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GRAIN YIELD AND PROTEIN OF BARLEY IN DEPENDENCE OF PHOSPHORUS AND POTASSIUM NUTRITION

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Abstract

The different levels of phosphorus and potassium nutrition on the productivity of two-rowed winter barley (Hordeum vulgare L.) cv. Kamenitza were studied under conditions of pot experiments. Two greenhouse pot experiments with increased nitrogen, phosphorus, and potassium fertilizing levels were conducted. The effect of potassium fertilization and different levels of nitrogen fertilizing was studied at the first experiment. The investigated nitrogen levels were 0, 200, 400 and 600 mg N/kg soil and the levels of potassium fertilizing were 0, 200, 400 mg K_2O/kg soil. The aim of the second pot experiment was to establish the effect of increasing levels of phosphorus fertilizing at a background of 400 mg N and 200 mg K_2O per kg soil on the barley grain and protein yields. The plants were grown in plastic pots (5L volume). Each pot was contained 5 kg soil (Molic fluvisol) with pH $_{(H2O)}$ - 7.3, humus content 3.2%, Nmin - 39.8 mg N/kg, available phosphorus (method of Egner - Riehm) - 102 mg P_2O_5/kg, and available potassium (2 N HCL) - 460 mg K_2O/kg. The different levels of mineral nutrition at two pot experiments were created by applying of NH_4NO_3, $Ca(H_2PO_4)_2.H_2O$, and K_2SO_4 in the form of water solutions. Thirty seeds were sown in each pot ant the plants were reduced to equal number in each pot (15) at tillering. Phosphorus and potassium fertilizing were a proved positive effect on the nutrient regime of barley plants, productivity and grain quality. Moderate phosphorus fertilizing 200 mg $P_2O_5.kg^{-1}$ soil combined with levels $N_{400}K_{200}$ showed the highest grain and protein yields and grain protein concentrations. Grain protein concentration increased from 12.5 to 13.5% and protein yield increased by 28.6%, compared to variant without phosphorus $N_{400}P_0K_{200}$. The K levels of 200 and 400 mg $K_2O.kg^{-1}$ soil increased the grain yield when were combined with nitrogen levels of 200 - 400 N mg/kg soil. The changes of potassium nutrient regime by fertilizing alone in a range K_0 - K_{400} on the background of N_0P_{200}, slightly affect the grain protein concentrations and yields of barley. The potassium fertilization demonstrated a positive effect on the concentrations of plant nitrogen at tillering. The concentrations of N and P of barley plants at tillering stage slightly depended on fertilizing levels P_0-P_{400}.

Key words: *barley, phosphorus, potassium, productivity, protein.*

INTRODUCTION

The winter barley in Bulgaria occupies at about 190 000 hectares and many factors negatively affect on barley production, but decisive of them are land property reform and fertilization. The mineral fertilizer application in Bulgaria was sharply decreased and the application of phosphorus and potassium, especially (Agrarian Report, 2012). The potassium balance in Bulgarian agriculture has always been a negative (Gorbanov et al., 1998). The phosphorus balance from a positive (+90 $kg.ha^{-1}$) has become a negative (Gorbanov and Gorbanova, 1998). Phosphorus and potassium nutrition in barley is influenced by levels of supplying of these nutrients, cultivation practices, crop species and environmental conditions (Dessougi et al., 2002; MacLead, 1999). The natural potassium reserves in Bulgarian soils are relatively high, but the need of potassium fertilizing is increased under intensive nitrogen and phosphorus applications (Rachovski et al., 2010). Compared to N, application of phosphorus and potassium has been neglected from many farmers and this has resulted in the continual depletion of soil P and K (Tomov et al., 2006). Inadequate P and K applications leads to imbalance in agricultural ecosystems and stagnation of yields will become more pronounced with time (Regmi et al., 2002). Long term experiments have shown that high yields and good grain quality can be achieved from balanced NPK supply (Belay et al., 2002). To ensure sustained crop production under intensive cropping, application of recommended doses of NPK is required (Rupa et al., 2003). A nitrogen-potassium interaction generally exists in agricultural ecosystems (Johnston and Milford, 2009). The effect of phosphorus and potassium fertilizing on the

productivity and grain quality of barley grown on soils with different available phosphorus and potassium in Bulgaria was studied on a small scale. The objective of the present study was to established the effect of increased levels of phosphorus and potassium on the yield and grain quality of barley plants under pot experiments.

MATERIALS AND METHODS

Two pot experiments with increased nitrogen, phosphorus, and potassium fertilizing levels were conducted under greenhouse conditions with barley variety Kamenitza. The effect of potassium fertilization and different levels of nitrogen fertilizing was studied at the first experiment. The investigated nitrogen levels were 0, 200, 400 and 600 mg N/kg soil and the levels of potassium fertilizing were 0, 200, 400 mg K_2O/kg soil. The aim of the second pot experiment was to establish the effect of increasing levels of phosphorus fertilizing at a background of 400 mg N and 200 mg K_2O per kg soil on the barley grain yield and protein. The plants were grown in plastic pots (5L volume). Each pot contained 5 kg Molic fluvy soil with $pH_{(H2O)}$ - 7.3, humus content 3.2%, Nmin - 9.8 mg $N.kg^{-1}$, available phosphorus (method of Egner - Riehm) - 109 mg $P_2O_5.kg^{-1}$, and available potassium (2 N HCL) - 460 mg $K_2O.kg^{-1}$. The different levels of mineral nutrition at two pot experiments were created by applying of NH_4NO_3, $Ca(H_2PO_4)_2.H_2O$, and K_2SO_4 in the form of water solutions.

Thirty seeds were sown in each pot at the beginning of December. The barley plants were reduced to equal number in each pot (15) at the tillering stage. The removed plants were used for analyses. The analyses of plant vegetative mass and grain were done after wet combustion using concentrated H_2SO_4 and H_2O_2 as a catalyst by using common methods (Tomov et al., 2009). The grain protein concentrations were calculated by multiplying total nitrogen concentrations of grain by factor 5.7 (% N total x 5.7). An overall analysis of variance (ANOVA) was performed to evaluate the effect of the experimental treatments on the referred variables, and Duncan's multiple range test (α = 0.95) was used in order to establish the difference among the means.

RESULTS AND DISCUSSIONS

The nitrogen supplying was the main factor affecting barley grain yields (Figure 1). The result showed yield decreasing when N level was higher then N_{600}. The potassium levels of 200 and 400 mg $K_2O.kg^{-1}$ soil increased the grain yield when were combined with nitrogen levels of 200-400 N mg/kg soil. A similar effect was observed in biomass productivity of barley at maturity (data not shown).

The highest grain yield was obtained at phosphorus fertilizing level of 200 mg $P_2O_5.kg^{-1}$ soil (Figure 2). The high level of P_{400} showed a negative effect on the productivity of barley grain and aboveground biomass, but the differences were no significant with level P_{400}. The similar results were obtained for barley biomass productivity.

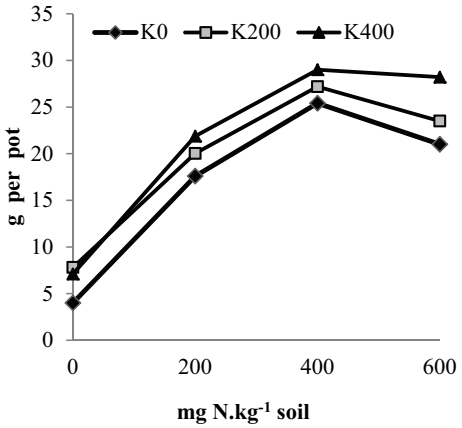

Figure 1. Barley grain yields in dependence of nitrogen and potassium levels of fertilizing.

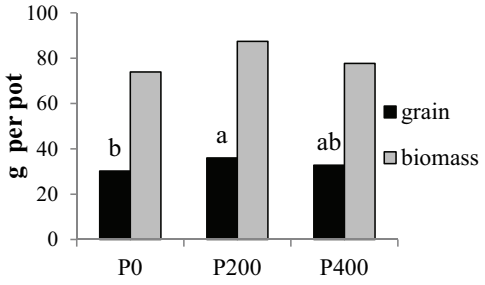

Figure 2. Barley productivity in dependence of phosphorus levels.

At tillering barley plants grown without nitrogen fertilizing had very low nitrogen concentration below 2.5% N (Table. 1). The potassium fertilization demonstrated a positive effect on the concentrations of plant nitrogen. All combinations of high potassium level K_{400} with nitrogen fertilizing 200 – 600 mg $N.kg^{-1}$ soil showed nitrogen concentrations higher then 4.5% N, or very good nitrogen supply of plants. The plants received a high amount of potassium (K_{400}) reacheded the optimal range values of a winter barley still at nitrogen level N_{200}. It proves the favorable role of the potassium on the nitrogen nutrition of this crop. The plants grown at levels $N_{400}K_{200}$ and $N_{600}K_0$ were demonstrated similar nitrogen concentrations.

Table 1. Effect of nitrogen and potassium levels on the nitrogen concentrations of barley plants at tillering

Variants	K_0	K_{200}	K_{400}
1. N_0P_{200}	2.08 c	2.15 c	2.21 c
2. $N_{200}P_{200}$	4.15 b	4.35 a	4.62 b
3. $N_{400}P_{200}$	4.38 a	4.40 a	4.75 a
4. $N_{600}P_{200}$	4.39 a	4.42 a	4.61 b

Values in each column followed by the same letters are not significantly different at $p<0.05$ according to Duncan's multiple range test.

The obtained results showed no significant effect of the phosphorus levels (ranged from 0 to 400 mg $P_2O_5.kg^{-1}$ soil) on the concentrations of plant nitrogen and potassium at tillering stage (Table 2). Applying of phosphorus 200 and 400 mg $P_2O_5.kg^{-1}$ soil was increased the concentration of this nutrient from 0.32% to 0.86% P_2O_5. The values of total phosphorus at tillering were higher than the sufficiency range levels for this stage of winter barley proposed by Bergmann (1992). The phosphorus fertilizing did not affect significantly potassium concentration of barley plants at tillering.

The changes of potassium nutrient regime by fertilizing alone in a range K_0 - K_{400} on the background of N_0P_{200}, slightly changed the grain protein concentrations and yields of barley (Table 3). The best results with regard to the grain protein concentration and yield were observed when a high potassium fertilizing K_{400} was combined with higher nitrogen supply $N_{400}P_{200}$ and $N_{600}P_{200}$. Simultaneously used a high level of nitrogen N_{600} and potassium levels K_{200} or K_{400} did not show the positive effect on the grain protein yield of barley.

Table 2. Effect of phosphorus fertilizing levels on the concentrations of nitrogen, phosphorus, and potassium of barley plants at tillering

Variants	N %	P_2O_5 %	K_2O %
1. $N_0P_0K_0$	2.21 b	0.30 c	3.20 b
2. $N_{400}P_0K_{200}$	4.53 a	0.32 c	4.23 a
3. $N_{400}P_{200}K_{200}$	4.39 a	0.72 b	4.19 a
4. $N_{400}P_{400}K_{200}$	4.44 a	0.86 a	4.25 a

*Mean values followed by the same letters are not significantly different at $p<0.05$ according to Duncan's multiple range test.

Table 3. Effect of nitrogen and potassium levels on the grain protein concentrations and yields of barley

Variants	K_0	K_{200}	K_{400}
Protein concentration, %			
N_0P_{200}	8.76 d	8.83 c	8.95 c
$N_{200}P_{200}$	10.70 c	11.80 b	13.50 b
$N_{400}P_{200}$	12.30 b	13.50 a	14.06 a
$N_{600}P_{200}$	13.10 a	13.80 a	14.30 a
Grain protein, g/pot			
N_0P_{200}	0.35 c	0.69 c	0.64 c
$N_{200}P_{200}$	1.88 b	2.36 b	2.95 b
$N_{400}P_{200}$	3.13 a	3.67 a	4.08 a
$N_{600}P_{200}$	2.75 a	3.24 a	4.03 a

Values in each column followed by the same letters are not significantly different at $p<0.05$ according to Duncan's multiple range test.

The highest values of grain protein concentrations and protein yields were established at moderate phosphorus fertilizing (200 mg $P_2O_5.kg^{-1}$ soil) combined with $N_{400}K_{200}$ (Table 4). As a result of phosphorus fertilizing P_{200} grain protein concentration increased from 12.5 to 13.5%. The obtained protein yield was by 28.6% higher in variant $N_{400}P_{200}K_{200}$ compared to variant without phosphorus $N_{400}P_0K_{200}$. The increasing of phosphorus level to P_{400} (N/P ratio one) at variant $N_{400}P_{400}K_{200}$ significantly decreased grain protein concentrations and yields of barley.

Table 4. Effect of phosphorus fertilizing levels on the grain protein concentrations and yields of barley

variants	Grain protein, %	Protein yield, g/pot
1. $N_0P_0K_0$	10.7 c	2.36 c
2. $N_{400}P_0K_{200}$	12.5 b	3.78 b
3. $N_{400}P_{200}K_{200}$	13.5 a	4.86 a
4. $N_{400}P_{400}K_{200}$	11.9 b	3.90 b

CONCLUSIONS

Under pot experiments phosphorus and potassium fertilizing had a proved positive effect on the nutrient regime of barley plants, productivity and grain quality. Moderate phosphorus fertilizing 200 mg $P_2O_5.kg^{-1}$ soil combined with levels $N_{400}K_{200}$ showed the highest grain and protein yields and grain protein concentrations. Grain protein concentration increased from 12.5 to 13.5% and protein yield increased by 28.6%, compared to variant without phosphorus $N_{400}P_0K_{200}$. The potassium levels of 200 and 400 mg $K_2O.kg^{-1}$ soil increased the grain yield when were combined with nitrogen levels of 200 - 400 N mg/kg soil. The changes of potassium nutrient regime by fertilizing alone in a range K_0 - K_{400} on the background of N_0P_{200}, slightly affect the grain protein concentrations and yields of barley. The potassium fertilization demonstrated a positive effect on the concentrations of plant nitrogen at tillering. The concentrations of nitrogen and potassium of barley plants at tillering stage slightly depended on phosphorus fertilizing levels P_0-P_{400}.

REFERENCES

Agrarian Report, 2012. Ministry of Agriculture, Bulgaria.

Belay A., Claassens A., Wehner F., 2002. Effect of direct nitrogen and potassium and residual phosphorus fertilizers on soil chemical properties, microbial components and maize yield under long-term crop rotation. Biol. Fert. Soils, 35, p. 420–427.

Bergmann W., 1992. Nutritional Disorders of Plants. Gustav Fischer Verlag, Jena-Stutgard-New York.

Dessougi H., Claassen N., Steingrobe B., 2002. Potassium efficiency mechanisms of wheat, barley and sugar beet grown on a K fixing soil under controlled conditions. Journal of Plant Nutrition and Soil Science, 165 (6), p. 732-737.

Gorbanov S., Gorbanova A., 1998. Phosphorus fertilization management and balance of phosphorus in Bulgarian agriculture. Biblioteca Fragmenta Agronomica, Vol. 3, Pulawy, p. 1-6.

Gorbanov S., Manolov I., Kostadinova S., 1998., Mineral balances and nitrate policies in Bulgaria. The Implementation of Nitrate Policies in Europe, Wissenschaftsverlag Vauk Kiel KG., p. 113-121.

Johnston A., Milford G., 2009. Nitrogen and potassium interactions in crops. The Potash Development Association, PO Box 697, York YO32 5WP, UK.

MacLead L., 1999. Effects of Nitrogen, phosphorus, and potassium and their interactions on the yield and kurnel weight of barley in hydroponics culture. Agronomy Jourmal, 61, p. 26-29.

Rachovski G., Kostadinova S., Manolov I., Yordanova N., 2010. Fifth years long-term fertilizing experiment of Agricultural University – Plovdiv, Agricultural University – Plovdiv. Scientific Works, vol. LV, book 1, p. 93-104.

Regmi A., Ladha J., Pasuquin E., Pathak, 2002. The role of potassium in sustaining yields in a long-term rice-wheat experiment in the Indo-Gangetic Plains of Nepal. Biol Fert Soils 36, p. 240–247.

Rupa T., Srivastava S., Swarup A., 2003. The availability of potassium in Aeric Haplaquept and Typic Haplustert as affected by long-term cropping, fertilization and manuring. Nutrient Cycling in Agroecosys, 65, p. 1-11.

Tomov T., Kostadinova S., Tomova M., 2006. Mineral balances and efficiency of fertilizing systems in field crop rotations. Proceedings of Sixth National Conference with International participation “Ecology and Helth”, May 18, 2006, Academic Publishing House of Agricultural University – Plovdiv, p. 171-176.

Tomov T., Rachovski G., Kostadinova S., Manolov I., 2009. Manual of agricultural chemistry. Academic Publishing House of Agricultural University – Plovdiv, p. 1-155.