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Full Length Research Paper

Intercropping of wheat (*Triticum aestivum*) and bean (*Vicia faba*): Effects of complementarity and competition of intercrop components in resource consumption on dry matter production and weed growth

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Wheat (*Triticum aestivum*) and bean (*Vicia faba* L.) sole crops and their mixture in three planting pattern (M_1: alternate-row intercrop, M_2: within-row intercrop, M_3: mixed intercrop) were used to investigate the amount of resource consumption in terms of photosynthetically active radiation (PAR) interception, water and nutrient uptake. The experiment was carried out as randomized complete block design with four replications. The results show that intercropping systems had a significant effect on environmental resources consumption, where intercropping systems had more light interception and water, and nutrient uptake compared to sole crops, suggesting the complementarity effect of intercropping components in resources consumption. The ability of wheat and bean was different in intercropping systems in absorbing nutrients because of their differences in root morphology and cation exchange capacity. Regarding weed suppressions, intercrops were more effective than wheat sole crops, which were related to lower availability of environmental resources for weeds in intercropping systems.

Key words: Cereals, competitive ratio, intercropping, legume, resource consumption.

INTRODUCTION

Intercropping of cereals and legumes is important for development of sustainable food production systems, particularly in cropping systems with limited external inputs (Adesogan et al., 2002). This may be due to some of the potential benefits for intercropping systems such as high productivity and profitability (Yildirim and Guvence, 2005), improvement of soil fertility through the addition of nitrogen by fixation and extraction from the component legume (Hauggaard-Nilsen et al., 2001), efficient use of environmental resources (Knudsen et al., 2004), reducing damages caused by pests, diseases and weeds (Banik et al., 2006; Sekamatte et al., 2003), and improvement of forage production and quality through the complementary effects of two or more crops grown simultaneously on the same area of land (Bingol et al., 2007; Lithourgidis et al., 2007; Ross et al., 2004).

Yield of intercropping are often higher than in sole cropping systems (Lithourgidis et al., 2007; Dahmardeh et al., 2009). The reasons are mainly that resources such as water, light and nutrients can be utilized more efficiently than in the respective sole cropping systems (Liu et al., 2006). The underlying principle of better resource use in intercropping is that, if crops differ in the way they utilize environmental resources when grown together, they can complement each other and make better combined use of resources than when they are grown separately (Ghanbari-Bonjar, 2000). Willey (1990) in a review on intercropping, considered resource use as the biological basis for obtaining yield advantages. Yield advantages occur when intercrop components compete only partly for the same plant growth resources, and inter-specific competition is less than intra-specific competition (Vandermeer, 1989). Ideally, cultivars suitable for intercropping should enhance the complementary effects between species (Davis and Woolley, 1993). Light, water and nutrients are more completely absorbed and converted to crop biomass by intercropping. This is a result of differences in competitive ability for growth factors between intercrop components (Ofori and Stern, 1987). In terms of competition, the components are not competing

Table 1. Physical and chemical characteristics of the soil experimental field.

Parameter	Value
Depth	0.60
Organic matter (%)	4.5
Texture	Silt loam
Mg (mg kg^{-1})	61.4
Ca (mg kg^{-1})	3151.14
K (mg kg^{-1})	175.16
P (mg kg^{-1})	40.16
N (mg kg^{-1})	2.06
pH	7.2

Table 2. The meteorological data for wheat-bean intercropping area in 2009 to 2010.

Month	Temperature (°C)	Rainfall (mm)
January	5.06	56.6
February	4.94	47.5
March	7.26	35.5
April	8.74	52.2
May	12.04	34.8
June	14.35	59.8
July	17.7	38.2
August	17.6	68.8
September	14.42	70.3
October	10.8	75.3
November	7.3	81.3
December	5.1	76.1

for the same ecological niches and interspecific competition is weaker than in-traspecific competition for a given factor (Vandermeer, 1989). Efficient utilization of available growth resources is fundamental in achieving sustainable systems of agricultural production. However during the last 50 years, agricultural intensification in terms of plant breeding, mechanization, fertilizer and pesticide use, intercropping has disappeared from many farming systems (Hauggaard-Nielsen et al., 2001).

It is important for agronomists to find ways to improve either or both the absorption and conversion efficiencies of intercrops. The success of intercrops relative to sole crops might be determined by various agronomic practices which affect the nature of the interaction between the species and thus, affect their use of limiting resources. Such practices include relative density of component crops, supplies of limiting resources and the intimacy with which crops are intercropped. This experiment deals with the intimacy of intercropping, that is, planting pattern. This experiment was designed to quantify the benefits of intercropping in terms of (i) resource consumption (ii) dry matter production and (iii) weed suppression.

MATERIALS AND METHODS

Experimental site

The experiment was carried out during the 2009 to 2010 growing season on a research field in Ramhormoz, Iran (46º36´ N, 31º16´ E, altitude 150 m above sea level). The soil texture of experimental site was silt loam with pH of 7.2. The research field is located in a semi-arid region, where the summer is hot and dry and winter is cold and rainy. Details of field and soil characteristics and meteorological data of experimental site are given in Tables 1 and 2.

Experimental design

The treatments were compared in a complete randomized block design with four replications. Five treatments were included in the experiment as showed in Table 3. The intercrop composition was based on the replacement design (Snaydon, 1991), in which total population was equivalent to sole crop optima. The plots size was 10.2 m^2 (1.07 × 6 m) and was drilled longitudinally.

Table 3. The description of experimental treatments.

Treatment	Description
B	Sole bean
W	Sole wheat
M_1	Alternate-row intercrop
M_2	Within-row intercrop
M_3	Mixed intercrop

B, sole bean; W, sole wheat; M_1, alternate-row intercrop; M_2, within-row intercrop; M_3, mixed intercrop.

Table 4. Diary of activities.

Date	Operation
17th October 2009	Harrow
20th October 2009	Experiment drilled
4th April 2010	1st PAR measurement
25th April 2010	2nd PAR measurement
14th May 2010	1st Soil moisture measurement
14th May 2010	3rd PAR measurement
28th May 2010	1st Temperature measurement
30th May 2010	4th PAR measurement
29th June 2010	2nd Soil moisture measurement
8th June 2010	2nd Temperature measurement
19th June 2010	5th PAR measurement
22nd June 2010	3rd Soil moisture measurement
7th July 2010	3rd Temperature measurement
11th July 2010	6th PAR measurement

Planting

The site was ploughed to 0.2 to 0.3 m depth after the removal of forage maize followed by harrowing in the early autumn prior to drilling of the trial. The wheat and bean were drilled on 20th, October 2009. Wheat and bean were sown to a depth of approximately 3 and 5 cm, respectively. Seed rates of 48 and 480 per m^2 seeds of bean and wheat were sown to allow for thinning down to an approximate plant population of 32 and 400 plants per m^2. The wheat cultivar, Marris Widgeon, was selected for its popularity. It was also hypothesized that long straw might reduce competitive shading by the beans. All wheat seeds were treated with Panctine® for protection against important seed-borne diseases. The bean cultivar chosen was Punch. During the growing season, the experimental site did not receive any agrochemical spray or fertilizer.

Measurement

Photosynthetically active radiation (PAR) was measured between 12 to 14 h on different occasions (Table 4). A sun fleck ceptometer (model SF-80T) was used to measure above the plant canopy and at the soil surface at five randomly selected locations within each plot. Mean values for each plot were then used to calculate the percentage of PAR, intercepted by the plant canopy.

Soil water balance was expected to be influenced by different canopy system. Soil water content at 0 to 0.25 m depth was determined on several occasions during the growing season (Table 4). Soil samples were taken from three locations within each plots and a well mixed sample from each plot was used to determine soil moisture content by gravimetric measurement. Soil temperature was recorded at depth of 0 to 10 cm below the surface on three occasions in all plots (Table 2), using a soil thermometer.

Nutrients uptake by intercropping components were determined by measuring Ca, Mg, K and P amount of wheat and bean tissues, using atomic absorption spectrophotometer (Model AA110).

At harvest time, the earlier mentioned plant parts were harvested by hand cutting the plant 2 cm above the soil surface from a 1 m^2 quadrate. Then intercrops were separated into wheat, bean and weeds. Samples were oven dried at 70°C to constant weights, and dry weight, grain yield were recorded.

Data analysis

Relative yield total for intercrops of wheat and bean was calculated:

$$RYT = (Y_{ij} / Y_{ii}) + (Y_{ji} / Y_{jj})$$

Where, Y is yield per unit area, Y_{ii} and Y_{jj} are sole crop yield of the component crops i and j, respectively and Y_{ij} and Y_{ji} are intercrop yield. A RYT > 1 indicate an advantage from intercropping in terms of environmental resource use. A RYT < 1 indicate that environmental resources for plant growth had been used more efficiently by sole crops than by the intercrops.

The competitive ability of bean for nutrient to wheat was evaluated by calculating the competitive ratio of bean with respect to wheat (CR_b) or competitive ratio of wheat with respect to bean

Table 5. Effect of different cropping system on percentage of PAR interception by crop canopies.

Cropping system	163 DAS	182 DAS	201 DAS	222 DAS	242 DAS	260 DAS	Mean
B	76.7^a	89.2^a	98.2^a	99.2^a	93.0^a	68.2^c	87.4^a
M_1	72.2^b	85.2^b	91.5^b	96.5^a	96.5^a	87.7^a	88.3^a
M_2	72.5^b	82.7^b	91.0^b	96.2^a	95.0^a	87.7^a	87.5^a
M_3	72.0^b	84.7^b	90.75^b	95.5^a	96.0^a	87.2^a	87.7^a
W	46.2^c	53.0^c	60.7^c	63.7^b	71.5^b	72.0^b	61.2^b
Mean	67.9	79.0	86.4	90.2	90.4	80.6	82.4

B, Sole bean; M_1, alternate-row intercrop; M_2, within-row intercrop; M_3, mixed intercrop; W, sole wheat; DAS, day after seeding; LSD for main effect of cropping system = 1.51.

Table 6. Effect of different cropping system on soil temperature at 0 to10 cm depth (°C).

Cropping system	B	M_1	M_2	M_3	W	Mean	LSD (P < 0.05)
200 DAS	13.1^c	14.3^b	14.4^b	14.7^b	16.5^a	14.6	0.40
227 DAS	13.6^d	13.8^{d,c}	14.0^{b,c}	14.2^b	14.1^a	14.1	0.32
256 DAS	20.7^a	18.6^b	18.7^b	19.0^b	19.6^a	19.6	0.68

B, Sole bean; M_1, alternate-row intercrop; M_2, within-row intercrop; M_3, mixed intercrop; W, sole wheat; DAS, day after seeding.

(CRw):

$$CR_b = (Yij / Yii \div Yji / Yjj) \times Zij / Zji$$

Where, CR_b is the competitive ratio of bean with respect to wheat; Yij is the nutrient uptake by bean in intercropping; Yii is the nutrient uptake by bean in sole crop; Yji is the nutrient uptake by wheat in intercropping; Yjj is the nutrient uptake by wheat in sole crop; Zij is the part of intercropping allocated to bean and Zji is the part of intercropping allocated to wheat.

Since the CR values of the two crops will in fact reciprocate of each other, it will often be sufficient to consider the values of only one (Willey, 1990). This ratio value gave the exact degree of competition, by indicating the number of times in which the dominant species is more competitive than the recessive species.

The analysis of variance of the data and the comparison of means on the basis of the least significant difference (LSD) were carried out, using MSTATC software.

RESULTS

PAR interception

The percentage of PAR interception was significantly (P < 0.01) affected by cropping system. The mean of PAR interception averaged over sampling dates by intercrop treatments and sole cropped bean were significantly (P < 0.05) higher than that for sole cropped wheat. The mean percentage of PAR interception for intercrop treatments and sole bean were similar (Table 5.). The mean PAR interception averaged over cropping system increased up to 242 DAS (Table 5.). The intercrops intercepted more PAR than that for wheat sole crop treatment.

Soil temperature

Soil temperature was significantly (P < 0.01) affected by cropping systems. The soil temperature for intercrops treatments at all the three sampling dates was significantly (P ≤ 0.05) lower than for sole cropped wheat (Table 6). At 200 and 277 DAS, soil temperatures under the sole bean canopy were significantly (P < 0.05) lower than for intercrop treatments.

However, at 256 DAS, this was reversed. This could be due to higher light interception by intercrops compared to sole crop bean later in the season (Table 5), resulting in more shading and lower soil temperatures.

Soil moisture content

The moisture content of soil was significantly (P < 0.01) influenced by cropping system (Table 7). Moisture content of soil in sole cropped wheat at all the three sampling dates was significantly (P < 0.05) higher than for intercrop treatments and bean sole crop. Except for 201 DAS, there were no significant differences between sole cropped bean and intercropped treatments.

Nutrient uptake

Total magnesium (Mg) uptake was significantly (P < 0.01) affected by cropping system (Table 8). Mg uptake by intercrops was significantly greater than for sole wheat (except for M_2); were also significantly greater than that

Table 7. Effect of different cropping system on percentage of soil moisture content at 0 to 20 cm depth.

Cropping system	B	M_1	M_2	M_3	W	Mean	LSD (P < 0.05)
201 DAS	17.5[c]	19.5[b]	19.0[b,c]	19.5[b]	21.5[a]	19.4	1.71
220 DAS	12.7[b]	14.2[b]	13.5[b]	13.7[b]	18.7[a]	14.6	1.73
241 DAS	18.2[b]	19.5[b]	18.7[b]	19.2[b]	23.0[a]	19.7	1.53

B, sole bean; M_1, alternate-row intercrop; M_2, within-row intercrop; M_3, mixed intercrop; W, sole wheat; DAS, day after seeding.

Table 8. Effect of different cropping system on nutrient uptake (kg ha^{-1}).

Cropping system	Mg	Ca	K	P
B	12.55[b]	39.89[a]	204.7[a,b]	33.29[a]
M_1	14.02[a]	43.97[a]	214.9[a]	34.46[a]
M_2	13.95[a,b]	43.5[a]	202.8[b]	32.31[a]
M_3	14.19[a]	40.37[a]	204.6[a,b]	32.10[a]
W	4.58[c]	4.36[b]	55.76[c]	11.23[b]
Mean	11.86	34.42	176.58	28.68

B, sole bean; M_1, alternate-row intercrop; M_2, within-row intercrop; M_3, mixed intercrop; W, sole wheat. Different letters in each column indicate significance at P ≤ 0.05 %.

Table 9. Effect of different cropping system on crops dry weight ($t.ha^{-1}$) and dry weight of weeds ($kgha^{-1}$).

Cropping system	B	M_1	M_2	M_3	W	Mean	LSD (P < 0.05)
Crop dry weight	13.38[b]	14.94[a]	14.68[a]	14.52[a]	6.24[c]	12.75	0.725
Weeds dry weight	154.0[a]	40.75[b,c]	38.75[b,c]	47.75[b]	25.25[c]	61.30	21.8

B, sole bean; M_1, alternate-row intercrop; M_2, within-row intercrop; M_3, mixed intercrop; W, sole wheat. Different letters in each row indicate significance at P ≤ 0.05 %.

of sole bean (Table 8). There were no significant differences between intercrops for Mg uptake. The mean Mg uptake by intercrop plots was 3.04 and 1.11 times that of sole wheat and sole bean plots, respectively.

Calcium (Ca) uptake also was significantly (P < 0.01) affected by cropping systems. Intercrops and sole bean showed significantly greater Ca uptake than for sole wheat (Table 8). In general, Ca uptake by intercrop treatments tended to be greater than for sole bean (Table 8), though this was not significant. The mean of Ca uptake by intercrops were 9.7 and 1.06 times greater than those of wheat and sole bean, respectively.

Potassium (K) uptake was significantly (P < 0.01) influenced by cropping system. Intercrops and sole bean treatments absorbed more K than wheat sole cropped (Table 8). Mostly, there was no significant difference between intercrops and bean sole crop. The mean potassium uptake, averaged over three intercrops was 3.7 and 1.02 times greater than those of sole wheat and sole bean, respectively.

Phosphorus (P) uptake was significantly affected by cropping system (P < 0.01). The amount of P captured by intercrops and bean sole crop treatments was significantly (P < 0.05) greater than that for sole wheat (Table 8). The mean of total P uptake by intercrops was 2.93 times greater than that of sole wheat. There was no significant difference between P uptake in intercrops and sole bean.

Dry weight of intercrop components

Dry weights of all intercrops were significantly (P < 0.05) greater than those of sole crops (Table 9) and exceeded the expected yield [(sole bean yield + sole wheat yield) / 2]. There was no significant difference between intercrops grown with different planting patterns. Bean sole crop produced significantly greater dry weight than wheat sole crop. The mean dry weight averaged over intercrops was 2.35 and 1.10 times that of sole wheat and sole bean, respectively (Table 9). The weed biomass in bean sole crop was significantly (P < 0.05) greater than in sole wheat sole crop and intercrops. Weed dry weight showed no significant differences between different intercrop

Table10. Effect of different cropping system on relative yield total for dry matter production.

Cropping system	M_1	M_2	M_3	Mean	LSD (P < 0.05)
RYT	1.50	1.42	1.45	1.46	0.088

M_1, alternate-row intercrop; M_2, within-row intercrop; M_3, mixed intercrop; W, sole wheat.

Table 11. Effect of different cropping system on intercrop competition for nutrient.

Cropping system	*CR_b for Mg	CR_b for Ca	**CR_w for K	CR_w for P
M_1	1.14^b	1.05^a	1.32^a	1.51^a
M_2	1.37^a	1.21^a	1.13^b	1.23^b
M_3	$1.29^{a,b}$	1.24^a	1.02^b	$1.31^{a,b}$
Mean	1.27	1.17	1.16	1.30

M_1, Alternate-row intercrop; M_2, within-row intercrop; M_3, mixed intercrop.
*Competitive ability of bean with respect to wheat (CR_b); **competitive ability of wheat with respect to bean (CR_w). Different letters in each column indicates significance at $P \leq 0.05$ %.

Table 12. Effect of different cropping system on relative yield total for nutrient uptake.

Cropping system	M_1	M_2	M_3	Mean	LSD (P < 0.05)
RYT for Mg	1.60	1.52	1.57	1.42	0.176
RYT for Ca	1.96	1.82	1.73	1.62	0.204
RYT for K	1.79	1.62	1.59	1.50	0.138
RYT for P	1.73	1.53	1.54	1.45	0.218

M_1, Alternate-row intercrop; M_2, within-row intercrop; M_3, mixed intercrop.

planting patterns. Weed dry weight in intercrops was greater than that for sole wheat (but apart from M_3,); not significantly greater than that of sole wheat (Table 9).

Resource complementarity in terms of dry weight

The mean level of resource complementarity, as measured by RYT was significantly greater than 1.0. This indicate that, the component crops used at least partially different resources. RYT across intercrop treatment were similar (Table 10). The mean RYT averaged over the intercrop treatments for dry weight and grain were 1.46 and 1.31, respectively. Therefore, dry weight and intercrop treatments were 46 and 31% more advantageous than sole crops, respectively.

Competitive ability for nutrient uptake

Competitive ratio value gives the exact degree of competition by indicating the number of times in which the dominant species is more competitive than the recessive species (Ghanbari-Bonjar, 2000). The competitive ratio of bean with respect to wheat (CR_b) for Mg was significantly (P < 0.05) greater than 1.0 (Table 11). The mean of CR_b averaged over three intercrops for Mg uptake was 1.20, indicating that for Mg uptake, bean was 1.20 times more competitive than wheat. The mean of CR_b for Ca uptake also was greater than 1.0 but statistically non significant (P > 0.05) (Table 11). The mean of CR_b averaged over three intercrops for Ca uptake was 1.17, indicating that concerning Ca uptake, bean was 1.17 times more competitive than the wheat.

The competitive ability of wheat with respect to bean (CR_w) for K and P uptake was significantly (P < 0.01 and P < 0.05, respectively) greater than 1.0 (Table 11). The mean of CR_w averaged over intercrops for K and P was 1.16 and 1.35, respectively, indicating that concerning K and P uptake, wheat was 1.16 and 1.35 times more competitive than bean.

Resource complementarity in terms of nutrient uptake

The mean level of resource complementarity in terms of nutrient uptake, as measured by RYT for Mg, Ca, P and K were significantly (P < 0.01) greater than 1.0 (Table 12). This means that, in terms of nutrient uptake, there was resource complementarity between wheat and bean in intercropping. The higher mean RYT averaged over intercrops for nutrient uptake was recorded for Ca (1.62), followed by K (1.50), P (1.45) and Mg (1.42). This indicate that, for Ca, K, P and Mg use efficiency, intercrops were 62, 50, 45 and 42 percentages more efficient compared to wheat and bean sole crops.

DISCUSSION

Wheat and bean reached their PAR interception at 260 and 222 DAS, respectively (Table 5). Therefore, solar radiation which would be otherwise wasted due to poor growth of wheat early in the season, and bean leaf senescence at the end of the season can be utilized more efficiently by wheat-bean intercropping. Thus, intercrop canopies can intercept PAR more effectively than sole crops. So, as concluded by Watiki et al. (1993) and Eskandari and Kazemi (2011), intercropping leads to an increase in the total amount of PAR captured and PAR seem to play a relatively important role in determining total intercrop productively. As concluded by Keating and Carberry (1993), wheat and bean can differ in PAR interception because of differences in their vertical arrangement of foliage and canopy architecture and can therefore intercept more PAR compared to sole crops.

The soil temperature was changed by the cropping system which agrees with the finding of Eskandari and Ghanbari (2009), so that soil temperatures under intercrops and bean sole crops were lower than under wheat sole crops. This could be due to higher light interception (Table 5), causing a higher shading and lower temperature, which agrees with the finding of Harris and Natarajan (1987), who suggested that the micro climate within the canopy of cropping systems were altered, so that shading reduced canopy temperature. Therefore, it seems as stated by Eskandari et al (2009), that percent of light interception by canopies would be a major factor affecting soil temperature.

Root system morphology and fine root distributions are cardinal factors in determining the magnitude of below ground interspecific competition in mixed species systems. To improve the utilization efficiency of soil nutrient resources by intercropping systems, the spatial distribution and activities of roots requires elucidation (Hauggaard-Nielsen et al., 2001). Wheat-bean intercrops and bean sole crop appeared to extract a similar but greater amount of soil water than sole crops of wheat. Intercropping may be more efficient at exploiting a larger total soil volume if component crops have different rooting habits, especially depth of rooting (Ahlawat et al., 1985). Lower soil moisture content in intercrops treatments compared to sole cropped wheat could not be due to higher evaporation from the soil surface, because soil temperatures under intercrops were lower than sole cropped wheat (Table 6). One explanation for more water extraction with intercrops and bean sole crops could be as a result of more intensive canopies such that the sole bean and intercrops were able to extract more water from the soil layers, finally resulting in a drier soil profile compared to that for sole wheat.

The nutrient uptake in terms of Mg, Ca, K, P and N in intercropping was higher than the mean for sole crops. Greater nutrient uptake is usually presumed to be possible because of some complementary exploration of the soil profile by the components crops (Ahlawat et al., 1985) or fuller use of resources over time (Willey, 1990). Higher total nutrient uptake has been reported by several authors (Bulson et al., 1997; Choudhury and Rosario, 1994; Kalka and Nepalia, 2006). The greater nutrient uptake has very often claimed to be associated with yield advantages (Willey, 1990; Choudhury and Rosario, 1994).

Bean was more competitive than wheat for Ca and Mg (Table 11). The roots of legumes generally have a root cation exchange capacity (CEC) about twice that of cereal roots. A plant root surface having high CEC might absorb relatively more divalent cations such as Ca and Mg than a plant root from a cereal, with a low root CEC (Ghanbari-Bonjar, 2000). However, wheat was more competitive than bean for P and K absorption (Table 11). This was in line with expectation since legumes are known to be poor competitors for phosphorus and potassium when intercropped with cereals because of their root morphology and cation exchange capacity of root surface (Francis, 1989; Martin and Snaydon, 1982). Concerning competition for nitrogen in wheat-bean intercropping, the bean component is capable of fixing atmospheric N_2 under favorable condition. So it seems important that the biological nitrogen fixation by the bean component should be considered, but in this experiment, there was no way to designate the amount of N derived from fixation and absorption from the soil. Therefore, CR for N was not accounted.

Dry matter for all intercrop treatments was greater than those of sole crops. More PAR interception, nutrient uptake and also greater water extract by intercrops could be the major reason for greater dry weight observed for intercropping over sole cropping. Greater resource use by intercrops was considered as the biological basis for obtaining yield advantage (Willey, 1990; Choudhury and Rosario, 1994; Ghanbari-Bonjar, 2000; Eskandari and Ghanbari, 2009). Hauggaard-Nielsen et al. (2001) reported that the pea-barley intercrop used light, soil water and nutrients more efficiently than sole crops due to differences in the competitive ability for environmental sources for plant growth.

The grain legume-cereal intercropping may provide an ecological method, utilizing competition and natural regulation mechanisms to manage weeds. Thus, grain legume-cereal intercropping may not only reduce the need for fertilizer inputs but also the use for herbicides. Greater crop yield and less weed growth may be achieved if intercrops are more effective than sole crops in utilizing resources in competition with weeds. Concerning weed suppression, intercrops showed an advantage over bean sole crops. This study shows how wheat-bean intercropping had a better competitive ability towards weeds compared to sole crops, and environmental resources were consequently used for crop grain production instead of weed biomass. The weed control advantage in this study was due to an effective utilization of plant growth resources. However, there was no significant difference between intercrops and sole wheat. Advantages of weed suppression have been reported for many intercrop systems (Bulson et al., 1997; Poggio, 2005; Mashingaizde et al., 2000; Mashingaizde, 2004, Eskandari and Kazemi, 2011). Since in this experiment, the intercrops gave greater dry matter yield and took up more nutrients, one would expect that intercropping exploits resources more intensively than the mean of the sole crops and should therefore, allow less weed growth.

Conclusion

In general, it can be concluded that environmental resource consumption, especially PAR interception and nutrient uptake in intercropping system was better than sole crop, suggesting that intercrop components have "complementarity effect" in obtaining environmental resource which is the result of different morphological and physiological characteristics of intercrop components. Wheat and bean has different ability to absorb cations because of different CEC of their root. The results of this experiment could provide some quantitative evidence for the hypothesis that greater environmental resources consumption (such as PAR and soil moisture) by intercrops is a primary cause of yield advantages.

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