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Effect of Clinoptilolitic-zeolite and Perlite Mixtures on the Yield and Quality of Strawberry in Soil-less Culture

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ABSTRACT

Most growing media for strawberries in soilless culture are peat moss, rockwool, coir, perlite or some other mixtures. Clinoptilolitic-zeolite as a cheap substrate may be replaced with commercial substrates due to high buffering and cation exchange capacity (CEC), retaining and releasing K and NH_4 ions. The effects of five different media based on 1:0, 3:1, 1:1, 1:3, 0:1 v/v of perlite and zeolite were evaluated on quantity and quality of strawberry (*Fragaria ananassa* cv. Camarosa) fruits in soilless culture. Plants were fertilized by nutrient solution containing macro and micronutrients at EC 0.9 - 1.4 dS m^{-1}, pH 5.8. Perlite/zeolite (P/Z) substrates 3:1 and 1:1 ratio (v/v) produced the highest fruit number per plant with 22.23 and 23.05 fruits, respectively, while zeolite alone showed the lowest fruit number. In addition, the greatest crown per plant and fruits yields were recorded on media P/Z 3:1 and 1:1 ratio, while number of flowers, fruits, fruit weight and yield/plant decreased on P/Z 1:3 ratio. Analysis of fruits indicated that highest dry weight (10.23%) total soluble solids (TSS), titrable acids (TA) and their highest ratio (10.57) were measured on P medium, whereas the highest TA was noted on Z and P/Z 1:3 ratio. The amounts of TA on P and mixtures of P/Z at 3:1 and 1:1 ratios showed no significant differences.

Key Words: Soilless culture; Substrate; Strawberry

INTRODUCTION

Strawberry is commonly produced as early spring crop or out-of-season in open field, glasshouse or polyethylene tunnel. Pests and diseases in soil culture have always been problems especially in protected areas (Gul *et al*., 2005). Suitable mixture of substrate in soil-less culture within greenhouse systems, extend harvesting duration, out of season strawberry production and increase in yield (Takeda, 1999). Material properties of substrate exhibit direct and indirect effects on plant physiology and production (Cantliffe *et al*., 2001). In order to grow strawberry, different substrates such as peat moss, coconut coir, perlite, rockwool and pine bark have been used. However, peat has been the best substrate for hydroponic culture (Lieten, 2001). Due to high price and not easy available peat moss, its replacement with other substrates has been conducted in developing countries (Cantliffe *et al*., 2001). There are different reports related to use of zeolite and perlite as substrates in hydroponic culture (Maloupa *et al*., 1999). Zeolits are crystal alumina silicate that has negative charge, which is balanced by one or two valence positively charged cations (Mumpton, 1999). Other properties of zeolites contain high absorption level, water retaining and releasing, high cation exchange capacity (CEC) and high buffering against to change of pH (Allen & Ming, 1995). High exchange potential of cation NH_4^+ and K^+ has been considered as an important property of zeolits (Maloupa *et al*., 1999). Kanazirska *et al.* (1997) reported decreasing potassium exchange in substartes of perlite and mixtures of perlite/zeolite cucumber hydroponic culture. Hence clinoptilite-zeolite have been suggested as a substrate in hydroponic culture (Kanazirska *et al*., 1997). Within Perlite and mixtures of perlite and zeolite in 1:1, 2:1 and 1:2 ratios, the ratio of 2:1 increased yield, soluble solides content and quality in tomato. Zeolite due to high CEC, capacity to hold water and nutrient lead to improved yield and fruit quality (Djedidi *et al*., 1997). Soilless culture of gerbera gave higher yield on perlite/zeolite (P/Z 1:1 ratio) than other mixtures, due to sufficient aeration and improved water retention capacity (Issa *et al*., 1997). Turhan and Atilla (2004) studied the effect of perlite alone and mixture of P/Z (1:1 ratio) on ionic composition in "camarosa" strawberry plantlets during vegetative phase. They found that using P/Z mixtures as substrate to grow strawberry may be beneficial. Zeolite is available in Iran in abundant anounts that has placed as a second mineral after iron stone. The objective of this investigation was to determine the effects of Z/P mixtures as substrate on yield and quality of strawberry fruits in vertical system soil-less culture.

MATERIALS AND METHODS

Dormant bare root culture of strawberry (*Fragaria ananassa* Cv. Camarosa) as a short day cultivar was prepared in October 2004. In order to assist flower initiation and forcing, the transplants experiment were incubated at 3°C and 85% RH for two weeks (Takeda, 1999). During three weeks in pots with perlite/coco peat (1:1 ratio) transplants produced 3 - 4 leaves with 1.5 cm crown diameter. Five different media mixtures with 1:0, 3:1, 1:1, 1:3, 0:1 v/v ratio of zeolite and perlite were prepared.

Physical and chemical characteristics of media including specific gravity, bulk density, water, air and total porosities, cation exchange capicity, pH and electrical conductivity are given in Table I. The hydroponic system was vertical and nutrition system open. The vertical system was made with four Styrofoam pots at 25 cm diameter in 1.1 meter height. The greenhouse was operated at 10 - 15°C during night and 20 - 25°C daily temperature. The columns were fixed at 1.3 columns m^{-2} and 21 plants m^{-2} density (16 plants $column^{-1}$). Lieten (1999) nutrient solution containing NO_3, NH_4, H_2PO_4, SO_4, K, Ca and Mg with 11.5, 0.5, 1.5, 1.5, 3.5, 4.5 and 1.5 mmol L^{-1} and micronutrients Fe, Mn, Zn, B and Cu with 20, 20, 10, 12 and 0.75 µmol L^{-1} 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 5.8 and 0.9 - 1.4 dS m^{-1}, respectively. Fruits were harvested from 15 February to 15 June 2005 twice a week. The fruits number, marketable yield and total yield of each replicate were determined. Fruits dry weight was taken by drying 100 g fresh fruit at 70°C in oven for 48 h. Titrable acid (TA) and total soluble solid content (TSS) were evaluated with NaOH (0.1 N) titration and refractometere, respectively. The fruit pH and EC were obtained. Anthocyanins content were measured by spectrophotometer at 512 nm wavelength. In order to determine the mineral nutrient content of fruits, standard procedures were adopted. Nitrogen was measured with Kjeldahl method. Phosphorus was determined colorometrically, K^+ and Na^+ by flame emission, Ca^{2+} and Mg^{2+} by atomic absorption spectrophotometer. The experiment was conducted in a complete randomized design with 3 replications. Data was analyzed by software SAS. The analysis of variance and Duncan multiple range test was used to find significant differences in the means.

RESULTS

Variance analysis of generative traits and production were significant ($P < 0.01$). Comparisons of media showed the highest flower (41 & 40.23) and fruit number (22.66 & 23.05) in mixtures of P/Z (3:1 & 1:1) v/v, whereas the lowest number were produced on Z medium only (Table II). Highest fruits yield was obtained at the largest amount on media P/Z 3:1 and 1:1 v/v, while number of flowers, fruits, fruit weight and yield/plant decreased on P, P/Z 1:3 and Z alone, respectively (Table II). The ratios of P/Z 3:1 and 1:1 increased number of crown $plant^{-1}$ significantly, whereas other media indicated a declined in these attributes. Highest marketable yield (119.29 g $plant^{-1}$) was produced on P/Z 3:1 and the lowest (37.54 g $plant^{-1}$) on Z.

Fruits quality analysis of treatments indicated that anthocyanins, pH and EC of fruits were not significant (Table III). However, other characters such as dry weight, total soluble solid/titrable acids (TSS/TA) and TA were significant (Table III). Highest dry weight (10.23%), TSS (7.87%) and ratio of TSS/TA (10.57) were measured on P medium, whereas the highest TA was observed on Z and P/Z 1:3. The amount of TA on P and mixtures of P/Z at 3:1 and 1:1 v/v indicated no-significant differences.

Mean comparison of nutrient elements of fruit were significant ($P < 0.01$) except phosphorus (Table IV). The Highest quantities of N and K^+ (1.74 & 0.47%, respectively) were found on P medium but Z showed at the lowest. Fruits on Z medium had higher calcium and magnesium (0.20 & 0.20%) than other substrates. The Highest amount of Na^+ was found on Z medium (0.27%), while it was lower on P and P/Z (1:3) media (0.06 & 0.12%, respectively).

DISCUSSION

The number of strawberry flowers and fruits are related to number and diameter of crowns, which can be used to predicted plant yield potential (Hancock, 1999). Inflorescence appears from apical meristem that is originated from the crown. Therefore, increase in crown branches may be suggested origin of flower (Lopez-Galarza *et al.*, 1997). In order to compensate limited uptake of nutrients in perennial plants such as strawberry, part of the nutrients reserve in crown and roots during the year can be remobilized in the next year (Taghliavini *et al*., 2005). In this study crown diameters were equal through the experiment. It seemed that during the flowering, high amount of nutrients were transferred to regenerative organs. This result is similar to Taghliavini *et al*. (2005), who report that small amount of carbohydrates and nutrients are stored in roots and crowns. A suitable growth was found in P/Z 3:1 and 1:1 media due to greater crown number than other treatments.

The fruit size is correlated to water content. Fruit as strong sink decreases absorption of water and nutrient on substrates with low ability of reserving water. Furthermore, with high EC of the rhziosphere, the plant water availability will be limited. Hence plant with low level of carbohydrate and water affect leaf number, leaf surface, fruit weight and size (Cantliffe *et al.*, 2001). Zeolite with high CEC causes easy storing and releasing of nutrients and improves water management in soil-less culture and perlite increase aeration in substrate. Therefore, in this study P/Z 3:1 and 1:1 media supplied sufficient water storing, suitable aeration, low salinity stress and no limitation of water for strawberry. Similarly, high yields have been observed in hydroponic culture of tomato (Djedidi *et al*., 1997), cucumber (Kanazirska *et al*., 1997), gerbera (Issa *et al*., 1997) and rose (Maloupa *et al*., 1999) with mixture of zeolite and perlite.

Fruit dry weight is an important factor in strawberry quality, which depends on water content in plant (Saied *et al*., 2005). In addition there are direct correlation between sugar concentration and nitrogen content of fruits (Lasertosa *et al*., 1999). Low water retained in perlite decreased plant water level, which caused an increase of dry weight. The higher acidity was found in media with higher proportion of zeolite than perlite. The reason for the higher acidity in substrate with high EC has been reported due to low

Table I. Physical and chemical properties in substrates

Substrates	specific gravity (gr/cm^3)	Bulk density (gr/cm^3)	Total prosity (%)	Water prosity (%)	Air prosity (%)	CEC (meq/100g)	pH	EC
Perlite	0.93	0.07	91.76	27.89	63.87	4	6.4	1.36
Perlite/zeolite(75+25)	1.29	0.23	82.03	31.56	50.47	75	6.77	1.4
Perlite/zeolite(50+50)	1.65	0.47	71.36	39.32	32.04	120	7.38	1.81
Perlite/zeolite(25+75)	1.95	0.79	64.5	40.4	24.1	148	7.7	2.93
Zeolite	2.17	1.14	57.23	42.4	14.83	170	8.13	3.01

Table II. Effect of substrate on quantitative properties

Substrates	Crown number	Crown diameter (cm)	Number of flowers	Number of fruits	Weight of fruits (g)	Yield (g/plant)	Marketable fruit (g/plant)
Perlite	2.55b**	1.98^{ns}	35.18b**	20.66b**	10.18bc**	210b**	101.21b**
Perlite/zeolite(75+25)	3.5a	2.51	41a	22.66ab	11.44ab	256.84a	119.29a
Perlite/zeolite(50+50)	4.62a	2.04	40.22a	24.04a	11.55a	260.81a	94.78b
Perlite/zeolite(25+75)	1.19c	1.77	29.06c	17.77c	8.87cd	158.87c	65.49c
Zeolite	1.61c	1.74	25.78c	12.19d	8.09d	98.83d	37.54d

Means in each column followed by similar letter are not significantly different at 1% and 5% level using DMRT
**: significant at 1% level, *: significant at 5% and ns: not significant

Table III. Effect of substrate on quality properties

Substrates	Dry weight (%)	T.S.S (°Brix)	Titrable acid (mg/100gFW)	T.S.S/T.TA	Anthocyanin (mg/100 g)	pH	EC
Perlite	10.23a**	7.87a**	0.74b*	10.57a**	384^{ns}	3.74^{ns}	5.07^{ns}
Perlite/zeolite (75+25)	7.89c	7.38b	0.75b	9.8ab	306	3.71	4.79
Perlite/zeolite (50+50)	7.76c	6.63c	0.84ab	7.89b	276	3.68	4.16
Perlite/zeolite (25+75)	8.26bc	6.43d	0.98a	6.56b	271	3.67	4.63
Zeolite	8.79b	6.42d	1.04a	6.17b	268	3.66	4.58

Means in each column followed by similar letter are not significantly different at 1% and 5% level using DMRT
**: significant at 1% level, *: significant at 5% and ns: not significant

Table 4. Effect of substrate on fruit nutrient elements

Substrates	Nitrogen (%)	Potassium (%)	Phosphorus (%)	Calcium (%)	Magnesium (%)	Natrium (%)
Perlite	1.74a**	0.47a**	1.43^{ns}	0.08c**	0.132c**	0.06d**
Perlite/zeolite (75+25)	1.64a	0.36ab	1.37	0.12b	0.142c	0.12cd
Perlite/zeolite (50+50)	1.44b	0.28bc	1.3	0.14b	0.164bc	0.18bc
Perlite/zeolite (25+75)	1.24c	0.20c	1.23	0.2a	0.189ab	0.2b
Zeolite	1.19c	0.15d	1.15	0.2a	0.206a	0.27a

Means in each column followed by similar letter are not significantly different at 1% and 5% level using DMRT
**: significant at 1% level, *: significant at 5% and ns: not significant

absorption of N, K^+ and better absorption of Ca^{2+} and Na^+ than anions such as SO_4^{2-} (Davis, 1964). Within substrates of tomato hydroponic culture, low level of acidity was observed in perlite, whereas it was higher in zeolite. Increased sugar content was related to improved flavor (Hancock, 1999). In fact perlite and P/Z 3:1 ratio showed the highest concentration of sugar and lowest one of TA.

Clinoptililite-zeolite can easily absorb NH_4^+ and K^+ (Mumpton, 1999). When zeolite was used alone, N and K^+ were lowest in fruits. Moreover, zeolite changes media pH and influences element absorption (Allen & Ming, 1995). Optimum pH of substrate for strawberry growth has been reported around 6 - 6.5, while perlite and P/Z 3:1 mixture presented the optimum pH. The lower absorption of N and K^+ was measured on substrates containing higher amount of zeolite. Absorption of K^+ and NH_4^+ and some elements such as Na^+ cause nutrient solution disorder. In addition, absorption of K^+ by zeolite decreases its level in the nutrient solution (Savvas *et al*., 2004). Calcium absorption and movement are related to water content of media. In this experiment, increased zeolite, enhanced water retention and Ca^{2+}. Fruits containing higher amount of Ca^{2+} and Mg^{2+} was seen on zeolite. Cell membranes can be protected by Ca^{2+} on substrates with high level of EC (Turhan & Atilla, 2004). These results are in agreement with Turhan & Atilla (2004) who report that higher proportion of zeolite leads to improved Ca^{2+} and lower Mg^{2+} in aerial parts. Since strawberry growth is inhibited by Na^+, it seems that high level of Na^+ in natural zeolite accumulated in leaves.

REFERENCES

Allen, E.R. and D.W. Ming, 1995. Recent progress in the use of natural zeolites in agronomy and horticulture. *Nat. Zeolites,* 93: 477–90

Cantliffe, D., J.N. Shaw, E. Jovicich, J.C. Rodriguez, I. Secker and Z. Karchi, 2001. Passive ventilated high-roof greenhouse production of vegetables in a humid mild winter climate. *Acta. Hort.,* 559: 515–20

Davis, J.N., 1964. Effect of nitrogen, phosphorous and potassium fertilizers on the non-volatile organic acids of tomato fruit. *J. Sci. Food Agric.,* 15: 665–73

Djedidi, M., D. Grasopoulos and E. Maloupa, 1997. The effect of different substrates on the quality of f. Carmello tomatoes (*Lycopersicon escullentum* MILL*)* grown under protection in a hydroponic system. *Chaiers Options Mediteraneenes,* 31: 379–83

Gul, A., D. Erogul and A.R. Ongum, 2005. Comparison of the use of zeolites and perlite as substrate for crisp-head lettuce. *Sci. Hort.,* 106: 464–71

Hancock, J.F., 1999. *Strawberries,* pp: 190–212. CABI Publishing

Issa, M., E. Maloupa and D. Gerasopoulos, 1997. Effects of the substrate on yield and quality of two gerbera vareteis grown under protection. *Chaiers Options Mediterranean's,* 31: 365–9

Kanazirska, V., H.R. Simidtchiev and K. Chakalov, 1997. Effect of zeolite on yield and Fruit quality of glasshouse cucumbers. In: *Proc. Natural Zeolites Conf.* Sofia, Italy, pp: 109–10

Lasertosa, G., V. Lateana, N. Montemurro, D. Palazzo, S. Vanadia, D. Anac and P.P. Martin, 1999. *Soil Fertility and Plant Nutrition Status of Strawberry in the Basilicata Region, Southern Italy,* pp: 159–62. Improved Crop Quality by Nutrient Management, Kluwer Academic Publishers

Lieten, F., 2001. Protected cultivation of strawberries in Central Europe. *Proc.5th North American Strawberry Conference,* p: 102–7. ASHS Press

Lieten, P., 1999. *Guideline for Nutrient Solutions, Peat Substrate and Leaf Values of "Elsanta" Strawberries*. Communication Cost Action 836 Integrated research in berries, 2th meeting Wg4. nutrition and soilless culture. Versailles. 16 - 18 December 1999

Lopez-Galarza, S., J.V. Marmoto, A. Sanbatista and J. Alagardo, 1997. Performance of waiting- bed strawberry plants with different numbert of crowns in winter planting. *Acta. Hort.,* 439: 439–43

Maloupa, E., C. Samartzidis, P. Couloumbis and A. Komnin, 1999. Yeild quality and photosynthetic activity of greenhouse- grown "Madelom" Roses on Perlite- Zeolite Substrate mixtures. *Acta. Hort*., 481: 97–9

Mumpton, F.A., 1999. Uses of natural zeolites in agriculture and industry. *Proc. Natl. Acad. Sci.* U.S.A., 96: 3463–70

Saied, A.S., A. Keutgen and G. Noga, 2005. The influence of NaCl salinity on growth, yield and fruit quality of strawberry cvs. 'Elsanta' and 'Korona'. *Sci. Hort*., 103: 289–303

Savvas, D., K. Samantouros, D. Paralemos, G. Vlachakos, M. Stamatakis and C. Vassilatos, 2004. Yeild and nutrient status in the root environment of tomatoes grown on chemically active and inactive inorganic substrates. *Acta. Hort*., 644: 377–83

Taghliavini, M., E. Baldi, P. Lucchi, M. Antonelli, G. Sorrenti, G. Baruzzi and W. Faedi. 2005. Dynamics nutrients uptake by strawberry plants (*Fragaria x ananassa* (L). Duch.). Grown in soil and Soilless Cultutre. *Euro. J. Agro*., 23: 15–25

Takeda, F., 1999. Strawberry production in soilless culture systems. *Acta. Hort*., 481: 289–95

Turhan, E. and E. Atilla, 2004. Effect of chloride application and different growth media on Ionic composition in strawberry plant. *J. Pl. Nut.,* 27: 1653–65

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