Research Article

Indigenous Soilless Substrate Compositions Affect Growth, Yield and Quality of Cut *Antirrhinum majus*

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Abstract | A study was conducted to develop indigenous soilless substrate compositions for improved growth, flower yield, stem quality and vase life of cut antirrhinum. Two experiments comprised of seven substrate compositions with variable ratios of saw dust (SD), peanut hulls (PH) and sugarcane pressmud (a by-product of sugar industry, which is rich in nutrients) or coco-coir (CC), rice hulls (RH) and sugarcane pressmud (PM) were used. Seeds were sown in plastic plug trays containing CC, silt (soil extracted from canal) and PM (1:1:1; v/v/v) substrate for seedling development and transplanted at the two to four leaf stage into lily crates with the treatment substrates. Plants grown in substrates containing SD + PH + PM (experiment I) indicated that plants grown in these soilless compositions died before flowering, while those grown in silt (control) performed best. While in experiment II, the highest quality plants were grown in 50% CC + 40% RH +10% PM. Quality was defined as plants with shortest production time (days), tallest plant height (cm), optimal leaf chlorophyll content (SPAD), highest leaf area (cm^2), fresh and dry weight (g), longest vase life (days). Substrates containing CC, RH and PM (50% + 40% + 10%; v/v/v) were superior to substrates of SD, PH and PM. For commercial cut antirrhinum production, substrates with locally available components of CC, RH and RM can be recommended.

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Introduction

Snapdragon (*Antirrhinum majus* L. Opus Pink.), a member of family Plantaginaceae, is a cut flower of the Mediterranean region. The unique flower shape with hinged florets differentiates the snapdragon from other cut flowers. Today, more than 20,000 cultivars are grown as commercial cut flowers worldwide. Snapdragon is classified into response groups based on growth and flowering habits in relation to environmental conditions (Ball, 1991).

Cut flower production is a major constituent of floriculture industry, which accounts for a massive share in floriculture business (Kendirli and Cakmak, 2007). An increasing demand of cut flowers has been observed in recent years but the lack of proper substrate components for production is a problem for successful cultivation. Inadequate soil conditions and water management result in poor plant quality and short post-harvest life (Starkey, 1998). To ensure good flower quality, maximum root development, early flower production and high yields of cut flowers, soilless substrates are used because of their low bulk

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density and higher porosity than field soil.

Compared to soil, soilless growing substrates are easier to handle and may provide a better growing environment. Many organic and in-organic materials are used as growing substrates and there is a continuing interest in the use of various agricultural by-products as organic nutrient sources for plants on account of their availability at lower cost and slow release nutritional constituents. The use of these materials also provide environmental benefits as reduction in ecosystem damage caused by soil or peat extraction and minimized impact of residue accumulation.

Many studies suggest cultivating in soilless substrates using organic waste products such as peanut hulls, sugarcane pressmud, rice hulls, coconut coir, saw dust or other composted organic products (Fred et al., 1997). These reusable components are often inexpensive and act as good alternatives because of their granular structure, chemical stability, mechanical strength, nutrient content, proper aeration, water holding capacity and water insolubility, which result in reduced fertilizer and irrigation rates as well as nursery costs, while supporting plant growth (Grigatti et al., 2007; Awang, 2009; Maharani et al., 2010; Tariq et al., 2012).

Keeping in mind the socio economic value of cut flowers and emerging needs to regulate the technology for commercial antirrhinum production and establishing maximum plant growth and flowering, this study was conducted with the objective to standardize soilless substrates for cut antirrhinum production by incorporating readily available agricultural by-products. A better understanding regarding the effectiveness of various growing substrates to improve growth, yield, manipulating soil characteristics and nutrient uptake would help to recommend a substrate to the industry for quality cut flower production.

Materials and Methods

The experiments were conducted at Floriculture Research Area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan, having geographical position at Latitude 31^0- 44^0 North, Longitude 73^0- 06^0 East and Altitude 184.4 m, during 2018-19, to evaluate the performance of various soilless substrates for cut *Antirrhinum majus* production.

Plant material

The seeds of snapdragon (*Antirrhinum majus* L. cv. 'Opus Pink') were purchased from local representative of Syngenta Goldsmith seeds, USA, and were sown during 3rd week of October, 2018, in 128-cell plastic plug trays with substrate mixture of coco coir, sugarcane pressmud and silt (1:1:1; v/v/v) for nursery raising. At 2-4 true leaf stage, seedlings were transplanted during 2nd week of December, 2018, in lilium plastic crates of 45 × 60 cm size at 7.5-10 cm depth and placed outdoors.

Substrate compositions

Two experiments were performed each having seven treatments. Different locally available and cheaper agricultural wastes, viz. coco coir, saw dust, rice hulls, peanut hulls and sugarcane pressmud were selected based on some preliminary studies and compared in various ratios. Experiment I consisted of soilless substrate components, using saw dust (SD), peanut hulls (PH) and sugarcane pressmud (PM), with combinations, SD50%: PH40%: PM10%; SD40%: PH50%: PM10%; SD30%: PH60%: PM10%; SD50%: PH30%: PM20%; SD40%: PH40%: PM20% and SD30%: PH50%: PM20%, respectively. Similar to experiment I, treatments in exp. II included soilless substrate components, using coco coir (CC), rice hulls (RH) and sugarcane pressmud (PM), with compositions mixtures, CC50%: RH40%: PM10%; CC40%: RH50%: PM10%; CC30%: RH60%: PM10%; CC50%: RH30%: PM20%; CC40%: RH40%: PM20% and CC30%: RH50%: PM20%. Silt (100%) was used as the control in both experiments. Different components were grouped together in each experiment to have all three basic components of a substrate to ensure water holding capacity, porosity and nutrient availability.

Fertilizer application

The plastic crates were thoroughly filled with the substrates according to the treatments and seedlings were transplanted with 12 seedlings in each crate. A basic application of N, P and K in the form of urea (46% N), single super phosphate (18% P_2O_5) and sulphate of potash (50% K_2O) was done @ 3-5 g per crate in all treatments, while additional fertilizer applications were made along with irrigations when required. Experiment was laid out according to completely randomized design (CRD) with three replications and all cultural practices such as weeding, hoeing, irrigation and fertilization were similar in all treatments of both experiments during the entire period.

Data collection

Data were collected on growth and flowering indices using standard procedures at harvest, when 2-3 lower florets were fully open. Plant height was measured at harvest from substrate surface to the tip of plant.

Growth parameters

The production time of the flowering stems were noticed from transplanting to the time of harvest. Three healthy and mature leaves were selected from each replication within a treatment to determine the leaf area and the leaf total chlorophyll contents. Eight plants were harvested from each replication to record the number of florets, number of leaves, floret diameter (mm) and stem diameter (mm). Both floret and stem diameter (mm) were measured with the Johnson digital caliper. Stems were weighed after harvest to measure fresh weight and after drying, at 70°C for 72 h, for dry weight (g).

Flower quality

The flower quality was estimated according to the method described by Cooper and Spokas (1991), based on a scale of 1 to 9, where 9 was high, 5 average and 1 poor quality flower stems. Vase life was measured by counting the number of days from placement of stems in distilled water in the postharvest laboratory, maintained at 22 ± 2° C temperature and 50-70% RH with 12h of daily light to the time of the 50% necrosis/wilting of flowering stems (Ahmad et al., 2011). The substrate NPK content was determined by the method described by Chapman and Parker (1961). While the physical parameters such as bulk density (BD), porosity (PO %) and water holding capacity (WHC %) of the substrate compositions were determined according to the methods described in the ICARDA (International Centre for Agriculture Research in the Dry Areas) manual.

Statistical analysis

Data were analyzed using analysis of variance (ANOVA) by the Fisher's technique and treatment means were compared using Least Significant Difference test at 5% level of probability (Steel et al., 1997).

Results and Discussion

Influence of substrate compositions on growth and flowering indices

Antirrhinum plants grown in SD + PH + PM compositions did not grow as well as plants in silt (100%) (Table 1). Snapdragons grown in silt had a production time (PT) of 109 d, plant height (PTH) (68 cm), number of leaves per stem (NOL) (198), number of florets (NOF) (26), leaf area (LA) (15 cm^2), leaf total chlorophyll content (LCC) (65 SPAD), floret diameter (FD) (68 mm), stem diameter (SD) (8 mm), fresh weight (FW) (26 g), dry weight (DW) (11 g), highest floret quality (FQ) (7) and longest vase life (VL) (6 days) (Table 2). For physico-chemical characteristics of the substrate containing SD + PH + PM, samples had 5.2-6.4 pH, 0.01-0.30 dS m^{-1} EC, 0.12-0.18 g cm^{-3} bulk density (BD), 78-90% porosity (POR) with 12-20% water holding capacity (WHC).

Experiment I

Among other treatments, substrate compositions consisting SD + PH + PM (50%:40%:10%) followed by SD + PH + PM (50%:30%:20%) resulted in comparatively better results than other treatments within experiment regarding vegetative and flowering characteristics along with their physico-chemical attributes. While in substrate compositions having SD + PH + PM (40%:50%:10%), SD + PH + PM (30%:60%:10%), SD + PH + PM (40%: 40%: 20%) and SD + PH + PM (30%:50%:20%), all plants were wilted and later declined due to too low pH and electrical conductivity (Table 5), leading to plant death before flowering.

Experiment II

While the results recorded in experiment II were found best when plants were grown in substrates consisting of 50% CC + 40% RH + 10% PM followed by 30% CC: 50% RH: 20% PM with maximum PTH (76 cm and 78 cm, respectively) (Table 3).

Growth attributes

Greater number of florets (NOF) (30) along with highest leaf area (LA) (19 cm^2) and leaf chlorophyll content (LCC) (67 SPAD) were recorded in plants grown with CC (50%) + RH (40%) + PM (10%), while highest number of leaves (NOL) (221) were observed when plants were grown with CC (30%) + RH (50%) + PM (20%) (Table 3). Similarly, maximum stem diameter (SD) (13 mm), fresh (FW) (34 g) and

Table 1: *Effect of various compositions of sawdust, peanut hulls and sugarcane pressmud on production time (PT), plant height (PTH), number of leaves per stem (NOL), number of florets per stem (NOF), leaf area (LA) and leaf total chlorophyll contents (LCC) (SPAD) of Antirrhinum majus* L.

Treatments	PT (d)	PHT (cm)	NOL	NOF	LA (cm²)	LCC (SPAD)
Control (Silt 100%)	109.0 c[z]	68.0 a	198.1 a	26 a	15.04 a	65.4 a
SD (50%) + PH (40%) + PM (10%)	114.0 b	35.0 b	88 b	10 b	11.10 b	60.2 b
SD (40%) + PH (50%) + PM (10%)	_[y]	_[y]	_[y]	_[y]	_[y]	_[y]
SD (30%) + PH (60%) + PM (10%)	_	_	_	_	_	_
SD (50%) + PH (30%) + PM (20%)	131.0 a	33.2 b	64.0 c	8.4 b	9.20 b	44.1 c
SD (40%) + PH (40%) + PM (20%)	_	_	_	_	_	_
SD (30%) + PH (50%) + PM (20%)	_	_	_	_	_	_
Significance[x]	<0.005	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[z]Means separation within columns by Fisher's LSD at P ≤ 0.05; [y]: All plants dead before flowering; [x]P values were obtained using General Linear Models (GLM) procedures of Statistix (version 8.1; Analytical Softwares). SD: Sawdust, PH: Peanut hulls, PM: Sugarcane pressmud.

Table 2: *Effect of various compositions of sawdust, peanut hulls and sugarcane pressmud on flower diameter (FD), stem diameter (SD), fresh weight (FW), dry weight (DW), flower quality (FQ) and vase life (VL) of Antirrhinum majus* L.

Treatments	FD (mm)	SD (mm)	FW (g)	DW (g)	FQ	VL (days)
Control (Silt 100%)	68.0 a[z]	8.0 a	26.0 a	11.0 a	7.4 a	6.0 a
SD (50%) + PH (40%) + PM (10%)	55.2 b	7.0 a	9.3 b	4.1 b	6.2 b	5.0 b
SD (40%) + PH (50%) + PM (10%)	_[y]	_[y]	_[y]	_[y]	_[y]	_[y]
SD (30%) + PH (60%) + PM (10%)	_	_	_	_	_	_
SD (50%) + PH (30%) + PM (20%)	45.1 c	5.0 b	6.3 c	2.3 c	5.0 c	4.0 c
SD (40%) + PH (40%) + PM (20%)	_	_	_	_	_	_
SD (30%) + PH (50%) + PM (20%)	_	_	_	_	_	_
Significance[x]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0072

[z]Means separation within columns by Fisher's LSD at P ≤ 0.05; [y]: All plants dead before flowering; [x]P values were obtained using General Linear Models (GLM) procedures of Statistix (version 8.1; Analytical Softwares). SD: Sawdust, PH: Peanut hulls, PM: Sugarcane pressmud.

Table 3: *Effect of compositions of coco coir, rice hulls and sugarcane pressmud on production time (PT), plant height (PTH), number of leaves per stem (NOL), number of florets per stem (NOF), leaf area (LA) and Leaf total chlorophyll contents (LCC) (SPAD) of Antirrhinum majus* L.

Treatments	PT (d)	PHT (cm)	NOL	NOF	LA (cm²)	LCC (SPAD)
Control (Silt 100%)	103 d[z]	66.1 d	149.0 d	25.1 c	12.2 d	64.0 b
CC (50%) + RH (40%) + PM (10%)	107 bc	76.4 b	168.4 c	30.0 a	19.0 a	67.4 a
CC (40%) + RH (50%) + PM (10%)	107 bc	66.0 d	204.0 b	27.4 b	14.3 c	60.0 cd
CC (30%) + RH (60%) + PM (10%)	106 c	57.0 f	119.0 e	19.0 e	10.2 e	57.3 e
CC (50%) + RH (30%) + PM (20%)	121 a	64.0 e	150.4 d	21.1 d	13.1 cd	58.1 de
CC (40%) + RH (40%) + PM (20%)	109 b	72.0 c	107.0 f	25.0 c	17.0 b	57.0 e
CC (30%) + RH (50%) + PM (20%)	108 b	78.3 a	221.0 a	28.0 b	19.0 a	60.1 c
Significance[y]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[z]Means separation within columns by Fisher's LSD at P ≤ 0.05; [y]P values were obtained using Statistix (version 8.1; Analytical Softwares) for optimizing various soilless substrates; CC: Coconut coir dust; RH: Rice hulls; PM: Sugarcane pressmud

dry (DW) (16 g) weight of stems and flower quality (7) was recorded for plants grown in substrate consisting of CC (50%) + RH (40%) + PM (10%), along with longest vase life (VL) of 9 days (Table 4).

Table 4: *Effect of various compositions of coco coir, rice hulls and sugarcane pressmud on floret diameter (FD), stem diameter (SD), fresh weight (FW), dry weight (DW), flower quality (FQ) and vase life (VL) of Antirrhinum majus* L.

Treatments	FD (mm)	SD (mm)	FW (g)	DW (g)	FQ	VL (days)
Control (Silt 100%)	64.1 a[z]	8.1 b	15.1 e	5.1 e	7.4 a	5.0 c
CC (50%) + RH (40%) + PM (10%)	54.1 c	13.0 a	34.0 a	16.0 a	7.0 ab	9.0 a
CC (40%) + RH (50%) + PM (10%)	64.0 a	7.0 bcd	24.0 c	11.1 b	6.4 b	5.2 c
CC (30%) + RH (60%) + PM (10%)	45.1 e	6.0 d	18.0 d	7.1 cd	4.0 c	5.0 c
CC (50%) + RH (30%) + PM (20%)	51.0 d	6 .0 cd	12.0 f	5.3 de	6.0 b	6.0 bc
CC (40%) + RH (40%) + PM (20%)	58.0 b	8.2 b	18.0 d	8.0 c	7.0 ab	6.2 b
CC (30%) + RH (50%) + PM (20%)	64.0 a	7.3 bc	25.4 b	13.0 b	7.1 ab	5.1 c
Significance[y]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[z]Means separation within columns by Fisher's LSD at P ≤ 0.05; [y]P values were obtained using Statistix (version 8.1; Analytical Softwares) for optimizing various soilless substrates; CC: Coconut coir dust; RH: Rice hulls; PM: Sugarcane pressmud.

Table 5: *Physio-chemical analysis of saw dust, peanut hulls and sugarcane pressmud for pH, EC (dS/m), bulk density (BD) (g cm^{-3}), porosity (POR%), water holding capacity (WHC%), nitrogen content (N%), phosphorous content (P%) and potassium content (K%).*

Treatments	pH	EC	BD	POR	WHC	N (%)	P (%)	K (%)
Control (Silt 100%)	7.0 a[z]	0.08 bc	0.50 a	48 d	51 a	1.1 d	0.1 c	0.02 cd
SD (50%) + PH (40%) + PM (10%)	6.1 b	0.30 a	0.18 b	90 a	18 bc	3.0 a	0.4 b	0.05 a
SD (40%) + PH (50%) + PM (10%)	5.2 c	0.10 b	0.12 d	85 b	12 d	1.2 cd	0.3 bc	0.01 d
SD (30%) + PH (60%) + PM (10%)	6.0 b	0.06 c	0.15 c	80 c	20 b	1.4 c	0.3 bc	0.04 b
SD (50%) + PH (30%) + PM (20%)	6.0 b	0.09 b	0.17 b	87 ab	17 bc	2.1 b	0.6 a	0.05 a
SD (40%) + PH (40%) + PM (20%)	6.0 b	0.01 d	0.14 c	84 b	14 c	1.2 cd	0.4 b	0.03 c
SD (30%) + PH (50%) + PM (20%)	5.4 c	0.06 c	0.15 c	78 c	15 c	1.5 c	0.2 c	0.03 c
Significance[y]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.005	<0.005	<0.005

[z]Means separation within columns by Fisher's LSD at P ≤ 0.05; [y]P values were obtained using General Linear Models (GLM) procedures of Statistix (version 8.1; Analytical Softwares) for soilless substrate components; SD: Sawdust; PH: Peanut hulls; PM: Sugarcane pressmud.

Table 6: *Physio-chemical analysis of coco coir, rice hulls and sugarcane pressmud for pH, EC (dS m^{-1}), bulk density (BD) (g cm^{-3}), porosity (POR%), water holding capacity (WHC%), nitrogen content (N%), phosphorous content (P%) and potassium content (K%).*

Treatments	pH	EC	BD	POR	WHC	N (%)	P (%)	K (%)
Control (Silt 100%)	7.0 a[z]	0.62 a	0.5 a	48 e	53 a	1.1 c	0.1 d	0.01 d
CC (50%) + RH (40%) + PM (10%)	6.1 ab	0.05 ab	0.11 e	90 b	11 c	1.8 a	0.4 a	0.04 a
CC (40%) + RH (50%) + PM (10%)	5.2 e	0.04 e	0.07 g	93 a	8 d	1.4 b	0.2 c	0.03 b
CC (30%) + RH (60%) + PM (10%)	5.5 cd	0.09 cd	0.11 f	89 b	14 b	1.0 cd	0.3 b	0.02 c
CC (50%) + RH (30%) + PM (20%)	6.0 ab	0.06 ab	0.14 c	85 c	14 b	1.3 bc	0.4 a	0.04 a
CC (40%) + RH (40%) + PM (20%)	5.6 c	0.04 c	0.13 d	82 d	13 bc	1.5 ab	0.2 c	0.03 b
CC (30%) + RH (50%) + PM (20%)	5.3 de	0.05 de	0.15 b	88 bc	15 b	1.7 a	0.4 a	0.04 a
Significance[y]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.005	<0.005	<0.005

[z]Means separation within columns by Fisher's LSD at P ≤ 0.05; [y]P values were obtained using General Linear Models (GLM) procedures of Statistix (version 8.1; Analytical Softwares) for soilless substrate components; CC: coco coir; RH: rice hulls; PM: Sugarcane pressmud.

Physico-chemical analysis

The pH and EC for different ratios of CC, RH and PM ranged between 5.2-6.1 and 0.04-0.09 dS m^{-1} and were within optimal range along with 0.07-0.15 g cm^{-3} bulk density, 82-93% porosity, and 8-15% WHC, respectively (Table 6).

Substrate NPK analysis

Substrate nitrogen and potassium were highest (3.0% and 0.05%) when plants were grown in SD (50%) + PH (40%) + PM (10%), while phosphorous contents were highest (0.6%) when plants were grown in SD (50%) + PH (30%) + PM (20%) (Table 5). The lowest nitrogen and phosphorous contents were recorded in silt (100%) with 1.1% and 0.1%, respectively, while lowest potassium content (0.01%) was recorded in substrate containing 40% SD + 50% PH + 10% PM, which lead to no flowering.

While in exp. II, nitrogen, phosphorous and potassium contents were highest in substrate containing CC (50%) + RH (40%) + PM (10%) with 1.8% nitrogen, 0.4% phosphorous and 0.04% potassium (Table 6).

Lowest nitrogen, phosphorous and potassium contents were recorded in silt (100%) with 1.1% nitrogen, 0.1% phosphorous and 0.01% potassium, hence giving poor quality flowers compared to various soilless substrate compositions.

All growing substrates used in both experiments revealed comparative results for the growth and flowering of cut antirrhinum. All vegetative attributes of the plant (plant height, stem diameter, leaf area, leaf total chlorophyll content, number of leaves per stem, stem fresh and dry weight) and floral characteristics (production time, floret diameter, number of florets per stem, flower quality and vase life) performed best in experiment II in substrates containing CC + RH + PM with 50% CC: 40% RH: 10% PM and 30% CC: 50% RH: 20% PM.

Influence of saw dust and peanut hulls

Plants grown in silt (100%) produced early flower production but with shorter vase life (5 days), while those grown in substrate containing SD, PH and PM declined due to low pH and electrical conductivity, leading to plant death before flowering. Sawdust and peanut hulls did not prove suitable as substrate component for cut antirrhinum production. These observations were in line with the findings of Riaz et al. (2015), who reported maximum plant height in *Gerbera jamesonii* cv. Hybrid Mix in the substrate composition of silt + coco coir dust.

Influence of coco coir and rice hulls

When plants were grown in substrate containing 50% coco coir along with other substrate compositions less than or equal to 50%, led to more vegetative growth and flowering (Tariq et al., 2012). Qasim et al. (2003) also found highest fresh and dry weight along with maximum number of leaves per stem of *Jasminum sambac* in growing substrate having coco coir. Rice hulls in ratios of 50% or 40% also proved to be good sources of nitrogen and phosphorous content as well as water holding capacity compared to silt, producing healthy plants with maximum height, number of florets and flower diameter in *Celosia cristata* (Awang et al., 2009).

Highest increase in leaf area was also observed in substrate composition of 50% coco coir, 40% rice hulls and 10% sugarcane pressmud compared to silt grown plants. Use of pressmud is better option to provide nutrients in the substrate for overall plant growth. These results were in line with Khayyat at al. (2007), who found maximum increase in leaf area of *Epipremnum aureum* when grown in rice hulls and coco coir. These substrates have lowest pH, EC, bulk density, water holding capacity and high porosity with respect to the plants grown in silt. These results are in line with the findings of Nash and Hegwood (1990), who reported that 50% rice hulls in the substrate elevates plant growth.

Conclusions and Recommendations

Use of coco coir and rice hulls along with sugarcane pressmud proved optimal for growth and flowering of cut antirrhinum compared to combinations of saw dust, peanut hulls and sugarcane pressmud. Therefore, growers may use coco coir, rice hulls and sugarcane pressmud as a cheaper and more readily available soilless substrate for cut antirrhinum production.

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Novelty Statement

This study is novel showing soilless substrate compositions of rice hulls, coco coir along with sugarcane pressmud to be an effective local and economic substrate alternative for high quality cut antirrhinum production.

Author's Contribution

Aqsa Ahmad conducted the trials by data collection and analysis for consecutive two years. Iftikhar Ahmad helped in designing the experiment and making arrangements for provision of inputs during research work, data analysis and contributed during write up and review of the manuscript. Malik F.H. Firdosi helped in NPK analysis and reviewed the paper. All authors read and approved the final manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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