EFFECT OF SPATIALLY VARIABLE TOP DRESSING ON WHEAT GRAIN QUALITY AND MINERAL NITROGEN CONTENT IN SOIL

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Abstract. The paper presents the results of winter wheat variable top dressing on grain quality and mineral nitrogen content in soil. The investigations revealed that application of variable fertilization increased the amount of absorbed components in the plant material and decreased variability of these values. Grain quality classified is as fodder grain due to low protein concentration (below 11.5%) and considerable number of germinated grains (c.a. 25%). Mineral nitrogen content in soil on the variably fertilized field was between 20 and 60% lower than on the field fertilized traditionally.

Key words: top dressing, grain quality, mineral nitrogen

Introduction

Revenues from agricultural holding specializing only in crop production depend on procurement prices. The best prices are offered for grain fulfilling high quality standards, where grain protein concentration exceeds 14% [Wyszomirski 2011].

Obtaining high quality grain depends on many factors. Some of them may be kept under control during the production process, but one is unable to influence the meteorological conditions. Crop yield and grain quality are affected by a timely sowing on good site [Wyszomirski 2011]. It ensures the availability of nutrients at the beginning of plant development, however in spring its is necessary to apply nitrogen top dressing depending on the plant development phase [Fotyma, Fotyma 2003; Zagórda et al. 2007]. Because nitrogen is most susceptible to washing out from the soil profile, application of spatially diversified rates due to plant requirements, reduces its loses from the soil profile [Jadczyszyn 1998].

Aim and scope of research

The aim of the investigations was determining the effect of nitrogen top dressing on winter wheat grain quality and mineral nitrogen residue in soil.

The scope of research comprised measurements conducted on two fields where winter wheat was cultivated. On the first field, with an area of 13ha uniform (fixed) rates were applied in the whole area, whereas on the field with the area of 19 ha, spatially variable fertilization was used, according to the crop requirements. The following tasks were accomplished:

– a relative chlorophyll content in leaves was determined and on this basis nitrogen requirement in the second and third rate was computed,
– total nitrogen (N-og), phosphorus (P), potassium (K), calcium (C) and magnesium (Mg) concentrations were assessed in sampled plant material before the second and third rate application,
– the yield was registered and maps of its spatial distribution on the selected fields were made,
– protein content was assessed in collected grain samples during harvest,
– the soil abundance in bioavailable forms of phosphorus, potassium, magnesium and mineral nitrogen was determined on the analysed fields after wheat harvest.

Material and methods

The research was conducted in 2011 on the fields of 19 and 13 ha area. The analysed soil was brown soil developed from silt deposits (clay silt), classified to heavy soils, IIIa soil quality class and good wheat complex. Winter wheat, Turnia c.v. was sown on the fields. Phosphorus and potassium fertilization rated respectively 70 $kg \cdot ha^{-1}$ and 125 $kg \cdot ha^{-1}$ was applied pre-sowing and in spring, when vegetation started, nitrogen fertilization on the level of 75 $kg \cdot ha^{-1}$ was conducted. Cultivation technology and dates of measures on the analysed fields were similar. Only fertilization with the second and third rate of nitrogen on the field with the area of 19 ha was conducted in spatially variable system.

Prior to nitrogen fertilizer application chlorophyll content in leaves was measured on the fields by means of SPAD 502DL chlorophyll meter [Zagórda et al. 2007]. The measurements were made on a 50 per 50 m grid (Fig.1) at the beginning of shooting phase and at the beginning of earing phase. On each testing ground measurement was made on 10plants and the averaged result was ascribed to the point in the centre of the grid polygon (Fig. 1) [Zagórda et al. 2007]. Digital maps and navigation on the fields were conducted using a module DGPS receiver with SiteMate 9.3 software (Farm Works).

The plants on which measurements were made were then sampled for chemical analysis for the contents of N-og, P, K, Ca and Mg. Total nitrogen was assessed by Kjeldahl's method, phosphorus and magnesium by absorption spectrophotomtery (colorimetry), while potassium and calcium by means of flame photometry. The second and third rate were determined on the basis of SPAD value quotient obtained in the measured and control areas [Fotyma, Fotyma 2003]. The measurements for the uniformly fertilized field (13 ha) provided a basis for determining nitrogen requirements, in case variable fertilization would be used on the field.

Nitrogen in diversified rates was sown using Rauch Alpha 1131 fertilizer distributor, steered by LH 5000GPS system cooperating with module DGPS with SiteMate VRA 9.3 application containing application maps [Zagórda et al. 2007]. Fertilization was conducted on the same day on both studied fields. Transverse uniformity of sowing was determined on the basis of comparison of the fertilizer amount collected in the containers placed between working paths (at the distance between containers 4 m).

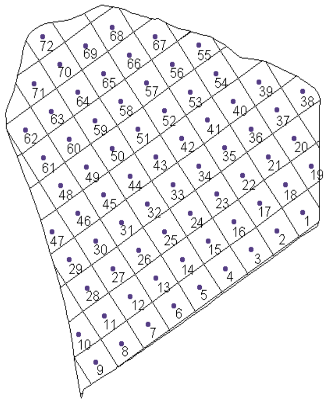


Fig. 1. Measuring points grid for the field where variable fertilization was conducted

Grain was harvested by means of Claas Lexion 430 combined harvester equipped with optical yield monitoring system made by Agrocom. During harvest grain was sampled for analyses for total nitrogen and protein content, in order to assess the quality of yield obtained in various fertilization systems. Maps of spatial diversification of yields were made using AgroMap 6.0 application produced by Agrocom enterprise.

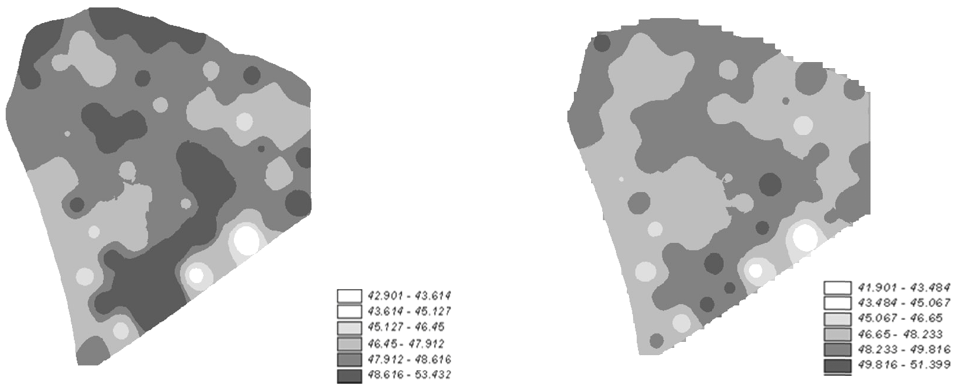
After the harvest soil samples were collected from the analysed fields to determine the soil abundance in bioavailable forms of phosphorus, potassium, magnesium and soil pH (from the depth of 0.2 m) and mineral nitrogen (from the depth of 0.3 – 0.6 0.9 m), which made possible determining the conditions for wheat growth. The soil pH was determined by potentiometric method. The contents of bioavailable forms of phosphorus and potassium were assessed using Egner-Riehm's method, while concentrations of bioavailable magnesium forms were determined using atomic absorption spectrometry. Mineral nitrogen content in the samples from three depths was determined by means of absorption spectrophotometry (colorimetry).

All analyses were conducted in an accredited laboratory (AB 759) of the Regional Chemical-Agricultural Station in Krakow. Combinations of the results of analyses and measurements with geographical coordinates of measurement points, statistical computations and creating the maps of spatial nitrogen top dressing were accomplished using ArcView GIS 3.3 application made by ESRI enterprise.

Results

A basis for making maps of spatially variable nitrogen top dressing were maps of chlorophyll content in leaves (Fig. 2). The results from the control areas were supplemented by the rates in the range of 0 to 40 $kg\cdot ha^{-1}$ collected in the field [Fotyma, Fotyma 2003]. On the field fertilized with a uniform rate, the second and third rate were the same, i.e. 40.8 $kg\cdot ha^{-1}$ for the whole area. On the field where variable fertilization was applied, average rates for the maps presented below were 29.1 $kg\cdot ha^{-1}$ for the second dose and on average

32.3 kg·ha^{-1} for the third. On the field where variable top dressing was conducted using the second rate the savings were 28.6% of the fertilizer, whereas for the third rate – 20.8%. In comparison with the research conducted by Zagórda et al. [2007] these savings of the top applied dressing were by about 50% lower on the basis of SPAD measurements.



a) b)

Fig. 2. Spatial diversification of chlorophyll content in leaves (SPAD measurement): a) before 2nd nitrogen rate application, b) before 3rd nitrogen rate application

During fertilization the measurement of dispersal uniformity was conducted for the working width 20m; the result was 8.2%. The obtained result meets the requirements for dispersal uniformity which ensures equal access to fertilizers for plants along the whole working width of the machine [Towpik 2009]. Securing equal working width irrespective of the fertilizer granulation was possible owing to exchangeable dispersing discs and possible setting the angle and length of blades on these discs [Towpik 2011]. Difference in fertilizer consumption and the quantity calculated from the maps of spatially variable fertilization were similar to presented in the paper by Zagórda and Walczyk [2008].

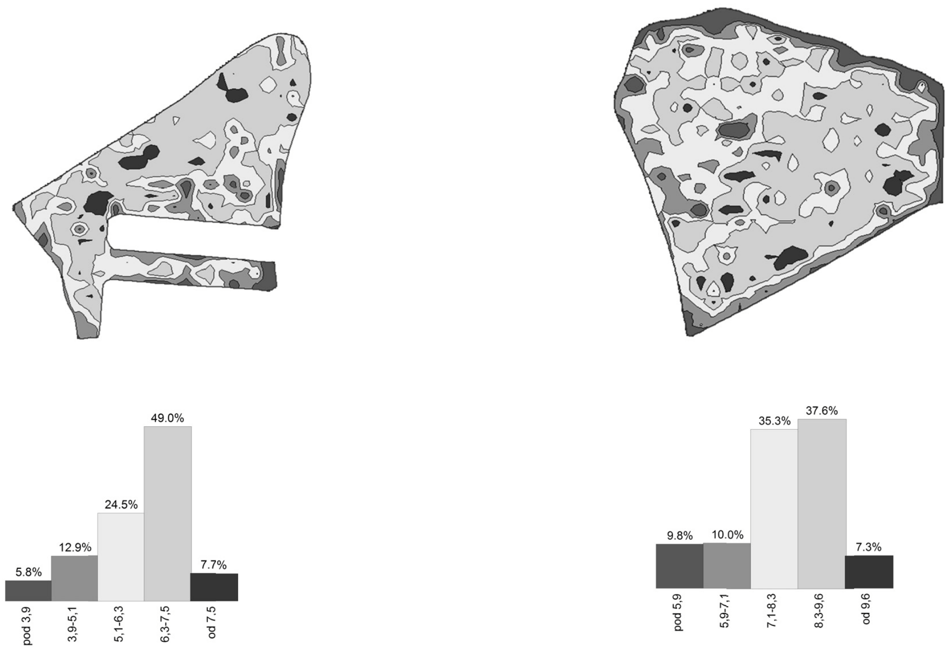
Variability of the minerals absorbed by plants on the field fertilized by the uniform rate was several-fold higher than on the field designed for variable fertilization (Tab. 1). Application of the second nitrogen rate in various ways stimulated plants in some points of the field and therefore increased variability coefficient resulting from the analysis of plant material gathered prior to the third fertilizer rate application.

Monitoring of yield made possible spatial visualisation of the crop yield in the area of the studied fields (Fig. 3). Higher yields were produced on the field where variable rates of nitrogen fertilizer were used (Fig. 3b) and average yield was c.a. 27% bigger in relation to the second field. Obtained results are much better than in the research conducted in 2007 [Zagórda et al.], where the difference in yield between areas with various fertilization systems was only 3%.

Table 1. Mineral contents in plant material [% d.m.]

Measurement	Specification	Fertilization system	N-og	P	K	Ca	Mg
Before 2nd N rate	Average	uniform	2.91	0.53	3.98	0.25	0.09
		variable	3.16	0.54	3.82	0.25	0.08
	Variability coefficient [%]	uniform	11.09	10.07	19.27	16.53	14.89
		variable	4.11	3.81	1.62	5.45	0.00
Before 3rd N rate	Average	uniform	2.60	0.32	2.53	0.18	0.09
		variable	1.57	0.31	2.14	0.16	0.08
	Variability coefficient [%]	uniform	9.98	11.10	10.75	9.78	14.86
		variable	7.16	2.99	6.25	5.26	6.79

Source: author's own calculations



a) b)

Fig. 3. Maps of spatial distribution of yields [t ·ha^{-1}]: a) field fertilized with a uniform fertilizer rate – average yield 6.14 t·ha^{-1}, b) field – fertilized with variable rate – average yield 7.48 t·ha^{-1}

The analysis of soil abundance in minerals (Tab. 2) revealed a slightly higher abundance of the field fertilized with variable rates. Also soil pH was much better on this field. It may explain higher yields produced on this field (Fig.3b). Higher value of the variability coefficient (Tab. 2) denotes that spatial diversification of soil abundance in nutrients occurs on this field, which concerns particularly magnesium (33.6%) and phosphorus (26.5%).

Table 2. Mineral contents in soil

Parameter	Fertilization system	pH in KCl	P [mg·kg^{-1}]	K [mg·kg^{-1}]	Mg [mg·kg^{-1}]
Average	uniform	4.29	41.4	177.2	47.4
	variable	5.22	61.7	184.6	69.2
Variability coefficient [%]	uniform	4.3	13.8	10.1	28.0
	variable	12.6	26.5	13.4	33.6

Source: author's own calculations

The soil testing for mineral nitrogen concentrations revealed that on the field receiving variable fertilization they were between 20 and 60% lower in all studied layers than on the fields fertilized with a uniform rate (Tab.3). The reason may be a higher soil pH (Tab.2), which favoured development of plant root system. Soil moisture on the researched objects was similar (Tab. 3) and changing slightly with depth.

Table 3. Mineral nitrogen concentrations in soil

Specification		Uniform fertilization			Variable fertilization		
Depth [m]	Description	s.m. [%]	$N\text{-}NO_3$ [mg·kg^{-1}]	$N\text{-}NH_4$ [mg·kg^{-1}]	s.m. [%]	$N\text{-}NO_3$ [mg·kg^{-1}]	$N\text{-}NH_4$ [mg·kg^{-1}]
0 □ 0,3	average	82.70	7.44	4.21	83.01	5.83	2.66
	var. coef. [%]	1.76	31.17	19.90	1.42	35.40	29.84
0,3 □ 0,6	average	83.28	5.89	2.48	83.26	3.61	1.50
	var.coef. [%]	1.23	38.83	20.55	0.89	50.19	40.65
0,6 □ 0,9	average	84.32	2.62	1.88	83.76	1.13	1.15
	var.coef. [%]	1.74	83.20	16.02	1.19	67.13	36.37

Source: author's own calculations

Grain quality analysis in view of protein content (Tab.4) did not qualify the harvested grain as quality wheat [Wyszomirski 2011]. It was caused by the weather conditions in 2011. In case of uniformly fertilized field germinated grain constituted c.a. 20% of the harvest and 25% on the field where variable fertilizer rate was applied. On the field fertilized with a variable rate, protein concentrations in grain were by 23% lower than in grain from the object fertilized with a uniform nitrogen rate. However, taking into consideration the variability coefficient we may notice that in view of protein content more balanced yield was gathered from the field where diversified nitrogen rate was applied due to chlorophyll content in leaves (tab. 4). The variability coefficient on this field was 34% lower than on the field where a uniform rate was used in the whole area.

Table 4. Contents of total nitrogen and protein in wheat grain

Parameter	Uniform fertilization		Variable fertilization	
	N-og	protein	N-og	protein
Average [% p.d.m.]	1.80	11.30	1.40	8.70
Var. coefficient [%]	3.98	4.01	2.67	2.64

Source: author's own calculations

Conclusions

1. The soil abundance in minerals and higher pH contributed to a higher yield harvested from the field receiving variable fertilization.
2. Optimal matching of the fertilizer with soil nitrogen requirements (application of variable fertilization) protects the upper soil layer against N leaching and decreases mineral nitrogen content in all studied layers from 20 to 60% better than on the field fertilized with a uniform rate.
3. Spatially variable nitrogen top dressing conducted on the basis of measurements of chlorophyll content in leaves contributed to balancing protein content in wheat grain and a decrease in the value of variability coefficient by 34%.

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WPŁYW PRZESTRZENNIE ZMIENNEGO NAWOŻENIA POGŁÓWNEGO NA JAKOŚĆ ZIARNA PSZENICY I ZAWARTOŚĆ AZOTU MINERALNEGO W GLEBIE

Streszczenie. W artykule przedstawiono wyniki zmiennego nawożenia pogłównego pszenicy ozimej na jakość ziarna i zawartość azotu mineralnego w glebie. Przeprowadzone badania wykazały, że stosowanie zmiennego nawożenia podniosło ilość pobranych składników w materiale roślinnym i obniżyło zmienność tych wartości. Jakość ziarna kwalifikowała je, jako paszowe ze względu na niską zawartość białka (poniżej 11,5%) i dużą ilość skiełkowanych ziaren (ok. 25%). Zawartość azotu mineralnego w glebie na polu nawożonym zmiennie była niższa niż na polu o nawożeniu tradycyjnym od 20 do 60%.

Słowa kluczowe: nawożenie pogłówne, jakość ziarna, azot mineralny

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