The Role of Rotation and Nitrogen Fertilization Level upon the Economic Indicators at Wheat and Corn Crops in Condition of a Long Term Experience

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Abstract

Since 1843 when Sir John Lawes and Sir Henry Gilbert started several long-term field experiments at Rothamsted Research, up to now a lot of long term experiences have been developed in the world. In this research we analysed the economic impact of crop rotation and nitrogen fertilization level upon the wheat crop. The research was performed in a long term experiment established in 1981, in a bifactorial experiment, at Moara Domneasca Experimental farm where Factor A is crop rotation duration with 6 gradual levels, and Factor B nitrogen fertilization level with 4 gradual levels.

This paper centralised the data collected in the last ten years (2003-2013). The results show: the increase in crop rotation durations determines an increase in the quantity and quality of production; the increase of nitrogen fertilization level leads to an increase in production; there is a significant linear correlation between crop rotation length, nitrogen and production; regarding the economic impact, the unitary production cost decreased along with increasing the crop rotation length and the nitrogen fertilization level.

Keywords: crop rotation, nitrogen fertilization level, unitary production cost, economic indicators.

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1. Introduction

The history of long term experiments began in 1843, when John Lawes, the owner of a fertilizer factory, together with Henry Gilbert started doing research on the influence of fertilizers on plant growth. They conducted the first long-term experiment with fertilizers, laid the groundwork for modern scientific agriculture, set the principles of crop plants nutrition and founded Rothamstead Research. In Romania the first long-term experiments were conducted by C. Hera and Z. Borlan in 1966, at ICCPT Fundulea, on cambic chernozem.

In time, researchers proved the favourable effects of crop rotation (Ciontu et al., 2010; Ciontu et al., 2011), whereas Budoi and Penescu (1996) stated that “crop rotation is the only agrotechnical measure with no material costs, it only requires that the farmer possesses skills”.

The present paper assesses the financial efficiency when applying rotation and fertilization, in the Crop Rotation Field at Moara Domneasca Experimental Farm, which was founded in 1981.

2. Materials and Methods

The research was conducted on the reddish preluvosoil located NE of Bucharest at 44.4988 latitude and 26.2507 longitude, under no irrigation.

The experiment was bifactorial organized according to the method of subdivided parcels in 4 repetitions where: factor A – the crop rotation comprised five graduations: a1 –monoculture; a2 two-year rotation: 1. wheat, 2. corn; a3 – three-year rotation: 1. soy, 2. wheat, 3. corn; a4 – four-year rotation: 1. peas, 2. wheat, 3. sugar beet, 4. corn and factor B – nitrogen fertilization varying when phosphorus fertilization is constant: b1 – N0P70 and b2 – N100P70.

The paper presents the mean data in the period 2003-2013 and, to allow comparisons, the mean data regarding the research period have been used.

The production expenditure \( C_p = \sum_{i=1}^{n} c_i \) is the sum of the expenses for a hectare during an agricultural year.

The Income \( V = \sum_{i=1}^{n} v_i \) is the sum of incomes obtained by selling the yield per hectare in an agricultural year.

The Revenue \( P = V - C_p \) is the difference between income and production expenses. In case the difference is positive a profit is made and in case the difference is negative a loss is made.

The Unitary Cost \( C_u = \frac{C_p}{Q} \), where Q is the yield per hectare

3. Results and Discussions

3.1. The influence of rotation and nitrogen fertilization on wheat and corn yields

The results of the measurements regarding the influence of crop rotation and nitrogen fertilization on wheat and corn yields are centralized in table 1. The analysis of the findings reveals that the wheat yields varied much, between 18.1 q/ha in monoculture and 28.5 q/ha in the 4-year rotation, when unfertilized, and between 31.9 q/ha in monoculture and 42.7 q/ha in the 4-year rotation when fertilized.

When unfertilized with nitrogen, the two-year rotation led to a yield boost of 5.3 q/ha, whereas in the three- and four-year rotations the largest yield boosts, of 10.3 q/ha and respectively 10.4 q/ha were recorded. The yield differences compared with the monoculture are statistically significant for the two-year rotation and very significant for three- and four-year rotations.

When fertilizing with N100 yield levels varied between 31.9 q/ha at monoculture and 47.4 q/ha at the three-year rotation. The increase in the rotation duration led to yield boost of 13.7 q/ha at the two-year rotation, respectively 13.5 q/ha at the three-year rotation, statistically distinctly significant, and the three-year rotation led to a very significant yield of 16.1 q/ha.
Table 1. The influence of crop rotation and nitrogen fertilization on wheat and corn yields.

<table>
<thead>
<tr>
<th>Rotation</th>
<th>Winter wheat</th>
<th>Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yield (q/ha)</td>
<td>Yield (q/ha)</td>
</tr>
<tr>
<td></td>
<td>Dif. / Signif.</td>
<td>Dif. / Signif.</td>
</tr>
<tr>
<td>b₁ - unfertilized</td>
<td>18.1 Mt</td>
<td>31.3 Mt</td>
</tr>
<tr>
<td>b₂ - N₁₀₀</td>
<td>31.9 Mt</td>
<td>47.5 Mt</td>
</tr>
<tr>
<td>a₁ - monocrop</td>
<td>13.8 ***</td>
<td>16.1 ***</td>
</tr>
<tr>
<td>a₂ - 2 year rotation</td>
<td>25.3 5.2</td>
<td>45.0 13.7 **</td>
</tr>
<tr>
<td>a₃ - 3 year rotation</td>
<td>28.4 10.3 ***</td>
<td>47.4 16.1 ***</td>
</tr>
<tr>
<td>a₄ - 4 year rotation</td>
<td>28.5 10.4 ***</td>
<td>44.8 13.5 **</td>
</tr>
</tbody>
</table>

Dl₅₅% = 4.64 q/ha; Dl₁₅₃% = 6.18 q/ha; Dl₀.₁₃% = 7.13 q/ha.

When fertilizing with N₁₀₀ the yield levels at corn varied between 47.5/q/ha at monoculture and 60.3 q/ha at the four-year rotation. The yield boosts were between 12.6 q/ha at the two-year rotation and 14.6 q/ha at the three-year rotation.

3.2. The influence of crop rotation and nitrogen fertilization on the economic indicators in wheat corn

The results of the calculations regarding the economic indicators for wheat crop are presented in table 2. The computation of the unitary production cost was made by calculating the average production expenses for the recorded yields. The average expenses made to produce wheat were of 1006 lei/ha for the N₀P₇₀ fertilization and of 1352 lei/ha for the N₁₀₀P₇₀ fertilization.

3.2.1. The influence of rotation and fertilization on the unitary production cost for wheat crop

When analyzing the influence of the rotation duration on the unitary cost for wheat crop for the N₀P₀ fertilization, it can be seen that the increase in the rotation duration led to a very significant decrease in the unitary cost, of 0.56 lei/kg in monoculture and 0.35 lei/kg in the three- and four-year rotations.

When fertilizing with 100 kg N/ha the costs varied between 0.42 lei/kg in monoculture and 0.32 lei/kg in the three- and four-year rotations. The increase in the rotation duration led to a very significant negative reduction of the unitary production cost in comparison with monoculture.

For the same rotation, the application of 100 kg nitrogen/ha led to a reduction in the unitary production cost for the monoculture, of 0.56 lei/kg when unfertilized and 0.42 lei/kg when fertilized. The decrease in the production cost was between 0.14 lei/kg for monoculture and 0.04 lei/kg for the three- and four-year rotations. The decrease of the unitary cost due to the application of fertilization for the same rotation is statistically relevant.

3.2.2. The influence of rotation and fertilization on the revenue at wheat crop

If we analyse the influence of the rotation duration on the revenue from wheat crop in the absence of nitrogen fertilization, it can be seen that the increase in the rotation duration led to a very significant increase of the revenue at 941.2 lei/ha for monoculture and 1482 lei/kg for four-year rotations.

For the N₁₀₀P₇₀ fertilization the revenue rose to 1658.8 lei/ha in monoculture and 2220 lei/kg in the four-year rotation; in comparison with the monoculture, the increase in rotation duration determined a statistically very significant increase.

When increasing the dose of nitrogen fertilization for the same rotation, it can be seen that the revenue increase of 717.6 lei/ha in monoculture and 800.8 lei/kg in the two-year rotation is statistically very significant.
Table 2. The influence of crop rotation and nitrogen fertilization on the economic indicators for wheat crop (expenses/ha: \( N_0 = 1006 \) lei/ha; \( N_{100} = 1352 \) lei/ha).

<table>
<thead>
<tr>
<th>The influence of the rotation duration</th>
<th>The influence of fertilization for the same rotation duration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unitary Cost (lei/kg)</td>
</tr>
<tr>
<td></td>
<td>( b_1 - N_0 )</td>
</tr>
<tr>
<td></td>
<td>( b_1 - N_0 )</td>
</tr>
<tr>
<td>a1 - monoculture</td>
<td>0.56 Mt</td>
</tr>
<tr>
<td>a2 -2-year rotation</td>
<td>0.43 Mt</td>
</tr>
<tr>
<td>a3 -3-year rotation</td>
<td>0.35 Mt</td>
</tr>
<tr>
<td>a4 -4-year rotation</td>
<td>0.35 Mt</td>
</tr>
<tr>
<td>DL-5%</td>
<td>0.019 Mt</td>
</tr>
<tr>
<td>DL-1%</td>
<td>0.032 Mt</td>
</tr>
<tr>
<td>DL-0.1%</td>
<td>0.042 Mt</td>
</tr>
</tbody>
</table>

3.2.3. The influence of rotation and fertilization on the profit at wheat crop

There was a large variation in the profit obtained at wheat crop under rotation but no fertilization. Thus, while monoculture generated a loss of 64.8 lei/ha, the increase in rotation duration led to a profit increase of up to 476 lei/ha in the four-year rotation and the increase in profit caused by the increase in rotation duration is statistically very significant.

For the \( N_{100}P_{70} \) fertilization the profit varied from 306.8 lei/ha in monoculture to 868.4 lei/ha in the four-year rotation.

For the same rotation, the application of a dose of 100 kg nitrogen/ha led to a very significant increase in profit varying from 371.6 lei/ha in wheat monoculture to 454.8 lei/ha in the two-year rotation.

3.2.4. The influence of rotation and fertilization on the profit rate at wheat crop

The analysis of the influence of the rotation duration on the profit rate at wheat crop reveals that, for a \( N_0P_0 \) fertilization, the increase in the rotation duration led to an increase in the profit rate varying from -6.4% for monoculture to 47.3% for the four-year rotation.

The fertilization with 100 kg N/ha resulted in a profit rate that varied from 22.7% in monoculture to 64.2% in the four-year rotation. The increase in the rotation duration led to a very significant increase in the profit rate compared to that of monoculture.

When comparing the figures of the profit rate resulted for the same rotation duration under fertilization with 100 kg nitrogen/ha, an increase in the profit rate varying from 29.1% for monoculture to 28.4% for the two-year rotation can be seen; this increase is very significant.

3.3 The influence of rotation and nitrogen fertilization on the economic indicators for corn crop

The main economic indicators calculated for corn crop are presented in table 3. The average expenses for corn crop taken into account for these indicators were of 11215 lei/ha for the \( N_0P_{70} \) fertilization and of 1561 lei/ha for the \( N_{100}P_{70} \) fertilization.

3.3.1. The influence of rotation and fertilization on the unitary production cost for corn crop

If we analyse the influence of rotation duration on the unitary production cost for corn crop under \( N_0P_0 \) fertilization, it can be seen that the increase in the rotation duration led to a very significant decrease of the unitary cost, from 0.39 lei/kg in monoculture to 0.26 lei/kg in the three-year rotation.
When fertilizing with 100 kg N/ha the costs varied from 0.33 lei/kg in monoculture and 0.25 lei/kg in the three-year rotation. The reduction in the unitary production cost for the $N_{100}P_{70}$ fertilization when increasing the rotation duration is a statistically significant difference in comparison with monoculture.

When comparing the figures of the unitary cost resulted from the increase in nitrogen fertilization, it can be seen that, for all the studied rotations, fertilization led to very significant negative reductions in the unitary costs, between 0.06 lei/kg in monoculture and 0.01 lei/kg for the other rotations.

### Table 3. The influence of crop rotation and nitrogen fertilization on the economic indicators at corn crop (expenses/ha: $N_0= 1215$ lei/ha; $N_{100}= 1561$ lei/ha).

<table>
<thead>
<tr>
<th></th>
<th>Unitary Cost lei/kg</th>
<th>Revenue lei/kg</th>
<th>Profit lei/ha</th>
<th>Profit rate %</th>
<th>Unitary Cost lei/kg</th>
<th>Revenue lei/kg</th>
<th>Profit lei/ha</th>
<th>Profit rate %</th>
<th>Unitary Cost lei/kg</th>
<th>Revenue lei/kg</th>
<th>Profit lei/ha</th>
<th>Profit rate %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$N_0$</td>
<td></td>
<td></td>
<td></td>
<td>$N_{100}$</td>
<td></td>
<td></td>
<td></td>
<td>Differences $N_{100}-N_0$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a1 - monoculture</td>
<td>0.39 Mt</td>
<td>1627.6 Mt</td>
<td>412.6 Mt</td>
<td>34.0 Mt</td>
<td>0.33 Mt</td>
<td>2470 Mt</td>
<td>909 Mt</td>
<td>58.2 Mt</td>
<td>-0.06 Mt</td>
<td>842.4 Mt</td>
<td>496.40 Mt</td>
<td>24.27 Mt</td>
</tr>
<tr>
<td>a2 - 2-year rotation</td>
<td>0.27 ooo</td>
<td>2340 ooo</td>
<td>1125 ooo</td>
<td>92.6 ooo</td>
<td>0.26 ooo</td>
<td>3125.2 ooo</td>
<td>1564.2 ooo</td>
<td>100.2 ooo</td>
<td>-0.01 ooo</td>
<td>785.2 ooo</td>
<td>439.20 ooo</td>
<td>7.61 ooo</td>
</tr>
<tr>
<td>a3 - 3-year rotation</td>
<td>0.26 ooo</td>
<td>2464.8 ooo</td>
<td>1249.8 ooo</td>
<td>102.9 ooo</td>
<td>0.25 ooo</td>
<td>3229.2 ooo</td>
<td>1668.2 ooo</td>
<td>106.9 ooo</td>
<td>-0.01 ooo</td>
<td>764.4 ooo</td>
<td>418.40 ooo</td>
<td>4.00 ooo</td>
</tr>
<tr>
<td>a4 - 4-year rotation</td>
<td>0.27 ooo</td>
<td>2329.6 ooo</td>
<td>1114.6 ooo</td>
<td>91.7 ooo</td>
<td>0.26 ooo</td>
<td>3153.6 ooo</td>
<td>1574.6 ooo</td>
<td>100.9 ooo</td>
<td>-0.01 ooo</td>
<td>806.0 ooo</td>
<td>460.00 ooo</td>
<td>9.13 ooo</td>
</tr>
<tr>
<td>DL5%</td>
<td>0.018</td>
<td>184.20</td>
<td>76.14</td>
<td>5.54</td>
<td>0.019</td>
<td>203.69</td>
<td>84.20</td>
<td>6.12</td>
<td>0.019</td>
<td>199.55</td>
<td>82.49</td>
<td>6.00</td>
</tr>
<tr>
<td>DL1%</td>
<td>0.024</td>
<td>226.01</td>
<td>105.22</td>
<td>7.58</td>
<td>0.027</td>
<td>249.94</td>
<td>116.36</td>
<td>8.38</td>
<td>0.026</td>
<td>244.85</td>
<td>113.99</td>
<td>8.21</td>
</tr>
<tr>
<td>DL0.1%</td>
<td>0.033</td>
<td>306.23</td>
<td>142.14</td>
<td>10.19</td>
<td>0.037</td>
<td>338.64</td>
<td>157.18</td>
<td>11.27</td>
<td>0.036</td>
<td>331.75</td>
<td>153.98</td>
<td>11.04</td>
</tr>
</tbody>
</table>

#### 3.3.2. The influence of rotation and fertilization on the revenue obtained from corn crop

If we analyse the influence the rotation duration on the revenue from corn crop in the absence of nitrogen fertilization, we notice that the increase in rotation duration led to a very significant increase of the revenue from 1627.6 lei/ha in monoculture to 2464.8 lei/ha for the four-year rotations.

For the $N_{100}P_{70}$ fertilization the revenue level increased from 2470 lei/ha in corn monoculture to 3229.2 lei/ha for the four-year rotation; in comparison with monoculture, the gain due to the increase in rotation duration led to a very significant increase.

When increasing the fertilization dosage from $N_0P_{70}$ to $N_{100}P_{70}$ for the same rotation, statistically very significant augmentations were recorded, varying from 842.4 lei/ha in monoculture and 764.4 lei/ha for the three-year rotation.

#### 3.3.3. The influence of rotation and fertilization on the profit obtained at corn crop

The profit obtained at corn crop under rotation, in the absence of fertilization, varied from 412.6 lei/ha in monoculture and 1249.8 lei/ha for the three-year rotation, the profit increases due to the increase in rotation duration being statistically very significant.

For the $N_{100}P_{70}$ fertilization the profit varied from 909 lei/ha in monoculture to 1668.2 lei/ha for the three-year rotation.

For the same rotation, the application of a fertilization dose of 100 kg nitrogen/ha led to a very significant profit increase varying from 496.4 lei/ha in corn monoculture to 785.2 lei/ha for the two-year rotation.

#### 3.3.4. The influence of rotation and fertilization on the profit rate at corn crop

When analysing the influence of rotation duration on the profit rate under $N_0P_0$ fertilization, it can be seen that the increase in the rotation duration led to an increase in the profit rate varying from 34% in monoculture to 102.9% for the three-year rotation.

Fertilization with 100 kg N/ha led to a profit rate that varied from 58.2% in monoculture to 106.9% for the three-year rotation. The increase in the rotation duration led to a very significant increase in the profit rate in comparison
with monoculture. By comparing the figures of the profit rate for the same rotation duration under fertilization with 100 kg nitrogen/ha, it can be seen that the profit rate increased from 24.27% in monoculture to 4% for the three-year rotation, the increase being very significant.

4. Conclusions

The yields for wheat and corn crops increased along with the increase in the rotation duration and in the dose of nitrogen fertilization; the increase was statistically relevant.

The unitary production costs decreased along with the increase in the rotation duration and in the dose of nitrogen fertilization both in wheat crop and in corn crop; the reductions of the unitary costs are statistically relevant.

The revenue from wheat and corn crops increased along with the increase in the rotation duration in comparison with monoculture and the increase in the fertilization dose led to yield gains.

The profit increased due to the increase in the rotation duration and the fertilization dose both for wheat crop and corn crop.

The profit rate at wheat and corn crop increased along with the increase in the rotation duration in comparison with monoculture and the increase in the fertilization dose.

Increasing the crop rotation duration influenced favorable the evolution for all the economical indicators.

5. Acknowledgements

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References