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Seed yield and yield components of intercropped barley (*Hordeum vulgare* L.) and annual medic (*Medicago scutellata* L.)

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Abstract

Seed availability of annual medic (*Medicago scutellata* L.), an annual legume which performs well in various forage cropping systems, is a major challenge for livestock producers in Iran. This study was conducted at the experimental farm of University of Tehran to determine if intercropping annual medic with barley (*Hordeum Vulgare* L.) can produce supplement medic seeds while barley grain yield as the main crop is not compromised in 2007 growing season. A randomized complete block design with eight cropping ratios comprising of one row of barley: one row of annual medic (1B:1M), 2B:2M, 4B:4M, 6B:6M, 6B:2M, 4B,2M, 2B,4M, and 2B:6M along with sole culture of barley and annual medic was studied. The overall results as indicated by Land Equivalent Ratio (LER) revealed that regardless of ratios, the grain yield of barley when intercropped with medic was lowered. The total seed yield of both crops however, was improved in some of the intercropping ratios when compared to the monoculture of either crop. The land equivalent ratio (LER) of the cropping ratio of 2H:2M was 1.32 which is an indication of 32 percent yield advantage over the sole cropping of the two crops. The results of this study indicated that although intercropping of annual medic with barley, using 6B:2M replacement series yielded 259 kg ha^{-1} less grain compared to barley sole cropping but it produced a 365 kg ha-1 annual medic seed which has significantly higher market value than barley.

Key words: Annual medic, barley, harvest index, intercropping, land equivalent ratio, seed yield.
Abbreviations: BGY: barley grain yield; EW: ear weight; HIB: harvest index barley; HIM: harvest index annual medic; MSY: medic seed yield; NGPE: number of grains per ear.

Introduction

Interest in agricultural production systems to reach high productivity has been increased over time (Dhima et al., 2007). Intercropping of cereals with legumes has been a common cropping system in arid and semi-arid areas such as Iran (Esmaeili et al., 2011). Capacity of the component species in an intercropping system to increase capture and use of biophysical resources often causes yield advantages compared to sole cropping systems (Jahansooz et al., 2007; Jahanzad et al., 2011; Sadeghpour et al., 2011). It is understood that competition for these natural resources by the co-existing species could, however, reduce the yields of component crops. Often reductions in the yields of individual species are, however, not large enough to reduce the total yield of the mixture relative to those of either sole crops (Jahansooz et al., 2007; Ogind and Walker, 2005). Annual medic, a high nutritional annual legume, performs well in a low-input intercropping system with cereals for forage production (Sadeghpour et al., 2011). While annual medic is able to tolerate shading and provides nitrogen, the companion cereal crops such as barley can grow fast, suppress weed pressure and therefore improve seed production (Simmons et al., 1995). The availability of annual medic seeds remains a major challenge and hampers the widespread use of this valuable crop (Esmaeili et al., 2011). There are limited reports on effect of various spatial arrangements on productivity of intercropped barley and annual medic. These reports indicated that the yield of barley and/or annual medic in an intercropped system can potentially be enhanced (Eshghizadeh et al., 2002; Moynihan et al., 1996; Simmons et al., 1995). In current study we used a wide range of cropping pattern to determine if intercropping annual medic with barley in a low-input condition can produce a supplement medic seed while the yield of barley as the main crop is not compromised.

Results and discussion

Barley grain yield and yield components

Cropping ratio had a significant effect on barley grain yield (Table 2). As expected, the higher ratio of barley in the intercropping, the higher barley grain was produced. Maximum barley grain yield was obtained from its sole culture in amount of 1416 kg ha^{-1} (Table 3). The relatively low yield of barley in this experiment was primarily due to high weed pressure. It was conceivable that when some planting rows of barley were replaced with annual medic the barley yield be reduced compared to its sole cropping. However, we hypothesized that barley grain yield per unit area may improve due to reduction in competition and therefore the total yield of harvested crops (barley grain plus annual medic seeds) may increase. Other reports indicated that barley grain yield per area unit grown with the association of various legumes improved due to the complementary effect of companion legume crops (Banik and Bagchi, 1993; Chatterjee and Bhattacharya, 1986; Ofori,

Table 1. Selected chemical properties of the top 0-30 cm of soil at the experimental site.

pH	Organic Matter g kg^{-1}	N %	P mg kg^{-1}	K mg kg^{-1}	Ca meq lit^{-1}	Fe mg kg^{-1}	Mn mg kg^{-1}	Zn mg kg^{-1}	Soil texture	Sand %	Silt %	Clay %
7.5	1.2	0.12	122	169	2.3	7.0	16.6	1.2	C.L*	30	38	32

*C.L: Clay-Loam

Table 2. Significance levels for seed yield and yield components of barley and annual medic.

SOV	BGY	MSY	NGPE	EW	1000 GWB	1000 SWM	HIB	HIM
CR	**	**	**	**	**	**	**	**

** Significant at P<0.01

BGY: barley grain yield; MSY: annual medic seed yield; NGPE: number of grains per ear; EW: ear weight; 1000 GWB: 1000 grain weight barley; 1000 SWM: 1000 seed weight annual medic; HIB: harvest index barley; HIM: harvest index annual medic.

1987). Intercropping of barley and annual medic creates a wavy canopy which is more efficient in light interception compared to the monoculture of companion crops. Biabani et al. (2008) reported that intercropping of two soybean cultivars which were varied in height created wavy canopy architecture and therefore improved final yield by 11 percent. Our study confirmed this because barley produced higher grain yield in alternate planting pattern of 1B:1M compared to the other 50:50 barley-medic patterns (Table 3). However, some reports have shown that no yield improvement of cereal crops was obtained when intercropped with legumes (Pirdham and Entz, 2008; Thorsted et al., 2006). Number of grain per ear was significantly (P<0.01) affected by different cropping ratios (Table 2). As annual medic rows increased in the cropping ratios, number of grain per ear increased and the highest number was gained from 2B:6M and 2B:4M treatments while the lowest one was recorded in B2:2M treatment (Table 3). There was a negative relationship between ear weight and number of grains per ear. Valentine's (1982) findings supported the results of this study about the negative relationship between ear weight and number of grain per ear. The effect of sowing patterns on ear weight of barley was significant (Table 2). The maximum ear weight obtained from B6:6M treatment while the minimum ear weight was gained from 2B:6M treatment (Table 3). In this study, ear weight didn't follow any particular order and varied among row configurations. It is reported that there was a weak association between ear weight and grain yield in barley (Valentine, 1982). The ANOVA showed a significant effect of different cropping ratios on barley 1000 grain weight (Table 2). The maximum 1000 grain weight was recorded from pure culture of barley (41 g) while the minimum one was gained from 2B:6M (30.3 g), which had no significant difference with 2B:4M (32.4 g). There was a strong correlation between grain yield and 1000 grain weight. Increasing in rows of annual medic caused a reduction in barley 1000 grain weight. Hadjichristodoulou (1990) reported that in 6-rows barley, 1000 grain weight was positively correlated with grain yield, straw yield and plant height.

Annual medic seed yield and component

Annual medic seed yield was significantly influenced by cropping ratios (Table 2). As stated for barley, the higher percentage of annual medic rows in the intercrops the higher medic seeds were harvested (Table 3). The highest medic seed yield (422 kg ha^{-1}) was harvested from 6M:2B probably due to the lower inter-specific competition between the two crops. In contrast, the lowest seed yield of annual medic was obtained from 2M:6B ratio in which annual medic was intensively suppressed by barley plants as the dominant component. The results of this study confirmed other reports (Jensen et al., 2006; Ross et al., 2004) that indicated legumes are not benefiting as much as non-legumes from wavy architecture canopies. 1000 seed weight of Annual medic was significantly (P<0.01) affected by different sowing patterns (Table 2). In this study, 1000 seed weight didn't follow a particular order and varied among treatments; however, it can be noted that there was a positive correlation between seed yield, 1000 seed weight of annual medic. The highest 1000 seed weight was observed from pure culture of annual medic (17.1 g) while the lowest one was recorded from 6B:2M (14.8 g) which showed 13% reduction in 1000 seed weight compared to pure stand of annual medic (Table 3).

Harvest index – Barley

Harvest index of barley was significantly (P<0.01) affected by different sowing patterns (Table 2). The highest HI (47) was gained from 1B:1M treatment which had no statistical difference with 2B:2M treatment (Table 3). The least HI was observed in 2B:6M treatment showing a 27% reduction in harvest index. Reduction in plant height lowered the dry weight of the vegetative parts and thereby lowered the straw yield which resulted in an increased harvest index. Also, it can be mentioned that greater total dry matter and crop harvest index led to an increase in seed yield due to its population. According to Singh and Stoskopt (1971) harvest index positively correlated with grain yield but negatively correlated with vegetative growth.

Harvest index – Annual medic

The results indicated that all treatments differed significantly in term of HI (P<0.001); The HI was highest in 2B:2M treatment averaging 28: however, there was no significant difference between this treatment and sole culture of annual medic, 6B:2M and 2B:6M. 2B:2M treatment had 8% higher harvest index than all treatments (Table 3). Overall, increment of annual medic rows was the cause of raising harvest index. Loffer et al. (1985) reported that in spring wheat, the harvest index correlation was negative in the case of grain protein concentration and positive in the case of grain protein yield and grain yield.

Land Equivalent Ratio

The land equivalent ratio (Table 4) exceeded unity in most intercropping systems in the experiments I indicating an

Table 3. Mean comparisons for yield and yield components of barley and annual medic.

SOV	BGY (kg ha^{1})	MSY (kg ha^{1})	NGPE	EW (g)	1000 GWB	1000 SWM	HIB	HIM
CR								
1B:1M	1040.0bc	249.3de	35.2bc	1.30a	36.7bc	16.8ab	47a	22.2d
2B:2M	916.2cd	352.3bc	28d	1.18cd	37.8b	17.2a	43.ab7	28.1a
4B:4M	825.5de	255.8de	37b	1.24ab	34.5cd	16.2bc	40.1bc	23.4cd
6B:6M	805.0de	292.3cd	29.2ab	1.27a	32.8d	15.7cd	41.6bc	24.7bcd
Sole B	1416.0a	-	28.2d	1.26ab	41a	-	38.6cd	-
6B:2M	1100.0b	192.5e	32.2cd	1.16cd	37.2b	15.3de	38.5cd	25.2abcd
4B:2M	1023.0bc	216.5de	30.7cd	1.19cd	38.8b	14.8e	37.9cd	24bcd
2B:4M	703.0e	301.8cd	43.2a	1.21bc	32.4de	16.6ab	40.9bc	22.5d
2B:6M	398.0e	422.5b	43.7a	1.15d	30.3e	17.0a	34d	26.2abc
Sole M	-	514.25a	-	-	-	17.1a	-	26.6abc

Means in each column with the same letter are not significantly different at P<0.05.

Table 4. LER of barley and medic seed yield.

Treatments	LER Grain		
	Barley	Medic	Total
1B:1M	0.73	0.48	1.21
2B:2M	0.64	0.68	1.32
4B:4M	0.58	0.49	1.07
6B:6M	0.57	0.57	1.14
6B:2M	0.77	0.37	1.14
4B:2M	0.72	0.42	1.14
2B:4M	0.49	0.59	1.08
2B:6M	0.28	0.82	1.10

B and M represent Barley and Annual medic, respectively

advantage of intercropping compared to the sole cropping. The highest LER value (1.32) was obtained from 2B:2M. The advantage of intercropping, expressed by LER>1 was related to the improved barley grain yields in intercropping while a minor reduction in annual medic seed yield occurred. The overall results indicated that economic efficiency can be improved through intercropping system. Similar reports on yield enhancement from intercropping of legume-nonlegume crops have been reported (Esmaeili et al., 2011; Gosh et al., 2006; Olorunmaiye, 2010).

Material and methods

Experimental site

This study was conducted at the experimental farm of University of Tehran, Iran (35° 48´ N, 50° 57´ W, 1312.5 m elevation) on a clay-loam soil and a semi-arid environment with 38-year average annual precipitation of 251 mm and annual average temperature of 13.5°C. Samples of soil in the top 30 cm were taken from experimental plots before seeding the plants. Selected chemical properties of the soil are presented in Table1.

Experimental design and cultural practices

The effect of different cropping patterns employing replacement design on seed yield of barley and annual medic was evaluated in a Randomized Complete Block Design (RCBD). Seed production of an Iranian native cultivar of barley (*Hordeum vulgare* CV. Karoon x Kavir) and annual medic (*Medicago scutellata* CV. Robinson), a native of Australia, were evaluated in an intercropping system in 2007. Arrangement consisted of 1B:1M (one row of barley: one row of annual medic) , 2B:2M, 4B:4M, 6B:6M, 6B:2M, 4B:2M, 2B:4M and 2B:6M along with sole culture of both crops. The previous crop was wheat which was harvested in July 2006. Before seeding, the experimental site was plowed by moldboard plow, harrowed and divided into four blocks, each contained ten plots. Plots consisted of various row numbers depending on intercropping ratios. Planting rows were 0.25m wide and 5m long. Within-row spacings were 5cm and 3cm for barley and annual medic, respectively. Plots were seeded on March 13th by hand and two extra rows on the border of each cropping pattern were considered as guard rows. One row of barley or annual medic were planted next to each side of a treatment plot (barley border was planted next to annual medic and annual medic bordered to barley). The plots were irrigated during the period between March and July when necessary. It was thought that intercropping of the crops will suppress the weeds therefore no weed control practice was applied in this experiment.

Measurements and data analysis

Excluding guard rows, four meters of all rows within each plot were hand harvested on 10th of July. Seed yields of both crops were individually determined and adjusted for the planting pattern (number of rows per plot). To measure grain yield component of barley, 10 plants were randomly selected from each plot and all yield components were measured on them. Intercropping advantage and competition between barley and annual medic in intercrops were calculated according to Mead and Willey (1980) and Willey and Rao (1980). Land equivalent ratio (LER) was used to quantify the efficiency of the intercropping treatments.

$$LER= (Y_{ab}/Y_{aa})+(Y_{ba}/Y_{bb})$$

where Y_{aa} and Y_{bb} are yields as sole crops and Y_{ab} and Y_{ba} are yields in intercrops. LER values greater than 1 indicate advantage of intercropping over monoculture.

Data were analyzed using ANOVA and GLM procedures of SAS. Effects were considered significant for P-values ≤0.05 from the F-test. Duncan multiple range test were conducted for mean comparisons.

Conclusion

The results of this study showed that the total yield of barley and annual medic can be improved by adopting certain intercropping patterns. The calculated LER exceeded unity in most cropping systems, indicating that intercropping was advantageous due to higher exploitation of the limited environmental resources. When barley and annual medic were intercropped with 2B:2M ratio, the overall yield was improved by 32 percent. Overall, based on the results of this experiment, 2B:2M, and 1B:1M cropping ratios could be suggested to farmers as beneficial cropping system practices.

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