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RESEARCH ARTICLE

Substrates Affect Plant Growth, Flower Yield, and Quality of Stock (*Matthiola incana* L.) and Zinnia (*Zinnia elegans* Jacq.)

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ABSTRACT

A study was conducted to evaluate the efficacy of various substrates to promote vegetative and reproductive growth of stock (*Matthiola incana* L. 'Midseason Cheerful White') and zinnia (*Zinnia elegans* Jacq. 'Benary's Giant Deep Red'). There were seven treatments comprising of peat, coco coir and conventional substrate (soil + silt + leaf mold, 1:1:1, v/v/v) alone or in different proportions. Use of coco coir plus peat or peat alone increased plant height, number of leaves plant^{-1}, leaf area, leaf chlorophyll contents, stem length, number of florets spike^{-1}, floret diameter, spike length and fresh and dry weight of stem, while decreased number of days to harvest of stock. However, substrates had no effect on vase life and stem diameter of stock. For zinnia, plant height and stem length were significantly higher ($P<0.0001$ and $P=0.0001$, respectively) in coco coir-based substrates. Growth and floral indices were significantly increased in peat-based and peat plus coco coir-based substrates. However, substrates had no effect on number of leaves and flowers plant^{-1} and vase life of zinnia. Leaf NPK contents of stock were higher ($P<0.0001$) in peat-based substrate, while in zinnia, K was significantly higher in peat. Leaf nitrogen contents of zinnia were higher ($P<0.0001$) in coco coir + conventional substrate, but leaf phosphorus contents were similar in all substrates. Results revealed the positive effects of coco coir alone or combined with peat for enhancing yield and quality of tested specialty cut flower crops.

INTRODUCTION

Stock (*Matthiola incana),* a winter annual, native of Mediterranean region, belongs to family Brassicaceae and is a popular specialty cut flower in the global markets. Due to its availability in a variety of conspicuous colors, which make it an excellent cut flower, its demand is increasing in the world flower markets (Ahmad and Dole, 2014). *Zinnia elegans* is another glorious flower of summer season. It belongs to family Compositae and is native to Mexico and Central America. Zinnia flowers exhibit bright colors with sturdy stems and reasonably long vase life and that's why gaining fame as specialty cut flower (Ahmad and Dole, 2014). Zinnia is used in borders, beds, edges and as cut flowers to be a good source of foreign exchange (Saleem et al., 2003).

Growing substrates have a significant role in production of quality ornamental crops. A good growing substrate affects the development of extensive root system, provides sufficient anchorage to plant, and allows gaseous exchange between plant roots and atmosphere (Abad et al., 2002). Growing substrate best suited for plant growth and development should have good physical properties. Rising quantities of wastes have diminished the utilization of soil and promoted the use of organic residues in agriculture (Papafotiou et al., 2004). With the passage of time, use of soilless substrates is gaining popularity for the production of container grown plants and greenhouse cut flower production. Selecting the best substrate is imperative to plant productivity (Paradiso and De Pascale, 2008). The physico-chemical attributes of soilless substrates are responsible for providing adequate support and nutrients to plants, but it should be light, porous and well drained (Noguera et al., 2003). Coco coir obtained from the coconut husk, which has excellent physical attributes**, is** good enough to provide excellent medium for container grown plants (Caron et al., 2005). Moreover, it is commonly accessible. There is an increasing trend to utilize different agricultural by-products and organic wastes as nutrient sources for ornamental container grown plants due to many common characteristics with peat (Mikkelsen, 2003). Peat has been widely used as growing substrate due to its good physical and chemical properties, but its resources are diminishing**,** so it would be wise to find alternative substances (Wilson et al., 2006; Michel et al., 2015). Coco coir is most extensively used as growing substrate alone and in combination with perlite or other constituents for the production of ornamental potted plants and cut flowers (Kim, 2007; Islam, 2008; Ahmad et al., 2015).

Floriculture is progressively emerging as an industry in Pakistan. Nursery and flower business is increasing day by day due to enhancement in aesthetic perception of the communities. Nursery raising and potting of annuals are important activities in nurseries and at specialty cut flower farms. But, old age practice among nurserymen and flower growers in Pakistan is the use of soil, silt and farmyard/leaf manure as conventional substrates. Availability of farmyard manure is decreasing due to increase in its usage in other agricultural and energy production activities. While, deforestation and reduced plantation in cities is also decreasing the availability of high quality leaf manure. Moreover, farmyard manure and leaf manure are major sources of weeds and later one is also sometimes associated with allelopathic effects caused by leaves of some plants e.g. eucalyptus. Peat, found in very limited quantities in northern areas of Pakistan, is also available in very limited quantities but at very high rates. Therefore, there was a need to find out alternatives of these components of conventional media for nurserymen and flower growers. During the last decade, the use of coconut coir (coconut fiber) has gained popularity because of its characteristics similar to those of peat (Hernandez-Apaolaza et al., 2005; Ahmad et al., 2012). It is available in various quantities in all big cities. Therefore, its usage as an alternate to conventional substrate (CS: soil + silt + leaf manure) and peat was evaluated employing a winter annual flower, stock, and a summer annual flower, zinnia.

Soilless substrates are generally used to produce the best quality cut flowers in the world. However, conventional substrate is commonly used for cut flower production in Pakistan. Due to increasing demand of cut flowers and introduction of new specialty cut flowers, there was a dire need to evaluate potential specialty cut flower species with different substrates. This study was conducted to evaluate the performance of cut stock and zinnia using coco coir, peat and conventional medium as growing substrates. The specific objectives of this study were to standardize growing substrates for production of the best quality specialty cut flowers and to compare suitability of coco coir and peat with conventional substrate used for flower production in Pakistan.

MATERIALS AND METHODS

Present study was conducted at Floriculture Research Area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan, (Latitude 31^{o}31N, Longitude 73^{o}10E and altitude 213m). Seeds of *Matthiola incana* L. (Midseason Cheerful White) and *Zinnia elegans* Jacq. (Benary's Giant Deep Red) were imported from USA and nursery was raised in 128-cell propagation plastic trays using peat as substrate. Stock was grown during winter while zinnia was grown during summer using same substrates under natural temperature and light conditions. Coco coir and peat were used individually and in different combinations mixed with conventional substrate [CS; soil + silt + leaf manure, (1:1:1, v/v/v)] to prepare different substrates. Treatments included conventional substrate (CS), coco coir (CC), peat (P), CS + CC (1:1, v/v), CS + peat (1:1, v/v), CC + peat (1:1, v/v) and CS + CC + peat (1:1:1, v/v/v). Pots of 30 cm size were thoroughly filled with substrates according to treatments and three week old seedlings were transplanted individually in the pots. Experiment was laid out according to completely randomized design (CRD) with three replications, each containing four plants of each treatment. All cultural practices such as hoeing, weeding, fertilization, irrigation, IPM, etc. were similar for all treatments during the entire period of study.

Data collection

Data were collected on growth and flowering indices using standard procedures. Plant height was measured at harvest from substrate surface to the top of the plant. Two healthy and mature leaves were selected from each replication within a treatment to determine leaf area and leaf total chlorophyll contents, which were estimated from the recently mature leaves. At harvest, flower diameter (zinnia) and floret diameter (stock) were measured with digital caliper. Stems were weighed to record fresh and dry weights. Flower quality was measured using method described by Cooper and Spokas (1991) based on a rating of 1-9, where 9 was best quality, 5 was average quality and 1 for poor quality flowers. Vase life was measured by counting the number of days from placement of stems in distilled water in a postharvest evaluation room maintained at 20 ± 2°C temperature with 12 h of day length to the time when 50% of petals/florets were wilted or necrotic (Ahmad and Dole, 2014). Leaf analysis was conducted to determine macronutrients absorbed by the plants from substrates. Leaf N, P and K were determined by using the method described by Champan and Parker (1961). Substrate pH was measured according to the method described by McKeague (1978) and McLean (1982), while EC was determined following the method described by Richards (1954). Organic matter was recorded according to the method described by Walkley (1947). Total N, P and K in growing substrates were measured using the method described by Bremner and Mulvaney (1982), Olsen et al. (1954) and Jackson (1962), respectively. Data recorded on physico-chemical attributes of substrates is presented in Table 6. Data collected were analyzed using Fisher's analysis of variance technique and treatment means were compared using LSD test at $P \leq 0.05$ (Steel et al., 1997).

RESULTS

Effect of growing medium on growth indices

Stock plants grown in peat produced maximum plant height (63.6 cm), stem length (61 cm), and fresh (41.6 g) and dry weight (6.8 g) of stem, while the combination of coco coir and peat significantly enhanced number of leaves per plant (40.6) (Table 1), leaf area (26.8 cm^2) and total chlorophyll contents (60.3 SPAD units) of stock as compared to other growing substrates. Stock plants grown in coco coir + peat were harvested earliest (after 97.2 days) compared to plants in other growing substrates (Table 2).

Zinnia plants grown in coco coir exhibited maximum plant height (105.4 cm) and stem length (63.6 cm), while stem diameter (7.5 mm), and fresh (19.5 g) and dry (4.6 g) weight of stem was highest for plants grown in peat (Table 4). Leaf area (27.4 cm^2) (Table 4) and total chlorophyll contents (58.7 SPAD units) of zinnia plants grown in coco coir + peat substrate were significantly higher than plants grown in other growing substrates (Table 5). Coco coir + peat grown plants also took minimum time (57.1 days) to reach harvesting stage (Table 5).

Floral characters in response to growing substrates

Peat grown stock plants had significantly superior floral characters, i.e., number of florets per spike (24.5), spike length (19.2 cm), (Table 2) and floret diameter (4.0 cm) (Table 3). Floret diameter of stock plants grown in peat and CS+CC+P (4.1 cm) substrate was statistically similar. Quality of flowers from plants grown in substrates other than CS (5.5) and CS + CC (5.8) was statistically similar and better than the flowers from CS and CS + CC substrate (Table 3).

Flower diameter of zinnia plants was highest (8.8 cm) in peat grown plants compared to the plants grown in other growing substrates (Table 5). Good quality flowers (8.8) of zinnia were observed in plants grown in peat compared to other studied substrates (Table 5).

Leaf NPK analysis of stock and zinnia

Leaf nitrogen and phosphorus contents of stock plants were highest (1.28% and 0.61%, respectively) in plants grown in peat, while leaf potassium contents were highest (0.6%) in plants grown in CS + P (Table 3).

Leaf nitrogen contents of zinnia (1.24%) were highest in plants grown in CS + CC (Table 5), while leaf phosphorus contents were similar results in all treatments and averaged 0.43%. Maximum leaf potassium contents (0.75%) were recorded in plants grown in CS + P (Table 5).

DISCUSSION

All growing substrates increased growth and flowering traits in both annual cut flowers compared to the conventional substrates (CS). All vegetative (plant height, stem length, fresh and dry weight of flower stem, leaf total chlorophyll contents, except number of leaves per plant), and floral characteristics (spike length, number of florets per spike, and floret diameter), as well as leaf nutrient status of stock plants were improved when grown in peat followed by CS+CC, CS+P, CC alone and CS+CC+P in descending order. Zinnia plants had maximum height and stem diameter in CC medium. While, stem diameter, fresh and dry weight of stems, flower diameter and quality and leaf nitrogen and potassium contents were higher in peat followed by various combinations of CC and P with each other or with CS, but were superior to CS. This enhanced growth and flowering behavior of both flowers in peat, coco-coir or their combination with

Table 1: Plant height, stem length, fresh weight of stem, dry weight of stem and number of leaves plant^{-1} of *Matthiola incana* L. as influenced by various growing substrates

Growing Substrates	Plant height (cm)	Stem length (cm)	Fresh weight of stem (g)	Dry weight of stem (g)	Number of leaves plant^{-1}
CS	51.6 c	49.2 c	26.2 c	3.7 d	23.8 d
Coco coir (CC)	58.2 b	55.6 b	35.6 ab	5.2 bc	32.6 b
Peat (P)	63.6 a	61.0 a	41.6 a	6.8 a	35.8 b
CS + CC	58.2 b	55.7 b	34.3 b	5.6 b	32.5 b
CS + P	57.8 b	55.2 b	34.8 ab	4.8 c	28.4 c
CC + P	58.2 b	55.6 b	38.9 ab	5.8 b	40.6 a
CS + CC + P	56.8 b	54.2 b	35.4 ab	5.3 bc	34.0 b
Significance	**	**	*	**	**

*,** = Significant at $P \leq 0.05$ or $P \leq 0.01$, respectively; CS = (Soil + silt + leaf manure, 1:1:1, v/v/v).

Table 2: Leaf area, leaf chlorophyll contents, days to harvest, number of florets spike^{-1} and spike length of *Matthiola incana* L. as influenced by various growing substrates

Growing Substrates	Leaf area (cm^2)	Leaf chlorophyll contents (SPAD)	Days to harvest (days)	No. of florets spike^{-1}	Spike length (cm)
CS	20.2 bc	46.1 c	115.4 a	15.3 c	11.4 d
Coco coir (CC)	20.3 bc	57.3 a	106.7 b	19.2 b	15.5 bc
Peat (P)	21.3 bc	58.2 a	107.8 b	24.5 a	19.2 a
CS + CC	21.7 bc	51.0 b	102.1 c	19.3 b	15.9 b
CS + P	22.1 b	44.3 c	110.3 b	18.5 b	13.1 cd
CC + P	26.8 a	60.3 a	97.2 d	22.6 a	16.4 b
CS + CC + P	18.3 c	46.9 bc	109.9 b	17.6 bc	12.4 d
Significance	**	**	**	**	**

*,** = Significant at P≤0.05 or P≤0.01, respectively; CS = (Soil + silt + leaf manure, 1:1:1, v/v/v).

Table 3: Floret diameter, flower quality, leaf nitrogen, leaf phosphorus and leaf potassium contents of *Matthiola incana* L. as influenced by various growing substrates

Growing Substrates	Floret diameter (cm)	Flower quality	Leaf nitrogen (%)	Leaf phosphorus (%)	Leaf potassium (%)
CS	3.2 b	5.5 b	0.82 d	0.42 c	0.29 d
Coco coir (CC)	3.9 a	7.5 a	1.12 b	0.49 b	0.47 b
Peat (P)	4.0 a	7.7 a	1.28 a	0.61 a	0.64 a
CS + CC	3.0 b	5.8 b	1.03 bc	0.49 b	0.49 b
CS + P	3.8 a	8.7 a	1.05 bc	0.59 a	0.67 a
CC + P	3.8 a	8.0 a	0.99 c	0.49 b	0.42 c
CS + CC + P	4.1 a	7.7 a	0.98 c	0.36 d	0.40 c
Significance	**	**	**	**	**

*,** = Significant at P≤0.05 or P≤0.01, respectively; CS = (Soil + silt + leaf manure, 1:1:1, v/v/v).

Table 4: Plant height, stem length, stem diameter, fresh weight of stem, dry weight of stem and leaf area of *Zinnia elegans* Jacq. as influenced by various growing substrates

Growing substrates	Plant height (cm)	Stem length (cm)	Stem diameter (mm)	Fresh weight of stem (g)	Dry weight of stem (g)	Leaf area (cm^2)
CS	78.1 d	49.5 bc	4.9 b	13.3 bc	3.3 b	20.0 c
Coco coir (CC)	105.4 a	63.6 a	5.2 b	12.4 bc	3.2 b	21.5 bc
Peat (P)	95.0 b	54.5 b	7.5 a	19.5 a	4.6 a	23.2 b
CS + CC	103.3 a	55.8 b	5.7 b	12.3 bc	3.1 bc	21.0 bc
CS + P	84.8 c	42.4 cd	5.0 b	12.7 bc	3.3 b	20.6 bc
CC + P	94.1 b	54.8 b	5.7 b	14.5 b	3.5 b	27.4 a
CS + CC + P	85.1 c	40.5 d	6.1 b	9.4 c	2.1 c	20.4 bc
Significance	**	**	**	*	*	**

*,** = Significant at P≤0.05 or P≤0.01, respectively; CS = (Soil + silt + leaf manure, 1:1:1, v/v/v).

each other or with CS can be attributed to the physico-chemical properties of the growing substrates (Riaz et al., 2008). Peat had lowest pH, higher EC, organic matter, nitrogen, phosphorus and potassium contents than CS and other substrates. While, CC had lowest EC, higher water holding capacity and organic matter than CS and had neutral pH. Therefore, enhanced growth and flowering, particularly of stock, in peat, coco-coir and media comprising these two, can be ascribed to its pH, water holding capacity and availability of nutrient elements, as observed earlier by Awang et al. (2009). Treder (2008) observed maximum chlorophyll contents in gerbera plants grown in coco-coir and peat based substrates. They attributed this high level of chlorophyll due to low to neutral pH of the two substrates, respectively, because plants grown in high pH substrates had low chlorophyll contents. It is also obvious from the results that number of florets per spike, spike length, floret diameter and flower quality were improved in peat and coco-coir and their combination with each other as well as with CS in stock, but same level of response was not observed in zinnia (Fascella and Zizzo 2005; Khayyat et al., 2007). Number of leaves per plant and chlorophyll contents of stock plants grown in substrates other than CS and CS+P were substantially high, especially for CC+P; results of coco-coir and peat were comparable (Tables 1 and 2) indicating that CC can be a substitute to peat. Moreover, CS+CC also provided better results than CS and CC alone as evident from previous results of tuberose (Ikram et al., 2012), gerbera (Ahmad et al., 2012), dahlia (Tariq et al., 2012), *Pinus pinea*, *Cupressus arizonica* and *C. sempervirens* (Hernandez-Apaolaza et al., 2005). Thus, physico-chemical

Table 5: Leaf chlorophyll contents, days to harvest, flower diameter, flower quality, leaf nitrogen and leaf potassium contents of *Zinnia elegans* Jacq. as influenced by various growing substrates

Growing substrates	Leaf chlorophyll contents (SPAD)	Days to harvest (days)	Flower Diameter (cm)	Flower quality	Leaf nitrogen (%)	Leaf potassium (%)
CS	44.5 c	73.3 a	6.4 c	7.3 b	0.78 e	0.38 c
Coco coir (CC)	52.2 b	58.2 c	7.5 b	7.3 b	1.14 bc	0.51 b
Peat (P)	50.6 b	63.7 b	8.8 a	8.8 a	1.15 ab	0.71 a
CS + CC	52.1 b	65.9 b	7.5 b	6.6 b	1.24 a	0.53 b
CS + P	51.7 b	64.1 b	7.4 b	8.6 a	1.03 d	0.75 a
CC + P	58.7 a	57.1 c	8.7 a	7.2 b	1.05 cd	0.51 b
CS + CC + P	58.4 a	72.4 a	7.5 b	7.2 b	1.03 d	0.33 d
Significance	**	**	**	*	**	**

*,** = Significant at P≤0.05 or P≤0.01, respectively; CS = (Soil + silt + leaf manure, 1:1:1, v/v/v).

Table 6: pH, electrical conductivity (EC), water holding capacity (WHC), organic matter (OM), total nitrogen (N), available phosphorus (P) and available potassium (K) of various growing substrates

Growing substrates	pH	EC (mS cm^{-1})	WHC (%)	OM (%)	N (%)	P (ppm)	K (ppm)
CS	7.3 a	0.98 cd	42.0 c	0.57 g	0.19 g	52.1 d	203.3 f
Coco coir	7.0 ab	0.76 e	75.7 a	0.96 c	0.52 d	81.5 c	370.0 e
Peat (P)	6.4 bc	1.05 c	70.0 a	1.36 a	0.7 a	96.5 ab	1550.0 a
CS + coco coir	6.6 abc	0.92 d	58.7 b	0.85 d	0.39 e	58.8 d	650.0 d
CS + P	6.9 ab	1.06 c	44.3 c	1.07 b	0.55 c	83.8 bc	1350.0 b
Coco coir + P	6.9 ab	1.17 b	60.0 b	0.75 e	0.63 b	98.3 a	255.0 f
CS + coco coir + P	5.9 c	1.83 a	57.3 b	0.66 f	0.26 f	57.5 d	950.0 c
Significance	*	**	**	**	**	**	**

*,** = Significant at P≤0.05 or P≤0.01, respectively; CS = (Soil + silt + leaf manure, 1:1:1, v/v/v); ppm=parts per million

properties of CC medium can be improved by using CS and CC in 1:1 ratio, as concluded earlier by Awang et al. (2009). Supplementation of CC with other substrates such **as** CS enhance**d** the air-filled porosity of the substrate (Awang et al., 2009) that increased growth and flowering of stock and zinnia in CS+CC than CC alone. CC increased water holding capacity, organic matter of the growing medium and also supplied NPK at higher rate (Abad et al., 2002; Chavez et al., 2008; Ahmad et al., 2012) compared to CS, but slightly less than peat and CS+P and therefore can substitute peat in Pakistan.

Conclusions

Results revealed positive effect of coco coir and peat for improvement of growth, yield and quality of both tested species, but had no effect on postharvest longevity. Peat alone and in combination with coco coir produced the best results regarding most of vegetative and reproductive parameters and proved better than conventional substrate used in Pakistan. Moreover, CC+CS also proved better (2^{nd} to peat + CC) than CS alone. Therefore, growers can use CC+CS as a cheaper substitute to peat or can combine peat with coco coir for commercial production of cut stock and zinnia and to get taller, sturdy stems to get higher returns at substantially lower cost of production.

Author's contributions

All authors have equally contributed in the manuscript.

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