Fertilization through Wastewater of Croton (*Codiaeum variegatum* Blume) in Zeolite-Containing Substrates

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ABSTRACT

'Petra' croton (*Codiaeum variegatum* Blume) was grown in peatmoss-perlite (PP), singly or with zeolitic tuff (PPZ). When the substrates reached 80% of available water, the plants were irrigated with tap water or wastewater alone or containing (ppm) 100N-44P-83K or 200N-88P-166K. The results indicate that zeolite increased plant width, fertilization increased node and leaf number and wastewater supplemented with 200N-88P-166K increased shoot weight. Tissue N was maximal for PP receiving wastewater or 200N-88P-166K and for both substrates receiving 100N-44P-83K through wastewater or 200N-88P-166K through tap water. Tissue P was maximal for 200N-88P-166K applied through wastewater to PP or through tap water to PPZ. Addition of 100N-44P-83K through wastewater or 200N-88P-166K through either water quality to PP resulted in the highest tissue K. Substrate pH decreased to 4.5 in PP receiving 200N-88P-166K, but increased to 8.3 in non-fertilized PPZ. Values of EC, N, P and Cl were maximal in PP receiving wastewater and minimal in PPZ. Electrical conductivity, N and P were the highest in PP receiving 200N-88P-166K and lowest in non-fertilized PPZ, whereas K was the highest in PPZ receiving 200N-88P-166K and lowest in non-fertilized PP. The substrate PPZ had higher K and Na than PP. Wastewater increased K in PP and Na in both substrates.

Keywords: Zeolite, Philipsitic tuff, Fertilizer solution, Salinity, Soilless media.

INTRODUCTION

Treated wastewater has become an alternative source of irrigation water (Biswas and Arar, 1988). Such a water source often contains significant amounts of dissolved salts, which may accumulate in the root zone resulting in excess salinity. The adverse effects of high salinity include reduced soil porosity, aeration and water potential resulting in physiological drought and toxicity of specific ions, especially Na and Cl (Hopkins, 1995).

Zeolites are crystalline, hydrated aluminosilicate minerals (Ming and Mumpton, 1989) with pores that contain loosely held water molecules and freely exchangeable cations, principally K, Na, Ca and Mg. Zeolites have a high cation-exchange capacity, ion adsorption and NH_4^+ selection properties. Thus, natural zeolite could be used as an NH_4^+ adsorbent and consequently as a controlled-release NH_4^+ fertilizer (Kithome et al., 1998). During fertilization, zeolite adsorbs excess N and K and expels Ca and Mg. When N and K become depleted in the soil, equilibrium is reversed and the nutrients are gradually released. It is known that N losses due to leaching, volatilization and

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denitrfication lead to a reduction in N fertilizer efficiency and to air and ground water contamination (Owens et al., 1992). Reduction in N losses could be, therefore, achieved by using natural zeolites as soil amendments (Barbarick and Pirela, 1983).

Zeolitic phillipsite is a widely occurring material in the volcanic tuffs in northeastern Jordan (Dwairi, 1987). This material, which contains 62% zeolite, was found to have high selectivity and cation-exchange capacity (1.98 meq.g^{-1}) for NH_4^+ removal from wastewater and for processes involving NH_4^+ adsorption as a soil amendment (Dwairi, 1993). Karam et al. (2004) reported that amending peatmoss-perlite substrate with zeolitic tuff reduced water and chemical fertilizer requirements of croton plants by around 29% without a corresponding decrease in plant growth and quality. Mohammad et al. (2004) concluded that zeolitic tuff as a component of horticultural substrates had mineral content high enough for croton growth for four months and that the substrate could be used without providing additional N, P and K. Karam et al. (2006) recommended amending peat-perlite substrates with zeolitic tuff to offset the adverse effect of wastewater on salinity and reduce leaching of nutrients. This study was initiated to determine the effect of fertilizer application rate on the growth of croton in substrates amended with zeolitic tuff and irrigated with wastewater.

MATERIALS AND METHODS

Two substrates were prepared: PP which consisted of (v/v) 1 Scandinavian peatmoss (Pindstrup, Denmark): 1 perlite, and PPZ which consisted of 3 PP: 1 untreated zeolitic tuff (Green Technology Group, Jordan). Zeolitic tuff consisted of 65% zeolite minerals, 30% palagonite and 5% silicate minerals and contained 2-3% Na_2O and 2% K_2O with CEC of 1.98 meq.g^{-1}.

Three air dried samples from each substrate were weighed, placed in a Ro-Tap shaker (20063 Cernusco S/N, Milano, Italy) and rotated at 160 r.min^{-1} for 3 minutes onto standard sieves (Unified Soil Classification System, USA) with mesh openings of 4.750, 2.00, 1.18, 0.85, 0.600, 0.425, 0.300, 0.250, 0.180 and 0.075 mm and sieve numbers of 4, 10, 16, 20, 30, 40, 50, 60, 80 and 200, respectively. The quantity of substrate collected on each sieve was weighed. A particle size distribution summation curve (Figure 1) was constructed by plotting the percent weight of sample which passed through a specific mesh screen against the logarithm of the mesh opening (Bilderback et al., 1982).

Three air dried samples from each substrate were weighed and placed into rubber cylindrical cores with height and diameter of 1 and 2.5 cm, respectively. The cores were seated on a ceramic plate and saturated for 24 hours by slowly adding water until the ceramic plate was sunk. The ceramic plate with the samples was placed in a pressure plate apparatus (Soil Moisture Equipment Co., Washington, USA) and subjected to four pressure values (1, 5, 10 or 1500 kPa) separately for 24 hours. The core was removed, weighed, oven dried for 24 hours at 105 °C and reweighed. Water holding capacity for each pressure point was determined and moisture retention curve (Figure 1) was constructed (Fonteno et al., 1981). Chemical analysis of the substrates is shown in Table 1.

Rooted cuttings of croton 'Petra' (6-8 cm high, 7-8 leaves) were transplanted into 2 L-plastic containers (15 cm in height, 16 cm in diameter) filled with one of the two substrates (480 g PP, 1150 g PPZ). The substrates were saturated with water, drained for 1 hour and weighed. This weight represented the weight of substrate at container capacity (White and Mastalerz, 1966). The plants were then randomized on a raised bench under greenhouse conditions (25°C day/16°C night, 40% RH, natural photoperiod).

Throughout the five-month experiment, the substrates were allowed to dry via evapotranspiration to 80% available water. The moisture deficit (20% of available water) was determined gravimetrically by regularly weighing the containers. Once an individual substrate reached the targeted water deficit, the plant was irrigated by hand with tap water (7.15 pH, 0.3 $dS.m^{-1}$ EC) or treated wastewater (6.6 pH, 2.3 $dS.m^{-1}$ EC) alone or containing (ppm) 100N-44P-83K or 200N-88P-166K. The volume of water or wastewater applied was equal to the water deficit plus an extra volume to allow for a 0.2 leaching fraction. The fertilizer solution was prepared from a 20N-8.8P-16.6K fertilizer (Grow More, CA) consisting of 3.9% NH_4-N, 5.9% NO_3-N, 10.2% urea-N, 0.05% Ca, 0.1% Mg, 0.2% S, 0.02% B, 0.05% Cu, 0.1% Fe, 0.05% Mn, 0.05% Zn and 0.0005% Mo. Wastewater contained ($meq.L^{-1}$) 32.5 total cations, 15.7 Na, 8.1 Ca, 8.7 Mg, 12.75 Cl, 1 CO_3, 6.75 HCO_3, 12 SO_4, (ppm) 41 NO_3, 47.6 P, 53 K, 0.529 Fe, <0.001 Zn, 0.106 Mn, <0.011 Cu, 0.04 Mo, <0.005 Co, <0.002 Cd, 0.017 Cr, 0.09 Pb, <0.01 Ni, 2259 total dissolved solids, 111 total suspended solids and (ppb) 2.78 Hg, 0.9 Se and 0.7 As.

At the end of the experiment, plant height (from the substrate surface to the shoot tip), plant width (average of two perpendicular widest pair of leaves), stem diameter, number of nodes, branches, leaves and roots, leaf area and shoot and root fresh and dry (70 °C for 48 hours) weights were recorded.

Tissue Analysis

Shoots (stem and leaves) were ground with a laboratory mill (Thomas Scientific, USA) to pass through a 0.5-mm sieve. Shoots were analyzed for total N using Kjeldahl digestion (Bremner and Mulvaney, 1982) and total P, K and Na using dry ash digestion by igniting 1 g tissue (550 °C for 5 hours), adding 5 ml of 2N HCl and filtering through Whatman 42 paper. Concentration of total P was determined by colorimetry, K and Na using a flame photometer (Jenway PFP7, UK) (Chapman and Pratt, 1961) and Cl by silver nitrate titration (Richards, 1954).

Substrate and Leachate Chemical Analysis

Before planting and at the end of the experiment, air-dried samples from each substrate were ground, sieved through a 2-mm sieve and extracted for the determination of pH and EC using 1 substrate: 5 water (w/v) (McLean, 1982). Available P was determined by extraction with sodium bicarbonate (Olsen et al., 1954), extractable K and Na by extraction with NH_4OAC (Thomas, 1982), total N using Kjeldahl digestion and Cl. In addition, leachates were collected in the middle and at the end of the experiment and analyzed for EC, pH and concentrations of NO_3-N and NH_4-N using ion selective electrodes (Sartorius PP-50, Germany), Na and Cl.

Statistical Analysis

Treatments were arranged as 2 substrate x 2 water quality x 3 fertilizer concentration factorial in a completely randomized design with five replicate plants per treatment combination. Data were subjected to analysis of variance using the General Linear Model Procedure of SAS (Statistical Analysis System, version 6.12, 1996). Mean values were compared using Least Significant Difference (LSD) at 5% significance level.

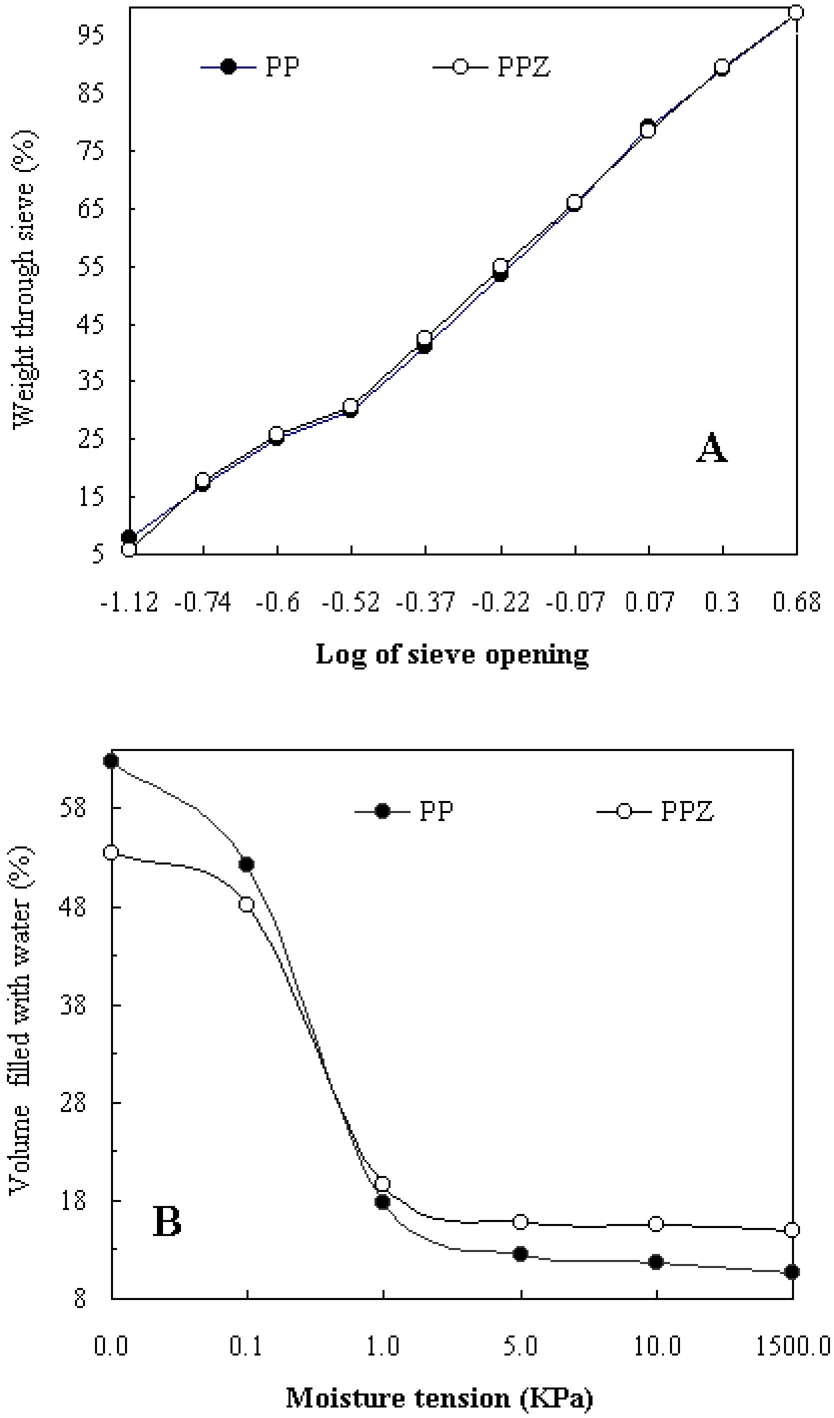

Figure 1. Particle size distribution summation curves (A) and moisture retention curves (B) of substrates composed of 1 peatmoss: 1 perlite (PP) or 3 PP: 1 zeolitic tuff (PPZ) (v/v).

Table 1. Chemical properties of substrates composed of 1 peatmoss: 1 perlite (PP) or 3 PP: 1 zeolitic tuff (PPZ) (v/v) before planting.

		EC	CEC	Organic matter	N	P	K	Na	Cl
Substrate	pH	($dS \cdot m^{-1}$)	(meq/100g)	(%)			(ppm)		
PP	6.77[z]	1.40	43.7	27.3	2858	12.1	1029	513	196
PPZ	8.64	1.23	47.0	15.4	1429	35.9	1735	1123	115

[z]Average of 3 replicates.

RESULTS

Plant Growth

No significant effects of the treatments were detected on plant height, stem diameter, leaf area or root characteristics. Plant width was significantly affected by the substrate, whereby it was greater (18.7 cm) in PPZ than in PP (15 cm) (Table 2). Number of nodes (14-16) and leaves (4-5) increased in fertilized plants compared to non-fertilized ones (11 nodes and 2 leaves). Shoot fresh and dry weights were the only growth parameters significantly affected by the interaction, namely of water quality and fertilizer concentration. Both parameters were maximal when wastewater was supplemented with 200N-88P-166K (Figure 2).

Table 2. Characteristics of croton grown in substrates composed of 1 peatmoss: 1 perlite (PP) or 3 peatmoss-perlite: 1 zeolitic tuff (PPZ) (v/v) and irrigated with wastewater or tap water containing different concentrations of the fertilizer.

Treatment	Plant width[z] (cm)	Number of nodes	Number of new leaves
Substrate (S)			
PP	15.0[y]	12.6	3.37
PPZ	18.7	14.2	4.57
Irrigation water (W)			
Wastewater	16.8	14.1	4.30
Tap water	16.9	12.7	3.63
Fertilizer N-P-K concn (ppm) (F)			
0-0-0	16.8	10.5 b	2.35 b
100-44-83	15.8	13.7 a	4.20 ab
200-88-166	18.0	16.0 a	5.35 a
Significance			
S	*	NS	NS
W	NS	NS	NS
F	NS	***	*
*S*W*	NS	NS	NS
S F*	NS	NS	NS
W F*	NS	NS	NS
*S*W* F*	NS	NS	NS

[z]The average of two perpendicular widths. [y]Average of 5 replicates. Means within columns having different letters are significantly different according to LSD ($P \leq 0.05$). NS,*,*** Nonsignificant or significant at $P \leq 0.05$ or 0.0001, respectively.

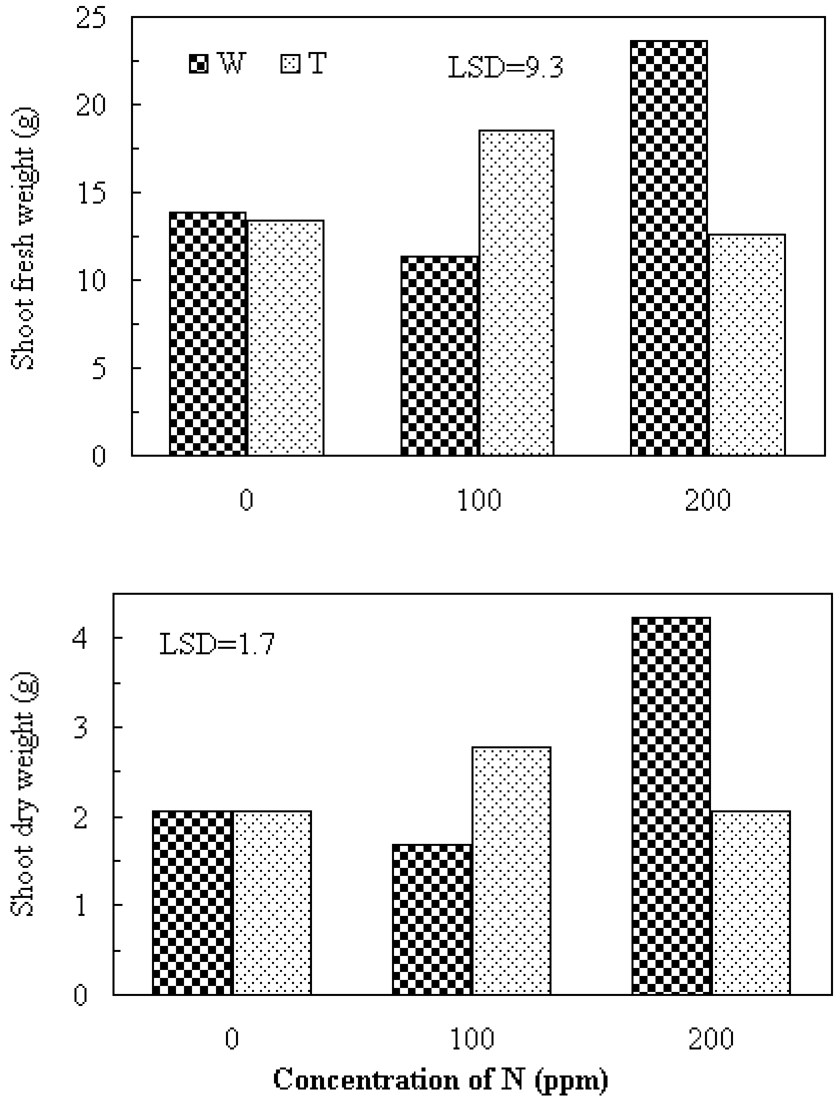

Figure 2. Fresh weight and dry weight of shoots of croton irrigated with wastewater (W) or tap water (T) containing different concentrations of the fertilizer.

Tissue Analysis

Concentrations of N, P, K and Na were significantly affected by interactions of the treatments (Figure 3). The highest N content (3.01-3.28%) was detected in plants grown in PP receiving wastewater or 200N-88P-166K, plants receiving wastewater supplemented with 100N-44P-83K and plants receiving tap water supplemented with 200N-88P-166K. Application of 200N-88P-166K through wastewater to PP or through tap water to PPZ resulted in the highest P level (0.41 or 0.44%, respectively). Wastewater increased P in all plants grown in PP and in non-fertilized plants grown in PPZ, but reduced this nutrient when PPZ was irrigated with 200N-88P-166K. Application of 100N-44P-83K through wastewater or 200N-88P-166K through either source of water to PP resulted in the highest K content (6.37-6.67%). Water quality had no significant effect on tissue K for PPZ. Irrigation with wastewater alone resulted in the highest Na content (4.2%). Fertilization of PP through tap water resulted in a lower Na content (2.38%) compared to the other treatments (3.73-4.06%). Tissue Cl was not affected by the treatments.

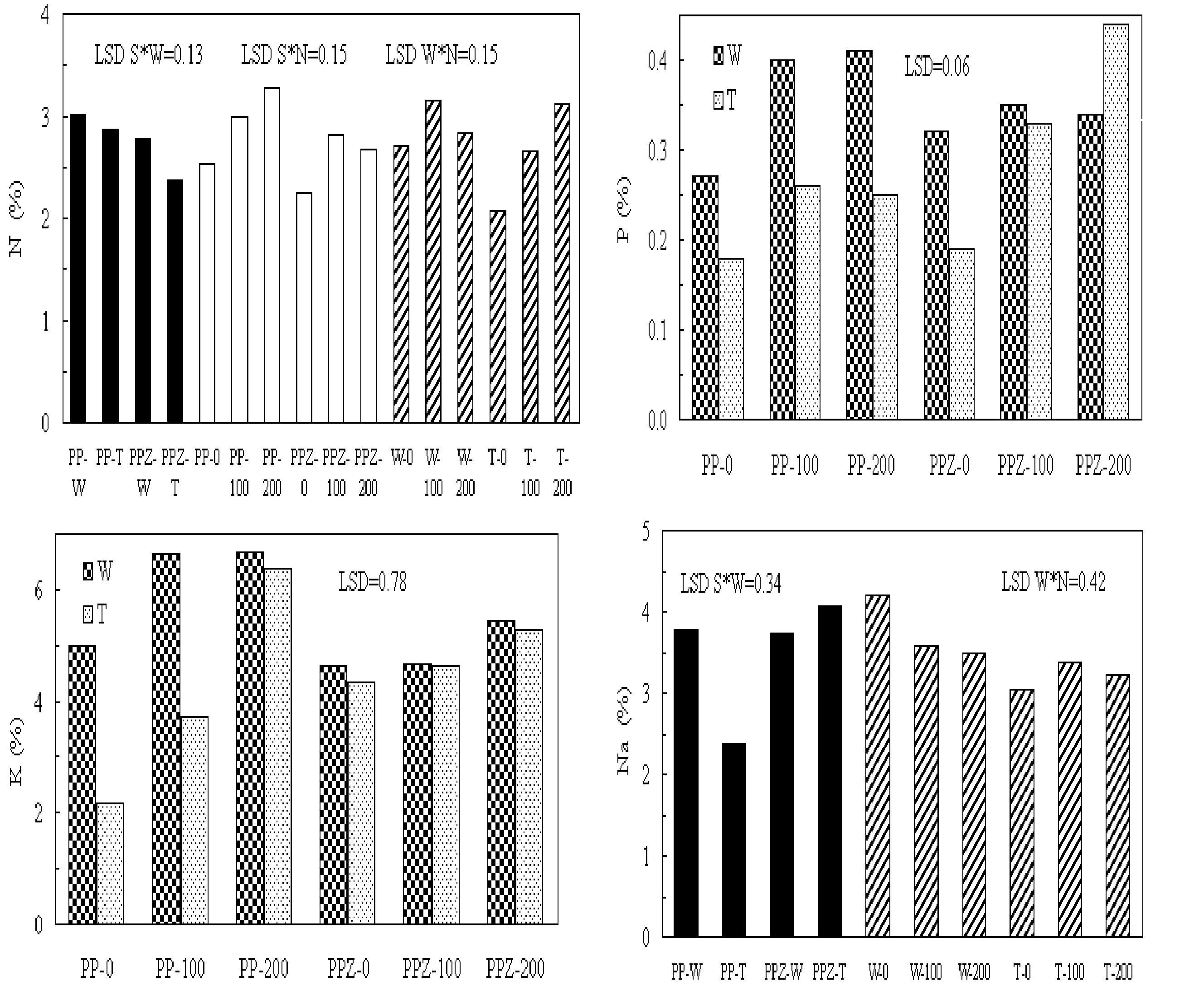

Figure 3. Concentration (% dry weight) of N, P, K and Na in shoots of croton grown in 1 peatmoss: 1 perlite (PP) or 3 peatmoss-perlite: 1 zeolitic tuff (PPZ) (v/v) and irrigated with wastewater (W) or tap water (T) containing different concentrations of the fertilizer.

Substrate and Leachate Chemical Analysis

Chemical properties of the substrate were significantly affected by the interactions of the treatments (Figure 4). Irrespective of water quality, pH drastically declined to

4.5 in PP supplied with 200N-88P-166K, but increased to 8.3 in non-fertilized PPZ. Wastewater increased EC, N, P, K, Na and Cl in PP, but had no significant effect on these parameters in PPZ except for Na, which was higher using wastewater. The substrate PP had higher EC, N, P and Cl than PPZ, but lower K and Na. Furthermore, EC, N and P were the highest in PP receiving 200N-88P-166K and the lowest in non-fertilized PPZ. On the other hand, K content was the highest in PPZ supplied with 200N-88P-166K and lowest in non-fertilized PP. As the fertilizer rate was increased, N content increased in PP and P and K contents increased in both substrates. Level of Na was much higher in PPZ than in PP and was elevated to 22311 ppm in PPZ receiving wastewater.

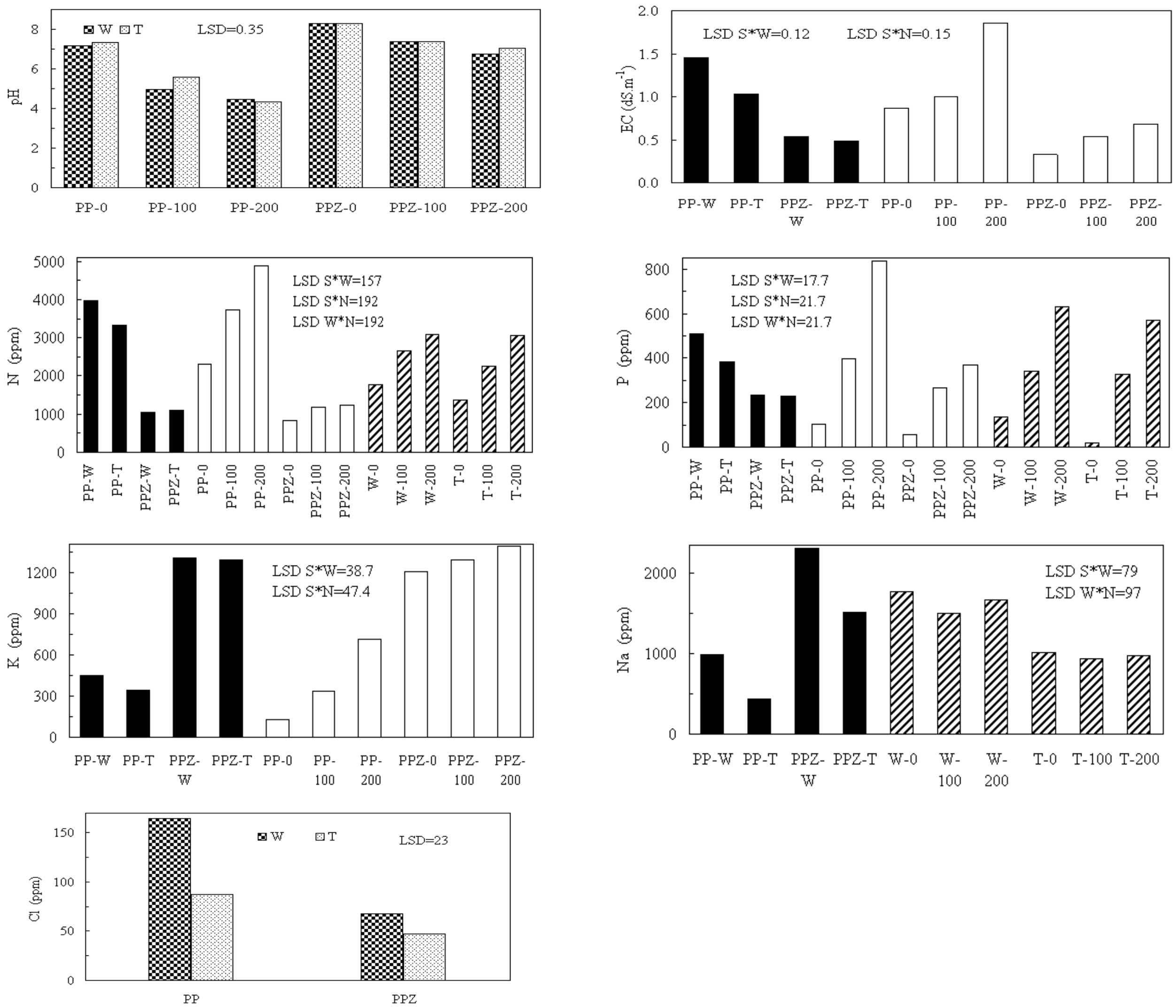

Figure 4. Chemical properties of substrates composed of 1 peatmoss: 1 perlite (PP) or 3 peatmoss-perlite: 1 zeolitic tuff (PPZ) (v/v) in which croton was grown and irrigated with wastewater (W) or tap water (T) containing different concentrations of the fertilizer.

Significant interaction effects of the treatments on chemical properties of the leachates collected in the middle (data not shown) and at the end of the experiment were detected (Figure 5). For all fertilizer rates, pH was higher for PPZ than for PP. The highest pH (7.8) was recorded for non-fertilized PPZ and the lowest (4.0) for fertilized PP, when both substrates received tap water. Wastewater increased EC, Na, Cl, NH_4 and NO_3 concentrations. Leachate EC, Na and NO_3 increased with increasing fertilizer rate. The maximum EC and Na contents were recorded for PPZ receiving 200N-88P-166K through wastewater and the minimum for PP receiving tap water alone. Application of wastewater alone or containing 100N-44P-83K to PP resulted in the highest Cl content. Amount of Cl leached was greater for PP than for PPZ when wastewater was used, but was negligible for both substrates when tap water was used. The amount of NH_4 leached was the same for both substrates receiving wastewater, but was higher for PP using tap water. For a particular water quality, the same amount of NO_3 leached from both substrates. The greatest NO_3 level was recorded for PPZ receiving 200N-88P-166K and the lowest for non-fertilized substrates.

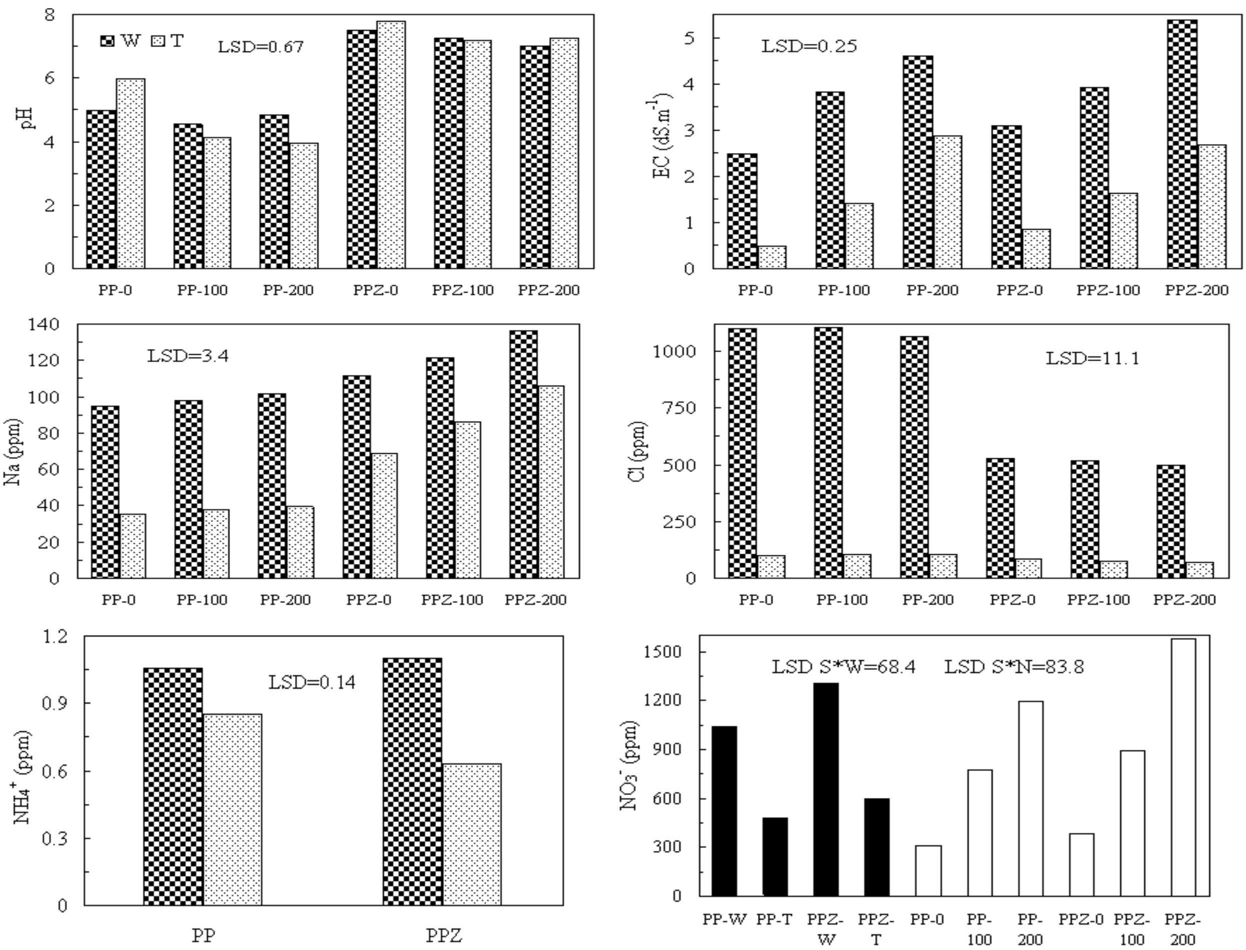

Figure 5. Chemical properties of leachates of substrates composed of 1 peatmoss: 1 perlite (PP) or 3 peatmoss-perlite: 1 zeolitic tuff (PPZ) (v/v), in which croton was grown and irrigated with wastewater (W) or tap water (T) containing different concentrations of the fertilizer.

DISCUSSION

Number of nodes and leaves was higher when the plants were fertilized indicating that fertilizer application was necessary even when wastewater was used. In a study with croton, Mohammad et al. (2004) used zeolitic tuff pretreated with ammonium phosphate and potassium sulfate along with different concentrations of a fertilizer solution. The authors reported no effect of the fertilizer concentration on plant growth and that non-fertilized plants showed satisfactory growth. The authors attributed this to the ability of the precharged zeolitic tuff to supply the plants with the required nutrients during the 5-month duration of the experiment. The zeolite used in the current study was not precharged and wastewater did not seem adequate to supply the plants with the required nutrients, which necessitated the application of supplemental fertilizer. This was also supported by the results of this study, where shoot fresh and dry weights were enhanced when the highest rate of the fertilizer was used along with wastewater. The increase in shoot weight as a result of increased leaf number occurred due to increased accumulation of N, P and K in the plants. Other growth parameters were not affected by the fertilizer rate. These findings agree with those obtained by Lewis (1981) who demonstrated that the use of untreated zeolite (clinoptilolite) with NH_4^+ fertilizers did not affect the height of Easter lily (*Lilium longiflorum*).

Application of tap water to PPZ resulted in the lowest tissue N because of the relatively low initial N content in PPZ and the absence of N in tap water. However, application of wastewater, which contained N, to PPZ increased tissue N to a level comparable to that in tap water-irrigated plants in PP, which had a higher initial N content than PPZ. A further increase in tissue N was obtained by applying wastewater to PP because of the high initial N contents in both PP and wastewater. The concentration of N in the fertilizer seemed to have an impact on tissue N. The same level of tissue N was obtained whether the plants received tap water containing 200N-88P-166K or wastewater containing 100N-44P-83K. It is apparent that the plants accumulated N as a result of increasing the fertilizer level in tap water, which was not the case when wastewater was used since tissue N decreased as a result of increasing the fertilizer to the highest level.

In both substrates, plants accumulated more P using wastewater alone compared to tap water indicating that wastewater, which contained this nutrient, supplied the plants with P (Cisneros, 1995). When wastewater was supplemented with the fertilizer, the response in tissue P was not the same in the substrates. In PP, wastewater still contributed to increased tissue P compared to tap water, but the fertilizer also increased tissue P since non-fertilized plants had lower tissue P. This may imply that the plants in PP benefited from wastewater and fertilization due to the relatively low initial P in the substrate. On the other hand, fertilization of PPZ through wastewater did not increase tissue P over non-fertilized plants or tap water-irrigated plants indicating that the plants obtained P from the substrate, which had a higher initial P than PP.

Although PPZ had higher initial K than PP, accumulation of K in the plants grown in PPZ was generally lower compared to PP, particularly when wastewater was used. This indicates impaired uptake of K in the presence of zeolite, which resulted in the accumulation of this nutrient in PPZ at the end of the experiment. It is possible that an undefined cation (probably Ca), which was readily adsorbed on the active sites of zeolite, was exchanged by K because the surface charge of zeolite has more affinity for K than Ca (Breck, 1974) resulting in the entrapment of K in the zeolite at positions not available for plant uptake. In the absence of zeolite (in PP), K seemed to be more available to the plants, thus the plants benefited from the application of wastewater and the fertilizer. Our results are in agreement with those reported by Rusan et al. (2003) which indicated that K content in lettuce increased at the highest rate of K application to the soil not amended with zeolite, but was as high in non-fertilized plants in the soil amended with zeolite.

When wastewater was used, fertilized plants had lower Na contents than non-fertilized ones, implying reduced uptake of Na possibly due to the competition between Na and K for the absorption sites of the roots (Rusan et al., 2003). Compared to tap water, wastewater increased Na levels in both PP and the plants grown in this substrate, indicating that a major source of Na was wastewater. On the other hand, there was no increase in tissue Na as a result of wastewater application to PPZ although the substrate had a much higher level of Na compared to PPZ irrigated with tap water or PP irrigated with wastewater. This indicates reduced uptake of Na in the presence of zeolite possibility because Na was readily adsorbed onto the active sites of zeolite, which has a relatively high affinity for Na (Breck, 1974). It may be concluded that there is no adverse effect of wastewater when zeolite is incorporated into the substrate.

At the end of the experiment, substrate pH, K and Na were higher and EC, N, P and Cl were lower in PPZ compared to PP. Such differences in these parameters, except P, between the two substrates were observed initially before planting (Table 1), indicating that plant uptake did not change their relative values. Although PPZ had higher P than PP at the start, it had lower P at the end, indicating possible depletion of P from PPZ through plant uptake. Wastewater had no consistent effect on substrate or leachate pH. A gradual increment of fertilizer rate caused a gradual decrement in substrate pH, probably as a result of acidification effect of nitrification. Zeolite-containing substrates and their leachates had higher pH compared to substrates free of zeolite, possibly due to the neutralizing effect of zeolite on pH (Mumpton, 1983). Wastewater increased EC of PP due to the enrichment of wastewater with total soluble solids. On the other hand, when the substrate was amended with zeolite, EC was reduced even when wastewater was used, indicating that zeolite was able to reduce salinity caused by wastewater. This may be explained by the fact that zeolite has the capacity to adsorb the ion pairs of the salt onto the hydroxyl groups found on the zeolite surface (Breck, 1974), rendering EC of the substrate solution to a favorable level for plant growth. The highest fertilizer level caused a drastic increase in EC of PP. On the other hand, a negligible increase in EC was observed when the highest fertilizer level was applied to PPZ. Amending substrates with zeolite and irrigation with wastewater increased EC of the leachate probably due to increased leaching of Na, which may imply the effect of initial high Na content in zeolitic tuff (Qian et al., 2001) and wastewater. Furthermore, increasing fertilizer level caused an increment in Na content of the leachates probably due to the competition between K and Na for the absorption sites of the roots and the excess K ions in the fertilizer which would reduce Na uptake by the plant (Rusan et al., 2003).

CONCLUSIONS

The results indicate that the incorporation of zeolitic tuff into peat-perlite increased plant width and reduced substrate EC, rendering the substrate more favorable to plant growth. The plants were normal and healthy. Irrigation with wastewater enhanced plant growth, increased nutrient uptake and compensated for partial fertilizer requirements.

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التسميد من خلال المياه العادمة المكررة لنبات الكروتون (*Codiaeum variegatum* Blume) المزروع في بيئة نمو من البيتموس والبيرلايت المحتوية على الزيولايت

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ملخـص

تمت في هذه الدراسة زراعة نبات الكروتون (*Codiaeum variegatum* Blume) من صنف (Petra) في بيئة نمو مكونة من خلطة (PP) من 1 بيتموس : 1 بيرلايت وحدها أو مخلوطة مع مادة الزيولايت (PPZ) بنسبة 1:3 حجما. كانت تروى النباتات خلال التجربة حين تصل نسبة الرطوبة في بيئة النمو إلى 80% من الماء المتوفر (available water) بالماء أو المياه العادمة المعاملة وحدها أو المحتوية على (جزء بالمليون) (100N-44P-83K) أو (200N-88P-166K). بينت النتائج أن استخدام الزيولايت في خلطة بيئة النمو أدى إلى زيادة عرض النبات، وأن التسميد أدى إلى زيادة عدد العقد والأوراق، بينما أدت المياه العادمة المحتوية على (200N-88P-166K) إلى زيادة وزن المجموع الخضري. سجلت أعلى نسبة نيتروجين في أنسجة النباتات المزروعة في (PP) المروية بالمياه العادمة أو المسمدة بـ (200N-88P-166K) وفي أنسجة النباتات المزروعة في كل من (PP) أو (PPZ) المروية بالمياه العادمة و (100N-44P-83K) أو المروية بالماء و (200N-88P-166K). كما أدى التسميد بـ (200N-88P-166K) المضاف مع المياه العادمة إلى (PP) أو المضاف مع الماء إلى (PPZ) إلى الحصول على أعلى نسبة فسفور في النبات، بينما احتوت النباتات المزروعة في (PP) المسمدة بـ (100N-44P-83K) المضاف مع المياه العادمة أو المسمدة بـ (200N-88P-166K) المضاف مع أي من مياه الري على أعلى نسبة من البوتاسيوم. بينت نتائج التحليل الكيميائي لبيئات النمو بعد انتهاء التجربة أنه بغض النظر عن نوعية مياه الري، فقد انخفضت حموضة (pH) بيئة النمو (PP) المسمدة بـ (200N-88P-166K) إلى (4.5) بينما ارتفعت إلى (8.3) في البيئة (PPZ) غير المسمدة. سجلت أعلى قياسات للتوصيل الكهربائي وتراكيز النيتروجين والفسفور والبوتاسيوم والكلور في (PP) المروي بالمياه العادمة وأقل قياسات في (PPZ) المروي بأي من مياه الري. كان التوصيل الكهربائي وتركيز النيتروجين والفسفور الأعلى في (PP) المسمد بـ (200N-88P-166K) والأقل في (PPZ) غير المسمد، بينما كان أعلى تركيز للبوتاسيوم في (PPZ) المسمد بـ (200N-88P-166K) وأقل تركيز في (PP) غير المسمد. كما احتوت بيئة النمو (PPZ) على نسب من البوتاسيوم والصوديوم أعلى من تلك الموجودة في (PP). تبين أيضا أن تركيز البوتاسيوم في (PP) والصوديوم في بيئتي النمو زاد باستخدام المياه العادمة.

الكلمات الدالة: زيولايت، بيئة النمو، محلول التسميد، الملوحة، الأوساط الخالية من التربة.

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