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Response of winter wheat to ameliorative phosphorus fertilization

Mirta Rastija, Jurica Jović, Dario Iljkić, Vlado Kovačević, Domagoj Rastija

University of J. J. Strossmayer in Osijek, Faculty of Agriculture, Kralja Petra Svačića 1d, Osijek, Croatia (mrastija@pfos.hr)

Abstract

In order to observe the response of different field crops in rotation, a field trial of increasing phosphorus fertilization was conducted in the 2011 in the Posavina Canton (Federation of Bosnia and Herzegovina) on a calcareous alluvial soil neutral reaction and poorly supplied with available phosphorus. P_2O_5 rates of 75, 225, 375, 525 and 975 kg ha^{-1} were applied. The effects of ameliorative phosphorus fertilization on the grain yield and some agronomic and quality traits of winter wheat grown in 2011/2012 season were shown. Response of wheat to phosphorus fertilization was less emphasized. Increased phosphorus amounts raised wheat grain yields up to 1.2 t ha^{-1} at the highest rate compared to basic fertilization, but no significant differences among phosphorus levels were determined. Increased yield is mainly a result of high ears density obtained at the fertilization treatments. Thousand grain weight and hectoliter weight as well as proteins, starch and gluten contents were not affected significantly by any treatment.

Keywords: winter wheat, yield, phosphorus fertilization

Introduction

Phosphorus is a macronutrient who plays a numerous important roles in plants. It is one of the most scarce plant nutrient and often represent the major limiting factor for crops yield. (Hinsinger, 2001., Vance et al., 2003.). According to some estimates, 5.7 billion hectares of the world's arable land has an insufficient amount of available phosphorus to maintain optimum crop production (Batjes, 1997). Unlike other macronutrients, the phosphorus concentration in the soil solution is often very low and ranges from 2 to 10µM (Raghothama,1999; Brady and Weil, 2002). In addition, due to the unique properties of the interaction of phosphorus with other elements, up to 80% of added phosphorus fertilizer can be fixed in the soil (Holford, 1997).

There are many factors that affect the phosphorus availability, but soil pH is the most important one, as solubility of the phosphate compounds are directly related to the soil pH. Phosphorus availability is limited both in acidic and alkaline soils. Most studies confirm that phosphorus mobility is the greatest between pH 6.0 to 6.5. It is well-known that at lower and higher pH, phosphorus can form the insoluble phosphate compounds. Phosphorus fertilization is very important factor for high yield achievement (Lott et al., 2011). Soils prone to phosphorus fixation need larger amounts of phosphorus fertilizer. Ameliorative fertilization or applications of higher phosphorus amounts can improve the soil fertility of phosphorus deficient soils and increase crops yields (Petošić et al., 2003). Some researches indicated that residual effect of phosphorus lasts longer than that of potassium (Kadar et al., 2010). Wheat have high phosphorus requirement, especially during the early growth stages, as phosphorus affects rooting and tillering. Phosphorus deficiency could limits the wheat yield by reducing the number of ears per area due to a poor tiller emergence (Rodriguez et al., 1999).

This research aimed to study the effects of increased phosphorus levels on the grain yield and some agronomic and quality traits of winter wheat.

Material and methods

A field trial of increasing phosphorus fertilization was conducted in the spring of 2011 in the Posavina Canton (Federation of Bosnia and Herzegovina) on a calcareous alluvial clay soil in order to observe the response of different field crops in rotation. A soil analysis prior to setting up the trial showed that soil is neutral reaction, quite rich in organic matter and potassium content, but very low in available phosphorus (Table 1).

Table 1. Soil chemical properties (0-30 cm depth) at the beginning of trial

pH (H_2O)	pH (KCl)	Org. matter	$CaCO_3$	AL-P_2O_5	AL-K_2O
		%	%	mg 100 g^{-1}	
8.03	7.06	4.17	3.79	5.4	25.65

Field trial was set up in a randomized complete block design in four replications. The size of basic plot was 60 m^2. Phosphorus fertilization treatments consisted of five rates as folows: 75, 225, 375, 525 and 975 kg P_2O_5 ha^{-1}. Basic phosphorus fertilization (75 kg P_2O_5 ha^{-1}) were done with superphosphate, while the source of P four increasing rates was monoammonium phosphate (MAP) containing 13% N and 53 % P_2O_5. In the next season trial was fertilized for wheat when experimental area received in total 153 kg N, 45 kg P_2O_5 and 45 kg K_2O. Soybean was grown in the 2011 as a previous crop, and winter wheat (cultivar Katarina) was sown at the end of October and harvested at the begining of July of 2012. Area of 1.0 m^2 was manually harvested from each plot for yield and ears number determinations. Wheat yield was calculated on 13% basis grain moisture. Protein and starch content in the grain were determined by near infrared spectroscopy (Infratec 1241, Foss Tecator). Data were statistically analyzed by ANOVA and t-test procedure at 0.05 probability level.

Table 2. Weather characteristics for winter wheat growing season 2011/2012 and 30-year mean values (Gradiste Weather Bureau)

Year/Month	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Sum
	Precipitation (mm)									
2011/2012	30	5	63	32	51	3	90	76	39	389
1961-1990	59	59	50	41	36	42	53	66	81	487
	Air temperatures (°C)									Mean
2011/2012	11.0	2.6	4.0	3.2	-3.4	9.5	13.0	16.9	22.8	8.7
1961-1990	11.3	5.6	1.7	0.3	2.4	6.9	11.5	16.7	19.6	8.4

The main features of 2011/2012 was drought in the beginning of growing season during early growth, dry and warm March, mild December and January and very cold February. The rest of the season was adequate regarding water amount for grain forming and filling. Total precipitation from October to June was 389 mm or about 20% less than 30-year mean, while the mean air temperature was slightly higher (Table 2).

Result and discussion

Average wheat grain yield (6.78 t ha^{-1}) was satisfactory, but response of wheat to phosphorus fertilization was less emphasized. Increased phosphorus amounts raised wheat grain yields up to 13% or by 1.2 t ha^{-1} at the highest rate, compared to basic fertilization, but there were no significant differences among phosphorus levels (Table 3). Increased yield is mainly a result of high ears density obtained at the fertilization treatments. It is well-known that tillering *i.e.* ears number per unit area represent very important yield component. Fioreze et al. (2011) reported that higher P levels increased tiller emergence, survival and yield, especially for secondary tillers. On the other hand, thousand grain weight, as well as hectolitre weight was somewhat lower than usual, and ranged from 31.3 to 33.1 g and 76.8 to 77.8 kg, respectively. Quality traits also were independent on fertilization, but baking quality regarding gluten content was relatively high (Table 3).

Table 3. Response of winter wheat to ameliorative phosphorus fertilization

Fertilization P_2O_5 kg ha^{-1}	Grain yield t ha^{-1}	Ears per m^2	1000 grain weight g	Hectolitre weight kg	Proteins %	Starch %	Wet gluten %	Total gluten %
75	6.21 b	756 b	33.0	77.8	12.6	67.0	32.5	33.7
225	6.90 a	795 b	32.9	77.3	13.4	66.3	32.5	37.5
375	6.81 a	831 b	32.2	76.8	12.7	67.0	32.2	32.9
525	6.94 a	840 ab	33.1	76.8	12.9	66.6	32.2	34.0
975	7.04 a	952 a	31.3	76.8	13.5	65.6	34.3	37.7
Average	6.78	835	32.5	77.1	13.0	66.5	32.7	35.2
$LSD_{0.05}$	0.54	116	ns	ns	ns	ns	ns	ns

Values followed by the same letter are not significantly different at $P \leq 0.05$ level

In the first year of experiment, when soybean was grown, at the treatment with 375 kg P_2O_5 ha^{-1} soybean grain yield increased by 20% compared to control. Further phosphorus doses did not gradually increase yield, but they affected grain quality and increase protein content (Antunović et al., 2012). Komljenović et al. (2010) reported about maize response to phosphorus ameliorative fertilization up to 1750 P_2O_5 in a four year experiment on a acid soil very poor in available phosphorus, where treatments considerably increased yield, but like in present study, there were no significant diferences among increasing P rates, what authors explained by interactions with weather conditions.

Many studies confirmed that the effects of ameliorative phosphorus fertilization are under great influences of weather characteristics. In the years characterized by adequate water supply better efficiency of fertilization as well as wheat yield and baking quality could be expected (Pepó, 2007).

Also, besides the pH, phosphorus availability depends on a number of other factors, such as organic matter, clay and heavy metal content, temperature, soil water-air relations and microbial activity. Drought, lack of oxygen, and especially low temperature can prevent the phosphorus uptake. Absence of a stronger response of wheat in this experiment could be attributed to a complex interactions of environmental factors.

Further research is needed regarding plant and soil analysis to reveal a residual effects of high phosphorus application. In a long-term experiment in Hungary on a calcareous soil poorly supplied with phosphorus, residual effect of superphosphate was evident eight years after initial application of 720 kg P_2O_5 ha^{-1}, as wheat grain yield was higher by 1.5 t ha^{-1}. Moreover, the residual effect of build-up P rates was measurable even 20 years after application (Kadar et al., 2010).

Conclusions

Response of wheat to ameliorative phosphorus fertilization in the second year after application was generally less pronounced although at the highest rate grain yield increased by 1.2 t ha^{-1}, but no significant differences among phosphorus levels were ascertained. Increased yield is primarily a result of high ears density, while phosphorus application didn't affect thousand grain weight. Further research and observing of trial is necessary to reveal the effects of high phosphorus application. Next step should be plant and soil analyses in order to determine the actual soil phosphorus availability. In the following years, the residual effects of ameliorative fertilization on the field crops in crop rotation could be expected.

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