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Influence of Row Ratio on Assessment of Yield and Economics of Wheat (*Triticum aestivum*) and Mustard (*Brassica nigra*) Intercropping System

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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

A field experiment was carried out during *Rabi* 2022 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P) on the topic "Influence of Row Ratio on Assessment of Yield and Economics of Wheat (*Triticum aestivum*) and Mustard (*Brassica nigra*) Intercropping System". to study treatments consisting with row Proportions with wheat and mustard intercropping. The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 8.0), low in organic carbon (0.28%), available N (225 kg/ha), available P (19.50 kg/ha) and available K (92

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kg/ha). There were 8 treatments each being replicated thrice and laid out in Randomized Block Design. The findings discovered that treatment 1 (Sole wheat cropping) recorded significant andmaximum number of effective tillers/m^2 (634.01), number of grains/spike (52.80), seed yield (4.02 t/ha), straw yield (6.73 t/ha) and Harvest index (37.39%) of wheat and treatment 2 (Sole mustard cropping) recorded significant and maximum number of siliqua/plant (210.47), number of seeds/siliqua (22.90), test weight (3.66 g), seed yield (1.27 t/ha), straw yield (2.65 t/ha) and Harvest index (32.33%) in mustard.However, Inter-cropping with wheat-mustard (4:1) rows recorded significant and higher Land Equivalent Ratio (1.11), Wheat equivalent yield (5,046 kg/ha).

Keywords: Wheat; mustard; intercropping; sole cropping; wheat equivalent yield; land equivalent yield; monetary advantage; yield.

1. INTRODUCTION

"Agriculture land is shrinking day by day as it is used for non-agricultural purposes. It is quite inevitable that production will be accommodated in existing crops/cropping systems. The country's food requirement is estimated to be over 300 million tonnes by 2030" [1]. "This additional output must come from existing cultivated land (143.8 million ha) and water resources." The necessity of the hour is to increase resource efficiency and vertical intensification of agricultural systems. This is possible with intercropping" [2]. "Wheat crop is the first important and strategic cereal crop for the majority of world's population. It is the most important staple food for about two billion people (36% of the world population) and it is responsible up to 70 per cent of daily calorie intake of the population living in rural regions. It is basically a temperate region crop but can also be grown under different sub-tropical and tropical conditions successfully. It is an important winter cereal contributing about 38% of the total food grain production in India. Wheat straw is an important source of fodder for a large Indian animal population. The nutritive value of wheat is also an important component for nearly 35 percent of world population as it contains, 71.2 grams of carbohydrates, 11-12 grams of protein, 1.5 grams of fat, 306 milligrams of phosphorus and 41milligroms of calcium per 100 g of wheat grain and it is rich in carbohydrate, protein, fat and minerals like nano zinc, iron and also contains vitamins such as thiamine and vitamin-B" (Gupta *et al.*2019).

"On global scale, the crop is grown over an area of 215.48 m ha with annual production of 731.46 mt and productivity of 33.9 q/ha during 2019-20 worldwide**.** India is the second largest producer of wheat in the world next only to China and the crop has provided the fastest pace of growth to Indian agriculture. Among cereals, wheat is next to rice in area (24.23 million ha) and production (75.6 million tones). In India, the major States where wheat is cultivated are Haryana, Punjab, Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, Maharashtra, Karnataka and highest productivity of wheat is recorded in Punjab, nearly 29.14 M ha area with annual production of 102.19 MT with average productivity of 3506.8 kg/ha in year 2018-19. Uttar Pradesh is the largest state of India with maximum contribution towards national production 35.03% from a large area 35.12%, but with productivity on a lower side of 2.7 tones/ha, the area is 9.2 M ha, with a production of 24.5 Mt and productivity of 2.7 t/ha in 2013-14" [3].

"Mustard is one of the important rabi season oilseed crops especially grown widely in northern India. It is popularly known as rai. India is one among the leading oilseed producing countries in the world. Mustard is the second most important edible oilseed crop next to groundnut. Mustard oil is used primarily for cooking and valued for vegetable, fodder, condiments and medicinal purposes. Mustard is nutritionally very rich and its oil content varies from 37 to 49 per cent. The seed and oil of mustard have a peculiar pungency due to a glycoside "Sinigrin" thus making it suitable for condiments and can be used for the preparation of pickles, curries and vegetables. In India, mustard is grown in an area of 6.7 m ha with a production of 7.80 mt (2015) and a productivity of 1,188 kg/ha" [4].

"India, Canada, China, Pakistan, Poland, Bangladesh and Sweden are the important mustard growing countries in the world. In India it is mainly cultivated in states *viz*., Rajasthan, Madhya Pradesh, Haryana, Punjab, Gujarat, Assam and West Bengal. In Karnataka, it is grown in an area of 2,000 hectare with a production of 1,000 tonne and a productivity of 333 kg/ha" [4]. One of the new vistas in the remunerative cultivation of oilseed brassicas in

the non-traditional areas is to select appropriate row ratio suited to particular agro-climatic situations which can yield more per unit of water and nutrients used. Though, mustard is sporadically raised as sprinkle crop or as mixed crop along with rabi crops such as wheat, barley, groundnut, lentil, chickpea, sorghum, coriander etc. to meet the domestic culinary requirements in southern parts of the country, meager attempts have been made in non traditional growing areas of Uttar Pradesh with respect to row ratio and nutrient management for particular set of environment to achieve potential yield.

Wheat and mustard intercropping is an ageold practice, notably in Northern India, to ensure yield stability and to meet the needs of both oil and grains. Due to changes in the demand and price environment for mustard seed and wheat grains, intercropping may be a boon to create better yield per unit area, generating more income given specified set of criteria, particularly row ratio as replacement series in wheat and mustard. Intercropping is an effective and potentially profitable method of boosting crop yield per unit area and time, particularly for small landholders. Winter oilseeds are becoming more popular as wheat replacement crops. This reflects the awareness of producers about diversification of the cropping system to fulfill their demand and to get the benefits of sound crop rotations on wheat yield. A better understanding of magnitude and mechanism of break-crop effects on wheat yield would allow management to maximize the potential benefits within cropping sequence. In order to feed the world's population, it is imminent to increase productivity per unit area of available land, which seems to be shrinking day by day.

At present, row intercropping has been proved to produce higher yield advantage over mixed intercropping. If recommended row ratio for specific area is adopted then farmers could utilize applied and available resources more efficiently and effectively on sustainable basis. With variation in row combination growth and development of both the component crops are being devated ultimately affects the yield attributes and yield, but at specific combination LER and yield advantage is definitely augmented. For obtaining higher return per unit land area intercropping appears to be one of the important aspect. It increases the efficiency of scarce resources and reduces the risk of failure of a single crop under a fluctuating environment. The major cause of low productivity of wheat and mustard in U.P. is their mixed cropping without proper proportion. Due to the greater competing ability of mustard, proper placement of mustard plant is more important than that of wheat. However, the information on their compatibility as an intercrop with wheat pertaining to optimum row ratio is very meagre. Keeping these issues in view, an experiment has been planned to investigate the feasibility of intercropping of mustard with wheat under varying row ratio for assessment of yield advantage in order to maximize the productivity and profitability of small and marginal farmers.

2. MATERIALS AND METHODS

A field experiment was carried out during *Rabi* 2022 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P) on the topic "Influence of Row Ratio on Assessment of Yield and Economics of Wheat (*Triticum aestivum*) and Mustard (*Brassica nigra*) Intercropping System". to study treatments consisting with row Proportions with wheat and mustard intercropping. There were 8 treatments each being replicated thrice and laid out in Randomized Block Design. The treatment combinations are treatment 1 (Sole wheat cropping), treatment2 (Sole mustard cropping), treatment3 (Wheat + mustard in 4:1 rows), treatment4 (Wheat + mustard in 6:1 rows), treatment5 (Wheat + mustard in 8:1 rows), treatment6 (Wheat + mustard in 4:2 rows), treatment7 (Wheat + mustard in 6:2 rows) and treatment8 (Wheat + mustard in 8:2 rows).

3. RESULTS AND DISCUSSION

3.1 Yield of Wheat

3.1.1 Number of effective tillers/running row meter

According to the data, Significant and maximum number of effective tillers/running row meter (634.01/m^2) was recorded with treatment 1 (Sole wheat cropping) as compared to rest of the treatments. However, the treatment 2 (Wheat + Mustard in 4:1 rows) was found to be statistically at par with treatment 1 (Sole Wheat cropping) [Table 1].significantly maximum number of effective tillers/running row meter was with sole wheat cropping could be due to reduced competition for nutrient requirement, which enhance better uptake of nutrients from soil in all stages, results in development of effective tillers of crop.

3.1.2 Number of grains/spike

The information showed that Maximum number of grains/spike (52.80) was recorded with treatment 1 (Sole wheat cropping) as compared to rest of the treatments and there was no significance difference between them [Table 1].

3.1.3 Test weight (g)

The data showed that, highest test weight (44.50g) was recorded with treatment 1 (Sole wheat cropping) as compared to rest of the treatments and there was no significance difference between them [Table 1].

3.1.4 Grain yield (t/ha)

The data revealed that, significantly higher seed yield (4.02 t/ha) was recorded with treatment 1 (Sole wheat cropping) as compared to rest of the treatments. However, the treatment 2 (Wheat + Mustard in 4:1 rows) was found to be statistically at par with treatment 1 (Sole Wheat cropping) [Table 1].Significantly higher grain yield was recorded with Sole wheat cropping might be due to efficient utilization of available resources such as space, nutrients and light. Similar findings were also reported by Ali et al. [5]. Further, significantly higher grain yield was recorded with (4:1) row proportion might be due to utilization of available resources such as space, nutrients, moisture and light and the grain yield of any plant which mainly depends on the production of photosynthates and its distribution among different plant parts. Agarwal et al. (2005) observed similar findings.

3.1.5 Straw yield (t/ha)

The data revealed that, significantly higher straw yield (6.73 t/ha) was recorded with treatment 1 (Sole wheat cropping) as compared to rest of the treatments. However, the treatment 2 (Wheat + Mustard in 4:1 rows) was found to be statistically at par with treatment 1 (Sole Wheat cropping) [Table 1].Significantly higher straw yield was recorded with Sole wheat cropping might be due to increase in plant growth and efficient utilization of available resources such as space, nutrients and light. Similar findings were also reported by Ali et al. [5]. Further, Significant and higher straw yield was recorded with (4:1) row proportion might be due to growth and development of plant with available resources and utilization of available resources such as space, nutrients, moisture and light and the grain yield of any plant which mainly depends on the production of photosynthates and its distribution among different plant parts. Agarwal et al. [6] observed similar findings as well.

3.1.6 Harvest index (%)

The data revealed that, significantly highest harvest index (44.20 %) was recorded with treatment 7 (Wheat + Mustard in 6:2 rows) as compared to rest of the treatments [Table 1].

3.2 Yield of Mustard

3.2.1 Number of siliqua/plant

The data revealed that, significantly maximum number of siliqua/plant (210.47) was recorded in treatment 2 (Sole mustard cropping) as compared to rest of the treatments. However, the treatment 3 (Wheat + Mustard in 4:1 rows) was found to be statistically at par with treatment 2 (Sole mustard cropping) [Table 2]. Significantly maximum siliqua/plant was recorded with sole wheat cropping could be due to reduced competition for nutrient requirement, which enhance better uptake of nutrients from soil in all stages, results in formation of maximum siliqua/plant.

3.2.2 Number of grains/siliqua

The information showed that significantly maximum number of seeds/siliqua(22.90) was recorded in treatment 2 (Sole mustard cropping) as compared to rest of the treatments. However, the treatment 3 (Wheat + Mustard in 4:1 rows) was found to be statistically at par with treatment 2 (Sole mustard cropping) [Table 2]. Significantly maximum number seeds/siliqua was recorded with sole mustard cropping could be due to utilization of available resourced and enhance pollen tube formation, pollen viability, starch utilization and chlorophyll biosynthesis, which results in better seed formation.

3.2.3 Test weight (g)

The data revealed that, significantly higher test weight (3.66 g) was recorded in treatment 2 (Sole mustard cropping) as compared to rest of the treatments. However, the treatment 3 (Wheat + Mustard in 4:1 rows) was found to be statistically at par with treatment 2 (Sole mustard cropping) [Table 2].

3.2.4 Grain yield (t/ha)

The data revealed that, significantly higher seed yield (1.27 t/ha) was recorded in treatment 2 (Sole mustard cropping) as compared to rest of the treatments. However, the treatment 3 (Wheat + Mustard in 4:1 rows) was found to be statistically at par with treatment 2 (Sole mustard cropping) [Table 2]. The Sole Mustard cropping method resulted in a significantly better grain yield, which may be attributable to the effective use of the space, nutrients, and light that were available. Similar findings were also reported by Ali et al. [5]. Further, Significant and higher grain yield of intercropping of wheat and mustard was recorded with (4:1) row proportion might be due to utilization of available resources such as space, nutrients, moisture and light and the grain yield of any plant which mainly depends on the production of photosynthates and its distribution among different plant parts. Similar results was also reported by Agarwal et al. [6].

3.2.5 Stover yield (t/ha)

The data revealed that, significantly higher stover yield (2.65 t/ha) was recorded in treatment 2 (Sole mustard cropping) as compared to rest of the treatments. However, the treatment 3 (Wheat + Mustard in 4:1 rows) was found to be statistically at par with treatment 2 (Sole mustard cropping) [Table 2]. It's possible that the effective use of resources like space, nutrients, and light led to the significantly higher stover output observed with sole mustard cultivation. Ali et al. (2000) also observed similar findings. Further, Significant and higher straw yield of intercropping of wheat and mustard was recorded with (4:1) row proportion might be due to utilization of available resources such as space, nutrients, moisture and light and the grain yield of any plant which mainly depends on the production of photosynthates and its distribution among different plant parts. Similar results was also reported by Agarwal et al. [5].

3.2.6 Harvest index (%)

The data revealed that,significantly highest harvest index (32.33%) was recorded in treatment 8 (Wheat + Mustard in 4:1 rows) as compared to rest of the treatments. However, the treatment 4 (Wheat + Mustard in 6:1 rows) and treatment 5 (Wheat + Mustard in 8:1 rows) was found to be statistically at par with treatment 8 (Wheat + Mustard in 4:1 rows) [Table 2].

3.3 Economics

3.3.1 Assessment of yield advantage of wheat and mustard intercropping system

Wheat equivalent yield (kg/ha)

Significant and higher wheat equivalent yield (5046 kg/ha) was recorded in treatment 3 (Wheat + Mustard in 4:1 rows) as compared to rest of the treatments. However, the treatment 7 (Wheat + Mustard in 6:2 rows) was found to be statistically at par with treatment 3 (Wheat + Mustard in 4:1 rows)[Table 3]. Significant and higher wheat equivalent yield was recorded with wheat-mustard (4:1) row proportion might be due to higher contribution by of wheat and mustard and their market price coupled with better utilization of resources by the component crops in intercropping system. These attributed to higher yield of both the crop due to good compatibility of system and enable to utilize nutrient, moisture, space and light efficiently by the crop. This could results in favourable influence on growth and yield components of mustard. Higher price of mustard in the market was also one of the factor for recording higher WEY, the higher yield of both the component crops. Similar results were reported by Megawer et al. (2010) and Awal et al. (2007).

Land Equivalent Ratio (LER)

Significant and higher Land Equivalent Ratio (1.11) was recorded in treatment 3 (Wheat + Mustard in 4:1 rows) as compared to rest of the treatments. However, the treatment 7 (Wheat + Mustard in 6:2 rows) was found to be statistically at par with treatment 3 (Wheat + Mustard in 4:1 rows) [Table 3]. Significant and higher Land Equivalent Ratio was recorded with wheat-mustard (4:1) row proportion might be due to better performance of both the crop obvious for component crop differed in its use of growth resources andefficiently utilise them. This resulted in higher yield per unit area than that produced by sole crop. Similar results were also found by Singh and Yadav (1990) and Das et al. (2012).

Monetary advantage (INR/ha)

Highest Monetary advantage (97,363.00 INR/ha) was recorded in treatment 3 (Wheat + Mustard in 4:1 rows) as compared to rest of the treatments. However, the treatment 7 (Wheat + Mustard in

6:2 rows) was found to be statistically at par with treatment 3 (Wheat + Mustard in 4:1 rows) [Table 3].

Cost of cultivation (INR/ha)

Cost of cultivation (37,634.00 INR/ha) was found to be higher in treatment 4 (Wheat + Mustard in 6:1 rows), treatment 5 (Wheat + Mustard in 8:1 rows), treatment 8 (Wheat + Mustard in 8:2 rows) and minimum cost of cultivation (31,223.00 INR/ha) was found to be in treatment 2 (Sole mustard cropping) as compared to other treatments [Table 4].

Gross return (INR/ha)

Gross returns (1,00,363.00 INR/ha) were found to be highest in treatment 3 (Wheat + Mustard in 4:1 rows) and minimum gross returns (78,889.00 INR/ha) was found to be in treatment 2 (Sole mustard cropping) as compared to other treatments [Table 4].

Net returns (INR/ha)

Net returns (64,312.00 INR/ha) were found to be highest in treatment 3 (Wheat + Mustard in 4:1 rows) and minimum net returns (47,666.00 INR/ha) was found to be in treatment 2 (Sole mustard cropping) as compared to other treatments [Table 4].

Benefit cost ratio (B:C)

Benefit Cost ratio (1.78) was found to be highest in treatment 3 (Wheat + Mustard in 4:1 rows) and minimum gross returns (1.47) was found to be in treatment 8 (Wheat + Mustard in 8:2 rows) as compared to other treatments [Table 4] [7-10].

Table 1. Influence of row ratio on growth and yield attributes of wheat

S.No	Treatments Combination	No. of effective tillers/m^2	No. of grains/spike	Test weight(g)	Seed yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
1	Sole Wheat cropping	634.01	52.80	44.50	4.02	6.73	37.39
3	Wheat + Mustard in 4:1 rows	622.16	51.87	44.23	3.46	4.73	42.28
4	Wheat + Mustard in 6:1 rows	568.83	50.60	43.42	3.56	5.32	40.08
5	Wheat + Mustard in 8:1 rows	551.05	50.47	43.20	3.45	5.13	40.19
6	Wheat + Mustard in 4:2 rows	592.53	51.00	43.63	3.29	4.53	42.05
7	Wheat + Mustard in 6:2 rows	604.38	51.40	44.09	3.35	4.62	44.20
8	Wheat + Mustard in 8:2 rows	539.20	50.13	43.02	3.41	5.04	40.33
	F test	S	NS	NS	S	S	S
	S Em (±)	10.85	0.23	0.10	0.07	0.05	2.58
	CD (p =0.05)	32.25	-	-	0.21	0.17	0.86

Table 2. Influence of row ratio on growth and yield attributes of mustard

S.No	Treatments Combination	No. of Siliqua/plant	No. of seeds/Siliqua	Test weight(g)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
2	Sole mustard cropping	210.47	22.90	3.66	1.27	2.65	32.33
3	Wheat + Mustard in 4:1 rows	205.43	22.23	3.58	0.33	0.85	27.74
4	Wheat + Mustard in 6:1 rows	194.78	21.01	3.27	0.24	0.40	37.16
5	Wheat + Mustard in 8:1 rows	189.86	19.74	3.06	0.23	0.37	37.79
6	Wheat + Mustard in 4:2 rows	197.62	21.15	3.52	0.29	0.77	27.60
7	Wheat + Mustard in 6:2 rows	200.11	21.74	3.52	0.32	0.80	28.36
8	Wheat + Mustard in 8:2 rows	184.05	19.15	2.97	0.22	0.34	39.15
	F test	S	S	S	S	S	S
	SEm (±)	1.24	0.31	0.03	0.01	0.01	0.96
	CD (p =0.05)	3.71	0.93	0.11	0.05	0.05	2.87

Table 3. Influence of row ratio on assessment of growth and yield advantage of wheat-mustardintercropping system

S.No	Treatments Combination	LER	WEY (kg/ha)	Monetary Advantage (INR/ha)
1	Sole wheat cropping	1.00	4,020	72,360.00
2	Solo mustard cropping	1.00	3,951	70,933.00
3	Wheat + Mustard in 4:1 rows	1.11	5,046	97,363.00
4	Wheat + Mustard in 6:1 rows	1.06	4,766	91,303.00
5	Wheat + Mustard in 8:1 rows	1.03	4,735	90,303.00
6	Wheat + Mustard in 4:2 rows	1.04	4,922	92,546.00
7	Wheat + Mustard in 6:2 rows	1.08	5,015	94,493.00
8	Wheat + Mustard in 8:2 rows	1.01	4,704	89,790.00
	F test	S	S	
	SEm (±)	0.05	10.89	
	CD (p =0.05)	0.03	33.06	

Table 4. Effect of row ratio under replacement series on economics of wheat and mustard intercropping system

S. No.	Treatment combinations	Total Cost of Cultivation (INR/ha)	Gross returns (INR/ha)	Net Return (INR/ha)	B:C ratio
1.	Sole Wheat cropping	34,935.00	90,550.00	55,615.00	1.59
2.	Sole Mustard cropping	31,223.00	78,889.00	47,666.00	1.53
3.	Wheat + Mustard in 4:1 rows	36,051.00	1,00,363.00	64,312.00	1.78
4.	Wheat + Mustard in 6:1 rows	37,634.00	94,493.00	56,859.00	1.51
5.	Wheat + Mustard in 8:1 rows	37,634.00	93,303.00	55,669.00	1.48
6.	Wheat + Mustard in 4:2 rows	36,051.00	95,546.00	59,495.00	1.65
7.	Wheat + Mustard in 6:2 rows	36,051.00	98,303.00	62,252.00	1.73
8.	Wheat + Mustard in 8:2 rows	37,634.00	92,790.00	55,156.00	1.47

4. CONCLUSION

Based on the above findings it was concluded that the effect of row ratio on growth and yield of wheat and mustard intercropping system. Intercropping with wheat-mustard in (4:1) rows (treatment 3) in wheat and mustard intercropping system recorded higher seed yield, higher Land equivalent ratio, wheat equivalent yield, monetary advantage, net returns and benefit cost ratio.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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