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Effect of Integrated Nutrient Management on Tuber Yield and Quality and Nutrient Uptake in *Coleus forskohlii* Briq.

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Abstract

A field experiment was conducted at Arabhavi located in the Western dry zone of Karnataka on a clay loam soil during kharif seasons of 2006 and 2007 to study the effect of biofertilizers in combination with organic manures and inorganic fertilizers on dry matter production, tuber yield and quality, nutrient uptake and economics in coleus (*Coleus forskohlii* Briq.) (cv. K-8). Recommended dose of FYM @ 15 t ha^{-1} and NPK @ 40:60:50 kg ha^{-1} along with 10 kg ha^{-1} each of *Azotobacter crucocum, Bacillus megateruim* (phosphorus solubilising bacteria) and *Glomus fasciculatum* (vesicular arbuscular mycorrhiza) produced significantly higher dry weight of leaves (70.21 g), stem (138.38 g), tuber (39.39 g), total dry weight (247.98 g) per plant, leaf dry matter (15.00%), stem dry matter (16.97%), tuber dry matter (14.02%), forskolin content (0.76%), uptake of N (115.83 kg ha^{-1}), P (49.59 kg ha^{-1}) and K (151.55 kg ha^{-1}), net returns (Rs. 39065 ha^{-1}) and B:C ratio (1.95).

Key words : *Coleus forskohlii*, dry matter production, tuber yield, forskolin, biofertilizers, nutrient uptake, B:C ratio

Introduction

Among the various commercially important medicinal plants, coleus (*Coleus forskohlii* Briq., Syn. *Coleus barbatus* Benth., *Plectranthus forskohlii* Willd.) is an economically important medicinal plant belonging to the family Lamiaceae. It has great value in the Indian drug industry. Being indigenous to India, *C. forskohlii* became prominent by virtue of being an exclusive source of forskolin (syn. coleonol), which is a diterpene compound (Shah et al., 1980). Forskolin present in its tubers is valued for its efficacy in the treatment of glaucoma, congestive cardiomyopathy, asthma, certain cancers etc. Recently, a sudden demand for forskolin from Europe, America and Japan for use in cosmetics has created a great demand for coleus in India for its tubers. Modern nutrient management strategy has shifted its focus towards the concept of sustainability and eco-friendliness. Continuous application of heavy doses of chemical fertilizers without organic manures or biofertilizers has led to a deterioration of soil health in terms of physical and chemical properties of soil, declining soil microbial activities, reduction in soil humus, increased pollution of soil, water and air. Some of the biofertilizers, viz., *Azotobacter* (AZT), vesicular arbuscular mycorrhiza (VAM) and phosphorus solubilising bacteria (PSB) are known to increase the yield and quality of crops. Hence, considering the safety of the environment and to maintain better soil health, it is imperative that plant nutrients are applied effectively by adopting the integrated nutrient management practices. Keeping this in view, an investigation was carried out to study the effect of biofertilizers in combination with organic manures and inorganic fertilizers on dry matter production, tuber yield and quality, uptake of N, P and K, soil nutrient status and economics in coleus.

Materials and Methods

The investigations were carried out at the Department of Medicinal and Aromatic Plants, Kittur Rani Channamma College of Horticulture, Arabhavi, Karnataka, geographically situated at 16°15’ N and 94°45’ E longitude and at an altitude of 612 m above mean sea level during kharif 2006 and 2007. The experimental site had clay loam soil with a pH of 7.6. The soil had low available N status (137.85 kg ha^{-1}) and high available P and K contents (34 and 225 kg ha^{-1} respectively). The total rainfall received during 2006 and 2007 was 387.6 and 329.62 mm, respectively, as against the normal rainfall of 406.9 mm per year. Maximum temperature of 37.1°C and minimum temperature of 11.7°C were recorded during April and January months, respectively, during 2006. The relative humidity ranged between 27.10 and 90.50% during 2006. Maximum temperature of 37.54°C and minimum temperature of 12.64°C were recorded during May and January months, respectively, during 2007. The relative humidity ranged from 38.57 to 96.48% during 2007. Surface soil samples (0-30 cm) collected before transplanting and after harvest of the crop were analysed for pH, available N, P and K by standard procedures. Dried plant samples were ground to a fine powder and were analysed for major nutrients as outlined by Piper (1966).

The experiment was laid out in Randomised Block Design and replicated thrice. The treatments comprised of:

- T_1 – Recommended dose (RD) of farmyard manure (FYM) @15 t ha^{-1} and NPK @ 40:60:50 kg ha^{-1}
- T_2 – RD FYM alone
- T_3 – RD FYM + vesicular arbuscular mycorrhiza (VAM) @10 kg ha^{-1}
- T_4 – RD FYM + VAM + 80% P + NK
- T_5 – RD FYM + VAM + 60% P + NK
- T_6 – RD FYM + phosphorus solubilising bacteria (PSB) @ 10 kg ha^{-1}
- T_7 – RD FYM + PSB + 80% P + NK
- T_8 – RD FYM + PSB + 60% P + NK
- T_9 – RD FYM + PSB + VAM + 70% P + NK
- T_{10} – RD FYM + PSB + VAM + 50% P + NK
- T_{11} – RD FYM + RD NPK + *Azotobacter* (AZT) @ 10 kg ha^{-1} + PSB @ 10 kg ha^{-1} + VAM @ 10 kg ha^{-1}
- T_{12} – RD FYM + AZT + PSB + VAM
- T_{13} – RD FYM + neem cake (NC) @ 1 t ha^{-1} + AZT + PSB + VAM
- T_{14} – Vermicompost (VC) @ 1 t ha^{-1}
- T_{15} – VC + VAM
- T_{16} – VC + PSB

The biofertilizers used in this experiment were *Glomus fasciculatum* (VAM), *Bacillus megaterium* (PSB) and *Azotobacter crucocum* (AZT). Thirty day old, healthy and uniformly rooted plants were transplanted to the main field at a spacing of 60 cm between rows and 40 cm between plants. Estimation of total N, P and K in FYM, neem cake and vermicompost was done following standard procedures (Jackson, 1973). The FYM contained 0.70% N, 0.63% P_2O_5 and 1.27% K_2O. The neem cake had 1.30% N, 0.20% P_2O_5 and 1.43% K_2O. The vermicompost had 0.80% N, 0.51% P_2O_5 and 0.46% K_2O. Forskolin content of pooled dried and powdered tubers was estimated using High Pressure Liquid Chromatography (HPLC). The data on dry matter production, tuber yield and quality, uptake of N, P and K, available N, P and K status of soil were subjected to Fisher’s method of analysis of variance (ANOVA) (Sundararaj et al., 1972).

Results and Discussion

Dry matter production and yield

In the present study, the total dry matter production and its partitioning to leaf, stem and tuber were significantly influenced by the application of VAM and PSB with organic manures and fertilizers (Fig. 1). The recommended dose (RD) of FYM and NPK + AZT + PSB + VAM (T_{11}) resulted in plants with significantly higher leaf (15.00%), stem (16.97%) and tuber dry matter contents (14.02%), dry weight of leaves (70.21 g), stem (138.38 g) and aerial parts (208.58 g) as well as total dry weight (247.98 g) per plant. Increase in leaf, stem and tuber dry matter by 10.5-11% over control could be attributed to the effective functioning of AZT, PSB and VAM, which produced bio-active substances showing similar effect as that of growth regulators, which helped in better uptake and utilisation of nutrients for promoting plant growth. The results are in conformity with the findings of Ravi (2004) in coleus, Rameshbabu (1996) in *Ashwagandha* and Velmurugan et al. (2008) in turmeric. The dry weight (83.46 g plant $^{-1}$) was least in

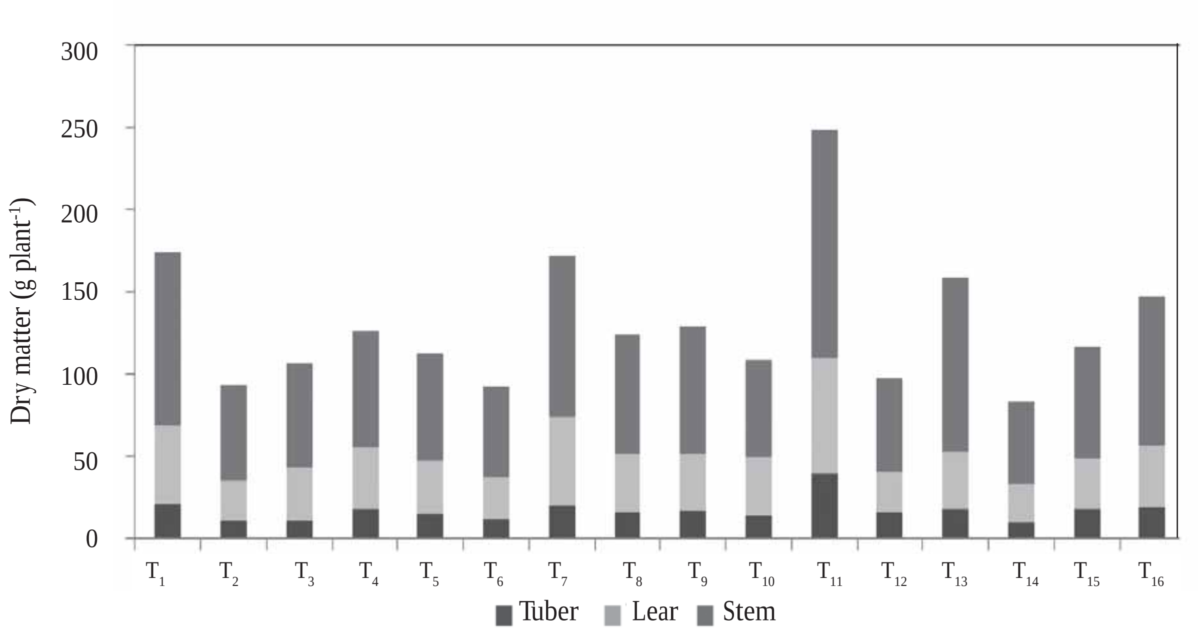

Fig. 1. Dry matter production and partitioning as influenced by integrated nutrient management in *Coleus foskohlii*

Table 1. Tuber yield and quality parameters as influenced by integrated nutrient management in *Coleus forskohlii*

Treatments	Dry weight of tubers (g plant^{-1})	Mean tuber dry weight (g tuber^{-1})	Tuber yield (dry wt. basis) (t ha^{-1})	Dry matter content of tubers (%)	Forskolin (%, w/w)	Forskolin yield (kg ha^{-1})
T_1	21.81	2.12	0.88	12.69	0.50	4.38
T_2	11.56	1.76	0.46	10.83	0.45	2.07
T_3	11.63	1.52	0.47	11.29	0.50	2.34
T_4	18.43	2.06	0.74	13.38	0.68	4.97
T_5	15.29	2.04	0.62	13.00	0.68	4.16
T_6	12.36	1.89	0.50	11.17	0.61	3.03
T_7	20.26	2.00	0.82	13.46	0.70	5.70
T_8	15.89	1.76	0.65	11.75	0.68	4.36
T_9	17.20	1.84	0.70	12.81	0.71	4.95
T_{10}	14.13	2.10	0.57	11.58	0.61	3.46
T_{11}	39.39	3.06	1.60	14.02	0.76	12.13
T_{12}	16.03	1.67	0.65	11.18	0.65	4.19
T_{13}	18.07	1.67	0.73	11.99	0.74	5.38
T_{14}	10.16	1.41	0.41	10.35	0.60	2.46
T_{15}	18.77	2.39	0.76	11.87	0.61	4.60
T_{16}	19.56	2.10	0.79	13.28	0.65	4.43
CD (0.05)	3.15	0.49	0.13	0.92	0.01	1.12

T_1: Recommended dose (RD) of farmyard manure (FYM) @15 t ha^{-1} and NPK @ 40:60:50 kg ha^{-1}; T_2: RD FYM alone; T_3: RD FYM + vesicular arbuscular mycorrhiza (VAM) @10 kg ha^{-1}; T_4: RD FYM + VAM + 80% P + NK; T_5: RD FYM + VAM + 60% P + NK; T_6: RD FYM + phosphorus solubilising bacteria (PSB) @ 10 kg ha^{-1}; T_7: RD FYM + PSB + 80% P + NK; T_8: RD FYM + PSB + 60% P + NK; T_9: RD FYM + PSB + VAM + 70% P + NK; T_{10}: RD FYM + PSB + VAM + 50% P + NK; T_{11}: RD FYM + RD NPK + *Azotobacter* (AZT) @ 10 kg ha^{-1} + PSB @ 10 kg ha^{-1} + VAM @ 10 kg ha^{-1}; T_{12}: RD FYM + AZT + PSB + VAM; T_{13}: RD FYM + neem cake (NC) @ 1 t ha^{-1} + AZT + PSB + VAM; T_{14}: Vermicompost (VC) @ 1 t ha^{-1}; T_{15}: VC + VAM; T_{16}: VC + PSB

plants which received vermicompost alone (T_{14}). The highest total dry weight per plant in T_{11} could be attributed to the promotion of growth and yield attributes due to greater uptake of nutrients into the plant system under the influence of biofertilizers. These are similar to the findings of Mahendran and Kumar (1998) in potato, Mahantesh (2002) in onion and Suja et al. (2005) in cassava.

The dry tuber yield per hectare and per plant and dry matter content of tubers varied significantly due to biofertilizers, organic manures and inorganic fertilizers (Fig. 1 and Table 1). The significantly highest dry tuber yield (1.60 t ha^{-1}) was observed in T_{11}, while the least dry tuber yield (0.41 t ha^{-1}) was obtained from the treatment T_{14}. The higher

Table 2. Effect of integrated nutrient management on nutrient uptake and soil nutrient status in *Coleus forskohlii*

Treatments	Nutrient uptake (kg ha^{-1})			Soil nutrient status (kg ha^{-1})		
	N	P	K	Available N	Available P	Available K
T_1	71.02	33.38	104.51	193.72	149.80	349.06
T_2	37.49	15.44	53.85	123.44	75.28	233.10
T_3	43.39	17.75	61.22	116.42	72.33	224.50
T_4	52.86	22.88	76.52	215.16	149.22	375.66
T_5	47.72	19.75	67.65	219.44	141.78	384.81
T_6	38.36	15.57	50.75	122.72	73.47	233.91
T_7	70.40	32.68	99.85	197.70	139.38	351.38
T_8	50.63	23.53	70.74	216.44	135.80	383.92
T_9	54.31	24.22	77.47	214.69	141.10	377.11
T_{10}	44.27	19.02	64.39	222.42	134.58	389.67
T_{11}	115.83	49.59	151.55	151.20	133.35	301.91
T_{12}	45.19	18.86	61.22	116.65	68.95	223.31
T_{13}	67.80	29.63	94.07	172.96	95.80	321.22
T_{14}	32.81	15.86	40.07	94.18	19.05	177.19
T_{15}	47.22	22.74	68.77	81.23	11.60	147.55
T_{16}	61.08	28.93	87.58	69.56	13.00	130.04
CD (0.05)	11.92	4.81	16.01	21.03	12.76	26.04

tuber yield in T_{11} could be attributed to effective utilisation of nutrients by the plants for the synthesis of metabolites and thereby maximum accumulation of dry matter in tubers. These findings are in conformity with the results of Ravi (2004) in coleus, Rameshbabu (1996) in *Ashwagandha*, Balakumbahan et al. (2005) in cassava and Velmurugan et al. (2008) in turmeric.

Tuber quality

Perusal of the data on forskolin content indicated that biofertilizers, organic manures and inorganic fertilizers significantly influenced the forskolin content (Table 1). The treatment, T_{11}, resulted in significantly higher forskolin content (0.76%) and yield (12.13 kg ha^{-1}), while minimum forskolin content (0.45%) and yield (2.07 kg ha^{-1}) was

Table 3. Economic analysis of integrated nutrient management in *Coleus forskohlii*

Treatments	Total cost of cultivation (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net profit (Rs. ha^{-1})	Cost : benefit ratio
T_1	39735.00	44000.00	4264.50	1:1.11
T_2	37688.00	23000.00	-14688.00	1:0.61
T_3	38088.00	23500.00	-14588.00	1:0.62
T_4	39888.00	37000.00	-2888.00	1:0.93
T_5	39640.50	31000.00	-8640.50	1:0.78
T_6	8088.00	25000.00	-13088.00	1:0.66
T_7	39888.00	41000.00	1112.00	1:1.03
T_8	39640.50	32500.00	-7140.50	1:0.82
T_9	40164.25	35000.00	-5164.25	1:0.87
T_{10}	39916.75	28500.00	-11416.75	1:0.71
T_{11}	40935.50	80000.00	39064.50	1:1.95
T_{12}	38888.00	32500.00	-6388.00	1:0.84
T_{13}	45888.00	36500.00	-9388.00	1:0.80
T_{14}	32188.00	20500.00	-11688.00	1:0.64
T_{15}	32588.00	38000.00	5412.00	1:1.17
T_{16}	32588.00	39500.00	6912.00	1:1.21

T_1: Recommended dose (RD) of farmyard manure (FYM) @15 t ha^{-1} and NPK @ 40:60:50 kg ha^{-1}; T_2: RD FYM alone; T_3: RD FYM + vesicular arbuscular mycorrhiza (VAM) @10 kg ha^{-1} ; T_4: RD FYM + VAM + 80% P + NK; T_5: RD FYM + VAM + 60% P + NK; T_6: RD FYM + phosphorus solubilising bacteria (PSB) @ 10 kg ha^{-1}; T_7: RD FYM + PSB + 80% P + NK; T_8: RD FYM + PSB + 60% P + NK; T_9: RD FYM + PSB + VAM + 70% P + NK; T_{10}: RD FYM + PSB + VAM + 50% P + NK; T_{11}: RD FYM + RD NPK + *Azotobacter* (AZT) @ 10 kg ha^{-1} + PSB @ 10 kg ha^{-1} + VAM @ 10 kg ha^{-1} ; T_{12}: RD FYM + AZT + PSB + VAM; T_{13}: RD FYM + neem cake (NC) @ 1 t ha^{-1} + AZT + PSB + VAM; T_{14}: Vermicompost (VC) @ 1 t ha^{-1}; T_{15}: VC + VAM; T_{16}: VC + PSB observed in the treatment RD FYM only (T_2). The variation in withanine, somniferene and curcumin content due to the influence of VAM, PSB and AZT in combination with organic manures and fertilizers was also reported by Rameshbabu (1996) in *Ashwagandha* and Velmurugan et al. (2008) in turmeric.

Nutrient uptake

Plants that received nutrients as per T_{11} had maximum N (1.16%), P (0.48%) and K (1.47%) contents. Similarly the total uptake of nutrients was significantly influenced by the application of nutrients as per T_{11} which resulted in the highest uptake of N (115.83 kg ha^{-1}), P (49.59 kg ha^{-1}) and K (151.55 kg ha^{-1}) (Table 2). The highest NPK status and uptake in plants could be attributed to the combined application of AZT + PSB + VAM with organic manures and NPK fertilisers, which helped in better availability and absorption of nutrients by the plants. The greater uptake of nutrients can also be related to higher dry matter production due to greater accumulation of metabolites. These results are in confirmation with the findings of Mahendran and Kumar (1998) in potato, Suja et al. (2005) in cassava and Kalyanasundaram et al. (2008) in sweet flag.

Soil nutrient status

In general, the nutrient balance sheet was negative for all the treatments. The data on available N, P and K status of the soil after harvest of the crop and balance sheet for available N, P and K revealed that the removal of nutrients was higher (NPK removal of 115.83, 49.59 and 151.55 kg ha^{-1} respectively) in the treatment T_{11}(Table 2) and therefore lower values for N, P and K contents was observed in the soil than the expected balance for these nutrients. However, the post experiment nutrient status of available N and K was higher in T_{10} and available P in T_4, T_5 and T_9 on par with T_1due to higher nutrient availability under the influence of biofertilizers (Table 2). These results are similar to that reported by Senthilkumar (2002) in African marigold.

Economic analysis

Due to higher tuber yield and dry matter production the treatment T_{11} resulted in higher net returns (Rs. 39065 ha^{-1}) and B:C ratio (1.95) (Table 3).

Conclusion

The present study revealed that the application of recommended dose of FYM @ 15 t ha^{-1} and NPK @ 40:60:50 kg ha^{-1} along with 10 kg ha^{-1} each of *Azotobacter crucocum*, *Bacillus megaterium* (phosphorus solubilising bacteria) and *Glomus fasciculatum*(vesicular arbuscular mycorrhiza) resulted in significantly higher tuber yield, dry matter and forskolin contents of tubers, nutrient uptake and profit.

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