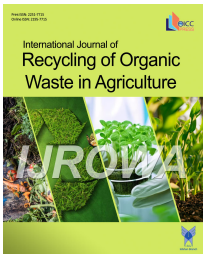

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Impact of potential biodegradable substrates on aromatic/ornamental plant growth and development

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Original Research

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Abstract:

Purpose: Soil mixtures play a key role in soil fertility and productivity. Keeping in view the importance of soil mixtures, our study aimed to find suitable, eco-friendly, and cost-effective soil substrates for better growth of aromatic plants.

Methods: Physico-chemical properties of substrates- banana peel (BP), groundnut shell (GS), coconut coir (CC) and rice husk (RH) were determined, further these substrates were mixed with soil to check their effect on growth and development of aromatic plants. GS was used in combination with other substrates to study its effect by observing various growth parameters and triplicate data was analyzed by two-way ANOVA.

Results: Nutrients estimation in selected substrates showed high potassium in GS, CC and RH while magnesium was high in BP. BP, GS, and CC have acidic pH while RH has neutral pH. CC showed higher moisture content and water holding capacity. A significant increase in rose height (37.33 ± 1.52 cm) and flowering (9 ± 1) was observed when supplemented with burned rice husk (BRH) and BP respectively. Similarly, daisy plant height and flowering were increased when supplemented with the GS. The elaborate study in marigold plants showed significant increase in height (38.2 ± 0.09 cm), leaf width (1 ± 0.1 cm) and leaf length (6 ± 0.09 cm) using GS + BRH while flowering (18 ± 1) was enhanced when supplemented with GS + BP.

Conclusion: The information emanating from this study may be valuable in selecting the appropriate soil mixtures from organic waste for sustainable plant growth.

Keywords: Aromatic; Substrate mixtures; Growth parameters; Nutrients; Ecofriendly; Agricultural waste

1. Introduction

Aromatic plants are known for their aroma, flavor, culinary component of cosmetics, medicine (therapeutics), health food etc. Various examples of aromatic plants are rose, marigold, jasmine, garlic, oregano, thyme etc. have a wide range of applications. Rose (*Rosa hybrid* Linn.) is a woody perennial flowering plant belonging to the Rosaceae family with application in the perfume industry, rose water (therapeutics), and food industries. Rose accounts for approximately 60% trade throughout the globe and in India (Maharashtra, Karnataka, Tamil Nadu, Rajasthan, Uttar Pradesh and West Bengal) around 1 Lakh hectare (ha) of land is under cultivation (Singh et al., 2022). Marigold (*Tagetes erecta*) belongs to the Asteraceae family with application in the food industry (food colours), nutritional supplement, cosmetics (as marigold cream, toner) and others. Approximately 342000 ha of land is under cultivation and cut flowers produced annually is 769000 metric tons ($2017-18$ advanced estimates). In India major states of marigold cultivation are Karnataka Tamil Nadu, West Bengal, Andhra Pradesh and Maharashtra (Malik et al., 2021). Crown daisy (*Chrysanthemum coronarium*) is herbaceous ornamental plant belonging to the Asteraceae family with application in garlands, food industry, vermifuge and therapeutics. In India, Maharashtra is one of the leading producers of crown daisy (Kedar et al., 2022). Growing media (substrate) is vital for plant growth and development as these plant media helps in maintaining balance between physical properties (density, porosity, moisture content, water holding capacity) and chemical properties (pH, electrical conductivity and nutrient contents). These physical and chemical properties

of substrates are responsible for providing adequate support, reservoirs for plant water, and nutrients. Also, the potential impacts of these substrates can lead to enlargement of flower size, may enhance translocation of nutrients from leaves to growing areas thereby enhancing floral morphogenesis. Since various formulations of alternative growing media for bedding, potting has already been effectively utilized across the globe as container substrate. Identification of suitable, effective, cheap, and natural substrates has potential to reduce the usage of commercial fertilizer (Yoon et al., 2007). Some of the selected aromatic plants were supplemented with various combination treatments of these substrates to study growth parameters like plant height, plant flowering, leaf length and width to identify most potential substrates for aromatic plants since combination treatments provide more specificity towards the findings. Generally, substrates for aromatic plants are applied according to combination strategy such as combination of peat, vermicompost and organic fertilizers. Also, peat produced globally is 28 metric tons approximately and it is non-renewable, has low rewetting capacity hence, identifying alternatives from waste is one of the best ways to overcome the problem of agricultural waste (Konduru et al., 1999; Michel, 2010).

Rice husk is a coating of rice (substrate), and its main components are silica and lignin (irresistible by humans so removed). It acts as compost (organic fertilizer) when added to soil thereby making the drainage system better and makes soil acidic which leads to growth of bud, the flowering of rose plants is enhanced. Burned rice husk is cheap and the most common substrate is made from incomplete/partial burning of rice husk thus, acts as good soil fertilizer and great soil conditioner which contain all macronutrients (N, P, K, Ca, and Mg) and micronutrients (Fe, Zn, Mn) (Carrijo et al., 2002; Handreck, 1993). Coconut fiber, made up of husk and short fiber from meso-carp of *Coco nucifera* is another common waste product of the coconut industry. It is the best alternative to peat, and it is used in combination with vermiculite, rock-wool and other substrates (Nichols, 2007; Gruda, 2012). Coconut fiber/coir is specifically designed substrate for garden roses, miniature shrub rose, climbing roses, hybrid tea roses wherein 10% coconut fiber is added Coconut fiber as substrate reduces the need for watering due to higher pH and lower cation exchange capacity and contains good amount of phosphorous and potassium which supports plant growth (Hernández et al., 2009; Ragel et al., 2019). Groundnut shell powder is the residual left containing calcium, phosphate, potassium, magnesium, zinc, small fat, protein, and trace elements so plant height, flowering and other growth parameters are favored. Groundnut shell is also utilized as growth media (substrate) as alternative to peat for the growth of ornamental plants and acts as antifungal agent (Adhikari et al., 2018). It has been reported that 75% of groundnut shell hulls show maximum growth in marigold plants as compared to 25% and 50% groundnut shell. Also, groundnut shell is a better substrate since it contains 44.46% air porosity, 34.87% water holding capacity (Verdonck and Gabriel, 1992; Torkashvand et al., 2015). Hence, it is better to reduce the usage of peat and enhance utilization of ground nut shells. Fruit peel (banana, orange, lemon, and pomegranate) is utilized as a substrate for plants since its effective growth parameter. Alkaline peels are utilized to minimize the amount of acid content present in soil (Mercy et al., 2014). Banana peel contains P, Mg and K (Gold element) which strengthens stem, protects from disease, and enhances bud development so added in dosage that does not harm the plant for healthy blossom and growth (Tewari et al., 1986). Analyzing the pH of fruit peels helps in quantifying the amount of powder required for that soil (Harivaindaran et al., 2009). Banana peel powder is used as substrate/nutrition specifically for rose plants since it requires more nutrients for flower development as compared to other plants.

Agricultural waste accumulation is underutilized despite their immense benefit as usage of biodegradable substrate which could replace them with chemical fertilizers. Demand for organic waste supplements is increasing with various health benefits and increase in plant productivity. Thus, the present study focuses on utilization of suitable substrates obtained from agricultural waste for enhancing the growth and development of aromatic/ornamental plants (Rose, Marigold and Crown Daisy) for efficient waste management. The hypothesis of this study is that substrates provide a variety of macro and micro minerals thus enriching soil health when used in appropriate amounts.

Here, the first objective is to analyze the physico-chemical properties of various substrates. The second objective is to select the better substrate for different aromatic/ornamental plants. Lastly, to identify the appropriate substrate combinations which can be recommended for the selected plants. Thus, utilizing agricultural waste for beneficial purposes is one of the best ways to overcome the problem of managing agricultural waste.

2. Materials and methods

The samples of aromatic/ornamental plants (Marigold cv. *Tagetes erecta* and Crown daisy cv. *Chrysanthemum coronarium*) were grown during the winter season of 2022 in growth chambers under controlled conditions and rose cuttings cv. *Rosa hybrid* Linn. were collected from Sunder Nursery in Kanjhawala, North-West Delhi, India at an elevation of 220 m above sea level.

Different substrates such as banana peel, groundnut shell, coconut coir and rice husk were obtained from agricultural waste (Table 1). Banana peels and groundnut shell mixture was obtained by fine grinding of dried banana peels and groundnut shell respectively. Coconut coir was obtained from the Sunder nursery and rice husk was collected from the fields of Kanjhawala, Delhi located at 28.72674°N

Table 1. Sampling of various aromatic plants (Rose, Marigold and Crown daisy) supplemented with various substrates (GS, BRH, CC and BP).

Aromatic Plants			Substrates/Nutrition
Rose	Marigold	Crown daisy	
A	A	A	Groundnut Shell (GS)
B	B	B	Burned Rice Husk (BRH)
C	C	C	Coconut Coir (CC)
D	D	D	Banana Peel (BP)

Figure 1. Various substrate treatments prepared for the experiment.

77.00248°E. Both substrates were dried and grinded to obtain fine powder. Further all four substrates/mixtures were stored in sterile air-tight polythene bags until its utilization in the future (Fig. 1).

The physical properties of substrates were measured by using several parameters such as pH, moisture content and water holding capacity (Fig. 2 (a), 2 (b) and 2 (d)). For determining the pH of samples, 1 gm of samples were added to 10 mL of distilled water, after which, the suspension was mixed thoroughly for 10 min using a magnetic stirrer. After 10 min, the pH values of samples were determined using pH meter (METTLER TOLEDO FP20 FiveEasy) (Fig. 2 (a)). For determining the moisture content, 2.5 gm of the samples were dried in an oven (Memmert UFE500) at 100 °C for 24 h (Hisham and Ramli, 2019; Dom et al., 2021) (Fig. 2 (b)). Initial and final weights of the samples were measured, and moisture content were calculated based on the following formula:

$$\text{Moisture content (MC)} = \frac{m_i - m_f}{m_i} \times 100$$

Water holding capacity (WHC) was determined by applying the method with little modification from (Chau et al., 1997). 2 gm dried samples were added to the centrifuge tube containing 25 mL distilled water. Then, the mixture was vortexed (Remi CM 101) for 5 min. Resulting mixture was centrifuged (Remi R-8C Plus) for 25 min at 3000 rpm at room temperature followed by measuring the volume

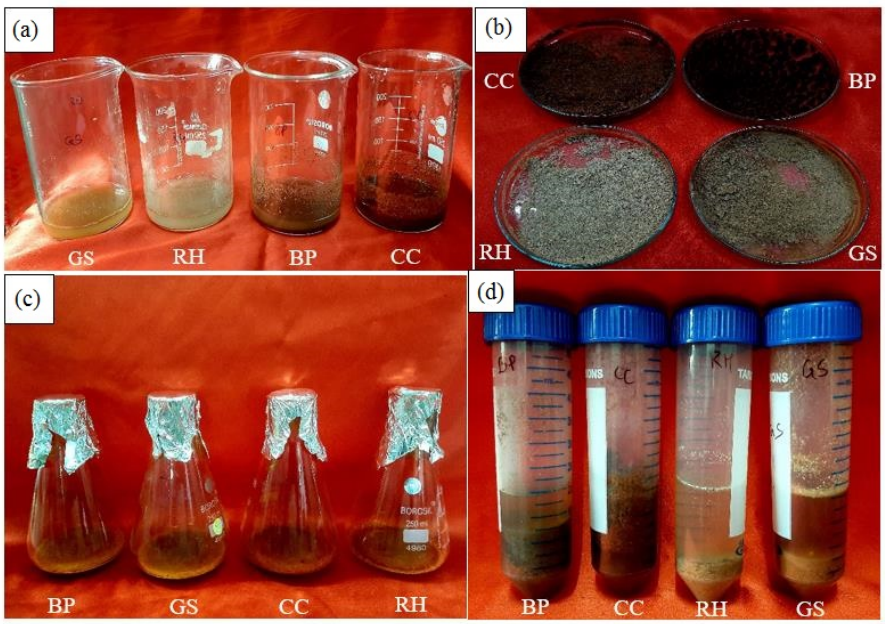

Figure 2. Determination of physico-chemical properties of various substrates
(GS: Groundnut Shell, BRH: Burned Rice Husk, CC: Coconut Coir and BP: Banana Peel).
(a) Substrates suspended in distilled water for pH measurements;
(b) Dried substates for moisture content analysis;
(c) Substrates predigested for mineral analysis using Atomic Absorption Spectrophotometer;
(d) Substrates used for water holding capacity analysis.

of the supernatant (Dom et al., 2021; Chau et al., 1997) (Fig. 2 (d)). WHC was calculated based on following two equations:

Gram of water held (g) = density of water (g/mL) × volume of supernatant (mL)

WHC (g/g) = gram of water held (g)/gram of sample used (g)

The chemical properties of the substrates were evaluated by determining the mineral contents. Minerals such as potassium (K), magnesium (Mg), zinc (Zn) and iron (Fe) were measured by Atomic Absorption Spectrophotometer (AAS) (AAS Model 3110, Perkin Elmer Corp., Norwalk, CT) according to method from (Singh et al., 2005) (Fig. 2 (c)). After determination of various physio-chemical properties, each substrate was supplemented to different plants after mixing with soil in the ratio of 3:1 whereas soil mixture without substrate was used as control. Further, one of the selected substrates i.e. groundnut shells was used in combination with other substrates in ratio of 1:1 and eventually mixed with soil in 3:1 ratio to study its effect on marigold plants. Saplings were treated with different substrate combinations made from groundnut shell (GS), burned rice husk (BRH), coconut coir (CC) and banana peel (BP). The different combinations were made as groundnut shell + rice husk (GS + RH), groundnut shell + coconut coir (GS + CC), groundnut shell + burned rice husk (GS + BRH), groundnut shell + banana peel (GS + BP) (Fig. 3). Plants were maintained in the growth chamber and were regularly-monitored for their overall growth. The effects of various substrates individually and in combination were analyzed by observing various growth parameters such as plant height, flowering, length and width of leaves at 10-, 20-, 30- and 40-days intervals.

Figure 3. Marigold saplings with different substrate combinations.

Data analysis

All the data were obtained in triplicates (n = 3). Each bar graph represents mean ± standard deviation (n = 3). Data were analyzed by performing Two-way ANOVA using GraphPad Prism 8.0. The statistical level of significance was set at 0.05.

3. Result and discussion

In the present study, selected physico-chemical properties such as pH, moisture content, water holding capacity and mineral content (Table 2) of various substrates (BP, GS, CC and RH) were evaluated as potential growing media for aromatic/ornamental plants.

One parameter i.e. pH indirectly/directly affects the plant growth and development since it indicates the nutrient availability of growing media. Variation in pH differed between various selected substrates of growing media (Table 2). Ideal substrate ranges between 5.2 – 6.3 (Abad et al., 1989). The optimum pH range of different plants is different for the optimum growth and development thus, in nutshell based on good availability of essential elements overall pH of the soilless media is around 6.0 (Awang et al., 2009). In line with this selected substrate such as banana peel, groundnut shell and coconut coir have acidic pH and are very close to the optimum range thus suggesting that these substrates can be utilized as alternative media to peat (Table 2). In present study the average pH for banana peel was 6.21 which lies within the optimum range (6.15 – 6.46) as observed by Dom et al. (2021) (Fig. 2 (a)). Thus, analyzing the pH of banana peels enables us to quantify the amount of powder required to maintain specific pH of soil to support growth of selected plant species (Harivaindaran et al., 2009). Another substrate i.e. ground nut shells showed an average pH of 6.4 suggesting its neutral nature (Table 2) which enables availability of the essential nutrients to plants that in turn leads to an increase in overall plant growth parameters (Adhikari et al., 2018). Coconut coir also showed an average pH of 6.35 which is close to the pH of groundnut shell. The average pH of coconut coir lies within the optimum range (5.2 – 6.9) as reported by Asiah et al. (2004). Unlike the acidic nature of

Table 2. Physico-chemical properties of various substrates.

Parameters	Banana Peel (BP)	Groundnut shell (GS)	Coconut coir (CC)	Rice Husk (RH)
pH	6.21 ± 0.03	6.43 ± 0.04	6.35 ± 0.03	7.13 ± 0.04
Moisture content (% w/w)	13.85 ± 0.29	11.38 ± 0.23	59.23 ± 1.24	8.05 ± 0.16
Water holding capacity (g water/g sample)	8.03 ± 0.04	4.35 ± 0.03	10.94 ± 0.04	3.44 ± 0.02
Mineral content (mg/100g)				
Potassium (K)	28.62 ± 0.01	705.11 ± 0.01	356 ± 1	1280.1 ± 0.1
Magnesium (Mg)	1708.66 ± 0.01	3.98 ± 0.01	1.06 ± 0.01	210.1 ± 0.09
Iron (Fe)	0.07 ± 0.01	6.96 ± 0.01	2.43 ± 0.01	2.18 ± 0.01
Zinc (Zn)	0.41 ± 0.01	3.2 ± 0.1	0.43 ± 0.01	0.62 ± 0.01

*Results are expressed as mean ± standard deviation; n = 3.

other substrates used in this study, rice husk showed neutral pH of 7.13 (Table 2) and this observation is in line with the previous finding of Thiyageshwari et al. (2018) whereby pH value of 7.1 was reported for rice husk. When rice husk as a substrate is added to soil; it makes the drainage system better and makes soil acidic which leads to the growth of flower buds (Michel, 2010).

The highest average moisture content of about $59.23 \pm 1.24\%$ was recorded for coconut coir and results obtained were similar as reported by Asiah et al. (2004). However, the lowest moisture content of $8.05 \pm 0.16\%$ was recorded in rice husk and this result is in corroboration with reports obtained by Thiyageshwari et al. (2018). The other two substrates such as banana peel and groundnut shell showed moisture content of $13.85 \pm 0.29\%$ and $11.38 \pm 0.23\%$ respectively (Fig. 2 (b)), (Table 2). The moisture content obtained for banana peel in our study is slightly higher than $9.1 - 9.3\%$ moisture content as reported by Syukriani et al. (2021) and Dom et al. (2021). This may be due to differences in the varieties of banana grown in different geographical regions which were used as source for collection of banana peel as a substrate. Whereas the moisture content in groundnut shell is like the one reported by Grandawa (2014).

Water Holding Capacity (WHC) is an ability of a sample to retain water i.e. freely available and is largely affected by size of the particle along with fibre present (Esposito et al., 2005). WHC is high in small particles thus, small particles retain more water as compared to large particles (Ross et al., 2012). The highest WHC of 10.94 ± 0.04 (g water/g sample) was recorded in coconut coir since it had the highest moisture content. High WHC could be associated with the high concentration of pectin and hemicellulose in fruits fibre (Castillo-Israel et al., 2015). From Table 2 it can be observed that the lower WHC of 3.44 ± 0.02 (g water/g sample) was recorded in rice husk and this result was in proximity as reported by Kuan et al. (2012). However, the WHC of groundnut shell and banana peel is 4.35 ± 0.03 (g water/g sample) and 8.03 ± 0.04 (g water/g sample) respectively (Fig. 2 (d)), (Table. 2). The WHC of groundnut shell obtained in our study showed less value as compared to the finding by Verdonck and Gabriel (1992) whereas WHC in banana peel showed slightly higher value in comparison to the WHC of $5.2 - 6.45$ (g water/g sample) as reported by Dom et al. (2021). This difference in WHC of banana peel and groundnut shell may be attributed to the varietal difference in plant species used as source for substrate collection. In nutshell, the highest WHC and moisture content observed in coconut coir could be due to low particle size and higher porosity.

The optimum balance of minerals is required for optimum growth and development of plants. Therefore, it is crucial to estimate the presence of various macro- and microminerals available in the substrates used in combination with soil to support plant growth. The estimation of macro-minerals (Potassium, K and Magnesium, Mg) and microminerals (Iron, Fe and Zinc, Zn) were analyzed in all four selected substrates by AAS. The highest magnesium content of 1708.66 mg/100g was present in banana peel whereas lowest was obtained in coconut coir with value of 1.06 mg/100g (Fig. 2 (c)), (Table 2). Study reported by Tewari et al. (1986) showed higher concentration of one of the gold elements i.e. magnesium in banana peel is in sync. with our finding which shows maximum Mg content in peel obtained from banana. Another selected macro-mineral i.e. Potassium was higher in rice husk with a value of 1280.1 mg/100g while lowest value of 28.62 mg/100g was observed in banana peel (Fig. 2 (c)). Other reports also suggested higher content of macronutrients such as K, Mg, N, P and Ca, and micronutrients (Fe, Mn, Zn) in rice husk (Michel, 2010). The estimation of micronutrient i.e. Fe showed the highest value in groundnut shell, 6.96 mg/100g whereas lowest value, 0.07 mg/100g was observed in banana peel (Fig. 2 (c)), (Table 2). Another selected micromineral, Zn, was highest in groundnut shell with a value of 3.2 mg/100g in contrary to the lowest value of 0.41 mg/100g obtained in banana peel. In coconut coir a considerable amount of potassium i.e. 356 mg/100g was observed after rice husk and groundnut shell respectively. The presence of potassium directly affects the turgor pressure and photosynthesis process which in turn favors various parameters of plant growth and development as reported by Ragel et al. (2019). The availability of other micronutrients such as Fe, Zn and Mg in coconut coir along with excellent moisture content and water holding capacity provides a good balance of available nutrients, in turn positively affecting plant growth and development.

Further after having a fair idea of physio-chemical properties of selected substrates, their effectiveness was observed in different aromatic/ornamental plants such rose, marigold and crown daisy.

In rose plants, among various substrates (Table 1) banana peel and burned rice husk showed significant increase in height at 10, 20, 30, 40 days (Fig. 4 (a)) and flowering were also more. However, flowering was only observed after 20 days, and it was more when soil was supplemented with banana peel followed by burned rice husk in comparison to groundnut shell powder and coconut coir which did not show any significant difference in flowering at 30 and 40 days when compared with control. While addition of groundnut shell powder and coconut coir showed no significant flowering for about 30 days, and around 40 days flowering is also observed (Fig. 4 (b)), (Table 3 (b)). In the present study maximum flowering was reported in Rose D when supplemented with banana peel powder followed by Rose B when supplemented with burned rice husk. The result obtained agrees with the previous finding which reported enhanced flowering with use of banana peel and rice husk (Michel, 2010; Harivaindaran et al., 2009). These substrates enhance accumulation of photo assimilate towards flower bud formation thus influencing flower morphogenesis (Michel, 2010). In nutshell, rose plant growth was found best when supplemented with substrates like banana peel powder and burned rice husk as compared to other substrates like coconut coir and groundnut shell powder.

Likewise in Daisy, soil mixture supplemented with groundnut shell powder showed maximum increase in height followed by burned rice husk (Table 3 (a)). Nutritional capacity

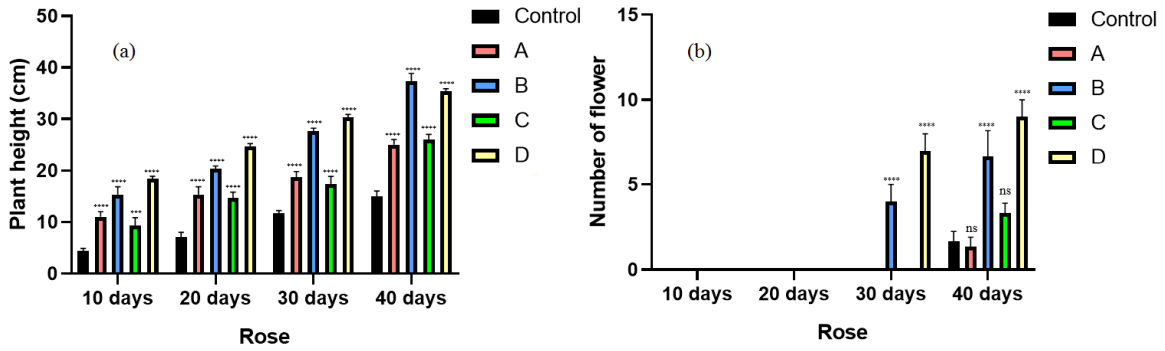

Figure 4. Effect of various substrate treatment; GS (A), BRH (B), CC (C), BP (D) in rose growth parameters (a) Plant height (b) Number of flowers. Each bar graph represents values in triplicates.
Results are expressed as mean ± standard deviation; n = 3. Significant differences were determined at $p < 0.05$ with two-way ANOVA using Turkey's HST analysis.

was found to be more suitable in groundnut shell powder when it was added to the daisy plant where drastic change was observed in plant height reaching to 50.23 ± 0.25 cm whereas plant height was only 35.46 ± 0.41 cm supplemented with burned rice husk. Flowering was also observed more when supplemented with groundnut shell powder at 40 days; however, no flowering was achieved at 30 days in treated and controlled daisy plants (Table 3 (b)).

Table 3. Impact of different substrate in rose, marigold and crown daisy (a) Plant height (b) Flowering.

Aromatic plants	Treatments	Height (cm) (10 days)	Height (cm) (20 days)	Height (cm) (30 days)	Height (cm) (40 days)
Rose	Control	4.33 ± 0.57	7 ± 1	11.66 ± 0.57	15 ± 1
	Rose A	11.1 ± 1	15.33 ± 1.52	18.66 ± 1.15	25 ± 1
	Rose B	15.33 ± 1.52	20.33 ± 0.57	27.66 ± 0.57	37.33 ± 1.52
	Rose C	9.33 ± 1.52	14.66 ± 1.15	17.33 ± 1.52	26 ± 1
	Rose D	18.33 ± 0.57	24.66 ± 0.57	30.33 ± 0.57	35.33 ± 0.57
Marigold	Control	2.76 ± 0.25	5.2 ± 1.05	9.26 ± 1.1	15.13 ± 1.02
	Marigold A	5.43 ± 0.4	8.66 ± 0.61	15.36 ± 0.35	37.26 ± 0.25
	Marigold B	5.8 ± 0.3	8.8 ± 0.39	20.3 ± 0.3	39.53 ± 0.5
	Marigold C	7.8 ± 0.26	12.86 ± 0.15	16.96 ± 1	19.63 ± 0.35
	Marigold D	4.16 ± 0.05	7.7 ± 0.2	13.83 ± 1.04	19.53 ± 0.41
Crown daisy	Control	2.23 ± 0.25	4.26 ± 0.25	6.43 ± 0.4	12.13 ± 0.15
	Crown daisy A	5.36 ± 0.35	9.13 ± 0.15	15.33 ± 0.3	50.23 ± 0.25
	Crown daisy B	5 ± 0.09	9.23 ± 0.2	14.4 ± 0.36	35.46 ± 0.41
	Crown daisy C	4.4 ± 0.36	8.2 ± 0.2	12.13 ± 0.15	20.7 ± 0.19
	Crown daisy D	3.26 ± 0.25	6.2 ± 0.2	10.4 ± 0.36	20.46 ± 0.25

(a)

Aromatic plants	Treatments	Flowering (no) (10 days)	Flowering (no) (20 days)	Flowering (no) (30 days)	Flowering (no) (40 days)
Rose	Control	-	-	-	1.66 ± 0.57
	Rose A	-	-	-	1.33 ± 0.57
	Rose B	-	-	4 ± 1	6.66 ± 1.52
	Rose C	-	-	-	3.33 ± 0.57
	Rose D	-	-	7 ± 1	9 ± 1
Marigold	Control	-	-	-	1.33 ± 0.57
	Marigold A	-	8.66 ± 0.57	16.33 ± 0.57	23.33 ± 0.57
	Marigold B	-	1.33 ± 0.57	5.33 ± 0.57	7.33 ± 0.57
	Marigold C	-	2.33 ± 0.57	6.33 ± 0.57	18.33 ± 0.57
	Marigold D	-	-	-	1.66 ± 0.57
Crown daisy	Control	-	-	-	1.33 ± 0.57
	Crown daisy A	-	-	5.33 ± 0.57	10.33 ± 0.57
	Crown daisy B	-	-	3 ± 1	5.33 ± 0.57
	Crown daisy C	-	-	-	2.33 ± 0.57
	Crown daisy D	-	-	-	2.33 ± 0.57

(b)

*Results are expressed as mean ± standard deviation; n = 3

In marigold at 10- and 20-days coconut coir showed more increase in plant height in comparison to other substrates. However, at 30- and 40-days maximum height was obtained when planted in soil mixture supplemented with burned rice husk followed by groundnut shell powder (Fig. 5 (a)). Flowering in marigold was maximum when soil was supplemented with burned rice husk and coconut coir (Fig. 5 (b)), (Table 3 (b)). In nutshell, soil mixture containing groundnut shell powder, burned rice husk and coconut coir is effective in overall growth and development of marigold plants as use of this substrate positively affected plant height and flowering (Figs. 5 (a-b)).

Utilizing combination treatments of various substrates is always preferred since it provides a mixture of nutrients from the two or more substrates mixtures to the plants. The effectiveness of groundnut shell in enhancing the marigold plant height and flowering has prompted us to make different substrate combinations by mixing groundnut shell powder with burned rice husk, rice husk, coconut coir and banana peel. Marigold was chosen to study the effect of different substrate combinations on plant growth and development due to its short life cycle in comparison to rose and crown daisy. The maximum height of marigold plant was observed when supplemented with a substrate in combination of burned rice husk and groundnut shell powder, GS + BRH at 10-, 20-, 30- and 40-days intervals (Figs. 6 (a), 7, 8), (Table 4 (a)). Flowering was only observed in marigold after 15 – 20 days and increase in flowering, maximum of 18 flowers were observed in substrate when treated with groundnut shell and banana peel followed by 16 flowers when marigold was supplemented with groundnut shell and

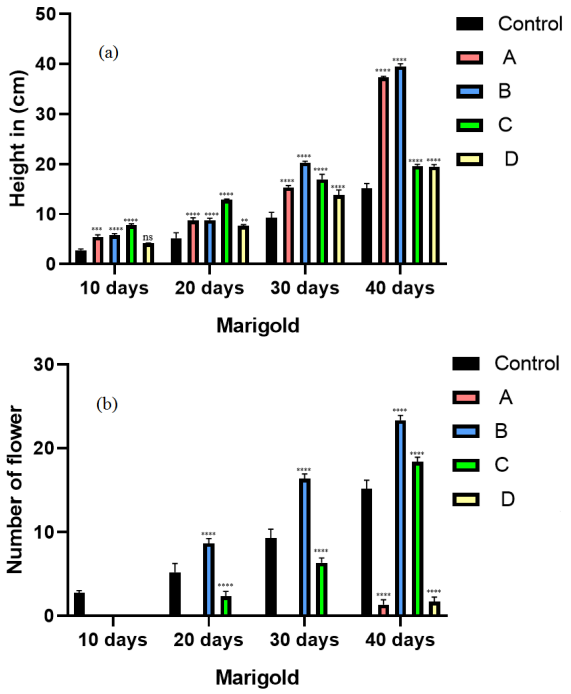

Figure 5. Effect of various substrate treatment; GS (A), BRH (B), CC (C), BP (D) in marigold growth parameters (a) Plant height (b) Number of flowers. Each bar graph represents values in triplicates. Results are expressed as mean ± standard deviation; n = 3. Significant differences were determined at $p < 0.05$ with two-way ANOVA using Turkey's HST analysis.

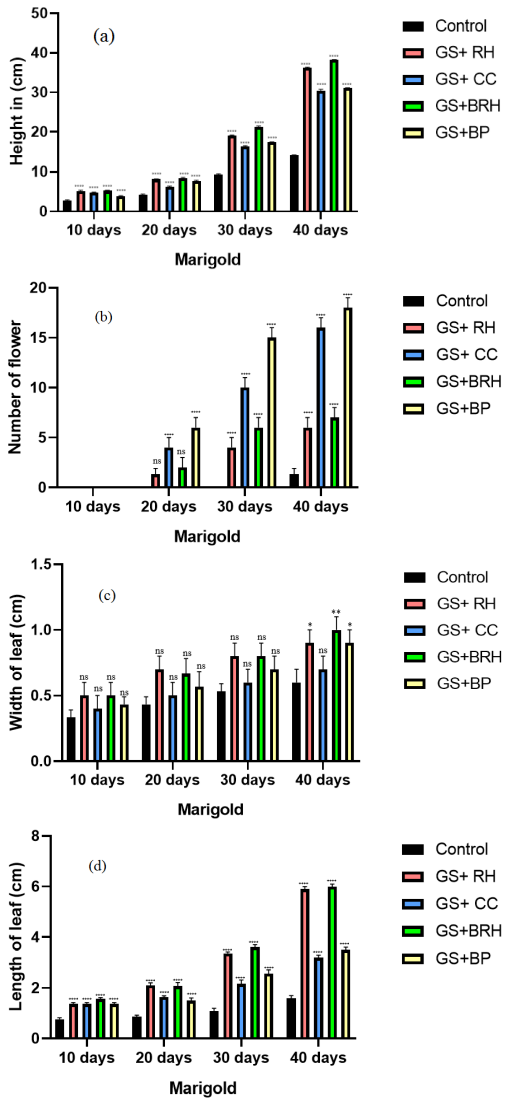

Figure 6. Effect of various substrate treatment in combinations; Groundnut shell (GS), Rice Husk (RH), Burned rice husk (BRH) and Coconut coir (CC) in marigold measured between 10 – 40 days (a) Plant height (b) Number of flower (c) Leaf width (d) Leaf length. Each bar graph represents values in triplicates. Results are expressed as mean ± standard deviation; n = 3. Significant differences were determined at $p < 0.05$ with two-way ANOVA using Turkey's HST analysis.

coconut coir (Figs. 6 (b), 7, 8), (Table 4 (d)).

A significant increase in leaf width was observed at 40 days when marigold saplings were supplemented with substrate combination of GS + BRH (Fig. 6 (c)), (Table 4 (c)) followed by GS + RH however there was no significant difference in leaf length observed at 10, 20 and 30 days with any of these combinations (Fig. 6 (d)), (Table 4 (b)). The results obtained from this study are in sync with the observation from Verdonck and Gabriel (1992) wherein it has been reported that 75% of groundnut shell hulls as substrate show maximum growth in marigold plants as compared to 25% and 50% groundnut shell. Hence, for marigold combination treatments of the GS + BRH and GS + BP is better combination treatment for overall growth and development of plants.

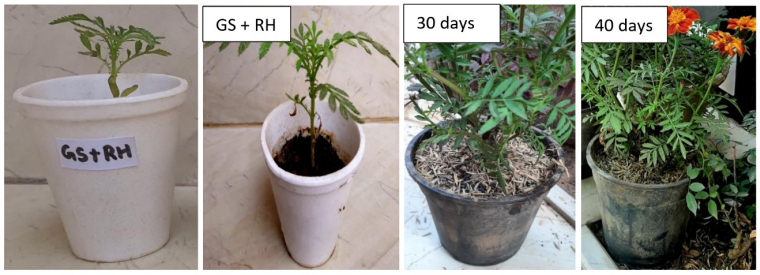

Figure 7. Marigold supplemented with groundnut shell (GS) and rice husk (RH) from initial day to 40th day which shows less flowering as compared to other substrate treatments.

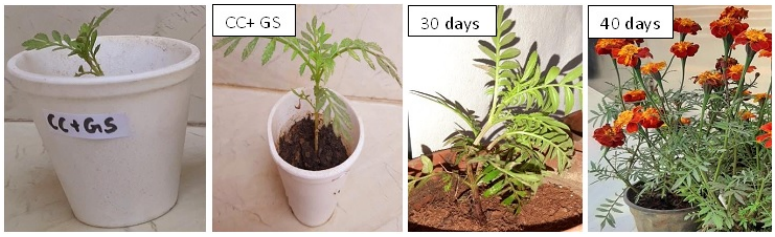

Figure 8. Marigold supplemented with coconut coir (CC) and groundnut shell (GS) treatment from initial day to 40th day which shows maximum flowering as compared to groundnut shell and rice husk treatment.

Table 4. Impact of combination of different substrate on various plant growth parameters in marigold (GS: Groundnut Shell, RH: Rice Husk, CC: Coconut Coir, BRH: Burned Rice Husk and BP: Banana Peel) (a) Plant height (b) Length of leaf (c) Width of leaf (d) Flowering.

Treatments	Height (cm) (10 days)	Height (cm) (20 days)	Height (cm) (30 days)	Height (cm) (40 days)
Control	2.73 ± 0.2	4.2 ± 0.2	9.26 ± 0.25	14.1 ± 0.09
GS + RH	5.2 ± 0.2	8.13 ± 0.15	19.06 ± 0.11	36.2 ± 0.19
GS + CC	3.9 ± 0.1	6.26 ± 0.15	16.3 ± 0.19	30.4 ± 0.36
GS + BRH	5.23 ± 0.15	8.36 ± 0.25	21.23 ± 0.25	38.2 ± 0.09
GS + BP	4.7 ± 0.2	7.7 ± 0.2	17.33 ± 0.15	31.1 ± 0.09
		(a)		
Treatments	Length of leaf (10 days)	Length of leaf (20 days)	Length of leaf (30 days)	Length of leaf (40 days)
Control	0.76 ± 0.05	0.86 ± 0.05	1.1 ± 0.1	1.6 ± 0.1
GS + RH	1.36 ± 0.05	2.06 ± 0.15	3.36 ± 0.05	5.9 ± 0.1
GS + CC	1.36 ± 0.05	1.63 ± 0.05	2.16 ± 0.15	3.2 ± 0.09
GS + BRH	1.56 ± 0.05	2.1 ± 0.1	3.6 ± 0.1	6 ± 0.09
GS + BP	1.36 ± 0.05	1.5 ± 0.1	2.56 ± 0.15	3.5 ± 0.1
		(b)		
Treatments	Width of leaf (10 days)	Width of leaf (20 days)	Width of leaf (30 days)	Width of leaf (40 days)
Control	0.33 ± 0.05	0.43 ± 0.05	0.53 ± 0.05	0.6 ± 0.09
GS + RH	0.5 ± 0.1	0.7 ± 0.1	0.8 ± 0.1	0.9 ± 0.1
GS + CC	0.4 ± 0.1	0.5 ± 0.1	0.6 ± 0.09	0.7 ± 0.1
GS + BRH	0.5 ± 0.1	0.66 ± 0.11	0.8 ± 0.1	1 ± 0.1
GS + BP	0.43 ± 0.05	0.56 ± 0.11	0.7 ± 0.1	0.9 ± 0.1
		(c)		
Treatments	Flowering (no) (10 days)	Flowering (no) (20 days)	Flowering (no) (30 days)	Flowering (no) (40 days)
Control	-	-	-	1.33 ± 0.57
GS + RH	-	1.33 ± 0.57	4 ± 1	6 ± 1
GS + CC	-	4 ± 1	10 ± 1	16 ± 1
GS + BRH	-	2 ± 1	6 ± 1	7 ± 1
GS + BP	-	6 ± 1	15 ± 1	18 ± 1
		(d)		

*Results are expressed as mean ± standard deviation; n = 3.

4. Conclusion

The need of the substrates varies from one plant to other plant since these substrates help in maintaining the balance between physical and chemical properties which in turn provides them with adequate mineral nutrients, support, and acts as a reservoir for plant growth. The different substrates such as groundnut shell, burned rice husk, coconut coir, and banana peel has shown potential to increase plant growth and development in marigold, rose and daisy plants as these substrates provides a variety of micro and macro elements which are essential to plants for growth and development. For rose plants banana peel as substrate is better in terms of flowering and height is significantly enhanced when supplemented with burned rice husk. The information emanating from this study shows the potential of using combined substrate of banana peel and burned rice husk for growth and development of rose plants. Further this study can be done at larger scale which would provide information for making appropriate mixtures for commercialization purposes. For marigold saplings substrate combination of groundnut shell with burned rice husk showed increase in plant height whereas flowering is increased in substrate combination of groundnut shell with banana peel. So, the appropriate mixture of this substrate has potential to increase overall growth and development of marigold plants. Further, this mixture can be applied to other aromatic plants for enhancement of flowering capacity and plant health. As these substrates are cheap, eco-friendly, natural, and mainly agricultural waste, thus its utilization is one of best ways to overcome the problem of agricultural waste. Hence, depending on the nature of plant species substrates can be modified for getting better growth and development of plants.

The generated information will further provide the way to find the best substrate for growth and development of specific plants.

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Authors contributions

The authors confirm the study conception, design and supervision Susmita Shukla, data collection: Sagar Ruhal; analysis and interpretation of results: Sagar Ruhal, Chanchal Kumari. Author draft manuscript preparation: Sagar Ruhal, Chanchal Kumari, Proofreading and editing: Susmita Shukla the results were evaluated by all authors and the final version of the manuscript was approved.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Conflict of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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