)	Yield (g)	Leaf number	Crown number
M1	48.77^{b}	10.4^{c}	0.2^{c}	0.79^{d}	8.69^{b}	31.75^{d}	9.38^{b}	26.56^{c}	18.08^{d}	177.8^{d}	23.77^{cd}	3.66^{bc}
M2	47.90^{b}	12.06^{b}	0^{c}	1.00^{a}	8.88^{b}	28.90^{e}	2.81^{d}	30.16^{b}	11.71^{f}	129.5^{e}	19.22^{d}	3.11^{c}
M3	54.17^{a}	12.22^{b}	0.5^{b}	0.96^{b}	8.43^{b}	28.78^{e}	7.73^{c}	27.65^{c}	16.15^{e}	173.4^{d}	28.88^{bc}	3.44^{bc}
M4	53.05^{a}	14.18^{a}	2^{b}	0.88^{c}	11.49^{a}	40.58^{a}	8.21^{bc}	36.13^{a}	19.71^{c}	222.1^{b}	39.88^{a}	5.66^{a}
M5	48.30^{b}	13.60^{a}	1.4^{b}	0.66^{e}	11.82^{a}	34.02^{c}	8.90^{bc}	22.56^{d}	20.72^{b}	236.6^{a}	32.55^{b}	4.55^{ab}
M6	47.87^{b}	12.12^{b}	3^{a}	0.99^{ab}	10.91^{a}	36.65^{b}	14.10^{a}	34.07^{a}	25.01^{a}	212.5^{c}	34.88^{ab}	4.66^{ab}
Significance	**	**	**	**	**	**	**	**	**	**	**	**

Same letter indicates no significant difference between treatments at 5% levels. M1= rice hull, M2= sycamore pruning waste, M3= 50% coco peat: 50% perlite, M4= 5% vermicomposts: 45% perlite: 50% coco peat, M5= 15 % vermicomposts: 40% perlite: 45% coco peat, M6= 25% vermicomposts: 35% perlite: 40% coco peat

Fragaria ananassa were used including Selva, Mrak (day neutral) and Camarosa (June bearer). June bearer cultivars produce runner more than day neutral (Strik, 2008), which is in agreement with result of this investigation. Generally, one of the strawberry propagation methods is using runner.

Comparisons of media showed that the highest of leaf area was related to M3 and M4, but there is no significant difference between other substrates at P<0.05. M4 and M5 had the highest of petiole length. The highest of runner number, dry weight of root and total biomass were related to M6, whereas the highest of root/shoot ratio was related to M2. The highest of yield was related to M5. Furthermore, the highest of fresh weight of shoot in M4 and the highest fresh weight of root was related to M4 and M6 (Table 4). Tehranifar et al. (2007) reported that the type of medium is effective on vegetative growth properties of strawberry cultivars, so that height of plant was higher in media with peat and coco peat compared with 100% sand and perlite, which was in agreement to the result of this experiment. Also, these results are similar to those reported by (Cantliffe et al., 2007b). Also, addition of 10 or 20% of vermicompost pig manure to a standard commercial potting medium significantly increased the weights of tomato seedlings, which is in agreement with the results of the experiments of Subler et al. (1998) and Atiyeh et al. (2000a).

Statistical analysis showed that interaction of substrate and cultivar significantly affected growth characteristic of strawberry in soilless culture system. Camarosa in substrate of M3 had highest leaf area and there was the lowest leaf area in Mrak cultivar and substrate of M5. Camarosa and Mrak in substrate of M4 had highest petiole length, while the lowest petiole was observed in Camarosa in substrate of M1. There were high of runner number in Camarosa cultivar in substrate of M4 and M6.

Table 5. Effect of substrate and cultivar on leaf area (cm^2), leaf number, crown number, petiole length (cm), number of runner and root/shoot in soilless culture system.

Treatment		Leaf area (cm^2)	Leaf number	Petiole length (cm)	Crown number	Number of runner	Root/shoot	Yield (g)
Substrate	Cultivar							
	Camarosa	45.13^{h}	19^{ef}	9.05^{i}	2.33^{fg}	0.00^{d}	0.64^{j}	128.09^{jk}
M1	Mrak	50.07^{efg}	27.33^{def}	11.30^{fgh}	4.33^{bcdefg}	0.66^{d}	0.57^{k}	214.45^{ef}
	Selva	51.10^{efg}	25^{def}	11.00^{fgh}	4.33^{bcdefg}	0.00^{d}	1.15^{c}	190.95^{g}
	Camarosa	47.06^{gh}	17,33^{f}	13.35^{bcd}	4.33^{bcdefg}	0.00^{d}	0.38^{l}	124.82^{k}
M2	Mrak	49.67^{fg}	24 d^{ef}	11.25^{fgh}	2.66^{fg}	0.00^{d}	1.28^{b}	140.28^{ij}
	Selva	46.98^{gh}	16.33f	11.60^{efg}	2.33^{fg}	0.00^{d}	1.35^{a}	123.38^{k}
	Camarosa	63.71^{a}	34^{bcd}	13.33^{bcd}	5^{bcde}	0.33^{d}	0.97^{e}	176.47^{h}
M3	Mrak	58.90^{b}	34.3^{3bcd}	12.90^{cde}	3.33^{defg}	1.00^{d}	1.04^{d}	203.07^{fg}
	Selva	39.91i	18.33^{ef}	10.43^{gh}	2g	0.33^{d}	0.86^{fg}	140.79^{i}
	Camarosa	61.88^{ab}	48.66^{a}	15.13^{a}	7.33^{a}	5.0^{a}	0.95^{e}	253.52^{ab}
M4	Mrak	52.11^{cde}	42^{abc}	15.30^{a}	6.67^{ab}	0.66^{d}	0.81^{gh}	264.14^{a}
	Selva	45.18^{h}	29de	12.13^{def}	3^{efg}	0.33^{d}	0.88^{f}	148.68^{i}
	Camarosa	54.77^{c}	32.66^{cd}	13.65^{bc}	5^{abcde}	2.33^{c}	0.80^{h}	236.18^{c}
M5	Mrak	36.27^{j}	40.66^{abc}	13.50^{bc}	4.66^{bcdef}	1.00^{d}	0.65^{j}	219.54^{de}
	Selva	53.85^{cd}	24.33^{def}	13.66^{bc}	4^{cdefg}	1.00^{d}	0.54^{k}	254.23^{a}
	Camarosa	53.25^{cde}	44.66^{ab}	14.56^{ab}	5.66^{abcd}	5.33^{a}	0.73^{i}	231.18^{cd}
M6	Mrak	45.62^{h}	43.33^{abc}	11.56^{fg}	6^{abc}	3.66^{b}	1.05^{d}	241.91^{bc}
	Selva	44.75^{h}	16.66^{f}	10.23^{hi}	2.33^{fg}	0.00^{d}	1.18^{c}	164.50^{h}
Significance		**	*	**	*	**	**	**

Same letter indicates no significant difference between treatments at 5% levels. M1= Rice hull, M2= sycamore pruning waste, M3= 50% coco peat: 50% perlite, M4= 5% vermicomposts: 45% perlite: 50% coco peat, M5= 15 % vermicomposts: 40% perlite: 45% coco peat, M6= 25% vermicomposts: 35% perlite: 40% coco peat.

The highest of root/shoot ratio was observed in Camarosa cultivar with M2 (Table 5). The highest of fresh and dry weight of shoot were observed in Camarosa cultivar with substrate of M5, and the lowest were observed in Selva cultivar in substrate of M6. There was the highest of fresh weight of root in Mrak cultivar in substrate of M6 and the lowest fresh weight was obtained in Camarosa in sycamore pruning waste. The driest weight of root was observed in Selva cultivar in substrate of rice hull. There was the lowest dry weight of root in Camarosa cultivar in substrate of M2. The highest of total biomass was observed in Mrak cultivar in substrates of M6 and M5. Also Selva cultivar in substrate of M1 and the lowest was obtained in Selva cultivar in substrate of M2 and M3. The highest of yield were related to Selva in M5 and Camarosa in M4 (Table 6.) Mrak cultivar is day neutral. These cultivars have poor vegetative growth because of much productivity.

On the other hand, there are positive relationships between yield with leaf number (Lieten, 2000) and crown number (Guttridge, 1985) and the result of this experiment is similar to previous results. Short

Table 6. Effect of substrate and cultivar on dry weight of shoot (g), fresh weight of shoot (g), dry weight of root (g), fresh weight of root (g) and total biomass (g) in soilless culture system.

Treatment		Dry weight of shoot (g)	Fresh weight of shoot (g)	Dry weight of root (g)	Fresh weight of root (g)	Total biomass (g)
Substrate	**Cultivar**					
M1	Camarosa	7.09[fg]	24.30[f]	5.71[fgh]	15.72[hi]	12.80[h]
	Mrak	8.80[def]	30.9[e]	3.59[hi]	17.80[h]	12.39[hi]
	Selva	10.19[cde]	40.05[c]	18.85[a]	46.16[b]	29.04[a]
M2	Camarosa	8.99[def]	25.34[f]	2.79[i]	9.80[j]	11.78[hij]
	Mrak	8.89[def]	34.44[de]	3.94[hi]	44.30[b]	12.83[h]
	Selva	8.75[ef]	26.93[f]	1.76[i]	36.36[c]	10.51[j]
M3	Camarosa	11.64[c]	33.24[ce]	8.04[ef]	35.12[de]	19.69[d]
	Mrak	6.12[g]	26.90[f]	11.27[cd]	28.0 3[f]	17.39[e]
	Selva	7.51[fg]	26.20[f]	3.87[hi]	22.61[g]	11.38[j]
M4	Camarosa	12.08[c]	47.54[b]	11.19[cd]	45.48[b]	23.28[c]
	Mrak	10.99[cd]	39.35[c]	9.11[de]	32.10[de]	20.10[d]
	Selva	11.40[c]	34.86[d]	4.35[ghi]	30.80[ef]	15.75[fg]
M5	Camarosa	8.23[efg]	23.95[f]	8.66[de]	19.26[gh]	16.90[ef]
	Mrak	19.137[a]	54.17[a]	11.20[cd]	35.37[cd]	30.34[a]
	Selva	8.10[efg]	23.94[f]	6.82[efg]	13.07[ij]	14.93[g]
M6	Camarosa	14.507[b]	48.08[b]	12.90[bc]	35.12[cd]	27.41[b]
	Mrak	15.68[b]	47.64[b]	14.29[b]	50.17[a]	29.97[a]
	Selva	2.54[h]	14.24[g]	15.12[b]	16.90[h]	17.66[e]
Significance		**	**	**	**	**

Same letter indicates no significant difference between treatments at 5% levels. NS, Non-significant; *,** significant at P = 0.05 or 0.01, respectively. M1= Rice hull, M2= sycamore pruning waste, M3= 50% coco peat+ 50% perlite, M4= 5% vermicomposts+ 45% perlite+ 50% coco peat, M5= 15 % vermicomposts+ 40% perlite+ 45% coco peat, M6= 25% vermicomposts+ 35% perlite+ 40% coco peat.

day cultivar of strawberry allocates dry matter in whereas day neutral root, cultivars allocate in leaf, which is because of differences in IAA, ABA and CK (plant growth substances) between these cultivars (Kafkafi, 1990). Hence, day neutral cultivars of strawberry will be of higher productivity and yield. On the other hand, higher yield in Mrak can be related to higher root to shoot ratio. This cultivar had suitable vegetative growth and high allocation of dry matter in root, therefore had highest yield.

Furthermore, analysis of variance of physical and chemical properties of substrate showed that all of physical and chemical properties are significant (P< 0.01) (Table 7). The highest of pH, EC and bulk density was related to M6 and the lowest EC and bulk density was related to M2 and M1, respectively while M6 was the lowest of porosity and the highest of porosity was related to M1. On the other hand, M3 had the highest of particle density and inorganic material, the lowest was observed in M2. The highest of organic material was observed in M2 and the lowest of organic material was related to M3 (Table 7). The

Table 7. Physical and chemical characteristics of different substrates.

Substrate	pH	EC (Ds/m)	Porosity	Bulk density	Particle density	Organic material	Inorganic material
M1	7.10[d]	0.83[e]	95.7[a]	0.079[f]	1.82[e]	59.94[b]	40.05[e]
M2	7.46[b]	0.65[f]	95.10[b]	0.086[e]	1.74[f]	68.69[a]	31.30[f]
M3	7.22[c]	1.32[d]	93.40[c]	0.141[d]	2.11[a]	36.24[f]	63.75[a]
M4	7.15[d]	1.95[c]	90.61[d]	0.194[c]	2.04[b]	38.75[e]	61.25[b]
M5	7.12[d]	2.43[b]	87.44[e]	0.253[b]	1.98[c]	42.66[d]	57.34[c]
M6	7.52[a]	2.73[a]	84.11[f]	0.304[a]	1.94[d]	47.88[c]	52.12[d]
Significance	**	**	**	**	**	**	**

Different letters indicate significant difference between treatments at 5% levels, NS, Non-significant; *,** significant at P = 0.05 or 0.01, respectively. M1= rice hull, M2= sycamore pruning waste, M3= 50% coco peat: 50% perlite, M4= 5% vermicomposts: 45% perlite: 50% coco peat, M5= 15 % vermicomposts: 40% perlite: 45% coco peat, M6= 25% vermicomposts: 35% perlite: 40% coco peat.

result of pH and EC are similar to those observed by Melgar-Ramirez and Pascual-Alex (2010). At the beginning of cultivation, the EC values increased above optimal range. Leaching by fertigation or irrigation cause reduction of EC of the substrate down which is similar to Altieri et al. (2010). The substrate, a medium in which roots can grow, also protected plant as physical support. It can be constituted of pure materials or mixtures. An adequate substrate for plant growing must present high water retention capacity, fast water drainage, and appropriate aeration. These characteristics are directly influenced by the substrate's particle size distribution and bulk density (Ansorena, 1994; Fernandes and Eduardo Corá, 2004). Porosity affects the balance between water and air content for each moisture level (Raviv et al., 1986).

In general, increasing the bulk density value decreased total porosity and increased water retention capacity. The results of this study are in agreement with those of Khalighi and Padasht-Dehkaee (2000) and Fernandes and Eduardo Corá (2004). The highest of biomass content was observed in M6 substrate, which had the highest of bulk density and consequently the highest of holding water capacity. One of the problems in hydroponic system is not having buffering property, but placing substrate in this system almost solved this problem. Between substrates, there were differences in this property. Providing better holding water and nutrition solution will be better for growth.

Conclusion

According to results of this experiment, for better growth and consequently higher yield, suitable substrate that will have high water holding capacity, suitable bulk density and better porosity must be chosen. Among the cultivars, Camarosa, which is a short day plant, consequently had high vegetative growth, while Mrak, day neutral, had high yield. Also, M4 and M5 were the best in the measured properties. Mrak in M4 had the highest yield.

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