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SUBSTRATES EFFECTS ON GROWTH, YIELD AND QUALITY OF *ROSA HYBRIDA* L.

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Abstract

The effects of various growing substrates, combinations of soil, silt, sand, press mud (PM) and rice hulls (RH) on plant growth, yield and quality of rose (*Rosa hybrida* L.) cvs. Kardinal, Anjlique and Gold Medal, were studied to standardize substrates for cut rose production and develop better management and quality production protocol. Plant height, number of leaves branch^{-1}, leaf area, number of flowers flush^{-1} plant^{-1}, bud diameter, flower diameter, fresh and dry weight of a flower, flower quality, stem length and stem diameter were maximum when plants were grown in a medium containing combination of Soil + PM + RH followed by Silt + PM and PM + RH. Moreover, plants raised in Soil + PM + RH produced early flowering. PM + RH contributed maximum leaf K contents while Silt + PM produced highest leaf Ca and Mg contents. Soil + Silt and Soil + Sand (traditional media used in the country for rose production) resulted poor plant growth and yield. Among cultivars, 'Kardinal' responded better to different substrates, while 'Gold Medal' was not affected. This study revealed that incorporation of agricultural by-products in traditional medium would help improve the yield and quality of cut roses.

Introduction

Rose, a symbol of affection, elegance, inspiration, sensuality, spirituality and source of aesthetic gratification for human beings, is one of the leading cut flowers in global floriculture trade. It belongs to genus *Rosa* of family Rosaceae, which contains 200 species and more than 18,000 cultivars (Gudin, 2000). It has always been the most favorite flower in the subcontinent. There is hardly any event where roses are not displayed in varied fashion. Cut rose flowers play an important role in interior decoration and add charm to different social and cultural ceremonies. Pakistan, being an agricultural economy, with diverse agro climatic conditions has a great potential for cut rose production. According to a survey, roses are being grown as cut flowers on 1,300 acres of land in Punjab (Khan, 2005) and an increase is being witnessed in rose cultivation in Pakistan. However, the technology being used is primitive which is a major hurdle in flourishing this industry in the country. Therefore, there is dire need to standardize production and handling technology for getting higher yields of better quality to compete in international markets. For this purpose, optimization of growing substrate is important as the substrates play a vital role in quality flower production.

Various soilless substrates have successfully been used for several decades to intensify production and reduce cost (Maloupa *et al*., 1992). These substrates have marked influence on plant's health and vigor by dint of their role as a basic medium. A light, rich, porous and well drained medium is considered ideal for roses. Higher yield of best quality stems is entirely based on physico-chemical characteristics of growing substrates. Moreover, the fact that roses, unlike most other crops, are being constantly harvested and thereby exhibiting large fluctuation of the transpiring area must be taken into consideration when attempting to select a growing medium. Fascella & Zizzo (2005) studied that soilless cultivation of roses grown in perlite/coconut coir dust increased yield and stem quality which might be related to the higher water holding capacity and cation exchange capacity of coconut coir, suggesting this organic material as one of the alternatives to peat for hydroponic culture. Cultivation of roses in soilless substrates is being practiced by using sand culture and nutrient flow technique (Takano, 1988); gravel culture (Sarro *et al*., 1989); organic substrates, mineral wool and aeroponics (Zieslin & Snir, 1989); rockwool (Kool & van de Pol, 1991) and perlite (Katsoulas & Baille, 1999). There is a continuing interest in using various agricultural byproducts as an organic nutrient source for plants on account of their easy availability at cheaper prices and higher, slow release nutritional constituents (Mikkelsen, 2003; Ahmad, 2009). In recent years, coco coir is increasingly used as substrate, because it not only has many characteristics in common with peat (Lennartson, 1997) but also acceptable pH, EC and other chemical properties (Abad *et al.,* 2002). A growing trend among growers is to identify alternative substrate components. Rice hulls have been identified as an alternative substrate component and are an agricultural byproduct which can be a suitable substrate component (Buck & Evans, 2010; Evans, 2008; Evans & Gachukia, 2004; Holcomb et al., 2008; Sambo et al., 2008). Rice hulls are a milling co-product of the rice industry which comprises around 20% of the rice grain at harvest (Kamath & Proctor, 1998). Rice hulls are obtained after steaming process and are, therefore, sterile and free of viable weed seed when initially produced. Because of their large elongated shape, they create large pores in the substrate that become air-filled after irrigation and drainage (Evans & Gachukia, 2004, 2007). Press mud and rice hulls have also been proved effective in improving yield and quality of cut roses (Ahmad, 2009). These agricultural wastes are easily available in the country at reasonably affordable price and can be used to improve the soil characteristics and nutrient availability which in turn will increase yield and quality.

Keeping in view the socio economic value of cut roses and emerging needs to standardize the technology for commercial rose production, this study was conducted with the objective to standardize growing substrate for cut rose production by incorporating easily available agricultural byproducts. A better understanding regarding the effectiveness of various growing substrates in improving growth, yield, manipulating soil characteristics and nutrient uptake would help to recommend a medium to the industry for quality rose production.

Materials and Methods

Present research work was conducted in the greenhouses at Institute of Horticultural Sciences, University of Agriculture, Faisalabad (Latitude 31°30N, longitude 73°10E and altitude 213m) where average maximum and minimum temperatures were 30 ± 4°C and 15 ± 3°C, respectively, during study period. The average maximum and minimum relative humidity was 75 and 35%, respectively. Different substrate components were mixed by volume and put in 75 cm deep polyethylene lined trenches as per treatments. There were eleven substrate combinations viz. Soil + Silt (1:1; v/v), Soil + Sand (1:1; v/v), Soil + PM (1:1; v/v), Soil + RH (1:1; v/v), Silt + Sand (1:1; v/v), Silt + PM (1:1; v/v), Silt + RH (1:1; v/v), Sand + PM (1:1; v/v), Sand + RH (1:1; v/v), PM + RH (1:1; v/v), and Soil + PM + RH (1:1:1; v/v/v), tested on three rose cvs. 'Kardinal', 'Anjlique' and 'Gold Medal'. Substrate samples were also analyzed to determine their physico-chemical properties viz. pH, EC, organic matter (%), moisture contents (%), K, Ca and Mg contents (Table 5). During first week of January, one year old healthy plants were transplanted and pruned to equal height (15 cm from bud union). There were three replications per treatment with ten plants per replicate. Experiment was laid out in a completely randomized design with factorial arrangements. All other cultural practices like fertilization, irrigation, weeding, IPM etc. were similar for all the treatments during entire study period. Data were collected for plant height, number of leaves branch^{-1}, leaf area (cm^2), leaf chlorophyll contents (mg g^{-1}), days to first flower, number of flowers flush^{-1} plant^{-1}, stem length (cm), bud diameter (cm), flower diameter (cm), stem diameter (cm) and fresh and dry weights of a flower (g). Flower quality was also estimated according to Cooper & Spokas (1991) and Dest & Guillard (1987). Analysis of variance (ANOVA) on data was performed using the GLM program of the STATISTICA 5.6 and means were separated using Tukey's test at $P \leq 0.05$ (Steel *et al*., 1997).

Results

Analysis of variance for plant height revealed significant ($p \leq 0.01$) differences among rose cultivars as well as growing substrates. For cultivars, 'Anjlique' and 'Kardinal' produced taller plants with 43.4 cm and 43.3 cm height, respectively, and were statistically at par with each other, while shorter plants with 34.5 cm height were recorded in 'Gold Medal' (Table 2). Among growing substrates, Soil + PM + RH produced taller plants (52.5 cm) followed by PM + RH and Silt + PM (48.0, 46.7 cm, respectively). Soil + RH and Silt + RH produced shorter plants with 32.2, 35.3 cm height, respectively (Table 1). Number of leaves branch^{-1} had significant differences among growing substrates, while cultivars were statistically similar. On average, all cultivars had 13.3 leaves branch^{-1}. Among growing substrates, Soil + PM + RH produced maximum leaves branch^{-1} (15.9) followed by PM + RH, Silt + PM with 15.4 and 14.4 leaves branch^{-1}, respectively. Plants grown in traditional media viz. Soil + Silt and Soil + Sand produced minimum leaves (11.5 and 11.5, respectively) as shown in Table 1.

Table 1. Effect of substrates on plant height, number of leaves branch^{-1}, leaf area, total leaf chlorophyll contents and days to flower of *Rosa hybrida* L. cvs. 'Kardinal', 'Anjlique' and 'Gold Medal'. Substrates were thoroughly mixed by volume, put in 75 cm deep trenches and plants were transplanted in first week of January. Means are average of three replicates of ten plants.

Substrates	Plant height (cm)	Number of leaves branch^{-1}	Leaf area (cm^2)	Leaf total chlorophyll contents (mg g^{-1})	Days to flower
Soil + Silt	35.9 de	11.5 e	45.16 c	38.49 d	76.1 a
Soil + Sand	38.8 cde	11.5 e	42.05 c	39.76 cd	73.8 b
Soil + PM	43.9 bc	13.5 cd	54.61 b	45.10 b	70.4 cd
Soil + RH	32.2 e	11.7 e	40.77 c	36.10 d	73.0 b
Silt + Sand	35.7 de	12.4 de	42.66 c	38.80 d	72.9 b
Silt + PM	46.7 ab	14.4 bc	56.72 b	50.26 a	69.5 d
Silt + RH	35.3 de	12.5 de	44.27 c	37.37 d	72.8 b
Sand + PM	35.6 de	13.9 c	55.87 b	43.59 bc	68.4 de
Sand + RH	39.8 cd	13.3 cd	45.61 c	38.70 d	72.4 bc
PM + RH	48.0 ab	15.4 ab	65.00 a	49.82 a	66.8 e
Soil + PM + RH	52.5 a	15.9 a	65.00 a	46.20 ab	67.3 e

Means sharing similar letter are statistically non-significant at p>0.05.

Table 2. Effect of cultivars on plant height, number of leaves branch^{-1}, leaf area, total leaf chlorophyll contents and days to flower of *Rosa hybrida* L. cvs. 'Kardinal', 'Anjlique' and 'Gold Medal'. Substrates were thoroughly mixed by volume, put in 75 cm deep trenches and plants were transplanted in first week of January. Means are average of three replicates of ten plants.

Substrates	Plant height (cm)	Number of leaves branch^{-1}	Leaf Area (cm^2)	Leaf total chlorophyll contents (mg g^{-1})	Days to flower
Kardinal	43.3 a	13.1 a	50.33 ab	44.50 a	68.1 c
Anjlique	43.4 a	13.6 a	53.28 a	42.96 a	70.0 b
Gold Medal	34.5 b	13.2 a	48.49 b	38.88 b	75.6 a

Means sharing similar letter are statistically non-significant at p>0.05.

Leaves with larger area (53.28 cm^2) were observed in 'Anjlique' followed by 'Kardinal' (50.33 cm^2) and 'Gold Medal' (48.49 cm^2; Table 2). Plants grown in Soil + PM + RH and PM + RH produced maximum leaf area (65.00 cm^2 each) followed by Silt + PM and Sand + PM (56.72 and 55.87 cm^2, respectively). Soil + RH and Soil + Sand had smaller leaves with minimum leaf area (40.77 and 42.05 cm^2, respectively). 'Kardinal' and 'Anjlique' had higher chlorophyll contents (44.50 and 42.96 mg g^{-1}, respectively) than 'Gold Medal' (38.88 mg g^{-1}; Table 2). Silt + PM produced maximum chlorophyll contents (50.26 mg g^{-1}) followed by PM + RH and Soil + PM + RH (49.82 and 46.20 mg g^{-1}, respectively). On the other hand, Soil + RH and Silt + RH had minimum chlorophyll contents (36.10 and 37.37 mg g^{-1}, respectively; (Table 1).

'Kardinal' produced early flowering after 68.1 days followed by 'Anjlique' (70.0 days) while 'Gold Medal' flowered after 75.6 days (Table 2). Among substrates, plants grown in PM + RH and Soil + PM + RH flowered earlier in 66.8 and 67.3 days, respectively (Table 1). On the other hand, plants grown in traditional media combinations along with rice hulls delayed flowering. Soil + Silt grown plants took maximum time to flower (76.1 days) followed by Soil + Sand, Soil + RH, Silt + Sand and Silt + RH which produced flowers after 73.8, 73.0, 72.9 and 72.8 days, respectively, and were statistically at par with each other (Table 1). Regarding number of flowers pant^{-1} flush^{-1}, 'Anjlique' produced maximum flowers (12.4) followed by 'Kardinal' (9.6), while 'Gold Medal' produced minimum flowers (6.6). Among substrates, plants grown in Soil + PM + RH and PM + RH produced maximum flowers plant^{-1} flush^{-1} (13.6 and 13.2, respectively; Fig. 1).

Among cultivars, 'Kardinal' had larger bud diameter (2.6 cm) followed by 'Gold Medal' (2.5 cm) and 'Anjlique' (2.5cm) (Table 4). For growing substrates, Soil + PM + RH excelled rest of treatments with 3.2 cm bud diameter followed by Sand + PM, PM + RH and Silt + PM with 2.9, 2.9 and 2.8 cm diameter, respectively. While plants grown in Soil + Silt, Soil + RH and Soil + Sand had minimum bud diameter (1.9, 2.2 and 2.4 cm, respectively) as shown in Table 3. For flower diameter, 'Kardinal' produced maximum flower diameter (5.5 cm) followed by 'Anjlique' (4.6 cm), whereas, 'Gold Medal' had minimum flower diameter (4.5 cm; Table 4). Among substrates, plants grown in Soil + PM + RH, Sand + PM, Silt + PM and PM + RH produced maximum flower diameter (5.7, 5.5, 5.4 and 5.3 cm, respectively) and were statistically at par. Plants grown in tradition substrate viz. Soil + Silt had minimum flower diameter (3.9 cm; Table 3).

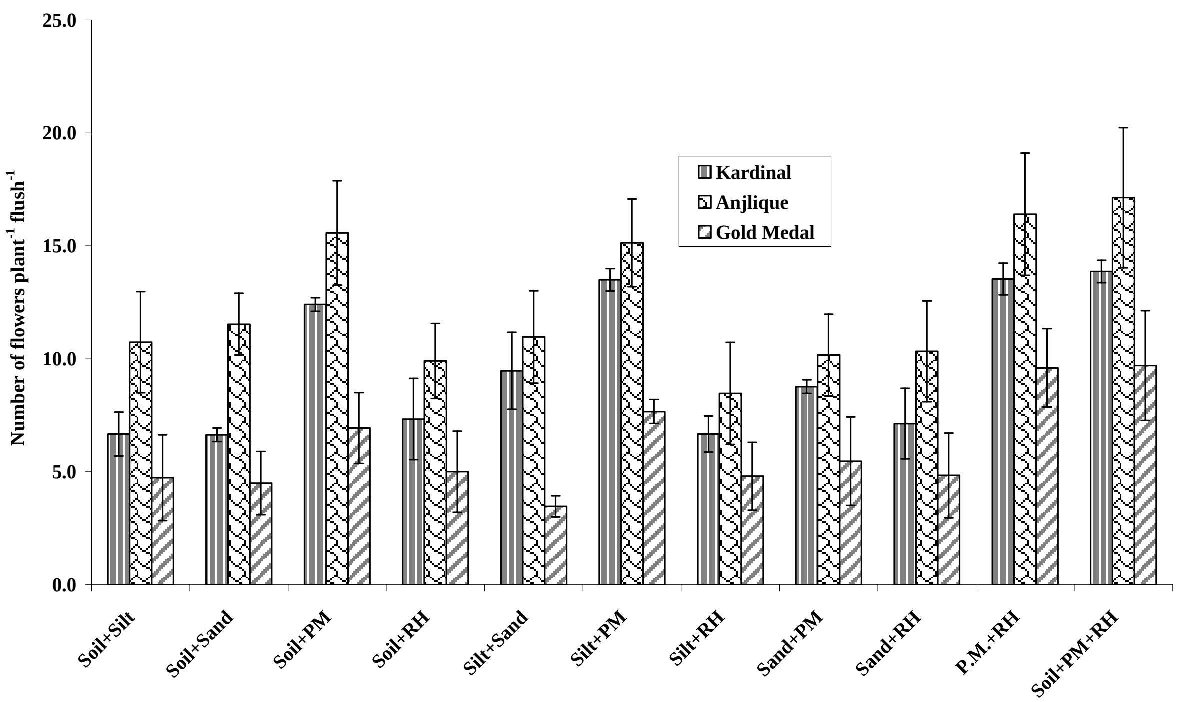

Fig. 1. Number of flowers plant^{-1} flush^{-1} of *Rosa hybrida* L. cvs. Kardinal, Anjlique and Gold Medal grown in different substrates. Substrates were thoroughly mixed by volume, put in 75 cm deep trenches and plants were transplanted in first week of January. Means are average of three replicates of ten plants.

For fresh weight of a flower, 'Kardinal' produced maximum fresh weight of a flower (8.8 g) followed by 'Anjlique' (7.6 g), while 'Gold Medal' had minimum fresh weight of a flower (7.42 g). Among substrates, Soil + PM + RH and PM + RH proved best with 9.3 and 8.5 g fresh weight, respectively (Table 3). Regarding dry weight of a flower, 'Kardinal' had higher dry weight (1.4 g) followed by 'Anjlique' (1.3 g). On the other hand, plants grown in Soil + PM + RH, PM + RH and Sand + PM had higher flower dry weight (1.9, 1.6, and 1.5 g, respectively), while Soil + Silt, Soil + Sand and Soil + RH had less dry weight (0.9, 1.1, and 1.1 g, respectively) as shown in Table 3.

Table 3. Effect of substrates on bud diameter, flower diameter and fresh &dry weight of a flower of *Rosa hybrida* L. cvs. 'Kardinal', 'Anjlique' and 'Gold Medal'. Substrates were thoroughly mixed by volume, put in 75 cm deep trenches and plants were transplanted in first week of January. Means are average of three replicates of ten plants.

Substrates	Bud diameter (cm)	Flower diameter (cm)	Fresh weight of a flower (g)	Dry weight of a flower (g)
Soil + Silt	1.9 f	3.9 e	6.6 g	0.9 f
Soil + Sand	2.4 e	4.2 de	7.0 fg	1.1 ef
Soil + PM	2.6 c	4.8 cd	7.8 cde	1.3 de
Soil + RH	2.2 d	4.4 de	7.2 efg	1.1 ef
Silt + Sand	2.5 c	4.7 d	7.4 def	1.2 de
Silt + PM	2.8 c	5.4 ab	8.5 cde	1.4 bcd
Silt + RH	2.5 c	4.6 d	7.5 efg	1.1 ef
Sand + PM	2.9 b	5.5 ab	8.2 bc	1.5 bc
Sand + RH	2.6 c	4.9 bcd	7.7 def	1.3 cde
PM + RH	2.9 b	5.3 abc	8.5 b	1.6 b
Soil + PM + RH	3.2 a	5.7 a	9.3 a	1.9 a

Means sharing similar letter are statistically non-significant at P>0.05.

Among cultivars, 'Anjlique' produced longer stems (43.6 cm) followed by 'Kardinal' (42.5 cm), while 'Gold Medal' had shorter stems (40. 9 cm). Among substrates, plant grown in Soil + PM + RH and PM + RH produced longer stems (49.5, and 47.1 cm, respectively), while plants raised in traditional medium, i.e., Soil + Silt had minimum stem length (34.2 cm; Fig. 3). For stem diameter, 'Anjlique' had maximum diameter (0.45 cm) followed by 'Gold Medal' (0.44 cm) while 'Kardinal' had minimum diameter (0.43 cm). Among substrate treatments, plants grown in Soil + PM + RH and PM + RH had greater stem diameter (0.52 and 0.50 cm, respectively). However, plants grown in Soil + Silt, Soil + Sand and Silt + RH had minimum stem diameter (0.37, 0.40 and 0.42 cm, respectively) as shown in Fig. 4. Among cultivars, 'Gold Medal' produced better quality flowers (6.4) followed by 'Anjlique' (6.1) and 'Kardinal' (6.1). Plants grown in substrates containing Soil + PM + RH and Sand + PM produced best quality flowers (7.9, and 7.7, respectively)while those grown in Soil + Silt and Soil + RH had poor flower quality (4.2, and 4.8, respectively) as shown in Fig. 2.

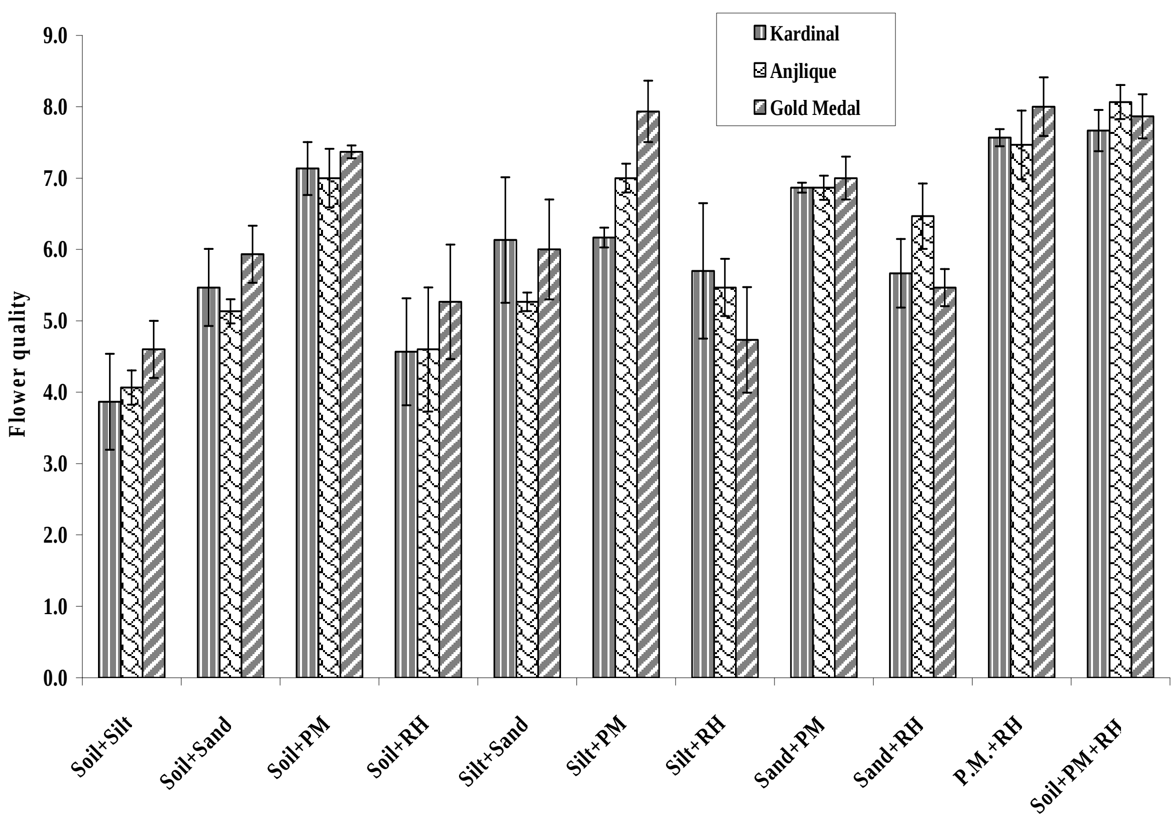

Fig. 2. Flower quality of *Rosa hybrida* L. cvs. Kardinal, Anjlique and Gold Medal grown in different substrates. Substrates were thoroughly mixed by volume, put in 75 cm deep trenches and plants were transplanted in first week of January. Means are average of three replicates of ten plants.

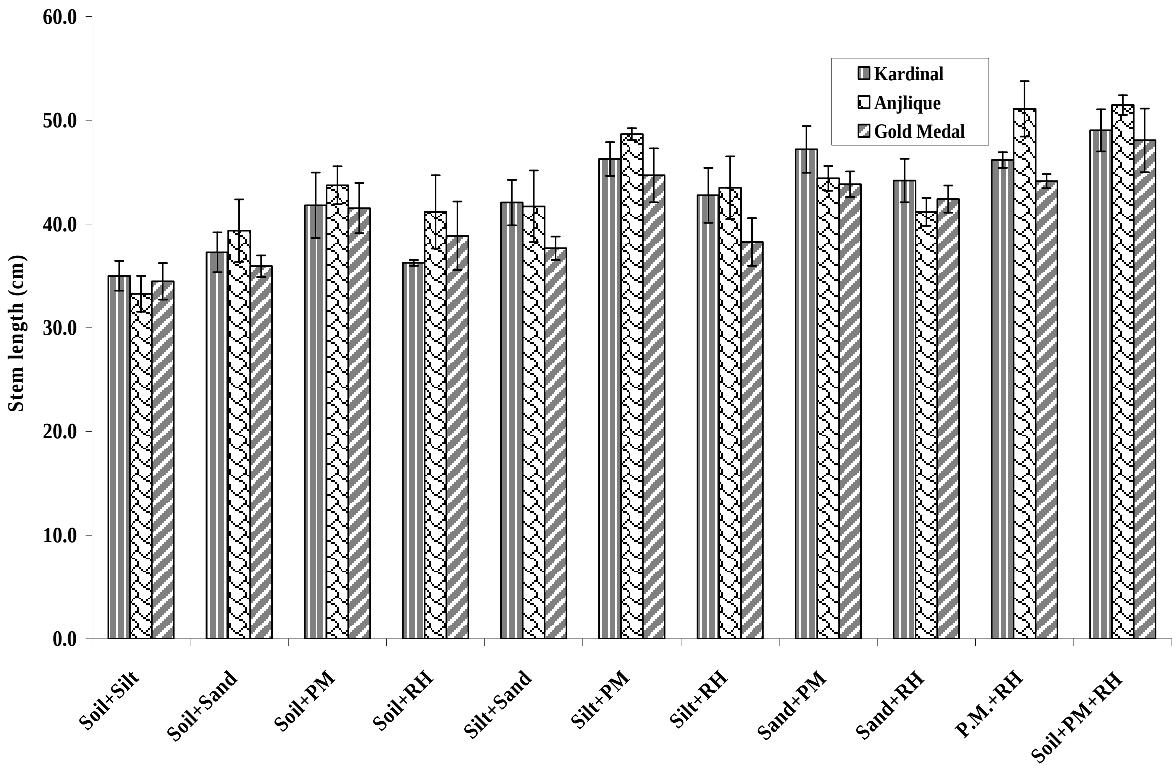

Fig. 3. Stem length (cm) of *Rosa hybrida* L. cvs. Kardinal, Anjlique and Gold Medal grown in different substrates. Substrates were thoroughly mixed by volume, put in 75 cm deep trenches and plants were transplanted in first week of January. Means are average of three replicates of ten plants.

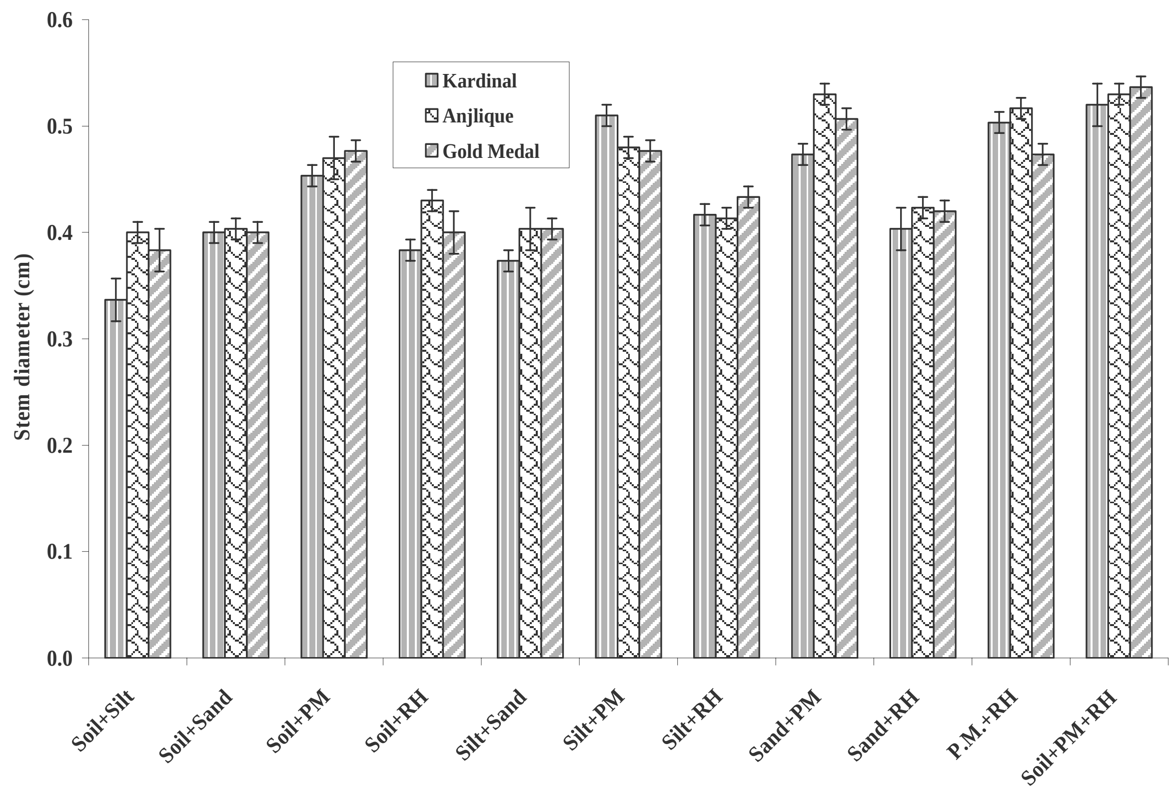

Fig. 4. Stem diameter (cm) of *Rosa hybrida* L. cvs. Kardinal, Anjlique and Gold Medal grown in different substrates. Substrates were thoroughly mixed by volume, put in 75 cm deep trenches and plants were transplanted in first week of January. Means are average of three replicates of ten plants.

The effect of growing substrates on K, Ca and Mg uptake was also measured. Among cultivars, 'Anjlique' had maximum K contents in leaves followed by 'Kardinal' while 'Gold Medal' had minimum leaf K (Fig. 5). Similar trend was observed for leaf Ca and Mg contents. Regarding substrates, leaf K contents were statistically similar while substrates containing soil and/or silt with pressed mud and/or rice hulls produced higher leaf Ca and Mg contents (Fig. 6 & 7).

Table 4. Effect of cultivars on bud diameter, flower diameter and fresh &dry weight of a flower of *Rosa hybrida* L. cvs. 'Kardinal', 'Anjlique' and 'Gold Medal'. Substrates were thoroughly mixed by volume, put in 75 cm deep trenches and plants were transplanted in first week of January. Means are average of three replicates of ten plants.

Substrates	Bud diameter (cm)	Flower diameter (cm)	Fresh weight of a flower (g)	Dry weight of a flower (g)
Kardinal	2.6 a	5.5 a	8.8 a	1.4 a
Anjlique	2.5 b	4.6 b	7.6 b	1.3 b
Gold Medal	2.5 b	4.5 b	7.4 b	1.2 b

Means sharing similar letter are statistically non-significant at P>0.05.

Table 5. Physico-chemical characteristics of growing substrates. Samples were collected before transplant and means are an average of three replicates.

Substrates	pH	EC (dSm^{-1})	Organic Matter (%)	K ($mg\ L^{-1}$)	Ca ($mg\ L^{-1}$)	Mg ($mg\ L^{-1}$)
Soil + Silt	7.7	0.80	0.86	0.9	5.39	1.84
Soil + Sand	7.8	1.21	0.5	0.8	0.00	0.00
Soil + PM	7.2	1.51	0.94	0.5	9.13	1.27
Soil + RH	7.1	1.84	0.71	0.9	8.66	1.20
Silt + Sand	7.0	1.99	0.81	1.0	7.15	1.04
Silt + PM	7.1	1.86	1.05	0.6	8.22	1.03
Silt + RH	7.0	1.63	0.15	0.5	10.67	1.31
Sand + PM	7.3	1.15	1.66	0.7	9.37	1.18
Sand + RH	6.4	1.89	1.89	0.6	9.55	0.83
PM + RH	6.1	2.70	2.38	0.5	8.93	0.91
Soil + PM + RH	6.2	2.54	2.13	0.5	9.60	1.43

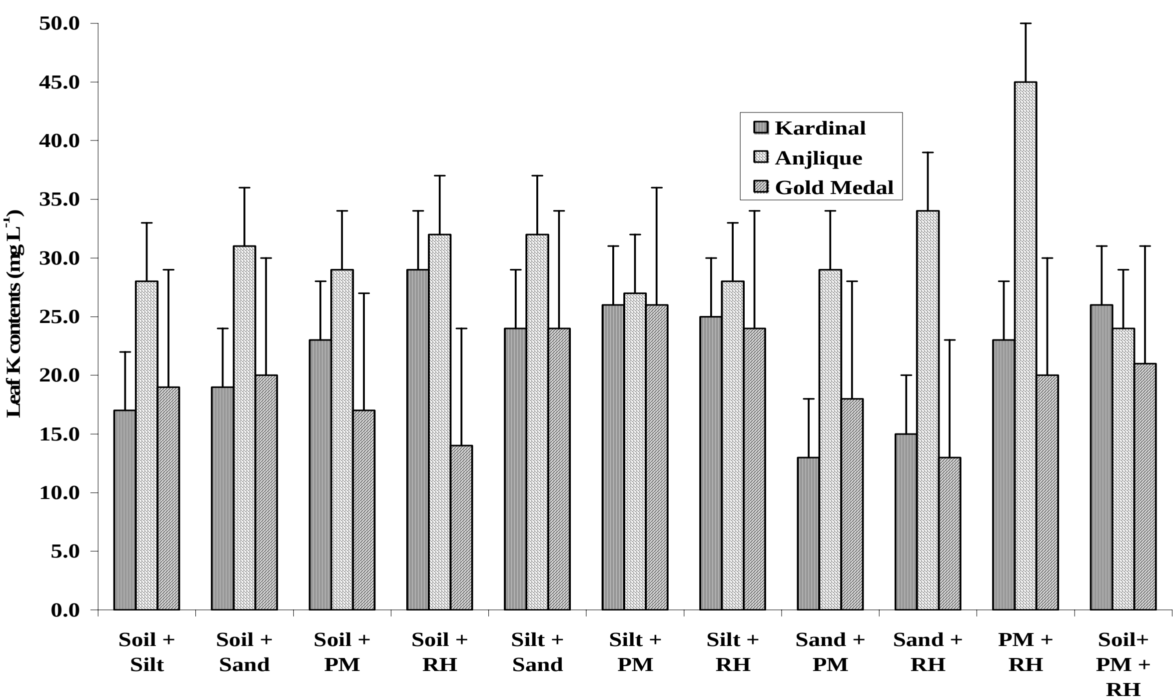

Fig. 5. Leaf K contents ($mg\ L^{-1}$) of *Rosa hybrida* L. cvs. Kardinal, Anjlique and Gold Medal grown in different substrates. Substrates were thoroughly mixed by volume, put in 75 cm deep trenches and plants were transplanted in first week of January. Means are average of three replicates of ten plants.

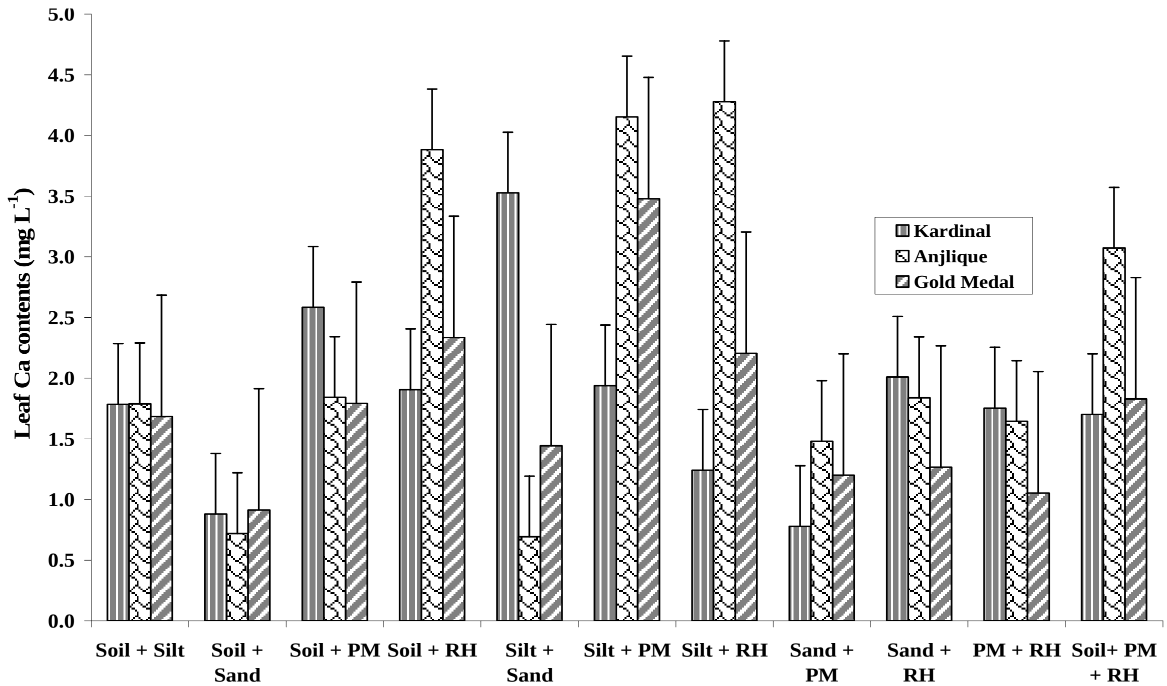

Fig. 6. Leaf Ca contents (mg L^{-1}) of *Rosa hybrida* L. cvs. Kardinal, Anjlique and Gold Medal grown in different substrates. Substrates were thoroughly mixed by volume, put in 75 cm deep trenches and plants were transplanted in first week of January. Means are average of three replicates of ten plants.

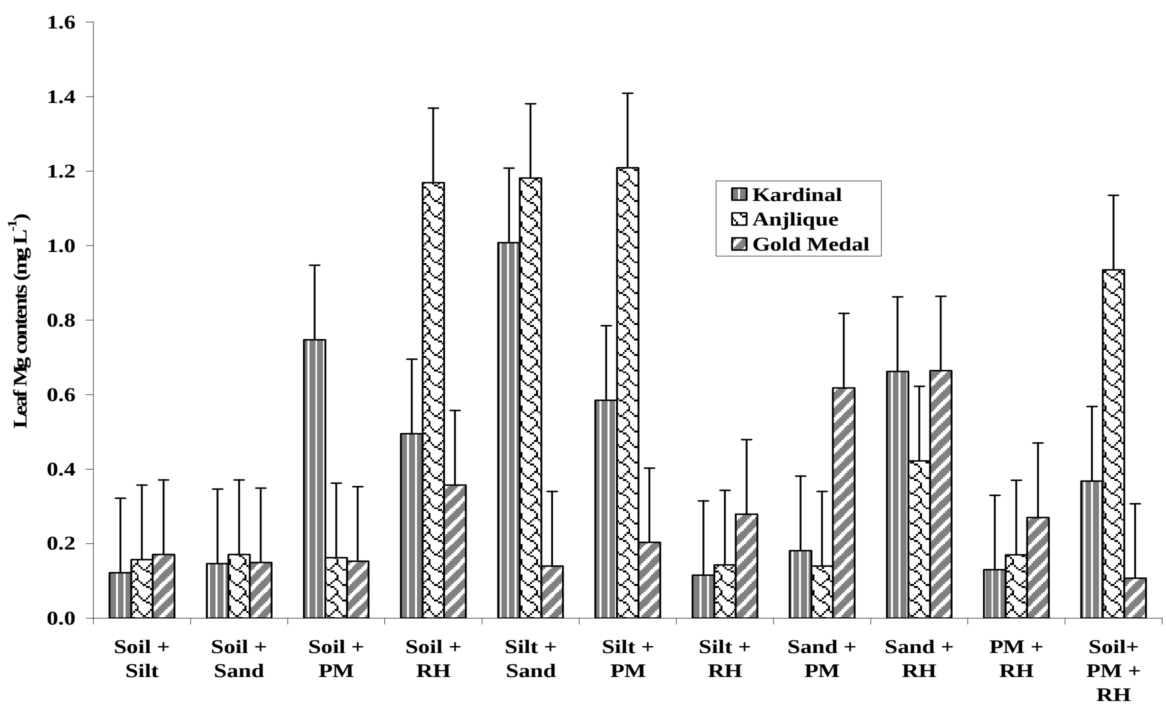

Fig. 7. Leaf Mg contents (mg L^{-1}) of *Rosa hybrida* L. cvs. Kardinal, Anjlique and Gold Medal grown in different substrates. Substrates were thoroughly mixed by volume, put in 75 cm deep trenches and plants were transplanted in first week of January. Means are average of three replicates of ten plants.

Discussion

Rose (*Rosa hybrida* L.) constitutes one third of total global cut flower production (Kras, 1999). The demand for cut roses has recently been increased tremendously in Pakistan (Khan, 2005). Pakistan being an agricultural country with diverse edaphic and climatic conditions has a great potential for floricultural production. For export quality cut rose flower production, modern technology needs to be introduced and tested to standardize agro techniques, essential for plant growth and yield. Soilless cultivation is widely practiced all over world for various horticultural crops as it permits good control of plant growth and development (van Os & Benoit, 1999; van Os *et al*., (2002). At the same time, produce quality is not adversely affected with increase in yield (Savvas, 2002). Regarding standardization of substrates, Soil + Press mud (PM) + Rice hulls (RH) (1:1:1; v/v/v) produced the taller plants with maximum large sized leaves branch^{-1}, maximum number of flowers plant^{-1} with greater bud and flower diameter, fresh and dry weight, flower quality, stem length and diameter while combination of Silt + PM produced leaves with maximum total chlorophyll contents and PM + RH produced earlier flowering. These results are in line with the findings of Maloupa *et al*., (1992); Fascella & Zizzo (2005) and Samartzids *et al*. (2005) who reported higher yield when roses were grown in various substrates. As many of plant growth, yield and quality parameters of all rose cultivars were positively affected by the substrate containing combination of both press mud and rice hulls, use of these organic agricultural byproducts would help in improving quality production. Similar findings have also been reported by Curry *et al.,* (2010) who reported no reduction of PGR efficiency if parboiled rice hulls are used in greenhouse substrates. Moreover, the results suggested that these organic substrates improved soil characteristics which helped plants to increase nutrient uptake by the plants which in turn increased yield as well as quality (Evans, 2008; Evans & Gachukia, 2004; 2007). Among cultivars, 'Anjlique' produced the taller plants with maximum sized leaves, flower yield plant^{-1}, stem length and diameter while 'Kardinal' had maximum total chlorophyll contents, produced early flowering, had maximum bud and flower diameter and fresh and dry weight, while 'Gold Medal' had best flower quality. These findings suggested that 'Anjleeq' is better cultivar for higher yield with long stems, 'Kardinal' is well suited for early production with larger bud size while 'Gold Medal' has better quality flowers than other tested cultivars (Fascella & Zizzo, 2005).

In summary, incorporation of rice hulls and press mud in traditional substrates improved the growth and quality indices and increased flower yield of *Rosa hybrida* L. cvs. 'Kardinal', 'Anjlique' and 'Gold Medal'. Of all combinations of substrates, Soil + PM + RH and PM + RH had more pronounced effect as compared with others. Among cultivars, 'Kardinal' responded better to these substrates as compared with 'Anjlique' and 'Gold Medal'. Incorporation of organic agricultural byproducts in conventional medium are more effective in inducing better growth and producing superior quality cut rose stems than traditional alone. Therefore, based on performance of tested rose cultivars, use of rice hulls and press mud improve the vigor of the plant to pave the way for higher yields of superior quality cut roses.

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