PHOSPHORUS CONTENT IN SOIL AND IN FRESH AND COOKED RED BEET IN DEPENDENCE ON DIFFERENT FERTILIZATION

Marko PETEK [1] – Mirjana HERAK ĆUSTIĆ [1] – Lepomir ČOGA[1]– Marija PECINA[3]

[1] Department of Plant Nutrition, Faculty of Agriculture, University of Zagreb, Svetošimunska cesta 25, HR-10000 Zagreb, Croatia, mpetek@agr.hr
[2] Department for Vegetable Crops, Faculty of Agriculture, University of Zagreb
[3] Department of Plant Breeding, Genetics and Biometrics, Faculty of Agriculture, University of Zagreb

Abstract:
Three-year field fertilization trial with red beet (*Beta vulgaris* var. *conditiva*) was carried out in a hilly-mountainous part of Croatia. The trial was set up according to the Latin square method with four fertilization treatments (unfertilized control, 5 kg m^{-2} stable manure, and 50 and 100 g m^{-2} NPK 5-20-30). The highest soil phosphorus content was obtained in the treatment with 100 g m^{-2} NPK 5-20-30 or stable manure (up to 139 mg P_2O_5 kg^{-1} soil). In all three investigation years, the highest fresh and cooked red beet phosphorus content was recorded in the treatment with 5 kg m^{-2} stable manure (400 and 358 mg P 100 g^{-1} dry weight). The highest values were recorded in 2005, probably owing to very good agroecological conditions. Cooked red beet phosphorus content was 10 % lower than in fresh red beet in all trial years.

Keywords: *Beta vulgaris* var. *conditiva*, phosphorus, fertilization, soil

Introduction

Soil is a renewable natural resource, whose restoration can be, among others, enhanced by adequate fertilization (Varallyay, 2007). Daniel and Gyori (2000), cited according to Čoga et al. (2007), report that prolonged application of phosphorus fertilizers, produced from raw phosphates containing high amounts of Cd, may lead to an increase in soil Cd and its accumulation in plants; thereby reducing the nutritional value of plants. High yields can only be obtained through the application of optimal NPK doses in balanced proportions (Poljak et al., 2007). Optimal fertilization would enable production of vegetables of high nutritional value, the consumption of which would supply the organism with sufficient amounts of vitamins and amino acids (Ćustić et al., 2002), as well as minerals (Russo, 1996) because sustainable agricultural production processes focus on the conversion of agricultural products into final food products (Husti, 2006). Phosphorus mobility in soil is low because of the generally low solubility of phosphate compounds and the strong P-binding capacity of soil components (Kadar, 2007). Kadar and Erno (2000) report that *Beta vulgaris* L. does not have a high soil P content requirement (150-200 mg P_20_5 kg^{-1} soil). Lešić et al. (2004) report that 50 kg P is necessary for red beet yields of 60 t ha^{-1}. Phosphorus, along with nitrogen and potassium, is the most important biogenic macroelement, because it enters into the composition of phosphatides, nucleotides, nucleic acids and enzymes. Red beet is recommended for the prevention of cancer appearance and its treatment (Bobek et al., 2000). Lešić et al. (2004) and Kołota and Adamczevska-Sowińska (2006) report that red beet contains 30-66 mg P 100 g^{-1} dry matter, similarly to Maynard and Hochmuth (1997), and Bergmann (1992) reports 0.2-0.6% P, while Herak Ćustić et al. (2007) report that up to 6.2 g P_2O_5 kg^{-1} fresh weight can be found in red beet. Red beet can be consumed fresh or processed, most commonly preserved cooked. Lisiewska et al.

(2006) maintain that cooking does not cause loss of any large amount of minerals from red beet. The goal of this research was to assess the influence of different fertilization treatments upon phosphorus levels in soil after harvest and in the edible parts of fresh and cooked red beet.

Materials and methods

Three-year (2003-2005) fertilization trial with red beet (cultivar Bikor), laid out according to the Latin square method with four treatments (unfertilized control, 5 kg m^{-2} stable manure, and 50 and 100 g m^{-2} NPK 5-20-30), was conducted in Jastrebarsko (2003) and Otočac (2004 and 2005), Croatia. Beet seed was sown directly into soil in the third decade of May. Harvest was done in the third decade of August. Plant spacing was 0.07 m x 0.40 m; the main plot area was 12 m^2. Half of each beet sample was analyzed fresh and the other half was first cooked in distilled water and then analyzed. Dry homogenized samples of plant material (105 °C) and air-dry soil were analyzed in triplicate and the results are presented as mean values. Soil phosphorus was determined according to Egner et al. (1960), while plant phosphorus was determined by spectrophotometer after digestion with concentrated HNO_3.

Table 1. Climatic characteristic for meteorogical stations Jastrebarsko and Otočac

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Air Temperature (°C)												
1961-1991, Jastrebarsko	-0.4	1.1	5.9	10.6	15.6	18.7	20.7	20.2	15.6	10.8	4.9	0.9
1961-1991, Otočac	-1.0	0.1	3.9	8.9	14.1	17.8	19.7	19.0	13.9	10.5	5.0	0.1
2003, Jastrebarsko	-1.2	-1.7	6.1	10.3	18.2	23.1	22.0	23.4	14.8	8.8	7.3	1.3
2004, Otočac	-2.1	0.9	1.6	9.2	11.8	17.0	19.4	19.8	14.2	12.8	4.9	0.8
2005, Otočac	-2.8	-4.2	1.2	8.8	14.1	17.8	19.9	17.0	14.8	10.4	4.5	-0.2
Precipitation (mm)												
1961-1991, Jastrebarsko	54	51	60	70	74	100	78	87	105	92	88	76
1961-1991, Otočac	79	68	75	89	86	77	47	81	127	113	137	127
2003, Jastrebarsko	91	44	7	39	45	96	56	68	131	100	59	32
2004, Otočac	103	93	99	138	119	96	34	40	105	125	122	163
2005, Otočac	35	60	61	127	117	39	97	231	95	121	169	187

Statistical analysis was conducted according to two models of analysis of variance (ANOVA) by the Latin Square design: a) combined analysis of experimental data from the year 2003 to 2005 and two stata of red beetroot (fresh and cooked) as repeated measurements and b) separate analysis for each year individually (SAS, 2002-2003). According to precipitation and temperature data for growing periods of all three years, 2005 was agroecologically the most favourable year for red beet production (Table 1).

Results and discussion

Results of chemical analyses of phosphorus in soil and in fresh and cooked red beet are given in Table 2. In all three trial years, statistically significant differences were determined in post-harvest soil phosphorus contents in dependence on fertilization. In

2003 and 2005, the highest and statistically significant phosphorus amount was recorded in fertilization with 100 g m^{-2} NPK 5-20-30 (73 and 99 mg P_2O_5 kg^{-1} soil, respectively). In 2004, the highest soil phosphorus content was determined in fertilization with stable manure (139 mg P_2O_5 kg^{-1} soil), which is not statistically different from the treatment with 100 g m^{-2} NPK 5-20-30 (127 mg P_2O_5 kg^{-1} soil). In all three trial years (in 2003 and 2004 also statistically significant), the lowest soil phosphorus content was determined in the unfertilized control treatment (21, 89 and 54 mg P_2O_5 kg^{-1} soil, respectively). In all three trial years, the highest phosphorus content in fresh beet at harvest was recorded in fertilization with 5 kg m^{-2} stable manure (270, 224 and 400 mg P 100 g^{-1} dry matter, respectively).

Table 2. Mean values of investigated treatments, in the period 2003-2005, for phosphorus in soil, and fresh and cooked red beet

Year Y	**Fert** F	**Soil** P_2O_5 (mg kg^{-1})			**Red beet** P (mg 100g^{-1} Dry Weight)					
			F	Y	Fresh		Cooked		Mean	F	Y
2003	Unfertilized	21	*c*		198	*b*	163		180	*b*	
	Manure	47	*b*		270	*a*	234		252	*a*	
	NPK50	41	*bc*		200	*b*	174		187	*b*	
	NPK100	73	*a*		186	*b*	197		191	*b*	
Mean		46		*c*	213		192		202		*b*
2004	Unfertilized	89	*c*		175		158		167	*b*	
	Manure	139	*a*		224		198		211	*a*	
	NPK50	108	*bc*		197		184		191	*ab*	
	NPK100	127	*ab*		197		174		185	*b*	
Mean		116		*a*	198	*a*	179	*b*	188		*b*
2005	Unfertilized	54	*b*		367		358		363		
	Manure	69	*b*		400		350		375		
	NPK50	61	*b*		344		303		324		
	NPK100	99	*a*		373		331		352		
Mean		71		*b*	371		336		353		*a*
Mean											
	Unfertilized	55	*c*		247		226		236	*b*	
	Manure	85	*ab*		298		261		279	*a*	
	NPK50	70	*b*		247		221		234	*b*	
	NPK100	100	*a*		252		234		243	*b*	
Mean		77			261		235		248		

§ Factor level means accompanied by different letters are significantly different, with error $p \leq 0.05$ according to Tukey's HSD test. Means without any letter indicate no significant differences

In 2005, phosphorus contents of fresh beet, as compared to the other two years, were significantly highest (344 to 400 mg P 100 g^{-1} dry matter). These values are in agreement with the literature data (Lešić, 2004; Kołota and Adamczevska-Sowińska, 2006; Maynard and Hochmuth, 1997; Bergman, 1992). Such situation in 2005 can be attributed to the most favourable agroecological conditions at the critical time of the growing period compared to the other two years. In all three trial years, no statistically significant differences between treatments were determined in cooked red beet in particular years while, like in fresh beet, relatively highest values were recorded in 2005. In general, it can be pointed out that the phosphorus content of cooked beet

decreased significantly ($p \leq 0.01$) by 10 % in all three years compared to fresh beet, which is somewhat higher decrease than reported by Lisiewska et al. (2006). This is also corroborated by strong correlations between fresh and cooked beet for each trial year (r=0.619, r=0.987, r=0.787, respectively). No statistically significant differences were determined in interactions between trial factors.

Conclusions

The highest phosphorus content values in fresh and cooked red beet were determined in fertilization with 5 kg m^{-2} stable manure. Phosphorus content of fresh beet decreased by 10 % compared to cooked beet. Fertilization with 100 g m^{-2} NPK 5-20-30 resulted in the highest post-harvest phosphorus content in soil. Based on the research results, combined fertilization with stable and mineral fertilizers is recommended for red beet.

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