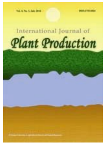

International Journal of Plant Production 8 (1), January 2014
ISSN: 1735-6814 (Print), 1735-8043 (Online)
www.ijpp.info

GUASNR

Forage yield and quality of barley-annual medic intercrops in semi-arid environments

A. Sadeghpour[a,*], E. Jahanzad[a], A.S. Lithourgidis[b], M. Hashemi[a], A. Esmaeili[c], M.B. Hosseini[c]

[a]*Stockbridge School of Agriculture, University of Massachusetts, Amherst, MA, 01003, USA.*
[b]*Department of Agronomy, Aristotle University Farm of Thessaloniki, 570 01 Thermi, Greece.*
[c]*Department of Agronomy and Plant Breeding, University of Tehran, Karaj, Tehran, Iran.*
*Corresponding author. E-mail: asadeghp@psis.umass.edu

Received 19 May 2013; Accepted after revision 16 August 2013; Published online 25 November 2013

Abstract

On-farm production of protein is limited in most dairy farm operations in arid and semi-arid environments. Cereal-legume intercropping could be a viable option to obtain forage with higher protein content. A two-year experiment was conducted during 2009 and 2010 growing seasons in a loamy soil to determine whether intercropping pattern of barley (*Hordeum vulgare* L.) and annual medic (*Medicago scutellata* L.) could increase forage quality while producing sufficient amount of forage yield. The results showed that when number of rows in 50:50 replacement intercropping decreased from six rows of barley and six rows of medic (6B:6M) (strip intercropping) to 4B:4M, 2B:2M and 1B:1M, barley forage yield increased by 9, 18 and 24% due to a wavy canopy created by 1B:1M and 2B:2M cropping ratios. Land Equivalent Ratio (LER) was highest (1.19) when barley was intercropped with annual medic in 1B:1M arrangement indicating that 19% more area would be required by a sole cropping system to yield similar of intercropping system. The highest protein yield was also obtained from 1B:1M ratio. Pure stand of annual medic had the highest Crude Protein (CP) content (310.7 g kg^{-1} of DM) whereas sole cropping of barley had the highest Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF). When both forage yield and quality was considered, the intercropping of barley and medic with 1B:1M ratio was superior to any other ratios and can be recommended to farmers as an alternative to barley alone.

Keywords: Annual medic; Barley; Crude protein; Forage; Intercropping; LER.

Abbreviations: ADF: acid detergent fiber, CP: crude protein, DMD: dry matter digestivity, DMI: dry matter intake, NDF: neutral detergent fiber, NE_1: net energy for lactation, RFV: relative feed value, TDN: total digestible nutrients.

Introduction

On-farm production of protein is limited in most dairy farm operations in developing countries specifically in arid and semi-arid environments (El-Morsy, 2009). To reduce the purchase of grain concentrates, it is desirable that more protein be produced on the farm which helps the dairy farming system to be more economically feasible (Sadeghpour et al., 2013). Intercropping of legumes and cereals has been proposed as a way of increasing on-farm protein production (Lithourgidis et al., 2006). Efficient use of natural biological cycles such as nitrogen fixation by legumes may stimulate yield of the non-legume crops in an intercropped system (Hauggaard-Nielsen et al., 2001). Intercropping of two or more crop species not only improves yield on a given land area by making more efficient use of the available growth resources (Jahanzad et al., 2011; Lithourgidis et al., 2011) but also enhances biological activities in the soil and suppresses weeds, pests and diseases (Trenbath, 1993).

The forage yield of monoculture legumes in a resource-limited condition is often low (Ates et al., 2013). Though annual medic is a low-yielding legume, it is considered as a high nutritional forage crop (Esmaeili et al., 2011; Sadeghpour and Jahanzad, 2012). Annual medic performs relatively well in a low-input intercropping system with cereals mainly due to its shading tolerance and ability to fix atmospheric nitrogen (Smeltekop et al., 2002). Cereals including barley can grow fast, suppress weed pressure and provide high yield in terms of dry weight, but the protein content of the forage is low (Lithourgidis et al., 2006; Hashemi et al., 2013). As a forage, barley has higher nutritive value than oat (*Avena sativa* L.), triticale (×*Triticosecale* rimpaui Wittm.) and winter wheat (*Triticum aestivum* L.) in intercropping systems (Ross et al., 2004). Barley forage had higher digestible dry matter (DM), lower acid detergent fiber (ADF) concentration and higher crude protein (CP) than oat (Carr et al., 2004). Moynihan et al. (1996) reported that intercropping of barley with annual medic increased barley yield by 9%, while intercropping of barley or oat with annual medic improved the annual medic yield compared to its sole culture (Simmons et al., 1995). Ross et al. (2004) also reported that barley intercropped with Berseem clover (*Trifolium alexandrinum* L.) provided greater total season protein as compared with the corresponding intercrops with oat or triticale. They also found that the earlier maturity of barley provided longer period for re-growth of Berseem clover.

Despite the fact that there is much published information on the forage yield and quality of cereal-legume intercropping system, limited information about forage yield and quality is available for intercropping of annual medic and barley in a wide range of cropping patterns specifically in semi-arid regions. The objective of current study was (i) to evaluate the performance of barley and annual medic sole crops as well as their intercropped for forage yield and quality and (ii) to examine the competitive relationship among intercrop systems.

Materials and Methods

Experimental site

A two-year field experiment was conducted during 2009 and 2010 growing seasons at the experimental farm of University of Tehran, Iran (35° 48´N, 50°57´W, 1312.5 m elevation) in a semi-arid environment. The experiment was established on a loamy (L) soil with pH 7.8, organic matter content 1.2 g kg^{-1} nitrogen, phosphorus and potassium content of 0.9, 0.15 and 0.14 g kg^{-1}, respectively. Soil samples in the top 30 cm were taken prior to planting. The same field was used in both experiments. Climatic data during the two growing seasons of the experiment are presented in Table 1.

Table 1. Monthly mean air temperature and total rainfall during the two growing seasons at the experimental site.

Month	Temperature (°C)			Rainfall (mm)		
	2009	2010	30 year average	2009	2010	30 year average
March	9.7	10.9	10.8	12.6	46.7	47.7
April	16.4	17.2	12.2	4.5	43.2	34.7
May	25.0	23.2	13.9	3.1	10.3	20.8
June	23.6	27.9	15.9	0.0	0.0	2.3
July	26.4	26.6	16.1	0.3	0.0	3.1
Total	-	-	-	20.5	100.2	108.6

Crop management and experimental design

Iranian native cultivar of barley (*Hordeum vulgare* cv. Karoon × Kavir) and annual medic (*Medicago scutellata* cv. Robinson), a native of Australia were used in this study. Intercropping ratios consisted of 1B:1M (one row barley: one row 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 experiment design was a randomized complete block with ten treatments with four replications. Plots consisted of various row numbers depending on intercropping ratios. Planting rows were 0.25 m wide and 5 m long. Within row spacing were 5 cm for barley and annual medic. Fields were under wheat (*Triticum aestivum* L.) cultivation prior to the experiment. Before seeding, the cultivation area was moldboard plowed and harrowed. Seeds were planted by hand on March 13th in 2009 and March 17th in 2010. After thinning, the planting density excluding guards for sole barley and annual medic was 80 plants m^{-2}. Planting density for 1B:1M (consisted of one row of barley and one row of annual medic on each of the two furrows) and 2B:2M was 200B:200M (200 barley plants; 200 annual medic plants) and 400B:400M, 600B:600M, 600B:200M 400B:200M, 200B:400M and 200B:600M for 4B:4M, 6B:6M, 6B:2M, 4B:2M, 2B:4M and 2B:6M, respectively. One row of barley or annual medic was planted next to each side of a treatment plot (barley bordered to annual medic and annual medic bordered to barley). No N fertilizer was applied to the experimental plots. The weeds were controlled twice each year manually early in the growing seasons. The plots were furrow-irrigated every 7 days during the period between March and July. A high output PVC irrigation water meter was used to measure the amount of water applied to each plot. Each plot received an approximate amount of 1.25 m^3 of water in each irrigations and the end of each plot was blocked to control the volume of water.

Measurements and data analysis

Barley and annual medic were hand harvested at the height of 5 cm on June 6th and 10th for 2009 and 2010 growing seasons, respectively when barely grains were at milk stage and annual medic was at 10-20% of flowering stage. Excluding guard rows, four meters of all rows within each plot were harvested by hand. At each time of harvest the fresh weight was measured and a representative subsample (0.5 kg biomass for each species) was collected from each plot. The subsamples were weighed and placed in a forced air oven at 65 °C for 72 hours to determine moisture content at each harvest. Biomass fresh weight was then adjusted by moisture content. Forage yields then adjusted based on planting pattern (number of rows per plot).

Intercropping advantage and competition between barley and annual medic in intercrops were calculated according to Mead and Willey (1980). Land Equivalent Ratio (LER) was used to quantify the efficiency of the intercropping treatments:

$$LER = (Y_{bm}/Y_{bb}) + (Y_{mb}/Y_{mm}),$$

Where Y_{bb} and Y_{mm} are yields of sole crops of barley and annual medics respectively and Y_{bm} and Y_{mb} are yields in intercropping system of barley with annual medic, respectively. Land equivalent ratio values greater than one indicate an advantage of intercropping over monoculture. Land equivalent ratio was also used to calculate monetary analysis.

The monetary advantage index (MAI) was calculated as described by (Dhima et al., 2007).

$$MAI = \text{monetary value of combined intercrops} \times (LER-1) / LER.$$

The higher the index value, the more profitable the cropping system.

A second set of random samples of 1 kg biomass from each plot was taken at the time of harvest for determination of forage quality. Samples were dried in a forced air oven for 72 h at 65 °C and prepared for chemical analysis. The samples were ground with a Wiley Mill to pass a 1-mm screen and analyzed for selected quality components. Total N was determined using the Kjeldahl method (Bremner, 1965) and crude protein (CP) was calculated by multiplying the N content by 6.25 (AOAC, 1980). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined using the procedure by Goering and Van Soest (1970). Total digestible nutrients (TDN), digestible dry matter (DDM), dry matter intake (DMI), relative feed value (RFV) and net energy for lactation (NE_l) were estimated according to the following equations adapted from Lithourgidis et al. (2006) and Jahanzad et al. (2013):

$$TDN = (-1.291 \times ADF) + 101.35,$$
$$DMI = 120\% \text{ NDF dry matter basis},$$
$$DDM = 88.9 - (0.779 \times \%\ ADF;\ \text{dry matter basis}),$$
$$RFV = \%\ DDM \times \%\ DMI \times 0.775,$$
$$NE_1 = [1.044 - (0.0119 \times \%\ ADF)] \times 2.205$$

Analysis of variance was performed using SAS statistical software version 9.1 (SAS Institute, 2003). Effects were considered significant for P-values ≤ 0.05 from the F-test. Duncan multiple range test was conducted for mean comparison.

Results and Discussion

Forage yield, protein yield and Land Equivalent Ratio

The analysis of variance for dry matter yield, crude protein yield, LER and MAI values indicated that there were significant differences among treatments; however, neither year nor year × seed ratio had significant effects. Therefore, treatment means averaged across growing seasons are presented in Table 2. Barley pure stand produced the highest biomass (4006 kg ha^{-1}).

It was conceivable that when some planting rows of barley were replaced with annual medic the barley yield was reduced compared with its sole cropping. The reduction in barley yield was due to the less amount of land per unit area compared to the barley pure stand. When number of rows in 50:50 replacement intercropping decreased from 6B:6M (strip intercropping) to 4B:4M, 2B:2M and 1B:1M barley forage yield was increased by 9, 18 and 24% (Table 2), which could be attributed to the lower intra-specific competition between barley plants and also the better use of resources such as light due to more wavy canopy created by 1B:1M and 2B:2M cropping ratios (Biabani et al., 2008; Esmaeili et al., 2011). Similarly, other studies reported that cereal monoculture had higher forage dry matter yield than when the cereal was mixed with legumes (Herbert et al., 1984; Ross et al., 2004; Jahanzad et al., 2011).

As stated for barley, the higher annual medic ratio in the intercrops the higher medic dry matter yield was obtained (Table 2). The highest medic forage production (2427 kg ha^{-1}) from annual medic sole crop was probably due to the higher unit area of land. In contrast, the lowest dry matter yield of annual medic was obtained from 2M:6B ratio (924 kg ha^{-1}) in which annual medic was intensively suppressed by barley plants as the dominant component. Generally, natural sensitivity of annual medic to weeds along with inter-specific competition with barley decreased forage dry matter of annual medic significantly. These results are in agreement with findings of Herbert et al. (1984) and Jahanzad et al. (2011) who reported that legume could be suppressed by higher number of cereal rows in the intercropping system.

Higher forage dry matter yield with acceptable protein content is the goal of a smallholder farmer when intercropping is practiced (Sadeghpour et al., 2013). Annual medic sole crop had the lowest dry matter production (2366 kg ha^{-1}), while barley sole crop had the greatest total dry matter production (4006 kg ha^{-1}), though it had no statistical difference with 1B:1M intercrop (3941 kg ha^{-1}) (Table 2). Low forage production is one of the drawbacks of sole legume production for forage despite their high protein content (Ates et al., 2013). On the other hand, cereals are reported to be superior in terms of producing forage dry matter than legumes (Hauggaard-Nielsen et al., 2001; Carr et al., 2004; Lithourgidis et al., 2007). Our results are similar with those reported the higher productivity of cereals in intercropping systems (Ross et al., 2004; Jahanzad et al., 2011). However, higher forage dry matter is desirable when protein content of the forage is high (Lithourgidis et al., 2006; Lithourgidis et al., 2007). Our findings showed that 1B:1M had the highest crude protein yield (1101 kg ha^{-1}) followed by 2B:2M (1037 kg ha^{-1}). Although annual medic has high crude protein content, it produces low dry matter yield thus, the overall crude protein yield produced by annual medic was the lowest (736 kg ha^{-1}). These results suggest that relying on annual medic alone as a source of on-farm protein is not sufficient to satisfy the farmers' need. Similar to annual medic sole crop, barley sole crop produced relatively lower protein yield due to the lower protein content compared to some planting patterns (953 kg ha^{-1}) which shows the benefit of intercropping in terms of higher forage dry matter and protein yield. It could be concluded that annual medic might reduce the total forage yield but will increase the overall crude protein yield of the forage which is a more desirable feed for animals.

The LER exceeded unity in four planting patterns (1B:1M, 2B:2M, 6B:2M and 4B:2M) (Table 2), which indicates that these intercrops had a distinctive yield advantage of mixed cropping system over monocultures in terms of more efficient use of the environmental resources for plant growth. On the other hand, total LER closer to 1.00 was found in the cases 4B:4M, 2B:4M and 2B:6M intercrops, which shows that there was no yield advantage or disadvantage over monocultures. 6B:6M intercrop had 8% below the unity showing yield disadvantage over sole crops. Similarly other studies have reported that intercropping of two or more crops may not necessarily lead to yield improvement maybe due to less disturbance of the habitat in homogeneous environment of sole cropping system (Mead and Willey, 1980; Midya et al., 2005). The highest total LER was obtained from

1B:1M (1.19) in present study showed that 19% more unit land area would be required to produce the same amount in a sole cropping system. Higher LER has been reported in many studies (Lithourgidis et al., 2007; Jahanzad et al., 2011; Sadeghpour et al., 2013) indicating the benefits which could be gained from intercropping of cereals and legumes probably due to better utilization of environmental resources. As expected, monetary advantage values (MAI) confirmed that 1B:1M is the most profitable planting pattern.

Table 2. Dry matter yield of barley (FYB), annual medic (FYM) and total (FYT), crude protein yields (CPY) of monocultures and intercrops and the land equivalent ratios (LER) and monetary advantage index (MAI) of intercrops. Means are averaged over two growing seasons (2009 and 2010) and four replications.

Treatment	FYB (kg ha^{-1})	FYM (kg ha^{-1})	FYT (kg ha^{-1})	CPY (kg ha^{-1})	LER_B	LER_M	LER_T	MAI
1B:1M	2614^{c}	1327^{c}	3941^{a}	1101^{a}	0.65^{b}	0.54^{b}	1.19^{a}	24.9^{a}
2B:2M	2380^{d}	1288^{d}	3668^{b}	1037^{b}	0.59^{c}	0.53^{b}	1.12^{b}	15.4^{b}
4B:4M	2143^{e}	1102^{ef}	3245^{c}	889^{e}	0.53^{d}	0.45^{d}	0.98^{e}	-2.62^{e}
6B:6M	1982^{f}	1052^{f}	3034^{d}	833^{f}	0.49^{ef}	0.43^{d}	0.92^{f}	-10.35^{f}
Barley	4006^{a}	-	4006^{a}	953^{d}	0.50^{de}	0.50^{c}	1.00^{de}	-
6B:2M	2833^{b}	924^{g}	3732^{b}	974^{cd}	0.70^{a}	0.38^{e}	1.08^{bc}	10.66^{bc}
4B:2M	2675^{c}	1122^{e}	3797^{b}	1002^{bc}	0.66^{b}	0.46^{d}	1.12^{b}	15.96^{b}
2B:4M	1856^{g}	1372^{c}	3228^{c}	960^{cd}	0.46^{f}	0.56^{b}	1.02^{de}	2.51^{d}
2B:6M	1697^{h}	1512^{b}	3209^{c}	965^{cd}	0.42^{g}	0.62^{a}	1.04^{cd}	5.17^{d}
Medic	-	2427^{a}	2427^{e}	735^{g}	0.50^{d}	0.50^{c}	1.00^{de}	-

Means in the same column followed by different letters differ significantly at $P<0.05$.
LER_B: LER for Barley, LER_M: LER for Medic, LER_T: Total LER.

Forage quality

The analyses of variance (ANOVA) for all data of the forage quality parameters indicated that there were significant differences among treatments, but there was no treatment by growing season interaction. Thus, treatment means averaged across growing seasons are presented (Table 3). Crude protein (CP) is often considered as the most important component of forage quality (Jahanzad et al., 2013). Legumes tend to have higher crude protein than cereal crops thus it is expected to see an overall improvement in CP when cereal crops are intercropped with legumes. In all planting patterns, CP content increased with increasing annual medic ratio in the intercropping (Table 3). In particular, annual medic sole crop had the highest CP content (310.7 g kg^{-1} of DM) followed by 2B:6M (304.5 g kg^{-1}

of DM) and 2B:4M (297.7 g kg^{-1} of DM), respectively. Sole cropping of barley, in contrast, had the lowest CP content (237.9 g kg^{-1} of DM). This result is in agreement with those reported by other researchers (Caballero et al., 1995; Javanmard et al., 2009). Also, Lithourgidis et al. (2006) reported an enhancement of crude protein of mixed forage of different cereals mixed with common vetch (*Vicia sativa* L.) in all cropping ratios.

Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) are also among important criteria for evaluating forage quality (Sadeghpour et al., 2013). In this study, ADF and NDF were influenced by cropping ratios where the highest ADF and NDF were obtained from sole cropping of barley (Table 3). As rows of annual medic increased in the mixed crop system, the ADF and NDF content of the forage decreased. The lowest NDF was obtained from annual medic sole culture (222.7 g kg^{-1} of DM) whereas, the highest value obtained from barley monoculture (305.7 g kg^{-1} of DM) followed by 6B:2M (289.8 g kg^{-1} of DM). Chapko et al. (1991) reported that cereal forage could have lower NDF and ADF contents in cereal-legume intercropping system, which agrees with the findings of the current study. Similarly Chen et al. (2004) reported that combined forage from a mixture of 4:4 barley-pea row configurations had lower NDF concentration than pure barley. However, they found no significant difference between intercropping ratios for ADF. These results do not agree with the results of the current study and this inconsistency could be attributed to the type of legume (peas vs. annual medic).

Voluntary intake of fodder is a primary factor for higher animal productivity (Ullah, 2010). The higher dry matter intake (DMI) is related to better voluntary intake and thereby for higher nutrient intake. Dry Matter Intake and Total Digestible Nutrient (TDN) were influenced by intercropping ratios and there was a difference between barley and annual medic sole cultures (Table 3). Dry Matter Intake and TDN were both higher in annual medic sole culture (41.1 g kg^{-1} of body weight and 725.9 g kg^{-1} of DM). Ullah (2010) reported that intake is higher for legumes than for non-legumes and for immature than mature forage. Also, Cabarello et al. (1995) indicated that there was a negative relationship between NDF and DMI which means when NDF is high the forage quality and the DMI are low (Horrocks and Vallentine, 1999). These results are in contrast with findings of Lithourgidis et al. (2006) who reported TDN for oat and triticale were higher than monoculture of common vetch. They suggested that the difference could be attributed to the different cultivars used in their experiment. As mentioned earlier, TDN refers to the nutrients that are available for livestock and are negatively related to the ADF concentration of the forage. Since ADF was higher in barley pure stand as well as in the cropping ratios with higher barley proportions (6B:2M and 4B:2M) lower TDN and DMI were observed as expected.

The effect of cropping ratio on Dry Matter Digestivity (DMD) was significant (Table 3). Annual medic sole culture had higher DMD than barley. The mixture of barley with annual medic therefore decreased DMD of the mixed forage. The highest DMD was obtained from annual medic monoculture (715.4 g kg^{-1} of DM) followed by 2B:6M (702.2 g kg^{-1} of DM). A similar trend was observed for the relative feed value (RFV) and NE_1. The RFV was higher in annual medic monoculture than in barley and all intercropping ratios (Table 3). The RFV index can be used to predict the intake and energy value of the forages using DMD and DMI (Lithourgidis et al., 2006) where RFV values more than 151% is considered prime according to Horrocks and Vallentine (1999). Results of this study indicated that presence of annual medic in the cropping ratios increased relative feed value of the forage to a relatively high extent. As a result, excluding barley sole crop, 6B:2M and 4B:2M, all other cropping ratios, had higher RFV value than 151. The highest RFV value was found in annual medic pure stand (228.0%). NE_1 (Mcal kg^{-1}) similarly was highest in annual medic and decreased with increasing proportion of the barley in the mixture.

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 1B:1M, 2B:2M, 6B:2M and 4B:2M cropping systems, indicating that these intercrops were advantageous due to higher exploitation of the limited environmental resources. When annual medic row numbers were higher in the cropping ratios, forage quality and CP content of the forage increased; however, based on the overall results of the experiment considering total forage yield and quality, the 1B:1M row ratio intercrop could be suggested to farmers to produce acceptable amount of forage which also has higher quality than sole cultures of barley or the other intercrops.

Table 3. Crude protein (CP), acid detergent fibers (ADF), neutral detergent fibers (NDF) content, total digestible nutrients (TDN), dry matter intake (DMI), dry matter digestivity (DMD), relative feed value (RFV) and net energy for lactation, in forage yield of barley and annual medic monocultures and their intercrops. Means are averaged over two growing seasons (2009 and 2010) and four replications.

Treatment	CP ($g\ kg^{-1}$)	ADF ($g\ kg^{-1}$)	NDF ($g\ kg^{-1}$)	TDN ($g\ kg^{-1}$)	DMI ($g\ kg^{-1}$)	DMD ($g\ kg^{-1}$)	RFV (%)	NE_1 ($Mcal\ kg^{-1}$)
1B:1M	279.5^{cd}	261.1^{c}	396.5^{d}	676.3^{c}	30.2^{d}	685.6^{c}	160.6^{d}	1.62^{c}
2B:2M	283.2^{c}	260.6^{c}	395.2^{d}	676.9^{c}	30.3^{d}	685.9^{c}	161.3^{d}	1.62^{c}
4B:4M	274.3^{d}	264.7^{c}	400.2^{d}	671.7^{c}	29.9^{d}	682.8^{c}	158.7^{d}	1.61^{c}
6B:6M	274.8^{cd}	264.8^{c}	397.5^{d}	671.6^{c}	30.1^{d}	682.7^{c}	159.4^{d}	1.61^{c}
Barley	237.9^{f}	305.7^{a}	526.2^{a}	618.7^{e}	22.8^{g}	656.5^{d}	115.1^{g}	1.49^{e}
6B:2M	261.0^{e}	289.8^{b}	468.5^{b}	639.2^{d}	25.6^{f}	663.2^{d}	131.6^{f}	1.54^{d}
4B:2M	263.9^{e}	286.2^{b}	450.8^{c}	643.9^{d}	26.5^{e}	666.0^{d}	137.1^{e}	1.55^{d}
2B:4M	297.7^{b}	244.8^{d}	353.6^{e}	700.6^{b}	33.9^{c}	698.2^{b}	183.6^{c}	1.66^{b}
2B:6M	300.5^{b}	239.6^{d}	345.1^{e}	704.1^{b}	34.7^{b}	702.2^{b}	189.2^{b}	1.67^{b}
Medic	310.7^{a}	222.7^{c}	291.8^{d}	725.9^{a}	41.1^{a}	715.4^{a}	228.0^{a}	1.72^{a}

Means in the same column followed by different letters differ significantly at $P<0.05$.

References

Association of Official Analytical Chemists (AOAC), 1980. Official Methods of Analysis, 11th ed. AOAC, Washington, DC, 125p.

Ates, S., Feindel, D., El Moneim, A., Ryan, J., 2013. Annual forage legumes in dryland agricultural systems of the West Asia and North Africa Regions: research achievements and future perspective. Grass and Forage Sci. doi: 10.1111/gfs.12074.

Biabani, A., Hashemi, M., Herbert, S.J., 2008. Agronomic performance of two intercropped soybean cultivars. Int. J. Plant Prod. 2 (3), 215-222.

Bremner, J.M., 1965. Total nitrogen. In: Black, C.A., et al. (Eds.), Methods of Soil Analysis. Part 2. Agron. Monogr. vol. 9. ASA, Madison, WI, pp. 1149-1178.

Caballero, R., Goicoechea, E.L., Hernaiz, P.J., 1995. Forage yields and quality of common vetch and oat sown at varying seeding ratios and seeding rates of common vetch. Field Crops Res. 41, 135-140.

Carr, P.M., Horsley, R.D., Poland, W.W., 2004. Barley, oat and cereal–pea mixtures as dryland forages in the northern great plains. Agron. J. 96, 677-684.

Chapko, L.B., 1991. Oat, oat-pea, barley and barley-pea for forage yield, forage quality, and alfalfa establishment. J. Prod. Agric. 4, 486-491.

Chen, C., Westcott, M., Neill, K., Wichman, D., Knox, M., 2004. Row configuration and nitrogen application for barley-pea intercropping in Montana. Agron. J. 96, 1730-1738.

Dhima, K.V., Lithourgidis, A.S., Vasilakoglou, I.B., Dordas, C.A., 2007. Competition indices of common vetch and cereal intercrops in two seeding ratio. Field Crops Res. 100, 249-256.

El-Morsy, M.H.M., 2009. Influence of cutting height and plant spacing on Sesbania (*Sesbania aegyptiaca* [Poir]) productivity under hyper-arid conditions in El-kharga Oasis, El-Wadi El-Gaded, Egypt. Int. J. Plant Prod. 3 (2), 77-84.

Esmaeili, A., Sadeghpour, A., Hosseini, S.M.B., Jahanzad, E., Chaichi, M.R., Hashemi, M., 2011. Evaluation of seed yield and competition indices for intercropped annual medic-barley. Int. J. Plant Prod. 4 (5), 395-404.

Goering, H.K., Van Soest, P.J., 1970. Forage Fiber Analysis: Apparatus Reagents, Procedures and Some Applications. Agric. Handbook 379. U.S. Government Printing Office, Washington, DC.

Hashemi, M., Farsad, A., Sadeghpour, A., Weis, S.A., Herbert, S.J., 2013. Cover crop seeding date influence on fall nitrogen recovery. J. Plant Nutr. Soil Sci. 176, 69-75.

Herbert, S.J., Putnam, D.H., Poos-Floyd, M.L., Vargas, A., Creighton, J.F., 1984. Forage yield of intercropped corn and soybean in various planting patterns. Agron. J. 76, 507-510.

Hauggaard-Nielsen, H., Ambus, P., Jensen, E.S., 2001. Interspecific competition, N use and interference with weeds in pea-barley intercropping. Field Crops Res. 70, 101-109.

Horrocks, R.D., Vallentine, J.F., 1999. Harvested Forages. Academic Press, London, UK.

Jahanzad, E., Sadeghpour, A., Hashemi, M., Zandvakili, O., 2011. Intercropping millet with soybean for forage yield and quality. American Society of America, Northestern Branch Chesapeake, Maryland. June 26-29. Abstract.

Jahanzad, E., Jorat, M., Moghadam, M., Sadeghpour, A., Chaichi, M.R., Dashtaki, M., 2013. Response of a new and a commonly grown forage sorghum cultivar to limited irrigation and planting density. Agr. Water Manage. 117, 62-69.

Javanmard, A., Mohammadi Nasab, A.D., Javanshir, A., Moghaddam, M., Janmohammadi, H., 2009. Forage yield and quality in intercropping of maize with different legumes as double-cropped. J. Food. Agric. Environ. 7, 163-166.

Lithourgidis, A.S., Vasilakoglou, I.B., Dhima, K.V., Dordas, C.A., Yiakoulaki, M.D., 2006. Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratios, Field Crops Res. 99, 106-113.

Lithourgidis, A.S., Dhima, K.V., Vasilakoglou, I.B., Dordas, C.A., Yiakoulaki, M.D., 2007. Sustainable production of barley and wheat by intercropping common vetch. Agron. Sustain. Dev. 27, 95-99.

Lithourgidis, A.S., Dordas, C.A., Damalas, C.A., Vlachostergios, D.N., 2011. Annual intercrops: an alternative pathway for sustainable agriculture. Aus. J. Crop Sci. 5, 396-410.

Mead, R., Willey, R.W., 1980. The concept of a land equivalent ratio and advantages in yields for intercropping. Exp. Agric. 16, 217-228.

Midya, A., Bhattacharjee, K., Ghose, S.S., Banik, P., 2005. Deferred seeding of blackgram (*Phaseolus mungo* L.) in rice (*Oryza sativa* L.) field on yield advantages and smothering of weeds. J. Agron. Crop Sci. 191, 195-201.

Moynihan, J.M., Simmons, S.R., Sheaffer, C.C., 1996. Intercropping annual medic with conventional height and semidwarf barley grown for grain. Agron. J. 88, 823-828.

Ross, S.M., King, J.R., O’Donovan, J.T., Spaner, D., 2004. Forage potential of intercropping berseem clover with barley, oat, or triticale. Agron. J. 96, 1013-1020.

Sadeghpour, A., Jahanzad, E., 2012. Seed yield and yield components of intercropped barley (*Hordeum vulgare* L.) and annual medic (*Medicago scutellata* L.). Aus. J. Agric. Eng. 3, 47-50.

Sadeghpour, A., Jahanzad, E., Esmaeili, A., Hosseini, M.B., Hashemi, M., 2013. Forage yield, quality and economic benefit of intercropped barley and annual medic in semi-arid conditions: Additive series. Field Crops Res. 148, 43-48.

SAS Institute, 2003. SAS/STAT User's Guide, Version 9.1. SAS Institute, Cary, NC.

Simmons, S.R., Sheaffer, C.C., Rasmusson, D.C., Stuthman, D.D., Nickel, S.E., 1995. Alfalfa establishment with barley and oat companion crops differing in stature. Agron. J. 87, 268-272.

Smeltekop, H., Clay, D.E., Clay, S.A., 2002. The impact of annual 'Sava' snail medic on corn production. Agron. J. 94, 917-924.

Trenbath, B.R., 1993. Intercropping for the management of pests and diseases. Field Crops Res. 34, 381-405.

Ullah, M.A., 2010. Forage production in panicum grass-legumes intercropping by combining geometrical configuration, inoculation and fertilizer under rainfed conditions. Ph.D. Thesis. University of Kassel. http://www.uni-kassel.de/upress/online/frei/978-3-89958-890-3.volltext.frei.pdf.