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Effects of seeding rates on competition indices of barley and vetch intercropping systems in the Eastern Mediterranean

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Abstract: Forage mixtures are common agricultural practices for the energy and protein needs of animals. In this study, common vetch (*Vicia sativa* L.), Hungarian vetch (*Vicia pannonica* L.), and barley (*Hordeum vulgare* L.) mixtures in different seeding rates were investigated in terms of forage yield and quality. In order to evaluate the effect of vetch, cereal intercropping and the competition/economic indices of 8 different legume–barley mixtures, along with their pure stands, were assessed during the 2008–2009 and 2009–2010 growth seasons in the Eastern Mediterranean region of Turkey. The field experiment was arranged as a randomized complete block design with 3 replications for each year. Intercropping indices were calculated by means of land equivalent ratio (LER), aggressivity (A), crowding ratio (CR), and actual yield loss (AYL). Competition indices revealed that both the common vetch–barley and the Hungarian vetch–barley intercroppings at a seeding ratio of 80%:20%, respectively, were advantageous due to their high yield, land use efficiency, and economic value compared to other mixtures or pure stands. All samples were analyzed for quality parameters such as dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF) content. While digestible dry matter (DDM) content did not differ among treatments, CP, NDF, ADF, TDN (total digestible nutrients), DDM, RFV (relative feed value), and NE_l (net energy for lactation) content significantly differed among the different vetches–barley mixtures ($P < 0.01$). The results emphasize that both vetch species combined with barley and using the seeding ratio of 80% vetch:20% barley should be profitable for farmers in terms of implementation and maximum yield per unit area under Eastern Mediterranean conditions.

Key words: Annual mixtures, barley, competition indices, plant density, *Vicia*

1. Introduction

Cereals and legumes are important crops providing energy and protein sources for livestock animals. Since the arable crop lands and ranges in the Eastern Mediterranean region of Turkey have been diminishing, intercropping systems may constitute a better approach for increasing forage yield per unit area. About 10 million km^2 areas around the world have a Mediterranean climate, including parts of the USA, Chile, Australia, South Africa, as well as Mediterranean countries (Iglesias, 2000). In such regions, legume and cereal mixtures have shown significant potential for higher forage yield and better soil conservation (Anil et al., 1998). Mixtures of legumes with cereals are expected to have advantages over pure stands in terms of forage yield and quality. In vetch–cereal intercroppings, cereals provide structural support for vetch growth, improving light absorption and allowing mechanical harvest (Lithourgidis et al., 2006). Furthermore, cereals are rich in carbohydrates while legumes are rich in proteins, serving a better digestive and nutritious feed for animals. Intercropping of cereal–legume species is also widespread due to its advantages for soil conservation (Anil et al., 1998), weed control, lodging resistance (Karagic et al., 2011), higher yield, and increased fodder quality (Lithourgidis et al., 2006). Different small grain cereals and vetches have been successfully used in cereal–legume intercropping systems (Dhima et al., 2007; Karagic et al., 2011; Lithourgidis et al., 2011).

Since a greater proportion of dry matter produced by barley during blooming and inflorescence is digestible and nutritious, barley is considered a superior quality forage crop compared to other cereals (Carr et al., 2004). Common vetch is a popular legume used for fresh and dry fodder and silage production in Turkey. Hungarian vetch, on the other hand, is under increasing demand due to its productivity. Strydhorst et al. (2008) reported that barley intercrops with legumes improve forage quality compared

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to pure stand barley. Furthermore, lupin–barley, faba bean–barley, and pea–barley intercroppings had higher protein yield compared to pure barley.

A large number of mathematical models have been proposed to recognize competition among plants. These models are summarized by Weigelt and Jolliffe (2003), who conclude that competition experiments are mainly composed of different plant densities and growing patterns. Therefore, most studies concentrate on comparing mixed growth performance with that of pure stands (Connolly et al., 2001; Weigelt and Jolliffe, 2003). Land equivalent ratio (LER), crowding ratio (CR), and aggressivity (A) are some of the frequently used competition indices to compare mixtures with pure stands (Bhatti et al., 2006; Dhima et al., 2007; Yılmaz et al., 2008; Erol et al., 2009; Wahla et al., 2009; Pasynkova and Zavalin, 2010; Rahetlah et al., 2010; Atis et al., 2012a). Forage quality was evaluated in terms of neutral detergent fiber (NDF) and acid detergent fiber (ADF), which were improved by intercropping relative to sole barley crop (Yolcu et al., 2009). On the other hand, pure barley forage quality was better than the quality of vetch–barley intercropping in terms of crude protein content and yield. However, considering the yield and quality per unit area and profit, vetch–barley mixtures seemed to prevail.

Although competition is one of the main factors affecting forage yield and quality in legume–cereal intercropping, there are few, if any, reports on the effect of different mix-proportion rates on the growth rate of common vetch–barley and Hungarian vetch–barley mixtures. To the best of our knowledge, Hungarian vetch is especially underinvestigated and/or underpracticed in the Eastern Mediterranean region. The objectives of this research were (a) to evaluate common vetch, Hungarian vetch, and barley pure stands as well as 4 mixtures in seeding ratio (mix proportions of 80:20, 60:40, 40:60, and 20:80 in percentages) for forage yield and quality parameters, and (b) to estimate the effect of competition between the 2 species used in the intercropping systems in Eastern Mediterranean conditions.

2. Materials and methods

2.1. Site description and climatic conditions

Experiments were conducted during the growth seasons of 2008–2009 and 2009–2010 at the Agricultural Research Station of Mustafa Kemal University, Hatay, Turkey, which is located at 36°15′N and 36°30′E. The region has a typical Mediterranean climate. The Figure shows the meteorological data of the experimental area during the growth season from November (N) to May (M), including monthly average temperature (T) and monthly total rainfall (R). Total precipitation of the growing season (November to April) was 1147 mm for 2008–2009 and 1031 mm for 2009–2010. Soil characteristics of the experimental area before sowing were clay type with pH of 7.12 and 6.45% $CaCO_3$, 74.1 kg ha^{-1} phosphorus, and 1.93% organic matter at the depth of 30 cm.

2.2. Plant materials, experimental design, and cultivation practices

Common vetch (*Vicia sativa* 'Ina'), Hungarian vetch (*Vicia panonica* 'Ege beyazi'), and barley (*Hordeum vulgare* 'Konavi') were used as plant materials. Ina has been recently adopted by farmers, while Ege beyazi has been commonly grown in the region as well as in other parts of Turkey. Konavi has been recently registered for forage purpose. This is the first time that these vetch and barley cultivars are tested in the Eastern Mediterranean region. Seed bed preparation included plowing, disk harrowing,

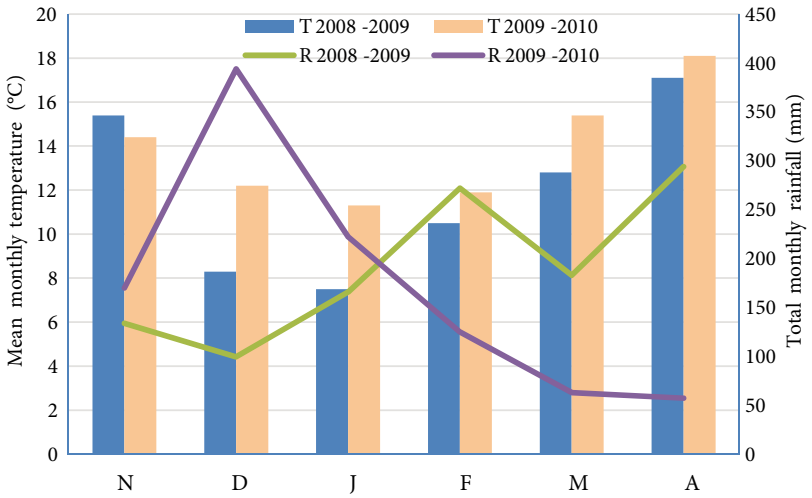

Figure. Meteorological data of the experimental area during the growing experiment (2008–2009 and 2009–2010 growing seasons).

and cultivation. Sowing was performed by hand during the second week of November in both growing seasons. The seed proportions were calculated on the basis of recommended sole seeding rate of 100, 120, and 200 kg per hectare for Hungarian vetch, common vetch, and barley, respectively. N-P fertilizer at the rate of 50 kg ha^{-1} N and 50 kg ha^{-1} P_2O_5 was uniformly applied to the soil before sowing. The seeds of all species were mixed in designated ratios prior to sowing (Table 1).

The experiment was a randomized complete block design with 11 treatments and 3 replications. The experimental plots had 6 rows with a row spacing of 20 cm and a row length of 5 m. Weed control was performed manually, but no irrigation was performed. All sole cropping and mixture treatments were manually harvested at the pod formation stage of vetches during both years (in the third week of April). To determine dry matter yield and crude protein yield, an area of 1 m^2 was harvested from each plot; the species were then separated and the respective yield was converted into kg ha^{-1}. After harvesting 1 kg of green forage, subsamples from each treatment were dried at 70 °C for 48 h to determine their quality parameters. The effect of the interaction among the species in the mixtures was calculated using competition indices.

2.3. Competition indices

In order to determine the land use efficiency of pure stands compared to intercrops, the land equivalent ratio (LER) has been widely used as an index. Such calculations reveal optimum intercropping patterns. LER values were calculated for vetch and barley and their mixtures as follows:

$LER = (LER_{vetch} + LER_{barley})$

$LER_{vetch} = (Y_{vb}/Y_v)$

$LER_{barley} = (Y_{bv}/Y_b)$, where LER_{vetch} and LER_{barley} were land equivalent ratios of vetch and barley, respectively, Y_v and Y_b were the yields of common vetch and Hungarian vetch barley as pure stand, and Y_{vb} and Y_{bv} were the yields of vetch and barley in the mixtures, respectively. When LER is greater than 1.00, the mixed growing favors the growth and yield of species. In contrast, when LER is lower than 1.00, the intercropping negatively affects the growth and yield of plants in mixtures (Cabellero et al., 1995; Dhima et al., 2007). Another index used to determine the competitive relationship between 2 crops in mixtures is aggressivity (A), (Bhatti et al., 2006). Aggressivity is formulated by McGilchrist (1965) as follows:

$A_{barley} = \{Y_{bv}/(Y_bZ_{bv})\} - \{Y_{vb}/(Y_vZ_{vb})\}$

$A_{vetch} = \{Y_{vb}/(Y_vZ_{vb})\} - \{Y_{bv}/(Y_bZ_{bv})\}$, where Z_{vb} and Z_{bv} were the seed rates of vetch and barley in the seed mixture. If $A_{barley} = 0$, both crops are equally competitive. If A_{barley} is positive, then the vetch is dominant in the mixture; if A_{barley} is negative, then the barley is dominant (Wahla et al., 2009).

Crowding ratio (CR) is another way to assess competitive ability between different species. CR gives stronger competitive ability to the crops and is also more advantageous than other indices. CR represents the ratio of individual LER of the 2 component crops in which they were initially sown. Then the CR index was formulated as follows:

$CR_{vetch} = (LER_{vetch}/LER_{barley})\ (Z_{bv}/Z_{vb})$

Table 1. Ratios of species in mixtures and related code numbers.

Treatment	Code	Mixtures	Mixture rates (%)	
			Legume	Barley
1	CV20B80	Common vetch	20	80
2	CV40B60	Common vetch	40	60
3	CV60B40	Common vetch	60	40
4	CV80B20	Common vetch	80	20
5	CV100	Sole cropping common vetch	100	0
6	HV20B80	Hungarian vetch	20	80
7	HV40B60	Hungarian vetch	40	60
8	HV60B40	Hungarian vetch	60	40
9	HV80B20	Hungarian vetch	80	20
10	HV100	Sole cropping hungarian vetch	100	0
11	B100	Sole cropping barley	0	100

The actual yield loss (AYL) is the proportionate yield loss or gain of intercrops in comparison to the respective sole crop. To be precise, it takes into account the actual sown proportion of the component crops with its sole stand (Dhima et al., 2007). In addition, partial AYL_{vetch} or AYL_{barley} represent the proportionate yield loss or gain of each species when grown as intercrops, relative to their yield in sole planting (Dhima et al., 2007). The AYL (Banik, 1996) was calculated as:

$AYL = AYL_{barley} + AYL_{vecth}$

where $AYL_{barley} = ((Y_{bv}/Z_{bv})/((Y_{bb}/Z_{bb})) - 1$ and

$AYL_{vetch} = ((Y_{vb}/Z_{vb})/((Y_{vv}/Z_{vv})) - 1$, where Zbv and Zvb represent the sown proportion of intercrop barley with vetch, and vetch with barley, respectively. The AYL can have positive or negative values indicating an advantage or disadvantage of intercropping when the main purpose is to compare yield on a per plant basis.

2.4. Forage quality analysis and calculations

Crude protein (CP), neutral digestible fiber (NDF), and acid digestible fiber (ADF) were determined for all samples. Nitrogen concentrations were determined by the Kjeldahl procedure and crude protein concentration was calculated with the formula of N concentration × 6.25. NDF and ADF were analyzed according to the sequential method of Van Soest et al. (1991), by adding α-amylase without sodium sulfite, using the ANKOM filter bag system with A220 fiber analyzer (ANKOM Technology, Fairport, NY, USA), and being expressed as exclusive residual ash. Cellulose (ADF-ADL) and hemicellulose (NDF-ADF) were calculated from the organic matter of the detergent fiber fractions.

Relative feed value (RFV) was calculated by using related dry matter digestibility (ADF) and related intake potential (NDF) as an index signifying forage quality. Relative feed value (RFV) was identified and formulated by Rohweder et al. (1978) and Van Dyke and Anderson (2002). All formulas are indicated below:

$DDM = 88.9 - (0.77 \times ADF\%)$

$DMI = (120/NDF\%)$

$RFV = DDM\% \times DMI\% \times 0.775$

$NE_1 = ((1.044 - (0.0119) \times ADF\%)) \times 2.205$, where DDM was digestible dry matter as percent (%) of dry matter, and DMI was dry matter intake as percent (%) of body weight.

Other statistical analyses were performed as follows: since the 2-year variances were homogeneous according to Barlett's test ($P < 0.05$) and there were no significant year × treatment interaction, 2-year data were combined and analyzed as a randomized complete block design. For this purpose, the blocks within years were combined and 6 blocks were analyzed. We used a fixed model for block and treatments. All data were subjected to analysis of variance (ANOVA) procedures using the SAS statistical software package 9.1 (SAS Institute, 2003). The post hoc comparisons were performed using Tukey's honestly significant difference (HSD) test.

3. Results

3.1. Dry matter yield

Differences among mixture rate means were significant ($P < 0.05$) for dry matter yield. The highest DMY was obtained from the mixture rates of HV80B20, and CV80B20 showed similar DMY. The former indicated 11.1% and the latter 7.6% yield increase compared to barley pure stand (Table 2). When the vetch mixtures were compared to each pure stand, yield increase ranged from 30.4% to 74.6%. In terms of dry matter yield, barley pure stands had statistically similar values to those of CV60B40 and HV60B40. Dry matter yield of HV100 was higher than that of CV100.

3.2. Crude protein yield

Crude protein yield among mixture rates was significantly influenced by intercropping patterns (Table 2). The maximum crude protein yields of 1461.5 kg ha^{-1} and 1325.4 kg ha^{-1} were obtained from CV80B20 and HV80B20, respectively. Other mixtures and pure stands had statistically similar CPY (Table 2). When compared to pure stands of barley, common vetch, and Hungarian vetch, CV80B20 showed a CPY gain as high as 55.0%, 40.3%, and 18.2%, respectively.

3.3. Land equivalent ratio

In general, partial LER_{vetch} value was lower in Hungarian vetch–barley mixtures than in common vetch–barley mixtures (Table 2). As expected, partial LER_{vetch} values decreased as the proportion of barley increased in the mix-proportion intercropping pattern (Table 2). The partial LER_{vetch} value was higher than 0.50 in the mix proportion of CV80B20; however, partial LER_{barley} values were higher than 0.50 in the remaining mix proportions. When the mixing rate of vetches was over 60%, the values of LER_{total} in the proportions were higher than 1.0. The LER values were highest in CV80B20 (1.38) intercropping followed closely by HV80B20 (1.25) barley intercropping. Therefore, 38%–25% extra area would be required for the same amount of yield using solitary cropping (Table 2). In general, partial LER values for Hungarian vetch mixtures appeared lower than those of common vetch.

3.4. Crowding ratio, aggressivity, and actual yield loss

Intercropped barley showed the highest crowding ratio (CR) values in all vetch–barley mixtures. Among the vetches, the Hungarian vetch had higher CR values than the common vetch (Table 3). Depending on the increase in vetch proportions, CR_{vetch} values showed a tendency to decrease when less than 60%; however, when they reached 80%, CR_{vetch} increased again.

All treatments (mix proportions), except for 80% vetch + 20% barley intercropping, had positive A_{barley}

Table 2. Dry matter yield (DMY), dry matter yield of barley (DMYB), dry matter yield of vetch (DMYV), crude protein yield (CPY), and land equivalent ration (LER) of intercrops.

Intercropping pattern	DMY (kg ha^{-1})	DMYB (kg ha^{-1})	DMYV (kg ha^{-1})	CPY (kg ha^{-1})	LER_{Vetch}	LER_{Barley}	LER_{Total}
CV20B80	6897.2	6203.4	693.8	906.4	0.14	0.77	0.91
CV40B60	7213.6	5892.1	1321.5	992.3	0.27	0.73	1.00
CV60B40	8114.8	6153.8	1961.0	1102.3	0.39	0.76	1.15
CV80B20	8690.3	4745.4	3944.9	1461.5	0.79	0.59	1.38
CV100	4976.2	–	4976.2	1120.1	–	–	–
HV20B80	7071.6	6323.9	747.7	893.7	0.14	0.78	0.92
HV40B60	7204.8	6487.4	717.4	879.5	0.13	0.80	0.93
HV60B40	8337.6	7297.0	1040.6	1070.9	0.19	0.90	1.09
HV80B20	8965.2	6558.1	2407.0	1325.4	0.44	0.81	1.25
HV100	5421.3	–	5421.3	1121.5	–	–	–
B100	8072.3	8072.3	–	944.7	–	–	–
Mean	7360.4	6414.8	2323.1	1074.4	0.31	0.77	1.08
$HSD_{(0.05)}$	367.6	39.1	28.5	51.6	0.05	0.05	0.05

Table 3. Crowding ratio (CR), aggressivity (A), and actual (AYL) yield loss for mixtures of barley with common vetch and Hungarian vetch in 4 seeding ratios (based on seeding rate kg ha^{-1}).

Intercropping pattern	Crowding ratio		Aggressivity		Actual yield loss		
	CR_{Vetch}	CR_{Barley}	A_{Vetch}	A_{Barley}	AYL_{Vetch}	AYL_{Barley}	AYL_{Total}
CV20B80	0.726	1.378	–0.597	0.597	–0.262	–0.120	–0.382
CV40B60	0.546	1.832	–0.024	0.024	0.123	0.020	0.143
CV60B40	0.345	2.902	–0.064	0.064	0.160	0.466	0.626
CV80B20	0.337	2.966	0.520	–0.520	0.817	0.618	1.436
HV20B80	0.704	1.420	–0.610	0.610	0.080	–0.115	–0.035
HV40B60	0.659	4.049	–0.425	0.425	0.039	0.217	0.256
HV60B40	0.319	7.064	–0.246	0.246	0.044	0.997	1.041
HV80B20	0.364	7.319	0.310	–0.310	–0.015	2.017	2.002
Mean	0.500	3.616	–0.142	0.142	0.123	0.513	0.636
$HSD_{(0.05)}$	0.097	1.252	0.211	0.211	0.219	0.174	0.296

values, indicating that barley was the dominant species in vetch–barley intercropping (Table 3). The highest barley proportions resulted in approximately 3 times higher aggressivity values than the lowest barley proportions in the mixtures.

In particular, AYL_{barley} had positive values in vetch–barley intercropping when the barley rate was less than 80% in all treatments (Table 3). The highest AYL_{barley} values were obtained from HV80B20 intercropping, while the lowest AYL_{barley} values were noted in CV20B80. Actual yield loss of barley in the mixtures was 3.2 times higher in HV80B20 than in CV8020. Barley yield losses diminished as the barley proportions increased in the mixtures (Table 3). The highest AYL_{vetch} value was noted in CV80B20,

while the lowest value was observed in CV20B80. The former had approximately 5-fold higher yield loss than the latter (Table 3). Comparing the 2 legumes, the common vetch showed higher AYL values than the Hungarian vetch. In general, both the Hungarian vetch–barley and common vetch–barley intercropping showed positive AYL values (except CV20B80 and HV80B20), indicating yield increases for both species (Table 3).

3.5. Forage quality properties

In general, all the quality features examined in this study appeared to be affected by the increase in the rate of vetches in the mixtures. Pure barley ADF and NDF values were higher than those of pure vetch species (Table 4). When we compared the vetch species, ADF and NDF values of common vetch were significantly lower than those of Hungarian vetch (Table 4). As the rate of barley increased in the mixtures, ADF and NDF values tended to increase (Table 4). The mixtures of the common vetch–barley had slightly lower ADF and NDF values compared to Hungarian vetch–barley mixtures (Table 4).

There were significant differences in the TDN content among the mixture rate treatments. The highest TDN was obtained in the common vetch sole cropping (Table 4). The increase in barley rate caused a significant decrease in the TDN content in vetch–barley intercropping.

The highest DMI value was obtained in the common vetch sole cropping, and the lowest from the sole barley crop (Table 4). It was determined that the DMI values corresponded to a body weight of 2.05% for pure barley, 2.51% for common vetch, and 2.38% for Hungarian vetch (Table 4). Accordingly, the elevated rates of vetch species in the mixtures resulted in increasing DMI values. On the other hand, common vetch mixtures had significantly higher DMI than Hungarian vetch mixtures, especially during vetch proportion, which was over 40% (Table 4). The results of DDM content appeared similar to those of DMI. However, there were no significant differences among treatments (Table 4).

As expected, RFV values are positively correlated with NDF and ADF contents since they are functions of each other. The highest RFV was determined in the pure stand of common vetch while the lowest RFV was observed in the pure stand of barley (Table 4). Comparing the same mix-proportions among treatments, RFV values were significantly higher in common vetch than in Hungarian vetch mixtures (Table 4). The average NE_l was 1.43%, and there were significant differences among the treatments in terms of NE_l values (Table 4). However, when the same mix-proportions were compared, only CV80B20 had significantly higher NE_l values than HV80B20 (Table 4). Considering the pure stand vetch species, NE_l value was higher in common vetch than in Hungarian vetch (Table 4).

Table 4. Acid detergent fiber (ADF), neutral detergent fiber (NDF), total digestible nutrients (TDN), dry matter intake (DMI), digestible dry matter (DDM), relative feed value (RFV), and net energy for lactation (NE_l) in dry forage yield of monoculture and mixtures of common vetch and Hungarian vetch with barley.

Intercropping pattern	ADF (g kg^{-1})	NDF (g kg^{-1})	TDN (g kg^{-1})	DMI (g kg^{-1})	DDM (g kg^{-1})	RFV (%)	NE_l (Mcal kg^{-1})
CV20B80	355.0	575.3	555.2	20.9	612.5	99.0	1.37
CV40B60	346.7	551.0	565.9	21.8	618.9	104.5	1.39
CV60B40	329.3	534.3	588.4	22.5	632.5	110.1	1.44
CV80B20	309.5	519.0	613.9	23.1	647.9	116.1	1.49
CV100	289.8	479.0	639.4	25.1	663.3	129.0	1.54
HV20B80	348.4	578.3	563.7	20.8	617.6	99.3	1.39
HV40B60	343.7	562.3	569.7	21.3	621.2	102.7	1.40
HV60B40	333.7	560.3	582.7	21.4	629.0	104.5	1.43
HV80B20	324.8	544.7	594.2	22.0	636.0	108.6	1.45
HV100	314.5	504.7	607.4	23.8	644.0	118.8	1.48
B100	361.8	587.3	546.4	20.5	607.1	96.2	1.35
Mean	332.5	545.1	584.3	22.1	630.0	108.1	1.43
$HSD_{(0.05)}$	5.2	7.1	6.7	0.3	n.s.	1.7	0.02

4. Discussion

4.1. Dry matter yield

Our findings confirmed that the increased seeding rate of vetches resulted in increased dry matter yield in vetch–barley intercropping. Similar results have been reported in triticale–vetch intercropping (Albayrak et al., 2004). Our findings also suggested that when scaling the barley, the vetches were physically supported by barley plants, and this resulted in better establishment and development (Lithourgidis et al., 2006; Karagic et al., 2011; Atis et al., 2012a). Although differences were statistically insignificant, Hungarian vetch mixtures had slightly more yield than the corresponding proportions of common vetch mixtures. Similarly, Bingol et al. (2007) obtained a slightly higher yield in Hungarian vetch–barley intercropping compared to common vetch–barley intercropping under Eastern Anatolian conditions. In our study, more than 60% of vetch content in the mixtures seemed to yield more barley compared to pure stand. The vertical growth of vetches, supported by barley, in all likelihood enhanced vetch establishment as well as nitrogen fixing roots, which also help barley grow better. Therefore, soil enrichment without extra input and with considerably higher forage yield could be possible in vetch–cereal intercropping. However, the arrangement of the right seeding ratio seems to be of critical importance, since DMY generally increased as the proportion of vetches was higher.

4.2. Crude protein yield

Crude protein yield of forage is one of the main criteria for forage quality. In all mixtures, an increase in the rate of vetch resulted in higher crude protein yield (Karagic et al., 2011). This was expected since legume establishment was greatly enhanced by the barley support, resulting in a higher protein-rich legume proportion in the mixture, especially over 60%. Albayrak et al. (2004) reported that common vetch harvested at 50% flowering time contained more protein content compared to Hungarian vetch. It seems that CPY is affected by different environments and/or genotypes. An increase in the rate of dry matter and crude protein content apparently resulted from the increase in the rate of vetches in the mixtures. Hungarian vetch and common vetch mixtures had highly similar CPY values in the same mixture rates. Although the DMY value of common vetch was lower than that of Hungarian vetch, CPY values were similar. This could be explained by the fact that common vetch had higher protein content than did Hungarian vetch. Albayrak et al. (2004) reported that protein content of common vetch was higher compared to hairy vetch and Hungarian vetch. Considering the Eastern Mediterranean conditions, warmer environments make Hungarian vetch more competitive in terms of CPY.

4.3. Land equivalent ratio

In our experiment, total LER values were higher than 1.00 during intercropping when the rate of vetch was 60% or higher, indicating that barley–vetch intercropping is more profitable. For most mixtures, the LER values of vetch were below 0.5, indicating that vetch has disadvantages in terms of land use efficiency (Rakeih et al., 2010). In our study, land use efficiency appeared to be higher in common vetch. This could be explained by the fact that Hungarian vetch is more sensitive to warm climate conditions, which affect its competitiveness with barley in terms of land use efficiency. Similar results were reported for legume–cereal intercropping (Hauggaard-Nielsen et al., 2006; Dhima et al., 2007; Yılmaz et al., 2008). Common vetch–barley intercropping mix-proportion of CV80B20 should be preferred for higher forage yield, especially for small farmers in Eastern Mediterranean conditions.

4.4. Crowding ratio, aggressivity, and actual yield loss

Crowding ratio values showed that barley was the most competitive crop in barley–common vetch and barley–Hungarian vetch intercropping. Our results were in accordance with the view that barley is the dominant species in vetch–barley intercropping (Dhima et al., 2007). Regarding the Hungarian vetch–barley mixtures, A_{barley} values continuously decreased due to the decline in the rate of barley within the common vetch–barley intercropping. Although A values of barley changed irregularly, the treatment means were statistically insignificant. AYL_{total} values that increased with the increasing rate of either vetch species in the mixtures showed that the intercropping of vetches–barley yielded advantages. Common vetch had higher AYL values than Hungarian vetch, suggesting that common vetch was more resistant to yield loss than Hungarian vetch in vetch–barley intercropping systems.

4.5. Forage quality properties

ADF and NDF concentrations are important forage quality characteristics (Cabellero et al., 1995; Assefa and Ledin, 2001). Our findings showed that the ADF and NDF values for sole common vetch were significantly lower than those for sole Hungarian vetch. However, when equal amounts of vetches in the mix-proportions were considered, ADF and NDF values were not significantly different. When the vetch ratio in the mixture increased, the ADF and NDF values decreased continuously. Pure stand barley had higher ADF and NDF concentration than the vetches, which suggested that barley had higher lignocellulosic material (Cabellero et al., 1995; Assefa and Ledin, 2001).

The TDN means the nutrients that are available for the animal and is a function of ADF and NDF content of the forage. In our experiment, the higher digestibility rate of legumes gave rise to a higher TDN content. The higher legume content in the mixtures resulted in an increased rate of TDN content, as suggested by previous

studies (Osman and Nersoyan, 1986; Roberts et al., 1989; Lithourgidis et al., 2006; Karagic et al., 2011).

Increased rate of vetches within vetch–barley intercroppings resulted in increased DMI values. Similar results have been reported by previous researchers (Yücel and Avci, 2009). The inverse relationship between DMI and NDF values also led to such results (Hackmann et al., 2008; Atis et al., 2012b). It was indicated that increased vetch rate in the mixtures will likely increase the quality of feed consumed by the animals.

Elevated vetch rate also resulted in increased DDM. However, this increase was not significant. Since DDM is a function of ADF and they are negatively correlated, the ADF contents of both vetch species were lower than those of barley (Karagic et al., 2011). Yücel and Avci (2009) pointed out that vetch DDM content was lower than that of triticale. Therefore, legume–cereal intercropping was likely to enhance the amount of DDM produced per unit area (yield).

RFV is an index that estimates the intake and energy value of the forages, and is derived from DDM and DMI. Our findings showed that the RFV of both vetch species in mixtures was significantly lower than that of the pure stands. The quality of mixtures was obviously lower than that of pure vetches. However, the yield of mixtures was significantly higher than that of pure vetches, suggesting a better gain from per unit area.

Increased rate of legumes in the mixtures resulted in an apparent increase in NE_1 values (Sadeghpour et al., 2014). Between the vetches and their mix proportions, NE_1 value was significantly higher in pure common vetch; however, only CV80B20 had significantly higher NE_1 value than HV80B20, while others were not significantly different from each other. The highest NE_1 value obtained from the common vetch with the highest proportion indicated that the degree of proportionality is also critical in terms of feed lactation.

In conclusion, it is crucial to produce greater forage yield, nutritional quality, and related nutrient yields per hectare for forage crops. The results of this study showed that Hungarian vetch produced relatively better yield results in vetch–barley intercropping, and hence can be considered an alternative to common vetch, which is widely used in intercropping mixtures in Mediterranean climates. The comparison of the 2 vetches indicated that both had similar quality, although Hungarian vetch mixtures had lower quality parameters. However, both pure sowing and the barley mixtures showed that Hungarian vetch produced a higher dry matter yield. The competitive index values showed that barley was the dominant species in the mixtures. Therefore, the seeding rate of barley should be kept below 40% in the mixture to ensure best quality and yield parameters. Both vetch species could be preferred for vetch–barley intercropping. However, the rate of the vetch should preferably be 80% in mixtures, as a vetch rate below 60% does not appear to be suitable in Eastern Mediterranean or similar ecological conditions. Another advantage of vetch–barley intercropping in such environments is that approximately 25%–38% or more areas could be saved for similar yield and quality parameters for forage crops.

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