



Evaluation of yield and yield components in intercropping of barley (*Hordeum vulgare* L.) with clover (*Trifolium resupinatum* L)

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Abstract

In order to evaluate yield and yield components of barley and clover at intercropping system while in heading and pasty harvesting stages an experiment was conducted at agricultural research farm of Sistan dam located in Zabol during 2013. Experiment was arranged in split plot based on randomized complete block design in three replications. Studied factors were two harvesting stages with two harvesting level including heading and pasty stages as a main factor and six different sowing combination treatments as a second factor including sole barley, sole clover, sole barley+25% clover, sole barley+ 50% clover, sole barley+75% clover and 100% clover treatments. Results showed that harvesting stage had significant effect on spike length, grain number per spike, 1000 grain weight, dry weight and harvest index of barely and fresh forage yield, dry forage, raw protein of clover plant and improved mentioned characters. Effect of sowing combination was meaningful on stem length, spike length, grain number per spike, grain yield, dry weight and harvest index of barley and fresh forage yield, dry yield, raw protein and raw fiber of clover plant. The highest Land Equivalent Ratio (LER) was belong to sole barley +25% clover treatment which demonstrated superiority of intercropping system to sole barley culture.

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Introduction

Increasing agricultural production to match increasing demand for food sources is inevitable (FAO, 2006). This causes excessive pressure on the base resources which threaten sustainable agricultural systems (Heidarisharifabad and Dorri, 2002). Sustainable agriculture refers to agricultural resource management which also obviates the changing needs of humanity, protecting environmental quality and capacity of the soil and water resources (Philipp, 2009). Components of sustainable agriculture could be listed as Agroforestry system, integrated pest management, crop rotation and intercropping (Tsubo *et al.*, 2005). Intercropping is cultivation of two or more plant species in same time and same field which most of the plants in their growth period is in close proximity to other plants (Caballero *et al.*, 2001).

One of the main reasons that farmers in all around the world are eager to intercropping system is that the yield obtained from intercropping is more than monoculture in the same field (Yang *et al.*, 2009). Increasing production at intercropping may be related to reduction of weed growth (Jokar *et al.*, 2006), reduction of pest and disease damages (Sekamatte *et al.*, 2003), more growth rate and better use of available resources (Gustave *et al.*, 2008). Several researchers indicated that the most success of high plant density in intercropping system is related to more sunlight attraction in early sowing season and better competition of this system with weed (Boquet *et al.*, 2003). Common cereal and legume intercropping mixtures are intercropping of maize (*Zea mays* L.) with soybean (*Glycine max*) or bean (*Phaseolus vulgaris* L.) or ground nut (*Arachis hypogaea* L.) and also intercropping of millet (*Panicum miliaceum* L.) with cowpea (*Vigna unguiculata* L.) or mung bean (*Vigna radiata* L.) (Aliyu and Emechebe, 2006). Legumes contain more protein and minerals and therefore be planted mixed with cereal grains, to compensate the deficit of grain protein (Ghanbari and Lee, 2002; Karadage, 2004).

Increasing yield of intercropping culture compare to sole culture such as barley (*Hordeum vulgare* L.)-

berseemclover (*Hordeum vulgare* L.) (Rahnama and Poori, 1996), Maize-soybean (Putnam *et al.*, 1985), Maize-cowpea (Dahmardeh *et al.*, 2011), vetch-barley (Karadage, 2004) have been previously reported. Eskandari (2005) at maize and bean intercropping as a forage production reported that dry weight of weed at intercropping was less than sole culture. At rice (*Oryza sativa* L.) and bean intercropping with different series, production has been increased due to reduction of interspecies competition compared to interspecies competition (Midya *et al.*, 2005). Other benefit of intercropping is weed controlling criteria of intercropping. Because of crops competition with weed, growth and development of weed have been preventing, hence, no-application of herbicides led to increasing of yield (Liebman and Davis, 2000). The most success in high plant density at intercropping is related to more attraction of sunlight at early plant sowing stage and better competition of this system with weed (Boquet *et al.*, 2003). Better weed control at maize-cucumber (*Cucumis sativus* L.) (Jokar *et al.*, 2006) and maize-zucchini (Safari, 2007) have been previously reported. At bean and maize intercropping just in 50:50 treatments land equivalent ratio for grain and dry matter production was more than one (Koocheki *et al.*, 2010). At maize and sunflower (*Helianthus annuus* L.) intercropping system maximum LER was achieved at 25% maize and 75% sunflower treatment. LER in this study indicated that grain yield at intercropping system has been increased compared to sole maize culture (Moosavian *et al.*, 2011). At maize and mung bean intercropping system, the highest LER for total yield before the corn spike harvesting was obtained from low plant density and sole mung bean treatments (Sarлак and Aghajani, 2009). The main aims of this study were evaluation of different barley cultivation series as a main crop at intercropping with clover and determination of yield and yield components and beneficially index of intercropping system.

Material and methods

Experimental location condition

In order to evaluate yield and yield components of barley and clover at intercropping system while in

heading and pasty harvesting stages an experiment was conducted at agricultural research farm of Sistan dam located in Zabol during 2013. Experimental field altitude was 483 meter above the sea level and saturated soil EC was 1.60×10^3 .

Experimental design and field preparing

Experiment was arranged in split plot based on randomized complete block design in three replications. Studied factors were two harvesting stage with two harvesting level as a main factor and six different sowing combination treatments as a second factor. Treatments were harvesting stage as a main factor with two level (heading and pasty stages) and sowing combination a second factor with six level including sole barley, sole clover, sole barley+25% clover, sole barley+ 50% clover, sole barley+75% clover and 100% clover treatments.

The varieties used in the experiments

Regional barley and Iranian clover were used varieties in this study.

Land preparation and planting methods

Field was prepared by moldboard plow during autumn of 2013. After crushing by disk and leveling the ground by leveler and preparing of farrows the field was ready to be planted. Wet planting was conducted at November by hand. Farrows were crushed and seeds were sown and high plant density was thinned at 3-4 leaf stage, though at final plants were 12.5 cm apart. Plots were prepared at 2*3 m size consist of 6 row 12.5 apart, hence, secondary plots at main plot was separated by one row and main plots was separated by 1.5 m space in order to removing interaction effects of neighbor plots. One day after sowing the first irrigation was conducted.

Characteristics of the study

Twenty plants were randomly selected in order to measurement of height and barley stem diameter. After removing marginal effects, 20 plants were harvested in order to evaluate barley grain yield components (spike length, grain number per spike, 1000 grain yield) and final grain yield and dry forage

yield. Samples were transferred to laboratory and dried at oven during 72 hours at 74 centigrade. Land equivalent ratio (LER) was used to evaluate intercropping compared to monoculture system.

$$\text{Equation (1)} \quad \text{LER (T)} = \text{LER (a)} + \text{LER (b)}$$

$$\text{Equation (2)} \quad \text{LER (a)} = Y_{ab} / Y_{aa}$$

$$\text{Equation (3)} \quad \text{LER (b)} = Y_{ba} / Y_{bb}$$

In this equivalent LER (T): land equivalent ratio, LER (a):land equivalent ratio for A species, LER (b): land equivalent ratio for B species, Y_{ab} : A species yield at intercropping, Y_{aa} : A species yield at sole cropping, Y_{ba} :B species yield at intercropping, Y_{bb} : b species yield at sole cropping.

Experimental Analysis

Data were analyzed by SAS (V: 9.1) and MSTAT-C and means compare were calculated by Duncan test at $p \leq 0.05$.

Results and discussion

Stem length

Analyze of variance of data showed that harvesting stage had no meaningful effect on stem length (Table 1). Maximum stem length (82.09) was achieved from heading stage (Table 2). It could be suggested that stem height reduction at pasty stage may be related to generation stage and assimilate transition to grain. Effect of sowing combination on barley stem indicated that the highest stem length (92.23 cm) was obtained from sole barley + 25% clover treatment which had significant differences with sole barley + 100% clover treatment (Table 2).

Increase of barley plant height at intercropping may be related to increasing of N availability which was fixed by legume; this results were agree with DehghanNiri (1995) results who investigate the intercropping of bitter vetch (*Vicia ervilia*) and spring barley. It seems that high clover density at sole barley + 100% clover treatment caused to reduction of barley stem compared to sole barley + 25% clover treatment.

Stem diameter

Analyze of variance of data showed that harvesting stage had no meaningful effect on stem diameter (Table 1). Maximum stem diameter (1.89 mm) was achieved from heading stage (Table 2). It seems that a partial difference at stem diameter is related to stopping of vegetation stage and beginning of generation stage. Sowing combination effects on

barley stem diameter have shown that maximum stem diameter (2.15 mm) was belong to sole barley + 25% clover treatment which had meaningful difference with sole barley + 100% clover treatment (Table 2). It could be resulted that a partial difference at stem diameter is caused by optimum plant density and minimum plant competition at intercropping.

Table 1. Analysis of variance of barley values affected by harvesting stage and sowing combination.

S.O.V	df									
		Stem diameter	Stem length	Leaf number	Spike length	Grain number per spike	1000 grain weight	Grain yield	Dry weight	Harvest index
Replication	2	0.09 ^{ns}	90.22 ^{ns}	0.02 ^{ns}	9.29 ^{ns}	12.83 ^{ns}	131.27 ^{ns}	1511.09 ^{ns}	758333.33 ^{ns}	26.99 ^{ns}
Harvesting stage (A)	1	0.17 ^{ns}	112.40 ^{ns}	0.58 ^{ns}	16.66 *	70.25*	566.89 *	196266.64 **	43200000 **	5845.05 **
R*A	2	0.006	15.91	0.03	0.68	3.33	18.20	3707.53	1575000	3.50
Sowing combination (B)	4	0.36 ^{ns}	639.81**	0.50 ^{ns}	11.76 **	303.06 **	94.16 ^{ns}	120279.75 **	14470833.33 *	455.76 **
A*B	4	0.06 ^{ns}	63.53 ^{ns}	0.88*	1.38 ^{ns}	15.59 ^{ns}	35.88 ^{ns}	8068.27 ^{ns}	5845833.33 ^{ns}	190.96 ^{ns}
Error	16	0.21	53.08	0.23	2.19	24.70	99.11	11602.83	3833333.33	69.88
C.V (%)	-	25.47	9.08	8.59	12.65	15.60	20.32	24.10	23.40	16.35

Ns statistically not significant, * statistically significant at the 5% level, ** statistically significantl at the 1% level.

Leaf number

Analyze of variance results have shown that harvesting stage had no significant effect on leaf number (Table 1). Maximum leaf number (5.81) was achieved from heading stage (Table 2). Effect of sowing combination on leaf number of barley showed that maximum leaf number (6) was belong to sole barley + 25% clover treatment which had no difference with sole barley + 100 clover treatment (Table 2). In about sole barley + 25% clover treatment it could be suggested that by increasing of plant density, green cover percentage had increased and subsequently by more sunlight attraction the yield production per unit was increased. At sole barley + 100% clover high plant density caused to increasing of plant competition and decreasing of leaf number. Researchers indicated that high efficiency of intercropping compared to monoculture is related to high green cover percentage and light use efficiency of intercropping (Hamzei, 2012).

Spike length

Analyze of variance results have shown that harvesting stage had significant effect on spike length (Table 1). Maximum spike length (12.44 cm) was achieved from pasty stage (Table 2). Having the highest grain number per spike in sole barley + 25% clover treatment may be increased spike length in this treatment. Sowing combination effect on spike of barley have shown that the highest spike length (92.33 cm) was observed at sole barley + 25% clover treatment which had significant difference with sole barley + 100% clover treatment (Table 2). The reason for this may be high grain number at pasty stage. Weston *et al.* (2002) reported that cereal monoculture system let to decreasing of yield component hence, intercropping of these could increase yield.

Grain number per spike

Analyze of variance results have shown that harvesting stage had significant effect on grain number per spike (Table 1). Maximum grain number per spike (33.37) was achieved from pasty stage

(Table 2). according to assimilate transition to inflorescence and its effect on flowers fertility and grain production it could be suggested that maximum grain number per spike at pasty stage is more than heading stage. Effect of sowing combination on grain number per spike relieved that maximum grain number (38.78) was achieved from sole barley+25%clover treatment which had significant difference with sole barley + 100% clover treatment (Table 2). As grain number per spike at intercropping

was more than barley monoculture treatment, it could be resulted that intraspecific competition had negative effect on this criteria and clover has poor compatibility compare to barley. Daraei Mofrad *et al.* (2007) in investigation of barley grain yield at intercropping with vetch found that minimum grain number per spike was obtained from sole barley culture and the maximum of it was obtained from 25% barley and 75% vetch treatment.

Table 2. Means compare of barley values affected by harvesting stage and sowing combination.

<i>Treat</i>	<i>Stem diameter</i>	<i>Stem length</i>	<i>Leaf number</i>	<i>Spike length</i>	<i>Grain number per spike</i>	<i>1000 grain weight</i>	<i>Grain yield</i>	<i>Dry weight</i>	<i>Harvest index</i>
	Harvesting stage								
Heading stage	1.89 a	82.09 a	5.81 a	10.95 b	30.31 b	44.63 b	366.01 b	9566.7 a	37.15 b
Pasty stage	1.74 b	78.22 a	5.53 b	12.44 a	33.37 a	53.33 a	527.78 a	7166.7 b	65.07 a
	Sowing combination								
Sole barley	1.85 ab	88.24 ab	5.80 ab	12.06 ab	29.86 b	47.98 a	386.08 b	9667 a	50.35 bc
Sole barley+25% clover	2.15 a	92.23 a	6.00 a	13.52 a	38.78 a	54.16 a	597.33 a	9833 a	64.74 a
Sole barley+50% clover	1.93 ab	80.16 bc	5.80 ab	12.15 ab	38.77 a	51.83 a	594.45 a	8417 a	52.14 b
Sole barley+75% clover	1.60 ab	72.56 cd	5.50 ab	10.95 bc	29.83 b	46.48 a	372.80 b	7917ab	47.32 bc
Sole barley+100% clover	1.55 b	67.60 d	5.26 b	9.80 c	21.95 c	44.45 a	283.82 b	6000 b	41.00 c

Means within the same column and rows and factors, followed by the same letter are not significantly difference ($p < 0.05$).

1000 grain weight

Analyze of variance results have shown that harvesting stage had significant effect on 1000 grain weight (Table 1). Maximum 1000 grain weight (53.33 g) was achieved from pasty stage (Table 2). It is obvious that 1000 grain weight was affected by assimilate transferred to plant inflorescence. In this case assimilate after pollination used in grain filling, had no effect on grain number criteria (admin-A-10-1-74-8d07834). Effect of sowing combination on 1000 grain weight indicated that maximum 1000 grain weight (54.16 g) was belong to sole barley + 25% clover treatment which had no significant difference with sole barley + 100% clover treatment (Table 2). 1000 grain weight was more affected by genetically factors than environmental factors and partial

differences at 1000 grain weight of sole barley + 25% clover treatment caused by optimum plant density and less intraspecific competition at intercropping system.

Grain yield

Analyze of variance results have shown that harvesting stage had significant effect on grain yield (Table 1). Maximum grain yield (527.78 kg\ha) was achieved from pasty stage (Table 2). It seems that harvesting of forage at early bud emersion and or in flower emersion, increased the forage harvesting times until ripening of seeds and this increased the use of natural resources, physiological ripening time, assimilate transition to seeds and storage of material which let to increasing of grain yield. This caused to

increasing of better using of natural resources in order to grain production (Sanderson and Elwinger, 2002) (admin-A-10-1-74-8d07834). Effect of sowing combination on grain yield showed that maximum grain yield (597.33 kg\ha) was achieved from sole barley + 25% clover treatment which had meaningful difference with sole barley+100% clover treatment

(Table 2). This results were agree with Daraei Mofrad *et al.* (2007) results who investigate barley grain yield and weed growth at intercropping system and in monoculture with vetch. They reported that by increasing of barley density and inter and intraspecific competition grain yield decreased.

Table 3. Analyze of variance of land equivalent ratio affected by harvesting stage and sowing combination.

S.O.V	df	LER Barley	LER Trifolium	LER Total
Replication	2	0.039ns	0.032ns	0.040ns
Harvesting stage (A)	1	0.070**	0.063**	0.266**
R*A	2	0.001	0.010	0.008
Sowing combination (B)	4	0.011ns	0.020ns	0.055**
A*B	4	0.0005ns	0.004ns	0.004ns
Error	16	0.007	0.006	0.007
C.V (%)	-	13.42	15.85	7.50

Statistically not significant, * Statistically significant at the 5% level, ** Statistically significant at the 1% level.

Dry weight

Analyze of variance results have shown that harvesting stage had significant effect on dry weight of barley (Table 1). Maximum dry weight of barley (9566.7 kg\ha) was achieved from heading stage (Table 2). High yield at heading stage demonstrated that maximum plant dry matter accumulation and photosynthetic products synthesis is occur in this growth stage then, by heading stage and remobilization to generation parts, quantity and quality of forage is dwindle and versus yield and yield components will increase. Effect of sowing combination on dry weight have shown that maximum dry weight (9833 kg\ha) was achieved

from sole barley + 25% clover treatment which had meaningful differences with sole barley + 100% clover treatment (Table 2). Decreasing of yield in sole barley + 100% clover treatment is related to intensive interspecific competition. Because by increasing of plant density plant environmental using share is decrease, this let to decreasing of total yield. Moyhan and Simonse (1996) indicated that intercropping of barley and alfalfa decreased the barley yield 6 to 76 % compare to sole culture. In other study Daraei Mofrad *et al.* (2007) reported that at intercropping of barley and vetch maximum grain yield was belong to sole barley culture.

Table 4. Means compare of land equivalent ratio affected by harvesting stage and sowing combination.

Treat	LER Barley	LER Trifolium	LER Total
	Harvesting stage		
Heading stage	0.68a	0.55a	1.23a
Pasty stage	0.57b	0.45a	1.02b
	Sowing combination		
Sole barley+25% clover	0.69a	0.56a	1.25a
Sole barley+50% clover	0.60a	0.53ab	1.14b
Sole barley+75% clover	0.60a	0.48ab	1.08b
Sole barley+100% clover	0.60a	0.43b	1.03b

Means within the same column and rows and factors, followed by the same letter are not significantly difference (P<0.05).

Harvest index

Analyze of variance results have shown that harvest index had significant effect on dry weight of barley (Table 1). Maximum harvest index (65.07%) was achieved from pasty stage (Table 2). This may be due to high grain yield in this treatment compare to other treatments. Effect of sowing combination on harvest index showed that maximum harvest index (64.74%) was attained from sole barley + 25% clover treatment which had meaningful difference with sole barley + 100% clover treatment (Table 2). This may cause by high grain yield in this treatment compare to other treatments. This result is agreed with Seyyedi *et al.* (2012) results.

Land equivalent ratio

Analyze of variance results have shown that harvest index had significant effect on land equivalent ratio (Table 3). Maximum land equivalent ratio (1.23) was achieved from pasty stage (Table 4).

Effect of sowing combination on land equivalent ratio have shown that maximum land equivalent ratio (1.25) was attained from sole barley + 25% clover treatment that have significant difference with sole barley + 100% clover treatment (Table 4). Mohsen Abadi and *et al.* (2009) in investigation of barley and vetch intercropping at different nitrogen fertilizer levels found superiority of intercropping compare to monoculture of barley and vetch. Shaygan *et al.* (2007) at intercropping of maize, millet and foxtail grass (*Setariaitalic*) reported that all the intercropping treatments had high LER compare to sole culture of them.

Analyze of variance of yield and yield components showed a superiority of sole barley + 25% clover treatment compare rest. The highest land equivalent ratio was belonging to sole barley + 25% clover treatment.

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