Effect ofinorganic fertilizers and biofertilizers on growth, yield and quality of Japanese mint (*Mentha arvensis* L.) var. Kosi".

Abstract :

Aim: To study about the effect ofinorganic fertilizers and biofertilizerson growth, yield and menthol content of Japanese mint.
Study Design: The experiment was carried out with 13 treatments in Randomized Block Design (RBD) with three replications.
Place and Duration of Study: Research trial was carried out at P.G block, College of Horticulture, Rajendranagar, SKLTSHU, Hyderabad during Feb-May 2022 and Aug- Nov 2022
Results: Among the different treatments, the results reported that the T_2 (100% RDF + *Azospirillum*)recorded highest growth, yield and essential oil content compared to other treatments.

Key words: Japanese mint; *azotobacter*; *azospirillum*; kosi.

1. INTRODUCTION:

Mint is the common name of *Mentha arvensis* L. having approximately 25 species of the genus *Mentha* belonging to family Lamiaceae.The mint species*Mentha arvensis,* termed as Japanese mint have 80-85% menthol contents (Ozguven and Kirici, 1999). Kosi is a new released, early variety of menthol mint (90-100 days) and produces higher oil content (0.3-1.2%) containing 81- 83% menthol (Verma *et al.* 2018).The crop is commercially cultivated as spring season crop (January–February to April–May) in Tarai and the central part of Uttar Pradesh and Uttarakhand, Punjab, Bihar and Haryana (Singh *et al.* 1998; Upadhyay *et al.* 2012).Mint is valued for its multipurpose uses in the field of pharmaceuticals, cosmetics as well as for flavoring foods, beverages and tobacco (Ohloff, 1994). Utilization of biofertilizers enhance productivity by bio;ogical nitrogen fixation or solubilization of insoluble phosphate or producing harmones, vitamins and other growth factors required for plant growth (Bhattacharyya *et al.* 2000)

2. MATERIAL AND METHODS:

2.1 THE EXPERIMENTAL SITE

The present investigation was conducted at College of Horticulture, Rajendranagar during Feb-May and Aug-Nov 2022. The experiment was laid out in randomized block design (RBD) with 13 treatments and 3 replications. The experimental site is situated at a latitude of 17□.32’ North, longitude of 78□.40’ East and altitude of 542.3 m above mean sea level.

2.2 THE EXPERIMENT DESIGN

The plots were demarcated into three [3] replications, each replication with thirteen treatments and experimental design followed is Randomized Block Design (RBD) replicated thrice consisting of T_1 : 100% RDF + *Azotobacter*; T_2 : 100% RDF + *Azospirillum*; T_3 : 100% RDF + *VAM*; T_4 : 100% RDF + *PSB*; T_5 : 75% RDF + *Azotobacter* ; T_6: 75% RDF + *Azospirillum*; T_7: 75% RDF + *VAM*; T_8 : 75% RDF + *PSB*; T_9: 50% RDF + *Azotobacter*; T_{10}: 50% RDF + *Azospirillum*; T_{11}: 50% RDF + *VAM*; T_{12}: 50% RDF + *PSB*; T_{13}: Control (RDF- 160: 50: 40 NPK kg/ha)

2.3 THE PARAMETERS DETERMINED

2.3.1 Growth parameters

The data recorded on growth parameters like plant height (cm), number of primary branches, number of secondary branches, number of leaves, leaf area (cm^2) and crop growth rate ($g\ m^{-1}\ day^{-1}$).

2.3.2 Yield parameters

The data recorded on yield parameters like fresh herb yield per hectare (q), essential oil content (%) and oil yield per hectare (kg).

2.3.3 Quality parameters

The data recorded on quality parameters like menthol content.

2.4 STATISTICAL ANALYSIS

The experimental data collected on various growth, flowering and yield components of plant were subjected to Fisher’s method of “Analysis of variance” (ANOVA) as outlined by [were analysed.

3. RESULTS AND DISCUSSION

The results of the present investigation regarding the response of inorganic fertilizers and biofertilizers on growth, yield and economics of Japanese mint have been discussed and interpreted in light of previous research work in India. The results of the experiment are summarized below and also presented in tables.

3.1 Growth parameters

3.1.1 Plant height

The plant height differed significantly among the treatments and increased with advancement of crop stage.

The data revealed that during season 1, at 30, 60, 90 and 120 DAP, among the treatments, highest plant height (26.17 cm, 40.60 cm, 49.83 cm and 55.53 cm respectively) was observed with T_2 (100% RDF + *Azospirillum*) which was statistically on par with T_1 (100% RDF + *Azotobacter*) (25.87 cm, 39.63 cm, 48.67 cm and 54.17 cm respectively), T_6 (75% RDF + *Azospirillum*) (25.23 cm, 37.53 cm, 47.17 cm, and 53.00 cm) and T_5 (75% RDF + *Azotobacter)* (25.00 cm, 37.40 cm, 46.96 cm and52.20 cm). The lowest plant height (15.30 cm, 30.87 cm, 35.73 cm and 41.40 cm) at 30, 60, 90 and 120 DAP was recorded in T_{11} (50% RDF + *VAM)*.

The data presented in table 1 revealed that during season 2, at 30, 60, 90 and 120 DAP, among the treatments, the highest plant height (24.83 cm, 39.27 cm, 48.50 cm and 54.00 cm respectively) was observed with T_2 (100% RDF + *Azospirillum*) which was statistically on par with T_1 (100% RDF + *Azotobacter*) (24.47 cm, 38.40 cm, 47.33 cm and 53.03 cm respectively), T_6 (75% RDF + *Azospirillum*) (23.90 cm, 38.30 cm, 45.83 cm and 52.33 cm) and T_5 (75% RDF + *Azotobacter*) (23.60 cm, 37.20 cm, 45.63 cm and 51.60 cm). The lowest plant height (14.57 cm, 29.53 cm, 34.40 cm and 40.07 cm) at 30, 60, 90 and 120 DAP was recorded in T_{11} (50% RDF + *VAM)*.

In both the seasons T_2 (100% RDF + *Azospirillum*) recorded maximum plant height. The highest plant height could be due to certain growth promoting substances secreted by biofertilizers i.e., *Azospirillum*and *Azotobacter* which in turn, might have led to better root development, better transportation of water, uptake and deposition of nutrients. This may be due to application of integrated nutrient management, increased the photosynthetic activity, chlorophyll formation, nitrogen metabolism and auxin contents in the plants which ultimately improving the plant height. These findings were in agreement with the findings of Khandeel*et al*. (2002) in *Ocimumbasillicum*, Apurva *et al*. (2017) in *Rauwolfia serpentina* and Aswani *et al*. (2020) in Japanese mint.

Table1. Effect of inorganic fertilizers and biofertilizers on plant height (cm) of Japanese mint (*Menthaarvensis* L.) var. Kosi during Feb-May and Aug-Nov 2022

Treatments	30 DAP		60 DAP		90 DAP		120 DAP	
	Feb-May 2022	Aug-Nov 2022	Feb-May 2022	Aug-Nov 2022	Feb-May 2022	Aug-Nov 2022	Feb-May 2022	Aug-Nov 2022
T_1: 100% RDF+Azotobacter	25.87	24.47	39.63	38.40	48.67	47.33	54.17	53.03
T_2 : 100% RDF + Azospirillum	26.17	24.83	40.60	39.27	49.83	48.50	55.53	54.20
T_3 : 100% RDF + VAM	23.63	22.23	36.43	35.03	43.50	42.17	48.57	47.23
T_4 : 100% RDF + PSB	22.83	21.50	36.20	34.87	42.53	41.20	47.20	45.87
T_5 : 75% RDF + Azotobacter	25.00	23.60	37.40	37.20	46.96	45.63	52.20	51.60
T_6 : 75% RDF + Azospirillum	25.23	23.90	37.53	38.30	47.17	45.83	53.00	52.33
T_7 : 75% RDF + VAM	21.07	20.33	33.53	32.20	38.37	37.03	44.90	43.57
T_8 : 75% RDF + PSB	20.97	20.30	33.10	31.77	38.50	37.17	44.73	43.40
T_9 : 50% RDF + Azotobacter	15.63	14.90	31.80	30.47	36.53	35.20	41.87	40.53
T_{10} : 50% RDF + Azospirillum	15.23	14.57	30.70	29.37	35.27	33.93	42.30	40.97
T_{11} : 50% RDF + VAM	15.30	14.57	30.87	29.53	35.73	34.40	41.40	40.07
T_{12} : 50% RDF + PSB	15.20	14.53	30.96	29.63	35.97	34.63	41.07	39.73
T_{13} : Control (RDF-160:50:40 NPK kg/ha)	21.67	20.93	35.73	34.40	42.37	41.03	46.33	45.00
SEm±	0.57	0.49	1.21	0.87	1.50	1.04	1.56	0.99
CD @ 5%	1.67	1.42	3.53	2.53	4.37	3.05	4.55	2.88

3.1.2. Number of primary branches per plant

The perusal of data pertaining to number of primary branches per plant during season 1 indicated that significantly maximum number of branches (11.07, 26.40 and 27.07) at 60, 90 and 120 DAP respectively was observed with the application of T_2 (100% RDF + *Azospirillum*) and was at par with T_1 (100% RDF + *Azotobacter*) (10.80, 25.73 and 26.50), T_6 (75% RDF + *Azospirillum*) (9.90, 25.13 and 24.60) and T_5 (75% RDF + *Azotobacter*) (9.80, 24.23 and 24.40). The minimum number of branches per plant (6.14, 18.23 and 20.83) at 60, 90 and 120 DAP respectively was recorded with T_{11}(50% RDF + *VAM)*.

The perusal of data pertaining to number of branches per plant during season 2 indicated that significantly maximum number of primary branches (10.40, 25.73 and 27.07) at 30, 60, 90 and 120 DAP respectively was observed with the application of

T_2 (100% RDF + *Azospirillum*) and was at par with T_1 (100% RDF + *Azotobacter*) (10.13, 25.07 and 26.50), T6 (75% RDF + *Azospirillum*) (9.23, 24.47 and 24.60) and T_5 (75% RDF + Azotobacter) (9.12, 23.93 and 24.23). The minimum number of primary branches per plant (5.48, 16.90 and 20.16) at 30, 60, 90 and 120 DAP respectively was recorded with T_{11} (50% RDF + *VAM*).

In the present study maximum number of branches per plant was recorded in T_2 (100% RDF + *Azospirillum*) which may be due to combined application of inorganic fertilizers and biofertilizer, which influenced the availability of nitrogen. As azospirillum helps in production of more amount of nitrogen availability to plants.These results were in conformity with Singh *et al* (2012) in stevia, Roshan *et al.* (2014) in coriander.

Table 2. Effect of inorganic fertilizers and biofertilizers on number of primary branches of Japanese mint (*Menthaarvensis* L.) var. Kosi during Feb-May and Aug-Nov 2022.

Treatments	**60 DAP**		**90 DAP**		**120 DAP**	
	Feb-May 2022	**Aug-Nov 2022**	**Feb-May 2022**	**Aug-Nov 2022**	**Feb-May 2022**	**Aug-Nov 2022**
T_1: 100% RDF+Azotobacter	10.80	10.13	26.50	25.17	25.73	25.07
T_2 : 100% RDF + Azospirillum	11.07	10.40	27.07	25.73	26.40	25.73
T_3 : 100% RDF + VAM	9.07	8.40	21.03	20.13	23.73	23.07
T_4 : 100% RDF + PSB	8.87	8.20	21.47	19.70	23.67	23.00
T_5 : 75% RDF + Azotobacter	9.80	9.12	24.40	23.17	24.23	23.93
T_6 : 75% RDF + Azospirillum	9.90	9.23	24.60	23.54	25.13	24.47
T_7 : 75% RDF + VAM	7.40	6.73	20.93	19.60	22.10	21.43
T_8 : 75% RDF + PSB	7.20	5.87	20.83	19.50	21.84	21.17
T_9 : 50% RDF + Azotobacter	7.03	6.37	19.23	17.90	21.14	20.47
T_{10} : 50% RDF + Azospirillum	6.53	5.87	18.73	17.40	21.02	20.35
T_{11} : 50% RDF + VAM	6.14	5.48	18.23	16.90	20.83	20.16
T_{12} : 50% RDF + PSB	5.81	5.15	17.53	16.20	20.43	19.76
T_{13} : Control (RDF-160:50:40 NPK kg/ha)	9.33	8.67	20.63	19.30	22.59	21.92
SEm±	0.46	0.46	0.99	0.94	0.68	0.67
CD @ 5%	1.35	1.33	2.90	2.75	1.98	1.97

3.1.3 Number of secondary branches per plant

Results of different treatments on number of secondary branches per plant is furnished in Table 3. A significant difference was observed among different treatments.

The perusal of data pertaining to number of secondary branches per plant during season 1 indicated that significantly maximum number of secondary branches (4.70 and 8.27) at 90 and 120 DAP respectively was observed with the application of

T_2 (100% RDF + *Azospirillum*) and was at par with T_1 (100% RDF + *Azotobacter*) (4.43 and 7.87) which is statistically on par with T_6 (75% RDF + *Azospirillum*) (4.23 and 7.50) and T_5 (75% RDF + *Azotobacter*) (4.13 and 7.30). The minimum number of branches per plant (1.00 and 3.67) at 30, 60, 90 and 120 DAP respectively were recorded with T_{11}(50% RDF + *VAM*).

The perusal of data pertaining to number of secondary branches per plant during season 2 indicated that significantly maximum number of secondary branches (4.57 and 8.13) at 90 and 120 DAP respectively was observed with the application of T_2 (100% RDF + *Azospirillum*) and was at par with T_1 (100% RDF + *Azotobacter*) (4.30 and 7.73) which was statistically on par with T_6 (75% RDF + *Azospirillum*) (4.12 and 7.40) and T_5 (75% RDF + *Azotobacter*) (4.01 and 7.17). The minimum number of primary branches per plant (1.00 and 3.53) at 90 and 120 DAP respectively was recorded with T_{11} (50% RDF + *VAM*).

In the present study maximum number of secondary branches per plant was recorded in T_2 (100% RDF + *Azospirillum*) which may be due to combined application of inorganic fertilizers and biofertilizer, which influenced the availability of nitrogen. As azospirillum helps in production of more amount of nitrogen availability to plants. Similar trend was observed by Khandeel*et al*. (2002) in *Ocimumbasillicum*, Singh *et al* (2012) in stevia.

Table 3.Effect of inorganic fertilizers and biofertilizers on number of secondary branches of Japanese mint (*Menthaarvensis* L.) var. Kosi during Feb-May and Aug-Nov 2022.

Treatments	90 DAP		120 DAP	
	Feb-May 2022	**Aug-Nov 2022**	**Feb-May 2022**	**Aug-Nov 2022**
T_1: 100% RDF+Azotobacter	4.43	4.30	7.87	7.73
T_2 : 100% RDF + Azospirillum	4.70	4.57	8.27	8.13
T_3 : 100% RDF + VAM	3.50	3.39	6.37	6.23
T_4 : 100% RDF + PSB	3.53	3.43	6.43	6.30
T_5 : 75% RDF + Azotobacter	4.13	4.01	7.30	7.17
T_6 : 75% RDF + Azospirillum	4.23	4.12	7.50	7.40
T_7 : 75% RDF + VAM	3.00	2.87	5.87	5.73
T_8 : 75% RDF + PSB	2.90	2.77	5.67	5.53
T_9 : 50% RDF + Azotobacter	1.80	1.67	3.87	3.73
T_{10} : 50% RDF + Azospirillum	1.10	1.07	3.77	3.63
T_{11} : 50% RDF + VAM	1.00	1.00	3.67	3.53
T_{12} : 50% RDF + PSB	1.00	1.00	3.67	3.53
T_{13} : Control (RDF-160:50:40 NPK kg/ha)	3.57	3.43	6.27	6.13
SEm±	0.26	0.20	0.36	0.38
CD @ 5%	0.77	0.57	1.04	1.10

3.1.4. Number of leaves per plant

The data pertaining to the number of leaves per plant at 30, 60, 90 and 120 DAP as influenced by the different inorganic fertilizers and biofertilizers treatments are presented in Table 4.

The data revealed that during season 1 maximum number of leaves per plant (30.60, 257.53, 760.87 and 947.53) at 30, 60, 90 and 120 DAP respectively was observed with T_2 (100% RDF + *Azospirillum*), and was at par with T_1 (100% RDF + *Azotobacter*) (28.40, 240.20, 748.20 and 921.87), T_6 (75% RDF + *Azospirillum*) (28.19, 235.20, 738.63 and 902.20) and T_5 (75% RDF + Azotobacter) (27.67, 233.83, 735.20 and 894.63). The minimum number of leaves per plant (25.67, 109.43, 459.12 and 602.10) at 30, 60, 90 and 120 DAP respectively was recorded with T_{11} (50% RDF + *VAM*).

The data presented in Table 4. revealed that during season 2 maximum number of leaves per plant (29.93, 250.87, 755.87 and 937.20) at 30, 60, 90 and 120 DAP respectively was observed with T_2 (100% RDF + *Azospirillum*), and was at par with T_1 (100% RDF + *Azotobacter*) (27.73, 236.87, 743.20 and 911.53), T_6 (75% RDF + *Azospirillum*) (27.53, 231.87, 733.63 and 894.87) and T_5 (75% RDF + *Azotobacter*) (27.00, 230.49, 730.20 and 886.97). The minimum number of leaves per plant (25.00, 106.09, 454.12 and 590.77) at 30, 60, 90 and 120 DAP respectively was recorded with T_{11} (50% RDF + *VAM*).

The higher number of leaves per plant during season 1 and season 2 was obtained under the treatment T_2 i.e., combined application of inorganic and biofertilizers (100% RDF + *Azospirillum*) The result revealed that the combined application of inorganic and biofertilizers recorded significantly maximum values at all the growth stages could be due to timely supply of all nutrients, resulted in luxurious vegetative growth of plant. Increased number of leaves are also related to bio-fertilizers applied which might have produced bioactive substances having similar effects as that of growth regulators which in turn has resulted in increasing the number of leaves. These findings were in agreement with the findings of Roshan *et al.* (2014) in coriander and Aswani *et al*. (2020) in Japanese mint.

Table 4. Effect of inorganic fertilizers and biofertilizers on number of leaves of Japanese mint (*Menthaarvensis* L.) var. Kosi during Feb-May and Aug-Nov 2022.

Treatments	30 DAP		60 DAP		90 DAP		120 DAP	
	Feb-May	Aug-Nov	Feb-May	Aug-Nov	Feb-May	Aug-Nov	Feb-May	Aug-Nov

	2022	**2022**	**2022**	**2022**	**2022**	**2022**	**2022**	**2022**
T_1: 100% RDF+Azotobacter	28.40	27.73	240.20	236.87	748.20	743.20	921.87	911.53
T_2 : 100% RDF + Azospirillum	30.60	29.93	257.53	250.87	760.87	755.87	947.53	937.20
T_3 : 100% RDF + VAM	26.63	25.30	194.97	191.63	645.30	640.30	749.07	737.73
T_4 : 100% RDF + PSB	26.93	25.60	218.63	215.30	638.40	633.40	762.63	751.63
T_5 : 75% RDF + Azotobacter	27.67	27.00	233.83	230.49	735.20	730.20	894.63	886.97
T_6 : 75% RDF + Azospirillum	28.19	27.53	235.20	231.87	738.63	733.63	902.20	894.87
T_7 : 75% RDF + VAM	25.73	25.07	179.07	175.73	565.87	560.87	652.63	641.96
T_8 : 75% RDF + PSB	25.20	24.53	172.53	169.20	554.30	549.30	648.63	637.63
T_9 : 50% RDF + Azotobacter	25.30	24.63	110.97	107.63	472.83	467.83	606.17	595.17
T_{10} : 50% RDF + Azospirillum	25.67	25.00	109.50	106.16	468.77	463.77	605.09	594.42
T_{11} : 50% RDF + VAM	25.67	25.00	109.43	106.09	459.12	454.12	602.10	590.77
T_{12} : 50% RDF + PSB	25.07	24.40	95.20	91.87	457.17	452.17	598.50	586.83
T_{13} : Control (RDF-160:50:40 NPK kg/ha)	26.10	25.43	165.93	162.60	639.27	634.27	679.60	675.60
SEm±	1.09	1.30	9.86	7.56	12.42	11.07	19.16	19.26
CD @ 5%	3.17	3.78	28.79	22.07	36.26	32.32	55.91	56.21

3.1.5 Leaf area (cm^2)

Data with regard to leaf area (cm^2) are furnished in Table 5. Leaf area was significantly influenced due to inorganic manures and biofertilizers in combined application at 30, 60, 90 and 120 DAP.

The perusal of data pertaining to leaf area during season 1 indicated that significantly maximum leaf area (3.97 cm^2, 8.12 cm^2, 13.05 cm^2 and 18.37 cm^2) at 30, 60, 90 and 120 DAP respectively was observed with application of T_2 (100% RDF + *Azospirillum*), and were on par with T_1 (100% RDF + *Azotobacter*) (3.94 cm^2, 8.07 cm^2, 12.97 cm^2 and 17.87 cm^2) and T_6 (75% RDF + *Azospirillum*) (3.92 cm^2, 7.96 cm^2, 12.25 cm^2 and 17.50 cm^2) and T_5 (75% RDF + *Azotobacter*) (3.91 cm^2, 7.23 cm^2, 12.20 cm^2 17.12 cm^2). The minimum leaf area (3.10 cm^2, 4.10 cm^2, 8.00 cm^2 and 13.80 cm^2) at 30, 60, 90 and 120 DAP respectively was recorded with T_{12} (50% RDF + *PSB)*.

The data presented in Table 5. revealed that during season 2 significantly maximum leaf area (3.90 cm^2, 7.98 cm^2, 12.91 cm^2 and 18.03 cm^2) at 30, 60, 90 and 120 DAP respectively was observed with application of T_2 (100% RDF + *Azospirillum*) and were on par with T_1 (100% RDF + *Azotobacter*) (3.88 cm^2, 7.94

cm^2, 12.83 cm^2 and 17.53 cm^2) T$_6$ (75% RDF + *Azospirillum*) (3.85 cm^2, 7.83 cm^2, 12.11 cm^2 g and 17.17 cm^2) and T$_5$ (75% RDF + *Azotobacter)* (3.85 cm^2, 7.30 cm^2, 12.06 cm^2 and 16.79 cm^2). The minimum leaf area (3.03 cm^2, 3.97 cm^2, 7.86 cm^2 and 13.47 cm^2) at 30, 60, 90 and 120 DAP respectively was recorded with T$_{12}$ (50% RDF + *PSB*).

The leaf area (cm^2) recorded was more in T$_2$ at 30, 60, 90, and 120 DAP during season 1 and season 2 might be due to higher availability of nutrients which have accelerated the synthesis of chlorophyll and amino acids which are associated with photosynthetic process of plants resulted in higher leaf area. These findings are in agreement with the findings of Khandeel*et al*. (2002) in *Ocimumbasillicum* and Roshan *et al.* (2014) in coriander.

Table 5. Effect of inorganic fertilizers and biofertilizers on leaf area (cm^2) of Japanese mint (*Menthaarvensis* L.) var. Kosi during Feb-May and Aug-Nov 2022.

Treatments	30 DAP		60 DAP		90 DAP		120 DAP	
	Feb-May 2022	Aug-Nov 2022	Feb-May 2022	Aug-Nov 2022	Feb-May 2022	Aug-Nov 2022	Feb-May 2022	Aug-Nov 2022
T$_1$: 100% RDF+Azotobacter	3.94	3.88	8.07	7.94	12.97	12.83	17.87	17.53
T$_2$: 100% RDF + Azospirillum	3.97	3.90	8.12	7.98	13.05	12.91	18.37	18.03
T$_3$: 100% RDF + VAM	3.72	3.66	6.62	6.56	10.70	10.57	16.49	16.16
T$_4$: 100% RDF + PSB	3.80	3.73	6.86	6.69	10.72	10.59	16.82	16.49
T$_5$: 75% RDF + Azotobacter	3.91	3.85	7.23	7.30	12.20	12.06	17.12	16.79
T$_6$: 75% RDF + Azospirillum	3.92	3.85	7.96	7.83	12.25	12.11	17.50	17.17
T$_7$: 75% RDF + VAM	3.68	3.62	6.16	6.03	9.39	9.26	15.81	15.48
T$_8$: 75% RDF + PSB	3.64	3.57	6.16	6.03	9.49	9.35	15.68	15.35
T$_9$: 50% RDF + Azotobacter	3.41	3.35	5.63	5.49	8.27	8.14	14.56	14.23
T$_{10}$: 50% RDF + Azospirillum	3.37	3.30	5.41	5.28	8.30	8.17	14.80	14.47
T$_{11}$: 50% RDF + VAM	3.23	3.17	4.40	4.27	7.70	7.57	14.42	14.09
T$_{12}$: 50% RDF + PSB	3.10	3.03	4.10	3.97	8.00	7.86	13.80	13.47
T$_{13}$: Control (RDF-160:50:40 NPK kg/ha)	3.44	3.37	6.88	6.44	9.88	9.75	15.61	15.28
SEm±	0.205	0.05	0.32	0.26	0.39	0.42	0.47	0.44
CD @ 5%	0.598	0.14	0.94	0.75	1.13	1.21	1.36	1.28

3.1.6 Crop growth rate (g m^{-2} d^{-1})

The data enunciated on crop growth rate (g m^{-2} d^{-1}) at 30 - 60, 60 - 90 and 90 - 120 DAP as affected by the application of inorganic fertilizers and biofertilizers during season 1 and season 2 are presented in the Table 6.

With respect to different treatments during season 1 there were significant differences on crop growth rate at 30 - 60, 60 - 90 and 90 -120 DAP. significantly maximum crop growth rate (1.60, 4.11 and 2.23 g m^{-1} day) at 30, 60, 90 and 120 DAP respectively was observed with application of T_2 (100% RDF + *Azospirillum*), and it was on par with T_1 (100% RDF + *Azotobacter*) (1.59, 3.94 and 2.13) and T_6 (75% RDF + *Azospirillum*) (1.57, 3.81 and 2.06) and T_5 (75% RDF + Azotobacter*)* (1.56, 3.79 and 1.98). The crop growth rate (1.46, 3.34 and 1.12) at 30, 60, 90 and 120 DAP respectively was recorded with T_{11} (50% RDF + *VAM*).

The crop growth rate (CGR) derived from 13 different treatments was determined from 30 to 120 DAP and the results are furnished in Table 6. The data presented in Table.6 revealed that during season 2 significantly maximum crop growth rate (1.55, 4.08 and 2.02) at 30, 60, 90 and 120 DAP respectively was observed with application of T_2 (100% RDF + *Azospirillum*) and were on par with T_1 (100% RDF + *Azotobacter*) (1.54, 3.92 and 1.93) T_6 (75% RDF + *Azospirillum*) (1.53, 3.76 and 1.81) and T_5 (75% RDF + *Azotobacter)* (1.53, 3.74 and 1.78). The minimum crop growth rate (1.44, 3.19 and 0.87) at 30, 60, 90 and 120 DAP respectively were recorded with T_{11} (50% RDF + *VAM*).

Dry matter produced for unit area during a particular time interval (CGR) is a product of NAR and LAI. It presents sum of CGR's of individual component. Major plant determinant of photosynthetic potential is developed and maintenance of photosynthetically active leaf area. The increasing crop growth rate due to combined application of inorganic fertilizers and biofertilizers may be due to the ready availability of macronutrients and nitrogen fixation by azospirillum and azotobacter there by increase in number of leaves, fresh weight and dry weight of leaves which increased the leaf area and leaf area index in treatment T_2 (100% RDF + *Azospirillum*) during season 1 and season 2.These findings were in agreement with the findings of Khandeel*et al*. (2002) in *Ocimumbasillicum* and Singh *et al.* (2012) in stevia.

Table 6. Effect of inorganic fertilizers and biofertilizers on crop growth rate (g m^{-1} day^{-1}) of Japanese mint (*Menthaarvensis* L.) var. Kosi during Feb-May and Aug-Nov 2022.

Treatments	30- 60 DAP		60- 90 DAP		120 DAP	
	Feb-May 2022	Aug-Nov 2022	Feb-May 2022	Aug-Nov 2022	Feb-May 2022	Aug-Nov 2022
T_1: 100% RDF+Azotobacter	1.59	1.54	3.94	3.92	2.13	1.93

T_2 : 100% RDF + Azospirillum	1.60	1.55	4.11	4.08	2.23	2.02
T_3 : 100% RDF + VAM	1.53	1.51	3.73	3.68	1.52	1.27
T_4 : 100% RDF + PSB	1.51	1.49	3.74	3.69	1.63	1.39
T_5 : 75% RDF + Azotobacter	1.56	1.53	3.79	3.74	1.98	1.78
T_6 : 75% RDF + Azospirillum	1.57	1.53	3.81	3.76	2.06	1.81
T_7 : 75% RDF + VAM	1.46	1.44	3.39	3.34	1.39	1.14
T_8 : 75% RDF + PSB	1.51	1.48	3.34	3.29	1.36	1.12
T_9 : 50% RDF + Azotobacter	1.51	1.48	3.29	3.24	1.21	0.97
T_{10} : 50% RDF + Azospirillum	1.51	1.48	3.32	3.27	1.29	1.04
T_{11} : 50% RDF + VAM	1.46	1.44	3.34	3.19	1.12	0.87
T_{12} : 50% RDF + PSB	1.51	1.48	3.34	3.29	1.19	0.94
T_{13} : Control (RDF-160:50:40 NPK kg/ha)	1.46	1.44	3.59	3.54	1.44	1.19
SEm±	0.02	0.01	0.12	0.13	0.12	0.09
CD @ 5%	0.05	0.03	0.34	0.37	0.36	0.26

3.1.7 Fresh herb yield per hectare (q)

Data on the fresh herb yield per hectare at harvest as influenced by different treatments are presented in Table 7. Significantly maximum fresh herb yield per hectare (225.04 q) was recorded in T_2 (100% RDF + *Azospirillum*), and was on par with T_1 (100% RDF + *Azotobacter*) (224.84 q) and T_6 (75% RDF + *Azospirillum*) (222.14 q) and T_5 (75% RDF + *Azotobacter)* (220.79 q). The fresh herb yield per plant (144.08 q) at 30, 60, 90 and 120 DAP respectively was recorded with T_{11} (50% RDF + *VAM*) during season 1.

With respect to different treatments, fresh herb yield per hectare was significantly affected at harvest. The treatment T_2 (100% RDF + *Azospirillum*) registered significantly maximum fresh herb yield per hectare (221.34 q) and was on par with T_1 (100% RDF + *Azotobacter*) (219.58 q) and T_6 (75% RDF + *Azospirillum*) (216.41 q) and T_5 (75% RDF + *Azotobacter*(21.20 q). The fresh herb yield per plant (139.78 q) at 30, 60, 90 and 120 DAP respectively was recorded with T_{11} (50% RDF + *VAM*) during season 2.

The increased fresh yield per hectare with application of 100% RDF + *Azospirillum* (T_2) in season 1 and season 2 could be attributed to increased plant height, number of branches, plant spread, number of leaves, leaf area and dry matter accumulation with this treatment. It is further evident from the data that use of biofertilizers alone or in combination with RDF differentially influenced the herbage yield of Japanese mint. However, the highest yield might be due to increase in plant height, number of leaves, and yield attributes viz., fresh weight of whole plant, fresh and dry weight of leaves. This might be due to the availability of the nutrients in readily available form. These findings were in agreement with the finding of Aswani *et al*. (2020) in Japanese mint

3.1.8 Essential oil content (%)

The data pertaining to essential oil content (%) influenced by the application of inorganic fertilizers and biofertilizers during season 1 and season 2 are presented in the Table 7.

The results indicated that in season 1, application of inorganic fertilizers and biofertilizers had significant influence on Essential oil content (%). Among the treatments, T_2 (100% RDF + *Azospirillum*) recorded significantly maximum essential oil content (0.91 %) which was statistically on par with T_1 (100% RDF + *Azotobacter*) (0.90 %), T_6 (75% RDF + *Azospirillum*) (0.89 %) T_5 (75% RDF + *Azotobacter*) (0.88 %), while minimum value (0.75%) was recorded in T_{11} (50% RDF + *VAM*).

All treatments differed significantly with respect to Essential oil content (%) during season 2. Among the treatments, T_2 (100% RDF + *Azospirillum*) recorded significantly maximum essential oil content (%) (0.83 %) which was statistically on par with T_1(100% RDF + *Azotobacter*) (0.82 %), by T_6 (75% RDF + *Azospirillum*) (0.82 %) and T_5 (75% RDF + *Azotobacter*) (0.81 %), while minimum value (0.66 %) was recorded in T_{11} (50% RDF + *VAM*).

Essential oil content and its yield is an important consideration in any aromatic crop in realizing the maximum returns. The essential oil content in Japanese mint was significantly influenced by the application of inorganic fertilizers and biofertilizers in summer and Kharif. In the present study, the plant supplied with T_2 (100% RDF + *Azospirillum*) recorded significantly the highest essential oil content compared to T_{11} (50% RDF + *VAM*) which recorded the least percentage of oil. This was due to the influence of combined application of fertilizers which helped in promoting the vegetative growth which inturn increased the herbage production, consequently the essential oil increased to a greater extent. These findings were in agreement with the findings of Khandeel*et al*. (2002) in *Ocimumbasillicum*andAswani *et al*. (2020) in Japanese mint.

Table 7. Effect of inorganic fertilizers and biofertilizers on fresh herb yield (q/ha), essential oil content (%), oil yield (kg/ha) of Japanese mint (*Menthaarvensis* L.) var. Kosi during Feb-May and Aug-Nov 2022.

Treatments	Fresh herb yield (q/ha)		Essential oil content (%)		Oil yield (kg/ha)	
	Feb-May 2022	Aug-Nov 2022	Feb-May 2022	Aug-Nov 2022	Feb-May 2022	Aug-Nov 2022
T_1: 100% RDF+Azotobacter	224.84	219.58	0.90	0.82	202.80	180.49
T_2 : 100% RDF + Azospirillum	225.04	221.34	0.91	0.83	205.69	184.15
T_3 : 100% RDF + VAM	190.35	189.39	0.84	0.76	159.89	144.12
T_4 : 100% RDF + PSB	200.67	191.86	0.85	0.77	170.57	148.28
T_5 : 75% RDF + Azotobacter	220.79	213.20	0.88	0.81	195.18	175.10
T_6 : 75% RDF + Azospirillum	222.14	216.41	0.89	0.82	197.70	176.66
T_7 : 75% RDF + VAM	176.17	175.20	0.83	0.74	145.69	129.48
T_8 : 75% RDF + PSB	172.05	171.90	0.83	0.75	143.32	128.07
T_9 : 50% RDF + Azotobacter	153.98	150.05	0.81	0.72	124.26	107.74

T_{10} : 50% RDF + Azospirillum	148.99	145.76	0.79	0.71	118.15	102.76
T_{11} : 50% RDF + VAM	144.08	139.78	0.75	0.67	109.31	93.75
T_{12} : 50% RDF + PSB	147.34	142.45	0.76	0.66	110.07	93.87
T_{13} : Control (RDF-160:50:40 NPK kg/ha)	182.52	180.96	0.83	0.75	150.88	135.48
SEm±	4.10	3.45	0.018	0.022	4.44	4.16
CD @ 5%	11.98	10.08	0.051	0.064	12.96	12.14

3.1.9. Essential oil yield (kg/ha)

Data with regard to the effect of inorganic fertilizers and biofertilizers on essential oil yield (kg/ha) is presented in Table 7.

The results indicated that in season 1 application of combination of inorganic fertilizers and biofertilizers had significant influence on Essential oil yield. Among the treatments, T_2 (100% RDF + *Azospirillum*) recorded significantly maximum essential oil yield (205.69 kg) which was statistically on par with T_1 (100% RDF + *Azotobacter*) (202.80 kg), T_6 (75% RDF + *Azospirillum*) (197.70 kg) and with T_5 (75% RDF + Azotobacter) (195.18 kg), while minimum value (109.31 kg) was recorded in T_{11} (50% RDF + *VAM*).

All treatments differed significantly with respect to essential oil yield (kg/ha). Among the treatments, T_2 ((100% RDF + *Azospirillum*) recorded significantly maximum essential oil yield (184.15 kg) which was statistically on par with T_1 (100% RDF + *Azotobacter*) (180.49 kg), T_6 (75% RDF + *Azospirillum*) (176.66 kg) and with T_5 (75% RDF + *Azotobacter*) (175.10), while minimum value (93.75 kg) was recorded in T_{11} (50% RDF + *VAM*) during season 2.

Oil production is the most important parameter in Japanese mint farming. Integrated nutrient management improve the chemical, physical and biological soil proprieties that reflect positively on plant growth and oil yield (Patra *et al.* 2000). These results are in conformity with cheena*et al.*(2020) in Ocimumgratissimum.

4. CONCLUSION: From the study it was concluded that different treatments have positive effect on growth and yield of Japanese mint. 75 %N +poultrymanure4 t/ha+ArkaMicrobial Consortium has shown best results compared to other treatments and proved to be the best treatment in Japanese mint.

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