

Varietal Differences in Phosphorus Content on Soils with Low pH

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Abstract: Phosphorus (P) is an essential nutrient required by plants for normal growth and development. P deficiency has been identified as one of major limiting factors of crop production in various soils throughout the world. P deficiency in acid soils is related to their more acid reaction, relatively heavier texture and more intensive P fixation capacity.

This paper presents results of an investigation on the content of phosphorus in cereal grains and straw as dependent on genotype and mineral nutrition. Fifty different varieties and lines of wheat, barley and oat were tested under different mineral nutrition treatments. The investigation was carried out in a vegetation trial in pots containing soil with highly acid reaction and a high content of mobile aluminium. The phosphorus content in grain and straw of different cereals varied considerably, being dependent on the investigated species and genotypes, as well as on mineral nutrition. A considerably higher P content was found in cereal varieties tolerant of low pH of soil, in the control (slightly acid soil), as well as under treatments with superphosphate and CaCO₃. The lowest P content in grains and straw was found under the treatment without P.

Key words: genotype, phosphorus, soils, low pH.

Introduction

Phosphorus (P) is an essential nutrient required by plants for normal growth and development (Mengel and Kirkby 2001). P deficiency has been identified as one of major limiting factors of crop production in various soils throughout the world. Phosphorus deficiency is a common mineral nutrition problem in both calcareous soils and acidic soils due to the formation of poorly soluble P complexes with calcium in alkaline and aluminum and iron in acidic soils (Bojić *et al.* 1997, Bosković-Rakočević and Bokan 2004, Gessa *et al.* 2005).

Phosphorous deficiency depresses plant growth. The leaf area of the plant is significantly reduced, whereas the chlorophyll content is generally not affected or even increased, making the darker green color of leaves a typical symptom of P deficiency (Marschner 1995). From an agronomic perspective, the strong reduction in the formation of reproductive organs under P deficiency makes adequate P supply to plants an important precondition for sufficient crop yields.

Phosphorus content in plants is closely related to soil acidity and Al content in the nutrient solution and in plants (Mengel and Kirkby 2001). Some acid soils have a considerable P fixation capacity, resulting in a deficiency of the nutrient to plants (Vance 2003). An increased Al content was found to be related to high P concentration in plants and significant differences emerged between the tested varieties (Barcelo *et al.* 1996). The mineral composition of plants changes in the presence of Al (Foy *et al.* 1989). In Al-treated plants, P concentration tended to decrease in the above-ground plant parts and to increase in the root. Plant phosphorus content is dependent on species and genotype. Different species and genotypes grown under identical conditions showed different accumulation of P. Under low pH and increased Al contents in the nutrient solution, Al-tolerant species and genotypes, P concentration was reduced in the above-ground plant parts (Foy *et al.* 1989, Osborne and Rengel 2002).

This study aimed at determining the effect of different nutrition treatments under low pH of soil on the accumulation of phosphorus in different cereal species and genotypes.

Materials and Methods

The experiment included 12 cultivars of winter wheat, 7 of spring barley and 7 of spring oats. The P content of grain and straw was determined in the following cultivars - wheat cultivars: Minister Dwarf; Pai Yu Pao; Mara; Skopljanka; Dobrudza; Norin 10; Peking 8; Morava; Zemunka; Seneca; Leda; KG-56; barley cultivars: Kraguj; Jantar; L-30/20; Dunavac; ZA-84; Jastrebac; Midzor; and oat genotypes: Slavuj; Rajac; Lovcen; L-10; L-18; L-24; L-30.

The trial was conducted in pots on very acid, Al toxic Vertisol soil [pH_(KCl) < 4.5]. The following treatments were used:

- K**—control—soil with a slightly acid reaction + 30 µg NPK per g of soil;
- H**— very acid soil + 30 µg/g NPK;
- HCa**— very acid soil + 30 µg/g NPK + 200 µg/g CaCO₃;
- HP₀**— very acid soil + 16 µg/g KAN + 6.6 µg/g KCl;
- HP₁**—very acid soil + 30 µg/g NPK + 25 µg/g superphosphate.

NPK was 15:15:15; CAN (27% N); superphosphate (17% P₂O₅) and KCl (60% K₂O). CaCO₃ in the form of finely milled lime was applied just before sowing whereas the fertilizer solutions were added at the beginning of spring. The trial was carried out over two years with three replications. Sowing was conducted in November. The plants were kept in a greenhouse during the winter and outdoors during the spring and summer. They were harvested at full maturity; measured and divided into grain and straw. Plant phosphorus concentration was established according to John (1970). The obtained data were evaluated by the analysis of variance and the significance between mean values was performed according to Mead *et al.* (1996).

Results and Discussion

The phosphorus content of cereal straw and grains varied significantly, being dependent on the investigated variety and mineral treatment (Table 1). It was significantly higher in the straw of the wheat cultivars Seneca and KG-56 than in that of other investigated cultivars. A considerable increase in P content of grain was found in wheat cultivars Minister Dwarf, Dobrudza and Seneca as compared to that of other investigated cultivars.

Tab. 1. P content of wheat straw and grain (mg/plant)

Treatments	Plant part	Varieties												Average
		1	2	3	4	5	6	7	8	9	10	11	12	
K	Straw	81	70	64	80	64	85	57	54	64	76	94	33	68
	Grain	410	563	316	407	451	467	504	376	346	195	352	385	398
H	Straw	110	67	53	71	34	40	60	54	60	77	60	51	61
	Grain	304	126	93	147	177	125	138	114	62	176	103	96	138
HCa	Straw	27	21	1	38	34	24	16	15	66	66	15	85	34
	Grain	68	12	1	57	77	36	21	54	12	177	6	15	45
HP ₀	Straw	24	20	26	31	76	47	33	23	45	39	19	35	35
	Grain	91	124	71	162	205	192	131	121	85	219	72	176	137
HP ₁	Straw	49	44	40	33	51	74	83	42	50	60	46	112	57
	Grain	310	200	18	188	285	219	234	233	202	425	131	261	237
Average	Straw	58	44	37	51	52	54	50	38	57	64	47	63	51
	Grain	237	205	126	192	239	208	206	180	141	238	133	187	191

LSD	A	B	AB	A	B	AB
0.05	7.23	4.67	16.17	27.60	20.87	72.31
0.01	9.56	6.17	21.38	32.34	27.60	95.60

Legend: (1) Minister Dwarf; (2) Pai Yu Pao; (3) Mara; (4) Skopljanka; (5) Dobrudza; (6) Norin 10; (7) Peking 8; (8) Morava; (9) Zemunka; (10) Seneca; (11) Leda; (12) KG-56; **A**—cultivar; **B**—treatments; **AB**—interaction

The cv. Mara, highly susceptible to low pH of soil (Jelic *et al.* 1998), had a very low content of phosphorus in the grains and straw of mature plants.

The P content of wheat grains and straw was significantly affected by different treatments (Table 1). The highest P content of cereal grains and straw was found in the control (slightly acid soil). This increase, compared to the other treatments conducted in highly acid soils, was particularly intensified in wheat varieties. The lowest P content was determined under the treatment without P. The use of P fertilizers in the form of superphosphate resulted in a significant increase of P accumulation in the plants, especially the grains. P content of grain and straw in mature wheat plants, as dependent on mineral treatment, is cultivar-specific, i.e. optimal P values should be determined for each variety.

The investigated barley varieties reacted differently to mineral nutrition (Table 2). All of them showed the lowest P accumulation under the treatment without P. However, the addition of P in the form of superphosphate and CaCO_3 led to a significant increase in P accumulation in barley grains. Also, significant differences in P content between different varieties indicated a varietal specificity of barley in terms of phosphorus nutrition.

Tab. 2. P content of barley straw and grain (mg/plant)

Treatments	Plant part	Varieties							Average
		1	2	3	4	5	6	7	
K	Straw	20	30	20	40	10	30	50	28
	Grain	320	350	280	340	350	260	330	318
H	Straw	30	30	30	40	0	40	40	36
	Grain	160	170	230	280	170	220	260	213
HCa	Straw	10	20	20	7	10	10	10	12
	Grain	1	60	90	60	80	30	60	54
HP ₀	Straw	30	20	30	30	30	50	30	31
	Grain	120	230	270	210	230	220	230	216
HP ₁	Straw	1	10	1	10	1	20	1	6
	Grain	350	240	300	320	370	290	380	321
Average	Straw	18	22	20	25	18	30	26	23
	Grain	190	210	234	226	240	204	252	222
LSD		A	B	AB	A	B	AB		
0.05		7.29	6.16	16.29	32.57	27.54	72.86		
0.01		9.68	8.18	21.64	43.27	36.58	96.76		

Legend: (1) Kraguj; (2) Jantar; (3) L-30/20; (4) Dunavac; (5) ZA-84; (6) Jastrebac; (7) Midzor;

A—cultivar; **B**—treatments; **AB**—interaction;

Phosphorus accumulation in oat plants varied considerably, being dependent on the investigated varieties and lines, as well as on mineral nutrition (Table 3). Significantly higher P accumulation was found in the grains of line 18 (L-18) and in the straw of cv. Slavuj. The absence of P fertilizer resulted in a considerable decrease of P accumulation in oat grains.

Tab. 3. P content of oat spring straw and grain (mg/plant)

Treatments	Plant part	Varieties							Average
		1	2	3	4	5	6	7	
K	Straw	50	60	60	30	60	60	40	51
	Grain	280	290	360	260	290	260	340	297
H	Straw	590	30	50	60	50	50	40	124
	Grain	320	180	240	200	260	280	320	257
HCa	Straw	18	36	16	20	22	20	23	22
	Grain	123	140	81	110	144	119	131	121
HP ₀	Straw	70	46	45	36	48	46	56	49
	Grain	274	214	236	277	301	271	341	273
HP ₁	Straw	47	42	30	46	78	68	64	53
	Grain	227	348	186	345	320	305	292	289
Average	Straw	155	43	40	38	52	49	45	60
	Grain	245	234	221	238	263	247	285	247
LSD		A	B	AB	A	B	AB		
0.05		7.29	6.16	16.29	23.04	19.47	51.52		
0.01		9.68	8.18	21.64	30.60	25.86	68.43		

Legend: (1) Slavuj; (2) Rajac; (3) Lovcen; (4) L-10; (5) L-18; (6) L-24; (7) L-30;

A–cultivar; **B**–treatments; **AB**–interaction;

The uptake of phosphates in soils with higher pH (around pH 6) is more intensified than the P uptake in soils having higher acidity (pH 4.5 to 5.0) (Baligar and Fageria 1997). This results in its deficiency and low content in the plants. Moreover, the presence of high amounts of Al in the medium reduces the uptake, transport and utilization of some essential elements, including phosphorus (Foy 1988).

Baligar and Smedley (1989) found that in the presence of 100 µmol/l of Al in the solution, the uptake of P and other essential elements is reduced 19–91%. In non-calcified soils, P content is reduced in the above-ground parts of susceptible varieties, whereas in tolerant varieties it either increases or does not change significantly. The tolerance to low soil pH and high Al content of Seneca and KG-56 wheat cultivars, Midzor and ZA-84 barley cultivars and most oat cultivars was reported in earlier research by the following authors (Jelić *et al.* 1998). The relationship between phosphorus nutrition and phosphorus content of plants and the tolerance of different cultivars and genotypes of cereal crops were reported by other authors as well (Kovačević *et al.* 2004, 2007).

Conclusions

The results of this study suggest the following:

Phosphorus content of grain and straw of different cereals changed considerably, being dependent on species, genotype and mineral nutrition. The lowest P content of grain and straw was found under the treatment without P fertilization. The applied superphosphate and CaCO₃ induced a significant increase in P accumulation in grains and straw of cereal plants. The investigated cereal varieties and genotypes showed highly different P contents of grain and straw. The highest P

content was found in the wheat cultivars Seneca and KG-56, barley cultivars Midzor and ZA-81 and most oat cultivars and lines that had been found in earlier research to be tolerant of low pH of soil and high Al content in the solution.

References

- Baligar V. C., Fageria N. K. (1997): Nutrient efficiency in acid soils: nutrient management and plant use efficiency. In Moniz A. C. *et al.* (eds), *Plant-Soil Interactions at Low pH-Sustainable Agriculture and Forestry Production*, Brazilian Soil Science Society Campinas/Vicosa, 75-95 pp.
- Bojić M., Bokan N., Rakočević-Bošković Lj., Stevović V. (1997): Effect of Different Materials on Mobile Aluminium (Al^{3+}) Neutralization with Maize Growing *Acta Agriculturae Serbica*, **4**: 67-71.
- Baligar V. C., Smedley D. M. (1989): Responses of forage grasses to aluminium in solution culture. *Journal of Plant Nutrition*, **12** (6): 783-796.
- Barcelo J., Poschenrieder Ch., Vazquez M. D., Gunse B. (1996): Aluminium phytotoxicity. In Rodrrigues-Barrueco C. (eds) *Fertilizers and Enviromnent*, 405-411pp.
- Bošković-Rakočević Lj., Bokan N. (2004): The effect of the acidity-neutralizing materials applied on the morphological traits of maize. *Acta Agriculturae Serbica*, **18**: 55-64.
- Foy C. D. (1988): Plant adaptation to acid, aluminum-toxic soils. *Commun. Soil Sci. Plant Anal.*, **19**: 959-987.
- Foy C. D., Dewald C. L., Berg A. W. (1989): Differential tolerances of two old world blustem genotypes to excess aluminium in acid soil and nutrient solution. *Journal of Plant Nutrition*, **12** (10): 1231-1254.
- Gessa E. C., Mimmo T., Salvatore D., Marzadori C. (2005): Effect of aluminium and pH on the mobility of phosphate through a soil-root interface model. *Plant and Soil*, **272**: 301-311.
- Jelić M., Stojanović J., Lomović S., Milivojević J. (1998): Response of some cultivars of cereals on soil acidity and Al toxicity. *Breeding and Small Grains. Proceedings*, 415-421.
- John M.K. (1970): Colorimetric determination of phosphorus in soil and plant materials with ascorbic acid. *Soil Science*, **109** (4): 214-220.
- Kovačević V., Brkić I., Šimić D., Bukvić G., Rastija M. (2004): The role of genotypes on phosphorus, zinc, manganese and iron status and their relations in leaves of maize on hydromorphic soil. *Plant, Soil Environm.*, **50** (12): 535-539.
- Kovacevic V., Seput M., Andric L., Sostaric J. (2007): Response of maize and soybeans to fertilization with phosphorus and potassium on acid soil. *Cereal Research Communications*, **35** (2): 645-648.
- Marschner H. (1995): *Mineral Nutrition of Higher Plants*. 2nd edn., Academic Press, London.
- Mead R., Curnow R. N., Hasted A. M. (1996): *Statistical methods in agriculturae and experimental biology*. Chapman & Hall, London.
- Mengel K., Kirkby E. A. (2001): *Principles of plant nutrition*. Kluwer Acad. Publ., Dordrecht, Boston, London.
- Osborne L. D., Rengel Z. (2002): Genotypic differences in wheat for uptake and utilisation of P from iron phosphate. *Aust. J. Agr. Res.*, **53**: 837-844.
- Vance C. P., Uhde-Stone C., Allan D. L. (2003): Phosphorus acquisition and use: critical adaptations by plants for securing a nonrenewable resource. *New Phytol.*, **157**: 423-447.

SORTNE RAZLIKE U SADRŽAJU FOSFORA U ZEMLJIŠTU NISKE PH VREDNOSTI

- originalni naučni rad -

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Rezime

Fosfor (P) je jedan od esencijalnih hranljivih elemenata potrebnih biljci za normalan rast i razvoj. Utvrđeno je da nedostatak P predstavlja jedan od glavnih ograničavajućih činilaca u ratarskoj proizvodnji na brojnim tipovima zemljištima širom sveta. Nedostatak P u kiselim zemljištima povezan je sa njihovom kiselom reakcijom, relativno težom strukturom i intenzivnijom sposobnošću vezivanja fosfora.

U radu su prikazani rezultati ispitivanja sadržaja fosfora u zrnu i slami žitarica u zavisnosti od genotipa i mineralne ishrane. Ispitano je 26 različitih sorti i linija pšenice, ječma i ovsu u različitim varijantama mineralne ishrane. Istraživanja su izvedena u kontrolisanim uslovima u vegetacionim sudovima sa zemljištem ekstremno kisele reakcije i visokim sadržajem mobilnog aluminijuma. Sadržaj fosfora u zrnu i slami različitih žitarica u značajnom stepenu je varirao u zavisnosti od ispitivanih vrsta i genotipa, kao i mineralne ishrane. Značajno veći sadržaj P utvrđen je u genotipovima tolerantnim prema niskoj pH vrednosti zemljišta, na kontrolnoj varijanti, kao i na varijantama na kojima su primenjeni superfosfat i CaCO_3 . Najmanji sadržaj P u zrnu i slami ispitivanih genotipova konstantovan je na varijanti bez primene P u ishrani biljaka.