Effect of Row ratio and Planting methods on Growth, Water Use Efficiency, Yield and Economics of Wheat (*Triticum aestivum* L.) and Mentha (*Mentha arvensis* L.)

Abstract

This study examines the intercropping system of wheat and mentha involves the simultaneous cultivation of two or more crops on the same piece of land for higher land productivity. Japanese mint, a member of the Lamiaceae family, has a potent essential oil. Oil extracted from the leaves for use in aromatherapy, food flavouring, and medicine. Hence, a field experiment was conducted to study the effect of Row ratio and Planting methods on Growth, Yield Performance of wheat (*Triticum aestivum* L.) and Mentha (*Mentha arvensis* L.) 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 ratio and planting methods. The experiment was laid out in Randomized Block Design (RBD) with three replication keeping one variety of Mentha 'Shivalik'& Wheat 'Unnat Halna'. The experiment consisting of nine treatments are T1:Sole Mentha direct sowing (50cm apart), T2:Sole Mentha transplanting (50cm apart), T3:Sole Wheat (25cm apart), T4:Wheat+Mentha (d, 1:1), T5:Wheat+Mentha (t, 1:1), T6:Wheat+Mentha (d, 2:2), T7:Wheat+Mentha (t, 2:2), T8:Wheat Paired+Mentha (d, 2:3), T9: Wheat Paired+Mentha (t, 2:3). The results indicated that Treatment 3 (T3) had the highest plant population (662.40 initially, 326 final), plant height (83.80 cm), and grain yield (39.80 q/ha) for wheat. In the case of mentha, Treatment 8 (T8) exhibited the maximum final plant population (119.43), plant height (72.51 at maturity), and equivalent oil yield (189.05 l/ha). Treatment 8 (T8) also recorded the highest total water use (647 mm), water use efficiency (0.292 kg/ha/mm of water), land equivalent ratio (1.50), and economic parameters such as gross return (228,868), net return (160,828), and B:C ratio (3.36). The maximum oil yield (163.35 l/ha) was found in Treatment 1 (T1).

Keyword: Wheat; Mentha; Growth; Water Use Efficiency; Row ratio; Planting methods

Introduction

Inter cropping is an agricultural practice that involves growing two or more crops on the same plot of land at the same time. This agricultural system has various advantages, including increased land productivity, more effective resource utilization, and income diversification (Gebru, 2015). The intercropping of wheat (Triticum aestivum L.) with mentha (Mentha arvensis L.) is one example. The intercropping system of wheat and mentha has various advantages. First, it maximizes the usage of resources such as water, sunlight, and nutrients by effectively exploiting multiple 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 (Salem *et al.*, 2017). Intercropping has long been recognized as a potentially advantageous crop production strategy. It provides yield stability in the face of variable weather and the prevalence of pests and diseases, which is critical for subsistence farmers (Brooker et al., 2015). Intercropping allows for greater energy harvesting by producing more biomass from the component crops. This not only protects against crop failure but also increases productivity by making better use of land, water, and soil energy in a vertical dimension. Researchers have found that intercropping has considerable advantages in terms of land use efficiency, crop yield, and monetary returns when compared to solitary cropping under diverse agro-climatic situations (Kumar et al., 2012). 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 (Justes *et al*., 2021).

Wheat (Triticum aestivum L.) is an important cereal crop for a large section of the global population. It is the principal staple meal for around two billion people (36% of the worldwide population), accounting for nearly 55% of global carbs and 20% of dietary calories (Breiman and Graur, 2016). Wheat outnumbers other grain crops in terms of land and productivity, making it the most important cereal grain crop grown under a variety of climatic circumstances. Wheat is farmed primarily for human use, with approximately 10% reserved for seed and industrial purposes 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 (Yang *et al*., 2020). Spikes in wheat have higher water use efficiency (WUE) than leaves, contributing up to 40% of total carbon fixation under moisture stress (Akhter *et al*., 2008).

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" (Taneja & Chandra, 2012). 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. Kothari and Singh, (1994) found that 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 & Mentha. With the following objectives; to determine the suitable row ratio of Wheat & 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 25º 26' and 26º 58' North latitude and 79º 31' and 80º 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 monson season from first week of July to last week of Septembesr. 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 Figure 1.

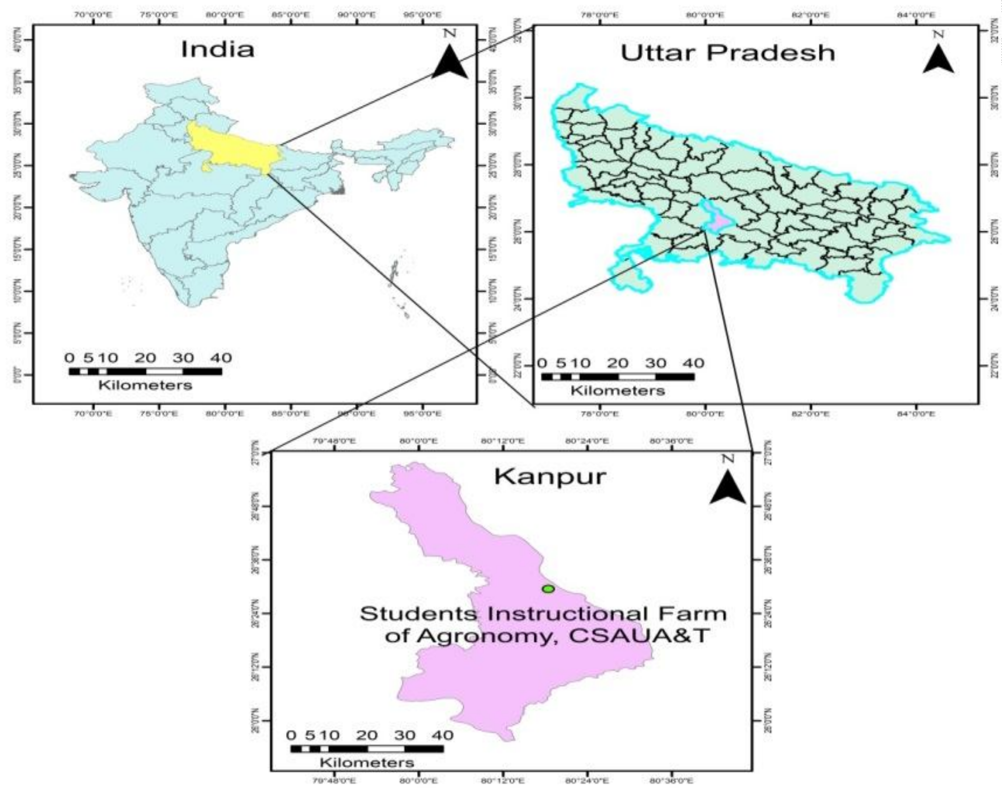

Fig. 1 LOCATION MAP OF THE STUDY AREA

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 kg ha^{-1}).

2.3 Experimental Details: The experiment was laid out in Randomized Block Design with three replication 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 (Direct sowing (d), 1:1), T5: Wheat + Mentha (Transplanting (t), 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.

2.6 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 for wheat, and the same amounts per hectare were applied for 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. The wheat variety used was 'Unnat Halna,' and the mentha variety was 'Shivalick.' 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 (DAS) 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.

2.7 Observations Recorded: During the study, the biometrical observations were collected at various stages of growth, including 30, 60, 90, and 100 DAS as well as at maturity. To minimize any potential sampling error, all necessary precautions were taken. The growth attributes and yield parameters such as plant population, plant height, total water use, water use efficiency (Angus & Van Herwaarden, 2001), yield and Land Equivalent yield (Caviglia *et al*., 2011) and economics were recorded. The obtained data were subjected to appropriate statistical analysis using the method outlined by Gomez and Gomez (1984) to determine any differences among the treatment means. The LSD test was used to compare treatment means at a 5% level of probability. The analysis was performed using SPSS Version 10.0, a statistical software package developed by SPSS, Chicago, and IL.

3. RESULTS AND DISCUSSION

3.1 Plant Population of Mentha: The data reveal that the intercropping system appears to reflect significant (P=0.05) variation on initial plant population and final plant population/ha (Table 1). The maximum final plant stand counted under intercropping system (128.02) which were counted in wheat + mentha (transplanting) as 2:3 row ratio followed by wheat+mentha as direct sowing (116.48) while minimum plant stand were observed in row ratio of 1:1 as wheat+mentha (transplanting). The Similar result observed by (Kumar *et al*., 2002)

3.2 Plant Population of wheat: The data reveal that the intercropping system appears to reflect significant (P=0.05) variation on initial plant stand and final plant stand/ha. The maximum final plant stand (658.2) was noticed in sole wheat cropping. however under intercropping system maximum plant stand (326.17) were recorded in row ratio of 1:1 as wheat+mentha as transplanting followed by wheat+mentha as direct sowing (323.0) while minimum plant stand were observed in row ratio of 2:2 as wheat + mentha (transplanting) the summarized data regarding plant stand of wheat (000 ha^{-1}) have been presented in Table 1. Clearly indicate that the initial and final plant stand of wheat sole is comparatively higher than other treatment combinations. The Similar result observed by (Kumar *et al*., 2002a)

3.3 Plant height of Mentha: The cropping system showed significant (P=0.05) variation on height of mentha at all the stages except at 30 days after sowing (Table 2). The intercropping of wheat + mentha transplanting (2:3), exhibited taller plants at all the stages in comparison to wheat + mentha direct (1:1). It might be due to beneficial effect of wheat intercrop on base crop mentha through increased nutrients availability and reduced competition between component crops for resource utilization particularly the space and solar radiation. Mints were grown in vegetative form under shade and sunlight condition. Growth parameters, such as absolute growth rate, leaf area index and specific leaf weight higher in plant grown in sunlight comparatively shade condition. (Patra *et al*., 2003), (Kumar *et al*., 2002b)

3.4 Plant height of wheat: The intercropping system affect significantly (P=0.05) the plant height (Table 2) measured at various growth stages at 30, 60, 90 days after sowing and at maturity. Wheat sole crop 25 cm exhibited numerically taller plants than mentha + wheat and wheat + mentha at 30, 60, 90 days after sowing as well as maturity stage. It might be due to no competition for space and light within mentha plants in wheat sole 25 cm which increase in plant height in sole as compared to intercropping treatment. Similar result was observed by (Kumar *et al*., 2002a)

3.5 Total water use: The data pertaining to total water use (Table 3) was found minimum (321 mm) in sole wheat and maximum (647 mm) in wheat + mentha (2:3). Wheat crop being less water requirement and more canopy coverage crop could be able to utilize less amount of soil moisture while comparatively more water requirement and less canopy coverage in mentha increased its water need. More water use by mentha than wheat either in sole or intercropping system. Similar result was observed by (Kumar *et al*., 2020).

3.6 Water use efficiency: The water use efficiency (Table 3) in term of mentha equivalent yield was computed maximum in wheat under intercropping and minimum wheat + menthe transplanting (1:1). The maximum water use efficiency recorded by wheat + mentha direct (2:3) may be attributed to increased mentha equivalent yield was in much greater proportion than total water use. Similarly, mentha sole also showed similar result and was found in intermediate group. However, mentha grown as sole crop recorded medium water use but tended to show minimum water use efficiency portraying yield of mentha grown as sole crop was much in proportion than total water use. Similar result was observed by (Kumar *et al.*, 2020).

3.7 Oil Yield of Mentha: The data pertaining to the fresh herbage yield (Table 3) at harvesting stage of crop significantly (P=0.05) affected by intercropping tiller however essential oil content was not significant during experiment. Mentha sole (135.82S q ha^{-1}) and essential oil (0.85%) recorded maximum essential oil followed by T8 (0.85%) while minimum was in variety T5 (0.82%). Similar result was observed by (Kumar *et al.*, 2002a)

3.8 Grain Yield of Wheat: Yield of the crop (Table 3) is the resultant of growth and yield contributing characters. The significant (P=0.05) 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 (20.90 q ha^{-1}) recorded under sloe wheat while minimum grain yield (39.80 q ha^{-1}) was obtained with T9 cropping systems. Similar result was observed by (Kumar *et al.*, 2001), (Kumar *et al.*, 2012) & (Wang *et al.*, 2019).

3.9 Oil Equivalent Yields: The data pertaining to cropping system was found to exhibit significant variation under mentha equivalent oil yield (Table 3). 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. To study the effect of different dates of planting for three menthol mint cultivars (Saksham, Kushal and Kosi) on herb yield, oil yield and oil quality. All three cultivars produced higher herb and oil yields when planted on 18 February, compared with planted on other dates. Average herb yield increased 85.71, 104.91 and 109.49 per cent. The similar result was observed by (Chauhan *et al.*, 2012) and (Kumar *et al.*, 2002a)

3.10 Land Equivalent Yield (LER): All the groups of intercropping produced more land equivalent ratio (Table 3) over sole wheat and mentha which may be attributed to more yield in intercropping over sole cropping. The maximum land equivalent ratio 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 it might be due to 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. Similar result was observed by (Kumar *et al*., 2012) and (Sarkar and Pal, 2004).

3.11 Economics: The data on economics (Table 4) viz., gross returns, net returns and benefit: cost ratio as influenced by different intercropping treatments during course of investigations have been presented in Table 4. Among the intercropping treatment the highest values of net return & B:C ratio (INR 160828) & (1:2.36) wheat + mentha (2:3) direct sowing while minimum values of net return & B:C ratio was recorded under (wheat sole), cropping systems (INR 76109) & (1.86) . Kumar *et al*. (2002b) reported that inter-cropping of mentha + wheat in 5:1 row ratio gave significantly higher net profit than all other treatments including sole cropping. Similar result was observed by (Jyoti *et al*., 2005), (Kumar *et al*., 2011) and (Tuti *et al*., 2012)

Table-1: Effect of intercropping system on plant stand (000/ha) of wheat and mentha under different treatments.

Treatments	Mentha		Wheat	
	Initial	Final	Initial	Final
T_1- sole mentha (d)	107.12	103.24	-	-
T_2- sole mentha (t)	108.26	102.30	-	-
T_3- sole wheat	-	-	662.4	658.2
T_4- w+m (d) 1:1	96.48	88.65	330.8	326.17
T_5- w+m (t) 1:1	105.03	86.84	331.6	323.0
T_6- w+m (d) 2:2	106.02	96.87	309.2	303.25
T_7- w+m (t) 2:2	108.03	93.18	308.6	300.46
T_8- w+m (d) 2:3	126.04	119.43	310.3	304.17
T_9- w+m (t) 2:3	128.02	116.48	311.6	303.83
SE (d)	3.03	5.52	9.21	7.85
C D(P=0.05)	6.51	11.85	20.07	17.12

Table-2: Effect of intercropping system on plant height (cm) under different treatment in mentha and wheat crop.

Treatments	Plant height of Mentha				Plant height of Wheat			
	30DAS	60DAS	90DAS	At maturity	30DAS	60DAS	90DAS	At maturity
T_1- sole mentha (d)	11.65	26.05	51.35	63.35	-	-	-	-
T_2- sole mentha (t)	13.25	27.55	54.41	66.18	-	-	-	-

T_3- sole wheat	-	-	-	-	15.98	61.36	83.80	83.60
T_4- w+m (d) 1:1	11.95	26.80	52.87	64.54	14.35	53.79	74.87	78.66
T_5- w+m (t) 1:1	13.40	90	55.16	67.40	13.75	56.85	71.25	76.46
T_6- w+m (d) 2:2	14.35	27.79	53.90	66.95	15.60	60.75	74.82	81.77
T_7- w+m (t) 2:2	14.58	28.29	55.92	68.65	14.95	59.72	68.65	80.35
T_8- w+m (d) 2:3	14.80	28.54	56.92	72.51	14.70	56.89	76.19	79.25
T_9- w+m (t) 2:3	14.65	27.25	54.44	68.70	15.95	59.70	76.96	80.35
SE (d)	1.21	0.79	1.27	1.51	0.62	0.92	1.46	1.68
C D(P=0.05)	NS	1.72	2.74	3.24	1.36	2.01	3.18	3.76

Table-3: Effect of intercropping system on total water use, Water use efficiency, Oil & Seed yield, Equivalent oil yield and land equivalent of wheat and Mentha

Treatments	Total water use (mm)	Water use efficiency (Kg/ha/ mm of water)	Yield		Equivalent Oil Yield of Mentha l/ha	LER
			Oil Yield of mentha (l/ha)	Grain Yield of Wheat (q/ha)		
T_1- sole mentha (d)	605	0.270	163.35	-	163.35	1
T_2- sole mentha (t)	574	0.278	159.83	-	159.83	1
T_3- sole wheat	321	0.180	-	39.80	57.74	1
T_4- w+m (d) 1:1	587	0.273	122.93	25.80	160.36	1.39
T_5- w+m (t) 1:1	576	0.253	110.61	24.60	146.03	1.3
T_6- w+m (d) 2:2	634	0.279	145.20	22.04	177.17	1.43
T_7- w+m (t) 2:2	622	0.282	143.64	21.90	175.41	1.44
T_8- w+m (d) 2:3	647	0.292	158.50	21.30	189.05	1.50
T_9- w+m (t) 2:3	643	0.289	155.65	20.90	185.97	1.49
SE (d)	-	-	6.30	1.31	5.44	0.08
C D(P=0.05)	-	-	13.52	2.85	11.53	0.17

Table-4: The Cost of cultivation gross return, net return and Benefit cost ratio of wheat and mentha.

Treatment	Cost of cultivation(INR)	Gross Return (INR)	Net return (INR)	B:C ratio
T_1- sole mentha (d)	57410	182952	125542	3.18
T_2- sole mentha (t)	61700	178114	120704	2.88
T_3- sole wheat	40730	116839	76109	2.86
T_4- w+m (d) 1:1	68030	193652	125662	2.84

T_5- w+m (t) 1:1	72320	177641	105321	2.45
T_6- w+m (d) 2:2	68030	212222	144192	3.11
T_7-w+m (t) 2:2	72320	210407	138087	2.90
T_8- w+m (d) 2:3	68030	228858	160828	3.36
T_9- w+m (t) 2:3	72320	225387	153076	3.11
SE (d)	-	-	-	-
C D(P=0.05)	-	-	-	-

4. CONCLUSION

In conclusion, the study investigated the impact of row ratio and planting methods on the growth, water use efficiency, yield, and economics of Wheat and Mentha. The findings revealed that Treatment 3 (T3) showed the highest plant population, plant height, and grain yield for wheat. For mentha, Treatment 8 (T8) exhibited the maximum final plant population, plant height, and equivalent oil yield. T8 also demonstrated the highest total water use, water use efficiency, land equivalent ratio, and economic parameters such as gross return, net return, and B:C ratio. The maximum oil yield was observed in Treatment 1 (T1). These results provide valuable insights for optimizing crop production and profitability when selecting row ratios and planting methods for wheat and mentha cultivation.

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