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Multilocation evaluation of induced mutants and soma clones of *Plectranthus barbatus* Andrews (= *Coleus forskohlii* (Wild) Briq.) on growth, yield and quality parameters

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Abstract

Evaluation of the mutants and soma clones under different location helped in identifying superior mutants for different morphological, yield and quality parameter. Mean values of six environments indicated that Mutant MV_7 recorded significantly maximum plant height, number of branches (71.63 cm; 48.23) which was superior over all other mutants and check variety K-8. For yield & quality parameters also mutant MV_7 has recorded maximum tuberous root length (29.17 cm), maximum fresh & dry tuberous root weight (666.81 g; 177.94 g, respectively) and produced maximum forskolin content (0.76%). Among locations, Bangalore location was more favorable for expression of maximum plant height, number of branches, number of leaves and leaf area at harvest (180 days) with mean value (67.73 cm; 48.34; 791.22 & 10465.75 cm^2, respectively) followed by Shimoga and Mandya. When yield parameters are considered, Bangalore location more favoured for maximum production of number of tuberous roots (17.83), tuberous root length (27.52 cm), root diameter (2.70 cm), fresh tuberous root weight (556.53 g) and dry tuberous root weight (143.77 g) & forskolin content (0.78 %). The superior mutant MV_7 was released as a variety "AISIRI" by State varietal release committee. Further, the mutant was also sent for registration to NBPGRI, New Delhi and a National ID- IC-547017 is also obtained and conserved at the Germplasm Conservation Centre, NBPGRI, New Delhi.

Key words: *Plectranthus barbatus* Andrews, mutants, somaclones, multilocation, forskolin, *AISIRI* variety

1. Introduction

Plants constitute one of the major sources of drug in traditional as well as modern medicine, almost throughout the world. These groups of plants are valuable source of income for a large number of small and marginal landholders in developing countries including India, provides raw materials for Pharmaceutical industries, thus earning foreign exchange.

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Due to the cumulative derogatory effect by the use of synthetic chemicals and antibiotics, during recent years, a definite trend in adoption of plant-based medicament is seen. Many of the plants are still collected from the wild. However, their indiscriminate collection has made the species vulnerable and is included in endangered list. Hence much importance is now given for the cultivation of medicinal plants. One such plant which is attaining economic importance in recent times is *Plectranthus barbatus* Andrews (Syn: *Coleus barbatus* Benth, belonging to family Labiatae (Lamiaceae). Commonly known as *Pashanbehdi* in Sanskrit, *Patharchur* in Hindi, *Makkandiberu* or *Manganaberu* in Kannada. It is one of the most significant potential medicinal crops of future as its pharmacopoeial properties have been discovered only recently. Its tuberous roots are found to be rich source of forskolin (syn. Coleonol) and is developed as a drug for hypertension, glaucoma, asthma, congestive heart failure and certain types of cancers. The plant is widely distributed all over the tropical and subtropical regions of India, Pakistan, SriLanka, Tropical East Africa, Brazil, Egypt, Arabia and Ethiopia.

In India, it is found in the sub tropical Himalayan regions from Kumaon to Nepal upto an altitude of 2400 m, Bihar and the Deccan Plateau of Southern India. It is cultivated in parts of Rajasthan, Maharashtra, Karnataka and Tamil Nadu in an area of about 2500 hectares.

Like any other crop in *Plectranthus barbatus* Andrews also, there is large variation with regard to plant growth, root yield and forskolin content. Genotypes show wide fluctuations in their yielding ability when grown in different environments. The capacity of a crop to perform well over a range of environment is important as its yield potential per se. It is especially so when the crop is grown over wide range of environmental conditions. Realizing the importance and need for such a comprehensive study in *Plectranthus barbatus* Andrews, an important upcoming medicinal crop which has great demand from pharmaceutical industries as it is used for various medicinal purposes. Hence the present investigation was undertaken with the following objective "To test the adaptability & performance of superior mutants and soma clones of *Plectranthus barbatus* Andrews on growth, yield and forksholin content in agro climatic zones of 5, 6 and 7 of Karnataka state".

2. Materials & Methods

The present study on "Evaluation of induced mutants and somaclones of *Plectranthus barbatus* Andrews for tuberous root yield and forskolin content" was undertaken by adopting multi-location trials at Sugandhavana, Medicinal and Aromatic section, Division of Horticulture, University of Agricultural Sciences, GKVK Bangalore (Zone-5), Zonal Agricultural Research Station, V.C.Farm, Mandya (Zone-6) and Agricultural Research Station, Honnavile, Shimoga (Zone-7). Material used in the study comprised of 9 induced mutants, 2 somaclonal mutants and one check K-8 which are developed in the Division of Horticulture. The procedure followed to do mutation is gamma-irradiation using cobalt-60 as source [1]. 800 tip cuttings of 15 cm length with 2-3 nodes of each accession were made. The cuttings were planted in polythene bags filled with pot mixture after the cuttings were dipped in Bavistin solution (2 g/l) to avoid initial infection of bacterial wilt. Polybags were kept inside polyhouse for rooting, daily irrigation was provided upto 45 days, after which the plants were ready for transplanting with well established root system. The main field was brought into fine tilth by ploughing twice and harrowing. Later the main field was laid out

Table 1. Plant height and Number of branches/ plant in Plectranthus barbatus mutants and somaclones in different locations and seasons at harvest

Mutant	Plant height (cm)									No. of Branches per plant								
	Bangalore			Mandya			Shimoga			Bangalore			Mandya			Shimoga		
	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean
MV_1	61.31	69.86	65.59	35.45	48.22	41.84	47.19	51.43	49.31	51.34	53.38	52.36	26.63	35.13	30.88	34.46	44.67	39.57
MV_2	54.89	59.47	57.18	30.43	40.23	35.33	54.29	55.61	54.95	46.25	51.29	48.77	25.34	29.63	27.49	32.54	41.38	36.96
MV_3	49.84	57.71	53.78	32.00	44.93	38.47	48.16	51.16	49.66	50.92	44.63	47.78	23.50	27.13	25.32	28.34	42.13	35.24
MV_4	66.68	76.45	71.57	38.79	52.61	45.70	48.08	64.00	56.04	49.75	58.42	54.09	18.96	31.42	25.19	39.50	40.30	39.90
MV_5	63.14	84.54	73.84	43.45	62.84	53.15	55.02	72.99	64.01	52.96	56.59	54.78	21.17	33.88	27.53	43.71	51.50	47.61
MV_6	58.74	54.75	56.75	29.88	49.48	39.68	51.87	50.50	51.19	43.08	47.96	45.52	20.34	34.46	27.40	33.42	38.71	36.07
MV_7	68.12	92.15	80.14	55.21	76.10	65.66	57.74	80.47	69.11	46.41	52.50	49.46	37.59	52.79	45.19	47.38	52.71	50.05
MV_8	70.00	73.24	71.62	35.34	64.70	50.02	47.84	51.47	49.66	44.54	46.63	45.59	22.13	30.17	26.15	36.09	39.54	37.82
MV_9	68.19	61.90	65.05	28.31	44.03	36.17	44.69	52.62	48.66	40.50	43.38	41.94	19.54	21.09	20.32	30.59	41.63	36.11
SV_1	70.60	102.93	86.77	34.00	54.37	44.19	44.99	74.01	59.50	48.71	54.25	51.48	18.13	35.24	26.69	40.21	47.05	43.63
SV_2	63.20	64.62	63.91	29.69	46.77	38.23	43.63	52.40	48.02	44.58	46.29	45.44	18.84	22.63	20.74	25.25	39.88	32.57
K-8	58.43	74.65	66.54	28.48	48.94	38.71	43.07	51.54	47.31	38.63	47.21	42.92	16.21	25.05	20.63	34.84	38.79	36.82
Mean	62.76	72.69	67.73	35.09	52.77	43.93	48.88	59.02	53.95	46.47	50.21	48.34	22.37	31.55	26.96	35.53	43.19	39.36
SEm±	2.55	3.22		1.24	0.75		1.74	1.11		3.39	1.37		1.22	1.44		1.36	1.21	
CD	6.18	7.81		3.00	2.08		4.22	2.67		NS	3.33		2.94	2.06		3.30	2.92	
CV(%)	7.04	7.68		6.12	5.04		6.18	3.25		12.63	4.73		9.40	7.89		6.63	4.84	

Table 2. Number of leaves / plant and leaf area in Plectranthus barbatus mutants and somaclones in different locations and seasons at harvest

Mutant	Number of leaves per plant									Leaf area (cm^2)								
	Bangalore			Mandya			Shimoga			Bangalore			Mandya			Shimoga		
	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean
MV_1	876.5	685.54	781.05	677.54	552.25	614.90	646.42	715.33	680.88	10415.97	10109.45	10262.71	8009.82	8263.24	8136.53	9006.00	10167.46	9586.73
MV_2	858.0	734.13	796.07	581.46	634.25	607.86	619.05	747.79	683.42	9918.06	10834.74	10376.40	7746.01	9672.53	8709.27	8222.16	9612.73	8917.45
MV_3	956.3	865.88	911.13	668.21	705.15	686.68	626.21	703.92	665.07	11391.07	10613.32	11002.20	7610.17	8382.24	7996.21	8521.37	9220.91	8871.14
MV_4	965.6	640.42	803.03	700.67	671.92	686.30	593.59	726.54	660.07	13406.34	11387.66	12397.00	7491.49	9235.98	8363.74	10161.0	9031.75	9596.42
MV_5	963.8	753.00	858.40	663.04	743.00	703.02	660.96	698.63	679.80	10667.00	10579.54	10623.27	8446.52	9623.09	9034.81	8566.48	9302.37	8934.43
MV_6	884.7	661.31	773.03	601.59	638.42	620.01	608.54	637.80	623.17	10219.61	9531.17	9875.39	7017.60	8081.38	7549.49	9228.49	8892.54	9060.52
MV_7	911.5	773.67	842.59	686.67	594.04	640.36	697.30	689.92	693.61	11665.26	9993.61	10829.44	8827.72	9051.6	8939.66	10802.27	8734.79	9768.53
MV_8	873.8	567.34	720.59	710.25	644.67	677.46	608.42	719.29	663.86	10337.38	9314.72	9826.05	7793.44	7995.50	7894.47	8516.26	8366.60	8441.43
MV_9	978.5	604.63	791.57	539.13	674.04	606.59	558.71	586.46	572.59	11184.09	10030.35	10607.22	7221.76	8117.71	7669.74	8200.76	9441.00	8820.88
SV_1	820.2	675.55	747.90	678.00	724.25	701.13	636.29	656.05	646.17	8784.60	10452.48	9618.54	8585.91	9433.08	9009.50	8376.11	10328.17	9352.14
SV_2	931.7	687.17	809.48	493.33	529.92	511.63	660.29	705.38	682.84	10486.32	11119.64	10802.98	6909.34	7960.14	7434.74	8125.89	9004.43	8565.16
K-8	743.5	576.05	659.80	612.79	637.63	625.21	521.05	692.67	606.86	8900.84	9834.81	9367.83	8209.69	8444.74	8327.22	8146.66	8614.42	8380.54
Mean	897.0	685.39	791.22	634.39	645.80	640.09	619.74	689.98	654.86	10614.71	10316.79	10465.75	7822.46	8688.44	8255.45	8822.80	9226.43	9024.61
SEm±	106.0	64.98		9.26	17.40		39.35	13.52		904.17	303.63		167.20	334.81		311.54	446.75	
CD	NS	NS		22.47	42.23		NS	32.82		NS	737.27		405.98	812.98		756.49	NS	
CV(%)	20.4	16.42		2.53	4.67		10.99	3.39		4.67	5.09		3.70	6.67		6.11	8.38	

Table 3. Number of tuberous root & Tuberous root length per plant in Plectranthus barbatus mutants and somaclones in different locations and seasons at harvest

Mutant	No. of tuberous root per plant									Tuberous root length (cm) per plant								
	Bangalore			Mandya			Shimoga			Bangalore			Mandya			Shimoga		
	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean	E1	E2	Mean
MV_1	16.83	17.38	17.11	8.55	10.00	9.28	10.75	13.04	11.90	23.39	26.83	25.11	17.67	19.13	18.40	17.77	14.24	16.01
MV_2	14.33	16.75	15.54	13.20	12.75	12.98	10.71	11.96	11.34	21.24	25.32	23.28	16.13	17.49	16.81	19.74	21.90	20.82
MV_3	17.67	18.46	18.07	10.92	9.71	10.32	11.38	12.04	11.71	24.53	21.74	23.14	14.48	18.30	16.39	21.81	19.25	20.53
MV_4	16.75	21.50	19.13	8.75	13.92	11.34	10.34	10.79	10.57	26.48	33.92	30.20	14.31	15.90	15.11	19.61	23.74	21.68
MV_5	20.46	26.21	23.34	13.88	16.13	15.01	13.76	22.80	18.28	28.78	38.13	33.46	20.25	30.23	25.24	22.66	29.48	26.07
MV_6	16.25	18.67	17.46	7.21	7.58	7.40	9.59	11.21	10.40	26.79	28.06	27.43	14.91	18.69	16.80	18.19	19.49	18.84
MV_7	17.62	21.21	19.42	16.96	17.46	17.21	15.96	17.96	16.96	27.30	34.71	31.01	25.95	30.12	28.04	26.15	30.77	28.46
MV_8	15.79	14.84	15.32	6.50	9.75	8.13	10.30	10.13	10.22	25.89	28.61	27.25	14.66	17.44	16.05	21.55	27.95	24.75
MV_9	14.33	17.00	15.67	7.04	10.25	8.65	9.84	8.59	9.22	25.29	26.29	25.79	13.35	15.95	14.65	16.27	22.00	19.14
SV_1	16.75	23.04	19.90	10.54	14.25	12.40	13.30	15.29	14.30	29.43	33.12	31.28	26.96	27.85	27.41	26.04	29.17	27.61
SV_2	15.87	16.17	16.02	8.05	10.96	9.51	9.79	9.75	9.77	26.08	27.75	26.92	11.85	16.96	14.41	21.24	23.51	22.38
K-8	16.54	17.42	16.98	7.33	9.50	8.42	10.67	10.96	10.82	24.23	26.66	25.45	13.15	16.44	14.80	21.77	22.39	22.08
Mean	16.60	19.05	17.83	9.91	11.86	10.88	11.37	12.88	12.12	25.79	29.26	27.52	16.97	20.38	18.67	21.07	23.66	22.36
SEm±	1.22	1.39		0.80	0.75		0.57	0.73		1.61	1.85		1.01	1.18		1.12	1.21	
CD	NS	3.38		1.92	1.82		1.39	1.77		NS	4.48		2.46	2.85		2.70	2.92	
CV(%)	12.76	12.68		13.95	11.01		8.72	9.82		10.83	10.96		10.33	10.01		9.16	8.84	

Table 4. Tuberous root diameter & Fresh tuberous root weight per plant in Plectranthus barbatus mutants and somaclones in different locations and seasons at harvest

Mutant	Tuberous root diameter (cm) per plant									Fresh tuberous root weight (g) per plant								
	Bangalore			Mandya			Shimoga			Bangalore			Mandya			Shimoga		
	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean
MV_1	2.41	2.84	2.63	1.72	2.06	1.89	1.88	2.32	2.10	448.83	598.29	523.56	275.84	351.88	313.86	367.59	440.96	404.28
MV_2	2.28	2.94	2.61	2.01	2.12	2.07	2.12	2.38	2.25	410.63	480.59	445.61	210.00	298.79	254.40	317.55	402.21	359.88
MV_3	2.25	2.47	2.36	1.55	2.32	1.94	2.09	2.05	2.07	363.33	564.09	463.71	212.88	311.50	262.19	398.63	439.50	419.07
MV_4	2.26	3.84	3.05	1.70	1.98	1.84	2.19	2.45	2.32	605.75	743.88	674.82	297.84	346.84	322.34	461.46	572.64	517.05
MV_5	2.71	3.87	3.29	2.11	2.67	2.39	2.67	3.57	3.12	714.42	798.17	756.30	310.88	433.75	372.32	559.54	684.00	621.77
MV_6	2.26	2.79	2.53	1.70	1.93	1.82	2.04	2.03	2.04	501.59	643.33	572.46	198.29	261.21	229.75	330.67	415.04	372.86
MV_7	2.58	3.50	3.04	2.89	2.95	2.92	2.55	3.09	2.82	739.50	758.96	749.23	557.46	597.92	577.69	620.46	726.54	673.50
MV_8	2.00	2.61	2.31	1.54	1.84	1.69	1.82	2.19	2.01	537.67	551.38	544.53	189.92	259.83	224.88	239.00	362.71	300.86
MV_9	2.38	2.66	2.52	1.44	1.83	1.64	1.73	2.34	2.04	364.71	417.58	391.15	190.21	281.46	235.84	301.13	346.33	323.73
SV_1	2.35	3.58	2.97	2.89	2.77	2.83	2.40	2.93	2.67	659.04	728.42	693.73	434.21	500.17	467.19	501.84	644.58	573.21
SV_2	2.56	2.58	2.57	1.95	1.91	1.93	2.01	2.53	2.27	370.21	520.09	445.15	316.21	197.17	256.69	158.09	253.29	205.69
K-8	2.33	2.75	2.54	1.58	1.69	1.64	2.00	2.29	2.15	388.08	448.25	418.17	197.38	285.79	241.59	278.25	329.34	303.80
Mean	2.36	3.04	2.70	1.92	2.17	2.05	2.13	2.51	2.32	508.65	604.42	556.53	282.59	343.86	313.23	377.85	468.10	422.97
SEm±	NS	**		**	**		**	**		17.73	22.13		33.81	16.77		14.95	14.49	
CD	NS	3.38		1.92	1.82		1.39	1.77		43.04	53.74		82.09	39.99		36.30	35.18	
CV(%)	12.76	12.68		13.95	11.01		8.72	9.82		6.03	6.34		20.72	8.30		6.85	5.36	

Table 5. Dry tuberous root weight per plant & Forskolin content (%) in Plectranthus barbatus mutants and somaclones in different locations and seasons at harvest

Mutant	Dry tuberous root weight (cm) per plant									Forskolin content (%)								
	Bangalore			Mandya			Shimoga			Bangalore			Mandya			Shimoga		
	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean	E_1	E_2	Mean
MV_1	123.96	138.88	131.42	77.29	113.16	95.23	83.64	124.79	104.22	0.74	0.87	0.81	0.56	0.80	0.68	0.48	0.55	0.52
MV_2	123.39	131.40	127.40	73.68	88.58	81.13	113.93	134.80	124.37	0.69	0.88	0.79	0.61	0.77	0.69	0.60	0.74	0.67
MV_3	132.93	151.44	142.19	70.22	120.86	95.54	126.36	138.87	132.62	0.70	0.86	0.78	0.61	0.76	0.69	0.59	0.75	0.67
MV_4	143.20	166.01	154.61	82.27	97.82	90.05	128.11	152.46	140.29	0.73	0.90	0.82	0.65	0.71	0.68	0.48	0.67	0.58
MV_5	171.21	219.61	195.41	111.75	154.12	132.94	144.67	203.28	173.98	0.81	1.06	0.94	0.52	0.70	0.61	0.47	0.52	0.50
MV_6	100.17	152.63	126.40	65.69	94.23	79.96	97.82	118.42	108.12	0.70	0.85	0.78	0.69	0.72	0.71	0.60	0.78	0.69
MV_7	169.16	208.33	188.75	147.69	162.81	155.25	166.13	213.52	189.83	0.72	0.95	0.84	0.53	0.81	0.67	0.71	0.83	0.77
MV_8	127.63	148.66	138.15	66.04	105.59	85.82	87.88	98.76	93.32	0.66	0.75	0.71	0.56	0.76	0.66	0.79	0.94	0.87
MV_9	115.82	104.87	110.35	48.82	95.97	72.40	91.45	93.46	92.46	0.66	0.85	0.76	0.37	0.75	0.56	0.62	0.66	0.64
SV_1	160.48	203.90	182.19	126.3	150.85	138.58	157.75	212.99	185.37	0.62	0.91	0.77	0.59	0.73	0.66	0.61	0.68	0.65
SV_2	100.71	119.45	110.08	61.70	87.46	74.58	85.79	87.90	86.85	0.67	0.80	0.74	0.48	0.62	0.55	0.68	0.85	0.77
K-8	125.69	110.91	118.30	74.33	116.79	95.56	96.11	117.89	107.00	0.70	0.73	0.72	0.54	0.61	0.58	0.65	0.70	0.68
Mean	132.86	154.67	143.77	83.82	115.69	99.75	114.97	141.43	128.20	0.70	0.87	0.78	0.56	0.73	0.64	0.61	0.72	0.66
SEm±	6.26	5.54		3.64	4.68		4.31	3.16		0.01	0.02		0.01	0.01		0.01	0.01	
CD	15.20	13.44		8.84	11.35		10.45	7.67		43.04	53.74		82.09	39.99		36.30	35.18	
CV(%)	8.16	6.20		7.53	7.00		6.49	3.87		6.03	6.34		20.72	8.30		6.85	5.36	

into required plot size of 2.4 x 2.4 m^2. Basal FYM @ 10 t ha^{-1} was applied to the plots and thoroughly mixed. The experiments involving twelve treatments replicated three times were laid out in Randomized Complete Block Design. Before transplanting, the plots were laid into ridges and furrows at a spacing of 60 cm between rows. The rooted cuttings of 45 days were transplanted during evening hours at spacing of 40 cm between plants. Transplanting was done during month of November for first crop and during June for second crop in Bangalore (Zone-5) and in other 2 locations (Zone-6 and Zone-7). The recommended dosage of 40:60:50 kg NPK ha^{-1} was applied in the form of Urea, Single Super Phosphate and Muriate of Potash. 50 per cent of Nitrogen, full dose of phosphorus and potash were applied at the time of transplanting as basal dose and remaining 50 per cent of nitrogen was applied one month after transplanting. Initial irrigation was provided at interval of 3 days, later 4 days depending on soil moisture condition and weather. Observations on growth parameters were recorded at 60 days interval till the time of harvest (180 days). At 180 days, observations on yield and yield attributes were recorded. Lab analysis was conducted at M/s Himalaya Drug Company, Bangalore during 2005-2007. The data obtained for 10 quantitative characters and one qualitative character on 9 mutants and 2 somaclonal mutants and the check K-8 over 3 locations and 2 seasons were subjected to two way analysis of variance using the method outlined by [2].

3. Results & Discussion

3.1. Growth parameters

Genotypes express fluctuations in their performance in different environments. E_1 refers to Rabi/Summer season (Nov. 2005-May 2006) crop and E_2 refers to the Kharif season (June 2006-Dec. 2006) respectively. Mutant SV_1 recorded significantly maximum plant height (70.60 cm: 102.93 cm) in Bangalore location, during E_1 & E_2 season, respectively when compared to other mutants and check variety K-8 (58.43 cm; 74.65 cm) (Table 1). Significantly maximum plant height under Mandya and shimoga location during both E_1 & E_2 season was recorded by mutant MV_7 (55.21; 76.10 cm; 57.74; 80.47 cm, respectively) When mean values of six environments were considered, significantly maximum grand mean plant height was recorded by mutant MV_7 (71.63 cm) which was superior over all to mutant and check variety K-8 (50.85). Among locations, Bangalore was more favourable for expression of plant height at harvest with mean value (67.73 cm) followed by Shimoga and Mandya (Table1). The variation in plant height at harvest could be due to inherent differences existing among the mutants and the environment and presence of apical dominance. The results are in conformity with the findings of [3] and [4]. Significant differences for number of branches across locations and seasons were observed (Table 1). As indicated by the environment mean E_2 season was more favourable season for production of number of branches in all the three locations. Among the location when combined mean values were considered, Bangalore location favoured the production of number of branches as it is proved by high mean value (48.34) followed by Shimoga (39.36) and Mandya (26.96) location.

On overall performance, when mean values of six environment was considered, the significantly maximum number of branches was recorded in mutant MV_7 (48.23) and minimum number of branches was recorded by MV_9 (32.91) mutant. Intrinsic potential and the robust nature of the genotype are

responsible for the difference in growth pattern and favourable environment are influenced for their potential expression of the mutant. Similar results were obtained by [5] in Coleus.

Under Bangalore location both the season showed non-significant difference for number of leaves (Table 2). E_2 season was more favorable for production of number of leaves at Mandya and shimoga location. Mutant MV_5 under Mandya location and mutant MV_7 at shimoga location has produced maximum number of leaves (703.02; 693.61), respectively. When mean values of combined season was considered, Bangalore location favoured for more production of number of leaves (791.22). On overall performance, when mean average values of six environment was considered MV_3 produced maximum number of leaves (754.29) which was on par with rest of the mutants. More number of leaves would mean larger leaf area causing higher photosynthetic area and therefore, the mutant has responded well to environment and produced maximum number of leaves. Similar observation was observed by [5] & [6] in coleus. E_2 season, favored more for maximum expression of leaf area in all the three locations. Among locations, when combined values was considered Bangalore location was more favourable for maximum leaf area (10465.75) expression. On overall performance, when mean values of six environments was considered MV_4 recorded maximum leaf area per plant (10119.05 cm^2). Minimum leaf area was recorded in K-8 (8691.86 cm^2). A large leaf area confers several advantages such as increased allocation of photo assimilates to alkaloid synthesis and thus increasing overall yield component. The results are in line with those obtained by [7] & [5].

3.2. Yield parameters

E_2 season favored production of more number of tuberous roots in all the three locations (Table 3). Among mutants, when combined mean values was considered significantly maximum number of tuberous root was produced by mutant MV_5 (23.34) in Bangalore, MV_7 (17.21) in Mandya and MV_2 (12.98) in Shimoga locations. When mean values of over locations is considered, Bangalore location favoured production of maximum number of tuberous root (17.83) followed by Shimoga (12.12) and Mandya (10.88) location. On overall performance, when mean values of six environments was considered, mutant M_5 has recorded maximum number of tuberous roots (18.87) which was on par with MV_7 (17.86) and least number of roots were harvested in MV_9 (11.18) mutant (Table 3). With respect to tuberous root length, E_2 season is more favourable for the production of maximum length of tuberous root in all the locations. MV_5 mutant produced significantly maximum root length (33.46 cm) at Bangalore, whereas mutant MV_7 favoured the expression of maximum tuberous root length of 28.04 cm and 28.46 cm at Mandya and Shimoga locations, respectively. When combined means of location was considered Bangalore location was more favoured for expression of maximum tuberous root length (27.52 cm) followed by Shimoga (22.36 cm) and Mandya (18.67 cm) location (Table 3).

On overall performance when mean values of six environments were considered, mutant MV_7 has produced maximum tuberous root length (29.17 cm).

In all the three locations, E_2 season was more favoured for the maximum expression of tuberous root diameter (Table 4). When combined mean for locations was considered,

Bangalore location was most favourable for the production of maximum tuberous root diameter (2.70 cm) followed by Shimoga (2.32 cm) and Mandya (2.05 cm) location. On overall performance, when values of six environment was considered, mutant MV_5 expressed maximum tuberous root diameter (2.93 cm) which was on par with MV_7 (2.93 cm). With respect to fresh tuberous root weight per plant, E_2 season mostly favored for the production of maximum fresh tuberous root weight in all the three locations (Table 4). Among the mutants studied in two seasons, mutant MV_5 has produced maximum fresh tuberous root weight per plant 756.30 g under Bangalore location Whereas under Mandya & Shimoga location mutant MV7 produced maximum fresh tuberous root weight (577.69; 673.50 g, respectively). When combined mean was considered Bangalore location was more favoured for the production of maximum fresh tuberous root weight (556.53 g) per plant. On overall performance, when values of six environments were considered, mutant MV_7 has produced maximum fresh tuberous root weight (666.81 g). Maximum dry tuberous root weight per plant was most favoured by E_2 season in all the three locations (Table 5). The combined mean average value was considered Bangalore location was more favoured for maximum dry tuberous root weight (143.77g) followed by Shimoga (128.20 g) and Mandya (99.75 g) location. On overall performance, when mean of six environments was considered, mutant MV_7 has recorded maximum dry tuberous root weight (177.94 g). Minimum dry tuberous root weight was recorded in mutant SV_2 (90.50 g) per plant. Maximum production of forskolin content was favoured by the E_2 season in all the three locations (Table 5). When combined mean values of both the seasons are considered under each location, Bangalore location was more favoured for maximum production of forskolin content (0.78%) followed by Shimoga (0.66%) and Mandya (0.64%) location. On overall performance, when mean values of six environments was considered, non-significant differences were found across the location and mutants, this may be due to the narrow range of forskolin content among mutants. However, mutant MV_7 produced maximum forskolin content (0.76%). It could be due to the inherent difference among the mutants because of their genetic makeup. It is clear from the results that the yield and quality parameters varied among the mutants and within the environment and season. Similar findings were recorded by [7], [9], [10], [8] &[5] .

The results of the present investigation thus can be summarized that the outstanding mutant MV_7 has performed well in all the three agro-climatic zones (viz. Zone-5, Zone-6 and Zone-7) of Karnataka producing high tuberous root yield and forskolin content against check genotype. The superior mutant MV_7 was released as a variety “AISIRI” by State varietal committee. Further, the mutant was also sent for registration to NBPGRI, New Delhi and a National ID- IC-547017 is also obtained and conserved at the Germplasm Conservation Centre, NBPGRI, New Delhi.

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