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ORIGINAL PAPER

EFFECTS OF DIFFERENT ROW SPACINGS AND SEEDING RATES ON CONTENT OF IMPORTANT MACRO-MINERALS IN FORAGE PEA*

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Abstract

This study was conducted to determine the effects of row spacings (RS) and seeding rates (SR) on the macro-mineral content of forage pea (*Pisum sativum* spp. *arvense* L.). For this purpose, field experiments were established in line with the Split Plots in Randomized Complete Block Design with three replications. According to the results, the content of the investigated macro-minerals ranged in the tested the row spacings, seeding rates and the growing seasons as follows: calcium (Ca) content 15.03 g kg^{-1} to 16.67 g kg^{-1}, magnesium (Mg) content 2.40 g kg^{-1} to 3.40 g kg^{-1}, phosphorus (P) content 3.74 g kg^{-1} to 4.74 g kg^{-1} and potassium (K) content 22.81 g kg^{-1} to 31.48 g kg^{-1} of forage dry matter (DM). It has been determined that these concentrations of minerals are sufficient for animal needs. Additionally, variance analysis showed that the Mg content of forage pea increased significantly ($P<0.01$) in the dry growing season, whereas the P and K content of forage pea decreased in the same growing season. Furthermore, a biplot analysis of the data from the two growing seasons showed that 20 cm RS was the best row spacing for reaching the highest Ca, P and K content, while 30 cm RS was found as the best spacing for the highest Mg content in forage pea. Additionally, 150 seed m^{-2} SR was the ideal seeding rate for obtaining the highest Ca and Mg content in the forage pea.

Keywords: biplot analysis, drought effect, forage pea (*Pisum sativum* spp. *arvense* L.), Ca content, Mg content, P content, K content

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INTRODUCTION

Quality forage deficit is one of the biggest challenges for animal husbandry in Turkey (Sayar et al. 2015). As annual cool season legume species, forage pea (*Pisum sativum* spp. *arvense* L.) is an important forage crops species, and it is of great importance in supplying quality forage for livestock in filling the deficit (Sayar, Han 2016). There are many factors affecting forage quality, such as plant species and variety, protein content and digestibility. Mineral elements in forages are of great importance in forage quality as well (McDowell, Arthington 2005).

According to their concentration in the living body, minerals are classified into two main groups; macro (major) and micro (trace) minerals (Kacar, Katkat 2021). Minerals are necessary for almost all vital processes of the living body, although they produce various effects on the body's functions (Spears 1994). For example, calcium (Ca) and phosphorus (P) take part in the formation of the basic structure of bones and teeth. Potassium (K) is important in osmotic pressure regulation and acid-base and water balances, nerve impulse transmission, muscle contractions and certain enzyme reactions (NRC 2000). Magnesium (Mg) is involved in the activation of more than 300 enzymes (Wacker 1980). According to Spears (1994), minerals optimize rumen microbial activity and enhance forage utilization. Hence, adequately supplying of these minerals is vital for the growth, health and reproduction of livestock (Jones, Tracy 2013, Márquez-Madrid 2017).

Minerals are not synthesized by an animal's body, and therefore they should be supplied from outside. And most of the minerals enter the animal body through feeds (Mineral 2022). Forages are the most important feed ingredient in animal nutritions. They have a crucial role in meeting the mineral requirement of livestock (Freer et al. 2007). Therefore, knowing the content of minerals in the forages has importance in animal feeding. Accordingly, many studies have been carried out to determine the mineral content of forages. Genarally, such research focuses on the content of nutrients in soil, plant genotypes, fertilization treatments, and plant maturity stages. However, the effect of plant density on forage mineral content has rarely been studied. Furthermore, the effect of different row spacings (RS) and seeding rates (SR), which are important components of plant density, on the mineral content of forage has never been studied together in forage pea.

The study was conducted for two growing seasons (2019-2020 and 2020-2021) in order to determine the effect of different row spacings (RS) and seeding rates (SR) on the Ca, Mg, P and K content of forage pea grown in rainfed conditions of Bismil, Diyarbakır, Turkey. Great variation was determined in precipitation amounts in the two growing seasons. The drought effect on the mineral content was particularly investigated in the study. The results of the research were also submitted to a biplot analysis, and the results were presented in biplot graphs.

MATERIALS AND METHODS

The plant materials of the research

This study was conducted for two consecutive growing seasons (2019-2020 and 2020-2021) in an experimental field of Bismil Vocational Training School, Dicle University, Bismil, Diyarbakır, Turkey (37°50′18″N, 40°38′52″E and altitude 541 m). The GAP Pembesi forage pea (*Pisum sativum* spp. *arvense* L.) cultivar was used as plant material of the research. The GAP Pembesi forage pea cultivar is a unique cultivar that was first registered in Southeastern Anatolia, in Turkey. The cultivar stands out for its earliness as well as with high forage and grain yields.

The research area

The field where the experiment was conducted was flat with hardly any erosion effect, and the soil layer had a medium deep profile. Soil analysis revealed that the experimental area soil had a sandy loam structure, and was light-brown in color. Furthermore, the organic matter (0.28%) and phosphorus (34.4 kg ha^{-1} P_2O_5) content of the soil was low, whereas the potassium (741 kg ha^{-1} K_2O) and calcium (8.33%) content of the soil was high. Owing to a relatively high limestone content of the soil, the pH status of the soil was alkaline (pH: 8.10). In contrast, the soil salinity was very low (0.002%).

The research area has a typical continental climate characteristic. Winters are cool and rainy, whereas summers are dry and hot. The long-term annual average (1975-2021) total precipitation is 482.4 mm, and most

Table 1

Weather conditions in the research area during the growing seasons and multi-year average (1975-2021)

Growing seasons	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Apr.	May	June	Mean
	Total Precipitation (mm) (monthly)										
2019-20	0.4	52.0	9.0	185.4	89.4	58.6	164.8	110.0	63.2	0.6	733.4
2020-21	0.0	0.0	54.0	27.6	39.1	40.2	43.0	5.6	2.8	0.0	212.3
1975-2021	3.9	31.7	53.8	70.1	70.1	67.8	65.7	68.5	42.8	8.0	482.4
Mean air temperature (°C) (monthly)											Total
2019-20	25.2	19.1	9.7	6.8	3.6	3.7	10.6	13.5	19.3	26.2	13.8
2020-21	27.7	20.0	10.6	4.7	4.1	7.0	8.4	15.9	23.8	27.9	15.0
1975-2021	24.9	17.3	9.5	3.9	1.6	3.6	8.3	13.8	19.2	26.2	12.8
Mean relative humidity (%) (monthly)											Mean
2019-20	27.9	50.9	57.7	86.3	77.7	75.1	72.4	71.0	57.4	35.1	61.2
2020-21	26.1	29.1	65.1	79.9	70.7	64.7	65.2	54.3	30.2	23.6	50.9
1975-2021	31.2	48.4	68.0	77.5	77.2	7.3	66.5	63.4	56.8	36.6	53.3

of the precipitation falls in the period between November and May. Monthly total precipitation and average temperature as well as humidity data in the research site for both growings seasons and multi-year average data are given in Table 1 (TMF 2021). Furthermore, when the climatic data of the research area, given in Table 1, are examined, it emerges that the total precipitation in the first growing season of the study (2019-2020) was higher than the long-term average and the precipitation amounts in the second growing season (2020-2021). For this reason, the 2009-2020 growing season was called the *rainy growing season* and the 2020-2021 growing season was referred to as the *drought growing season*. Additionally, due to this high precipitation amount, monthly temperature values in the 2019-2020 growing season were found lower than the long-term average and in the 2020-2021 growing season records. In contrast, the relative humidity means of this growing season were higher than the long-term average and the data from the 2020-2021 growing season (Table 1).

The experiment of the study

The research trials were established according to the Split Plots in Randomized Complete Block Design with three replications under the rainfed conditions. In the experiments, 4 row spacings, 10 cm, 20 cm, 30 cm and 40 cm, were placed in the main plots of the trials, while 4 seeding rates, 50, 100, 150 and 200 seeds m^{-2}, were placed in the sub-plots of the trials. Accordingly, 16 combinations of row spacings and seeding rates were studied in the research. Sowings was performed by placing seeds in seed beds, earlier opened with a marker, in the last week of November in both growing seasons. During the sowing, a dose of 150 kg diammonium phosphate fertilizer (DAP 18-46-00) per hectare was applied. The trials were carried out without using any pesticides. Weed control in the trials was done manually.

The investigated traits

Harvesting of the plots for forage were made in the full-blooming stage of the plants. Then, 500 g fresh forage samples taken from each plot were kept in an oven at 70°C for 48 h. Afterwards, the dried forage samples were thoroughly ground in a laboratory mill. Calcium (Ca), Magnesium (Mg), Phosphorus (P) and Potassium (K) contents of the ground forage samples were determined in the Dicle University Science and Technology Application and Research Center Laboratory, in a Foss Model 6500 NIRS (Near Infrared Reflectance Spectroscopy) analytical device, using C-0904FE-Hay and Fresh Forage calibration (Basaran et al. 2011, Sayar 2016, Basbag et al. 2018, Başbag et al. 2021).

Statistical analyses

In the study, the statistical analyses of data were made by using the JMP 5.0.1 statistical software package (SAS Institute 2002), and the least significant difference (LSD) test at the 0.05 probability level (Steel, Torrie 1960) was used for determining the differences between the means. Furthermore, a biplot analysis was made and its graphs plotted in Genstat statistical package program (VSN International 2011). And interpretations of the graphs followed the approach of Yan, Kang (2003).

RESULTS AND DISCUSSION

Analysis of variance (ANOVA) showed that there were statistically significant differences among the row spacings (RS) and seeding rates (SR) and in both rainy (2019-2020) and dry (2020-2021) growing seasons in terms of the calcium (Ca) content in forage pea. However, there were no statistically significant differences between the means of the growing seasons in terms of the calcium (Ca) content. Additionally, it should be emphasized that the highest Ca content was determined in both growing seasons from forage pea in the 20 cm RS and 150 seeds m^{-2} SR treatments (Table 2).

Table 2

Forage pea calcium (Ca) content (g kg^{-1} DM) according to the different row spacings (RS) and seeding rates (SR) in the rainy (2019-2020) and dry (2020-2021) growing seasons[+]

Row spacings (cm)	Ca (g kg^{-1} of DM)				
	seeding rates (seeds m^{-2})				
	50	100	150	200	means
	rainy season (2019-2020)				
10	16.40*a-b*	16.06*a-c*	16.14*a-c*	15.82*b-d*	16.10*a*
20	16.48*a*	15.61*c-e*	16.14*a-c*	15.81*b-d*	16.01*ab*
30	15.28*d-e*	15.73*c-d*	15.58*c-e*	15.13*e*	15.43*c*
40	15.42*d-e*	15.43*d-e*	16.41*a*	15.78*c-d*	15.76*b*
Means	15.89*ab*	15.71*b*	16.07*a*	15.64*b*	15.83
LSD (%5)	RS: 0.28** SR:0.28* RS x SR: 0.57* years: ns				
CV (%)	2.12				
Dry season (2020-2021)					
10	14.54*h*	16.12*b-c*	16.19*b-c*	15.88*b-d*	15.68*b*
20	16.67*a*	15.33*e-g*	16.22*a-b*	15.76*b-e*	16.00*a*
30	15.74*c-f*	15.03*g*	15.89*b-d*	15.49*d-g*	15.54*b*
40	15.47*d-g*	15.93*b-d*	15.28*f-g*	15.36*e-g*	15.51*b*
Means	15.60*b*	15.60*b*	15.89*a*	15.62*b*	15.68*B*
LSD (%5)	RS: 0.22** SR: 0.22* RS x SR: 0.45** years: ns				
CV (%)	1.78				

[+] The means with the same letter in the same column are not different using the LSD (5%) test. Significant at * $P \le 0.05$, ** $P \le 0.01$, ns – non-significant

Furthermore, Table 2 shows that the mean Ca content of forage pea ranged from 15.03 g kg^{-1} to 16.67 g kg^{-1} of DM among the treatments and the growing seasons.

Khan et al. (2007) reported that the Ca content of forages ranged from 3.15 g kg^{-1} to 4.92 g kg^{-1} of DM. They also reported that the Ca content was sufficient to obtain the optimum performance from ruminants. Similarly, it was reported in NRC (2000), and by McDowell, Arthington (2005) and Onal Asci et al. (2018) that the Ca content in forage dry matter (DM) should be at least 3.00 g kg^{-1} of DM to avoid any Ca deficiency. According to Sabah, Celik (2001), Basbag et al. (2011) and Sayar (2016), Ca deficiency leads to osteomalacia in young animal and bone deformations in elderly ones. Additionally, they noted that in poultry it leads to the eggs to be thin-shelled. Furthermore, McDowell (1992) and Spears (1994) cited that Ca deficiency causes reduction of the growth and milk yield of livestock. As for the Ca content of forages, Khan et al. (2007) reported that temperate forages generally contain more Ca than those grown in the tropics. Underwood (1981) and Spears (1994) also reported that forages obtained from legume species have more Ca than those from grass (*Poaceae*) species. Accordingly, the determined Ca content of forage pea, a cool season legume species, in the study was found to be higher than the reported reference Ca content, and it was easily sufficient for livestock's Ca requirements. On the other hand, Pursley et al. (2019) reported that the Ca content in forage pea changed from 6.70 g kg^{-1} to 9.30 g kg^{-1} of forage DM. These results were found to be lower than the Ca content determined in our study. The differences in the Ca content of the soil of the trial sites and the genotypes used in different studies can be specified as a reason of the above differences. Also, Marković et al. (2009) reported that the Ca content of forages varied from 9.76 g kg^{-1} to 31.98 g kg^{-1} of DM. This range of the Ca content confirmed our Ca content findings.

The forage pea magnesium (Mg) content in forage dry matter showed statistically highly significant ($P<0.01$) differences between the growing seasons. Accordingly, the average Mg content determined in forage pea in the dry growing season 2020-2021 (3.26 g kg^{-1} DM) was higher than in the rainy growing season 2019-2020 (2.57 g kg^{-1} DM). Additionally, statistically significant differences were detected among the row spacings (RS) and the seeding rates (SR) in terms of the Mg content of forage pea in both growing seasons. Similarly, the RS x SR interaction for the Mg content was found to be statistically significant for both of the growing seasons as well. In addition, when the Mg content means, given in Table 3, were examined, it appeared that the Mg content changed from 2.40 g kg^{-1} DM to 3.40 g kg^{-1} of DM among the RS and the SR treatments. Similarly, Onal Ascı et al (2018) reported that the Mg content of forage pea cultivars changed from 2.5 g kg^{-1} to 3.3 g kg^{-1} in forage DM in different plant maturity stages and during two growing seasons. The reported Mg content was found to be in full agreement with our findings about the Mg content.

Table 3

Forage pea magnesium (Mg) content (g kg^{-1} DM) means according to combinations of different row spacings (RS) and seeding rates (SR) in the rainy (2019-2020) and the dry (2020-2021) growing seasons[+]

Row spacings (cm)	Mg (g kg^{-1} of DM)				
	seeding rates (seeds m^{-2})				
	50	100	150	200	Means
	rainy season (2019-2020)				
10	2.54*b-d*	2.63*a-c*	2.60*a-d*	2.65*a-c*	2.61
20	2.81*a*	2.44*c-d*	2.40*d*	2.53*b-d*	2.54
30	2.50*b-d*	2.59*a-d*	2.64*a-c*	2.69*a-b*	2.61
40	2.54*b-d*	2.41*d*	2.64*a-c*	2.57*b-d*	2.54
Means	2.60	2.52	2.57	2.61	2.61
LSD (%5)	RS: ns	SR:ns	RS x SR: 0.22*	years:0,04**	
CV (%)	2.12				
Dry season (2020-2021)					
10	3.29*b-d*	3.25*c-e*	3.21*d-f*	3.14*f*	3.22*c*
20	3.40*a*	3.20*d-f*	3.28*b-e*	3.33*a-c*	3.30*a*
30	3.34*a-b*	3.20*d-f*	3.32*a-c*	3.20*e-f*	3.27*ab*
40	3.14*f*	3.14*f*	3.39*a*	3.35*a-b*	3.26*bc*
Means	3.29*ab*	3.20*c*	3.30*a*	3.25*b*	3.26
LSD (%5)	RS: 0.04**	SR: 0.04*	RS x SR: 0.08**	years: 0,04**	
CV (%)	1.53				

[+] The means with the same letter in the same column are not different using the LSD (5%) test. Significant at * $P \leq 0.05$, ** $P \leq 0.01$, ns – non-significant

In many scientific references, it is reported that the Mg content in animal feeds should not be under 1.00 g kg^{-1} of DM to avoid abnormalities caused by Mg deficiency in livestock (ARC 1980, Spears 1994, NRC 2000, McDowell, Arthington 2005, Márquez-Madrid et al. 2017). Accordingly, the Mg content determined in forage pea in the study was found to be sufficient for livestock requirements. On the other hand, same as the Ca content, the Mg content of legume forages is higher than those of grass species (Underwood 1981, Spears 1994). Accordingly, Acıkgoz (2001) reported that when livestock is fed with only grass forages for a long time, without legume forages, the so-called *grass tetany disease* can be precipitated by Mg deficiency. Ensminger et al. (1990) also reported that when grass tetany or hypomagnesemic tetany disease develops, livestock show such symptoms as spasm of the legs and holding the head back. They also noted that magnesium is called an anti-stress mineral, and it helps to calm livestock by reducing hypersensitivity of the nervous system. Furthermore, magnesium takes part in the activation of enzymes and transformation sugar into energy in the blood. However, it was reported that Mg supplementation in feeds not only eliminates the adverse effects of Mg deficiency in livestock but also increases the intake and digestibility of feeds (Wilson 1980, Reid, Jung 1991, Spears 1994).

Table 4

Forage pea phosphorus (P) content (g kg^{-1} DM) means according to combination of row spacings (RS) and seeding rates (SR) in the rainy (2019-2020) and the dry (2020-2021) growing seasons^{+}

Row spacings (cm)	P (g kg^{-1} of DM)				
	Seeding rates (seeds m^{-2})				
	50	100	150	200	Means
	rainy season (2019-2020)				
10	4.60*b*	4.52*b-c*	4.40*c-e*	4.45*b-d*	4.49*a*
20	4.29*e*	4.34*d-e*	4.77*a*	4.46*b-d*	4.47*ab*
30	4.37*c-e*	4.48*b-d*	4.35*d-e*	4.12*f*	4.33*c*
40	4.29*e*	4.38*c-e*	4.42*c-e*	4.48*b-d*	4.39*bc*
Means	4.39*b*	4.43*ab*	4.49*ab*	4.38*b*	4.42*A*
LSD (%5)	RS: 0.06**	SR:0.06*	RS x SR: 0.14**	years: 0.05**	
CV (%)	2.04				
Dry season (2020-2021)					
10	3.84*e-g*	3.98*b-d*	3.93*c-e*	3.87*e-f*	3.91
20	4.06*a-b*	3.90*d-e*	3.74*h*	4.03*a-b*	3.93
30	3.80*f-h*	3.89*e*	4.00*a-c*	4.00*a-c*	3.92
40	3.78*g-h*	4.07*a*	3.87*e-f*	3.79*f-h*	3.88
Means	3.87*c*	3.96*a*	3.89*bc*	3.92*ab*	3.91*B*
LSD (%5)	RS: 0.04**	SR: 0.04*	RS x SR: 0.08**	years: 0.05**	
CV (%)	1.28				

$^{+}$ The means with the same letter in the same column are not different using the LSD (5%) test. Significant at * $P \leq 0.05$, ** $P \leq 0.01$, ns – non-significant

Forage pea phosphorus (P) content in forage dry matter showed statistically highly significant ($P<0.01$) differences between the growing seasons. In contrast to the Mg content, the average P content determined in the dry growing season 2020-2021 (3.91 g kg^{-1} DM) was found to be lower than in the rainy growing season 2019-2020 (4.42 g kg^{-1} DM). Consistent with our findings, McDowell (1992) and Spears (1994) reported that drought and advancing plant maturity reduce the P content of forages. Moreover, the interaction of row spacings (RS) and seeding rates (SR) was found to be highly significant ($P<0.01$) for both growing seasons. While differences among the RS for the P content were found to be non-significant in dry growing season (2020-2021), they were highly significant in the rainy growing season

(2019-2020). In the rainy seasons, the P content determined in the 10 cm and 20 cm RS treatment was higher than determined in the 30 cm and 40 cm RS treatment. Furthermore, statistically significant differences were found among the SR treatments for both growing seasons. Accordingly, 100 seeds m^{-2} and 150 seeds m^{-2} treatments had higher P content in the rainy growing season (2019-2020), and 100 seeds m^{-2} and 200 seeds m^{-2} treatments had higher P content in the dry growing season (2020-2021). Conversely, 50 seeds m^{-2} SR treatment had the lowest P content in both of the growing seasons. On the other hand, the mean P content in forage pea varied from 3.74 g kg^{-1} DM to 4.74 g kg^{-1} DM among the RS, the SR treatments and the growing seasons.

Largely consistent with our findings, Onal Asci et al. (2018) reported that the P content of forage pea cultivars varied from 3.20 g kg^{-1} to 5.10 g kg^{-1} in forage dry mater. Actually, it was reported by NRC (2000), McDowell and Arthington (2005) and Márquez-Madrid (2017) that 2.50 g kg^{-1} of P content in forage dry matter would be sufficient for animal requirements. With this mind, the P content determined in forage pea in our study from different treatments was found to be sufficient to meet livestock P requirements. However, P deficiency occurs when animals are fed with low-phosphorus feeds. According to Underwood (1981) and Spears (1994), signs of P deficiency in livestock as follows: decrease in growth, milk production and efficiency of feeds, loss of appetite, impaired reproduction, and fragility and weakening of bones. With P supplementation, these undesirable disorders caused by P deficiency can be eliminated.

Statistically highly significant ($P<0.01$) differences were determined between the growing seasons in terms of the potassium (K) content of forage pea. Accordingly, the determined average K content in the rainy growing season 2019-2020 (30.08 g kg^{-1}) was found higher than in the dry growing season 2020-2021 (24.79 g kg^{-1}). Also, statistically highly significant ($P<0.01$) differences were found among the row spacings (RS) and the seeding rates (SR) and RS x SR interaction for the K content of forage pea in the dry growing seasons (2020-2021). However, the differences among the RS and the SR treatments and RS x SR interaction were found to be non-significant in the rainy growing season (2019-2020) – Table 5. When data in Table 5 were examined, it appeared that the K content of forage pea varied from 22.81 g kg^{-1} DM to 31.48 g kg^{-1} DM among the RS and the SR treatments and the growing seasons.

Meanwhile, much consistency was detected between our K content findings and the K content determined by Onal Asci et al. (2018) – 20.9-33.6 g kg^{-1} of DM in forage pea cultivars. Clanton (1980) suggested that K requirements of growing cattle under range conditions are 3.0 g kg^{-1} to 4.0 g kg^{-1} potassium in forage DM, whereas the K requirements of gestating beef cows are 5.0 g kg^{-1} to 7.0 g kg^{-1} potassium in forage DM. In fact, the K content determined in forage pea in this experiment were quite above the reference data,

Table 5

Forage pea potassium (K) content (g kg^{-1} DM) means according to combination of different row spacings (RS) and seeding rates (SR) in the rainy (2019-2020) and the dry (2020-2021) growing seasons^{+}

Row spacings (cm)	K (g kg^{-1} of DM)				
	seeding rates (seeds m^{-2})				
	50	100	150	200	Means
	rainy season (2019-2020)				
10	29.15	30.07	28.98	29.80	29.50
20	28.72	29.80	32.02	30.06	30.15
30	30.30	30.08	30.02	28.45	29.71
40	30.56	31.30	30.53	31.48	30.97
Means	29.68	30.31	30.39	29.95	30.08 A
LSD (%5)	RS: ns	SR:ns	RS x SR: ns	years: 0.55**	
CV (%)	3.48				
Dry season (2020-2021)					
10	22.81*h*	25.69*b-c*	25.42*b-d*	25.08*c-e*	24.75*ab*
20	24.85*d-e*	24.73*d-e*	24.43*e-f*	25.43*b-d*	24.86*ab*
30	23.88*f-g*	24.82*d-e*	26.51*a*	25.07*c-e*	25.07*a*
40	24.56*e-f*	26.14*a-b*	23.57*g-h*	23.58*g-h*	24.46*b*
Means	24.03*c*	25.34*a*	24.98*ab*	24.79*b*	24.79*B*
LSD (%5)	RS: 0.39*	SR: 0.38**	RS x SR: 0.79**	years: 0.55**	
CV (%)	1.93				

$^{+}$ The means with the same letter in the same column are not different using the LSD (5%) test. Significant at * $P \leq 0.05$, ** $P \leq 0.01$, ns – non-significant

and sufficient to meet potassium requirements of livestock. On the other hand, Underwood (1981) and Spears (1994) reported that signs of potassium deficiency are rather nonspecific and include pica, eating or craving of things that are not food or feed, and reduced feed intake, growth, and milk production. Hence, potassium (K) supplementation is critical in dairy cattle during early or peak lactation for obtaining high levels of milk yield and milk protein content.

Evaluation with biplot analysis

According to combined results from the two growing seasons, a biplot graph was plotted, indicating that PC1 (the first Principal Component) and PC2 (the second Principal Component) accounted for 33.51% and 62.32% of the total variation, respectively, and the total PC score was found to be 95.83% (Figure 1). Additionally, the total PC scores were determined as 87.49% and 71.12% for the biplot graphs submitted in Figure 2 and Figure 3, respectively. Many researchers reported that total PC score should

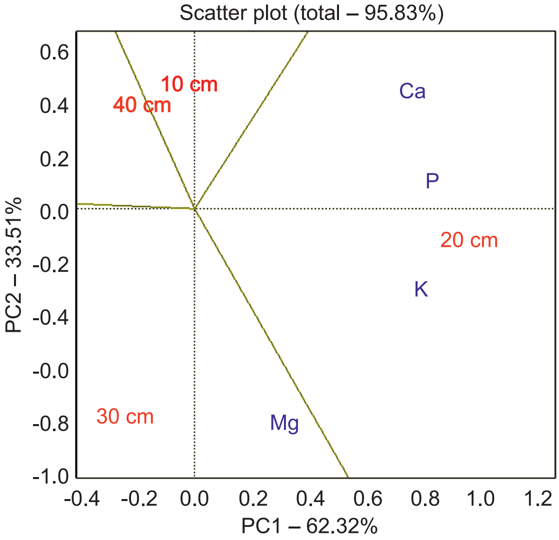

Fig. 1. Biplot graph showing the relation between different row spacings (RS) and macro- elements in forage pea

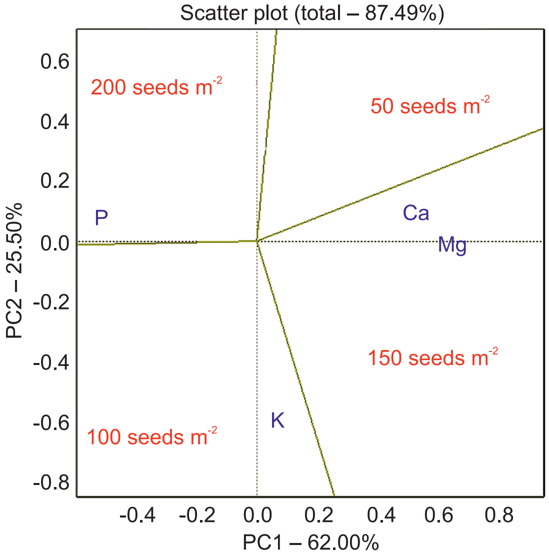

Fig. 2. Biplot graph showing the relation between different seeding rates (SR) and macro-elements in forage pea

be at least 50% for reliable interpretation of biplot graphs (Yan et al. 2000, 2007, Firincioglu et al. 2012, Kilic et al. 2012, Kendal et al. 2016, Başbag et al. 2021). It was determined that the total PC score of the biplot graphs in our study were above this value (Figures 1, 2, 3). Hence, the available total PC scores of the biplot graphs were found to be sufficient to make inter-

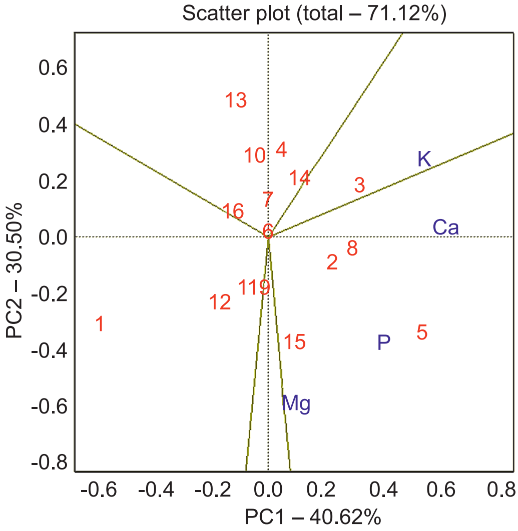

Fig. 3. Biplot graph showing interaction of different row spacings (RS) and seeding rates (SR) in terms of macro-minerals in forage pea. The macro-minerals: K – potassium, Ca – calcium, P – phosphorus, Mg – magnesium; Treatments: 1 – 10 cm and 50 seeds m^{-2}, 2 – 10 cm and 100 seeds m^{-2}, 3 – 10 cm and 150 seeds m^{-2}, 4 –10 cm and 200 seeds m^{-2}, 5 – 20 cm and 50 seeds m^{-2}, 6 – 20 cm and 100 seeds m^{-2}, 7 – 20 cm and 150 seeds m^{-2}, 8 – 20 cm and 200 seeds m^{-2}, 9 – 30 cm and 50 seeds m^{-2}, 10 – 30 cm and 100 seeds m^{-2}, 11 – 30 cm and 150 seeds m^{-2}, 12 – 30 cm and 200 seeds m^{-2}, 13 – 40 cm and 50 seeds m^{-2}, 14 – 40 cm and 100 seeds m^{-2}, 15 – 40 cm and 150 seeds m^{-2}, 16 – 40 cm and 200 seeds m^{-2}

pretations on these graphs safely. Furthermore, Yan and Kang (2003), Ilker et al. (2009) and Sayar, Han (2015) reported that traits or environments close to each other and located in the same direction on a biplot graph indicate that there is a positive and significant relationship between the traits or the environments. And that they take part in the same group or sector.

Biplot analysis, based on combined results from the two growing seasons revealed that there was highly significant and positive relation between Ca, P and K content with regard to different row spacings (RS) in forage pea. In addition, the 20 cm RS treatment was found to be superior for the Ca, P and K content in forage pea. On the other hand, the 20 cm RS treatment was found to be superior for the Mg content. However, the biplot analysis revealed that no relationship was found between the 10 cm and 40 cm RS treatments and the content of the investigated macro-minerals (Figure 1).

The biplot graph showing relations between different seeding rates (SR) and the macro-minerals in forage pea is shown in Figure 2. According to the two-year results, the 150 seeds m^{-2} treatment came to the fore in terms of the Ca and Mg content. Also, there was a significant and positive relation between the Ca and Mg content of forage pea with regard to different SR. Moreover, the 100 seeds m^{-2} SR treatment came to the fore in terms of the K content, while the 200 seeds m^{-2} treatment was the best for the P content. However, no significant relation between the 50 seeds m^{-2} treatment and any mineral versus the seeding rates was identified.

The biplot graph showing the interactions between row spacings (RS) and seeding rates (SR) in terms of the content of the investigated macro-minerals in forage pea from the two-growing seasons is given in Figure 3. When Figure 3 was examined, it emerged that the 10 cm and 150 seeds m^{-2} (3) treatments come to fore in terms of the potassium (K) content. On the other hand, the 10 cm and 100 seeds m^{-2} (2), 20 cm and 50 seeds m^{-2} (5), 20 cm and 200 seeds m^{-2} (8) and 40 cm and 150 seeds m^{-2} treatments were the best for the Ca and P content. In the same way, the 30 cm and 50 seeds m^{-2} (9) treatment was found to be the best for the Mg content in forage pea. However, no significant relationship between the content of investigated macro-minerals and the remaining RS and SR combinations was determined (Figure 3).

CONCLUSIONS

The results of the study showed that statistically highly significant (P<0.01) differences were detected between growing seasons in terms of the magnesium (Mg), phosphorus (P) and potassium (K) content in forage pea. However, no statistical differences between the growing seasons in terms of the Ca content were identified. The results also showed that the Mg content of forage pea increased in the dry growing season (2020-2021), while the P and K content decreased in the same growing season. Additionally, data form the two growing seasons were submitted to biplot analysis, revealing that 20 cm row spacing (RS) was the most appropriate treatment in terms of the Ca, P and K content in forage pea, whereas 30 cm RS was found to be the best for the Mg content. However, 10 cm RS and 40 cm RS were not significantly correlated with any of the investigated macro-minerals. The biplot analysis also showed that 150 seeds m^{-2} seed rating (SR) was the best amount of seeds in forage pea sowing to reach the highest Ca and Mg content. Likewise, 100 seeds m^{-2} was found to be the best for the K content, and 200 seeds m^{-2} was superior for the P content. However, there no statistically significant relationship between the 50 seeds m^{-2} treatment and the investigated macro-minerals in forage pea was determined.

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