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Productivity of common wheat (*Triticum aestivum* L.) grown after various predecessors and nitrogen fertilization rates

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Abstract. During the period 2008-2011 the influence of the predecessors wintering peas, spring peas, sunflower and common wheat and different levels of nitrogen fertilization: 0 (N₀), 40 (N₄₀), 80 (N₈₀), 120 (N₁₂₀) kg/ha after legumes and 0 (N₀), 60 (N₆₀), 120 (N₁₂₀), 180 (N₁₈₀) kg/ha after the other predecessors on the productivity of common wheat was studied on the experimental field of the Department of Plant Growing, Trakia University. It was found that with cultivation of common wheat without fertilization after legume predecessors higher yields by 9.4 % were obtained compared to the other predecessors. The highest yields were obtained at fertilization with the highest nitrogen rates: after legume predecessors 4069.8 kg/ha grain; after sunflower and wheat 3853.2 kg/ha of grain. The strongest influence on the productivity of common wheat had nitrogen fertilization as a factor with 79.80 %. The yield of wheat grain correlates very well with the level of nitrogen fertilization and can be determined approximately by regression equations based on the quantity of nitrogen as an independent variable.

Keywords: common wheat, productivity, predecessors, nitrogen fertilization

Introduction

A number of authors have made research on the effect of various stages in the growing technology on the productivity and quality of common wheat grain. The influence of nitrogen fertilization, tillage and predecessors are studied by Angus and Fischer (1991), Anderson (2008), Rieger et al. (2008), He et al. (2009), Dogan and Bilgili (2010). The application of leaf microfertilizers during wheat vegetation increases grain number and grain mass per ear as also increases the crude protein content in grain (Stoyanova and Petkova, 2010). The combined use of liquid leaf fertilizers WuXiaI microplant and Codice have increased grain yield by 69.7% (Stoyanova, 2008). Mineral fertilization with N₄₀P₆₀K₁₈₀ kg/da total for the crop rotation unit corn - wheat increases crude protein yield by 75.5% on average, and fodder units by 51.6% on average compared to the non-fertilized controls (Bazitov et al., 2013). The effect of some mixed fertilizers on the productivity and quality of the durum wheat has been established by Delchev et al. (2006) and Delchev (2007).

The influence of predecessors and fertilization on yield and grain quality at different varieties of common wheat is studied in Dobrudzha region - Northeast Bulgaria (Ivanova et al., 2009; Ivanova et al., 2010; Ivanova and Tsenov, 2012) and in Southeast Bulgaria (Delibaltova, 2008; Delibaltova et al., 2010; Delibaltova and Kirchev, 2016). According to Ivanova and Tsenov (2012), the positive effect of leguminous predecessor is well expressed under conditions of drought. The productivity of wheat decreased with only 9% after predecessor bean and with 21-25% after a fodder maize, sunflower and grain maize. According to Delibaltova (2008), Delibaltova and Kirchev (2016) the most suitable predecessor for common wheat under the conditions of Southeast Bulgaria is coriander. After it is realized with 3.6% and 6.8% higher yield compared with predecessors sunflower and barley. Wheat planted after oilseed rape have significantly higher shoot biomass and grain yield than wheat planted after maize (Rieger et al., 2008). The effect of various herbicides and herbicide combinations on the productivity of several common wheat varieties has been found in Stara Zagora region, South Central Bulgaria by Georgiev (2014), Stoyanova and Georgiev (2014). Under the same conditions the effect of predecessors and nitrogen fertilization in triticale has been found by Gerdzhikova (2015). The effect of various predecessors and the simultaneous impact of different levels of nitrogen fertilization on the productivity of wheat has not been studied in this region. That is the purpose of the present study.

Material and methods

The experiment was conducted on the experimental field of the Department of Plant Growing, Trakia University during the period 2008-2011. The study is set out using a block method in 4 replicates with test plot size of 20 m² and reported plot of size 10 m². Common wheat, Diamant variety, was grown after predecessors: wintering peas, spring peas, sunflower and common wheat. The following levels of nitrogen fertilization were applied: 0 (N₀), 40 (N₄₀), 80 (N₈₀), 120 (N₁₂₀) kg/ha after wintering peas and spring peas and 0 (N₀), 60 (N₆₀), 120 (N₁₂₀), 180 (N₁₈₀) kg/ha after sunflower and common wheat. The crops were grown without irrigation under conventional production systems. The soil is typically meadow cinnamon. In the layer 0-30 cm humus content is 1.55%. The soil is poorly stocked with nitrogen and phosphorus and well stocked with potassium. The reaction is slightly acidic to neutral.

The data were processed statistically by ANOVA with Statistics 6 for Windows.

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Results and discussion

Heat conditions during the three vegetation periods in which wheat was grown - 2008-2009, 2009-2010, 2010-2011 were with average air temperature 9.8 °C, 9.8 °C, 9.5 °C, respectively, slightly higher than average for the period 1953-2007 (9.1 °C) (Figure 1). November and December were with higher temperatures during the study period. In January lower average monthly temperatures were recorded in 2009 and 2010 by 0.8 °C and 0.2 °C, respectively. Spring months were with temperatures close to the typical for the region. Warmer than the average for the region were May and June. Differences ranged from 0.2 °C to 1.4 °C in May and from 0.3 °C to 1.3 °C in June. In terms of precipitation the most favorable was the vegetation period 2009-2010 with rainfall amount 535.4 mm - by 30.1% higher than the average for the period 1953-2007. The most unfavorable was the vegetation period 2010-2011 with an amount of precipitation 33.6% lower than the average, while in 2008-2009 it was 21.7% lower. The distribution of rainfall in 2008-2009 and 2010-2011 was uneven and can be expected to have an impact on wheat productivity.

Climatic conditions vary during the years of the study, which is reflected on the influence of the studied factors on wheat productivity as well. The most favorable were the conditions during the vegetation period of vintage year 2010. In the variants without fertilization yields ranged from 2810.5 kg/ha after predecessor wheat to 3096.0 kg/ha after wintering peas (Table 1). The lowest were the yields in vintage year 2011, when during stages of stem elongation, ear emergence and flowering rainfall was below the normal for the region. Grain yield in the variants without nitrogen fertilization varied from 2317.5 kg/ha after predecessor wheat to 2625.0 kg/ha after wintering peas. Grain yields in 2009 occupy an intermediate position with values in variants without nitrogen fertilization from 2415.8 kg/ha after wheat to 2828.0 kg/ha after predecessor spring peas. On average for the study period yields were from 2514.6 kg/ha after wheat to 2839.8 kg/ha after wintering peas. 

Legume predecessors have positive effect on wheat grain yield. And all three years of the experiment, after wintering and spring peas in variants without fertilization higher yields of grain were obtained on average compared to the average values of these variants after sunflower and wheat, by 269.2 kg/ha (10.6%) in 2009, 208.8 kg/ha (7.3%) in 2010, 248.8 kg/ha (10.5%) in 2011, respectively. On average for the study period grain yield was by 242.3 kg/ha (9.4%) higher after legume predecessors. Similar results are obtained by Anderson (2008) and Dogan and Bilgili (2010).

The application of increasing nitrogen fertilization rates leads to increased grain yields after all predecessors and in each year of the study. In fertilization with the highest nitrogen rates the highest yield is obtained. Compared to the non-fertilized variant the relative increase in yield by years and predecessors was as follows:

- After wintering peas and fertilizing with $N_{40}$ - from 32.5%.
- After sunflower and fertilization with $N_{80}$ - from 42.0% to 49.9%, an average of 44.9%.
- After common wheat and fertilization with $N_{120}$ - from 42.8% to 53.5%, an average of 47.0%.
- After common wheat and fertilization with $N_{160}$ - from 41.5% to 56.5%, an average of 50.6%.

The most effective nitrogen fertilizer rates established by other researchers are 120-160 kg/ha (Angus and Fischer, 1991; Delibaltova, 2008; Rieger et al., 2008; He et al., 2009; Dogan and Bilgili, 2010; Delibaltova and Kirchev, 2016).

Although the highest yields of wheat grain are obtained by fertilization with the highest nitrogen fertilizer rate, the determining of the optimal rate can be done by comparing the different levels of fertilization. The average grain yield after legume predecessors for the study period without nitrogen fertilization was 2832.8 kg/ha. In fertilization with 40 kg/ha of nitrogen, yield increased by 304.2 kg/ha or 10.7%, while in fertilization with 80 kg/ha of nitrogen, grain yield compared to $N_0$ increased by 921.3 kg/ha - (32.5%). The increase compared to the previous nitrogen rate was with 617.1 kg/ha grain -
19.7%. When fertilizing with 120 kg/ha yield increased by 1237 kg/ha - 43.7%, but compared to the previous level of fertilization (Nₐ) the increase was with 315.8 kg/ha, i.e. by 8.4%, compared to fertilization with 40 kg/ha - 932.9 kg/ha (29.7%).

The average grain yield after predecessors sunflower and common wheat for the study period without fertilization with nitrogen was with 2590.5 kg/ha. In fertilization with 60 kg/ha of nitrogen yield increased by 378.2 kg/ha or 14.6%, in fertilizing with 120 kg/ha of nitrogen grain yield compared to N₀ increased by 907.2 kg/ha - 35.0%. The increase compared to the previous nitrogen rate was with 529 kg/ha grain - 17.8%. In fertilizing with 180 kg/ha yield increased by 1262.7 kg/ha grain compared to N₀ - 48.4%, but compared to the previous fertilization level the increase was with 355.5 kg/ha, i.e. by 10.2%, compared to fertilization with 60 kg/ha - 884.5 kg/ha (29.8%).

The level of proof of differences in wheat grain yield under the influence of predecessors and the level of nitrogen fertilization was different from year to year. In 2009 after legume predecessors differences in wheat grain yields between the nitrogen fertilization levels are statistically proved at P < 0.05, but the differences between the same nitrogen fertilization levels after wintering and spring peas are not statistically proved. While growing wheat after predecessors wheat and sunflower differences are shown between the different levels of nitrogen fertilization and at the same level of fertilization. That confirms the lower productivity of wheat after non-leguminous predecessors sunflower and wheat.

In 2010 differences in grain yield between nitrogen fertilization levels are statistically proved at P < 0.05, but the differences

### Table 1. Grain yield of common wheat after various predecessors and nitrogen fertilization rates by years and average for the period 2009-2011, kg/ha

<table>
<thead>
<tr>
<th>Predecessor</th>
<th>Nitrogen fertilization, kg/ha</th>
<th>2009</th>
<th>% to N₀</th>
<th>2010</th>
<th>% to N₀</th>
<th>2011</th>
<th>% to N₀</th>
<th>Average 2009 - 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>kg/ha</td>
<td>%</td>
<td>kg/ha</td>
<td>%</td>
<td>kg/ha</td>
<td>%</td>
<td>kg/ha</td>
</tr>
<tr>
<td>1. Wintering peas</td>
<td>80</td>
<td>3706.0*</td>
<td>132.4</td>
<td>3987.5*</td>
<td>128.8</td>
<td>3495.0*</td>
<td>133.1</td>
<td>3729.5</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>4011.0*</td>
<td>143.3</td>
<td>4290.8*</td>
<td>138.6</td>
<td>3835.0*</td>
<td>146.1</td>
<td>4045.6</td>
</tr>
<tr>
<td>Average (40-120)</td>
<td></td>
<td>3416.3</td>
<td>129.5</td>
<td>3683.6</td>
<td>125.3</td>
<td>3199.4</td>
<td>129.2</td>
<td>3630.9</td>
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<tr>
<td>0</td>
<td>2828.0*</td>
<td>100.0</td>
<td>100.0</td>
<td>2617.5*</td>
<td>100.0</td>
<td>2828.5</td>
<td>100.0</td>
<td>3045.8</td>
</tr>
<tr>
<td>40</td>
<td>3189.8*</td>
<td>112.8</td>
<td>112.7</td>
<td>3465.6*</td>
<td>114.2</td>
<td>3571.5*</td>
<td>134.4</td>
<td>3778.3</td>
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<tr>
<td>2. Spring peas</td>
<td>80</td>
<td>3729.8*</td>
<td>131.9</td>
<td>4088.3*</td>
<td>134.8</td>
<td>3517.5*</td>
<td>134.4</td>
<td>3778.3</td>
</tr>
<tr>
<td></td>
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<td>143.3</td>
<td>4306.3*</td>
<td>142.0</td>
<td>3924.0*</td>
<td>149.9</td>
<td>4094.0</td>
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<td>129.3</td>
<td>3710.7</td>
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<td>2666.4</td>
<td>100.0</td>
<td>3005.1</td>
</tr>
<tr>
<td>40</td>
<td>3047.0</td>
<td>114.0</td>
<td>113.6</td>
<td>3203.3*</td>
<td>114.0</td>
<td>2733.8*</td>
<td>118.0</td>
<td>2923.2</td>
</tr>
<tr>
<td>3. Sunflower</td>
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<td>3564.5</td>
<td>133.4</td>
<td>3795.5*</td>
<td>130.9</td>
<td>3265.0*</td>
<td>134.5</td>
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<tr>
<td></td>
<td>180</td>
<td>3893.5</td>
<td>145.7</td>
<td>4141.8*</td>
<td>142.8</td>
<td>3725.0*</td>
<td>153.5</td>
<td>3920.1</td>
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<tr>
<td>Average (60-180)</td>
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<td>131.1</td>
<td>3532.6</td>
<td>129.1</td>
<td>3023.1</td>
<td>132.7</td>
<td>3488.9</td>
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<td>% 5/6</td>
<td>% 5/6</td>
<td>% 5/6</td>
<td>% 5/6</td>
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<tr>
<td>5. Average leguminous predecessor (1-2)</td>
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<td>106.5</td>
<td>4037.9</td>
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<tr>
<td>Average (40-120)</td>
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<td>100.0</td>
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<td>6. Average other predecessor (3-4)</td>
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<tr>
<td>Average (60-180)</td>
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<td>100.0</td>
<td>3211.9</td>
<td>100.0</td>
<td>3439.8</td>
</tr>
</tbody>
</table>

* The differences in yields between the variants are statistically proven at P < 0.05 if not identical letters.
between the same levels of nitrogen fertilization are not statistically
proved after legumes and after sunflower and wheat.

In 2011 differences in grain yield of wheat between the same
levels of nitrogen fertilization after wintering and spring peas and
after sunflower and wheat are not statistically proved. The
differences at the same levels of fertilization are proved between
leguminous and non-leguminous predecessors.

The analysis of the level of impact of factors on grain yield
(Table 2) proved that nitrogen fertilization had the greatest effect on
that parameter by 79.80%. Next in importance are the conditions
throughout the years of conducting the experiment by 12.97%.
Third is the impact of the predecessor – 4.68%. The level of proving of the
factors is very high p < 0.001.

Productivity of common wheat grown after various
predecessors and levels of nitrogen fertilization correlates very well
to the amount of nitrogen input. That allows to determine in advance
grain yields by regression equations based on nitrogen input as an
independent variable within the specified range about nitrogen
fertilization level depending on the type of predecessor (Table 3).

The determination coefficient $R^2$ varies from 0.810 to 0.844. It is
high enough and shows that the link between wheat grain yield and
nitrogen fertilization is very good. In that way through a second order
polynomial yields can be determined with good accuracy. All
equations have very high level of statistical reliability. This allows to
use them in the practice for approximate determination of grain yield.

### Conclusion

The highest grain yields of common wheat (after legume
predecessors wintering and spring pea – 4069.8 kg/ha; after
sunflower and wheat – 3853.2 kg/ha) are obtained by fertilization
with the highest applied nitrogen rates (N$_{120}$ and N$_{180}$). In growing
common wheat without fertilization after legume predecessors 9.4% higher yields are obtained in comparison with the other
predecessors. In growing wheat after grain predecessor, optimum
yield is obtained by fertilization with 80 kg/ha nitrogen and after
another predecessor - with 120 kg/ha nitrogen. On the productivity of
common wheat the greatest influence is exerted by nitrogen
fertilization as a factor of 79.80%. The impact of the year is 12.97% and
of the predecessor - 4.68%. Wheat grain yield correlates very well
with the level of nitrogen fertilization and can be approximately
determined by regression equations based on the quantity of
imported nitrogen as an independent variable.

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**Instruction for authors**

**Preparation of papers**
Papers shall be submitted at the editorial office typed on standard typing pages (A4, 30 lines per page, 62 characters per line). The editors recommend up to 15 pages for full research paper (including abstract references, tables, figures and other appendices). The manuscript should be structured as follows: Title, Names of authors and affiliation address, Abstract, List of keywords, Introduction, Material and methods, Results, Discussion, Conclusion, Acknowledgements (if any), References, Tables, Figures.

The title needs to be as concise and informative about the nature of research. It should be written with small letter /bold, 14/ without any abbreviations.

Names and affiliation of authors
The names of the authors should be presented from the initials of first names followed by the family names. The complete address and name of the institution should be stated next. The affiliation of authors is designated by different signs. For the author who is going to be corresponding by the editorial board and readers, an E-mail address and telephone number should be presented as footnote on the first page. Corresponding author is indicated with *.

Abstract should be not more than 350 words. It should be clearly stated what new findings have been made in the course of research. Abbreviations and references to authors are inadmissible in the summary. It should be understandable without having read the paper and should be in one paragraph.

Keywords: Up to maximum of 5 keywords should be selected not repeating the title but giving the essence of study.

The introduction must answer the following questions: What is known and what is new on the studied issue? What necessitated the research problem, described in the paper? What is your hypothesis and goal?

Material and methods: The objects of research, organization of experiments, chemical analyses, statistical and other methods and conditions applied for the experiments should be described in detail. A criterion of sufficient information is to be possible for others to repeat the experiment in order to verify results.

Results are presented in understandable tables and figures, accompanied by the statistical parameters needed for the evaluation. Data from tables and figures should not be repeated in the text. Tables should be as simple and as few as possible. Each table should have its own explanatory title and to be typed on a separate page. They should be outside the main body of the text and an indication should be given where it should be inserted.

Figures should be sharp with good contrast and rendition. Graphic materials should be preferred. Photographs to be appropriate for printing. Illustrations are supplied in colour as an exception after special agreement with the editorial board and possible payment of extra costs. The figures are to be each in a single file and their location should be given within the text.

Discussion: The objective of this section is to indicate the scientific significance of the study. By comparing the results and conclusions of other scientists the contribution of the study for expanding or modifying existing knowledge is pointed out clearly and convincingly to the reader.

Conclusion: The most important consequences for the science and practice resulting from the conducted research should be summarized in a few sentences. The conclusions shouldn’t be numbered and no new paragraphs be used. Contributions are the core of conclusions.

References:
In the text, references should be cited as follows: single author: Sandberg (2002); two authors: Andersson and Georges (2004); more than two authors: Andersson et al. (2003). When several references are cited simultaneously, they should be ranked by chronological order e.g.: (Sandberg, 2002; Andersson et al., 2003; Andersson and Georges, 2004). References are arranged alphabetically by the name of the first author. If an author is cited more than once, first his individual publications are given ranked by year, then come publications with one co-author, two co-authors, etc. The names of authors, article and journal titles in the Cyrillic or alphabet different from Latin, should be transliterated into Latin and article titles should be translated into English. The original language of articles and books translated into English is indicated in parenthesis after the bibliographic reference (Bulgarian = Bg, Russian = Ru, Serbian = Sr, if in the Cyrillic, Mongolian = Mo, Greek = Gr, Georgian = Geor., Japanese = Ja, Chinese = Ch, Arabic = Ar, etc.)


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Animal welfare
Studies performed on experimental animals should be carried out according to internationally recognized guidelines for animal welfare. That should be clearly described in the respective section “Material and methods”.

Acknowledgements (if any), References, Tables, Figures.