Temporal variability of available phosphorus, potassium and magnesium in arable soil

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ABSTRACT

The investigation is focused on the illustration of the temporal changes in spatial variability of the Mehlich III available phosphorus, potassium and magnesium in the 10.5 ha part of the whole 54 ha field, located near Český Brod. Soil is characterized as Orthic Luvisol. To estimate temporal variability of available nutrients, soil samples were taken in 2001–2003 four times per year (twice in spring and twice in the autumn periods). For the description of field variability of selected soil parameters coefficient of variation (*CV*), experimental variograms with fitted models and relative nugget effect parameters have been used. Three year results shows that the lowest temporal variability, characterized by relative nugget effect had available Mg (4–23%) and P (13–29%) and K (15–49%).

Keywords: temporal variability; spatial variability; phosphorus; potassium; magnesium; Mehlich III

Development of Global Positioning Systems (GPS) and Geographical Information Systems (GIS) and their utilization in commercial field were not first tools for description of spatial differences in soils, but many years ago mapping soil spatial variability was studied (Cline 1944 – cit. Pierce and Sadler 1997, Le Clerq et al. 1962). These studies and new results show that the spatial variability of soil properties vary from sampled field.

Plant nutrition optimising based on site-specific application of fertilizers can not go without accomplished spatial variability of soil agrochemical properties mapping where excepting pH the soil available phosphorus, potassium and magnesium are very important parameters. The higher spatial variability of parameters mentioned above, the higher opportunity of variable rate application of P, K and Mg fertilizers. Wollenhaupt et al. (1994) relate soil available P, K and Mg to the properties with medium spatial variability.

Soil agrochemical properties are affected from large amount of soil processes, which are working together but their activity and interaction vary both in time and space. Peck and Melsted (1973) suggest that existing of seasonal variability of soil test results are going to change because of factors affecting the nutrient uptake by plants and nutrient replenishment of soil solution (sorption, desorption, water transport, soil microbial activity, soil pH, CEC). Experiments focused on soil sampling time effect on the spatial variability of soil available nutrients (P, K, Mg), previously published with different results. Although Kowalenko (1991) and Hoskinson et al. (1999) detected distinct soil available nutrient content derived from spring and autumn sampling period, Dampney et al. (1997), Pierce and Nowak (1999) and Štípek (2003) stated that the spatial variability of soil available nutrients was not influenced by the different sampling time. Discrepancy of the published results can be according to the results of Zbíral (2001), due to extraction method used in soil tests. While a higher variation in the soils available nutrient content obtained using weak extraction (0.01M $CaCl_2$ e.g.) methods can be expected, and strong extraction methods, where an official method of soil testing in the Czech Republic (Mehlich III) is included, can minimize seasonal fluctuation of soil available nutrient level.

Satisfactory high spatial variability together with low temporal change in soil available nutrient content, determined using appropriate soil test gives an assumption for the cost benefit of mapping soil agrochemical properties and variable-rate application of fertilizers.

MATERIAL AND METHODS

The study of spatial heterogeneity of soil properties at Klučov field of area 54 ha (Orthic Luvisol) located near Český Brod, was examined (Brodský et al. 2001, 2004, Borůvka et al. 2002). To investigate temporal variability of soil available phosphorus, potassium and magnesium the highest spatially variable part of experimental field with an area of 10.5 ha was chosen. Soil samples were collected

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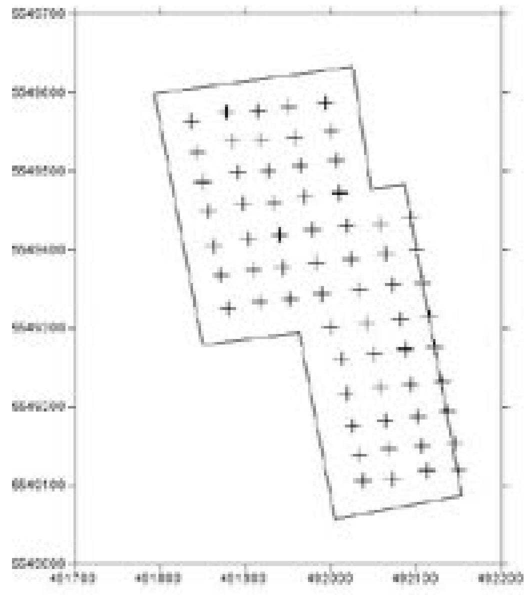

Figure 1. Soil sampling points

from the topsoil (0–30 cm) using the point sampling method with a regular grid square pattern 40 × 40 m. The soil sampling point map is presented in Figure 1. All point sample locations were recorded as x, y coordinates with GPS receiver Garmin II+ in datum WGS-84. 14 individual core samples taken from each point with a 3 m radius from a centre point represent an appropriate soil sample for analysis. Soil samples were taken in 2001–2003 period always two spring and two autumn times (Table 1). A set of soil samples was homogenized, air-dried and sieved on the mesh. Fine earth fraction was analysed for Mehlich III available P, K and Mg. The Scalar (San System) segmented continuous flow analysis with photometric detector was used for the detection of P. The Spectr AA-300 (Varian) atomic absorption spectrometer was used for the detection of K and Mg.

Table 1. Soil sampling times

1st collection	6.4.2001
2nd collection	27.4.2001
3rd collection	12.10.2001
4th collection	15.11.2001
5th collection	29.3.2002
6th collection	16.4.2002
7th collection	1.10.2002
8th collection	30.10.2002
9th collection	24.3.2003
10th collection	15.4.2003
11th collection	10.11.2003
12th collection	28.11.2003

Table 2. Results of used reference material

Reference material (ppm)	W 99-2-3		
	P	K	Mg
Certified	56	140	232
Measured	54	139	233

Quality assurance of analytical data was ensured by repeated measurements of certified reference material obtained from the International Soil Analytical Exchange organized by WEPAL (University of Wageningen, Netherlands). Characteristics of the used reference materials are summarized in Table 2.

Summary statistics data were processed using Statgraphics v.4. Experimental variograms with fitted models were processed in software GS+. To express the level of spatial dependence was used the relative nugget effect [Co/(Co+C)] described in Cambardella and Karlen (1999).

RESULTS AND DISCUSSION

The soil agrochemical properties data sets, obtained from soil analysis, were initially evaluated using basic statistics parameters. Results summarized in Table 3 show available P average from 19 to 29 ppm. Average values of available K ranged between 134 and 216 ppm and available Mg from 118 to 139 ppm, respectively.

The highest spatially variable was soil available P content with coefficient of variation (*CV*) from 50% in the last collection time to 64% (7., 8. and 11. time of sampling). These results reflect, in contrast to Hoskinson et al. (1999), a stable level of spatial variability. This fact is strengthened by a correlation coefficient between the first collection data set and the others. To evaluate the spatial dependence of the soil available P data sets experimental variograms with fitted models were constructed (Figures 2 to 4). The data sets derived from 1st, 5th and 9th sampling time compared in this case. Relative nugget effect presented as [Co/(Co+C)] ranged from 13 to 29% which means a strong spatial dependence of soil available P. Almost the same semivariance shape and generally low soil available P content in this field, allow to say that neither spatial variability of soil P nor site-specific application of P fertilizers, derived from soil analysis results was affected by the different sampling times.

Soil available K variability derived from coefficient of variation shows relatively low levels (*CV* = 17–31%). However relative nugget effect varied from 15% in 5th sampling time to 49% in the last period shows medium and strong spatial depend-

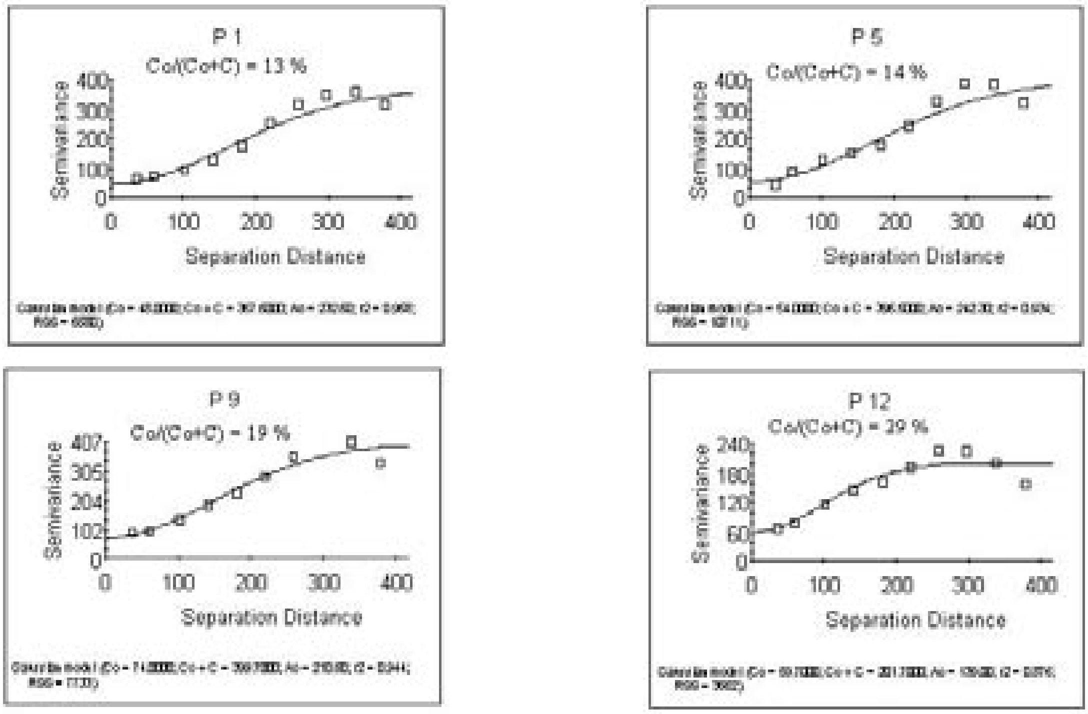

Figure 2. Isotropic variograms of the 1st, 5th, 9th and the last sampling time P data sets

Table 3. Summary statistics of soil available nutrients (P, K, Mg) in the experimental field over the period 2001–2003

	Sampling time	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
P (ppm)	average	26	28	24	25	29	28	19	23	25	26	25	24
	min	8	8	8	9	9	7	5	7	9	10	6	10
	max	67	69	60	71	70	75	53	57	67	66	86	65
	SD	14.1	17.0	13.3	15.4	14.6	16.5	12.4	14.6	15	14	16	12
	median	21	22	19	18	25	24	16	16	18	20	18	21
	CV (%)	54	61	56	62	51	58	64	64	60	54	64	50
	R^2		0.9270	0.8899	0.8725	0.8912	0.9310	0.8768	0.8804	0.8905	0.8960	0.8550	0.7985
K (ppm)	average	190	177	204	202	216	203	183	179	207	199	142	134
	min	131	101	140	67	144	144	123	100	132	139	48	86
	max	299	265	363	382	327	298	321	280	320	326	213	288
	SD	35.1	32.6	42.8	44.0	42.0	35.0	39.6	36.3	41	40	44	31
	median	188	174	192	194	215	199	176	183	203	193	150	128
	CV (%)	18	18	21	22	19	17	22	20		20	31	23
	R^2		0.6902	0.7059	0.6323	0.5023	0.7293	0.4453	0.3373	0,7306	0.6977	0.4414	0.6081
Mg (ppm)	average	138	137	138	139	131	131	118	119	130	123	125	128
	min	100	79	95	46	96	86	81	77	104	98	89	96
	max	192	188	174	182	166	173	269	157	160	161	174	198
	SD	20.5	21.1	16.2	20.1	15.5	18.4	24.9	18.8	14	13	20	22
	median	135	135	137	138	129	129	113	118	132	123	125	123
	CV (%)	15	15	12	14	12	14	21	16	11	11	16	17
	R^2		0.8075	0.8438	0.7853	0.8309	0.8731	0.4599	0.6591	0,8016	0.8384	0.8305	0.6105

R^2 means the correlation coefficient between the 1st sampling time data set and the others

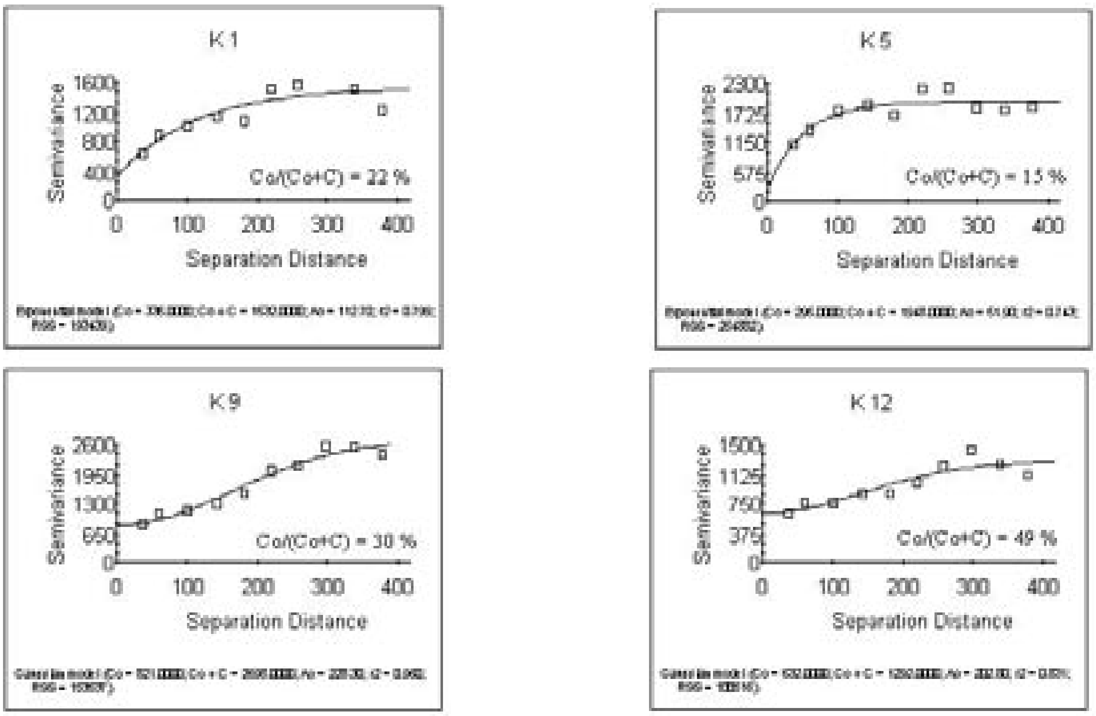

Figure 3. Isotropic variograms of the 1st, 5th, 9th and the last sampling time K data sets

ence of soil available K. Correlation coefficients differences and different shape of experimental variograms showing the change in soil spatial variability of the soil available K content. A distinct change in the average and median of the derived data is not apparent. This means that most of an experimental field has convenient and good soil available K content. Similarly to soil P content, the temporal variation in soil available K content did not influence site-specific application of K fertiliz-

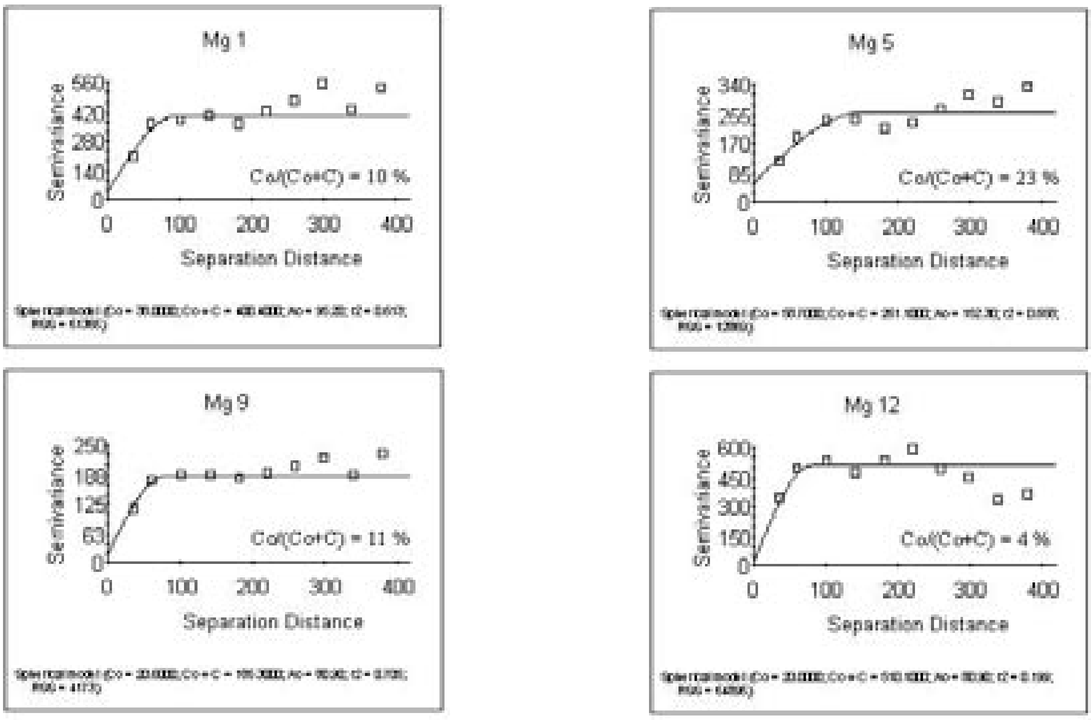

Figure 4. Isotropic variograms of the 1st, 5th, 9th and the last sampling time Mg data sets

ers, derived from soil analysis data. Differences in soil available K in samples, taken in diverse sampling time could be influenced by various soil moisture condition.

The spatial variability of soil available Mg content characterized by coefficient of variation fluctuated in range 11–24%. These established low amounts are in consistent with results of Dampney et al. (1997) and Štípek (2003). However relative nugget effect ranged between 4 and 23% of the total semivariance, which means moderate to a strong spatial dependence. Spatial variability derived from data sets of 1st, 5th and 9th and the last sampling time does not differ from each other.

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ABSTRAKT

Časová variabilita obsahu přístupného fosforu, draslíku a hořčíku na orné půdě

Na vybraném pozemku o výměře 54 ha byla vybrána část o rozloze 10,5 ha s nejvyšší úrovní prostorové variability obsahu přístupného P, K a Mg ve výluhu Mehlich III. Z tohoto území byly v průběhu tří let (2001–2003) odebírány opakovaně vzorky půdy z čtvercové sítě bodů 40 × 40 m a byla analyzována časová variabilita obsahu přístupných živin (P, K a Mg). Dosažené výsledky ukazují nejnižší časovou proměnlivost, charakterizovanou relativním efektem nugget, u obsahu přístupného Mg (4–23 %), následuje P (13–29 %) a K (15–49 %).

Klíčová slova: časová variabilita; prostorová variabilita; fosfor; draslík; hořčík; Mehlich III

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