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INFLUENCE OF MEDIA AND NUTRIENT SOLUTIONS ON GROWTH, YIELD AND QUALITY OF COLEUS (*Plectranthus barbatus* Andr.) UNDER SOILLESS CULTURE

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Abstract- The present investigation was carried out at Sugandhavana, Medicinal and Aromatic section, Division of Horticulture, University of Agricultural Sciences, Bangalore (Zone- 5). Coleus (*Plectranthus barbatus*) is an important medicinal plant species, contains forskolin, which is mainly used to reduce the blood cholesterol level. Incidence of soil borne diseases and nematodes is a limiting factor for growing the crop in soil media. To overcome this, the work was initiated to standardize the soilless growth media and nutrient solution concentration in coleus cultivar *Aisiri* for growth, yield and forskolin content. Among the different media and nutrients, the plants grown under cocopeat media with 150 per cent of recommended dose of fertilizers for normal soil grown crops responded well with high vegetative growth such as plant height, number of branches, fresh and dry weight of shoot. Among the different root parameters, root diameter and dry matter accumulation was significantly higher in cocopeat media with 80 per cent of recommended dose of fertilizers (864 mg plant^{-1} nitrogen, 768 mg plant^{-1} phosphorous and 960 mg plant^{-1} potassium). Significantly high yield parameters such as fresh and dry weight of roots (410 and 114 g plant^{-1}, respectively) and yield per unit area (1.71 kg m^{-2}) were observed in cocopeat media with 80 per cent of recommended dose of fertilizers. The active principle, forskolin content (1.00 per cent) was also found to be maximum in plants grown under cocopeat media with 80 per cent of recommended dose of fertilizers.

Keywords- coleus, soilless culture, nutrient solution, forskolin, cocopeat media

Introduction

Plectranthus barbatus Andr. (Syn. *Coleus forskohlii* Briq.) belongs to the family Lamiaceae and is commonly known as Coleus or *Pashanbhedi* (Sanskrit) grown throughout India for its tuberous roots. The roots are found to be a rich source of forskolin (coleonol) used as a potential drug for hypertension, congestive heart failure, eczema, colic, respiratory disorders, painful urination, insomnia, and convulsions [1]. Forskolin is the one popular drug used extensively to reduce the blood cholesterol level. It is originated in the Indian sub-continent and distributed in the subtropical Himalayas from Kumaon to Nepal, Bihar and Deccan Peninsula of South India as well as Sri Lanka, Egypt, Arabia, Ethiopia, tropical East Africa and Brazil [2]. It is a perennial herbaceous plant grows to about 45-60 cm height, bushy and spreading habit. The root is typically golden brown, thick, fibrous and radially spreading and it is the only species of the genus to have fasciculated tuberous roots [3]. In coleus, root -knot caused by *Meloidogyne incognita* and bacterial wilt by *Ralstonia solanacearum* are the two major constraints prevailing throughout the production areas [4,5]. In the last few years, the cultivation of coleus has suffered a set back due to the wilt incidence. Growing coleus on substrate culture will be the answer to overcome this problem along with increasing the yield and quality of tuberous roots. The present investigation was carried out to study the growth, yield and forskolin content of *Plectranthus barbatus*, cultivar *Aisiri* (which is a mutant, MV_7 of coleus local variety k-8, released from University of Agricultural Sciences, Bangalore, Karnataka with high root yield and forskolin content) in response to different substrates such as cocopeat, vermiculite, sand and their combinations with different concentrations of nutrient solutions.

Materials and Methods

The pot culture studies with selected media were conducted at Sugandhavana, Medicinal and Aromatic Section, Department of Horticulture, University of Agricultural Sciences, Bangalore (Zone-5). The experimental site is located at an altitude of 930 m above mean sea level in semi-arid tropics with mean annual rainfall of 890 mm.

Terminal stem cuttings of the variety *Aisiri* (MV_7) were taken from healthy plants. Forty five days old rooted cuttings were transplanted to the experimental pots containing different growing media. The experiment was laid out in factorial completely randomized design replicated twice with five potting media and six nutrient concentrations [Table-1]. The treatments with different concentrations of nutrients along with control (recommended dose of fertilizers/ RDF, *i.e.*, 1080 mg plant^{-1} nitrogen, 960 mg plant^{-1} phosphorous and 1200 mg plant^{-1} potassium)) were imposed 15 days after planting. Water soluble complex fertilizer, urea and potassium chloride (KCl) were used as sources of fertilizer. The treatment was imposed in 32 split doses applied at four days interval. The application of nutrients solution was stopped 15 days before harvesting of the crop. Along with the treatments, Hoagland's micronutrient solution was applied uniformly to all plants irrespective of treatments. Modified Hoagland solution prepared as described by Taiz and Zeiger was used for the study [6]. Whole plants were uprooted 180 days after transplanting and tuberous roots were separated from shoot, washed, chopped and were dried in oven at 50°C for two days. The dried roots were

powdered and were used for analysis of forskolin. Observations on vegetative parameters were recorded at 30 days interval till harvest and yield parameters at harvesting stage (mean of five plants from each replication and each treatment). The statistical analysis was carried out as per Sundararaj et al [7].

Results and Discussion

Influence of Media and Nutrient Solutions on Growth Parameters

Among the different media, the plants grown under cocopeat recorded high vegetative growth such as plant height and number of branches [Table-2]. This may be mainly attributed to better moisture availability and favorable aeration conditions of the media. Similar results were obtained with *Celocia cristata*, golden pothos and strawberry plants grown in 100 per cent cocopeat media recorded maximum number of leaves compared to other media [8-10]. The least growth parameters were observed in control (M_1, sand). Sand media is known to contain a very few elements and has no significant buffer or cat-ion exchange capacity (CEC) and lacks water holding capacity. Sand media contains less humus and less clay which could result in lower plant spread and biomass [11]. Significantly high fresh and dry weight of shoot per plant was recorded with cocopeat media and it was minimum in vermiculite media [Table-3]. Sand and vermiculite used separately as growing media recorded significantly lower growth parameters compared to others. It could be attributed to the high carbon-nitrogen (C/N) ratio for vermiculite and low nitrogen in sand and vermiculite resulting in nitrogen shortage, which in turn leads to restricted cell division and growth of cells [12].

Among the different nutrient concentrations, plant height and number of branches were maximum in 150 per cent of recommended dose of fertilizers. This might be due to the fact that nitrogen, which is largely used for protein synthesis and higher nitrogen availability has a favourable effect on cell multiplication and elongation resulting in increased plant height and spread. Therefore when nitrogen supply is adequate proteins are formed from manufactured carbohydrates which help in increasing plant height [13]. Nitrogen supply is related to carbohydrate utilization enhancing protein synthesis which allows the plants to grow faster, increased rate of metabolism, cell division, cell elongation and thereby stimulate apical growth as well as formation of leaves [14]. In the present study, this is evident from the increased number of branches and leaves per plant with increased nutrient levels at all the stages.

Plants treated with Hoagland's solution recorded lower plant spread followed by 50 per cent of RDF. Kulkarni *et al*. while studying the effect of half-strength Hoagland's nutrient solution on seedling growth of *Diascoria dregeana*, recorded best growth performance, whereas, a deficiency of either nitrogen, phosphorous or potassium negatively affected seedling growth [15]. Thus, the application of moderate quantity of nutrients was recommended in raising healthy seedlings.

Table 1- Potting media and nutrient solution dosages used in the experiment

Factor 1	Media	Factor 2	Nutrient solution	Nutrient concentration (mg plant^{-1})		
				Nitrogen	P_2O_5	K_2O
M_1	Sand (control)	F_1	*RDF in soil	1080	960	1200
M_2	Coco-peat	F_2	50% of RDF	540	480	600
M_3	Vermiculite	F_3	80% of RDF	864	768	960
M_4	Coco-peat + sand (1:1)	F_4	120% RDF	1296	1152	1440
M_5	Vermiculite + sand (1:1)	F_5	150% RDF	1620	1440	1800
		F_6	Control (Hoagland's solution)	-	-	-

*Recommended Dose of Fertilizers for coleus plant by the university

Table 2- Influence of media and nutrient solution on plant height and number of branches in coleus variety *Aisiri* at harvest (180 DAP)

Treatments	Plant height (cm)						Number of branches					
	M_1	M_2	M_3	M_4	M_5	Mean	M_1	M_2	M_3	M_4	M_5	Mean
F_1	49.25	60.6	55.7	57	59.8	56.47	14.85	15.65	15.9	14.7	19.1	16.04
F_2	51.2	59.85	54.2	56.8	62.1	56.83	15.4	14.6	14.6	15.8	17.7	15.62
F_3	54.5	68.15	54.9	53.75	51.4	56.54	16.7	21.25	14.9	13.45	13.75	16.01
F_4	57.2	57.75	55.4	59.6	60.45	58.08	17.3	16.4	14.85	15.6	15.7	15.97
F_5	59.4	69.4	55	57.55	66.25	61.52	15.7	17.4	15.4	15.8	19.7	16.8
F_6	54.4	59.8	50.35	59.4	59.85	56.76	12.4	15.35	13.35	16.7	16.15	14.79
Mean	54.33	62.59	54.26	57.35	59.98	57.7	15.39	16.78	14.83	15.34	17.02	15.87
Statistical information												
	S.Em±		CD@5%	F-test			S.Em±		CD@5%	F-test		
M	1.01		2.91	**			0.56		1.61	**		
F	1.1		3.19	**			-		-	NS		
M*F	2.47		7.13	**			-		-	NS		

** Significantly different at 5% level of probability, NS= Non-Significant.

Where M-Media; F-Nutrient solutions; M_1-sand; F_1-RDF; M_2-cocopeat; F_2- 50% of RDF; M_3-vermiculite; F_3- 80% of RDF; M_4- sand+cocopeat (1:1); F_4- 120% of RDF; M_5- sand +vermiculite (1:1); F_5- 150% of RDF; F_6- Hoagland's solution

Table 3- Influence of media and nutrient solution on fresh and dry weight of shoot in coleus variety *Aisiri* at harvest (180 days)

Treatments	Fresh weight of shoot (g/plant)						Dry weight shoot (g/plant)					
	M_1	M_2	M_3	M_4	M_5	Mean	M_1	M_2	M_3	M_4	M_5	Mean
F_1	240	450	315	315.2	406.1	345.26	24	41.45	30.5	28.1	38.4	32.49
F_2	290	410	244	210.2	361	303.04	24.75	38.3	23.3	18.5	34.7	27.91
F_3	360	370	238	320.2	345.4	326.72	35.5	35.7	22.7	29.4	31.2	30.9
F_4	390	480	312.5	349	452.5	396.8	39.6	43.4	28.8	31.5	43.5	37.36
F_5	570	476	257	351.2	415	413.84	50	45.75	24.5	33.9	38.8	38.59
F_6	410	411	250	335.4	345	350.28	39	39.1	22.35	31.95	32.85	33.05
Mean	376.67	432.83	269.42	313.53	387.5	355.99	35.48	40.62	25.36	28.89	36.58	33.38
Statistical information												
	S.Em±		CD@5%	F-test			S.Em±		CD@5%	F-test		
M	11.63		33.6	**			1.12		3.25	**		
F	12.74		36.81	**			1.23		3.56	**		
M*F	28.5		82.31	**			2.75		7.95	**		

** Significantly different at 5% level of probability.

Where M-Media; F- Nutrient solutions; M_1-sand; F_1-RDF; M_2-cocopeat; F_2- 50% of RDF; M_3-vermiculite; F_3- 80% of RDF; M_4- sand+cocopeat (1:1); F_4- 120% of RDF; M_5- sand +vermiculite (1:1); F_5- 150% of RDF; F_6- Hoagland's solution

Influence of Media and Nutrient Solutions on Root and Yield Parameters

Root diameter, fresh and dry weight of roots and dry matter accumulation was significantly higher in cocopeat media (M_2) [Table-4], [Table-5], [Table-6]. The maximum root length was observed in plants grown under media composition of sand and vermiculite (M_5) followed by M_1 (sand) and M_2 (cocopeat) and it was the minimum in vermiculite grown plants. Mixing sand with inorganic substrates allows for the best nutrient uptake and sufficient growth and development due to optimized water and oxygen holding [16]. Therefore, compared to vermiculite media, the combination of vermiculite and sand resulted in maximum root length. The root length in sand media is fairly good because sand grains constantly hold water at the lower part of the layer from the bottom of the pot and therefore roots tend to grow deeper [17].

However, the root diameter and dry matter accumulation was maximum with M_2 (cocopeat) [Table-6]. This may be mainly due to the lower C/N ratio in cocopeat compared to other media with higher cation exchange capacity, helps the roots to absorb more mineral nutrition and dry matter accumulation in roots [18]. The higher root to shoot ratio was noticed in vermiculite media grown plants. Root growth was found to increase with increased internal porosity, which increases gaseous diffusion downward towards the root tips. Root to shoot ratio has been observed under low total nutrient concentration and higher air space [17].

M_2F_3 (cocopeat with 80 % of Recommended Dose of fertilizer, RDF) recorded maximum root diameter, fresh and dry weight of roots and dry matter accumulation. Root to shoot dry weight ratio was maximum in M_3F_3 (vermiculite media with 80 % RDF) followed by M_1F_3 (Sand media with 80 % RDF). Coleus plants, in general, are known for profuse vegetative growth with a wide root to shoot ratio, often resulting in low yields due to improper source-sink relationship. Higher supply of nitrogen promotes shoot growth more than root growth leading to a typical fall in root to shoot dry weight ratio [19]. Apparently, cocopeat had the most appropriate physical characteristics as well a high level of nutrition holding capacity and thus gave the highest values for most of the root growth parameters measured in this study [20].

Table 4- Influence of media and nutrient solution on root length and root diameter in coleus variety *Aisiri* at harvest (180 days)

Treatments	Root length (cm)						Root diameter (cm)					
	M_1	M_2	M_3	M_4	M_5	Mean	M_1	M_2	M_3	M_4	M_5	Mean
F_1	25.8	35.67	24.45	25.83	31.3	28.61	1.62	2.07	1.41	1.37	1.98	1.69
F_2	23.8	23.13	21.98	20.45	30.88	24.05	1.36	1.94	1.67	1.35	1.59	1.58
F_3	34.1	28.5	28.75	28.5	33.5	30.67	2.1	2.65	2.08	1.9	2.12	2.17
F_4	31.63	24.88	21.95	26.5	33.83	27.76	1.97	1.87	2	1.47	1.76	1.81
F_5	32.48	24.75	25.8	29.5	30.25	28.56	1.74	2.19	2.05	1.65	1.75	1.88
F_6	27.6	31.3	28.27	30.2	31.7	29.81	1.88	2.06	1.85	1.75	1.93	1.89
Mean	29.23	28.04	25.2	26.83	31.91	28.24	1.78	2.13	1.84	1.58	1.85	1.84
Statistical information												
	S.Em±		CD@5%	F-test			S.Em±		CD@5%	F-test		
M	1.39		4	**			0.07		0.2	**		
F	-		-	NS			0.08		0.22	**		
M*F	-		-	NS			-		-	NS		

** Significantly different at 5% level of probability, NS= Non-Significant.

Where M-Media; F- Nutrient solutions; M_1-sand; F_1-RDF; M_2-cocopeat; F_2- 50% of RDF; M_3-vermiculite; F_3- 80% of RDF; M_4- sand+cocopeat (1:1); F_4- 120% of RDF; M_5- sand +vermiculite (1:1); F_5- 150% of RDF; F_6- Hoagland's solution

Table 5- Influence of media and nutrient solution on fresh and dry weight of roots in coleus variety *Aisiri* at harvest (180 days)

Treatments	Fresh weight of roots (g/plant)						Dry weight of roots (g/plant)					
	M_1	M_2	M_3	M_4	M_5	Mean	M_1	M_2	M_3	M_4	M_5	Mean
F_1	312.25	390.1	315.3	318.95	346	336.52	61.25	86.67	57.5	52.76	79	67.44
F_2	309.3	365.05	296.1	280	333	316.69	55.5	77	49.3	38.33	67.83	57.59
F_3	352.9	410	356.15	339.05	362	364.02	98.75	114	85.5	68	93.84	92.02
F_4	347.95	365.25	328.3	319.4	334.9	339.16	92	74.5	60.5	54.75	67.5	69.85
F_5	332.75	380	336.35	331.7	346.6	345.48	58.33	87.25	68	63.4	72.75	69.95
F_6	350.3	372.9	331.4	328.2	356.5	347.86	75	89.75	63.5	67	79.1	74.87
Mean	334.24	380.55	327.27	319.55	346.5	341.62	73.47	88.19	64.05	57.37	76.67	71.95
Statistical information												
	S.Em±		CD@5%	F-test			S.Em±		CD@5%	F-test		
M	4.26		12.3	**			1.86		5.38	**		
F	4.67		13.48	**			2.04		5.9	**		
M*F	-		-	NS			4.56		13.18	**		

** Significantly different at 5% level of probability, NS= Non-Significant.

Where M-Media; F- Nutrient solutions; M_1-sand; F_1-RDF; M_2-cocopeat; F_2- 50% of RDF; M_3-vermiculite; F_3- 80% of RDF; M_4- sand+cocopeat (1:1); F_4- 120% of RDF; M_5- sand +vermiculite (1:1); F_5- 150% of RDF; F_6- Hoagland's solution

Table 6- Influence of media and nutrient solution on root to shoot ratio and dry matter accumulation in coleus variety *Aisiri* at harvest (180 days)

Treatments	Root to shoot ratio						Dry matter accumulation (g/plant)					
	M_1	M_2	M_3	M_4	M_5	Mean	M_1	M_2	M_3	M_4	M_5	Mean
F_1	2.55	2.09	1.92	1.88	2.06	2.1	85.25	128.12	88	80.86	117.4	99.93
F_2	2.23	2.01	2.12	2.12	1.96	2.09	80.25	115.3	72.6	56.83	102.53	85.5
F_3	2.82	3.19	3.77	2.32	3.01	3.02	134.25	149.7	108.2	97.4	125.04	122.92
F_4	2.34	1.71	2.11	1.74	1.55	1.89	131.6	117.9	89.3	86.25	111	107.21
F_5	1.22	1.91	2.77	1.87	1.88	1.93	108.33	133	92.5	97.3	111.55	108.54
F_6	1.93	2.3	2.84	2.09	2.42	2.31	114	128.85	85.85	98.95	111.95	107.92
Mean	2.18	2.2	2.59	2.01	2.15	2.22	108.95	128.81	89.41	86.27	113.24	105.33
Statistical information												
	S.Em±		CD@5%	F-test			S.Em±		CD@5%	F-test		
M	0.06		0.16	**			2.57		7.42	**		
F	0.06		0.18	**			2.81		8.13	**		
M*F	0.14		0.4	**			6.29		18.17	**		

** Significantly different at 5% level of probability.

Where M-Media; F- Nutrient solutions; M_1-sand; F_1-RDF; M_2-cocopeat; F_2- 50% of RDF; M_3-vermiculite; F_3- 80% of RDF; M_4- sand+cocopeat (1:1); F_4- 120% of RDF; M_5- sand +vermiculite (1:1); F_5- 150% of RDF; F_6- Hoagland's solution

The yield parameters, fresh and dry weight of tuberous roots, yield per unit area and yield per hectare were significant for media and nutrient solution treatments. Among the growing media, significantly high fresh and dry weight of roots (380.55 and 92.02 g plant^{-1}, respectively), yield per unit area (1.32 kg m^{-2}) were recorded in M_2 (cocopeat) [Table-5] & [Fig-1]. Better root development in cocopeat media may be due to optimum mineral and water absorption and cation exchange capacity of root system and better heat properties of cocopeat. Cocopeat has good physical properties, high total pore space, high water content, low shrinkage, low bulk density and slow biodegradation [21,22]. Among the nutrient concentrations, F_3 (80 % of RDF) recorded the maximum yield parameters like fresh and dry weight of roots, dry tuber yield. The lowest tuberous root yield was recorded in plants grown in 50 per cent of RDF (F_2). The moderate root yield per plant was observed with higher concentration of nutrient solution (at 120 and 150 % of RDF). This is mainly due to excessive fertilization that could lead to negative consequences on the yield parameters [23].

Interaction between media and nutrient solution concentrations resulted in maximum yield parameters in M_2F_3 (coopeat with 80 % RDF) followed by M_1F_3 (Sand with 80 % RDF). Significantly low yield per plant was obtained in M_4F_2 (sand + cocopeat with 50 % RDF). Since the sand mixtures allowed moderate leaf development, leads to poor root growth and the differences in the water/air relationship of the various rooting media. Mechanical impedance and reduced porosity might also contribute to restricted root formation [24].

Influence of Media and Nutrient Solutions on Forskolin Content

The forskolin content in tuberous roots of coleus recorded maximum (0.72 %) in cocopeat media (M_2) followed by sand media (0.71 %), that differed significantly from all other treatments [Fig-2]. Interaction between media and nutrient concentrations resulted in maximum forskolin content (1.00 %) in M_2F_3 treatment followed by M_1F_3 (0.86 %). Pedneault *et al*. reported that in *Achillea millefolium*, the total flavonoids concentration of hydroponically-grown root (1.92 %

w/w) was 3.8 times higher than field-grown root (0.51 % w/w) on dry weight basis [25]. Manjunathaswamy and Prasanna recorded 0.76 and 0.74 per cent forskolin, respectively in the tuberous roots of coleus variety MV_7 under field conditions [26,27]. Compared to that, plants grown in cocopeat with 80 % RDF recorded around 25 per-cent more forskolin content under substrate culture.

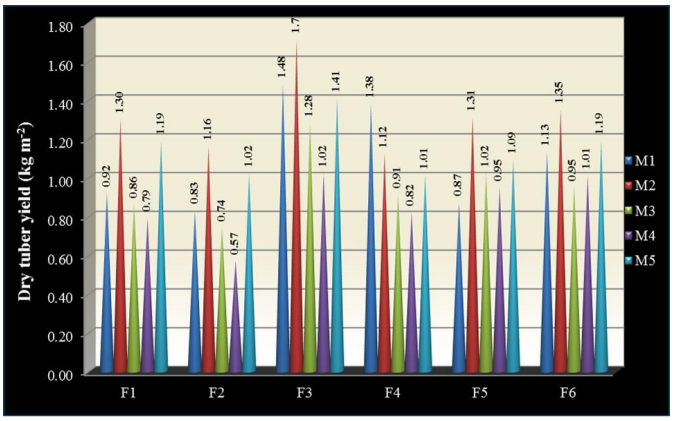

Fig. 1- Influence of media and nutrient solution on dry tuber yield (kg m^{-2}) of coleus variety *Aisiri* at harvest (180 days)

M_1-sand; F_1-RDF; M_2-cocopeat; F_2- 50% of RDF; M_3-vermiculite; F_3- 80% of RDF; M_4- sand+cocopeat (1:1); F_4- 120% of RDF; M_5- sand +vermiculite (1:1); F_5- 150% of RDF; F_6- Hoagland's solution

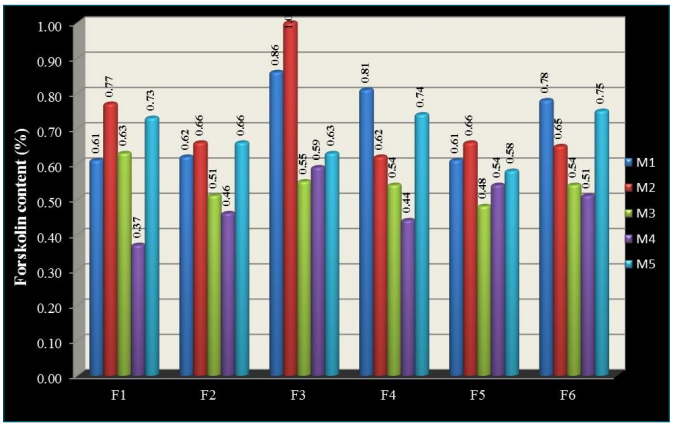

Fig. 2- Influence of media and nutrient solution on forskolin content of coleus variety *Aisiri* at harvest (180 days)

M_1-sand; F_1-RDF; M_2-cocopeat; F_2- 50% of RDF; M_3-vermiculite; F_3- 80% of RDF; M_4- sand+cocopeat (1:1); F_4- 120% of RDF; M_5- sand +vermiculite (1:1); F_5- 150% of RDF; F_6- Hoagland's solution

Conclusion

Among different growth media used for planting of coleus variety *Aisiri* (MV_7), cocopeat was found to be the best for soilless culture with respect to both vegetative and yield parameters. Nutrient concentrations significantly influenced the plant growth. Among them, 150 per cent of RDF (Recommended Dose of Fertilizers) recorded maximum vegetative parameters but for root crops like coleus optimum root yield is important. Maximum yield parameters were observed under 80 per cent of RDF in coleus. Optimum growing conditions in coleus for getting maximum forskolin concentration was cocopeat media with 80 per cent of RDF.

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