Pak. J. Bot., 46(2): 759-766, 2014.

EFFICIENCY OF WHEAT *BRASSICA* MIXTURES WITH DIFFERENT SEED RATES IN RAINFED AREAS OF POTOHAR-PAKISTAN

SARTAJ KHAN[1*], M. AJAB KHAN[2], M. AKMAL[3], MUSHTAQ AHMAD[2], M. ZAFAR[2] AND ASMA JABEEN[4]

[1]*National Agricultural Research Center (NARC) Islamabad, Pakistan*
[2]*Department of Plant Sciences, Quaid-i-Azam University, Islamabad, Pakistan*
[3]*Department of Agronomy, University of Agriculture, Peshawar, Pakistan*
[4]*Department of Environments, Fatima Jinnah Women University, Rawalpindi, Pakistan.*
[*]*Corresponding author's e-mail: khansartaj56@yahoo.com*

Abstract

Mixed over sole cropping is advantageous under the rainfed conditions in Pakistan. This avoids risk of complete crop failure and may returns higher income. The study aimed to investigate appropriate seed-rates combination for wheat-*Brassica* as mixed- or intercropped in rainfed conditions. Experiments were conducted at National Agricultural Research Center (NARC), Islamabad Pakistan during winter 2004-05 and 2005-06 using 10 treatments for wheat and *Brassica* as sole and mixed- or intercropped with 100 and 5 kg ha^{-1} for sole crop and 100 kg ha^{-1} for wheat with 40, 50, 60, and 70% lower than the recommended for *Brassica*. Sowing was done in 3rd week of October each year, in lines spaced 30cm. Fertilizer was applied N 48, P_2O_5 34 and K_2O 18 (kg ha^{-1}). *Brassica* was manually removed for fodder at flowering. Seed rate (SR) significantly ($p<0.05$) affected wheat grain yield. Cropping system (CS) significantly ($p<0.05$) affected grain yield of *Brassica*. Interactions of CS and SR were also significant ($p<0.05$) for both species. Planned mean comparison for grain yield was found significant ($p<0.05$) for wheat and brassica. Grain yield for sole wheat was 4.28t ha^{-1} but reported higher in mixed than intercropped. Grain yield of wheat decreased with increase in seed rate of *Brassica* as intercropped. Higher grain yield (4.39 t ha^{-1}) of wheat was recorded for seed rates combinations 100:50 (%) as wheat:*Brassica* intercropped. The land equivalent ratio (LER) for mixed or intercropped system was higher than the sole crop and it increased with increase in the seed rate of *Brassica* as mixed crop but decreased as intercropped. The high LER was associated to treatment 100:50 (%) seed rates combination for wheat:*Brassica* as intercropped. Intercropped resulted the greater LER (1.78) than the mixed crop (1.66) and was found most effective for sustainable production in the rainfed areas for a higher net return.

Introduction

Livestock is an integral part of the agriculture sector in rainfed areas. It provides draught manpower as well as milk and meat for home consumption and livelihood. According to an estimate, around 70% of the dairy holds in Pakistan still operate under conditions of subsistence by maintaining herds of 3 to 4 animals (Bhatti & Khan, 1996; Burki *et al.,* 2005). Normally shortage of livestock feed as green fodder in rainfed areas occurs during May-June in summer and Dec.-Jan. in winter seasons each year. In the rainfed region where farmers have marginal or small landholdings and agriculture is primarily rainfed, practice of the intercropping or mixed cropping is practicable and worthwhile. It not only increases productivity per unit area but also makes the best use of land, water and other resources to minimize risk of crop failure (Riaz *et al*., 2002). An important factor in the farmers' cropping and stocking decisions are the level of risk in the system and their attitude to deal with that risk. Individual farm enterprises suffer from risks related to both the physical yield and unit price. Therefore, intercropping has gained interest because of potential advantages over the mono-crop or sole cropping system. About 78% of wheat crop in rainfed areas is commonly mixed with *Brassica* (Hobbs *et al.,* 1985). Farmers harvest *Brassica* from their fields round the season as per need and requirements. The green *Brassica* is then mixed with wheat straw or other crop residues and fed to the animals as fodder. Some *Brassica* plants are left until the harvest to get seed for the next season sowing. Seed rates and plant stands of *Brassica* vary from field to field but on average a seed rate of 2.5 kg ha^{-1} is commonly in practice (Hobbs *et al.,* 1985). In such cropping system, use of the recommended seed rates for wheat crop and different quantities of the *Brassica* seed results severe competition during the vegetative growth for the companion crops, if rainfall is sufficient during the season. For the intercropping or mixed cropping system spatial arrangement through seeding proportion is highly important, because the crop in mixture is complementary or generally has no adverse effect on the overall productivity (Kumar & Thakur, 2006). In situations where farmers have priorities to opt for the mixed cropping e.g., Potohar region in Pakistan, the existing practice of mixed crops cultivation can be improved using optimum seeding proportion of the companion crops in the mixtures.

Hobbs *et al*., (1985) has reported that if *Brassica* has been removed as fodder there were no significant ($p<0.05$) differences in the wheat yields between the treatments. Although mixed cropping reduced wheat yields on average by 0.82 t ha^{-1} compared to the only 0.29 t ha^{-1} for intercropping, but a high coefficient of variation made these differences statistically non-significant at 95% level of confidence. None of the intercropping gave better gross returns than mustard fodder alone, but mixing of 50% and 70% *Brassica* with wheat gave better gross returns than the sole *Brassica* fodder. Similarly, in another research study Sharma *et al*., (1986) found that lower population of *Brassica* in a wheat field either mixed or in alternate rows has resulted in an increased profit while increased *Brassica* population had depressing effect on wheat yield, resulting in a relatively lower profit. Net income (NI), cost benefit ratio (CBR) and land equivalent ratio (LER) were also observed higher when *Brassica* was intercropped with wheat (Ali *et al*., 2000). In a study conducted by Tahir *et al*., (2003) compared competition functions of different intercropping systems (e.g.

Brassica, wheat, gram, lentil and linseed). They reported that wheat was the most competitive crop to *Brassica* reflected the maximum Relative crowding coefficient (RCC) and minimum aggressivity. Kumar & Thakur (2006) reported significantly higher wheat yield, total productivity and net returns of sole crop compared to wheat intercropped with *Brassica*. It was also reported that number of fertile tillers per unit area, number of spikelets per spike, number of grains per spike and grain yield were not influenced by gram intercropping in wheat and on average yield in intercropped was almost the same as in sole wheat crop, nevertheless, *Brassica* intercrop significantly reduced yield (Tsuba *et al*., 2001; Dhima *et al*., 2007). Ahmad & Quresh (2001) also observed non-significant effect ($p<0.05$) of intercropping on plant height, days to flowering and physiological maturity of the companion crops while grain yield of wheat and *Brassica* significantly ($p<0.05$) decreased in the intercropping compared to the sole crop. This study was aimed to identify the optimum seed rate of *Brassica* to be planted mixed with wheat as rainfed crop in the area and get maximum economic returns from the main crop i.e. wheat in the region.

Materials and Methods

The experiment was conducted at National Agricultural Research Center (NARC), located at 499 m above the sea level, 33° 33 N 73° 04'E during winter 2004-05 and repeated in 2005-06, for two consecutive seasons in rainfed conditions. Soil of the experimental site was clay loam with a pH 7.0 and organic matter in the top surface soil within 30cm depth was about 2.5%. Sodium bicarbonate extractable P was 39.0 mg kg^{-1} and extractable K contents were 195 mg kg^{-1}. Annual rainfall, temperature and humidity for the crop growth seasons are shown in Fig. 1. The experiment was conducted in three replications, in a randomized complete blocks design. The following treatments based on seeding rates as mixed copped and inter cropped were used for this study.

Treatments		
T_1	100:00	Wheat (100 kg ha^{-1}) as sole crop
T_2	100:40	Wheat (100 kg ha^{-1}) and *Brassica* (2.0 kg ha^{-1}) as Mixed crop
T_3	100:50	Wheat (100 kg ha^{-1}) and *Brassica* (2.5 kg ha^{-1}) as Mixed crop
T_4	100:60	Wheat (100 kg ha^{-1}) and *Brassica* (3.0 kg ha^{-1}) as Mixed crop
T_5	100:70	Wheat (100 kg ha^{-1}) and *Brassica* (3.5 kg ha^{-1}) as Mixed crop
T_6	100:40	Wheat (100 kg ha^{-1}) and *Brassica* (2.0 kg ha^{-1}) as Intercrop
T_7	100:50	Wheat (100 kg ha^{-1}) and *Brassica* (2.5 kg ha^{-1}) as Intercrop
T_8	100:60	Wheat (100 kg ha^{-1}) and *Brassica* (3.0 kg ha^{-1}) as Intercrop
T_9	100:70	Wheat (100 kg ha^{-1}) and *Brassica* (3.5 kg ha^{-1}) as Intercrop
T_{10}	100:00	*Brassica* (5.0 kg ha^{-1}) as sole crop

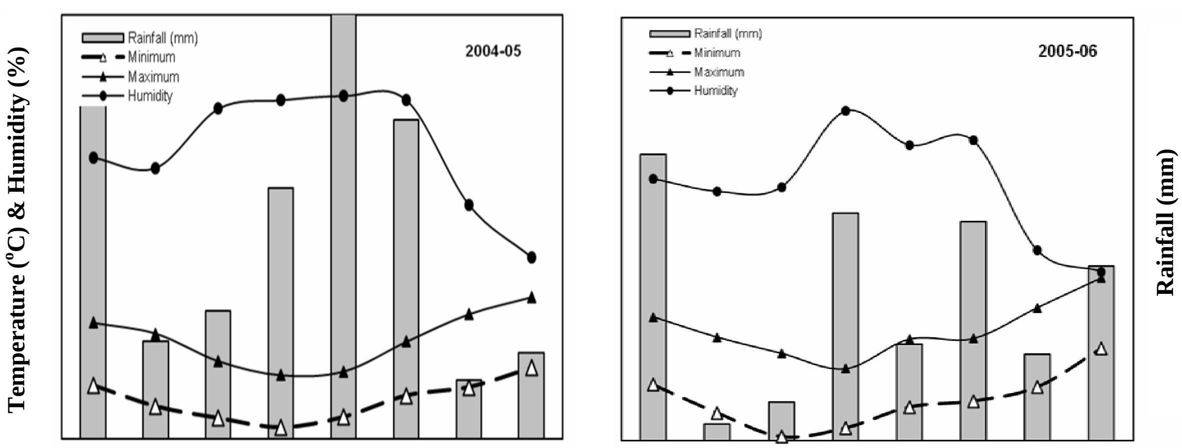

Fig. 1. Weather data of crop growth seasons for the year 2004-05and 2005-06 of the study period recorded at National Agricultural Research Centers (NARC), Islamabad.

Sowing of all the treatments combinations were made in rows equally spaced at 30cm distance in a 3.0 m x 6.0 m subplots using single row drill. Two sole crops treatments i.e. wheat (Cv. Wafaq) and *Brassica* (Cv. BARD-1) were planted alone in respective plots. The mixed crops were planted by mixing the seed of both species together for each row and intercropped treatments were planted using three rows of wheat and two of *Brassica* alternatively in a subplot. A total of 10 rows were maintained for each experimental unit, i.e. sole, mixed and intercropped treatments in subplots. Different seed rates (i.e., 2, 2.5, 3, 3.5 kg ha^{-1}) were 40, 50, 60 and 70 percent lower then the recommended seed rate (5 kg ha^{-1}) of *Brassica*. All treatments were supplied with a uniform fertilizer rates as recommended for wheat crop under the rainfed conditions by applying 48, 34 and 18 kg ha^{-1} N, P and K, respectively. Fertilizer source was Single Superphosphate (SSP), Urea and Potassium sulphate. All nutrients were applied at once at the time of sowing prior to the seedbed preparation. Soil was prepared before sowing using disc plough and cultivator runs twice followed by planking. One half of the treatments (sole, mixed and intercropped) were harvested as fodder at 50 percent blooming stage while the other half was allowed to mature for grain yield estimation.

Measurement and observations: Plant height was recorded at flowering stage in field by randomly selecting ten representative plants per experimental units at two locations and averaged for a single reading. For green fodder yield, half of the plot per treatment (i.e., 5 rows) were harvested and weighed. After weighing, about one kilogram green sample was taken for dry matter determination. The green fodder was oven dried at 70°C until a constant weight reached. Mixed crops of wheat-*Brassica* were harvested and separated for both the species composition (w/w). The samples were weighed individually for wheat and *Brassica* species and representative samples of the individual species were oven dried at 70°C and their weights adjusted accordingly. For data regarding yield components, 10 representative plant samples were collected and their number of leaves, tillers (in wheat), pods (in *Brassica*) and 1000-grain weight (in wheat) were recorded. Crops were harvested in the second week of April each time. Pooled data was compared for different biological indices and the economics were calculated on the basis of market prices of the produce. Data were analyzed using MSTAT-C software. For analysis of the combine data, sole crop treatments i.e., wheat and *Brassica* were excluded respectively to compare the rest of the treatments. Data of individual seasons were analyzed first and the parameters found with homogenous variances with Bartlett's test were combined for the two seasons. The efficiency of intercropping systems was assessed based on different parameters, such as land equivalent ratio (Rao & Willey, 1980), and monetary advantage. Land equivalent ratio (LER) and monetary advantage (MA) were calculated as per procedure explained by Subedi (1997) using the following equations.

a. LER = Intercrop yield of *Brassica* ÷ sole crop yield of Brassica + Intercrop of Wheat ÷ sole crop yield of wheat

b. Monetary advantage was used for economic performance of the mixed and intercrops (Willey, 1979).

   Monetary advantage = GR x LER-1/LER

   where GR is gross return and LER is Land Equivalent Ratio

c. Cost Benefit Ratio (CBR) was calculated as, CBR = Gross margin/Cost of cultivation (Pakistani rupees, 1 US $ = 100 Pak Rupee).

Results

Plant height: Data on height (cm) of wheat and *Brassica* are given in Table 1. The analysis of the data revealed that cropping system (CS) significantly affected plant height in both wheat and *Brassica*. Seed rate (SR) significantly affected plant height of *Brassica* only. The interactive response of CS x SR was significant for plant height of both wheat and *Brassica*. The planned means comparison between sole vs. rest was also significant ($p<0.05$) for plant height of both wheat and *Brassica*. The plant height of sole wheat was 103.07 cm which decreased with increase in the seed rates of *Brassica* in mixed cropping system. Whereas in intercropped system wheat plants attained more height as compared to mixed cropping system. Plant height in *Brassica* showed inconsistent response to seed rates increase in both mixed and intercropped systems. Plant height in *Brassica* was higher in mixed than intercropped systems, which usually improved with increase in seed rate of *Brassica* and taller plants were observed in 100:70 wheat-*Brassica* combinations.

Leaf number: Data regarding number of leaves plant^{-1} are given in Table 1. The analysis of variance table revealed that cropping system significantly ($p<0.05$) affected number of leaves plant^{-1} in wheat only. Seed rate significantly ($p<0.05$) affected the number of leaves plant^{-1} in both wheat and *Brassica*. The interaction between cropping system and seed rate for number of leaves plant^{-1} was significant for *Brassica* only while mean comparison was significant ($p<0.05$) for wheat only. Number of leaves plant^{-1} for wheat sole was higher in the intercropping than mixed cropping systems. It is mostly increased with increase in seed rate of *Brassica*. Higher number of leaves plant^{-1} was recorded at 100:70 wheat-*Brassica* combinations followed by at 100:60. Planned mean comparison indicated that wheat as sole crop resulted in less number of leaves plant^{-1} as compared to rest of the treatments. Number of leaves plant^{-1} for *Brassica* sole decreased with increase in seed rate at mixed system with higher recorded at 100:40 wheat-*Brassica* combinations. However, this character showed inconsistent response to increasing the seed rates of *Brassica* in intercropping system. Higher number of leaves plant^{-1} was noted at 100:70 wheat-*Brassica* combinations and decreased with increase in the seed rate of *Brassica*.

Tiller number (Wheat): Data regarding number of tillers m^{-2} are given in Table 1. Analysis of the data revealed that cropping systems and seed rates significantly ($p<0.05$) affected the tillers m^{-2} of wheat. The interaction between cropping system and seed rates was not significant ($p<0.05$) while planned mean comparison showed significant differences. Number of tillers m^{-2} for wheat sole crop were higher in mixed as compared to intercropping system but decreased with increase in seed rates of *Brassica*. Higher number of tillers m^{-2} was obtained at 100:40 wheat-*Brassica* combinations followed by at 100:50 seeding rate.

Green fodder yield (blooming stage): Data regarding green fodder yield t ha^{-1} at 50 percent flowering are given in Table 1. Analysis of variance table showed that cropping system and seed rates significantly ($p<0.05$) affected the green fodder yield of both wheat and *Brassica*. The interaction between cropping system and seed rate was significant for wheat only. Planned mean comparison for the green fodder yield was also significant ($p<0.05$) for both wheat and *Brassica*. Green fodder yield for sole wheat crop was higher in the intercropping compared to mixed cropping systems. Green fodder yield of wheat crop decreased with increase in the seed rate of *Brassica* in mixed cropping system but showed inconsistent responses to the increasing seed rate of *Brassica* in the intercropped system. The higher green fodder yield in wheat was recorded at 100:70 wheat-*Brassica* intercropping system. This mostly decreased with increase in the seed rate of *Brassica*. Green fodder yield for *Brassica* sole was 10.0 t ha^{-1} while *Brassica* was higher in mixed as compared to the intercropping system. This increased with increase in seed rates of the *Brassica* and was higher at 100:70 wheat-*Brassica* combinations.

Table 1. Plant height (cm), number of leaves, tiller number of wheat, and green fodder yield (kg ha^{-1}) of wheat and *Brassica* planted with different seeding rates in combinations as mixed cropped and intercropped.

Cropping system	Seed rate of wheat: *Brassica* (%)	Plant height (cm)		Number of leaves plant^{-1}		Number of tiller plant^{-1}	Green fodder Yield tha^{-1}	
		Wheat	***Brassica***	**Wheat**	***Brassica***	***Wheat***	***Wheat***	***Brassica***
Sole		103.07	64.10	6.05	8.57	57.83	32.80	35.01
Rest		102.5	62.98	6.24	7.81	54.46	29.75	25.82
Mixed (W + B)	100 : 40	102.58abc	68.24b	6.12	9.55a	56.83	29.93bc	20.18
	100 : 50	103.50ab	57.43e	5.87	6.87d	55.50	29.62c	19.30
	100 : 60	102.02bc	66.60b	6.23	7.47c	54.50	29.49cd	33.83
	100 : 70	101.12c	71.80a	6.47	7.18cd	54.00	28.77de	34.27
Intercropping (W + B)	100 : 40	101.13c	60.08d	6.30	8.20b	54.17	30.67ab	17.38
	100 : 50	102.60abc	53.72f	6.20	7.32cd	54.33	30.13abc	17.75
	100 : 60	103.23ab	61.81d	6.25	7.33cd	52.83	28.52e	28.83
	100 : 70	103.83a	64.10c	6.45	8.57b	53.50	30.87a	35.01
$LSD_{0.05}$		**1.53**	**1.96**	**NS**	**0.47**	**NS**	**0.80**	**NS**
Mixed (W + B)		102.30	66.02	6.17	7.77	55.21	29.45	26.89
Intercropping (W + B)		102.70	59.93	6.30	7.85	53.71	30.05	24.74
	100:40	101.86	64.16b	6.21b	8.88a	55.50a	30.30a	18.78c
	100:50	103.05	55.57c	6.03c	7.09c	54.92ab	29.88a	18.52c
	100:60	102.63	64.20b	6.24b	7.40c	53.67b	29.00b	31.33b
	100:70	102.48	67.95	6.46a	7.88b	53.75b	29.82a	34.64a
$LSD_{0.05}$		**NS**	**1.39**	**0.17**	**0.33**	**1.30**	**0.56**	**2.09**

Note: Means followed by same letter within a column are not statistically different from each other using least significant difference (LSD) test ($p<0.05$)

Pod number (*Brassica*): Data regarding number of pods plant^{-1} in the *Brassica* are given in Table 2. Analysis of the data revealed that cropping systems and seed rates significantly ($p<0.05$) influenced pods plant^{-1} in *Brassica*. The interaction between cropping system and seed rate and planned mean comparison was also significant. Number of pods plant^{-1} for the sole *Brassica* decreased with increase in seed rate of *Brassica* in mixed cropping system while it showed inconsistent response to increasing rate of *Brassica* in the intercropping system. Higher number of pods plant^{-1} was recorded at 100:50 wheat-*Brassica* combinations in intercropping system followed by at 100:50 wheat-*Brassica* in the mixed cropping system. It was higher in mixed as compared to intercropping system. Number of pods plant^{-1} showed inconsistent pods plant^{-1} with increasing seed rates of *Brassica*. Planned mean comparison indicated that *Brassica* sole produced less number of pods plant^{-1} than rest of the treatments.

1000-Grain weight (wheat): Data regarding 1000-grains weight (g) in wheat and *Brassica* are given in Table 2. Analysis of the data revealed that both cropping system and seed rate significantly affected 1000-grain weight in wheat. The interaction between cropping system and seed rate was non-significant ($p<0.05$). Planned mean comparison was also non-significant. Thousand grains weight for wheat sole crop was higher in the mixed as compared to the intercropping system and also showed inconsistent response to increasing the seed rates of *Brassica*. Higher grain weight was recorded at 100:50 wheat-*Brassica* combinations followed by 100:60.

Dry matter (DM), Grain and stray yield: Data regarding straw yield (SY) t ha^{-1} of wheat are given in Table 2. Analysis of the data revealed that cropping system and seed rates significantly ($p<0.05$) affected SY. The interaction between CS and SR was significant ($p<0.05$) for SY of wheat while planned mean comparison was reported non- significant ($p<0.05$). It decreased with increase in seed rates under mixed cropping system while increased with increase in seed rates in the intercropping. Higher SY was recorded at 100:40 wheat-*Brassica* mixed cropped systems followed by at 100:50 wheat-*Brassica* the intercropping system. The SY showed inconsistent response to increasing seed rates of *Brassica* with higher yield was obtained at 100:50 wheat-*Brassica* combinations followed by treatment 100:70 wheat-*Brassica* combinations. Data regarding DM yield t ha^{-1} at 50 percent flowering (Table 2) revealed that seed rates significantly ($p<0.05$) affected the DM yield of wheat only. The interaction between cropping system and seed rate was significant for wheat only, while planned mean comparison was significant ($p<0.05$) for *Brassica* only. Dry matter yield for wheat grown as sole crop decreased with increase in the seed rates of *Brassica* in mixed cropping system. However, it showed inconsistent response to increasing seed rates of *Brassica* in the intercropped system and was higher (9.77 t ha^{-1}) at 100:40 wheat-*Brassica* intercropping systems. Dry matter yield of wheat mostly decreased with increase in the seed rates of *Brassica* and was observed higher (9.49 t ha^{-1}) at 100:40 wheat-*Brassica* combinations. The planned mean comparison indicated that DM yield for sole *Brassica* crop was higher than rest of the treatments. Analysis of the data revealed that seed rate significantly ($p<0.05$) affected the grain yield in both wheat and *Brassica*. However, the cropping system also significantly ($p<0.05$) affected the grain yield of *Brassica* only. The interaction between cropping system and seed rates was significant for both wheat and *Brassica*. Planned mean comparison for the grain yield was also significant for both wheat and *Brassica* in intercropping system. Overall grain yield on average for sole wheat was higher (4.28 t ha^{-1}). Grain yield of wheat was higher in mixed as compared to the intercropping system. This increased with increase in the seed rates of *Brassica* in mixed cropping system and was reported higher (4.06 t ha^{-1}) at 100:70 wheat-*Brassica* mixed cropping system. However, it decreased with increasing seed rates of *Brassica* in the intercropped system and was higher (4.39 t ha^{-1}) at 100:50 wheat-*Brassica* intercropping systems. Grain yield decreased with increase in seed rates of the *Brassica* in the intercropping systems. Grain yield for sole crop of *Brassica* was 1.48 t ha^{-1}, which was higher in the intercropping as compared to the mixed system. Grain yield increased with the increase in seed rates of *Brassica* both in mixed as well as in the intercropping systems. Higher grain yield (1.48 t ha^{-1}) of *Brassica* was obtained at 100:70 wheat-*Brassica* in the intercropping system followed by 1.34 t ha^{-1} in both mixed- (100:70) and intercropping (100:60) systems. Planned mean comparison indicated that *Brassica* sole resulted in the higher grain yield as compared to rest of the treatment combinations.

Land equivalent ratio (LER) and monetary advantage (MA): Data regarding LER are given in Table 3. LER increased with the increase in seed rates of *Brassica* in mixed cropping system but decreased with the increase in seed rates of *Brassica* in the intercropping system. Higher LER was calculated in 100:50 wheat-*Brassica* combinations in the intercropping system followed by 100:70 combinations in the mixed cropping system. Generally, the intercropped system resulted in greater LER (1.78) compared to the mixed cropping system (1.66). The yield advantages were examined in monetary terms and it was found that monetary advantage increased with increase in the seed rates of *Brassica* in the mixed cropping system but decreased with the increase in the seed rates of *Brassica* in the intercropping system. Higher monetary advantage (Rs. 42,669) was recorded in 100:50 wheat-*Brassica* at the intercropping system followed by 100:70 in the mixed cropping systems (Rs. 41,053). Overall picture of the study indicated that intercropping system resulted in greater monetary advantage as compared to the mixed cropping system.

Table 2. Dry matter yield (kg ha^{-1}), straw yield (kg ha^{-1}), pod number ($plant^{-1}$), grains weight (000 g^{-1}) and grain yield (kg ha^{-1}) of wheat and *Brassica* planted with different seeding rates in combinations as mixed cropped and intercropped.

Cropping system	Seed rate of wheat: *Brassica* (%)	Dry matter yield tha^{-1}		Straw yield	Number of Pods	1000 Grain weight	Grain yield tha^{-1}	
		Wheat	***Brassica***	***Wheat***	***Brassica***	***Wheat***	***Wheat***	***Brassica***
Sole		9.93	5.00	20.00	288.50	45.55	4.28	1.48
Rest		9.28	4.42	18.38	294.44	42.71	3.83	1.22
Mixed (W + B)	100 : 40	9.20cd	3.15	19.56	304.67 ab	42.61	4.06 abc	0.94 f
	100 : 50	9.00d	3.02	18.86	308.00 a	47.21	3.88 bc	1.03 e
	100 : 60	9.16cd	4.61	18.36	290.00 cd	42.41	3.76 c	1.13 d
	100 : 70	9.13cd	4.63	18.04	283.50 d	41.76	3.82 bc	1.34 b
Intercropping (W + B)	100 : 40	9.77a	2.63	16.60	274.50 e	39.03	4.26 ab	1.26 c
	100 : 50	9.43abc	2.67	19.16	309.50 a	42.58	4.39 a	1.25 c
	100 : 60	9.02d	4.22	17.66	296.83 bc	44.02	3.23 d	1.34 b
	100 : 70	9.54ab	5.00	18.76	288.50 cd	42.21	3.24 d	1.48 a
$LSD_{0.05}$		**0.37**	**NS**	**1.06**	**8.61**	**NS**	**0.49**	**0.04**
Mixed (W +B)		9.12	3.85	18.70	296.54	43.45	3.88	1.11
Intercropping (W +B)		9.44	3.63	18.04	292.33	41.96	3.78	1.33
	100:40	9.49a	2.89	18.08	289.58 bc	40.82	4.04 a	1.10 d
	100:50	9.21b	2.84	19.02	308.75 a	44.80	4.07 a	1.14 c
	100:60	9.09b	4.42	18.00	293.42 b	43.21	3.56 b	1.24 b
	100:70	9.34ab	4.82	18.40	286.00 c	41.98	3.65 b	1.41 a
$LSD_{0.05}$		**0.26**	**NS**	**0.74**	**6.09**	**2.61**	**0.34**	**0.03**

Note: Means followed by same letter within a column are not statistically different from each other using least significant difference (LSD) test ($p<0.05$)

Table 3. Land equivalent ratio (LER) and monetary advantage (MA) of sole wheat and *Brassica* planted with different seeding rates in combinations as mixed cropped and intercropped.

Cropping system	Seed rate of wheat: *Brassica* (%)	LER	Gross income (Rs./ha)	Net income	Seed constant	Labor cost	Monetary advantage
Sole Wheat (W)	100 : 00	1.00	59370	59370	1600	4817	0
Sole Mustard (M)	00 : 100	1.00	36958	36958	150	4446	0
Mixed (W + M)	100 : 40	1.53	77089	77089	1660	6299	26577
	100 : 50	1.58	78427	78427	1675	6299	28663
	100 : 60	1.67	82242	82242	1690	6299	33090
	100 : 70	1.85	89282	89282	1705	6299	41053
Intercropping (W + M)	100 : 40	1.84	89142	89142	1660	5928	40807
	100 : 50	1.87	91622	91622	1675	5928	42669
	100 : 60	1.66	79375	79375	1690	5928	31626
	100 : 70	1.76	83306	83306	1705	5928	35874
Mixed cropping system	-	1.66	81760	81760	1683	6299	32346
Intercropped system	-	1.78	85861	85861	1683	5928	37744

Discussion

Wheat being main specie of the experiment, showed a reduction in plant height with the increasing seed rates of *Brassica* in a descending fashion at mixed but contrary to that in the intercropping. It is natural when density within rows increases, there is more overcrowding towards the space inter-competition. The variations in plant heights when grown as sole or mixed/intercropped with *Brassica* are in accordance with the findings of Mandal *et al*., (1991). They reported that wheat intercropped with rapeseed has decreased plant height due to its exhaustive competition and dominant plant nature in the canopy. Ahmad & Quresh (2001) also reported a decrease in the plant height of wheat when intercropped with the rapeseed crop. However, Sharma *et al*., (1986) and Khan (1984) reported that plant height of wheat was not affected due to intercropping of wheat and *Brassica*. Increased *Brassica* seeding rates had an adverse effect on its leaf number but had a positive effect on the leaf number in wheat. It is quite logical that increased seed rates of the *Brassica* may have overcrowded the crop canopy and hence resulted a reduction in the leaf number in *Brassica*. The reason for variation in different intercropping systems could be due to the competitions between two crops for nutrients and moisture as well as space in the canopy. Moreover, plant density and height also contributed to variation in the leaf number. Changes in the seed rates and growth behavior of the *Brassica* were the main reasons of differences in the leaf number of the species in the cropping systems. The results further supported the findings of Mandal *et al*., (1985) and Ghosh (2004). Data on tillers plant^{-1} revealed that cropping system and seed rate has significantly ($p<0.05$) affected the tiller number in wheat. This might be due to space availability for tillers production under the mixed or intercropping. It was observed in this study that interaction effect of cropping system and seed rates were non-significant ($p<0.05$). It means that space was limited in either case for wheat crop within the canopy. Productive tillers plant^{-1} was higher in the mixed compared to the intercrop. It might be due to uniform space for intercropped than the mixed crop for each individual plant. Moreover, tillers plant^{-1} decreased with increasing seed rates of *Brassica* is quite possible that space for wheat tiller was limited by the existence and expansion of *Brassica*. Ali *et al*., (2000) and Akhtar (2004) reported lower number of tillers per unit area in case of wheat-*Brassica* and wheat-linseed association systems. This was attributed to the exhaustive competition between companion crops for external growth factors. In the literature, pods plant^{-1} of *Brassica* was not affected ($p<0.05$) when sown mixed in wheat in a field experiment conducted by Sharma *et al*., (1986). Contrary to this Zulfiqar *et al*., (2000) reported that intercropping with wheat decreased the number of pods plant^{-1} in the *Brassica.* Seeding rates has significantly ($p<0.05$) affected the green fodder yield of both wheat and *Brassica*. Higher seed rates of *Brassica* showed the high green fodder ($p<0.05$), which was naturally associated to high density per unit area resulting more biomass. In intercrop, wheat was not affected as much as affected in the mixed crop. In the intercrop, wheat was restricted to grow within the rows in the assigned spacing and hence have less effect of the companion wheat crop to over shadow the growing tillers. Dry matter also showed a similar response for the main as well as the possible interactions of seeding rates treatments recorded for green fodder production. These findings are in agreement with findings of the Srivastava & Bohra (2006).

The magnitude of grain development in wheat is associated by its 1000-grain weight. Our data were non-significant. Sharma *et al.*, (1986) did not found any effect on 1000-grain weight of wheat due to intercropping of *Brassica*, which was similar with our findings. Contrary to that, Agegnehu *et al*., (2006) and

Banik *et al.*, (2006) reported that grain weight spike^{-1} varied significantly ($p<0.05$) under the various intercropping systems. Mono-cropped wheat gave significantly higher grain weight spike^{-1} than that of the intercrop with other crops. In another experiment, Zulfiqar *et al.*, (2000) found that 1000-grain weight was significantly ($p<0.05$) influenced by different intercropping systems. Overall grain yield of sole crop of wheat was higher as compared to the mixed crop of wheat with *Brassica*. It is obvious that this happened because of no competition from companion crop of *Brassica*. Grain yield of wheat was affected ($p<0.05$) by methods of sowing. It was higher in the mixed cropping than the intercropping. This might be due to inter competition of wheat plants in a row as the intercropped treatments were sown in rows using three wheat and two *Brassica* rows alternatively in a subplot. There was less competition between the individual wheat plants in mixed cropping than found within the row in the intercropping system. This leads to higher *Brassica* grain yield and lower wheat yield. Intercropping resulted in an average wheat grain loss of 2.57 percent compared to the mixed cropping system. This difference was partly due to the lower *Brassica* plants and partly due to more intense competition between plants within the rows in the intercropped plants. Our results are also in agreement with findings of Hobbs *et al*., (1985) and Khan *et al*., (2005).

LER for the mixed and intercropped system was higher than sole crops. These results are similar with findings of the Ahmad & Quresh (2001) who also reported higher LER for the intercropping system than the sole crops. Akhter *et al.,* (2004) reported that higher yield of wheat and lentil was achieved when both crops were sown in lines than broadcast systems. In the mixed cropping treatments, the different percentage of LER indicated that mixed cropping increased productivity per unit area in comparison with the sole cropping but did not prove from these studies. This might be due to canopy size and growth aggressiveness of the species in the mixed or intercropped system. Sole cultivation of either species (wheat or *Brassica*) was not found comparable with the mixed or intercropped for unit return. Wheat grown mixed with *Brassica* for grain production was economical than that grown for fodder. The data pertaining to economic analysis along with all relevant calculations indicated that wheat inter-cropping systems under our studies gave considerably higher ($p<0.05$) net income per hectare than the wheat alone. Among the intercropping systems, high net income was obtained in wheat than mixed cropping system of wheat-*Brassica*. Zulfiqar *et al*., (2000) and Verma *et al*., (1997) calculated monetary gains of wheat-canola intercropping and reported the highest income from the canola with wheat as rainfed crop. Akhter *et al.,* (2004) also found the highest monetary advantage for wheat-*Brassica* intercropped system. Srivastava & Bohra (2006) reported that wheat and *Brassica* intercropping more remunerative than that of the sole stands for net return. However, the selection of an appropriate variety of *Brassica* is essential to be identified for the area under the prevailing cropping system (Rathi *et al.*, 1992). It is concluded that mixed cropping of wheat with *Brassica* at 100:50 seeding ratio is recommended for the production of green fodder of *Brassica* without adverse effects on the grain yield of wheat accomplishing maximum monetary benefits in the rainfed areas of Potohar in Pakistan.

References

Agegnehu, G.A., A. Ghizam and W. Sinebo. 2006. Yield performance and land-use efficiency of barley and faba bean mixed cropping in Ethopian highlands. *European J. Agron.,* 25: 202-207.

Ahmad, G. and Z. Quresh. 2001. Better use of land through intercropping of Canola with wheat. *Sarhad J. Agric*., 17: 363-366.

Akhter, N., A. Md. Alim, M.M. Islam, Z. Naher, M. Rehman and A. S.M. Iqbal Hossain. 2004. Evaluation of mixed and intercropping of lentil and wheat. *J. Agron*., 3: 48-51.

Ali, Z., M.A. Malik and M.A. Cheema. 2000. Studies on determining a suitable canola-wheat intercropping pattern. *Int. J. Agri. Biol*., 2: 1-2.

Banik, P., A. Midya, B.K. Sarkar and S.S. Ghose. 2006. Wheat and chickpea intercropping systems in an additive series experiments: advantages and weed smothering. *European J. Agron*., 24: 325-332.

Bhatti, M.B. and S. Khan. 1996. Fodder production in Pakistan. In: *Proceedings of National Conference on the Improvement, Production and Utilization of Fodder Crops in Pakistan*. (Eds.): M. Banaras Bhatti, Khan Sartaj. NARC, pp. 230.

Burki, A.A., M.A. Khan and F. Bari. 2005. The state of Pakistan's dairy sector. An Assessment. CMER Working Paper no. 05-34. Lahore University of Management Sciences, DHA, Lahore Cantt.

Dhima, K.V., A.A. Lithourgidis, I.B. Vasilakoglou and C.A. Dordas. 2007. Competition indices of common vetch and cereal intercrops in two seeding ratio. *Field Crops Res.*, 100: 249-256.

Ghosh, P.K. 2004. Growth, yield and economics of groundnut/cereal fodder intercropping systems in semi-arid tropics of India. *Field Crop Res*., 88: 227-237.

Hobbs, P.R., Abdur-Razzaq, N.I. Hashmi, Muhammad Munir and B.R. Khan. 1985. Effect of mustard grown as a mixed intercrop on yield of wheat. *Pak. J. Agric. Res.,* 6: 241-247.

Khan, M., R.U. Khan, A. Wahab and A. Rasheed. 2005. Yield and yield components of wheat as influenced by intercropping of chickpea, lentil and rapeseed in different proportions. *Pak. J. Agric. Sci*., 42: 1-3.

Khan, M.A. 1984. Studies on intercropping of linseed and mungbean in wheat planted in different geometrical patterns. M.Sc. (Hons) Thesis, Department of Agronomy, University of Agriculture, Faisalabad, Pakistan.

Kumar, A. and K.S. Thakur. 2006. Effect of *Brassica* spp., and their sowing proportions on productivity, competition and economics of wheat (*Triticum aestivum*) + *Brassica* mixed cropping system under rainfed conditions of Himachal Pradesh. *Indian J. Agron*., 51: 259-262.

Mandal, B.K., A. Saha, T.K. Kundu and A.K. Ghorai. 1991. Wheat based intercropping and effect of irrigation and mulch on growth and yield. *Indian J. Agron*., 36, Supplement, pp. 23-29.

Mandal, B.K., S. Dasgupta and P.K. Roy. 1985. Effect of intercropping on yield components of wheat, chickpea and mustard under different moisture regions. Zeitschrift-fur-Acker-Und-pflarizenbau India, 155: 261-7.

Rao, M.R. and R.W. Willey. 1980. Preliminary studies of intercropping combinations based on pigeon pea or sorghum. *Exp. Agric*., 16: 29-39.

Rathi, K.S., R.K. Dubey and H. Singh. 1992. Evaluation of mustard (*Brassica juncea*) varieties in association with potato (*Solanum tuberosum*). *Indian J. Agron*., 37: 237-239.

Riaz, A., M. Ejaz, U. Ehsan and M.A. Nadeem. 2002. Effect of nitrogen management on agro-economic efficiency of different wheat-based intercropping systems. *Pak. J. Agri. Sci*., 39: 25-27.

Sharma, K.C., Y. Sing, P.C. Gupta, S.K. Tripathy, A.K. Bhardwaj and S.P. Singh. 1986. Plant population and spatial arrangement in wheat-mustard intercropping. *Indian J. Agron*., 31: 154-157.

Srivastava, R.K. and T.S. Bohra. 2006. Performance of wheat (*Triticum aestivum*) + Indian mustard (*Brassica juncea*) intercropping in relation to row ratio, Indian mustard variety and fertility levels. *Indian J. Agron*., 51: 107-111.

Subedi, K.D. 1997. Wheat intercropping with Toria (*Brassica Campestris* var. Toria) and pea (*Pisum sativum*) in the subsistence farming system of the Nepalese hills. *J. Agric. Sci. Cambridge*. 128: 283-289.

Tahir, M., M.A. Malik, A. Tanveer and A. Rashid. 2003. Competition functions of different canola-based intercropping systems. *Asian J. Plant Sci*., 2: 9-11.

Tsubo, M., S. Walker and E. Mukhala. 2001. Comparisons of radiation use efficiency of mono-inter-cropping systems with different row orientations. *Field Crops Res*., 71: 17-29.

Verma, U.N., S.K. Pal, M.K. Singh and R. Thakur. 1997. Productivity, energetics and competition functions of wheat (*Triticum aestivum* L.) plus Indian mustard (*Brassica juncea* L.) intercropping under varying fertilizer level. *Indian J. Agron*., 42: 201-4.

Willey, R.W. 1979. Intercropping-Its importance and research needs. Part 1. Competition and yield advantages. Field Crop Abstracts. 32: 1-10.

Zulfiqar, A., A.M. Muhammad and A.C. Mumtaz. 2000. Studies on determining a suitable canola-wheat intercropping pattern. *Int. J. Agri. Biol*., 2: 42-44.

(Received for publication 13 April 2012)