INFRASTRUKTURA I EKOLOGIA TERENÓW WIEJSKICH
INFRASTRUCTURE AND ECOLOGY OF RURAL AREAS

Nr III/2/2017, POLISH ACADEMY OF SCIENCES, Cracow Branch, pp. 1275–1284
Commission of Technical Rural Infrastructure

DOI: http://dx.medra.org/10.14597/infraeco.2017.3.2.098

EFFECT OF SPRINKLER IRRIGATION AND NITROGEN FERTILISATION ON THE YIELD AND BAKING VALUE OF SPRING WHEAT GRAIN

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Abstract

The aim of the research was to evaluate the effect and interaction of sprinkler irrigation and nitrogen fertilisation on the grain yield and baking value of 'Monsun' spring wheat cultivar grown in light compacted soil. A field experiment was performed in 2013-2014 in an experimental field of the Department of Land Improvement and Agrometeorology, the UTP University of Science and Technology, at Mochełek, in the vicinity of Bydgoszcz. It was found that sprinkler irrigation significantly increased the spring wheat grain yield. The grain from sprinkler-irrigated stands demonstrated greater plumpness; it contained significantly less protein and gluten and showed a lower sedimentation value, as compared with the grain of non-sprinkler-irrigated plants. However, the protein yield produced under sprinkler irrigation conditions was on average 11% higher, compared to the control conditions. The effect of nitrogen fertilisation on the spring wheat grain yield and quality correspond to earlier findings. Similarly to other research reports, a regular yield increase and enhanced quality of baking features along with an increase in the nitrogen rate were identified. Considering the quantitative and baking features of the grain yield, it was found that the optimal nitrogen fertilisation rate in 'Monsun' spring wheat, in both water variants, was 180 kg·ha^{-1} (pre-sowing 120 kg ·ha^{-1} and top dressing 60 kg ·ha^{-1}).

Key words: sprinkler irrigation, spring wheat, nitrogen fertilisation, baking value of grain

INTRODUCTION

The production potential and competitiveness of agriculture in central Poland are decreased due to the occurrence of precipitation deficits. The deficits concern all the crops, also wheat the grain of which is the basic material in the country's food economy. The earlier research shows that precipitation deficits in spring wheat growing in the dominant third – and fourth-valuation class soils of the kujawsko-pomorski region, at the time of intensified water requirements, are 65 mm on average. In very dry periods, which occur at 20% frequency, such deficits are two times higher (Żarski and Dudek 2009, Żarski *et al.* 2013). The deficits mostly result in decreased yields and harvest size; they are also the cause of lower technological grain applicability which cannot be enhanced by other agrotechnical practises, including nitrogen fertilisation.

The effect of nitrogen fertilisation on the spring wheat grain yield and quality is well known and constantly improved thanks to the results of numerous field experiments (Buczek *et al.* 2011, Gąsiorowska and Makarewicz 2008, Kocoń 2005, Kołodziejczyk *et al.* 2012, Kulig *et al.* 2009, Ralcewicz *et al.* 2009, Sułek and Podolska 2008) and pot experiments (Cacak-Pietrzak and Sułek 2007). A high number of experiments cover also the effect of sprinkler irrigation and the interaction of water and nitrogen on spring wheat yielding (Chmura *et al.* 2009, Rakowski 2003a,b, Żarski *et al.* 2002, Żarski 2009). However, over the recent years, the number of those experiments has decreased due to a lack of cost-effectiveness of cereal crops sprinkler irrigation and thus a limited interest in that agricultural producers' practise (Chmura *et al.* 2009, Kledzik *et al.* 2015).

The reason to resume the research in the Bydgoszcz facility aimed at investigating a response of spring wheat to sprinkler irrigation comes from a conviction that in the future sprinkler irrigation would be applied at a much larger scale due to the necessity of the country's agriculture to become modern and competitive (Łabędzki 2009, Rzekanowski 2010, Rzekanowski *et al.* 2011). As for cereal crops, sprinkler irrigation should be, first of all, applied in high-quality spring wheat and spring malting barley cultivars production technology (Żarski 2009, Żarski *et al.* 2013).

The primary objective of the research was to determine the production effectiveness of sprinkler irrigation of 'Monsun' high-quality spring wheat cultivar in terms of grain baking value enhancement and identifying an optimal rate of nitrogen fertilisation when exposed to sufficient water factor.

MATERIAL AND METHODS

The field experiment was performed in 2013 and 2014 in the experimental field of the Experiment Station, the Uniwersytet Technologiczno-Przyrodniczy (UTP University of Science and Technology), at Mochełek, in the vicinity of Bydgoszcz. High-quality 'Monsun' spring wheat cultivar was used for research. The experiment was performed in Haplic Luvisol, representing IVa soil valuation class and very good rye soil suitability complex. In terms of the level of compactness, it is a light soil deposited on compact formation (sand on shallow-deposited sandy clay loam).

The two-factor experiment was performed in split-plot, in four repetitions. The plot area for harvest was 5.80 m^2. The first factor included sprinkler irrigation in two variants: W_0 – without sprinkler irrigation, W_1 – sprinkler irrigation to provide readily available water in the soil surface layer throughout the wheat vegetation period. The sprinkler-irrigation dates were determined with the balance irrigation-control method (Drupka 2006), daily monitoring of soil moisture was carried out from 11 May to 20 July, based on the meteorological data from the measurement point located 500 m away. The second experiment factor included nitrogen fertilisation in four variants: N_0 – without fertilisation (control objects), N_1 – pre-sowing fertilisation 60 $kg \cdot ha^{-1}$, N_2 – pre-sowing fertilisation 120 $kg \cdot ha^{-1}$, N_3 – fertilisation 180 $kg \cdot ha^{-1}$ (pre-sowing 120 $kg \cdot ha^{-1}$ and top dressing 60 $kg \cdot ha^{-1}$).

Technological grain analyses were performed at the Food Industry Cereals Crop Grain Quality Evaluation Laboratory of the Sub-Department of Agricultural Chemistry of the said University (Knapowski *et al.* 2015). The content of total protein and the amount of wet gluten as well as the Zeleny sedimentation value were assayed using Infratec 1241 Grain Analyzer, and the falling number – with the Hagberg method (PN-ISO-3093).

Statistical calculations were performed with the analysis of variance of a two-factor experiment in split-plot, with the Tukey test, applying the ANALWAR – 5.1. FR software package.

RESULTS

In the 2013 2014 vegetation periods, the average spring wheat sprinkler irrigation requirements amounted to a total of 60 and 85 mm, respectively (Table 1). An application of 3-4 irrigation rates was required. In the 2013 period, the requirements mostly resulted from an uneven distribution, and in 2014 – from a decreased amount of precipitation. In general, however, despite a variation in the total precipitation in the critical period, both vegetation periods, in terms of spring wheat sprinkler irrigation requirements, did not differ considerably. In both periods, sprinkler irrigation was applied mostly in the second and third decade of June and in the first decade of July.

Table 1. Precipitation in the decades of the 2013-2014 spring wheat sprinkler irrigation period and the irrigation rates applied

Year	Period of spring wheat irrigation						
	II decade of May	III decade of May	I decade of June	II decade of June	III decade of June	I decade of July	Total
Rainfall (mm)							
1986-2015	16.0	16.2	16.6	17.5	20.9	23.8	111.0
2013	9.1	64.6	5.8	0.0	43.5	35.0	158.0
2014	10.6	23.0	10.2	12.0	22.7	14.4	92.9
Number of days without readily available water in the spring wheat root layer on non-irrigated plots							
2013	0	0	0	8	4	0	12
2014	0	0	1	8	4	5	18
Irrigation rates (mm)							
2013				20	20	20	60
2014		20		25	20	20	85

Source: own data and elaboration

As a result of sprinkler irrigation, irrespective of the nitrogen fertilisation rate, there was a significant increase in the grain yield by 1.05 $Mg \cdot ha^{-1}$, which is 19.4% higher compared to control (Table 2). Per-unit effectiveness of applying 1 mm of irrigation water was 14.5 $kg \cdot ha^{-1}$. Grain from irrigated stands showed a significantly higher thousand grain weight and bulk density of grain. In terms of quality features referring to the baking value, as compared with the non-sprinkler irrigated plants, the grain contained less protein and wet gluten; moreover, it showed a significantly lower Zeleny sedimentation value and a lower falling number.

Nitrogen fertilisation, irrespective of the water factor, differentiated the grain yield and its quality features more than sprinkler irrigation (Table 3). The highest grain yields were produced by fertilising spring wheat with the nitrogen rate of 120 and 180 $kg \cdot ha^{-1}$. The effect of nitrogen fertilisation on the grain weight was less unambiguous. As for baking features, the effect of fertilisation was significant and unambiguous, leading to a regular increase in the content of total protein, amount of wet gluten and the sedimentation value with the nitrogen rate. A significantly higher falling number was recorded for the grain of the plants fertilised with nitrogen at the amount of 180 kg·ha^{-1}, as compared with the other fertilisation variants.

Table 2. Effect of sprinkler irrigation on the spring wheat features studied

Variants of water factor	Grain yield	Thousand grain weigh	Weight of hectolitre	Total protein content	Wet gluten content	Sedimentation value	Falling number
	Mg·ha^{-1}	g	kg·hl^{-1}	g·kg^{-1}	%	cm^3	s
W_0	5.40	49.9	80.1	138.0	34.7	48.2	523
W_1	6.45	52.1	80.8	128.1	31.2	40.1	484
$NIR_{0,05}$	0.30	1.3	0.4	6.3	2.2	4.7	21
Difference (%)	19.4	4.4	0.9	-7.2	-10.1	-16.8	-7.5

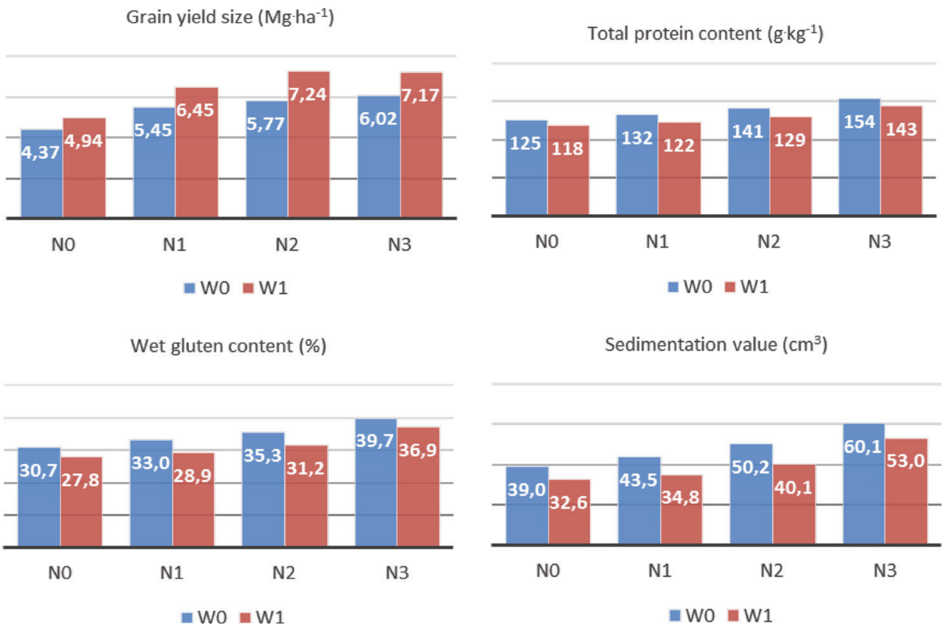
Source: own data and elaboration

Table 3. Effect of nitrogen fertilisation on the spring wheat features studied

Variants of fertilisation level	Grain yield	Thousand grain weigh	Weight of hectolitre	Total protein content	Wet gluten content	Sedimentation value	Falling number
	Mg·ha^{-1}	g	kg·hl^{-1}	g·kg^{-1}	%	cm^3	s
N_0	4.65a	50.3b	80.3a	121.5a	29.3a	35.8a	502a
N_1	5.95b	52.4a	80.3a	127.0b	31.0b	39.1b	486a
N_2	6.50c	50.4b	80.3a	135.0c	33.2c	45.2c	496a
N_3	6.59c	50.8b	80.8b	148.7d	38.3d	56.6d	533b
$NIR_{0,05}$	0.28	1.5	0.4	2.6	0.8	0.8	21

Source: own data and elaboration

The interaction between sprinkler irrigation and nitrogen fertilisation was significant for four wheat features, out of seven (Figure 1). The highest grain yield and its increase as a result of sprinkler irrigation were recorded by fertilising wheat with the nitrogen rate of 120 kg·ha^{-1}. However, considering the grain quality features, the most favourable nitrogen rate under sprinkler irrigation conditions was 180 kg·ha^{-1}. The grain of plants fertilised with that rate and sprinkler irrigated contained significantly more protein, gluten, and showed a higher sedimentation value, as compared with the other fertilisation variants.

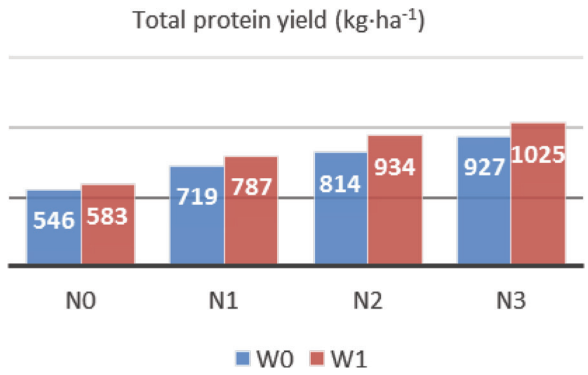


Source: own data and elaboration

Figure 1. Effect of the interaction between sprinkler irrigation and nitrogen fertilisation on the yield and selected 'Monsun' spring wheat grain quality features (top left: grain yield; top right: total protein content, bottom left:wet gluten content, bottom right: sedimentation value)

DISCUSSION

The variation in 'Monsun' wheat features due to sprinkler irrigation and nitrogen fertilisation is a confirmation of earlier results, which mostly refer to the effect of nitrogen fertilisation on the grain yield size and quality features. All the authors (Buczek *et al.* 2011, Cacak-Pietrzak and Sułek 2007, Gąsiorowska and Makarewicz 2008, Kocoń 2005, Kołodziejczyk *et al.* 2012, Kulig *et al.* 2009, Ralcewicz *et al.* 2009, Sułek and Podolska 2008) found an increase in the yield, in the content of protein and in the amount of gluten, as well as an increase in the sedimentation value as results of increased nitrogen rates. However, one should note that the grain quality parameters, especially the amount of gluten, the sedimentation value and the falling number, were, in general, high and mostly cultivar-specific (Stępniewska 2015).



Source: own data and elaboration

Figure 2. Effect of sprinkler irrigation and nitrogen fertilisation on the 'Monsun' spring wheat protein yield

The effects of sprinkler irrigation depended on meteorological conditions, mostly on the precipitation amount and distribution. The research years and the periods of intensified water requirements in wheat demonstrated average precipitation conditions (SPI in the period May through June was 0.81 in the first research year, and in the second one – 0.19). The yield increase produced due to sprinkler irrigation was consistent with the one forecast by Żarski *et al.* (2013) based on the variation in the SPI value in the kujawsko-pomorski region. The value can be considered average for the soil and climate conditions. Similarly, the effect of sprinkler irrigation on baking features of wheat grain corresponds with earlier findings (Rakowski 2003a,b, Żarski *et al.* 2002, Żarski 2009). Despite the decrease in the content of protein and the amount of gluten as well as the sedimentation value, an unfavourable effect of that practice on the grain quality cannot be stated. The grain was more plump, as compared with the grain of the non-sprinkler irrigated plants, and a decreased protein content was excessively compensated by an increase in yield. As a result, the total protein yield per area unit under the conditions of irrigation and high nitrogen fertilisation was significantly higher, as compared with the non-sprinkler irrigated or lower nitrogen fertilisation rate variants (Figure 2).

CONCLUSIONS

1. Sprinkler irrigation significantly increased the spring wheat grain yield and the production effect can be considered average for the soil and climate conditions. The grain from sprinkler irrigated stands showed greater plumpness, contained significantly less protein and gluten, and

demonstrated a lower sedimentation value, as compared with the grain of the non-sprinkler irrigated plants. However, the protein yield produced under sprinkler irrigation conditions was on average 11% higher, as compared with the control conditions.

2. The effect of nitrogen fertilisation on the spring wheat grain yield and quality corresponds with earlier findings. Along with an increase in nitrogen rate, a regular yield increase and baking features enhancement were found.
3. Considering the quantitative and baking features of the grain yield, the optimal 'Monsun' spring wheat nitrogen fertilisation rate in both water variants was 180 $kg \cdot ha^{-1}$ (pre-sowing 120 $kg \cdot ha^{-1}$ and top dressing 60 $kg \cdot ha^{-1}$).

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Received: 10.03.2017
Accepted: 14.06.2017