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ORIGINAL PAPER

YIELD, SOME CELL WALL COMPONENT AND MINERAL CONTENTS OF FODDER PEA (*PISUM SATIVUM* SSP. *ARVENSE* L. POIR) FORAGE AS INFLUENCED BY CULTIVAR, GROWTH STAGES AND PHOSPHORUS APPLICATION

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Abstract

The objectives of this study were to evaluate the effect of cultivars, growth stages and different phosphorus doses on forage yield, some cell wall components and macro-element content of fodder pea. This research was conducted during 2014-2019 on farmland (41°12′24″ N, 27°18′23″ E) in Muratli-Tekirdag, Turkey, in a randomized split block design with four replications. Each year, the fertilizer treatments were comprised of five levels of phosphorus (triple superphosphate (TSP), P 43%) viz-0 (control), 30, 60, 90 and 120 kg ha^{-1}. At all growth stages (pre-bud, ½ bloom and full-bloom), some morphological characters, crude fiber, acid detergent fiber, neutral detergent fiber, acid detergent lignin, calcium, potassium, magnesium, phosphorus contents, herbage and dry matter yields of two fodder pea cultivars at each treatment were determined. The highest main stem length (127.1 cm), main stem diameter (4.1 mm), number of branches per plant (4.3 pcs), number of leaves main stem (24.3 pcs), leaf/stem ratio (2.1), herbage yield (50.8 Mg ha^{-1}) and dry matter yield (11.1 Mg ha^{-1}) values were found at application of 60 kg P ha^{-1}. Increasing phosphorus doses resulted in a decrease in crude fiber, neutral detergent fiber, acid detergent fiber and acid detergent lignin contents. The highest potassium (16.9 g kg^{-1}), calcium (16.6 g kg^{-1}), magnesium (4.5-4.6 g kg^{-1}) and phosphorus (3.5 g kg^{-1}) content was found at applications of 60 to 120 kg P ha^{-1}. The content of these macro-elements increased with advancing maturity.

Keywords: growth stage, fiber content, fodder pea, forage yield, mineral content, *Pisum arvense* L.

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INTRODUCTION

Fertilizer management has a vital role in the success or failure of the production of forage and other crops. It is an important factor for obtaining higher yields of forage crops, which needs to be investigated under local conditions as soil fertility varies greatly and response varies from genotype to genotype in species. Application of balanced fertilizer increases vegetative growth and improves yield and quality of herbage/hay in forage crops. Phosphorus (P) is classified as a major essential nutrient even though its content in forage crops is much lower than contents of nitrogen (N) and potassium (K), and for field pea and other forage legumes particularly, lower than that of calcium (Ca). Supplying these elements in forage legumes and grasses fields could be increase forage yield and quality properties. For example, Wolday et al. (2015) reported a positive effect of N, P and K applications on yield and quality traits of forage crops. In general, P treatment causes an increase in the crude protein content due to enhancing nitrogen uptake by plants. Phosphorus fertilization affects dry matter yield and chemical composition of forage crops (Dasci et al. 2010, Yuksel, Turk 2019).

For forage crops to be of superior quality, they must be high in four factors: (a) nutrients, (b) digestibility, (c) palatability, and (d) efficiency of utilization. However, growth stages of forage crops affect the fodder yield, palatability, digestibility and chemical composition cell wall components, protein, mineral and vitamin contents – Tenikecier, Ates (2018). Generally, fodder pea (*Pisum sativum* ssp. *arvense* L. Poir) is more digestible and passes through the digestive tract more rapidly than other low quality forage crops; hence, herbivores will consume more of it. High forage production and quality for fodder pea depends on genotypes, environmental factors, sowing time, harvest stage, soil fertility and other cultivation techniques. It is rich in high quality protein. Although the levels of cell wall components in fodder pea are lower than in forage grasses (*Poaceae* sp.), the cell walls of fodder pea are highly lignified and less available than forage grasses. It is also rich in minerals and pro-vitamins or vitamins, especially carotenoids and ergocalciferol. They made fodder pea one of the best feeds for ruminant and non-ruminants (Ates, Tenikecier 2020). After a literature review, some morphological characters, forage yield and quality traits in newly developed these fodder pea cultivars (cv. Ates and cv. Tore) at different growth stages under the application of different phosphorus doses were determined in our research for the first time. The objectives of this research were to evaluate the effect of cultivars, growth stages and different phosphorus doses on forage yield, some cell wall components and mineral content of fodder pea.

MATERIALS AND METHODS

Study site and experimental design

This study was conducted during 2014-2019 on farmland (41°12′24″ N, 27°18′23″ E) in Muratli-Tekirdag (Figure 1), Turkey in randomized split

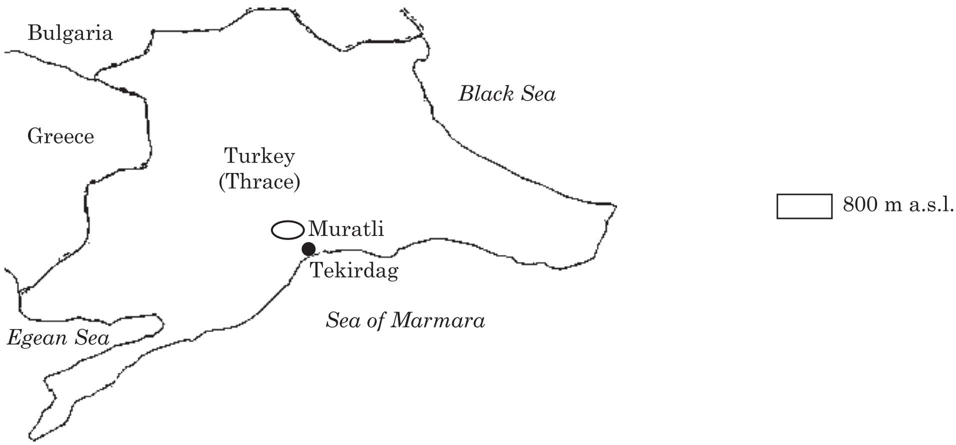

Fig. 1. Experimental area in Thrace, Turkey

block design with four replications. This field was on black soil – vertisol (total P content of 40.12 kg ha^{-1}, total potassium (K) content of 447.33 kg ha^{-1}, organic matter of 1.04% and pH 7.3) at 111 m above sea level with a total precipitation of 590 mm on average and an annual overall temp. of 13.97°C. There was no differences between the temperatures, rainfalls during experiments in all years. Certified seeds of the fodder pea cultivars Ates and Tore were used. These cultivars were obtained every year from Tekirdag Namik Kemal University, Faculty of Agriculture, Department of Field Crops. Each plot consisted of 50 rows 26 cm apart and 47 m in length. The seeds were sown with a seeder at the density of 120 kg ha^{-1} on 5 November 2014, 12 November 2015, 30 October 2016, 7 November 2017 and 15 November 2018, thus the study covered the years 2014-19. Each year, the fertilizer applications were comprised of five doses of phosphorus (triple superphosphate (TSP), P 43%) viz-0 (control), 30, 60, 90 and 120 kg P ha^{-1}. Besides, basal fertilizer containing urea (45 kg N ha^{-1}) was incorporated into the soil at the time of seedbed preparation.

Measurements of morphological characters

At all growth stages (pre-bud, ½ bloom and full-bloom), twenty-five plants were randomly taken from the plot of each treatment in all the replicates and the main stem length (cm), main stem diameter (mm), number of branches per plant (pcs), number of leaves per main stem (pcs), leaf length (cm) and leaf/stem ratio were determined. Main stem diameter was measured between the second and third node. Leaf length was determined on a leaf at the third node of the main stem. Plant samples were manually separated to leaves and stems, which were weighted to determine the leaf/stem ratio. To estimate herbage yield (Mg ha^{-1}) of fodder pea cultivars, a sample from 20 square meters was harvested at pre-bud, ½ bloom and full-bloom stages from each plot. Approximately 500 g samples were oven-dried at 65°C for 48 h, to determine dry matter and to calculate the yield (Mg ha^{-1}) – Benou et al. (2020).

Chemical analyses

Dry samples were ground to small (0.5 mm) pieces and used for laboratory analyses. Crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) contents (g kg^{-1}) were determined following the Van Soest et al. (1991) and AOAC (2019). Potassium (K), calcium (Ca) and magnesium (Mg) contents (g kg^{-1}) were found using a flame atomic absorption spectrophotometer – FAAS (Varian - Spectra AA-220 model, California, USA). The P content (g kg^{-1}) was quantified spectrophotometrically using the vanadium-molybdate phosphoric acid yellow color method (Jackson 2005). All samples were analyzed in duplicate.

Statistical analyses

The data were analyzed using a MSTAT-C statistical computer package. The same programme was used for the comparison (Fisher's least significant difference, LSD) of the means from the five years.

RESULTS AND DISCUSSION

The applied P doses affected the morphological characters, cell wall components, macro-element content, herbage and dry matter yields (Tables 1 to 3). In addition, the growth stages showed significant effects on the main stem length, number of leaves per main stem, leaf/stem ratio, herbage yield, dry matter yield, cell wall components and macro-elements. On the other hand, effects of a cultivar, P dose x cultivar interaction, growth stage x cultivar interaction and P dose x growth stage x cultivar interaction on herbage and dry matter yields, morphological characters, cell wall components and macro-elements were not significant ($P>0.05$). The P dose x growth stage interaction was observed for cell wall components, macro-elements, morphological characters, herbage and dry matter yields, except the main stem diameter, number of branches per plant and leaf length. No differences between the cultivars were observed for morphological characteristics, cell wall components, macro-element content, herbage and dry matter yields for five-year averages (*P*>0.05).

Morphological characters and yield

As shown in Tables 1 and 2, the highest main stem length (127.1 cm), main stem diameter (4.1 mm), number of branches per plant (4.3 pcs),

Table 1

Effects of different phosphorus doses and growth stages on some morphological characters in fodder pea cultivars

Treatments		Main stem length (cm)	Main stem diameter (mm)	No. of branches per plant (pcs)	No. of leaves per main stem (pcs)	Leaf length (cm)
P doses(PD), kg ha^{-1}						
0		120.2*c*	3.4*c*	3.0*c*	21.2*c*	22.6*c*
30		122.4*b*	3.4*c*	3.1*c*	22.1*c*	23.0*c*
60		127.1*a*	4.1*a*	4.3*a*	24.3*a*	25.3*a*
90		125.6*b*	3.7*b*	3.8*b*	23.3*b*	24.1*ab*
120		121.8*b*	3.7*b*	3.8*b*	23.4*b*	23.9*b*
Growth stages (GS)						
Pre-bud		117.5*c*	3.6	3.4	21.1*c*	24.1
½ bloom		123.9*b*	3.7	3.7	23.0*b*	23.8
Full-bloom		128.9*a*	3.9	3.8	24.5*a*	24.5
Cultivars (C)						
Ates		123.4	3.7	3.5	22.8	24.0
Tore		123.3	3.7	3.7	22.9	23.6
Mean		123.4	3.7	3.6	22.9	23.8
Analysis of variance	*df*					
PD	4	*	**	**	**	**
$Error_1$	12					
GS	2	*	ns	ns	**	ns
C	1	ns	ns	ns	ns	ns
PD x C	4	ns	ns	ns	ns	ns
PD x GS	8	*	ns	ns	**	ns
GS x C	2	ns	ns	ns	ns	ns
PD x GS x C	8	ns	ns	ns	ns	ns
$Error_2$	45					

*, ** significant at 0.05 and 0.01 level, respectively. For each main effect, values within columns followed by the same letter are not significant. *df* – degrees of freedom, ns – not significant

Table 2

Effects of different phosphorus doses and growth stages on leaf/stem ratio, CF and NDF content, herbage and dry matter yields in fodder pea cultivars

Treatments		Leaf/stem ratio	Herbage yield (Mg ha^{-1})	Dry matter yield (Mg ha^{-1})	Crude fiber (g kg^{-1})	NDF (g kg^{-1})
P doses(PD), kg ha^{-1}						
0		1.8*c*	40.6*d*	9.0*c*	231.4*a*	430.1*a*
30		1.8*c*	41.3*c*	9.0*c*	231.7*a*	430.0*a*
60		2.1*a*	50.8*a*	11.1*a*	220.1*b*	421.2*b*
90		1.9*b*	45.9*b*	10.0*b*	221.0*b*	421.0*b*
120		1.9*b*	46.1*b*	10.0*b*	220.1*b*	420.8*b*
Growth stages (GS)						
Pre-bud		2.3*a*	41.2*c*	8.1*c*	204.9*c*	415.1*c*
½ bloom		2.0*ab*	44.5*b*	10.0*b*	228.0*b*	421.7*b*
Full-bloom		1.6*b*	49.8*a*	11.4*a*	236.8*a*	437.1*a*
Cultivars (C)						
Ates		1.9	45.0	9.9	225.8	425.1
Tore		1.9	44.8	9.7	223.9	424.1
Mean		1.9	44.9	9.8	224.9	424.6
Analysis of variance	*df*					
PD	4	**	*	*	*	**
$Error_1$	12					
GS	2	**	*	*	*	*
C	1	ns	ns	ns	ns	ns
PD x C	4	ns	ns	ns	ns	ns
PD x GS	8	**	*	*	*	**
GS x C	2	ns	ns	ns	ns	ns
PD x GS x C	8	ns	ns	ns	ns	ns
$Error_2$	45					

*, ** significant at 0.05 and 0.01 level, respectively. For each main effect, values within columns followed by the same letter are not significant. *df* – degrees of freedom, ns – not significant

number of leaves per main stem (24.3 pcs), leaf/stem ratio (2.1), herbage yield (50.8 Mg ha^{-1}) and dry matter yield (11.1 Mg ha^{-1}) values were found at the application of 60 kg P ha^{-1}. Nevertheless, the maximum leaf length (24.1-25.3 cm) was measured at applications of 60 and 90 kg P ha^{-1}. At the full-bloom stage, the highest main stem length (128.9 cm), number of leaves per main stem (24.5 pcs), herbage (49.8 Mg ha^{-1}) and dry matter (11.4 Mg ha^{-1}) yields were determined in the fodder pea cultivars. In addi-

Table 3
Effects of different phosphorus doses and growth stages on macro-element, ADF and ADL content in fodder pea cultivars

Treatments		ADF ($g\ kg^{-1}$)	ADL ($g\ kg^{-1}$)	K ($g\ kg^{-1}$)	Ca ($g\ kg^{-1}$)	Mg ($g\ kg^{-1}$)	P ($g\ kg^{-1}$)
P doses(PD), kg ha^{-1}							
0		304.4*a*	51.1*a*	15.7*b*	15.6*b*	4.0*b*	2.5*b*
30		303.7*a*	51.2*a*	15.9*b*	15.7*b*	4.1*b*	2.4*b*
60		292.4*b*	48.9*b*	16.9*a*	16.6*a*	4.6*a*	3.5*a*
90		292.2*b*	49.0*b*	16.9*a*	16.6*a*	4.6*a*	3.5*a*
120		292.4*b*	48.9*b*	16.9*a*	16.6i	4.5*a*	3.5*a*
Growth stages (GS)							
Pre-bud		280.2*c*	48.1*b*	15.9*bc*	15.7*c*	4.2*b*	2.4*b*
½ bloom		295.1*b*	49.6*b*	16.4*b*	16.2*b*	4.3*b*	3.4*a*
Full-bloom		315.7*a*	51.5*a*	17.1*a*	16.6*a*	4.6*a*	3.5*a*
Cultivars (C)							
Ates		297.3	49.4	16.4	16.1	4.3	3.0
Tore		296.8	50.1	16.6	16.3	4.4	3.2
Mean		297.0	49.8	16.5	16.2	4.4	3.1
Analysis of variance	*df*						
PD	4	**	**	**	**	**	**
$Error_1$	12						
GS	2	**	**	**	**	**	**
C	1	ns	ns	ns	ns	ns	ns
PD x C	4	ns	ns	ns	ns	ns	ns
PD x GS	8	**	**	**	**	**	**
GS x C	2	ns	ns	ns	ns	ns	ns
PD x GS x C	8	ns	ns	ns	ns	ns	ns
$Error_2$	45						

** significant at 0.01 level. For each main effect, values within columns followed by the same letter are not significant. *df* – degrees of freedom, ns – not significant

tion, a significant P dose x growth stage interaction was observed for the main stem length, number of leaves per main stem, leaf/stem ratio, herbage and dry matter yields. The highest main stem length, number of leaves per main stem, leaf/stem ratio, herbage and dry matter yields were obtained from 60, 90 and 120 kg P ha^{-1} doses at the full-bloom stage (Figures 2 and 3). The morphological characters measured in this research are important traits used to estimate forage yield and quality. Besides, forage yield and quality of fodder pea are known to be complex properties governed by polygenes, and therefore influenced by environmental conditions and cultivation factors.

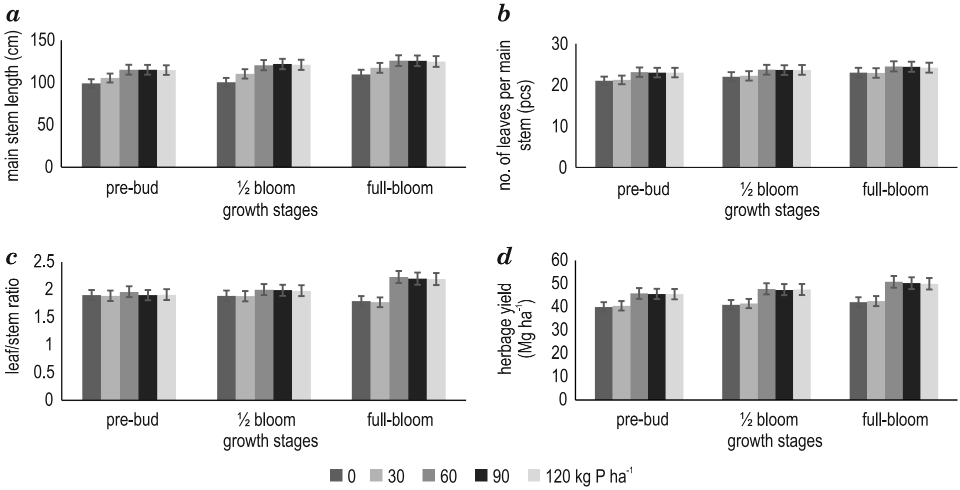

Fig. 2. Effects of phosphorus doses and growth stages on main stem length (*a*), number of leaves per main stem (*b*), leaf/stem ratio (*c*) and herbage yield (*d*) of fodder pea cultivars

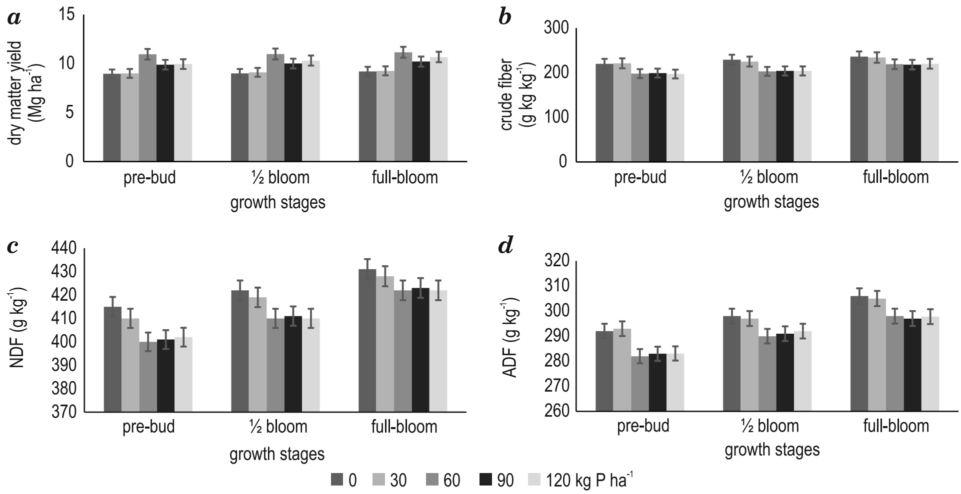

Fig. 3. Effects of phosphorus doses and growth stages on dry matter yield (*a*), crude fiber (*b*), NDF (c), and ADF (*d*) content of fodder pea cultivars

However, low yields in such soils could mainly be due to the deficiency of nutrients, such as P, Ca and Mg, or to low pH and toxicity of soil aluminum (Al), iron (Fe) and manganese (Mn) (Manore, Altaye 2018). In previous studies, herbage and hay yields were reported respectively as between 8.7-52.7 Mg ha^{-1} and between 1.2-9.6 Mg ha^{-1} (Geren, Alan 2012, Cacan et al. 2019). Servet and Ate (2004) reported that the main stem length, number of branches per plant, leaf length, number of leaves per main stem and herbage yield ranged from 100.5-124.3 cm, 3.4-6.2, 19.8-24.8 cm, 19.5-23.0 and 14.1 to 28.2 Mg ha^{-1}, respectively, in fodder pea genotypes at the full-bloom stage. Erman et al. (2009) determined that the plant height, number of branches, shoot dry weight, number of pods, seed yield and biomass yield in fodder pea increased at 60 kg P ha^{-1} application. Bilgili et al. (2010) found that forage yield produced by field pea (*P. sativum* L.) genotypes ranged from 1.61 to 3.6 Mg ha^{-1} with an average protein concentration of 15.3% in field pea genotypes at the full-bloom stage. Tekeli, Ates (2011) mentioned that field pea grew to a height of 4 m under suitable ecological and cultivation conditions, whereas Kosev et al. (2013) reported this value to be only 30.72-76.10 cm in spring field pea. Kavut et al. (2016) determined that the dry matter yields of fodder pea varieties varied between 7.2 and 8.9 Mg ha^{-1} when grown at 20 cm row spacing in the Aegean region. Yadav, Dhanai (2017) reported that 30 to 90 kg ha^{-1} applications of P to fields sown with pea cultivars were beneficial by increasing the biological and straw yields. Besides, they observed that the plant height and number of branches per plant increased significantly with the increasing doses of phosphorus. Islam et al. (2019) stated that fertilizer exerts significant influence on yield, vigorous growth and yield attributes of legumes. Present findings coincide with those earlier ones.

Cell wall components

Increasing phosphorus doses resulted in a decrease in the CF, NDF, ADF and ADL content. While the highest CF (231.4-231.7 g kg^{-1}), NDF (430.0-430.1 g kg^{-1}), ADF (303.7-304.4 g kg^{-1}) and ADL (51.1-51.2 g kg^{-1}) were obtained from control and 30 kg P ha^{-1} dose, the lowest values were obtained from 60, 90 and 120 kg P ha^{-1} doses (Tables 2 and 3). The cultivar effect on cell wall components was not significant (P>0.05). The effects of growth stages were significant for CF, NDF, ADF and ADL. The CF, NDF, ADF and ADL content increased from 204.9 to 236.8 g kg^{-1}, 415.1 to 437.1 g kg^{-1}, 280.2 to 315.7 g kg^{-1}, 48.1 to 51.5 g kg^{-1}, respectively, with advancing maturity. The P dose x growth stage interaction had significant effects on CF, NDF, ADF and ADL. The lowest CF, NDF, ADF and ADL were obtained from 60, 90 and 120 kg P ha^{-1} doses at each growth stage (Figures 3 and 4). Fodder pea quality should be considered as the set of characteristics that determine the feeding value for ruminant and non-ruminant animals. The feeding value can be measured in terms of production of meat, milk, or wool. Forage, especially fodder pea, may supply from 10 to 99% of the protein required and 15 to 100% of the energy required for ruminant and non-ruminant animals, depending on the type of animal and season of the year. The requirement of a 500 kg beef cattle (*Bos taurus* L.) of superior milking ability nursing a calf the first 3 to 4 months postpartum is a minimum of 28.6 Mcal of digestible energy (NRC 2001). These requirements can be satisfied with an 11.8 kg of DM (Essig 1985) from fodder pea. Daily intake of digestible DM is more closely correlated with DM intake than with DM digestibility. In most forage crops, the cell wall components account for 55-85% of DM. These components of forage crop species are affected by the aforementioned factors (Tenikecier,

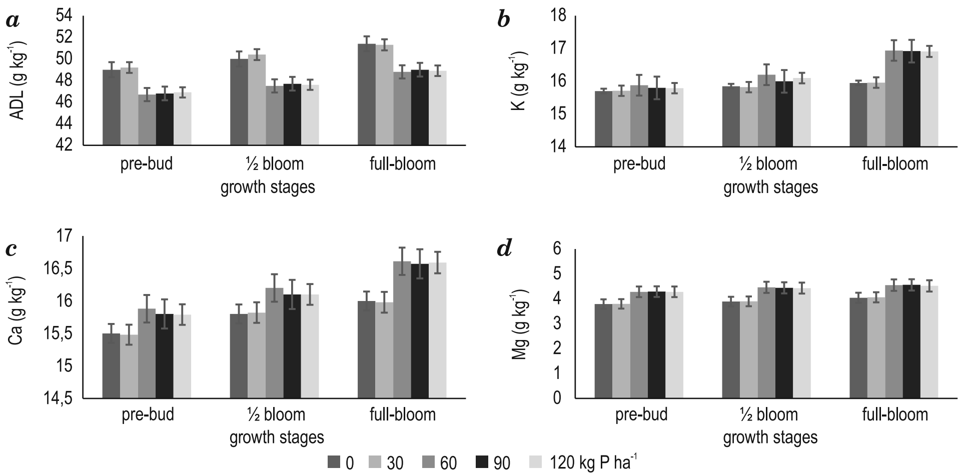

Fig. 4. Effects of phosphorus doses and growth stages on ADL (*a*), K (*b*), Ca (*c*), and Mg (*d*) content of fodder pea cultivars

Ates 2018). Young plant cells have the primary cell wall, but also the secondary cell wall develops as the plant matures. This makes mature plants to be more fibrous (Arzani at al. 2004). The ADF, NDF and ADL content increased with advancing plant growth. This could be explained by the decrease in the proportion of leaves and increase of the proportion of stems with advanced maturity. The trend of the increasing ADL, ADF and NDF content parallel to the plant's increasing maturity is normally reverse in terms of protein (Yuksel, Turk 2019). Forage grasses are higher in NDF, ADF and ADL at a given stage of growth than forage legumes. The quality of forage crops is best estimated by their potential dry matter intake and dry matter digestibility, which are determined by the NDF and ADF fractions, respectively. Both NDF and ADF increase as the plant matures, thus depreciating the quality of the forage (Ates, Tenikecier 2019). ADF and NDF ratios were reported as between 21.5-40.5% and between 32.3-54.3%, respectively (Tan et al. 2013, Asci et al. 2015, Cacan et al. 2019). Yuksel, Turk (2019) reported that increasing phosphorus doses resulted in a decrease in the NDF and ADF content. Current findings are similar.

Macro-element content

The results presented in Table 3 showed that all the three doses of P viz. 60, 90 and 120 kg ha^{-1} gave significantly higher K, Ca, Mg and P contents in fodder pea cultivars over control and 30 kg P ha^{-1} dose. The highest K (16.9 g kg^{-1}), Ca (16.6 g kg^{-1}), Mg (4.5-4.6 g kg^{-1}) and P (3.5 g kg^{-1}) contents were found at applications of 60 to 120 kg P ha^{-1}. The means of K, Ca, Mg and P contents from the fodder pea cultivars are not significantly different according to the LSD test at the P=0.01 level of probability. The effects of growth stages were significant for K, Ca, Mg and P (P<0.01). The content of macro-elements increased with advancing maturity. The significant phosphorus dose x growth stage interaction was observed for these elements. The lowest K, Ca, Mg and P contents were obtained from control and 30 kg P ha^{-1} dose at each growth stage (Figures 4 and 5). The general func-

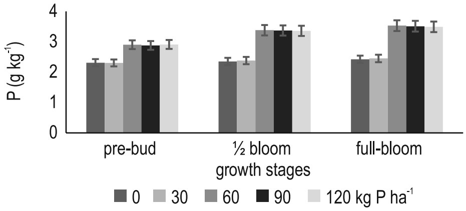

Fig. 5. Effects of phosphorus doses and growth stages on P content of fodder pea cultivars

tions of macro- and micro-elements for ruminant and non-ruminant animals are as follow: (a) give rigidity and strength to the skeletal structure, (b) engage in mineral-vitamin relationships, (c) activate enzyme systems, (d) serve as constituents of the organic compounds, such as protein and lipid, which make up the muscles, organs, blood cells, and other soft tissue of the body, (e) exert characteristic effects on the irritability of muscles and nerves, (f) control fluid balance-osmatic pressure and excretion, (g) regulate acid-base balance (Ensminger et al. 1990). There is a direct and most important relationship between the content and availability of mineral elements in the soil and the mineral composition of forage crops. Sometimes, the concentration of an essential mineral in the soil is so low that forage crops growing on it will not contain enough of the mineral to meet the dietary requirements of ruminant and non-ruminant animals. At other times, forage crops may contain such high concentrations of a certain mineral(s) that they are toxic to the animals that eat them. Such soil/plant/animal relationships are particularly important with respect to macro- and micro-elements (Ensminger et al. 1990). Acute and chronic dietary deficiencies in macro and micro-elements have significant impact on production efficiency of rangelands throughout the world (Pinchak et al. 1989). The content of macro- and micro-elements in forage crops depends on soil parameters and available amounts of elements in it, fertilization and other cultivation treatments, climatic conditions as well as plant growth stages and different morphological parts of crops (Ates et al. 2020, Ates, Tenikecier 2020). For example, it has been reported that the Mg uptake, transport, and re-translocation were influenced by the availability of K and Ca. Plant Mg uptake is strongly influenced by the availability of other cations, such as ammonium, sodium, Ca, and K. Unspecific Mg transporters for its uptake can be blocked by high plant available K concentrations in the rhizosphere (Koch et al. 2019, Guan et al. 2020). The K, Ca and Mg levels in plants are usually in the range 1.3-2.5%, 0.7-3.0% and 0.2-1.2%, respectively, which is adequate for plant growth (Tekeli et al. 2003). Some researchers found that the K content of samples varied between 0.9 and 5.4% in different wild plant species (Ayan et al. 2006). The K content of the samples studied during this investigation was within these limits. NRC (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, 0.1-0.4% for Ca, 0.1-0.4% for P and 0.04-0.1% for Mg. Gizachew, Smit (2005), who investigated the CP and mineral composition of major crop residues and supplemental feeds, reported contents of 16.0 g kg^{-1} for Ca and 19.9 g kg^{-1} for K in grass pea (*Lathyrus sativus* L.) haulms. 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 the full-bloom stage. Ates (2012) obtained 1.67-1.68% K, 1.55-1.63% Ca, 0.43-0.44% Mg and 0.28-0.33% P content in DM from fodder pea. Kostopoulou et al. (2015) reported the content of K, Ca and Mg in the leaves ranging from 14.61 to 23.53 g kg^{-1}, 17.55 to 18.32 g kg^{-1} and 4.50 to 4.96 g kg^{-1}, respectively, in yellow melilot (*Melilotus officinalis* L.). Tenikecier, Orak (2020) reported that P, K, Ca and Mg content in narbon vetch (*Vicia narbonensis* L.) genotypes varied from 0.30 to 0.41%, 1.72 to 2.73%, 0.83 to 1.25% and 0.20 to 0.44%, respectively, which is similar to the present findings.

CONCLUSION

The results from treatments with the different phosphorus doses and at different growth stages of fodder pea cultivars in climatic conditions of Thrace region of Turkey can be summarized as follows:

1. On average from five years, the morphological characters, forage yield, mineral and cell wall compositions of fodder pea cultivars were affected by the different phosphorus doses and at different growth stages.

2. Phosphorus applications increased herbage and dry matter yields as well as the cobntent of macro-elements but decreased crude fiber, ADF, NDF and ADL contents.

3. The main stem length, number of leaves per main stem, crude fiber, NDF, ADF, ADL, K, Ca, Mg and P contents, herbage and dry matter yields increased with advancing growth.

4. When the results obtained were evaluated together, it emerged that application of 60 kg P ha^{-1} for high forage yield and quality properties should be recommended, and the tested fodder pea cultivars should be harvested at the full bloom stage.

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