Legume Research, , 40(4) 2017 : 677-683
Print ISSN:0250-5371 / Online ISSN:0976-0571

AGRICULTURAL RESEARCH COMMUNICATION CENTRE
www.arccjournals.com/www.legumeresearch.in

Effects of sowing ratio and harvest periods on hay yields, quality and competitive characteristics of Hungarian vetch – cereal mixtures

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Received: 14-11-2016 Accepted: 21-04-2017 DOI: 10.18805/lr.v0i0.8411

ABSTRACT

Since Hungarian vetch has semi-decumbent stem, it is commonly grown in mixture to prevent lodging of plants. Hungarian vetch, barley, wheat and triticale were sown as pure and in vetch-cereal mixtures (70:30, 60:40, 50:50, 40:60) and harvested at two periods (pure cereals and mixtures were harvested at flowering and milk-dough stage of cereals; pure vetch was harvested at flowering and initial pod-set). Barley in all mixtures had negative impacts on development of Hungarian vetch. Considering hay yields, crude protein yields and land equivalent ratios, it was concluded that 70% Hungarian vetch + 30% triticale and 60% Hungarian vetch + 40% triticale mixtures under terrestrial climate sown in fall and harvested at milk-dough stage of triticale were advantageous.

Key words: Cereal hays, Competition, Hungarian vetch, Intercropping, Yield.

Abbreviations: ADF: acid detergent fiber, NDF: neutral detergent fiber, LER: land equivalent ratio, A: aggressivity, CR: competitive ratio, NIRS: near infrared spectroscopy, SE: Standard error.

INTRODUCTION

Hungarian vetch being resistant to cold and drought can be sown in regions with harsh winters (Tas *et al.,* 2007). The plants fix about 100 kg N ha^{-1} through biological fixation (Ramseier, 2016). Hungarian vetch is also sown in the fallow lands in cereal-fallow systems. However, plants have semi-decumbent growth and lodges usually after fruit set. Intercropping is, therefore, practiced to prevent lodging; and generally cereals are used in mixtures. Since ecological factors are moderated under intercropping systems, intercropping is more yielding than sole cropping. However, since there is a competition among the plants in mixture for water, light and nutrients, the species to be used in mixtures, mixture ratios and harvest dates should be well-adjusted to get the desired benefits from intercropping systems (Onal Asci *et al.,* 2015). The present study was, therefore, conducted to determine the effects of harvest dates and mixture ratios on yield, quality and competition characteristics of Hungarian vetch-cereal mixtures.

MATERIALS AND METHODS

Experiment was conducted in Yozgat, Turkey (34° 28' 03" E, 39° 37' 03" N, altitude 770 m) during the growing seasons of 2013-14 and 2014-15. Soil was slightly alkaline (pH = 8.20), slightly saline (0.018%) with clay-loam texture, having moderate lime (7.93% $CaCO_3$) medium phosphorus (86.2 kg P_2O_5 ha^{-1}), high potassium (484.7 kg K_2O ha^{-1}) and low organic matter (1.91%) content.

There were significant differences in precipitations and temperature during the vegetation periods and the long-term averages (Figure 1).

Hungarian vetch (*Vicia pannonica* Crantz cv. Altınova 2002) and cereals (*Hordeum vulgare* L. cv. Tarm 92, *Triticum aestivum* L. cv. Pehlivan and *x Triticosecale* Wittmack cv. Karma 2000) were sown in pure and in mixtures (vetch:cereal respectively as; 70:30, 60:40, 50:50, 40:60) on 9 October, 2013 and 10 October, 2014. Using split plot design with 4 replications; harvest times as main plots and mixtures in subplots. Seed was sown with a drill as to have 5 m long 8 rows in each subplot with 20 cm row spacing. In pure sowings, 220 kg ha^{-1} seed was used for barley, 180 kg ha^{-1} for wheat, 200 kg ha^{-1} for triticale and 100 kg ha^{-1} for Hungarian vetch. The amount of seed to be used in mixtures was determined based on mixture ratios and they were sown in alternative rows. Fertilizer was applied to all plots at sowing (80 kg P_2O_5 and 30 kg N and in spring 20 kg N ha^{-1}). Pure Hungarian vetch was harvested at flowering and initial pod-set periods and the cereals were harvested at flowering and milk-dough stages. Harvested herbage was separated, weighted as vetch and cereal and then dried at 60 °C until a constant weight. Acid detergent fiber (ADF), neutral detergent fiber (NDF) and crude protein ratios of vetch and cereal samples were determined by NIRS and weighted ratios in mixtures were calculated. To determine the competition among the plants, Land Equivalent Ratio (LER), Aggressivity

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Table 1: Hay yield (kg ha^{-1}) as influenced by stage of harvest in sole and intercropping***.

Mixture	Harvest stage I		Harvest stage II	
	Year 1	Year 2	Year 1	Year 2
100 HV	3289 ^{Db1}	4866 ^{DEa1}	4100 ^{GHIb1}	5288 ^{Ea1}
100 B	5985 ^{ABb1}	9836 ^{Aa1}	6516 ^{ABCDa1}	7343 ^{Da2}
70HV+30B	6806 ^{Ab1}	8469 ^{ABa1}	5768 ^{DEFGHb1}	7341 ^{Da1}
60HV+40B	5976 ^{ABb1}	8708 ^{ABa1}	6038 ^{CDEFb1}	7762 ^{Da1}
50HV+50B	6412 ^{ABb1}	8018 ^{BCa1}	6671 ^{ABCDa1}	7765 ^{Da1}
40HV+60B	5671 ^{ABb1}	8646 ^{ABa1}	5799 ^{DEFGb1}	7462 ^{Da2}
100 W	3215 ^{Db1}	5842 ^{DEa2}	4028 ^{HIb1}	7728 ^{Da1}
70HV+30W	3733 ^{CDb1}	5936 ^{DEa2}	4658 ^{EFGHIb1}	8184 ^{CDa1}
60HV+40W	3820 ^{CDb1}	6359 ^{CDEa2}	4071 ^{GHIb1}	8776 ^{CDa1}
50HV+50W	3886 ^{CDb1}	5564 ^{DEa2}	4302 ^{FGHIb1}	8829 ^{CDa1}
40HV+60W	3366 ^{Db1}	5535 ^{DEa2}	3755 ^{Ib1}	9846 ^{BCa1}
100 T	5839 ^{ABa2}	4801 ^{Ea2}	6289 ^{BCDEb1}	11194 ^{ABa1}
70HV+30T	5863 ^{ABa2}	5247 ^{DEa2}	7578 ^{ABCb1}	12594 ^{Aa1}
60HV+40T	5461 ^{ABCa1}	6606 ^{CDa2}	8153 ^{Ab1}	11453 ^{ABa1}
50HV+50T	4855 ^{BCDa2}	5339 ^{DEa2}	6515 ^{ABCDb1}	9766 ^{BCba1}
40HV+60T	5386 ^{ABCa2}	5150 ^{DEa2}	7884 ^{ABb1}	10679 ^{Ba1}
SE	125.4			

***: year*mixture*harvest stage p<0.001

In the same year and harvest time, mixture means that do not share a common uppercase letter are significantly different (p<0.05)

In the same mixture and harvest time, year means that do not share a common lowercase are significantly different (p<0.05)

In the same year and mixture, harvest time means that do not share a common number are significantly different (p<0.05)

(A) and Competitive Ratio (CR) were calculated with the following equations;

$$LER = LER_v + LER_c \quad ,$$

$$LER_v = \left(\frac{Y_{vi}}{Y_v}\right), LER_c = \left(\frac{Y_{ci}}{Y_c}\right)$$

Y_v and Y_c are respectively the pure crop yields of Hungarian vetch and cereals; Y_{vi} and Y_{ci} are respectively the yields of Hungarian vetch and cereals in mixture (Dhima *et al.,* 2007).

$$A_c = \left(\frac{Y_{ci}}{Y_c Z_{ci}}\right) - \left(\frac{Y_{vi}}{Y_v Z_{vi}}\right)$$

$$A_v = \left(\frac{Y_{vi}}{Y_v Z_{vi}}\right) - \left(\frac{Y_{ci}}{Y_c Z_{ci}}\right)$$

Z*ci* and Z*vi* are respectively the ratios of cereal and vetch in mixture.

$$CR_c = \left(\frac{LER_c}{LER_v}\right)\left(\frac{Z_{vi}}{Z_{ci}}\right)$$

$$CR_v = \left(\frac{LER_v}{LER_c}\right)\left(\frac{Z_{ci}}{Z_{vi}}\right)$$

The assumptions of data normality and homogeneity of variance were tested with the Kolmogorov-Smirnov test and the Levene's test, respectively. Means were compared with Tukey's HSD test at the alpha 5% level.

RESULTS AND DISCUSSION

Year*harvest date*mixture interaction was significant (p<0.001). Hay yields of mixtures increased with the progress of harvest time and yields were higher in the second year. Water is being the most significant factor influencing plant growth. It is quite usual to have higher yields in the second year with higher precipitations. Also, delayed harvest and prolonged vegetation duration, helped higher harvest. All Hungarian vetch-cereal intercropping systems had higher yields than pure Hungarian vetch during both years and the yields of intercropping systems varied based on species and ratio of cereals used in mixtures (Table 1). Similar results were also reported by Cacan and Yilmaz (2015) and Dordas *et al.* (2012). Differences in yields of mixtures were mainly because of differences in tillering characteristics, climate and soil requirements, plant heights and flowering periods of cereals in mixtures. Wheat experienced significant reductions due to droughts during first year, therefore, Hungarian vetch – wheat mixtures had lower yields than the other mixtures in both harvest periods. Barley mixtures on the other hand had lower yields in the second harvest of the second year than from the first harvest (Table 1). Among the cereal species, barley is harvested the first, it has also shallow root system and hence the productivity was limited by soil available moisture. Therefore, barley might have exposed to drought conditions during the second harvest period. Therefore, lower leaves of barley dried out and Hungarian vetch plants were quite weak (data not shown). Triticale is usually harvested the last and it was least influenced by climate and soil. It was the tallest cereal and less tillering than the other species (data not shown). Cereals may tolerate reduction in sowing ratios

Table 2: Crude protein (%) as influenced by stage of harvest in sole and intercropping**.

Mixture	Harvest stage I		Harvest stage II	
	Year 1	Year 2	Year 1	Year 2
100 HV	21.97 ^{Aa1}	23.33 ^{Aa1}	18.55 ^{Aa2}	18.41 ^{Aa2}
100 B	14.36 ^{Ea1}	13.06 ^{EFa1}	13.28 ^{CDEa1}	11.52 ^{CDEa1}
70HV+30B	17.13 ^{CDEa1}	16.04 ^{CDEa1}	13.28 ^{CDEa2}	13.98 ^{BCDa2}
60HV+40B	15.50 ^{DEa1}	16.40 ^{CDa1}	13.78 ^{BCDEa2}	13.66 ^{BCDa2}
50HV+50B	15.64 ^{DEa1}	14.90 ^{CDEFa1}	13.58 ^{CDEa2}	14.15 ^{BCDa1}
40HV+60B	15.54 ^{DEa1}	14.71 ^{CDEFa1}	14.19 ^{BCDEa1}	13.90 ^{BCDa1}
100 W	15.20 ^{DEa1}	13.41 ^{DEFa1}	12.64 ^{DEa2}	11.07 ^{DEa2}
70HV+30W	20.58 ^{ABa1}	16.52 ^{Cb1}	16.22 ^{ABCa2}	15.42 ^{ABa1}
60HV+40W	20.10 ^{ABCa1}	17.23 ^{BCb1}	16.19 ^{BCa2}	15.71 ^{ABa1}
50HV+50W	20.07 ^{ABCa1}	17.39 ^{BCb1}	16.80 ^{ABa2}	14.03 ^{BCDb2}
40HV+60W	17.84 ^{BCDa1}	16.38 ^{CDa1}	15.83 ^{ABCa1}	14.48 ^{BCa1}
100 T	15.05 ^{DEa1}	12.77 ^{Fb1}	11.67 ^{Ea2}	9.92 ^{Ea2}
70HV+30T	17.60 ^{BCDb1}	19.90 ^{Ba1}	13.35 ^{CDEa2}	12.82 ^{BCDEa2}
60HV+40T	17.43 ^{CDEa1}	17.61 ^{BCa1}	13.45 ^{CDEa2}	12.22 ^{CDEa2}
50HV+50T	17.27 ^{CDEa1}	16.94 ^{BCa1}	15.04 ^{BCDa2}	12.29 ^{CDEb2}
40HV+60T	16.63 ^{DEa1}	17.23 ^{BCa1}	14.87 ^{BCDa1}	12.63 ^{BCDEb2}
SE	0.61			

**: year*mixture*harvest stage $p<0.01$
In the same year and harvest time, mixture means that do not share a common uppercase letter are significantly different ($p<0.05$)
In the same mixture and harvest time, year means that do not share a common lowercase are significantly different ($p<0.05$)
In the same year and mixture, harvest time means that do not share a common number are significantly different ($p<0.05$)

Table 3: Crude protein yield of treatment at two harvest time (kg ha^{-1}) as influenced by stage of harvest in sole and intercropping***.

Mixture	Harvest stage I		Harvest stage II	
	Year 1	Year 2	Year 1	Year 2
100 HV	723 ^{CDEb1}	1142 ^{ABCDEa1}	754 ^{CDEFb1}	972 ^{EFa2}
100 B	864 ^{ABCDb1}	1285 ^{ABCa1}	866 ^{ABCDEa1}	852 ^{Fa2}
70HV+30B	1166 ^{Aa1}	1355 ^{ABa1}	761 ^{CDEFb2}	1027 ^{EFa2}
60HV+40B	928 ^{ABCb1}	1428 ^{Aa1}	833 ^{BCDEb1}	1062 ^{DEFa2}
50HV+50B	1006 ^{ABCa1}	1195 ^{ABCDa1}	901 ^{ABCDa1}	1099 ^{CDEFa1}
40HV+60B	883 ^{ABCDb1}	1272 ^{ABCa1}	817 ^{BCDEb1}	1038 ^{EFa2}
100 W	494 ^{Eb1}	776 ^{FGa1}	509 ^{Fb1}	859 ^{Fa1}
70HV+30W	769 ^{BCDEb1}	988 ^{CDEFa2}	757 ^{CDEFb1}	1261 ^{BCDEa1}
60HV+40W	770 ^{BCDEb1}	1098 ^{BCDEa2}	659 ^{DEFb1}	1376 ^{ABCa1}
50HV+50W	785 ^{BCDEa1}	964 ^{DEFa2}	729 ^{CDEFb1}	1236 ^{BCDEa1}
40HV+60W	600 ^{DEb1}	902 ^{DEFGa2}	592 ^{EFb1}	1426 ^{ABa1}
100 T	878 ^{ABCDa1}	612 ^{Gb2}	733 ^{CDEFb1}	1113 ^{CDEFa1}
70HV+30T	1036 ^{ABa1}	1044 ^{CDEFa2}	1007 ^{ABCb1}	1610 ^{Aa1}
60HV+40T	950 ^{ABCb1}	1161 ^{ABCDEa2}	1095 ^{ABb1}	1399 ^{ABCa1}
50HV+50T	839 ^{BCDa1}	905 ^{DEFGa2}	979 ^{ABCb1}	1198 ^{BCDEa1}
40HV+60T	896 ^{ABCDa2}	887 ^{EFGa2}	1169 ^{Ab1}	1350 ^{ABCDa1}
SE	6.04			

***: year*mixture*harvest stage $p<0.001$
In the same year and harvest time, mixture means that do not share a common uppercase letter are significantly different ($p<0.05$)
In the same mixture and harvest time, year means that do not share a common lowercase are significantly different ($p<0.05$)
In the same year and mixture, harvest time means that do not share a common number are significantly different ($p<0.05$)

to some extent through their tillering capability and further they can form sufficient number of plants per unit area. But, if sowing density increase, competition among tillers increase. As a result of competition, tiller grow weakly. Barley and wheat tillered more than triticale and thus the tillers in mixtures including these species and including 50 and 60% triticale were probably weaker. Thus in all mixtures, cereal ratios in hay were close to each other (data not shown). Importantly, the species used in mixtures and mixture ratios might have influenced the competition among plants, the amount of N supplied to cereal by vetch and soil biological activity (Cengel *et al.,* 2009) and all these factors might have

Table 4: ADF and NDF (%) as influenced by stage of harvest in sole and intercropping.

Factor	Factor level	ADF		NDF
		Year 1	Year 2	
Mixture	100 HV	30.03 ^{Cb}	33.76 ^{Aa}	44.94 ^{G}
	100 B	36.06 ^{Aa}	34.32 ^{Aa}	62.22 ^{AB}
	70HV+30B	32.29 ^{BCa}	34.15 ^{Aa}	59.65 ^{BC}
	60HV+40B	32.53 ^{ABCb}	35.00 ^{Aa}	59.78 ^{BC}
	50HV+50B	31.53 ^{Cb}	34.24 ^{Aa}	57.64 ^{CDE}
	40HV+60B	30.80 ^{Cb}	33.77 ^{Aa}	58.51 ^{BCD}
	100 W	35.30 ^{ABa}	34.73 ^{Aa}	65.96 ^{A}
	70HV+30W	31.91 ^{BCa}	34.25 ^{Aa}	54.47 ^{EF}
	60HV+40W	32.00 ^{BCa}	34.11 ^{Aa}	52.67 ^{F}
	50HV+50W	32.50 ^{ABCa}	34.10 ^{Aa}	52.82 ^{F}
	40HV+60W	32.59 ^{ABCa}	34.27 ^{Aa}	54.57 ^{EF}
	100 T	32.80 ^{ABCa}	34.69 ^{Aa}	64.70 ^{A}
	70HV+30T	32.49 ^{BCa}	34.76 ^{Aa}	55.54 ^{DEF}
	60HV+40T	32.74 ^{ABCa}	34.90 ^{Aa}	58.17 ^{CDE}
	50HV+50T	32.80 ^{ABCb}	36.00 ^{Aa}	57.95 ^{CDE}
	40HV+60T	32.84 ^{ABCa}	34.89 ^{Aa}	59.34 ^{BCD}
SE		0.63		1.58
Harveststage	1	31.69 ^{Ab}	32.65 ^{Ba}	55.18 ^{B}
	2	33.46 ^{Aa}	36.35 ^{Aa}	59.69 ^{A}
SE		0.84		1.80
Year	1			58.10 ^{a}
	2			56.77 ^{b}
SE				1.80

For ADF:year*mixture $p<0.05$, year*harvest stage $p<0.05$
In the same year, means of mixture that do not share an uppercase letter are significantly different ($P<0.05$).
In the same mixture, means of year that do not share a lowercase letter are significantly different ($P<0.05$).
In the same year, means of harvest time that do not share an italic uppercase letter are significantly different ($P<0.05$).
In the same harvest time, means of year that do not share an italic lowercase letter are significantly different ($P<0.05$).
For NDF: year $p<0.05$, mixture $p<0.001$, harvest stage $p<0.01$
Means of mixtures that do not share an uppercase letter are significantly different ($P<0.05$).
Means of years that do not share a lowercase letter are significantly different ($P<0.05$).
Means of harvest times that do not share an italic uppercase letter are significantly different ($P<0.05$).

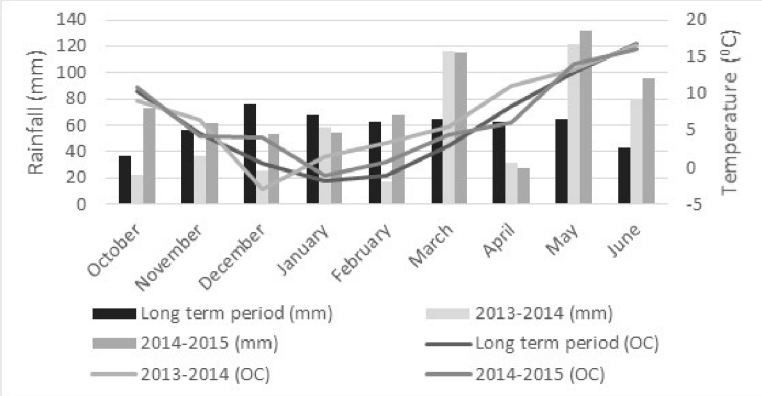


Figure 1: Temperature and precipitations of experimental years and long-term averages

further influenced the yield levels. Therefore, the highest hay yield was obtained from the second harvest period of 70HV+30T and 60HV+40T mixtures in both years (Table 1). Thusly, 70% decrease in triticale ratio resulted in about 20% decrease in yield obtained from triticale as compared to pure sowing (data not shown).

Crude protein yields were directly related to hay yields and crude protein ratios. Hay yield and protein ratio were influenced by plant species, growth stages, climate and mixture ratios. Crude protein ratios of legumes were higher than cereals. Inclusion of a legume into hay increased crude protein ratios of intercropping systems. Cereals in

Table 5: LER, CRc and CRv value of treatments

Mixture	LER***				CR*c****				CR*v***	
	Harvest stage I		Harvest stage II		Harvest stage I		Harvest stage II			
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
100 HV	1.00 ^{Ba1}	1.00 ^{Ba1}	1.00 ^{Ca1}	1.00 ^{Ea1}	-	-	-	-	-	-
100 B	1.00 ^{Ba1}	1.00 ^{Ba1}	1.00 ^{Ca1}	1.00 ^{Ea1}	-	-	-	-	-	-
70HV+30B	1.39 ^{Aa1}	1.06 ^{Bb1}	0.92 ^{Cb2}	1.13 ^{DEa1}	4.34 ^{Aa2}	4.10 ^{Aa1}	27.31 ^{ABa1}	3.67 ^{Ab1}	0.17 ^{Ea}	0.27 ^{Da}
60HV+40B	1.16 ^{ABa1}	1.05 ^{Ba1}	0.96 ^{Cb1}	1.20 ^{CDEa1}	3.60 ^{Aa2}	3.58 ^{Aa1}	18.48 ^{Ba1}	2.59 ^{Ab1}	0.18 ^{Ea}	0.34 ^{Da}
50HV+50B	1.24 ^{ABa1}	0.97 ^{Bb2}	1.04 ^{Ca1}	1.20 ^{CDEa1}	3.56 ^{Aa2}	2.25 ^{Aa1}	27.64 ^{Aa1}	1.88 ^{Ab1}	0.23 ^{DEa}	0.50 ^{Da}
40HV+60B	1.04 ^{Ba1}	1.03 ^{B1}	0.92 ^{Cb1}	1.13 ^{DEa1}	3.09 ^{Aa1}	1.64 ^{Aa1}	8.71 ^{Ca1}	1.51 ^{Ab1}	0.25 ^{DEb}	0.65 ^{CDa}
100 W	1.00 ^{Ba1}	1.00 ^{Ba1}	1.00 ^{Ca1}	1.00 ^{Ea1}	-	-	-	-	-	-
70HV+30W	1.1 ^{ABa1}	1.14 ^{ABa2}	1.17 ^{BCa1}	1.34 ^{ABCDa1}	1.89 ^{Aa1}	1.95 ^{Aa1}	2.02 ^{Ca1}	1.27 ^{Aa1}	0.54 ^{CDEa}	0.71 ^{CDa}
60HV+40W	1.19 ^{ABa1}	1.21 ^{ABa2}	1.01 ^{Cb1}	1.44 ^{ABCa1}	1.58 ^{Aa1}	0.80 ^{Aa1}	1.79 ^{Ca1}	0.83 ^{Aa1}	0.65 ^{BCDb}	1.29 ^{ABa}
50HV+50W	1.20 ^{AB1}	1.07 ^{Ba2}	1.07 ^{Cb1}	1.40 ^{ABCDa1}	1.15 ^{Aa1}	0.62 ^{Aa1}	1.43 ^{Ca1}	0.83 ^{Aa1}	0.81 ^{ABCb}	1.54 ^{Aa}
40HV+60W	1.06 ^{Ba1}	1.04 ^{Ba2}	0.94 ^{Cb1}	1.54 ^{ABa1}	1.00 ^{Aa1}	0.75 ^{Aa1}	0.89 ^{Ca1}	0.61 ^{Aa1}	1.11 ^{Ab}	1.63 ^{Aa}
100 T	1.00 ^{Ba1}	1.00 ^{Ba1}	1.00 ^{Ca1}	1.00 ^{Ea1}	-	-	-	-	-	-
70HV+30T	1.22 ^{ABa1}	1.09 ^{ABa2}	1.39 ^{ABb1}	1.62 ^{Aa1}	3.99 ^{Aa1}	1.41 ^{Aa1}	5.69 ^{Ca1}	1.79 ^{Aa1}	0.26 ^{DEb}	0.65 ^{CDa}
60HV+40T	1.14 ^{ABb2}	1.38 ^{Aa1}	1.48 ^{Aa1}	1.42 ^{ABCDa1}	2.22 ^{Aa1}	2.26 ^{Aa1}	4.00 ^{Ca1}	1.39 ^{Aa1}	0.41 ^{CDEa}	0.60 ^{Da}
50HV+50T	1.00 ^{Ba1}	1.11 ^{ABa1}	1.18 ^{BCa1}	1.24 ^{CDEa1}	1.67 ^{Aa1}	1.41 ^{Aa1}	2.44 ^{Ca1}	0.82 ^{Aa1}	0.56 ^{CDEb}	0.99 ^{BCa}
40HV+60T	1.10 ^{ABa2}	1.07 ^{Ba1}	1.51 ^{Aa1}	1.25 ^{BCDEb1}	1.27 ^{Aa1}	1.11 ^{Aa1}	0.76 ^{Ca1}	0.87 ^{Aa1}	1.10 ^{ABa}	1.05 ^{BCa}
SE	0.059				1.88				0.133	

***: year*harvest stage*mixture $p<0.001$, **:year*mixture $p<0.01$

For LER and CR*c*: In the same year and harvest time, mixture means that do not share a common uppercase letter are significantly different ($p<0.05$)

In the same mixture and harvest time, year means that do not share a common lowercase are significantly different ($p<0.05$)

In the same year and mixture, harvest time means that do not share a common number are significantly different ($p<0.05$)

For CR*v*: In the same year, means of mixture that do not share an uppercase letter are significantly different ($P<0.05$).

In the same mixture, means of year that do not share a lowercase letter are significantly different ($P<0.05$).

mixtures may benefit from N supplied by legumes, thus crude protein ratios of mixtures may be higher than pure cereal cropping. The results are in conformity with Onal Asci *et al.* (2015) who reported that crude protein ratio of triticale in forage pea-triticale mixtures was higher than pure triticale. Thus, crude protein ratios of mixtures were either significantly higher or similar with pure cereals (Table 2).

Intercropping systems had higher crude protein yields than both pure legume and cereal plots (Table 3) owing to higher yields (Table 1) and crude protein ratios (Table 2) of mixtures. Therefore, it was concluded that for high protein yield pure barley and all vetch- barley mixtures should be harvested in the first harvest period and 70HV+30T, 60HV+40T and 40HV+60T mixtures should be harvested in the second harvest period. However, Kusvuran *et al.* (2014) obtained maximum crude protein yields from 80% Hungarian vetch + 20% barley mixture probably for the reason that performance of mixtures may differ under differing ecological conditions.

Hay ADF ratio usually increases with the progress of plant growth. Therefore in both years, ADF ratios of the first harvest were lower than the second harvest (Table 4). Legumes generally had lower ADF ratios than those of cereals. As expected, the lowest ADF ratio was found in pure Hungarian vetch plot. Contrary to expectation, ADF ratios in many treatments increased during the second year. Inclusion of legume into intercropping system decreased the ADF ratios of hay but such a decrease was not proportional to sowing ratios. Besides, the mixtures including 50 and 60% triticale had higher ADF ratios than pure triticale plots in both years. Similar to findings were reported by Budakli Carpici and Celik (2014).

Drought accelerated plant growth and plants thickened cell walls to diminish the negative impacts of droughts. Since NDF is an indicator of cell wall components, a high NDF ratio in the first year was expected. Since, NDF ratio of legumes is lower than gramineae, the highest NDF ratios were observed in pure cereals and the lowest value was found in pure Hungarian vetch and all mixtures had lower NDF ratios than pure cereals, however, decrease was not parallel to sowing ratios. Similar findings were reported by Onal Asci *et al.* (2015). Among the cereals, although wheat had the greatest NDF ratio, the NDF ratios of vetch-wheat mixtures were lower than the NDF ratios of the other mixtures (Table 4). Such a case was because of weak development of wheat in the first year and thus increased Hungarian vetch ratio in resultant hay. Stem ratio, cellulose and hemicellulose accumulation in cell wall increase with the progress of plant growth. Plant stems also have higher amount of tissues with thick cell walls than the leaves. As a result of all these processes, NDF ratio of hay increased in the second harvest period.

Root and stem structures, mineral requirements and root cation exchange capacities of Hungarian vetch and cereals used in mixtures are different (consequently benefiting from soil nutrients are different) from each other. Also, Hungarian vetch is able to supply N to cereals. In both years, mixtures including 30 and 40% wheat and triticale were found to be superior in the first harvest period and 30 and 40% triticale mixtures were found to be superior over the other mixtures in the second harvest period (Table 5). Despite the insignificant differences in A values, cereals were dominant in dry years (A*c* positive) and Hungarian vetch was dominant in wet years (A*v* positive).

Cereals had negative impacts on development of Hungarian vetch (barley in all mixtures, 30 and 40% triticale mixtures and 30% wheat mixture) in both harvest periods (CR*c*>1) (Table 5). Since barley is an early species, it probably depletes moisture and nutrients; since triticale is a tall species, its light competition probably negatively affected the development of Hungarian vetch. Besides, CR*v* was < 1 in mixtures with barley, in 30, 40 and 50% triticale mixtures in both years (Table 5) revealing that Hungarian vetch had positive effects on development of barley and triticale. Since Hungarian vetch is a legume, it supported the growth of cereals through N supply. Yilmaz *et al.* (2015) also reported that Hungarian vetch had positive effects on development of barley in mixtures.

CONCLUSION

Hungarian vetch + cereal intercropping systems produced higher hay yield with 30% triticale + 70% Hungarian vetch and 40% triticale + 60% Hungarian vetch mixture when harvested at milk-dough stage of triticale. 100B, 70HV+30B, 60HV+40B, 50HV+50B and 40HV+60B mixtures had high crude protein yields when they were harvested at flowering stage of barley and 70HV+30T, 60HV+40T and 40HV+60T mixtures had high crude protein yields when they were harvest at milk-dough stage of triticale. Further, majority of mixtures were superior over pure sowings (LER>1). Therefore, it was concluded that under terrestrial climate, 70HV+30T and 60HV+40T mixtures should be sown in fall and harvested at milk-dough stage of triticale.

ACKNOWLEDGEMENT

This Project was supported by OMU BAP with Project number PYO.ZRT.1904.14.002. We thanks to Dr. Yeliz Kasko Arici for statistic analysis. A part of data given on the article is taken from Erdem Gulumser's phd thesis.

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