



Effect of Row Ratio and Planting Methods on Growth, Yield Performance of Wheat (*Triticum aestivum* L.) and Mentha (*Mentha arvensis* L.)

Awanish Kumar^{a++*}, Sarvesh Kumar^{a#}, Pradeep Kumar^a,
Utkarsh Singh^{b†}, Sanjay Yadav^{a†} and Shikhar Verma^{ct}

^a Department of Soil Conservation and Water Management, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur-208002, Uttar Pradesh, India.

^b Department of Agronomy, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh -224229, India.

^c Department of Agronomy, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur-208002, Uttar Pradesh, India.

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

This study was investigated the effects of row ratio and planting methods on the cultivation of wheat (*Triticum aestivum* L.) and mentha (*Mentha arvensis* L.). Mentha is also called Japanese mint, it is an important essential oil-bearing plant of the family Lamiaceae. Essential oil obtained from the

⁺⁺ M.Sc (Ag), Student;

[#] Professor;

[†] Ph.D. Research Scholar;

*Corresponding author: E-mail: awanishkumar243@gmail.com;

leaves used in aromatherapy, flavour, and pharmaceutical industries. Hence, a field experiment was conducted during 2016-17 at the Soil Conservation and Water Management Farm to investigate the response of mentha when intercropped with wheat under various row ratios and planting methods. The trial was laid out in Randomized Block Design (RBD) with three replications keeping one variety of Mentha 'Shivalik' & Wheat 'Halna'. The experiment consisting of nine treatments are T1:Sole Mentha direct sowing (50 cm apart), T2:sole mentha transplanting (50 cm apart), T3:sole wheat (25 cm apart), T4:wheat+mentha (1:1), T5:wheat+mentha (1:1), T6:wheat+mentha (2:2), T7:wheat+mentha (2:2), T8:wheat paired+mentha (2:3), T9: wheat paired+mentha (2:3). The results showed that the highest number of leaves per plant (457 at maturity) and number of branches per plant (80.97 at 90 DAS) were observed in Wheat Paired+Mentha (T9). The sole wheat (T3) exhibited the maximum number of tillers per plant in wheat (6.20). wheat+mentha (T4) had the highest yield attributes for wheat. The higher herbage yield of mentha (177 q/ha) was found in wheat+mentha (T7). Sole Mentha direct sowing (T1) gave the highest oil content (0.85%) and oil yield (163.35 l/ha) of mentha. The wheat paired+mentha (T8) recorded the highest equivalent oil yield (189.97 l/ha) and land equivalent ratio (1.50). However, sole wheat (T3) yielded the maximum grain yield (39.80 q/ha), straw yield (74.52 q/ha), and harvesting index (38.95%).

Keywords: *Wheat; mentha; growth; yield; row ratio; planting methods.*

1. INTRODUCTION

Intercropping is an agricultural practice that involves the simultaneous cultivation of two or more crops on the same piece of land. This cropping system offers several advantages such as maximizing land productivity, efficient resource utilization, and diversification of income sources [1]. One such inter cropping system is the combination of wheat (*Triticum aestivum* L.) and mentha (*Mentha arvensis* L.). The intercropping system of wheat and mentha offers several advantages firstly; it maximizes the utilization of resources such as water, sunlight, and nutrients by effectively utilizing different layers of the crop canopy. The vertical structure of wheat and the spreading nature of mentha complement each other, allowing for efficient resource capture and utilization. Secondly, inter cropping can help in weed suppression as the dense canopy of both crops can shade out weed growth, reducing the need for herbicides and manual weeding. Moreover, the release of volatile oils from mentha plants can act as a natural deterrent to certain pests and diseases, potentially reducing the need for chemical pesticides [2]. Intercropping has long been recognized as a potentially beneficial system of crop production. It offers stability in yield during unpredictable weather conditions and the occurrence of pests and diseases, which is vital for subsistence farmers [3]. Intercropping enables the harvesting of more energy by producing a higher biomass from the component crops. This not only provides insurance against crop failure but also enhances productivity

through the efficient use of land, water, and soil energy in a vertical dimension. Researchers have reported significant advantages in land use efficiency, crop productivity, and monetary returns in intercropping compared to sole cropping under various agro-climatic conditions [4]. Intercropping leads to more efficient solar energy use and harnesses the benefits of positive interactions in crop associations. These advantages are generally more pronounced in widespread crops and stressful environments. Overall, mixture densities and relative proportions of component crops are crucial in determining yield and production efficiency of intercropping systems (Reddy, 2004).

Wheat (*Triticum aestivum* L.) is a vital cereal crop for a significant portion of the world's population. It serves as the primary staple food for around two billion people (36% of the world population), providing nearly 55% of global carbohydrates and 20% of food calories (Breiman and Graur, 2016). Wheat exceeds other grain crops in acreage and production, making it the most important cereal grain crop cultivated across a wide range of climatic conditions. Wheat is primarily grown for human consumption, with about 10% reserved for seed and industry uses, such as starch, paste, malt, dextrose, and gluten production. Wheat grain contains essential nutrients, including carbohydrates, proteins, fats, vitamins, and crude fibers. Early biomass production in wheat allows for more efficient use of soil water, particularly in Mediterranean climates [5]. Spikes in wheat have higher water use efficiency (WUE)

than leaves, contributing up to 40% of total carbon fixation under moisture stress [6].

Japanese Mint (*Mentha arvensis* L.) is a valuable medicinal and aromatic crop native to Brazil. Commercial production of mint began in Japan around 1870, leading to the name "Japanese mint" [7]. Mint production spread to other countries including China, South America, and India. Major mint-producing states in India include Uttar Pradesh, Uttarakhand, Punjab, and Bihar. Japanese mint is a fast-growing, hairy-leaved herb that can reach up to 1.5 meters in height under favorable conditions. Its oil is widely used in the food, pharmaceutical, and perfumery industries, as well as in balms, cough drops, inhalers, toothpaste, and mouthwash. The production cost of mint oil in India was relatively low compared to other mint-growing countries due to the availability of cheap labor and low input costs. They concluded that mint oil has significant export potential, and the future of the mint industry in India is promising, but full potential exploitation depends on the extent to which technological advancements are utilized and remunerative prices are established. With the following objectives; to study the effect of

planting methods on the production of Wheat and Mentha; to determine the suitable row ratio of Wheat and Mentha; to study the effects of treatments on resource conservation and to analyze the effects of treatments on economics.

2. MATERIALS AND METHODS

2.1 Experimental Site

The Kanpur district is situated in sub-tropical region of Uttar Pradesh in part of Gangetic alluvium, lying between the river Ganga and Yamuna. It lies between 25° 26' and 26° 58' North latitude and 79° 31' and 80° 34' East longitude. The elevation of the Kanpur is approximately 125.9 meters above Mean Sea Level. The average annual rainfall of the district is about 800 mm. The major portion of rainfall is received during monsoon season from first week of July to last week of September. The region is classified as agro-climatic zone V (Central Plain Zone) of Uttar Pradesh. The experimental field was located in the same area for both years of the study, as shown in Fig. 1.

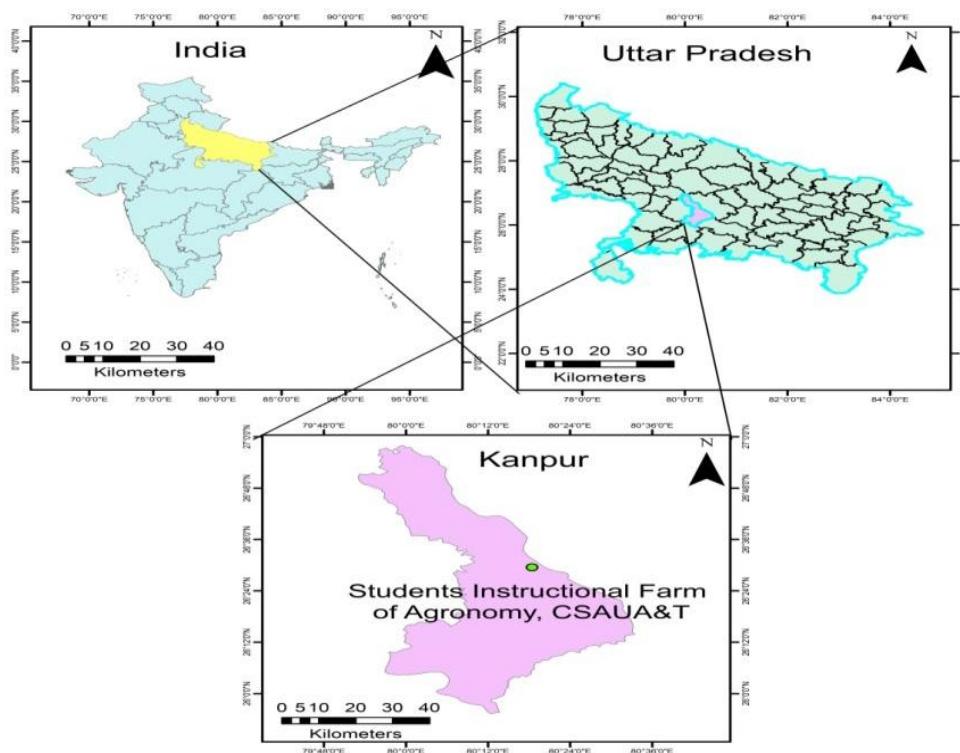


Fig. 1. Location map of the study area

2.2 Soil Characteristics

The soil of the experimental field was sandy loam in texture with fairly deep. Soil samples were collected from (0-25 cm) depth from all the replications before sowing to determine the status of the soil. The data with respect to mechanical composition and physico-chemical characterizations of soil are soil pH (7.3), EC (0.36 dSm^{-1}), bulk density (1.35 Mg m^{-3}), Particle density (2.60 Mg m^{-3}), field capacity (18.6 %), porosity (48.07 %), organic carbon (0.33 %), total N (0.03 %), available P_2O_5 (17.85 kg ha^{-1}), available K_2O ($131.30 \text{ kg ha}^{-1}$).

2.3 Experimental Details

The experiment was laid out in Randomized Block Design with three replication keeping variety of mentha 'Shivalik' and wheat 'Halna'. The experiment consisting of nine treatments are T1: sole mentha direct sowing (50 cm apart), T2: sole mentha transplanting (50 cm apart), T3: sole wheat (25 cm apart), T4: wheat + mentha (Direct sowing 1:1), T5: wheat + mentha (transplanting 1:1), T6: wheat + mentha (direct sowing 2:2), T7: wheat + mentha (transplanting 2:2), T8: wheat paired + mentha (direct sowing 2:3), T9: wheat paired + mentha (transplanting 2:3). The size of each plot was (18 m^2), 4.5 m long and 4.0 m width.

2.4 Agronomical Practices Adopted

The field preparation for the experiment involved ploughing with a tractor-drawn disc harrow in the second half of December. Two criss-cross ploughings were performed with a cultivator followed by planking. The application of nutrients included 120 kg of nitrogen, 60 kg of phosphorus, and 60 kg of potash per hectare in wheat, and the same amounts per hectare were applied in mentha, according to the respective treatments. Half of the nitrogen, along with the full doses of phosphorus and potassium, was applied as a basal application, while the remaining half of the nitrogen was top-dressed 30 days after sowing. Sowing of wheat and mentha was done manually in furrows created by a traditional plough. The spacing for wheat was 25 cm, while for mentha it was 50 cm using both flat and 25:25 cm intercrop treatments. The seed rate was adjusted to maintain the desired plot geometry according to the treatment requirements. Furrows were covered with light single planking immediately after sowing to conserve soil moisture. The seed rate for wheat

was 80 kg/ha, while mentha suckers were planted at a rate of 400 kg per hectare. Wheat seeds were presoaked for 4 days, and mentha suckers were cut into small pieces and kept in shade for 3 days to enhance germination. Irrigation was applied based on crop requirements throughout the experiment. Thinning was carried out 15 days after sowing to maintain a proper and uniform plant population. Weeding and hoeing were performed to ensure a weed-free condition in the field and minimize weed-related issues. Crop maturity was determined, and the first cutting was conducted on May 12, 2017, where plants were cut from the ground level, immediately weighed for fresh weight, and then sent to an oil extraction unit. The second cutting took place on July 8, 2017.

2.5 Observation Recorded

The total number of green leaves was counted from three tagged plants in each plot, and the average number of leaves per plant was calculated. The total number of tillers emerging from the main shoot of each tagged plant in each plot was counted. The length of the ear head in the tagged plant of each plot was measured using a meter scale. The weight of grains per ear head in each plot was measured using a balance. A sample of grains was taken from the produce of each plot to determine the 1000-grain weight. A count of 1000 grains was taken, and their weight was measured using an electronic balance. The yield of grains per plot was recorded in kilograms after threshing and then converted to quintals per hectare (q/ha) for all treatments. The yield of straw per plot was recorded and then converted to quintals per hectare (q/ha) for all treatments. Harvest index (%) was calculated by the following formula [8].

$$\text{H.I. (\%)} = \frac{\text{Grain yield (q/ha)}}{\text{Biological yield (q/ha)}} \times 100$$

(Biological yield = Grain yield + Straw yield)

Land Equivalent Ratio (LER): The Land equivalent ratio is the relative land area under sole crops that is required to produce the yield achieved in intercropping. In the present experiment, the land equivalent ratio was estimated by following equation (Oyejola & Mead, [9]).

$$\text{LER} = \frac{Y_a}{S_a} + \frac{Y_b}{S_b}$$

Where,

Ya and Yb= Yield of Intercrops 'a' and 'b' respectively

Sa and Sb= Yield of individual crops 'a' and 'b' respectively in pure stand

2.6 Statistical Analysis

The data collected during the experimental period and after harvest of the experiment was statistically analyzed employing the following statistical techniques given by Fisher's & Yates, [10].

3. RESULTS AND DISCUSSION

3.1 Mentha

The data reveals that the growth and oil yield of mentha (Tables 1, 3) significantly affected by different row ratio and planting methods. The maximum number of leaves/plant was observed under row ratio of 2:3 in wheat-mentha followed by 2:2 row ratio and significantly superior over sole treatments of direct sowing methods. The data recorded from the practical site that the Number of branches/plant was more in wheat: mentha (2:3) there after wheat sole and wheat: mentha (2:2), (2:3) and (1:1) have been recorded from the crop, the data indicated that intercropping system were influenced significantly. The fresh herbage yield at harvesting stage of crop significantly affected by intercropping tiller. However, essential oil content was not significant during experiment. Mentha sole crop (135.82 q ha^{-1}) and essential oil (0.85%) recorded maximum followed by T8 (0.85%) while minimum was in T5 (0.82%). It is evident from Table 4 that highest mentha equivalent oil yield (189.05 l/ha) was recorded under row ratio 2:3 of wheat + mentha as direct sowing followed by row ratio of 2:3 of wheat + mentha (transplanting) which were significantly superior over other treatments however minimum mentha equivalent oil yield (57.74 q/ha) were recorded from sole wheat. The different cropping system was found to exhibit significant variation under mentha equivalent oil yield. The mentha under intercropping gave significantly the highest mentha equivalent oil yield than other cropping system, the improvement in growth parameters of mentha and wheat might have occurred because the crop enjoyed a competition free environment for light, water and nutrients. The similar result observed by Chauhan et al. [11] conducted a field experiment in CIMAP, Lucknow

for two years (2007-08 and 2008-09). To study the effect of different dates of planting in three menthol mint cultivars (Saksham, Kushal and Kosi) on herb yield, oil yield and oil quality. Average herb yield increased 85.71, 104.91 and 109.49 per cent. All the groups of intercropping produced more land equivalent ratio over sole wheat and mentha which may be attributed to more yield in intercropping over sole cropping. The maximum LER of 1.50 was found in wheat + mentha (2:3) intercropping. Higher LER value with 2:3 row ratio of mentha with wheat indicate better adoptability of the intercropping system and efficient utilization of natural resources viz. space, light as well as applied inputs by the component crop having different characteristics viz. nutrient requirements, root system and canopy structures. The similar results were observed by [12], (Brar et al. 2000), [13,14,15] and [16].

3.2 Wheat

The data pertaining to yield attributes (Table 2) viz., number of tillers/plant, length of spike, number of ear/plant, number of grain/plant, 1000-grain weight (g) were significantly affected by row ratio and planting methods. Clearly indicate that intercropping of wheat and mentha significantly affect the length of spike and number of tillers per plot. The maximum length of spike (13.17 cm) and number of tillers per plot recorded under row ratio of wheat and mentha (direct sowing) as 1:1 and minimum tiller under sole wheat. The data observed from the experimental site that the number of ear/plant, number of grain/plant and 1000-seed weight (g) was more in wheat: mentha (1:1) row ratio their after wheat: mentha (2:2) and (1:1) have been recorded from the crop, the data indicated that cropping system were influenced significantly all the yield attributing characters of crop. The data pertaining to grain yield (Table 4) of the crop is the resultant of growth and yield contributing characters. The significant variation in growth characteristics and yield attributes as a result of differential intercropping treatments further led to marked variation in yield of wheat. Among the intercropping system, there were significant variation in grain yield was recorded. As regards of cropping systems maximum grain yield (39.80 q ha^{-1}) recorded under sole wheat while minimum grain yield (20.90 q ha^{-1}) was obtained with T9 cropping systems (2:3). Similar result was observed by [4] and [17]. The data of straw yield of wheat was recorded under various treatment combinations and presented in

Table 3. Among the intercropping system there were significant variation in straw yield was recorded. The maximum straw yield (74.52 q ha⁻¹) found under sole wheat while minimum straw yield (39.38 q ha⁻¹) was obtained with T5

cropping systems. The values calculated for the harvest index in relation to intercropping system and significantly maximum harvest index calculated under sole wheat. The similar results were observed by [14,16,17,18-20].

Table 1. Effect of intercropping system on Number of leaves and branches/plant of mentha under different treatments

Treatments	No. of leaves/plant				No. branches/plant		
	30DAS	60DAS	90DAS	At maturity	30DAS	60DAS	90DAS
T ₁ - sole mentha (d)	28.40	62.65	217.80	405.15	14.33	24.35	67.35
T ₂ - sole mentha (t)	30.04	64.45	234.80	434.90	15.31	26.13	73.88
T ₃ - sole wheat	-	-	-	-	-	-	-
T ₄ - w+m (d) 1:1	29.54	67.14	234.35	434.64	13.80	25.20	69.54
T ₅ - w+m (t) 1:1	29.22	63.54	224.49	415.64	14.56	27.49	73.60
T ₆ - w+m (d) 2:2	30.45	68.30	239.42	446.15	14.22	25.96	72.66
T ₇ - w+m (t) 2:2	29.14	67.95	239.21	445.82	16.20	27.74	76.36
T ₈ - w+m (d) 2:3	30.55	71.75	225.03	454.34	14.75	26.95	73.95
T ₉ - w+m (t) 2:3	30.86	69.72	247.12	457.72	16.90	29.01	80.97
SE (d)	0.93	1.45	3.50	14.18	0.96	0.95	1.91
C D(P=0.05)	N.S	3.11	7.52	8.97	N.S	2.05	4.09

Table 2. Effect of intercropping system on Number of tillers / and Yield ttributes under different treatment in wheat crop

Treatments	Yield attributes of wheat				
	No. of tillers/plant	length of spike	No. of ear/plant	No. of grain/plant	1000-grain weight (g)
T ₁ - sole mentha (d)	-	-	-	-	-
T ₂ - sole mentha (t)	-	-	-	-	-
T ₃ - sole wheat	6.20	11.13	10.58	43.44	37.56
T ₄ - w+m (d) 1:1	5.39	13.27	10.80	42.85	38.66
T ₅ - w+m (t) 1:1	5.30	11.98	10.75	39.73	38.23
T ₆ - w+m (d) 2:2	6.00	11.84	10.58	44.71	37.56
T ₇ - w+m (t) 2:2	5.90	11.40	10.45	41.27	35.68
T ₈ - w+m (d) 2:3	5.40	11.46	10.20	44.22	35.68
T ₉ - w+m (t) 2:3	5.35	11.98	9.76	43.44	34.35
SE (d)	0.41	0.29	0.36	0.92	0.53
C D(P=0.05)	N.S	0.65	N.S	2.01	1.16

Table 3. Effect of intercropping system on fresh herbage yield and essential oil content at harvesting stage under different treatment in mentha crop

Treatments	Fresh herbage yield of mentha (q/ha)	Oil content in Mentha (%)	Oil yield of menthe (l/ha)	Equivalent Oil yield of mentha (l/ha)
T ₁ - sole mentha (d)	135.82	0.85	163.35	163.35
T ₂ - sole mentha (t)	134.25	0.84	159.83	159.83
T ₃ - sole wheat	-	-	-	57.74
T ₄ - w+m (d) 1:1	100.80	0.82	122.93	160.36
T ₅ - w+m (t) 1:1	92.91	0.84	110.61	146.03
T ₆ - w+m (d) 2:2	120.51	0.83	145.20	177.17
T ₇ - w+m (t) 2:2	177.78	0.82	143.64	175.41
T ₈ - w+m (d) 2:3	134.72	0.84	158.50	189.05
T ₉ - w+m (t) 2:3	130.74	0.84	155.65	185.97
SE (d)	7.08	0.01	6.30	5.44
C D(P=0.05)	15.20	NS	13.52	11.53

Table 4. Effect of intercropping system on Yield of wheat and land equivalent ratio of Wheat and Mentha

Treatments	Land Equivalent Ratio (LER)	Grain yield (q/ha)	Straw yield (q/ha)	Harvest index (%)
T ₁ - sole mentha (d)	1.0	-	-	-
T ₂ - sole mentha (t)	1.0	-	-	-
T ₃ - sole wheat	1.0	39.80	74.52	38.95
T ₄ - w+m (d) 1:1	1.39	25.80	40.13	37.80
T ₅ - w+m (t) 1:1	1.30	24.60	39.58	37.45
T ₆ - w+m (d) 2:2	1.43	22.04	39.90	37.31
T ₇ - w+m (t) 2:2	1.44	21.90	39.84	37.79
T ₈ - w+m (d) 2:3	1.50	21.30	47.79	37.62
T ₉ - w+m (t) 2:3	1.49	20.90	48.85	38.63
SE (d)	0.08	1.31	2.37	0.38
C D(P=0.05)	0.17	2.85	5.16	NS

4. CONCLUSION

In conclusion, the study found that Wheat Paired+Mentha (T9), exhibited the highest number of leaves and branches per plant, sole wheat (T3) had the maximum number of tillers per plant in wheat, and Wheat Paired+Mentha (T4) showed the highest yield attributes for wheat. For mentha, Wheat Paired+Mentha (T7) had the highest herbage yield, sole mentha (T1) had the highest oil content and oil yield, and Wheat Paired+Mentha (T8) recorded the highest equivalent oil yield and land equivalent ratio. Sole wheat (T3) yielded the maximum grain yield, straw yield, and harvesting index for wheat. These findings provide valuable insights for optimizing growth and yield performance in wheat and mentha cultivation by selecting appropriate row ratios and planting methods.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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