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GENETIC VARIABILITY OF MINERAL ELEMENTS CONCENTRATION IN PEPPER VARIETIES (*CAPSICUM ANNUUM* L.)

ABSTRACT: Pepper (*Capsicum annuum* L.) is one of the major members of the vegetable kingdom. The differences between the individual varieties in mineral nutrition and the uptake of mineral elements have provoked our interest for the investigations of their genotype specificity. The chemical composition of pepper leaves at flowering and at the end of the growing season was analysed. On the average, the content of total ash was app. 22%, namely 19—20% (soluble) and 2—3% (insoluble) at both stages. The highest accumulation values were obtained with nitrogen, then potassium, calcium and phosphorus, whereas the lowest with sodium. The most remarkable genotypic differences were recorded at the end of the growing season. The results obtained clearly demonstrate the chemical heterogeneity of pepper varieties. This crop may be grown successfully only if specificity of its mineral nutrition is known.

KEY WORDS: pepper, variety, mineral elements, concentration diversity

INTRODUCTION

The individual plant varieties show different resistance against high and low temperatures, plant diseases and pests, different length of the vegetation period and different specificity to the individual ions, i.e. elements of mineral nutrition, simply defined as the genotypic specificity of mineral nutrition (Sarić and Loughman, 1983). Content of mineral elements highly correlates with the genetic specificity of plants. The problem of genetic specificity of the content of elements and plant nutrition is of a great importance from both the theoretical and practical aspects. There are many data elaborating this topic (Klimaševski and Černiševa, 1980; Sarić, 1981; Bugevski et al., 2007) while most investigations have been aimed at the differences between the individual genotypes in the content of mineral elements. Among the plant species investigated are different wheat cultivars, inbred lines of maize and sunflower, as well as many other plant species (B l a m e y, 1980; S a r i ć and K o v a č e v i ć, 1980). A great number of cultivars show differences in the specific content of mineral elements (S a r i ć and K r s t i ć, 1983). There are also data presenting the investigations on pepper varieties (S o m o s, 1984; M e r k u l o v et al., 2000). Like with other plant species, there are differences between the pepper genotypes in production of organic matter (G v o z d e n o - v i ć et al., 1996; G v o z d e n o v i ć et al., 2000) and the requirements for elements of mineral nutrition (G v o z d e n o v i ć and T a k a č, 2004). The pepper is an important vegetable being characterized by different varieties intended for different use, i.e. row pepper, ground dried pepper, hot pepper and so on. Its mineral composition is very important particularly when it is used as row pepper. Pepper contains high content of N, K, Ca, P, Mg, Fe, and other elements. There are data showing that edible parts contain 5—6% mineral substances calculated per dry matter (Ć i r i ć, 1973). For it, the present work has as objective to evaluate the chemical heterogeneity of different pepper varieties and to determine the percentage of the individual elements in leaves, i.e. their accumulation.

MATERIAL AND METHODS

The experiments were set up in the greenhouse at Rimski Šančevi, Institute of Field and Vegetable Crops, Novi Sad. Each pepper variety was planted in three replicates, 20 plants per replicate. Before transplanting, experimental plots were fertilized with 10 g NPK (15:15:15)/m^2. Plants were dressed with 10 g AN (ammonium nitrate) and 10 g NPK/m^2 four times during the growing season, hoed four times and treated with insecticides two times. Pepper leaves were sampled at flowering and at the end of growing season. Chemical analyses of soil (Table 1) show that it was weak alkaline soil moderate in humus, poor in N and with P and K exceeding tolerant values. High P and K suggests the omission of P and K fertilizers (K a s t o r i, 2000), imposing the need for greater amounts of N.

Tab. 1 — Chemical composition of soil analyzed at the end of growing season

Parameters	Values	Categories	Limiting values
in KCl	7.37	Weak alkaline	7.21—8.20
pH in H_2O	7.80	Weak alkaline	7.31—7.80
$CaCO_3$ (%)	3.85	Moderate carbonate	2.01—5.00%
Humus (%)	3.01	Moderate humus	3.01—5.00%
Nitrogen (%)	0.150	I group	< 0.200%
P_2O_5 (mg/100 g soil)	107.60	Exceeding tolerant values	> 50.01 mg/100 g soil
K_2O (mg/100 g soil)	61.0	Exceeding tolerant values	> 50.01 mg/100 g soil

The pepper variety Plamena, Anita, Amfora, Novosađanka, Lombardija, Una, Vranjska, Krušnica, L-127, and SM-1 were analyzed. Ten standard plants per replication of each variety were sampled.

Nitrogen content in dry matter was determined by the standard Kjeldahl method (N e l s o n and S o m m e r s, 1973). Total, soluble and insoluble ash was determined in plant material by incinerating dried and ground samples at 450°C (S a r i ć et al., 1990). Phosphorus concentration was determined by spectrophotometry from the stock solution by the ammonium-vanado-molybdate method (G e r i c k e and K u r m i e s, 1952) while the content of K, Ca and Na by flame photometry (S a r i ć et al., 1990) and expressed per dry matter.

The results obtained were statistically processed by the analysis of variance using MSTAT program. Treatments were compared by the Duncan's test, at the significance level of a = 0.05, to obtain LSD values. Means of the analyzed parameters were ranked and designated with letters.

RESULTS AND DISCUSSION

One of the factors affecting the production of plant biomass is the concentration of mineral elements. Productivity, i.e. synthesis of organic matter is an important factor in all the plant species and genotypes within these species, followed by the investments primarily in mineral fertilizers. Concentration of ash macroelements and ash content may vary in different varieties and between different plant organs (S a r i ć and L o u g h m a n, 1983). Investigations of mineral composition based on total (raw) ash, as well as soluble (pure) and insoluble ash portions show that the ash content relies on a pepper genotype. E r m a k o v a and A r a s i m o v i č (1961) quoted that the ash content in edible part of the pepper fruit may vary between 1.03 and 11.82%.

According to the results presented in Table 2, the highest content of total ash in leaves at flowering was obtained with the variety Novosađanka (24.32%) whereas the lowest with SM-1 (20.08%). Based on the results of Duncan's test, tested varieties may be classified into the 6 statistically significant groups.

The highest soluble ash values were recorded in leaves of the variety Novosađanka (21.72%) and the variety Amfora (21.54%) whereas the lowest in the variety Vranjska (19.67%), Lombardija (19.47%) and Una (19.27%). Based on the results of Duncan's test, the tested varieties may be classified into the 5 groups.

The differences between leaves in content of insoluble ash suggest the classification into the 3 statistically significant groups where the highest values of insoluble ash were obtained with the variety Novosađanka (2.60%) and the variety SM-1 (2.53%) whereas the lowest with the variety L-127 (1.44%).

At the end of the growing season (Table 3), the highest total ash was found in the variety Amfora (24.96%) whereas the lowest in the variety Krušnica (19.64%). Based on the results of the Duncan's test, the tested varieties may be classified into the 8 statistically significant groups.

The highest content of soluble ash was recorded in leaves of the variety Amfora (21.78%) whereas the lowest in the variety SM-1 (13.82%). Based on the results of the Duncan's test, the tested varieties may be classified into the 7 groups.

Tab. 2 — Content of ash and macroelements in leaves of different pepper varieties at flowering

Variety	Total ash	Insoluble ash	Soluble ash	N	P	K	Ca	Na
	% in DM				mg % in DM			
ANITA	23.33 ab	2.21 ab	21.12 ab	3.94 bc	382 bc	3729 b	487 a	150 abc
VRANJSKA	21.95 cd	2.28 ab	19.67 c	3.77 c	327 cde	3709 bc	470 a	117 c
NOVOSAĐANKA	24.32 a	2.60 a	21.72 a	4.11 bc	545 a	3875 ab	471 a	104 c
AMFORA	23.88 ab	2.35 ab	21.54 a	4.06 bc	349 cd	4417 a	479 a	121 bc
UNA	20.93 de	1.66 ab	19.27 c	4.22 abc	278 def	3667 bc	241 d	100 c
PLAMENA	22.58 bc	2.04 ab	20.54 abc	4.03 bc	464 ab	3959 ab	325 bc	150 abc
SM-1	20.08 e	2.53 a	17.55 d	4.58 ab	180 g	3959 ab	276 cd	117 c
KRUŠNICA	21.68 cd	1.89 ab	19.79 bc	4.80 a	247 efg	3375 bcd	356 b	121 c
L-127	21.33 cde	1.44 b	19.89 bc	4.29 abc	484 a	3083 cd	330 bc	200 a
LOMBARDIJA	21.07 de	1.61 ab	19.47 c	4.15 abc	215 fg	2833 d	294 bcd	175 ab
Average	22.11	2.06	20.05	4.19	347	3660	373	135
$LSD_{0.05}$	1.27	0.91	1.32	0.60	85.90	586.60	67.22	50.26

The differences in the content of insoluble ash of the pepper leaves suggest the classification of the tested varieties into the 6 statistically significant groups, where the highest content of insoluble ash was found in the variety Vranjska (3.69%) whereas the lowest in the variety Una (2.59%).

Based on the number of statistically significant groups, one may conclude that the chemical heterogeneity of pepper plants was greater at the end of the growing season when the differences between varieties were greater and the total ash was higher.

Tab. 3 — Content of ash and macroelements in leaves of different pepper varieties at the end of growing season

Variety	Total ash	Insoluble ash	Soluble ash	N	P	K	Ca	Na
	% in DM				mg % in DM			
ANITA	22.37 cd	2.65 c	19.72 bc	3.93 ab	154 c	3438 b	633 d	83 ab
VRANJSKA	22.30 cde	3.69 a	18.61 d	3.59 g	268 ab	2646 c	834 a	83 ab
NOVOSAĐANKA	22.79 b	3.15 abc	19.64 bc	3.87 bcd	267 ab	3563 b	693 cd	75 ab
AMFORA	24.96 a	3.18 abc	21.78 a	3.79 cde	189 c	4021 b	809 ab	92 a
UNA	22.56 bc	2.59 c	19.97 b	4.03 a	163 c	5021 a	685 cd	75 ab
PLAMENA	21.98 de	2.82 bc	19.16 cd	3.74 ef	194 ab	4688 a	760 abc	88 ab
SM-1	17.29 g	3.47 ab	13.82 f	3.54 g	192 c	2688 c	643 d	67 b
KRUŠNICA	19.64 f	3.16 abc	16.48 e	3.74 def	201 c	3625 b	701 cd	71 ab
L-127	21.94 e	2.74 bc	19.21 cd	3.63 fg	257 b	3980 b	693 cd	92 a
LOMBARDIJA	22.02 de	2.67 c	19.35 bc	3.90 abc	307 a	3688 b	701 bcd	83 ab
Average	21.78	3.01	18.77	3.78	229	3736	715	81
$LSD_{0.05}$	0.39	0.71	0.61	0.13	45.20	534.80	101.60	20.77

Nitrogen is the most widespread element in nature. In green plants, app. 50% of total nitrogen is found in leaf proteins while of that amount, more than 70% is bound in chloroplasts and only 10—20% or less is free in the form of nitrate or ammonia (S a r i ć et al., 1987). There is a close relationship between the growth of vegetative plant parts and the amount of available nitrogen (S o -

m o s, 1984). By analysing the nitrogen content in different parts of pepper plants, K a u f m a n n and V o r w e r k (1971) reported on its highest content in leaves (3.6%) and fruit (3.3%) while lower values were recorded in stem and root (app. 2%). According to M a r k o v i ć (1998), the highest N content was found in leaves and fruit (3.63% in leaf dry matter and 3.33% in fruit). Moreover, the highest nitrogen content was found in young pepper plants, gradually decreasing with senescence. M e c s (1974) in his work on seasoning pepper and the percentage of N during its growing reported on its highest content at flowering. Hot varieties contain more nitrogen than sweet ones. By analyzing the variability of the leaf nitrogen content (Tables 2 and 3) it may be concluded that the average nitrogen content was higher (4. 19%) at flowering than at the end of the growing season (3.78%). At the flowering stage, the highest nitrogen content was obtained with the variety Krušnica (4.80%) whereas the lowest with the variety Vranjska (3.77%), (5 statistically significant groups). At the end of the growing season, the highest nitrogen content was recorded in the variety Una whereas the lowest in the variety SM-1 (3.54%), (9 statistically significant groups).

In the pepper crop, content of P (essential element) is considerably lower than that of N. Its greatest accumulation is recorded at full flowering. The highest content of this element was recorded in pepper fruit while somewhat lower in leaves, stem, and root (M e c s, 1974). In pepper, phosphorus content is app. 10 times lower than that of nitrogen (200—300 mg %), decreasing from the beginning to the end of growing season. By comparing hot and sweet peppers, M e c s (1974) found that former contain higher phosphorus than latter. Phosphorus means (Tabs 1 and 2) were higher at flowering (347 mg %) than at the end of the growing season (229 mg %), confirming the data published elsewhere (G v o z d e n o v i ć and T a k a č, 2004). The highest P at flowering was recorded in the variety Novosađanka (545 mg %) whereas the lowest in the variety SM-1 (180 mg %). Differences in content of this macroelement were recorded between all the analyzed varieties except Novosađanka and L-127. At the end of the vegetation season, five varieties (Anita, Amfora, Una, SM-1 and Krušnica) showed no differences in content of this element, three varieties (Vranjska, Novosađanka and Plamena) exhibited somewhat higher P content with no mutual differences between varieties whereas the highest P was recorded in the variety L-127 (257 mg %) and Lombardija (307 mg %).

The role of K in plant respiration, photosynthesis, and synthesis and transport of carbohydrates, being essential for high yield and high quality of vegetables was analyzed (K a s t o r i, 1991). This element is present in plants in the form of ions, loosely bound to the protoplasmic colloids, as well as in the form of organic and inorganic salts (S a r i ć et al., 1987). The pepper crop contains considerable amounts of potassium. Its requirements for this element range from 140 to 210 kg/ha (K a s t o r i, 1991). According to S o m o s (1984), the largest portion of potassium is present in leaves (4700—6800 mg %) and stem (2600—4800 mg %) while its content in root is between 1900 and 3200 mg %. Potassium content in fruit is rather low, ranging from 2700 to 3400 mg %. The absolute amount of potassium in fruit showed low variations during the growing season (K a u f m a n n and V o r w e r k, 1971). In our investigations (Table 2), flowering values of potassium were classified into the 7 statistically significant groups. Potassium content in leaves ranged from 4417 mg % (Amfora) to 2833 mg % (Lombardija). Irrespective of pepper variety, averages amounted 3660 mg %. Average value at the end of the growing season was 3 660 mg %. The highest content was found in the variety Una (5 021 mg %) whereas the lowest in the variety SM-1. No significant variations between varieties were obtained, except the variety Una and SM-1.

The role of Ca in life processes of plants has many forms (M i x and M a r s c h n e r, 1976). The most important is maintenance of structure and function of cell membranes, nonspecific activation of certain enzymes, acid neutralization, and its impact on swelling of protoplasmic colloids (K a s t o r i, 1983). The highest Ca content is recorded in leaves, then stem and root whereas the lowest in seed. Its concentration increases with senescence (S a r i ć et al., 1987). During ripening, Ca content decreases in fruit whereas increases in leaves. According to M a r k o v i ć (1998), Ca content relies on pepper variety and plant organ, ranging from 0.60% to 3.60%. Our results (Table 2) show significant differences between the average Ca content in leaves at flowering (373 mg %) and at the end of the growing season (715 mg %).

The content of Na in plants relies on a great number of factors like plant species and environmental conditions. Na controls the osmotic pressure and takes part in neutralization of acids originated from different processes in plants. The uptake of Na ions increases with plant senescence (S a r i ć et al., 1987). According to S a n h e z - C o n d e (1970), sodium content in pepper plants may range from 1 to 2% compared with dry matter whereas F r e d e r i c k et al. (1962) quoted app. 10 mg %. The results presented in Table 2 show that the Na concentration in leaves showed far less values when compared with other elements. Its average content at flowering was 81 mg % while at the end of growing season it was 135 mg %. When compared with other macroelements, Na exhibited the smallest variability, irrespective of pepper variety and ontogenetic phase. Due to high requirements for mineral elements and supplementary irrigation, lengthen growing season, and genotype differences, for high yields this crop requires application of app. 8—120 kg/ha of nitrogen, 65—100 kg/ha of phosphorus and 140—210 kg/ha of potassium (K a s t o r i, 1991; L a z i ć et al., 1998).

CONCLUSION

Differences between pepper varieties in content of ash and mineral elements in leaves at flowering and at the end of growing season were recorded in this study. No significant differences between varieties in the content of insoluble ash, irrespective of developmental stage, were found while the highest total ash was found in leaves of variety Novosađanka and Amfora. As for the content of mineral elements in pepper leaves, nitrogen is ranked first, then potassium, calcium and phosphorus whereas sodium is the last. The results obtained clearly demonstrate the chemical heterogeneity of pepper varieties. This crop may be grown successfully only if specificity of its mineral nutrition is known.

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ГЕНЕТИЧКА ВАРИЈАБИЛНОСТ КОНЦЕНТРАЦИЈЕ МИНЕРАЛНИХ ЕЛЕМЕНАТА КОД РАЗЛИЧИТИХ СОРТИ ПАПРИКЕ (*CAPSICUM ANNUUM* L.)

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Резиме

Паприка (*Capsicum annuum* L.) представља једну од водећих повртарских култура а како се поједине сорте међусобно разликују по захтевима за минералном исхраном као и изношењем елемената из земљишта приносом потребно је испитати њихову генотипску специфичност. У раду је специфичност минералне исхране испитана одређивањем хемијског састава листа у фази цветања и на крају вегетације. Добијени резултати показују да је садржај укупног пепела у просеку износио у обе испитиване фазе око 22%, растворног 19—20%, нерастворног 2—3%. На основу резултата може се закључити да се у паприци од свих макроелемената највише накупља азот, одмах затим следе калијум, калцијум, фосфор, док натријума има процентуално најмање. Генотипске разлике нарочито су изражене на крају вегетације. Резултати указују да је у циљу успешне производње паприке неопходно водити рачуна о специфичним потребама сорти за минералним материјама.