DESERT

DESERT
Online at http://jdesert.ut.ac.ir

DESERT 16 (2011) 153-158

Evaluation of quantity and quality of the yield of two wheat cultivars in intercropping system

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Received: 14 February 2010; Received in revised form: 4 July 2010; Accepted: 3 September 2010

Abstract

In order to evaluate the yield, yield components and protein contents of two wheat cultivars (Zarrin and Gaspard) in sole cropping and intercropping systems,an experiment was conducted using replacement serious technique and different combinations of intercropping with high plant density and optimal of each cultivar. A factorial experiment was conducted in the form of randomized complete block design (RCBD) with three replications at the research farm of Agriculture Faculty of University of Zanjan at 2008-2009. The results showed that planting patterns has significant effect (α= 0.01) on grain yield, the average number of grain per spike and protein content of each cultivar.The effect of plant density levels on grain yield of Zarrin cultivar was significant (α= 0.01).The results indicated that the highest grain yield(9611 kg ha^{-1}) was obtained from 2:2 ratios of (50% Zarrin+50% Gaspard) cultivars in plant density of 400 seed per m^2 which had Land Equivalent Ratio (LER) above 1.79.Land equivalent Ratio Index(LER) calculation showed that all intercrops had advantage compare to sole cropping system.

Keywords: Intercropping system; Land equivalent ratio (LER); Sole cropping; Wheat

1. Introduction

Increasing world population and the urgent need of food products are of the basic problems of today's world. Yet most challenging problem in today's world, is food security of human as a first need(Essiet, 2001). In recent years, there has been increased interest in agricultural production systems in order to achieve high productivity and promote sustainability over time. Several factors can affect growth of the species used in intercropping, including cultivar selection, seeding ratios, and competition between mixture components (Caballero *et al*., 1995 and Carr *et al*., 2004). Competition is one of the factors that can have a significant impact on yield of mixture compared with pure cereal stands (Caballero *et al*., 1995). Higher yields have been reported when competition between the two species of the mixture was lower than competition within the same species (Vandermeer, 1990). Interplant competition usually includes competition for soil water,available nutrients, and solar radiation (Buxton and Fales ,1993). Competition can also have a significant impact on the growth rate of the different species used in mixtures. Several indices such as land equivalent ratio, relative crowding coefficient, competitive ratio, aggressivity, actual yield loss, monetary advantage, and intercropping advantage have been developed to describe competition and economic advantage in intercropping (McGilchrist, 1965; Ghosh, 2004 and Midya *et al*., 2005). Mixtures of field crops are still extensively grown in traditional agriculture, but where more mechanized methods are used, monocultures are more common. Also growing of variety mixtures instead of pure line varieties has been proposed as a means of obtaining higher and more stable yields. The suggested advantages of this cropping system include yield stability under adverse environmental conditions, efficient use of limited growth resources, biological diversity and potential

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control of pests and diseases. Many studies have shown that intercropping system out yielded monocultures of component crops (Baumann *et al*., 2001 and Lesoing and Francis, 1999).

The superiority of mixed cultivars over pure stands has been attributed generally to the significant variations of morphological characteristics including root system, plant height and leaf orientation which result in efficient exploitation of environmental resources, specifically light interception. Increased lodging resistance, improved disease resistance and weed control also have been reported by Jokinen (1991). Review of previous experiments results show that Bayat and Tabasi wheat intercropping in different plant density and combination to cause intercropping yield increase is the sole cropping systems (Mazaheri, 1990) and also the highest seeds yield was obtained from 50:50 ratios of Tajan(T) – Zagros(Z) cultivars in plant density of 400 seed in m^2 which had Land Equivalent Ratio (LER) above 1.25 . Calculation of LER revealed that seed yield in treatment TZTZTZ was 25% higher than the pure stand (Biabani, 2009). Intercropping of wheat varieties, especially varieties that have a height difference the yield may be increased. Why this is crisp and used to create canopy effectively from environmental sources of radiation, that to cause increased intercropping yield is the sole cropping systems (Sharifi and *et al*., 2000).The main objective of this study was to obtain the appropriate plant density and planting pattern, also to increase production quantity and quality or usefulness of grain yield of two wheat cultivar under intercropping.

2. Materials and methods

This study was conducted in 2008-2009 at research farm of Zanjan Agricultural faculty (36Â°, 37` N and 48Â°, 49.5` E), Zanjan - Iran. In this location, the average annual rainfall is 293.5 mm with altitude of 1634 meters above sea level. The soil of the experimental site was loamy clay with pH 7.54. Two wheat cultivars of Zarrin and Gaspard were used in this study. They were with average height of 85-95 and 70-80 cm, respectively. The design of the experiment was a factorial two plant densities of 330 (b_1) and 400 (b_2) seed in m^{-2} with six intercropping ratios of ofZarrin and Gaspard cultivars (two sole cropping and four intercropping), included: a_1=100% Zarrin, a_2=replacement with ratio of 1:1(50% Zarrin+ 50% Gaspard), a_3=replacement with ratio of 1:2(33% Zarrin+67% Gaspard), a_4=replacement with ratio of 2:1(67% Zarrin+33%Gaspard), a_5=replacement with ratio of 2:2 (50% Zarrin+ 50%Gaspard), a_6=100%Gaspard) in completely randomized blocks with 12 treatments. The final harvest area for measurement of grain at maturity was 1.6 m^{-2} taken from the 4 central rows. At harvest time, 10 plants of each cultivar were harvested randomly and used for determination of yield components including plant height, number of grains in spike and seed weight.

The advantage of intercropping and the effect of competition between the two species used in a mixture were calculated using different competition indices. The land equivalent ratio (LER) was used as the criterion for mixed stand advantage as both wheat cultivars were desired species (Willey and Osiru, 1972). In particular, LER indicates the efficiency of intercropping for using the resources of the environment compared with monocropping (Mead and Willey, 1980). The value of unity is the critical value. When the LER is greater than one the intercropping favors the growth and yield of the cultivars. In contrast, when LER is lower than one the intercropping negatively affects the growth and yield of the plants grown in mixtures (Ofori and Stern, 1987 and Caballero et al., 1995).
TheLER was calculated as:

$$LER = L_Z + L_G) \quad (1)$$

$$L_{Zarrin} = (Y_{ZG}/Y_Z), \quad L_{Gaspard} = (Y_{GZ}/Y_G) \quad (2)$$

where Y_Z and Y_G are the yields of Zarrin and Gaspard,respectively, as sole crops and Y_{ZG} and Y_{GZ} are the yields of Zarrin and Gaspard, respectively, as intercrops. Another coefficient that was used is the relative crowding coefficient (RCC or K) which is a measure of the relative dominance of one species over the other in a mixture (De Wit, 1960). The K was calculated as:

$$K(RCC) = (K_{Zarrin}\, K_{Gaspard}) \quad (3)$$

$$K_{Zarrin} = Y_{ZG}\, Y_{GZ} / (Y_Z - Y_G) Z_{ZG}, \quad K_{Gaspard} = Y_{GZ}\, Y_{ZG} / (Y_G - Y_Z) Z_{GZ} \quad (4)$$

where Z_{ZG} is the sown proportion of Zarrin in mixture with Gaspard and Z_{GZ} the sown proportion of Gaspard in mixture.When the product of the two coefficients (K Zarrin K Gaspard) is greater than one, there is a yield advantage, when K is equal to one there is no yield advantage, and when it is less than one there is a disadvantage.

Aggressivity is another index that is often used to indicate how much the relative yield increase in 'a' crop is greater than that of 'b' crop in an intercropping system (McGilchrist, 1965). The aggressivity is derived from the equation:

$$A_{Gaspard} = (Y_{GZ}/Y_G Z_{GZ}) - (Y_{ZG}/Y_Z Z_{ZG}) \quad (5)$$

if $A_{Gaspard}$=0, both crops are equally competitive, if $A_{Gaspard}$ is positive then the Gaspard is dominant, if $A_{Gaspard}$ is negative then the Gaspard is the dominated species. Accordingly,aggressivity for Zarrin can be derived from the equation $A_{Zarrin} = (Y_{ZG}/Y_Z Z_{ZG})$ _ $(Y_{GZ}/Y_G Z_{GZ})$. Also, competitive ratio (CR) is another way to assess competition between different species. The CR gives a better measure of competitive ability of the crops and is also advantageous as an index over K and aggressivity (Willey and Rao, 1980). The CR represents simply the ratio of individual LERs of the two component crops and takes into account the proportion of the crops in which they are initially sown. The CR is calculated according to the following formula:

$$CR_{Zarrin} = (LER_Z/LER_G)(Z_{GZ}/Z_{ZG}),$$
$$CR_{Gaspard} = (LER_G/LER_Z)(Z_{ZG}/Z_{GZ}) \quad (6)$$

Moreover, Banik et al. (2000) reported that the actual yield loss (AYL) index gave more precise information about the competition than the other indices between and within the component crops and the behaviour of each species in the intercropping system, as it is based on yield per plant. The AYL is the proportionate yield loss or gain of intercrops in comparison to the respective sole crop, i.e., it takes intoaccount the actual sown proportion of the component crops with its pure stand. In addition, partial actual yield loss (AYL Zarrin or AYL Gaspard) represent the proportionate yield loss or gain of each species when grown as intercrops, relative to their yield in pure stand. The AYL is calculated according to the following formula (Banik, 1996):

$$AYL = AYL_{Zarrin} + AYL_{Gaspard} \quad (7)$$

$$AYL_{Zarrin} = \{[(Y_{ZG}/X_{ZG})/(Y_Z/X_Z)]-1\},$$
$$AYL_{Gaspard} = \{[(Y_{GZ}/X_{GZ})/(Y_G/X_G)]-1\} \quad (8)$$

The AYL can have positive or negative values indicating an advantage or disadvantage accrued in intercrops when the main objective is to compare yield on a per plant basis. Also, intercropping advantage (IA) was calculated using the following formula (Banik et al., 2000):

$$IA = IA_{Zarrin} + IA_{Gaspard} \quad (9)$$

$$IA_{Zarrin} = AYL_{Zarrin} \times P_{Zarrin},$$
$$IA_{Gaspard} = AYL_{Gaspard} \times P_{Gaspard} \quad (10)$$

where P Gaspard and Zarrin is the commercial value of wheat (the current price is 3700 Rial per Kg.Data were analyzed using ANOVA. Effects were considered significant for p=0.01 from the F-test.Duncan multiple range test were conducted for mean comparison.

3. Results

The summary of statistical analysis of data for grain yield, yield components, plant height and protein content is shown inTable 1. Ratio showed a significant ($p<0.01$) effect on grain yield, protein content and number of grain in spike for both cultivars, but was for grain weight and plant height no significant Table 1. Plant density had a significant ($p<0.01$) effect on grain yield of Zarrin cultivar. Intercropping ratio×density had significant ($p<0.01$) effect on grain yield and protein content for both cultivars (Table 1). The more grain yields obtained from pure stands of the two cultivars were 6270 and 4537 kg ha^{-1} for Zarrin and Gaspard, respectively. Replacing one and two row of them together that is 1:1(9312 kg ha^{-1}), 1:2 (9475 kg ha^{-1}), 2:1 (7018 kg ha^{-1}) and 2:2 (9611 kg ha^{-1}) (Table 2) resulted increase in seed yield compared with their sole cropping. The results indicated that they could have utilized environmental resources available mixed planting system more efficiently.The LER characterizes the performance of an intercrop by giving the relative land area under sole crops, required to produce the yields achieved in intercropping (Mead and Willey, 1980).

A value of greater than one for LER indicates the advantage of intercropping over monoculture cropping system. In this experiment LER values were more than 1 for all intercropping ratios in densities. Maximum LER value (1.79) obtained from intercropping ratio (2:2) of the Zarrin and Gaspard cultivars (Table 2). Among the components of grain yield, No one than yield components were not affected significantly by plant density (Table 1) .In all cases, total LER value for treatments increased with different seeding ratios in mixtures.Yield advantage in terms of total LER was greatest in the cases of Zarrin - Gaspard mixture (1.79) at the (2:2) seeding ratio and of Zarrin - Gaspard mixture (1.78) at the (1:2) seeding ratio (Table 2). This indicates that 79% and 78% more area would be required by a sole cropping system to equal the yield of intercropping system (Midya et al. , 2005). In these cases, total LER was significantly different from 1.00, which shows an advantage from intercropping over pure stands in terms of the use of environmental resources for plant growth (Mead and Willey, 1980).

The results indicated that the highest grain yield total was obtained from (2:2) ratios of Zarrin-Gaspard mixture with plant density 400 of seed in m^2 which had Land Equivalent Ratio (LER) above 1.79 Calculation of LER revealed that grain yield in treatment a_5b_2 was 53.28 and 111.83 percent higher than sole cropping of Zarrin and Gaspard cultivars, respectively(Table 2). The results suggest clearly that in a mixed planting system where they could have utilized environmental resources available to both cultivars more efficiently. Therefore, in a condition like this, higher yield would be obtained from intercropping of cultivars compared with the yield from their sole cropping.The results indicated that the highest protein content was obtained from sole cropping systems for each Zarrin and Gaspard cultivars (Table 2).

Table 1. Analysis of variance of Grain yield, Protein content, Plant height and yield components of Zarrin and Gaspard cultivars

	Protein ontent (%) MS		Grain yield (kgha^{-1}) MS		No.of grain in spike MS		Grain weight (gr) MS		Plant height (cm) MS	
Treatments	Zarrin	Gaspard	Zarrin	Gaspard	Zarrin	Gaspard	Zarrin	Gaspard	Zarrin	Gaspard
Intercropping atio (R)	7.16**	15.23**	716630.3**	7439277.3**	93.22**	33.46**	3.3^{ns}	9.8^{ns}	60.75^{ns}	60.08^{ns}
Density (D)	0.97^{ns}	7.12^{ns}	1084656.6**	1273945.3^{ns}	16.38^{ns}	3.52^{ns}	0.57^{ns}	19.97^{ns}	0.45^{ns}	45.63^{ns}
R × D	2.95**	3.43**	2088715.4**	1155073.3**	10.08^{ns}	21.27**	1.58^{ns}	1.59^{ns}	28.03^{ns}	21.05^{ns}

** Significant at the 0.01 probability levels, ns: Not significant (p>0.01)

Table 2. Grain yield, Protein content and Land Equivalent Ratio (LER) for sole cropping and intercropping system of Zarrin and Gaspard cultivars in six seeding ratios and two plant densmty

	Treatments	seed ratios			Protein content (%) grain yield(kg ha^{-1})		LER
		Zarrin	Gaspard	Total	Zarrin	Gáspard	
a_1b_1	100	6270	` _	6270	18.31	_	
a_1b_2	10°	5786	_ ((	57x6	16®06	_	
a_2b_1	(1:1)	6164	3147	9312	14®93	` 16.x1	q.7
a_2b_2	(1:1)	4710	1980	6690	14.93	13.43	1.2
a_3b_1	(1:2)	5690	3785	9475	16.87	15.58	1.78
a_3b_2	(1:2)	6162	2477	8639	15.56	16.02	1.55
a_4b_1	(2:1)	5897	1121	7018	13.81	14.06	1.19
a_4b_2	(2:1)	4595	1351	5946	15.00	14.25	1.04
a_5b_1	(2:2)	5846	2916	8762	15.18	13.37	1.6
a_5b_2	(2:2)	5975	3636	9611	15.75	12.25	1.79
a_6b_1	100	_	4537	4537	17.50_		
a_6b_2	100	_	4002	4002	_	16.50	

a_1: Sole cropping of Zarrin a_2,a_3,a_4 and a_5: ratios of intercropping
a_6: Sole cropping of Gaspard b_1: Optimal plant density b_2: High plant density

A similar trend to that of LER, Aggressivity, CR, and RCC or K was also observed for AYL. In particular, AYL $_{Zarrin}$ had positive values in the all Zarrin-Gaspard mixture (Table 3), which indicates a yield advantage for Zarrin cultivar, robably because of the positive effect of Gaspard on Zarrin when grown in association, the Zarrin cultivar was the dominant one because the partial AYL of Zarrin cultivar was greater than the partial AYL of Gaspard, the AYL index can give more precise information than the other indices on the inter- and intra-specific competition of the component crops and the behavior of each species involved in the intercropping systems. Quantification of yield loss or gain due to association with other species or the variation of the plant population could not be obtained through partial LERs, whereas partial AYL shows the yield loss or gain by its sign and as well as its value. In contrast, in some mixtures, the AYL$_{Gaspard}$ negative sign indicating a yield loss, compared with its sole crop yield (Table 3) , this could not compensate the yield loss of the corresponding species in mixture indicating a disadvantage of intercropping (AYL negative). The total AYL was positive in the all mixtures (Table 3), indicating an advantage from intercropping over sole cropping.

Similarly, the IA, which is also an indicator of the economic feasibility of intercropping systems, indicated that the most advantageous mixtures was the Zarrin-Gaspard mixture at the (1:2) seeding ratio, with IA values +1.07, (Table 3). All the other treatments showed positive IA value. The fact that IA values were positive for all the treatments, indicate that these intercropping systems had the highest economic advantage. These findings were also in agreement with the results of LER and the other competition indices (Table 2). Similarly, Ghosh (2004) found that when the LER and RCC were higher there is also significant economic benefit expressed with higher MAI values. The total K or RRC was above one in all the cases of Zarrin-Gaspard mixtures which indicates a definite yield advantage due to intercropping. K values followed a similar trend with the LER values (Table 3).

Table 3. Actual yield loss or gain (AYL), Intercropping advantage (IA) and Relative Crowding Coefficient (RCC) for sole cropping and intercropping systems of Zarrin and Gaspard cultivars in six seeding ratios and two plant density

Treatments	Seed ratios	Actual yield loss			Intercropping advantage			Relative Crowding Coefficient (RCC)
		AYL_{zarrin}	$AYL_{gaspard}$	AYL_{total}	IA_{zarrin}	$IA_{gaspard}$	IA_{total}	
a_1b_1	100							
a_1b_2	100							
a_2b_1	(1:1)	0.96	0.45	1.41	0.48	0.22	0.7	1.35
a_2b_2	(1:1)	0.62	- 0.01	0.61	0.31	- 0.005	0.3	1.64
a_3b_1	(1:2)	1.74	0.3	2.05	0.87	0.15	1.02	1.04
a_3b_2	(1:2)	2.22	- 0.07	2.15	1.11	- 0.03	1.07	1.72
a_4b_1	(2:1)	0.4	- 0.21	0.18	0.2	- 0.1	0.1	3.63
a_4b_2	(2:1)	0.18	0.02	0.20	0.09	0.01	0.1	2.35
a_5b_1	(2:2)	0.86	0.34	1.2	0.43	0.17	0.6	1.38
a_5b_2	(2:2)	1.06	0.81	1.88	0.53	0.4	0.93	1.13
a_6b_1	100							
a_6b_2	100							

a_1: Sole cropping of Zarrin a_2,a_3,a_4 and a_5: ratios of intercropping
a_6: Sole cropping of Gaspard b_1: Optimal plant density b_2: High plant density

The results of aggressivity conformed with those of LER and the relative crowding coefficient.In particular,Zarrin was the dominant cultivar(A Zarrin positive) in all the treatments of Zarrin-Gaspard mixtures ,and Gaspard was the nondominant cultivar as measured by the negative value of aggressivity(Table 4).In all mixtures the values of CR for Zarrin were greater than for Gaspard indicating the dominance of Zarrin. This clearly shows that in all the mixtures, Zarrin was more competitive than the associated Gaspard. In all cases, the CR of Gaspard decreased as the proportion of Zarrin increased in the mixtures. Moreover, the values of CR for Zarrin were greater than for Gaspard in all seeding ratios (Table 4).

Table 4. Aggressivity index (A) and Competitive ratio index (CR) for sole cropping and intercropping systems of Zarrin and Gaspard cultivars in sixseeding ratios andtwo plant density

Treatments	Seed ratios	Aggressivity (A)		Competitive ratio (CR)	
		A_{zarrin}	$A_{gaspard}$	CR_{zarrin}	$CR_{gaspard}$
a_1b_1	100				
a_1b_2	100				
a_2b_1	(1:1)	0.12	- 0.12	1.35	0.73
a_2b_2	(1:1)	0.15	- 0.15	1.64	0.60
a_3b_1	(1:2)	0.01	- 0.01	2.11	0.47
a_3b_2	(1:2)	0.223	- 0.223	3.49	0.28
a_4b_1	(2:1)	0.34	- 0.34	1.79	0.55
a_4b_2	(2:1)	0.228	- 0.228	1.15	0.86
a_5b_1	(2:2)	0.13	- 0.13	1.38	0.72
a_5b_2	(2:2)	0.06	- 0.06	1.13	0.87
a_6b_1	100				
a_6b_2	100				

a_1: Sole cropping of Zarrin a_2,a_3,a_4 and a_5: ratios of intercropping
a_6: Sole cropping of Gaspard b_1: Optimal plant density b_2: High plant density

4. Discussion and Conclusion

Creation of a broader environmental tolerance and canopy architecture associated with intercropping of wheat cultivars may enhance wheat grain yield. In the present study, intercropping of the two wheat cultivars created a wavy type canopy consisted of alternate rows of shorter and taller plants. In contrast to the monoculture of either cultivar, this canopy architecture had a greater potential for intercepting radiation and thus dry matter production. Earlier studies have demonstrated an enhancement effect of intergenotypic competition on grain yield of wheat cultivars grown in intercropping systems (Jokinen, 1991;

Valentine, 1982; Juskiw *et al*., 2000 and Biabani, 2009). The results obtained in the present study are consistent with these reports. The yield advantage of the intercropping systems indicated 35.7% and 91.6% increase compared with the sole crop of the Zarrin and Gaspard cultivars, respectively. These results were in agreement with descriptions of present study. Mixture of varieties benefit from the association by production of more uniform leaf distribution and also by reduction of competition among plants for using of sunlight with created a wavy canopy because of high different between cultivars which causes to intercept more sunlight.

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