RESPONSE OF SOYBEAN TO PHOSPHORUS FERTILIZATION UNDER DROUGHT STRESS CONDITIONS

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Abstract: The field experiment was conducted on clay soil with five phosphorus (P) fertilization rates (a = 75, b = 225; c = 375; d = 525; e = 975 kg P_2O_5 ha^{-1}) on March 12, 2011 in Prud (Posavian Canton, Federation B&H, Bosnia and Herzegovina). The choice of experimental plots was based on previous soil test. The source of P was monoammonium phosphate or MAP (13% N + 53 % P_2O_5). The experiment was conducted in four replicates (basic plot 60 m^2). The type of experimental soil was calcareous alluvial, low in plant available P and rich in K. Soybean (cultivar *Lucija*, originating from Agricultural Institute Osijek, Croatia) was sown on April 30, 2011 and harvested on September 14, 2011. The 2011 growing season was less favorable for soybean because of water shortage and higher air-temperatures. For example, precipitation quantity in August (Gradiste: about 20 km distance from the experiment) was only 4 mm (mean 1971-1990: 66 mm) accompanied by mean air-temperature 23.4 °C (mean 1971-1990: 20.7 °C). Moreover, in the second 10-day period of July mean air-temperature was 25.5 °C and without precipitation. Under these conditions achieved soybean yields were low (mean 2111 kg ha^{-1}). However, P fertilization alleviated this type of abiotic stress. Increase P fertilization from 75 to 375 kg P_2O_5 ha^{-1}, soybean yield was increased up to 20%, whereas further increase of P rates resulted with lower yield to the control level.

Keywords: soybean yield, oil, protein, phosphorus fertilization, drought stress

Introduction

Drought is main abiotic constraint responsible for heavy production losses because soil drying have a serious influence on plant growth, development and crop yield. The climatic–change models predict that in many regions of Europe drought losses and yield variability of field crops will increase (Pogson et al., 2011). Soil drought inhibits plant nutrient uptake and decrease mineralization of soil organic matter (Buljovicic and Engels, 2001). On the other hand, nodulation and nitrogen fixation in soybean are sensitive to water deficit, which can have negative effects on soybean yield. Serraj and Sinclair (1998) reported that it is important to develop drought–tolerant cultivars to improve yield stability and N_2 fixation (inoculated with *Bradyrhizobium japonicum*).
Phosphorus is a major plant essential nutrient which cannot be replaced by another element to sustain plant life and phosphorus fertilization is important component for high yield achievement (Lott et al., 2011.).
The aim of this study was to observe influence of phosphorus fertilitation on soybean yield and grain quality in drought stress conditions.

Materials and methods

The field experiment and soil characteristics
The field experiment was started on March 12, 2011 in Prud (Posavian Canton, Bosnia and Herzegovina) on clay soil with five phosphorus (P) fertilization rates (a = 75, b = 225; c = 375; d = 525; e = 975 kg P_2O_5 ha^{-1}). The selection of the experimental plot was

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based on previous soil test (sampling 0-30 cm in February 22, 2011): pH_{H2O} = 8.03, pH_{KCl} = 7.06; Humus = 4.17; $CaCO_3$ = 3.79%; available P and K determined by the AL-method = 5.4 mg P_2O_5 and 25.65 mg K_2O/100 g. The source of P was monoammonium phosphate or MAP (13% N + 53 % P_2O_5). Nitrogen added by MAP was equalized to level of 110 kg N ha^{-1} for the a–c tretaments by using CAN (calcium ammonium nitrate: 27% N). The experiment was conducted in four replicates (basic plot 60 m^2). The highest P rate of 220 kg N ha^{-1} was added with MAP. The experimental soil was calcareous alluvial soil type, low in plant available P and rich in K. Furthermore, it is dark coloured and in drought period incline to form cracks. Soybean (cultivar *Lucija*, originating from Agricultural Institute Osijek, Croatia) was sown on 30 April 2011 and harvested on 14 Sept. 2011. From each basic plot area of 3.0 m^2 was manually harvested. Soybean plants were enumerated, pods were separated and harvested by special combine. Soybean yield was calculated on 13% basis grain moisture.

Chemical and statistical analysis
Oil content in the grain was determined by nuclear magnetic resonance (NMR) spectroscopy method. Protein and starch content in grain was determined by Near Infrared spectroscopic method on Foss Tecator ("Infratec 1241 Grain Analyzer"). The data were statistically analyzed by ANOVA and treatment means were compared using t-test and LSD at 0.05 and 0.01 probability levels.

Collection of the weather data
The State Hydrometeorological Institute in Zagreb was the source for weather data (precipitation and mean air-temperatures): Gradiste (close to Zupanja; Croatia Weather Bureau), distancing about 20 km in NE direction from the experiment.

Results and discussion

The growing season 2011 was less favorable for soybean because of water shortage and higher air–temperatures, especially in August. For example, precipitation quantity in August (Gradiste: about 20 km distance from the experiment) was only 4 mm (mean 1971–1990: 66 mm) accompanied by mean air–temperature 23.4 ^{o}C (mean 1971–1990: 20.7 ^{o}C). Also, in the second 10–day period of July mean air–temperature was 25.5 ^{o}C and without precipitation.

Under these environmental conditions acieved soybean yield was low (mean 2111 kg ha^{-1}). Worldwide measurements prove that atmosphere warming up with precipitation decreasing tendency, but producers mainly meet its harmful consequences (Köles et al., 2011). Based on a 3–year study of 132 genotypes from Agricultural Institute in Osijek (Croatia), Vratarić et al. (2005) determined that average soybean yield was about 3 t ha^{-1}, grain protein content about 38% and oil about 22%.

Table 1. Weather characteristics for Gradiste Weather Bureau (close to Zupanja, Croatia) in 2011 growing season (Meteorological and Hydrological Service, 2011).

The period	Gradiste (close to Zupanja, Croatia) Weather Bureau The growing season 2011 and (LTM = long-term mean 1971-1990)									
	May	June	July			August			Sept.	
			1-10	11-20	21-31	1-10	11-20	21-31		
	Precipitation (mm)									Total
2011	48	37	38	0	46	4	0	0	16	189
LTM	66	81	72			66			56	341
	Mean air–temperature (°C)									Mean
2011	20.3	21.1	22.9	25.5	19.2	22.2	22.9	25.1	20.7	21.6
LTM	16.7	19.6	21.2			20.7			16.6	19.0

The growing season 2011 was less favorable for soybean because of water shortage and the higher air–temperatures, especially in August. For example, precipitation quantity in August (Gradiste: about 20 km distance from the experiment) was only 4 mm (long–term mean or LTM: 1971–1990 = 66 mm) and it was accompanied with mean air–temperature 23.4 °C (mean 1971–1990: 20.7 °C). In the second 10–day period of July mean air–temperature was 25.5 °C and without precipitation. Also, in the 5–month period May–September, precipitation quantities were 189 mm or 45% lower and air–temperatures were 2.6 °C higher compared to LTM.
However, under these conditions P fertilization had considerable effects on increase soybean yield. With P fertilization (375 kg P_2O_5 ha^{-1}) soybean yield was increased up to 20% and further increase of P rates resulted with lower yield to the control level (*Table 2*).

Table 2. Effect of phosphorus fertilization on soybean yield and grain quality

Response of soybean (cultivar *Lucija*) to phosphorus fertilization – location Prud (PDR = plant density realization; TGW = 1000 grains weight)						
Fertilization (12. 03. 2011.)		Yield	PDR	TGW	Percent in grain	
	kg P_2O_5 ha^{-1}*	kg ha^{-1}**	plants ha^{-1}	(g)	Proteins	Oil
a/ Control	75	2111	373330	155.8	37.56	23.18
b/ P-1	225	2445	363330	154.5	38.58	22.68
c/ P-2	375	2527	366663	153.9	37.80	23.00
d/ P-3	525	2356	356666	153.0	37.05	23.65
e/ P-4	975	2367	360000	156.9	40.12	21.99
LSD 5%		240	–	ns	1.23	0.79
LSD 1%		ns			1.72	1.11
Average		2361	363997	154.8	38.22	22.90

* source of P: MAP (13% N + 53% P_2O_5) – N equalized to 110 kg N ha^{-1} for the a–c treatments by CAN (calcium–ammonium nitrate 27% N);
** grain yield calculation on 13% moisture and PDR 364000 plants ha^{-1}

Kovacevic et al. (2007) reported that soybean yield of 3,60 t ha^{-1} increased by 21% with P ameliorative fertilization (1500 kg ha^{-1}) on acid soil (pH_{KCL}=3.7) and that P and K fertilization did not have influence on protein and oil content in grain.

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In our study (neutral soil pH_{KCL}=7.06) increase in P dose had no significant effect on 1000 grains weight, whereas 975 kg of P significantly increased protein content (from 37.56% to 40.12%) and reduced oil content in grain (from 23.18% to 21.99%) compared to the control and other fertilization variants (*Table 2*).

Conclusions

Based on one year research, on neutral pH soil, poor in available P and in unfavorable weather conditions (high air-temperatures and lack of precipitation) increase P fertilization from 75 to 375 kg P_2O_5 ha^{-1} increased soybean yield for 20% compared to control level. Further P fertilization increase up to 975 kg P_2O_5 ha^{-1} did not increase grain yield, but it have influence to grain quality, increase protein content and reduced oil content. In the next years we expecting residual effects of ameliorative fertilization on the field crops in crop rotation.

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