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Integrated Nutrient Management Combination with Biofertilizers and Plant Growth Substances on Yield and Quality of Medicinal Coleus (*Coleus forskohlii* Briq.)

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A B S T R A C T

The experiment was carried out during August 2005 to February 2006 in Department of Agronomy, Agricultural College and Research Institute, Madurai, Tamil Nadu. The experiment was laid out in split plot design. The treatment combination of 100 % RDF (40:60:50 kg NPK ha^{-1}) + FYM (12.5 t ha^{-1}) + Azophos (Azosprillum and Phosphobacteria) (2 kg ha^{-1}) with GA_3 100 ppm (spraying at 60, 90 and 120 DAP) registered significantly higher plant height and internode length of coleus plant. Application of 100 % of RDF + FYM + Azophos with panchagavya 3% registered higher number of laterals, number of leaves and stem girth. Application of 100 % RDF + FYM + Azophos with humic acid 0.1 % registered higher lamina length and lamina breadth, shoot dry weight and dry matter production. The combination of 100 % of RDF + FYM + Azophos with NAA 50 ppm registered significantly higher shoot fresh weight. The biometric observations were recorded at 60, 90, 120 DAP and at harvest. The biochemical parameters were also recorded at harvest. The major nutrients were analysed and the uptake was calculated. The qualities of coleus were tested at harvest. The treatment 100 % RDF +FYM + Azophos with humic acid 0.1% registered significantly higher leaf area index, chlorophyll content, crop growth rate, relative growth rate and absolute growth rate, tuber number, tuber length, tuber diameter, tuber volume, fresh and dry tuber yield per plant and fresh and dry tuber yield per hectare. Among the combinations, 100 % of RDF + FYM + Azophos with panchagavya 3% registered higher harvest index. The treatment 100 % of RDF + FYM + Azophos with humic acid 0.1 % registered significantly higher forskolin content and amount of essential oil. Application 100 % RDF + FYM + Azophos with panchagavya 3% registered significantly higher total alkaloid and starch content of tubers. The soil available nutrient status, nutrient uptake and soil organic carbon content were influenced by 100 % of RDF + FYM + Azophos with humic acid 0.1 %. Judicious combination of 100 % RDF (40:60:50 kg NPK ha^{-1}) + FYM (12.5 t ha^{-1}) + Azophos (2 kg ha^{-1}) with humic acid 0.1 % (spraying at 60, 90 and 120 DAP) is recommended to get better yield with improved quality of coleus tubers, greater net returns and benefit cost ratio. Humic acid is slightly higher in price than panchagavya and hence next best choice is 100 % RDF (40:60:50 kg NPK ha^{-1}) + FYM (12.5 t ha^{-1}) + Azophos (2 kg ha^{-1}) with panchagavya 3 % (spraying at 60, 90 and 120 DAP) to obtain similar productivity and quality of coleus tubers in addition to maintain better soil ecosystem leading to sustainable agriculture.

Keywords

Coleus, Panchagavya, Humic acid, GA3, Essential oil, Azophos and Forskolin.

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Introduction

Coleus forskohlii is a perennial herb with fleshy, fibrous roots that grows wild in the warm, sub tropical and temperate areas in India, Burma, and Thailand. *C. forskohlii* is cultivated in India for use as a condiment. According to World Health organization, the international market of herbal products is estimated to be US dollar 62 billion which is poised to grow to US dollar 5 trillion by the year 2050. India's share in global export market of medicinal plants related trade is estimated to be 0.5%. In recent years, coleus forskolii has gained recognition as the only known plant source of the diterpene, forskolin (De Souza, 1991). Combined use of inorganic fertilizers with biofertilizers recorded significantly superior of plant height and number of leaves, leaf area, and yield of herbage in patchouli (*Pogostemon cablin* pellet).

Humic substances influences biological mechanisms and physiological process in plants and this may include the possibilities of humic acid behaving as plant growth regulator. Panchagavya is a combination of give products obtained from the cow. These are cow dung, cow urine, cow milk, curd and ghee. Scientists are discovering the value of the unique combination of five products of cow. Panchagavya is a single organic input, which can act as a growth promoter and immunity booster.

To meet the food demands of growing human population, fertilizers are needed to increase the production of food crops. Inorganic fertilizer is a substance applied to soils or directly onto plants to provide nutrients optimal for their growth and development. The essential nutrients are Nitrogen, Phosphorous and Potassium. These are soluble and immediately available to the plants. That can easily absorb and metabolized by plants (Chen 2006). Biofertilizers play a very significant role in improving soil fertility by fixing atmospheric nitrogen, both, in association with plant roots and without it, solubilize insoluble soil phosphates and produces plant growth substances in the soil. They are in fact being promoted to harvest the naturally available, biological system of nutrient mobilization (Venkatashwarlu, 2008). The enhanced microbial dynamics in turn increased plant growth parameter, root-shoot biomass and rice yield as well as soil health due to more availability of nutrients and plant growth promoting substances, thus satisfying all the criteria for sustainability (Yuvaraj, 2016**).**

In Tamil Nadu, it is grown in an area of 5000 hectares with the total production of 8,000 tonnes of dried tuberous root yield. It is predominantly grown in Salem, Dharmapuri, Erode, Coimbatore, Dindigul, Thiruvannamalai, Cuddulore, Vellore, Villupuram, Karur, Tuticorin and Trichy districts. Due to its assured income, farmers in these districts have shown keen interest in doing contract farming with private companies. In view of the above, it was felt appropriate to study the effect of levels fertilizers dose with farm manure, biofertilizers on growth, yield and nutrient uptake in coleus.

Materials and Methods

Field experiment was conducted to study the effect of integrated nutrient management on the yield and quality of coleus (*Coleus forskohlii* Briq.) during August 2005 to February, 2006 in Department of Agronomy, Agricultural College and Research Institute, Madurai, Tamil Nadu. The experiment was laid out in split plot design with three replications. The main plots consisted of six integrated nutrient managements viz., M_1-50: 75: 62.5 kg NPK ha^{-1} (125 % of RDF), M_2-40:

60: 50 kg NPK ha^{-1} (100 % of RDF), M_3-30: 45: 37.5 kg NPK ha^{-1} (75 % of RDF), M_4-50: 75: 62.5 kg NPK ha^{-1} (125 % of RDF) + FYM (12.5 t ha^{-1}) + Azophos (Azosprillum and Phosphobacteria) (2 kg ha^{-1}), M_5- 40: 60: 50 kg NPK ha^{-1} (100 % of RDF) + FYM (12.5 t ha^{-1}) + Azophos (2 kg ha^{-1}) and M_6-30: 45: 37.5 kg NPK ha^{-1} (75 % of RDF) + FYM (12.5 t ha^{-1}) + Azophos (2 $kgha^{-1}$), RDF – Recommended Dose of Fertilizer. The subplot consist of five Plant growth substances viz., S_1 - Naphthalene acetic acid (NAA) 50 ppm, S_2 - Gibberellic acid (GA_3) 100 ppm, S_3 - Humic acid (0.1 %), S_4 - Panchagavya (3 %) and S_5 - Control (Water spray) spray at 30, 60 and 90 days after planting. crop planted on 18.08.2005 and harvested on 04.02.2006.

The main field was ploughed two times and brought fine tilth. The ridges were formed at 60 cm apart. Terminal cutting of 10-12 cm long 3 to 4 pairs of leaves were planted 30 cm apart in the ridges. First irrigation was given at the time of planting and the second irrigation was given on the third day. Subsequent irrigations were given 10 to 12 days interval.

Humic acid material is a byproduct of obtained from lignite, supplied by Neyveli Lignite Corporation. The humic acid as potassium humate used for the experiment was obtained from Tamil Nadu agricultural university, Coimbatore. Panchagavya was used in the study. It contains cow dung - 500ml, cow urine - 300ml, cow milk - 200ml, curd - 200 ml, ghee - 100 ml, sugarcane juice-100 ml, coconut water - 200 ml. mixed well all materials in container and kept in fermentation for ten days. The contents were stirred for 20 minutes both in the morning and evening to create aerobic microbial activity.

Biometric observations plant height, dry matter production and yield attributes like Number of tubers per plant and length of tubers, fresh and dry tuber yield per hectare were observed in regular intervals. Chemical analysis of soil and plant samples was analyzed for nitrogen, phosphorus, potassium content. Forskolin present in the tuber of coleus was determined by High Performance Thin Layer Chromatography (HPTLC). Serial dilution of soil sample was prepared and counting different microorganisms bacteria, fungi and actinomycetes and their population.

Results and Discussion

Growth parameters

The experiment field data revealed that increase in all the growth attributes were noticed with each increasing level of fertilizers combination with bio fertilizers. The interaction on plant height was significant at harvest. Among various combinations, 100 % of RDF + FYM + Azophos with GA_3 100 ppm (M_5S_2) registered significantly higher plant height of 90.33 cm at harvest. The treatment 75 % of RDF alone with control (M_3S_5) recorded the lower plant height of 55.17 cm. Combined application of 100 % of RDF + FYM + Azophos with panchagavya 3 % improved the plant height at harvest in coleus. The results are in accordance with the findings of Kanimozhi (2003), Veeraragavathatham *et al.*, (1988) and Prabhaharan (2005) in *Coleus forskohlii* (Table 1). The treatment 100 % of RDF + FYM + Azophos with humic acid 0.1 % (M_5S_3) registered higher dry matter production of 11.47 t ha^{-1} at harvest which was comparable with 100 % of RDF + FYM + Azophos with panchagavya 3% (M_5S_4). The treatment combination of 75 % of RDF alone with control (M_3S_5) registered significantly lowest dry matter production. The DMP was improved and the magnitude increase was in the range of 48.96 per cent at harvest. INM and humic acid application might have boosted up crop growth leading to improvement in various growth characters. The results corroborated with the findings of Mailappa (2003) who observed, improved growth of tapioca with combined application of NPK and humic acid spray.

Yield attributes

100 % RDF + FYM + Azophos with humic acid 0.1 % (M_5S_3) registered significantly higher tuber number and length of tuber of 29.01 and 22.69 cm at harvest, respectively. This combination (M_5S_3) was comparable with 75 % of RDF + FYM + Azophos with humic acid 0.1 % (M_6S_3) at 90 DAP. The treatment 75 % of RDF alone with control (M_3S_5) recorded the lowest tuber number and tuber length. As far as the tubers per plant is concerned, application of 100 % of RDF + FYM + Azophos with humic acid 0.1 % spray had better results at 90, 120 DAP and at harvest in the range of 47, 35 and 56 per cent over 75 % RDF with control (Table 1). Phosphorus is an element responsible for better tuber development which is an established fact and this would have influenced this character. FYM increased the physical condition of soil, apart from its supply of organic matter and micronutrients. Supply of essential micronutrient like zinc through FYM would have favoured the native auxin synthesis in the meristematic tissue. Once the growth of the meristem is triggered it would lead to a rapid sink for absorption of essential major nutrients as well as photosynthesis in the developed and developing leaves. The dry matter accumulation is a result of translocation system of proton co-transport. This might have been possible by better absorption of potassium from the soil in treatments which received both organic and inorganic nutrition. These results were confirmed with finding of the Remesh Babu (1996), Vijayabharathi (2002) in ashwagandha, and supported by Paturde *et al.,* (2002) in Safed musli, Somanath *et al.,* (2005) and Prabhaharan (2005) in *Coleus forskohlii*.

Application of 100 % RDF +FYM + Azophos (M_5) recorded higher fresh and dry tuber yield of 19.918 and 2.988 t ha^{-1} which was comparable with 75 % of RDF + FYM + Azophos (M_6) and 125 % RDF + FYM + Azophos (M_4). The treatment 75 % of RDF alone (M_3) recorded lowest fresh and dry tuber yield of 13.562 and 2.034 t ha^{-1}. Among plant growth substances, humic acid 0.1 % (S_3) registered higher fresh and dry tuber yield of 18.238 and 2.736 t ha^{-1} which were comparable with panchagavya 3 % (S_4) recorded 18.082 and 2.712 t ha^{-1} of fresh and dry tuber yield. Control (S_5) recorded lowest fresh and dry tuber yield of 15.149 and 2.272 t ha^{-1}. Interaction effect was significant at harvest. 100 % RDF + FYM + Azophos with humic acid 0.1 % (M_5S_3) registered significantly higher fresh and dry tuber yield of 23.091 and 3.464 t ha^{-1}. The treatment combination of 75 % of RDF without any growth substances (M_3S_5) recorded the lowest fresh and dry tuber yield (Table 2).

Combined application of NPK and FYM increased the fresh and dry weight of tubers in *Coleus forskohlii*. This might be due to humic substances present in farmyard manure which could have mobilized the reserve food materials to the sink through increased activity of hydrolyzing and oxidizing enzymes. This combined application would have helped in better availability and utilization of nutrients. All these scavenging effects might have made quick mobilization and availability of nutrients, which would have aided in increased plant growth and improved the fresh and dry tuber yield. All these factors could ultimately result in higher yield in this particular treatment. The present study is in line with the findings of Prabhaharan (2005) in *Coleus forskohlii*.

Table.1 Effect of INM and spray of plant growth substances on plant height (cm), DMP, Number of tubers, length of tubers at harvest

Plant growth substances	**Integrated Nutrient Management**													
	Plant height (cm)							**DMP (t ha^{-1})**						
Treatments	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**MEAN**	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**MEAN**
S_1	63.27	57.33	56.67	68.17	69.87	67.61	**63.82**	9.01	8.95	7.98	10.35	10.76	10.27	**9.55**
S_2	82.32	84.17	81.33	80.98	90.33	86.89	**84.41**	8.63	8.42	8.21	9.38	9.48	9.41	**8.92**
S_3	64.93	63.60	64.33	65.67	71.97	67.52	**66.07**	9.23	9.20	9.04	10.34	11.47	10.80	**10.01**
S_4	72.50	58.33	60.50	57.33	67.00	68.36	**64.00**	9.33	9.35	8.76	10.27	10.98	10.36	**9.84**
S_5	62.45	61.00	55.17	75.65	65.27	56.30	**62.64**	8.31	8.23	7.70	8.88	9.12	8.82	**8.51**
MEAN	**69.09**	**64.57**	**62.00**	**69.56**	**72.29**	**70.02**		**8.90**	**8.83**	**8.34**	**9.85**	**10.36**	**9.93**	
		M	**S**	**M at S**	**S at M**				**M**	**S**	**M at S**	**S at M**		
	SEd	0.55	0.68	1.58	1.66			SEd	1.29	0.46	1.63	1.12		
	CD(0.05)	1.23	1.36	3.23	3.34			CD(0.05)	2.87	0.92	3.50	2.26		
	Number of tubers per plant							**Length of tubers**						
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**MEAN**	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**MEAN**
S_1	18.73	21.54	21.50	22.54	24.50	26.50	**22.55**	20.75	20.75	16.35	17.86	17.98	17.50	**18.53**
S_2	21.56	20.31	21.54	21.35	23.50	21.98	**21.71**	18.64	18.64	17.15	18.78	18.79	19.36	**18.56**
S_3	20.50	21.54	19.50	23.50	29.01	25.89	**23.32**	17.86	17.86	17.90	19.25	22.69	19.78	**19.22**
S_4	26.35	21.50	22.01	24.00	23.41	21.65	**23.15**	15.70	15.70	17.95	20.09	18.78	20.00	**18.04**
S_5	22.50	20.50	18.50	22.50	24.50	21.54	**21.67**	15.98	15.98	11.45	17.50	18.60	17.17	**16.11**
MEAN	**21.93**	**21.08**	**20.61**	**22.78**	**24.98**	**23.51**		**17.79**	**17.79**	**16.16**	**18.70**	**19.37**	**18.76**	
	SEd	**M**	**S**	**M at S**	**S at M**				**M**	**S**	**M at S**	**S at M**		
	CD(0.05)	0.25	0.14	0.39	0.33				0.20	0.12	0.36	0.30		
CD(0.05)	CD(0.05)	0.56	0.27	0.82	0.67			CD(0.05)	0.44	0.25	0.70	0.61		

NS – Non significant

Table.2 Effect of INM and plant growth substances on fresh and dry tuber yield, net return and BC ratio at harvest stage of coleus

Plant growth substances	**Integrated Nutrient Management**													
	Fresh tuber yield (t ha^{-1})							**Dry tuber yield (t ha^{-1})**						
Treatments	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**MEAN**	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**MEAN**
S_1	14.707	15.514	14.137	19.813	20.628	19.760	**17.427**	2.206	2.327	2.121	2.972	3.094	2.964	**2.614**
S_2	12.779	13.755	12.911	15.833	17.264	18.388	**15.155**	1.917	2.063	1.937	2.375	2.590	2.758	**2.273**
S_3	14.884	14.687	14.517	21.068	23.091	21.180	**18.238**	2.233	2.203	2.178	3.160	3.464	3.177	**2.736**
S_4	15.964	15.147	14.709	20.652	21.370	20.648	**18.082**	2.395	2.272	2.206	3.098	3.206	3.097	**2.712**
S_5	14.636	13.094	11.533	16.962	17.236	17.435	**15.149**	2.195	1.964	1.730	2.544	2.585	2.615	**2.272**
MEAN	**14.594**	**14.439**	**13.562**	**18.866**	**19.918**	**19.482**		**2.189**	**2.166**	**2.034**	**2.830**	**2.988**	**2.922**	
	M	**S**	**M at S**	**S at M**				**M**	**S**	**M at S**	**S at M**			
SEd	0.47	0.12	0.54	0.29				0.07	0.02	0.08	0.04			
CD(0.05)	1.06	0.24	1.18	0.58				0.16	0.04	0.18	0.09			
	Net return (Rs ha^{-1})							**BC ratio**						
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**MEAN**	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**MEAN**
S_1	88588	95809	85023	125903	133196	126603	**109187**	3.7	4.0	3.7	4.4	4.6	4.5	**4.1**
S_2	70679	79298	72909	91061	103437	113282	**88444**	3.1	3.3	3.2	3.3	3.7	3.9	**3.4**
S_3	88494	87435	86609	134708	151961	136768	**114329**	3.6	3.6	3.6	4.4	4.9	4.6	**4.1**
S_4	98158	91984	88942	132019	138516	133126	**113791**	3.9	3.8	3.7	4.4	4.7	4.6	**4.2**
S_5	89000	76845	64535	103378	106207	108417	**91397**	3.8	3.5	3.0	3.8	4.0	4.1	**3.7**
MEAN	**86984**	**86274**	**79604**	**117414**	**126663**	**123639**		**3.6**	**3.6**	**3.5**	**4.1**	**4.4**	**4.3**	

Table.3 Effect of INM and foliar spray of plant growth substances on bacterial population (x10^6 CFU g^{-1} dry soil) at 60 DAP and at harvest. Initial population: Bacteria – 168.6 x10^6 CFU g^{-1} dry soil

Plant growth substances	Integrated Nutrient Management													
	60 DAP							At harvest						
Treatments	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**MEAN**	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**MEAN**
S_1	145.70	152.40	165.30	185.70	191.30	190.30	**171.78**	168.30	174.60	176.20	194.10	2350.30	215.70	**194.03**
S_2	145.90	153.30	164.80	187.60	192.80	189.50	**172.32**	169.40	172.10	172.60	189.40	224.60	212.30	**190.07**
S_3	145.60	154.70	166.50	187.40	193.70	190.10	**173.00**	171.30	175.70	167.50	196.30	237.60	220.40	**194.80**
S_4	146.70	154.40	167.40	188.60	195.80	197.50	**175.07**	172.40	176.40	169.40	198.80	235.40	223.90	**196.05**
S_5	162.30	173.80	167.50	175.40	174.50	175.60	**171.52**	168.50	173.80	170.30	188.50	232.70	214.20	**191.33**
MEAN	**149.24**	**157.72**	**166.30**	**184.94**	**189.62**	**188.60**		**169.98**	**174.52**	**171.20**	**193.42**	**233.12**	**217.30**	
	M	**S**	**M at S**	**S at M**				**M**	**S**	**M at S**	**S at M**			
SEd	2.83	0.47	3.02	1.16				4.35	0.25	4.38	0.61			
CD(0.05)	6.31	NS	NS	NS				9.69	0.50	9.75	1.24			

Table.4 Effect of INM and foliar spray of plant growth substances on fungal population (x10^3 CFU g^{-1} dry soil at 60DAP and at harvest. Initial population: Fungi – 19.4 x10^3 CFU g^{-1} dry soil

Plant growth substances	Integrated Nutrient Management													
	60 DAP							At harvest						
Treatments	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**MEAN**	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**MEAN**
S_1	15.60	16.70	19.80	22.70	28.60	25.90	**21.55**	17.60	18.90	20.90	24.60	30.70	27.80	**23.42**
S_2	16.80	18.60	18.50	23.80	29.40	26.40	**22.25**	18.70	20.10	19.90	25.80	31.50	28.60	**24.10**
S_3	16.40	18.40	20.70	24.50	30.80	27.80	**23.10**	19.80	19.60	20.90	26.40	32.80	29.40	**24.82**
S_4	17.10	17.60	20.90	24.90	31.20	26.70	**23.07**	18.40	19.80	21.50	26.90	33.40	29.10	**24.80**
S_5	16.10	19.10	19.20	23.40	29.80	27.10	**22.45**	17.60	20.80	20.30	25.80	31.80	29.70	**24.33**
MEAN	**16.40**	**18.08**	**19.82**	**23.86**	**29.96**	**26.78**		**18.42**	**19.84**	**20.70**	**25.90**	**32.04**	**28.92**	
	M	**S**	**M at S**	**S at M**				**M**	**S**	**M at S**	**S at M**			
SEd	0.86	0.06	0.87	0.14				0.90	0.06	0.91	0.14			
CD(0.05)	1.92	NS	NS	NS				2.00	0.11	2.02	0.27			

Table.5 Effect of INM and foliar spray of plant growth substances on actinomycetes population (x10^3 CFU g^{-1} soil at 60DAP and at harvest. Initial population: actinomycetes – 21.9x10^3 CFU g^{-1} dry soil

Plant growth substances	Integrated Nutrient Management													
	60 DAP							At harvest						
Treatments	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**MEAN**	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**MEAN**
S_1	16.40	19.60	21.10	23.80	30.80	27.40	**23.18**	19.80	21.60	24.10	26.40	32.60	30.90	**25.90**
S_2	17.80	20.50	22.50	25.80	31.20	27.90	**24.28**	19.40	22.80	24.60	27.90	33.40	29.40	**26.25**
S_3	18.20	21.90	23.20	25.90	33.60	29.70	**25.42**	20.60	23.40	25.90	28.10	35.60	30.10	**27.28**
S_4	19.70	20.90	23.90	27.90	32.40	28.40	**25.53**	21.50	22.60	26.10	29.20	33.40	30.50	**27.20**
S_5	19.40	21.80	21.50	25.80	31.50	29.40	**24.90**	22.10	23.80	23.40	27.10	33.50	31.60	**26.92**
MEAN	**18.30**	**20.94**	**22.44**	**25.84**	**31.90**	**28.56**		**20.68**	**22.84**	**24.82**	**27.74**	**33.70**	**30.50**	
	M	**S**	**M at S**	**S at M**				**M**	**S**	**M at S**	**S at M**			
SEd	0.83	0.08	0.84	0.19				0.80	0.07	0.81	0.17			
CD(0.05)	1.84	NS	NS	NS				1.78	0.14	1.80	0.34			

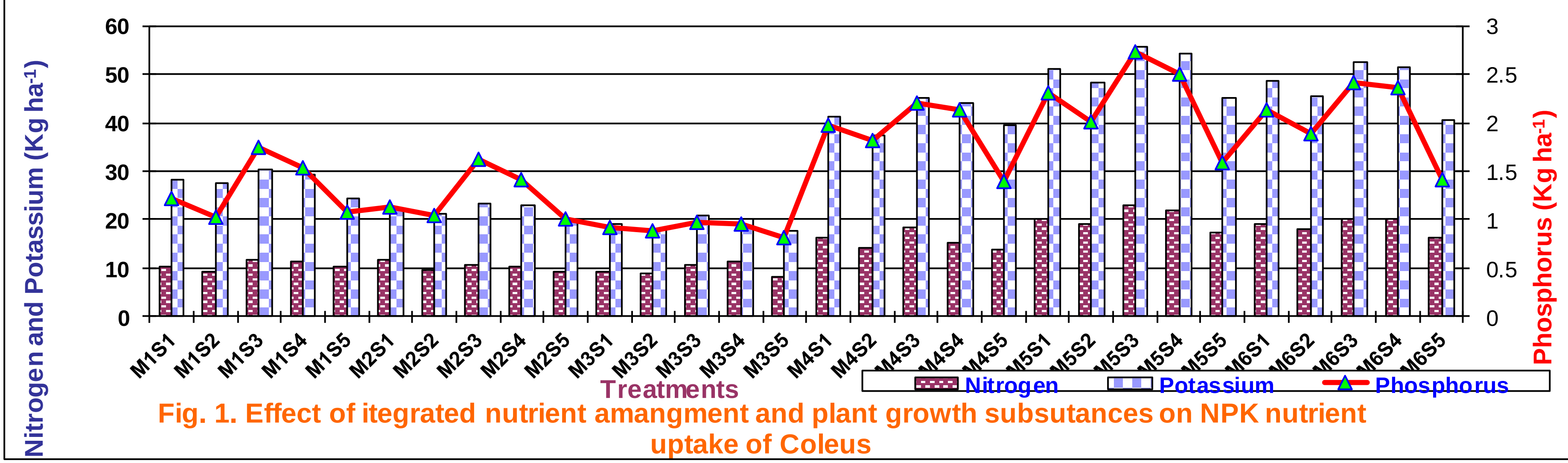

Fig. 1. Effect of itegrated nutrient amangment and plant growth subsutances on NPK nutrient uptake of Coleus

Inoculation of Azophos was found to increase the dry weight of root as reported by Vijayabharathi (2002) in ashwagandha.

Nutrient uptake

The uptake of nutrients was significantly improved by the combined application of 100 % of RDF + FYM + Azophos with humic acid 0.1 % foliar spray which registered higher uptake of nitrogen, phosphorus and potassium of 23.05, 2.73 and 55.70 kg ha^{-1} (with the range of 187, 237 and 215 per cent over control and 5.8, 8.7 and 2.5 per cent over 100 % of RDF + FYM + Azophos with panchagavya 3 % foliar spray. The uptake of N, P and K might have increased photosynthesis and translocation of photosynthates in to coleus tubers. These results are in line with the findings of Prabhaharan (2005) and Somanath *et al.*, (2005) in *Coleus forskohlii* (Fig. 1).

Microbial attributes

The combination of 100 % of RDF + FYM + Azophos with humic acid 0.1 % registered significantly higher bacterial, fungal and actinomycetes population in the range of 41, 89, 83 per cent over 125 % RDF alone with NAA 50 ppm spray at harvest. Compare to initial microbial population, Panchagavya (S_4) registered significantly higher bacterial, fungi population (In the range of 16 and 28 per cent). Humic acid 0.1% registered significantly higher population of actinomycetes (24 per cent) at harvest. Higher availability of nitrogen, phosphorus and potash in the soil under farm yard manure addition with Azophos could be due to favorable microbial activity and the enhanced biomass addition to the soil and also as result of improved soil physical and biological property of of soil (Tables 3, 4 and 5). These result accordance with the effects of chemical fertilizer and biofertilizer on the growth and yield production of rice by Shah and Rajendra (2014). Integrated application of consortium biofertilizer (*Azotobacter*/*Azospirillium*) along with inorganic fertilizers significantly improved the microbial population, soil enzyme activities and available NPK in soil as compared to inorganic fertilizers alone. The treatment having inorganic fertilizers combined with biofertilizer (*Azospirillum and phosphobateria)* was found to be most effective in bacteria and fungi population at 90 days of rice crop except actinomycetes population which was maximum in treatment having recommended dose of inorganic nutrients, microbial enzyme activities like Alkaline phosphatase, Dehydrogenase and Urease in soil of rice field at 90 days (Yuvaraj, 2016**).** The use of chemical fertilizers increase the plants growth and yield as well as deplete essential nutrients of soil in long term usage. Whereas the organic manures and biofertilizers increase the plants productivity without any harmful effects on the soil. While the combined application of biofertilizers along with organic manures for the crop cultivation can improve their productivity as well as soil health (Rajasekaran *et al.*, 2015).

Forskolin content

Quality characters were considerably improved by different INM practices with plant growth substances and they were comparable among themselves. The positive effect of 100 % of RDF + FYM + Azophos with humic acid 0.1 % showed an increase in forskolin content by 1.04 per cent. Similarly, 75 % RDF + Azophos + FYM with panchagavya 3 % registered the forskolin content of 0.96 per cent and application of 75 % RDF alone with control recorded the lowest forskolin content of 0.92 per cent. Rajangam (2005) reported that forskolin content was increased in the treatment combination of mound method planting with cycocel 250 ppm. The increased level of forskolin content may be due to the action of micronutrients from FYM and growth hormones produced by the Azophos. Cow dung It contains undigested fibre, epithelial cells, bile pigments and salts, rich in nitrogen, phosphorous, potassium, sulphur, micronutrients, intestinal bacteria and mucus. Varahamihara, Surapala and Someshwara Deva also used milk in ancient times. It has been reported to be an excellent sticker and spreader; a good medium for saprophytic bacteria and virus inhibitor.

This result is in accordance with the findings of Somanath *et al.*, (2005) found that 20 t ha^{-1} FYM alone recorded highest forskolin content in *Coleus forskohlii*.

Net return and Benefit cost ratio

100 % of RDF + FYM + Azophos with humic acid 0.1 % (M_5S_3) recorded highest net return Rs 1,51,961 ha^{-1} and the treatment 75 % of RDF alone with control (M_3S_5) recorded the lowest net return of Rs 64,535 ha^{-1}. 100 % of RDF + FYM + Azophos with humic acid 0.1 % (M_5S_3) registered the highest benefit cost ratio of 4.9. Application of 75 % of RDF alone with control (M_1S_5) recorded the lowest benefit cost ratio of 3.0. Among various treatment combinations tried, combination of 100 % of RDF + FYM + Azophos with humic acid 0.1% (M_5S_3) resulted in highest dry tuber yield of 3.464 kg ha^{-1} and this treatment combination resulted in the net return of Rs. 1,51,961. There was significant increase in the net return to the tune of 135 per cent increase over the treatment of 75 % RDF alone with control. Application of 100 % of RDF + FYM + Azophos with humic acid 0.1% (M_5S_3) showed higher BCR of 4.9 with the range of 63 per cent over 75 % RDF alone with control. These results are in accordance with Ravi (2004), Somanath *et al.*, (2005) and Prabhaharan (2005) in *Coleus forskohlii*.

On the basis of field and laboratory data the treatment combination of 100 % RDF + FYM + Azophos with GA_3 100 ppm registered significantly higher plant height. The treatment 100 % of RDF + FYM + Azophos with humic acid 0.1 % registered higher DMP, number, tuber length, forskolin content N, P and K. Application of 100 % of RDF (40:60:50 kg NPK ha^{-1})+ FYM (12.5 t ha^{-1})+ Azophos (2 kg ha^{-1}) with humic acid 0.1 % registered highest net return and benefit cost ratio and next best is 100 % of RDF (40:60:50 kg NPK ha^{-1})+ FYM (12.5 t ha^{-1})+ Azophos (2 kg ha^{-1}) with panchagavya 3 %. Hence concluded that the treatment combination of 100 % RDF + FYM + Azophos with humic acid 0.1 % is recommended to get better yield with improved quality of coleus tubers, higher forskolin content greater net returns and benefit cost ratio in addition to maintain soil health.

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