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IMPROVE OF GRAIN YIELD AND QUALITY OF WINTER WHEAT BY NITROGEN INPUTS

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Abstract

*Wheat is an important food crop and is by far the most popular cereal in Europe, Romania being among the six important producers. In Giurgiu County at S.C. AZOCHIM S.R.L farm it was designed a field experiment for investigation of variability of the yield components (yield, plant height, spikes/m^2, number of grains per ear, thousand kernel weight TKW) and variability of quality parameters (wet gluten and crude protein contents) influenced by mineral fertilization and wheat variety. It was developed a bifactorial experiment where **a** factor was wheat variety (Glosa, Miranda) and **b** factor was fertilization. It was adopted three fertilization schemes: starter (NPK 16:16:16) (**V1**), starter (NPK 16:16:16) + CAN (calcium ammonium nitrate) + AN (ammonium nitrate) (**V2**) and starter (NPK 16:16:16) + UAN (urea ammonium nitrate) (**V3**). An efficient nitrogen transfer into grains was obtained by splitting nitrogen fertilization. The results indicated that three applications of liquid fertilizer UAN (V3) increased the proteins levels and produced the highest yields for both wheat varieties. The same trend was recorded for plant height, spikes/m^2, number of grains per ear and for quality parameters. Concerning TKW, fertilization did not lead to significant differences, but it was observed higher values for 'Miranda in comparison with Glosa.*

Key words: *fertilization, nitrogen, wheat, yield.*

INTRODUCTION

Wheat is an important food crop and it is considered that its production accounts for more than 20% of the world's arable land (Liu et al., 2016). In Europe, wheat is by far the most popular cereal, Romania being among the six important producers. In Romania, the average area used for winter wheat culture is about 2 million hectares with total production that ranges between 1-12 million tonnes/year (Bunta et al., 2011).

Balanced fertilization ensure high productivity of wheat and nitrogen is considered as the most influential factor for good quality of grains, protein content and bread-making quality. Accordingly, there are many studies concerning correlations between fertilization and yield components or quality parameters for wheat (Basso et al., 2010; Bunta et al., 2011; Hlisnikovsky et al., 2016; Panayotova et al., 2017).

As nitrogen is one of the most influential factors that control plant development, the extensive use of mineral nitrogen fertilizers has led in the last decade to a significant increase of crop yields, this being the main objective of the farmers. Lately, has surfaced the interest the minimization of harmful effects of application of high doses of mineral fertilizers (contamination of ground waters, eutrophication of surface waters, N_2O emissions) (Basso et al., 2010; Büchi et al., 2016). The important changes in fertilization practices are associated with aforementioned environmental aspects but also with economic ones: fabrication of mineral nitrogen is costly and energy consuming (Büchi et al., 2016).

Other important aspect, subject of many discussions, is related with nitrogen fertilizer type and application manner in order to obtain the best yield and quality parameters. In literature there are inconsistent opinions regarding comparisons between liquid and dry nitrogen sources for wheat crop (Walsh et al., 2016). According to Watson and co-workers (Watson et al., 1992), it appear that liquid products are more efficient (high crop yield and quality) and environmental friendly.

Also, some studies concerning the efficiency of splitting of nitrogen doses on yield indicated that the application of nitrogen in more than two splits increased grain weight per ear

(Abdin et al., 1996). Other authors (El-Agrodi et al., 2011) suggest that split application had beneficial effects on yield and yield components. Therefore, under the same experimental conditions it is recommended to add 120 kg/ha in four splits to obtain the best result of quantity and quality of the wheat.

Taking into consideration the demand for wheat high yields but also the necessity for good quality parameters (wet gluten and high protein content) required for bread-making properties, at Giurgiu County at S.C. AZOCHIM S.R.L farm it was developed a study that aimed with: (**i**) investigation of variability of yield components (yield, plant height, spikes/m^2, number of grains per ear, thousand kernel weight TKW) and (**ii**) study of variability of quality parameters (wet gluten and crude protein contents), both influenced by mineral fertilization and wheat variety.

It was developed a bifactorial experiment where **a** factor was wheat variety (Glosa, Miranda) and **b** factor was fertilization. It was adopted three fertilization schemes: STARTER (NPK 16:16:16) (**V1**); STARTER (NPK 16:16:16) + CAN (calcium ammonium nitrate) + AN (ammonium nitrate) (**V2**); STARTER (NPK 16:16:16) + UAN (urea ammonium nitrate) (**V3**).

MATERIALS AND METHODS

Experimental site

Experimental research was carried out at AZOCHIM SRL located in Călugăreni commune, Giurgiu County (Figure 1).

Figure 1. The position of experimental plots

Wheat varieties

For the experiment were chosen Glosa and Miranda varieties, both obtained at NARDI Fundulea.

Fertilizers

In the experiment were used NPK 16:16:16, calcium ammonium nitrate (CAN) with 27% N, ammonium nitrate (AN) with 33.5% N and liquid fertilizer urea ammonium nitrate (UAN) with 32% N.

Experimental design

It was developed a bifactorial experiment where **a** factor was wheat variety (Glosa, Miranda) and **b** factor was fertilization (Table 1). The experiment consisted in three variants (**V1, V2, V3**) and three replicates.

Table 1. Description of the experimental scheme

a factor = wheat variety	b factor = fertilization
a_1 - Glosa a_2 - Miranda	b_1 – STARTER (NPK 16:16:16) (**V1**) b_2 – STARTER (NPK 16:16:16) + CAN + AN (**V2**) b_3 – STARTER (NPK 16:16:16) + UAN (**V3**)

Soil and plant analyses

A presentation of performed analyses, methods and apparatus are synthesized in Table 2.

Table 2. Analyses, methods and instrumentation

Analyses	Method	Apparatus
Soil		
pH_{H2O} (1:2.5)	potentiometry	Hanna pH-meter
Total soluble salts (1:5)	conductometry	Hach sens Ion 7
Potassium (mobile form), K_{AL}	flame emission spectrometry	Sherwood 410
Phosphorus (mobile form), P_{AL}	spectrophotometry	CECIL 2041 spectrometer
Humus content	Walkley-Black-Gogoașă	-
Plant		
Wet gluten	manual method	-
Crude protein content (on the basis of total nitrogen content)	Kjeldahl method	HACH Digesdahl

P_{AL} - mobile form of phosphorus using for extraction ammonium acetate-lactate (AL);
K_{AL} - mobile form of potassium using for extraction ammonium acetate-lactate (AL).

Fertilization and applied treatments

For both wheat varieties was adopted the same technology and phytosanitary treatments, the difference being represented by the type of applied fertilizer (solid or liquid) and the split of the total dose. Solid fertilizers (**V2**), CAN and AN, were applied in March and April, respectively using a dose of 300 kg/ha composed from 200 kg/ha (CAN) and 100 kg/ha (AN) and totalising 120 kg N/ha. Liquid fertilizer (**V3**), UAN, applied in a dose of 300 kg/ha that was split in three equal fractions that contributed with 128 kg N/ha.

The sowing was done in October, first decade and harvesting in July, the third decade (Table 3).

Table 3. Fertilization (solid vs. liquid fertilizers) and treatments scheme for Glosa and Miranda

Period of time	Fertilizer and phytosanitary treatments		Dose	
October, I^{st} decade	NPK 16:16:16		200 kg/ha	
March, I^{st} decade	CAN	*UAN*	200 kg/ha	*100 kg/ha*
April, I^{st} decade	Gamma Cyhalothrin (insecticide)		0.08 L/ha	
	40 g/L proquinazid + 160 g/L tebuconazole + 320 g/L prochloraz (fungicide)		1 L/ha	
	69 g/L fenoxaprop-P-ethyl + 34.5 g/L cloquintocet-mexyl (herbicide)		1 L/ha	
	250 g/L thifensulfuron methyl + 250 g/L tribenuron methyl (herbicide)		40 g/ha	
April, II^{nd} decade	AN	*UAN*	100 kg/ha	*100 kg/ha*
May, I^{st} decade	-	*UAN*	-	*100 kg/ha*
May, II^{nd} decade	Plonvit Opty (foliar fertilizer)		3 L/ha	
	Tebuconazole 200 g/L + Trifloxystrobin 100 g/L (fungicide)		1 L/ha	
	Thiacloprid 240 g/L (insecticide)		0.3 L/ha	

CAN - calcium ammonium nitrate, solid fertilizer;
AN - ammonium nitrate, solid fertilizer;
UAN - urea ammonium nitrate, liquid fertilizer.

RESULTS AND DISCUSSIONS

Agrochemical soil analysis (Table 4) indicated that soil reaction was weak acidic for Miranda (0-20 cm) plot, moderately acidic for Miranda (0-40 cm) and Glosa (0-20 cm) plots and very weak acidic for Glosa (20-40 cm) plot. Total soluble salts contents indicate a non saline soil, meanwhile humus contents correspond to medium level. Mobile form of phosphorus (P_{AL}) was classified as medium content for Glosa (20-40 cm) plot and high content for all three other ones. Potassium content (K_{AL}) ranged between 360-540 mg/kg which is considered very high content.

Table 4. Soil agrochemical analysis

Wheat variety plot	pH	Total soluble salts, %	Humus, %	$P_{AL,}$ mg/kg	$K_{AL,}$ mg/kg
Glosa (0-20 cm)	5.77	0.02496	2.87	57.2	460
Glosa (20-40 cm)	6.64	0.02304	2.62	29.2	360
Miranda (0-20 cm)	5.90	0.02528	2.93	68.0	540
Miranda (20-40 cm)	5.72	0.01984	3.12	66.7	400

1. Results concerning yield related to mineral fertilization and wheat variety

The results indicated that using liquid fertilizer (UAN) by splitting the total dose (300 kg/ha) in three equal fractions lead to the highest yields for both wheat varieties (8232 kg/ha and 7404 kg/ha, respectively) (Table 5). Comparing the both wheat varieties it may be noticed that the same fertilization level conducted to higher yields for Glosa. The variance analysis concerning wheat variety influence on yield indicates significant differences for all experimental variants.

Table 5. Influence of wheat variety (a factor) and of mineral fertilization (b factor) on yield (kg/ha)

Yield, kg/ha			
b= fertilization / a= wheat variety	b_1	b_2	b_3
a_1= Glosa	a6014c	a7452b	a8232a
a_2= Miranda	b4683c	b6247b	b7404a
B constant, A variable: LSD 5%=193* kg/ha ; LSD 1%=308 kg/ha; LSD 0.1%=583 kg/ha A constant, B variable: LSD 5%=214* kg/ha; LSD 1%=311 kg/ha; LSD 0.1%=467 kg/ha			

b_1-STARTER; b_2-STARTER+CAN+AN; b_3-STARTER+UAN
There were made interpretations by LSD 5% indicated in the table by *

2. Results concerning plant height related to mineral fertilization and wheat variety

In comparison with variant **V1** (STARTER), fractionate application of fertilizer and fertilizer type produced significant differences on plant height. Application of liquid fertilizer (UAN) determined the highest height for both wheat varieties, 95 cm for Glosa and 107.5 cm for Miranda.

At the same fertilization level, plant height is higher for Miranda in comparison with Glosa. Also, variance analysis concerning the influence of wheat variety on plant height indicates significant differences for all experimental variants.

Table 6. Influence of wheat variety (a factor) and of mineral fertilization (b factor) on plant height (cm)

Plant height, cm			
b= fertilization / a= wheat variety	b_1	b_2	b_3
a_1= Glosa	b81.5c	b90.0b	b95.0a
a_2= Miranda	a93.0c	b106.0b	a107.5a
B constant, A variable: LSD 5%=2.10* cm ; LSD 1%=3.40 cm; LSD 0.1%=6.70 cm. A constant, B variable: LSD 5%=2.27* cm; LSD 1%=3.30 cm; LSD 0.1%=4.97 cm.			

b_1-STARTER; b_2-STARTER+CAN+AN; b_3-STARTER+UAN
There were made interpretations by LSD 5% indicated in the table by *

3. Results concerning spike number/m^2 related to mineral fertilization and wheat variety

Analyzing the influence of mineral fertilization and wheat variety on spike number/m^2, it may be noticed that, in contrast to **V1** variant (STARTER), application of nitrogen fertilizers and their type conducted to significant differences. Application of UAN liquid fertilizer in three equal fractions produced the highest number of spike/m^2, as it follows: 420 spikes/m^2 for Glosa and 410 spikes/m^2 for Miranda (Table 7). Concerning fertilizer type, it may be observed differences between both wheat varieties: 20 spikes/m^2 for Glosa and 25 spikes/m^2 for Miranda.

Comparing both wheat varieties maintaining the same fertilization level it may be observed that number of spikes/m^2 is higher for Glosa. Also, variance analysis concerning influence of wheat variety on number of spike/m^2 indicates significant differences for all experimental variants.

Table 7. Influence of wheat variety (a factor) and of mineral fertilization (b factor) on spikes/m^2

Number of spikes/m^2			
b= fertilization / a= wheat variety	b_1	b_2	b_3
a_1= Glosa	a358b	a400a	a420a
a_2= Miranda	a342c	a385b	a410b
B constant, A variable: LSD 5%=23.55* no. spikes/m^2; LSD 1%= 46.30 no. spikes/m^2; LSD 0.1%=124.38 no. spikes/m^2			
A constant, B variable: LSD 5%= 24.01* no. spikes/m^2; LSD 1%=55.39 no. spikes/m^2; LSD 0.1%= 176.35 no. spikes/m^2			

b_1-STARTER; b_2-STARTER+CAN+AN; b_3-STARTER+UAN
There were made interpretations by LSD 5% indicated in the table by *

4. Results concerning number of grains per ear related to mineral fertilization and wheat variety

The fertilizer type and the split of the fertilizer dose produced yield significant differences, application of liquid fertilizer being more efficient for both wheat varieties: 49 grains per ear for Glosa and 43 grains per ear for Miranda (Table 8). For the same fertilization level it has been found that number of grains per ear was higher for Glosa. Applied fertilizers at Glosa produced an increase with 4 grains per ear in the case of **V2** variant and with 7 grains per ear in the case of **V3** variant in comparison with **V1**. For 'Miranda', the increase was with 6 grains per ear for **V2** and 10 grains per ear for **V3** as against with **V1**. The variance analysis indicates significant differences for all experimental variants. Nitrogen supply will affect the number of grains set on individual ears/spikes determined early from double ridge to floret initiation by the timing of the applied nitrogen (http:www.yara.co.uk/crop-nutrition/crops/wheat/yield/increasing-wheat-grain-numbers-per-ear)

Table 8. Influence of wheat variety (a factor) and of mineral fertilization (b factor) on number of grains/ear

Number of grains per ear			
b= fertilization / a= wheat variety	b_1	b_2	b_3
a_1= Glosa	a42c	a46b	a49a
a_2= Miranda	b33c	b39b	a43a
B constant, A variable: LSD 5%=6.03* no.grains/ear; LSD 1%= 13.12 no.grains/ear; LSD 0.1%=39.46 no.grains/ear			
A constant, B variable: LSD 5%= 2.87* no.grains/ear; LSD 1%=4.11 no.grains/ear; LSD 0.1%= 6.28 no.grains/ear			

b_1-STARTER; b_2-STARTER+CAN+AN; b_3-STARTER+UAN
There were made interpretations by LSD 5% indicated in the table by *

5. Results concerning number of thousand kernel weight (TKW) related to mineral fertilization and wheat variety

The value of TKW for the same fertilization level is higher for Miranda as against Glosa. The variance analysis concerning the influence of wheat variety on yield indicates significant differences for all experimental variants. Differentiate fertilization produced increase of TKW with 0.5 g for **V2** variant for Glosa and the same increase for **V3** for Miranda, as against **V1** in both cases. As conclusion, the TKW index is a wheat variety character and it is not influenced by type or fertilization level (Table 9).

Table 9. Influence of wheat variety (a factor) and of mineral fertilization (b factor) on TKW

TKW, g			
b= fertilization / a= wheat variety	b_1	b_2	b_3
a_1= Glosa	a40.0a	a40.5a	b40.0a
a_2= Miranda	a41.5a	a41.5a	a42.0a
B constant, A variable: LSD 5%=1.87* g; LSD 1%= 3.84 g; LSD 0.1% = 10.85 g			
A constant, B variable: LSD 5%= 1.21* g; LSD 1%=1.76 g; LSD 0.1%= 2.65 g			

b_1-STARTER; b_2-STARTER+CAN+AN; b_3-STARTER+UAN
There were made interpretations by LSD 5% indicated in the table by *

6. Results concerning wet gluten content related to mineral fertilization and wheat variety

Wet gluten content increased with nitrogen fertilization and fractionate application of UAN determined the highest values: 26.1% for Miranda and 25.8% for Glosa (Table 10). For the same fertilization level, the wet gluten content is higher for Miranda as against Glosa. Also, variance analysis indicates significant differences for all experimental variants. After fertilization it was observed an increase of wet gluten for Miranda with 2.6% for **V2** and with 3.4% for **V3**. For Glosa, the increase was with 2.3% for **V2** and 3.2% for **V3**, all comparisons being made as against **V1**.

Table 10. Influence of wheat variety (a factor) and of mineral fertilization (b factor) on wet gluten content

Wet gluten content, %			
b= fertilization / a= wheat variety	b_1	b_2	b_3
a_1= Glosa	a22.6c	a24.9b	a25.8a
a_2= Miranda	a22.7c	a25.3b	a26.1a
B constant A variable: LSD 5%=0.67* % ; LSD 1%=1.01%; LSD 0.1%=1.72% A constant B variable: LSD 5%=0.78* % ; LSD 1%=1.14%; LSD 0.1%=1.71%			

b_1-STARTER; b_2-STARTER+CAN+AN; b_3-STARTER+UAN
There were made interpretations by LSD 5% indicated in the table by *

7. Results concerning crude protein content related to mineral fertilization and wheat variety

In comparison with **V1** variant, the fertilizer type and the split of the dose produced significant increase of protein content. Application of liquid fertilizer UAN conducted to the highest contents of protein for both wheat varieties: 13.45% for Glosa and 13.76% for Miranda (Table 11).

For the same fertilization level, crude protein content was higher for Miranda. Variance analysis indicates significant differences for all variants.

The fertilization led to increases of 0.47% for Miranda for **V2** and 1.06% for **V3**, meanwhile for Glosa the increase was of 0.68% for **V2** and 1.13% for **V3**, as against **V1**.

According to literature, high quality flours are characterized by protein content higher than 12%. Moreover, splitting nitrogen fertilization into three or four applications increases yield and protein content as compared to single or dual application (Yara International ASA), situation which is consistent with our results.

Table 11. Influence of wheat variety (a factor) and of mineral fertilization (b factor) on crude protein content

Crude protein content, %			
b= fertilization / a= wheat variety	b_1	b_2	b_3
a_1= Glosa	a12.32b	a13.00a	a13.45
a_2= Miranda	a12.70b	a13.29a	a13.76a
B constant A variable: LSD 5%=0.85* % ; LSD 1%=1.34%; LSD 0.1%=2.48% A constant B variable: LSD 5%=0.95* % ; LSD 1%=1.39%; LSD 0.1%=2.09%			

b_1-STARTER; b_2-STARTER+CAN+AN; b_3-STARTER+UAN
There were made interpretations by LSD 5% indicated in the table by *

CONCLUSIONS

In the field experiment developed at S.C.AZOCHIM S.R.L. in Giurgiu County it was investigated the variability of the yield components (yield, plant height, spikes/m^2, number of grains per ear, TKW) and the variability of quality parameters (wet gluten and crude protein contents) influenced by mineral fertilization and wheat variety. The experimental results allowed obtaining the conclusions presented below:

1. The application of liquid fertilizer UAN in three fractions produced the highest yields for both wheat varieties.

2. Application of UAN produced the highest plant height: 95 cm for Glosa and 107.5 cm for Miranda.

3. Application of UAN liquid fertilizer in three equal fractions produced the highest number of spike/m^2, as it follows: 420 spikes/m^2 for Glosa and 410 spikes/m^2 for Miranda.

4. Concerning number of grains per ear, the application of liquid fertilizer was more efficient for both wheat varieties: 49 grains per ear for Glosa and 43 grains per ear for Miranda.

5. The TKW index is a wheat variety character and it is not influenced by type or fertilization level.

6. Wet gluten and protein contents increased with nitrogen fertilization and fractionate application of UAN.

7. Results of our study suggested that choice of liquid nitrogen fertilizer might be important in winter wheat culture, with positive results obtained with UAN explained by reduced mineralization of these fertilizers due to dry weather conditions in spring inducing better nitrogen availability during protein storage.

8. As general conclusion, application of liquid fertilizer by splitting the total dose in three equal fractions, conducted to the best values for yield components and quality parameters.

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