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Yield attributes, yield and economics of wheat (*Triticum aestivum*) + compact mustard (*Brassica juncea*) intercropping under 5:1 row proportion in relation to fertility levels and seeding densities of two wheat varieties

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ABSTRACT

A two-year field experiment was conducted during *rabi* season of 2005–06 and 2006–07 at Varanasi on wheat + compact-mustard intercropping in 5:1 row proportion. The treatments involved three fertilizer doses, i e 100%, 120% and 140% of recommended NPK to wheat accompanied with 100% recommended NPK to mustard; two wheat varieties (HD 2824 and HUW 468) and three seed rates of wheat (100 kg, 115 kg and 130 kg/ha). Increasing fertilizer doses from 100% to 140% RFD applied to wheat accompanied with 100% RFD to mustard exhibited marked increase in yield-attributing characters, grain yield and straw yield. Application of 120 and 140% RFD recorded 6.4 and 10.2% higher LER respectively than 100% RFD. Similar trend was observed for RCC, AYL, IA, net returns and monetary advantage. Conversely, all the fertility levels didn't cause any significant variation on yield attributes, yield, LER, AYL and monetary returns of intercrop mustard. The wheat variety HIV 2824 showed distinct superiority over HUW 468 with respect to spikes/m, test weight, grain yield/m, grain yield, straw yield, LER, RCC, net returns and monetary advantage in wheat + mustard intercropping system. Increasing wheat seed rates from 100 to 130 kg/ha reduced the average spike length, test weight and harvest index though the differences being significant only between lowest and highest seed rates. However, increasing wheat seed rates up to highest level resulted in lucid improvement of spikes/m, grain yield/m, grain yield, LER, RCC, net returns and monetary advantage. However, the reverse trend was noticed for AYL and 1A.

Key words: Economics, Fertility level, Seeding density, Wheat + mustard intercropping, Wheat variety, Yield, Yield attributes

Intercropping is an advanced agro-technique and is considered to be an effective and potential mean of increasing crop production per unit area and time, particularly for farmers with marginal and small holdings. It provides an efficient utilization of environmental resources, decreases the cost of production, provides higher financial stability to farmers, decreases pest damage, inhibits weeds growth as compared to sole cropping, and improves soil fertility through fertilizers increasing to the system besides improving yield and quality.

The nutrients use in wheat + mustard intercropping system is usually based on requirement of both the component crops (wheat and mustard) and the availability of nutrients from a common pool, though they have different requirements. This calls for an assessment of nutrient need of wheat and mustard in intercropping. In earlier studies conducted on wheat + mustard (5:1) intercropping with compact mustard variety Sanjukta Aschesh, the maximum productivity and profit were obtained with application of 100% RFD to both the crops (Srivastava and Bohra 2006). However, wheat being not as aggressive as mustard, it looks feasible that the LER and net return could further improve with the enhancement of nutrient use in wheat.

The highest yielding genotypes in sole cropping do not necessarily remain so when grown as intercrops signifying better selection of genotypes specifically for intercropping. Though mixed and intercropping of wheat and mustard is very common in northern India, the ideal genotypes are either not available and if available they have not been tested for their compatibility in different agro-climatic conditions. However, in a recent study in Varanasi (Srivastava and Bohra 2006) it was reported that mustard variety Sanjukta Aschesh is quite effective in 5:1 wheat + mustard intercropping but no systematic effort has so far been made to find out the suitable

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wheat genotypes for wheat + mustard intercropping in the country in general and Varanasi region in particular.

Plant population is a dominant yield determinant in intercropping system, which could be manipulated for better advantage in a particular environmental situation. Information on spatial arrangement is thus necessary to optimize plant stand of component crops in intercropping system for additional yield advantage, enabling lesser competition for moisture, nutrients and light. Maintaining 100% plant population of mustard variety Sanjukta Aschesh has been found suitable for 5:1 wheat + mustard intercropping but optimum wheat population has not yet been worked out. Keeping these facts in consideration the present study was undertaken with an objective to evaluate the effect of varying fertility levels and seeding density of two wheat varieties on yield traits, yield and economics of wheat + compact mustard intercropping under 5:1 row proportion.

MATERIALS AND METHODS

The field study was carried out during two consecutive winter seasons of 2005–06 and 2006–07 at the Agricultural Research Farm of Banaras Hindu University, Varanasi in Northern Gangetic Alluvial Plain of India (83°03'0"E longitude; 25°18'0"N latitude and an altitude of 128.93 m above sea level). The experimental soil was Gangetic alluvial (*Ustochrept*) with pH 7.6. It was moderately fertile being low in organic carbon (0.39%), available nitrogen (198.4 kg/ha) and medium in available phosphorus (15.7 kg/ha) and potassium (215.4 kg/ha). The experiment was laid out in split-plot design with 3 replications. It involved six treatment combinations of three fertility levels (100%, 120% and 140% of recommended NPK to wheat accompanied with 100% NPK to mustard) and two wheat varieties (HD 2824 and HUW 468) in main plots. Each main plot was divided into three sub-plots to allocate three seeding density (100 kg, 115 kg and 130 kg/ha) to main crop wheat. The three extra plots for two sole wheat varieties (HD 2824 and HUW 468) and a sole Indian mustard (Sanjukta Aschesh) were taken for the estimation of yield and monetary advantage. The experimental plot size was 18.9 m^2 having 5.4 m in length and 3.5 m in width. Treatments were separated by 1 m plot border. The same field was used in both the years.

Seedbed preparation including ploughing, disk harrowing and planking was done as per main crop wheat. The wheat was sown at a row spacing of 22.5 cm and plant-to-plant distance was maintained as per seed rate in intercropping system as well as in sole stand. However, in mustard thick sowing both in sole as well as intercropping system was done at a row spacing of 36.0 cm in sole stand, whereas in intercropping system, sowing was according to main crop. The plant-to-plant distance of mustard on rows was maintained at 12 cm by thinning at 14 and 21 days after sowing. Wheat and mustard under intercropping were sown in 5:1 row proportion in replacement series.

The recommended doses of NPK to wheat was 120 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha, whereas to mustard, it was 90 kg N + 40 kg P_2O_5 + 40 kg K_2O + 30 kg S/ha. However, in intercropping system 100% recommended dose of fertilizers was applied to mustard rows, whereas to main crop wheat, fertilizer was applied as per treatment. Conversely, the full recommended dose of P and K along with half dose of N was applied as basal to both the crops in sole as well as intercropping system. Rest of half dose of N to wheat was top-dressed into two equal splits at tillering and ear emergence stages (30 and 65 DAS), however, to mustard; it was top-dressed at 30 DAS. Fertilizer requirement of both the crops was met through urea, diammonium phosphate, single super phosphate and muriate of potash.

Data were subjected to analysis of variance (ANOVA) using the SPSS program: Version 8 (SPSS, 1998). A combined analysis of variance over two growing seasons was performed for yield and different indices. The Bartlett's test employed to check the homogeneity of variance of each parameter among years indicated that they were homogenous. The ANOVA was performed by using a split plot design with 18 and/or 21 treatments replicated three times. Treatment mean differences were separated and tested by Fisher's protected least significant difference (LSD) at $P = 0.05$ significance level. Because the analysis of variance indicated no treatment × experimental time interaction, the values are reported as mean of the two growing seasons. Weather data were recorded daily near the experimental site and are presented as mean monthly data for both years.

RESULTS AND DISCUSSION

Effect of weather

The weather conditions during the crop period differed markedly in two years of experimentation particularly with respect to rainfall. The rainfall received during 2005–06 was only 19.1 mm as compared to 2006–07 receiving quite high (138.4 mm). Consequently, more number of irrigation were given to both the crops during first year. The average temperatures particularly at reproductive stages of both the component crops were more conducive during 2006–07. Therefore, the weather conditions were more favourable to the experimental crops during second year of experimentation.

Yield attributes of component crops

In wheat + mustard intercropping system, application of increasing fertilizer doses from 100% to 140% RFD to wheat accompanied with 100% RFD to mustard exhibited significant increase in spikes/m, average spike length, and grains/spike. This could be attributed to greater absorption of nitrogen, phosphorus and potassium at higher fertility levels, which led to increased photosynthates production and accumulation (data not reported). Moreover, the combined application of NPK at higher rates might have enhanced the process of tissue differentiation, i e from somatic to reproductive phase, meristematic activity and development of floral primordia, leading thereby to increased flowering and grain setting. In wheat, the sink lies in spike, so at higher fertility levels, more photosynthates might have translocated from leaves *via* stem to sink, i e spikelet and grains, producing bigger spike with higher number of grain which were heavier in weight However, the various levels of fertilizer applied to wheat failed to influence the various yield traits of mustard to the level of significance obviously due to mustard itself receiving 100% RFD.

As regards the two wheat varieties, HD 2824 showed its distinct superiority over HUW 468 with respect to spikes/m and test weight however, HUW 468 produced significantly longer spike and higher number of grain/spike compared to HD 2824 in association with mustard in intercropping system (Table 1). Here, it is pertinent to mention that HD 2824 had accommodated 30.7% lesser plants/unit area than the HUW 468 (Data not reported) but due to its profuse tillering and 44.4% heavier test weight, it produced significantly more number of spikes/m and grain yield/m than the other variety. Similar pattern was observed in sole stands of wheat varieties with respect to grain yield/m. However, the intercrop grain yield/m was significantly higher than the sole crop yield of both the wheat varieties. This could be ascribed to the better nutritional condition and higher average planting density of wheat under intercropping system. However, the two wheat varieties in intercropping system failed to exert marked influence on yield attributes of mustard (Table 2). This shows that mustard being aggressive in nature could not be affected by dominated component wheat.

Increasing seed rates of wheat from 100 to 130 kg/ha resulted in lucid improvement of spikes/m though the difference remained on par between 115 and 130 kg seed rate (Table 1). This could be ascribed to the higher number of plants, tillering and thereby the effective tillers per unit area produced at higher seed rates of wheat. However, in wheat + mustard intercropping, wheat grows as a down storey crop, so the taller component (mustard) reduces the penetration of solar radiation to the wheat. This accompanied with the production of higher number of spikes/m at 130 kg/ha seed rate resulted into increased production of ear bearing tillers with shorter spikes, lesser number of grains/spike, and lower test weight of seeds (Table 1). Moreover, the number of

Table 1 Yield attributes and yield of wheat as influenced by fertility levels and seeding densities of two wheat varieties under wheat + mustard (5:1) intercropping (pooled data of two years)

Treatment	Spikes/m	Spike length (cm)	Grains/ spike	Test weight (g)	Grain yield linear/m (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
Fertility level (wheat + mustard)*								
100% + 100%	109 a	9.6 a	44.6 a	39.27 a	142.4 a	3312.0 a	4633.9 a	B 41.76 a
120% + 100%	118 b	10.0 b	47.2 b	39.68 b	153.3 b	3586.0 b	5095.0 b	41.39 a
140% + 100%	124 c	10.3 c	51.1 c	40.23 b	158.6 b	3681.0 b	5320.7 b	A 40.97 a
SEm±	1.64	0.08	1.05	0.19	2.2	42.0	42.3	0.18
LSD (P=0.05)	5.17	0.25	3.31	0.59	6.8	131.0	133.2	0.57
Wheat variety								
HD 2824	122 b	9.3 a	40.8 a	46.94 b	159.7 b	3710.0 b	5273.1 b	41.41 a
HUW 468	112 a	10.6 b	54.5 b	32.51 a	143.2 a	3343.0 a	4760.0 a	41.34 a
SEm±	1.34	0.07	0.86	0.15	1.8	34.0	34.5	0.15
LSD (P=0.05)	4.22	0.21	2.70	0.48	5.6	107.0	108.7	NS
Seed rate (kg/ha)								
100	109 a	B 10.2 a	50.3 b	B 40.35 a	139.7 a	3361.0 a	4718.5 a	41.68 b
115	119 b	9.9 a	47.3 a	39.68 a	153.8 b	3600.0 b	5101.7 b	41.45 b
130	124 b	A 9.7 a	45.4 a	A 39.15 a	160.7 b	3618.0 b	5229.4 c	40.99 a
SEm±	2.58	0.10	0.82	0.25	2.8	32.0	41.0	0.14
LSD (P=0.05)	7.49	0.30	2.36	0.72	8.2	92.0	118.8	0.40
Sole vs. intercrop								
Sole wheat (HD 2824)	107 b	9.4 a	41.2 a	45.29 c	145.3 b	4556.0 c	6717.7 c	40.44 b
Sole wheat (HUW 468)	102 a	10.7 c	55.5 c	33.00 a	135.1 a	4131.0 b	6149.6 b	40.21 a
Intercrop mean	117 c	10.0 b	47.7 b	39.73 b	151.4 c	3526.0 a	5016.5 a	41.37 c
SEm±	1.42	0.08	0.68	0.18	1.6	16.0	22.5	0.08
CD (P=0.05)	4.10	0.22	1.98	0.51	4.5	46.0	65.1	0.22

*100% RFD to wheat and mustard are 120 kg N - 60 kg P_2O_5 - 60 kg K_2O and 90 kg N – 40 kg P_2O_5 – 40 kg K_2O – 30 kg S/ha, respectively grains/spike is determined by the product of spikelets/spike and fertile florets/spike in wheat. Nevertheless, it is interesting to note that total number of spikes/m proved decisive in deciding the grain yield/m that increased correspondingly with increasing seed rates from 100 to 130 kg/ha, difference being significant only between 100 and 115 kg seed rates. However, the different seed rates of wheat did not influence the yield attributes of mustard (Table 2).

Yield of component crops

The favourable effect of fertilizer doses on yield attributing characters of wheat in wheat + mustard intercropping, viz. average spike length, grains/spike, and test weight was reflected on grain yield/m and ultimately on the grain yield kg/ha (Table 1). Consequently, grain and straw yield increased with increasing fertility levels to wheat up to 140% RFD accompanied with 100% RFD to mustard but the difference between 120% and 140% RFD remained statistically on par. Good response of wheat to higher doses of NPK has also been reported by other workers (Bohra and Srivastava 2002). However, the harvest index of wheat declined with increasing fertility levels up to 140% RFD, the difference being significant only between 100 and 140% RFD applied to wheat. This shows that increasing fertility levels failed to contribute efficiently to grain production. It was further observed that the seed yield, stover yield and harvest index of mustard did not differ significantly due to varying fertility levels applied to wheat. As regards the grain yield of two wheat varieties in intercropping system, wheat variety HD 2824 proved markedly superior over HUW 468 and it produced 11.0% higher grain yield than HUW 468. This seems to be due to better grain yield/m of the former than latter. Moreover, there was a difference of 12 days in the maturity of two wheat varieties; the gaps between the harvesting of intercrop mustard and the two wheat varieties HD 2824 and HUW 468 were 29 and 19 days, respectively. This clearly indicated that in wheat + mustard intercropping, wheat variety HD 2824 due to its long maturity period, remained competition free for longer duration after the harvest of mustard than the other variety. The better genetic potential of wheat variety HD 2824 has also been reported by Malik *et al.* 2005. Similarly, owing to its taller plants and profuse tillering HD 2824 produced significantly higher straw yield in intercropping (Table 1). On the contrary, the two wheat

Table 2 Yield attributes and yield of mustard as influenced by fertility levels and seeding densities of two wheat varieties under wheat + mustard (5:1) intercropping (Pooled data of two years)

Treatment	Number of siliqua per main shoot	Number of siliqua per plant	Length of siliqua (cm)	Number of seeds/ siliqua	Test weight (g)	Seed yield/plant (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
Fertility level (wheat + mustard)*									
100% + 100%	48 a	354 a	4.40 a	13.1 a	2.74 a	18.3 a	690.0 a	2327.5 a	22.9 a
120% + 100%	50 a	371 a	4.50 a	13.3 a	2.75 a	19.4 a	732.5 a	2427.5 a	23.2 a
140% + 100%	51 a	381 a	4.59 a	13.4 a	2.76 a	19.6 a	741.0 a	2449.2 a	23.2 a
SEm±	0.84	6.63	0.06	0.14	0.02	0.8	15.0	65.0	0.25
LSD (*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Wheat variety									
HD 2824	50 a	374 a	4.49 a	13.3 a	2.74 a	19.4 a	745.5 a	2465.0 a	23.2 a
HUW 468	50 a	364 a	4.50 a	13.1 a	2.76 a	18.8 a	717.0 a	2337.8 a	23.5 a
SEm±	0.69	5.41	0.05	0.11	0.01	0.7	12.0	53.1	0.21
LSD (*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Seed rate (kg/ha)									
100	50 a	378 a	4.61 a	13.3 a	2.77 a	19.4 a	741.5 a	2443.3 a	23.3 a
115	50 a	367 a	4.47 a	13.2 a	2.75 a	19.1 a	728.5 a	2401.7 a	23.3 a
130	49 a	361 a	4.41 a	13.2 a	2.73 a	18.8 a	713.0	2359.2 a	23.2 a
SEm±	0.66	5.09	0.04	0.14	0.02	0.5	15.5	62.4	0.20
LSD (*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sole vs intercrop									
Sole mustard	49 a	352 a	4.54 a	13.16 a	2.71 a	18.5 a	1735.5 b	5624.4 b	23.6 a
Intercrop mean	50 a	369 b	4.50 a	13.23 a	2.75 b	19.1 a	726.0 a	2401.4 a	23.2 a
SEm±	0.37	2.86	0.03	0.08	0.01	0.3	8.5	35.1	0.11
LSD (*P*=0.05)	NS	8.32	NS	NS	0.02	NS	24.5	102.0	NS

*100% RFD to wheat and mustard are 120 kg N - 60 kg P_2O_5 - 60 kg K_2O and 90 kg N – 40 kg P_2O_5 – 40 kg K_2O – 30 kg S/ha, respectively.

varieties did not affect significantly on seed yield, stover yield and harvest index of mustard.

The grain yield/m improved correspondingly with increasing seed rates from 100 to 130 kg/ha but the difference between the medium and highest seed rates remained statistically at par. This shows that spikes/m proved more decisive in determining the grain yield/m than other yield contributing characters. The similar pattern of grain yield/m was reflected on grain yield of wheat; 115 and 130 kg seed rates being at par with each other both produced significantly higher grain yield than lowest seed rate. However, increasing wheat seed rates in wheat + mustard intercropping significantly improved the straw yield. This could be attributed to the higher number of plants per unit area and dry matter accumulation of wheat at higher seed rates. The significant decline in the harvest index of wheat was noticed with increasing seed rates of wheat from 100 to 130 kg/ha (Table 1), this shows the inefficient translocation and partitioning of photosynthates to the sink at higher seeding density. On the other hand, the various seeding density of wheat failed to influence the seed yield, stover yield and harvest index of mustard to the level of significance.

Competitive indices

Data presented in Table 3 showed that application of increasing fertilizer doses from 100 to 140% of the recommended NPK to wheat accompanied with 100% recommended NPK to mustard, significantly enhanced partial LER of wheat (LER_{wheat}) but it did not affect the partial LER of mustard ($LER_{mustard}$). The values of $LER_{mustard}$ lower than 0.5 indicate yield advantage of mustard for wheat in intercropping at all the fertility levels (Chen *et al.* 2004). The total LER also enhanced with increasing fertilizer doses to wheat from 120 and 140% RFD though remained comparable recorded significantly higher LER than 100% RFD to wheat. This clearly shows 25% and 28% yield advantage of intercropping system at 120% and 140% RFD, respectively compared to 17% at 100% RFD to wheat. The yield advantage due to increasing fertilizer doses is further supported by the product of relative crowding coefficients of wheat and mustard 'K'. AYL index gives more precise information about competition than other indices between and within the

Table 3 LER, relative crowding coefficient, actual yield loss and intercropping advantage as influenced by fertility levels and seeding densities of two wheat varieties under wheat + mustard (5:1) intercropping (Pooled data of two years)

Treatment	Land equivalent ratio (LER)			Relative crowding coefficient (RCC or k)			Actual yield loss (AYL)			Intercropping advantage (IA)		
	LER_{wheat}	$LER_{mustard}$	LER	k_{wheat}	$k_{mustard}$	System (K)	AYL_{wheat}	$AYL_{mustard}$	AYL	IA_{wheat}	$IA_{mustard}$	IA
Fertilizer dose (wheat + mustard)*												
100% + 100%	0.764 a	0.409 a	1.173 a	0.716 a	3.487 a	2.498 a	-0.085 a	1.453 a	1.368 a	-19.9 a	726.3 a	706.4 a
120% + 100%	0.826 b	0.422 a	1.248 b	1.202 b	3.681 a	4.436 b	-0.009 b	1.531 a	1.522 b	-2.0 b	765.3 a	763.3 b
140% + 100%	0.849 c	0.426 a	1.275 c	1.559 c	3.707 a	5.785 c	0.017 c	1.544 a	1.562 b	4.1 c	772.1 a	776.2 b
SEm±	0.007	0.006	0.009	0.103	0.089	0.336	0.008	0.036	0.037	1.94	17.9	18.03
CD (*P*=0.05)	0.022	NS	0.027	0.325	NS	1.057	0.026	NS	0.116	6.10	NS	56.80
Wheat variety												
HD 2824	0.854 b	0.423 a	1.278 b	1.600 b	3.703 a	5.939 b	0.025 b	1.540 a	1.565 b	5.9 b	770.0 a	775.9 b
HUW 468	0.770 a	0.413 a	1.183 a	0.718 a	3.546 a	2.540 a	-0.076 a	1.478 a	1.402 a	-17.8 a	739.2 a	721.3 a
SEm±	0.006	0.005	0.007	0.084	0.072	0.274	0.007	0.029	0.030	1.58	14.6	14.72
CD (*P*=0.05)	0.018	NS	0.023	0.265	NS	0.863	0.021	NS	0.095	4.98	NS	46.38
Seed rates of Wheat												
100	0.774 a	0.424 a	1.199 a	0.797 a	3.721 a	2.959 a	-0.071 b	1.546 a	1.475 a	-16.7 a	773.1 a	756.4 a
115	0.829 b	0.420 a	1.249 b	1.404 b	3.638 a	5.174 b	-0.005 a	1.518 a	1.513 a	-1.2 b	758.8 a	757.7 a
130	0.833 b	0.411 a	1.244 b	1.276 b	3.516 a	4.586 b	-0.001 a	1.463 a	1.464 a	0.0 b	731.7 a	731.7 a
SEm±	0.006	0.007	0.007	0.094	0.104	0.680	0.008	0.026	0.039	1.81	20.5	19.87
CD (*P*=0.05)	0.019	NS	0.021	0.277	NS	1.978	0.022	NS	NS	5.27	NS	NS
Sole vs. intercrop												
Sole wheat	1.000		1.000	1.000		1.000						
Sole wheat	1.000		1.000	1.000		1.000						
Sole mustard		1.000	1.000		1.000	1.000						
Intercrop mean	0.812	0.418	1.230	1.159	3.625	4.240						

*100% RFD to wheat and mustard are 120 kg N - 60 kg P_2O_5 - 60 kg K_2O and 90 kg N – 40 kg P_2O_5 – 40 kg K_2O – 30 kg S/ha, respectively component crops (Banik *et al.* 2000). The negative values of actual yield loss of wheat (AYL_{wheat}) signify the negative effect of the intercrop mustard on wheat but it is interesting to note that AYL_{wheat} reduced significantly with increasing fertilizer doses to wheat up to highest level (Table 3). This could be ascribed to enhanced competitiveness of wheat at higher levels of nutrient application which resulted in minimizing the intercropping disadvantage of wheat and thereby improving the intercropping advantage of wheat (1A wheat) at higher fertility levels and led to the higher values of AYL and intercropping advantage (1A).

Between the two wheat variety in wheat + compact mustard (5:1) intercropping, HD 2824 exhibited its distinct superiority over HUW 468 in respect of LER_{wheat} (Table 3). This was due to its better relative competitiveness with dominant intercrop mustard (k_{wheat}) compared to HUW 468. However, the two wheat varieties failed to influence the $LER_{mustard}$ as well as $k_{mustard}$ indicating that HD 2824 in spite of being more competitive and dominant than HUW 468 did not affect the $LER_{mustard}$ adversely. The total LER with respect to intercropping of compact mustard in association with wheat (HD 2824) was markedly higher than HUW 468. The production efficiency of the intercropping system in association with wheat variety HD 2824 was 8% higher than the HUW 468. However, the product of the relative crowding coefficients of wheat and mustard 'K' showed the yield advantage of the system with wheat variety HD 2824.

Actual yield loss of wheat varieties followed the same trend as LER_{wheat} and k_{wheat} but the differences were too wide. This could be ascribed to the better competing ability and prolonged competition free period of HD 2824 after harvest of mustard. However, mustard being highly aggressive and competitive, actual yield loss of mustard did not differ much in association with two wheat varieties but to some extent it compensated the actual yield loss (AYL) of wheat variety HUW 468 and led to the positive values of AYL for wheat + mustard intercropping. Nevertheless, due to its better competitiveness, HD 2824 registered significantly higher yield advantage in terms of actual yield loss as compared to HUW 468.

The positive value of partial intercropping advantage for wheat variety HD 2824 indicated that intercropping had economic advantage but with the other variety HUW 468, the negative values signify disadvantage (Table 3). These results were similar to the value obtained for AYL. The optimistic values of total IA for both the wheat varieties indicated intercropping advantage but the intercropping advantage of the system in association with wheat variety HD 2824 was significantly higher than HUW 468.

With reference to the seed rates of wheat, maximum LER (1.249) of the intercropping was obtained at 115 kg seed rate closely followed by 130 kg seed/ha (1.244) but both proved significantly superior to 100 kg seed/ha (1.199). This shows that the production efficiency of the wheat + compact mustard intercropping in 5:1 row arrangement was maximum with 115 kg/ha seed rate of wheat and the normal density of mustard and attributed mainly to the better LER_{wheat} at higher seed rates. These results are further supported by values of relative crowding coefficient. It may further be noted in Table 3 that increasing wheat seed rates significantly enhanced the actual yield loss of wheat (Banik *et al.,* 2000). The positive values of AYL of the system signify yield advantage of the intercropping system at all the seed rates of wheat but it followed the declining trend similar to AYL_{wheat}. As intercropping advantage is based on AYL, the intercropping advantage of wheat was declined significantly with

Table 4 Economics of wheat + mustard (5:1) intercropping in relation to fertility levels and seeding densities of two wheat varieties (pooled data of two years)

Treatment	Cost of cultivation	Gross returns	Net returns	MAI (₹/ha)
		(₹/ha)		
Fertilizer dose (wheat + mustard)*				
100% + 100%	23 042 a	59 750 a	36 708 a	5 413 a
120% + 100%	23 439 b	63 942 b	40 503 b	8 061 b
140% + 100%	23 904 c	65 401 b	41 497 b	8 908 b
SEm±		465	465	318
CD (*P*=0.05)		1 466	1 466	1 001
Wheat variety				
HD 2824	23 462 a	65 623 b	42 161 b	8 150 b
HUW 468	23 462 a	60 439 a	36 977 a	6 771 a
SEm±		380	380	259
CD (*P*=0.05)		1 197	1 197	817
Seed rates of wheat				
100	23 202 a	61 054 a	37 852 a	6 316 a
115	23 452 b	64 015 b	40 563 b	8 117 b
130	23 730 b	64 023 b	40 293 b	7 949 b
SEm±		343	359	179
CD (*P*=0.05)		993	1040	519
Sole vs. intercrop				
Sole wheat (HD 2824)	21 630 b	59 274 c	37 644 c	
Sole wheat (HUW 468)	21 630 b	53 840 b	32 210 b	
Sole mustard (Sanjukta Aschesh)	17 780 a	41 600 a	23 820 a	
Intercrop mean	23 462 c	63 031 d	39 569 d	7 924
SEm±		188	197	98
CD (*P*=0.05)		544	570	284

Commercial price of wheat grain and straw are ₹ 10.80 and ₹ 1.50/kg, respectively;
Commercial price of mustard seed stover are ₹ 23.00 and ₹ 0.30/kg, respectively.
* 100% RFD to wheat and mustard are 120 kg N-60 kg P_2O_5-60 kg K_2O and 90 kg N-40 kg P_2O_5-40 kg K_2O-30 kg S/ha, respectively

increasing seed rates. Similarly, the 100 and 115 kg seed rates of wheat recorded significantly higher intercropping advantage of the system than 130 kg seed rate.

Economics

In general, intercropping of wheat and compact-mustard in 5:1 row proportion was found highly remunerative than growing either of component crops in sole stand (Table 4). Application of increasing fertility levels from 100% to 140% recommended NPK to wheat accompanied with 100% RFD to mustard correspondingly enhanced the gross return, net return and monetary advantage index; though the differences remained non-significant between 120% and 140% RFD. This could be ascribed to the better LER at higher levels of fertilizer application (Srivastava and Bohra 2006). Among the two wheat varieties, HD 2824 proved its distinct superiority over HUW 468 with respect to gross return, net return and MAI. Here, it is interesting to note that in wheat + mustard intercropping, proper selection of genotype is not only important for dominant component mustard (Srivastava *et al.* 2007) but also to the dominated wheat. However, among the seed rates of wheat, 115 and 130 kg/ha though remained on par, both established significant advantage over 100 kg seed/ha with respect to gross return, net return, B:C ratio and MAI. This indicated that though there exist a parabolic relationship between yield and plant population in grain crops like wheat but in wheat + compact-mustard intercropping (5:1), wheat seed rate at 115 kg/ha was most productive and remunerative. As regards the sole stand of component crops, mustard was found least remunerative than the two wheat varieties (Table 4).

The present study concluded that wheat variety HD 2824 (Poorva) at 115 kg seed rate and 140% recommended NPK may be intercropped with compact-mustard variety Sanjukta Aschesh at 100% RFD in 5:1 row proportion to achieve the maximum yield, best land utilization as well as monetary return under irrigated condition of Varanasi.

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