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Energy productivity, fertilization rate and profitability of wheat production after various predecessors II. Profitability of wheat production

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2University of Agribusiness and Rural Development, 78 Dunav, 4000 Plovdiv, Bulgaria

Abstract. In the course of our study on the adaptation of modern genotypes common winter wheat (Triticum aestivum) to the requirements of sustainable agriculture data were received concerning the influence of the predecessor and nitrogen fertilizer rate on energy efficiency and recyclable nitrogen fertilization and profitability of productivity. We share these data with the scientific community, as they are up-to-date and informative in both theoretical and practical aspects. The analyses are based on data from field experiments fertilizer derived after predecessor cereals – regular crop of sorghum, millet, maize and legumes after predecessor - separate sowing of chickpeas. Energy efficiency of nitrogen fertilization was calculated as the ratio between the energy supplied in the additional grain yield and energy input in the form of fertilizers. Refundable efficiency of nitrogen fertilization is the additional amount of nitrogen accumulated in the grain, with respect to the applied nitrogen fertilization. Economic profitability of production is evaluated by coefficient R = P/Ra (ratio of benefits/costs). The results show that energy efficiency and recyclable nitrogen fertilization are on average five times higher after cereal than after legumes predecessor, and decreased with increasing the fertilizer rate, the decrease was statistically significant only for the first item (exponent). Profitability ratio of production after the introduction of legumes predecessor in crop rotation increases by an average of 42% and retains maximum values of fertilization levels 0.06, 0.12 and 0.18 t/ha nitrogen. Profitability of wheat production using pre-legumes crop is not determined by the parameters nitrogen fertilizer rate and energy efficiency of nitrogen fertilization and refundable efficiency of nitrogen fertilization.

Keywords: wheat (Triticum aestivum), energy efficiency, refundable efficiency, profitability, nitrogen fertilization, predecessor

Introduction

One of the methods for assessing the sustainable development of agriculture is the method of energy flow. The agro-technical factors of fertilization are about 30% of the energy inputs into the production of wheat, an average of 30% of the increase in yields and around 40% of greenhouse gases (Naydenov and Zaharinnov, 2012; Azarpour, 2012; Gharderjani et al., 2013; Shahan et al., 2008). According to some authors, the introduction of precision farming systems, reducing the levels of nitrogen fertilization and improvement of technologies for drying of crops, are comparable in the size of their effect measures to protect the environment and improve energy efficiency in wheat production, but the decrease in fertilizer rates suggests economic loss that is unlikely to be implemented by farmers unless they are forced to do so (Meyer-Aurich et al., 2012). Other authors also agree that the intensity of the energy consumed in the production of wheat is not proportional to the size of the final product. Different studies show that the minimization of some investments, combined with the rationalization of crop rotation, give the best results (De Stefanis et al., 2012; Rahimizadeh et al., 2010; Shamabadi, 2012). Ziaei et al. (2013) conclude that factors such as the total agricultural policies, the market for buying and selling, socioeconomic characteristics, including the main food of the population in different regions, and the definition of strategic culture have great influence on the choice of farmers in their production program. In our country, with the traditional costs for growing crops, the profitability of wheat production is the lowest in comparison with those of other grains. The main financial purpose of farms must be aimed at achieving long-term profitability. The Common Agricultural Policy of the European Union promotes a shift to extensive crop production and low costs, which in the future can be expected to complicate the problem of irrational structure of production in the agricultural sector. However, considering the economic analysis in the next twenty years in Bulgaria, agriculture is expected to become one of the leading sectors in the GDP of the country and to require high cost investments (Vasilev, 2009; Ivanov, 2010; Lyubenova 2012; Uzunova-Kostova, 2013).

The aim of this study was to establish the influence of predecessors and nitrogen fertilizer rate on energy and recyclable efficiency, but also on the production profitability under condition of IPGR Sadovo.

Material and methods

The analyses are based on data from field experiments fertilizer derived during the period 2005 – 2010 in the experimental field of Institute of Plant Genetics Resources (IPGR), Sadovo on Pellic Vertisol. The methods of initiating and finalizing the experiment and recording biometric indicators are described in our previous publications. Yields and chemical composition of production are subjected to mathematical processing of the results obtained. Genotypes included in the study have been created by different breeding methods during a long period of time – from 1972 to 2008: Sadovo 1 (♀ Jubilejna x ♂ Bezostaja-1, 1972), Pobeda (♀ Triticum sphaerococcum var. rotundatum x ♂ [(Triticum durum x Secale montanum) x Bezostaja-1 x Meksikan], 1984), Zdravko (♀

* e-mail: zlatnapg@abv.bg
### Results and discussion

**Energy efficiency of nitrogen fertilization**

The results show that the energy efficiency of nitrogen fertilization is an average of five times higher after cereal than after legumes predecessor and significantly decreased with an increase of the fertilizer rate corresponding to that established by other authors (Rahimizadeh et al., 2010). Polynomial model of the dependence of the energy efficiency of fertilization on nitrogen fertilizer rate showed that in cereal predecessor by increasing the nitrogen fertilizer 0.001 t/ha energy efficiency increases as the step of the regression is 0.4. Maximum value of energy efficiency of fertilization is reported at 0.12 t/ha fertilizer nitrogen, followed by a decrease in values with step 0.2. After legumes predecessor energy efficiency of fertilization was the highest at the lowest fertilizer rate – 0.06 t/ha fertilizer nitrogen. With the increase of fertilizer nitrogen fertilization energy efficiency of fertilization decreases more steeply than the other parameters – the regression coefficient is 1.3. (Figure 2013; Stankov, 2012).

The above results are confirmed by the analysis of variance which varies according to the energy efficiency of nitrogen fertilization on fertilization rates of the variety and its predecessor is high in all variants of fertilization. Statistically significant negative differences between the versions are established of the variations MJ/kg grain, 15.80 MJ/kg straw, 80 MJ/kg nitrogen (Balaur and Tetyu, 1983; Kirchev, 2005; Kostadinova and Panayotova, 2002, 2013; Koteva, 2002; Kadrev, 1984; Mineev, 2006; Todorov, 1990; Tonev, 1997; Hristov et al., 2010).

- Refundable efficiency of nitrogen fertilization – additional amount of nitrogen accumulated in the grain is estimated, with respect to the applied nitrogen fertilization.
- Economic profitability of production – coefficient R = P/Ra (ratio of benefits/costs). The calculations of revenues and costs of production are data as of 2010 (Agricultural Report, 2010; Agrostatistics MAF, 2010).

**Refundable efficiency of nitrogen fertilization**

The polynomial model of dependence of the recyclable efficiency of nitrogen fertilization on nitrogen fertilizer rate is similar to the regression analysis for energy efficiency and shows the same 5-fold difference in refundable efficiency in crop after different predecessors and the same levels of extremes in the values of the investigated parameter. After cereal predecessor by increasing the nitrogen fertilizer by 0.001 t/ha efficiency initially increases. The step of the regression is 0.09, and the maximum value is at fertilization

![Figure 1. Energy efficiency of fertilization after various predecessors](image)

\[
y = -0.1878x^2 + 0.3585x + 3.8225 \\
R^2 = 0.9695
\]

\[
y = 0.175x^2 - 1.265x + 2.52 \\
R^2 = 0.9977
\]
rate 0.12 t/ha fertilizer nitrogen. After bean predecessor the refundable efficiency of fertilization was the highest at the lowest fertilizer rate – 0.06 t/ha fertilizer nitrogen (Figure 2). The results of analysis of variance also copy this energy efficiency of fertilization, as those statistically significant differences between the variants are not established. Fluctuation of refundable efficiency of nitrogen fertilization on fertilization rates of variety and predecessor is high at all levels of fertilization (Table 3). The total deviation of refundable efficiency of nitrogen fertilization after cereal predecessor of variety and nitrogen fertilizer rate is with average strength (R = 24), and after legumes predecessor – high (R = 98) (Table 2).

Profitability of production

The polynomial model of the dependence of the profitability of production on nitrogen fertilization shows a totally different picture compared to the above indicators. The profitability ratio in the

Table 1. Grain yield obtained from different precursors and levels of fertilization, t/ha

<table>
<thead>
<tr>
<th>Variety</th>
<th>Precursor</th>
<th>0</th>
<th>0.06</th>
<th>0.12</th>
<th>0.18</th>
<th>0.24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereal</td>
<td>Sadovo 1</td>
<td>1.95</td>
<td>5.1</td>
<td>3.42</td>
<td>5.22</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>Diamant</td>
<td>1.5</td>
<td>4.1</td>
<td>2.87</td>
<td>5.31</td>
<td>3.46</td>
</tr>
<tr>
<td></td>
<td>Sadovo 772</td>
<td>1.43</td>
<td>4.99</td>
<td>2.8</td>
<td>5.33</td>
<td>3.76</td>
</tr>
<tr>
<td></td>
<td>Borjana</td>
<td>2.32</td>
<td>4.68</td>
<td>4.3</td>
<td>4.91</td>
<td>5.73</td>
</tr>
<tr>
<td></td>
<td>Geya 1</td>
<td>1.48</td>
<td>5.43</td>
<td>2.85</td>
<td>4.78</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td>Guiness</td>
<td>1.54</td>
<td>5.24</td>
<td>2.83</td>
<td>5.83</td>
<td>4.32</td>
</tr>
</tbody>
</table>

Table 2. Variance analysis by fertilizer rates, variation in the energy and recyclable efficiency of nitrogen fertilization

<table>
<thead>
<tr>
<th>Fertilizer rates, t/ha</th>
<th>M</th>
<th>S</th>
<th>R</th>
<th>Sm%</th>
<th>M</th>
<th>S</th>
<th>R</th>
<th>Sm%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.06</td>
<td>2.9</td>
<td>1.7</td>
<td>59</td>
<td>15</td>
<td>0.4</td>
<td>0.3</td>
<td>69</td>
<td>17</td>
</tr>
<tr>
<td>0.12</td>
<td>2.6</td>
<td>1.9</td>
<td>72</td>
<td>18</td>
<td>0.4</td>
<td>0.2</td>
<td>63</td>
<td>16</td>
</tr>
<tr>
<td>0.18</td>
<td>1.9</td>
<td>1.5</td>
<td>77</td>
<td>19</td>
<td>0.3</td>
<td>0.2</td>
<td>73</td>
<td>18</td>
</tr>
<tr>
<td>0.24</td>
<td>1.5</td>
<td>1.2</td>
<td>82</td>
<td>20</td>
<td>0.3</td>
<td>0.2</td>
<td>66</td>
<td>17</td>
</tr>
</tbody>
</table>

Figure 2. Refundable efficiency of nitrogen fertilization after various predecessors
The introduction of bean predecessor in crop rotation increases by an average of 42%. Maximum values remain at levels of fertilization 0.06, 0.12 and 0.18 t/ha N, which indicates that the profitability in this case is determined by the level of fertilization (Figure 3). This result is supported also by variational analysis, according to which the overall variation of production profitability after cereal predecessor of variety and nitrogen fertilizer rate predecessor is high (R = 32), and after legumes predecessor – slight (R = 9). The difference between the two variants is statistically significant at P = 0.1% (Table 3). The comparison of regression analyses also shows case independence of profitability of production from energy and refundable efficiency of nitrogen fertilization, irrespective of the predecessor. After cereal predecessor higher regression coefficient was observed with an increase in nitrogen fertilizer 0.001 t/ha profitability of production increased by 0.8 step, and maximum values of the coefficient of profitability reported at the highest fertilization rates 0.18 ÷ 0.24 t/ha active substance. Variation in the profitability of production in fertilization rates of the variety and the predecessor is higher in the variety and nitrogen fertilizer rate predecessor is high (R = 32), and control sample without fertilization (R = 55) and low by fertilizer rate after legumes predecessor – slight (R = 9). The difference between 0.06 t/ha fertilizer nitrogen (R = 32), average power is at 0.12 t/ha fertilizer nitrogen (R = 18) and 18 kg/da nitrogen fertilizer (R = 15) and low at 0.24 t/ha nitrogen fertilizer (R = 14). The following positive statistical differences of variants of the control without fertilization are established: about 0.12 t/ha fertilizer nitrogen at P = 1%, about 0.18 t/ha fertilizer nitrogen at R = 0.1% and about 0.24 t/ha fertilizer nitrogen in P = 0.1% (Table 4).

### Conclusion

Energy efficiency and refundable efficiency of nitrogen fertilization were on average five times higher after cereal than after legumes predecessor, and decreased with increasing the fertilizer rate, the decrease was statistically significant only for the first

### Table 3. Variance analysis by previous culture, variation in the energy efficiency, recyclable efficiency and the production profitability of fertilization

<table>
<thead>
<tr>
<th>Indices</th>
<th>Cereal</th>
<th>Leguminous</th>
<th>Cereal</th>
<th>Leguminous</th>
<th>Cereal</th>
<th>Leguminous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The energy efficiency</td>
<td>Recyclable efficiency</td>
<td>The production profitability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>3.4</td>
<td>0.5---</td>
<td>0.5</td>
<td>0.1</td>
<td>1.4</td>
<td>2.0+++</td>
</tr>
<tr>
<td>S</td>
<td>1.0</td>
<td>0.5</td>
<td>0.1</td>
<td>0.1</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>R</td>
<td>29</td>
<td>98</td>
<td>24</td>
<td>98</td>
<td>32</td>
<td>9</td>
</tr>
<tr>
<td>Sm%</td>
<td>4</td>
<td>13</td>
<td>3</td>
<td>13</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

![Figure 3. Profitability of production after various predecessors](image)

Mathematical model of dependence after cereal predecessor
Mathematical model of dependence after leguminous predecessor

### Table 4. Variance analysis by fertilizer rates, variation in the production profitability

<table>
<thead>
<tr>
<th>Fertilizer rates, t/ha</th>
<th>M</th>
<th>S</th>
<th>R</th>
<th>Sm%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 st.</td>
<td>1.2*</td>
<td>0.6</td>
<td>55</td>
<td>14</td>
</tr>
<tr>
<td>0.06</td>
<td>1.5</td>
<td>0.5</td>
<td>31</td>
<td>8</td>
</tr>
<tr>
<td>0.12</td>
<td>1.7++</td>
<td>0.3</td>
<td>18</td>
<td>5</td>
</tr>
<tr>
<td>0.18</td>
<td>1.8+++</td>
<td>0.3</td>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td>0.24</td>
<td>1.8++</td>
<td>0.2</td>
<td>13</td>
<td>3</td>
</tr>
</tbody>
</table>

Mathematical model of dependence after cereal predecessor
Mathematical model of dependence after leguminous predecessor

$$y = -0.0286x^2 + 0.1714x + 1.76$$

$$R^2 = 0.9524$$

$$y = 0.0929x^2 - 0.8071x - 0.02$$

$$R^2 = 0.9969$$
parameter. Profitability ratio of production after the introduction of legumes predecessor in crop rotation increases by average of 42% and retains maximum values at fertilization rates 0.06, 0.12 and 0.18 t/ha nitrogen. Profitability of wheat production by using pre-bean crop is not determined by the parameters of nitrogen fertilizer rate, energy and refundable efficiency of nitrogen fertilization.

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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”.
