International Journal of

Agricultural Research

ISSN 1816-4897

Academic Journals Inc.

www.academicjournals.com

International Journal of Agricultural Research 1 (4): 384-389, 2006
ISSN 1816-4897

Effects of Natural Zeolite on Growth and Flowering of Strawberry (*Fragaria×ananassa* Duch.)

Gh. Abdi, M. Khosh-Khui and S. Eshghi
Department of Horticultural Science,
College of Agriculture, Shiraz University, Shiraz, Iran

Abstract: Effects of natural zeolite on growth and flowering of strawberry were studied. The experiment was conducted as a complete randomized design with 4 treatments (0, 1, 2 and 3 g zeolite/kg soil) and 5 replications. Application of natural zeolite increased the available nitrogen, potassium, phosphorus, calcium and magnesium of the medium. Zeolite also increased net photosynthetic rate, stomatal conductance, water use efficiency, mesophyll efficiency, petiole length, leaf area, specific leaf weight, fresh and dry weights of shoots and roots, fruit weight and number of achenes of strawberry. However, zeolite did not affect length:diameter ratio, vitamin C and total soluble solids of the strawberry fruits.

Key words: Soil nutrition, strawberry, zeolite

Introduction

Strawberry (*Fragaria×ananassa* Duch.) belongs to Rosaceae family. The expansion of strawberry culture in the world for its considerable income and nutrient characteristics has drawn the attention of most growers (Hancock, 1999). Based on FAO statistical data, the area under strawberry culture in Iran equals 3000 ha (FAO, 2004). Among strawberry cultivars, 'Selva' produces high yielding fruits with good appearance and high flavor. As this cultivar is a day-neutral plant, in most places, its production is economic in spring, summer and fall (Hancock, 1999). Fruit yields of strawberry cultivars depend on soil fertility and water availability during growing season and since strawberry is a perennial plant, its continuous production leads in fertility reduction of soil. Thus, adequate water and nutrients should be supplied during the growth period for high yield production.

Nutrients are used to maximize crop production but should not have any detrimental effects on environment. The water efficiency of surface irrigation system in Iran is low and nitrogenous fertilizers should be added to soil at a higher level. Therefore, leaching of nitrogen fertilizer occurs resulting in underground water pollution particularly in soils with light texture. These facts, dictate improving water and fertilization management to decrease the pollution of underground water resources.

In recent years, attention is paid to development of sustainable agriculture and hence the natural minerals as soil amendments are applied to improve physical and chemical properties of soil. This operation results in increasing water retention and better consumption of fertilizer during the growth period. Recently, zeolite group of minerals has emerged as having considerable potential in a wide variety of agricultural processes. The unique ion exchange, dehydration-rehydration and adsorption properties of zeolite materials promise to contribute significantly to many years of agricultural and aquaculture technologies (Mumpton, 1999b). Zeolites are crystalline, hydrated aluminosilicates of alkali and earth metals that possess infinite, three-dimensional crystal structures. They are further characterized by an ability to lose and gain water reversibly and to exchange some of their constituent elements without major change of structure. Nearly 50 natural species of zeolites have been recognized

Corresponding Author: M. Khosh-Khui, Department of Horticultural Science, College of Agriculture, Shiraz University, Shiraz, Iran Tel: 987116280901-3 Fax: 987112286113

and more than 100 species having no natural counterparts have been synthesized in the laboratory. The important zeolites include analcime, chabazite, clinoptilolite, erionite, faujasite, ferrierite, heulandite, laumontite, mordenite and phillipsite (Breck, 1974; Meier and Olsen, 1987; Mumpton, 1999b). The most common natural zeolite is clinoptilolite. The empirical and unit-cell formulae of clinoptilolite are: (Na, K_2O). Al_2O_3 l 10SiO_2 l6 H_2O or (Na_4K_4) (AlO_6Si_4O). 24H_2O. Elements or cations within the first set of parentheses in the formula are known as exchangeable cations; those within the second set of parentheses are called structural cations, because with oxygen they make up the tetrahedral framework of the structure. Loosely bound molecular water is also present in the structures of all natural zeolites, surrounding the exchangeable cations in large pore spaces (Meier and Olsen, 1971; Mumpton, 1999a).

The great effectiveness of zeolites as natural sources of trace elements supplementing NPK and its high adsorption ability have been reported (Kolyagin and Kucherenko, 2003). Natural zeolites are used extensively in Japan as amendments for sandy, clay-poor soils. The pronounced selectivity of clinoptilolite $NH4^{++}$ and K^+ also was exploited in slow-release chemical fertilizers (Minato, 1968). By using clinoptilolite-rich tuff as a soil conditioner, significant increases in the yields of wheat (13-15%), eggplant (19-55%), apples (13-38%) and carrots (63%) were reported when 4-8 ton acre zeolite was used (Mumpton, 1999b). The addition of clinoptilolite also increased yields of barley, potato, clover and wheat after adding 15 t ha^{-1} to Ukrainian sandy loam soils (Mazur *et al*., 1986). Clinoptilolite amended to a potting medium for chrysanthemums behaved like a slow-release K-fertilizer, yielding the same growth for the plants as daily irrigation with Hoagland's solution (Hershey, 1980). The addition of NH_4^+-exchanged clinoptilolite in greenhouse experiments resulted in 59 and 53% increase in root weight of radishes in medium- and light-clay soils, respectively (Lewis *et al.,* 1984). A 10% addition of clinoptilolite to sand used in the construction of golf-course greens substantially reduced NO_3^- leaching and increased fertilizer-N uptake by creeping bent-grass, without disturbing the drainage, compaction, or ''playability'' of the greens (Ferguson *et al*., 1986; Nus and Brauen, 1991; Hung, 1992). The growth of plants in synthetic soils consisting of zeolites with or without peat, vermiculite and the like has been termed zeoponics. In Bulgaria, a nutrient-treated zeoponic substrate used for growing crops and the rooting of cuttings in greenhouses produced greater development of root systems and larger yields of strawberries, tomatoes and peppers, without further fertilization (Mumpton, 1999a). By using a treated Bulgarian clinoptilolite product, cabbage and radishes have been grown aboard the Russian space station Mir (Mumpton, 1999a). Tomatoes and cucumbers were grown commercially outdoors in Cuba by using zeoponic substrate and vegetables currently are supplied to Moscow in the winter from greenhouses that use zeoponic synthetic soils (Mumpton, 1999a). Similarly, the use of clinoptilolite in medium increased yield of sugar cane in Thailand (Supapron *et al*., 2002).

The aim of this study was to investigate the effects of using different amounts of natural zeolite in medium, on growth and flowering of strawberry and chemical properties of the soil.

Materials and Methods

A greenhouse experiment was conducted during 2004 and 2005 on strawberry cv. 'Selva'. The soil samples were collected before and after strawberry plantation for soil nutrient analyses. Plants were planted in 3 kg pots filled with a 1:1 (v/v) mixture of soil and leaf mold to evaluate the effects of zeolite application in soil on vegetative growth and yield of strawberry plants. Plants were monthly fertilized with a complete fertilizer (Rosasol Even) at concentration of 1.5 g L^{-1}. The experiment was a completely randomized design with 4 treatments and 5 replications. Means were compared using Duncans new multiple range test (DNMRT). Plants were maintained in a heated greenhouse under natural light (>800 μ mol m^{-2} s^{-1}) at a day temperature of 25±2°C and night temperature of

13±2°C and a RH of 55±5%. Photosynthetic rate, transpiration and stomatal conductance were measured by a portable photosynthesis meter (Lci, ADC, England). Middle leaflet of the youngest fully expanded leaf of each plant was used for this purpose. Mesophyll efficiency and water use efficiency were calculated by dividing the photosynthetic rate by sub-stomatal CO_2 and by dividing the photosynthetic rate by transpiration, respectively (Liorens *et al*., 2003). Mean of leaf areas (Delta T. Image Divces) of two leaves in each plant was measured. Specific leaf weight (SLW) was determined by drying and weighing 10 leaf disks each with an area of about 0.64 cm^2. Chlorophyll content was determined by spectrophotometer (Saini *et al*., 2001). Weight of primary and secondary fruits, their number of achenes and yields were also measured. Vitamin C content was determined by iodine titration method. Fresh weights of shoot and root were weighed, then dried (at 70°C for 48 h) and weighed. Nitrogen was analyzed by Kjeldahl method, phosphorus (by bray 2) potassium (by flame photometer) calcium and magnesium (by atomic absorption) and cation exchange capacity (by ammonium saturation).

Results

Soil Analysis

The analyses of chemical properties of soil used in this investigation before strawberry plantation and after fruit harvesting are shown in Tables 1 and 2, respectively.

Photosynthetic Rate and Stomatal Conductance

Zeolite in all levels increased significantly photosynthetic rate and stomatal conductance compared to control. However, there were no significant differences among zeolite treatments. Using 2, 3 g kg^{-1} soil zeolite treatments resulted in significant increase in stomatal conductance compared to 1 g zeolite per kg soil and control (Table 3).

Table 1: Chemical properties of soil before strawberry cv. 'Selva' planting

pH	CEC (cmol kg^{-1})	N (%)	P (mg kg^{-1})	K (mg kg^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})
5.9	4.79	0.05	5.5	110.3	3.31	0.78

Table 2: Chemical properties of soil after planting strawberry cv. 'Selva' at the end of experiment

Zeolite (g kg^{-1} soil)	CEC (cmol kg^{-1})	N (%)	P (mg kg^{-1})	K (mg kg^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})
0	4.79	0.05	5.5	133	4.13	0.62
1	4.83	0.13	18.7	132	5	0.83
2	4.91	0.14	18.7	145	6.5	0.85
3	4.99	0.14	19.7	137	6.5	0.92

Table 3: Effects of zeolite on photosynthetic rate, stomatal conductance, mesophyll efficiency and water use efficiency of strawberry cv. 'Selva'.

	Zeolite (g kg^{-1} soil)			
Traits	0	1	2	3
Photosynthetic rate µmol m^{-2} s^{-1}))	20.586b†	29.628a	29.512a	26.650a
Stomatal conductance Mol m^{-2} s^{-1}))	0.2210c	0.678ab	0.7460a	0.4620a
Mesophyll efficiency (µmol m^{-2} s^{-1}/vpm)	0.13c	0.23b	0.21b	0.28a
Water use efficiency (µmol m^{-2} s^{-1}/mmol m^{-2} s^{-1})	2.12b	2.60a	2.83a	3.12a

† In each row means having the same letter(s) are not significantly different at 5% level of probability using DNMRT

Mesophyll and Water Use Efficiency

Using 3 g zeolite per kg soil produced the highest mesophyll and water use efficiency. The application of zeolite in all levels significantly increased ME and WUE in comparison to control (Table 3).

Leaf Area and Petiole Length

Application of zeolite increased significantly leaf area and petiole length of cv. 'Salva' compared to control (Table 4).

Specific Leaf Weight and Chlorophyll Content

There were no significant differences between 1 and 2 g zeolite/kg soil treatments and control. But, specific leaf weight in 3g kg^{-1} zeolite treatment was significantly higher than control. Zeolite significantly increased chlorophyll content compared to control. But, there were no significant differences among zeolite treatments (Table 4).

No. of Achenes, Fruit Weight, Vitamin C and Yield

Number of achenes, fruit weights of primary and secondary fruits increased when the amount of zeolite in medium increased. Vitamin C content of fruits did not change in all treatment. Strawberry yield was proportionately increased by all zeolite treatments (Table 5).

Shoot and Root Fresh and Dry Weights

Increase of amount of zeolite in medium resulted in increasing shoot fresh and dry weights. Only 1 g kg^{-1} zeolite treatment increased significantly root fresh and dry weights comparing to control plants (Table 6).

Table 4: Effects of zeolite on leaf area, petiole length, specific leaf weight and chlorophyll content of strawberry cv. 'Selva'

	Zeolite (g kg^{-1} soil)			
Traits	0	1	2	3
Petiole length (cm)	20.586b†	29.628a	29.512a	26.650a
Leaf area (cm^2)	85.81c	134.47ab	157.9a	187.61a
Specific leaf weight (mg cm^{-2})	0.13c	0.23b	0.21b	0.28a
Chlorophyll content (μmol m^{-2} s^{-1})	2.12b	2.60a	2.83a	3.12a

†In each row means having the same letter(s) are not significantly different at 5% level of probability using DNMRT

Table 5: Effects of zeolite on fruit weight and number of achenes, length:diameter (L/D) ratio of fruits, vitamin C content and yield of strawberry cv. 'Selva'

	Zeolite (g kg^{-1} soil)			
Traits measured	0	1	2	3
Number of achenes in primary fruits	261b†	277.4ab	299a	298.6a
Number of achenes in secondary fruits	162.26b	244.4a	239.1a	218ab
Fruit weight (g) of primary fruits	8.72b	11.83a	11.7a	10.83a
Fruit weight (g) of secondary fruits	4.69b	6.71a	6.42a	6.35a
Length:diameter ratio of fruits	1.36a	1.61a	1.41a	1.74a
Vitamine C (mg/100 mL Juice)	77.40a	77.89a	80.227a	70.609a
Yield (g)	70.02b	87.97a	91.39a	104.69a

†In each row means having the same letter(s) are not significantly different at 5%level of probability using DNMRT

Table 6: Effect of zeolite on fresh and dry weights of shoots and roots of strawberry cv. 'Selva'

	Zeolite (g $k^{-1}g$ soil)			
Traits measured	0	1	2	3
Fresh weight of root (g)	21.136b†	34.864a	26.73b	25.12ab
Dry weight of root (g)	4.912b	7.59a	6.82b	5.79ab
Fresh weight of shoot (g)	29.6c	41.32b	38.9b	57.64a
Dry weight of shoot (g)	9.709c	12.53ab	12.8b	18.17a

†In each row means having the same letter(s) are not significantly different at 5% level of probability using DNMRT

Discussion

Results of this study indicated that the amount of mineral elements including N, P, K, Ca^{+2}, Mg^{+2} in soil were considerably increased by zeolite application. It is shown that holding cations such as ammonium and plant nutrients by zeolite are performed by absorption in its porous matrix and by cation exchange capacity (Minato, 1968). Increase in N element in this experiment is in agreement with the findings of Hung and Petrovic. (1995) who reported that the application of zeolite improved nitrogen efficiency in soil about 16 to 22%. Furthermore, zeolite reduced the leaching of ammonium and nitrate up to 86 to 99% from the soil. Also, Breen and Martin. (1981) reported that nitrogen deficiency in strawberry plants resulted in reduction of growth and yield and also reduced fruit quality. Similarly, zeolite increased the amount of P in soil because of having P in its structure as P_2O_5 and also due to reduction of leaching (Mumpton, 1999a).

It is demonstrated that zeolite had a potential to adsorb K^+ from chemical fertilizers and reduce leaching and being used as slow-release K fertilizer (Hershy *et al*., 1980; Carolino *et al*., 1998). Improvements in many traits in this study may be attributed to the increase in K content of soil. As it is shown that K has important roles in pH stability, osmotic adjustment, enzyme activation, photosynthesis, protein synthesis, cell enlargement, stomatal opening and vascular transduction (Marschner, 1995).

Similar effects were found in calcium and magnesium, which were in the range 4.9-6.6 kg^{-1} and 0.72-0.96 kg^{-1}, respectively. This result was in agreement with those of Mazur *et al*. (1986) who pointed out that zeolite improved calcium and magnesium in the soil.

In this study, zeolite increased photosynthesis rate, which was probably due to availability of different elements and water for plants by using zeolite. Nitrogen deficit in kiwifruit reduced photosynthesis rate by 50% (Smith and Buvalda, 1998). Yasud *et al*., (1995) indicated an increase in soil water content in the available moisture zone and the decrease in hydraulic conductivity proportional to zeolite addition. Similarly, presence of sufficient potassium and water resulted in opening stomata and increasing stomatal conductance which resulted in increased photosynthesis rate, mesophyll efficiency and water use efficiency. In this study, the application of zeolite with chemical fertilizer increased plant fertilizer efficiency and increased growth, leaf area, petiole length and number of achenes in strawberry plant. Leaf area, shoot and root dry and fresh weights of radish were significantly increased by the combination of nitrogen and zeolite compared to use of nitrogen alone (Lewis *et al*., 1984). Koljajic *et al*. (2003) reported that increasing the amount of zeolite significantly increased the dry matter, protein and crude fiber contents in beet.

Acknowledgement

Authors wish to thank Mr. M. Hamidian for providing the plant materials for this research.

References

Breck, D.W., 1974. Zeolite Molecular Sieves: Structure, Chemistry and Use. J. Wiley and Sons Inc., London, England.

Breen, P.J. and L.W. Martin, 1981. Vegetative growth response of three strawberry cultivars to nitrogen. J. Am. Soc. Hortic. Sci., 106: 226-272.

Carlino, J.L., K.A. Williams and E.R. Allen, 1998. Evaluation of zeolite based soilless root media for potted Chrysanthemum production. Hortic. Technol., 8: 373- 378.

FAO, 2004. FAOSTAT Agricultural Statistic Database. Retrieved from: http://www.fao.org

Ferguson, G.A., I.A. Pepper and W.R. Kneebone, 1986. Growth of creeping bentgrass on a new medium for turfgrass growth: clinoptilolite zeolite-amended sand. Agron. J., 78: 1095-1098.

Hancock, J.F., 1999. Strawberries. CABI Publishing, New York, USA., pp: 237.

Hershey, D.R., J.L. Paul and R.M. Carson, 1980. Zeolite. HortScience, 15: 87-89.

Hung, Z.T., 1992. Clinoptilolite zeolite as an amendment of sand for golf green root zones. Ph.D. Thesis, Cornell Univ., Ithaca, NY, USA.

Hung, Z.T. and A.M. Petrovic, 1995. Clinoptilolite zeolite effect on evaporation rate and shoot growth rate of bentgrass on sand base grass. J. Turfgrass Manage., 25: 35-39.

Koljajic, V., N. Djordjevic, G. Grubic and M. Adamovic, 2003. The influence of zeolite on the quality of fresh beet pulp silages. J. Agric. Sci., Belgrade, 48: 77-84.

Kolyagin, Y., S. and S.P. Kucherenko, 2003. Yield and long-term effect fertilizers. Sakharnaya-Svekla, 3:17-18.

Lewis, M.D., F.D. Moore and K.L. Goldsberry, 1984. Clinoptilolite a fertilizer N exchanger. HortScience, I8: 235-239.

Liorens, L., J. Penuelas and I. Filella, 2003. Diurnal and seasonal variations in the photosyntetic performance and water relation of two co-accuring Mediterranean shrubs, *Erica multiflora* and *Globulavia alypum*. Physiol. Plant., 118: 84-95.

Marschner, H., 1995. Mineral Nutrition of Higher Plants. Academic Press, London, England.

Mazur, G.A., G.K. Medvid and I.T. Gvigora, 1986. Use of natural zeolite to increase the fertilizer of coarse soils. Soviet Soil Sci., 16: 105-111.

Meier, W.M. and D.H. Olsen, 1971. Zeolite Frameworks. Advance. Chem. Series, No. 101, Am. Chem. Soc., 155-170.

Meier, W.M. and D.H. Olson, 1987. Atlas of Zeolite Structure Types, Utterworths, London, England.

Minato, H., 1968. Characteristics and uses of natural zeolites. Koatsu Gasu, 5: 536-547.

Mumpton, F.A., 1999a. La roca magica: Uses of natural zeolites in agriculture and industry. Proc. Natl. Acad. Sci., USA., 7: 3463-3470.

Mumpton, F.A., 1999b. Mineralogy and geology of natural zeolite. University of New York, USA.

Nus, J.L. and S.E. Brauen, 1991. Clinoptilolite zeolite as an amendment for the establishment of creeping bentgrass on sand media. HortScience, 26: 117-119.

Saini, R.S., K.D. Sharma, O.P. Dhankhar and R.A. Kaushik, 2001. Laboratory Manual of Analytical Techniques in Horticulture. Agrobios, India, pp: 134.

Smith, G.S. and J.B. Buvalda, 1998. Kiwifruit. In: Handbook of Environmental Physiology of Fruit Crops: Temperate Crops'. (Eds. Schaffer, B., P.C. Andersen) CRC Press, Inc, Boca Raton, Florida, pp: 135-156.

Supapron, L., P. Limtong, K. Watanprapat and T. Patsarayeangyong, 2002. Effect of zeolite and chemical fertilizer on the change of physical and chemical properties on Lat Ya soil series for sugarcane.17th WCSS., Thailand, 1-7.

Yasuda, H., K. Tacoma, N. Mizuta and H. Inside, 1995. Water retention variety of dune sand due to zeolite addition. Bull. Fac. Agric., Tottori Univ., 48: 27-34.