Phosphorus concentration in soil and in winter wheat plants

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Abstract

Mineral nutrition is one of the most important factors affecting plant processes. The aim of the experiments was to test one of the main macronutrients, phosphorus (P), for its effect on wheat yield, and to determine the biological need for P at defined periods of plant growth. The studies were conducted as a field trial at the Experimental Station of Latvia University of Agriculture for two years with four winter wheat varieties with different nitrogen applications. P_2O_5 concentration was determined at the three Zadoks Growth Stages (32, 51, and 69). P concentration in the three plant parts: leaves, stems and ears was also determined at these growth stages. Leaf P_2O_5 concentration from the middle of stem elongation until late flowering decreased by 0.8 % for no-nitrogen variant and 0.1 % for N_{120} variant. Stem P_2O_5 concentration changed by 1.0 % for the N_0 variant and by 1.5 % for the N_{120} variant between ZGS-32 and ZGS-69. Close correlation was found between P concentration in wheat leaves and P concentration in soil at depth 0-20 cm and 20-40 cm at ZGS 51. P concentration in leaves at ZGS 51 was negatively correlated with grain yield. There was a negative correlation between grain yield and soil P concentration.

Media summary

Field trials were established to obtain a theoretical foundation describing phosphorus distribution between plant parts in relation to soil phosphorus because till now we have only experiential investigation.

Key words:

Nutrient uptake, phosphorus concentration, vegetative growth, Triticum aestivum L., grain yield, soil

Introduction

Mineral nutrition is one of the most important factors affecting plant processes. Soil physical and chemical characteristics greatly affect the phosphorus (P) nutrition of plants (Karaman at al. 2001). It is the nutrient most frequently limiting yield on newly farmed and formerly unfertilized soils. Phosphorus is the most 'temperamental' of the major crop nutrients, with low mobility and efficiency of use (Tivy, 1990). In winter wheat, response to plant nutrients is different between growing seasons. Several researchers (Elkina, 2001; Gyori et al., 1996) have concluded that the observed differences during nutrient accumulation are dependent on the geographic location of the site. The optimal concentration of a nutrient differs with the specific phase of plant development. (Gyori et.al., 1996) reported that the optimal nitrogen (N) and P concentrations in dry matter of winter wheat leaves, that is, N-2.5 to 3.6 %, P_2O_5 - 0.22 to 0.33 % at ear time-anthesis applied to crops growing in different geographically diverse zones. This study was conducted to examine the relationships between soil P and plant P at defined periods of plant growth and wheat yield.

Methods

A field trial was conducted over two years (1998 and 1999) at the Experimental Station of Latvia University of Agriculture. The soil was a sod-calcareous medium loam with the following agrochemical properties (0-20 cm depth): humus content – 1,7-2,3 %, pH_{KCl} 6,6-7,0, available phosphorus concentration 105-130 mg/kg, available potassium 150-210 mg/kg (method of Egner – Riem (Jekabsone et.al. 1997)). Before sowing, basal fertilizer NPK(6:24:30) 200 kg/ha was applied. There were four winter wheat varieties with different nitrogen applications: early -season and medium intensive variety Donskaja polukarlikovaja (DON) with fertilizer NH_4NO_3 regime N-60+60 and Sirvintas-1 (SIR) with two fertilizer regimes (N-0, and N-60+60); and late, and intensive variety Moda (MOD) with three nitrogen regimes (N-

0, N-60+60, and N-60+70+40), and Bussard (BUS) (N-60+70+40). Split nitrogen dressing was applied in the following way:

- at an early period of vegetation for the first time;
- at an end of shooting into stalks for the second time;
- at an end of shooting into ears for the third time.

There were four replicates, and the data presented are the averages for 2 years.

The material for plant analyses was collected at the Zadoks Growth Stage (Zadoks at.al. 1974) (ZGS) 32 (beginning of shooting into stalk), at the ZGS 51 (beginning of shooting into ears), at the ZGS 69 (end of flowering). Total P concentration (P_2O_5) in leaves, stems, and ears was determined (Jekabsone, 1997). Plant material was dried, ground and a subsample ashed in a muffle furnace. The ash was heated with nitric acid and then extracted with a solution of calcium lactate. P in solution was determined colorimetrically by a molybdate / stannous chloride method. At the three Zadoks Growth Stages soil was sampled down to 60 cm depth from each field to determine total P concentration using standard lab methods. P concentration (P_2O_5) in soil was analyzed by means of the vanado-molybdate method after dry digestion (Jekabsone, 1997). The method was based on the analysis described for plant tissue (above) but before extraction with calcium lactate, the soil was dried.

During the experimental period, meteorological conditions differed year by year. In 1998, the start of the vegetation period was favorable; rainfall in May and July was more than 288% and 160% of the norm, respectively. In 1999, spring was early. The average temperature exceeded the norm by 3,4^{o}C in April and by 2,8^oC in June. April and May were characterized by lack of rainfall (54 % and 70 % of mean). Rainfall in June exceeded the norm by 112 %. July was also dry (rainfall 67 % of mean). The plants suffered from deficient moisture.

Results

The P concentration in leaves at 3 growth stages is shown in Table 1. Leaf P_2O_5 concentration from the middle of stem elongation until late flowering decreased by 0.8 % for the N-0 variant and 0.1 % for N_{120} variant (Table 1). Stem P concentration (data not shown) changed by 1.0 % for the N_0 variant and by 1.5 % for the N_{120} variant to compare ZGS-32 and ZGS-69. P concentration in leaves is relatively stable compared to other nutrient elements (Karele and Ruza, 2001).

The mean values for total P concentration measured in the 0-20 cm layer of each plot, each year are shown in Table 1 (data for the 20-40 and 40-60 cm layers is not presented).

Table 1. Phosphorus concentration in wheat leaves (%P_2O_5) and in soil at 0-20cm depths (P_2O_5 mg/kg) at 3 times of sampling

Variant Cultivars/ N treatments	ZGS 32		ZGS 51		ZGS 69	
	Leaves	Soil	Leaves	Soil	Leaves	Soil
DON N60+60	1.74?0.1	94?11.3	1.06?0.1	100?8.4	1.28?0.5	120?9.1
SIR N-0	1.46?0.4	99?12.4	1.20?0.1	116?5.4	1.02?0.2	103?8.2
SIR N60+60	1.10?0.2	58?10.0	1.03?0.2	79?4.3	0.82?0.3	150?10.3

MOD N-0	1.48?0.4	154?15.3	1.29?0.1	100?7.3	1.14?0.3	181?11.3
MOD N60+60	1.67?0.1	78?7.8	0.99?0.1	65?3.6	1.01?0.1	94?6.8
MODN60+70+40	1.68?0.1	99?12.6	1.05?0.1	102?5.1	1.21?0.1	92?4.1
BUS N-60+70+40	1.43?0.5	63?8.5	1.06?0.2	79?4.7	0.90?0.2	71?3.6

There was no significant correlation between P concentration of winter wheat above ground plant material and P concentration in different soil depth layers, except a close correlation between P concentration in wheat leaves and soil P at depths 0-20 and 20-40 cm (Fig.1.) at beginning of shooting into ears (r=0,81-0,92) at $LSD_{0.05}$=0.754. Consequently, most intensive P uptake from soil to plant leaves was at beginning of shooting into ears (ZGS 51).

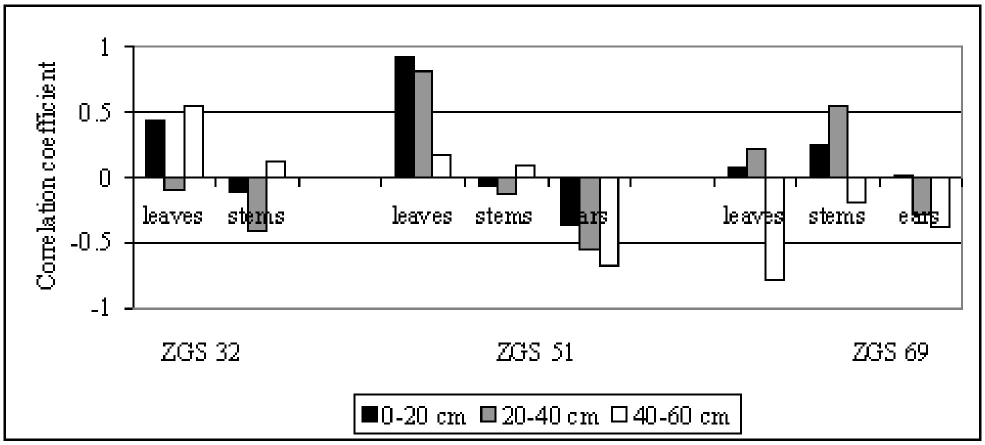

Figure 1. Correlation between phosphorus concentration in soil and winter wheat plant parts for 7 variants: 4 varieties with different nitrogen application

Figure 2. demonstrates the relation of P concentration in soil at depth 0-20 cm and P concentration of winter wheat leaves at ZGS 51 which could be represented by a straight line thus there were obtained the following regression equations: R=401,85x-333,8. This is the exception in Fig.1. A close negative correlation was found between P concentration in wheat leaves and P concentration in the soil at depth 40 – 60 cm at the end of flowering (r=-0,79).

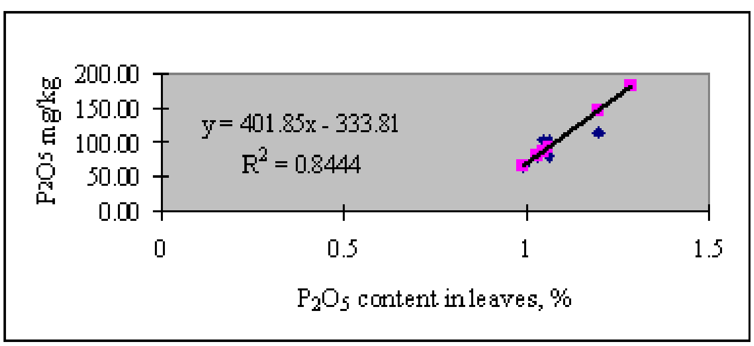

Figure 2. Relation between phosphorus concentration in soil at depth 0-20 cm and phosphorus concentration of winter wheat leaves at ZGS51 for four cultivars with different nitrogen application average in two years.

There was close negative correlation between P concentration in leaves and grain yield at ZGS-51 (Fig.3.). But, at the end of flowering there was a close positive correlation between P in ears and grain yield. Consequently, P concentration is one of the factors important for yield.

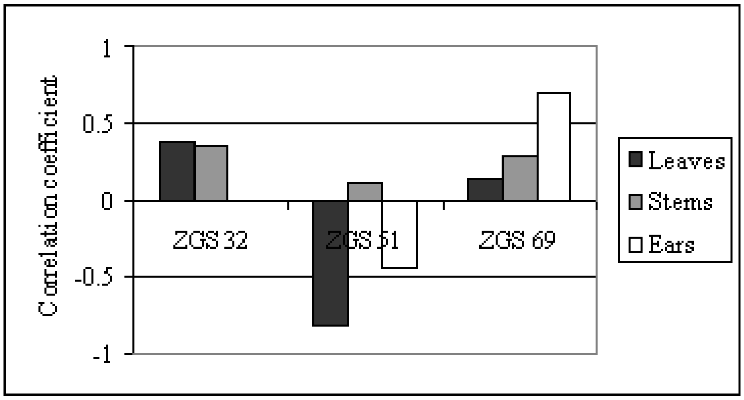

Figure 3. Correlation between phosphorus concentration in winter wheat plant parts and grain yield.

The correlation between grain yield and soil P concentration was found to be negative at depth 20-40 cm at ZGS 32 (Fig.4.).

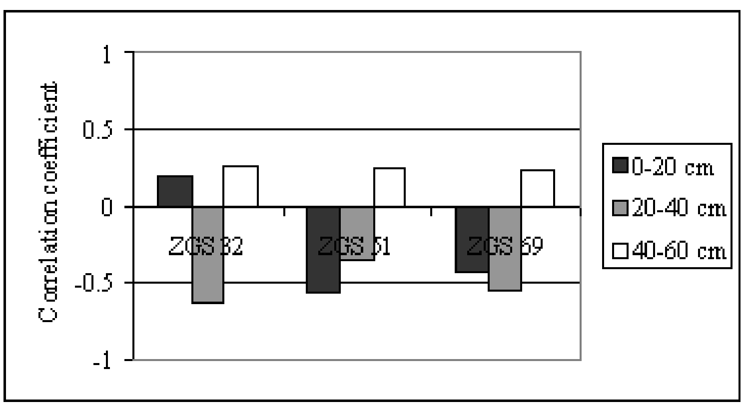

Figure 4. Correlation between P_2O_5 concentration in soil and grain yield

Conclusions

Concentrations of P_2O_5 decreased in the leaves throughout the season. Leaves had the major proportion of P concentration in young plants. Close correlation was found between P concentration in wheat leaves and P concentration in soil at depth 0-20 cm and 20-40 cm at ZGS 51. P concentration of winter wheat leaves at ZGS 51 had essential effect on grain yield and had close negative correlation among the distribution of P concentration in leaves and grain yield at ZGS-51. There was found a negative correlation between grain yield and soil P concentration at 20-40 cm depth at the beginning of shooting into stalk.

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