

## **Effect of integrated nutrient management on growth, yield and menthol content of Japanese mint (*Mentha arvensis* L.) Var. Kosi.**

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

**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 highest growth, yield and essential oil content compared to other treatments.**

**Key words: 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. 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 (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). 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. 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. 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 17 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 seventeen treatments and experimental design followed is Randomized Block Design (RBD) replicated thrice consisting of T<sub>1</sub> : 50% N + FYM 20 t/ha, T<sub>2</sub> : 50% N + FYM 20 t/ha + Arka Microbial Consortium T<sub>3</sub> : 50 % N + vermicompost 4 t/ha, T<sub>4</sub> : 50 % N + vermicompost 4 t/ha + Arka Microbial Consortium, T<sub>5</sub> : 50 % N + poultry manure 4 t/ha, T<sub>6</sub> : 50% N + poultry manure 4 t/ha + Arka Microbial Consortium, T<sub>7</sub> : 50 % N + neem cake 1 t/ha, T<sub>8</sub> : 50 % N + neem cake 1 t/ha + Arka Microbial Consortium, T<sub>9</sub> : 75 % N + FYM 20 t/ha, T<sub>10</sub> : 75 % N + FYM 20 t/ha + Arka Microbial Consortium, T<sub>11</sub> : 75% N + vermicompost 4 t/ha, T<sub>12</sub> : 75 % N + vermicompost 4 t/ha + Arka Microbial Consortium, T<sub>13</sub> : 75% N + poultry manure 4 t/ha, T<sub>14</sub> : 75 % N + poultry manure 4 t/ha + Arka Microbial Consortium, T<sub>15</sub>: 75 % N + neem cake 1 t/ha, T<sub>16</sub>: 75 % N + neem cake 1 t/ha + Arka Microbial Consortium, T<sub>17</sub>: Control

## **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<sup>2</sup>) and crop growth rate (g m<sup>-1</sup> day<sup>-1</sup>)

### **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 [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

The data pertaining to plant height in Table 1 as influenced by the effect of different treatments revealed that during season 1, significantly 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<sub>14</sub> (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium) and was at par with T<sub>12</sub> (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<sub>17</sub> 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<sub>14</sub> (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium) which was statistically on par with T<sub>12</sub> (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<sub>17</sub> control.

In both the seasons T<sub>14</sub> (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 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 and resulted in higher plant height. Similar report has been reported by Pramod *et al.* (2020) in sweet basil, Choudhary *et al.* (2011) in fenugreek, Himanshu *et al.* (2018) in kalmegh

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 <sub>1</sub> : 50% N + FYM 20 t/ha	14.63	10.18	36.60	27.10	49.60	39.47	50.13	49.63

T2 : 50% N + FYM 20 t/ha + AMC	16.33	11.87	38.00	30.77	50.20	42.98	52.73	54.37
T3 : 50 % N + vermicompost 4 t/ha	16.33	11.70	38.13	30.90	50.00	43.75	52.67	53.80
T4 : 50 % N + vermicompost 4 t/ha + AMC	21.33	16.03	38.40	31.70	51.40	44.73	52.93	54.53
T5 : 50 % N + poultry manure 4 t/ha	15.00	10.60	38.07	31.57	49.67	42.73	52.33	53.87
T6 : 50% N + poultry manure 4 t/ha + AMC	21.33	13.13	38.13	31.70	50.40	43.00	52.93	54.57
T7 : 50 % N + neem cake 1 t/ha	11.00	9.37	26.13	29.70	43.67	41.00	40.07	51.37
T8 : 50 % N + neem cake 1 t/ha + AMC	12.97	15.17	27.60	31.10	45.80	43.17	43.07	54.70
T9 : 75 % N + FYM 20 t/ha	18.60	17.36	39.80	33.83	51.47	45.37	56.53	54.80
T10 : 75 % N + FYM 20 t/ha + AMC	24.60	25.80	39.90	36.27	52.60	49.30	58.33	57.73
T11 : 75% N + vermicompost 4 t/ha	24.60	23.07	40.60	33.73	51.53	45.37	56.33	54.37
T12 : 75 % N + vermicompost 4 t/ha + AMC	28.93	27.03	44.20	38.73	55.47	51.83	62.2	60.20
T13 : 75% N + poultry manure 4 t/ha	24.30	23.00	39.47	33.13	51.80	45.48	56.20	54.50
T14 : 75 % N + poultry manure 4 t/ha + AMC	32.00	28.67	45.00	40.17	56.00	52.17	63.00	61.13
T15: 75 % N + neem cake 1 t/ha	20.97	15.79	35.93	33.03	50.13	45.43	53.93	54.87
T16: 75 % N + neem cake 1 t/ha + AMC	23.63	25.63	33.07	34.60	52.27	48.33	57.47	56.90
T17: Control	7.33	6.63	21.67	13.37	31.67	18.22	37.60	31.87
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

**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.**

### 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<sub>14</sub> (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium) and was at par with T<sub>12</sub> (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium) (13.20, 28.67, 32.00), followed by T<sub>10</sub> (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<sub>17</sub> (Control).

The perusal of data pertaining to 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<sub>14</sub> (Vermicompost 750 kg/ha + Farmyard Manure 3.75 t/ha + Neem cake 375 kg/ha) and was

at par with T<sub>12</sub> (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium) (11.80, 27.13 and 30.34), followed by T<sub>10</sub> (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<sub>17</sub> (Control).

In the present study maximum number of primary branches per plant was recorded in T<sub>14</sub> (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 (2008) in stevia, Dadiga and Jain (2017) 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 <sub>1</sub> : 50% N + FYM 20 t/ha	6.53	4.33	13.67	11.47	17.00	15.47
T <sub>2</sub> : 50% N + FYM 20 t/ha + AMC	8.87	7.27	15.67	13.87	19.33	18.07
T <sub>3</sub> : 50 % N + vermicompost 4 t/ha	7.87	6.33	15.67	13.83	18.33	17.23
T <sub>4</sub> : 50 % N + vermicompost 4 t/ha + AMC	9.87	9.27	17.67	16.00	20.33	19.13
T <sub>5</sub> : 50 % N + poultry manure 4 t/ha	7.87	6.33	13.67	11.87	17.33	16.07
T <sub>6</sub> : 50% N + poultry manure 4 t/ha + AMC	9.87	8.40	16.67	14.20	20.33	19.07
T <sub>7</sub> : 50 % N + neem cake 1 t/ha	5.87	5.33	11.00	11.80	13.33	15.13
T <sub>8</sub> : 50 % N + neem cake 1 t/ha + AMC	6.20	7.33	12.00	15.00	14.00	17.90
T <sub>9</sub> : 75 % N + FYM 20 t/ha	10.87	9.67	21.67	20.00	25.33	25.17
T <sub>10</sub> : 75 % N + FYM 20 t/ha + AMC	11.87	10.90	27.00	25.57	29.33	28.44
T <sub>11</sub> : 75% N + vermicompost 4 t/ha	10.87	10.23	23.33	23.00	26.67	26.30
T <sub>12</sub> : 75 % N + vermicompost 4 t/ha + AMC	13.20	11.80	28.67	27.13	32.00	30.34
T <sub>13</sub> : 75% N + poultry manure 4 t/ha	10.87	9.40	23.00	22.00	26.67	26.07
T <sub>14</sub> : 75 % N + poultry manure 4 t/ha + AMC	13.67	12.00	30.67	27.81	32.67	32.07
T <sub>15</sub> : 75 % N + neem cake 1 t/ha	9.93	9.40	13.67	23.00	23.00	24.23
T <sub>16</sub> : 75 % N + neem cake 1 t/ha + AMC	11.20	10.87	26.33	25.34	28.00	27.87
T <sub>17</sub> : Control	3.20	2.60	7.33	7.51	9.33	9.50
SEm±	0.36	0.34	0.92	0.66	1.11	1.00
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<sub>14</sub> (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium) and was at par with T<sub>12</sub> (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium) (7.59 and 9.90), followed by T<sub>10</sub> (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<sub>17</sub> (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<sub>14</sub> (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium) and was at par with T<sub>12</sub> (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium) (6.83 and 9.87), followed by T<sub>10</sub> (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<sub>17</sub> (Control).

In the present study maximum number of secondary branches per plant was recorded in T<sub>14</sub> (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. This character 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.* (2011) in kalmegh, Yeboah *et al.* (2012) in *Artemisia annua*, Dadiga and Jain (2017) 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
T1 : 50% N + FYM 20 t/ha	3.80	2.43	4.20	2.63
T2 : 50% N + FYM 20 t/ha + AMC	4.33	3.63	4.80	4.27
T3 : 50 % N + vermicompost 4 t/ha	3.92	3.37	4.39	3.80
T4 : 50 % N + vermicompost 4 t/ha + AMC	4.66	4.77	4.86	5.17
T5 : 50 % N + poultry manure 4 t/ha	3.66	3.10	4.00	3.33
T6 : 50% N + poultry manure 4 t/ha + AMC	4.80	4.37	5.33	4.70
T7 : 50 % N + neem cake 1 t/ha	2.80	2.37	3.53	2.89
T8 : 50 % N + neem cake 1 t/ha + AMC	3.26	3.37	4.66	4.80

T9 : 75 % N + FYM 20 t/ha	5.53	5.23	5.80	5.70
T10 : 75 % N + FYM 20 t/ha + AMC	6.33	6.20	9.24	9.43
T11 : 75% N + vermicompost 4 t/ha	6.00	5.63	6.90	6.48
T12 : 75 % N + vermicompost 4 t/ha + AMC	7.59	6.83	9.90	9.87
T13 : 75% N + poultry manure 4 t/ha	6.21	5.47	6.48	6.07
T14 : 75 % N + poultry manure 4 t/ha + AMC	7.73	7.03	10.47	10.53
T15: 75 % N + neem cake 1 t/ha	4.93	4.77	5.20	5.39
T16: 75 % N + neem cake 1 t/ha + AMC	6.27	6.03	8.77	9.33
T17: Control	1.73	1.30	2.13	1.67
sEm+	0.28	0.20	0.28	0.26
CD @ 5%	0.80	0.58	0.80	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<sub>14</sub> (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium), and was at par with T<sub>12</sub> (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium) (40.60, 270.60, 782.00, 1115.00), followed by T<sub>10</sub> (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<sub>17</sub> (Control).

The data presented in Table 4.5. 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<sub>14</sub> (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium), and was at par with T<sub>12</sub> (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<sub>17</sub> (Control).

The higher number of leaves per plant during season 1 and season 2 was obtained under the treatment T<sub>14</sub> 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 (2013) in Japanese mint, Rahman *et al.* (2014) in tulsi and pudina, Bajeli *et al.* (2016) in Japanese mint, Gurmanpreet *et al.* (2019) in Japanese mint, Pramod *et al.* (2020) in sweet basil Salem (2021) in *Mentha piperata*.

**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
T1 : 50% N + FYM 20 t/ha	30.37	23.93	84.37	74.33	198.67	166.67	734.67	609.63
T2 : 50% N + FYM 20 t/ha + AMC	31.97	26.67	86.63	82.00	204.00	168.67	773.67	734.80
T3 : 50 % N + vermicompost 4 t/ha	31.37	25.67	99.37	86.07	215.00	179.00	732.00	679.60
T4 : 50 % N + vermicompost 4 t/ha + AMC	32.97	26.60	91.63	76.00	389.00	345.33	780.67	725.80
T5 : 50 % N + poultry manure 4 t/ha	30.97	24.60	76.97	73.27	223.33	192.33	610.67	653.70
T6 : 50% N + poultry manure 4 t/ha + AMC	32.50	27.00	96.50	84.67	370.00	331.33	794.00	742.83
T7 : 50 % N + neem cake 1 t/ha	22.97	26.33	72.97	55.33	128.33	155.00	571.67	519.29
T8 : 50 % N + neem cake 1 t/ha + AMC	24.47	25.67	77.80	66.00	139.33	159.67	692.67	700.47
T9 : 75 % N + FYM 20 t/ha	33.63	30.60	168.30	184.67	638.00	640.00	986.33	942.73
T10 : 75 % N + FYM 20 t/ha + AMC	36.90	34.20	256.90	238.67	771.33	735.00	1039.00	995.50
T11 : 75% N + vermicompost 4 t/ha	33.97	30.63	211.97	195.00	691.00	653.33	993.33	950.17
T12 : 75 % N + vermicompost 4 t/ha + AMC	40.60	36.47	270.60	247.33	782.00	747.00	1115.00	1056.83
T13 : 75% N + poultry manure 4 t/ha	33.51	29.33	214.18	195.33	757.67	713.67	1003.33	956.60
T14 : 75 % N + poultry manure 4 t/ha + AMC	41.93	38.00	283.93	252.67	818.67	769.33	1130.67	1071.73
T15: 75 % N + neem cake 1 t/ha	30.97	27.67	159.63	152.13	583.33	603.67	852.33	928.40
T16: 75 % N + neem cake 1 t/ha + AMC	35.40	33.27	236.13	236.67	749.00	723.00	1024.67	983.50
T17: Control	19.03	12.00	43.03	36.33	91.33	88.00	220.67	216.03
SEm±	1.31	0.74	4.92	4.43	13.24	10.42	30.10	21.26
CD @ 5%	3.78	2.13	14.17	12.78	38.14	30.01	86.69	61.23

### 3.1.5 Leaf Area (cm<sup>2</sup>)

The influence of different treatments on leaf area (cm<sup>2</sup>) 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<sup>2</sup>, 8.65 cm<sup>2</sup>, 14.38 cm<sup>2</sup>, 19.73 cm<sup>2</sup> respectively) were recorded in T<sub>14</sub> (75 % N + poultry manure 4 t/ha + Arka Microbial Consortium) which were on par with T<sub>12</sub> (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium) (4.03 cm<sup>2</sup>, 8.50 cm<sup>2</sup>, 13.26 cm<sup>2</sup> and 18.96 cm<sup>2</sup>) followed by T<sub>10</sub> (75 % N + FYM 20 t/ha + Arka Microbial Consortium) (3.96 cm<sup>2</sup>, 7.55 cm<sup>2</sup>, 12.18 cm<sup>2</sup> and 17.35 cm<sup>2</sup>) during season 1, while it was minimum in T<sub>17</sub> (Control) ( 3.03 cm<sup>2</sup>, 4.63 cm<sup>2</sup>, 6.74 cm<sup>2</sup> and 8.48 cm<sup>2</sup>).

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

The leaf area (cm<sup>2</sup>) recorded was more in T<sub>14</sub> at 30, 60, 90, and 120 DAP during season 1 and season 2 might be due to the increasing of cell enlargement, cell number, 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 (Khedr and Farid, 2000). 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<sub>3</sub>. The present investigated results were in accordance to those found, Prabu and Arumugam (2013) in Japanese mint, Rahman *et al.* (2014) in tulsi and pudina, Bajeli *et al.* (2016) in Japanese mint, Gurmanpreet *et al.* (2019) in Japanese mint, Pramod *et al.* (2020) in sweet basil Salem (2021) in *Mentha piperata*.

**Table 5. Effect of integrated nutrient management on leaf area (cm<sup>2</sup>) 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
T1 : 50% N + FYM 20 t/ha	3.20	2.93	6.75	6.24	9.33	8.53	14.15	11.00
T2 : 50% N + FYM 20 t/ha + AMC	3.28	2.88	6.81	6.41	9.77	9.30	15.35	13.78
T3 : 50 % N + vermicompost 4 t/ha	3.28	2.81	6.86	6.44	9.74	9.54	15.46	14.07
T4 : 50 % N + vermicompost 4 t/ha + AMC	3.30	2.90	6.86	6.51	9.70	9.62	15.70	13.81
T5 : 50 % N + poultry manure 4 t/ha	3.25	2.85	6.81	6.44	9.67	9.06	15.36	14.43
T6 : 50% N + poultry manure 4 t/ha + AMC	3.30	2.83	6.80	6.73	9.61	9.89	15.80	13.61
T7 : 50 % N + neem cake 1 t/ha	3.25	2.78	6.36	6.17	8.36	8.37	13.60	13.95
T8 : 50 % N + neem cake 1 t/ha + AMC	3.30	2.83	6.41	6.37	8.46	9.17	14.06	13.81
T9 : 75 % N + FYM 20 t/ha	3.30	2.87	7.01	7.37	10.77	11.22	16.36	15.12
T10 : 75 % N + FYM 20 t/ha + AMC	3.96	3.43	7.55	7.61	12.18	12.23	17.35	16.73
T11 : 75% N + vermicompost 4 t/ha	3.27	3.15	6.94	7.42	11.03	11.32	16.58	15.02
T12 : 75 % N + vermicompost 4 t/ha + AMC	4.03	3.63	8.50	8.28	13.26	13.04	18.96	17.90

T13 : 75% N + poultry manure 4 t/ha	3.33	3.10	7.02	7.39	11.09	11.43	16.60	15.36
T14 : 75 % N + poultry manure 4 t/ha + AMC	4.03	3.63	8.65	8.51	14.38	13.91	19.73	18.23
T15: 75 % N + neem cake 1 t/ha	3.29	3.10	6.44	7.13	9.89	10.62	16.20	15.43
T16: 75 % N + neem cake 1 t/ha + AMC	3.96	3.59	7.13	7.57	11.58	11.71	17.15	16.43
T17: 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

### 3.1.6 Crop growth rate ( $\text{g m}^{-2} \text{d}^{-1}$ )

The data enunciated on crop growth rate ( $\text{g m}^{-2} \text{d}^{-1}$ ) 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 4.6.

With respect to different treatments in season 1 there were significant differences on crop growth rate at 30 - 60, 60 - 90 and 90 -120 DAP. The treatment T<sub>14</sub> (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<sub>12</sub> (75 % N + vermicompost 4 t/ha + Arka microbial consortium) (1.91, 5.31 and 2.15) Whereas the treatment T<sub>17</sub> (Control) recorded minimum CGR (0.32, 0.95 and 1.04) at 30 - 60, 60 - 90 and 90 -120 DAP respectively.

The Crop Growth Rate (CGR) derived from 17 different treatments was determined from 30 to 120 DAP and the results are furnished in Table 4.11. It was observed that the treatment T<sub>14</sub> (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<sub>12</sub> (75 % N + vermicompost 4 t/ha + Arka microbial consortium) (1.86, 5.06 and 1.85). In contrast, T<sub>17</sub> (Control) plants maintained the lowest CGR (0.06, 0.07 and 0.09) over its growth period during season 2.

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, 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 Leaf area and Leaf area Index in treatment T<sub>14</sub> (75 % N + poultry manure 4 t/ha + Arka microbial consortium) during season 1 and season 2. Similar variations in growth parameters were reported by Chandana *et al.* (2018) in kalmegh and Mounika *et al.* (2021) in ambrette.

**Table 4.6 Effect of integrated nutrient management on crop growth rate ( $\text{g m}^{-1} \text{ day}^{-1}$ ) 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
T1 : 50% N + FYM 20 t/ha	0.96	0.93	3.05	2.82	1.38	1.25
T2 : 50% N + FYM 20 t/ha + AMC	1.39	1.34	3.04	2.82	1.31	1.09
T3 : 50 % N + vermicompost 4 t/ha	1.22	1.20	3.06	2.86	1.29	1.32
T4 : 50 % N + vermicompost 4 t/ha + AMC	1.26	1.21	3.25	3.03	1.31	1.36
T5 : 50 % N + poultry manure 4 t/ha	1.13	1.11	3.31	3.08	1.18	1.13
T6 : 50% N + poultry manure 4 t/ha + AMC	1.33	1.28	3.15	3.17	1.39	1.18
T7 : 50 % N + neem cake 1 t/ha	0.52	0.49	2.45	2.23	0.92	0.60
T8 : 50 % N + neem cake 1 t/ha + AMC	0.71	0.66	2.89	2.67	0.68	0.35
T9 : 75 % N + FYM 20 t/ha	1.51	1.48	3.35	3.10	1.55	1.25
T10 : 75 % N + FYM 20 t/ha + AMC	1.67	1.63	5.04	4.75	1.93	1.76
T11 : 75% N + vermicompost 4 t/ha	1.57	1.54	3.66	3.42	1.53	1.33
T12 : 75 % N + vermicompost 4 t/ha + AMC	1.91	1.86	5.31	5.06	2.15	1.85
T13 : 75% N + poultry manure 4 t/ha	1.71	1.68	3.81	3.56	1.58	1.29
T14 : 75 % N + poultry manure 4 t/ha + AMC	1.96	1.91	5.39	5.14	2.29	2.09
T15: 75 % N + neem cake 1 t/ha	1.45	1.43	3.34	3.09	1.28	1.06
T16: 75 % N + neem cake 1 t/ha + AMC	1.56	1.51	4.99	4.70	1.88	1.76
T17: 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 4.7

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

With respect to treatments with combination of inorganic fertilizers, organic manures and AMC, fresh yield per hectare was significantly affected at harvest. The treatment T<sub>14</sub> (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<sub>12</sub> (75 % N + vermicompost 4 t/ha + Arka Microbial Consortium) (242.81 q) followed by T<sub>10</sub> (75 % N + FYM 20 t/ha + Arka Microbial Consortium) (229.88 q), whereas treatment T<sub>17</sub> (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<sub>14</sub> (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, in turn, improved the 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 line with Vineeta pandey *et al.* (2015) in geranium and basil, Gurmanpreet Kaur *et al.* (2019) in Japanese mint, Pramod *et al.* (2020) in sweet basil, Gayatri *et al.* (2023) in Japanese mint.

### 3.2.2 Essential oil yield (kg ha<sup>-1</sup>)

Results on effect of combination of inorganic fertilizers, organic manures and AMC on essential oil yield (kg ha<sup>-1</sup>) are presented in Table 4.7

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<sub>14</sub> (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<sub>12</sub> (75 % N + vermicompost 4 t/ha + Arka microbial consortium) (266.67 kg), followed by T<sub>10</sub> (75 % N + FYM 20 t/ha + Arka microbial consortium) (252.59 kg), while minimum value (58.10 kg) was recorded in T<sub>17</sub> (Control).

All treatments differed significantly with respect to essential oil yield (kg/ha). Among the treatments, T<sub>14</sub> (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<sub>12</sub> (75 % N + vermicompost 4 t/ha + Arka microbial consortium) (212.13 kg) followed by T<sub>10</sub> (75 % N + FYM 20 t/ha + Arka microbial consortium) (197.01 kg), while minimum value (52.22 kg) was recorded in T<sub>17</sub> (Control) during season 2.

The essential oil content is an important parameter that determines the oil yield of Japanese mint during season 1 and season 2. Essential oil is synthesized from products of photosynthesis through enzymatic actions. Higher oil recovery had 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. Providing of photosynthetic nutrient boost and metabolic processes 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.

**Table 4.7. 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 <sub>1</sub> : 50% N + FYM 20 t/ha	181.63	177.33	167.55	135.80
T <sub>2</sub> : 50% N + FYM 20 t/ha + AMC	190.27	185.38	179.08	149.77
T <sub>3</sub> : 50 % N + vermicompost 4 t/ha	184.49	180.79	168.86	143.77
T <sub>4</sub> : 50 % N + vermicompost 4 t/ha + AMC	191.96	187.66	180.66	151.59
T <sub>5</sub> : 50 % N + poultry manure 4 t/ha	184.49	182.35	171.79	145.48
T <sub>6</sub> : 50% N + poultry manure 4 t/ha + AMC	192.10	188.69	178.86	152.80
T <sub>7</sub> : 50 % N + neem cake 1 t/ha	137.78	132.59	122.42	82.98
T <sub>8</sub> : 50 % N + neem cake 1 t/ha + AMC	149.09	141.75	136.36	93.39
T <sub>9</sub> : 75 % N + FYM 20 t/ha	209.23	206.35	205.30	156.12
T <sub>10</sub> : 75 % N + FYM 20 t/ha + AMC	233.43	229.88	252.59	197.01
T <sub>11</sub> : 75% N + vermicompost 4 t/ha	212.79	210.64	213.25	163.71
T <sub>12</sub> : 75 % N + vermicompost 4 t/ha + AMC	245.04	242.81	266.67	212.13
T <sub>13</sub> : 75% N + poultry manure 4 t/ha	213.78	211.41	218.38	168.03
T <sub>14</sub> : 75 % N + poultry manure 4 t/ha + AMC	246.62	244.54	269.97	218.17
T <sub>15</sub> : 75 % N + neem cake 1 t/ha	195.70	192.81	182.97	136.75
T <sub>16</sub> : 75 % N + neem cake 1 t/ha + AMC	215.92	211.40	220.51	169.86
T <sub>17</sub> : Control	86.72	83.78	58.10	52.22
sEm+	1.89	2.57	2.12	2.86
CD @ 5%	5.45	7.40	6.11	8.25

### 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 1 are presented in the Table 4.8.

The results indicated that during season 1, application of inorganic fertilizers, organic manures and AMC had significant influence on essential oil content (%). Among the treatments, T<sub>14</sub> (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<sub>12</sub> (1.09 %) and T<sub>10</sub> (1.08 %), while minimum value (0.67%) was recorded in T<sub>17</sub> (Control).

Among the treatments, T<sub>14</sub> (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<sub>12</sub> (0.96 %) and T<sub>10</sub> (0.95 %), while minimum value (0.62%) was recorded in T<sub>17</sub> (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, the plant supplied with T<sub>14</sub> (75 % N + poultry manure 4 t/ha + Arka microbial consortium) recorded significantly the highest essential oil content compared to T<sub>17</sub> (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.* (2015) in geranium and basil, Gurmanpreet Kaur *et al.* (2019) in Japanese mint, Pramod *et al.* (2020) in sweet basil, Aswani *et al.* (2021) in Japanese mint, Pavithra *et al.* (2021) in Japanese mint and Gayatri *et al.* (2023) 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 4.8

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<sub>14</sub> (75 % N + poultry manure 4 t/ha + Arka microbial consortium) recorded significantly maximum menthol content (77.21%) which was on par with T<sub>12</sub> (75 % N + vermicompost 4 t/ha + Arka microbial consortium) (76.59 %), T<sub>10</sub> (74.40 %) and T<sub>16</sub> (74.92 %) while minimum value (65.53 %) was recorded in T<sub>17</sub> (Control).

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

**Table 4.8. 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

T1 : 50% N + FYM 20 t/ha	0.92	0.77	70.06	66.26
T2 : 50% N + FYM 20 t/ha + AMC	0.94	0.81	69.52	65.62
T3 : 50 % N + vermicompost 4 t/ha	0.92	0.80	71.29	67.59
T4 : 50 % N + vermicompost 4 t/ha + AMC	0.94	0.81	71.97	68.37
T5 : 50 % N + poultry manure 4 t/ha	0.93	0.80	69.10	65.30
T6 : 50% N + poultry manure 4 t/ha + AMC	0.93	0.80	70.89	66.99
T7 : 50 % N + neem cake 1 t/ha	0.89	0.75	60.44	56.84
T8 : 50 % N + neem cake 1 t/ha + AMC	0.91	0.78	66.56	62.86
T9 : 75 % N + FYM 20 t/ha	0.98	0.85	72.33	70.31
T10 : 75 % N + FYM 20 t/ha + AMC	1.08	0.95	74.40	75.05
T11 : 75% N + vermicompost 4 t/ha	1.00	0.87	73.23	69.83
T12 : 75 % N + vermicompost 4 t/ha + AMC	1.09	0.96	76.59	76.15
T13 : 75% N + poultry manure 4 t/ha	1.02	0.89	73.00	70.66
T14 : 75 % N + poultry manure 4 t/ha + AMC	1.09	0.98	77.21	77.01
T15: 75 % N + neem cake 1 t/ha	0.93	0.80	72.95	68.83
T16: 75 % N + neem cake 1 t/ha + AMC	1.02	0.90	74.92	73.77
T17: 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

- 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.
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