RESEARCH

Seeding rate and cultivar impacts on nutrient uptake of field pea under fertile soil condition

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ABSTRACT

Plant density is an important agronomic factor that affects crop growth, development, and yield. The optimum plant density to attain the highest yield can vary with genotype, production and, environmental factors. A field experiment was conducted at Bursa Uludag University Agricultural Area to evaluate the effects of seeding rate and variety on plant nutrient uptake of field pea (*Pisum sativum* L.) cultivars (Ulubatli, Kirazli, Golyazi, and Urunlu). Some very important factors responsible for low yield are plant density under field conditions and the selection of unsuitable cultivars. The adoption of pea cultivars that are more productive and better adapted to cultivation regions and the increase in plant population per area are important strategies to obtain higher productivity under field conditions. Plant density is one of the most effective agronomic factors for determining optimum plant nutrient uptake. The factorial experiment was arranged in a completely randomized block design with three replicates per treatment. Four cultivars and five seeding rates (75, 100, 125, 150, and 175 g seed m^{-2}) were evaluated. Results showed that plant nutrient uptake was affected by seeding rate and pea cultivars. The maximum rate of plant nutrient uptake occurred at a density of 100-125 g seed m^{-2} and for 'Kirazli', 'Golyazi', and 'Urunlu'. However, 'Ulubatli' showed minimum values of nutrient uptake. Regarding macro- and micronutrients, varieties on the average had mean nutrient uptake with the following sequence: N > K > Ca > P > Mg, Na, Fe > Mn > Zn > Cu. Pea varieties and seeding rates should be considered in the fertilization program.

Key words: Cultivars, pea, *Pisum sativum*, plant nutrient, seeding rates.

INTRODUCTION

Plant density is one of the most effective agronomic factors for determining yield, which is individually affected by cultivars and climatic conditions as well as the production system (Zandi et al., 2011). Optimum crop plant density varies considerably depending on the conditions of the growing area and soil fertility status. Plant distance is an important factor for higher production and gives plants an equal opportunity to survive and make the best use of other inputs (e.g., water, plant nutrients). Many studies have been conducted with the aim of determining the optimum plant density or seeding rate (Cupina et al., 2010; Dahmardeh et al., 2010; Thandiwe and Rickertsen, 2011; Türk et al., 2011; Uzun et al., 2017).

When planting density is relatively low, resources (water, light, and plant nutrients) are made available for plant growth, and competition for these resources is relatively low. As planting density increases, competition also increases, and plant growth tends to decrease. There is therefore an optimal planting density, that is, less than optimal densities favor growth and greater than optimal densities reduce growth (Siqueira et al., 2014). For each crop and under specific environmental conditions, the optimum plant population should usually be determined by local research.

Peas (*Pisum sativum* L.) are widely grown for hay, pasture, or silage production. Field pea (*P. sativum*) is an important crop for its protein content (Olle, 2017). The most widely grown pea varieties in Turkey are "Ulubatli, Kirazli, Golyazi, and Urunlu". As a forage crop, pea hay and seed have high-quality protein, are rich in P and Ca, and are a good source of vitamins, especially vitamins A and D. These qualities make field pea one of the best animal feeds and is almost indispensable for efficient and economical livestock feeding (Tan et al., 2012). A wide range of field pea varieties are currently being evaluated for adaptation and yield performance. In addition, fertilization recommendations for pea production in the growing areas must be developed (Türk et al., 2011). The objectives of this research study were to study the effect of different seeding rates and cultivars on plant nutrient uptake in four field pea cultivars under fertility soil conditions. The amount of fertilizer can therefore be determined on the basis of planting density and economic benefits.

MATERIALS AND METHODS

Experimental area

Field trials were conducted in 2010 and 2011 in the experimental area of the Department of Field Crops, Faculty of Agriculture, Bursa Uludag University located in the Bursa Province, Marmara Region, Turkey. The experimental fields were located in the coastal area of northwest Turkey (40°13' N, 28°52' E; 70 m.a.s.l.) The mean temperatures recorded by the State Meteorology Department during the plant growth period (November to June) in the trial area are shown in Table 1.

Field experiment

The factorial experiment was arranged in a completely randomized block design with three replicates per treatment. Four pea (*Pisum sativum* L.) cultivars (Kirazli, Ulubatli, Golyazi, and Urunlu) and five sowing rates (75, 100, 125, 150, and 175 g seed m^{-2}) were evaluated. Two semi-leafless cultivars (Ulubatli and Kirazli) and two leafy cultivars (Golyazi and Urunlu) were used in this study. Field pea cultivars were sown with an Oyjort experimental drill. The plot size was 1.4 × 10 = 14 m^2, which consisted of 8 rows with 17.5 cm spacing. The previous crop was wheat (*Triticum sativum* Lam.) in 2010 and 2011. Before seeding, 30 kg N ha^{-1} as ammonium nitrate (AN) was applied. Weeds were manually controlled as needed. No irrigation was applied during the growing season.

The soil is Eutric Vertisol according to the FAO/Unesco (1974 and 1990 classification system) (Özsoy and Aksoy, 2004; 2007). The soil is clay loam, which is deep and slightly alkaline (pH 7.79 to 8.03), with a low calcium carbonate content (1.61% to 2.67%) and a low organic matter content (1.35% to 1.82%). The total N content per plot and year fluctuated between 0.098% and 0.127%, 31.85 and 62.03 mg P kg^{-1}, and 1.25 and 0.68 meq K 100 g^{-1}. Soil micronutrient content was sufficient for pea production (Table 2) (Kacar, 2014). Before sowing, N (30 kg N ha^{-1}), P (30 kg P_2O_5 ha^{-1}), and K (30 kg K_2O ha^{-1}), 15:15:15, were applied to the plots as basal fertilizer.

Plant analysis. At harvest time, all the plants of each treatment within 1 m^2 were harvested and a number of samples were taken to determine plant nutrient concentrations. Plant samples were rinsed with tap water and rinsed twice with deionized water. Plant material was dried in a forced-air oven at 65 ºC for 48 h. Plant dry weights were determined and plot yield was calculated. Dried plants were used in the analysis. Results were evaluated according to plot DM yield. Plant total N was determined with a Buchi K-437/K-350 digestion/distillation unit (BUCHI Labortechnik AG, Flawil, Switzerland) according to the Kjeldahl method. Total elements of plant samples were digested with HNO_3 and H_2O_2 (Berghof MWS 2

Table 1. Temperature, precipitation, and relative humidity values for experimental years and long-term growing seasons in Bursa, Turkey.

Month	Temperature			Precipitation			Relative humidity		
	2010	2011	Long-term	2010	2011	Long-term	2010	2011	Long-term
	ºC			mm			%		
November	10.0	15.5	10.3	80.6	24.0	85.4	84.5	68.6	72.4
December	9.8	9.5	7.1	119.1	152.6	96.4	77.7	79.8	71.7
January	6.6	5.8	5.4	149.7	72.4	80.3	77.3	81.5	71.2
February	9.4	6.1	5.9	178.9	18.4	66.2	77.4	74.4	69.6
March	9.0	8.2	8.5	115.3	67.4	62.7	77.8	77.0	68.9
April	13.5	10.6	13.0	63.4	76.8	65.2	71.3	78.3	67.1
May	19.3	16.8	17.7	29.4	27.3	43.4	64.3	75.7	64.8
June	22.7	22.2	22.4	135.2	14.0	33.6	68.8	63.3	58.7
Total/Mean	12.5	11.8	11.3	871.6	452.9	533.2	74.9	74.8	68.1

Table 2. Selected soil properties.

Properties	2010	Classes	2011	Classes
Sand, %	33.9		33.9	
Silt, %	19.7	Clay loam	17.6	Clay loam
Clay, %	46.6		48.5	
pH	8.03	Alkaline	7.79	Slightly alkaline
Electrical conductivity, µS cm^{-1}	652.0	Saltless	390.0	Saltless
Lime, %	2.67	Low	1.61	Low
Organic matter, %	1.82	Low	1.35	Low
Total N, %	0.127	Sufficient	0.098	Sufficient
NH_4-N, mg kg^{-1}	92.86		45.45	
NO_3-N, mg kg^{-1}	22.10		trace	
Available P, mg kg^{-1}	62.03	Excessive	31.85	Excessive
Available K, cmol kg^{-1}	1.246	Excessive	0.685	Sufficient
Available Na, cmol kg^{-1}	0.504	Sufficient	0.361	Sufficient
Available Ca, cmol kg^{-1}	55.88	Excessive	34.93	Excessive
DTPA extractable Cu, mg kg^{-1}	2.000	Sufficient	1.937	Sufficient
DTPA extractable Zn, mg kg^{-1}	0.885	Sufficient	0.509	Sufficient
DTPA extractable Mn, mg kg^{-1}	29.81	Sufficient	31.95	Sufficient
DTPA extractable Fe, mg kg^{-1}	6.382	Excessive	11.88	Excessive

DTPA: Diethylenetriaminepentaacetic acid.

DAP 60K, Berghof Products+Instruments, Eningen, Germany), P was measured colorimetrically, and the other elements (K, Ca, Mg, Fe, Cu, Zn, Mn) were analyzed from extracts by inductively coupled plasma-optical emission spectrometry (ICP OES) (OPTIMA 2100 DV; Perkin Elmer, Waltham, Massachusetts, USA) (Kacar, 2014).

An ANOVA was performed with the JMP 5.0.1 software (1989-2002; SAS Institute, Cary, North Carolina, USA). The statistical significance of the treatments was determined at the 0.05 and 0.01 probability levels by the F-test. For the differentiation of means, Duncan's test was applied.

RESULTS AND DISCUSSION

In the present study, the effects of seeding rate on plant nutrient (N, P, K, Ca, Mg, Na, Fe, Cu, Zn, and Mn) uptake in four forage pea cultivars were determined. The ANOVA indicated that cultivars, seeding rates, and the cultivar × seeding rate, cultivar × year, and seeding rate × year interactions were significantly affected by nutrient uptake in the two experimental years (Table 3).

Plant nutrient uptake was calculated as the product of DM yield and plant nutrient concentrations (Table 4) (Uzun et al., 2017). According to our results, the highest DM yield was obtained for 'Kirazli' in both 2010 and 2011. Dry matter yields ranged from 0.749 to 0.979 kg m^{-2} for 'Kirazli' in both years. In the first (0.795 kg m^{-2}) and second year (1.053 kg m^{-2}), the highest DM yields were achieved at the 125 g seed m^{-2} seeding rate. Dry matter yields decreased as seeding rates increased. Lateral branch and shoot number decreased with increasing seeding rates (especially at 150-175 g seed m^{-2}) in both years. In the cultivar × seeding rate interaction, the highest DM yield was for 'Kirazli' at 125 seed g m^{-2} with 0.932 kg m^{-2} in 2010 and 1.550 kg m^{-2} in 2011. Dry matter yield was higher in 2011 than in 2010.

Table 3. The ANOVA results for different plant variety traits at different seeding rates.

Source	DF	Dry yield	N	P	K	Ca	Mg	Na	Fe	Cu	Zn	Mn
Cultivar (C)	3	*	**	**	**	**	**	**	*	**	**	**
Seeding rate (D)	4	*	**	**	**	**	**	**	**	**	**	**
Year (Y)	1	*	**	**	**	**	**	**	*	**	**	ns
Cultivar × Seeding rate	12	*	**	ns	ns	**	**	**	**	*	ns	ns
Cultivar × Year	3	*	ns	ns	ns	ns	*	ns	**	**	ns	*
Seeding rate × Year	4	*	**	*	ns	ns	*	ns	**	ns	ns	ns
C × D × Y	12	*	**	ns	ns	ns	ns	ns	**	ns	ns	ns
Error	78											

*, **Significant at the 0.05 and 0.01 probability levels, respectively; ns: nonsignificant; DF: degrees of freedom.

Table 4. Effects of different seeding rates on dry matter yield measured in different cultivars.

	DM yield, kg m^2					
Seeding rate	75 g	100 g	125 g	150 g	175 g	Mean
Cultivars			2010			
Kirazli	0.726c	0.826b	0.932a	0.675de	0.588h	0.749A
Ulubatli	0.524ij	0.666ef	0.667d-f	0.548i	0.464k	0.574D
Golyazi	0.694d	0.731c	0.845b	0.645fg	0.519j	0.687B
Urunlu	0.586h	0.636g	0.734c	0.586h	0.458k	0.600C
Mean	0.633C	0.715B	0.795A	0.613D	0.507E	
			2011			
Kirazli	0.850e-g	1.076b	1.550a	0.997c	0.824fg	0.979A
Ulubatli	0.671j	0.846e-g	1.009bc	0.867e-g	0.733h-j	0.826C
Golyazi	0.799gh	0.984cd	1.041bc	0.886ef	0.802gh	0.907B
Urunlu	0.715ij	0.914de	1.009bc	0.743hi	0.572k	0.791D
Mean	0.759D	0.955B	1.053A	0.873C	0.733D	

Uppercase letters in the same row and lowercase letters in the same column indicate differences ($P < 0.05$) according to Duncan's test.

Combined data demonstrated that the interaction between cultivar and plant density had significant effects on plant nutrient uptake. There were significant differences among pea cultivars; 'Kirazli' and 'Urunlu' had the highest value for N, P, Ca, Mg, Na, Fe, and Cu uptake. In addition, the highest value was obtained for the 125 seed g m^{-2} treatment. The lowest value was recorded for 'Ulubatli' at the lowest plant density (75 seed g m^{-2}). These results demonstrate that the performance of the pea cultivars can vary according to plant density. This result has been previously described (Gan et al., 2003; Spies et al., 2010; Türk et al., 2011). Two semi-leafless cultivars (Ulubatli and Kirazli) and two leafy cultivars (Golyazi and Urunlu) were used in this study. Semere and Froud-Williams (2001) reported that semi-leafless field pea cultivars were less competitive than leafy cultivars. Leafy pea cultivars had greater leaf area, plant height, and shoot DM attributes and greater root and shoot competitive abilities than semi-leafless pea cultivars. This shows that leafy pea cultivars not only had a greater leaf canopy but a more extensive root system than the semi-leafless pea cultivars. The difference in root competitive ability and shoot competitive ability between the two cultivars was the same, and this probably indicates that the difference in shoot morphology was reflected in root morphology.

Nitrogen uptake of pea cultivars varied between 144.5 and 288.1 kg ha^{-1} depending on the seeding rate. The highest N uptake was obtained for 'Kirazli' at 125 g seed m^{-2} (Table 5). The N uptake was ranked as 125 > 100 > 150 > 75 > 175 g seed m^2 in both years (Table 6). It varied between 180.8 kg ha^{-1} in 2010 and 240.7 kg ha^{-1} in 2011 (Table 7).

Nitrogen is the most frequently required nutrient in a crop fertilization program. Applying N usually reduces N fixation, but starter N applied early and prior to the onset of N fixation has been recommended for field pea production when soil N content is low (Clayton et al., 1998). McKenzie et al. (2001) reported that there are no benefits from using starter N and, when there are, these are generally minimal. Deibert and Utter (2004) pointed out that the highest seed yields (3.5 t ha^{-1}) were obtained when 135 kg ha^{-1} N fertilizer was applied. Low N stress is one of the factors that most frequently occurs under high plant density and limits plant production. Low N availability in soils is an important yield-limiting factor (Banziger and Lafitte, 1997). According to these results, the amount of applied N should be 210-280 kg ha^{-1} when the seeding rate is 125 g seed m^2 as per the selected cultivars.

The P uptake of pea cultivars ranged from 17.3 to 31.0 kg ha^{-1} depending on the seeding rate (Table 4). The cultivars were ranked as Kirazli (26.1 kg ha^{-1}) > Ürünlü (22.7 kg ha^{-1}) > Gölyazi (22.5 kg ha^{-1}) > Ulubatli (20.6 kg ha^{-1}) for P uptake. The highest P uptake was obtained for 'Kirazli' at 125 g seed m^{-2}. The P uptake was ranked as 125 > 100 > 150 > 75 > 175 g seed m^{-2} in both years. It varied between 20.0 kg ha^{-1} in 2010 and 25.9 kg ha^{-1} in 2011.

Phosphorus is required for pea growth and N fixation. Sandaña and Pinochet (2014) reported that P uptake of pea ranged from 1.55 to 2.98 kg ha^{-1}. Therefore, applying 30-35 kg P_2O_5 ha^{-1} is sufficient to meet crop requirements (Lafond and Pageau, 2010). Other researchers have indicated that pea responds to high fertilization rates. Tawaha and Turk (2004) found that field pea yields were maximized by high seeding rates (90 g seeds m^{-2}) and high P fertilization levels (53 kg ha^{-1}).

Phosphorus helps root development, flower initiation, and seed and fruit development; it has reduced disease incidence in some plants and has improved the quality of certain crops. According to these results, the amount of applied P should be 24.2-31.0 kg ha^{-1} when the seeding rate is 125 g seed m^{-2} as per the selected cultivars.

Table 5. Effects of different seeding rates on plant nutrient uptake of pea cultivars (Cultivar × Seeding rate).

	Seeding rate					
	75 g	100 g	125 g	150 g	175 g	Mean
Cultivars	Nitrogen, kg ha^{-1}					
Kirazli	210.5ef	256.7b	285.1a	222.7de	175.2i	230.0A
Ulubatli	144.5j	184.0hi	218.0e	183.1hi	150.2j	176.0C
Golyazi	218.7e	249.7bc	288.1a	208.7efg	171.9i	227.4A
Urunlu	198.1fgh	237.1cd	277.8a	193.5gh	140.6j	209.4B
Mean	192.9D	231.9B	267.2A	202.0C	159.5E	
	Phosphorus (P_2O_5), kg ha^{-1}					
Kirazli	22.1e-h	29.1ab	31.0a	26.7b-d	21.4f-j	26.1A
Ulubatli	18.3i-k	21.8f-i	24.2d-f	19.7g-k	19.3h-k	20.6C
Golyazi	23.1e-g	23.7d-f	25.5c-e	22.0e-h	18.2jk	22.5B
Urunlu	21.4f-j	23.1e-g	28.8a-c	23.1a	17.3k	22.7B
Mean	21.2C	24.4B	27.4A	22.9BC	19.0D	
	Potassium (K_2O), kg ha^{-1}					
Kirazli	135.7	173.8	177.7	155.3	127.0	153.9A
Ulubatli	95.0	139.8	134.9	107.1	108.9	117.2B
Golyazi	148.1	125.9	144.6	132.2	100.6	130.3B
Urunlu	151.3	154.3	183.7	155.6	997.0	148.9A
Mean	132.5C	148.5AB	160.2A	137.6BC	109.0D	
	Calcium, kg ha^{-1}					
Kirazli	71.8cd	75.9a-c	85.5a	74.3a-c	56.6ef	72.8A
Ulubatli	49.5fg	82.6a-c	61.9de	60.4ef	53.6e-g	61.6B
Golyazi	76.8a-c	77.6a-c	83.9ab	73.2bc	54.9e-g	73.3A
Urunlu	61.6de	74.3a-c	78.9a-c	58.9ef	43.8g	63.5B
Mean	64.9B	77.6A	77.5A	66.7B	52.2C	
	Magnesium, kg ha^{-1}					
Kirazli	14.3d-g	17.2ab	18.2a	15.8b-d	12.7g-i	15.6A
Ulubatli	10.6 jk	15.9b-d	13.7e-h	12.7g-i	11.9h-j	13.0C
Golyazi	15.3b-f	15.1c-f	15.5b-e	14.0d-g	11.0i-k	14.2B
Urunlu	12.8g-i	14.7d-g	16.8a-c	13.3f-h	9.6k	13.4BC
Mean	13.3B	15.7A	16.1A	14.0B	11.3C	
	Sodium, kg ha^{-1}					
Kirazli	4.909d-f	6.535ab	6.500ab	5.574cd	4.932c-f	5.690A
Ulubatli	3.828g	5.163c-e	5.221c-e	5.137c-e	4.180fg	4.706C
Golyazi	5.368c-e	4.844d-f	5.748bc	4.726ef	3.772g	4.892BC
Urunlu	5.181c-e	5.270c-e	6.618a	5.069c-e	3.570g	5.142B
Mean	4.821C	5.453B	6.022A	5.127BC	4.114D	
	Iron, g ha^{-1}					
Kirazli	451.1bc	659.5bc	725.6abc	574.5bc	432.0bc	568.6A
Ulubatli	393.6bc	643.1bc	516.4bc	436.8bc	499.9bc	498.0A
Golyazi	672.1bc	1088.2a	608.6bc	501.1bc	401.4bc	654.3A
Urunlu	561.8bc	797.3 ab	655.0bc	449.6bc	358.5 c	564.4A
Mean	519.7B	797.0A	626.4AB	490.5B	422.9B	
	Copper, g ha^{-1}					
Kirazli	39.2d-f	49.4a-c	50.2ab	43.9b-d	37.6d-g	44.1A
Ulubatli	31.4gh	40.9d-f	41.5d-f	36.2e-h	34.6f-g	36.9B
Golyazi	43.9b-d	43.5b-d	43.6b-d	43.0c-e	32.0g-h	41.2A
Urunlu	39.7d-f	42.7c-e	52.8a	40.9d-f	30.0h	41.2A
Mean	38.5C	44.1AB	47.0A	41.0BC	33.6D	

Continuation Table 5.

	Seeding rate					
	75 g	100 g	125 g	150 g	175 g	Mean
Cultivars	Zinc, g ha^{-1}					
Kirazli	117.0	160.2	171.9	155.9	124.5	145.9AB
Ulubatli	111.6	128.7	154.8	137.8	118.9	130.4B
Golyazi	157.1	170.8	169.7	162.1	127.9	157.5A
Urunlu	142.7	167.5	188.4	177.0	122.4	159.6A
Mean	132.1B	156.8A	171.2A	158.2A	123.4B	
	Manganese, g ha^{-1}					
Kirazli	240.2	304.3	329.6	275.5	229.5	275.8B
Ulubatli	224.1	302.9	238.3	240.3	212.4	243.6C
Golyazi	304.7	280.2	305.5	248.2	194.9	266.7BC
Urunlu	288.3	426.2	389.9	266.9	240.1	322.3A
Mean	264.3B	328.4A	315.8A	257.7B	219.2C	

Uppercase letters in the same row and lowercase letters in the same column indicate differences ($P < 0.05$) according to Duncan's test.

Phosphorus fertilization should be based on soil analysis. Higher P fertilization rates are recommended if P is deficient in the soil. In soils with optimum to high P levels, farmers should add the amount of P removed by the pea crop to maintain the soil with an adequate P level. The P deficiency causes a purple color in leaves. Moreover, in soils with moderate plant available K status, applying 50 kg ha^{-1} is sufficient to meet crop requirements and maintain soil fertility (Lafond and Pageau, 2010).

Potassium has many functions in plant growth. It is essential for photosynthesis, activates enzymes to metabolize carbohydrates to manufacture amino acids and proteins, facilitates cell division and growth by helping to move starches and sugars between plant parts, adds stalk and stem stiffness, increases disease resistance, increases drought tolerance. It also regulates the opening and closing of stomata, gives plumpness to the grain and seed, improves firmness, texture, size and color of fruit crops, and increases the oil content of oil crops (Romheld and Kirkby, 2010).

The K uptake of pea cultivars varied between 95.0 and 183.7 kg ha^{-1} depending on the seeding rate. The cultivars were ranked as Kirazli (153.9 kg ha^{-1}) > Ürünlü (148.9 kg ha^{-1}) > Gölyazi (130.3 kg ha^{-1}) > Ulubatli (117.2 kg ha^{-1}) for K uptake. The K uptake was ranked as 125 > 100 > 150 > 75 > 175 g seed m^{-2} in both years. It varied between 146.0 kg ha^{-1} in 2010 and 129.1 kg ha^{-1} in 2011.

Potassium stimulates the processes of protein synthesis and the linking of amino acids in simple proteins. In soils with a low available K concentration, the recommended mean rate of this component should be increased by 20% to 30%. The recommended K rate is 80-100 kg ha^{-1} for a mean pea seed yield of 3-4 Mg ha^{-1} (Czuba, 2001).

Table 6. Effects of different seeding rates on plant nutrient uptake of pea cultivars (Cultivar × Year).

Cultivars	N	P	K	Ca	Mg	Na	Fe	Cu	Zn	Mn
	kg ha^{-1}					g ha^{-1}				
	2010									
Kirazli	200.9	24.0	171.7a	79.1a	15.4	4.697	581.1	43.7	119.5	299.9
Ulubatli	143.3	18.0	125.8cd	65.1bc	12.3	3.705	442.2	34.1	110.3	242.3
Golyazi	198.2	18.9	136.1bc	77.5a	12.7	4.029	548.4	34.6	127.0	271.9
Urunlu	180.8	19.3	150.4b	66.2bc	12.0	4.138	523.5	35.9	131.2	307.3
Mean	180.8B	20.0B	146.0A	72.0A	13.1B	4.143B	523.8B	37.1	122.0B	280.4A
	2011									
Kirazli	259.2	28.1	136.0bc	66.5bc	15.9	6.683	556.0	44.4	172.2	251.7
Ulubatli	208.7	23.3	108.5d	58.0d	13.6	5.706	553.8	39.7	150.4	244.8
Golyazi	256.7	26.0	124.4cd	69.1b	15.7	5.754	760.1	47.8	188.0	261.5
Urunlu	238.0	26.1	147.5b	60.8cd	14.9	6.145	605.3	46.6	188.1	337.3
Mean	24.07A	25.9A	129.1B	63.6B	15.0A	6.072A	618.8A	44.6	174.7A	273.8A

Uppercase letters in the same row and lowercase letters in the same column indicate differences ($P < 0.05$) according to Duncan's test.

Table 7. Effects of different seeding rates on plant nutrient uptake of pea cultivars (Seeding rate × Year).

Seeding rate ($g m^{-2}$)	N	P	K	Ca	Mg	Na	Fe	Cu	Zn	Mn
	kg ha^{-1}					g ha^{-1}				
					2010					
75	176.5f	19.9de	146.6	72.4	13.2d	4.072	552.1b	36.8de	116.6de	284.8bc
100	199.0de	21.9cd	162.7	82.9	14.9c	4.583	602.0b	40.7cd	135.9cd	335.6a
125	229.5c	23.8c	171.8	83.1	15.0c	4.844	613.5b	42.8bc	133.0cd	319.1ab
150	169.1f	18.7e	133.1	68.6	12.3d	3.896	473.2b	34.2ef	123.3c-e	243.9de
175	129.8f	16.0f	115.8	52.9	10.0e	3.318	378.2b	30.9f	101.3e	218.4e
Mean	180.8	20.0	146.0	72.0	13.1	4.143	523.8	37.1	122.0	280.4
					2011					
K75	209.4d	22.5c	118.4	57.5	13.3d	5.571	487.2b	40.3cd	147.6c	243.8de
100	264.8b	26.9b	134.3	72.3	16.5ab	6.323	992.0a	47.6ab	177.8b	321.2ab
125	305.0a	30.9a	148.7	72.0	17.1a	7.199	639.3b	51.2a	209.5a	312.5ab
150	234.9c	27.0b	142.0	64.8	15.6bc	6.357	507.9b	47.8a	193.1ab	271.5cd
175	189.1e	22.1cd	102.3	51.6	12.7d	4.909	467.6b	36.3de	145.6c	220.0e
Mean	240.7	25.9	129.1	63.6	15.0	6.072	618.8	44.6	174.7	273.8

Uppercase letters in the same row and lowercase letters in the same column indicate differences ($P < 0.05$) according to Duncan's test.

In a 2-yr field study conducted in Melfort, Saskatchewan, nutrient uptake in the pea seed at harvest was estimated as 132 kg N ha^{-1}, 14 kg P ha^{-1}, and 40 kg K ha^{-1} in the first year, while the nutrient uptake was 79 kg N ha^{-1}, 9 kg P ha^{-1}, and 24 kg K ha^{-1} in the second year; this wide temporal variation in nutrient uptake in the second year is attributed to lower seed yield and harvest indexes due to hail damage (Malhi et al., 2007). A study in North Dakota reported nutrient requirements of field pea as 0.034 kg N, 0.0041 kg P, and 0.0115 kg K per kilogram seed yield at harvest, indicating that tillage practices, fertilization, and their interaction with the climate influence biomass accumulation, seed yield, and nutrient uptake in the field pea production systems (Deibert and Utter, 2004).

Calcium uptake of pea cultivars varied between 43.8 and 85.5 kg ha^{-1} depending on seeding rate. The highest Ca uptake was obtained for 'Kirazli' at 125 g seed m^{-2}. The Ca uptake was ranked as 125 > 100 > 150 > 75 > 175 g seed m^{-2} in both experimental years. It ranged from 72.0 kg ha^{-1} in 2010 to 63.6 kg ha^{-1} in 2011. Candráková et al. (2014) reported that the Ca uptake of pea (seed + biomass) was 41.09 kg ha^{-1} under the conditions of a warm and moderately arid continental climate with an average annual temperature of 9.07 °C and average annual precipitation of 561 mm. According to Fecenko and Lozek (2000), pea seeds using normal nutrients extract 25 kg Ca t^{-1} from the crop.

Calcium is a component of the cell walls and participates in producing new growing points and root tips. It provides elasticity and expansion to the cell walls, which keeps growing points from becoming rigid and brittle. It is immobile in plants and remains in the older tissue throughout the growing season. It acts as a base for neutralizing organic acids generated during the growing process and helps carbohydrate translocation and N absorption (Hepler, 2005).

Magnesium uptake of pea cultivars varied between 9.6 and 18.2 kg ha^{-1} depending on the seeding rate. The cultivars were ranked for Mg as Kirazli (15.6 kg ha^{-1}) > Gölyazi (14.2 kg ha^{-1}) > Ürünlü (13.4 kg ha^{-1}) > Ulubatli (13.0 kg ha^{-1}). The highest Mg uptake was obtained for 'Kirazli' at 125 g seed m^{-2}. The Mg uptake was ranked as 125 ≥ 100 > 150 ≥ 75 > 175 g seed m^{-2} in 2010 and 125 > 100 > 150 > 75 ≥ 175 g seed m^{-2} in 2011. Candráková et al. (2014) reported that Mg uptake of pea (seed + biomass) was 13.91 kg ha^{-1} under the conditions of a warm and moderately arid continental climate with an average annual temperature of 9.07 °C average and annual precipitation of 561 mm. According to Fecenko and Lozek (2000), pea seeds using normal nutrients extract 3.6 kg Mg t^{-1} from the crop.

Magnesium is a component of the chlorophyll molecule, which is the driving force of photosynthesis. It is essential for carbohydrate (sugars) metabolism, and is an enzyme activator in nucleic acid (DNA and RNA) synthesis. It regulates the uptake of other essential elements, serves as a carrier of phosphate compounds throughout the plant, facilitates carbohydrate (sugars and starches) translocation, and enhances oil and fat production (Guo et al., 2016).

Sodium uptake of pea cultivars ranged from 3.570 to 6.535 kg ha^{-1} depending on the seeding rate. The cultivars were ranked as Kirazli (5.690 kg ha^{-1}) > Ürünlü (5.142 kg ha^{-1}) > Gölyazi (4.892 kg ha^{-1}) > Ulubatli (4.706 kg ha^{-1}). The highest Na uptake was obtained for ‘Kirazli’ at 100 g seed m^{-2}. The Na uptake was ranked as 125 > 100 > 150 > 75 > 175 g seed m^{-2} in both years.

Micronutrients are indispensable for plant growth and play an important role in balanced crop nutrition. Some important micronutrients include Cu, Fe, Mn, and Zn. They are as important to plant nutrition just as N, P, K, Ca, Mg, Na, Fe, Cu, Zn, and Mn. A lack of any one of the micronutrients in the soil can limit plant growth, even if the other soil nutrients are in sufficient amounts.

Iron is important for crop growth and food production. Plant Fe uptake is through the ferrous (Fe^{2+}) cation. Iron is a component of many enzymes associated with energy transfer, N reduction and fixation, and lignin formation (Rout and Sahoo, 2015). The Fe uptake of pea cultivars varied between 358.5 and 1088.2 g ha^{-1} depending on the seeding rate. The highest Fe uptake was obtained for ‘Gölyazi’ at 100 g seed m^{-2}. It was 523.8 g ha^{-1} in 2010 and 618.8 g ha^{-1} in 2011.

Copper uptake of pea cultivars varied between 30.0 and 52.8 g ha^{-1} depending on the seeding rate. Cultivars were ranked as Kirazli (44.1 g ha^{-1}) > Ürünlü (41.2 g ha^{-1}) = Gölyazi (41.2 g ha^{-1}) > Ulubatli (36.9 g ha^{-1}). The highest Cu uptake was obtained for ‘Kirazli’ and ‘Urunlu’ at 125 g seed m^{-2}. The Cu uptake was ranked as 125 > 100 > 150 > 75 > 175 g seed m^{-2} in both years. Copper activates enzymes and catalyzes reactions in several plant growth processes (Ayala and Sandmann, 1988; Adhikari et al., 2016).

Zinc uptake of pea cultivars ranged from 111.6 to 188.4 g ha^{-1} depending on the seeding rate. The cultivars were ranked as Ürünlü > Gölyazi > Kirazli > Ulubatli in both experimental years. The highest Zn uptake was obtained for ‘Urunlu’ at 125 g seed m^{-2}. The Cu uptake was ranked as 100 > 125 > 150 > 75 > 175 g seed m^{-2} in 2010 and 125 > 150 > 100 > 175 > 75 g seed m^{-2} in 2011. Zinc is taken up by plants as the divalent Zn^{+2}. It was one of the first micronutrients recognized as essential for plants and the one that most commonly limited yields. Although Zn is required only in small amounts, high yields are impossible without it.

Manganese uptake of pea cultivars varied between 194.9 and 426.2 g ha^{-1} depending on the seeding rate. The Mn uptake was ranked as 100 > 125 > 75 > 150 > 175 g seed m^{-2} in 2010 and 100 > 125 > 150 > 75 > 175 g seed m^{2} in 2011. The highest Mn uptake was obtained for ‘Urunlu’ at 125 g seed m^{-2} in both years. The cultivars were ranked as Ürünlü > Gölyazi > Kirazli > Ulubatli in both yearsManganese primarily functions as part of plant enzyme systems. It activates several important metabolic reactions and plays a direct role in photosynthesis. Manganese accelerates germination and maturity while increasing P and Ca availability (Mousavi et al., 2011; Hafeez et al., 2013).

Harmankaya et al. (2010) reported that protein content and mineral composition of pea were significantly different among the 19 pea cultivars. In addition, researchers have mentioned that such variations in mineral content of pea samples might be due to their genetic origin. Several crops show genotypic differences in their competitive ability (McDonald et al., 2007). Results obtained in the study may be related to the genetic characteristics of pea cultivars. When choosing varieties for cultivation, it is important to consider their susceptibility to plant nutrient uptake and soil properties, climate adaptive capacity, and other agronomic features relevant to the growing region. Results obtained in this study were also comparable to the findings of other authors (Wang and Daun, 2004; Yoshida et al., 2007; Harmankaya et al., 2009).

CONCLUSIONS

There is considerable genetic variation in cultivated pea and a wide range of varieties is available, which have a broad spectrum of traits. When selecting a pea variety, one must consider crop use, region, sowing date, seeding rate, yield potential, frost and disease resistance or tolerance, ease of harvesting, and marketing options.

Seeding rate and pea cultivar are the most significant factors affecting yield parameters. Decreased yield is evident at seeding rates above or below the optimum rates. In this study, the effects of seeding rate on plant nutrient uptake (N, P, K, Ca, Mg, Na, Fe, Cu, Zn, and Mn) were determined in four forage pea cultivars under the conditions found in the Bursa Province, Turkey. Nitrogen, the most frequently obtained element, varied between 129.8 and 305.0 kg ha^{-1} according to the pea cultivars and climatic conditions. In addition, K ranged from 108.5 to 177.0 kg ha^{-1}, 58.0-79.1 kg Ca ha^{-1}, and 18.0-28.1 kg P ha^{-1}. Field pea cultivars contained various levels of microelements. According to this study and considering the cultivar × seeding rate interaction, ‘Kirazli’ and ‘Golyazi’ at 125 g seed m^{-2} were recommended for higher N uptake, ‘Kirazli’ for P uptake, and ‘Kirazli’ and ‘Urunlu’ for K and microelement uptake. The Fe, Cu, and Zn uptake of ‘Golyazi’ was higher than for the other cultivars. Plant density at approximately 125 g seed m^{-2} may be more suitable for pea grown under the study conditions, and increasing plant density does not significantly return increased product yield. These results revealed that field pea cultivars may provide a sufficient amount of plant nutrient elements to meet animal mineral requirements. We should pay attention to the mentioned issues when creating a fertilization program.

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