Journal of Experimental Agriculture International

Volume 46, Issue 9, Page 294-308, 2024; Article no.JEAI.122057
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Effect of Integrated Nutrient Management on Growth, Herb Yield and Menthol Content of Japanese Mint (*Mentha arvensis* l.) Var. Kosi

K. Stella [a*], J. Cheena [b++], A. Kiran Kumar [c#], K. Venkatlaxmi [b†], B. Madhavi [d‡] and S. Praneeth Kumar [e‡]

[a] Department of Plantations, Spices, Medicinal and Aromatic crops, College of Horticulture, Sri Konda Laxman Telangana State Horticultural University, Hyderabad, India.
[b] College of Horticulture, Sri Konda Laxman Telangana State Horticultural University, Mahabubabad, Telangana, India.
[c] Administrative Office, Sri Konda Laxman Telangana State Horticultural University, Mulugu, Siddipet, Telangana, India.
[d] Fruit Research Station, Sri Konda Laxman Telangana State Horticultural University, Sangareddy, Telangana, India.
[e] Floriculture Research Station, Sri Konda Laxman Telangana State Horticultural University, Hyderabad, Telangana, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jeai/2024/v46i92826

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/122057

Original Research Article

Received: 23/06/2024
Accepted: 25/08/2024
Published: 01/09/2024

[++]*Associate Dean;*
[#]*Director of Research;*
[†]*Associate Professor;*
[‡]*Scientist;*
**Corresponding author: E-mail: stella.m7129@gmail.com;*

Cite as: *Stella, K., J. Cheena, A. Kiran Kumar, K. Venkatlaxmi, B. Madhavi, and S. Praneeth Kumar. 2024. "Effect of Integrated Nutrient Management on Growth, Herb Yield and Menthol Content of Japanese Mint (Mentha Arvensis l.) Var. Kosi". Journal of Experimental Agriculture International 46 (9):294-308. https://doi.org/10.9734/jeai/2024/v46i92826.*

ABSTRACT

Aim: To study about the effect of integrated nutrient management on growth, yield and menthol content of Japanese mint.

Study Design: The experiment was carried out with 17 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 75 % N + poultry manure 4 t/ha + Arka microbial consortium recorded maximum plant height (63.00 cm and 61.13 cm), number of primary branches (32.67 and 32.07), number of secondary branches (11.47 and 10.53), number of leaves (1130.67 and 1071.73), leaf area (19.73 cm2 and 18.23 cm2), fresh herb yield per hectare (246.62 q and 244.54 q) and essential oil yield (269.97 kg and 239.98 kg) which was statistically on par with 75% N + vermicompost 4 t/ha + Arka microbial consortium.

Keywords: Japanese mint; organic manures; arka microbial consortium; kosi.

1. INTRODUCTION

Mint is the common name of *Mentha arvensis* L. having approximately 25 species of the genus *Mentha* belonging to family Lamiaceae. Different species of the family Lamiaceae have been cultivated in different parts of the world and the major producing countries of mint are India, China, Vietnam and Brazil (Kumar et al. 2000) [1-4]. In India, it is cultivated in an area of more than 0.30-0.35 million hectares and produces approximately 0.030-0.035 million metric tonnes of essential oil per annum [5,6]. Different mint species often contains 40-85% menthol as major constituent. The mint species *Mentha piperita*, known as American peppermint contain 50-55% and *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 [7]. Mint has a potent flavour and gastrointestinal aftertaste [8]. It is also used in oral products e.g, tooth paste and mouth fresheners, due to its physiological cooling effect. The area under menthol mint cultivation in India is estimated to be 0.15 million hectares with annual production of 20,000 metric tons of essential oil. 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). Use of chemical fertilizer, herbicide and pesticide in horticulture for increasing yield and controlling weeds and pests will contaminate the water, air, food, decrease soil fertility, inhibit growth of soil microorganisms and hazard human health. This negative effect of agricultural practices could be reversed by the correct utilization of manures and/ or crop residues within cropping system either alone or in combination with organic fertilizer [5,9]. Beside these, utilization of organic manure is recommended for retaining productivity of problem soils, reducing the usages of chemical fertilizer, improving economy and minimizing environmental problems.

2. MATERIALS 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 17 treatments and 3 replications. The experimental site is situated at a latitude of 17º.32' North, longitude of 78º.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 seventeen treatments and experimental design followed is Randomized Block Design (RBD) replicated thrice consisting of T_1 : 50% N + FYM 20 t/ha, T_2 : 50% N + FYM 20 t/ha + Arka Microbial Consortium T_3 : 50 % N + vermicompost 4 t/ha, T_4 : 50 % N + vermicompost 4 t/ha + Arka Microbial Consortium, T_5 : 50 % N + poultry manure 4 t/ha, T_6 : 50% N + poultry manure 4 t/ha + Arka Microbial Consortium, T_7 : 50 % N + neem cake 1 t/ha, T_8 : 50 % N + neem cake 1 t/ha + Arka Microbial Consortium, T_9 : 75 % N + FYM 20 t/ha, T_{10} : 75 % N + FYM 20 t/ha + Arka Microbial Consortium, T_{11} : 75% N +

vermicompost 4 t/ha, T_{12} : 75 % N + vermicompost 4 t/ha + Arka Microbial Consortium, T_{13} : 75% N + poultry manure 4 t/ha, T_{14} : 75 % N + poultry manure 4 t/ha + Arka Microbial Consortium, T_{15}: 75 % N + neem cake 1 t/ha, T_{16}: 75 % N + neem cake 1 t/ha + Arka Microbial Consortium, T_{17}: Control.

2.3 The Parameters Determined

2.3.1 Growth parameters

2.3.1.1 Plant height

Plant height was measured from the base to the tip of the plant from five randomly tagged plants in each treatment at 30, 60, 90 days after planting (DAP) and at final harvest and their mean values were worked out and presented.

2.3.1.2 Number of primary branches

Number of primary branches of the plant was counted from five randomly tagged plants in each treatment at 60, 90 days after planting (DAP) and at final harvest and their mean values were worked out and presented.

2.3.1.3 Number of secondary branches

Number of secondary branches of the plant was counted from five randomly tagged plants in each treatment at 90 and 120 days after planting and at final harvest and their mean values were worked out and presented.

2.3.1.4 Number of leaves

Number of leaves of the plant was counted from five randomly tagged plants in each treatment at 30, 60, 90 days after planting (DAP) and at final harvest and their mean values were worked out and presented.

2.3.1.5. Leaf area (LA)

Leaves of five plants selected for fresh herb weight were separated and the leaf area was measured on LI-3100 Leaf area meter at 30, 60, 90 days after transplanting and at harvest and expressed as cm^2.

2.3.1.6 Crop growth rate (CGR)

The dry matter accumulation per unit land area is called as crop growth rate. After calculating the dry weight per plant, crop growth rate per plant was calculated at 60, 90 DAP and at final harvest. The CGR was calculated by the formula.

$$CGR = \frac{W2 - W1}{t2 - t1} \times \frac{1}{P}$$

Where, W_1 and W_2 are dry weight of the whole plant at time t_1 and t_2 respectively per unit land area (P).

2.3.2 Yield parameters

2.3.2.1 Fresh herb yield per hectare

Fresh herbage weight from each plot was calculated by separating the herb from the root of the entire plants was converted to per hectare and it was expressed in quintals (q).

2.3.2.2 Essential oil content

Essential oil from fresh herbage was extracted by using Clevenger apparatus. One kilogram of fresh herbage was chopped and taken into the mantle. One litre of water was added to the mantle and boiled at 90^{o}C. The percentage of oil extracted from fresh herbage was calculated by using the following formula.

$$\text{Essential oil (\%)} = \frac{Weight\ of\ the\ oil}{Weight\ of\ the\ herbage \times\ 100}$$

2.3.2.3 Oil yield

Oil yield was calculated by multiplying the fresh herb yield at harvest with respective essential oil content obtained by distillation process (on fresh weight basis) and expressed as litre/ha.

$$\text{Oil yield } \left(\frac{\text{Kg}}{\text{ha}}\right) = \frac{\text{Oil content (\%)} \times \text{ Fresh herbage yield}}{100}$$

Extraction of oil from Japanese mint by Clevenger's Apparatus: Oil from fresh herbage was extracted by using clevenger's apparatus. Apparatus consist of one round bottom flask of 1000 ml which is connected with another two way round flask which holds raw material. The top flask is connected with condenser through the connecter. The separating funnel is used for the separation of essential oil and water (Shahin, 2017.)

Oil extraction Procedure: Fresh shoots of Japanese mint along with leaves are cut into pieces within half a day after collection. The cut herbage of 250-500 g boiled with 1000 ml of distilled water in a Clevenger apparatus until oil distillation ceased after 5-6 hours. The volume of essential oil (ml) was determined from a calibrated trap. The essential oil in the distillate was dried over anhydrous Na_2SO_4 and kept in the freezer.

2.3.2.4 Menthol content

The mint oil was subjected to Gas chromatography using Flame Ionization detector fitted with electronic integrator using a 25 mm BP-20 fused silica column.

The Gas chromatography capillary column (30 m × 0.25 mm, 0.25 µm) programmed with temperature from 60 to 230ºC at 3ºC/min and then at 70 to 230ºC at 4ºC/min. Hydrogen gas was the carrier gas with injection volume 0.02 µl. Identification was based on retention time of standard compounds. The relative amount of individual components were calculated based on percent pack area relative to total peak area from the GC/FID analyses without using correction factor. Menthol content were expressed in percentage (%).

2.4 Statistical Analysis

The experimental data collected on various growth and yield components of plant were subjected to Fisher's method of "Analysis of variance" (ANOVA) as outlined by [7] were analysed.

3. RESULTS AND DISCUSSION

The results of the present investigation regarding the response of inorganic fertilizers, organic manures, arka microbial consortium and their combinations 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

Significant maximum plant height (32.00 cm, 45.00 cm, 56.00 cm and 60.00 cm) at 30, 60 and 90 days after planting (DAP) and at harvest respectively) was observed with T_{14} (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium) and was at par with T_{12} (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium (28.93 cm, 44.20 cm, 55.47 cm and 62.2 cm respectively). The lowest plant height (7.33 cm, 21.67cm, 31.67 cm and 37.60 cm) at 30, 60, 90 and 120 DAP was recorded in T_{17} control.

During season 2, significantly maximum plant height (28.67 cm, 40.17 cm, 52.17 cm and 61.13 cm respectively) was observed with T_{14} (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium) which was statistically on par with T_{12} (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium) (27.03 cm, 38.73 cm, 51.83cm, and 62.20 cm) at 30, 60 and 90 days after planting (DAP) and at harvest respectively). The lowest plant height (7.33 cm, 21.67 cm, 31.67 cm and 37.60 cm) at 30, 60, 90 DAP and at harvest was recorded in T_{17} control.

In both the seasons T_{14} (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium) recorded maximum plant height. Significant increase in plant height in the present study might be due to the differential response of nutrient combinations which ensured ready availability of nutrients for initial requirement through the inorganic source and at slow pace as long-term availability through organic source which has a role in cell division, other physiological processes. Similar report has been reported by Pramod et al .[10] in sweet basil, Choudhary et al*.* [11] in fenugreek, Himanshu et al*.* [7] in kalmegh.

3.1.2 Number of Primary branches per plant

Influence of different treatments on number of branches per plant is furnished in Table 2. A significant difference was observed among different treatments.

The perusal of data pertaining to number of primary branches per plant during season 1 indicated that significantly maximum number of primary branches (13.67, 30.67, 32.67) at 60, 90 and 120 DAP respectively were observed with the application of T_{14} (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium) and was at par with T_{12} (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium) (13.20, 28.67, 32.00), followed by T_{10} (75 % N + FYM 20 t/ha + Arka Microbial Consortium) (11.87, 27.00, 29.33). The minimum number of branches per plant (3.20, 7.33 and 9.33) at 30, 60, 90 and 120 DAP respectively were recorded with T_{17} (Control).

Table 1. Effect of integrated nutrient management on plant height (cm) of Japanese mint (*Mentha arvensis* 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 : 50% N + FYM 20 t/ha	14.63	10.18	36.6	27.1	49.6	39.47	50.13	49.63
T_2 : 50% N + FYM 20 t/ha + AMC	16.33	11.87	38	30.77	50.2	42.98	52.73	54.37
T_3 : 50 % N + vermicompost 4 t/ha	16.33	11.7	38.13	30.9	50	43.75	52.67	53.8
T_4 : 50 % N + vermicompost 4 t/ha + AMC	21.33	16.03	38.4	31.7	51.4	44.73	52.93	54.53
T_5 : 50 % N + poultry manure 4 t/ha	15	10.6	38.07	31.57	49.67	42.73	52.33	53.87
T_6 : 50% N + poultry manure 4 t/ha + AMC	21.33	13.13	38.13	31.7	50.4	43	52.93	54.57
T_7 : 50 % N + neem cake 1 t/ha	11	9.37	26.13	29.7	43.67	41	40.07	51.37
T_8 : 50 % N + neem cake 1 t/ha + AMC	12.97	15.17	27.6	31.1	45.8	43.17	43.07	54.7
T_9 : 75 % N + FYM 20 t/ha	18.6	17.36	39.8	33.83	51.47	45.37	56.53	54.8
T_{10} : 75 % N + FYM 20 t/ha + AMC	24.6	25.8	39.9	36.27	52.6	49.3	58.33	57.73
T_{11} : 75% N + vermicompost 4 t/ha	24.6	23.07	40.6	33.73	51.53	45.37	56.33	54.37
T_{12} : 75 % N + vermicompost 4 t/ha + AMC	28.93	27.03	44.2	38.73	55.47	51.83	62.2	60.2
T_{13} : 75% N + poultry manure 4 t/ha	24.3	23	39.47	33.13	51.8	45.48	56.2	54.5
T_{14} : 75 % N + poultry manure 4 t/ha + AMC	32	28.67	45	40.17	56	52.17	63	61.13
T_{15}: 75 % N + neem cake 1 t/ha	20.97	15.79	35.93	33.03	50.13	45.43	53.93	54.87
T_{16}: 75 % N + neem cake 1 t/ha + AMC	23.63	25.63	33.07	34.6	52.27	48.33	57.47	56.9
T_{17}: Control	7.33	6.63	21.67	13.37	31.67	18.22	37.6	31.87
	0.57	0.49	1.21	0.87	1.5	1.04	1.56	0.99
CD @ 5%	1.67	1.42	3.53	2.53	4.37	3.05	4.55	2.88

The number of primary branches per plant during season 2, indicated that significantly maximum number of primary branches (12.00, 27.81 and 32.07) at 60, 90 and 120 DAP respectively were observed with the application of T_{14} (Vermicompost 750 kg/ha + Farmyard Manure 3.75 t/ha + Neem cake 375 kg/ha) and was at par with T_{12} (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium) (11.80, 27.13 and 30.34), followed by T10 (75 % N + FYM 20 t/ha + Arka Microbial Consortium) (10.90, 25.57, 28.44). The minimum number of branches per plant (2.60, 7.51 and 9.50) at 60, 90 and 120 DAP respectively were recorded with T_{17} (Control).

In the present study maximum number of primary branches per plant was recorded in T_{14} (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium). Present result might be attributed to the readily available nutrients through inorganic fertilizers and effect of organic fertilizer that improves physical, chemical, and biological properties of soil i.e. increasing soil organic matter, cation exchange capacity, water holding capacity and availability of mineral nutrients and this in turn, increases number of primary branches and also this can be attributed to the reason that the taller plants could bear a greater number of branching nodes. These results are in harmony with those obtained by Soumya [12] in stevia, Dadiga and Jain [13] in coriander.

Table 2. Effect of integrated nutrient management on number of primary branches of Japanese mint (*Mentha arvensis* 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 : 50% N + FYM 20 t/ha	6.53	4.33	13.67	11.47	17	15.47
T_2 : 50% N + FYM 20 t/ha + AMC	8.87	7.27	15.67	13.87	19.33	18.07
T_3 : 50 % N + vermicompost 4 t/ha	7.87	6.33	15.67	13.83	18.33	17.23
T_4 : 50 % N + vermicompost 4 t/ha +AMC	9.87	9.27	17.67	16	20.33	19.13
T_5 : 50 % N + poultry manure 4 t/ha	7.87	6.33	13.67	11.87	17.33	16.07
T_6 : 50% N + poultry manure 4 t/ha + AMC	9.87	8.4	16.67	14.2	20.33	19.07
T_7 : 50 % N + neem cake 1 t/ha	5.87	5.33	11	11.8	13.33	15.13
T_8 : 50 % N + neem cake 1 t/ha + AMC	6.2	7.33	12	15	14	17.9
T_9 : 75 % N + FYM 20 t/ha	10.87	9.67	21.67	20	25.33	25.17
T_{10} : 75 % N + FYM 20 t/ha + AMC	11.87	10.9	27	25.57	29.33	28.44
T_{11} : 75% N + vermicompost 4 t/ha	10.87	10.23	23.33	23	26.67	26.3
T_{12} : 75 % N + vermicompost 4 t/ha + AMC	13.2	11.8	28.67	27.13	32	30.34
T_{13} : 75% N + poultry manure 4 t/ha	10.87	9.4	23	22	26.67	26.07
T_{14} : 75 % N + poultry manure 4 t/ha + AMC	13.67	12	30.67	27.81	32.67	32.07
T_{15}: 75 % N + neem cake 1 t/ha	9.93	9.4	13.67	23	23	24.23
T_{16}: 75 % N + neem cake 1 t/ha + AMC	11.2	10.87	26.33	25.34	28	27.87
T_{17}: Control	3.2	2.6	7.33	7.51	9.33	9.5
SEm±	0.36	0.34	0.92	0.66	1.11	1
CD @ 5%	1.02	0.99	2.66	1.91	3.21	2.89

3.1.3 Number of secondary branches per plant

Influence 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 (7.73 and 10.47) at 90 and 120 DAP respectively were observed with the application of T_{14} (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium) and was at par with T_{12} (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium) (7.59 and 9.90), followed by T_{10} (75 % N + FYM 20 t/ha + Arka Microbial Consortium) (6.33 and 9.24). The minimum number of branches per plant (1.73 and 2.13) at 30, 60, 90 and 120 DAP respectively were recorded with T_{17} (Control).

The perusal of data pertaining to number of secondary branches per plant during season 2, indicated that significantly maximum number of secondary branches (7.03 and 10.53) at 90 and 120 DAP respectively were observed with the application of T_{14} (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium) and was at par with T_{12} (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium) (6.83 and 9.87), followed by T_{10} (75 % N + neem cake 1 t/ha + Arka Microbial Consortium) (6.20 and 9.43). The minimum number of branches per plant (1.30 and 1.67) at 90 and 120 DAP respectively were recorded with T_{17} (Control).

In the present study maximum number of secondary branches per plant was recorded in T_{14} (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium). The number of secondary branches per plant was influenced significantly concerning the combined application of organic manures and inorganic fertilizers and AMC which might be due to the increased rates of photosynthesis and photosynthates. Increase in the number of secondary branches is also found to be related to the endogenous hormonal level and apical dominance in the plant. These results are in accordance with the findings of Shivanna et al. [14] in kalmegh, Yeboah et al. (2012) in *Artemisia annua*, Dadiga and Jain [13] in coriander.

Table 3. Effect of integrated nutrient management on number of secondary branches of Japanese mint (*Mentha arvensis* 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 : 50% N + FYM 20 t/ha	3.8	2.43	4.2	2.63
T_2 : 50% N + FYM 20 t/ha + AMC	4.33	3.63	4.8	4.27
T_3 : 50 % N + vermicompost 4 t/ha	3.92	3.37	4.39	3.8
T_4 : 50 % N + vermicompost 4 t/ha + AMC	4.66	4.77	4.86	5.17
T_5 : 50 % N + poultry manure 4 t/ha	3.66	3.1	4	3.33
T_6 : 50% N + poultry manure 4 t/ha + AMC	4.8	4.37	5.33	4.7
T_7 : 50 % N + neem cake 1 t/ha	2.8	2.37	3.53	2.89
T_8 : 50 % N + neem cake 1 t/ha + AMC	3.26	3.37	4.66	4.8
T_9 : 75 % N + FYM 20 t/ha	5.53	5.23	5.8	5.7
T_{10} : 75 % N + FYM 20 t/ha + AMC	6.33	6.2	9.24	9.43
T_{11} : 75% N + vermicompost 4 t/ha	6	5.63	6.9	6.48
T_{12} : 75 % N + vermicompost 4 t/ha + AMC	7.59	6.83	9.9	9.87
T_{13} : 75% N + poultry manure 4 t/ha	6.21	5.47	6.48	6.07
T_{14} : 75 % N + poultry manure 4 t/ha + AMC	7.73	7.03	11.47	10.53
T_{15}: 75 % N + neem cake 1 t/ha	4.93	4.77	5.2	5.39
T_{16}: 75 % N + neem cake 1 t/ha + AMC	6.27	6.03	8.77	9.33
T_{17}: Control	1.73	1.3	2.13	1.67
SEm±	0.28	0.2	0.28	0.26
CD @ 5%	0.8	0.58	0.8	0.76

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 combination of inorganic fertilizers, different organic manure and AMC treatments are presented in Table 4.

The data revealed that during season 1 maximum number of leaves per plant (41.93, 283.93, 818.67 and 1130.67) at 30, 60, 90 and 120 DAP respectively were observed with T_{14} (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium), and was at par with T_{12} (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium) (40.60, 270.60, 782.00, 1115.00), followed by T_{10} (75 % N + FYM 20 t/ha + Arka Microbial Consortium) (36.90, 256.90, 771.33, 1039.00). The minimum number of leaves per plant (19.03, 43.03, 91.33 and 220.67) at 30, 60, 90 and 120 DAP respectively were recorded with T_{17} (Control).

The data presented in Table 4. revealed that during season 2, maximum number of leaves per plant (38.00, 252.67, 769.33 and 1071.73) at 30, 60, 90 and 120 DAP respectively were observed with T_{14} (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium), and was at par with T_{12} (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium) (36.47, 247.33, 747.00 and 1056.83). The minimum number of leaves per plant (12.00, 36.33, 88.00 and 216.03) at 30, 60, 90 and 120 DAP respectively were recorded with T_{17} (Control).

The higher number of leaves per plant during season 1 and season 2 was obtained under the treatment T_{14} i.e., combined application of inorganic fertilizers, organic source of nutrients and AMC (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium). The number of leaves is dependent on the plant height, number of nodes and also on the number of branches both primaries and secondaries arising on the main shoot of the plant. More number of branches per plant is likely to produce more leaves. These results are in agreement with the findings of, Prabu and Arumugam [15] in Japanese mint, Rahman et al*.* [16] in tulsi and pudina, Bajeli et al*.* [17] in Japanese mint, Gurmanpreet et al*.* [18] in Japanese mint, Pramod et al. [10] in sweet basil Salem [19] in *Mentha piperata*.

3.1.5 Leaf area (cm^2)

The influence of different treatments on leaf area (cm^2) is furnished in Table 5. Leaf area was significantly influenced due to combination of inorganic fertilizers, organic manures and AMC at 30, 60, 90 and 120 DAP.

All treatments showed significant difference with respect to leaf area at all growth stages. Significantly maximum value (4.03 cm^2, 8.65 cm^2, 14.38 cm^2, 19.73 cm^2 respectively) were

Table 4. Effect of integrated nutrient management on number of leaves of Japanese mint (*Mentha arvensis* 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 : 50% N + FYM 20 t/ha	30.37	23.93	84.37	74.33	198.67	166.67	734.67	609.63
T_2 : 50% N + FYM 20 t/ha + AMC	31.97	26.67	86.63	82	204	168.67	773.67	734.8
T_3 : 50 % N + vermicompost 4 t/ha	31.37	25.67	99.37	86.07	215	179	732	679.6
T_4 : 50 % N + vermicompost 4 t/ha + AMC	32.97	26.6	91.63	76	389	345.33	780.67	725.8
T_5 : 50 % N + poultry manure 4 t/ha	30.97	24.6	76.97	73.27	223.33	192.33	610.67	653.7
T_6 : 50% N + poultry manure 4 t/ha + AMC	32.5	27	96.5	84.67	370	331.33	794	742.83
T_7 : 50 % N + neem cake 1 t/ha	22.97	26.33	72.97	55.33	128.33	155	571.67	519.29
T_8 : 50 % N + neem cake 1 t/ha + AMC	24.47	25.67	77.8	66	139.33	159.67	692.67	700.47
T_9 : 75 % N + FYM 20 t/ha	33.63	30.6	168.3	184.67	638	640	986.33	942.73
T_{10} : 75 % N + FYM 20 t/ha + AMC	36.9	34.2	256.9	238.67	771.33	735	1039	995.5
T_{11} : 75% N + vermicompost 4 t/ha	33.97	30.63	211.97	195	691	653.33	993.33	950.17
T_{12} : 75 % N + vermicompost 4 t/ha + AMC	40.6	36.47	270.6	247.33	782	747	1115	1056.83
T_{13} : 75% N + poultry manure 4 t/ha	33.51	29.33	214.18	195.33	757.67	713.67	1003.33	956.6
T_{14} : 75 % N + poultry manure 4 t/ha + AMC	41.93	38	283.93	252.67	818.67	769.33	1130.67	1071.73
T_{15}: 75 % N + neem cake 1 t/ha	30.97	27.67	159.63	152.13	583.33	603.67	852.33	928.4
T_{16}: 75 % N + neem cake 1 t/ha + AMC	35.4	33.27	236.13	236.67	749	723	1024.67	983.5
T_{17}: Control	19.03	12	43.03	36.33	91.33	88	220.67	216.03
SEm±	1.31	0.74	4.92	4.43	13.24	10.42	30.1	21.26
CD @ 5%	3.78	2.13	14.17	12.78	38.14	30.01	86.69	61.23

Table 5. Effect of integrated nutrient management on leaf area (cm^2) of Japanese mint (*Mentha arvensis* 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 : 50% N + FYM 20 t/ha	3.2	2.93	6.75	6.24	9.33	8.53	14.15	11
T_2 : 50% N + FYM 20 t/ha + AMC	3.28	2.88	6.81	6.41	9.77	9.3	15.35	13.78
T_3 : 50 % N + vermicompost 4 t/ha	3.28	2.81	6.86	6.44	9.74	9.54	15.46	14.07
T_4 : 50 % N + vermicompost 4 t/ha + AMC	3.3	2.9	6.86	6.51	9.7	9.62	15.7	13.81
T_5 : 50 % N + poultry manure 4 t/ha	3.25	2.85	6.81	6.44	9.67	9.06	15.36	14.43
T_6 : 50% N + poultry manure 4 t/ha + AMC	3.3	2.83	6.8	6.73	9.61	9.89	15.8	13.61
T_7 : 50 % N + neem cake 1 t/ha	3.25	2.78	6.36	6.17	8.36	8.37	13.6	13.95
T_8 : 50 % N + neem cake 1 t/ha + AMC	3.3	2.83	6.41	6.37	8.46	9.17	14.06	13.81
T_9 : 75 % N + FYM 20 t/ha	3.3	2.87	7.01	7.37	10.77	11.22	16.36	15.12
T_{10} : 75 % N + FYM 20 t/ha + AMC	3.96	3.43	7.55	7.61	12.18	12.23	17.35	16.73
T_{11} : 75% N + vermicompost 4 t/ha	3.27	3.15	6.94	7.42	11.03	11.32	16.58	15.02
T_{12} : 75 % N + vermicompost 4 t/ha + AMC	4.03	3.63	8.5	8.28	13.26	13.04	18.96	17.9
T_{13} : 75% N + poultry manure 4 t/ha	3.33	3.1	7.02	7.39	11.09	11.43	16.6	15.36
T_{14} : 75 % N + poultry manure 4 t/ha + AMC	4.03	3.63	8.65	8.51	14.38	13.91	19.73	18.23
T_{15}: 75 % N + neem cake 1 t/ha	3.29	3.1	6.44	7.13	9.89	10.62	16.2	15.43
T_{16}: 75 % N + neem cake 1 t/ha + AMC	3.96	3.59	7.13	7.57	11.58	11.71	17.15	16.43
T_{17}: Control	3.03	2.42	4.63	4.67	6.74	6.46	8.48	7.93
SEm±	0.18	0.24	0.34	0.26	0.53	0.43	0.64	0.44
CD @ 5%	0.51	0.68	0.99	0.74	1.52	1.23	1.84	1.27

recorded in T_{14} (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium) which were on par with T_{12} (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium) (4.03 cm^2, 8.50 cm^2, 13.26 cm^2 and 18.96 cm^2) followed by T_{10} (75 % N + FYM 20 t/ha + Arka Microbial Consortium) (3.96 cm^2, 7.55 cm^2, 12.18 cm^2 and 17.35 cm^2) during season 1, while it was minimum in T_{17} (Control) (3.03 cm^2, 4.63 cm^2, 6.74 cm^2 and 8.48 cm^2).

The data revealed that during season 2, maximum leaf area (3.63 cm^2, 8.51 cm^2, 13.91 cm^2 and 18.23 cm^2) at 30, 60, 90 and 120 DAP respectively was observed with application of T_{14} (Vermicompost 750 kg/ha + Farmyard Manure 3.75 t/ha + Neem cake 375 kg/ha) which were on par with T_{12} (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium) (3.63 cm^2, 8.28 cm^2, 13.04 cm^2 and 17.90 cm^2) followed by T_{10} (75 % N + FYM 20 t/ha + Arka Microbial Consortium) (3.43 cm^2, 7.61 cm^2, 12.23 cm^2 and 16.73 cm^2) while it was minimum in T_{17} (Control) (2.42 cm^2, 4.67 cm^2, 6.46 cm^2 and 7.93 cm^2).

The leaf area (cm^2) recorded was maximum in T_{14} during season 1 and season 2 which might be due to cell enlargement, increase in the number of cells, number of leaves or all of them. These results may be attributed to the effect of organic manures in increasing levels of endogenous hormones in treated plants which could be interpreted by cell division and cell elongation [20]. Further, this may be due to the physiological roles of vitamins and amino acids in the effect of organic treatments which increased role of the metabolic processes and levels of indigenous hormones, i.e., IAA and GA_3. The present investigated results were in accordance with Prabu and Arumugam [15] in Japanese mint, Rahman et al*.* [16] in tulsi and pudina, Bajeli et al*.* [17] in Japanese mint, Gurmanpreet et al*.* [18] in Japanese mint, Pramod et al. [10] in sweet basil Salem [21] in *Mentha piperata*.

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 different treatments during season 1 and season 2 are presented in the Table 6.

The treatment T_{14} (75 % N + poultry manure 4 t/ha + Arka microbial consortium) recorded maximum CGR (1.96, 5.39 and 2.29) which was statistically on par with T_{12} (75 % N + vermicompost 4 t/ha + Arka microbial consortium) (1.91, 5.31 and 2.15) Whereas the treatment T_{17} (Control) recorded minimum CGR (0.32, 0.95 and 1.04) at 30 - 60, 60 - 90 and 90 - 120 DAP respectively.

It was observed that the treatment T_{14} (75 % N + poultry manure 4 t/ha + Arka microbial consortium) produced higher CGR (1.91, 5.14 and 2.09 respectively) at 30 - 60, 60 - 90 and 90 -120 DAP than the other treatments, which was statistically on par with T_{12} (75 % N + vermicompost 4 t/ha + Arka microbial consortium) (1.86, 5.06 and 1.85). In contrast, T_{17} (Control) plants maintained the lowest CGR (0.06, 0.07 and 0.09) over its growth period during season 2.

Dry matter produced per unit area during a particular time interval (CGR) is a product of NAR and LAI. It presents sum of CGR's of individual component. The increasing crop growth rate due to combined application of inorganic fertilizers, organic manures and AMC may be due to the efficient utilization of available resources viz., nutrients, water, light there by increase in number of leaves, fresh weight and dry weight of leaves which increased the crop growth rate in treatment T_{14} (75 % N + poultry manure 4 t/ha + Arka microbial consortium) during both the seasons. Similar variations in growth parameters were reported by Chandana et al*.* (2018) in kalmegh and Mounika et al*.* (2021) in ambrette.

Table 6. Effect of integrated nutrient management on crop growth rate (g m-1 day-1) of Japanese mint (Mentha arvensis L.) var. Kosi during Feb-May and Aug-Nov 2022

Treatments	30-60 DAP		60-90 DAP		90-120 DAP	
	Feb-May 2022	Aug-Nov 2022	Feb-May 2022	Aug-Nov 2022	Feb-May 2022	Aug-Nov 2022
T_1 : 50% N + FYM 20 t/ha	0.96	0.93	3.05	2.82	1.38	1.25
T_2 : 50% N + FYM 20 t/ha + AMC	1.39	1.34	3.04	2.82	1.31	1.09
T_3 : 50 % N + vermicompost 4 t/ha	1.22	1.2	3.06	2.86	1.29	1.32
T_4 : 50 % N + vermicompost 4 t/ha + AMC	1.26	1.21	3.25	3.03	1.31	1.36
T_5 : 50 % N + poultry manure 4 t/ha	1.13	1.11	3.31	3.08	1.18	1.13
T_6 : 50% N + poultry manure 4 t/ha + AMC	1.33	1.28	3.15	3.17	1.39	1.18
T_7 : 50 % N + neem cake 1 t/ha	0.52	0.49	2.45	2.23	0.92	0.6
T_8 : 50 % N + neem cake 1 t/ha + AMC	0.71	0.66	2.89	2.67	0.68	0.35
T_9 : 75 % N + FYM 20 t/ha	1.51	1.48	3.35	3.1	1.55	1.25
T_{10} : 75 % N + FYM 20 t/ha + AMC	1.67	1.63	5.04	4.75	1.93	1.76
T_{11} : 75% N + vermicompost 4 t/ha	1.57	1.54	3.66	3.42	1.53	1.33
T_{12} : 75 % N + vermicompost 4 t/ha + AMC	1.91	1.86	5.31	5.06	2.15	1.85
T_{13} : 75% N + poultry manure 4 t/ha	1.71	1.68	3.81	3.56	1.58	1.29
T_{14} : 75 % N + poultry manure 4 t/ha + AMC	1.96	1.91	5.39	5.14	2.29	2.09

Treatments	30-60 DAP		60-90 DAP		90-120 DAP	
	Feb-May 2022	Aug-Nov 2022	Feb-May 2022	Aug-Nov 2022	Feb-May 2022	Aug-Nov 2022
T_{15}: 75 % N + neem cake 1 t/ha	1.45	1.43	3.34	3.09	1.28	1.06
T_{16}: 75 % N + neem cake 1 t/ha + AMC	1.56	1.51	4.99	4.7	1.88	1.76
T_{17}: Control	0.32	0.27	0.95	0.88	1.04	1.44
SEm±	0.08	0.06	0.05	0.07	0.08	0.09
CD @ 5%	0.22	0.19	0.15	0.21	0.24	0.26

3.2 Yield Parameters

3.2.1 Fresh herb yield per hectare (q)

Data on the fresh yield per hectare at harvest as influenced by combination of inorganic fertilizers, organic manures and AMC treatments in Japanese mint are presented in Table 7.

Significantly maximum value (246.62 q) was recorded in T_{14} (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium) was statistically on par with T_{12} (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium) (245.04 q) followed by T_{10} (75 % N + FYM 20 t/ha + Arka Microbial Consortium) (233.43 q) during season 1, while it was minimum in T_{17} Control (86.72 q).

The treatment T_{14} (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium) recorded maximum fresh yield per hectare (244.54 q) which was statistically on par with T_{12} (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium) (242.81 q) followed by T_{10} (75 % N + FYM 20 t/ha + Arka Microbial Consortium) (229.88 q), whereas treatment T_{17} (Control) recorded minimum fresh yield per hectare (83.78 q) during season 2.

In both the seasons the highest fresh herb yield per plant was registered in T_{14} (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium). The increase in fresh weight of herbage in treatments may be due to combined application of organic manures and inorganic fertilizers and AMC which increased the photosynthetic activity, nitrogen metabolism and auxin content in the plants, which in turn, improved the plant height, number of primary branches, number of leaves, leaf area per plant and all these growth parameters were correlated with the fresh herb yield of plant and results in higher whole biomass of the plant. These results are in confirmity with Vineeta pandey et al*.* (2015) in geranium and basil, Gurmanpreet Kaur et al*.* [18] in Japanese mint, Pramod et al*.* [10] in sweet basil, Gayatri et al*.* [22] in Japanese mint.

3.2.2 Essential oil yield (kg ha^{-1})

Results on effect of combination of inorganic fertilizers, organic manures and AMC on essential oil yield (kg ha^{-1}) are presented in Table 7.

The results indicated that during season 1, application of combination of inorganic fertilizers, organic manures and AMC had significant influence on essential oil yield. Among the treatments, T_{14} (75 % N + poultry manure 4 t/ha + Arka microbial consortium) recorded significantly maximum essential oil yield (269.97 kg) which was on par with T_{12} (75 % N + vermicompost 4 t/ha + Arka microbial consortium) (266.67 kg), followed by T_{10} (75 % N + FYM 20 t/ha + Arka microbial consortium) (252.59 kg), while minimum value (58.10 kg) was recorded in T_{17} (Control).

All treatments differed significantly with respect to essential oil yield (kg/ha). Among the treatments, T_{14} (75 % N + neem cake 1 t/ha + Arka microbial consortium) recorded significantly maximum essential oil yield (218.17 kg) which was on par with T_{12} (75 % N + vermicompost 4 t/ha + Arka microbial consortium) (212.13 kg) followed by T_{10} (75 % N + FYM 20 t/ha + Arka microbial consortium) (197.01 kg), while minimum value (52.22 kg) was recorded in T_{17} (Control) during season 2.

The essential oil content is an important parameter that determines the oil yield of Japanese mint during both the seasons. Essential oil is synthesized from products of photosynthesis through enzymatic actions. Higher oil recovery resulted in the increase in number of leaves as well as number of inflorescences. A positive correlation between increased leaf yield and oil content was reported by Arularasu and Sambandamurthi (1999) in Tulsi. The synthesis of essential oils is dependent on photosynthetic activity.

Table 7. Effect of integrated nutrient management on fresh herb yield per ha (q) and oil yield per ha (kg) of Japanese mint (*Mentha arvensis* L.) var. Kosi during Feb-May and Aug-Nov 2022

Treatments	Fresh herb yield (q/ha)		Oil yield (kg/ha)	
	Feb-May 2022	Aug-Nov 2022	Feb-May 2022	Aug-Nov 2022
T_1 : 50% N + FYM 20 t/ha	181.63	177.33	167.55	135.8
T_2 : 50% N + FYM 20 t/ha + AMC	190.27	185.38	179.08	149.77
T_3 : 50 % N + vermicompost 4 t/ha	184.49	180.79	168.86	143.77
T_4 : 50 % N + vermicompost 4 t/ha + AMC	191.96	187.66	180.66	151.59
T_5 : 50 % N + poultry manure 4 t/ha	184.49	182.35	171.79	145.48
T_6 : 50% N + poultry manure 4 t/ha + AMC	192.1	188.69	178.86	150.53
T_7 : 50 % N + neem cake 1 t/ha	137.78	132.59	122.42	99.69
T_8 : 50 % N + neem cake 1 t/ha + AMC	149.09	141.75	136.36	110.76
T_9 : 75 % N + FYM 20 t/ha	209.23	206.35	205.3	174.96
T_{10} : 75 % N + FYM 20 t/ha + AMC	233.43	229.88	252.59	218.09
T_{11} : 75% N + vermicompost 4 t/ha	212.79	210.64	213.25	183.01
T_{12} : 75 % N + vermicompost 4 t/ha + AMC	245.04	242.81	266.67	233.5
T_{13} : 75% N + poultry manure 4 t/ha	213.78	211.41	218.38	187.77
T_{14} : 75 % N + poultry manure 4 t/ha + AMC	246.62	244.54	269.97	239.98
T_{15}: 75 % N + neem cake 1 t/ha	195.7	192.81	182.97	154.56
T_{16}: 75 % N + neem cake 1 t/ha + AMC	215.92	211.4	220.51	189.82
T_{17}: Control	86.72	83.78	58.1	52.22
SEm±	1.89	2.57	2.12	3.99
CD @ 5%	5.45	7.4	6.11	11.5

Photosynthetic nutrient boost and metabolic processes are correlated to cell division and elongation (Hatwar et al. 2003). According to Pandey and Patra (2015) nitrogen plays a key role in the division, growth and development of cells that stimulate essential oil accumulation via higher density of oil glands due to the improvement in biomass yield.

3.2.3 Essential oil content (%)

The data pertaining to essential oil content (%) as influenced by the application of inorganic fertilizers, organic manures and AMC during season 1 and season 2 are presented in the Table 8.

Among the treatments, T_{14} (75% N + poultry manure 4 t/ha + Arka microbial consortium) recorded significantly maximum essential oil content (1.09%) which was statistically on par with T_{12} (1.09%) and T_{10} (1.08%), while minimum value (0.67%) was recorded in T_{17} (Control).

Among the treatments, T_{14} (75% N + poultry manure 4 t/ha + Arka microbial consortium) recorded significantly maximum essential oil content (0.98%) which was statistically on par with T_{12} (0.96%) and T_{10} (0.95%), while minimum value (0.62%) was recorded in T_{17} (Control) during season 2.

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 combination of inorganic fertilizers, organic manures and AMC during season 1 and season 2. In the present study, T_{14} (75 % N + poultry manure 4 t/ha + Arka microbial consortium) recorded significantly the highest essential oil content compared to T_{17} (Control) which recorded the least percentage of oil. Furthermore, it has been observed that N favoured the synthesis of many organic compounds such as proteins, enzymes, amino acids etc. the last two substances have a key role in the biosynthesis of many constituents of essential oils (Sarrou et al. 2016). The results confirmed with the findings Vineeta pandey et al. [23] in geranium and basil, Gurmanpreet Kaur et al. [18] in Japanese mint, Pramod et al. [10] in sweet basil, Aswani et al. [24] in Japanese mint, Pavithra et al. [25] in Japanese mint and Gayatri et al. [22] in Japanese mint.

3.3 Quality Parameters

3.3.1 Menthol content (%)

Data on effect of combination of inorganic fertilizers, different organic manures and AMC on menthol content (%) are presented in Table 8.

Table 8. Effect of integrated nutrient management on essential oil content (%) and menthol content of Japanese mint (*Mentha arvensis* L.) var. Kosi during Feb-May and Aug-Nov 2022

Treatments	Essential oil content (%)		Menthol content (%)	
	Feb-May 2022	Aug-Nov 2022	Feb-May 2022	Aug-Nov 2022
T_1 : 50% N + FYM 20 t/ha	0.92	0.77	70.06	66.26
T_2 : 50% N + FYM 20 t/ha + AMC	0.94	0.81	69.52	65.62
T_3 : 50 % N + vermicompost 4 t/ha	0.92	0.8	71.29	67.59
T_4 : 50 % N + vermicompost 4 t/ha + AMC	0.94	0.81	71.97	68.37
T_5 : 50 % N + poultry manure 4 t/ha	0.93	0.8	69.1	65.3
T_6 : 50% N + poultry manure 4 t/ha + AMC	0.93	0.8	70.89	66.99
T_7 : 50 % N + neem cake 1 t/ha	0.89	0.75	60.44	56.84
T_8 : 50 % N + neem cake 1 t/ha + AMC	0.91	0.78	66.56	62.86
T_9 : 75 % N + FYM 20 t/ha	0.98	0.85	72.33	70.31
T_{10} : 75 % N + FYM 20 t/ha + AMC	1.08	0.95	74.4	75.05
T_{11} : 75% N + vermicompost 4 t/ha	1	0.87	73.23	69.83
T_{12} : 75 % N + vermicompost 4 t/ha + AMC	1.09	0.96	76.59	76.15
T_{13} : 75% N + poultry manure 4 t/ha	1.02	0.89	73	70.66
T_{14} : 75 % N + poultry manure 4 t/ha + AMC	1.09	0.98	77.21	77.01
T_{15}: 75 % N + neem cake 1 t/ha	0.93	0.8	72.95	68.83
T_{16}: 75 % N + neem cake 1 t/ha + AMC	1.02	0.9	74.92	73.77
T_{17}: Control	0.67	0.62	65.53	61.63
SEm±	0.004	0.009	1.27	1.73
CD @ 5%	0.011	0.026	3.65	4.98

The results indicated that during season 1, combined application of inorganic fertilizers, organic manures and AMC had significant influence on menthol content. Among the treatments, T_{14} (75% N + poultry manure 4 t/ha + Arka microbial consortium) recorded significantly maximum menthol content (77.21%) which was on par with T_{12} (75% N + vermicompost 4 t/ha + Arka microbial consortium) (76.59%), T_{10} (74.40%) and T_{16} (74.92%) while minimum value (65.53%) was recorded in T_{17} (Control).

All treatments differed significantly with respect to menthol content (%). Among the treatments, T_{14} (75 % N + poultry manure 4 t/ha + Arka microbial consortium) recorded significantly maximum essential oil yield (77.01%) which was on par with T_{12} (75% N + vermicompost 4 t/ha + Arka microbial consortium) (76.15 %), T_{10} (75.05%) and T_{16} (73.77%) while minimum value (61.63%) was recorded in T_{17} (Control) during season 2 [26-31].

4. CONCLUSION

From the study it was concluded that different treatments have positive effect on growth and yield of Japanese mint. 75 % N + poultry manure 4 t/ha + Arka microbial consortium has shown best results compared to other treatments and proved to be the best treatment in Japanese mint. Combined application of inorganic fertilizers and organic manures ensured readily available nutrients for initial requirement through inorganic sources and longer availability through organic source. Besides biofertilizers improves soil environment and increases nitrogen fixation and phosphorus solubilization. The continuous availability of nutrients resulted in more nutrient uptake by plant there by maximum herb yield.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

ACKNOWLEDGEMENT

The authors are highly thankful to SKLTSHU, Rajendranagar, Hyderabad for the help and support rendered in carrying out the research trial.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Chand SNK, Patra M, Anwar, Patra DD. Agronomy and uses of Menthol mint (Mentha arvensis) – Indian perspective. Proc. Indian Natl. Sci. Acad.. 2004;3:269-297.
2. Clark GS. An aroma chemical profile: Menthol. Perfum. Flavor. 1998;23:33–46.
3. Lawrence BM. Mint: The genus Mentha. CRC Press, Boca Raton, FL; 2007.
4. Singh KM, Saini SS. Planting date, mulch and herbicide rate on the growth, yield and physicochemical properties of menthol mint (*Mentha arvensis L*.). Weed tech. 2008;22(4):691-698.
5. Kumar D, Kumar R, Singh AK, Verma K, Singh KP, Nilofer, Kumar A, Kaur P, Singh A, Pandey J, Khare P, Singh S. Influence of planting methods on production of suckers (rhizome or propagative material), essential oil yield, and quality of menthol mint (*Mentha arvensis* L.). International Journal of Current Microbiology and Applied Science. 2020;9(7):3675-3689.
6. Kumar A, Verma N, Nilofer Kaur P, Kumar D, Ghosh D, Singh A, Siddiqui A, Kumar N, Singh AK, Khare P, Singh S. Physiological and chemical changes induced by transparent polythene+ green net shed on *Pelargonium graveolens* L. mother plants during monsoon season. IndustrialCrops and Products. 2022;188:115686.
7. Himanshu Verma, Negi MS, Archana Joshi, Babita Belal, Anil Shukla, Mahapatra BS, Jai Paul. Growth Attributes of Kalmegh [*Andrographis paniculata* (Burm.f.) Wall Nees] as influenced by integrated nutrient management under Tarai conditions of Uttarakhand. International Journal of Chemical Studies. 2018;6(5):2947-2949.
8. Taneja S, Chandra S. Mint. Handbook of herbs and spices. Elsevier; 2012.
9. Mandal Asit, Ashok K. Patra, Dhyan Singh, Anand Swarup, Ebin Masto R. Effect of long-term application of manure and fertilizer on biological and biochemical activities in soil during crop development stages. Bioresource Technology. 2007; 98(18):3585-3592.
10. Pramod MB, Sivakumar V, Uma Jyothi K, Ravindra Babu M, Umakrishna K. Influence of organic manures and inorganic fertilizers on growth and yield parameters of sweet basil (*Ocimum basilicum* L.) International Journal of Chemical Studies. 2020;8(4):4032-4036.
11. Choudhary BR, Gupta AK, Parihar CM, Jat SL, Singh DK. Effect of integrated nutrient management on fenugreek (*Trigonella foenum graecum*) and its residual effect on fodder pearlmillet (*Pennisetum glaucum*) Indian Journal of Agronomy. 2011; 56(3):189-195.
12. Soumya DV. Integrated management practices on growth, yield and quality of stevia. M.Sc. (Hort.) Thesis submitted to the University of Agricultural Sciences; 2008.
13. Dadiga A, Jain PK. Comparison between different fertilization sources and their combinations on the growth and yield of coriander (*Coriandrum sativum* L.). Agriculture Update. 2017;12(8):2187-93.
14. Shivanna SG, Ramesh G, Santaram A. Interactive influence of organic manures and inorganic fertilizers on growth and yield of Kalmegh. (Andrographis paniculata Nees.). International Research Journal of Plant Science. 2011;2(1):16-21.
15. Prabu M, Shakila, Arumugam. Studies on organic nutrition in growth and yield of Japanese mint (*Mentha arvensis* L.). The Asian Journal of Horticulture. 2013;8(1): 126-128.
16. Rahman KM, Sattar MA, Rahman GMM. Effect of fertilizer and manures on growth and yield of tulsi and pudina medicinal plant. Journal of Environmental Sciences and Natural Resources. 2024;7(2):13-16.
17. Bajeli J, Tripathi S, Kumar A, Tripathi A, Upadhyay RK. Organic manures a convincing source for quality production of Japanese mint (*Mentha arvensis* L.). Industrial Crops Products. 2015;83: 603-06.
18. Gurmanpreet Kaur, Amanpreet Singh, Harpreet Singh, Kamalesh Kumar. Effect of Integrated Nutrient Management on growth and yield of Japanese mint (*Mentha arvensis* L.). Research Journal of Chemical and Environmental Sciences. 2019;7(3):30-34.
19. Salem M, Al-Amri. Response of growth, essential oil composition, endogenous hormones and microbial activity of Mentha piperita to some organic and biofertilizers agents. Saudi Journal of Biological Sciences. 2021;28:5435–5441.
20. Khedr ZMA, Farid S. Response of naturally virus infected tomato plants to yeast extract and phosphoric acid application. Annals of Agric. Sci. Moshtohor. 2000; 38(2):927-939.

21. Salem M, Al-Amri. Response of growth, essential oil composition, endogenous hormones and microbial activity of *Mentha piperita* to some organic and biofertilizers agents. Saudi Journal of Biological Sciences. 2021;28:5435–5441.
22. Gayatri A, Prasanna Kumar B, Vijayapadma SS, Naram Naidu L, Sasikala K and Dr. K Uma Krishna. Effect of planting date and INM on growth and yield in mint (*Mentha arvensis* L.) during summer season under north coastal plains of Andhra Pradesh. The Pharma Innovation Journal. 2023;12(4):2045-2050
23. Vineeta Pandey, Patra DD. Crop productivity, aroma profile and antioxidant activity in *Pelargonium graveolens* L'Hér. under integrated supply of various organic and chemical fertilizers. Industrial Crops and Products. 2015;67:257-263.
24. Aswani JS, Pushpa TN, Srikantprasad D, Chaya Patil P, IBIB. Biradar and Vijaykumar Gangaraddi. Influence of biofertilizers and bioformulations on biomass and essential oil yield of menthol mint (*Mentha arvensis* L.) Medicinal Plants. 2020;12(1):139-143
25. Pavithra M, Srikantaprasad D, Pushpa TN, Hiremath JS, Jalawadi S, Nandimath ST. Effect of spacing, bio formulations and bio fertilizers on growth of menthol mint (*Mentha arvensis* L.). The Pharma Innovation Journal. 2021;10(11):233- 236.
26. Ahmad H, Al-Fraihat, Sati YA, Al-dalain, Ziad B, AlRawashdeh. Effect of organic and biofertilizers on growth, herb yield and volatile oil of marjoram plant grown in Ajloun region, Jordan. Journal of Medicinal Plants Research. 2011;5(13):2822-33.
27. Chand S, Pandey A, Anwar M, Patra DD. Influence of integrated supply of vermicompost, biofertilizer and inorganic fertilizer on productivity and quality of rose scented geranium (*Pelargonium species*). Indian Journal of Natural Products and Resources. 2011;2(3):375-382.
28. Gomez KH, Gomez AA. Statistical procedures for agriculture research. John Willy and Sons, Inc., New York; 1984.
29. Lothe NB, Mazeed A, Pandey J, Patairiya V, Verma K, Semwal M, Verma RS, Verma RK. Maximizing yields and economics by supplementing additional nutrients for commercially grown menthol mint (*Mentha arvensis L*.) cultivars. Industrial Crops and Products. 2021;160:113110.
30. Sarrou Eirini, Chatzopoulou Paschalina, Theodoros Koutsos V, Stavros Katsiotis. Herbage yield and essential oil composition of sweet basil (*Ocimum basilicum L*.) under the influence of different mulching materials and fertilizers. Journal of Medicinal Plants Studies. 2016; 4(1):111-117.
31. Shahi VB, Singh PN. Effect of organic and inorganic sources of nutrients on yield and yield attributes of lemon grass (*Cymbopogon flexuosus*). Annals of Horticulture. 2013;6(1):49-55.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of the publisher and/or the editor(s). This publisher and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/122057