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 Močełek, 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 Mochelek, 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 valu-
ation 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 irriga-
tion 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 bal-
ance 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 in-
cluded nitrogen fertilisation in four variants: $N_0$ – without fertilisation (control
objects), $N_1$ – pre-sowing fertilisation 60 kg ha$^{-1}$, $N_2$ – pre-sowing fertilisation
120 kg ha$^{-1}$, $N_3$ – fertilisation 180 kg ha$^{-1}$ (pre-sowing 120 kg ha$^{-1}$ and top dressing
60 kg ha$^{-1}$).

Technological grain analyses were performed at the Food Industry Cereals
Crop Grain Quality Evaluation Laboratory of the Sub-Department of Agricultu-
ral 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 ANAL-
WAR – 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

<table>
<thead>
<tr>
<th>Year</th>
<th>II decade of May</th>
<th>III decade of May</th>
<th>I decade of June</th>
<th>II decade of June</th>
<th>III decade of June</th>
<th>I decade of July</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986-2015</td>
<td>16.0</td>
<td>16.2</td>
<td>16.6</td>
<td>17.5</td>
<td>20.9</td>
<td>23.8</td>
<td>111.0</td>
</tr>
<tr>
<td>2013</td>
<td>9.1</td>
<td>64.6</td>
<td>5.8</td>
<td>0.0</td>
<td>43.5</td>
<td>35.0</td>
<td>158.0</td>
</tr>
<tr>
<td>2014</td>
<td>10.6</td>
<td>23.0</td>
<td>10.2</td>
<td>12.0</td>
<td>22.7</td>
<td>14.4</td>
<td>92.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of days without readily available water in the spring wheat root layer on non-irrigated plots</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>0 0 0 8 4 0 12</td>
</tr>
<tr>
<td>2014</td>
<td>0 0 1 8 4 5 18</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Irrigation rates (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>20 20 20 60</td>
</tr>
<tr>
<td>2014</td>
<td>20 25 20 20 85</td>
</tr>
</tbody>
</table>

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 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 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 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**

<table>
<thead>
<tr>
<th>Variants of water factor</th>
<th>Grain yield Mg ha(^{-1})</th>
<th>Thousand grain weigh g</th>
<th>Weight of hectolitre kg·hl(^{-1})</th>
<th>Total protein content g kg(^{-1})</th>
<th>Wet gluten content %</th>
<th>Sedimentation value cm(^3)</th>
<th>Falling number s</th>
</tr>
</thead>
<tbody>
<tr>
<td>(W_0)</td>
<td>5.40</td>
<td>49.9</td>
<td>80.1</td>
<td>138.0</td>
<td>34.7</td>
<td>48.2</td>
<td>523</td>
</tr>
<tr>
<td>(W_1)</td>
<td>6.45</td>
<td>52.1</td>
<td>80.8</td>
<td>128.1</td>
<td>31.2</td>
<td>40.1</td>
<td>484</td>
</tr>
<tr>
<td>NIR(_{0.05})</td>
<td>0.30</td>
<td>1.3</td>
<td>0.4</td>
<td>6.3</td>
<td>2.2</td>
<td>4.7</td>
<td>21</td>
</tr>
<tr>
<td>Difference (%)</td>
<td>19.4</td>
<td>4.4</td>
<td>0.9</td>
<td>-7.2</td>
<td>-10.1</td>
<td>-16.8</td>
<td>-7.5</td>
</tr>
</tbody>
</table>

Source: own data and elaboration

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

<table>
<thead>
<tr>
<th>Variants of fertilisation level</th>
<th>Grain yield Mg ha(^{-1})</th>
<th>Thousand grain weigh g</th>
<th>Weight of hectolitre kg·hl(^{-1})</th>
<th>Total protein content g kg(^{-1})</th>
<th>Wet gluten content %</th>
<th>Sedimentation value cm(^3)</th>
<th>Falling number s</th>
</tr>
</thead>
<tbody>
<tr>
<td>(N_0)</td>
<td>4.65a</td>
<td>50.3b</td>
<td>80.3a</td>
<td>121.5a</td>
<td>29.3a</td>
<td>35.8a</td>
<td>502a</td>
</tr>
<tr>
<td>(N_1)</td>
<td>5.95b</td>
<td>52.4a</td>
<td>80.3a</td>
<td>127.0b</td>
<td>31.0b</td>
<td>39.1b</td>
<td>486a</td>
</tr>
<tr>
<td>(N_2)</td>
<td>6.50c</td>
<td>50.4b</td>
<td>80.3a</td>
<td>135.0c</td>
<td>33.2c</td>
<td>45.2c</td>
<td>496a</td>
</tr>
<tr>
<td>(N_3)</td>
<td>6.59c</td>
<td>50.8b</td>
<td>80.8b</td>
<td>148.7d</td>
<td>38.3d</td>
<td>56.6d</td>
<td>533b</td>
</tr>
<tr>
<td>NIR(_{0.05})</td>
<td>0.28</td>
<td>1.5</td>
<td>0.4</td>
<td>2.6</td>
<td>0.8</td>
<td>0.8</td>
<td>21</td>
</tr>
</tbody>
</table>

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.
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 Sulek 2007, Gąsiorowska and Makarewicz 2008, Kocoń 2005, Kołodziejczyk et al. 2012, Kulig et al. 2009, Ralcewicz et al. 2009, Sulek 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).
Effect of sprinkler irrigation and nitrogen fertilisation...

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
J. Żarski, S. Dudek, R. Kuśmierek-Tomaszewska, T. Knapowski, W. Kozera

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 ha\(^{-1}\) (pre-sowing 120 kg ha\(^{-1}\) and top dressing 60 kg ha\(^{-1}\)).

REFERENCES


Effect of sprinkler irrigation and nitrogen fertilisation...


