SOIL PHOSPHOROUS AND POTASSIUM APPARENT RECOVERY BY FIELD CROPS

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Abstract. *Data from 72 field trials using the same layout was carried out in four locations in Latvia during 2008-2012 was used. Experimental crops: winter and spring wheat, winter rye, winter and spring rape, spring barley and potatoes. In each experiment soil before planting of crops was tested in two depths: 0-20 cm and 20-40 cm and plant available phosphorous and potassium (Egner-Riehm method) was determined. Using data of bulk density, PK content was transformed on 0-20 and 0-40 cm soil layer and expressed as tons per ha. Apparent recovery of soil PK (soil PK recovery efficiency) was calculated as the difference in PK uptake in plots not receiving fertilisers and PK content in the soil (kg ha^{-1}) within the depth of 0-20 or 0-40 cm and expressed as a proportion of these two values. It was found that soil phosphorous apparent recovery in average consisted as 8.68% if calculated based on 0-20 cm soil layer or 4.96% – if calculated based on 0-40 cm soil layer and has small differences depending on crops. Soil potassium recovery was significantly different depending on crops. In average cereals and rape utilised 12.76% from its content in 0-20 cm soil layer or 6.79% from content in 0-40 cm soil layer. Potatoes – 62.04% and 32.81% subsequently. It is possible to use the developed soil phosphorous and potassium recovery factors for fertilising planning in situations where PK containing fertilisers are used regularly and residual effect of its is applications is prospective.*

Key words: *fertiliser recommendations; plant nutrient utilisation; soil fertility tests.*

INTRODUCTION

The effective use of nutrients is the main goal for fertiliser use planning. Additionally nitrogen and phosphorous management has a great environmental concern. Soil is the primary source of nutrients for crops and therefore assessment of its nutrient supplying power has a great interest. Nutrient pool, its availability, abiotic and biotic factors regulating plant nutrient uptake by crops are the topics having importance for research and practical farming. As normally crops utilise only part of nutrients applied by fertilisers, some accumulation of low mobility ones like phosphorous and potassium under periodical fertilisation could happen. These nutrients might have the certain positive residual effect on the next crops and therefore could be taken into account in fertiliser planning.

Investigations done by several authors concerning phosphorous availability reveal that phosphates in the soil are deposited on solid particles by help of adsorption, absorption and chemical reactions [2-3]. Phosphorous is fixed on the surface on clay particles, carbonates, Fe and Al oxides or incorporated into its structure. Fixation energy could differ due to the composition of solid phase and therefore desorption processes might be different, some part of phosphates are more mobile and are able to return back in the soil solution, another part – are more immobile. Plant available soil phosphorous is crop limiting factor only below the certain critical level and therefore not always are necessary to return back amount off-taken by yield annually [2-3]. Building up the soil phosphorous using increased rates of fertilisers not always is the best way of farming strategy. Probably it is better to define some optimum soil phosphorous (as well as potassium) range in which moderate annual PK applications could provide crops with nutrients.

The main purpose of this publication is to discuss about the possibility of crops to utilise the soil phosphorous and potassium under its annual applications and to access the soils' PK apparent recovery.

MATERIALS AND METHODS

Data from field trials carried out in 2008-2012 was used. All together 72 field trials using the same layout was carried out in four locations of Latvia – Peterlauki (56º 32′, 23º 43′), Priekuli (57º 18′, 25º 20′), Vecauce (56º 28′, 22º 52′) and Stende (57º 11′, 22º 33′). The experiments were laid out in a randomised complete block design at each site with four replicates of each treatment. Plot size 20-25 m^2 (depending on crop). In each trial 9 fertilising treatments were compared but for this publication only plots not receiving fertilisers were used. After harvesting yield of main product and by-product was accounted and phosphorous and potassium in content the yield was determinate. Taking into consideration this values, PK uptake was calculated (the main product plus by-product without postharvest residues).

Soils in experimental sites were typical for Latvia agricultural land. In Peterlauki *Endoprotocalcic Chromic Stagnic Luvisol* (*Clayic*, *Cutanic*, *Hypereutric*), silty clay loam/clay; in Priekuli *Endoeutric Endoluvic Stagnosol* (*Drainic*, *Loamic*), fine sandy loam; in Vecauce *Calcaric Luvic Endostagnic Phaeozem* (*Protoanthric*, *Loamic*), sandy loam/loamy sand and in Stende *Eutric Stagnic Retisol* (*Cutanic*, *Drainic*, *Loamic*), sandy clay loam (WRB, 2014) [3]. Every year before establishment of experiment, soil sampling was done and following parameters were analysed for the depth of 0-20, 20-40 and 40-60 cm of topsoil: pH in 1 *M* KCl suspension, plant available phosphorous and potassium (Egner-Riehm method), organic carbon (Tyurin's method). For transformation of soil organic carbon data to soil organic matter (SOM), Van Bemmelen factor – 1.724 was used. Soil density and field water capacity was also determinate for every depth of soil (undisturbed sample saturation in 100 mL steel cylinders). Using data of bulk density, PK content was transformed on 0-20 and 0-40 cm soil layer and expressed as tons per ha. Apparent recovery of soil PK (soil PK recovery efficiency) was calculated as the difference in PK uptake in plots not receiving fertilisers and PK content in the soil (kg ha^{-1}) within the depth of 0-20 or 0-40 cm and expressed as a proportion of these two values.

For data processing standard methods of descriptive statistics (correlation, variance, *t*-test) was used.

RESULTS AND DISCUSSION

Soil fertility characterization is given in Table 1. As experimental plots were located in the different fields annually, parameters differ. In most cases soil phosphorous and potassium level is medium to high or very high according rating used for soil fertility tests in Latvia. These soils are periodically receiving phosphorous and potassium fertilisers and are not nutrient depleted. Therefore the further discussion will be only for situation, when crops were not treated with PK fertilisers for one year (one growing season) but not for the long time.

Table 1

Soil properties in experimental sites

Location	pH KCl	Soil organic matter, %	P_2O_5	K_2O
			mg kg^{-1}	
0-20 cm				
Peterlauki	6.6-7.2	1.9-3.1	102-240 (M/H)*	153-295 (M/H)
Priekuli	4.6-6.3	1.9-3.1	115-258 (M/VH)	93-232 (M/H)
Vecauce	6.3-7.3	1.9-2.7	133-391 (H/VH)	90-240 (M/H)
Stende	5.3-6.7	1.9-2.7	83-251 (M/VH)	126-189 (M/H)
20-40 cm				
Peterlauki	6.6-7.4	1.3-2.6	59-171 (L/H)	119-256 (M/H)
Priekuli	4.6-6.3	1.5-2.3	65-191 (M/VH)	102-260 (M/H)
Vecauce	6.4-7.2	1.8-2.3	122-374 (H/VH)	86-220 (M/H)
Stende	5.2-6.4	0.9-2.3	59-208 (L/VH)	101-178 (M/H)

* **Note:** in parenthesis – nutrient value: L – low, M – medium, H – high and VH – very high.

Crop yield and PK uptake by crops' yield is shown in Table 2. Yield data are given in two columns – A plots not receiving any fertilisers, or "pure zero", but column B – plots received PK fertilisers but without nitrogen. Data shows, that there were very little yield increase due to PK fertilisation if the nitrogen was absent. One year PK fertiliser lack was not the limiting factor for plant growth. Crops' yield obtained in experimental plots was comparatively high taking into consideration that nitrogen fertilisation was not applied.

PK uptake by yield is given for situation when no any fertilisers were used for crops, e.g. "pure zero". Share of soil for providing crops nutrient requirements is rather considerable. This type of plant nutrient uptake could be rather referred as biological uptake, e.g. nutrients necessary to be absorbed by plants during the vegetation. Only share of PK in roots and stubble is absent. Normally by-products of potatoes and rape always are left on the field but straw of cereals – depending on farmers needs. This type of plant nutrient uptake does not show exactly that part of nutrients, which is removed from field due to the commercial activity. These values depend on farming practice, which could differ year by year.

Table 2

Crop yield and phosphorus and potassium uptake by main and by-product

Crop	Location	Yield, t ha^{-1}			Uptake by yield, kg ha^{-1}	
		main product**		by-product		
		A	B	A	P_2O_5	K_2O
Winter wheat	Peterlauki (8)*	5.03	5.19	7.55	48.86	96.44
	Stende (8)	5.85	6.14	4.85	52.40	67.03
Spring wheat	Peterlauki (5)	3.85	4.01	4.52	46.17	49.34
	Stende (3)	3.32	3.47	4.16	47.70	53.08
Rye	Priekuli (7)	3.76	4.14	3.93	39.51	51.06
	Stende (8)	5.52	5.97	5.81	55.48	88.64
Spring barley	Peterlauki (5)	3.79	3.97	3.03	38.95	49.78
	Priekuli (3)	2.74	2.90	2.89	29.11	39.71
	Stende (3)	3.22	3.07	2.14	34.23	36.07
Winter rape	Peterlauki (4)	2.88	2.81	5.02	48.04	82.41
	Vecauce (4)	2.15	2.23	4.52	47.83	87.63
Spring rape	Peterlauki (3)	1.36	1.40	3.02	29.09	44.66
	Vecauce (3)	1.37	1.54	3.56	34.38	50.55
Potatoes	Priekuli (8)	31.10	31.75	12.40	42.31	252.06

Note: * in parenthesis – number of trials;
** column A – plots not receiving any fertilisers,
column B – plots receiving only PK fertilisers.

Soil phosphorus and potassium apparent recovery was calculated in two ways – only for topsoil (0-20 cm) and for all depth to the 40 cm (Table 3-4). Normally the second assumption is more reasonable for crop root distribution and therefore for plant nutrient absorption. But in soil fertility tests usually only top 20 cm is sampled and analysed considering that so called plough layer is more or less homogenous as a result of periodical mixing. In Latvia situation this tillage layer usually is somewhere between 25 to 30 cm deep, deeper than 0-20 cm layer but more shallow as 0-40 cm. For practical purposes the use of topsoil (0-20 cm) data is fully acceptable.

Soil phosphorous recovery was at the range from 4.11 to 12.37% if calculated on the 0-20 cm soil layer basis. There is not so important crop influence compared with soil type, if it is grouped according to the WRB principles. Spring wheat was able to recover from *Luvisol* 11.74±2.84% of phosphorous but only 6.59±4.08% from *Retisol*. *Retisol* and *Stagnosol* was also less providing phosphorous source for spring barley, but *Phaeozem* – for winter rape.

Soil potassium apparent recovery was higher – from 6.45±3.24% to 20.13±6.11%. Very high it was for potatoes – 62.04±13.17% because this element has high concentration in both parts of yield – in tubers as well as in leaves. There was a small difference in soil potassium recovery taking into consideration soil type. Only for spring rape recovery rate from *Phaeozem* was significantly higher compared with *Luvisol*.

Analysis of variance showed that there were not significant differences in phosphorous and potassium recovery from the soil by winter wheat, rape and potatoes depending on location of experiment, crop variety and meteorological conditions of year. For rye significant impact was observed only by year conditions.

Table 3

Soil phosphorous apparent recovery, %

Crop	Soil	Apparent recovery, %			
		0-20 cm		0-40 cm	
		mean	standard deviation	mean	standard deviation
Winter wheat	*Luvisol*	11.88	1.63	6.95	0.97
	Retisol	11.28	6.40	6.56	3.64
Spring wheat	*Luvisol*	11.74	2.84	6.92	2.32
	Retisol	6.59	4.08	3.48	1.58
Rye	*Stagnosol*	7.93	4.30	4.32	2.47
	Retisol	12.37	7.51	6.21	3.55
Spring barley	*Luvisol*	9.86	3.54	5.73	2.42
	Stagnosol	4.60	0.14	2.82	0.25
	Retisol	4.11	0.54	2.28	0.14
Winter rape	*Luvisol*	10.13	5.08	6.03	2.96
	Phaeozem	5.93	1.27	3.24	0.76
Spring rape	*Luvisol*	5.34	3.24	3.22	1.43
	Phaeozem	5.76	2.73	2.99	0.20
Potatoes	*Stagnosol*	10.06	1.56	6.11	0.82

Table 4

Soil potassium apparent recovery, %

Crop	Soil	Apparent recovery, %			
		0-20 cm		0-40 cm	
		mean	standard deviation	mean	standard deviation
Winter wheat	*Luvisol*	17.86	6.96	10.11	3.92
	Retisol	14.82	3.51	7.75	1.91
Spring wheat	*Luvisol*	9.16	2.98	4.81	2.43
	Retisol	8.24	0.76	3.84	0.08
Rye	*Stagnosol*	12.81	5.50	7.01	3.13
	Retisol	20.13	6.11	10.25	3.63
Spring barley	*Luvisol*	7.51	3.82	4.59	1.36
	Stagnosol	6.46	1.31	3.49	0.89
	Retisol	6.52	2.15	3.00	0.66
Winter rape	*Luvisol*	15.28	8.09	8.66	4.49
	Phaeozem	18.17	3.10	9.51	1.21
Spring rape	*Luvisol*	6.45	3.24	3.79	2.03
	Phaeozem	16.54	2.30	8.32	1.20
Potatoes	*Stagnosol*	62.04	13.17	32.81	5.10

As it is important for practical purposes to assess the soil phosphorous and potassium supplying potential from the topsoil, some calculations of correlation between PK content in soil and its apparent recovery was done (Table 5). In average the correlation was higher for soil phosphorous with exception for potatoes, compared with soil potassium. High correlation of these parameters for potassium was for spring rape, winter rape and potatoes.

Table 5

Correlation between PK content in 0-20 cm and apparent recovery

Crop	Phosphorous	Potassium
Winter wheat	-0.81	-0.10
Spring wheat	-0.81	-0.36
Rye	-0.71	-0.40
Spring barley	-0.67	-0.58
Winter rape	-0.86	-0.74
Spring rape	-0.63	-0.98
Potatoes	-0.48	-0.70
All crops, average	**-0.67**	**-0.41**

Average values of soil phosphorous and potassium apparent recovery by certain crop and also for all crops are given in Table 6. These values could be used for practical purposes in fertilising planning depending on methods of soil testing – only for 0-20 cm or for 0-40 cm depth. There was small difference in phosphorous recovery if to include all the crops in one single average value, or to separate values between cereals, rape in one hand and potatoes on the other hand. But such distribution is important for assessment of soil potassium recovery values.

Table 6

Soil phosphorous and potassium apparent recovery, % (average values)

Crop	Phosphorous		Potassium	
	0-20 cm	0-40 cm	0-20 cm	0-40 cm
Winter wheat	11.58	6.76	16.34	8.93
Spring wheat	9.17	5.20	8.70	4.33
Rye	10.15	5.27	16.47	8.63
Spring barley	6.19	3.61	6.83	3.69
Winter rape	8.03	4.64	16.73	9.09
Spring rape	5.55	3.11	11.50	6.06
Cereals, rape	**8.45**	**4.77**	**12.76**	**6.79**
Potatoes	10.06	6.11	62.04	32.81
All crops, average	**8.68**	**4.96**	**19.80**	**10.51**

CONCLUSIONS

Soil phosphorous and potassium pool is important source for crops' PK requirement and its apparent recovery factors could assess the share of these recourses for plant nutrition.

It is possible to use the developed soil phosphorous and potassium recovery factors for fertilising planning in situations where PK containing fertilisers are used regularly and residual effect of its is applications is prospective.

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