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THE EFFECTIVENESS OF NITROGEN-PHOSPHORUS FERTILIZATION IN WINTER WHEAT (*TRITICUM AESTIVUM* L.) CULTIVATION

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Abstract

RUSEK, P., M. MIKOS-SZYMAŃSKA, M. KARSZNIA, U. SIENKIEWICZ-CHOLEWA and J. IGRAS, 2016. The effectiveness of nitrogen-phosphorus fertilization in winter wheat (*Triticum aestivum* L.) cultivation. *Bulg. J. Agric. Sci.*, 22: 752–755

The objective of the study was to evaluate the effect of the ureasuperphosphate (USP) fertilizer effectiveness on yield and quality of winter wheat in comparison to coventional fertilizer (CSP – concentarted superphosphate with urea). In the years 2011–2014, the field experiments were conducted in a randomized complete block design with four replications. In the research, USP and CSP (40% P_2O_5) with urea (46% N) fertilizers were applied at two doses: optimal (80 kg P_2O_5, 168 kg N/ha) and reduced (50 kg P_2O_5, 105 kg N/ha).The results indicate that USP fertilizer has showed good assimilability of nitrogen and phosphorus by plants and equivalent to studied conventional fertilizer. The average yields of wheat were statistically significant higher averagely by about 30% after application of USP and CSP with urea fertilizers comparing to wheat yield from non-fertilized plots. The nitrogen-phosphorus fertilization increased the nitrogen, protein and gluten contents in wheat grains and had the positive influence on wheat quality. The studied USP fertilizer product showed a good fertilization value.

Key words: plant nutrition,wet gluten content, protein content, mineral fertilizer

Introduction

Fertilization is a significant and dynamic part of the crop growing technology and has the highest effect on the formation of the economic part of the grain wheat yield (Ivanova et al., 2007). Fertilizers constitute an integral part of improved crop production technology. Nitrogen and phosphorus are the important factors that affect the yield and quality of wheat. If there is no enough amount of nitrogen fertilizer, the yield and quality of wheat will become worse and on the contrary, excessive nitrogen application will result in lower use efficiency of nitrogen in wheat and more environmental pollution (Dogan and Bilgili, 2010; Liu and Shi, 2013). Adequate nitrogen supply improves protein content of vegetative organs as well as storage tissuses and manufactures protein from carbohydrates (Tisdale et al., 1993). Phosphorus is the second most essential element of crop production (Haileselassie et al., 2014). Adequate phosphorus enhances many aspects of plant physiology like photosynthesis, flowering, seed maturity and seed development (Ziadi et al., 2008).Together with basic fertilization, the introduction of sulphur to soil is recomended which is responsible for nitrogen use efficiency. In many regions in the world S deficiency has been recognized as a limiting factor for crop production (Scherer, 2001).

The aim of the study was to evaluate of new nitrogen-phosphorus fertilizer USP effectiveness in comparison to conventional fertilizer (concentrated superphosphate /CSP/

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with urea) on yield and quality of winter wheat. Research hypothesis has assumed that USP fertilizer product will be a good source of well assimilable major nutrients such as nitrogen, phosphorus and sulphur for plants. The beneficial effects of USP fertilizer on development, yield and quality of winter wheat and equivalent performance to conventional fertilizers were expected.

Materials and Methods

In the years of 2011–2014, in Goczałków Górny Farm, there were conducted field experiments on the agricultural suitability of a new fertilizer product called ureasuperphosphate (USP) manufactured in the Fertilizer Department in New Chemical Syntheses Institute. The USP is the NP fertilizer type with calcium and sulphur containing N – 20%, P_2O_5 – 9%, CaO – 12%, and SO_3 – 19%. The components of fertilizer are urea, ammonium sulphate, calcium phosphates and calcium sulphate. The main raw materials used for USP production were phosphate rocks (P_2O_5~30% by weight), concentrated sulphur acid (95%), urea (N – 46%), and the additives such as magnesite (MgO 30–44% by weight), ammonia, surface active agent and technological water.The production technology of USP is described in European Patent (2014).

The field experiments were conducted in a randomized complete block design with 4 replications. The plot area was 720 m^2. In the field experiments, USP and CSP (40% P_2O_5) with urea (46% N) fertilizers were applied at two doses: optimal (80 kg P_2O_5, 168 kg N/ha) and reduced (50 kg P_2O_5, 105 kg N/ha). For the evaluation of studied fertilizer effectiveness, the control plots without NP fertilization were settled. The examined fertilization was introduced to the soil at two dates – before sowing and at the top dressing. Topdressing optimal dose of 80 kg P_2O_5/ha was applied at two dates (doses) by the end of tillering, and the reduced dose of 50 kg P_2O_5/ha was applied once. Experimental objects were as follows: control, CSP (P) + urea (N) ^{I*}, CSP (P) + urea (N) ^{II}, USP (NP) ^{I}, USP (NP) ^{II}, where *I – optimal dose NP (80 kg P_2O_5, 168 kg N/ha) and II – reduced dose NP (50 kg P_2O_5, 105 kg N/ha). The plant crops subjected to investigation were two quality wheat cultivars (*Akteur* and *Julius*) and one bread wheat cultivar (*Fidelius*). The field experiments were established on medium soil (light loam), good wheat complex, bonitation class IIIa. The soil $pH_{(1M\ KCl)}$ was in the range of 5.2–6.1, and it was appropriate for wheat cultivation. During the growing season, the leaves in the phase of wheat stem elongation (BBCH 30) were collected in order to determine the state of plant nutrition regarding their N and P requirements. The total nitrogen and phosphorus contents in dry matter of wheat leaves were determined as related to the optimal range, developed by Bergmann (1986). After harvest, the grain wheat yield and thousand grain weight were determined. Total nitrogen and phosphorous contents were determined by control flow analysis (CFA), protein and gluten contents in wheat grains were determined by optical near-infrared technology (NIR). The results were subjected to analysis of variance and differences were evaluated with the Tuckey's test ($p \leq 0.05$).

Results and Discussion

Meteorological conditions over the study period after fertilizers application were favourable for wheat growing. High temperatures in May and June and the lack of rainfall in 2012 limited to some extent the absorption of phosphorus and nitrogen by plants. However, heavy rains in June and July could have caused significant losses of nitrates from the soil. Periodically heavy rainfall in May and June in 2013 and in May and July in 2014, probably caused the significant losses of ammoniacal nitrogen in leaching process (Table 1). Mean nitrogen contents were found in the leaves of wheat from the fertilized treatments. Those nitrogen contents indicate sufficient plant nutrition, regarding this nutrient, according to the optimal ranges by Bergmann (1986). The low N_{tot} concentration in plants on unfertilized plots (2.76% N in DM) was insufficient for the plants. The CSP with urea and USP fertilization at both doses led to an optimal nitrogen nutrition of wheat (3.43–3.83% N). Similar N_{tot} contents in variants fertilized with USP and CSP with urea can claim that the nitrogen from urea was absorbed by plants equally well as with the studied USP product. With respect to the nutritional wheat requirements, the plants from control plots were characterized by the lowest phosphorus content (0.31%). In the

Table 1
Precipitation and air temperature in years of study

Month	Mean temperature, ºC			Precipitation, mm		
	2011/12	2012/13	2013/14	2011/12	2012/13	2013/14
XI	3.6	5.1	5.2	0.4	34.4	191.4
XII	3.8	–0.4	10.7	30.5	27.6	109.3
I	1.3	–1.5	1.0	47.5	62.3	32.5
II	–4.0	–0.2	3.9	40.9	57.2	5.9
III	6.2	–1.0	6.4	14.5	41.5	55.5
IV	9.3	8.9	10.2	48.0	68.8	40.8
V	15.2	13.8	13.3	38.9	119.1	100.8
VI	16.9	17.0	16.6	67.1	159.1	17.7
VII	19.7	20.3	21.4	122.8	33.9	82.6
VIII	19.2	18.8	17.9	83.2	42.5	48.2

plots where the sources of phosphorus were the CSP with urea and USP fertilizers, plants were characterized by better phosphorus nutrition (0.39–0.42% P). There were not stated any significant differences between fertilized plots (Table 2). According to research conducted by Bojović and Marcović (2009) mineral fertilization has very positive effect on nitrogen content in wheat leaves and nitrogen uptake is much better by the addition of phosphorus and potassium to the soil. Moreover, according to above study, wheat leaves from unfertilized soil were characterized by the lowest N content.

Table 2
Total nitrogen (N) and phosphorous (P) contents in wheat leaves

Fertilization	Content, % DM	
	N	P
Control	2.76	0.31
CSP + urea I	3.83	0.42
CSP + urea II	3.79	0.40
USP I	3.49	0.40
USP II	3.42	0.39
Optimal content*	2.3–3.8	0.25–0.50

** valuation acc. to Bergmann*

The wheat yields have increased under the optimal doses of concentrated superphosphate with urea by 22–32% compared to objects without the NP fertilization. The effects of the yield-forming fertilization of USP fertilizer at the optimal dose resulted in the increase of yields by 32–43% (Table 3). In 2012 and 2014, there were not stated any statistically significant differences in wheat yields depending on studied fertilizers. In 2013, the wheat yield under USP fertilization was significantly higher comparing to CSP with urea fertilization at the optimal dose (Table 3).

Summer rainfall was favourable for nitrogen leaching and to some extent the USP granulation could be the limiting agent for this process. The reduced doses of studied fertilizers were equally effective. From objects with the CSP with urea and USP fertilization, the wheat yields were at a similar level (insignificant differences). Only in the field experiment in 2013, reducing the fertilizer doses resulted in a significant decrease of wheat yield. The higher yields were followed by the increase in the thousand grains weight (TGW) of wheat. The equivalent effects were confirmed by the yield statistical synthesis (Table 3). Research conducted by Mandic et al. (2015) revealed that wheat grain yields have very strong positive correlation with TGW ($r = 0.99$, $p \leq 0.01$).

Table 3
Yields of winter wheat and 1000 grains weight (TGW)

Fertilization	Yield, t/ha				TGW, g
	2012	2013	2014	Mean	
Control	5.81^{a*}	5.75^{a}	7.00^{a}	6.16^{a}	48.11
CSP + urea I	7.10^{bc}	7.62^{c}	9.25^{c}	7.99^{bc}	49.41
CSP + urea II	6.82^{b}	6.88^{b}	9.00^{bc}	7.57^{b}	49.48
USP I	7.81^{c}	8.25^{d}	9.25^{c}	8.44^{c}	49.84
USP II	7.26^{bc}	7.00^{b}	8.75^{b}	7.50^{bc}	49.14
LSD $_{(0,05)}$	0,760	0,449	0,427	0,794	

** Yields marked with the same letter are not significantly different according to Tukey's test ($p < 0.05$)*

Wheat grain quality depends to a large extent on the genetic factors (cultivar) (Rao et al., 1993) but also it is influenced by the habitat factors (soil, weather) (Hlisnikovsky et al., 2015, Rao et al., 1993) and agricultural technology (Ellmann, 2011; Woźniak and Gos, 2014). The quality of bread wheat is estimated based on grain quality parameters. For the baking purposes, protein and gluten contents are the most important quality parameters. The minimum protein content in bread wheat should be not less than 11.0% DM and in quality wheat not less than 11.8% (ČSN, 2006). Gluten as a storage protein determines the technological value of the flour and the volume and elasticity of the dough. The gluten content in bread wheat should not be less than 20–23% and in quality wheat not less than 23–25% (ČSN, 2006). The average protein and gluten content in studied wheat grains were the lowest in control objects. Furthermore, protein content (10% DM) in wheat from those objects did not meet the required standards. Under the influence of both CSP with urea and USP fertilizers, the increase in protein and gluten contents were observed (Table 4).Protein content of wheat significantly increased with increasing nitrogen fertilizer (Hussain et al., 2006). Molla-Ali-Akbari and Lotfollahi (2015) concluded that different levels of N and P had significant effects on seed nitrogen and protein percentage in wheat grains.

Table 4
Quality parameters of winter wheat grain (mean values)

Fertilization	Content, % DM			
	N	P	Protein	Gluten
Control	1.63	0.27	10.0	23.5
CSP + urea I	1.80	0.26	12.0	26.3
CSP + urea II	1.77	0.27	11.4	25.6
USP I	1.72	0.28	11.5	26.2
USP II	1.68	0.28	11.0	25.1

Conclusions

The new fertilizer product (USP) has showed a good NP bioavailability for plants, similar to studied conventional fer-

tilizer, as evidenced by optimal concentrations of these compounds in the plants during the vegetation period. N and P uptake by plants from studied fertilizers was approximately equal. Yield-forming effect of nitrogen and phosphorus entered into the soil in the form of USP fertilizer as well as single CSP with urea were comparable.The average yields of wheat were statistically significant higher by about 30% after application of USP and CSP with urea fertilizers comparing to wheat yield from non-fertilized plots. The USP fertilization has increased the nitrogen content, protein and gluten contents, and improved the quality of wheat grain. The USP product was characterized by a good fertilization value.

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