Turkish Journal of Range and Forage Science, 2022, 3(1): 11-17
doi: 10.51801/turkjrfs.1073958

Research

Turkish Journal of Range and Forage Science

https://dergipark.org.tr/tr/pub/turkjrfs

Effects of Different Forage Pea and Rye Mixtures on Forage Yield and Quality

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A R T I C L E I N F O

Received *15/02/2022*
Accepted *09/05/2022*

Keywords:

Mixture ratio
Pisum sativum ssp. *arvense* L.
Quality
Secale cereale L.
Yield

A B S T R A C T

This study was carried out in the 2018-19 vegetation period to determine the appropriate mixture ratios of forage pea (*Pisum sativum* ssp. *arvense* L.) and rye (*Secale cereale* L.) under rainfed conditions of Kırşehir province, Türkiye. The layout of the experiment was randomized blocks with three replications and the treatments were pure rye, pure forage pea and four different mixtures of forage pea and rye (20% FP + 80% R, 40% FP + 60% P, 60% FP + 40% R, 80% FP + 20% R). The highest green forage yield (2395.1 kg da^{-1}), dry matter yield (833.3 kg da^{-1}), and crude protein yield (71.0 kg da^{-1}) were obtained from pure rye sowings. The highest crude protein ratio (15.6%), the lowest NDF (39.3%) and ADF (31.1%) ratios were obtained from pure forage pea sowings. The increase in the rye ratio of the mixtures increased the yield, while the increase in the forage pea ratio caused an increase in the forage quality. The results revealed that pure rye and a mixture of 20% FP + 80% R can be recommended to obtain high dry matter yield, and 40% FP + 60% R mixture for yield and quality under continental climate conditions as in Kirsehir province of Türkiye.

1. Introduction

The cultivation of at least two similar or different species together in the same field is defined as mixed cropping, which is recommended to increase yield and quality in forage crops (Acar et al., 2006). Crop yield increases when different species and varieties had better utilize the resources such as soil, water, light and plant nutrients (Francis and Smith, 1985; Baumann et al., 2002; Seydosoglu and Bengisu, 2019). High quality forage is obtained due to the high protein content of legumes and carbohydrate content of cereals used in the mixtures. Therefore, the cultivation of cereal-legume is the most common among mixed cropping systems.

Forage pea is existed in the natural flora of Türkiye and it is a delicious and nutritious annual forage legume for ruminants (Konuk and Tamkoc, 2018). Rye (*Secale cereale* L.), which is resistant to low temperatures and productive in humid and cool climates, is used in the production of forage as well as a valuable crop with the seeds around the world (Newell and Butler, 2013). The rye can grow in extreme conditions by using soil moisture very efficiently in addition to very good adaptability (Ceri and Acar, 2019). The rye, which is a cereal crop, loses its palatability rapidly by the maturation, which reduces the preference of producers to cultivate as a forage crop. Therefore, the appropriate species and varieties and the cereal + legume mixture ratios should be determined to obtain high forage yield and quality in a particular region or ecological conditions (Lithourgidis et al., 2006). The average green forage yield of Taşkent

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pea variety in Çanakkale ecological conditions was reported as 2136.2 kg da^{-1}, dry matter yield as 394.4 kg da^{-1}, crude protein ratio as 18.1%, NDF ratio as 40.8, and ADF ratio as 31.8% (Alaturk et al. (2021). Yolcu et al. (2009) investigated the yields of barley, wheat, rye, oat and their mixtures with Hungarian vetch, and they recorded the highest green forage and dry matter yields from pure rye and rye + Hungarian vetch mixture. The researchers stated that forage obtained with pure Hungarian vetch was high in crude protein and low in NDF and ADF ratios (Kocer and Albayrak, 2012; Onal et al., 2015; Baxevanos et al., 2017) Cherney et al. (1985) stated that both the anatomical structures and chemical compositions of cereals and legumes can lead to differences in ADF ratios. In this study, forage yield and quality of different rye-forage pea mixture combinations were investigated in Kırşehir ecological conditions.

2. Materials and Methods

The research was carried out in the experimental fields of Kırşehir Ahi Evran University during 2018-2019 vegetation period. Total precipitation and relative humidity were lower than the long-term average, and the temperature was above the long-term average values during the experiment (Table 1).

The soils of the experimental field were clayey-loam textured, highly calcareous (22.23%), rich in available potassium (159.9 kg da^{-1}), insufficient in available phosphorus (5.95 kg da^{-1}) and poor in organic matter (1.00%) content (Karaman, 2012). Pure and mixed sowings were carried out manually on 13 November using 20 cm inter row spacing. In order to use rainwater more effectively in dry agricultural areas where the annual precipitation distribution is irregular, the trial was established in winter seasons. Each plot had 10 rows with 5 m length. Aslım-95 rye (*Secale cereale* L.) and Taşkent forage pea (*Pisum sativum* ssp. *arvense* L.) cultivars were used as plant material of the experiment. Six treatments composed of pure sowings of forage pea (FP) and rye (R), and four different mixtures (20% FP + 80% R, 40% FP + 60% R, 60% FP + 40% R, 80% FP + 20% R) were examined. The amount of seeds used in pure sowing was calculated as 100 seed m^2 in forage pea (Konuk and Tamkoc, 2018), and 500 seed m^2 in rye (Anonymous, 2022). The amount of seeds in the mixtures was calculated considering the amount of seeds used in pure sowing and the ratio in the mixture (Onal and Egritas, 2017).

The layout of the experiment was randomized blocks with three replications. Before sowing, 6 kg da^{-1} P_2O_5 and 4 kg da^{-1} N fertilizers were applied to the plots, and 4 kg da^{-1} N fertilizer was applied during tillering-stem elongation period (Aydın, 2009). The forage peas were in full flowering, while rye was in early flowering, and the plants were harvested on 15 June, 2019. The heights from the soil surface to the plant tip were measured in 10 randomly selected plants for pure species in each plot and in 10 plants of each species in mixtures before the harvest. During the harvest, one row from the edges of each plot and 50 cm from the beginning and end of each plot were considered as side effects (Gocmen and Parlak, 2017). The plants in the remaining part of the plots were harvested with a scythe and weighed to determine the green forage yield (GFY). In each plot, a 500 g of harvested fresh plants were sampled and were dried at 60 ºC until reaching a constant weight to calculate dry matter yields (DMY) (Sleugh et al., 2000).

Table1. Climate data of Kirsehir province*

	Precipitation (mm)		Relative Humidity (%)		Temperature (°C)	
	2018-19	LTA	2018-19	LTA	2018-19	LTA
October	41.4	30.4	62.3	62.7	14.4	13.1
November	21.0	41.6	66.8	72.4	8.2	6.3
December	101.1	47.1	81.4	79.0	3.3	2.0
January	42.2	44.3	79.3	79.0	0.8	-0.1
February	42.8	31.6	71.4	74.1	4.2	1.3
March	10.2	36.7	56.4	67.2	6.3	5.6
April	29.0	42.4	64.0	63.3	9.7	10.9
May	17.1	45.6	52.7	61.3	17.5	15.4
Average/Total	304.8	319.6	66.8	69.9	8.1	6.8

* Turkish State Meteorological Service, LTA = Long-Term Average

In pure sowings, quality analyses were carried out using single species and both species were separately analyzed in mixture sowings, and calculated considering amount of ratio in the mixtures. The nitrogen content of the species and mixtures was determined by the Kjeldahl method, and the nitrogen contents were multiplied by the coefficient of 6.25 to calculate the crude protein ratios (CPR) (AOAC, 2005). Crude protein yields (CPY) of species and mixtures were calculated by multiplying crude protein ratios with dry matter yields. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents were determined using an ANKOM200 Fiber analyzer (Anonymous, 2020). The data were subjected to analysis of variance in the MSTAT-C statistical software and the LSD test was used for the comparing the means for different treatments (Yurtsever, 2011).

3. Results and Discussion

The difference between plant heights of rye was statistically significant ($p<0.05$) while the difference between plant heights of forage peas was not statistically significant. Plant height of pure sowing and mixtures varied between 147.2 and 154.5 cm in rye and between 43.6 and 53.9 cm in forage pea (Table 2). The increase of tillering in rye plants and the related competition within the species can be associated with the increase in the heights of rye plants. Hatipoglu et al. (1999); Tas (2011) indicated that the cereals are tillered rapidly in the spring, and plant heights increase following the cool winter months. The plant heights of 80 local rye populations in Bingol province ecological conditions was reported between 120.9 and 146.5 cm and the mean plant height for Aslım-95 rye variety was 130.7 cm (Kabak and Akcura (2017). In a similar study conducted under Erzurum ecological conditions, the plant heights of 8 rye genotypes were reported between 145.7 and 168.02 cm (Karatas et al., 2020). The plant height of forage peas at the center of Konya province ranged between 94.1 to 119.2 cm in summer sowings, and between 76.21 and 110.3 cm in winter sowings (Konuk and Tamkoc, 2018). The researchers indicated that plant heights of forage peas at Konya Altınekin ecological conditions were between 94.0 and 110.3 cm in summer sowing, and between 170.0 and 181.0 cm in winter sowings. The difference in plant height between summer and winter sowings was associated to the differences in genotypes. In addition, the researchers stated that the plants were weak due to the late winter sowings, which caused damage due to frost heave and low temperatures, and the plants could not reach sufficient height (Konuk and Tamkoc, 2018). The reason of the shorten plant height were related to the severe terrestrial radiation in winter season and sudden temperature increase in spring season in research. The differences in plant heights reported by different researchers may be related to the fact that plant height is a genotypic character but is affected by different ecological conditions and agricultural practices (Ozer et al., 2005).

The green forage yield varied between 888.5 and 2395.1 kg da^{-1} and the differences in green forage yield between the treatments were statistically significant ($p<0.01$) (Table 3). Konuk and Tamkoc (2018) stated that the harsh winter conditions and high terrestrial radiation could damage forage pea and negatively affect the yield. The green forage yield in pure rye sowings and in mixtures increased as the rye ratio increased. The highest green forage yield was obtained from pure rye and 20% FP + 80% R mixture sowings.

Table 2. Plant Heights of Rye and Forage Pea

	Plant Height (cm)	
Species and Mixtures	**Rye**	**Forage Pea**
Pure Rye / Pure Forage Pea (%100)	154.5 a*	43.6
%20 FP + %80 R	151.3 ab	46.7
%40 FP + %60 R	149.9 ab	46.3
%60 FP + %40 R	147.2 b	45.9
%80 FP + %20 R	151.7 ab	53.9
Mean	150.9	47.3
CV	11.56%	11.27%

*: The means with different lowercase letters in the same column are significantly different ($p<0.05$)

Rye increased the green forage in the mixture and this might be due to its rapid tillering in the spring and increased height, which was caused by its competitive ability (Lithourgidis and Dordas, 2010). Karatas et al. (2020) reported the biological yield of Aslım 95 rye cultivar and 8 different rye genotypes between 1307.7 and 1487.4 kg da^{-1} in Erzurum ecological conditions. In a similar study conducted by Konuk and Tamkoc (2018) stated that the biological yield of forage pea ranged between 234.8 and 1359.2 kg da^{-1} in two different locations.

The effect of species and mixture ratios on average dry matter yield was statistically significant ($p<0.01$). The lowest mean dry matter yield (233.2 kg da^{-1}) was recorded in pure forage pea sowing and the highest dry matter yield (833.3 kg da^{-1}) was obtained in pure rye sowing (Table 3). The dry matter yield increased with the increase in rye ratio and decreased with the increase in forage pea ratio of the mixtures. Hatipoglu et al. (1999); Gündüz (2010) stated that cereals grow very vigorously in spring compared to legumes and caused higher dry matter yield and higher carbohydrate content. Dordas et al. (2012) stated that the dry matter yield could change depending on the legume ratio in the mixtures. The dry matter yield of pure forage pea in Kirsehir ecological conditions was reported as 308.3 kg da^{-1} by Yavuz (2017), and between 166.9 and 1190.3 kg da^{-1} in Konya-center and Konya-Altınekin ecological conditions by Konuk and Tamkoc (2018). The average yield of 50% vetch + 50% rye mixture in Bursa ecological conditions was reported as 635.5 kg da^{-1} by Acıkgoz and Cakmakci (1986). Yield differences among different studies may be due to pure and mixed sowings, differences in environmental conditions, especially in winter, and the effects of seasonal distribution of precipitation on plant growth.

Crude protein ratio was significantly different ($p<0.01$) between pure sowing and mixtures. The highest crude protein ratio was obtained from pure sown forage peas (15.6%), while the lowest ratio was recorded in pure rye (8.5%) sowing (Table 3). The increase in the ratio of forage peas of mixtures caused an increase in the crude protein ratio. Acar et al. (2017), which decreased with the decrease in the ratio of forage peas. In addition, crude protein ratio of pure forage pea and all mixtures were higher than the pure rye sowings. Similarly, Yavuz (2017); Lithourgidis et al. (2011); Pozdisek et al. (2011) indicated that protein ratio of legumes and legume + cereal is higher than the pure cereal sowings. Yavuz (2017); Lithourgidis et al. (2011); Pozdisek et al. (2011) also stated that the highest crude protein ratio was recorded in pure forage pea sowings, and the crude protein ratio of forage pea + cereal mixtures was higher than the pure cereal sowings. The crude protein ratio of Taşkent forage peas in Kirsehir ecological conditions was reported as 17.54% by Yavuz (2017). Uzun et al. (2012) showed that the crude protein ratio of forage pea varieties in Bursa ecological condition was between 15.4 and 14.2%, Acikgoz and Cakmakci (1986) reported the crude protein ratio as 5.1%, 5.8%, 7.6% and 9.5% in different agricultural applications of rye.

Crude protein yields varied between 36.3 and 71.0 kg da^{-1} and the effect of treatments on the crude protein yield was statistically significant ($p<0.01$) (Table 3). The lowest crude protein yield was obtained from pure forage pea sowings. The crude protein yield of pure rye and mixtures were statistically similar but higher than pure forage pea.

Table 3. Yield and Quality Traits of Species and Mixtures

Species and Mixtures	GFY (kg da^{-1})	DMY (kg da^{-1})	CPR (%)	CPY (kg da^{-1})	NDF (%)	ADF (%)
Pure Rye (%100)	2395.1 a**	833.3 a**	8.5 f**	71.0 a**	61.3 a**	39.5 a**
%20 FP + %80 R	2177.8 ab	708.1 b	9.9 e	70.0 a	56.6 b	38.1 ab
%40 FP + %60 R	1931.3 bc	599.7 bc	11.3 d	67.8 a	52.3 c	36.6 bc
%60 FP + %40 R	1810.3 c	531.5 cd	12.8 c	67.5 a	48.0 d	35.2 cd
%80 FP + %20 R	1662.8 c	468.3 d	14.2 b	66.2 a	43.6 e	33.7 d
Pure Forage Pea (%100)	888.5 d	233.2 e	15.6 a	36.3 b	39.3 f	31.1 e
Mean	1811.0	562.4	12.1	63.1	50.2	35.7
CV	9.81%	10.93%	3.47%	11.39%	2.05%	3.29%

**: The means with different lowercase letters in the same column are significantly different ($p<0.05$). GFY; Green forage yield, DMY; Dry matter yields, CPR; Crude protein ratios, CPY ;Crude protein yields, NDF: Neutral detergent fiber ratio, ADF; Acid detergent fiber rate

The crude protein yield was directly related to the crude protein ratio and dry matter yield. Therefore, obtaining high crude protein yield in pure rye sowings that had a high dry matter yield is an expected outcome (Table 3). Acıkgoz and Cakmakci (1986) indicated that crude protein yield of 50% vetch + 50% rye mixture at the beginning of spiking varied between 22.2 and 71.8 kg da^{-1}. Yavuz (2017) reported that the crude protein yields of the forage pea + oat mixtures were higher than the crude protein yields of pure sowing. Mut et al. (2006) determined the crude protein yield of Aslım-98 Rye variety was 60 kg da^{-1} at the beginning of spiking and 83 kg da^{-1} during milk dough period. The differences between the results may be attributed to the differences in dry matter yield and crude protein yield, as well as pure and mixed sowings of the species and cultivars used in the experiments.

The NDF ratio was significantly different ($P<0.01$) between pure sowings and mixtures. The lowest NDF ratio was obtained in pure-sown forage pea (39.3%), and the NDF ratio increased with the increase in the rye ratio of the mixtures. The highest NDF ratio was obtained from pure rye (61.3%) (Table 3). The difference between cereals and legumes has been associated with high cell wall substances of cereals than legumes, while legumes have more cellular compounds and less cell walls Cherney et al. (1985); Tan and Mentese (2003). The results revealed that the NDF and ADF ratios of rye was high, and the ratios of NDF and ADF were lower in forage peas (Table 3). The NDF ratio of Aslım-98 rye variety was reported as 59.08% by Kose et al. (2019) and Taşkent forage pea variety was reported as 40.15 % by Yavuz (2017).

The ADF ratio in pure rye was significantly ($p<0.01$) higher (39.5%) than the ADF ratio of pure forage pea (31.1%) and other mixtures, except for 20% FP + 80% R (Table 3). The difference in ADF ratios between forage pea and rye is an expected situation because the difference in the ADF ratios may be associated with the low leaf/stem ratio of the cereals in addition to the rapid maturation (Tan and Mentese, 2003). The increase of the forage pea ratio in the mixture decreased the ADF ratio, while the ADF ratio increased with the increase in the rye ratio (Table 3). Linn and Martin (1989); Lithourgidis et al. (2006) stated that the ADF ratio of the mixtures increased with the increase in the cereal ratio and decreased as the legume ratio increased. The ADF ratio of Aslım-98 rye variety under Yozgat ecological conditions was 35.74% (Kose et al. (2019). The ADF ratio of wheat + rye at the first and second harvest was 33.41% and 37.16%, respectively (Guney (2020), and the ADF ratios of forage pea was 30.33 % (Yavuz, 2017).

4. Conclusion

The increase in drought under changing climatic conditions increased the importance of sustainable agriculture and adequate quality food supply. Limited environmental resources could be used more effectively by mixed cropping systems, and this is an efficient solution to sustain agricultural production, especially in arid and semi-arid regions. In this study, forage pea and rye were evaluated by sowing purely or as mixture in different ratios to increase the hay quality. The results revealed that the purely-sown rye or rye + forage pea mixtures, which contains more than 60% rye had higher yield but the increase of forage pea ratio in mixtures increased the quality. A mixture of pure rye and 20% FP + 80% R can be grown to obtain high dry matter yield. However, a mixture of 40% FP + 60% R can be recommended to obtain high yield and quality.

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