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Effects of Different Substrates on Plant Growth, Yield and Quality of Watermelon Grown in Soilless Culture

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Abstract: Different substrates (perlite, peat, mix of basaltic tuff, andezitic tuff, mix of andezitic tuff and peat (1:1) and sand) were compared for the soilless culture of watermelon in greenhouse based on plant growth, yield, fruit quality and plant nutrient uptake. The highest vegetative growth was observed in basaltic mix, sand, peat and greenhouse soil respectively. The weakest growth occured in mix of andezitic tuff and peat. While the highest yield was gained from perlite, the lowest yield was from andezitic tuff and mix of basaltic tuff. As regard to fruit quality, the results were also similar to the yield. There was no significant difference between total soluble solid contents and rind thickness. All fruit samples taken from the substrates were found sufficient as regard to total soluble solids. The highest plant nutrition content was determined in mix of basaltic tuff in which plants were fed better in comparison to other substrates.

Key words: Watermelon · soilless-culture · growing media · yield · quality

INTRODUCTION

In plant production, higher productivity can be achieved depending upon how efficiently environmental conditions can be controlled. Environmental conditions may relatively and effectively be controlled under greenhouse conditions. Climatic factors in greenhouses such as temperature, air humidity, light and gas content of air might be managed to the sufficient levels that are necessary for full plant growth. Hence, much more yield and quality can be obtained in demanded seasons.

As an alternative plant cultivation technique, soilless culture, expanded enormously during the 1980s due to its advantages over cultivation in soil [1]. This technique has been used widely in middle and western European countries [2]. The techniques facilitated to take under control of soil borne diseases and to protect soil and underground water from pollution caused by pesticides and fertilizers specifically nitrogen. In greenhouse vegetable production, substrate/aggregate culture is widely used soilless culture technique. Since substrate culture requires cheaper beginning material and it creates a buffer zone around the roots, it is accepted by the farmers widely. The substrates need to have some characteristics. These are high water holding capacity, having air space despite the high moisture content, high drainage ability, low level of degradation speed, having very limited and/or less pathogen and pest, not having toxic material (or having at the very minute amounts), keeping up its characteristics for long time and being cheap [3, 4].

In Çukurova region, watermelon producers face some problems such as decreasing yield and increasing pathogen population in early watermelon production. These are due to repeat and intensive watermelon cultivation in the same area. Since watermelon production is highly affected by soil fatigue, watermelon can not be grown efficiently on the same field without four or five years of plant rotation [5]. In addition to these factors, watermelon prices are high in certain periods and early watermelon production becomes very essential for both domestic and international market.

In this study, the effects of different substrates on watermelon plant growth, yield, fruit quality and nutrient content were investigated in soilless culture.

MATERIALS AND METHODS

The study was performed on in 500 m^2 unheated glasshouse in Department of Horticulture, Faculty of

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Table 1: Physical, Chemical characteristics and nutrients content of substrates before planting

		P	AT	PT	S	BM	GS
N (%)		Trace	Trace	1.2	Trace	3.2	0.3
P (%)		Trace	Trace	0.4	0.3	2.1	0.004
K (%)		3.1	2.1	0.5	1.1	1.3	2.8
Ca (%)		Trace	0.3	0.9	1.2	4.1	3.1
Mg (%)		Trace	0.2	0.7	0.7	8.1	2.0
Fe (mg l^{-1})		Trace	0.3	0.8	2.0	7300	4.0
Zn (mg l^{-1})		Trace	0.1	0.4	0.3	165	0.5
Mn (mg l^{-1})		Trace	0.1	0.3	0.4	1000	0.5
Cu (mg l^{-1})		Trace	Trace	0.4	Trace	60	6.0
PH		6.6	6.7	7.9	7.6	7.1	7.5
Salt (%)		0.002	0.01	1.84	0.18	0.08	0.15
Porosity (%)	Macro	32	21	45	8	39	26
	Micro	35	32	36	33	37	16
	Total	67	63	81	45	76	42
Particle Size (%)	1-3 mm	12	6	--	98	18	43
	3-6 mm	29	32	--	2	35	7
	6-15 mm	59	62	--	--	47	50

Table 2: Concentration of nutrients in the cultivation solution

Macro elements	Concentration (mg l^{-1})	Micro elements	Concentration (mg l^{-1})
N	192.20	Fe	1.68
P	57.97	Mn	0.85
K	361.28	B	0.44
Ca	132.33	Zn	0.30
Mg	29.40	Mo	0.016
S	24.72	Cu	0.85

Agriculture, University of Çukurova in the spring of 1998 and 1999.

The watermelon cultivar Crisby F_1 grown intensively in Çukurova region was used as plant material. Organic and inorganic materials were chosen as substrate materials (Table 1) and andezitic tuff (AT) from Capadocia region, peat (PT) from Bolu, sand (S), perlite (P), mix of basaltic tuff (BT) from Osmaniye, a newly introduced material to Turkey for soilless culture [6] and greenhouse soil (GS). All substrates were new and they were used for one year only.

Troughs made of black PVC material with dimensions of 240 x 25 x 15 cm (U shape) were used as containers. In the system, 12 liters medium was used per plant. Open system was used. A pump with 1 kW power was used for water distribution [7]. For the water distribution, drip irrigation system pipe was used.

Nutrient solution was prepared from modified nutrient solution developed for melon cultivation (Table 2) [8]. EC and pH of the solution were measured by a portable EC meter and they were calibrated and/or adjusted with nitric and phosphoric acid and kept up between 6.5-7.0 during the study. Irrigation schedule and dose: Two different irrigation doses were used depending on plant developmental stage. In March and April doses of 2 liters water plant^{-1} day^{-1} were applied. In May and June, doses of 4 liters water plant^{-1} day^{-1} were applied. Amount of water was decreased to 0.5 liter water/plant one week before harvest to prevent fruit cracking and some other disorder of fruit. Irrigation was done by two days intervals.

Seeds were pregerminated at 28°C for 24 h and were sown into 10 x 8 pots filled with mix of perlite and peat (1:1). When seedlings had 3-5 true leaves, they were transplanted into the troughs filled with the substrates at 50 cm spacing. Space between through (between rows) was 2 m. Seeds were sown at 12.01.1999 and seedling transplanted at 20.03 1999. The experiment was established according to Randomized Blocks with 4 replicates. Data were analyzed with variance analysis and means were compared by Tukey test (5% significant level). MSD (mean significant difference) was presented.

One month after transplanting (20.04.1999) diameter of hypocotyl and main stem were measured by a compass and length of main stem was measured in 5 plants in each plot. These parameters were also measured after harvest. Moreover, date and node number of the first male and female flowers were determined by daily observation. Flowering time was calculated as day from sowing date. After harvest, plants were rooted up carefully and root fresh weight was determined.

Harvest was done 80 Days After Transplanting DAT. In three fruits from each plot, mean fruit weight (kg), diameter (cm), length (between peduncle and blossom end) (cm), rind thickness (mm) and soluble solids (%) were determined.

Analysis of N, P, K, Mg, Fe, Zn, Cu, Mn, pH and salt were done in substrates in both before planting and after harvest. In flowering time, 8th leaf was taken as sample [9] and macro (N, P, K, Ca, Mg) and micro elements (Fe, Zn, Mn, Cu,) analysis were done [10]. In substrates, phosphorous as colorimetric [11], usable potassium [12], calcium and magnesium [10] microelement analysis [13], pH [14] and total salt in soil [15] were done. For substrate analysis, samples were taken from substrate and analysis were done by 3 parallels before planting, on the other hand, after harvest samples were taken from each replicate and mixed. Three parallels reading were done from mixed samples for each characteristics and element. Leaf from each replicates were taken and mixed. Three parallels reading were done for each element and mean of the 3 readings were presented.

RESULTS

Vegetative growth results 30 DAT were presented in Table 3. Among the parameters measured, only difference was found in hypocotyl diameter between substrates. The thickest hypocotyl was measured in the plants grown on BT. This was followed by the plants grown on GS, PT and P respectively. The lowest value in hypocotyl thickness was observed in AT.

Formation of the first male flower was observed 97 to 101 days after sowing based on substrates. While the plants in BT (96.75 days) and AT (96.75 days) flowered first, the plants grown in greenhouse soil (101 days) flowered last. Formation of the first female flower was observed 100 and 103 days after sowing and this 3 days difference was not found statistically significant. In andezitic tuff, a weak medium, female flower formed on 6.5th node on main stem and the plants grown in greenhouse soil, plant formed female flower on 9th node. Other substrates presents results between these two values (Table 3). In node number of female flower formed on was not influenced by treatments.

After harvest the thickest hypocotyl was determined in the plants grown in BT with 13.12 mm. The plants grown on AT and PT had the weakest hypocotyl with 9.34 and 8.91 mm, respectively. Similar results were obtained as regard to main stem diameter and length. The highest number of nodes on main stem was determined in the plants grown on BT and P. In terms of root fresh weight, The heaviest root was produced by the plants grown on BT and S with 44.40 and 28.50 g, respectively while the lowest value was determined in the plants grown on PT and AT (Table 4).

Perlite was also ranged in the first place as regard to yield. It was followed by PT, S and GS. The lowest yield was obtained from the plants grown on AT and BT (Table 5). The heaviest fruit was determined in the plants grown on PT (7675 g) and the smallest fruits were obtained from the plants grown BT (3250 g). There was no statistical difference concerning total soluble solids and rind thickness between the treatments (Table 5).

In Tables 6 and 7, main macro and microelement analysis, salt content and pH of substrates after the harvest were presented. As it is shown in the tables, BT had the highest concentration of plant nutrients. This mixture has more N, P, Ca, Mg, Fe, Zn, Mn and Cu than

Table 3: Hypocotyl, main stem diameter and main stem length of the plants 30 DAT and blooming time and node number of male and female flowers

				Female flower		Male flower	
Substrates	Hypocotyl diameter (mm)	Main stem diameter (mm)	Main stem length (mm)	Time (day)	Node (number)	Time (day)	Node (number)
P	5.58bc	3.65	93.00	100.50	7.75ab	99.00ab	5.50
AT	5.50c	3.43	78.00	99.75	6.50b	96.75b	4.50
PT	6.03a-c	3.78	98.50	102.00	7.50ab	99.00ab	5.75
S	6.63a-c	3.63	101.00	101.00	7.50ab	98.50ab	5.25
MB	6.95a	3.85	101.00	99.75	7.75ab	96.75b	4.75
GS	6.73ab	3.53	93.50	103.00	9.00a	101.00a	6.25
MSD (% 5)	1.20	ns	ns	ns	ns	3.24	ns

Table 4: Hypocotyl diameter, main stem diameter and length, node number of main stem and root fresh weight of the plants after harvest

Substrates	Hypocotyl diameter (mm)	Main stem diameter (mm)	Main stem length (cm)	Node number of main stem	Root fresh weight (g)
P	10.14cd	4.59bc	353.50a-c	57.85	28.50a-c
AT	9.34d	4.10c	246.75c	52.33	17.00c
PT	8.91d	4.20c	262.28bc	48.60	12.40c
S	11.79ab	4.61bc	284.75a-c	55.38	40.25a
BT	13.12a	5.64ab	377.00a	57.70	44.40a
GS	11.27bc	6.80a	362.25a-c	46.63	26.08bc
MSD (%5)	2.12	1.21	95.18	ns	17.55

Table 5: Total yield and fruit characteristics of watermelon grown in different substrates

Substrates	Total yield (kg plot^{-1})	Fruit weight (g)	Fruit diameter (cm)	Fruit length (cm)	Rind thickness (mm)	Total soluble solids (%)
P	30.67a	5013.0ab	19.00ab	21.25ab	10.70	10.80
AT	7.48d	5275.0ab	18.50ab	20.50ab	11.14	10.25
PT	23.63ab	7675.0a	23.13a	26.50a	12.38	10.25
S	20.94bc	5417.0ab	20.50ab	21.63ab	14.09	10.25
BT	9.96d	3250.0b	16.50b	17.63b	10.70	10.20
GS	19.93bc	4490.0b	19.50ab	21.18ab	11.20	10.88
MSD (%5)	7.74	3379	5.55	5.28	ns	ns

Table 6: Plant nutrient content and some chemical characteristics of substrates after harvest

	P	AT	PT	S	BT	GS
N (%)	1.3	Trace	0.7	0.2	1.2	0.3
P (%)	0.0002	Trace	0.2	0.1	1.7	0.0004
K (%)	2.1	1.9	0.3	0.7	0.6	2.1
Ca (%)	0.6	0.3	0.6	0.4	3.2	2.6
Mg (%)	0.3	0.2	0.5	0.6	7.2	1.7
Fe (mg l^{-1})	0.3	0.2	0.2	0.2	7231.0	3.0
Zn (mg l^{-1})	0.3	0.1	0.1	0.1	148.0	0.4
Mn (mg l^{-1})	0.1	0.1	0.1	0.2	943.0	0.4
Cu (mg l^{-1})	0.2	0.1	0.3	0.1	55.0	5.0
PH	6.7	6.9	7.6	7.5	7.2	7.6
Salt (%)	0.002	0.03	0.09	0.09	0.08	0.17

Table 7: Concentration of macro and micronutrients in watermelon leaves grown in different substrates

	Macro elements (%)				Micro elements (mg l^{-1})				
Substrates	N	P	K	Ca	Mg	Fe	Zn	Mn	Cu
P	1.9	0.23	2.6	0.3	0.50	19	12	17	5
AT	1.8	0.22	2.6	0.4	0.40	21	12	16	5
PT	2.2	0.30	2.2	1.2	0.35	43	14	21	11
S	1.7	0.26	2.1	1.7	0.42	38	13	30	9
BT	3.6	0.36	2.7	1.7	0.70	62	26	37	11
GS	2.1	0.22	2.4	2.3	0.64	48	19	28	7

both soil and other substrates. According to these results, the plants grown on BT consisting all plant nutrients except Ca were fed better than the plants grown on other substrates. However, it was noticed that N content of the plants is much more above (2-3%) than the normal level. As it is well known, overfeeding with N promotes vegetative growth and in contrast it causes to recede in generative growth. Consequently, it brings about reduction in yield. In addition to this, early flowering observed in BT was probably related to its heat absorbing ability due to its dark color.

DISCUSSION AND CONCLUSION

In the lights of our results it was seen that watermelons with deep and strong root system can be grown successfully in the soilless culture. In this study, perlite was found the most promising substrate among seven different substrates. In similar studies in melon [16] and watermelon [17, 18], it was also found that perlite was the most efficient medium in soilless culture. The use of perlite for soilless crop production was described by Wilson [19], Wilson and Hitchen [20] and Wilson *et al.* [21]. Perlite has the highest water and plant nutrient holding capacity. Moreover, it has also high aeration ability, powerful capillarity, low heat conductivity and it provides support and darkness to plant needs [22]. Nowadays, due to these reasons, producers have accepted perlite as the most popular substrate. Mix of basaltic tuff added to the experiment in the second year gave a good vegetative growth but fruit set was affected negatively by mix of basaltic tuff. In this study andezitic tuff, provided from Capadocia region of Turkey gave the worst results. Andezitic tuff restricted the vegetative and generative growth of watermelon. Similar effects of andezitic tuff were reported for tomato, eggplant [23, 24] and also for cucumber [25]. According to these reports andezitic tuff caused the lowest yield and vegetative growth among substrates they used. Peat, an organic substrate, gave a positive response in the first year, but in the second year, the results were negative and very much similar to that of andezitic tuff. The main reason may be the fact that the peat used in the first year was decomposted completely and packed regularly. In the second year, the peat brought (as a mass) unpacked and it was noticed that organic materials in the peat did not decomposted completely. In the light of our results it is concluded that perlite can be used as a main soilless culture substrate for watermelon production. If water holding capacity is managed, more successful results may be obtained from BT.

REFERENCES

1. De Rijk, G. and E. Schrevens, 1998. Distribution of nutrients and water in rockwool slabs. Scentia Horticulturae, 72: 277-285.
2. Garnaud, J.C., 1992. Protected Cultivation in French Mediterranean. Plasticulture, 90: 45-50.
3. Klougart, A., 1983. Substrates and Nutrient Flow. Acta Horticulturae, 150: 297-313.
4. Grass, R., 1985. Proprietes Physiques des Substrates in Les Cultures Hors Sol, ed. Blanc, D., INRA Publ., Paris, pp: 79-126.
5. Messiaen, C.M., 1974. Le Potager Tropical (1-généralités). Agence de Coop.,Culturelle et Technique Publ., Paris - France, pp: 196.
6. Karaman, C., Z. Kaya and H. Özbek, 1998. Possibility of Bazaltic tuff and pirit use in sustainability of soil productivity. TÜBİTAK/TARP Project Number: 1913.
7. Abak, K., A. Sevgican, H. Çolakoğlu, N. Eryüce, A. Gül, N. Baytorun, G. Çelikel and M. Paksoy, 1994. Researches on Soilless Culture in Greenhouse Cultivation. TUBITAK (The Scientific and Technical Research Council of Turkey) Project No: TOAG 884, Ankara, Turkey, pp: 84.
8. Peron, J.Y., P. Lemanceau, S. Charpentier and G. Chasseriaux, 1984. Soilless culture of melon. P.H.M. Revue Horticole, 250: 25-31.
9. Bergmann, W., 1993. Ernaehrungstörungen bei Kulturpflanzen. Gustav Fischer Verlag. Jena, Stuttgart, pp: 388.
10. Kacar, B., 1972. How to determine fertilizer needs of soil. University of Ankara, Faculty of Agriculture Publ., No: 453, Ankara.
11. Murphy, I. and J.P. Riley, 1962. A Modified Single Solution Method for the Determination of Phosphate in Natural Waters, Anal. Chem. Acta., 27: 31-36.
12. Pratt, P. F., 1965. Potassium, Method of Soil Analysis Part 2. Amer. Soc. of Agron. Inc. Madison, Wisconsin, USA., pp: 1019-1030.
13. Lindsay, W.L. and W.A. Norwell, 1978. Development of a DPTA Soil Test Zinc, Iron, Manganese and Cupper. Soil Sci. Soc. Am. J., 42: 725-729.
14. Shlichting, E. and H. Blume, 1966. Bodenkundlichhes pracktikum. Paul Parey Verlag, pp: 432.
15. Soil Survey Staff, 1962. Soil survey manual. USDA, Handbook No: 18, pp: 503.
16. Daşgan, H.Y. and C. Olympus, 1995. The Effects of Substrates on the Plant Growth, Fruit Production and Quality of Hydroponically Grown Sweet Melon (*Cucumis melo*, L.). Turkey 2th National Horticulture Congress Rp., V II, Adana, pp: 221-225.
17. Park, S.G., B.S. Lee and S.J. Chung, 1999. Effect of substrates on growth and fruit quality of "Mudeungsan" watermelon grown in hydroponics. Journal of the Korean Soc. for Hort. Sci., 40: 419-424.

18. Grudina, R., N. Fadda, F. Chessa, S. Leoni, G. Serra, F. Tononi and S. Leoni, 1994. Two years of watermelon cultivation in soilless culture. Acta-Horticulturae, 361: 574-577.
19. Wilson, G.C.S., 1980. Perlite system for tomato production. Acta Hort. (99): 159 -166. Cited by: Winsor and Schwarz. 1990. Soilles Culture for Horticultural Crop Production.
20. Wilson, G.C.S. and G.M. Hitchen, 1984. The developments in hydroponics systems for the production of glasshouse tomatoes. Procceeding 6^{th} Int. Congr. Soilless Culture. ISOSC. Wageningen-Holland, pp: 793-800.
21. Wilson, G.C.S., D.A. Hall and A.J. McGregor, 1984. Perlite cultur of tomatoes. West of Scotland Agriculture College, Auchincruwe, Technical Note No. 219, pp: 6.
22. Sevgican, A., 1999. Protected Vegetable Cultivation (Soilless Culture). V. II. University of Ege, Faculty of Agriculture. Publ. No: 526, Izmir, pp: 130.
23. Çelikel, G. and K. Abak, 1995. Quality of tomato grown in soilles culture. Turkey 2^{th} National Horticulture Congress Rp., V II, Adana, pp: 37-40.
24. Çelikel, G. and K. Abak, 1995. Yield, Quality and Precocity in Eggplant grown by Soilless Culture in Different Substrates. Turkey 2^{th} National Horticulture Congress Rp., V II, Adana, pp: 126-130.
25. Gul, A., 1955. Effects of usage period of substrates to yield in cucumber cultivation in greenhouse. Turkish National Congress on Horticulture, V. II, Adana, pp: 181-186.