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THE MINERAL, AMINO ACID AND FIBER CONTENTS AND FORAGE YIELD OF FIELD PEA (*PISUM ARVENSE* L.), FIDDLENECK (*PHACELIA TANACETIFOLIA* BENTH.) AND THEIR MIXTURES UNDER DRY LAND CONDITIONS IN THE WESTERN TURKEY

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ABSTRACT

The objective of this research was to determine the yield and forage quality traits (green fodder yield, dry matter yield, amino acid, fibre and mineral contents) of field pea (*Pisum arvense* L.), fiddleneck (*Phacelia tanacetifloia* Benth.) and their mixtures under dry land conditions. The field pea was sown with fiddleneck as follow: field pea 75% + fiddleneck 25%; field pea 50% + fiddleneck 50%; field pea 25% + fiddleneck 75%. Besides, pure field pea and fiddleneck were sown. The highest green fodder (50.2 t ha-1) and dry matter yield (10.3 t ha^{-1}) were obtained from 50% field pea + 50% fiddleneck mixture, while minimum green fodder yield (40.1 t ha^{-1}) and dry matter yield (7.8 t ha^{-1}) were recorded in pure fiddleneck. The maximum total AA (125.7 g kg^{-1}) and CP (150.4 g kg^{-1}) were found in pure field pea. The highest NDF (44.0-44.7%) and ADF (37.1-38.1%) were determined for pure fiddleneck and 25% field pea + 75% fiddleneck mixture, respectively. The effects of species and different mixture ratios on K, P, Ca and Mg contents were significant. The differences between species and mixtures for cystine contents (0.3-0.4 g kg^{-1}) were non-significant. The species and mixtures affected all other AA contents.

Key words: amino acid, fibre, forage, mineral content, mixture, *Pisum arvense* L., *Phacelia tanacetifolia* Benth.

INTRODUCTION

Worldwide, grasslands cover about 3500 million hectares, more than the double of arable land (Carlier, 2010). Livestock production systems throughout the world are based on forages, with grassland feeds being predominant. Grasslands can furnish high quality, low-cost feed for both wild and domesticated, herbivores and omnivores. The efficient use of grasslands, however, requires very careful planning and good management of both animals and forage crops. The use of some type of rotational grazing is essential to control plant growth and furnish animals with the amount and quality of forage necessary to meet their nutritional requirements. Careless planning and bad management of the grasslands in the world has resulted in a great deficiency in forage production (Cherney and Fick, 2001; Ates and Tekeli, 2005). Moreover, permanent grasslands area decreased. For example, permanent meadows and pastures decreased in Europe, progressively, from 410.3 to 181.1 and 176.3 Mha in 1990, 2000 and 2008, respectively (Anonymous, 2010).

The forage used to feed livestock in less developed and developing countries, such as Turkey, is provided by grazing land, forage crops, and secondary products of other cultivated plants (Tekeli and Ates, 2011). Traditionally, in the Anatolia and Mediterranean regions, mixtures of some annual forage legumes with winter cereals and crops from other families are used extensively for forage production (Papastylianou, 2004; Lithourgidis et al., 2006). Field pea (*Pisum arvense* L.) is mainly used for hay and grain production in these regions, however, this plant is sometimes used alone or combination with winter and spring cereals as whole-crop forage. Fiddleneck (*Phacelia tanacetifloia* Benth.) is an important source of high quality nectar and pollen for honeybees (*Apis* spp.) and bumblebees (*Bombus* spp.). Besides, it is used for forage, ornamental and cover crops (Ates et al., 2010a). The aim of this work was to determine the yield and forage quality

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properties (green fodder yield, dry matter yield, and amino acid, fibre and mineral contents) of field pea, fiddleneck and their mixtures, under dry land conditions.

MATERIAL AND METHODS

The study was conducted during 2006-2008 in Tekirdag (41.0 °N, 27.5 °E), western Turkey, located at about 5 m altitude above sea level and with a total precipitation of 482 mm on average and an annual mean temperature of 10.5°C. During the growing season (November to July), in the two experimental years, the average precipitation was 378 mm and 365 mm, with the temperatures being similar to the long-term average, apart from a slightly higher temperature in 2008. The soil of the experimental area was xeralf, low in organic matter (0.98-1.22%), moderate in phosphorus (P) content (average of 60.7 kg ha^{-1}), but rich in potassium (K) content (600.3 kg ha^{-1}) and with pH 7.3-7.4.

Certified seed of the fiddleneck variety Turan-92 and the field pea variety Ates were used. The field pea was sown in mixture with fiddleneck as follow: field pea 75% + fiddleneck 25%; field pea 50% + fiddleneck 50%; field pea 25% + fiddleneck 75%. The seed rates for each species in the mixtures were calculated using the following formulas (Avcioglu, 1997):

Utilization Value (UV) = Seed purity (%) x Germination vigour (%)/100;

Seed Rate in Mixture = Ratio of species in mixture (%) x Sowing rate (kg ha^{-1})/UV.

The species were seeded in alternate rows. Besides, pure field pea and fiddleneck were sown. Row distances of 25 cm, sowing rates of 120 kg ha^{-1} (field pea) and of 20 kg ha^{-1} (fiddleneck) were used (Servet and Ate, 2004; Ates et al., 2010a). The plots were of 3.5 x 5 m, arranged in a randomized block design with three replicates. Plots were seeded in the autumn (November 3, 2006 and November 9, 2007) and no fertilizer or irrigation was applied after sowing and during growth. Forage was harvested by cutting a 3 by 1 m area of each plot to a 3 cm stubble height when field peas reached full-bloom (first year, May 20; second year, May 14) (Servet and Ate, 2004). Samples were weighed and the green fodder yield (t ha^{-1}) was calculated per hectare. Samples (500 g herbage approximately) were put in an air circulation oven at 55 °C for 48 h and stored for one day at room temperature and weighed (Ates et al., 2010b). Later, the dry matter (DM) yield (t ha^{-1}) was calculated. All dried samples were ground to small (<2 mm) pieces and used for the analyses. The crude protein (CP) content (in DM, g kg^{-1}) was determined by the micro-Kjeldahl method. The amino acid (AA) content (in DM, g kg^{-1}) was determined by automatic aminoalyzer AAA-881 after hydrochloric acid hydrolysis. After plant samples were wet-fired with nitric-perchloric acid, P content (in DM, %) was determined spectrophotometrically. K, calcium (Ca) and magnesium (Mg) contents (in DM, %) were found using an atomic adsorption spectrophotometer. The neutral detergent fibre (NDF, %) and acid detergent fibre (ADF, %) were determined following the procedures described by Kok et al. (2007). All samples were analysed in triplicate for CP, ADF, NDF, AA and mineral contents. Variance tests were applied for statistical analysis. Whenever the interaction with years was not significant, means of two years for treatments were compared by the Duncan's Multiple Range Test. These results were analysed using the TARIST statistical program.

RESULTS AND DISCUSSION

Both species and mixture rates showed significant differences in green fodder yield and dry matter yield (Table 1). The highest green fodder (50.2 t ha^{-1}) and dry matter yields (10.3 t ha^{-1}) were obtained from 50% field pea + 50% fiddleneck mixture, while minimum green fodder yield (40.1 t ha^{-1}) and dry matter yield (7.8 t ha^{-1}) were recorded in pure fiddleneck. Aasen et al. (2004) recorded 5.63-13.21 t ha^{-1} dry matter yields from field pea, whereas Clark (2007) found these values to be only 5.60 t ha^{-1} for Austrian winter peas under colder climatic conditions. Feeding and agronomic value of field pea-safflower (*Carthamus tinctorius* L.) mixtures was investigated by Arslan et al. (2008). They reported that the green fodder and dry matter yields ranged from 32.18-37.34 t ha^{-1} and 9.87-11.23 t ha^{-1}, respectively, in field pea-safflower mixtures. Ates et al. (2010) stated that the fiddleneck provided 9.26 t ha^{-1} of dry matter yield at budding stage, similar to the present findings.

Table 1. Botanical composition, green fodder and dry matter yields of field pea-fiddleneck mixtures, pure pea and fiddleneck (the means of two years)

Treatments	Yields		Botanical Composition, g kg^{-1}		
	Green fodder yield, t ha^{-1}	Dry matter yield, t ha^{-1}	Field Pea	Fiddleneck	Other species[1]
75 % Pea + 25 % Fiddleneck	44.7b*	9.2b	681.1	233.3	85.6
50 % Pea + 50 % Fiddleneck	50.2a	10.3a	487.1	500.5	12.4
25 % Pea + 75 % Fiddleneck	43.5b	8.3c	246.7	722.2	31.1
100 % Field Pea	45.6b	9.4b	989.9	-	10.1
100 % Fiddleneck	40.1c	7.8d	-	978.7	21.3

[1] Other species: *Papaver rhoeas* L., *Hordeum murinum* L., *Brassica nigra* L., *Lolium multiflorum* Lam., *Poa annua* L., *Galium aparine* L., *Ranunculus* spp., *Taraxacum officinale* F.H. Wigg.
* Means followed by the same letter are not significantly different according to Duncan's Multiple Range Test at 5 % level.

Contents of CP, NDF, ADF, minerals, total amino acid and AA varied significantly depending on the species and mixture rates (Table 2 and Figures 1-6). The maximum total AA (125.7 g kg-1) and CP (150.4 g kg-1) were found in pure field pea. When the grass and other species rates increased in the mixture, the fibre contents increased and CP content of hay decreased as expected. The highest NDF (44.0-44.7%) and ADF (37.1-38.1%) were determined for pure fiddleneck and 25% field pea + 75% fiddleneck mixture, respectively ($P \leq 0.01$).

Forage quality is usually measured by the amount and availability of nutrients contained in the forage. The ultimate test of forage quality, however, is animal performance. Three factors that effect animal performance are: (a) Intake - forage must be palatable if it is to be consumed in adequate quantities to produce the desired performance; (b) Digestibility nutrient content - once the forage is eaten, it must be digested and converted to animal products; (c) Toxic factors - the forage must be free of components, which are harmful to the animals. Many factors affect forage quality for animals, so that no one characteristic can serve to predict animal production. Some of the important factors that determine forage quality for animals are stage of maturity, chemical composition, legume-grass or other species ratios, physical form, foreign material (particularly weeds and dust), damage or deterioration during harvest and storage, and the presence of anti-quality substances such as estrogens, thyrotoxic factors, and toxic amines and their condensation products (Tekeli and Ates, 2005). Hubbard (2011) stated that forage legumes insure good protein for ruminants. High-producing dairy cows need hay with at least 20% CP, less than 30% ADF, and less than 40% NDF. Forages with better CP, ADF, and NDF values are not necessarily better for milk production. When CP is less than 35%, much of the forage passes through the rumen without being absorbed, so it is essentially wasted (Redfearn et al., 2008). The CP content and fractionation varied depending on the forage crop species or varieties (Ates et al., 2010b). For example, Endura kura clover (*Trifolium ambiguum* M.B.), alfalfa (*Medicago sativa* L.) and red clover (*T. pretense* L.) had similar CP contents (average of 194 g kg^{-1}), which were higher than that of Rhizo kura clover (177 g kg^{-1})

(Seguin et al., 2002). Servet and Ate (2004) reported 18.03-18.31% CP ratios in field pea. However, Arslan et al. (2008) obtained values of 19.77% for CP, 29.45% for ADF and 37.98% for NDF contents from the field pea. Geren and Kaymakkavak (2007) reported that the CP ratios of fiddleneck varied from 12.1 to 14.1%. Ates et al. (2010a) emphasized that the CP, ADF, NDF and acid detergent lignin (ADL) ratios ranged from 6.65 to 13.22%, 36.20-37.33%, 41.42-45.60% and 16.41-23.70% respectively, in fiddleneck at different growth stages. The present results were similar to those reported by these researchers.

The effect of species and different mixture ratios on K, P, Ca and Mg contents were significant (Table 2). The lowest K content (1.67%) and P content (0.28%), as well as the highest Ca content (1.63%), were determined in the pure field pea. The pure fiddleneck and 25% field pea + 75% fiddleneck mixture showed lower values than the field pea and other mixtures for Mg content (0.29-0.33%). Forage crops are important sources of the minerals essential for animal health. The content of individual minerals in forages varies greatly depending on species, soil, growth stages, biotic and abiotic stress conditions, and management factors. Eighteen mineral elements are known to be required by at least some animal species. They can be divided into two groups (macro and microelements) based on the quantity required in the forage. Macro elements (Ca, K, P, Mg etc.) are required in amounts ranging from a few tenth of a gram to one or more grams per day. The mineral elements are contained in approximately 1.5-5.5% of the animal body; out of which 1.4% Ca, 0.8% P, 0.19% K, and 0.046% Mg (Ates et al., 2010a).

Acute and chronic dietary deficiencies in macro and micro minerals have significant impact on production efficiency of rangelands throughout the world (Pinchak et al., 1989). Anonymous (2001) reported that the requirement for major mineral nutrients for gestating beef cows or lactating beef cows is 0.6-0.8% (w/w) for K, 0.18-0.44% for Ca, 0.18-0.39% for P, and 0.04-0.1% for Mg.

Some researchers found that K contents of samples varied between 0.96 and 5.44% in different wild plant species (Tan and Yolcu, 2001; Ayan et al., 2006). K contents of the samples studied during this investigation were within these limits. Arslan et al. (2008) emphasized that K, Ca, Mg and P ratios ranged from 1.78%, 1.66%, 0.45% and 0.31% respectively, in field pea. Blackwood (2007) obtained values of 13 g kg^{-1} for Ca, 2 g kg^{-1} for P and 4.5 g kg^{-1} for K contents from the cowpea (*Vigna unguiculata* (L.) Walp.) at full-bloom stage. The K, Ca and P contents recorded in the present experiment were higher than those reported by Blackwood (2007).

Table 2. Total amino acids (AA), crude protein (CP), calcium (Ca), potassium (K), magnesium (Mg), phosphorus (P), neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents in dry matter (DM) of field pea and fiddleneck mixtures, pure pea and fiddleneck (the means of two years)

Indicators	75% Pea + 25% fiddleneck	50% Pea + 50% fiddleneck	25% Pea + 75% fiddleneck	100% Field pea	100% Fiddleneck
Total AA, g kg^{-1}	117.5b*	106.4c	90.5d	125.7a	80.5e
CP, g kg^{-1}	138.7b	124.7c	114.1d	150.4a	103.3d
NDF, %	42.1c	43.7b	44.0a	41.7c	44.7a
ADF, %	32.6c	35.1b	37.1a	30.8d	38.1a
Ca, %	1.09b	1.23b	0.94c	1.63a	0.87c
K, %	1.83c	1.90b	2.13a	1.67d	2.23a
Mg, %	0.40a	0.37a	0.29b	0.44a	0.33b
P, %	0.33c	0.41b	0.50a	0.28d	0.57a

*Means in the same column, followed by the same letter are not significantly different according to Duncan's Multiple Range Test at 1% level.

The differences between species and mixtures for cystine contents (0.3-0.4 g kg^{-1}) were determined to be non-significant. The species and mixtures significantly affected all other AA contents (Figures 1 to 6). The field pea had the highest contents of aspartic acid (14.9 g kg^{-1}), threonine (6.6 g kg^{-1}), lysine (8.5 g kg^{-1}), arginine (5.5 g kg^{-1}), isoleucine (4.6 g kg^{-1}), histidine (3.4 g kg^{-1}), proline (18.3 g kg^{-1}), phenylalanine (5.7 g kg^{-1}), and tyrosine (4.5 g kg^{-1}). Fiddleneck had the lowest content of alanine (9.4 g kg^{-1}), leucine (4.8 g kg^{-1}), and serine (5.3 g kg^{-1}).

The minimum glycine (4.8 to 4.9 g kg^{-1}) content was determined in fiddleneck and 25% field pea + 75% fiddleneck mixture, respectively. The highest valine (6.2-6.5 g kg^{-1}), methionine (0.4-0.5 g kg^{-1}), and glutamic acid (14.8-15.3 g kg^{-1}) were obtained in field pea and 75% field pea + 25% fiddleneck mixture, respectively. The AA and not protein per se are the required nutrients. Absorbed AA are used principally as building blocks for the synthesis of proteins, and therefore are vital to the maintenance, growth, reproduction, lactation, and other physiological activities of animals (Ates et al., 2010b). Penkov et al. (2003) found that lysine, histidine, arginine, aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, cystine, valine, methionine, isoleucine, leucine, tyrosine, and phenylalanine contents (in DM) ranged from 8.5 g kg^{-1}, 3.3 g kg^{-1}, 6.0 g kg^{-1}, 16.5 g kg^{-1}, 6.2 g kg^{-1}, 6.8 g kg^{-1}, 13.9 g kg^{-1}, 17.4 g kg^{-1}, 6.4 g kg^{-1}, 7.3 g kg^{-1}, 0.6 g kg^{-1}, 6.4 g kg^{-1}, 0.6 g kg^{-1}, 4.6 g kg^{-1}, 9.7 g kg^{-1}, 4.3 g kg^{-1}, and 6.2 g kg^{-1} respectively, in diploid red clover (*Trifolium pretense* L.). The AA and fibre contents of four different annual forage legumes at full-bloom stage were investigated by Ates at al. (2010b). They reported that the AA contents in different annual forage legumes varied by the species. The present results are similar to those reported by these researchers.

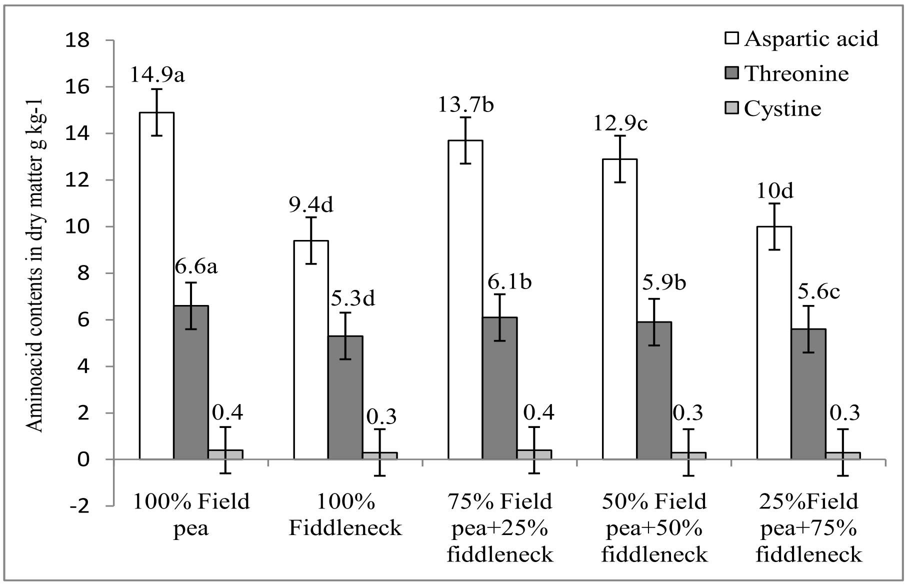

Figure 1. Aspartic acid, threonine and cystine contents in field pea, fiddleneck and mixtures
(Bars followed by the same letter are not significantly different according to Duncan's Multiple Range Test at 1% level)

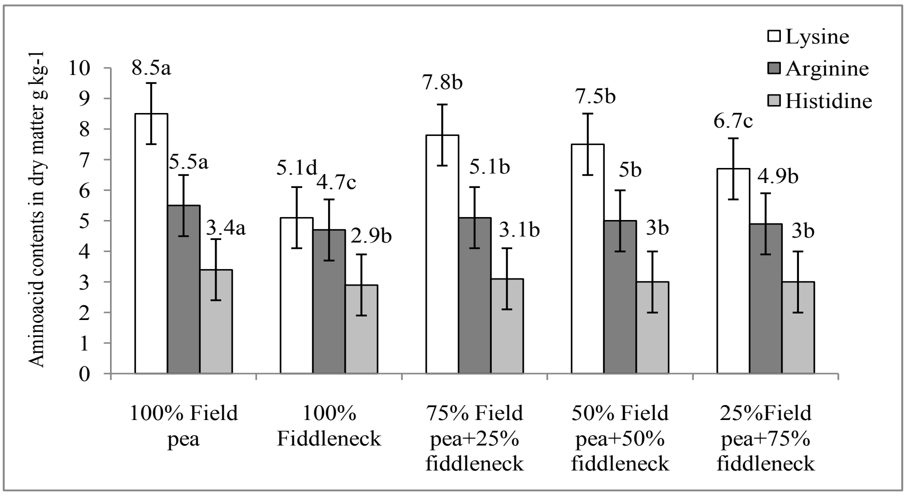

Figure 2. Lysine, arginine and histidine contents in field pea, fiddleneck and mixtures
(Bars followed by the same letter are not significantly different according to Duncan's Multiple Range Test at 1% level)

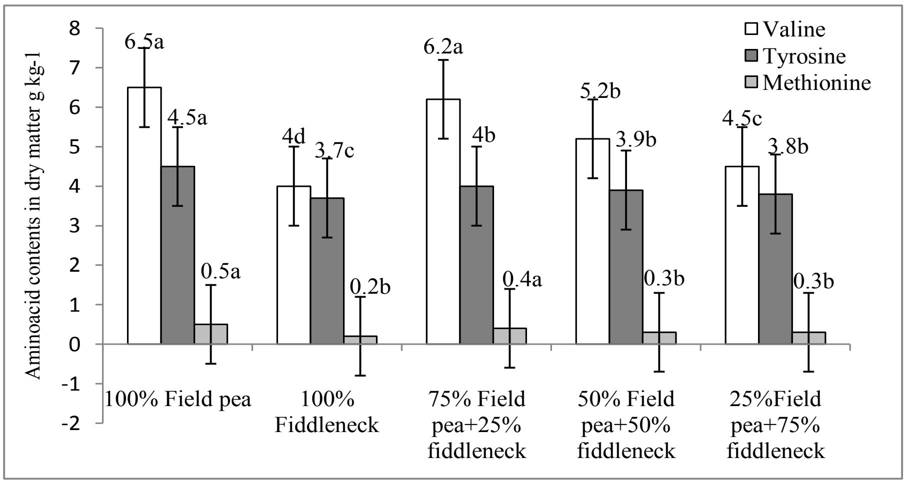

Figure 3. Valine, tyrosine and methionine contents in field pea, fiddleneck and mixtures
(Bars followed by the same letter are not significantly different according to Duncan's Multiple Range Test at 1% level)

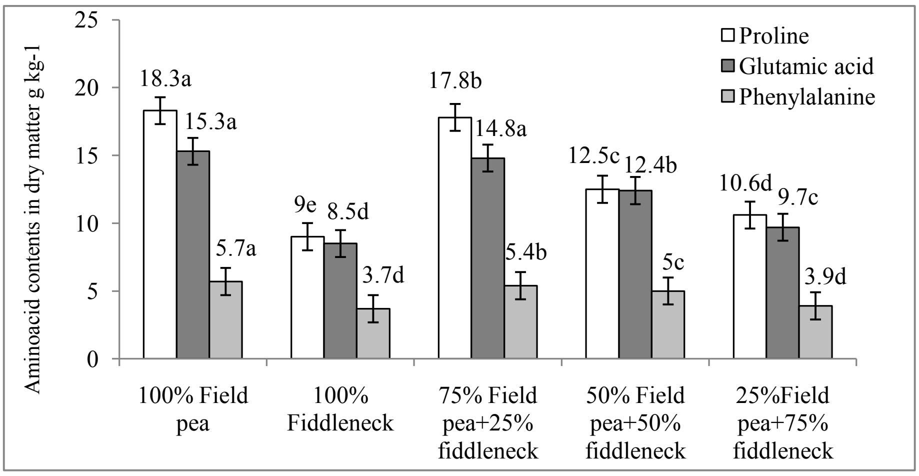

Figure 4. Proline, glutamic acid and phenylalanine contents in field pea, fiddleneck and mixtures
(Bars followed by the same letter are not significantly different according to Duncan's Multiple Range Test at 1% level)

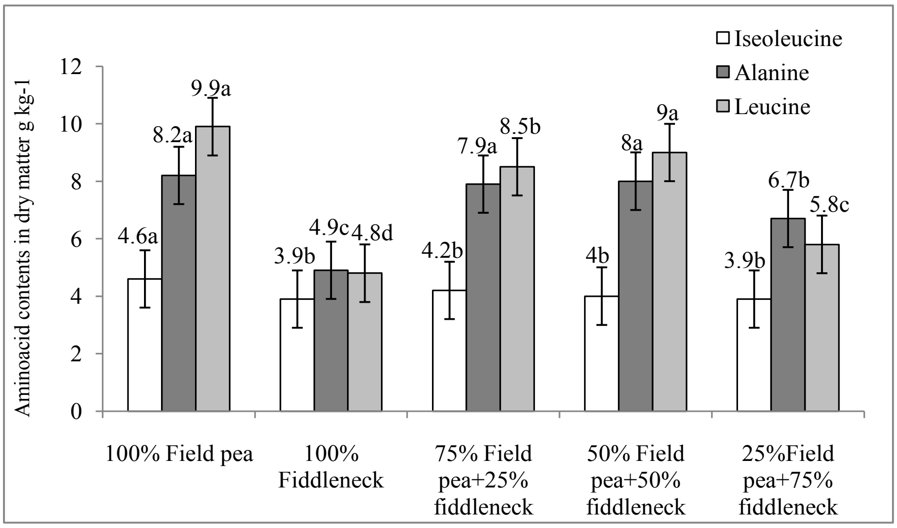

Figure 5. Isoleucine, alanine and leucine contents in field pea, fiddleneck and mixtures
(Bars followed by the same letter are not significantly different according to Duncan's Multiple Range Test at 1% level)

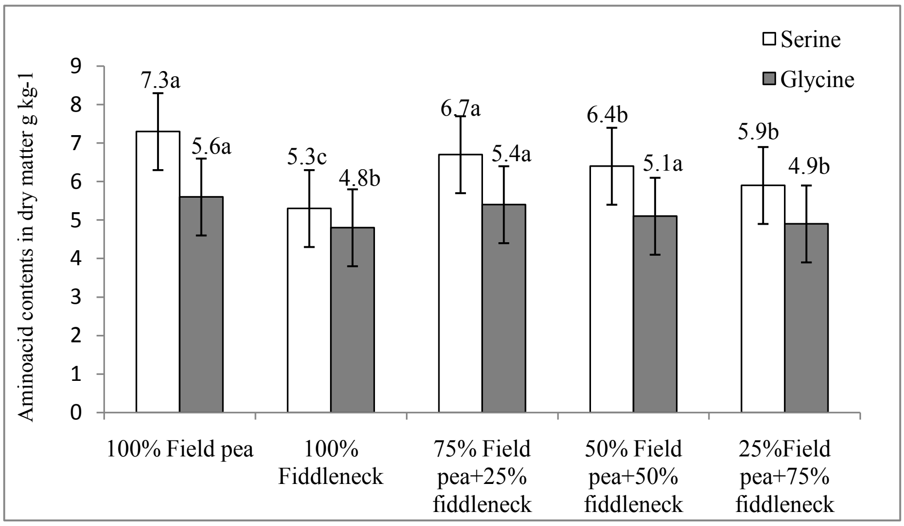

Figure 6. Serine and glycine contents in field pea, fiddleneck and mixtures
(Bars followed by the same letter are not significantly different according to Duncan's Multiple Range Test at 1% level)

CONCLUSIONS

Fresh fodder yield, dry matter yield, fibre, mineral and amino acid contents were affected by different species and mixtures. According to fresh fodder yield, dry matter yield, mineral and amino acid contents, the field pea, 75% field pea + 25% fiddleneck and 50% field pea + 50% fiddleneck mixture were more suitable and could be suggested for utilization as fresh or dried feed in livestock.

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