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Influence of planting techniques, type of cuttings, PGRs and seasons on yield attributes in medicinal coleus (*Plectranthus forskohlii* Willd.)

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Abstract
An experiment was conducted to study the influence of planting techniques, type of cuttings, PGRs and seasons on growth, tuber yield and quality in medicinal coleus (*Plectranthus forskohlii* Willd.) under northern dry zone of Karnataka. The experiment was conducted in split-split plot design with main plot: four treatments, sub plot 1: nine treatments and sub plot 2: two treatments. The interaction effect of planting techniques with the type of cuttings, PGRs and seasons (AXBXS) recorded that, $A_2B_6S_1$ - Un rooted cuttings in ridge and furrow with the spray of CCC 750 ppm in the *Kharif* has obtained maximum dry tuberous yield. To obtain maximum tuber yield in medicinal coleus, planting of un rooted cuttings in ridge and furrow method of planting along with CCC-750 ppm (Sprayed at 60 & 90 DAT) in *Kharif* can be suggested to farmers to cultivate medicinal coleus crop under Northern dry zone of Karnataka.

Keywords: Medicinal coleus, tuber yield, seasons

Introduction
The plant *Plectranthus forskohlii* Willd. (Medicinal coleus, 2n=30) belongs to the family *Lamiaceae*, is a perennial aromatic herb with annual stems and perennial roots (Shah, 1996) [11]. Though, there are about 300 species of *coleus* but, only the species *Plectranthus forskohlii* contains the diterpene, forskohlin (Mariya *et al.*, 2013) [4]. Because of its therapeutic uses the demand for its dry tuberous roots increased in recent times. This compelled some farmers to go for the cultivation of this crop. User industries are also promoting organized cultivation of coleus.

The tuberous roots of medicinal coleus contains 'forskolin' – a diterpenoid, which is being used to develop drugs to treat hypertension, glaucoma, asthma, congestive heart failure and certain types of cancers (De Souza, 1986) [1]. It's used as an ancient root drug recorded in ayurvedic De materia medica under the Sanskrit name 'Makandi' or 'Mayini' (Shah, 1996) [11]. There are several ethno medicinal uses of tubers and leaves of coleus for human as well as veterinary ailments throughout the world. In India, the roots are traditionally used in the preparation of pickles in households and by industries in the states of Gujarat, Maharashtra, Karnataka and Tamil Nadu.

The growth of a plant is the net result of diverse metabolic activities taking place in different parts of the plant during its growth and development in accordance with supply of growth factors *viz.*, water, light, temperature and nutrient from the environment. The basic biological principle that the quantity and quality of growth of a plant are controlled by its genetic potential and environment acting through its physiological, biochemical processes and conditions. The synthesis, accumulation and translocation of the metabolites to the economic parts of the plant are mainly influenced by the genetic makeup of variety, planting methods, type of cutting, use of growth regulators, environmental conditions and others.

The medicinal coleus can be propagated both from seeds and stem cuttings. Raising seedlings from seeds is a difficult process, as the viability of seeds is poor (8-10%). This method should be adopted only for breeding new varieties. For mass propagation of the plant, stem cuttings are found to be ideal. It was necessary to understand whether to plant the rooted cuttings or direct planting of the cuttings (Farooqi and Sreeramu, 2004) [2].

According to the earlier studies, planting method is a soil management tool which affects plant growth and yield. Method of planting is an important factor for higher production and gives equal opportunity to the plants for their survival and best use of other inputs. Understanding the proper planting method is very important to increase yield and to decrease interference with weeds. A certain methods of planting like flat bed method or ridge and furrow method for

a specific root crop may provide an optimum space to maximize vegetative parts, which subsequently receives higher solar energy and results in maximum yield. Plant spacing is an important factor for tuber production as it influences interplant competition (Shahidul *et al*., 2002) [12].

In addition, plant growth regulation is one of the important factor which controls growth and development of various characters and use of a suitable plant growth regulator will help in obtaining higher yields. Among the various plant growth regulators that influence higher production, type of plant growth regulator and its concentration are the most important (Nichols *et al.,* 2003) [6].

Further, it is also known that climatic conditions can change the vegetal secondary metabolism and consequently, alter the composition of essential oils throughout the seasons of the year. The variation in chemical composition of the essential oils is known to vary with the seasonal variation (Senthilkumar and Venkatesalu, 2010) [10]. Hence it was very necessary to find out the suitable season for the higher yields.

Keeping this in view, an investigation was initiated to study the influence of planting techniques, type of cuttings, PGRs and seasons on growth, tuber yield and quality in medicinal coleus (*Plectranthus forskohlii* Willd.) with the objective to identify the suitable season for cultivation of coleus under northern dry zone of Karnataka.

Material and Methods

The present investigation was carried out during *Kharif* and *Rabi* seasons of 2018-19 at Haveli farm, which comes under College of Horticultural Sciences, Bagalkot, University of Horticultural Sciences, Bagalkot, Karnataka. The experiment was laid out in split - split plot design with planting techniques with the type of cuttings as main plot and Growth Regulators as sub plot 1 and seasons as sub plot 2.

Treatments comprised of four main plots and subplot 1: Nine, subplot 2: Two Main plot comprised of planting techniques with the type of cuttings (A) and subplots included growth regulators (B). Further, to identify the best season among *Kharif* and *Rabi*, Season was taken as one more factor as sub plot 2 and analysed under Split-Split plot design. The treatment details are as follows-

Main plot: Planting techniques with the type of cuttings (A)

1. A_1- Rooted cuttings in ridge and furrow, 2. A_2 - Un rooted cuttings in ridge and furrow, 3. A_3 - Rooted cuttings in flat bed, 4. A_4 – Un rooted cuttings in flat bed

Sub plot 1: Growth Regulators (B) (Sprayed at 60 and 90 DAT)

1. B_1- Gibberlic Acid (GA_3) -100 ppm, 2. B_2- Gibberlic Acid (GA_3) - 150 ppm, 3. B_3- Napthalene Acetic Acid (NAA) - 20 ppm, 4. B_4- Napthalene Acetic Acid (NAA) - 30 ppm, 5. B_5- Cycocel (CCC) - 500 ppm, 6. B_6- Cycocel (CCC) -750 ppm, 7. B_7- Mepiquat Chloride (MC) - 500 ppm, 8. B_8- Mepiquat Chloride (MC) -750 ppm, 9. B_9- Control – Water spray

Sub plot 2: Seasons (*Kharif* and *Rabi*)

The experiment was conducted in the two seasons of *Kharif* and *Rabi* and observation recorded during the experiment on the yield and yield attributes.

The data on quality component was subjected to Fisher's method of analysis of variance (ANOVA) as outlined by Sundararaj *et al.* (1972) [14].

Result and Discussion

Influence of seasons (*Kharif* and *Rabi*) on yield attributes of medicinal coleus

Influence of planting techniques with the type of cuttings, PGRs and seasons on number of tubers and dry tuberous yield in medicinal coleus

Influence of planting techniques with the type of cuttings, PGRs, seasons and their interactions on number of tubers (Table 1) and dry tuberous yield in medicinal coleus is depicted in Table 2 and Fig. 1a, 1b and 1c.

The effect of planting techniques with the type of cuttings (A) on number of tubers in medicinal coleus (pooled) was significantly maximum in A_2– Un rooted cuttings in ridge and furrow (13.19) and the effect of PGRs on number of tubers was significantly maximum with the spray of B_6– CCC 750 ppm (12.43). Further, the interaction effect of (AXB), it was noticed that, maximum number of tubers were obtained in A_2B_6 - Un rooted cuttings in ridge and furrow + CCC 750 ppm (16.25) which was on par with A_2B_8 - Un rooted cuttings in ridge and furrow + MC 750 ppm (14.85), A_2B_1- Un rooted cuttings in ridge and furrow + GA_3 100 ppm (15.20) and A_2B_2- Un rooted cuttings in ridge and furrow + GA_3 150 ppm (14.73).

The effect of planting techniques with the type of cuttings (A) on dry tuberous yield in medicinal coleus (pooled) was significantly maximum in A_2– Un rooted cuttings in ridge and furrow (2.69 t/ha) and the effect of PGRs on dry tuberous yield was significantly maximum with the spray of B_6– CCC 750 ppm (2.29 t/ha) and was on par with B_8– MC 750 ppm (2.24 t/ha), B_1 - GA_3 100 ppm (2.11 t/ha), B_2 - GA_3 150 ppm (2.23 t/ha) and B_5-CCC 500 ppm (2.22 t/ha). Further, the interaction effect of (AXB), in the Fig.1a it was noticed that, maximum effect of growth regulators was observed on A_2 – Un rooted cuttings in ridge and furrow and maximum yield was obtained with the spray of B_6 – CCC 750 ppm. Hence, maximum yield was obtained with the interaction effect of A_2B_6 - Un rooted cuttings in ridge and furrow + CCC 750 ppm (3.21 t/ha).

Direct planted cuttings had a higher chance of survival than rooted cuttings as transplanting stress is obviously not experienced during direct planting as they will be well acclimatized in the soil. This lead to good establishment of the cuttings lead to increased production of yield and yield related parameters. Higher number of tubers, fresh and dry weight of tubers in ridge and furrow method of planting might be due to more bulk density, porosity and aeration of soil. In addition with the spray of growth retardants, they are capable of redistribution of dry matter in the plant parts thereby bringing about improvement in yield. Hence the interaction effect of un rooted cuttings in ridge and furrow + CCC 750 ppm (A_2B_6) was proved to be the superior treatment. The results are in conformity with the authors, Sunilkumar (2005) in medicinal coleus, Radha Krishna, 2005 in medicinal coleus.

Table 1: Influence of planting techniques with the type of cuttings, PGRs, seasons and their interactions on number of tubers in medicinal coleus.

Treatments	A_1		Mean of A_1xB	A_2		Mean of A_2xB	A_3		Mean of A_3xB	A_4		Mean of A_4xB	Mean of B	Mean of BxS	
	S_1	S_2		S_1	S_2		S_1	S_2		S_1	S_2			S_1	S_2
B_1	16.20	9.23	12.72	17.23	13.16	15.20	7.50	10.50	9.00	7.46	6.43	6.95	10.96	12.10	9.83
B_2	9.30	12.30	10.80	13.16	16.30	14.73	7.53	9.03	8.28	7.43	6.46	6.95	10.19	9.36	11.02
B_3	14.23	6.46	10.35	15.03	10.80	12.92	10.46	7.26	8.86	7.46	5.13	6.30	9.60	11.80	7.41
B_4	13.13	10.36	11.75	15.36	10.32	12.84	8.20	8.40	8.30	7.13	5.80	6.47	9.84	10.96	8.72
B_5	16.40	6.90	11.65	18.33	7.03	12.68	10.03	5.43	7.73	8.46	4.93	6.70	9.69	13.31	6.07
B_6	20.30	9.33	14.82	24.30	8.20	16.25	11.36	9.46	10.41	11.30	5.20	8.25	12.43	16.82	8.05
B_7	13.06	5.65	9.36	14.90	7.23	11.07	11.50	6.50	9.00	8.40	5.20	6.80	9.06	11.97	6.15
B_8	17.23	7.60	12.42	21.16	8.53	14.85	11.80	6.53	9.17	9.60	6.66	8.13	11.14	14.95	7.33
B_9	7.03	7.36	7.20	7.30	9.23	8.27	9.53	5.46	7.50	7.20	6.50	6.85	7.45	7.77	7.14
Mean of AxS	14.10	8.35		16.31	10.09		9.77	7.62		8.28	5.81				
Mean of A/S			11.22			13.19			8.69			7.05		12.11	7.97
	A		B		S		AxB		AxS		BxS		AxBxS		
SEm±	0.62		0.55		0.25		1.10		0.77		0.51		1.55		
C.D	1.51		1.08		0.51		2.17		1.02		1.53		3.07		

Legend:					
Main plot: Planting techniques with the type of cuttings (A)		**Sub plot 1: Growth Regulators (B) – Sprayed at 60 & 90 DAT**			
1	A_1 - Rooted cuttings in ridge and furrow	1	B_1 - Gibberlic Acid (GA_3)- 100 ppm	6	B_6- Cycocel (CCC) -750 ppm
2	A_2 - Un rooted cuttings in ridge and furrow	2	B_2 - Gibberlic Acid (GA_3) - 150 ppm	7	B_7- Mepiquat Chloride (MC) - 500 ppm
3	A_3- Rooted cuttings in flat bed	3	B_3- Napthalene Acetic Acid (NAA) - 20 ppm	8	B_8- Mepiquat Chloride (MC) -750 ppm
4	A_4 - Un rooted cuttings in flat bed	4	B_4 - Napthalene Acetic Acid (NAA) - 30 ppm	9	B_9- Control – Water spray
		5	B_5 - Cycocel (CCC) -500 ppm		**Sub plot 2: Season**
					S_1:*Kharif*
					S_2: *Rabi*

Table 2: Influence of planting techniques with the type of cuttings, PGRs, seasons and their interaction on dry tuberous yield (t/ha) in medicinal coleus.

Treatments	A_1		Mean of A_1xB	A_2		Mean of A_2xB	A_3		Mean of A_3xB	A_4		Mean of A_4xB	Mean of B	Mean of BxS	
	S_1	S_2		S_1	S_2		S_1	S_2		S_1	S_2			S_1	S_2
B_1	2.84	2.16	2.50	2.68	2.59	2.60	2.40	1.17	1.79	1.69	1.69	1.69	2.22	2.45	1.98
B_2	2.50	1.93	2.22	2.86	2.89	2.88	2.06	1.54	1.80	1.77	1.74	1.76	2.23	2.25	2.20
B_3	2.63	2.01	2.32	2.71	2.34	2.53	2.50	1.90	2.20	1.80	0.86	1.33	2.10	2.41	1.78
B_4	2.55	2.08	2.32	2.71	2.84	2.78	2.35	1.61	1.98	1.77	0.76	1.27	2.09	2.35	1.82
B_5	3.18	1.82	2.50	3.85	1.74	2.80	2.71	1.22	1.97	2.47	0.76	1.62	2.22	3.05	1.39
B_6	3.41	1.56	2.49	4.66	1.48	3.21	2.76	0.86	1.81	2.63	0.91	1.77	2.29	3.37	1.20
B_7	3.10	1.56	2.33	3.57	1.54	2.56	2.71	1.46	2.09	1.93	0.55	1.24	2.06	2.83	1.28
B_8	3.26	1.59	2.43	4.19	1.07	2.63	2.90	1.38	2.14	2.63	0.91	1.77	2.24	3.25	1.24
B_9	1.22	1.64	1.43	1.95	1.80	1.88	1.54	0.83	1.19	0.99	1.38	1.19	1.42	1.43	1.41
Mean of AxS	2.74	1.81		3.24	2.14		2.43	1.33		1.96	1.06				
Mean of A/S			2.28			2.69			1.88			1.51		2.60	**1.59**
	A		B		S		AxB		AxS		BxS		AxBxS		
SEm±	0.09		0.09		0.04		0.18		0.12		0.08		0.25		
C.D	0.22		0.18		0.08		0.36		NS		0.26		0.52		

Legend:					
Main plot: Planting techniques with the type of cuttings (A)		**Sub plot 1: Growth Regulators (B) – Sprayed at 60 & 90 DAT**			
1	A_1 - Rooted cuttings in ridge and furrow	1	B_1 - Gibberlic Acid (GA_3)- 100 ppm	6	B_6- Cycocel (CCC) -750 ppm
2	A_2 - Un rooted cuttings in ridge and furrow	2	B_2 - Gibberlic Acid (GA_3) - 150 ppm	7	B_7- Mepiquat Chloride (MC) - 500 ppm
3	A_3- Rooted cuttings in flat bed	3	B_3- Napthalene Acetic Acid (NAA) - 20 ppm	8	B_8- Mepiquat Chloride (MC) -750 ppm
4	A_4 - Un rooted cuttings in flat bed	4	B_4 - Napthalene Acetic Acid (NAA) - 30 ppm	9	B_9- Control – Water spray
		5	B_5 - Cycocel (CCC) -500 ppm		**Sub plot 2: Season**
					S_1:*Kharif*
					S_2: *Rabi*

Among the seasons, the effect of seasons on number of tubers was recorded to be significantly highest in *Kharif* (12.11) as compared to *Rabi* (7.97) and dry tuberous yield in medicinal coleus was significantly highest in *Kharif* (2.60 t/ha) as compared to R*abi* (1.59 t/ha). The reason for maximum number of tubers and yield in the *Kharif* could be due to light intensity, temperature and relative humidity influence crop growth and development. The maximum day temperature in rainy season was 31.85 ^{0}C, where as the night average temperature was 21.74 ^{0}C, however, winter season had maximum average temperature of 36.34 ^{0}C and night temperature was 16.35 ^{0}C. The average night temperature was very less in winter which have hindered the vegetative growth as well as the yield of the tubers.

The maximum average relative humidity in rainy season was 58.81%, whereas, winter season had maximum average relative humidity of 38.39 (%). Hence, optimum Relative humidity for the growth of medicinal coleus was in rainy season than winter.

Kharif has received average rainfall of about 77.83 mm where *Rabi* has not received rains. Water is the most important for the life of the plants where the crop have received sufficient

uptake of water in rainy season. Hence, the plant height, number of branches, number of leaves per plant, internodal length, leaf area and leaf area index were influenced by growing environment and was maximum in rainy season in all the treatments as compared to that of winter season. This may be due to enhanced photosynthesis and respiration due to the favourable micro-climatic conditions in the rainy season. The results of present study confirms the previous finding which describes that during winter, geranium subjected to night temperature stresses ended up producing low biomass yield because of reduction in levels of photosynthesis and damaging effects of solarisation (Mittal *et al.*, 2013) [4].

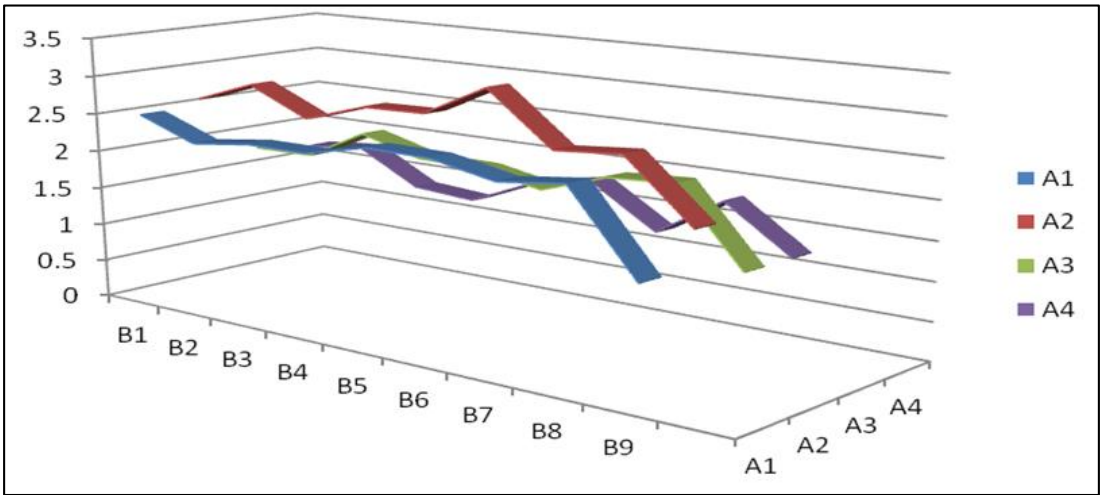

Fig 1a: Interaction effect of planting techniques with the type of cuttings and PGRs on dry tuberous yield (t/ha) (pooled yield)

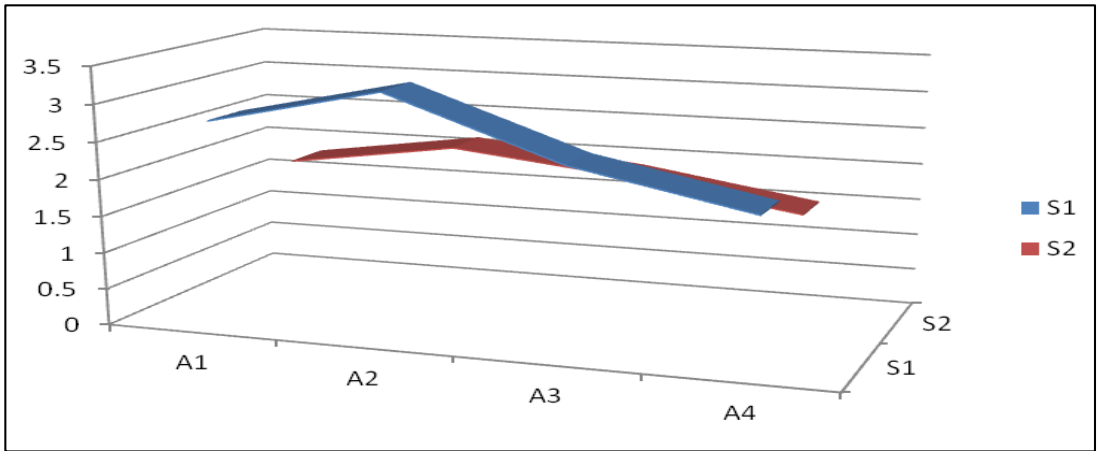

Fig 1b: Interaction effect of planting techniques with the type of cuttings and seasons (*Kharif* and *Rabi*, 2018-19) on dry tuberous yield (t/ha) in medicinal coleus

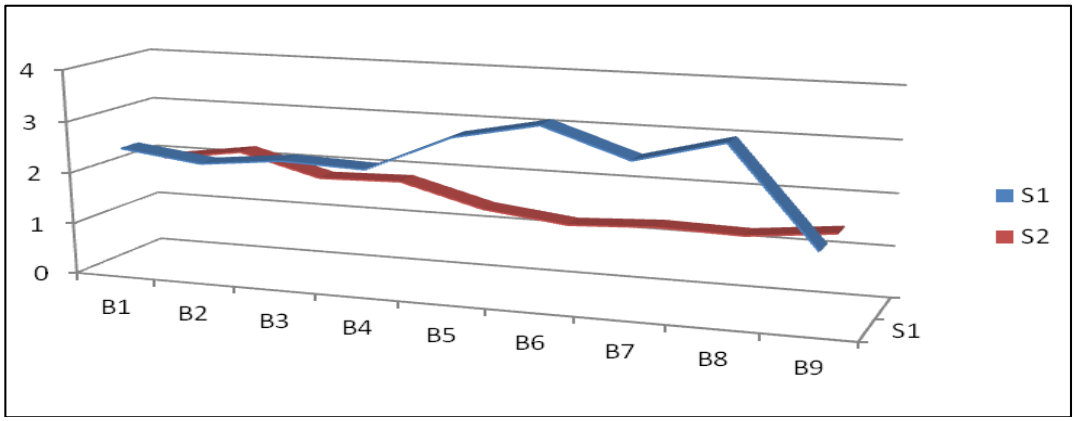

Fig 1c: Interaction effect of growth regulators and seasons (*Kharif* and *Rabi*, 2018-19) on dry tuberous yield (t/ha) in medicinal coleus

In addition, the interaction effect of planting techniques with the type of cuttings and seasons on number of tubers (AXS) was significantly maximum in A_2S_1- Un rooted cuttings in ridge and furrow in *Kharif* (16.31). This confirms that planting of un rooted cuttings in ridge and furrow in the *Kharif* was the favourable season. Further, the interaction effect of planting techniques with the type of cuttings and seasons *ie*., (AXS) was noticed to be non significant, which indicates that, there is no effect of season on the planting techniques with the type of cuttings. However, in the Fig.1b, it was observed that rooted and un rooted cuttings planted in the ridge and furrow method of planting had much influence

of rainy season than rooted and un rooted cuttings planted in the flat beds. However, there is no much effect of *rabi* on planting techniques with the type of cuttings.

The interaction effect of BXS *ie.,* Growth Regulators (B) and Seasons, maximum number of tubers were observed in B_6S_1 – Spray of CCC 750 ppm in *Kharif* (16.82), further, it was noticed that, the interaction effect of Growth Regulators (B) and Seasons on dry tuber yield was significantly maximum in B_6S_1 – Spray of CCC 750 ppm in *Kharif* (3.37 t/ha) and was on par with B_8S_1 (3.25 t/ha) - Spray of MC 750 ppm in *Kharif* In the Fig. 1c, it is clear that, there is no effect of seasons over the spray of growth regulators from B_1-B_4, where as growth retardants have higher effect of the *Kharif* season where maximum yield was obtained in the *Kharif* compared to the *Rabi*. The increase in number of tubers and dry tuber yield in B_6S_1– Spray of CCC 750 ppm in *Kharif* and B_8S_1 - Spray of MC 750 ppm in *Kharif* (3.25 t/ha) due to growth retardant could be attributed to increase in distribution of number of tubers per plant, length of tubers, volume of tubers, diameter of tubers, fresh weight and dry weight of tubers. It might be due to increase in the chlorophyll content and nitrate reductase activity due to growth retardants which also might have contributed for increase in yield and yield components in the *Kharif* season and season also plays a major role where the favourable season for the growth of good quality coleus was the rainy season as the optimum water, temperature, light and relative humidity are gained in the rainy season comparing to that of winter season.

Further, the interaction effect of planting techniques with the type of cuttings, PGRs and seasons (AXBXS) on number of tubers was noticed to be maximum in $A_2B_6S_1$ - Un rooted cuttings in ridge and furrow with the spray of CCC 750 ppm in the *Kharif* has obtained higher number of tubers and the interaction effect of planting techniques with the type of cuttings, PGRs and seasons on dry tuberous yield was noticed to be maximum in $A_2B_6S_1$ - Un rooted cuttings in ridge and furrow with the spray of CCC 750 ppm in the *Kharif* (4.66 t/ha) and was on par with $A_2B_8S_1$- Un rooted cuttings in ridge and furrow with the spray of MC 750 ppm in the *Kharif* (4.19 t/ha). Hence, planting of un rooted cuttings in ridge and furrow method of planting with the spray of CCC 750 ppm and also MC 750 ppm in the *Kharif* season can be suggested as the best treatments compared to others. The results are in confirmation with the findings of Sunilkumar (2005) in medicinal coleus, Radha Krishna, 2005 in medicinal coleus, Yang 1995 [16] in eucalyptus, John *et al.,* 2000 in pine, Pandita and Hooda, 1979 [7] and Sruthi *et al*., 2016 [13] have opined that, plant height, leaf area, and total biomass were significantly high in S2 (monsoon) in marigold.

Conclusion

Comparing Kharif and Rabi

The interaction effect of planting techniques with the type of cuttings, PGRs and seasons (AXBXS) recorded that, $A_2B_6S_1$ - Un rooted cuttings in ridge and furrow with the spray of CCC 750 ppm in the *Kharif* has obtained maximum dry tuberous yield.

To obtain maximum tuber yield in medicinal coleus, planting of un rooted cuttings in ridge and furrow method of planting along with CCC-750 ppm (Sprayed at 60 & 90 DAT) in *Kharif* can be suggested to farmers to cultivate medicinal coleus crop under Northern dry zone of Karnataka.

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