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Reuse of wastewater from phosphate fertilizer factories can combat soil alkalinity and improve quality of potted gardenia (*Gardenia jasminoides* Ellis)

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Key words: Cape Jasmine; industrial effluent; growth media; wastewater; soil acidity.

Abstract

In the current study, gardenia (*Gardenia jasminoides* Ellis) plants were grown in three growth media; peat moss, clay and rice straw. Acidic wastewater from Manquebad Superphosphate Fertilizer Factory (Assiut, Upper-Egypt) was applied as soil drench (200 ml/pot) at 0, 10, 20 and 30 days. Pots of gardenia were arranged in a complete randomized block design with three replicates and repeated for two successive growing seasons. Peat moss produced the best vegetative and flowering growth of gardenia which could be assigned to its low pH and high organic matter content. Rice straw-grown plants had better vegetative growth than clay-grown ones in terms of plant height, number of leaves, branches and internodes, internode length, fresh and dry weights of shoots and roots, number and diameter of flowers and possessed the highest leaf contents of phosphorus, potassium, cupper and manganese. Plants grown in clay were thicker with bigger leaves resulting in higher total leaf area, and were characterized by the highest shoot-root ratio, more flowers and higher leaf contents of chlorophylls a&b, nitrogen and iron. The application of the acidic water improved vegetative and flowering growth and leaf nutrient content of those plants grown in both clay and rice straw. Increasing the frequency of acidic water application to 10-day interval caused a significant improvement in all vegetative and flowering characteristics and leaf nutrient content. In conclusion, using acidic water at 10-day interval can improve the quality of rice straw and clay to be used as good substitutes for peat moss.

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Introduction

With the decline in the fertility of agricultural soil and the increase in newly reclaimed land in Egypt, the need for fertilizers has increased. Because of the cooling process requirements, fertilizer manufacturing facilities may have an overall large water demand, with high wastewater effluent discharge. Facilities designed on a once-through process cooling stream generally discharge from 1000 to over 10,000 m^3/hour wastewater effluents (Yapijakis and Wang, 2006). Fertilizer manufacturing causes problems within all environmental media, that is, air and water pollution, and solid wastes disposal difficulties. In particular, liquid waste effluents generated from phosphate fertilizer production streams originate from a variety of sources as mentioned by Yapijakis and Wang (2006). These sources include wastes from raw water filtration, clarification, softening and deionization, closedloop cooling tower blowdown, boiler blowdown, contaminated water or gypsum pond water, wastewater from spills and leaks. In addition, they include nonpoint-source discharges that originate from dry fertilizer dust covering the general plant area and then dissolve in rainwater, which become contaminated. Generally, the control of wastewater discharges from phosphate fertilizer industry in various countries differs significantly according to their culture and rules.

One of the major industries in Manquabad area (10 km from Assiut City, Upper-Egypt) is the Superphosphate Factory. The effluent of this factory is often discharged into the main stream of the River Nile. In this process, sulfuric anhydride is produced, which in the presence of moisture forms sulfuric acid. It is inevitable, therefore, that very small quantities of sulfuric acid could be found in the effluent of the factory. Generally, the material discharged into the River Nile consists of gaseous, liquid and solid materials (Norris & Brink, 1976; Khallil and Abdel-Sater, 1992). The level of pollution emitted by the Superphosphate Factory was debatable for long time. The pollution of water as well as food stuffs has been reduced significantly over the past few years in localities surrounding this factory (Abd El- Nasser *et al.*, 2003).

With the progressive increase in global population, the gap between supply and demand for water is widening and reaching alarming levels that in some parts of the world is posing a threat to human existence. Scientists around the globe are working on new approaches for conserving water. This could include utilizing wastewater (Hussain *et al.*, 2002). Growing ornamental plants is a fertile field for the reuse of industrial effluent. Most potted ornamental plants are produced in artificial growing media such as peat moss which has been traditionally used as an important ingredient in preparing potting media due to its low pH, high water-holding and cation exchange capacities. Peat moss has been found to boost the growth of many ornamental plants such as *Ficus benjamina* (Saleh, 2000), *Dieffenbachia amoena* (D'Angelo and Titone, 1988), *Philodendron erubescens* (Nabih and El-Khateeb, 1991). Nowadays, due to the high cost and unstable supply of peat moss, the ordinary soil or any organic material, such as composted agricultural residues, could be used as substitutes (El-Tarawy, 1990). High pH value of composted substrates and the heavy soil represent a problem when used as growth media for pot plants. Therefore, some acidic amendments are needed to reduce their pH to a proper value. Industrial wastewater of Superphosphate Fertilizer Factory known for its low pH value represents an accessible and cheap alternative to combat soil alkalinity. This could be applied on a large scale in localities surrounding the factory to save money spent on buying soil conditioners or expensive growth media such as peat moss and protect the environment especially the River Nile, from the direct discharge of industrial effluents.

Gardenia is a semitropical evergreen shrub with ovate, glossy and dark green leaves (Davidson, 1989). It is important for both cut flower production and landscape design. This plant grows best in a warm, humid and in locations that afford abundant sunlight. It requires a rich, moist, acidic (pH 5.0–5.5) and well-drained soil high in organic matter and free of nematodes. Organic matter levels can be increased with soil amendments such as peat moss, ground bark and compost. However, proper soil pH is essential because it affects the availability of mineral elements. A soil pH above 6.0 increases the possibility of micronutrient deficiencies; particularly iron (Kent and Andrew, 2006). Being an acid-loving plant, gardenia is a perfect choice to test the efficacy of the irrigation with acidic water in acidifying alkaline growth media.

Therefore, the main objective of this study was to test the feasibility of the reuse of industrial acidic wastewater of the Manquebad superphosphate fertilizer factory, in agricultural irrigation to overcome its direct discharge in the River Nile, and to combat soil alkalinity and, therefore, help find a cheaper and readily available alternative for high costly peat moss using the clay soil and composted rice straw. For this purpose, gardenia (*Gardenia jasminoides* Ellis, Family Rubiaceae) plant was chosen to investigate the effect of irrigation with acidic wastewater on various growth media.

Materials and methods

The present experiment was conducted during 2011/2012 and 2012/2013 seasons at the Floriculture Experimental Farm, Faculty of Agriculture, Assiut University, Assiut, Egypt.

Plant material

Peat moss-grown seedlings of gardenia were obtained from Egygreen Nurseries, CENTECH (El Mansoureya, Giza, Egypt). Uniform seedlings were selected and subsequently transplanted into14-cm and 25-cm diameter plastic pots filled with the corresponding growth media (Table 1). Plants were kept under lath-house conditions until the end of the experiment. All plants received a weekly fertilization dose of Agrowmore foliar fertilizer (13-4-42 + 1 NPK + MgO). Irrigation, weeding and other agricultural practices were performed as usual.

Table 1. Characteristics of the growth media used at the beginning of the experiment (average of both seasons).

Media	Soluble ions meq/100g soil*						K mg/100g soil	pH**	EC* *mS/cm*	Organic matter %
	Cations			Anions						
	Ca^{2+}	Mg^{2+}	Na^{+}	HCO_3^-	Cl^-	$SO_4^=$				
Peat	0.45	0.90	0.60	0.54	0.88	0.53	0.34	5.26	0.39	96.23
Rice straw	0.32	0.57	0.47	0.44	0.51	0.41	0.53	8.06	0.33	77.52
Clay	3.23	2.50	3.81	3.26	3.65	2.63	0.23	8.14	1.97	1.72

* Soil-water extract (1:5); **Soil-water suspension (1:2.5); EC, electrical conductivity.

Growth media

Peat moss was German dug peat without lime and inorganic fertilizers, slightly decomposed brought from Floratorf, Germany. The detailed methodology of composting process of rice straw is presented elsewhere (El-Keltawi *et al.*, 2012). Briefly, shredded rice straw were subjected to a composting process in 70 cm height and 2 m wide piles involving regular wetting and turning over to keep about 50 - 60% moisture for 45 days. Clayey soil was collected from the local soil of the Floriculture Experimental Farm, Faculty of Agriculture, Assiut University, Egypt. The characteristics of the growth media used in this study are presented in Table 1.

Industrial wastewater

The industrial wastewater (acidic water) was obtained from Manquebad Superphosphate Fertilizer Factory (Egyptian Financial and Industrial Co. JSC (EFIC), Manquebad, Assiut, Upper-Egypt). This acidic water is the residues water proceeded from producing sulphuric acid and its general characteristics include:

pH 3.1; EC (mS/cm) 0.27; Fe 1.13 ppm; Cu 0.07 ppm; Mn 0.14 ppm; Zn 0.28 ppm; K 2.0 ppm.

Experimental procedures

Uniform seedlings of gardenia were grown in 25-cm diameter plastic pots filled with various growth substrates. Pots were arranged in a complete randomized block design (split-plot) with three replicates and ten pots for each plot. The main plots comprehend three growth substrates (peat moss, rice straw and clay). Each main plot was divided into four sub-plots representing time intervals (0, 10, 20 and 30 days) of acidic water treatment which was applied as soil drench (200 ml/pot) after a week from transplanting. The same procedures were followed for both growing seasons.

Measurements

At the end of the growing season, data were recorded on vegetative growth characteristics; plant height (cm), branch number/plant, internode number/plant, internode length (cm), leaf number/ plant , total leaf area/plant (cm^2), fresh and dry weights of shoots and roots (g) and shoot-root ratio. Flowering data included; flower number/ plant, flower weight (g) and flower diameter (cm). Leaf pigment content was determined in fresh leaf samples which were extracted by using acetone 80% and determined colorimetrically according to Metzner *et al.* (1965). Thereafter, chlorophyll "a", chlorophyll "b" and carotenoids were measured using spectrophotometer at wave lengths of 663, 644 and 452.5 nm, respectively, and data were then calculated using the following equations:

Chlorophyll "a"= $10.3_{E663} - 0.918_{E644}$ = μg/l

Chlorophyll "b" = $19.3_{E644} - 3.87_{E663}$ = μg/l

Carotenoids = $4.2_{E452.5}$ – (0.0264 chlorophyll "a" + 0.426 chlorophyll "b") = μg/l

Data were converted to mg/g fresh weight of leaves and then total chlorophylls "a + b" was calculated. Leaf content of nutrients was determined in 0.2 g dried leaf samples digested using 5 ml conc. sulphuric acid. The mixture was heated for 10 minutes, and then 0.5 ml perchloric acid was added and heated continually until a clear solution was obtained. The digested solution was qualitatively transferred to a 100 ml volumetric flask using deionized water (Piper, 1967). The final digested solution was used to determine nitrogen by using the modified micro Kjeldahal method (Black *et al.*, 1965). Phosphorus was determined spectrometrically using the chlorostannus-phosphomolybdic acid method in a sulphoric acid system and potassium by the flame photometer (Jackson, 1973). Iron, cupper, manganese and zinc were determined using an atomic absorption spectrophotometer model GBC 906AA.

Statistical analysis

Data were subjected to the statistical analysis using "F" test according to Snedecor and Cochran (1989). Means were compared using the Least Significant Differences (LSD) test at 5% level of probability according to Gomez and Gomez (1984).

Results

Vegetative growth

The data presented in Fig. 1. and Table 2. demonstrate that peat moss-grown plants were significantly taller, heavier and thicker and had more branches, leaves and internodes and bigger leaf area and longer internodes than those grown in either rice straw or clay. Rice straw-grown plants surpassed those grown in clay in terms of plant height, number of leaves, branches and internodes, internode length, fresh and dry weight of shoots and roots during both seasons. However, plants grown in clay soil were thicker with bigger leaves and hence higher total leaf area, and characterized by the highest shoot-root ratio.

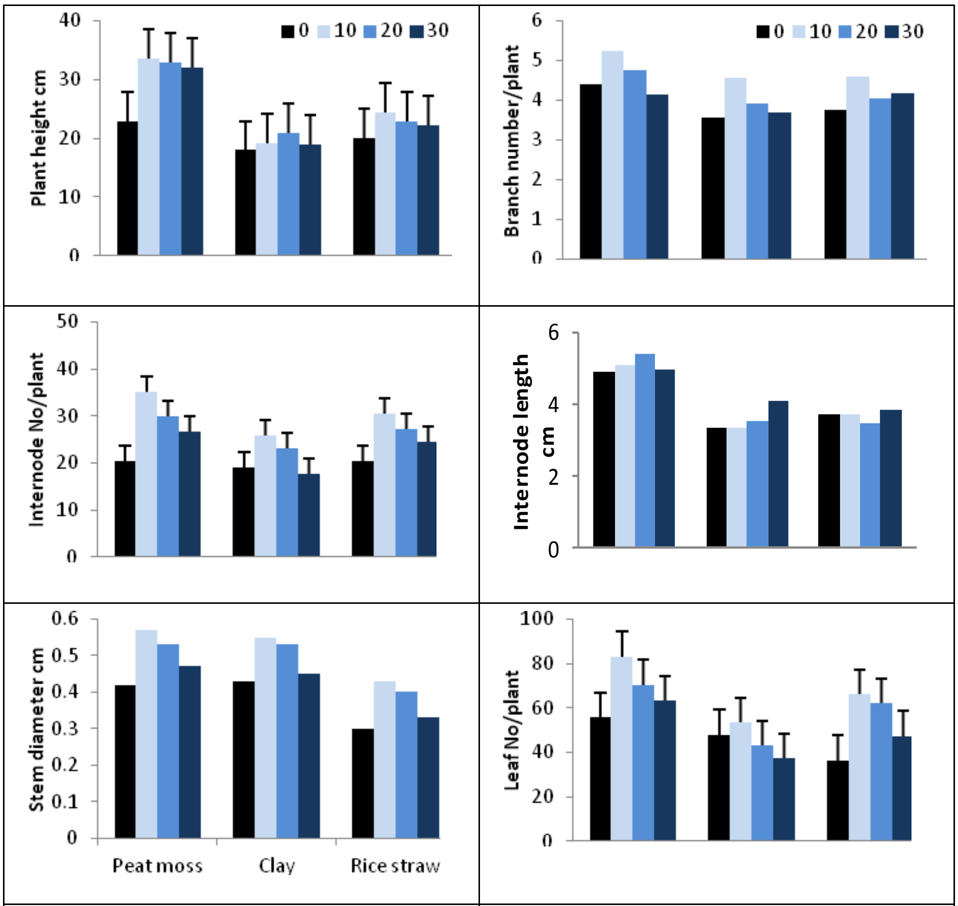
A marked increase in different growth parameters was associated with the treatment of acidic water at 10- and 20-day intervals, respectively. Apparently, the most frequent application of acidic water, every 10 days, produced the greatest increase in all vegetative characteristics of gardenia plants comparing with the other treatments including the control (untreated ones). In case of shoot/root ratio 30-day interval acidic water treatment gave the best results.

ANOVA analysis revealed a significant effect of the interaction between the growth media and the acidic water treatments in most of vegetative growth parameters except branch number, internode length and stem diameter. The interaction of peat moss with 10- or 20-day intervals of the acidic water application produced the best results. Rice straw-grown plants treated with acidic water at 10 days followed the peat-grown ones.

Table 2. Effect of different growth media and acidic water application intervals on some vegetative growth parameters of gardenia; shoot and root fresh weights (FW) and dry weights (DW) and shoot/root ratio.

Media (M)	Acidic water intervals (AW)	Vegetative growth parameters									
		Shoot FW g		Shoot DW g		Root FW g		Root DW g		Shoot/Root ratio	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Peat	0	20.78	22.65	7.41	8.02	43.91	38.16	6.76	5.98	0.47	0.60
	10	51.37	47.41	18.29	20.67	70.17	63.33	9.32	9.01	0.73	0.75
	20	44.79	42.03	14.45	15.45	55.62	51.42	7.94	7.22	0.81	0.82
	30	32.99	36.67	11.67	13.52	46.95	42.60	6.56	6.33	0.71	0.86
	Mean	37.48	37.19	12.96	14.42	54.16	48.88	7.65	7.14	0.68	0.76
Clay	0	12.28	11.50	3.77	4.33	8.58	10.00	1.47	2.00	1.45	1.16
	10	23.26	25.98	7.95	7.68	21.10	24.21	3.53	3.89	1.11	1.09
	20	19.94	21.33	6.61	6.81	15.35	18.67	3.07	3.41	1.32	1.15
	30	13.43	15.17	4.45	4.70	10.42	14.50	2.21	2.36	1.29	1.05
	Mean	17.23	24.66	5.69	5.88	13.86	16.85	2.57	2.92	1.29	1.11
Rice straw	0	13.51	15.24	4.19	5.01	10.06	9.41	2.04	2.17	1.35	1.62
	10	30.22	32.06	11.32	13.22	35.79	32.20	6.44	6.20	0.93	1.00
	20	23.60	27.52	8.42	9.56	25.78	24.77	4.46	4.66	0.92	1.11
	30	17.60	19.71	5.68	6.32	13.49	18.40	2.50	2.67	1.31	1.07
	Mean	21.23	23.63	7.40	8.53	21.28	21.20	3.86	3.93	1.13	1.20
Means of AW	0	15.52	16.46	5.12	5.79	20.85	19.19	3.42	3.83	1.09	1.13
	10	35.95	35.15	12.52	13.86	42.35	39.91	6.43	6.37	0.92	0.95
	20	29.44	30.29	9.83	10.61	32.25	31.62	5.16	5.10	1.02	1.03
	30	21.34	23.85	7.27	8.18	23.62	25.17	3.76	3.79	1.10	0.99
LSD 0.05	M	1.48	2.06	0.48	0.62	3.62	1.81	0.13	0.46	0.13	0.15
	AW	1.82	2.27	0.78	0.97	1.99	2.10	0.56	0.33	N.S.	N.S.
	M×AW	3.16	3.93	1.35	1.69	3.46	3.64	0.97	0.57	0.26	0.25

NS indicates insignificant differences using ANOVA.



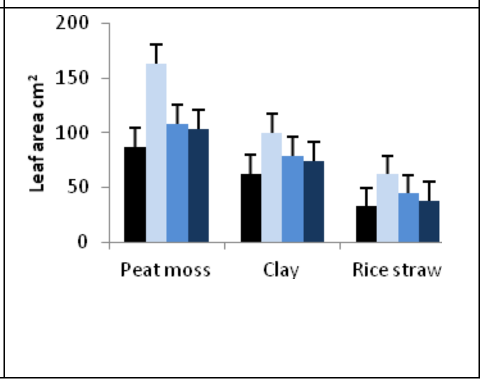


Fig. 1. Effect of certain growth media (peat moss, clay and rice straw) and acidic water application intervals (0, 10, 20 and 30 days) on vegetative growth characteristics of gardenia plants. Vertical bars indicate LSD 0.05 of the interaction between the media and acidic water intervals. No bars indicates insignificant differences with ANOVA.

Flowering

Regarding number, weight and diameter of gardenia flowers, peat moss showed a significant increase comparing with either rice straw or clay (Table 3). Clay-grown plants had significantly more flowers than those grown in rice straw, heavier and bigger flowers were recorded in rice straw-grown plants. The most frequent application of acidic water (10-day interval) significantly boosted the flowering of gardenia plants comparing with less frequent treatments. In agreement with the results of vegetative growth, the interaction between peat moss and acidic water treatment at 10- and 20-day intervals, respectively, produced the best flowering results.

Leaf pigment content

Leaves of gardenia plants grown in peat moss possessed significantly the highest content of both chlorophylls a and b followed by clay-grown plants (Table 3). Conversely, rice straw medium produced the highest leaf carotenoids content followed by clay in both seasons. Application of acidic water favored leaf pigments content. Leaf content of both chlorophylls a and b significantly increased as the frequency of the acidic water application was increased with 10-day interval producing the best results. Carotenoids content was highest in the leaves of the untreated plants and declined with the application of acidic water. Plants with the highest leaf content of chlorophylls a and b and the lowest content of carotenoids were observed with the interaction between peat moss and acidic water at 10-day interval.

Table 3. Effect of different growth media and acidic water application intervals on flowering characteristics and leaf pigment content of gardenia.

Media (M)	Acidic water intervals (AW)	Flowering characteristics						Leaf pigment content					
		Flower No/plant		Flower weight g		Flower diameter cm		Chl "a" mg/g		Chl "b" mg/g		Caroten. mg/g	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Peat	0	7.00	6.00	2.47	2.56	6.40	6.20	3.09	2.85	2.71	2.82	2.81	2.69
	10	18.00	16.00	2.94	3.10	7.60	7.30	4.15	3.91	3.47	3.58	2.15	2.06
	20	13.00	14.00	2.64	2.75	7.00	6.90	3.86	3.60	2.97	3.41	2.27	2.32
	30	10.00	9.00	2.58	2.64	6.80	6.60	3.37	3.18	2.97	3.06	2.50	2.47
	Mean	12.00	11.25	2.66	2.76	6.95	6.75	3.62	3.30	3.13	3.22	2.44	2.39
Clay	0	3.00	4.00	2.13	2.06	4.80	4.50	2.44	2.25	1.99	2.10	3.11	3.20
	10	7.00	9.00	2.31	2.35	5.70	5.20	2.81	2.75	2.64	2.63	2.63	2.78
	20	4.00	6.00	2.26	2.20	5.40	5.00	2.63	2.48	2.49	2.51	2.73	2.84
	30	4.00	5.00	2.19	2.11	5.10	4.80	2.47	2.34	2.18	2.34	2.94	2.91
	Mean	4.00	6.00	2.22	2.18	5.25	4.88	2.59	2.46	2.32	2.39	2.85	2.93
Rice straw	0	1.00	2.00	2.27	2.31	6.30	6.40	1.94	2.07	1.78	1.85	3.18	3.08
	10	3.00	5.00	2.59	2.70	7.20	7.00	2.42	2.58	2.38	2.29	2.91	2.84
	20	2.00	4.00	2.51	2.62	6.80	6.70	2.31	2.40	2.02	2.14	3.14	3.00
	30	2.00	3.00	2.35	2.38	6.50	6.60	2.15	2.26	1.92	1.97	3.23	3.17
	Mean	2.00	3.50	2.43	2.50	6.70	6.68	2.21	2.33	2.03	2.06	3.11	3.02
Means of AW	0	3.67	4.00	2.29	2.31	5.83	5.70	2.49	2.39	2.16	2.26	3.04	2.99
	10	9.33	10.00	2.61	2.72	6.83	6.50	3.13	2.97	2.83	2.83	2.56	2.56
	20	6.33	8.00	2.47	2.52	6.40	6.20	2.93	2.83	2.63	2.69	2.71	2.72
	30	5.33	5.67	2.37	2.38	6.13	6.00	2.66	2.59	2.36	2.46	2.89	2.85
LSD 0.05	M	1.17	2.82	0.11	0.07	0.66	0.25	0.13	0.17	0.09	0.16	0.04	0.04
	AW	1.58	1.58	0.14	0.11	0.24	0.26	0.11	0.19	0.07	0.12	0.03	0.11
	M×AW	2.74	2.73	N.S.	N.S.	N.S.	N.S.	0.19	N.S.	0.13	N.S.	0.05	N.S.

NS indicates insignificant differences using ANOVA, Chl=chlorophyll, caroten.= carotenoids.

Leaf nutrient content

Table 4. shows that peat-grown plants were inferior to those grown in clay or rice straw in almost all nutrient contents in leaves except for zinc and nitrogen which insignificantly differed from clay-grown plants. Clay medium, however, produced the highest leaf nitrogen and iron contents. Plants grown in rice straw possessed the highest leaf phosphorus, potassium, cupper and manganese contents. The application of acidic water caused a significant increase in leaf nutrient content which was clear as the frequency of the acidic water application was increased as 10-day interval produced the best results. Rice straw-grown plants treated with acidic water at 10-day interval produced the highest leaf content of K, Cu, Mn and Zn. Meanwhile, the interaction effect was insignificant in case of N, P and Fe.

Table 4. Effect of different growth media and acidic water application intervals on leaf nutrient content of gardenia.

Media (M)	Acedic water (AW)	Leaf nutrient content													
		N %		P %		K %		Fe ppm		Cu ppm		Mn ppm		Zn ppm	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Peat	0	2.20	2.34	0.82	0.86	0.65	0.71	800	700	25.50	22.40	88.00	80.00	205.50	214.00
	10	3.54	3.64	1.00	1.07	0.95	1.03	1300	1150	30.50	31.60	110.50	107.00	297.50	282.00
	20	3.38	3.41	0.97	0.94	0.85	0.89	1000	900	28.00	26.50	106.00	98.00	243.50	261.00
	30	2.94	2.85	0.84	0.89	0.70	0.74	900	825	28.00	25.00	96.50	90.50	237.00	245.00
	Mean	3.10	3.06	0.91	0.94	0.79	0.84	1000	894	28.00	26.40	100.30	93.90	245.90	250.50
Clay	0	2.98	3.06	0.80	0.76	0.65	0.69	1200	1250	29.00	28.20	66.00	68.50	150.00	166.00
	10	3.40	3.55	1.10	1.06	1.20	1.26	1600	1500	41.50	39.00	112.50	106.00	270.00	281.00
	20	3.20	3.32	0.84	0.89	0.95	1.04	1500	1475	38.50	37.20	87.00	99.00	252.50	246.00
	30	3.18	3.27	0.82	0.85	0.75	0.80	1400	1350	36.00	33.00	82.00	87.00	207.00	205.00
	Mean	3.19	3.30	0.89	0.89	0.89	0.95	1425	1394	36.30	34.40	86.90	90.10	219.90	224.50
Rice straw	0	2.32	2.25	0.94	1.00	0.75	0.69	800	750	30.00	31.40	96.00	91.00	194.50	187.00
	10	2.80	2.87	1.14	1.19	1.60	1.51	1300	1150	89.00	81.60	138.00	142.00	217.50	210.00
	20	2.67	2.73	1.12	1.16	1.50	1.42	1100	1025	92.50	76.70	122.50	125.00	205.50	203.00
	30	2.47	2.38	0.99	1.07	0.90	0.85	1000	900	48.50	52.50	115.50	100.50	201.00	194.00
	Mean	2.57	2.56	1.05	1.11	1.19	1.12	1050	956	65.00	60.60	118.00	114.60	204.60	198.50
Means of AW	0	2.61	2.55	0.85	0.87	0.68	0.70	933	900	28.20	27.30	83.30	79.80	183.30	189.00
	10	3.25	3.35	1.08	1.11	1.25	1.27	1400	1267	53.70	50.70	120.30	118.30	261.70	257.70
	20	3.08	3.15	0.98	0.99	1.10	1.12	1200	1133	53.00	46.80	105.20	107.30	233.80	236.70
	30	2.86	2.83	0.88	0.94	0.78	0.80	1100	1025	37.50	36.80	98.00	92.70	215.00	214.70
LSD 0.05	M	0.18	0.21	0.08	0.04	0.09	0.02	73.20	15.20	3.07	1.13	4.70	3.70	3.36	7.11
	AW	0.20	0.08	0.06	0.06	0.07	0.07	80.10	52.50	1.82	2.06	1.90	3.00	5.29	4.32
	M×AW	N.S.	0.14	N.S.	0.11	0.13	0.12	N.S.	90.90	3.15	3.59	3.30	5.20	9.68	7.47

NS indicates insignificant differences using ANOVA.

Discussion

Farmers require high quality growth media at low cost. There are different types of growth media each of which has particular characteristics that can be improved in different ways. Although peat moss is characterized by high organic matter content (96.23 %) and low pH (5.26) and electrical conductivity "EC" (0.39 mS/cm) in addition to its high water-holding capacity, it has become more costly and less readily available to the pot plant industry. Clay, on the other hand, is the most common soil in Egypt characterized by high cations & anions content, high EC (1.97 mS/cm), low organic matter content (1.72 %) and high pH (8.14), in addition to its low cost. Composted rice straw has high organic matter content (77.52 %), high pH (8.06), low cations, anions and EC. This noticeable variation in the characteristics of the three growth media used in our experiment was directly reflected on growth of gardenia. Generally, peat moss produced the most vigorous plants with the best vegetative and flowering growth characteristics with high chlorophyll content. Rice straw was superior to clay in boosting vegetative and flowering growth of gardenia. Clay-grown plants were characterized only by thicker stems and bigger leaf area. Priority in vegetative growth of peat-grown plants resulted in significantly better flowering characteristics. Clay, however, produced plants with more flowers than rice straw-grown plants.

The suitable pH and EC values of peat moss and its high water-holing capacity supply valuable water in adequate quantities for turgidity and enlargement of cells, consequently stimulating stem elongation (Mohamed and Khalil, 1992). Besides, the size of mineral particle, their shape, porosity, surface texture and density within a substrate are very important and they affect bulk density, pore space, air and water capacities (Spomer, 1974; Beardsell *et al.,* 1979; Fonteno *et al.,* 1981; Bunt 1983; Handreck, 1983; Wilson, 1983). In agreement with our results, several investigators demonstrated the favorable effect of peat moss as a potting medium, for example Abdul-Hafeez (2003), El-Gendy *et al.* (1995) and Saleh (2000). They found that peat moss increased the number of branches per plant, number of internodes and leaf characteristics. The favorable effect of peat moss on root growth may be attributed to its high organic matter content, which increases the microorganisms' activity in the medium. In this regard, Arshad and Frankenbergr (1989) found that microorganisms have the capability to produce ethylene in the rhizosphere region of the plant, which enhances root development and distribution. The metabolites produced by microorganisms increase cell permeability resulting in stimulating root growth (Aryal *et al*., 1999).

The results of our experiment also indicated that the application of acidic water improved plant quality. This effect significantly increased as the frequency of the application was increased to 10-day intervals. The pH of acidic water, as previously mentioned is low enough (3.1) to combat alkalinity of the growth media which could be the reason of the favorable effect of this treatment. This is in accordance with the fact that gardenia prefers acidic soil (pH 4.5-5.5). Any healthy plant needs a medium which provides adequate and balanced water and nutrients, the conditions for the improved and oriented beneficial biological activities (Harris, 1978). Low pH of the growth medium corresponds to high plant quality because the pH is an important factor indirectly influencing plant growth through its effects on mineral nutrients availability and microbial activity. The pH ranges from 5.5 to 6.5 or 5.0 to 6.5 are recommended for most foliage crops grown in soil or artificial media, respectively (Conover and Poole, 1990).

Our results identified a strong relationship between the frequency of acidic water application and the increase in leaf nutrient content. Reduction in the pH after the application of acidic water could explain the increase in leaf nutrients content. Leaf nitrogen content was a key factor in improving vegetative and flowering characteristics. High leaf nitrogen content of peat-grown plants (3.10 %) and clay-grown ones (3.19) resulted in vigorous vegetative and flowering growth, respectively. High leaf nitrogen content was associated with high chlorophyll a&b content. Clay produced plants with high leaf nitrogen and iron content and consequently more flowers than rice straw-grown plants. High leaf content of phosphorus, potassium, cupper and manganese of rice straw-grown plants caused a noticeable improvement in flower weight and diameter. Nitrogen is essential for protein biosynthesis in plants. At the higher concentrations of nitrogen, there is a tendency to increase leaf cell number and cell size and consequently increase leaf formation. Conversely, low nitrogen availability would cause a decrease in protein synthesis, which subsequently causes a decrease in cell size cell division (Devlin and Witham, 1983). The positive correlation between chlorophyll content and nitrogen accumulation in leaves was demonstrated by Ibrahim (2006). High concentrations of leaf nutrients and chlorophylls (a&b) in clay-gown plants were proved by Mousa *et al.* (2004). In agreement with our results, they also indicated that peat moss boosted vegetative growth of pothos plants whereas it reduced shoot-root ratio and leaf content of N, P and K.

Conclusions

This article signifies that agricultural use of industrial wastewater from the superphosphate industry may be safer and a beneficial means for the disposal of industrial effluent. Our results indicated that both rice straw and clay could resemble good substitutes for peat moss when amended with acidic water every 10 days. The success in the usage of rice straw as a growth medium could help in the bioconversion of a part of such accumulated rice straw which is one of the main agricultural wastes in Egypt. It consists about 3.5 million tons annually, causing an ecological problem unless it is well exploited. We recommend future trials to enhance physical and chemical properties of both clay and rice straw using mixtures of various substrates and to test various treatments of acidic water.

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