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EFFECTS OF DIFFERENT FOLIAR POTASSIUM TREATMENTS ON SEED YIELD AND QUALITY OF CAPIA PEPPERS

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ABSTRACT

This study was conducted to investigate the effects of different foliar potassium treatments on greenhouse seed yield and quality of BT BUR – KAP capia pepper (*Capsicum annum*) cultivar. In addition to soil available K_2O content, 1, 2, 4 and 8 kg da^{-1} K_2O treatments were performed with 15% nitrogen-containing potassium nitrate fertilizer. The greatest seed yield (34.50 kg da^{-1}) was obtained from 2 kg da^{-1} K_2O treatment. As compared to the control treatment, 2, 4, 8 kg da^{-1} K_2O treatments yielded better seed germination ratios and mean germination times. For under-cover capia pepper seed production, seed yield and quality, the best outcomes were achieved with 2 kg da^{-1} K_2O treatments. Seed macro and micro elements and pre-harvest leaf amino acids were also investigated in this study. While all treatments yielded similar Mn, B, Fe, Cu, S and Na contents with the control treatment, K, Mg, Ca, P, N and Zn contents of potassium treatments were greater than the values of the control treatment. As compared to the control treatment, potassium treatments increased leaf total amino acid, cysteine, valine, tryptophan, leucine, proline, aspartate, asparagine, serine, glutamine, glycine, arginine and tyrosine contents. It was concluded based on present findings that in greenhouse capia pepper seed production, 2 kg da^{-1} K_2O treatments had the best outcomes for seed yield, germination and vigor.

KEYWORDS:
Capia pepper, foliar potassium, seed quality, seed yield

INTRODUCTION

Pepper is commonly consumed in fresh, pickled, paste, flaked and powder forms. It is the second largest undercover crop of Turkey after tomatoes. Undercover and open-field pepper productions are always increasing. While pepper production of Turkey was 2 127 000 tons in 2014, the value increased to 2 608 172 tons in 2017. The capia pepper production of 829 809 tons in 2014 increased to 1 107 713 tons in 2017. With these production quantities, pepper has the third place after tomato and watermelon [1]. World pepper production including undercover and open field production is about 36 143 113 tons [2]. Recently, Turkey is the world's third largest pepper producer after China and Mexico [3].

Chemical fertilizers are among the most significant inputs in plant production. However, excessive fertilizers result in yield losses and soil degradation. Therefore, optimum fertilizer quantities should be determined in advance for every crop and plant to be cultured.

Plant yields are influenced by several factors. Plant nutrition is among the most important of them. Quite high yields are achieved with proper and sufficient fertilization program [4]. Among the plant nutrients, potassium play a great role in plant stoma quantities, water use efficiency, sugar transport and conversion into carbohydrates, enzyme activities, protein synthesis and seed quality [5, 6]. Potassium also improves plant resistance to biotic and abiotic stressors and thus improves both yield and quality [7, 8].

There are several studies indicating improved yield, quality and chemical composition with potassium fertilizer treatments. Potassium significantly increased yield and quality of peppers and tomatoes [9, 10, 11].

Soil and foliar potassium fertilizer treatments were reported to increase yield and quality in several plants. Greatest values were reported for plant height, number of leaves, plant fresh weight, yield, number of fruits per plant, plant sugar content and amino acid content with potassium treatments in spray forms [8, 11, 12].

In present study, effects of different potassium doses in spray forms on capia pepper seed yield and quality was investigated. Before the fruit harvest for seeds, the relationships between amino acid content and seed quality were also investigated.

MATERIALS AND METHODS

Study area. Experiments were conducted in a polycarbonate experimental greenhouse of Erciyes

TABLE 1
Monthly average indoor temperatures and relative humidity values

Months	May	June	July	August	September	October
Temperature ^{0}C	21.87	24.39	26.63	27.24	23.32	20.14
Relative Humidity (%)	56.23	51.64	47.13	42.17	36.48	43.64

TABLE 2
Greenhouse soil characteristics

Soil Depth(cm)	Texture	pH	OM (%)	Lime (%)	EC (dS M^{-1})	Available K_2O (kg da^{-1})	Available P_2O_5 (kg da^{-1})	Available N (kg da^{-1})
0-30	Loam	7.75	2.96	13.26	0.18	56.65	10.25	10.78

OM= Organic Matter

University (38° 70' 50" N, 35° 53' 28" E) in the year 2016. Greenhouse indoor average temperature and relative humidity values are provided in (Table 1). Average temperatures varied between 20.14 - 27.24 ^{0}C and relative humidity values varied between 34.48 - 56.23%. Soil samples were taken from 0-30 cm soil profile and analyses were performed on these soil samples. Experimental soils were loamy in texture, unsaline and slightly alkaline with moderate organic matter and lime contents and sufficient available phosphorus, nitrogen and potassium (Table 2).

Plant Material. BT –BUR-KAP capia pepper seedlings of Bursa Seed Co. were used as the plant material of the study. BT –BUR-KAP cultivar is available open-field culture, fresh consumption, pepper paste production, frying and roasting. Fruits are flat and widened and get dark shiny red color when ripened. Fruit length is 16-18 cm, width is 6 cm and flesh thickness is 4-5 mm. Homogeneously grown potted seedlings produced by Akdeniz Seedling Co. were planted into greenhouse seed beds on 26.04.2016 when they reached to 5-6 true-leaf stage of growth. Experiments were conducted in randomized blocks design with 3 replications with 3 plants in each replication. Seedlings were planted in two rows at 100 x 60 x 60 cm. Seed fruits were harvested on 18.10.2016. Seeds were removed from the fruits and they were dried in a laboratory at 25 ± 5^{0}C and <50% relative humidity for a week. Following the drying, moisture content of the seeds was determined in accordance with the principles specified by International Seed Tests Association with the aid of Constant Low Temperature Oven Method [13]. For accurate estimation of the effects of treatments on seeds, seed moisture contents were tried to be equivalent before the seed germination, micro and macro element analyses. Germination tests were performed on 200 seeds in 4 replications (50 seeds in each replication) to determine seed vigor [13]. Germinated seeds were counted and removed from the germination cups and countings were continued until the 21st day. The seeds with a rootlet length of 0.5 cm were accepted as germinated. Rooting media was irrigated as needed. Germination tests were conducted in climate cabins at 25 ^{0}C. Seed vigor was identified as percent germination at the end of 21st day. Seeds were placed in petri dishes with filter papers above and below the seeds. Mean germination time was calculated in accordance with [14].

Fertilizer Treatments. To determine the effects of different doses of potassium fertilizers, pure potassium nitrate (13% N and 45.5% K_2O) was dissolved in water as to have 1, 2, 4 and 8 kg da^{-1} K_2O and foliar sprays were performed with an hand pulverizator. All treatments were applied once above the plants at fruit formation period as to cover the entire plant. Control plants were treated only with water. Following the harvest, randomly selected seeds were subjected to macro-micro element analyses.

Soil Analyses. Soil texture was determined with the aid of Bouyoucus hydrometer method [15]. Soil pH values were measured potentiometrically in 1:2.5 soil-water solution with a pH meter with a glass electrode [16]. Soil lime content was determined volumetrically with a Scheibler calcimeter [17]. Soil organic matter contents were determined with the aid of Smith-Weldon method [18]. For available potassium contents, soil samples were shaken in ammonium acetate (1 N, pH=7.0) and resultant extracts were then read in an ICP-OES device [19]. Available phosphorus contents were determined through the readings in a spectrophotometer with the aid of molibdophosphoric blue color method [20]. Samples were subjected to wet-digestion in salicylic acid + sulphuric acid + salt mixture and then nitrogen contents were determined with the aid of micro-kjheldahl method [21].

Seed and Plant Analyses. Seeds were subjected to wet-digestion in salicylic acid + sulphuric acid mixture and seed nitrogen contents were determined with the aid of micro-kjheldahl method [22]. Plant samples were subjected to wet-digestion in nitric acid – perchloric acid [23] and macro-micro elements (P, K, Ca, Mg, Na, S, Fe, Mn, Zn, Cu and B) were read in an ICP OES spectrophotometer (Inductively Couple Plasma spectrophotometer) (Perkin-Elmer, Optima 2100 DV, ICP/OES, Shelton, CT 06484-4794, USA) [24]. Fresh leaf samples were taken before the last harvest and they were kept in a freezer at -20 °C until the analyses for amino acids. Free amino acid composition of plant samples was determined in accordance with the methods (HPLC method) specified by [25] and [26]. Agilent 1200 model HPLC equipped with single detector (UV) and Zorbax Eclipse-AAA 4.6 x 150 mm, 3.5 µm (Agilent PN 963400-902) column was used to determine free amino acid composition of the samples.

Statistical Analyses. Experiments were conducted in randomized blocks design with 3 replications. Experimental data were subjected to variance analysis with "SSPS 13.0 for Windows" statistical software and significant means were compared with LSD test at 0.05 significance level.

RESULTS AND DISCUSSION

Effects of foliar potassium treatments on pepper seed yields. Considering the effects of foliar potassium treatments on seed yields, it was observed that 2, 4 and 8 kg da^{-1} K_2O treatments increased seed yields, but the effects of only 2 kg da^{-1} K_2O treatments on seed yields were found to be significant. The greatest seed yield (34.504 kg da^{-1}) was obtained from 2 kg da^{-1} K_2O treatment and the lowest seed yield (22.308 kg da^{-1}) was obtained from 1 kg da^{-1} K_2O treatment. Seed yield of control treatment was 22.532 kg da^{-1} (Table 3).

The 2, 4 and 8 kg da^{-1} K_2O treatments significantly increased seed germination ratios. The greatest germination ratio (95.5%) was observed in 8 kg da^{-1} K_2O treatment and germination ratio of the control treatment was 77.5%. As compared to the control treatment, 2, 4 and 8 kg da^{-1} K_2O treatments reduced mean germination times. The longest mean germination time (9.12 days) was observed in 1 kg da^{-1} K_2O treatments and the shortest mean germination time (6.03 days) was observed in 4 kg da^{-1} K_2O treatment. Mean germination time of the control treatment was 8.18 days.

Effects of foliar potassium treatments on seed nutrients. Potassium treatments yielded similar seed Na, Cu, Fe, Mn and B contents with the control treatment, but increased seed K, Mg, Ca, N, P and Zn contents as compared to the control. Potassium treatments increased seed potassium content. The greatest potassium content (13735 mg kg^{-1}) was obtained from 8 kg da^{-1} K_2O treatments and the lowest potassium content (11234 mg kg^{-1}) was obtained from the control seeds. The greatest Mg content (2412 mg kg^{-1}) was obtained from 8 kg da^{-1} K_2O treatments and the lowest Mg content (2170 mg kg^{-1}) was obtained from the control seeds. While 1, 2 and 4 kg da^{-1} K_2O treatments increased seed Ca contents as compared to the control, 8 kg da^{-1} K_2O treatment yielded similar Ca contents with the control treatment. The greatest N content (1.74 mg kg^{-1}) was obtained from 8 kg da^{-1} K_2O treatments and the lowest N content (1.44 mg kg^{-1}) was obtained from the control seeds. The greatest P content (3022 mg kg^{-1}) was obtained from 8 kg da^{-1} K_2O treatment and the lowest P content (2621 mg kg^{-1}) was obtained from the control seeds (Table 4).

TABLE 3
Effects of foliar potassium treatments on pepper seed yields

	Seed yield kg/da	Yield per plant (gr)	Germination ratio (%)	Mean germination time (day)	Seed moisture content (%)
Control	22.53 b	10.82 b	77.5 b	8.18 a	6.26
1 kg K da^{-1}	22.31 b	10.71 b	76.5 b	9.12 a	6.27
2 kg K da^{-1}	34.50 a	16.56 a	88.0 a	6.31 b	6.28
4 kg K da^{-1}	26.85 ab	12.89 ab	89.5 a	6.03 b	6.21
8 kg K da^{-1}	31.29 ab	15.02 ab	95.5 a	6.79 b	6.32

* Different letters indicate significant differences at P <0.05.
** Different letters indicate significant differences at P <0.01.

TABLE 4
Effects of foliar potassium treatments on seed macro nutrients

	K^{**}	Mg^{*}	Ca^{**}	N^{**}	P^{**}	S^{ns}	Na^{ns}
			mg/kg				%
Control	11234 c	2170 b	2435 b	1.44 c	2621 c	1266	878
1 kg K	12145 b	2234 ab	2657 a	1.56 b	2712 b	1244	912
2 kg K	12760 b	2322 a	2788 a	1.67 a	2878 b	1312	887
4 kg K	13100 a	2344 a	2612 a	1.72 a	2934 a	1324	812
8 kg K	13735 a	2412 a	2446 b	1.74 a	3022 a	1233	789

* Different letters indicate significant differences at P <0.05.
** Different letters indicate significant differences at P <0.01.

Considering seed micro element contents, differences observed only in seed Zn contents. The greatest Zn content (40.19 mg kg^{-1}) was obtained from 2 kg da^{-1} K_2O treatment and the lowest Zn content (30.99 mg kg^{-1}) was obtained from 4 kg da^{-1} K_2O treatment. Seed Zn content of the control treatment was 34.12 mg kg^{-1} (Table 5).

There was a negative correlation between seed germination ratio and mean germination time. Such a correlation revealed that mean germination times shortened, thus seed vigor increased with increasing germination ratios. While germination ratios positively correlated with seed N, K, Mg and P contents, there was a negative correlation between germination ratio and seed Na content (Table 6).

Seed germination ratios and mean germination times did not have any significant correlations with Ca, Zn, Cu and Fe contents.

Effects of foliar potassium treatments on plant amino acid contents. Plant stress status was assessed through analyzing the effects of foliar potassium treatments on leaf amino acid contents. As compared to the control, all treatments significantly increased total amino acid content of leaf samples. The greatest total amino acid content (100.42 nmol ul^{-1}) was obtained from 4 kg da^{-1} K_2O treatment and the west value (71.65 nM ul^{-1}) was obtained from the control plants. It was observed when the amino acid contents were assessed in detail that 1, 2, 4 and 8 kg da-1 K_2O treatments significantly increased leaf aspartate, asparagine, glutamine, glycine, tyrosine, cysteine, tryptophan and proline contents as compared to the control. It was also observed that 2, 4 and 8 kg da^{-1} K_2O treatments increased leaf arginine, valine and leucine contents as compared to the control (Table 7).

TABLE 5
Effects of foliar potassium treatments on seed micro nutrients

	Zn**	Fe^ns	Cu^ns	Mn^ns	B^ns
			mg/kg		
Control	34.12 b	25.16	2.27	13.30	8.79
1 kg K	36.57 b	25.57	2.82	14.76	7.68
2 kg K	40.19 a	23.45	2.44	15.67	9.12
4 kg K	30.99 c	24.55	2.34	14.56	8.55
8 kg K	36.22 b	28.77	2.12	15.89	8.70

* Different letters indicate significant differences at P <0.05

TABLE 6
Correlations of germination ratio and mean germination time with seed macro and micro nutrients

	GR	MGT	N	K	Mg	P	Na	Mn
GR	1.00							
MGT	-0.838*	1.00						
N	0.906*	-0.765	1.00					
K	0.923*	-0.677	0.979**	1.00				
Mg	0.960**	-0.738	0.975**	0.993**	1.00			
P	0.969**	-0.783	0.979**	0.986**	0.997**	1.00		
Na	-0.845*	0.654	-0.693	-0.743	-0.768	-0.789	1.00	
Mn	0.727	-0.461	0.817*	0.846*	0.839	0.804	-0.327	1.00

* Correlations are significant at P <0.05.
** Correlations are significant at P <0.01.

TABLE 7
Effects of foliar potassium treatments on leaf amino acids, pmol ul^{-1}

	Aspartate	Glutamate	Asparagine	Serine	Glutamine	Histidine	Glycine	Threonine	Arginine	Alanine	Tyrosine
Control	2,64 b	1,11	4,99 b	5,54 b	4,02 b	3,08	1,76 b	3,92	10,15 b	11,69	0,67 c
1 kg K	3,32 a	1,50	7,13 a	6,08 b	6,14 a	4,08	2,73 a	4,98	12,80 ab	12,98	0,82 b
2 kg K	3,54 a	1,74	8,11 a	6,76 a	6,34 a	3,94	2,98 a	5,54	13,64 a	12,51	0,83 b
4 kg K	3,77 a	1,85	8,05 a	7,11 a	7,20 a	4,39	3,21 a	6,39	14,54 a	13,96	0,96 a
8 kg K	3,40 a	1,74	9,28 a	6,87 a	7,10 a	4,00	3,55 a	5,75	13,11 a	12,72	0,95 a

	Cysteine	Valine	Methionine	Tryptophan	Phenylalanine	Isoleucine	Leucine	Lysine	Sarcosine	Proline	Total amino acid, nmol/ul
Control	1,30 c	0,70 b	1,25	0,93 b	1,11	2,23	1,62 b	3,10	8,49	0,05 d	71,65 e
1 kg K	1,70 b	0,83 ab	1,69	1,87 a	1,35	2,23	1,99 b	3,72	8,77	0,10 c	88,17 d
2 kg K	1,85 b	0,92 a	1,80	1,80 a	1,39	2,48	2,17 a	4,14	8,45	0,20 a	92,47 c
4 kg K	1,99 b	1,06 a	1,92	2,01 a	1,58	2,61	2,34 a	4,35	9,43	0,15 b	100,42 a
8 kg K	2,21 a	0,96 a	1,73	1,83 a	1,56	2,52	2,58 a	4,21	8,80	0,10 c	96,38 b

TABLE 8
Correlations of germination ratio and mean germination times with leaf amino acids

	GR	MGT	AS	CY	LE	LY	VA	TR	ASR	GL	SE	GLY
GR	1.00											
MGT	-0.83*	1.00										
AS	0.620	- 0.639	1.00									
CY	0.88*	- 0.623	0.910*	1.00								
LE	0.90*	- 0.648	0.788	0.998*	1.00							
LY	0.816*	- 0.748	0.958**	0.928*	0.919*	1.00						
VA	0.789	- 0.776	0.942**	0.87*	0.876*	0.970**	1.00					
TR	0.526	- 0.408	0.952**	0.82*	0.794	0.902*	0.855*	1.00				
ASR	0.858*	- 0.803	0.822*	0.985**	0.976**	0.929*	0.941*	0.864*	1.00			
GL	0.747	- 0.577	0.937**	0.950**	0.936**	0.968**	0.938**	0.952**	0.941**	1.00		
SE	0.863*	-0.832*	0.927*	0.911*	0.913*	0.988**	0.981**	0.834*	0.898*	0.933*	1.00	
GLY	0.837*	- 0.594	0.859*	0.993**	0.984**	0.948**	0.889*	0.834	0.990**	0.975**	0.918*	1.00

GR: Germination ratio, MGT: Mean germination time, TAC: Total amino acid content, AS: Aspartate, CY: Cysteine, LE: Leucine, LY: Lysine, VA: Valine, TR: Tryptophan, ASR: Asparagine, GL: Glutamine, SE: Serine, GLY: Glycine.

TABLE 9
Correlations of germination ratio and mean germination times with the rest of leaf amino acids

	GR	MGT	AR	TY	AL	PH	ME	IS	SA	GL	HI	TE
GR	1.00											
MGT	-0.838*	1.00										
AR	0.623	-0.623	1.00									
TY	0.81*	-0.651	0.88*	1.00								
AL	0.386	-0.415	0.87*	0.81*	1.00							
PH	0.81*	-0.645	0.894*	1.000**	0.879*	1.00						
ME	0.697	-0.648	0.986**	0.958**	0.871*	0954**	1.00					
IS	0.901*	-0.941**	0.813*	0.862*	0.647	0.860*	0.834*	1.00				
SA	0.181	-0.323	0.616	0.562	0.896*	0.576	0.609	0.507	1.00			
GL	0.781	-0.731	0.971**	0.952**	0.784	0.945**	0.984**	0.879*	0.489	1.00		
HI	0.500	-0.430	0.953**	0.895*	0.928*	0.894*	0.963**	0.665	0.667	0.907*	1.00	
TE	0.770	-0.745	0.966**	0.967**	0.863*	0.965**	0.986**	0.930*	0.640	0.979**	0.915*	1.00

GR: Germination ratio, MGT: Mean germination time, AR: Arginine, TY: Tyrosine, AL: Alanine, PH: Phenylalanine, ME: Methionine, IS: Isoleucine, SA: Sarcosine, GL: Glutamate, HI: Histidine, TE: Treonine

With increasing K_2O doses, seed germination ratios increased, thus correlations were observed among leaf Tyrosine, Phenylalanine, İsoleucine, Cysteine, Leucine, Lysine, Asparagine, Serine, Glycine contents together with increasing germinations (Table 8).

Since a positive correlation was observed between leaf Tyrosine, Phenylalanine, Isoleucine, Cysteine, Leucine, Lysine, Asparagine, Serine, Glycine contents and seed germination, it was thought that seed germination could be estimated ahead (Table 9). A germination test in pepper seeds takes about 21 days. There was a negative correlation between mean germination time, which can be taken as an indicator of seed vigor and serine, and isoleucine. Increasing leaf serine and isoleucine contents were observed with decreasing mean germination times. Therefore, it is possible to estimate seed vigor ahead by measuring leaf Serine and Isoleucine contents.

CONCLUSION

In this study, potassium treatments increased total amino acid contents as compared to the control treatment. Present findings comply with the results of earlier studies [8, 11, 12, 27]. Together with K, 13% N treatments also were found to be effective in increasing leaf amino acids. N exists in structure of Tryptophan amino acid. Therefore, leaf Tryptophan contents increased with increasing N treatments (Table 7).

Germination ratios increased with increasing K doses (Table 3). Such findings comply with the results of earlier studies [28, 29, 30] indicating that potassium retarded early plant development, phosphorus resulted in early ripening, thus prevented insufficient seed fills.

Pre-harvest leaf Isoleucine and Serine contents positively correlated with seed germination and negatively correlated with seed vigor. Further research is recommended to investigate similar correlations of Isoleucine and Serine with the seed germination and vigor of the other pepper cultivars and vegetable species cultured in open-fields.

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