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Assessment of yield and economics of menthol mint (*Mentha arvensis* L.) with different biofertilizers and organics

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Abstract
A field experiment was conducted to study the effect of different bioformulations and biofertilizers on yield and economics of menthol mint cultivation. The study revealed that the highest fresh herbage (34.50 t/ha), shade herbage (29.42 t/ha) and oil (290.87 kg/ha) yield were recorded in T_{11}: (RDF) (150: 60: 60 NPK kg/ha and FYM-10 t/ha) + panchagavya (3%) + amritpani (3%) + humic acid (0.2%) + Arbuscular mycorrhiza fungus (*Glomus intraradices*), *Azotobacter chroococcum* + *Azospirillum brasilense* + Phosphorous solubilizing bacteria (PSB). While, lowest fresh herbage (15.69 t/ha), shade herbage (12.45 t/ha) and oil (98.61 kg/ha) yield were noticed in T_1 (control): RDF (150: 60: 60 NPK kg/ha and FYM-10 t/ha). Maximum gross returns (Rs 3,63,591), net returns (Rs 2,80,168) and benefit: cost ratio (3.36) were recorded in T_{11} whereas, minimum benefit: cost ratio was recorded in T_1 (control).

Keywords: Menthol mint, bioformulations, humic acid, biofertilizers, benefit cost ratio

Introduction
India is the home of thousands of aromatic plants species and naturalized many exotic aromatic plants such as mints, citronella, geranium, patchouli and lavender mainly because of its varied climatic conditions. The varied agro-climatic conditions prevailing in India enables the commercial cultivation of different aromatic crops. Agro-techniques developed by different institutes ensured increased production, productivity and quality raw materials supply for the domestic as well as International markets. Now, India is a pioneer producer of certain aromatic crops like menthol mint. Menthol mint has emerged as a competent cash crop in North Indian plains in view of high market price for its essential mint oil. Uttar Pradesh accounts 90 per cent of production, many other states like Punjab, Rajasthan *etc.*, are getting into mint cultivation (Farooqi and Sreeramu, 2001) [4].
Although usage of chemical fertilizers has revolutionized Indian agricultural system, but reports shows that about 50 per cent of the applied fertilizers leaches down in the soil and water bodies. This has alleviated some serious health issues and environmental problems. Keeping these challenges in mind, crop production must be achieved through environmentally safer and economically viable techniques. Biofertilizers contains beneficial microorganisms which can accelerate and improve the plant growth and yield through proper nutrient fixation and mobilization (Kumar and Kumar, 2019) [6]. Similarly, cow based products like panchagavya and amrutpani contains several growth promoting substances which can have synergistic effect on beneficial microorganisms in the soil. Hence, these inputs can increase the nutrient uptake as well as reduce the usage of costly chemical fertilizers. These organic inputs can be incorporated with conventional crop production system for developing a sustainable crop production system and to produce products with less chemical resilience. Keeping this in view, yield and economic assessment of this integrated nutrient management have been studied in Menthol mint (*Mentha arvensis* L.) cultivation.

Material and methods
This study was conducted at Department of Plantation, Spices, Medicinal and Aromatic crops, Kittur Rani Channama College of Horticulture (KRCCH), Arabhavi, Karnataka, during *kharif*

season of 2018 and 2019. It is situated at an altitude of 612 m above mean sea level, at a latitude of 16º 15' N and a longitude of 94º 45'E. This experimental site falls under Northern Dry Zone of Karnataka. The soil of the experimental site is characterized by sandy clay loam soil (vertisols) with neutral pH (7.0). The experiment was laid out in randomized block design with three replications and treatments are T_1: Control (RDF) (150: 60: 60 NPK kg/ha and FYM-10 t/ha), T_2: T_1 + Arbuscular Mycorrhiza Fungus (AMF), T_3: Arbuscular Mycorrhiza Fungus (AMF), T_4: RDF + Humic acid (HA) at 0.2 % dilution (Drench), T_5: RDF + Panchagavya (PG) at 3% dilution (Spray), T_6: RDF + Panchagavya (PG) at 3% dilution (Drench), T_7: RDF + Amritpani (AP) at 3% dilution (Spray), T_8: RDF + Amritpani (AP) at 3% dilution (Drench), T_9: RDF + PG + AP + HA (Drench and Spray), T_{10}: T_9 + AMF, T_{11}: T_{10} + *Azotobacter chroococcum* + *Azospirillum brasilense* + Phosphorous solubilizing bacteria (PSB), T_{12}: AMF + *Azotobacter chroococcum* + *Azospirillum brasilense* + PSB + PG + AP + HA. Plots of 3.6 m width and 4.5 m length were laid out and separated by bunds of 60 cm width. The stolons of cv. Kosi were uprooted from the mother plants and cut into 7.0 to 10.0 cm long cuttings with 2-3 nodes. These stolons were dipped in 0.3 per cent copper oxychloride for 5-10 minutes before planting.

AMF inoculum (*Glomus intraradices*) was obtained from Department of Agricultural Microbiology, KRCCH, Arabhavi and applied at the time of planting. The first treatment of amritpani and panchagavya (3%) was given as stolon treatment at the time of planting. Remaining treatments were given as drench or spray at fifteen days interval up to harvest of crop as per the treatment details. *Azospirillum brasilense*, *Azotobacter chroococcum*, Phosphate solubilizing bacteria inoculums were obtained from Department of Agricultural Microbiology, College of Horticulture, UHS, Bagalkot. Inoculums of *Azotobacter chroococcum*, *Azospirillum brasilense*, PSB (625 g/ha) were mixed with farmyard manure and kept for one week. This mixture was broadcasted in the plots just before planting. Light irrigation was provided immediately after planting. The crop was harvested at 120 days after planting and when 50 per cent flowering was observed. The plants were cut 1 to 4 cm from the ground level by using sharp sickle. Harvesting is done during late morning hours to get more percentage of oil from the leaves. Fresh and shade herbage yield was recorded. Essential oil was extracted from the shade herbage using hydro steam distillation method. Price of the inputs prevailing in India during July 2018 to September 2019 was considered for working out the economics of various treatment combinations (table 2) and cost of cultivation was computed as per treatments. Average menthol mint oil price in September, 2019 is Rs 1250 (economictimes.com). Net returns per hectare were calculated by deducting the cost of cultivation from gross returns per hectare. The benefit cost ratio was worked out by using the formula:

$$B:C = \frac{\text{Gross returns (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

The data on yield observations were subjected to statistical analysis using the Fischer's method of analysis of variance technique as given by Panse and Sukhatme (1969) [8].

Results and discussion

Application of bioformulations and bioinoculants exhibited significant influence on yield of menthol mint plants. Treatment T_{11} showed maximum fresh and shade herbage yield per hectare (34.50 & 29.42 t/ha) and minimum shade herbage yield was noticed in treatment T_7 (15.69 & 12.45 t/ha), closely followed by T_1 (16.44 & 13.21 t/ha). Highest oil yield per hectare was recorded in plants treated with T_{11} (290.87 kg/ha) and T_1 yielded lowest (98.61 kg/ha) essential oil yield per hectare (Table 1). Drenching of bioformulations can add extra nutrients to the soil, while AM fungus can enhance the surface area of absorption of plants. Biofertilizers *viz.*, *Azotobacter* and *Azospirillum* can fix atmospheric nitrogen, increase plant residue decomposition and mineralization in the soil. Synergistic action of these biofertilizers and bioformulations might have increased the plant growth as well as yield parameters. These results are in line with the findings of Rajamanickam *et al.* (2011) [10] in Japanese mint, Sandeep *et al.* (2011) [12] and Arango *et al.* (2012) [1] in pepper mint, Copetta *et al*. (2006) [3] in basil, Padmapriya *et al*. (2010) [7] in *Gymnea sylvestre*, Srivastava (2017) [13] in kalmegh and Bijit (2016) [2] in sarpagandha.

Economic analysis is the ultimate deciding factor for adapting any technology from experiment plot to the farmer's field. Pooled economics data of 2018 & 2019 was worked out and presented in Table 3. In the present study, benefit: cost ratio (B:C) was observed to be maximum (3.36) in T_{11} and minimum (1.19) in T_1. Higher gross returns (Rs 3,63,591) and net returns (Rs 2,80,168) in T_{11} was mainly due to increased herbage and oil yield. Combined application of inorganic fertilizers, bioformulations and biofertilizers resulted in higher cost of cultivation per hectare (Rs 82,680) in T_{11}. Similar results were reported by Rajamanickam *et al*. (2011) [10] in Japanese mint, Ravikumar *et al*. (2012) [11] in coleus, Pramodkumar *et al.* (2018) [9] in ashwagandha and Tripura (2012) [14] in turmeric.

Considering the yield and benefit: cost ratio, incorporation of bioformulations and biofertilizers in conventional menthol mint cultivation (T_{11}) can become an economically viable method for increasing the profit of farmers.

Table 1: Effect of bio-formulations and bio-fertilizers on fresh and shade dried herbage yield (t/ha) and essential oil yield (kg/ha) during 2018 and 2019

Treatments	Fresh herbage yield (t/ha)			Shade dried herbage yield (t/ha)			Essential oil yield (kg/ha)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T_1: Control (RDF) (150: 60: 60 NPK kg/ha and FYM-10 t/ha)	16.52	16.37	16.44	13.21	13.20	13.21	100.42	96.79	98.61
T_2: T_1 + Arbuscular Mycorrhiza Fungus (AMF)	23.28	25.93	24.60	20.84	20.35	20.60	193.07	183.98	188.52
T_3: Arbuscular Mycorrhiza Fungus (AMF)	19.80	22.63	21.22	18.06	17.99	18.03	146.38	142.90	144.64
T_4: T_1 + Humic acid (HA) at 0.2 % dilution (Drench)	16.59	16.72	16.65	13.27	13.45	13.36	109.45	106.60	108.03
T_5: T_1 + Panchagavya (PG) at 3 % dilution (Spray)	18.29	17.93	18.11	14.63	14.44	14.54	119.41	112.33	115.87
T_6: T_1 + Panchagavya (PG) at 3 % dilution (Drench)	18.12	18.64	18.38	14.50	14.80	14.65	116.67	114.37	115.52
T_7: T_1 + Amritpani (AP) at 3 % dilution (Spray)	15.81	15.56	15.69	12.65	12.25	12.45	110.91	102.32	106.62

T_8: T_1 + Amritpani (AP) at 3 % dilution (Drench)	17.61	17.11	17.36	14.09	13.60	13.85	117.01	111.03	114.02
T_9: T_1 + PG + AP + HA (Drench and Spray)	20.23	20.60	20.42	16.19	16.23	16.21	137.43	132.50	134.97
T_{10}: T_9 + AMF	28.07	30.54	29.31	24.68	25.45	25.06	246.85	240.55	243.70
T_{11}: T_{10} + *Azotobacter chroococcum* + *Azospirillum brasilense* + Phosphorous solubilizing bacteria (PSB)	33.07	35.93	34.50	28.68	30.16	29.42	293.98	287.76	290.87
T_{12}: AMF + *Azotobacter chroococcum* + *Azospirillum brasilense* + PSB + PG + AP + HA	24.62	24.81	24.72	19.69	19.62	19.66	174.28	169.44	171.86
S.Em ±	1.62	1.38	1.11	1.60	0.95	0.88	17.18	13.28	11.74
CD @ 5%	4.75	4.05	3.26	4.68	2.78	2.57	50.40	38.94	34.44
CV (%)	13.37	10.92	8.99	15.77	9.31	8.64	19.14	15.33	13.31

Table 2: Prevailing input costs of the experiment during 2018-19

Sl. No.	Input	Unit	Rate (Rs/unit)
1.	Cost of planting material (stolons)	kg	20.00
2.	FYM	tonne	1250.00
3.	AM fungi	kg	100.00
4.	Panchagavya	lit	30.00
5.	Amrutpani	kg	40.00
6.	*Azotobacter chroococcum*	kg	100.00
7.	*Azospirillum brasilense*	kg	100.00
8.	Phosphate solubilising bacteria	kg	100.00
9.	Urea	kg	6.44
10.	Single super phosphate	kg	12.50
11.	Muriate of potash	kg	36.60
12.	Neem oil	lit	150.00
13.	Hexaconazole	lit	200.00
14.	Labour charges	Man day	200.00
15.	Distillation charges	tonne	1000.00

Table 3: Economics of menthol mint (*Mentha arvensis* L.) cultivation as influenced by different bioformulations and biofertilizers

Treatments	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
T_1: Control (RDF) (150: 60: 60 NPK kg/ha and FYM-10 t/ha)	56,281	1,23,260	66,985	1.19
T_2: T_1 + Arbuscular Mycorrhiza Fungus (AMF)	66,411	2,35,655	1,69,490	2.56
T_3: Arbuscular Mycorrhiza Fungus (AMF)	53,704	1,80,796	1,27,129	2.37
T_4: T_1 + Humic acid (HA) at 0.2 % dilution (Drench)	58,835	1,35,034	76,106	1.29
T_5: T_1 + Panchagavya (PG) at 3 % dilution (Spray)	60,948	1,44,833	83,979	1.38
T_6: T_1 + Panchagavya (PG) at 3 % dilution (Drench)	61,815	1,44,397	82,434	1.33
T_7: T_1 + Amritpani (AP) at 3 % dilution (Spray)	59,718	1,33,272	73,753	1.24
T_8: T_1 + Amritpani (AP) at 3 % dilution (Drench)	62,155	1,42,521	80,610	1.30
T_9: T_1 + PG + AP + HA (Drench and Spray)	67,504	1,68,709	1,01,185	1.50
T_{10}: T_9 + AMF	78,493	3,04,619	2,25,739	2.86
T_{11}: T_{10} + *Azotobacter chroococcum* + *Azospirillum brasilense* + Phosphorous solubilizing bacteria (PSB)	82,680	3,63,591	2,80,168	3.36
T_{12}: AMF + *Azotobacter chroococcum* + *Azospirillum brasilense* + PSB + PG + AP + HA	63,771	2,14,829	1,51,096	2.37

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