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Impact of Ameliorative Phosphorus Fertilization on Soil, Maize and Wheat Status

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Authors' contributions

This work was carried out in collaboration between all authors. Author BS conducted of the experiment, field works. Authors MM and VK did the field works, performed statistical analyses, managed literature searches. Author VK wrote the protocol and wrote the first draft of the manuscript. Authors DI and RS performed analyses grain quality parameters. All authors read and approved the final manuscript.

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ABSTRACT

Acid reaction and nutritional imbalances, mainly low levels of plant available phosphorus (P) are often limiting factors of soil fertility in Bosnia and Herzegovina (B&H). The aim of this study was testing the impact of ameliorative P fertilization on soil properties and status of maize and wheat on acid soil (pH in 1n KCl: 4.0) of Tuzla Canton in B&H.
The experiment of increasing rates of P fertilization has been started in spring of 2013. The experiment was conducted by randomized complete block design in four replicates (basic plot 63 m^2). Monoammonium phosphate (12% N + 52% P_2O_5) was added to standard fertilization (kg ha^{-1}: 150 N + 50 P_2O_5 + 50 K_2O) in amounts as follows (P_2O_5 kg ha^{-1}): 75, 475, 875, 1275 and 1675. In the next two years only standard fertilization was applied for crop rotation maize (2013) – maize

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(2014: crop was complete damaged by flood) – winter wheat (2014/2015).
By increasing P rates the contents of mobile P were increased from 7.66 mg P_2O_5 100 g^{-1} to 20.10 mg P_2O_5 100 g^{-1} or 2.6 times. Also, maize yields were considerably increased up to 17%. (6.68 and 7.82 t ha^{-1}, for control and the highest rate of applied P, respectively). Yield of wheat was significantly increased by P fertilization up to 14% (4.35 and 5.02 t ha^{-1}, for control and the highest P rate respectively). However, for significant improvement of baking quality parameters (protein, wet gluten and sedimentation) the lowest P rate in level 475 kg P ha^{-1} was sufficient.

Keywords: Grain yield; grain quality; wheat; maize; phosphorus fertilization.

1. INTRODUCTION

The soils of Bosnia and Herzegovina (B&H) are generally not so favorable for physical and chemical properties. Acid reaction and nutritional unbalances, mainly low levels of plant available phosphorus (P) are oft limiting factors of soil fertility [1-3] in Bosnia and Herzegovina (B&H). It is estimated that about 25% of agricultural land of B&H are pseudogley or similar soils [4]. Also, the mean consumption of mineral fertilizer per hectare of arable land was 19.5 kg ha^{-1} on 1022000 ha in B&H for 2005-2009 periods [5].

Usual recommendations for improvement of physical and chemical properties of pseudogley and other acid soils are liming, enrichment with organic matter and adequate mineral fertilization, especially with phosphorus [6-13].

The aim of this study was to the impact of ameliorative phosphorus fertilization on soil properties and status of maize and wheat on acid soil of Tuzla Canton in B&H.

2. MATERIALS AND METHODS

2.1 The Field Experiment

The experiment of increasing rates of phosphorus fertilization was started on April 16, 2013. A soil plot owned by the Fruit Tree Nursery Srebrenik (Tuzla Canton, B&H) was selected based on the previous soil test (pH in 1n KCl: 4.0; mobile phosphorus determined by the AL-method: 6.6 mg P_2O_5 100 g^{-1}).

MAP (monoammonium phosphate: 12% N + 52% P_2O_5) was used as a source of phosphorus in amounts as follows (P_2O_5 kg ha^{-1}): 75 (a), 475 (b), 875 (c), 1275 (d) and 1675 (e).The experiment was conducted by randomized complete block design in four replicates (basic plot 63 m^2: nine 10-m long rows). These amounts of MAP were added to standard fertilization (kg ha^{-1}: 150 N + 50 P_2O_5 + 50 K_2O). In the next two years only standard fertilization was applied for crop rotation maize (2013) – maize (2014: crop was complete damaged by flood) – winter wheat (2014/2015).

Maize (the hybrid Pioneer 39F58-X105; FAO 250) was sown by the pneumatic sowing machine on planned density 68028 plants ha^{-1}) at the beginning of May and harvested in mid-October 2013. Maize was harvested manually. Four internal rows were harvested from each basic plot. Mass of ear was weighed by precise electronic balance. Grain yields were calculated on 14% grain moisture basis.

Sowing of winter wheat (cultivar *Srpanjka*) was prolonged to the beginning of November 2014 out of optimal term for sowing because of oversupply of precipitation in October. Wheat was harvested manually at the beginning of July 2015. Ears from square meter area (4 x 0.25 m^2) were cut and harvested by special trashing machine and weighed by precise electronic balance.

2.2 Sampling, Chemical and Statistical Analysis

Ten ears of maize from each treatment were used for determination of grain moisture and grain share in ear weighing by precise electronic balance. Grains of wheat originating from 1 m^2 harvested area were used as an initial sample for grain quality parameters determination.

Grain moisture of maize was determined by portable electronic grain moisture instrument (WILE-55, Agro electronics, Finland).

Realized plant density was determined by counting of plants from four harvested rows in level of basic plot and their addition in level of treatment (sum of four replicates).

Protein, starch, wet gluten and sedimentation value was determined by Near Infrared transmission spectroscopic method on Foss Tecator Infratec 1241 Grain Analyzer in Agrochemical laboratory of Agricultural Institute Osijek.

The data were statistically analyzed by ANOVA and treatment means were compared using t-test and at 5% probability levels ($P_{0.05}$).

Soil sampling to 25 cm of depth was made by auger at the beginning of March 2014.

Plant available P in soil was determined by the AL-method [14] while pH and organic matter were determined according to ISO standard. [15,16].

2.3 Weather Characteristics

Meteorological data (monthly values of precipitation and mean air-temperatures) of Federal Hydrometeorlogical Institute Sarajevo (Tuzla Weather Bureau 25 km distant from the experimental site) were used for characterization of the growing season with the aspect of maize (2013) and winter wheat (2014/2015) growing. Comparison of individual growing season weather characteristics was made based on 30-year averages (1961-1990).

In general, water deficit in combination with the higher temperatures in July and August is often in connection with low yields of maize. In accordance with the global climatic changes, air-temperature during maize growth of the first 15 years of 21st century in Tuzla were 17.4℃ or for 1.3℃ above LTM 1961-1990, with amplitude from 16.3℃ to 18.9℃ [17]. Based on observation of wheat yields in the last 15 years (2000-2014) precipitation similar to that which is usual, together with balanced monthly distribution characterized the more favorable growing season of wheat. while weather deviations as either drought or excessive precipitation in combination with high temperatures resulted in considerably lower yields in B&H [18]. Similar observations were found regarding impacts of weather characteristics on yields of winter wheat in Croatia and Hungary [19,20].

Precipitation in May-September period of 2013 was 364 or close to 20% below long-term average, while average air-temperature at same period was 18.4℃ or for 1.1℃ higher. However, in critical stages of maize need for water (July and August) precipitation and temperature regimes were mainly favorable for maize. With that regard, the 2013 growing season was without serious weather excesses (Table 1).

The growing season 2014/2015 was mainly favorable for wheat growing. Precipitation in October-June period was adequate for normal growth and development of wheat. In accordance with global climatic change, air-temperature was for 1.6℃ higher in comparison with average 1961-1990 (8.6℃ and 7.0℃, respectively).

Table 1. The meteorological data for maize growing season

Tuzla: The 2013 growing seasons of maize and long-term means (LTM: 1961-1990)*												
Year	Monthly precipitation (mm)						Monthly mean air-temperatures (ºC)					
	May	June	July	Aug	Sept	Σ	May	June	July	Aug	Sept	X
2013	31	168	74	55	36	*364*	15.7	18.6	20.9	21.6	15.0	*18.4*
LTM	92	111	94	84	64	*445*	14.8	17.7	19.3	19.3	15.4	*17.3*

Table 2. The meteorological data for winter wheat growing season

Tuzla: Precipitation (mm) and mean air-temperatures (ºC)										
	Nov.	Dec.	Jan.	Febr.	March	April	May	June	Total	Mean
The 2014/2015 growing season										
mm	23	76	76	61	112	58	122	93	621	
℃	8.7	2.9	2.3	2.3	6.0	10.7	16.7	19.0		8.6
The long-term means (LTM): 1961-1990										
mm	71	72	59	55	61	76	92	111	597	
℃	5.6	0.9	-0.8	1.7	5.7	10.4	14.8	17.7		7.0

3. RESULTS AND DISCUSSION

Phosphorus fertilization considerably affected P availability because by increasing P rates contents of mobile P were close to linearly increased from level of low availability (7.66 mg P_2O_5 100 g^{-1}) on control to level of 20.10 mg P_2O_5 100 g^{-1} or 2.6 times. However, potassium availability was significantly increased only by application of the highest P rate up to 28%. The remaining tested parameters (pH, hydrolitical acidity and organic matter) were independent of P fertilization (Table 3).

As affected by phosphorus fertilization, maize yields were considerably increased up to 17%. (6.68 and 7.82 t ha^{-1}, for control and the highest rate of applied P, respectively). With that regard, only the highest P dose was significantly effective, while by applying the lower three levels yields increases were in range of statistical error, probably because of the application of fertilizer before maize sowing and its shallow incorporation in the soil by the later soil tillage treatments. Plant density and grain moisture were independent of applied P fertilization (Table 4). Yield of wheat was significantly increased by P fertilization up to 14% (4.35 and 5.02 t ha^{-1}, for control and the highest P rate respectively). However, for significant improvement of baking quality parameters of wheat grain (protein, wet gluten and sedimentation) the lowest P rate in level 475 kg P ha^{-1} was sufficient (Table 5).

Yield and baking quality parameters of wheat grain are under considerable influences of environmental and hereditary factors [21-24].

In order to observe the response of different field crops in rotation, a field trial of increasing phosphorus fertilization up to 975 kg P_2O_5 ha^{-1} was conducted in the Posavian Canton in B&H on a calcareous alluvial soil poorly supplied with available phosphorus. Increased phosphorus amounts raised wheat grain yields up to 1.2 t ha^{-1} at the highest rate compared to basic fertilization. Thousand grain weight and hectoliter weight as well as proteins, starch and gluten contents were not affected significantly by any treatment [25] Application of the higher rate of NPK fertilizers in three years of testing (two dry years and one year with average precipitation) significantly increased wet gluten contents in wheat grain and the higher values of wet gluten were observed under dry year conditions [26].

The effects on bread-making quality of crop rotation and fertilization were evaluated in a long term experiment. Protein concentration evaluated for 12 years varied from 10.0% to 12.8% with years and from 10.70% to 13.21% among treatments. In the wheat-maize rotation, maximum yield and quality was achieved with the highest rate of NPK fertilizers [27].

However, there are literature data that the addition of phosphate fertilizers may reduce the protein content of the grain and baking quality of wheat. This effect does not always occur and it varies between sites, with soil phosphate status and with cropping history [28].

Jolankai and Birkas [29] reported about precipitation impacts on yield and quality of winter wheat In long term field trials during a 15 year period. Yield quality was highly influenced by different crop years. Wet gluten content proved to be a most stable characteristic. Protein and sedimentation figures were more variable in relation with the precipitation of crop years. Annual values of protein and wet gluten contents were from 12.5% to 17.6% and from 27.4% to 38.8%, respectively.

Varga et al. [30] found that milling and baking quality of wheat is mainly determined by the genetic basis, however it can be influenced by management techniques.

Table 3. Impact of P fertilization (April, 2013) on soil status (March, 2014)

April 2013 P_2O_5 kg ha^{-1}		March 2014: Surface soil layer to 25 cm of depth (Hy: hydrolitical acidity)					
		pH		%	mg 100 g^{-1}		Cmol kg^{-1}
		H_2O	KCl	Org. matter	P_2O_5	K_2O	Hy
a	75	4.96	3.80	2.14	7.66	13.23	8.00
b	475	4.88	3.72	2.19	9.05	14.86	8.88
c	875	4.75	3.67	2.17	12.69	15.75	9.02
d	1275	4.78	3.69	2.15	16.73	16.08	9.26
e	1675	4.86	3.70	2.26	20.10	16.92	9.19
	$P_{0.05}$	ns	ns	ns	3.15	3.05	ns

Table 4. Response of maize to phosphorus fertilization

Fertilization (April 2013) P_2O_5 kg ha^{-1}		Response of maize (the 2013 growing season): grain yield, plant density and grain moisture at harvest (GM)			
		Grain yield t ha^{-1}	Plant density		Graim moisture %
			Plants ha^{-1}	% of planned*	
a	75	6.68	55155	81.1	18.0
b	475	7.21	59718	87.8	17.5
c	875	7.11	60909	89.5	17.8
d	1275	7.05	57734	84.9	17.7
e	1675	7.82	57139	84.0	18.0
Average		7.17	58131	85.4	17.8
$P_{0.05}$		0.61			ns

** 100% = 68028 plants ha^{-1} (distance in row: 21 cm)*

Table 5. Response of wheat to phosphorus fertilization

Response of wheat (the 2015 growing season) - abbreviations: hectoliter weight (HW), 1000 grain weight (TGW), wet gluten (WG) and sedimentation (Sed.)							
Fertilization P_2O_5 (kg ha^{-1})		Grain yield (t ha^{-1})	Grain quality parameters				
			kg	%			ml
			HW	Protein	Starch	WG	Sed.
a	75	4.35	78.5	9.8	74.9	23.0	27.8
b	475	4.44	79.8	11.6	71.6	29.1	35.3
c	875	4.39	80.5	12.3	71.3	30.5	41.5
d	1275	4.42	80.1	12.6	70.5	31.4	41.8
e	1675	4.98	80.7	12.3	70.5	31.0	38.5
Average		4.52	79.9	11.7	71.8	29.0	37.0
$P_{0.05}$		0.53	ns	1.2	3.1	2.9	3.0

4. CONCLUSION

Ameliorative P fertilization up to 1675 kg P_2O_5 ha^{-1} in the form of monoammonium phosphate considerably affected P availability for maize and wheat in acid soil of Tuzla Canton. As affected by phosphorus fertilization, maize and wheat yields were considerably increased up to 17% and 14%, respectively. Also, applied fertilization considerably improved baking quality of wheat grain (protein, wet gluten and sedimentation).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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