**Integrating nutrient management with conservation agriculture for mint crop production**

**ABSTRACT**

**Aim:** This study investigated how reduced tillage practices with varying levels of fertilizer application influenced the growth, yield, and essential oil production of *Mentha arvensis* within an arecanut + carrot (*rabi*) – mint (*pre-kharif*) cropping sequence.

**Study Design:** Randomized block experimental design.

**Place and Duration of study:** The investigation was conducted at the Balindi Research Farm, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal in 2019-20 and 2020-21 cropping season.

**Methodology:** The study examined the effects of three fertilizer levels, each replicated five times, on vegetative parameters like plant height, leaf number, branching, and spread during the crop's growth stages and oil yield

**Results:** Higher fertilizer levels significantly enhanced vegetative growth and yield parameters. Plant height at 30, 60 and 90 days after planting (DAP) increased to 26.44 cm, 32.9 cm, and 56.68 cm, respectively, with the highest fertilizer dose (T1 -100:60:60 NPK kg ha). Similarly, number of leaves per plant also saw an increase to 178, 194, and 219 at the corresponding time points. Additionally, plant spread expanded to 20.99 cm, 28.93 cm, and 47.64 cm, and the number of primary branches increased to 6.62, 6.81, and 18.29 at 30, 60, and 90 DAP, respectively. The number of secondary branches also demonstrated growth, reaching 3.52 at 60 DAP and 4.20 at 90 DAP. The overall projected herb yield and oil yield at the end of the study was found to be 22.21 metric tons per hectare (t ha-1) and 254.95 l ha-1 was recorded under T1 (100:60:60 NPK kg ha-1)

**Conclusion:** These findings show that implementing conservation agriculture principles, including reduced tillage, crop diversification and supplying balanced nutrient levels to crop significantly enhanced crop performance and maintains soil health promoting sustainable agricultural production.

***Keyword: tillage, fertilizer, growth, yield, mint***

**INTRODUCTION**

Japanese mint (*Mentha arvensis* L.) is a perennial herbaceous plant belonging to the Lamiaceae family. It is known as menthol mint, wild mint, corn mint, field mint. It is originated in Eurasia; the genus includes 19 species and 13 natural hybrids (Kumar et al. 2011). Mint is cultivated across tropical and subtropical regions globally, including China, India, Brazil, Japan, France, and the USA (Lawrence, 2007; Singh, K.M. and Saini, S.S, 2008). In India, it thrives as a widely cultivated aromatic crop in the Indo-Gangetic plains. This herbaceous perennial possesses a unique growth structure, comprising above-ground main stems with sizable leaves and flowers, above-ground runners with succulent stems bearing small leaves, and underground suckers known as stolons. *M. arvensis* initially found its place as a primary *rabi* season crop in India during the 1980s but later established itself as an intercrop in the North Indian plains (Farooqi and Sreeramu, 2001).

The primary impetus behind the cultivation of *M. arvensis* lies in its volatile oil (VO) primarily concentrated in the leaves and extracted through a distillation process (Johnson, M.E. et al., 2012 and Behera, M.S. et al., 2015. Fresh *Mentha arvensis* L. herbs typically contain 0.5% to 0.8% of oil, serving as a natural source of menthol, which constitutes 70 to 85% of the oil content (Taneja and Chandra, 2012; Croteau et al., 2005; Upadhyay et al., 2014). This oil is of paramount importance as an intermediate raw material for menthol crystallization (Berger, 2007; Kamatou *et al*., 2013; Skalicka-Wozniak and Walasek, 2014). Additionally, *M. arvensis* yields other valuable compounds such as mint terpenes, menthone, isomenthone, menthyl acetate, which find extensive applications in the pharmaceutical, cosmetic, food, and flavor industries.

At present, India leads the world in both the production and export of mint oil and its associated products, boasting a production capacity of approximately 40,000 tons. India's contribution to global mint production currently stands at an impressive 80-85% (CSIR-CIMAP).

Successful crop production hinges on maintaining healthy and fertile soil, balanced nutrients to the plant. Yet, for achieving sustainable crop production and to meet the market demand, conservation agriculture (CA) (Kassam et al., 2009; Lal, 2015a) can be promoted as a solution. Conservation agriculture is a resource conserving technology, that integrates minimum or no tillage (NT), permanent soil cover (that leaves at least 30% of the soil covered between harvest and planting) and diversified crop species that include legumes ([FAO, 2019](https://www.frontiersin.org/articles/10.3389/fsufs.2020.00031/full#B53)). And mint is a nutrient- demanding crop, uptakes substantial quantities of N, P and K (Yadav et al., 1983, Patra et al., 2002). These nutrients plays a vital role in the growth, yield and overall crop quality. Adequate amounts of nitrogen increased the essential oil (Omidbeygi, 2011). So, this work has been focused on optimizing the fertilizer levels for enhancing the herb and oil yield under conservation agriculture strategy.

**MATERIAL AND METHODS**

Field experiment was conducted for two consecutive years *i.e.,* 2019-20 and 2020-21 at Balindi Research Farm, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal. The research station was located at 22°57’ N 88°32’ E, with an altitude of 9.75 m above the mean sea level. Topographic situation of the experimental site comes under the well-drained gangetic new alluvial soil (order: Inceptisol) of West Bengal having clay type of soil. Topsoil texture was granular with an organic carbon content of 0.91%, pH level of 7.57, 227.8 kg of available nitrogen, 35.4 kg of available P2O5 (phosphorus), and an impressive 340.26 kg of available K2O (potassium) per hectare (kg ha-1).

This study adopted sustainable land management practices aligning with conservation agriculture principles, within the inter-rows of an arecanut plantation. Stubbles of previous crop (carrot) from the inter-row spaces, weeds etc. were removed, land was cleared off for mint crop and plots were prepared without tillage. This choice was made to reduce soil disturbance and enhance soil health and structure, consistent with the principles of conservation agriculture. Plots of 6m x 2m were laid out in Randomized Block design with four treatments replicated five times. The treatment details are T1: 100:60:60 NPK kg ha-1, T2: 75:45:45 NPK kg ha-1 T3: 50:30:30 NPK kg ha-1, T4: Control.

Good quality planting material (stolons) was procured from CIMAP, Lucknow. Stolons were cut into smaller pieces and spread on raised bed incorporated with vermicompost and covered with straw for proper rooting. The sprouted stolons after attaining a height 7-10 cm were ready for transplanting in the main field. Cuttings were ready for transplanting in the main field in 20 days. They are planted at 50 cm between the row and 20 cm from plant to plant. In accordance with the experimental design, different nutrient levels were applied to the plots to assess their impact on carrot growth. These treatments were carefully administered to understand their influence on crop development and yield. Half the quantity of nitrogen, full amount of phosphorus and potassium was applied as basal. Remaining Nitrogen was applied in two equal split doses *i.e.,* 30 and 45 days after the first application. All the recommended cultural practices of irrigation, weeding, fertilizer mixing, etc. were followed as per requirement during the growth period. Crop was harvested at 100 days after planting during bright sunny weather. It was done by cutting the herb by means of sickle keeping 2-3 cm above the ground.

**RESULTS AND DISCUSSION**

**Growth parameters**

Data on plant height, number of leaves per plant, number of primary branches and number of secondary branches per plantwere recorded during various growth stages at 30, 60 and 90 days after planting respectively were recorded and presented in the Tables.

**Plant height**

The data presented in Table 1 clearly indicates that different levels of fertilizer application in the context of conservation agriculture practices led to significant variations across all growth stages for both years of analysis. When analyzed the combined data, it became apparent that an increase in the fertilizer application rate had a positive effect on plant height at all growth stages, namely 30, 60, and 90 days after planting (DAP). Among all the treatment groups, it was particularly noteworthy that the highest fertilizer dose (100:60:60 NPK kg ha-1) resulted in a substantial increase in plant height, ranging from 26.44 cm (30 DAP) to 32.99 cm (60 DAP) and finally reaching 56.68 cm (90 DAP). In contrast, plants in the control group exhibited the shortest height at all growth stages. Similar results were also reported by Izhar et al. (2015), Kumar and Sood (2011) that higher dose of NPK fertilizers was more effective and increased plant height. And mint being a heavy feeder of nutrients and absorbs significant quantities of NPK (Yadav et al*.,* 1983 and Patra et al*.,* 2002)

**Number of leaves per plant**

Similar to the impact on plant height, the number of leaves per plant also exhibited notable variations across different levels of fertilizer application, as depicted in Table 1. When conducted a comprehensive analysis by pooling the data, it became evident that an escalation in nutrient application significantly influenced the rate of growth concerning the number of leaves, and this effect was consistent across all growth stages. Specifically, at 30, 60, and 90 days after planting (DAP), the number of leaves per plant were observed to be 178, 194, and 219, respectively. This data highlights the positive correlation between fertilizer dosage and leaf growth, with higher nutrient levels resulting in an increased number of leaves per plant at each growth stage. As reported by Kumar et al. (2010) that the availability of NPK increased vegetative growth. Under higher concentration of nitrogen, increase in cell number resulted in increased production of leaves (Bijimol and Singh, 2001).

**Number of primary branches per plant**

Branches are plant organs that play an important role because they determine the position of the leaves. Similar to plant height and number of leaves per plant, number of primary branches showed similar trend (Table 2), T1 (100:60:60 NPK kg ha-1) recorded highest number of leaves per plantfollowed by T2 (75:45:45 NPK kg ha-1) at all growth stages *i.e.,* 30 DAP (4.75), 60 DAP (5.93), 90 DAP (14.83). Minimum number (2.92, 3.78 and 8.15) was observed in T4 (control) during all the growth stages. Availability of nutrients in sufficient quantities initiates plant metabolic activities so that process of cell division, cell elongation and tissue formation has increased which also increases plant growth in this case is the number of branches (Leghari,S.J et al., 2016)

**Table 1. Effect of different nutrient levels on plant height (cm) and number of leaves per plant of mint under CA system**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatment** | **Plant height (cm)** | | | **Number of leaves per plant** | | |
| **30 DAP** | **60 DAP** | **90 DAP** | **30 DAP** | **60 DAP** | **90 DAP** |
| **T1** | 26.44 | 32.99 | 56.68 | 178 | 194 | 219 |
| **T2** | 23.77 | 29.23 | 48.98 | 155 | 176 | 190 |
| **T3** | 19.87 | 28.16 | 43.54 | 134 | 155 | 181 |
| **T4** | 17.66 | 20.60 | 32.62 | 103 | 123 | 130 |
| **S.Em (±)** | **0.56** | **0.34** | **0.35** | **0.38** | **0.22** | **0.36** |
| **C.D (0.05)** | **1.74** | **1.07** | **1.10** | **1.20** | **0.69** | **1.12** |

*\*T1 (100:60:60 NPK kg ha-1); T2 (75:45:45 NPK kg ha-1); T3 (50:30:30 NPK kg ha-1); T4 (Control)*

**Number of secondary branches per plant**

Secondary branching was significantly influenced by the different levels of fertilizer (Table 2). Higher dose of fertilizer *i.e.,* T1 (100:60:60 N, P2O5 and K20 kg/ha) recorded highest number of secondary branches at 60 (3.52) and 90 DAP (4.20), followed by 3.08, 3.28 at 60, 90 DAP respectively under T2 (75:45:45 N, P2O5 and K20 kg/ha). Lowest number of secondary branches at 60 DAP (1.59) and 90 DAP (1.70) was under T4 (control) treatment.

**Table 2. Effect of different nutrient levels on number of primary and secondary branches of mint**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Treatment** | **Number of primary branches per plant** | | | **Number of secondary branches per plant** | |
| **30 DAP** | **60 DAP** | **90 DAP** | **60 DAP** | **90 DAP** |
| **T1** | 5.54 | 6.81 | 18.29 | 3.52 | 4.20 |
| **T2** | 4.75 | 5.93 | 14.83 | 2.95 | 3.28 |
| **T3** | 3.99 | 5.30 | 12.92 | 2.79 | 2.93 |
| **T4** | 2.92 | 3.78 | 8.15 | 1.56 | 1.70 |
| **S.Em (±)** | **0.20** | **0.22** | **0.40** | **0.25** | **0.16** |
| **C.D (0.05)** | **0.62** | **0.68** | **1.25** | **0.79** | **0.50** |

*\*T1 (100:60:60 NPK kg ha-1); T2 (75:45:45 NPK kg ha-1); T3 (50:30:30 NPK kg ha-1); T4 (Control)*

**Plant spread (cm)**

Mint has highly spreading nature of branches which cover the soil surface. It has recorded high spreading nature of branches (Table 3). Availability of NPK in significantly higher quantities to the crop resulted in enhanced the horizontal of plant growth and increased the plant spread and with the advancement of age plant spread increased consistently. Maximum plant spread *i.e.,* 20.99 cm at 30 DAP increased further to 28.93 cm at 60 DAP and 47.64 cm at 90 DAP was found under T1 (100:60:60 NPK kg ha-1) followed by 17.98 cm, 23.94 cm, and 43.57 cm at 30, 60 and 90 DAP respectively was observed in T2 (75:45:45 NPK kg ha-1). In case of plots under control treatment, plant spread was lowest (10.80 cm, 13.95 cm and 24.72 cm) at all growth stages. The higher plant spread at all growth stages under highest dose of fertilizer may be attributed to more number of leaves per plant and branches per plant. Similar findings were reported by Muniramappa et al. (1997) in Kalmegh, Lokesh and Gangadharappa (2007) in *Solanum* *nigrum.*

**Projected herb yield (t ha-1)**

The data representing the herbage yield (t ha-1) was presented in theTable 3. Application of different levels of fertilizer has significant influence on herb yield. Maximum herbage yield of 22.21 t ha-1  was recorded from highest dose of NPK (T1-100:60:60 NPK kg ha-1) and minimum herbage yield (12.24 t ha-1) was recorded under T1 (100:60:60 NPK kg ha-1).

**Oil yield (l ha-1)**

Oil yield (l ha-1) was significantly influenced by the different levels of fertilizer. Perusal of the data presented in the Table 3 similar pattern of variation like herb yield was observed in case of oil yield. Increasing level of fertilizer dose showed increase in yield and it also ultimately increased oil yield. Highest oil yield of 254.95 l ha-1 was recorded under T1 (100:60:60 NPK kg ha-1**)** followed by 229.51 l ha-1 T2 (75:45:45 NPK kg ha-1**)**. Lowest yield was under control (120.28 l ha-1) Oil yield was significantly influenced by the growth and yield parameters. Increase in nutrient dose resulted in more vegetative growth (plant height, number of leaves, number of primary and secondary branches) especially due to nitrogen and it was reflected in the oil yield. Similar findings were reported by Verma et al. (2017), Anwar et al. (2010).

**Table 3. Effect of conservation agriculture practices on plant spread (cm), Projected herb yield (t ha-1) and oil yield (l ha-1) of mint**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Treatment** | **Plant spread (cm)** | | | **Projected herb yield t ha-1** | **Oil yield l ha-1** |
| **30 DAP** | **60 DAP** | **90 DAP** |
| **T1** | 20.99 | 28.93 | 47.64 | 22.21 | 254.95 |
| **T2** | 17.98 | 23.94 | 43.57 | 20.10 | 229.51 |
| **T3** | 15.17 | 20.94 | 39.73 | 17.93 | 191.68 |
| **T4** | 10.80 | 13.95 | 24.72 | 12.24 | 120.28 |
| **S.Em (±)** | **0.24** | **0.28** | **0.29** | **0.27** | **1.29** |
| **C.D (0.05)** | **0.75** | **0.88** | **0.90** | **0.84** | **4.03** |

*\*T1 (100:60:60 NPK kg ha-1); T2 (75:45:45 NPK kg ha-1); T3 (50:30:30 NPK kg ha-1); T4 (Control)*

Based on the present experimental findings, it was found that application of higher dose of nitrogen, phosphorus and potassium positively improved the fresh herb yield. Herb yield was highest in T1 (22.21 t ha-1) compared to other treatments with 25% and 50% reduced dose of fertilizer and the lowest yield (12.24 t ha-1) was in control. The increase in various growth parameters (plant height, number of leaves, number of primary and secondary branches and plant spread) showed a significant positive correlation with yield. This positive association of growth with yield might be the reason for increased yield. Availability of excess quantity of nutrients to plants enhanced photosynthetic leaf area surface which in turn favors crop vegetative growth and accumulation of secondary metabolites. Similar results were reported by Rao et al*.* (1983), Munsi (1992), Anwar et al. (2010) and Kumar and Sood (2011), Shormin et al. (2009).

**CONCLUSION**

All the growth and yield parameters showed increasing trend along with increase in fertilizer concentration. In case of nitrogen, it plays a vital role in various physiological processes**,** main constituent of protein, plant growth hormones and protoplasm, which might have led to cell division and cell enlargement and promotes promotes leaves, stem and other vegetative part’s growth and development. Nitrogen also encourages the uptake and utilization of other nutrients including potassium, phosphorous and controls overall growth of plant [Bloom, A.J. 2015 and Hemerly, A., 2016]. Then the availability of phosphorus stimulates the photosynthesis**,** energy storage and helps in strengthening of root and potassium increases crop vigor and imparts disease resistance and more availability of these nutrients resulted in enhancing vegetative growth of crop. Less or reduced vegetative growth of crop was found in control due to less availability of required nutrients (Kumar et al*.,* 2010). Similar results were reported by Kumar and Sood (2011). Adoption of CA principles in the perennial horticulture cropping systems effectively manages soil health and offers a scope for crop diversification.

**REFERENCES**

# [1]  Kumar, P., Mishra,S., Malik, A & Satya, S(2011). Insecticidal properties of Mentha species: A review. Industrial crops and products. 34(1), 802-817.

[2] Lawrence, B.M. (2007).Mint: The genus *Mentha*. CRC Press. Boca Raton, Florida.

[3] Singh, K.M. and Saini, S.S. (2008). Planting date, mulch, and herbicide rate effects on the growth, yield, and physiochemical properties of menthol mint (*Mentha arvensis*). Weed Technology, 22(4), 691-698.

[4] Farooqi, A. A & Sreeramu, B.S. (2001). Cultivation of Medicinal and Aromatic Crops. Universities Press

[5] Johnson, M.E., Wesely, G., Kavitha, M.S. and Uma, V. (2011).Antibacterial activity of leaves and inter-nodal callus extracts of *Mentha arvensis.* L. Asian Pacific Journal of Tropical Medicine, 4(3),196-200.

[6] Behera, M.S., Mahapatra, P.K., Singandhupe, R.B. and Kanan, K. (2015).Fertigation studies in Japanese mint (*Mentha arvensis L.)* under humid climate in Odisha, India. African Journal of Agricultural Research, 10(11), 1320-1330Top of Form

[7] Taneja, S. C., and Chandra, S. (2012).Mint*.* In*-* Handbook of Herbs and Spices. 2nd Edn. Sawston, Cambridge: Woodhead Publishing, 366–387.

[8] Croteau, R.B., Davis, E.M., Ringer, K.L. & Wildung, M.R. (2005). Menthol biosynthesis and molecular genetics. Naturwissenschaften , 92(12), 562-577

[9] Upadhyay, R.K., Bahl, J.R., Patra, D.D. & Tewari, S.K.(2015) A New Agro-technology for increasing oil yield and yield contributing characters of menthol mint ( *Mentha arvensis* L.). Journal of Essential oil-bearing plants, 18(4), 785-790

[10] Berger, R. G. (2007). Flavours and Fragrances: Chemistry, Bioprocessing and Sustainability. New York, PA: Springer Science & Business Media.

[11] Kamatou, G. P. P., Vermaak, I., Viljoen, A. M., & Lawrence, B. M. (2013). Menthol: a simple monoterpene with remarkable biological properties. Phytochemistry, 96,15–25.

[12] Wozniak, K.S & Walasek, M. (2014). Preparative separation of menthol and pulegone from peppermint oil (*Mentha piperita* L.) by high-performance counter-current chromatography. Phytochemistry Letters*.* 10, xciv–xcviii.

[13] Kassam, A. H. & Friedrich, T. (2009). Perspectives on Nutrient Management in Conservation Agriculture. Invited paper, *IV World Congress on Conservation Agriculture*, New Delhi, India.

[14] Lal, R. (2015a). Sequestering carbon and increasing productivity by conservation agriculture. Journal of Soil and Water Conservation*,* 70, 55A−62A.

[15]. ([FAO, 2019](https://www.frontiersin.org/articles/10.3389/fsufs.2020.00031/full#B53)). Conservation Agriculture

[16] Yadav, R. L., Mohan, R. & Ram, M. (1983). Yield and quality of essential oil of Japanese mint as affected by N-rates and row-spacing. Madras Agricultural Journal, 70**,** 454-457.

[17] Patra, D. D., Anwar, M., Chand, S., Kiran, U., Rajput, D. K. & Kumar, S. (2002). Nimin and *Mentha spicata* oil as nitrification inhibitors for optimum yield of Japanese mint. Communications in soil science and plant analysis, 33(3-4), 451-460.

[18]. Omidbeygi, R. (2011). Processing of medicinal plants. 2, 289

[19] Izhar, M., Khan, M., Yasmin, T. and Zahid, N. Y. (2015). Differential effect of fertilizers on menthol contents in mint (*Mentha Arvensis*). American Research Journal of Agriculture, 1(1),55-60

[20] Kumar V. & Sood, M. (2011). Effect of transplanting time, spacing and fertilizers on herbage and oil yield of *Mentha piperita* L. International Journal of Farm Sciences*,* 1(2): 68-74.

[21] Kumar, A. & Patro, H. K. (2010). Effect of Zinc and Sulphur on herb, oil yield and quality of menthol mint (*Mentha arvensis* L.) var. Kosi. Journal of Chemical and Pharmaceutical Research, 2(4), 642-648.

[22] Bijimol, G. & Singh, A. K. (2001). Effect of spacing and nitrogen on flowering, flower quality and post-harvest life of gladiolus. Journal of Applied Horticulture*,* 3(1), 48-50.

[23] Leghari, S.J., Wahocho, N.A., Laghari, G.M., Laghari, A.H., Bhabhan, G.M., Talpur, K.H., Bhutto, T.A., Wahocho, S.A. & Lashari, A.A. (2016). Advances in Environmental Biology, 10(9), 209-218

[24] Muniramappa, R. P., Farooqi, A. A., Gowda, H. G. R. & Maricapu, S. (1997). Influence of macronutrients on yield and active principle content in kalmegh. Journal of Medicinal and Aromatic Plant Sciences*,* 19(4), 1039-1042.

[25] Lokesh, M. D. & Gangadharappa, P. M. (2007). Effect of plant density and nutrients on growth and herbage yield in makoi (*Solanum nigrum* L.). Journal of Asian Horticulture*,* 3(3), 169-173.

[26] Rao, B.R.R., Rao, E. V. S. P. & Singh, S. P. (1983). Influence of NPK fertilization on the herbage yield, essential oil content and essential oil yield of bergamot mint (*Mentha citrata* EHRH.). Indian Perfumer*,* 27(2), 77-79

[27] Munsi, P.S. (1992). Nitrogen and Phosphorus nutrition response in Japanese mint cultivation. Acta Horticulturae*,* 306, 436-443.

[28] Anwar, M., Chand, S. & Patra, D. D. (2010). Effect of graded levels of NPK on fresh herb yield, oil yield and oil composition of six cultivars of menthol mint (*Mentha arvensis* Linn.). Indian Journal of Natural products and resources, 1(1), 74-79

[29] Shormin, T., Khan, M. A. H. and Alamgir, M. (2009). Response of different levels of nitrogen fertilizer and water stress on the growth and yield of Japanese mint (*Mentha arvensis* L.). Bangladesh Journal of Scientific and Industrial Research, 44(1), 137-145.

[30] Bloom, A.J. (2015). The increasing importance of distinguishing among plant nitrogen sources. Current opinion in plant biology, 25, 10-16.

[31] Hemerly, A. (2016). Genetic controls of biomass increase in sugarcane by association with beneficial nitrogen-fixing bacteria’’, In Plant and Animal Genome XXIV Conference. Plant and Animal Genome, during month of January .