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Performance of wheat *(Triticum aestivum)* + Indian mustard *(Brassica juncea)* intercropping in relation to row ratio, Indian mustard variety and fertility levels

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ABSTRACT

A field experiment was conducted during the winter seasons of 1999–2000 and 2000–2001 at Varanasi, Uttar Pradesh, to evaluate the effect of varying row ratio, Indian mustard [*Brassica juncea* (L.) Zernj. & Cosson] variety and fertility levels on yield potential, competitive function and economics of wheat + Indian mustard intercropping. Association of wheat with Indian mustard under 5 :1 row ratio was found more sustainable, as it accounted for higher value in terms of land-equivalent ratio (LER) and relative crowding coefficient (1.690) and was economically more remunerative. For association with wheat, Indian mustard var. 'Sanjucta Asesh' proved economically viable than 'Vardan' with a minimum depression in yield and yield attributes of wheat. To achieve higher yield advantage and efficient resource utilization, an application of 100% recommended dose of fertilizer to both the component crops was found imperative. Though performance of wheat was better in its sole stand, Indian mustard varieties thrived better in intercropping treatments to their solid stands.

Key words : Wheat + mustard intercropping, Row ratio, Mustard variety, Fertility, LER, Economics, Relative crowding coefficient

In northern India, wheat is the most important grain crop and rapeseed–mustard is the largest group of oilseeds during winter season. One of the major causes of low productivity of wheat and Indian mustard in eastern Uttar Pradesh is their mixed cropping where proper proportion of the component crops is generally not maintained.

In wheat + Indian mustard intercropping, various row combinations have been found optimum for different varieties of wheat and Indian mustard in the country. As the Indian mustard variety shows the greater competing ability, selection of mustard is more important than that of the wheat. Two varieties of mustard, viz 'Sanjucta Asesh' and 'Vardan', have been recommended for mixed or intercropping in the country. However, information on compatibility of these varieties as an intercrop with wheat pertaining to optimum and sustainable row ratio and fertilizer levels under Varanasi conditions is still lacking. Hence a field experiment was carried out to find out suitable row ratio, Indian mustard variety and fertility level for wheat + Indian mustard intercropping under irrigated conditions.

MATERIALS AND METHODS

The experiment was conducted during the winter seasons of 1999–2000 and 2000–01 at the research farm of the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The soil was Gangetic alluvial (Ustochrept), with pH 7.4. It was low in organic carbon (0.42%), available nitrogen (210.0 kg/ha) and medium in available phosphorus (14.40 kg/ha) and potassium (172.12 kg/ha). The experiment was laid out in split-plot design, comprising 6 treatment combinations of wheat + Indian mustard intercropping in replacement series at 3 different row proportions (8:1, 5:1 and 2:1) along with 2 Indian mustard varieties 'Sanjucta Asesh' and 'Vardan' in main plots. Each main plot was divided into sub-plots to assign 3 fertility levels (one-third, two-thirds and full recommended dose of NPK, i.e. 90 kg N + 45 kg P_2O_5 + 45 kg K_2O/ha), to intercrop Indian mustard, whereas wheat received 100% recommended dose of NPK (120 kg N + 60 kg P_2O_5+60 kg K_2O/ha) invariably. Three extra plots of sole wheat 'HUW 468' and sole Indian mustard varieties 'Sanjucta Asesh' and 'Vardan' were taken in each replication for estimation of land-equivalent ratio (LER), relative crowding coefficient, competitive ratio and aggressivity. Accordingly, 18 treatment combinations were formed along with sole wheat and 2 varieties of Indian mustard. Fertilizer application to the pure crops of wheat and Indian mustard was done at 100% of their recommended dose. However, in intercropping system full recommended dose of fertilizer was applied to the wheat rows according to its

respective population, whereas to the intercropped Indian mustard, fertilizer was applied according to treatments in rows. Full recommended doses of P and K along with 50% N was applied as basal to both the crops in sole as well as intercropping system. Rest 50% N to Indian mustard was top-dressed 30 days after sowing. However, to the wheat crop, remaining N was applied in 2 equal splits at tillering and ear-emergence stages. Fertilizer requirement of both the crops was met through urea, diammonium phosphate and muriate of potash.

The crops were sown in the second fortnight of November during both the years with 100, 5 and 3.5 kg seed/ha for 'HUW 468' wheat and 'Sanjucta Asesh' and 'Vardan' Indian mustard. Desired plant population in sole and intercrop Indian mustard was maintained by thinning of extra plants 2 times, at 15 and 25 days after sowing. The total rainfall received during the crop period was 17.7 and 11.0 mm in 1999–2000 and 2000–01 respectively. The competitive functions of each intercropping treatment were worked out as mentioned by Katyayan (2005). Grain or seed yield index was calculated according to Singh and Gupta (1994) where sole stand of wheat or Indian mustard was taken as 100. However, to work out this index for row ratio and fertility levels, mean yield of 2 varieties of Indian mustard was taken as 100.

RESULTS AND DISCUSSION

Yield attributes of component crops

Increasing proportion of Indian mustard from 8:1 to 2:1 row ratio of wheat + Indian mustard intercropping, markedly reduced grains/spike, effective tillers/m and 1,000-grain weight of wheat (Table 1). This can be ascribed to the greater competition exerted by dominant Indian mustard crop for light, space and nutrients. Of 2 Indian mustard varieties, 'Vardan' proved significantly more detrimental than 'Sanjucta Asesh' on yield attributes of wheat. 'Sanjucta Asesh', owing to its short-statured and highly compact growth habit, caused comparatively less shading effect over wheat. However, fertilizer applied to Indian mustard did not influence the yield attributes of wheat. Nevertheless, in its pure stand, wheat recorded significantly higher grains/spike, effective tillers/m and 1,000-grain weight than intercrop mean.

The siliquae/plant were highest under 8:1 row combination and reduced significantly with an increase in Indian mustard population from 8:1 to 2:1 row ratio of wheat + Indian mustard system. This might be owing to availability of more space, light and nutrients to the Indian mustard. In intercropping system, 'Vardan' showed an edge over 'Sanjucta Asesh' and produced significantly higher siliquae/plant and 1,000-seed weight than the latter. How-

Table 1. Effect of row ratio, Indian mustard variety and fertility levels on yield attributes and yields of wheat and Indian mustard in wheat + Indian mustard intercropping (pooled data of 2 years)

Treatment	Wheat					Indian mustard				
	Grains/ spike	Effective tillers/ linear m	1,000-grain weight (g)	Grain yield (q/ha)	Mean yield index	Seeds/ siliqua	Siliquae/ plant	1,000-seed weight (g)	Seed yield (q/ha)	Mean yield index
Row ratio (Wheat : Indian mustard)										
8:1	42.45	74.24	38.19	47.50	86.88	11.56	375.67	3.27	4.04	21.36
5:1	40.44	66.04	37.66	41.14	75.25	11.34	335.33	3.33	6.28	33.21
2:1	38.73	50.90	37.16	28.03	51.27	11.01	291.38	3.41	9.19	48.60
CD (P=0.05)	1.02	4.18	0.63	2.13		NS	28.87	NS	0.88	
Indian mustard variety										
'Sanjucta Asesh'	41.71	66.80	37.52	41.09	75.16	12.14	312.31	2.70	5.82	33.54
'Vardan'	39.37	60.65	37.82	36.69	67.11	10.46	355.95	3.97	7.20	35.17
CD (P=0.05)	0.83	3.41	NS	1.74		0.48	23.57	0.13	0.72	
Fertility levels (Wheat + mustard)*										
100% + 100%	40.11	62.76	37.78	38.21	69.89	11.80	374.31	3.45	7.29	38.55
100 % + 66.67%	40.52	63.47	37.64	38.95	71.25	11.19	337.38	3.33	6.49	34.21
100% + 33.33%	40.98	64.95	37.59	39.51	72.27	10.91	290.70	3.23	5.74	30.35
CD (P=0.05)	NS	NS	NS	NS	NS		0.54	0.41	0.46	
Sole vs. intercrop										
'Sanjucta Asesh' (sole)						12.82	241.15	2.38	17.35	100.00
'Vardan' (sole)						10.71	277.30	3.89	20.47	100.00
'Wheat' (sole)	45.88	82.25	38.66	54.67	100.00					
Intercrop mean	40.54	63.73	37.67	38.89	71.14	11.30	333.13	3.34	6.51	34.43
CD (P=0.05)	1.48	5.54	0.96	4.05		0.95	34.54	0.23	1.14	

*Recommended dose of N–P_2O_5–K_2O kg/ha (wheat : 120-60-60; Indian mustard: 90-45-45)

ever, seeds/siliqua showed the reverse trend. With every increase in the rate of fertilizer application to Indian mustard from 33.33% to 100% of the recommended dose significantly increased seeds/siliqua, siliquae/plant and 1,000-seed weight. Higher yield traits in Indian mustard under highest fertility levels was found mainly owing to greater absorption of nutrients through adequate availability and supply of N, P and K under the highest level which led to increased photosynthates accumulation and higher biomass production.

Grain or seed yield

The lowest wheat yield was recorded with the highest mustard proportion when 1 row of Indian mustard was sown after every 2 rows of wheat. The area under wheat reduced by 33.3, 16.7 and 11.1%, respectively, in 2:1, 5:1 and 8:1 row ratios causing reduction in wheat yield of 48.7, 24.8 and 13.1% on mean wheat yield index basis along with other competitive factors in intercropping systems. These results confirm the findings of Singh *et al.* (1991). Indian mustard varieties showed a depressing effect on the grain yield of wheat. The extent of reduction in the yield of wheat was the maximum (32.9%) due to 'Vardan' compared to its sole stand; and it was significantly higher than 'Sanjucta Asesh'. Varying fertilizer doses to Indian mustard rows also remained ineffective in causing profound influence on yield of wheat crop in intercropping system. However, the grain yield of wheat was significantly higher in pure stand than intercrop mean.

The effect of inter-row competition in Indian mustard was just reverse to that of wheat due to greater canopy of Indian mustard, intercepting greater part of light, thereby putting wheat crop to a disadvantage. The row ratio of 2:1 gave significantly higher seed yield of Indian mustard over 5:1 and 8:1 row ratios. Similarly, 5:1 row ratio exhibited its distinct superiority to 8:1. The seed-yield index was the maximum where 2 rows of wheat were alternated with 1 row of Indian mustard. The crop of Indian mustard replaced 11.1, 16.7, and 33.3% area of wheat, respectively, in 8:1, 5:1 and 2:1 row ratios with corresponding increase in seed yield of Indian mustard on basis of yield of respective sole crops as 100%. This could be ascribed to the greater competitive and aggressive nature of mustard (Table 3). These results corroborate the findings of Singh *et al.* (1991). Significant difference was observed in seed yield of Indian mustard varieties in association with wheat and 'Vardan' gave 23.7% higher seed yield and 4.9% higher seed yield index than 'Sanjucta Asesh'. Every increase in fertilizer dose of Indian mustard from 33.33% to 100% of the recommended dose significantly increased the seed yield and mean yield index of mustard, indicating that any curtailment of fertilizer to Indian mustard ad-

Table 2. Effect of row ratio, Indian mustard variety and fertility levels on nitrogen (N), phosphorus (P) and potassium (K) uptake (kg/ha) by component crops and system in wheat + Indian mustard intercropping (pooled data of 2 years)

Treatment	Wheat			Indian mustard			System		
	N	P	K	N	P	K	N	P	K
Row ratio (Wheat : Indian mustard)									
8:1	113.06	19.63	107.09	20.83	3.35	16.73	133.90	22.98	123.82
5:1	102.00	17.69	98.02	34.99	5.59	29.41	137.00	23.28	127.43
2:1	74.64	13.01	75.54	55.98	8.96	48.62	130.62	21.97	124.17
CD (P=0.05)	5.16	0.81	4.22	4.79	0.99	4.37	NS	NS	3.10
Indian mustard variety									
'Sanjucta Asesh'	99.93	17.32	97.39	32.17	5.21	25.29	132.10	22.52	122.68
'Vardan'	93.21	16.23	89.71	42.36	6.72	37.88	135.58	22.96	127.59
CD (P=0.05)	4.22	0.67	3.44	3.91	0.81	3.57	NS	NS	2.53
*Fertility levels**									
Wheat + Indian mustard									
100% + 100%	97.79	17.13	93.46	42.81	7.03	35.87	140.59	24.16	129.33
100% + 66.67%	96.61	16.81	93.53	37.27	5.91	31.68	133.88	22.72	125.22
100% + 33.33%	95.31	16.39	93.67	31.73	4.96	27.20	127.04	21.35	120.86
CD (P=0.05)	NS	NS	NS	1.52	0.83	1.12	3.20	0.64	3.25
Sole vs. intercrop									
'Sanjucta Asesh' (sole)				88.10	14.26	72.82	88.10	14.26	72.82
'Vardan' (sole)				110.01	17.45	98.36	110.01	17.45	98.36
Wheat (sole)	144.43	25.33	141.38				144.43	25.33	141.38
Intercrop mean	96.57	16.78	93.55	37.27	5.96	31.59	133.84	22.74	125.14
CD (P=0.05)	6.46	1.29	6.48	2.71	1.48	2.00	5.69	1.13	5.78

*Recommended dose of N-P_2O_5-K_2O kg/ha (wheat : 120-60-60; Indian mustard: 90-45-45)

versely affects its yield.

Nutrient uptake

Wheat recorded the maximum total uptake of N, P and K at 8:1 row ratio, followed by 5:1 and 2:1 row ratios and the difference between any 2 row ratios was significant (Table 2). As expected, the reverse trend was observed for Indian mustard. Intercropping of wheat with 'Sanjucta Asesh' Indian mustard recorded significantly higher N, P and K uptake than the intercropping with 'Vardan' because of higher yield of wheat in this combination. Similarly, 'Vardan' recorded significantly higher N, P and K uptake than 'Sanjucta Asesh'. Varying fertility levels did not affect the N, P and K uptake by the wheat. However, successive increase in levels of fertility to Indian mustard rows significantly increased the N, P and K uptake in Indian mustard. This may be attributed to the greater availability of nutrients at higher rate of fertilizer application, which in turn increased the nutrient content, yield and nutrient uptake.

Maximum N, P and K uptake by the intercropping system was recorded in 5:1 row ratio owing to overall higher productivity of the system, as evident from higher LER value (Tables 2, 3). Similarly, higher N, P and K uptake was recorded when 'Vardan' was grown in association with wheat than 'Sanjucta Asesh' which may be ascribed to commensurately higher yield of 'Vardan' (Table 1). In wheat +Indian mustard intercropping, every increment in recommended dose of fertility from 33.33 to 100% to mustard brought about successive and significant increase in N,P and K uptake by the system owing to higher yield of Indian mustard at higher rates of fertilizer application, indicating direct and strong positive relationship of nutrient uptake with mustard yield.

Yield advantage and competitive functions

In wheat + Indian mustard intercropping, 5:1 and 8:1 row ratios were found comparable but both recorded significantly higher yield advantage and greater biological efficiency over 2:1 row ratio. Yield advantage of 8.4 and 8.1% was registered in 5:1 and 8:1 row ratios, which indicates similar yield to that of the pure stand of both the crops even with 8.4 and 8.1% reduced land, justifying their desirability over monoculture of wheat or Indian mustard. Singh and Gupta (1994) also reported higher yield advantage under wider row ratio of wheat + Indian mustard intercropping. In addition, relative crowding coefficient, which also showed the yield advantage, was higher at wider row ratios than 2:1, similar to total LER. The aggressive nature of Indian mustard, made it more competitive than wheat. The aggressivity of Indian mustard was the maximum at 5:1 row ratio of wheat + Indian mustard intercropping, followed by 8:1 and 2:1 row ratios.

Table 3. Effect of row ratio, Indian mustard variety and fertility levels on competitive functions and economics of wheat + Indian mustard intercropping (pooled data of 2 years)

Treatment	Competitive functions						Economics	
	LER	Relative crowding coefficient	Competitive ratio		Aggressivity		Net return (Rs/ha)	Benefit : cost ratio
			Wheat	Indian mustard	Wheat	Indian mustard		
Row ratio (Wheat : Indian mustard)								
8:1	1.081	1.775	0.528	1.951	–0.926	0.926	28,410	1.77
5:1	1.084	1.690	0.464	2.230	–1.085	1.085	28,634	1.79
2:1	1.000	1.040	0.538	1.917	–0.687	0.687	25,466	1.63
CD (P=0.05)	0.045	0.164	0.052	NS	0.085	0.085	0.085	
Indian mustard variety								
'Sanjucta Asesh'	1.087	1.716	0.563	1.821	–0.765	0.765	27,616	1.74
'Vardan'	1.023	1.288	0.457	2.245	–1.034	1.034	27,391	1.72
CD (P=0.05)	0.037	0.134	0.043	0.278	0.070	0.070		
Fertility levels (Wheat + Indian mustard)								
100% + 100%	1.085	1.684	0.440	2.323	–1.134	1.134	28,493	1.78
100% + 66.67%	1.053	1.487	0.509	2.014	–0.885	0.885	27,530	1.73
100% + 33.33%	1.027	1.334	0.582	1.762	–0.680	0.680	26,487	1.68
CD (P=0.05)	0.036	0.102	0.038	0.192	0.067	0.067		
Sole crop								
'Sanjucta Asesh' Indian mustard	1.000						21,348	1.42
'Vardan' Indian mustard	1.000						28,205	1.87
Wheat	1.000						25,430	1.56

*Recommended dose of N-P_2O_5-K_2O kg ha^{-1} (wheat : 120-60-60; mustard : 90-45-45)

Significantly higher total LER as well as biological efficiency of wheat + Indian mustard intercropping was obtained with Indian mustard variety 'Sanjucta Asesh' than 'Vardan'. Intercropping of 'Sanjucta Asesh' with wheat not only resulted in higher yield proportion of wheat but also led to higher productivity of the system over 'Vardan'. 'Vardan' proved more aggressive and competitive than 'Sanjucta Asesh' and caused adverse effect on the main crop wheat. Relative crowding coefficient further indicated that the biological efficiency of the system was distinctly better with 'Sanjucta Asesh' than 'Vardan'.

Aggressivity of Indian mustard as well as its competitive ratio in wheat + Indian mustard intercropping enhanced markedly with increasing levels of fertilizer application to Indian mustard causing corresponding decline in these indices for wheat. The maximum total LER was observed at highest fertility level followed by medium and lowest fertility. The relative crowding coefficient at various fertility levels, further confirmed the results of LER, indicating maximum yield advantage of wheat + Indian mustard intercropping system with the application of full recommended doses of NPK to both the crops and the lowest when fertilizer application to Indian mustard was curtailed by 66.67%.

Economics

An intercropping of wheat + Indian mustard was more remunerative than their sole stands for net return (Table 3). Among different row combinations, wheat + Indian mustard in 5:1 row ratio gave the maximum net return and benefit : cost ratio (1.79), followed by 8:1 row ratio but both were found distinctly better than 2:1 row ratio. 'Sanjucta Asesh' in association with wheat, was found remunerative than 'Vardan'. Rathi *et al.* (1992) also advocated the selection of suitable mustard variety for higher net return in intercropping system. Application of 100% recommended doses of fertilizer to both the component crops in wheat + Indian mustard intercropping system was most profitable, as it gave a net return of Rs 28,493/ ha and benefit : cost ratio of 1.78. However, with the reduction in fertilizer doses to Indian mustard, the profitability declined, indicating that in wheat + Indian mustard intercropping to achieve the maximum profit no curtailment in the recommended fertilizer dose to Indian mustard is feasible.

Thus to achieve higher yield advantage and efficient resource utilization in wheat + Indian mustard intercropping, 1 row of Indian mustard var. 'Sanjucta Asesh' be taken after every 5 rows of wheat and both the component crops be fertilized with 100% recommended fertilizer dose.

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