Indian Journal of Agricultural Sciences **88** (4): 530–9, April 2018/Article

Productivity, compatibility and economics of wheat (*Triticum aestivum*) and Indian mustard (*Brassica juncea*) intercropping as influenced by farmyard manure and fertilizer levels under irrigated conditions

RAJESH KUMAR SINGH[1], UMENDRA SINGH[2] and RAMAWATER MEENA[3]

Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh 221 005

Received: 3 February 2017; Accepted: 22 December 2017

ABSTRACT

A field experiment was conducted during winter (*rabi*) seasons of 2010-11 and 2011-12 at Institute of Agricultural Sciences, Banaras Hindu University, Varanasi to evaluate the productivity, compatibility and economics of wheat (*Triticum aestivum* L.) and Indian mustard (*Brassica jancea*) intercropping as influenced by row proportions, farmyard manure (FYM) and fertilizer levels under irrigated conditions. The experiment was laid out in three times replicated split plot design, where main-plots received four wheat + Indian mustard intercropping row proportions (8:1, 6:2, 8:2 10:2) and sub-plots got four levels of the combined application of farmyard manure (15 and 30% N) and fertilizer (75 and 100% recommended doses of fertilizer) applied on area basis. The productivity of wheat and mustard in wheat + mustard intercropping in terms of yield parameters, viz. grains/spike, spikelets/spike, 1,000-grain weight and seed yield as well as straw yield in wheat, and siliquae/plant and seeds/siliqua of Indian mustard, were significantly higher with row proportion of 8:1 over 10:2, 8:2 and 6:2. However, seed yield and stover yield of Indian mustard was higher in 6:2 row proportion which was at par with 8:2 and 10:2 row proportions. Wheat + Indian mustard intercropping under 10:2 row proportion proved more remunerative and recorded higher yield advantage than 8:1, 8:2 and 6:2 row proportions as judged by total land equivalent ratio, monetary advantage, net return and benefit: cost ratio. The aggressivity was higher for Indian mustard than wheat. Application of 15% or 30% N through FYM + 100% recommended doses of fertilizer (RDF) significantly enhanced yield attributes and yield of wheat and Indian mustard. The highest total land equivalent ratio and aggressivity of Indian mustard indicated superiority of the application of 30% N through FYM + 100% RDF. However, benefit: cost ratio was highest in the application of 15 kg N through FYM +100% RDF.

Key words: Farmyard manure, Fertilizer level, Intercropping, Mustard, Row proportion, Wheat

Intercropping is attracting more interest in developed countries, primarily due to claims that it can provide increased yields in an environmentally sustainable manner.

In India, wheat (*Triticum aestivum* L.) with Indian mustard (*Brassica juncea* L.) intercropping is an old and important cropping system under both irrigated and rainfed conditions. Growing cereals with pulses and oilseeds endowed with varying rooting depth and growth pattern help in better extraction of soil moisture and nutrients from different layers of the soil profile. Further, it is also known to intercept more solar energy and give comparatively higher stability and insurance of yield during aberrant weather conditions than sole crops (Willey 1979 and Mandal and Mahapatra 1990). Intercropping of wheat with mustard is ecologically suitable, economically viable, operationally feasible and socially acceptable cropping system during winter season in India (Ghoniskar and Shinde 1994). The country still is presently surplus in the production of wheat but in spite of quantum jump in oilseed production during the last two decades, its production is not sufficient to meet country's growing edible oil demands. This is attributed to improvement in standard of living with better purchasing power of people due to better economic growth as well as the high growth rate of Indian population. Its scarcity has necessitated the import of 51% of our requirements at a huge cost of ₹ 56910 crores (2013-14) (Hedge and Sudhakara Babu 2014). Intercropping is a feasible and viable agronomic practice for stepping up the production of oilseeds from a unit of land during a cropping period. Plant spatial arrangement and balanced fertilization in intercropping have important effects on the balance of competition between component crops and their productivity. Mixed cropping of mustard with wheat is very common in eastern Uttar Pradesh which is one of the major causes of low productivity of wheat and mustard in the region. Scientific approach of intercropping of these two crops increases the productivity per unit area per unit time under a certain situation where two crops are grown in intercropping at a certain proportion

[1]Assistant Professor (e mail: rajeshsingh.bhu@gmail.com), Department of Agronomy; [2]Research Scholar (e mail: umeendra4558@gmail.com); [3]Assistant Professor (e mail: rmeena78@gmail.com), Department of Soil Science and Agricultural Chemistry.

(Srivastava *et al.* 2007). Accordingly, their compatible combination for the maximum utilization of natural resources based on complementarity is essential. It has been proved beyond doubt that in wheat + mustard intercropping, the competition offered by mustard is much higher than wheat. Thus, it can be altered to some extent by modification of row proportion and supplementation with adequate fertilizers. Research on the compatibility as intercrops between wheat and mustard are also quite scanty although these are extensively cultivated throughout the country. Realising the importance of these facts, the present investigation was therefore, proposed to assess the productivity, compatibility and economics of wheat and Indian mustard intercropping as influenced by row proportions, farmyard manure and fertilizer levels under irrigated conditions.

MATERIALS AND METHODS

The field experiment was carried out during two consecutive winter (*rabi*) seasons of 2010-2011 and 2011-2012 at the Agricultural Research Farm of the Banaras Hindu University (BHU), Varanasi (25°18′0″ N latitude, 83°03′0″ E longitude and altitude of 128.9 m above mean sea level) in Northern Gangetic Alluvial Plain of India. The soil of the experimental site was sandy clay loam (Order Inceptisol, Type Ustochrept) and having of 0.48% organic carbon, 190.50 kg/ha $KMnO_4$ oxidizable N, 19.85 kg/ha 0.5 N $NaHCO_3$ extractable P, 213.44 kg/ha 1.0 N NH_4OAC exchangeable K and 7.41 pH at the beginning of experiment. The experiment was laid out in split plot design, comprising four row proportions of wheat + mustard intercropping, i.e. 8:1, 6:2, 8:2 and 10:2 in main plot and each main plot was divided into 4 sub-plots with two levels of farmyard manure (15 and 30% N through farmyard manure) and two fertilizer levels (75 and 100% RDF to wheat and Indian mustard). The two extra plots of sole wheat 'HUW-234' and sole Indian mustard 'Vardan' were taken for the estimation of yield, competitive indices and economics. Thus, 16 treatment combinations were formed along with 2 sole crops of wheat and Indian mustard, and these were replicated thrice. The experimental plot of 22.95 m^2 (7.65 m × 3.00 m) was separated by 1 m plot-border. The crops were sown in the last week of November during both the years with seed rate of 120 kg/ha for wheat (HUW 234) and 4 kg/ha for mustard (Vardan). Seed rate was regulated according to the proportions of area under each crop in intercropping. In sole as well as in intercropping system, wheat was sown at a row spacing of 22.5 cm and plant to plant distance was maintained as per seed rate. However in sole mustard, thick sowing was done at a row spacing of 45 cm. The plant to plant distance of mustard both under sole and intercropping was maintained at 12 cm by two thinning at 14 and 21 days after sowing. The recommended doses of fertilizers for wheat and Indian mustard at the rate of 120 kg N/ha, 60 kg P_2O_5/ha and 60 kg K_2O/ha were applied as 100% RDF, and in intercropping the fertilizer dose was adjusted for proportionate areas of the crop. In sole wheat and sole Indian mustard as well as in intercropping, full dose of P and K and half of the dose of N were applied as basal at sowing. The remaining N in wheat was top dressed in two equal splits after the first and second irrigations. In mustard, remaining N was top dressed at 35 days after sowing. Fertilizers used were urea, single superphosphate and muriate of potash. Well decomposed farmyard manure (0.6% N, 0.2% P and 0.5% K) was incorporated in the soil one month prior to sowing of the crop as per treatments. The other cultural operations were done as per recommendation and crop requirement. Weather data of average temperature (^{0}C), and average rainfall (mm) evapo-transpiration (mm) were recorded daily from the meteorological observatory of the Department of Agronomy (BHU), which is located about 25 m distance from the experimental plot. All the yield attributes and yield, viz. grains/spike, spikelets/spike and 1000-grain weight, grain yield and straw yield in wheat, and siliquae/plant, seeds/siliqua, 1000-seed weight, seed yield and stover yield in Indian mustard, were recorded as per standard method at harvest. 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.

$$\text{Grain or Seed yield index (\%)} = \frac{\text{Intercropping yield (kg/ha)}}{\text{Sole cropping yield (kg/ha)}} \times 100$$

Available nitrogen, phosphorus and potassium contents in initial soil were determined by alkaline potassium permanganate method, Olsen's method and flame photometrically, respectively (Jackson 1973). Total nitrogen, phosphorus and potassium contents of wheat (grain and straw) and mustard (seed and stover) samples at the time of harvesting were estimated by modified micro-kjeldahl, vanadomolybdate phosphoric acid yellow colour and flame photometer methods, respectively (Jackson 1973). The percentage content was then multiplied by the total biomass produced for estimation of N, P and K uptake (kg/ha). The seed of Indian mustard from the seed lot was taken for estimation of seed quality like oil with the help of Soxhlet's extraction method (AOAC 1980) and the protein content were computed using factor 5.75 multiplied by N content in seed. Economic parameters (cost of cultivation, gross return, net return, B: C ratio and monetary advantage) were calculated on the basis of common cost of cultivation for sole wheat ₹ 27,364/ha and for sole mustard ₹ 23,597/ha, and the prevailing selling prices of wheat grain ₹ 14.00/kg, wheat straw ₹ 4.5/kg, mustard seed ₹ 40.00/kg and stover ₹ 1.50/kg.

Land equivalent ratio (Mead and Willey 1980) and aggressivity (Mc Gilchrist 1965) were calculated by the following formula:

Land equivalent ratio (LER): = Li + Lj = (Yij/Yii) + (Yji/Yjj)

where, Y is the yield per unit area, Yii and Yjj are sole crop yields of the component crops i (wheat) and j (mustard) and Yij and Yji are intercrop yields. The partial LER values Li and Lj, represent the ratios of the yields of crop i and j

when grown as intercrops, relative to sole crops.

Aggressivity (A): The aggressivity shows the degree of dominance of one crop over other when sown together.

$$Aij = (Yij/Yii \times Zij) - (Yji/Yjj \times Zji)$$

where, Aij is aggressivity value for component crop 'i' and Zij and Zji are the proportion of the component crops.

The experimental data pertaining to each parameter of study were subjected to statistical analysis by using the technique of analysis of variance and their significance was tested by "F" test at 0.05 probabilities.

RESULTS AND DISCUSSION

Effect of weather

The meteorological data showed marked variation in weather condition during two years of experimentation. Rainfall received during 2011-12 (46.2 mm) was quite high as compared to 2010-11 (22.1 mm). Meanwhile, the temperature particularly at reproductive phases of both the crops was more conducive during second year. This resulted in a slightly better performance of the crops during 2011-12 than 2010-11.

Yield attributes and yield

Grains/spike, spikelets/spike and 1000-grain weight of wheat in wheat + mustard intercropping were found significantly lower as compared to sole stand (Table 1). The significantly higher grains/spike, spikelets/spike, 1000-grain weight, grain yield and straw yield of wheat, and siliquae/plant, seed/siliqua, 1,000-seed weight of Indian mustard were recorded at 8:1 row proportion in wheat + mustard intercropping which was followed by 10:2, 8:2 and 6:2 row proportions except in Indian mustard, where seed yield and stover yield were maximum at 6:2 row proportion and remained at par with 8:2 row proportion. This could be ascribed to the inter-generic competition between the component crops for possible under and above ground resources, viz. space, nutrients and moisture. These results corroborrated with the findings of Srivastava *et al.* (2007) and Singh and Bohra (2012).

Increase in farmyard manure and fertilizer levels from 15% N through FYM + 75% RDF to 30% N through FYM + 100% RDF applied to wheat and Indian mustard correspondingly increased grains/spike, spikelets/spike and 1000-grain weight, grain yield and straw yield of wheat, and siliquae/plant, seeds/siliqua, 1000-seed weight, seed yield and stover yield of Indian mustard. Among the farmyard manure and fertilizer levels, grains/spike, spikelets/spike and 1000-grain weight, grain yield and straw yield of wheat, and siliquae/plant, seeds/siliqua, 1000-seed weight, seed yield and stover yield of Indian mustard were significantly higher at 30% N through FYM + 100% RDF than 30% N through FYM + 75% RDF and 15% N through FYM + 75% RDF during both the years, though the difference between 30% N through FYM + 100% RDF and 100% RDF + 15% N through FYM were statistically at par with each other.

Data indicated the adverse effect of mustard on wheat under the various row proportions of wheat + mustard intercropping. Grain yield index was increased with the increasing wheat proportions. On the contrary, the lowest grain yield index was recorded at the highest Indian mustard proportion on area basis when two rows of mustard were sown after every six rows of wheat (Table 2). In wheat + mustard intercropping, the area under wheat reduced by 25, 20, 18 and 16%, respectively in 6:2, 10:2, 8:2 and 8:1 row proportions. The corresponding yield reduction in wheat yield on percent wheat grain-yield index basis was noted to be 92.85, 85.37, 76.91 and 70.40% during first year and 94.71, 85.54, 77.31 and 70.94% during second year, respectively in comparison to sole stand (which was taken as 100). In Indian mustard, seed yield index of mustard was decreased with every increase in proportion of wheat rows. Accordingly, the seed yield index was obtained maximum (51.2% in 2010-11 and 50.3% in 2011-12) with six rows of wheat alternated with two rows of mustard. Indian mustard replaced 11.12, 16.67, 20 and 25% area of wheat in 8:1, 10:2, 8:2, and 6:2 row proportions respectively, with corresponding seed yield of 35.73, 42.55, 46.33 and 51.22% during first year, and 37.16, 43.49, 45.12 and 50.38% during second year, respectively in comparison to sole stand. It showed that the seed yield of mustard was proportionately higher than area replaced. The application of increasing in farmyard manure and fertilizer levels from 15% N through FYM + 75% RDF to 30% N through FYM + 100% RDF applied to wheat and mustard correspondingly increased grain yield index of wheat during both the years. The highest grain yield index was recorded with 30% N through FYM + 100% RDF treatment which was statistically at par with 15% N through FYM + 100% RDF, and both these treatments proved significantly superior to 30% N through FYM + 75% RDF and 15% N through FYM + 75% RDF.

Competitive indices

While comparing the different row proportions, corresponding decrease in partial land equivalent ratio of wheat was observed due to reducing wheat proportion in wheat + Indian mustard intercropping. Accordingly, the maximum partial land equivalent ratio of wheat was observed under 8:1 row proportion which was significantly superior to 10:2, 8:2 and 6:2 row proportions, respectively. The reverse trend was observed for Indian mustard (Table 3). However, wheat + Indian mustard intercropping produced marked variation on total land equivalent ratios during both the years and were greater than unity, indicating a greater biological efficiency in utilizing land, space and nutrients over respective sole crops. It indicated 21-32% higher yield advantage compared to sole cropping. The total land equivalent ratio which is the function of partial land equivalent ratios of wheat and mustard was found comparable at 10:2 and 8:1 row proportions, but both recorded significantly higher yield advantage over 8:2 and 6:2. This might be due to efficient effect of light, moisture and nutrients, besides reduced competition from taller component (Indian mustard) on shorter component (wheat).

Table 1 Effect of row proportion, farmyard manure and fertilizer level on yield attributes and yields of wheat in wheat + Indian mustard intercropping

Treatment	Grains/ spike		Spikelets/ spike		1,000-grain weight (g)		Grain yield (kg/ha)		Straw yield (kg/ha)		Grain yield index (%)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Row proportion (Wheat + Mustard intercropping)												
8:1	43.78	46.41	16.64	16.69	42.11	43.12	4174	4358	5227	5627	90.83	92.69
6:2	34.91	35.95	14.08	14.11	36.77	37.50	3165	3265	4105	4405	68.86	69.43
8:2	37.43	38.93	14.91	14.94	38.51	39.32	3457	3557	4334	4634	75.24	75.66
10:2	39.80	41.79	15.73	15.77	39.93	40.85	3838	4004	5125	5491	83.52	85.13
SEm±	0.63	0.70	0.23	0.24	0.39	0.40	106	116	111	120		
CD (P=0.05)	2.18	2.42	0.81	0.82	1.36	1.39	367	402	383	416		
Farmyard manure and fertilizer level												
15% N through FYM + 75% RDF	36.79	38.48	14.06	14.10	35.94	36.74	3338	3482	4382	4723	72.65	74.04
15% N through FYM + 100% RDF	40.26	42.11	16.50	16.53	42.14	43.06	3841	3964	4852	5193	83.58	84.31
30% N through FYM + 75% RDF	37.79	39.53	14.14	14.17	36.24	37.04	3471	3607	4513	4863	75.54	76.72
30% N through FYM + 100% RDF	41.07	42.96	16.66	16.70	43.00	43.95	3983	4131	5045	5378	86.67	87.85
SEm±	0.56	0.59	0.16	0.16	0.38	0.39	72	89	88	91		
CD (P=0.05)	1.63	1.71	0.47	0.48	1.12	1.14	209	259	258	265		
Sole vs. Intercrop												
Sole (Control)	49.07	52.50	26.60	26.68	41.23	42.22	4495	4702	5601	5971	100.00	100.00
Intercrop	38.98	40.77	15.34	15.38	39.33	40.20	3658	3796	4698	4981	79.61	80.73
SEm±	1.15	1.23	0.61	0.62	1.86	1.90	155	184	185	192		
CD (P=0.05)	3.32	3.54	1.77	1.78	5.35	5.47	445	530	532	552		

Table 2 Effect of row proportion, farmyard manure and fertilizer level on yield attributes and yields of mustard in wheat + Indian mustard intercropping

Treatment	Siliquae/ plant		Seeds/ siliqua		1,000-seed weight (g)		Seed yield (kg/ha)		Stover yield (kg/ha)		Seed yield index (%)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Row proportion (Wheat + Mustard intercropping)												
8:1	389.91	413.31	12.18	12.79	3.85	4.00	647	702	2374	2552	34.00	35.60
6:2	347.46	361.36	10.44	10.65	3.29	3.36	945	978	3120	3268	49.90	49.70
8:2	350.70	364.72	10.63	10.95	3.36	3.46	851	901	2978	3119	44.90	45.80
10:2	354.00	371.70	10.73	11.16	3.45	3.59	777	867	2916	3101	41.00	44.10
SEm±	6.09	7.15	0.28	0.29	0.40	0.41	36	41	97	106		
CD (P=0.05)	21.07	24.75	0.98	1.02	NS	NS	125	143	335	368		
Farmyard manure and fertilizer level												
15% N through FYM + 75% RDF	348.17	364.86	10.38	10.74	2.86	2.95	677	724	2442	2664	35.69	36.74
15% N through FYM + 100% RDF	369.48	387.14	11.55	11.96	3.79	3.91	861	926	3124	3204	45.44	47.07
30% N through FYM + 75% RDF	350.18	366.96	10.44	10.80	3.34	3.45	744	794	2523	2812	39.29	40.38
30% N through FYM + 100% RDF	374.25	392.14	11.63	12.04	3.97	4.10	938	1004	3300	3360	49.48	51.07
SEm±	5.51	6.33	0.17	0.17	0.30	0.30	27	31	68	78		
CD (P=0.05)	16.09	18.47	0.49	0.51	NS	NS	78	89	200	227		
Sole vs Intercrop												
Sole (Control)	400.45	428.48	15.41	16.34	4.23	4.49	1896	1969	6586	6756	100.00	100.00
Intercrop	360.52	377.77	11.00	11.39	3.49	3.60	805	862	2847	3010	42.48	43.82
SEm±	10.95	12.65	0.52	0.55	0.63	0.65	56	65	147	164		
CD (P=0.05)	31.55	36.45	1.51	1.59	NS	NS	162	187	424	471		

NS: Non significant

Table 3 Effect of row proportion, farmyard manure and fertilizer level on land equivalent ratio and aggressivity index of wheat and mustard in wheat + Indian mustard intercropping

Treatment	Land equivalent ratio (LER)						Aggressivity index			
	Wheat (L_w)		Mustard (L_M)		Total (L_w+ L_M)		Wheat (A_{wm})		Mustard (A_{mw})	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Row proportion (Wheat + Mustard intercropping)										
8:1	0.908	0.927	0.340	0.356	1.25	1.28	-2.04	-2.16	2.04	2.16
6.2	0.689	0.694	0.499	0.497	1.19	1.19	-1.08	-1.06	1.08	1.06
8:2	0.752	0.757	0.449	0.458	1.20	1.21	-1.30	-1.34	1.30	1.34
10:2	0.835	0.851	0.410	0.442	1.25	1.29	-1.46	-1.63	1.46	1.63
SEm±	0.015	0.017	0.016	0.019	0.02	0.02	0.07	0.08	0.07	0.08
CD (P=0.05)	0.052	0.060	0.054	0.066	0.06	0.06	0.23	0.28	0.23	0.28
Farmyard manure and fertilizer level										
15% N through FYM + 75% RDF	0.743	0.755	0.373	0.375	1.08	1.11	-1.17	-1.23	1.17	1.23
15% N through FYM + 100% RDF	0.854	0.858	0.468	0.471	1.29	1.31	-1.57	-1.66	1.57	1.66
30% N through FYM + 75% RDF	0.772	0.780	0.408	0.408	1.15	1.17	-1.35	-1.42	1.35	1.42
30% N through FYM + 100% RDF	0.886	0.892	0.508	0.508	1.36	1.39	-1.79	-1.89	1.79	1.89
SEm±	0.013	0.013	0.015	0.015	0.02	0.02	0.05	0.05	0.05	0.05
CD (P=0.05)	0.038	0.039	0.042	0.044	0.04	0.05	0.15	0.15	0.15	0.15

Srivastava *et al.* (2007) and Singh *et al.* (2014) also reported higher yield advantage under wider row proportions of wheat + Indian mustard intercropping.

Partial LER of both the crops increased with progressive increase in farmyard manure and fertilizer levels from 15% N through FYM + 75% RDF to 30% N through FYM + 100% RDF. The maximum partial land equivalent ratio of wheat and partial land equivalent ratio of mustard were recorded with the highest level of farmyard manure and fertilizer at 30% N through FYM with 100% RDF which was statistically at par with 15% N through FYM with 100% RDF, and both these farmyard manure and fertilizer levels proved significantly superior to 30% N through FYM + 75% RDF and 15% N through FYM + 75% RDF. Further, the total land equivalent ratio was highest at the farmyard manure and fertilizer level of 30% FYM with 100% RDF followed by 15% N through FYM with 100% RDF, 30% N through FYM + 75% RDF and 15% N through FYM + 75% RDF levels.

The aggressive nature of Indian mustard made it more competitive than wheat. The aggressivity of Indian mustard was maximum at 8:1 row proportion of wheat + Indian mustard intercropping followed by 10:2, 8:2 and 6:2 row proportions. Aggressivity of Indian mustard in wheat + Indian mustard intercropping was enhanced markedly with increasing levels of farmyard manure and fertilizer and this resulted in corresponding decline in the aggressivity of wheat mainly due to greater shading effect exerted by mustard at the highest farmyard manure and fertilizer level of 30% N through FYM + 100% RDF. Such relationships among the component crops in intercropping systems were reported by Dhima *et al.* (2007). As the wheat was dominated by mustard, its aggressivity at various farmyard manure and fertilizer levels were reverse to that of mustard and it proved the least aggressive at the farmyard manure and fertilizer level of 15% N through FYM + 75% RDF.

Protein and oil content (%) in mustard and their yield

Marked effect of wheat + mustard intercropping row proportion was noticed on protein content and oil content and their yields in Indian mustard. Increasing proportion of wheat to mustard rows from 6:2, 8:2, 10:2 and 8:1 resulted in concomitant decline in protein content and oil content, and their yields and eventually, maximum seed protein yield of mustard was noted under the row proportion of 6:2 which was remained at par with 8:2 row proportion (Table 4). The lowest seed protein yield was recorded in 8:1 row proportion during both the years. The increased seed yield of Indian mustard from narrow to wider row proportions of wheat and Indian mustard might have resulted in dilution of seed protein content and oil content. Singh and Gupta (1994) also reported enhanced seed oil content at narrow row ratio. In farmyard manure and fertilizer levels, the application of 30 kg N through FYM + 100% RDF obtained significantly highest protein content and their yield which was at par with 15 kg N through FYM + 100% RDF during both the years. This may be due to the fact that more availability of nitrogen increased the proportion of protein substances in the seed. On the contrary, oil per cent in Indian mustard seeds tend to decrease with the increase in levels of farmyard manure and fertilizer up to 30% N by FYM + 100% RDF. The reduction in oil is due to higher rate of nitrogen appears to be due to conversion of carbohydrates into protein. Maximum oil content was recorded with 15% N through FYM + 75% RDF which was at par with 30% N through FYM + 75% RDF. However,

Table 4 Effect of row proportion, farmyard manure and fertilizer level on protein content, protein yield, oil content and oil yield of mustard in wheat + mustard intercropping

Treatment	Seed protein content (%)		Seed protein yield (kg/ha)		Seed oil content (%)		Seed oil yield (kg/ha)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Row proportion (Wheat + Mustard intercropping)								
8:1	18.35	18.52	118.91	130.36	37.80	37.88	244.07	265.52
6:2	19.84	20.10	189.08	198.82	39.38	39.51	370.63	384.41
8:2	19.19	19.44	163.82	175.86	39.19	39.29	333.10	353.51
10:2	18.78	18.94	146.30	165.26	38.83	38.91	301.10	336.73
SEm±	0.29	0.31	9.62	9.92	0.32	0.32	14.72	15.46
CD (P=0.05)	0.99	1.07	33.27	34.34	1.09	1.10	50.94	53.51
Farmyard manure and fertilizer level								
15 %N through FYM + 75% RDF	18.17	18.31	123.14	132.74	39.68	39.78	269.09	288.32
15% N through FYM + 100% RDF	19.47	19.82	168.58	184.68	38.19	38.29	329.57	355.26
30% N through FYM + 75% RDF	18.67	18.75	139.24	149.06	39.38	39.48	293.57	313.99
30% N through FYM + 100% RDF	19.85	20.11	187.16	203.83	37.94	38.04	356.67	382.61
SEm±	0.24	0.27	6.57	7.55	0.22	0.22	10.16	11.50
CD (P=0.05)	0.69	0.80	19.16	22.03	0.63	0.63	29.66	33.56
Sole vs. Intercrop								
Sole (Control)	14.64	14.86	277.45	292.55	40.05	40.18	759.21	790.84
Intercrop	19.04	19.25	154.53	167.58	38.80	38.90	312.22	335.04
SEm±	0.48	0.54	14.15	15.71	0.52	0.56	22.09	24.33
CD (P=0.05)	1.38	1.57	40.76	45.25	1.49	1.62	63.62	70.09

the reverse trend was observed in oil yield. This could be attributed to the highest seed yield obtained under the highest farmyard manure and fertilizer level which decreased markedly with every curtailment in farmyard manure and fertilizer levels.

Total NPK uptake

The uptake of NPK by wheat was significantly highest with 8:1 row proportion of wheat + mustard which was at par with 10:2 row proportion, but was significantly higher than the 8:2 and 6:2 row proportions (Table 5). However, the maximum NPK uptake by mustard was observed in 6:2 row proportion which was at par with 8:2 row proportion during both the years. The uptake of nitrogen, phosphorus and potassium by wheat and mustard was found to governed chiefly by their respective proportion and thereby yield of grain or seed and straw or stover at various row proportions of wheat and mustard intercropping. The NPK uptake also increased with an increase of farmyard manure and fertilizer levels applied to the wheat + mustard intercropping and were observed to be maximum at the application of 30 kg N through FYM + 100% RDF which remained at par with 15 kg N through FYM + 100% RDF during both the years. This could be attributed to the greater availability and supply of nitrogen, phosphorus and potassium at higher levels of farmyard manure and fertilizer application (Singh and Singh 2014). Further, the increase in uptake by wheat and mustard crops grown as sole as well as in intercropping might be due to variation in production of biomass under different treatments.

Soil fertility status

Soil samples analyzed after cropping indicated that the row proportion of wheat + mustard intercropping did not affect significantly available nutrients (N, P and K) in the soil (Table 6). However, comparatively higher values were noticed under 8:1 row proportion of wheat + mustard followed by 6:2 and 8:2 row proportions, and the lowest were under 10:2 row proportion of wheat + mustard intercropping during both the years of study. In farmyard and fertilizer levels, significantly higher availability of N, P and K in the soil was observed in treatments receiving 30% N through FYM + 100% RDF than 30% N through FYM + 75% RDF and 15% N through FYM + 75% RDF during both the years, though the difference between 30% N through FYM + 100% RDF and 100% RDF + 15% N through FYM were statistically at par with each other in available soil N and K during second year. It might be due to indirect addition of partial nitrogen through FYM and enhanced microbial activity which convert organically bound nitrogen to inorganic form (Singh and Singh 2014). Besides primary nutrients, organic sources contribute sizeable quantity of secondary nutrients also and found to improve the fertility of soil.

Table 5 Effect of row proportion, farmyard manure and fertilizer levels on total N, P and K uptake of wheat and Indian mustard in wheat + Indian mustard intercropping

Treatment	Wheat						Mustard					
	Total N uptake (kg/ha)		Total P uptake (kg/ha)		Total K uptake (kg/ha)		Total N uptake (kg/ha)		Total P uptake (kg/ha)		Total K uptake (kg/ha)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Row proportion (Wheat + Mustard intercropping)												
8:1	92.95	97.73	14.67	15.52	88.34	94.82	33.77	36.67	5.44	5.94	31.01	33.75
6:2	77.09	81.09	12.94	13.68	71.42	76.37	51.14	53.59	8.70	9.20	43.25	45.83
8:2	81.42	85.32	13.25	13.94	75.16	79.98	45.80	48.80	7.55	8.14	39.79	42.27
10:2	89.42	92.45	13.97	14.58	86.28	92.02	41.60	45.77	6.94	7.71	38.12	41.25
SEm±	2.64	2.72	0.30	0.35	2.23	2.26	2.09	2.58	0.41	0.46	1.45	2.11
CD (P=0.05)	9.14	9.40	1.02	1.23	7.73	7.82	7.22	8.91	1.43	1.59	5.01	7.29
Farmyard manure and fertilizer level												
15% N through FYM + 75% RDF	74.29	78.20	11.78	12.49	72.97	78.41	34.76	37.73	5.81	6.32	32.02	35.25
15% N through FYM + 100% RDF	91.08	94.12	14.91	15.59	84.08	89.57	47.49	50.74	7.88	8.45	41.92	43.80
30% N through FYM + 75% RDF	78.64	83.00	12.45	13.12	75.84	81.37	38.04	41.55	6.29	6.88	33.40	37.54
30% N through FYM + 100% RDF	96.79	101.27	15.68	16.52	88.31	93.85	52.02	54.81	8.64	9.32	44.82	46.51
SEm±	2.07	2.33	0.28	0.35	1.48	1.85	1.81	1.73	0.31	0.42	1.33	1.57
CD (P=0.05)	6.05	6.80	0.80	1.01	4.32	5.39	5.27	5.06	0.90	1.22	3.87	4.60
Sole												
Wheat	119.82	124.78	21.35	22.23	103.28	109.44	83.38	87.12	14.38	15.18	84.20	91.70
Mustard	85.10	89.15	13.71	14.43	80.30	85.80	43.08	46.21	7.16	7.74	38.04	40.77
SEm±	4.41	4.67	0.55	0.68	3.28	3.83	3.63	3.75	0.66	0.83	2.62	3.29
CD (P=0.05)	12.71	13.46	1.58	1.97	9.44	11.02	10.45	10.80	1.90	2.38	7.55	9.49

Table 6 Effect of row proportion, farmyard manure and fertilizer levels on available N, P and K status of soil after harvest

Treatment	Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Row proportion (Wheat + Mustard intercropping)						
8:1	201.02	208.22	20.91	22.29	224.4	233.27
6:2	198.23	204.24	20.17	21.46	214.67	222.19
8:2	197.22	204.12	20.80	22.07	214.95	222.67
10:2	196.72	204.68	20.11	22.89	219.35	228.58
SEm±	2.07	2.3	0.29	0.54	2.70	2.96
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Farmyard manure and fertilizer level						
15% N through FYM + 75% RDF	179.05	185.93	17.59	18.82	204.99	213.66
15% N through FYM + 100% RDF	208.57	226.08	22.79	24.04	226.00	231.20
30% N through FYM + 75% RDF	186.68	214.86	20.00	19.98	209.24	218.91
30% N through FYM + 100% RDF	218.81	226.55	24.32	25.89	233.13	240.36
SEm±	1.69	2.19	0.27	0.52	2.40	2.78
CD (P=0.05)	4.93	6.39	0.79	1.52	7.04	8.12
Sole						
Wheat	189.82	194.78	21.35	22.23	203.28	209.44
Mustard	198.17	205.35	20.85	22.17	217.75	225.78
SEm±	3.51	4.29	0.54	1.02	4.59	5.55
CD (P=0.05)	NS	NS	NS	NS	NS	NS

NS: Non significant

Table 7 Effect of row proportion, farmyard manure and fertilizer level on economics of wheat and mustard in wheat + Indian mustard intercropping

Treatment	Cost of cultivation ($\times 10^3$ ₹/ha)	Gross return* ($\times 10^3$ ₹/ha)		Net return ($\times 10^3$ ₹/ha)		B:C ratio		Monetary advantage ($\times 10^3$ ₹/ha)	
		2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Row proportion (Wheat + Mustard intercropping)									
8:1	34.97	118.70	126.06	83.73	90.09	2.40	2.61	27.12	35.01
6:2	34.67	110.96	115.60	76.29	80.93	2.20	2.33	21.36	25.63
8:2	34.78	112.47	117.78	77.69	83.00	2.24	2.39	22.14	27.26
10:2	34.85	119.28	127.58	84.43	92.73	2.43	2.66	27.34	37.80
SEm±	-	1.92	2.36	1.31	1.58	0.05	0.07		
CD (P=0.05)	-	6.66	8.18	4.52	5.46	0.18	0.26		
Farmyard manure and fertilizer level									
15% N through FYM + 75% RDF	31.89	103.24	109.43	71.35	77.54	2.24	2.43	8.69	12.92
15% N through FYM + 100% RDF	33.74	121.50	127.88	87.76	94.14	2.60	2.79	32.15	40.22
30% N through FYM + 75% RDF	35.89	108.71	115.04	72.81	79.14	2.03	2.20	15.51	20.55
30% N through FYM + 100% RDF	33.74	127.95	134.68	90.21	96.94	2.39	2.57	41.59	52.00
SEm±		1.85	2.28	1.29	1.49	0.05	0.06		
CD (P=0.05)		5.41	6.66	3.76	4.36	0.14	0.15		
Sole									
Wheat	27.36	97.44	101.03	69.18	72.77	2.45	2.58		
Mustard	23.60	85.71	88.88	61.37	64.55	2.52	2.65		
SEm±		3.62	4.46	2.52	2.93	0.10	0.13		
CD (P=0.05)		10.43	12.84	7.25	8.45	0.28	0.38		

Economics

In general, intercropping of wheat and mustard in 10:2 and 8:1 row proportion were more remunerative than growing either of the component crops in pure stand as well as wheat + mustard in 6:2 row proportion (Table 7). Among the four row proportions in wheat + mustard intercropping, 10:2 row proportion recorded highest gross return, net return and benefit:cost which was at par with 8:1 row proportion and both proved remunerative over 8:2 and 6:2 row proportions. Nevertheless, the highest monetary advantage yield remained associated with 10:2 row proportion followed by 8:1, 8:2 and 6:2 row proportions, respectively. The higher monetary advantage obtained at 10:2 row proportion also signifies its better land equivalent ratio than other row arrangements. In sub-plot treatments, increase in farmyard manure and fertilizer levels from lower to higher levels increased the gross return, net return as well as monetary advantage during both the years but decreased the benefit: cost ratio due to increased cost of cultivation. Accordingly, the application of 30 kg N through FYM + 100% RDF resulted in significantly higher gross return and net return, and also increased cost of cultivation, which was at par with 15 kg N through FYM + 100% RDF except in gross return. However, the benefit: cost ratio was observed significantly highest in the application of 15 kg N through FYM +100% RDF. This suggests that in wheat + mustard intercropping curtailment of 15 kg N through FYM is possible. The similar trend was observed for monetary advantage that could be attributed to the improvement in land equivalent ratio with increasing levels of farmyard manure and fertilizer and better market price of mustard.

Thus, to achieve higher yield advantage and efficient resource utilization in wheat + Indian mustard intercropping, 10 rows of wheat be taken after every 2 rows of Indian mustard and the component crops be fertilized with 15% N through FYM +100% RDF.

REFERENCES

AOAC. 1980. *Official Methods of Analysis*, pp. 376–84, Edn. 13, Association of Official Analytical Chemists (AOAC), Washington DC, USA.

Dhima K V, Lithourghis A S, Vasilakoglou I B and Dordas C A. 2007. Competition indices for common vetch and cereals intercrops in two seeding ratio. *Field Crops Research* **100**: 249–56.

Ghoniskar C P and Shinde C P. 1994. Intercropping in wheat and mustard pays more than mixed cropping. *Indian Farming* **44**: 7–9.

Hedge D M and Sudhakara Babu. S N. 2004. Balanced fertilization for nutritional quality in oilseeds. *Fertilizer News* **49**: 57–62, 65-66 & 93.

Jackson M L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd, New Delhi.

Mandal B K and Mahapatra S K. 1990. Barley, lentil and flax under different intercropping systems. *Agronomy Journal* **82**: 1066–68.

McGilchrist C A. 1965. Analysis of competition experiments. *Biometrics* **21**: 975–85.

Mead R and Willey R W. 1980. The concept of a land equivalent ratio and advantages in yields for intercropping. *Experimental Agriculture* **16**: 217–8.

Singh A K and Bohra J S. 2012. Competitive indices of wheat + compact-mustard intercropping in a 5:1 row proportion as influenced by fertilizer doses and seed rates of wheat varieties. *Archives of Agronomy and Soil Science* **58**: 1399–412.

Singh Amitesh Kumar, Singh Rajesh Kumar and Singh Umendra. 2014. Production potential and competitive indices of Indian mustard (*Brassica juncea* L.) based intercropping with wheat (*Triticum aestivum* L.) and lentil (*Lens culinaris* L.) under different row ratios of eastern Uttar Pradesh. *Archives of Agronomy and Soil Science* **60**: 225–37.

Singh R V and Gupta P C. 1994. Production potential of wheat and mustard cropping systems under adequate water supply conditions. *Indian Journal of Agricultural Research* **28**: 219–24.

Singh Rajesh Kumar and Singh Amitesh Kumar. 2014. Production potential, nutrient uptake and economics of Indian mustard (*Brassica juncea* L.) under integrated nutrient management practices. *Indian Journal of Agricultural Sciences* **84**:142–48.

Srivastava R K, Bohra J S and Singh R K. 2007. Yield advantage and reciprocity functions of wheat (*Triticam aestivum* L.) + Indian mustard (*Brassica juncea* L.) intercropping under varying row ratio, variety and fertility level. *Indian Journal of Agricultural Sciences* **77**: 139–44.

Willey R W. 1979. Intercropping its importance and research needs. Competition and yield advantages. *Field Crop Abstracts* **32**: 1–10.