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THE EFFECT OF NITROGEN FERTILISERS ON THE GRAIN YIELD OF DIFFERENT CULTIVARS OF WINTER WHEAT

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The article deals with the effect of nitrogen fertilizer on the yield of different cultivars of winter wheat. Field experiments were conducted in 2011–2013 at the Experimental Station of Aleksandras Stulginskis University in carbonate shallow gleyic leached soil, (*Calc(ar)i-Epihypogleyic Luvisol*). The object of the investigation was winter wheat cultivars 'Zentos' and 'Ada'. In sowing time the wheat was treated with granular superphosphate (P_{60}) and potassium chloride (K_{60}), and in spring, after the vegetative growth had resumed, in tillering time (BBCH 23–15) with ammonium nitrate (N_{60}). Additionally, foliar fertilizer urea solution was used: N_{30}, N_{40} at booting stage (BBCH 34–36) and N_{15}, N_{30} at milk ripening stage (BBCH 71–74). It has been established that application of nitrogen fertilizer at booting and milk ripening stages increased the yield of wheat cultivars 'Zentos' and 'Ada' (0.06–1.74 and 0.41–1.74 t ha^{-1}). The correlation and regression analysis confirmed that wheat grain yield statistically significantly correlated with nitrogen fertilizer application rates. The correlative relationships were very strong ($r = 0.983$ and $r = 0.987$). Irrespective of additional fertilization, genetic properties of the cultivars also had influence on the yield.

Keywords: yield, nitrogen fertilizer, winter wheat.

INTRODUCTION

According to overall production, wheat is the most common crop in the world after rice and corn. Annually, more than 600m tons of it is grown for food and feed (Shewry, 2009). Nitrogen is the most important fertiliser necessary for plant growth and the production of biomass (Lian-peng et al., 2012; Murozuka et al., 2014).

Meteorological conditions in Lithuania are not favourable to have an ample and good quality winter wheat yield each year. Therefore ways are sought to optimise the process of plant nutrition, especially with nitrogen. The effect of nitrogen on wheat, with foliar fertilisation, also depends heavily on the time of fertiliser application (Maikštėnienė et al., 2006).

For winter crops nitrogen is necessary throughout the whole period of their vegetation. However, at different development stages the effect of N on the formation of grain yield varies (Diekmann and Fishbeck, 2005). The greatest amount of nitrogen is required at the 5th –7th stages of organogenesis process (at booting – seedling growth stages). This is the time of intensive cell division as well as the metabolism of proteins and other biologically active substances (Fageria et al., 2006; Šlapakauskas ir Duchovskis, 2008). Having optimised wheat nutrition with nitrogen, in tillering time more shoots develop, at booting stage more productive stems are formed and after flowering protein content in grain increases (Maikštėnienė et al., 2006; Leliūnienė et al., 2013; Vagusevičienė et al., 2013).

Winter wheat growing conditions and productivity change, depending upon climate change (Lazauskas et al., 2012). Crop can suffer not only from long-term but also from short-term adverse meteorological conditions (Gelvonauskis et al., 2000; Šabajevienė et al., 2008; Lukatkin et al., 2012). The yield losses incurred due to climate change can be reduced by correctly selecting plants or their cultivars and by applying appropriate growing technologies (Brazaitytė et al., 2008; Duchovskis et al., 2015).

Plant yield potential is fully exhausted under favourable environmental conditions (Long et al., 2006; Zhu et al., 2008). Both the demand for nitrogen and maximum yield are genetically programmed (Balogh et al., 2007), therefore it is necessary to choose not only the fertiliser application rates optimal for a certain cultivar, but also fertilisation strategies optimal for different climatic conditions (Tranavičienė, 2009).

The aim of the work is to investigate the effect of nitrogen fertiliser on the grain yield of different cultivars of winter wheat.

MATERIALS AND METHODS

The investigation was carried out during the period between 2011 and 2013, at the Experimental Station of Aleksandras Stulginskis University. The object of the research: cultivars of winter wheat 'Zentos' (Germany) and 'Ada'

(Lithuania). The soil: carbonate shallow gleyic leached soil, (IDg8-k) *Calc(ar)i-Epihypogleyic Luvisol* (*LVg-p-w-cc*). According to the values of agrochemical indicators, over the research years the soil was neutral and weakly alkaline (pH_{KCl} 7.0–7.2) with medium humus content (2.48–2.70 %) and high phosphorus (271.0–296.8 mg kg^{-1} P_2O_5) and potassium content (178.0–184.0 mg kg^{-1} K_2O).

The two-factor field experiment was conducted in five variants with four replications, factor A being winter wheat cultivars and factor B – nitrogen fertilizer application rates. Total plot size of the experiment was 40 m^2 (4x10) and harvested plot size was 20 m^2 (2x10). The plots were arranged in random order.

Winter rape was the preceding crop of winter wheat. Autumn ploughing (25 cm in depth), cultivation, harrowing, sowing and the application of phosphorus and potassium fertilisers ($P_{60}K_{60}$) were major tasks to set up the experiment. The seeding rate was 4.5 million fertile seeds per ha^{-1}. The sowing process was performed by seeding machine Kverneland Accord m-drill, 3.5 cm in the soil.

Granular superphosphate (P_{60}) and potassium chloride (K_{60}) fertilisers were spread during sowing, while ammonium nitrate (N_{60}) in spring, in tillering time (BBCH 23–25), after the vegetation had resumed. Additionally, the plants were treated with foliar fertilizer urea solution: N_{30}, N_{40} at booting stage (BBCH 34–36) and N_{15}, N_{30} at milk ripening stage (BBCH 71–74).

The scheme of the experiment:

Factor A (winter wheat cultivars):

1. ‘Zentos’
2. ‘Ada’

Factor B (nitrogen fertilizer application rates):

1. Control – ($P_{60}K_{60}$) in sowing time + N_{60} in tillering time (Background).
2. Background + N_{30} at booting stage + N_{15} in milk ripening stage.
3. Background + N_{30} at booting stage + N_{30} in milk ripening stage.
4. Background + N_{40} at booting stage + N_{15} in milk ripening stage.
5. Background + N_{40} at booting stage + N_{30} in milk ripening stage.

The system of plant protection against diseases and weeds was applied. The winter wheat was sprayed with herbicides (BBCH 19–20 and BBCH 27), fungicides (BBCH 37 and BBCH 65–67) as well as growth regulators (BBCH 32 and BBCH 37).

The meteorological conditions of the experiment are described according to the registered data of Noreikiškės based Kaunas Meteorological Station. In 2011 September was warm and humid. The monthly average of the month was 13.6 °C (1.4 °C higher than the multi annual average). The monthly precipitation exceeded the multi average of September by 20.1 mm. The level of moisture (HTC – 1.81) and warmth after the sowing was favourable for the germination and development of winter wheat. The temperature close to multi annual averages prevailed until the middle of November. December was unusually warm. The average temperature reached 1.9 °C. January was warmer than usual, while February was 5.5 °C colder than the multi annual average. The beginning of March was dominated by wintry weather (–1.2–5.2 °C). A period of spring-like weather started from the second decade of the month. The average temperature in April reached 7.7 °C; the level of precipitation was 72.3 mm. Over the rest of the vegetative period of the plants the temperature remained close to multi annual averages. However, the amount of precipitation varied considerably: it was either higher or lower than the multi annual averages. The wheat was harvested on 2 August.

In 2012 wheat was sown on 17 September. The average temperature of the month was 12.2 °C, close to the multi annual average. Monthly precipitation exceeded multi annual September average by 13.2 mm. the wheat sprouted well and evenly, took root, and their vegetation period continued until the middle of November. Although the winter was not warm, the crop wintered well. The vegetation of the plants resumed in the middle of April. The average temperature of the month reached 5.5 °C (1.2 °C lower than the multi annual); the precipitation was 56.5 mm. May was warm and humid enough (HTC – 1.28). The average temperature reached 16.1 °C (3.5 °C higher than the multi annual). The average temperature in June was 18.5 °C (close to the multi annual average). The precipitation was 45.9 mm (HTC – 0.83). The weather in July was changeable. In the first decade of the month there was only 1.5 mm of rainfall, and the average temperature was 19.1 °C. The second decade was marked by heavy rain (79.8 mm), and the average temperature was 17.6 °C. The precipitation during the third decade reached 37.2 mm, and the average temperature again reached 19.1 °C. On 31 July the wheat had reached hard dough maturity and was thrashed.

The methods of the agrochemical analyses of the soil: soil pH_{KCl} – potentiometric, 1 N KCl extract (LST ISO 10390:2005); organic carbon (C), % – Tyurin (ISO 10694:1995); humus, % – calculated by multiplying the amount of carbon by a factor of 1.724; mobile phosphorus (P_20_5) and potassium (K_2O), mg kg^{-1} – Egner–Riehm–Domingo (A–L) (GOST 26208–84).

The stages of wheat development are presented according to BBCH scale (Meier, 1997).

The harvest of wheat crop has been calculated by a computerized weighing system in the combine harvester. Crop yield has been recalculated with crop moisture being 14 % and the crop being absolutely clean.

Statistical processing of the yield data has been performed using dispersive analysis method *ANOVA*, software package *SELEKCIJA*. Dispersive analysis of two factor data has been employed (Tarakanovas ir Raudonius, 2003). Correlation and regression have been calculated with software program *STATISTIKA 7* (Hill and Levicki, 2005).

The symbols used in the article:

* – statistically significant, when, respectively, the degree of probability is 95 % ($P < 0.05$);

** – statistically significant, when, respectively, the degree of probability is 99 % (*P* < 0.01);

(*P* > 0.05) – no significant differences;

LSD_{05} – margin of significant disparity when the degree of probability is 95 %; LSD_{01} – margin of significant disparity when the degree of probability is 99 %.

RESULTS AND DISCUSSION

One of the most important and effective factors leading to an increase in yield and improvement of quality indicators is application of nitrogen fertilizer (Ehdaie and Waines, 2001; Acevedo et al., 2002; Mašauskas and Mašauskienė, 2002).

In each year of the experiment winter wheat grain yield rose due to nitrogen fertilizer used at booting and milk ripening stages. In 2012 treatment of 'Zentos' plants with $N_{30} + N_{15}$, $N_{30} + N_{30}$, $N_{40} + N_{15}$ and $N_{40} + N_{30}$ fertiliser application rates increased the yield (0.06–0.55 t ha^{-1}), as compared to control plot plants; the rise was not considerable (*P* > 0.05) (Table 1).

Table 1. Winter wheat yield (t ha^{-1}), 2012–2013

Winter wheat cultivars (Factor A)	Nitrogen fertilizer application rates (Factor B)				
	$N_{60} + N_0 + N_0$	$N_{60} + N_{30} + N_{15}$	$N_{60} + N_{30} + N_{30}$	$N_{60} + N_{40} + N_{15}$	$N_{60} + N_{40} + N_{30}$
2012					
'Zentos'	6.88	6.94	7.21	7.43	7.43
'Ada'	3.79	4.20	4.85	5.02	4.72
$LSD_{05\ AxB}$ = 0.745; $LSD_{01\ AxB}$ = 1.006;					
2013					
'Zentos'	5.41	6.79	7.28	7.20	7.40
'Ada'	5.78	7.20	7.48	6.81	7.52
$LSD_{05\ AxB}$ = 0.394; $LSD_{01\ AxB}$ = 0.532					

The comparison of the yields of 'Zentos' wheat treated with different application rates ($N_{30} + N_{30}$ with $N_{30} + N_{15}$, $N_{40} + N_{30}$ with $N_{40} + N_{15}$, $N_{40} + N_{15}$ with $N_{30} + N_{15}$ and $N_{40} + N_{30}$ with $N_{30} + N_{30}$) did not reveal any significant differences (*P* > 0.05). The wheat of cultivar 'Ada' fertilized with $N_{30} + N_{30}$ and $N_{40} + N_{15}$ fertiliser application rates at booting and milk ripening stages produced a considerably bigger yield (1.06–1.23 t ha^{-1}) (*P* < 0.01), as compared to with control plot plants. A substantial addition to the yield (0.93 t ha^{-1}) (*P* < 0.05) was also achieved in the wheat treated with $N_{40} + N_{30}$ fertiliser application rate, in comparison to control plot plants. Fertilization with $N_{30} + N_{15}$ fertiliser application rate, as compared to unfertilized wheat, did not have any significant influence on the yield (*P* > 0.05). However, the yield was substantially improved (0.82 t ha^{-1}) (*P* < 0.05) by fertilisation with a higher (N_{40}) fertilizer application rate at booting stage, and with N_{15} fertiliser application rate at milk ripening stage, in comparison to the wheat treated with $N_{30} + N_{15}$ fertiliser application rate. The comparison of 'Ada' plants fertilized with different application rates ($N_{30} + N_{30}$ with $N_{30} + N_{15}$, $N_{40} + N_{30}$ with $N_{40} + N_{15}$ and $N_{40} + N_{30}$ with $N_{30} + N_{30}$) did not show any significant effect of the fertilizer on the yield (*P* > 0.05). Irrespective of additional fertilization, wheat genotype influenced the yield. Cultivar 'Zentos' wheat in tillering time treated with N_{60} fertiliser application rate produced a substantially more copious (3.09 t ha^{-1}) (*P* < 0.01) harvest, as compared to 'Ada' wheat fertilized with the same application rate. 'Zentos' plants additionally treated with nitrogen fertilizer cropped considerably better (2.36–2.74 t ha^{-1}) (*P* < 0.01), in comparison to additionally fertilised 'Ada' wheat.

In 2013 cultivar 'Zentos' wheat yield was on average 5.0 % lower, while that of 'Ada' 54.0 % higher than in 2012 when the wheat was lodged due to unfavourable meteorological conditions. Additional fertilization at booting and milk ripening stages considerably increased (1.38–1.99 and 1.03–1.74 t ha^{-1}) (*P* < 0.01) 'Zentos' and 'Ada' yields, as compared to the plants in control plots. 'Zentos' wheat treated with $N_{30} + N_{30}$ application rates at booting and milk ripening stages cropped substantially more copiously (0.49 t ha^{-1}) (*P* < 0.05), as compared with the wheat fertilized with $N_{30} + N_{15}$ application rates. The yield was significantly improved (0.41 t ha^{-1}) (*P* < 0.05) by fertilization with a higher (N_{40}) application rate at booting stage, and with N_{15} application rate at milk ripening stage, in comparison to the wheat treated with $N_{30} + N_{15}$ application rate. Fertilization with $N_{40} + N_{30}$ application rate, as compared to the wheat treated with $N_{40} + N_{15}$ application rate, did not have any significant impact on the yield (*P* > 0.05). No considerable improvement (*P* > 0.05) in the yield was established after the fertilisation with $N_{40} + N_{30}$ application rate, in comparison to the wheat treated with $N_{30} + N_{30}$ application rate. Fertilization with $N_{40} + N_{30}$ application rate at booting and milk ripening stages increased the yield considerably (0.71 t ha^{-1}) (*P* < 0.01) in 'Ada' plants, as compared to the wheat fertilized with $N_{40} + N_{15}$ application rate. The comparison of the yields of 'Ada' plants treated with different fertilizer application rates ($N_{30} + N_{30}$ with $N_{30} + N_{15}$, $N_{40} + N_{15}$ with $N_{30} + N_{15}$ and $N_{40} + N_{30}$ with $N_{30} + N_{30}$) no significant differences (*P* > 0.05) were established. The yield of cultivar 'Ada' wheat was not improved substantially (*P* > 0.05) by the fertilization with N_{60} application rate in tillering time, in comparison to 'Zentos' plants treated with N_{60} application rate. Genetic peculiarities of the cultivar did not manifest themselves. 'Ada' plants treated with $N_{30} + N_{15}$ application rate produced a considerably bigger harvest (0.41 t ha^{-1}) (*P* < 0.05) than 'Zentos' wheat fertilized with the same fertilizer application rate. The cross-comparison of the yields of 'Ada' and 'Zentos' wheat treated with $N_{30} + N_{30}$, $N_{40} + N_{15}$ and $N_{40} + N_{30}$ did not reveal any significant differences (*P* > 0.05).

The correlation and regression analysis of the data showed that the yield of winter wheat statistically significantly depended on nitrogen fertilizer application rates (Fig. 1).

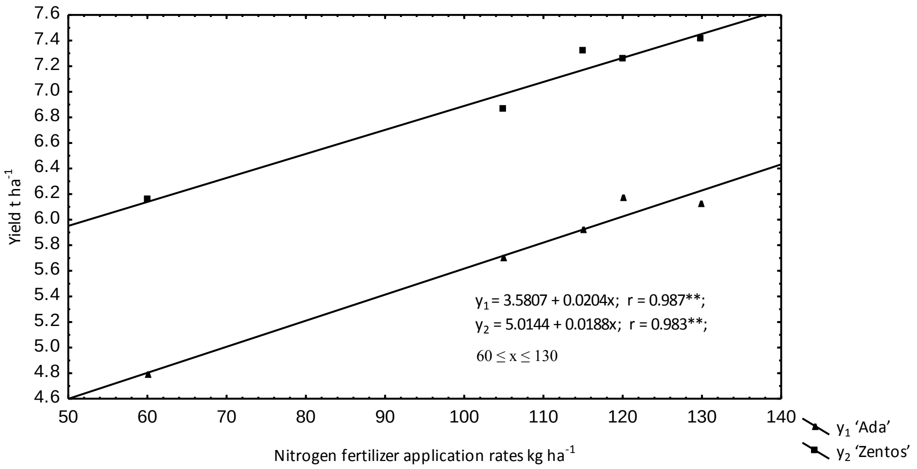

Figure 1. The dependence of winter wheat yield (y_1, y_2, t ha^{-1}) on nitrogen fertilizer application rates (x, kg ha^{-1}), 2012–2013
Note: ** – statistically significant, when, respectively, the degree of probability is 99 % ($P < 0.01$)

The dependence of the yield (y_1, y_2; t ha^{-1}) on nitrogen fertilizer application rates (x; kg ha^{-1}) was best reflected by the following linear regression equations: $y_1 = 3.5807 + 0.0204x$; $y_2 = 5.0144 + 0.0188x$. Correlative relations obtained were very strong ($r = 0.987$**; $r = 0.983$**).

Scientific literature states that the application of nitrogen fertilizer at late stages of development – after seedling growth – increases the concentration of nitrogen in the upper part of the plant, prolongs the vegetative growth of the flag leaf, activates the photosynthesis process and may even cause the renewal of micro-roots (Daniel and Triboi, 2000). It has been proved by different research that fertilization of winter wheat after flowering creates more favourable conditions for protein synthesis in the cells building grain mass (Lomoko, 1998). It is likely that the plants in our experiments assimilated nitrogen fertilizer directly, which contributed to the formation of larger yield.

CONCLUSIONS

Additional fertilization with nitrogen at booting and milk ripening stages increases wheat yield. The correlation and regression analysis shows that wheat yield statistically significantly depends on nitrogen fertilizer application rates. The dependence on fertilizer application rates is best described by linear regression equations. Correlative relationships obtained are very strong. Irrespective of additional fertilization, wheat genotype also has influence on the yield.

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