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Yield and yield components of wheat as influenced by intercropping of oilseed rape and fertilizers

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Abstract

A field experiment was carried out at Research Farm of Tabriz University, Tabriz, Iran, over consecutive 2 winter seasons (2010-2012) in order to study the profitability of wheat (*Triticum aestivum* L.) and oilseed rape (*Brassica napus* L.) intercropping under 2 types of fertilizer. A sole crop of wheat (A_1) was compared with 8:3 (A_2), 12:4 (A_3) and 16:5 (A_4) row proportions of wheat-oilseed rape intercropping systems under 100% chemical fertilizers and 50% chemical fertilizers + biofertilizers. The results showed that grain yield increased by 22.25, 25.38 and 13.72 percent over sole crop of wheat in case of intercropping of wheat-oilseed rape at 8:3, 12:4 and 16:5 rows, respectively. The 12:4 rows combination gave significantly higher number of spike/m^2 (611.6), grain yield (610.3 g/m^2) and biological yield (1353.0 g/m^2) than that of sole wheat (513.4, 455.3 g/m^{2}and 1072.7 g/m^2, respectively). According to measured traits, A_2 and A_3 had no statistically significant difference and so sole crop of wheat had the lowest value for all of studied traits. In 2010-2011, spike length and grain umber per spike were more than those of 2011-2012, while the number of spike per plant and per unit area, 1000 grain weight and harvest index were greater in 2011-2012. Treatment 100% chemical fertilizer had significantly higher grain yield (575.8 g/m^2) and biological yield (1301.7 g/m^2) than that of 50% chemical fertilizer + biological fertilizers. Therefore, it was concluded that strip intercropping of wheat and oilseed rape in 8:3, and 12:4 row ratio had the maximum yield components that it led to increase grain yield.

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Introduction

Intercrops have the potential to exceed the yields possible in monocultures of their component species (Willey, 1979; Liebman, 1988). It is a common feature in traditional farming of small landholders. It provides farmers with a variety of returns from land and labor, often increases the efficiency with which scarce resources are used and reduces the failure risk of a single crop that is susceptible to environmental and economic fluctuation (Khan *et al.,* 2005).

Khan *et al.,* (2005) concluded that intercropping of chickpea and wheat in 1:1 ratio gave the maximum increase in the grain yield of wheat. Long *et al.,* (2001) reported that wheat-maize and wheat-soybean strip intercropping led to advantage 40-70% in yield for wheat intercropped with maize and 28–30% for wheat intercropped with soybean. Similarly, Banik *et al.,* (2006) indicated that intercropping systems registered significant increase in total productivity per unit area and improve land use efficiency.

Growing cereals with oilseeds of varying rooting depths and growth patterns facilitates better extraction of soil moisture and nutrients from different soil profiles. In addition to increased water- and nutrient-use efficiency (Yang *et al.,* 2010), intercropping is also known to intercept more solar energy and provide comparatively higher yield stability (Tsubo *et al., 2003*) and yield insurance during aberrant weather conditions compared with sole crops (Willey, 1979; Sinha *et al.,* 1985; Mandal *et al.,* 1991). A substantial increase in total production over space and time not by means of costly inputs, but by the simple expedient of growing crops together is the unique advantage associated with intercropping, in particular, microclimatic manipulation is shown to be appreciably more limited in sole cropping than in intercropping (Stigter and Baldy, 1995). Kerrio and Aslam (1986) suggested that 2 crops of differing height, canopy and growth habits can be grown simultaneously with *the least competition*. Malik *et al.,* (1998) reported that yield and yield components of wheat were significantly affected by association of chickpea, lentil and rapeseed while Mikhov *et. al.,* (1991) stated that wheat yield in pure stand was significantly higher than mix cropping under rain filed conditions.

Due to the growth in human populations fertilizers were used to increase crop production and meet the rising demands for food. Increases in the production cost, and the hazardous nature of chemical fertilizers for the environment has led to a resurgence of interest in the use of biofertilizers for enhanced environmental sustainability, lower cost production and good crop yields. Plant growth promoting rhizobacteria, PGPR (e.g. *Azotobacter chroococcum* as free living nitrogen fixing bacteria and *Bacillus megatherium* as phosphate dissolving bacteria) that have been successful in promoting the growth of crops such as canola, soybean, lentil, pea, wheat and radish have been isolated (Timmusk *et al.,* 1999). Seed inoculation of wheat varieties with P solubilizing and phytohormone producing *Azotobacter chroococcum* showed better response compared with controls (Kumar *et al.,* 2001). Mader *et al.,* (2011) found that inoculation of wheat with PGPR augmented wheat grain yield by 31% as compared to un-inoculated controls.

Considering that wheat (*Triticum aestivum* L.) is the most important cereal in the world and it plays a vital role in global agricultural economy (FAO, 2003), and oilseed rape is one of the most important oilseed crops, the objective of this study therefore, to investigate wheat yield and yield components as influenced by intercropping of oilseed rape and chemical and biological fertilizers.

Material and methods

Site description, experimental design and treatments

A field experiment was conducted during winter seasons of 2010-2011 and 2011-2012 at Research Farm of Tabriz University, Tabriz, Iran (Latitude, X: 46° 17´ E; Y: 38° 05´ N, Altitude 1360m a.s.l.). The factorial set of treatments was arranged with in randomized complete block design (RCBD) in 3 replications with 4 cropping system treatments (A_1: monoculture of wheat, A_2: strip intercropping of wheat-oilseed rape with 8 rows of wheat and 3 rows of oilseed rape, A_3: strip intercropping with 12 rows of wheat and 4 rows of oilseed rape and A_4: strip intercropping with 16 rows of wheat and 5 rows of oilseed rape) and 2 types of fertilizer (B_1: 100% chemical fertilizer and B_2: 50% chemical + biological fertilizers). Chemical fertilizers included Triple superphosphate (46% P) and Urea (46% N) and biofertilizers were Barvar2 (include phosphate dissolving bacteria) and Nitrazhin (include free living nitrogen fixing bacteria). For B_1 and B_2 treatment, 100 kg/ha of Triple superphosphate and 200 kg/ha Urea as well half of these quantities + biological fertilizers were used, respectively. Triple superphosphate was applied at sowing time but Urea was used as equal split at 3 stages: sowing time, stem elongation and before anthesis. Biofertilizers applied at sowing time as seed inoculation. The seeds of wheat (cultivar: Alvand) and oilseed rape (cultivar: Okapi) were sown by hand as over density on 15 Sep. 2010 and 2011 and after overwintering were reached to optimum density on April. Plot size in each cropping system was different (A_1: 15 m^2 A_2: 22.5 m^2 A_3: 30 m^2 and A_4: 35 m^2) and consisted of different number of rows of 5m length, spaced 20 cm apart for both plant. All plots were irrigated immediately after sowing, but subsequent irrigations were carried out as a weekly. Hand weeding of the experimental area was done as when required.

Weather data

Weather data were recorded daily near the experimental site and are reported as mean monthly data according Walter and Gusen methods (P=2T) for both the years (Figure 1).

Measurement of wheat yield and yield components

At maturity, 10 wheat plants from each plot were harvested to determine spike length, spike number per plant, grain number per spike and 1000 grain weight. Finally, plants in 2 m^2 of each plot were harvested and spikes number was counted; then grain detached from the spike and grain yield per unit area was recorded.

Data analysis

Analysis of variance of the data was carried out, using SAS (9.1). Duncan's multiple range test was applied to compare means of each trait at 5% probability. Excel software was used to draw figures.

Results

Variance analysis of the data for wheat (Table 1) showed significant response to years for spike length, spike per plant, grain number per spike, 1000 grain weight, spike number per unit area and harvest index. All traits, exception 1000 grain weight were significantly affected by cropping systems. Fertilizer treatments had significant effect on grain and biological yield per unit area. Neither cropping system nor fertilizers had significant effect on 1000 grain weight (Table 1).

Cropping systems × fertilizers interaction was just significant on spike number per unit area. Year × fertilizers and year × cropping systems × fertilizers interactions had no significant effect on under study traits (Table 1).

In 2010-2011, the values of spike length and grain number per spike were more than those of 2011-2012 while spike number per plant and per unit area, 1000 grain weight and harvest index were more in 2011-2012 (Table 2).

Wheat in its sole stand significantly recorded lower yield and yield components. In A_2 and A_3, spike length was significantly higher than that of A_1. A_4 had no significant difference with the other treatments. Mean number of spike per plant was high in A_2 and A_3 as they had significant difference with A_1 and A_4. The highest and the lowest grain number per spike were observed in A_3 (30.18) and A_1 (22.68), respectively. All of intercropping systems produced more harvest index compare to monoculture of wheat (Table 3).

Table 1. Analysis of variance results for yield and yield components of wheat at different cropping systems and fertilizers in 2 growing seasons.

S.O.V	df	Spike length	Spike per plant	Grain number per spike	1000 grain weight (g)	Spike number/m²	Grain yield (g/m²)	Biological yield (g/m²)	Harvest index (%)
Y	1	40.15**	8.15*	1211.53**	1589.73**	86953.99**	666.77	1759.94	10.84*
Y × B	4	0.46	3.33*	25.25	8.37	6008.72*	2401.08	5504.88	2.47
C.S.	3	3.63**	10.94**	143.88**	10.97	26052.88**	57010.32**	208700.38**	15.42**
F	1	1.72	0.69	69.80	7.50	6025.60	46408.66**	196514.57**	1.37
C.S. × F	3	0.35	1.29	13.41	7.06	4762.68*	8381.97	34333.97	0.43
Y × CS	3	1.27	2.06	50.53	5.84	2308.58	7210.49	21342.88	5.19
Y × F	1	1.84	0.03	0.98	1.88	179.41	522.72	9866.78	3.22
Y × CS × F	3	0.38	2.32	9.15	18.06	2562.77	596.92	4263.08	0.91
E	28	0.77	1.26	26.42	9.19	1663.76	3558.47	14930.34	2.10
C.V. (%)		11.21	14.57	19.58	7.56	7.24	10.95	9.87	3.30

*Statistically significant at $p \leq 0.05$. **significant at $p \leq 0.01$. Y: year, B: block, C.S.: cropping system, F: fertilizer and E: error.

Table 2. Mean comparison for yield components of wheat in 2 growing seasons.

Treatment	Spike length	Spike per plant	Grain number per spike	1000 grain weight (g)	spike number/m²	Harvest index (%)
Year						
2010-2011	8.74ᵃ	7.31ᵇ	31.28ᵃ	34.35ᵇ	520.27ᵇ	43.42ᵇ
2011-2012	6.91ᵇ	8.14ᵃ	21.24ᵇ	45.86ᵃ	605ᵃ	44.36ᵃ

Different letter (s) indicates significant difference at $p \leq 0.05$.

The highest spike number per unit area was obtained in 12:4 row ratios of wheat and oilseed rape (611.6) followed by 8:3 (592.2) and 16:5 (534.1) treatments. Wheat monoculture had the lowest value (513.4) for spike per unit area (Figure 2). Similarly, the maximum grain yield per unit area was observed in A_3 (610.3 g/m²) that it was followed by A_2 (585.7 g/m²), without significant different. In contrasts, the minimum grain yield was achieved in sole crop of wheat (455.3 g/m²) (Figure 3a). Also, the highest and lowest the biological yield were belonged to 4:12 proportion of oilseed rape and wheat (1353.0 g/m²) and wheat monoculture (1072.7 g/m²) (Figure 3b). A_2 (8:3) and A_3 (12:4) had no significant difference in spike number, grain and biological yield per unit area, but they had significant difference with A_4 (16:5) and A_1 (wheat sole crop). Difference in biological yield per unit area between A_4 and A_1 was significant as same as grain yield and A_4 produced more grain and biological yield per unit area compare with A_1.

100% chemical fertilizer treatment had the positive and significant effect on grain and biological yield per unit area. Whereas, 50% chemical fertilizer + biofertilizer treatment led to produce low values of the mentioned traits (Table 4).

Table 3. Mean comparison for yield components of wheat for 4 cropping systems.

Treatment	Spike length	Spike per plant	Grain number per spike	Harvest index (%)
Crop. Sys.				
A_1	7.12^{b}	6.62^{b}	22.68^{c}	42.35^{b}
A_2	8.07^{a}	8.62^{a}	28.07^{ab}	43.87^{a}
A_3	8.41^{a}	8.42^{a}	30.18^{a}	45.04^{a}
A_4	7.71^{ab}	7.25^{b}	24.13^{bc}	44.32^{a}

Different letter (s) indicates significant difference at $p \leq 0.05$, A_1: monoculture of wheat, A_2: strip intercropping of wheat-oilseed rape with 8 rows of wheat and 3 rows of oilseed rape, A_3: strip intercropping with 12 rows of wheat and 4 rows of oilseed rape and A_4: strip intercropping with 16 rows of wheat and 5 rows of oilseed rape.

Cropping systems × fertilizers interactions led to significant effect on spike number per unit area as A_3B_1 treatment combination with 652.2 spike/m^2 was the highest that it had no significant difference with other treatment combinations, exception of A_1B_1 (511.4 spike/m^2) and A_1B_2 (515.4 spike/m^2), it means that intercropping systems could be profitable under either B_1 or B_2 for spike/m^2 trait and sole crops of wheat under B_1 and B_2 treatments had the lowest number of spike per unit area compare whit intercrops (Figure 4).

Table 4. Mean comparison for yield and yield components of wheat for 2 types of fertilizer.

Treatment	Grain yield (g/m^2)	Biological yield (g/m^2)
Fertilizer		
B_1	575.84^{a}	1301.69^{a}
B_2	513.65^{b}	1173.72^{b}

Different letter (s) indicates significant difference at $p \leq 0.05$, B1: 100% chemical fertilizer and B2: 50% chemical + biological fertilizer.

Discussion

Intercropping yields that approximate or exceed those of monocultures of the component crop species are necessary for the producer of intercropping system. In order to the continued cropping, our results showed that all intercropping combinations increased seed yield compared to sole crop of wheat. Mandal *et al.,* (1991), Malik *et al.,* (1998), Li *et al.,* (2001) and Khan *et al.,* (2005) reported the similar findings that intercropping systems are a beneficial method for increasing grain yield of wheat.

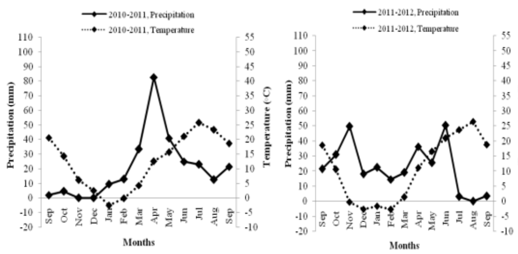

Fig. 1. Ambrothermic diagram (Walter and Gusen methods, P=2T) for monthly rainfall and mean air temperature during two growing seasons of the study (2010-2011 and 2011-2012).

In this study, seed yield increased 22.25, 25.38 and 13.72 percent in comparison with sole crop of wheat intercropping treatments of wheat-oilseed rape at 8:3, 12:4 and 16:5 rows, respectively. Intercropping 12:4 was superior over farmers' practice of planting pure crop and other intercropping treatments. Therefore, among intercropping systems, treatment of 12:4 combination significantly gave higher spike/m^2 (611.6), grain yield (610.3 g/m^2) and biological yield (1353.0 g/m^2) than that of sole wheat (513.4, 455.3 g/m^2 and 1072.7 g/m^2, respectively) (Figures 2, 3a and 3b). The mean of spike length, number of spike per plant and spike per unit area were higher for A_2 and A_3 as they consequently produced more grain yield per unit area than those of A_1 and A_4 (Table 3 and Figures 2 and 3a). The combinations of 8:3, 12:4 and 16:5 with 43.87%, 45.04% and 44.32% harvest indexes showed the profitability of intercropping systems (Table 3). Khan *et al.,* (2009) conducted a research on the intercropped wheat with oilseed rape and found that intercropping of 3 rows of wheat with 2 rows of oilseed rape produced the highest wheat seed yield. Bora (1999) concluded that to achieve higher yield advantage, a proper row ratio is necessary to maintain in row intercropping of wheat and mustard, because aerial competitive behavior of these 2 crops in association varies at different sowing proportion. This differential behavior of the 2 component crops with respect to inter-row competition may be due to their varying canopy height and spread. Average wheat canopy is lower than the mustard, and spread of mustard plants is greater than wheat. Thus, in intercropping, mustard has the advantage as it is more exposed to the sun and wheat suffers more as it grows under the mustard canopy (Singh *et al.,* 1992b; Singh *et al.,* 1995). Our results indicated that 16:5 row ratio of wheat and oilseed rape had almost similarly grain yield and yield components with monoculture of wheat, whereas, 12:4 (wheat-oilseed rape) and 8:3 combinations with produce high amount of yield components, at the least had more grain yield in comparison with 16:4 combination. It was observed that in various wheat and mustard intercropping treatments, the adverse effect of mustard increased with its increasing population and the lowest wheat yield was recorded at highest mustard population (Srivastava and Bohra, 2006; Srivastava *et al.,* 2007). In a field experiment conducted for 3 years at west Champaran in Bihar, wheat was intercropped with *B. juncea* in varying row ratio of 3:1, 3:2, 6:1, 6:2, 9:1 and 9:2, and the highest mean LER of 1.14 was recorded in 9:1 and 6:2 row combinations (Singh *et al.*, 1995). In general, the yield of the component crops in wheat and oilseed rape intercropping system has been found to improve with corresponding increase in their proportion in the system. This may probably be due to the differences among genotypes, fertilizer application, seed rate and other cultural and management practices. However, the specific row combination of wheat and oilseed rape is necessary to maximize yield advantage. Therefore, scope exists to improve and to stabilize the productivity and profitability from wheat and oilseed rape intercropping through proper adoption of row ratios.

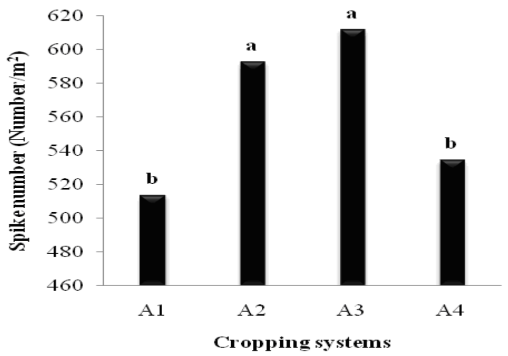

Fig. 2. Spike number per square meter of wheat at various cropping systems.

Different letter (s) indicates significant difference at $p \leq 0.05$, A_1: monoculture of wheat, A_2: strip intercropping of wheat-oilseed rape with 8 rows of wheat and 3 rows of oilseed rape, A_3: strip intercropping with 12 rows of wheat and 4 rows of oilseed rape and A_4: strip intercropping with 16 rows of wheat and 5 rows of oilseed rape.

In this investigation, the meteorological data depicted in figure 1 showed the marked variation in weather conditions during 2 years of experiment. Precipitation during the crop season in 2011-2012 was 57.3 mm higher than during 2010-2011, particularly in September, October and November. Consequently, to meet the water requirement of crops, more irrigation was given during the first year than the second. The average temperature during September, October and November, coinciding with the establishment and rosette form of wheat plants, remained colder during second year than the first, but in 2011, there was snow covering from November month. This resulted in a slightly better performance of crops during 2011-2012 than during 2010-2011. Harvest index at the second season was significantly higher than that of the first season. However, the difference of grain yield between 2 growing seasons was not statistically significant (Table 1).

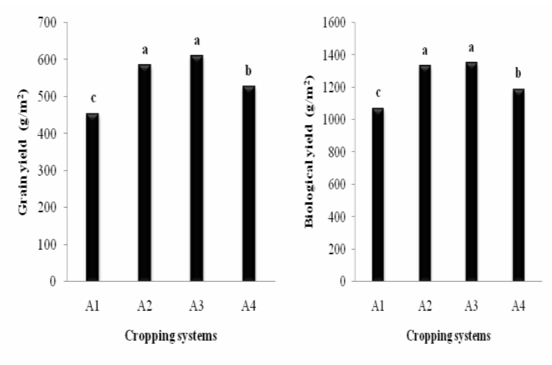

Fig. 3. Grain yield (a) and biological yield (b) of wheat at various cropping systems.

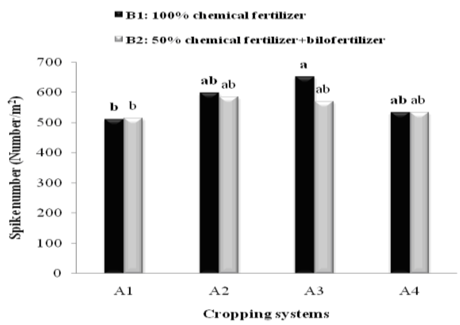

Fig. 4. Cropping systems effect on spike number per unit area at various types of fertilizer.

Application of the mixed chemical and biological fertilizers is one of the most important sustainable agriculture principles (Roy and Singh, 2006). Biofertilizers could be replaced instead of chemical fertilizers due to the hazardous nature for the environment. In this research, different types of fertilizer showed the significant variation on some of yield components, grain and biological yield, so that, B_1 treatment was better than B_2 treatment (Table 4). Thus, in this study biological fertilizers + 50% chemical fertilizer could not help plant for the production of same amount of grain yield per unit area compared to 100% chemical fertilizer treatment. Difference of grain yield/m^2 between B_1 and B_2 was 10.8%. These results are in contradictory with several reports on wheat and oilseed rape showing the positive role of biofertizers application on yield and yield components (Gupta and Samnotra, 2004; Khalid *et al.,* 2004; Ebrahimi *et al.,* 2007; Megawar and Mahfouz, 2010). Changes in biological production and yield in response to N supply have been observed in wheat (Fischer, 1993).

According to our results, it was suggested, strip intercropping of wheat and oilseed rape in 8:3, and 12:4 row ratios had the maximum yield components that it led to increase grain yield and it was concluded that other treatment combinations of chemical and biological fertilizers can apply in order to achieve profitable results for wheat yield and likewise environment.

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