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RESEARCH ARTICLE

Weed suppression potential of annual medic in strip intercropping with barley

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Abstract

In organic cereal production weed infestation remains a major issue. Intercropping cereals with legumes not only may lead to increased cereal production but can be effective in weed suppression and improving forage quality. The objective of this study was to investigate the potential of annual medic (*Medicagoscutellata* L.) in controlling weeds and improving barley (*Hordeumvulgare* L.) production in an organic low-input cropping system. Intercropping treatments were consisted of 1B:1M (one row of barley: one row of annual medic), 2B:2M, 4B:4M, 6B:6M, along with sole culture of both crops. The highest total dry matter yield was recorded from barley pure stand. Weed pressure was increased with increasing the number of annual medic rows and the greatest weed biomass was yielded from annual medic sole culture (1060 kg ha^{-1}). This was in contrast to our expectation and suggest that annual medic is not weed suppressive. Although LER higher than unity was found in two of the four intercropping treatments (1B:1M, 2B:2M), trade-offs need to be evaluated to determine whether adding protein to the system by introducing annual medic can justify intercropping barley-annual medic in an organic cropping system with limited input.

INTRODUCTION

In Iran, as well as many other developing countries, multi-cropping has been practiced for many years and cereal/legume intercropping is perhaps the most common practice among other cropping systems (Esmaeili et al., 2011; Jahanzad et al., 2014). In low-input cropping systems such as organic agriculture weeds are major issues due to lack of herbicides use (Liebman and Davis, 2000). Intercropping cereals with legumes often can be an alternative to reduce weed pressure and improve crop yields (Liebman and Davis, 2000). Cereals are fast growing crops which can produce acceptable amount of biomass in resource-limited conditions (AghaAlikhani et al., 2012; Jahanzad et al., 2013). Annual medic is an excellent choice for cereal intercrops because it tolerates shading and fixes nitrogen and might compete with weeds and reduce the weed biomass (Sadeghpour et al., 2013b). Eshghizadeh et al. (2004) reported that intercropping of barley and annual medic decreased medic seed production but the total yield had more stability than sole crop. Moynihan et al. (1996) found that intercropping of barley and annual medic increased barley yield by 9 percent at MorrisCenter. Simmons et al. (1995) claimed that intercropping reduced barley yields by an average of 6 percent at Rosemount, 30 percent at St.Paul and 70 percent at Becker compared to its monoculture. They, also, in the study of intercropping of barley, oat and annual medic found that intercropping of barley and oat with annual medic increased annual medic yield compared to its sole culture.

Improved competition with weeds has been emphasized as one of the benefits of intercrops (Liebman and Davis, 2000). Moynihan et al. (1996) reported that Intercropping barley with medic reduced weed biomass by an average of 65 percent in three research centers. Szumigalski and Van Acker (2005) resulted that annual intercrops can enhance both weed suppression and crop production compared to sole crops. Poggio (2005) in the study of barley-pea (*Pisumsativum* L.) intercropping concluded that barley tended to greatly suppress the growth of weed and pea plants which could be explained by the greater nitrogen accumulation in barley.

This study was conducted to determine the effect of annual medic-barley intercropping on improving forage production, nitrogen uptake, and ability of annual medic to reduce weed pressure in a low-input organic cropping system.

MATERIALS AND METHODS

Experimental site

A study was carried out at the experimental farm of University of Tehran, Iran (35° 48´ N, 50° 57´ W, 1312.5 m elevation) during the 2007 growing season. The soil at the experimental station is classified as a TypicHaplocambid in the USDA classification (KeshavarzAfshar et al., 2014), and climate is considered semi-arid with 38-year average annual precipitation of 251 mm and annual average temperature of 13.5^{o}C. Soil samples (0-30 cm) were collected from initiating the experiment. Selected chemical properties of the soil are presented in Table1.

Experimental design and cultural practices

Experimental design was a Randomized Complete Block Design (RCBD) with four replications. Intercropping treatments were consisted of 1B:1M (one row of barley: one row of annual medic) , 2B:2M, 4B:4M, 6B:6M, along with sole culture of both crops.An Iranian native cultivar of barley (CV. Karoon x Kavir) and a native Australian annual medic (CV. Robinson) was evaluated in this study. Prior to seeding, the experimental site was plowed by moldboard plow, harrowed and divided into four blocks, each contained ten plots. Depending on intercropping treatments, certain number of rows were allocated to each plot. Planting rows were 0.25m wide and 5m long. Within-row spacing was 5 and 3cm for barley and annual medic, respectively. Both barley and annual medic was planted on March 13th by hand. In each plot, 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. Weeds were not controlled during this experiment to assess the ability of annual medic in suppressing weeds alone and when intercropped with barley.

Measurements and data analysis

After guard rows were excluded from the plots, four meters of all rows within each plot were hand harvested on 10th of July. Forage yield of both crops were individually determined and adjusted for the planting pattern (number of rows per plot). At the time of harvest, fresh weight of barley, annual medic and weeds were measured and then samples were dried at oven (60 $^{\circ}$C) for 48 h. Then the dry matter yield of barley, annual medic and weeds was measured. Competition between crops was calculated according to Mead and Willey (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. The LER was also calculated for total forage production and weed biomass to evaluate the dominance of crops versus weeds in herbicide-free cropping system.

To determine the competition between weeds and crops, total crop biomass was divided by weed biomass as described in Curran et al. (2012). Data were analyzed using ANOVA and GLM procedures of SAS (SAS, 2003). Effects were considered significant for P-values ≤0.05 from the F-test. Duncan multiple range test were conducted for mean comparisons.

RESULTS

Forage yield

The results showed a significant effect ($p<0.05$) of different sowing patterns on barley forage dry matter. Among intercropping ratios, the highest total dry matter of forage was obtained from barley sole culture (Fig. 1). Barley was more effective in controlling weeds thus, its sole culture had greater vegetative growth due to higher light and nutrient use efficiency. The lowest forage dry matter of barely was obtained in 6B:6M combination which could be attributed to higher population of weeds along with interspecies competition between barely and medic for resources. In contrast to our expectation, annual medic was unable to reduce weed pressure and interspecies competition with barley decreased forage dry matter of annual medic. There was no significant differences among annual medic treatments with annual medic on average producing 744 kg ha^{-1} dry matter yield (Fig. 1). Similar to barley, annual medic sole culture was the highest yielding treatment with 1347 kg ha^{-1} dry matter yield.

Despiteserver weed infestation in annual medic sole culture, annual medic had the highest dry matter yielddue to greater area allocated to pure culture of annual medic. Total forage dry matter was greatest in barley pure stand with 3182 kg ha^{-1} whereas, annual medic sole culture was the lowest yielding treatments when total forage yield was considered (Fig. 2). Increasing the number of rows from 2B:2M to 4B:4M and 6B:6M resulted in 14 and 20 percent total dry matter yield reduction.

Weed biomass

Our results suggested that annual medic was unable to significantly reduce the weed pressure in barley-annual medic intercrops. In general, a negatively linear relationship was existed between total dry matter yield and weed biomass and the lower the total crop dry matter yield, the greater the weed pressure was with the highest weed biomass recorded from annual medic pure stand (1060 kg ha^{-1}) (Fig. 2). In contrast to annual medic, barley was the highest yielding crop with lowest weed pressure perhaps due to its allelopathic potential (Sadeghpour and Jahanzad, 2012).

Land equivalent ratio and weed competition

Results from LER values (Fig. 3) showed that the highest LER for forage production was obtained from 2B:2M treatment indicating that growth resources were used 10 percent more efficiently in this treatment than sole crops, while the lowest LER was gained from 4B:4M treatment. In strip intercropping treatments (4B:4M, 6B:6M), LER decreased to less than unity showing the disadvantages of intercropping in these treatments. Results of partial LER suggested that annual medic was benefited from intercropping with barley (1B:1M; 2B:2M) which could be explained by lower sole culture of annual medic due to severe competition with weeds. Although several studies have confirmed the profitability of intercropping in terms of LER, yet results are species dependent and mixtures of cereal with legume may or may not yield in LERs higher than the unity (1.0).

According to Curran et al. (2012) and Sadeghpour et al. (2015), a grower can estimate the weed-crop competition by dividing the crop to weed biomass and simply present the results as a ratio. In their studies, switchgrass (*Panicumvirgatum* L.) was the main crop which has a slow growth and difficult to establish and they in some cases suggested switchgrass to weed ratio below 1.0. In our study, the smallest ratio was yielded from annual medic (1.3) with the highest weed biomass and lowest total crop yield (Fig. 4). Barley on the other hand, had the greatest ratio (14.5) which indicated the high weed suppressive ability of the barley. Our study suggested that perhaps adding annual medic might improve the quality of total forage, however, if barley is used for grainthen the presence of annual medic might neither reduce the weed pressure nor improve the barley yield by competing with barley plants.

DISCUSSION

Intercropping did not improve total forage dry matter yield compared to sole culture of barley (Fig. 1). As number of rows increased, barley yield decreased which could be explained by less wavy shape of intercrops in higher row numbers suggesting lower light interception (Esmaeili et al., 2011).Moynihan et al. (1996) found that intercropping of barley and annual medic increased barley yield by 9 percent at Morris center.Simmons et al. (1995) reported that yield of annual medic-barley intercropping depends on medic species and the total forage dry matter (of both barley and annual medic) was higher than their sole cropping treatments which was in contrast to our findings. Our results were somewhat similar to those reported by Sadeghpour et al. (2014) who suggested similar or higher yields of barley sole culture to intercropping treatments under weed-free conditions.

Pure stand of barley, in contrast to annual medic, was the highest yielding crop with lowest weed pressure perhaps due to its allelopathic potential (Sadeghpour and Jahanzad, 2012). Our findings were in agreement with Poggio (2005) who reported that barley tended to greatly suppress the growth of weed in barley-pea intercropping which could be explained by the greater nitrogen accumulation in barley. Our results suggest that perhaps annual medic in mixture with barley could potentially improve the protein content of the total forage but trade-offs need to be evaluated in terms of labor for weeding in this crop and increased in protein content of the forage. If weeded, annual medic is a prime forage for animals with crude protein more than 18 percent which can boost the quality of the total forage with cereals and enhance the profitability of the farmers by saving money which would have otherwise been invested in buying protein supplements (Sadeghpour et al., 2013a).

Results from LER values (Fig. 3) showed that the highest LER for forage production was obtained from 2B:2M treatment indicating that growth resources were used 10 percent more efficiently in this treatment than sole crops, while the lowest one was gained from 4B:4M treatment. In strip intercropping treatments (4B:4M, 6B:6M), LER decreased to less than one showing the disadvantages of intercropping in these treatments. The results of this study corroborated the findings of several researchers (Hauggaard-Nielsen et al., 2006 and Vasilakoglou et al., 2008). A crop-weed ratio was assessed similar to those of Curran et al. (2012) and Sadeghpour et al. (2015). Results confirmed that barley sole culture was the superior treatment in terms of weed control and producing higher yield.

CONCLUSION

Barley sole culture was highest productive treatment and shifting from barley to annual medic although increase the LER, but reduced the total forage production by 23 percent in the highest yielding intercropping ratio (2B:2M). Our results suggested that adding annual medic does not improve weed suppression in barley. Trade-offs need to be evaluated to determine whether adding protein to the system by introducing annual medic can justify intercropping barley-annual medic in an organic cropping system with limited input. Annual medic was the dominant species in intercropping with barley which was due to low dry matter yield recorded from annual medic pure stand.

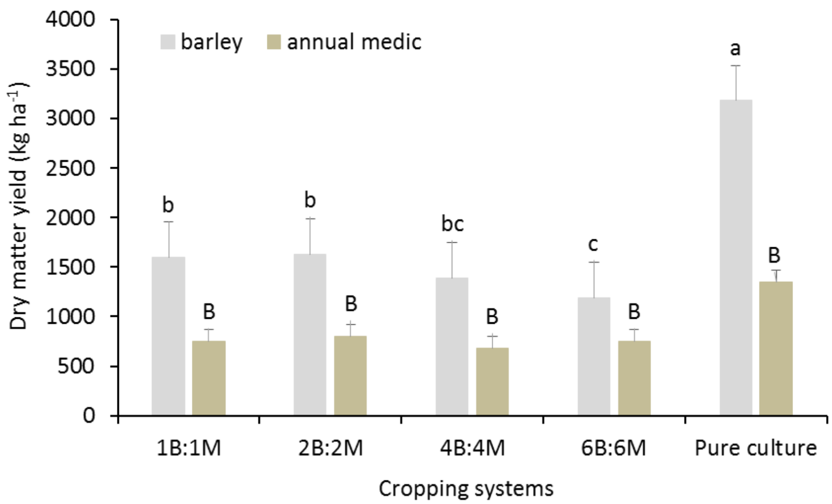

Figure 1. Dry matter yield as influenced by barley and annual medic sole cultures and their mixtures.
Means in the same column followed by different letters differ significantly at P<0.05.
Lowercase letters were used for mean separation of barley and capital letters were used for mean separation of annual medic.

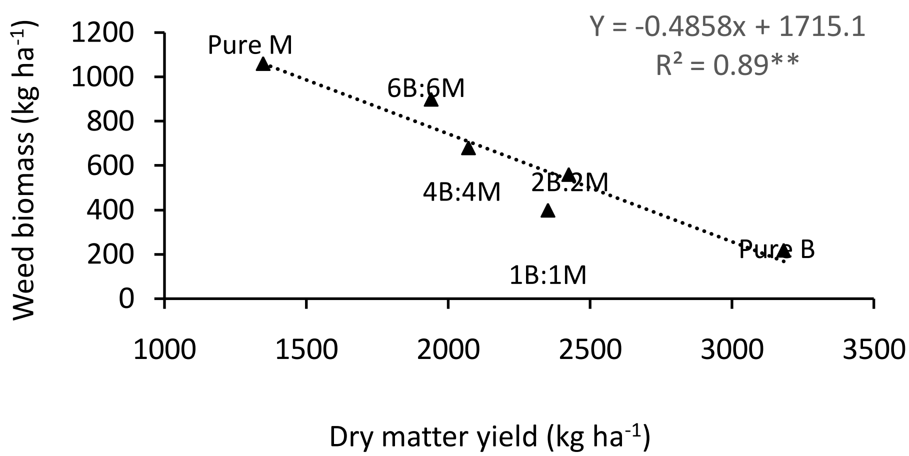

Figure 2. Simple regression between total forage dry matter yield and weed biomass.
**; significant at P<0.001

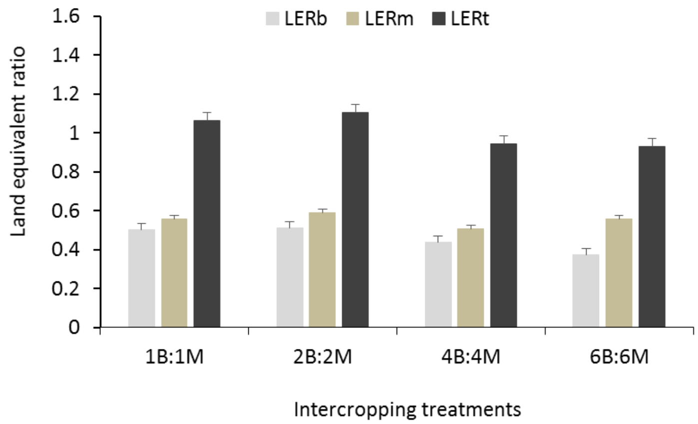

Figure 3. Partial and total land equivalent ratio of barley and annual medic.
LERb, LER for barley; LERm, LER for annual medic; LERt, Total LER.

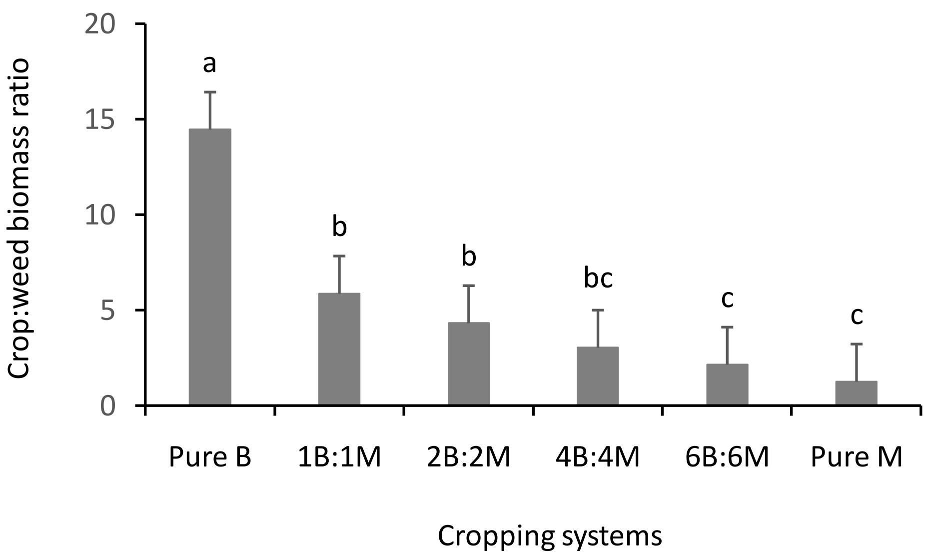

Figure 4. Total crop to weed biomass ratio in barley and annual medic sole cultures and their intercrops. Means in the same column followed by different letters differ significantly at P<0.05.

Table 1- Chemical properties of the soil at the experimental site at 0-30 cm depth.

O.C[1] %	Ec dS m^{-1}	pH se	Zn mg kg^{-1}	Mn mg kg^{-1}	Ca meq lit^{-1}	Na meq lit^{-1}	K mg kg^{-1}	P mg kg^{-1}	N %	Soil texture	Sand %	Silt %	Clay %

[1]. Organic Carbon

0.6	3.94	7.5	1.2	8.5	2.29	1.09	169.5	12.2	0.12	C.L[2]	30	38	32

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