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Cost evaluation of the application of the differentiated nitrogen doses on winter wheat field

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Abstract. The materials derived from the studies of the spatial within-field variability were used in this research. The experiment was carried out in the Experimental Station Baborówko (wielkopolskie voivodship) belonging to the Institute of Soil Science and Plant Cultivation – National Research Institute (IUNG-PIB), in Puławy. The map of the variation of the nitrogen doses is based on detailed analysis of the spatial variability of field and the vegetation indices. Three types of nitrogen fertilization were used to assess the economic effect of the systems – an intensive – heavy fertilization system (according to which, the dose of 100 kg N ha^{-1} was applied on the whole field), a highly intensive – very heavy fertilization system (where 160 kg N ha^{-1} was applied), and a varied system, where a varied (within the field) dose of N was implemented and was defined on the basis of the maps of the potential productivity of the fields. The analysis showed that the unit cost of the nitrogen fertilizer per hectare was 233 PLN in the heavy fertilization system, 373 PLN very heavy fertilization system and 311 PLN in the system with the differentiated doses of N. The use of the varied nitrogen rates within the same field, allowed the costs to be reduced by about 16.7% compared to the scenario of a highly intensive use of nitrogen fertilizers. However, compared to the intensive scenario, these costs were 33.3% higher.

key words: economic assessment, map of the differentiated nitrogen rates, intense (heavy) fertilization system

INTRODUCTION

In the concept of the sustainable development, the increasingly important issues are related to protection of natural resources. The impact of agriculture on the environment is largely determined by fertilization. The fertilization treatment is an essential element of the agricultural practices, which allows high yields to be obtained and a high level of soil fertility to be maintained. The use of excessively high rates of fertilizers (particularly those of nitrogen) can affect the dispersion of the nutrients into the environment, especially into water and air (Igras, 2006). Too low rates of nitrogen, which do not fully cover the fertilizer needs of plants can reduce the size and quality of crop yield and deteriorate soil fertility. Fertilizer cost has a significant share in the structure of the direct costs and ranges from 30 to 50% depending on the crop (Skarżyńska, 2007). Therefore, both for the economic and environmental reasons, the optimal method of application of fertilizers are sought (Ostergaard, 1997; Begiebing et al., 2007; Griffin, 2007). One of the method involves adjusting the rates of nutrients to the potential productivity of the field resulting primarily from the chemical properties of the soil. Economic effects resulting from the differentiation of the fertilizers rates of are not clearly proven, and the discrepancy in the assessment of the economic effects is tremendous (Jadczyszyn, 2004b; Begiebing et al., 2007; Griffin, 2007).

The aim of this study was to assess the cost of varied fertilizer nitrogen rate depending on the potential productivity of the field.

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MATERIAL AND METHODS

The material used in the study came from the research of spatial variability of cultivated wheat fields, conducted in the Experimental Station IUNG-PIB in Baborówko (wielkopolskie voivodship). The station conducts large--area experiments on an area of 53.6 ha in crop-rotation with winter wheat, spring barley and winter rape with applying the principles of the precision farming.

The standardized agrotechnology adopted in the integrated agriculture is used according to the recommendations of IUNG-PIB for integrated farming.

The soil-agricultural map 1:1000 was applied to determine the spatial variation of the soil and the nutrients abundance (Oczoś, 1994) as well as the results of soil tests carried out in a grid with a resolution of 24 m. The aerial photographs taken between 2005–2007 were used to estimate the vegetation index maps. The photographs were taken at the shooting, early anthesis and milk-ripe stages of winter wheat (Pudełko et al., 2006).

The spatial data from the soil maps, aerial photographs and maps of the electromagnetic resistance of the soil were used to assess the yield potential of the experimental field. The measurement of soil electromagnetic resistance was performed using EM 38, which is currently the world's most popular remote device for assessing of the variability of physico-chemical properties of the soil.

The quality assessment and classification of aerial photographs were made based on the measurement of electromagnetic conductivity of the soil, which significantly depends on the granulometric composition of the soil. The spatial data were converted to digital form in a geographic information system (GIS) and were the basis for compiling the map for the optimization of nitrogen fertilization rates (Pudełko, 2005, 2006).

The evaluation of the costs of nitrogen application on 48.83 hectares field of winter wheat, was made on the basis of actual costs of fertilizer which would be incurred in the precision farming system, assuming that the dose is varied on the basis of the map of potential field productivity. This result was compared to the cost of fertilizer application in intensive and highly intensive system of fertilization. In the intensive system a nitrogen rate of 100 kg N ha^{-1} was assumed, whereas in a highly intensive (very heavy fertilization) system of 160 kg N ha^{-1}. In a system of the different nitrogen rate, the rate was variable and ranged from 100 to 160 kg N ha^{-1}. The cost estimate assumed a unit price of nitrogen in ammonium nitrate of the spring of 2007.

RESULTS AND DISCUSSION

The large mosaic of soil was observed both in the region of Wielkopolska and the fields of the experimental station Baborówko. The research conducted under the LOTON project enabled the diagnosis and analysis of the variability range of the soil conditions of the experimental fields. The analysis of the collected spatial data showed the significant differences in soil conditions within the analyzed experimental field. A large range of the soil conditions variability was also confirmed by the aviation pictures and measurements of the electromagnetic conductivity of the soil.

The research conducted in the LOTON project demonstrated the need for diversification of the nitrogen rates in the separate zones of the field because of the soil conditions. It was also confirmed by aerial photographs and measurements of the electromagnetic conductivity of the soil. In this connection, a vector map of nitrogen rates was compiled, producing four different zones (Fig. 1). Maps were prepared on the basis of the spatial data obtained by teledetection methods (Kozyra and Pudełko, 2006; Pudełko et al. 2007). The map of the nitrogen rates additionally took into account the agronomic possibilities (distance of technological paths) and the differentiation capacity of the fertilizer rates of the fertilizer spreader Bogbal EX-Trend type.

Table 1. The amount of nitrogen in each zone.

Zone	Rate of nitrogen [kg ha^{-1}]	Area [ha]	Amount of nitrogen [kg]
1	100	2.17	217.0
2	120	18.05	2166.0
3	140	22.65	3171.0
4	160	5.96	953.6
1–4		48.83	6507.6

Figure 1 shows the spatial extent of each zone with different nitrogen rates. The information about the surface of each zone and the amount of nitrogen applied is given in Table 1. The total amount of nitrogen needed in the field of winter wheat was calculated on that basis.

In earlier studies Jadczyszyn et al. (2004) suggest that the intake of nitrogen by winter wheat in the experimental field ranged from 110 to 180 kg N ha^{-1} for the range of variability in yield from 4.6 to 7.6 t ha^{-1}. Nitrogen rates were determined for the above range of yield variability using the fertilizer advice software NAWSALD (Jadczyszyn, 2004a). The recommendations show that the nitrogen rates should range between 100 for the lowest yield to 160 kg N ha^{-1} for the highest yield. For the comparison the cost of nitrogen fertilizer application a following assumptions were made: the lower limit of the range was taken as the intensive system of nitrogen fertilization, while the upper limit was assumed as the highly intensive fertilization regime, and the rates of nitrogen were chosen accordingly. The comparison

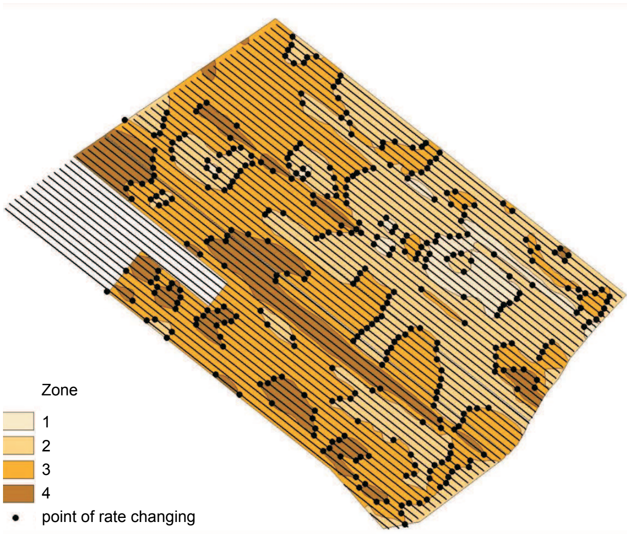

Fig. 1. The map of the differentiation of the nitrogen rates.

Table 2. The amount of nitrogen and the fertilizing costs in each fertilization system.

Fertilization system	Nitrogen rate [kg ha^{-1}]	Amount of nitrogen [kg]	Fertilizer costs [PLN]	Unit fertilizer cost [PLN ha^{-1}]
Intensive	100	4883.0	11 377.39	233.0
Highly intensive	160	7812.8	18 203.82	372.8
Based on the map of potential productivity of the field	differentiated	6507.6	15 162.71	310.5

of the different systems is presented in Table 2 assuming for calculations a unit price of nitrogen in the ammonium nitrate as 2.33 PLN per 1 kg N.

In a Danish study the direct benefit from the use of different rates of nitrogen fertilization was estimated at 15–50 $ per hectare (Griffin, 2007). In a study conducted by Begiebing et al. (2007) the differentiation of nitrogen rates in the cultivation of winter wheat allowed the reduction of the total rate from 19 to 43 kg N ha^{-1}.

The study carried out by the authors showed that the unit costs of nitrogen fertilizer in different systems are diversified and were around 233 PLN ha^{-1} in the intensive system, and around 373 PLN ha^{-1} in the highly intensive system and about 311 PLN ha^{-1} in system with the differentiated rates of nitrogen. The use of varied nitrogen rates allowed the cost of fertilizers application to be reduced by 16.7% (an average of 27 kg N ha^{-1}) in relation to the highly intensive system. However, compared to the intensive system, these costs were higher by around 33.3%. It should be noted that, in accordance with the fertilizers recommendations that take into consideration the soil conditions of the experimental field the use of the lowest dose of nitrogen should be limited only to the surface of 2.17 ha. The use of nitrogen in the whole field under intensive fertilization system may not meet the nutritional requirements of plants and result in lower yields. The research conducted by Podolska et al. (2005) on the economic and qualitative assessment of winter wheat crops, depending on the level of the nitrogen fertilization showed that to achieve maximum grain yield of wheat, the rate of 140.6 kg N ha^{-1} was necessary. The application of this rate on the surface of the entire field would result in the cost of buying fertilizer at about 15 997 PLN, i.e. higher by 5.5% than estimated in the investigations in the variant with differentiate N doses.

The results gained in the study are representative for the Wielkopolska region, characterized by a large mosaic of the soils as well as the weather conditions unfavourable for yields, mainly due to the drought stress. The presented study shows only a general picture of possible use of techniques that involve variable dosing of nutrients in plant fertilization

CONCLUSIONS

1. The study shows that a large range of variability in soil conditions of the experimental field gives rise to the differentiation of nutrients within the same experimental field.
2. The use of varied rates of nitrogen in the production of winter wheat gave the chance to reduce the cost of application of fertilizers by 16.7% (an average of 27 kg N ha^{-1}) in relation to the application of uniform nitrogen rates
3. The maps of the differentiation of fertilizer rates should be developed for each field individually. Other factors such as weather conditions during the growing season will impact the expected economic effect

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