Pak. J. Bot., 55(3): 1169-1174, 2023. DOI: http://dx.doi.org/10.30848/PJB2023-3(41)

YIELD, QUALITY AND COMPETITION PARAMETERS OF FORAGE RAPE

MEHMET CAN[1], SÜLEYMAN ZEYBEK[1], ÖZLEM ÖNAL AŞÇI[2], YELIZ KASKO ARICI[3], İLKNUR AYAN[1] AND ZEKI ACAR[1]

[1]*Department of Field Crops, Faculty of Agriculture, Ondokuz Mayis University, Samsun, Turkey*
[2]*Department of Field Crops, Faculty of Agriculture, Ordu University, Ordu, Turkey*
[3]*Faculty of Medicine, Biostatistics Department, Ordu University, Ordu, Turkey*
** Corresponding author: Mehmet CAN E-mail: zir.mehmet@gmail.com*

Abstract

Growing lots of crops probably would be restricted by global warming in the close future, necessary precautions should be developed. Because of its rapid growing ability and could be growing in winter period without irrigation, research activities, recently, were focused on forage rape to keep and also increase high quality roughage production. Forage rape can be grown alone, as well as grown with rye, oat, barley and annual ryegrass as binary mixture. This study was carried out in coastal area of Central Black Sea Region in Turkey during the 2015-16 and 2016-17 vegetation periods for two years. In the study forage rape (FR) cv Lenox, Hungarian vetch (HV) cv Tarm Beyazı-98, common vetch (CV) cv Nilüfer, forage pea (FP) cv Özkaynak and oat (O) cv Faikbey were used. Forage rape was planted with the other ones as binary mixture (50:50), as well as pure stand of crops. Aim of the study was to determine forage yield and some quality traits, and to investigate competition between the crops. In the consequence of this study it was determined that hay yields of all mixtures were superior to pure stands of the same crops. Competition was effected by crops and years. Though, all mixtures had advantage compare to pure stands (LER>1 and ACYL positive), consider together hay and CP yields, ADF and NDF ratios, especially FR+FP, FR+HV and FR+CV mixtures were superior to the other treatments. To increase high quality forage production these mixtures can be recommended in similar environmental conditions.

Key words: Forage rape, Mixture, Competition, Quality.

Introduction

Turkey is under semiarid climatic conditions with less than 400 mm annual precipitation in majority of the lands. On the other hand, Turkey would be one of the most effected countries from global warming. According to IPCC predictions, vast area of Turkey will expose severe hot and dry conditions, temperature will rise up to 2^{o}C (2-3^{o}C in summer), winter rainfall is going to be increase 10% while summer rainfall will decline 5-10%. In consequence, it is expected that soil moisture will decrease 15-25% in summer period in 2050 (Anon., 2014).

Since global warming will restrict to grow lots of crops (Uğur, 2008), in the scope of necessary precautions new cultivars and technics should be developed. Because of its rapid growing ability and could be growing in winter period without irrigation, research activities, recently, were focused on forage rape to meet roughage gap.

Forage rape can be grown alone, as well as grown with rye, oat, barley and annual ryegrass as binary mixture (Geun *et al.,* 2005; Shoaib *et al.,* 2014). Intercropping is one of the sustainable agricultural technics (Bauman *et al.,* 2002), in the result of lots of study conducted about this topic, it was determined that intercropping can increase yield and total profit, it help to effectively use some inputs, such as soil, water and manpower and provides some advantages in terms of ecological agriculture and decrease environmental hazards (Fordham, 1983; Francis, 1985; Hook & Gascho, 1988; Akman & Kara, 2001; Bauman *et al.*, 2002). But, sometimes advantages of intercropping could not obtain because of the competition to reach the moisture, light and nutrients between the crops. For this reason, suitable plant species and cultivars should be chosen in intercropping systems (Lithourgidis *et al.*, 2011a). This study was carried out to determine forage yield and some quality traits, and to investigate competition between the species in the binary mixture of forage rape with Hungarian vetch, common vetch, forage pea and oat.

Material and Methods

This study was carried out in coastal area of Central Black Sea Region (41^{o} 21' N, 36^{o} 15' E, altitude is 195 m asl) in Turkey during the 2015-16 and 2016-17 vegetation period for two years as winter crop. The experimental area soil texture is clay, slightly acid (pH= 6.45), saltless (0.052 mmhos/cm), limeless (1.91%) and organic matter content is low (1.36%). Phosphorus and potassium contents of soil are 35.25 and 310 kg ha^{-1}, respectively (Anon., 2016).

Compare to two growing seasons there were considerable differences between the years in terms of temperature and precipitation values (Table 1). In the study forage rape (FR) cv Lenox, Hungarian vetch (HV) cv Tarm Beyazı-98, common vetch (CV) cv Nilüfer, forage pea (FP) cv Özkaynak and oat (O) cv Faikbey were used. Forage rape was planted with the other ones as binary mixture (50:50), as well as pure stand of crops. The experiment was established according to randomized block design with 4 replicates. Each plot had 8 rows with 20 cm row spacing and crops were planted alternative rows in mixture plots. Seeds were sown at 15.10.2015 and 28.02.2017 the first and second year, respectively. Sowing ratios were 30 kg ha^{-1} for FR, 80 kg ha^{-1} HV and CV, 100 kg ha^{-1} for O and 160 kg ha^{-1} for FP in pure stands. Half of these amounts were used in binary mixture plots. Before sowing 27 kg ha^{-1} N (ammonium nitrate) and 69 kg ha^{-1} P_2O_5 (DAP) was applied to all plots. 25 kg ha^{-1} N legumes contain plots and 40 kg ha^{-1} N for without legumes plots were applied in spring. The harvest was made at blossoming stage of FR (end of April) in the first year and at the end of shooting stage of FR (end of May) in the second year. At the harvest time, leguminous crops were at budding stage and oat was at the beginning of raceme stage. Harvested forage was sorted, weighted and dried in an oven at 60°C until a constant weight (Curran *et al.*, 1993). Crude protein (CP), ADF, NDF, calcium, magnesium, phosphorus and potassium contents of samples were determined by NIRS device with IC-0904FE calibration program and weighted ratios in mixture were calculated. CP ratio was multiplied with hay yield to calculate CP yield. N uptake was calculated by using CP yield/6.25 formula (Carr *et al.*, 1998).

To determine the competition amongst the crops Land Equivalent Ratio (LER), Aggressivity (A), Competitive Ratio (CR) and Actual Yield Loss (ACYL) were calculated with the following equations. LER indicates the efficiency of intercropping for using the environmental resources compared with mono-cropping and calculated as;

$$LER = (LERr + LERo) \quad (2)$$

$$LERr = \frac{Yrm}{Yr} \quad (3)$$

$$LERo = \frac{Yom}{Yo} \quad (4)$$

Yr and Yo are the yields of FR and the other crops, respectively as mono-crops and Yrm and Yom are the yield of FR and the others, respectively, in mixture (Kızılşimşek & Erol, 2000).

when LER < 1 monocrop is superior to mixture, LER=1 there is no difference, LER>1 intercrop is superior to monocrop (Boz, 2006).

Aggressivity was calculated as;

$$A_r = \left(\frac{Y_{ri}}{Y_r Z_{ri}}\right) - \left(\frac{Y_{oi}}{Y_o Z_{oi}}\right)$$

$$A_o = \left(\frac{Y_{oi}}{Y_o Z_{oi}}\right) - \left(\frac{Y_{ri}}{Y_r Z_{ri}}\right)$$

Zri and Zoi are the ratios of FR and the others in mixture.

when Ar=0 is both crops have equal aggressivity (competition power), if Ar value is positive FR is dominant (Dhima *et al.*, 2007; Lithourgidis *et al.*, 2011b).

Competition Ratio (CR) was calculated with the following equations;

$$CR_r = \left(\frac{LER_r}{LER_o}\right)\left(\frac{Z_{oi}}{Z_{ri}}\right)$$

$$CR_o = \left(\frac{LER_o}{LER_r}\right)\left(\frac{Z_{ri}}{Z_{oi}}\right)$$

when CRr < 1 FR has positive effect, contrary of this, CRr >1 FR has negative effect (Vasilakoglou & Dhima, 2008).

Actual Yield Loss (ACYL) was calculated as follows;

$$ACYL = AYL_o + AYL_r$$

$$ACYL_o = \left[\left(\frac{Y_{oi}/Z_{oi}}{Y_o/Z_o}\right)\right] - 1$$

$$ACYL_r = \left[\left(\frac{Y_{ri}/Z_{ri}}{Y_r/Z_r}\right)\right] - 1$$

If ACYL value is positive mixture has advantage, in other words, ACYL value is negative mixture has disadvantage (Dhima *et al.*, 2007).

The data were tested for normality using the Shapiro-Wilk test and for homogeneity of variance using the Bartlett's test prior to the analyses. Two-way ANOVA (with repeated block experiments in different years) followed by Tukey's post-test was used to compare the groups. A p-value was considered statistically significant if lower than or equal to 0.05 (2-sided). All statistical analyses were performed using the Minitab v17 (Minitab Inc., State College, Pennsylvania, USA) statistical software.

Table 1. Monthly temperature and precipitation value of experimental area in 2015-16, 2016-17 and long term periods.

Months	Temperature (°C)			Rainfall (mm)		
	2015-2016	2016-2017	Long term	2015-2016	2016-2017	Long term
November	14.3	12.5	12.4	28.6	42.4	83.5
December	8.4	5.9	9.3	100	184.4	79.6
January	7.5	6.2	7.2	88.1	78.8	64.9
February	11.3	7.5	7.2	30.9	40.1	53.3
Mach	10.2	9.4	8.2	109.6	65.1	61.6
April	13.8	10.2	11.3	49.9	85.8	58.7
May	16.9	15.3	15.5	188.2	70.9	51.5

Regional Meteorological Agency of Samsun (1960-2017)

Table 2. Hay yield, CP ratio and yield and N uptake values of treatments.

Year	Treatment	Hay yield (t ha^{-1})	CP (%)	CP Yield (t ha^{-1})	N Uptake (t ha^{-1})
2016	FR	5.90Ca	20.810Aa	1.27Ca	0.20Ca
	FR+HV	14.16Ba	19.836Aa	2.79ABa	0.45ABa
	FR+O	18.478Aa	13.793Ba	2.56Ba	0.41Ba
	FR+FP	18.89Aa	19.227Aa	3.64Aa	0.58Aa
	FR+CV	14.18Ba	22.657Aa	3.19ABa	0.51ABa
	HV	6.09Ca	19.782Aa	1.20Ca	0.19Ca
	O	9.25Ca	10.425Ba	0.97Ca	0.16Ca
	FP	5.21Ca	19.321Aa	0.99Ca	0.16Ca
	CV	5.49Ca	21.327Aa	1.18Ca	0.19Ca
2017	FR	4.28Da	16.381Ba	0.69Da	0.11Da
	FR+HV	12.32ABa	18.163ABa	2.25Aa	0.36Aa
	FR+O	15.39Aa	13.893Ba	2.16Aa	0.35Aa
	FR+FP	10.51BCb	19.780Aa	2.07ABb	0.33ABb
	FR+CV	12.94ABa	18.448ABa	2.41Aa	0.39Aa
	HV	4.78Da	22.054Aa	1.05CDa	0.17Da
	O	8.19CDa	7.217Ca	0.58Da	0.93Da
	FP	6.40CDa	18.072ABa	1.15BCDa	0.18BCDa
	CV	8.04CDa	20.501Aa	1.64ABCa	0.26ABCa
P-Value		YearX Treatment: 0.000***	YearX Treatment: 0.016*	YearX Treatment: 0.000***	YearX Treatment: 0.000***

*, Statistically significant ($p<0.05$), ***, Statistically significant ($p<0.001$); The difference between treatment means without a common capital letter on the same year is significant ($p<0.05$); The difference between year means without a common small letter on the same treatment is significant ($p<0.05$)

Results and Discussion

Adverse climatic conditions and different sowing dates affected growth pattern of crops and mixtures in both years, thus regard the hay yield, CP ratio and yield and N uptake interactions of year*treatment were found to be significant (Table 2). In the first year the plants have longer growing period because of earlier sowing date. In addition, in the second year precipitation of March was far less than the same month of previous year (Table 1). Consequence of these factors, hay yields of the treatments in the first year higher than those of the second year, except for pure O and FP. Hay yield of all mixtures were higher than pure stands while oat gave the highest hay yield out of pure stands. In general, mixtures give higher yields because, they get more benefits from ecological conditions (Lithourgidis *et al.*, 2011a). Rape and legumes have broad leaves and taproots, while oat has narrow leaves and fibrous root. Probably, there is less competition between rape and oat for light compare to rape and legumes. Though legumes can fix nitrogen, probably rape get limited benefits those nitrogen because, crops were planted alternative rows. In consequence, FR+O mixtures gave higher yield in both years.

Regard the CP ratio all treatments were in the same statistical group, except for oat and its mixtures. Low CP ratio was expected from oat, because it is a gramineous. Sun *et al*., (2015), stated that as rape ratio was increasing in perennial ryegrass + rape mixture, CP ratio of forage was inclined.

CP yield and N uptake level of all mixtures were higher than pure stands. Especially, FR+HV, FR+FP and FR+CV mixtures had high CP yield and N uptake values in both years. Both high hay yields and CP ratios of those crops increased CP yield of the mixtures. It was determined in some previous studies that CP yield of mixtures were higher than pure stands (Acar *et al.,* 2017; Aşçı & Eğritaş, 2017). N uptake values of mixtures, generally, higher than pure stands (Musa *et al.,* 2010).

Climate, plant species, cultivars, plant tissues and development stages affected ADF and NDF levels of herbage. Results of these factors, consider ADF and ADF levels of forage year*treatment interaction was to be significant ($p<0.05$) (Table 3). Sowing date difference between the two years affect to growing stages and other traits of forage rape. In the second year, stalks of forage rape was lesser than the first year was, thus herbage was mainly consist of leaves. Leaves contain less ADF and NDF (Aşçı & Acar, 2018). The highest ADF and NDF levels were determined for oat in both years. Since ADF and NDF ratios of both legumes and FR, those values obtained from the other treatments lesser than pure oat. Legumes have more tissues consist of thin cell wall compare to gramineous plants (Tan & Menteşe, 2003). Stalks of legumes used this study were thinner than FR. In addition, both shorter FR plants and thinner legume plants were determined in mixture plots (data not shown). Consequences of these factors, ADF and NDF ratios of FR + Legumes mixtures were lower than FR+O mixtures. Fiber content of FR is, generally, lower than the other cool season forage crops (Darby, 2012). As FR ratio increasing in perennial ryegrass + FR mixture, ADF and NDF components of herbage were declined (Sun *et al.,* 2015). In the study, the forages obtained from the treatments, except for pure oat, were very good quality (ADF<35) in both years. Herbage was evaluated regard the NDF contents as follows; 41-46% is very good, 47-53% is good, 54-60% is acceptable and 61-65% is rejected (Anon., 2009). Quality of the herbage harvested from pure FR and HV and FR+HV, FR+FP, FR+CV mixtures were very good in both years.

Table 3. ADF and NDF ratios of herbage.

Year	Treatment	ADF (%)	NDF (%)
2016	FR	31.493ABa	39.913Da
	FR+HV	31.135ABa	40.606CDa
	FR+O	33.602ABa	55.415Ba
	FR+FP	30.417ABa	42.350CDa
	FR+CV	28.665Ba	37.352Da
	HV	34.918ABa	42.835CDa
	O	37.153Aa	64.876Aa
	FP	34.172ABa	48.928BCa
	CV	30.177ABa	42.350CDa
2017	FR	19.317Cb	26.197Eb
	FR+HV	27.841Ba	35.054Da
	FR+O	31.127ABa	47.842Ba
	FR+FP	27.314Ba	38.612CDa
	FR+CV	26.769BCa	35.930Da
	HV	32.089ABa	41.645BCDa
	O	36.424Aa	60.697Aa
	FP	32.786ABa	45.827BCa
	CV	32.444ABa	46.049BCa
P-Value		Year X Treatment: 0.003**	Year X Treatment: 0.000***

, Statistically significant ($p<0.01$); *, Statistically significant ($p<0.001$); The difference between treatment means without a common capital letter on the same year is significant ($p<0.05$); The difference between year means without a common small letter on the same treatment is significant ($p<0.05$)

Table 4. Ca, K and Mg contents of herbage (%).

Year	Treatment	Ca	K	Mg
2016	FR	1.448Aa	2.878Aa	0.296Ab
	FR+HV	1.270Aa	2.925Aa	0.287Ab
	FR+O	0.714Ba	2.748ABa	0.174Bb
	FR+FP	1.227Aa	2.673ABa	0.287Aa
	FR+CV	1.337Aa	2.980Aa	0.307Aa
	HV	1.272Aa	3.052Aa	0.296Aa
	O	0.468Ba	2.628ABa	0.125Ba
	FP	1.343Aa	2.348Ba	0.313Aa
	CV	1.192Aa	2.773ABa	0.323Aa
2017	FR	1.535Aa	2.554Aa	0.403Aa
	FR+HV	1.434ABa	2.521Aa	0.392ABa
	FR+O	0.929Da	2.385ABa	0.293Ca
	FR+FP	1.268ABCDa	2.565Aa	0.340ABCa
	FR+CV	1.367ABCa	2.738Aa	0.364ABCa
	HV	1.359ABCa	2.595Ab	0.306ABCa
	O	0.227Ea	1.980Bb	0.095Da
	FP	1.018CDa	2.431Aa	0.273Ca
	CV	1.103BCDa	2.690Aa	0.303BCa
P-Value		Year X Treatment: 0.008**	Year X Treatment: 0.004**	Year X Treatment: 0.000***

, Statistically significant ($p<0.01$); *, Statistically significant ($p<0.001$); The difference between treatment means without a common capital letter on the same year is significant ($p<0.05$); The difference between year means without a common small letter on the same treatment is significant ($p<0.05$)

In terms of Ca, K and Mg contents of herbage year*treatment interaction was significant (Table 4). As to know, dicotyledons can uptake more Ca compare to monocotyledons. Moreover, Ca contents of various plant parts are different each other. Consider K uptake there are important diversity amongst the plant species and also cultivars. Leguminous plants can uptake more Mg compare to non-legumes (Kacar & Katkat, 2009). Accordance with these findings, the lowest Ca and Mg ratios were determined for pure oat stands and it was followed by FR+O mixtures. The lowest K concentration was determined for FP and O in the first and second years, respectively. Feeds should have at least 0.3% Ca for ruminants (Tejeda *et al.*, 1985; Kidambi *et al.*, 1989). Ca concentration of the herbage is enough for ruminants, except for pure oat in the second year. For ruminant consumption, roughage should contain at least 0.8% K (Tejeda *et al.*, 1985) and 0.1% Mg (Kidambi *et al.*, 1989). K and Mg contents of herbage obtained from all treatments are enough for ruminants, except for Mg level of pure oat in the second year.

Plant species and cultivars, growing stage (Kacar & Katkat, 2009), intercropping (Lithourgidis *et al.*, 2011a) can affect P uptake. Consider the P content, there is a considerable variety amongst the plant parts (Pederson *et al.*, 2002). Significant differences were found amongst the years ($p<0.001$) and treatments ($p<0.01$) in terms of P content of herbage (Table 5). Average P concentration of herbage ranged from 0.369 to 0.422%. Hungarian vetch has the highest P content. P contents of FR, O, FP and CV were increased in mixture plots. Aşçı *et al.*, (2018) revealed that when they grew triticale and FP as pure stands and binary mixture, P content of crops increased in binary mixture plots. Forages should contain between 0.18-0.39% P for ruminants (Anon., 2001; Tekeli & Ateş, 2005). P concentration of pure HV and FR+FP mixtures was over to ruminant demands.

Table 5. P contents of herbage.

Treatment	P (%)
FR	0.369B
FR+HV	0.378B
FR+O	0.387AB
FR+FP	0.395AB
FR+CV	0.388AB
HV	0.422A
O	0.382B
FP	0.384B
CV	0.380B

The difference between treatment means without a common letter is significant ($p<0.05$)

Root and stalk habitus, mineral demands, cation exchange capacity and benefits getting from minerals, growth rate of plants used this study are different each other. For example, FR and FP are the earliest crops. Consequences of these factors, competition amongst the plants were varied. To determine the competition amongst the crops some parameters such as; Land Equivalent Ratio (LER), Agressivite (A), Competitive Ratio (CR) and Actual Yield Loss (ACYL) are investigated (Dhima *et al.*, 2007). According to variance analysis, regard the LER and ACYL (ACYLr and ACYLo) values year*treatment interactions were statistically significant ($p<0.001$ and $p<0.01$, respectively). Closely examine the LER values, forage yield of all mixtures were superior to pure stands (LER>1.0) and ACYL values demonstrated that mixtures had advantages compare to pure stands (ACYLr and ACYLo positive). On the other hand, especially reflection of FR+FP was varied between the years (Table 6). These values showed that mixtures got more benefit from environmental conditions compare to pure stands (Albayrak *et al.*, 2004). Copur Dogrusoz *et al.*, (2019) reported that legumes and turnip intercropping was more profitable than their sole sowing.

Table 6. LER, ACYLr and ACYLo values in mixtures.

Year	Treatment	LER	ACYL r	ACYL o
2016	FR+HV	2.446Ba	1.593Aa	1.299Ba
	FR+O	2.349Ba	0.687Ab	2.012ABa
	FR+FP	3.589Aa	2.208Aa	2.971Aa
	FR+CV	2.578Ba	1.669Aa	1.487Ba
2017	FR+HV	2.736Aa	1.941Aa	1.532Aa
	FR+O	2.763Aa	2.616Aa	0.909Aa
	FR+FP	1.947Ab	0.799Aa	1.096Ab
	FR+CV	2.355Aa	2.104Aa	0.607Aa

The difference between treatment means without a common capital letter on the same year is significant ($p<0.05$); The difference between year means without a common small letter on the same treatment is significant ($p<0.05$)

Table 7. CRr values in the mixtures.

Year	Treatment	CRr
2016	FR+HV	1.138Aa
	FR+O	0.583Ab
	FR+FP	0.880Aa
	FR+CV	1.068Aa
2017	FR+HV	1.173ABa
	FR+O	1.905ABa
	FR+FP	0.840Ba
	FR+CV	2.001Aa

The difference between treatment means without a common capital letter on the same year is significant ($p<0.05$); The difference between year means without a common small letter on the same treatment is significant ($p<0.05$)

Table 8. CRo values in the mixtures.

Treatment	CRo
FR+HV	0.927AB
FR+O	1.256AB
FR+FP	1.368A
FR+CV	0.776B

The difference between treatment means without a common letter is significant ($p<0.05$)

According to variance analysis results, consider the Ar and Ao values, difference between the years was only significant while differences between the years and treatments for CRo ($p<0.01$ and $p<0.05$, respectively) and interaction of year*mixture for CRr ($p<0.05$) were significant. Even if competition of FR with the other crops varied between the years, FR was dominant in mixtures in the second year, except for FP (Ar=0.008). Thus, except FP, Ao values were negative in the second year (Data not shown). In the second year FR plants had more shadow because it grew short and leafy. When we look at the CR values FR had positive effect on FP (CRr<1) (Table 7) and HV and CV made positive effect on FR (CRo<1) (Table 8) (Vasilakoglou & Dhima, 2008). These results can be attributed that FR would have supported to FP to grow erect, on the other hand HV and CV would have supplied N to FR. The results obtained from this study were accordance with conclusion of Acar *et al.*, (2017), Aşçı & Eğritaş (2017), they revealed that competition amongst the crops in the mixture can be varied depend on species and sowing ratios.

Conclusion

In the consequence of this study it was determined that hay yields of all mixtures were superior to pure stands of the same crops. Competition was effected by crops and years. Though, all mixtures had advantage compare to pure stands (LER>1 and ACYL positive), consider together hay and CP yields, ADF and NDF ratios, especially FR+FP, FR+HV and FR+ CV mixtures were superior to the other treatments. To increase high quality forage production these mixtures can be recommended in our similar environmental conditions.

Acknowledgement

This Project was supported by OMU BAP with Project number PYO.ZRT.1904.15.016. A part of data given on the article is taken from Süleyman Zeybek's Ms thesis.

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(Received for publication 22 December 2021)