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Integrating Nutrient Management with Conservation Agriculture Practices for Mint Crop Production

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Authors' contributions

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

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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 with four treatments and each replicated five times. Treatment details are T_1 -100:60:60 NPK kg ha, T_2: 75:45:45 NPK kg ha^{-1} T_3: 50:30:30 NPK kg ha^{-1}, T_4: Control
Place and Duration of Study: The investigation was conducted at the Balindi Research Farm,

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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 (T_1 -100:60:60 NPK kg ha^{-1}). 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 tons per hectare (t ha^{-1}) and 254.95 litres ha^{-1} was recorded under T_1 (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.

Keywords: Tillage; fertilizer; growth; yield; mint.

1. 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 and 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 USA (Lawrence, 2007; Singh and Saini, 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, et al*.,* 2011; Behera 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 (Croteau et al*.,* 2005; Taneja and Chandra, 2012; Upadhyay et al*.,* 2015). This oil is of paramount importance as an intermediate raw material for menthol crystallization (Berger, 2007; Kamatou et al., 2013; Wozniak and Walasek, 2014). Additionally, *M. arvensis* yields other valuable compounds such as mint terpenes (Kapp, 2015), menthone, isomenthone and menthyl acetate which find extensive applications in the pharmaceutical, cosmetic, food and flavor industries (Croteau, 1991; Guedes et al*.,* 2016).

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 and Friedich, 2009; Lal, 2015a) can be promoted as a solution. Conservation agriculture is a resource conserving technology, that integrates minimum or no tillage, 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). 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.

2. MATERIALS 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, available nitrogen 227.8 kg ha^{-1}, available P_2O_5 35.4 kg ha^{-1} (phosphorus) and an impressive 340.26 kg of available K_2O (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 T_1: 100:60:60 NPK kg ha^{-1}, T_2: 75:45:45 NPK kg ha^{-1} T_3: 50:30:30 NPK kg ha^{-1}, T_4: Control.

Good quality planting material (stolons) was procured from CIMAP, Lucknow. Stolons were cut into smaller pieces and spread on raised bed followed by these were 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.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Data on plant height, number of leaves per plant, number of primary branches and number of secondary branches per plant were recorded during various growth stages at 30, 60 and 90 days after planting respectively were recorded and presented in the Tables 1 and 2.

3.1.1 Plant height (cm)

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. 17.66 cm (30 DAP) to 20.60 cm (60 DAP) and finally reaching 32.62 cm (90 DAP). Similar results were also reported by; Kumar and Sood, (2011); Izhar et al*.* (2015) 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; Patra et al*.,* 2002). Nitrogen being a main constituent of protein, plant growth hormones and protoplasm plays a vital role in various physiological processes which might have led to cell division and cell enlargement and promotes 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, 2015 and Hemerly, 2016).

3.1.2 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, in contrast 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 and Patro (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).

3.1.3 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), T_1 (100:60:60 NPK kg ha^{-1}) recorded highest number of primary branches per plant 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 T_4 (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, et al*.,* 2016).

3.1.4 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.,* T_1 (100:60:60 N, P_2O_5 and K_20 kg/ha) recorded highest number of secondary branches at 60 (3.52) and 90 DAP (4.20). Lowest number of secondary branches at 60 DAP (1.56) and 90 DAP (1.70) was under T_4 (control). NPK applied is absorbed and increase the metabolic activities which further increases the number of branches by promoting the formation of new lateral shoots and inducing the formation of floral buds. Similar findings were reported by Sharma et al*.* (2017).

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
T_1	26.44	32.99	56.68	178	194	219
T_2	23.77	29.23	48.98	155	176	190
T_3	19.87	28.16	43.54	134	155	181
T_4	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)*

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
T_1	5.54	6.81	18.29	3.52	4.20
T_2	4.75	5.93	14.83	2.95	3.28
T_3	3.99	5.30	12.92	2.79	2.93
T_4	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)*

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		
T_1	20.99	28.93	47.64	22.21	254.95
T_2	17.98	23.94	43.57	20.10	229.51
T_3	15.17	20.94	39.73	17.93	191.68
T_4	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)*

3.1.5 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 T_1 (100:60:60 NPK kg ha^{-1}) respectively. 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.*

3.2 Yield Parameters

3.2.1 Projected herb yield (t ha^{-1})

The data representing the herbage yield (t ha^{-1}) was presented in the Table 3. Application of different levels of fertilizer has significant effect on herb yield. Maximum herbage yield of 22.21 t ha^{-1} was obtained from 100:60:60 NPK kg ha^{-1} which was significantly superior over all other treatments and minimum herbage yield (12.24 t ha^{-1}) was recorded under control. Vegetative growth which is of commerce is more influenced by nitrogen. Nitrogen is one of the key components of amino acids, proteins and nucleic acids. Presence of this element in abundance stimulates the production of new leaves from terminal meristem of the stem and lateral buds of older leaves. It ultimately increases the yield of aerial parts (Fathi, 2020).

3.3 Quality Parameters

3.3.1 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 T_1 (100:60:60 NPK kg ha^{-1}**)** followed by 229.51 L ha^{-1} T_2 (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 Anwar et al*.* (2010); Verma et al. (2017).

Based on the present experimental findings, it was found that higher yields was obtained from higher NPK dose. 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. 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 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, 2015; Hemerly, 2016). Then the availability of phosphorus stimulates the photosynthesis**,** energy storage and helps in strengthening of root and potassium increases crop vigour 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 and Patro, 2010). Similar results were reported by Rao et al. (1983), Munsi (1992), Shormin et al. (2009), Anwar et al. (2010), Kumar and Sood (2011), Hassan et al. (2015), Pooja et al. (2018) and Ganve et al.(2023).

4. CONCLUSION

The results of the study concluded that application of higher dose of nitrogen, phosphorus and potassium positively improved the fresh herb yield. Maximum herb yield was in highest dose of fertilizer (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. Adoption of CA principles in the perennial horticulture cropping systems and integrating with nutrient management effectively manages soil health, offers a scope for crop diversification and ultimately increases crop 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 this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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