Turk J
Field Crops
2020, 25(1), 18-25
DOI: 10.17557/tjfc.737476

# YIELD, QUALITY AND COMPETITION PROPERTIES OF GRASS PEA AND WHEAT GROWN AS PURE AND BINARY MIXTURE IN DIFFERENT PLANT DENSITIES

*Ibrahim ATIS[1*], Sait ACIKALIN[2]*

*[1]Hatay Mustafa Kemal University, Faculty of Agriculture, Department of Field Crops, Hatay, TURKEY*
*[2] Altinozu District Directorate of Agriculture and Forestry, Hatay, TURKEY,*
** Corresponding author: iatis15@hotmail.com*

Received: 20.11.2019

**ABSTRACT**

**Mixtures of annual forage legumes with winter cereals for forage are practiced traditionally in the Mediterranean conditions. The objectives of this study were to compare grass pea and wheat pure stands as well as their mixtures in different plant densities under two seeding ratios for forage yield and quality and to estimate the effect of competition between the two species used in the intercropping systems. The experimental design was split plot in a randomized complete block with three replications. The main plot treatments were plant densities (350, 500 and 650 plant m$^{-2}$) and sub-plots treatments were four sowing norm (pure grass pea (GP), 60% GP+ 40% W, 70% GP+ 30% W and pure wheat (W)). The results of the present study showed that plant densities do not have a significant effect on forage yield and quality, while the effect of mixture and pure stands on forage yield and quality were significant. According to the two-year average results, 60% GP + 40% W mixture gave the best results in terms of yield and quality. Calculated LER values showed that wheat+grass pea mixtures were more advantageous than pure stand of both species. As result of this research, 350 plant m$^{-2}$ plant density and 60% GP + 40% W mixture can be recommended.**

**Keywords: Competition, forage quality, grass pea, plant density**

## INTRODUCTION

Grass pea (*Lathyrus sativus* L.) is a multipurpose plant that can used as pulse crop for human nutrition, food grain and roughage for animal feeding and as green manure for soil improvement (Karadag, 2009). Grass pea was cultivated in 12790 ha (TUIK, 2019) and it is mostly used as forage and rarely human food in Turkey (Basaran et al., 2011). Lodging is a major problem in cultivation because grass pea is a plant with thin stems. It is therefore recommended that grass pea may be planted together with winter cereals. Wheat, barley, oats and triticale are often preferred for this purpose (Wall and Campbell, 1993; Karadag and Buyukburc, 2003; Karadag and Buyukburc, 2004; Rakeih et al., 2010). Wheat is grown for forage as an increased importance in the rations of ruminant animal diet because of improved successful silage techniques (Anil et al., 1998).

Intercrops of legumes and cereals have some advantages over pure stands. Crops within the intercropping system use the ecological resources efficiently and they can produce more yield compare to their pure stands. Cereals use the nitrogen fixed by the legumes. Protein and energy contents of forage produced from intercrops are balanced and the feed from intercrop has higher feeding value compared to the feed from pure stands of mixture components (Karadag and Buyukburc, 2003; Tuna and Orak, 2007; Atis et al., 2012). In addition, the used cereal increases the utilization of light by providing support to legume and facilitates mechanical harvesting (Holland and Brumer, 1999).

Besides these advantages, the intercropping systems create some disadvantages over pure sowing. The management of the crops is an important problem for the intercropping systems. Intra-specific and inter-specific competition for limited resources in mixed planting systems can change all balances (Haynes, 1980). To determine competition among the plants, different mathematical models could be used (Weigelt and Jolliffe, 2003). Land equivalent ratio (LER), competitive ratio (CR) and aggressivity (A) are some of the competition indexes frequently used to compare mixture and pure stand (Dhima et al., 2007; Yilmaz et al., 2008; Wahla et al., 2009; Yilmaz et al., 2015; Baxevanos et al., 2017).

Legumes used in the intercropping systems are often less competitive than cereals and therefore, for the benefits of the intercropping system, legumes may need to be in a higher proportion than cereals in the mixture during seeding (Lithourgidis et al., 2011). In addition, varying seed amounts of the species in the mixture affect forage yield, feed quality and competition conditions (Osman and Nersoyan, 1986; Lithourgidis et al., 2011; Yilmaz et al., 2015; Dogrusoz et al., 2019). Therefore it is important to determine the correct sowing combination of species in the intercropping systems. Although many studies have been conducted on the mixtures of grass pea with cereals, the number of studies examining the competition of grass pea and cereals is quite limited.

The quality of the feed produced is as important as the forage yield. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) are commonly used as standard forage testing techniques for determination of forage quality. ADF can be used to calculate digestibility, while intake potential is predicted through NDF (Ball et al., 2001). Relative feed value (RFV) calculated by using ADF (representing dry matter digestibility) and NDF (showing intake potential) is an index indicating forage quality (Rohweder et al., 1978; Hackmann et al., 2008).

The objectives of this research were to compare grass pea and wheat pure stands as well as their mixtures in three plant densities (350, 500 and 650 plants $m^{-2}$) under four seeding norm (two pure stands and two mixture) for forage yield and quality and to estimate the effect of competition between the two species used in the intercropping systems.

## MATERIALS AND METHODS

### *Site description*

This study was conducted during the winter plant growth seasons of 2013 and 2014 at the Agricultural Research Station of Mustafa Kemal University, which is located at 36°15′N and 36°30′E in the Eastern Mediterranean regions of Turkey. The region has typical Mediterranean climate. Figure 1 shows meteorological data of the experimental area during the growing season, with monthly average temperature and monthly total rainfall. As it can be seen in Figure 1, the 2012-13 winter season was rainy, while the 2013-14 winter and the 2014 spring season were extremely drought. Study area had clay soil with pH of 7.12, having 6.45% $CaCO_3$, 74.1 kg $ha^{-1}$ phosphorus, and 1.93% organic matter at the depth of 30 cm.

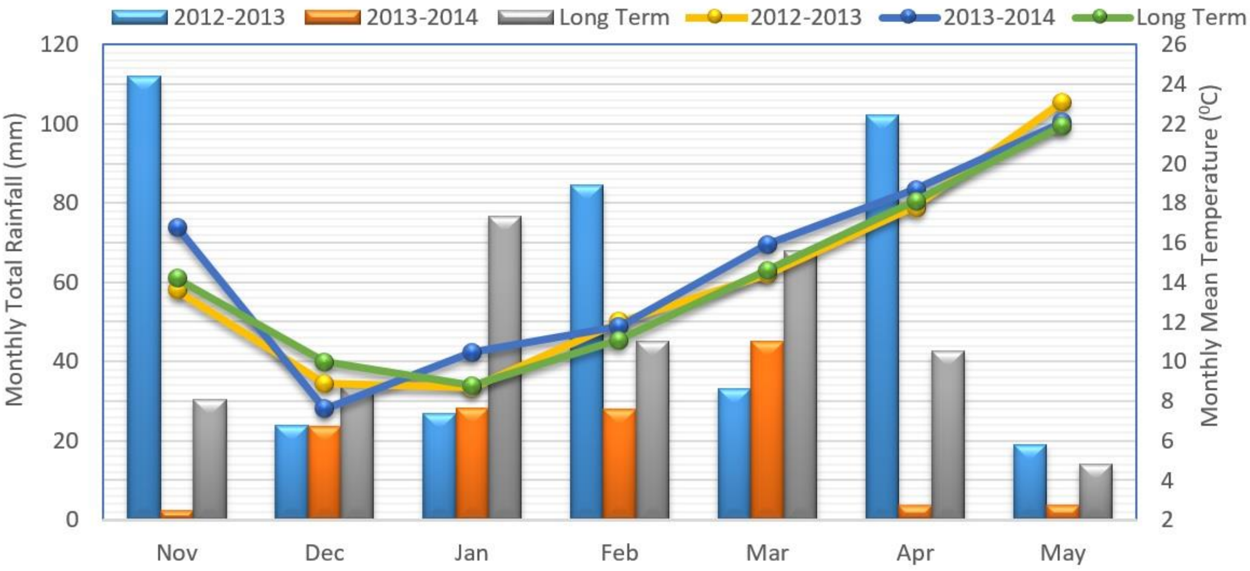


**Figure 1**. Monthly mean air temperature and total rainfall during the study and long term data (means of 20 years)

### *Crop management and experimental design*

Grass pea (GP) (cv. Gurbuz 2001) and wheat (W) (cv. Sagittario) were grown as pure stands and intercrops. Seed bed preparation included ploughing, disk harrowing, and cultivation. Sowing was performed by hand on third week of November in 2012 and 2013. Fertilizer rates of 50 kg $ha^{-1}$ N and $P_2O_5$ were applied at sowing. The experimental design was split plot in a randomized complete block with three replications. The main plot treatments were plant densities (350 plant $m^{-2}$, 500 plant $m^{-2}$ and 650 plant $m^{-2}$) and sub-plots treatments were four sowing norm (pure grass pea, 60% GP+ 40% W, 70% GP+ 30% W and pure wheat) based on seed number. Thousand seeds weight of grass pea was 134.6 g and the thousand kernel weight of wheat was 33.2 g. The amount of seed to be used to the unit area has been calculated by considering the weight of thousand kernel weight of both species. Experimental plots had 6 rows with row spacing of 20 cm and a row length of 5 m. Mixtures were planted in the same row with in plots. In the experiment, irrigation was not performed but weed control was maintained manually. Plants were cut to a stubble height of approximately 5 cm at the pod formation stage of grass pea. 500 g green forage sample from each treatment was taken after harvest, species were separated by hand and then they were dried at 65 ºC for dry matter determinations. On plots less than 500 g sample for each species, all the plant material was taken as sample. Dried samples were ground in a mill to pass a 1 mm screen for chemical analysis.

### *Forage quality analysis and calculations*

Crude protein, NDF and ADF were determined for all samples. Nitrogen contents were determined by the Kjeldahl procedure and crude protein concentration was calculated by the formula of N content × 6.25 (Karabulut and Canbolat, 2005). NDF and ADF were analyzed considering the method of Van Soest et al. (1991) by adding α-amylase without sodium sulfite and using the ANKOM filter bag system with A220 fiber analyzer (ANKOM Technology, Fairport, NY), and expressed as exclusive residual ash.

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

DDM = 88.9 – (0.77×ADF%); DMI= (120/NDF%); RFV= DDM% × DMI% × 0.775.

Where, DDM was digestible dry matter as % of dry matter, and DMI was dry matter intake as a % of body weight.

### *Competition indexes and calculations*

The land equivalent ratio (LER) was used as index for mixed stand advantage for both legume (grass pea) and cereal (wheat). LER values were calculated as fallow:

$LER= (LER_{grass\ pea} + LER_{wheat})$,

$LER_{grass\ pea}=(Y_{gw}/Y_g)$,

$LER_{wheat}=(Y_{wg}/Y_w)$

Where $Y_g$ and $Y_w$ were the yields of grass pea and wheat as sole crop, respectively, and $Y_{vw}$ and $Y_{wv}$ were yields of grass pea and wheat in the mixture, respectively. When LER is greater than 1, the mixed growing favors the growth and yield of species. In contrast, when LER is lower than 1, the mixed growing negatively affects the growth and yield of plants grown in mixture (Dhima et al., 2007). The other index used to determine the competitive relationship between two crops in mixtures is aggressivity (A), (Bhatti et al., 2006). If the calculated aggressivity value of one mixture partner is negative, the aggressivity value of the other partner is positive of the same value. Therefore the results were given as the aggressivity values of wheat. Aggressivity is formulated by McGilchrist (1965) as below:

$A_{wheat}= \{Y_{wg}/(Y_wZ_{wg})\}- \{Y_{gw}/(Y_gZ_{gw})\}$

Where, $Z_{gw}$ and $Z_{wg}$ were the seed rates of grass pea and wheat in the seed mixture. If $A_{wheat} = 0$ both crops are equally competitive, If $A_{wheat}$ is positive, then the wheat is dominant, if $A_{wheat}$ is negative, then the wheat is dominated by grass pea in the mixture (Wahla et al., 2009).

Competitive ratio (CR) is another way to assess competitive ability between different species. The CR gives more desirable competitive ability for the crops and also advantages over other indexes. The CR represents simply the ratio of individual LER of the two component crops in which they are initially sown. Then, the CR index was formulated as below;

$CR_{grass\ pea}= (LER_{grass\ pea}/LER_{wheat})\ (Z_{wg}/Z_{gw})$; $CR_{wheat}= (LER_{wheat}/LER_{grass\ pea})\ (Z_{gw}/Z_{wg})$

### *Statistical analyses*

Data were analyzed by using the MSTAT-C computer software program. The ANOVA was performed by using split plot design in a randomized complete block with the 3 main plot treatments and 4 sub-plot treatments replicated three times for yield and quality properties and with the 3 main plot treatments and 2 sub-plot treatments (only mixtures) replicated three times for competition indices. Significant differences among the mean values were compared by Duncan multiple range test.

## RESULTS AND DISCUSSION

### *Yield and forage quality*

The effect of plant densities on dry matter yield was not significant during all experiment years. Dry matter yields were 8.33, 9.39 and 9.24 t $ha^{-1}$ for 350, 500 and 650 plant $m^{-2}$, respectively, in the first year. While dry matter yields of second year were 3.94, 3.82 and 4.11 t $ha^{-1}$ for 350, 500 and 650 plant $m^{-2}$ for plant densities. According to the mean values over two years, dry matter yield obtained from plant densities were statistically similar. Accordingly, the increase in the number of plants per unit area did not cause an increased yield.

The dry matter yields of pure stands and mixed sowings showed significant differences in both years. The lowest dry matter yields were obtained from pure stand grass pea in both years. The highest dry matter yield of 11.4 t $ha^{-1}$ was obtained from pure stand wheat in the first year. This values fallowed by dry matter yield of 60% GP+ 40% W mixture (10.4 t $ha^{-1}$) . Dry matter yield of pure grass pea was lower than pure wheat stands and mixtures in the second year. Dry matter yields of pure wheat and mixtures were statistically similar in the second year. Generally, increased seed rate of wheat in mixtures significantly increased the hay yield of mixtures. Some previous researches also reported that increased cereal rates in legume-cereal mixtures resulted in higher dry mater or hay yield (Karadag and Buyukburc, 2003; Kokten et al., 2009; Lithourgidis et al., 2006; .Dhima et al., 2007). Our results showed that there were significant differences between the average dry matter yields obtained in the first and second years. Averages of total dry matter yields were 8.99 t $ha^{-1}$ and 3.96 t $ha^{-1}$ during first and second year, respectively. Higher dry matter yields during first year may be due to higher rainfall (Table 1). This situation suggests that growing performance and competition of species in the mixture depend on ecological factors (Hauggaard-Nielsen et al., 2006; Kokten et al., 2009; Atis et al., 2012). The results also indicated that wheat was more affected by the drought in the second year. The seen drought in the second year, it caused 59 % yield loss in pure wheat production and 29 % grass pea yield loss compared to the first year. Crude protein yield was significantly influenced by plant densities in the first year, while it wasn't significantly influenced in the second year (Table 1). The protein yields of 500 and 650 plant $m^{-2}$ densities were higher than 350 plant $m^{-2}$ density in the first year. Crude protein yields were 1125.6, 1308.1 and 1271.8 kg $ha^{-1}$ for 350, 500 and 650 plant $m^{-2}$, respectively, in the first year. Crude protein yields were 822.7, 772.1 and 817.2 kg $ha^{-1}$ for 350, 500 and 650 plant $m^{-2}$, respectively, in the second year, but these values were statistically not significant. As the average of two years, crude protein yields of 350, 500 and 600 plant $m^{-2}$ plant densities were determined as 974.1 kg $ha^{-1}$, 1040.1 kg $ha^{-1}$ and 1044.5 kg $ha^{-1}$, respectively. According to average of two year values, an increase in protein yield was observed due to the increase in plant density, but this increase was insignificant. However, the significant difference in protein yields due to plant density in the first year is a result of changes in hay yield and protein content due to ecological conditions during the year. The effect of ecological conditions on dry matter yield, protein content and competition features of mixture counterparts may have caused these differences (Atis et al., 2012). There were significantly differences among protein yields of pure stands and mixtures in the first year (Table 1). Pure grass pea had lower protein yields than other treatments. Protein yields obtained from pure wheat and mixture treatments (60%GP+40%W and 70%GP+30%W) were statistically similar. The main reason for this situation is that the dry matter yield of pure grass pea is quite low compared to other treatments. Generally, crude protein yields of the mixtures were higher than the pure grass pea sowings (Karadag and Buyukburc, 2003; Karadag and Buyukburc, 2004). Protein yields recorded in the second year were not statistically different. This was due to the fact that the decrease in the production of the grass pea in the second year due to drought was proportionally lower than wheat. According to the two-year average results, protein yields of pure wheat and mixtures were higher than pure grass pea. Yearly average crude protein yield was 1235.2 kg $ha^{-1}$ in the first year and 805.0 kg $ha^{-1}$ in the second year. Despite the higher protein contents in the second year (Table 1), low protein yield could be explained by the low yields of hay obtained in the second year (Karadag and Buyukburc, 2004; Kusvuran et al., 2014). Livestock needs protein for growth and milk production and protein yield unit area directly are related to crude protein contents and total forage yield. Thus, the total amount of protein produced per unit area is one of the most important quality characteristics (Cabellero et al., 1995; Lithourgidis et al., 2006).

**Table 1.** Means of plant densities and sowing norm on dry matter yield, crude protein yield and crude protein content

| | **Dry Matter Yield ($t\ ha^{-1}$)** | | | **Crude Protein Yield ($kg\ ha^{-1}$)** | | | **Crude Protein Content (%)** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **2013** | **2014** | **Mean** | **2013** | **2014** | **Mean** | **2013** | **2014** | **Mean** |
| **Plant Density** | | | | | | | | | |
| 350 plant $m^{-2}$ | 8.33 | 3.94 | 6.14 | 1125.6 b$^{+}$ | 822.7 | 974.1 | 14.4 | 17.2 | 15.8 |
| 500 plant $m^{-2}$ | 9.39 | 3.82 | 6.61 | 1308.1 a | 772.1 | 1040.1 | 14.7 | 17.3 | 16.0 |
| 650 plant $m^{-2}$ | 9.24 | 4.11 | 6.68 | 1271.8 a | 817.2 | 1044.5 | 15.0 | 17.5 | 16.3 |
| **Pure and Mixture Sowings** | | | | | | | | | |
| 100% Grasspea | 4.40 d$^{+}$ | 3.10 b | 3.76 c | 893.7 b | 719.9 | 806.8 b | 20.2 a | 22.6 a | 21.4 a |
| 100% Wheat | 11.4 a | 4.26 a | 7.85 a | 1332.7 a | 811.8 | 1072.2 a | 11.6 d | 13.1 d | 12.4 d |
| 60% GP+ 40% W | 10.4 b | 4.31 a | 7.37 ab | 1362.7 a | 864.8 | 1113.7 a | 13.1 c | 16.6 c | 14.8 c |
| 70% GP+ 30% W | 9.67 c | 4.16 a | 6.92 b | 1351.8 a | 819.4 | 1085.6 a | 14.0 b | 17.1 b | 15.2 b |
| **Mean (Year)** | 8.99 A$^{*}$ | 3.96 B | | 1235.2 A | 805.0 B | | 14.7 B | 17.3 A | |

$^{+)}$ Values with the different small letter in a column in a year are significantly different according to the Duncan test at P<0.05

$^{*)}$ Yearly means shown the different capital letter in a line are significantly different according to the Duncan test at P<0.05

Crude protein content was not significantly influenced by plant densities during both years (Table 1). The maximum protein contents of 15.0% and 17.5% were obtained from 650 plants $m^{-2}$ plant density during first and second years, respectively. However, these values were not different from the protein contents determined at other plant densities. Crude protein contents of pure stands and mixtures varied significantly in both years. Crude protein contents ranged 20.2% to 11.6% in first year and 22.6% to 13.1% in the second year. In both years, pure grass pea had the highest protein content while pure wheat had the lowest protein content. Crude protein contents of mixtures had values of between pure wheat and pure grass pea. In mixtures, crude protein content increased as grass pea seeding proportion increased within mixture. These results are in agreement with those reported by Karadag and Buyukburc (2003), Basaran et al. (2018), Seydosoglu and Gelir (2019).

The effects of plant densities on NDF content were not significant in both years (Table 2). NDF contents were ranged 48.9% to 49.9% in the first year and 45.5% to 46.8% in the second year. NDF content was significantly influenced by pure and mixture sowings during two years. The highest NDF content was obtained from pure wheat stand while the lowest NDF content was obtained from pure grass pea stand during two years (Table 2). Karadag et al. (2011) reported that NDF contents of grass pea varieties ranged from 42.6% to 51.2%. In another study, the NDF content of grass pea was found as 48.6% (Poland et al., 2003). Canbolat (2012) determined the NDF content as 49.9% for wheat. Our NDF values were lower than those of these researchers. This might be due to many reasons such as the genetic structure of the varieties, the ecological conditions and the different agricultural practices. However, this is a favorable situation as the low content of NDF is desirable. Annual forage legumes are expected to have a lower NDF content than winter cereals (Salawu et al., 2001; Ghanbari-Bonjar and Lee, 2003). The NDF content of the two mixture treatments were not different. NDF content recorded in the first year were higher than recorded in the second year. The main reason for this may be the fact that the grass pea is higher ratio in the second year's hay (data not shown).

**Table 2**. Means of plant densities and sowing norm on NDF content, ADF content and RFV

| | **NDF Content (%)** | | | **ADF Content (%)** | | | **RFV** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **2013** | **2014** | **Mean** | **2013** | **2014** | **Mean** | **2013** | **2014** | **Mean** |
| **Plant Density** | | | | | | | | | |
| 350 plant m$^{-2}$ | 48.9 | 45.5 | 47.2 | 28.7 | 26.5 | 27.6 | 128.8 | 142.3 | 135.6 |
| 500 plant m$^{-2}$ | 49.9 | 46.8 | 48.4 | 29.7 | 27.1 | 28.4 | 124.4 | 137.3 | 130.8 |
| 650 plant m$^{-2}$ | 49.5 | 46.0 | 47.8 | 28.9 | 26.1 | 27.5 | 127.9 | 141.2 | 134.2 |
| **Pure and Mixture Sowings** | | | | | | | | | |
| 100% Grasspea | 40.9 c$^{+}$ | 37.5 c | 39.2 c | 26.6 c | 24.1 c | 25.3 c | 155.5 a | 174.3 a | 164.9 a |
| 100% Wheat | 55.4 a | 52.6 a | 54.0 a | 30.9 a | 28.9 a | 29.9 a | 109.2 c | 117.6 c | 113.4 c |
| 60% GP+ 40% W | 50.7 b | 47.2 b | 48.9 b | 29.5 b | 26.7 b | 28.1 b | 121.2 b | 134.2 b | 127.7 b |
| 70% GP + 30% W | 50.8 b | 47.2 b | 49.0 b | 29.3 b | 26.6 b | 27.1 b | 121.3 b | 134.9 b | 128.1 b |
| **Mean (Year)** | 49.5 A$^{*}$ | 46.1 B | | 29.1 A | 26.6 B | | 126.8 B | 140.3 A | |

$^{+)}$ Values with the different small letter in a column in a year are significantly different according to the Duncan test at P<0.05

$^{*)}$ Yearly means shown the different capital letter in a line are significantly different according to the Duncan test at P<0.05

While the effects of plant densities on the ADF content were insignificant, the effect of mixture and pure stands were statistically significant (Table 2). According to the two-year average results, ADF contents varied from 27.5% to 28.4% depending on plant densities. The highest ADF content was obtained from pure wheat stand while the lowest ADF content was obtained from pure grass pea stand during two years (Table 2). In previous studies, ADF contents of grass pea were reported to range between 26.1% and 39.1% (Poland et al., 2003; Basaran et al., 2011; Karadag et al., 2011; Kavut et al., 2014). The findings in our current study were close to the values reported by previous researchers. Mixtures had values between pure stands and the ADF contents of the two mixtures were very close in both years. Since grass pea sowing rates used in mixed sowing were not reflected on the obtained product, the contribution of grass pea to forage quality was limited.

Relative feed value (RFV) values was not significantly influenced by plant densities during both years. According to the two-year average results, RFV values varied from 130.8 to 135.6 depending on plant densities (Table 2). RFV values of pure and mixed sowings showed significant differences in both years. The maximum RFV values were obtained from pure grass pea stand in both years. Basaran et al. (2011) reported that RFV values of grass pea ranged between 129 and 185 in the study conducted with 21 grass pea genotypes. The RFV value we have determined for grass pea was within the limits of these researchers. The minimum RFV values were obtained from pure wheat stand. RFV value for wheat determined in current study was within the limits reported in the previous studies (Canbolat, 2012; Cacan and Yilmaz, 2015). RFV values of the mixtures were very close to each other. RFV is an estimate of overall forage quality and it is calculated from intake and digestibility of dry matter (Rohweder et al., 1978) and 100 is the reference value. This value represents full bloom alfalfa (Moore and Undersander, 2002; Hackmann et al., 2008). RFV showed a case in parallel with NDF and ADF contents, due to calculated by using them. According to the RFV value, forage quality of pure grass pea was in premium level while forage qualities of mixtures were in good level (Putnam, 2004).

### *Competition indices*

LER value is often used to compare the mixture and pure sowing efficiency (Dhima et al., 2007; Yilmaz et al., 2008). LER values were significantly influenced by plant densities during both years (Table 3). LER values showed an increasing tendency with increasing plant densities in the first year, while the highest LER value was determined at 650 plant m$^{-2}$ density in the second year. This difference between years can be considered as a reflection of the drought occurring in the second year. In fact, when the partial LER values are examined, it is seen that the LER value of grass pea was significantly higher in the second year compared to the first year, and vice versa for wheat (not data shown). The effects of mixtures were not significant in terms of LER value during both years. LER values calculated in the present study were greater than 1 in all plant densities and mixture rates (Table 3). This result indicated that mixture of grass pea and wheat were advantageous compared to their pure stands for all plant densities and mixture ratios. Similar advantages for mixtures have been reported in some other studies (Yilmaz et al., 2008; Pasynkova and Zavalin, 2010; Zajac et al., 2013; Yilmaz et al., 2015), while the others have focused disadvantages of intercropping (Lithourgidis et al., 2006; Dhima et al., 2007; Kokten et al., 2009; Rakeih et al., 2010). This disadvantage may be mainly due to species used, mixture ratios, ecological conditions and experimental years (Lithourgidis et al., 2006; Dhima et al., 2007; Baxevanos et al., 2017).

**Table 3**. Means of plant densities and mixture rate on LER and $A_{Wheat}$

| | LER | | | $A_{wheat}$ | | |
|---|---|---|---|---|---|---|
| **Variable** | **2013** | **2014** | **Mean** | **2013** | **2014** | **Mean** |
| **Plant Density** | | | | | | |
| 350 plant m$^{-2}$ | 1.52 a$^{+}$ | 1.26 b | 1.39 a | 0.30 b | -1.07 b | -0.39 c |
| 500 plant m$^{-2}$ | 1.37 ab | 1.02 b | 1.20 b | 0.62 a | -0.63 a | -0.01 b |
| 650 plant m$^{-2}$ | 1.21 b | 1.64 a | 1.42 a | 0.67 a | -0.42 a | 0.13 a |
| **Mixtures** | | | | | | |
| 60% GP+ 40% W | 1.39 | 1.33 | 1.36 | 0.37 b | -1.31 b | -0.47 b |
| 70% GP + 30% W | 1.34 | 1.29 | 1.32 | 0.68 a | -0.10 a | 0.29 a |
| **Mean (Year)** | 1.37 | 1.31 | | 0.53 A$^{*}$ | -0.70 B | |

+) Values with the different small letter in a column in a year are significantly different according to the Duncan test at P<0.05
*) Yearly means shown the different capital letter in a line are significantly different according to the Duncan test at P<0.05

Aggressivity values of wheat ($A_{wheat}$) were positive in the first year but negative in the second year (Table 3). These results showed that wheat was the dominant species in the mixture of grass pea and wheat in the first year, while grass pea was the dominant species in the second year (Table 3). This can be interpreted as a result of the extreme drought seen in the second year. In fact, grass pea is one of the most important plants known for its drought resistance (Jiang et al., 2013). The effects of plant densities on the $A_{wheat}$ content were statistically significant during both years. $A_{wheat}$ values of 500 and 650 plant m$^{-2}$ densities were higher than 350 plant m$^{-2}$ density during both years. This situation shown that aggressivity of wheat has decreased against grass pea with increasing plant densities. Also, the decrease in the proportion of wheat in the mixture significantly increased $A_{wheat}$ value. This finding is in agreement with Asci et al. (2015), which states that $A_{triticale}$ value decreases due to the increasing triticale ratio in triticale+ pea mixture. However, previous studies conducted on annual forage legume + cereal mixture shown that the aggressivity value varies significantly according to the plant species (Dhima et al., 2006), environmental conditions (Baxevanos et al., 2017) and growing years (Asci et al., 2015).

CR values of both species were not significantly influenced by plant density during both years, but the effects of mixtures on CR values of wheat and grass pea were statistically significant (Table 4). CR values determined according to mixture rates showed an opposite trend between two years. In the first year, the CR values of both species decreased due to the increasing rate of the species, while in the second year the opposite was observed. On the contrary, the $CR_{wheat}$ value increased due to the increasing rate of the wheat in the first year, while in the second year the opposite was observed for wheat. When the average annual CR values were analyzed, it was seen that the CR value of grass pea increased significantly in the second year compared to the first year, while the CR value of wheat decreased significantly. These results of CR confirmed with those of LER and aggressivity. As mentioned above, this result is a reflection of the difference in rainfall between years. These results showed that which species are dominant in cereal + legume mixtures is directly influenced by environmental conditions (Atis et al., 2012; Baxevanos et al., 2017).

**Table 4**. Means of plant densities and mixture rate on $CR_{grasspea}$ and $CR_{wheat}$

| | $CR_{grasspea}$ | | | $CR_{wheat}$ | | |
|---|---|---|---|---|---|---|
| **Variable** | **2013** | **2014** | **Mean** | **2013** | **2014** | **Mean** |
| **Plant Density** | | | | | | |
| 350 plant m$^{-2}$ | 0.83 | 3.16 | 1.99 | 1.22 | 0.41 | 0.81 |
| 500 plant m$^{-2}$ | 0.66 | 2.45 | 1.55 | 1.53 | 0.58 | 1.05 |
| 650 plant m$^{-2}$ | 0.63 | 2.84 | 1.73 | 1.64 | 0.59 | 1.11 |
| **Mixtures** | | | | | | |
| 60% GP+ 40% W | 0.77 a$^{+}$ | 3.91 a | 2.34 a | 1.33 b | 0.30 b | 0.82 b |
| 70% GP + 30% W | 0.64 b | 1.72 b | 1.18 b | 1.59 a | 0.74 a | 1.17 a |
| **Mean (Year)** | 0.71 B$^{*}$ | 2.82 A | | 1.46 A | 0.52 B | |

+) Values with the different small letter in a column in a year are significantly different according to the Duncan test at P<0.05
*) Yearly means shown the different capital letter in a line are significantly different according to the Duncan test at P<0.05

## CONCLUSIONS

The results of the present study showed that plant densities do not have a significant effect on forage yield and quality and therefore plant density of 350 plant $m^{-2}$ may be recommended to reduce seed cost. Hovewer, economic analysis should be done for more accurate evaluation. The effect of mixture and pure stands of grass pea + wheat mixtures on forage yield and quality were significant. According to the two-year average results, 60% GP + 40% W mixture gave the best results in terms of yield and quality. Calculated LER values showed that wheat + grass pea mixtures were more advantageous than pure stand of both species. The competition indices examined showed that the competitiveness of the species changed depending on environmental factors and that grass pea was the dominant species against wheat in dry conditions. Second year drought caused significantly differences all the investigated characteristics, except LER, between the years. Drought in the second year caused a significant decrease in dry matter yield, while wheat was more affected species by drought.

## ACKNOWLEDGEMENTS

The authors are grateful to Hatay Mustafa Kemal University Coordinatorship of Scientific Research Projects for financial supports (Project No: 3800). A part of first year data given on the article is taken from Sait Acikalin's Ms thesis.

## LITERATURE CITED

Anil, L., J. Park, R.H. Phipps and F.A. Miller. 1998. Temperate ıntercropping of cereals for forage: a review of the potential for growth and utilization with particular reference to the UK. Grass and Forage Sci. 53: 301-317.

Asci, O.O., Z. Acar and Y.K. Arici. 2015. Hay yield, quality traits and interspecies competition of forage pea-triticale mixtures harvested at different stages. Turk. J. Field Crops 20: 166-173.

Atis, I., K. Kokten, R. Hatipoglu, S. Yilmaz, M. Atak and E. Can. 2012. Plant density and mixture ratio effects on the competition between common vetch and wheat. Aust. J. Crop Sci. 6: 498-505.

Basaran, U., H. Mut, O. Onal-Asci, Z. Acar and I. Ayan. 2011. Variability in forage quality of Turkish grass pea (*Lathyrus sativus* L.) landraces. Turk. J. Field Crops 16: 9-14.

Basaran, U., E. Gulumser, H. Mut and M.C. Dogrusoz. 2018. Determination of silage yield and quality of grasspea+ cereal intercrops. Turk. J. Agric. Food Sci. Tech. 6(9): 1237-1242 (in Turkish).

Baxevanos, D., I.T. Tsialtas, D.N. Vlachostergios, I. Hadjigeorgiou, C. Dordas and A. Lithourgidis. 2017. Cultivar competitiveness in pea-oat intercrops under Mediterranean conditions. Field Crop. Res. 214: 94-103.

Bhatti, I.H., R. Ahmad, A. Jabbar, M.S. Nazir and T. Mahmood. 2006. Competitive behaviour of component crops in different sesame-legume intercropping systems. Int. J. Agric. Biol. 8:165-167.

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

Canbolat, O. 2012. Comparison of in vitro gas production, organic matter digestibility, relative feed value and metabolizable energy contents of some cereal forages. J. Fac. Vet. Medicine Kafkas Univ. 18: 571-577 (in Tukish).

Cacan, E. and H.S. Yilmaz. 2015. Effects on hay yield and quality of different Hungarian vetch + wheat mixture ratio in Bingol conditions. Turk. J. Agric. Nat. Sci. 2(3): 290–296 (in Tukish).

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

Dogrusoz, M.C, H. Mut, U. Basaran and E. Gulumser. 2019. Performance of legumes-turnip mixtures with different seed rates. Turk. J. Agric. Food Sci. Tech. 7(1): 81-86.

Ghanbari-Bonjar, A. and H.C. Lee. 2002. Intercropped field beans (*Vicia faba*) and wheat (*Triticum aestivum*) for whole crop forage: effect of nitrogen on forage yield and quality. J. Agr. Sci. 138:311-315.

Hackmann, T.J., J.D. Sampson and J.N. Spain. 2008. Comparing relative feed value with degradation parameters of grass and legume forages. J. Anim. Sci. 86: 2344–2356.

Haynes, R.J. 1980. Competitive aspects of the grass- legume association. Adv. Agron. 33: 227-261.

Hauggaard-Nielsen, H,. M.K. Andersen, B. Jornsgaard and E.S. Jensen. 2006. Density and relative frequency effects on competitive interactions and resource use in pea-barley intercrops. Field Crop. Res. 95:256-267

Holland, J.B. and E.C. Brummer. 1999. Cultivar effects on oat-berseem clover intercrops. Agron. J. 91: 321 – 329.

Jiang, J., M. Su, Y. Chen, N. Gao, C. Jiao, Z. Sun, F. Li and C. Wang. 2013. Correlation of drought resistance in grass pea (*Lathyrus sativus*) with reactive oxygen species scavenging and osmotic adjustment. Biologia 68(2): 231-240.

Karabulut, A. and O. Canbolat. 2005. Feed evaluation and analysis methods. Bursa: Uludag University Press (in Turkish).

Karadag, Y. and U. Buyukburc. 2003. Effects of seed rates on forage production, seed yield and hay quality of annual legume -barley mixtures. Turk. J. Agric. For. 27:169-174.

Karadag, Y. and U. Buyukburc. 2004. Forage qualities, forage yields and seed yields of some legume–triticale mixtures under rainfed conditions. Acta. Agr. Scand. B-S. P. 54: 140-148.

Karadag, Y. 2009. Grass pea (*Lathyrus sativus* L.). In: Forage Crops, Legume Forage Crops, Volume II, Ed. Avcioglu, R., Hatipoglu, R. and Karadag, Y., 471-479, Ministry of Agriculture and Rural Affairs Publication (in Turkish).

Karadag, Y, M. Yavuz, M. Karaalp, S. Akbay and H. Kir. 2011. The determination of the yield and quality characteristics of some grass pea lines under Tokat Kazova ecological conditions. IX. Turkey Field Crops Congress, 12-15 September, Volume III, Bursa, pp. 1625-1630 (in Turkish).

Kavut, Y.T., H. Geren, H. Soya, R. Avcioglu and B. Kir. 2014. Effects of rate mixture and time of harvest on the winter second crop performances of mixtures of some annual legumes and Italian ryegrass. Journal of Agriculture Faculty of Ege University 51(3): 279-288 (in Turkish).

Kokten, K., F. Toklu, I. Atis and R. Hatipoglu. 2009. Effects of seeding rate on forage yield and quality of vetch (*Vicia sativa* L.) triticale (*Triticosecale* Wittm.) mixtures under east Mediterranean rainfed conditions. Afr. J. Biotechnol. 8:5367-5372.

Kusvuran, A, M. Kaplan and R.I. Nazli. 2014. Intercropping of Hungarian vetch (*Vicia pannonica* Crantz.) and barley (*Hordeum vulgare* L.) under different plant varieties and mixture rates. Legume Res. 37 (6): 590-599.

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

Lithourgidis, A.S., D.N. Vlachostergios, C.A. Dordas and C.A. Damalas. 2011. Dry matter yield, nitrogen content, and competition in pea cereal intercropping systems. Eur. J. Agron. 34: 287-294.

McGilchrist, C.A. 1965. Analysis of competition experiments. Biometrics 21: 975–985.

Osman, A.E. and N. Nersoyan. 1986. Effect of the proportion of species on the yield and quality of forage mixtures and on the yield of barley in the following year. Exp. Agr. 22: 345–351.

Moore, J.E. and D.J. Undersander. 2002. Relative forage quality: an alternative to relative feed value and quality index. In: Proceedings 13th Annual Florida Ruminant Nutrition Symposium, 10- 11 January, Florida, pp: 16–32.

Pasynkova, E.N. and A.A. Zavalin. 2010. Evaluation of the efficiency of spring wheat and vetch mixed crops. Rus. Agric. Sci. 36: 5–8.

Poland, C., T. Galler and L. Tisor. 2003. Effect of chickling vetch (*Lathyrus sativus* L.) or alfalfa (*Medicago sativa*) hay in gestating ewe diets. Lathyrus Lathyrism Newsletter 3:38–40.

Putnam, D. 2004. Forage quality testing and markets; where are we going? In: Proceedings of the National Alfalfa Symposium and 34th California Alfalfa Symposium, 13-15 December, San Diego, CA, USA, pp. 327-344.

Rakeih, N., H. Kayyal, A. Larbi and N. Habib. 2010. Forage yield and competition indices of triticale and barley mixed intercropping with common vetch and grasspea in the Mediterranean Region. Jordan J. Agric. Sci. 6: 194-207.

Rohweder, D.A., R.F. Barnes and N. Jorgensen. 1978. Proposed hay grading standards based on laboratory analyses for evaluating quality. J. Anim. Sci. 47:747-759.

Salawu, M.B., A.T. Adesogan, C.N. Weston and S.P. Williams. 2011. Dry matter yield and nutritive value of pea/wheat bi-crops differing maturity at harvest, pea to wheat ratio and pea variety. Anim. Feed. Sci. Tech. 94: 77-87.

Seydosoglu, S. and G. Gelir. 2019. A research on the silage properties of grasspea (*Lathyrus sativus* L.) and barley (*Hordeum vulgare* L.) herbages mixed at different rates. Igdir Univ. J. Inst. Sci.Tec. 9(1): 397-406 (in Turkish).

TUIK. 2019. Crop production statistics; forage crops. http://www.tuik.gov.tr/PreTablo.do?alt_id=1001 (Accessed April 12, 2019).

Tuna, C. and A. Orak. 2007. The Role of intercropping on yield potential of common vetch (*Vicia sativa* L.) /oat (*Avena sativa* L.) cultivated in pure stand and mixtures. J. Agric.Biolog. Sci. 2:14-19.

Van Dyke, N.J. and P.M. Anderson. 2002. Interpreting a Forage Analysis. Alabama Cooperative Extension. Circular ANR-890.

Van Soest, P.J., J.B. Robertson and B.A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.

Wahla, I.H., R. Ahmad, Ehsanullah, A. Ahmad and A. Jabbar. 2009. Competitive functions of components crops in some barley based intercropping systems. Int. J. Agric. Biol. 11: 69–72.

Wall, D.A. and C.G. Campbell. 1993. Competitiveness of *Lathyrus* grown in monoculture and intercropping systems with cereals. J. Prod. Agric. 6: 399-403.

Weigelt, A. and P. Jolliffe. 2003. Indices of plant competition. Journal of Ecology 91: 707–720.

Yilmaz, S., M. Atak and M. Erayman. 2008. Identification of advantages of maize-legume intercropping over solitary cropping through competition indices in the East Mediterranean Region. Turk. J. Agric. For. 32:111-119.

Yilmaz, S., A. Ozel, M. Atak and M. Erayman. 2015. Effects of seeding rates on competition indices of barley and vetch intercropping systems in the Eastern Mediterranean. Turk. J. Agric. For. 39: 135-143.

Zajac, T., A. Oleksy, A. Stoklosa, A. Klimek-Kopyra and B. Kulig. 2013. The development competition and productivity of linseed and pea-cultivars grown in a pure sowing or in a mixture. Eur. J. Agron. 44: 22-31.