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RESPONSE OF GARDENIA PLANTS GROWN UNDER VARIOUS GROWTH MEDIA AND FERROUS SULFATE APPLICATION

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With the rising costs and the declining availability of peat, it is necessary to look for alternative materials to be used as growth media. Clay soil and composted rice straw are cheap and readily available candidates once there pH is adjusted. In the current study, growth of *Gardenia jasminoides* Ellis was compared in different growth substrates (peat moss, clay and composted rice straw) treated with ferrous sulfate (200 ml/pot) at various time intervals (0, 10, 20 and 30 days). Peat moss produced the best vegetative and flowering growth characteristics along with the highest leaf content of chlorophylls a & b, N, K and Mn in both seasons. Rice straw-grown plants showed moderate growth proving superior to clay-grown ones in terms of plant height, branch number, internode number and length, shoot fresh and dry weights, flower diameter, leaf content of carotenoids, P and Cu. Using of ferrous sulfate enhanced the performance of both rice straw and clay. This effect was clear as the frequency of the application was increased and the most frequent application (10-day interval) produced generally the best results. Composted rice straw and clay soil treated with ferrous sulphate at 10-day interval were comparable to peat moss regarding their effect on growth and flowering of gardenia plants.
Keywords: *Gardenia jasminoides*, ferrous sulfate, growth media, soil acidity, indoor plants.

INTRODUCTION

Gardenia (*Gardenia jasminoides* Ellis) is one of about 250 species of flowering plants in the family Rubiaceae, native to the tropical and subtropical regions of Africa, southern Asia and Australia. It is a fragrant flowering evergreen tropical shrub reaching 4-8 feet tall and wide (Davidson, 1989; Kobayashi and Kaufman, 2006). In Japan and China, the gardenia flower represents feminine grace, subtlety, and artistry. Gardenia has a reputation for being difficult to grow. It prefers a rich, moist, well-drained, acid soil (pH of 4.5-5.5) and therefore acidic types of media and fertilizers are recommended (Gough, 1984). In previous studies several investigators, for example El Keltawi *et al*. (2012) have demonstrated the possibility of using composted rice straw as a growth medium for gardenia plants. They, however, suggested that the enhancement of such substrates is inevitable.

Growth media is one of the most important factors for growing plants. Healthy plant growth depends on the development and care given to the root system and hence demands of container growth media have dramatically increased within the last 30 years (Shumack, 1974). In Egypt, peat moss is one of the most common substrates for the production of ornamental plants in pots, usually imported from Europe, due to its high physical and chemical stability and low degradation rate. The cost of high quality peat for horticultural use, together with the declining availability of peat in the near future due to environmental constraints, especially in countries without peat moss resources, make it necessary to look for other materials to be used (Garcia-Gomez *et al*., 2002). With the rising costs of traditional soilless media components, the interest has increased in composting as a way for bioorganic systems to be used in sustainable agriculture instead of ecologically undesirable materials. One of the main agricultural wastes in Egypt is rice straw, which consists about 3.5 million tons produced annually; causing ecological problem unless it is not well exploited (El-Mashad *et al.,* 2003; Khan *et al*., 2006). The use of these organic materials provides environmental benefits as ecosystem damage caused by soil or peat extraction is avoided and the impact of residue accumulation is minimized (Raviv *et al*., 1986). There are also economic benefits, as the use of residues means lower costs than those of conventional materials (Ingelmo *et al*., 1998; Hernandez-Apaolaza *et al*., 2005). The main drawback of composted rice straw or clay soil is their high pH which has a major role in the availability of nutrient ions to the plants. Alkaline soil or water could cause leaf chlorosis in gardenia and can be overcome by applying iron sulfate or iron chelate to the soil.

Iron deficiency (iron chlorosis) affects many desirable landscape and crop plants. An effective means of supplying iron deficient plants with supplemental iron is by spraying fertilizer on the plant leaves. A commonly used material for this purpose is ferrous sulfate ($FeSO_4.2H_2O$) which occurs as crystals containing 98.0-104.0% of ferrous sulfate heptahydrate. An equivalent rate of chelated iron can be used instead, but the more expensive chelated forms of iron offer little advantage for foliar application. Although foliar applications can provide fast, temporary relief from nutrient deficiencies, they treat only the symptoms and don't correct the underlying problem (high soil pH). Also, they may need to be repeated a couple of times a week (Locke *et al*., 2006). Soil application of such compounds is usually a more efficient strategy to overcome Fe chlorosis of crops grown on calcareous soils as compared with treatments based on inorganic Fe salts or weak Fe-complexes (Lucena, 2006).

The main objective of this work was to study the feasibility of enhancing the performance of clay and rice straw as cheap and readily available substrates for gardenia growth in container. The efficacy of ferrous sulfate application as soil drench at different time intervals was investigated.

MATERIALS AND METHODS

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

Healthy and vigorous seedlings (6-month old) of *Gardenia jasminoides* were carefully selected as being uniform in their size. German peat moss (Floratorf Company) slightly decomposed without lime and inorganic fertilizers were used. Shredded rice straw was subjected to a composting process for 45 days by regular wetting and turning over to conserve 50 - 60% moisture as recommended by El-Keltawi *et al*. (2012). Nile Clay soil was also used in the current study. The chemical and physical properties of the growth media used in this study are shown in Table 1. Ferrous sulfate was obtained from the Superphosphate Fertilizer Factory; Egyptian Financial and Industrial Co. JSC (EFIC), Manquebad, Assiut, Egypt.

***Experimental procedures*:**Gardenia plants were grown singly in plastic pots, each one was 4.5 l. Three growth substrates were used i.e. peat moss, rice straw and clay soil. Ferrous sulfate solution (25 mM) was applied as soil drench at a rate of 200 ml/pot every 10, 20 or 30 days starting a week after planting in the assigned growth substrates, except the control treatment. The experiment consisted of 12 treatments (3 growth substrates × 4 intervals of ferrous sulfate) arranged in completely randomized blocks in a split-plot design, three growth media as main plots and four treatments of ferrous sulfate as sub-plots. Each treatment contained ten pots and replicated three times. All plants sprayed weekly with 2 g/l of Agrowmore foliar fertilizer (13-4-42 + MgO). Plants were grown under lath-house conditions (70% shade) until full flowering stage for both seasons. All horticultural practices were done as usual whenever needed.

At the end of the experiment (on October 20th) of both seasons data were recorded on vegetative and flower characteristics. Leaf pigments were also determined calorimetrically according to Metzner *et al.* (1965). Selected samples of leaves from different treatments were washed immediately with deionized water and dried at 70º C for 24 h. The dried leaf tissue was grounded in a stainless steel Wiley mill preparatory to wet ashing with sulfuric-percholoric acid procedure. Nitrogen was determined by using the modified micro-kjeldahl method (Black *et al.*, 1965) while Phosphorus was determined calorimetrically as phosphomolybdate, and potassium by flame photometer (Jackson, 1973). Iron, copper, manganese and zinc in leaves were also estimated by atomic absorption methods. Data were statistically analyzed according to Snedecor and Cochran (1989). Statistical analysis and graphs were performed using STATISTICA program (StatSoft. Inc., 2006).

RESULTS

***Vegetative and flowering growth characteristics*:**Vegetative and flowering growth characteristics of gardenia plants varied significantly in different growth media (Tables 2a,b, & 3). Overall, peat moss produced the strongest growth in terms of all vegetative and flowering growth parameters except shoot/root ratio (0.67 and 0.68 in both seasons, respectively) due to the high root fresh weight (44.96 and 47.28 g in both seasons, respectively), which is the denominator of the shoot/root equation, of peat-grown plants. The plants grown in clay were as thick as those in peat moss, and they possessed more (48.17 and 49.46 in both seasons, respectively) and bigger leaves (92.59 and 102.39 cm^2 in both seasons, respectively) and heavier roots (15.12 and 14.50 g in both seasons, respectively) than those grown in rice straw. Growing plants in rice straw, however, produced taller plants with more internodes and branches,

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); Abbreviations: Ca, Calcium; Mg, Magnesium, Na, Sodium; HCO3, Bicarbonate; Cl, Chlorine; SO4, Sulphate; EC, electrical conductivity,

Table 2a. Effect of different growth media and ferrous sulfate application on vegetative growth of gardenia plants.

Media (M)	Ferrous sulfate intervals (Fe)	Vegetative growth parameters											
		Plant height cm		Branch No/plant		Internode No/plant		Internode length cm		Stem diam. cm		Leaf No/plant	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
	0	22.89	19.65	4.41	4.33	20.50	19.66	4.93	3.65	0.42	0.43	55.83	69.66
	10	29.61	34.92	4.78	5.03	31.40	33.60	4.51	5.22	0.56	0.55	73.35	87.50
Peat	20	28.49	31.05	4.61	4.87	29.61	28.45	4.58	5.35	0.55	0.50	61.11	79.16
	30	27.39	28.67	4.49	4.61	25.83	24.18	4.79	5.62	0.47	0.47	60.78	72.50
	Mean	27.09	28.55	4.57	4.71	26.84	26.47	4.70	4.96	0.50	0.49	62.77	77.21
	0	17.94	15.22	3.56	3.16	19.14	16.45	3.37	2.91	0.43	0.40	47.83	42.40
	10	20.66	23.60	4.48	4.13	25.88	28.33	3.64	3.48	0.57	0.58	55.11	56.18
Clay	20	21.17	21.17	4.17	3.97	23.16	26.67	3.81	3.18	0.50	0.55	47.61	52.01
	30	18.44	20.03	3.88	3.75	19.78	21.83	3.65	3.45	0.45	0.50	42.11	47.23
	Mean	19.55	20.01	4.02	3.75	21.99	23.32	3.62	3.26	0.49	0.51	48.17	49.46
	0	20.05	16.91	3.76	4.00	20.45	17.65	3.74	3.94	0.30	0.27	36.39	38.07
	10	23.33	25.66	4.67	4.81	25.33	30.40	4.30	4.05	0.37	0.40	58.45	61.18
Rice straw	20	22.72	23.42	4.40	4.62	24.36	28.23	4.15	3.84	0.33	0.37	45.28	59.60
	30	22.22	20.5	3.86	4.27	20.45	23.50	4.25	3.75	0.32	0.35	37.60	48.78
	Mean	22.08	21.61	4.17	4.23	22.65	24.95	4.11	3.89	0.33	0.35	44.43	51.91
	0	20.29	17.23	3.91	3.83	20.03	17.92	4.01	3.50	0.38	0.37	46.69	50.04
Means of	10	24.53	28.05	4.64	4.66	27.54	30.78	4.15	4.25	0.50	0.51	62.30	68.29
Fe	20	24.13	25.21	4.39	4.49	25.71	27.78	4.18	4.12	0.46	0.47	51.33	63.59
	30	22.68	23.07	4.08	4.21	22.02	23.17	4.23	4.27	0.41	0.44	46.83	56.17
	M	2.62	3.34	N.S.	0.45	1.45	N.S.	N.S.	0.64	0.06	0.06	13.45	4.44
LSD 0.05	Fe	1.34	2.19	0.36	0.34	3.24	2.69	N.S.	N.S.	0.07	0.06	6.54	4.97
	M×Fe	N.S.*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

*NS indicates non-significant differences using ANOVA

Table 2b. Effect of different growth media and ferrous sulfate application on vegetative growth of gardenia plants.

Media (M)	Ferrous sulfate intervals (Fe)	Vegetative growth parameters											
		Total leaf area/plant cm^2		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	1st	2nd
Peat	0	86.94	81.26	20.78	22.65	7.41	8.02	43.91	38.16	6.76	5.98	0.47	0.59
	10	127.07	152.43	37.00	40.60	13.09	16.40	48.65	55.67	7.43	8.13	0.76	0.73
	20	116.21	138.60	36.51	37.51	12.11	14.09	44.84	50.06	7.29	7.42	0.82	0.75
	30	95.30	108.53	26.99	29.43	9.42	10.32	42.45	45.23	5.43	6.50	0.64	0.66
	Mean	106.38	120.21	30.32	32.55	10.51	12.21	44.96	47.28	6.73	7.01	0.67	0.68
Clay	0	62.70	66.02	12.28	11.50	3.77	4.33	8.58	10.00	1.47	2.00	1.45	1.16
	10	123.73	131.15	24.51	26.18	8.45	7.18	22.55	20.18	4.07	4.81	1.09	1.31
	20	110.35	120.67	19.61	21.33	6.67	6.34	20.03	15.22	3.80	4.12	0.98	1.43
	30	73.57	91.70	12.45	15.20	4.32	5.26	9.31	12.60	0.99	2.23	1.35	1.21
	Mean	92.59	102.39	17.21	18.55	5.80	5.78	15.12	14.50	2.58	3.29	1.22	1.28
Rice straw	0	32.61	40.53	13.51	15.24	4.19	5.01	10.06	9.41	2.04	2.17	1.35	1.62
	10	74.41	89.15	29.32	32.60	8.63	9.89	16.08	17.89	2.73	3.50	1.85	1.83
	20	45.98	74.06	21.74	24.50	7.52	8.23	13.34	14.67	2.27	2.89	1.63	1.69
	30	45.14	49.17	14.51	16.87	4.03	6.11	10.27	12.50	1.23	2.43	1.42	1.37
	Mean	49.58	63.23	19.77	22.30	6.10	7.48	12.44	13.62	2.07	2.75	1.56	1.63
Means of	0	60.75	62.60	15.52	16.46	5.12	5.79	20.85	19.19	3.42	3.38	1.09	1.13
Fe	10	108.47	124.24	30.28	33.13	10.06	11.16	29.09	31.25	4.74	5.48	1.23	1.29
	20	90.85	111.11	25.95	27.78	8.77	9.55	26.07	26.65	4.45	4.81	1.14	1.29
	30	71.34	83.13	17.98	20.50	5.93	7.45	20.68	23.44	2.55	3.72	1.14	1.08
LSD 0.05	M	4.22	2.54	1.67	1.4	0.53	1.82	1.88	3.4	0.64	0.26	0.15	0.25
	Fe	4.84	5.34	1.78	2.81	0.63	0.89	1.93	2.12	0.36	0.56	N.S.*	N.S.
	M×Fe	8.39	9.25	3.09	N.S.	N.S.	1.54	3.35	3.67	0.63	N.S.	2.79	N.S.

*NS indicates non-significant differences using ANOVA; FW=fresh weight, DW=dry weight

longer internodes, heavier shoots, higher shoot/root ratio, bigger flowers and higher leaf content of carotenoids comparing with those grown in clay.

The application of ferrous sulfate led to a significant improvement in all vegetative and flowering characteristics of gardenia plants, except in internode length and shoot/root

Table 3. Effect of different growth media and ferrous sulfate application intervals on flowering characteristics and leaf pigments content of gardenia plants.

Media (M)	Ferrous sulfate intervals (Fe)	Flowering characteristics						Leaf pigments 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	7.0	6.0	2.47	2.56	6.40	6.20	3.09	2.85	2.71	2.82	2.81	2.69
	10	13.0	15.0	3.24	3.17	7.30	7.40	4.79	4.52	3.42	3.53	2.03	2.09
	20	11.0	10.0	2.98	2.91	7.20	7.10	3.87	3.49	3.56	3.39	2.05	2.15
	30	10.0	8.0	2.71	2.83	6.60	6.50	3.58	3.34	3.29	3.19	2.19	2.29
	Mean	10.3	9.8	2.77	2.87	6.88	6.80	3.83	3.55	3.24	3.23	2.27	2.31
Clay	0	3.0	4.0	2.13	2.06	4.80	4.50	2.44	2.25	1.99	2.10	3.11	3.20
	10	10.0	12.0	3.16	2.85	6.10	6.20	2.83	3.41	2.64	2.54	2.57	2.48
	20	8.0	9.0	2.80	2.74	5.70	5.50	2.54	3.20	2.56	2.41	2.69	2.60
	30	5.0	7.0	2.53	2.30	5.40	5.10	2.45	3.02	2.24	2.27	2.92	2.87
	Mean	6.5	8.0	2.65	2.49	5.50	5.33	3.31	2.97	2.36	2.33	2.82	2.79
Rice straw	0	1.0	2.0	2.27	3.31	6.30	6.40	1.94	2.07	1.78	1.85	3.18	3.08
	10	4.0	5.0	2.82	2.73	7.00	6.90	2.84	2.73	2.02	2.13	2.95	2.81
	20	3.0	5.0	2.63	2.64	6.60	6.80	2.63	2.50	2.12	2.08	2.95	2.98
	30	3.0	3.0	2.45	2.41	6.40	6.50	2.56	2.39	1.84	1.93	3.11	3.05
	Mean	2.8	3.8	2.54	2.52	6.58	6.65	2.49	2.42	1.94	1.99	3.05	2.98
Means of Fe	0	3.7	4.0	2.29	2.31	5.83	5.70	2.49	2.39	2.16	2.26	3.04	2.99
	10	9.0	10.7	2.96	2.92	6.80	6.83	3.82	3.55	2.69	2.73	2.52	2.46
	20	7.3	8.0	2.80	2.76	6.50	6.47	3.34	3.06	2.75	2.63	2.56	2.58
	30	6.0	6.0	2.56	2.51	6.13	6.03	3.20	2.92	2.46	2.46	2.74	2.74
LSD 0.05	M	1.52	2.5	0.16	0.05	0.3	0.41	0.13	0.15	0.11	0.07	0.05	0.08
	Fe	1.63	1.58	0.22	0.11	0.38	0.33	0.12	0.11	0.05	0.12	0.04	0.11
	M×Fe	2.82	2.74	0.38	0.19	0.65	0.58	0.2	0.19	0.09	N.S.*	0.07	0.19

*NS indicates non-significant differences using ANOVA; Chl=chlorophyll, caroten.= carotenoids

ratio. All treatments of ferrous sulfate boosted all growth characteristics over the control (untreated plants) except in root fresh and dry weights during the first season, where the untreated plants surpassed those treated at 30-day interval. The promotive effect of ferrous sulfate increased as the frequency of the ferrous sulfate application was increased producing the best results when the highest frequent application (10-day interval) was used. The interaction effect was found non-significant in most of the vegetative characteristics except leaf area and fresh and dry weights of shoots and roots. Plants grown in peat moss and treated with ferrous sulfate at 10-day interval recorded the best interaction effect regarding vegetative and flowering growth.

***Leaf pigments*:**Data shown in Table 3 demonstrate that peat moss was superior to both clay and rice straw for leaf content including chlorophylls a and b. Clay-grown plants possessed significantly higher chlorophylls a (3.31, 2.97) and b (2.36, 2.33 in both seasons, respectively) than those grown in rice straw. The highest leaf content of carotenoids, however, was recorded in rice straw-grown plants. Application of ferrous sulfate increased leaf pigment contents comparing with the untreated plants (control). Leaf content of both chlorophylls a & b increased significantly as the frequency of the ferrous application was increased with 10-day interval producing the best results. The untreated plants, on the other hand, possessed the highest leaf content of carotenoids which declined with the application of ferrous sulfate. The interaction effect between the growth media and the treatments of ferrous sulfate was proved significant and the best results were recorded in peat moss-grown plants treated with ferrous sulfate at either 10- or 20-day intervals.

***Leaf nutrients*:**Gardenia plants grown in clay or rice straw were superior to those grown in peat moss in leaf nutrients content except for N, K and Mn (Table 4). The differences between Clay-grown plants and peat-grown ones were not significant in terms of N and K, whilst they possessed the highest Fe (1550, 1505) and Zn (259.4, 255.3 ppm in booth seasons, respectively) contents in leaves. Rice straw produced the highest P and Cu contents in plant leaves. A linear increment in leaf nutrients content was recorded as the frequency of the application of ferrous sulfate was increased. The most frequent application of ferrous sulfate (10-day interval) produced the best results. The interaction effect was found non-significant in case of leaf phosphorus content. The interaction between 10-day interval of ferrous sulfate and peat moss produced the best results regarding N and Mn,

Table 4. Effect of different growth media and ferrous sulfate application intervals on leaf nutrients content of gardenia plants.

Media (M)	Ferrous sulfate intervals (Fe)	Leaf nutrients 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	25.5	22.4	88.0	80.0	205.5	214.0
	10	3.70	3.84	0.98	1.05	1.60	1.54	1400	1240	85.0	81.0	156.0	141.0	212.0	227.0
	20	3.65	3.52	0.98	1.00	1.00	1.10	1200	1100	58.0	62.0	142.0	130.0	209.5	216.0
	30	3.45	3.31	0.86	0.91	0.95	0.98	900	950	38.5	36.5	101.5	105.0	195.0	215.0
	Mean	3.24	3.25	0.91	0.96	1.05	1.08	1075	998	51.8	50.5	121.9	114.0	205.5	218.0
Clay	0	2.98	3.06	0.80	0.76	0.65	0.69	1200	1250	29.0	28.2	66.0	68.5	150.0	166.0
	10	3.38	3.51	1.11	1.05	1.75	1.79	1900	1750	45.0	47.2	92.0	95.5	391.0	380.0
	20	3.30	3.42	1.07	1.01	0.95	0.98	1700	1600	42.0	43.9	73.0	80.0	275.5	261.0
	30	3.25	3.29	1.03	0.89	0.70	0.76	1400	1420	37.0	36.0	69.5	73.0	221.0	214.0
	Mean	3.23	3.32	1.00	0.93	1.01	1.06	1550	1505	38.3	38.8	75.1	79.1	259.4	255.3
Rice straw	0	2.32	2.25	0.94	1.00	0.75	0.69	800	750	30.0	31.4	96.0	91.0	194.5	187.0
	10	3.42	3.51	1.11	1.15	1.00	1.03	1700	1500	94.5	90.0	141.5	134.0	300.5	285.0
	20	3.37	3.30	1.05	1.09	0.90	0.97	1100	1000	80.0	74.6	117.5	112.0	246.0	254.0
	30	3.31	3.18	0.97	1.02	0.80	0.84	900	850	42.5	48.0	102.5	104.0	231.5	240.0
	Mean	3.11	3.06	1.02	1.07	0.86	0.88	1125	1022	61.8	60.9	114.4	110.3	243.1	241.5
Means of Fe	0	2.61	2.55	0.85	0.87	0.68	0.70	933	896	28.2	27.3	83.3	79.8	183.3	189.0
	10	3.39	3.62	1.07	1.08	1.45	1.45	1667	1497	74.8	72.7	129.8	123.3	301.2	297.3
	20	3.43	3.41	1.03	1.03	0.95	1.02	1333	1233	60.0	59.9	110.8	107.3	243.0	243.7
	30	3.34	3.26	0.95	0.94	0.82	0.86	1067	1073	39.3	40.3	91.2	94.0	215.8	223.0
LSD 0.05	M	N.S.*	0.09	0.04	0.07	0.07	0.07	29.93	42.7	0.31	0.62	3.41	2.91	9.33	5.17
	Fe	0.30	0.10	0.07	0.06	0.12	0.12	55.59	67.3	2	1.79	5.91	5.03	6.97	6.5
	M×Fe	N.S.	0.18	N.S.	N.S.	800	1200	96.18	116.6	3.47	3.09	205.5	209.5	12.09	11.27

*NS indicates non-significant differences using ANOVA

however the same treatment with clay or rice straw was better in terms of the P, K, Fe, Cu and Zn.

Table 6. Correlation matrix of gardenia leaf content of N, K, Cu and Mn, and plant growth parameters.

Variables	N	K	Cu	Mn
Plant height	0.60*	0.54*	0.58*	0.79*
Flower No/plant	0.60*	0.75*	0.26	0.39
Flower weight	0.35	0.66*	0.45*	0.58*
Chlorophyll "a"	0.59*	0.63*	0.42*	0.61*

Correlations marked with an asterisk (*) are significant at $p < 0.05$.

DISCUSSION

Peat moss has been most commonly used as a growth medium for container plant production. In spite of the many advantages of peat in terms of low pH, high organic matter content and high water-holding capacity, its high production expenses and low availability, make it necessary to look for alternative materials (Bunt, 1983; Garcia-Gomez *et al*., 2002). The current research compared both clay and composted rice straw with peat moss as growth media for gardenia plants. Both of clay and rice straw are characterized by high pH (Table 1.) and therefore the soil application of ferrous sulfate at different time intervals was investigated.

Our results indicate that peat moss was superior to both clay and rice straw for most of the vegetative and flowering characteristics as well as leaf content of chlorophylls a&b of gardenia plants. When averaged over both seasons and ascribed to the results of peat-grown plants (Fig. 1), gardenia plants grown in clay recorded 101 and 185% increases in stem diameter and shoot/root ratio, respectively, compared with peat-grown ones. But, this percentage ranged from 32 to 91% in root fresh weight and flower weight, respectively. Clay also produced high leaf content of chlopropyll a&b with 85 and 72%, respectively, of peat-grown plants in comparison with 67 and 61%, respectively, in rice straw-grown plants. Rice straw produced stronger plants compared with clay in most of the vegetative and flowering characteristics ranging from 28 to 236% in root fresh weight and shoot/root ratio ascribed to peat-grown plants. These differences cannot be explained on the basis of leaf nutrients content, although there was a significant correlation coefficient (at $p<0.05$, Figs 2 & 3) between leaf content of both N and K, and most of the vegetative growth characteristics, in addition to Cu and Mn in case of

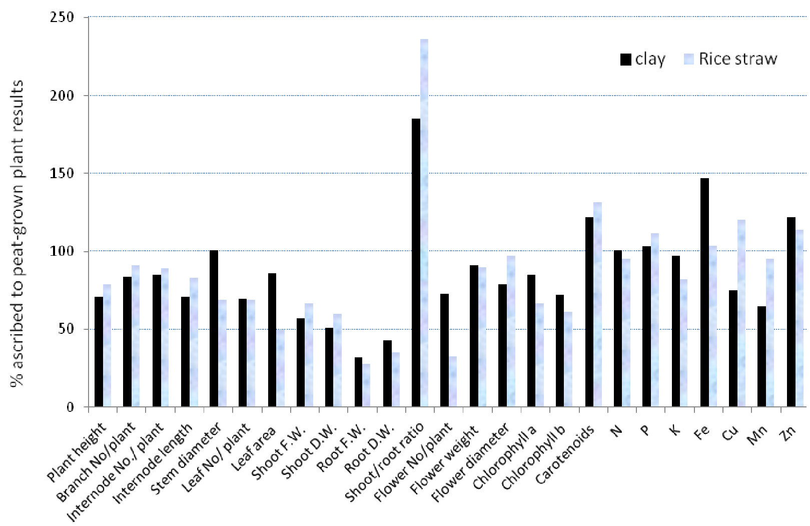

Figure 1. Vegetative, flowering and chemical composition parameters of gardenia plants grown in clay and rice straw as percentage ascribed to peat-grown plants. The two-season-averaged data of plants grown in clay or rice straw were divided by that of peat-grown ones and then multiplied by 100.

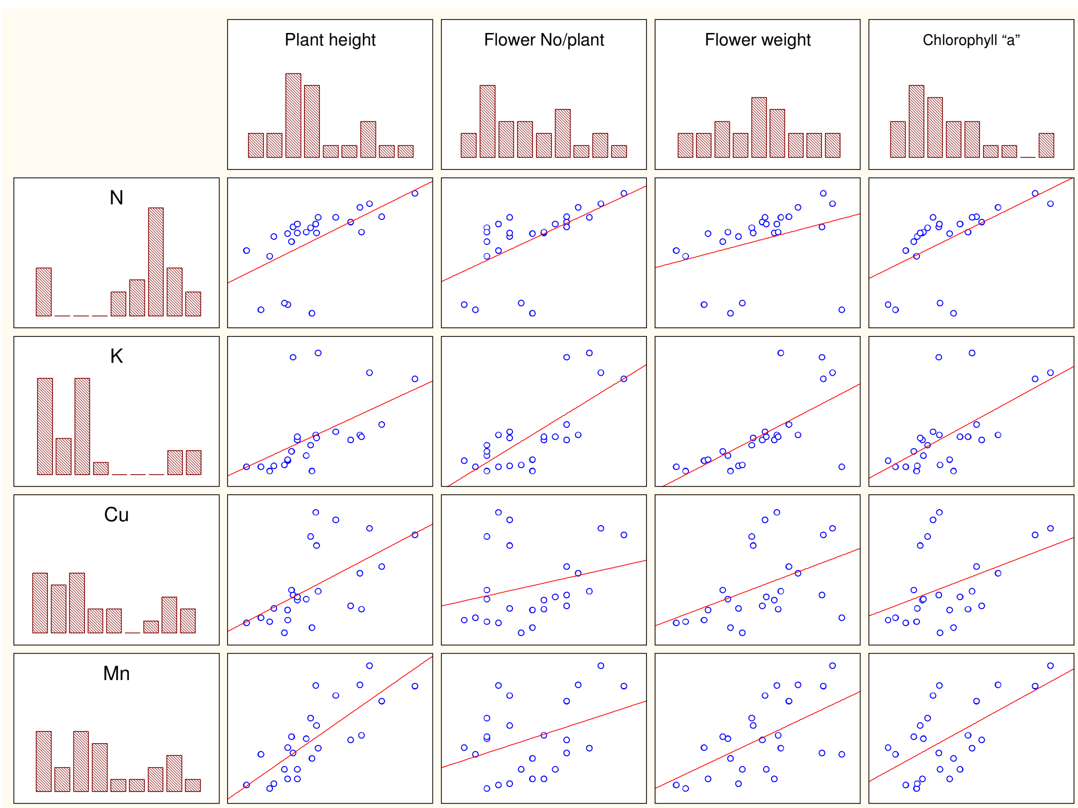

Figure 2. Scatterplot matrix for selected growth parameters of gardenia plant. The complete matrix of all possible variable combinations is not shown for shortness purposes.

flowering and leaf content of chlorophylls a&b, the regression (R^2) was not significant in almost all cases. Although the correlation analysis can quantify the degree of association between variables, it cannot provide reasons for such association (Gomez and Gomez, 1984). To demonstrate the correlation nature between plants growth and leaf nutrients content, some variables were chosen for shortness purposes. A strong correlation was found among almost all vegetative growth parameters and therefore plant height was chosen to resemble the other parameters along with flower number and weight and leaf content of chlorophyll a. The correlation coefficient between these variables and leaf content N, K, Cu and Mn is shown in Figures 2&3. The percentage of the variation in the vegetative growth accounted for by the linear function of the leaf nutrients content could be calculated through the equation [100 $(r)^2$]. For example, 36%, 29%, 33.64% and 62.41% of the positive variation in plant height is accounted for by the positive linear function of N, K, Cu and Mn, respectively. 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 pothos 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 nutrients content of N, P and K.

The results obtained herein could be explained on the basis of high organic matter content (96.23 %) of peat moss in addition to its proper pH (5.26) and electrical conductivity "EC" (0.39 mS/cm) and high water-holding capacity. These properties help supply valuable water in adequate quantities for turgidity and enlargement of cells, consequently stimulate stem elongation (Beardsell *et al.,* 1979; Mohamed and Khalil, 1992). Many investigators, such as Abdul-Hafeez (2003), demonstrated the priority of peat moss in boosting plant growth. On the other hand, both clay and rice straw are characterized by high pH (8.14 & 8.06, respectively). Meanwhile, the organic matter content of rice straw (77.52%) is rather high comparing with that of clay (1.72%). This could explain for the superiority of rice straw to clay in boosting vegetative and flowering growth of gardenia.

The efficacy of the ferrous sulfate application in improving growth media and subsequently plant growth characteristics was proved. This effect was clear as the frequency of the application was increased with the highest frequent application producing the best results. This effect could be attributed to the effect of ferrous sulfate in reducing the growth medium pH. 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. Gardenia plant prefers acidic soil (pH 4.5-5.5) making it more susceptible to the increase in the growth medium pH. The reduction in the pH affects the nutrients availability which directly affects plant vegetative and flowering growth.

***Conclusions*:** In short, improvement of clay and rice straw as growth media for container plants production is possible using the soil drench application of ferrous sulfate at 10-day time interval. Acceptable vegetative and flowering growth of gardenia plants could be attained in either clay and rice straw with much lower cost comparing with that of peat moss. In addition, exploitation of ecologically problematic rice straw could provide environmental benefits whilst ecosystem damage caused by soil or peat extraction is avoided and the impact of residue accumulation is minimized.

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