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Address of Editorial office:
Agricultural Science and Technology Faculty of Agriculture, Trakia University Student's campus, 6000 Stara Zagora
Bulgaria
Telephone: +359 42 699330
+359 42 699446
www.agriscitech.eu

Technical Assistance:
Nely Tsvetanova
Telephone: +359 42 699446
E-mail: editoffice@agriscitech.eu
Productivity of durum wheat cultivar Predel at nitrogen-phosphorous fertilization

L. Plescuta*

Department of Plant Production, Faculty of Agriculture, Trakia University, 6000 Stara Zagora, Bulgaria

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Abstract. The effect of nitrogen-phosphorus fertilization at nitrogen rates 0, 80, 120 and 160 kg.ha\(^{-1}\) and 0, 80 and 120 kg.ha\(^{-1}\) for phosphorus has been studied in durum wheat Predel cultivar, grown on leached vertisol soil type during the period 2012-2014 in the field of the Field Crops Institute – Chirpan. The results show that at alone nitrogen fertilization grain yield reaches 3.75 t.ha\(^{-1}\) at moderate N\(_{120}\), while at alone phosphorus fertilization the increase compared to the non-fertilized control (2.50 t.ha\(^{-1}\)) is insignificant. At combined N\(_{80}\)P\(_{120}\), the highest grain yield was obtained during the period - 4.50 t.ha\(^{-1}\), with 57.41% above the control. The harvest index of durum wheat grain variety Predel is 0.353 on average. Good HI results are formed at fertilization with P\(_{120}\) and N\(_{80}\)P\(_{120}\).

Keywords: durum wheat, fertilization, vertisol soil

Introduction

Optimizing mineral fertilization of agricultural crops is one of the most important agro-technical means for creating a favourable environment for plant development, for providing the needed nutrients and increasing the yield. As a result of the optimal fertilization rate soil fertility improves and sustainable economic growth of farms is achieved (Gerganov, 2009).

The use of nitrogen fertilizers in wheat growing is one of the techniques that influences and strongly affects growth and productivity (Bindrabadan, 1999; Vandeleur et al., 2005; Ruggiero and Angelino, 2007). Protein synthesis in plant tissues is directly dependent on nitrogen fertilization, especially in maize and cereals (Stoyanova and Petkova, 2009).

Durum wheat needs nitrogen throughout its vegetative season. For the formation of 100 kg of grain under the conditions of Bulgaria, 3.0-3.7 kg N is extracted (Panayotova and Dechev, 2004; Dechev et al., 2010; Almaliev et al., 2014). Nitrogen fertilization should be well balanced with the soil phosphorus and potassium content and provide for the generation of planned high yields, including amounts covering for nitrogen losses due to washing out (Yanev et al., 2006). Kolev (2005) also reports that the main requirement for high yield coupled with good grain quality is for plants to receive the optimal amount of nitrogen during vegetation.

Ercoli and Mariotti (2006) stated that significant differences in yield, dry matter and nitrogen quantity accumulation have been found in experiments with durum wheat varieties in Italy at fertilization with 150 kg N/ha, 150 kg P\(_{2}O\(_{5}\)/ha and 150 kg K\(_{2}O/ha. In the evaluation of grain yields of durum wheat varieties grown at different fertilization rates, Dechev and Panayotova (2010) found that on average for a 11-year period grain yield was 4267 t ha\(^{-1}\), the latter growing from 3189 t ha\(^{-1}\) without fertilization to 4930 t ha\(^{-1}\) at N\(_{120}\).

The objective of the present study is to investigate the effect of nitrogen-phosphorus fertilization on the yield of durum wheat variety Predel at different fertilization rates.

Material and methods

The study was conducted with durum wheat variety Predel during the period 2012 – 2014 in stationary fertilization experiment with two-field crop rotation of cotton-durum wheat under non-irrigated conditions in the field of the Field Crops Institute (FCI) – Chirpan at leached vertisol soil type. The field experiment was carried out by block method with 12 variants at plot size of 10 m\(^{2}\) (2.40 x 4.20 m) in 4 replications. For side guards between the fertilized plots concrete slabs were placed and the transverse guard is 1.50 m. The study includes the Bulgarian durum wheat variety Predel, created at Field Crops Institute - Chirpan.

Nitrogen fertilization at rates N\(_{0}\), N\(_{80}\), N\(_{120}\), N\(_{160}\) was applied. With regard to phosphorus, the tested fertilization rates are P\(_{0}\), P\(_{80}\), P\(_{120}\), P\(_{160}\). The autonomous and complete combined effect of nitrogen and phosphorus has been traced. Nitrogen as ammonium nitrate was applied twice: 1/3 pre-sowing and 2/3 as early spring feeding. Phosphorus as triple superphosphate for durum wheat was applied with the pre-sowing field cultivation. The control is non-fertilized durum wheat.

According to FAO classification the soil in the field of FCI - Chirpan is a leached vertisol (Pellic vertisols) and as a whole it belongs to the most fertile and widespread and significant soils in Bulgaria. It is suitable for growing field crops and has the potential to form high yields. It is distinguished by a powerful humus horizon (70-100 cm) and by humus content it refers to the moderate humus soils. The soil reaction is from slightly acid to neutral. The soil in the experimental field has volume weight of 1.15-1.2 g.cm\(^{-3}\) and a relative density of 2.4-2.6. The sorption capacity is high - 35-45 meq/100 g of soil. The total nitrogen stock in the 0-30 cm layer is 500-600 kg.da\(^{-1}\). The amount of total phosphorus is 100-250 mg/100 g of soil. The soil is characterized by high moisture content, due to the high percentage of clay minerals, low water permeability and total porosity, poor to moderate with digestible nitrogen, poor supply of digestible phosphorus and good supply of exchange and reserve.
Agrochemical analyses show that the mineral nitrogen content averaged 41.20 mg.kg⁻¹ soil for the 0-20 cm layer and for the subplough layer 30.03 mg.kg⁻¹ soil. The content of mobile phosphates is low - 3.0-4.4 mg/100 g soil in the 0-20 cm layer and 2.6 to 3.0 mg/100 g soil for the soil layer 20-40 cm. The soil is well supplied with digestible potassium - an average of 19.8 mg/100 g soil (19.5-20.1 mg/100 g of soil) in the 0-20 cm layer and 17.8 mg/100 g of soil for the 20-40 cm layer (Table 1).

According to precipitation supply 2012 and 2013 are moderately dry, while 2014 is moist (Figure 2).

**Results and discussion**

The results obtained from the survey, averaged for the period 2012 – 2014, indicate that mineral fertilization has a very good effect on durum wheat productivity. This has also been found in the studies by Kostadinova and Panayotova (2002) and other authors who also found that the application of nitrogen has strong effect on grain yield from durum wheat. As a result of the natural soil fertility (without potassium.

Table 1. Soil supply with nutrient elements at field experiment with durum wheat

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>NH₄-N</th>
<th>NO₃-N</th>
<th>Nₘₕ</th>
<th>P₂O₅ (mg/100 g)</th>
<th>K₂O (mg/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avarage 0-20</td>
<td>25.80</td>
<td>15.40</td>
<td>41.20</td>
<td>3.2</td>
<td>19.8</td>
</tr>
<tr>
<td>Avarage 20-40</td>
<td>20.02</td>
<td>10.01</td>
<td>30.03</td>
<td>2.8</td>
<td>17.8</td>
</tr>
</tbody>
</table>

Figure 1. Average diurnal air temperature during the vegetation period of durum wheat (2012-2014)

Figure 2. Monthly amount of precipitation during the vegetation period of durum wheat (2012-2014)
fertilization) during the studied period, Predel variety forms an average grain yield of 2.50 t.ha⁻¹, within the following limit during the years from 2.62 to 2.74 t.ha⁻¹ (Table 2).

Differences in grain yields between the studied nitrogen fertilization rates throughout the period are substantial. The studied alone N fertilization, which is often applied in cereal crops, shows an increase in average yields up to a rate of N₁₂₀, - an average of 3.75 t.ha⁻¹, with 49.87% above the untreated control. The high nitrogen fertilization rate N₁₆₀ reduces the yield by 8.11% compared to the non-fertilized control. The yield reached a maximum of 2.78 t.ha⁻¹, 6.5% above the control. On comparing to the non-fertilized control and in the harvest 2012 the studied period showed an insignificant increase in grain yield rate of 120 kg.ha⁻¹ - 3.94 t.ha⁻¹, proven to exceed the other fertilization rates and years are significant (Table 3). With the independent action of the factors, the nitrogen fertilization rate is the strongest source of variation (14.02% of total effect), proven at p ≤ 0.001. The conditions over the years also have high impact (9.99%). The effect of phosphorous nutrition is insignificant (0.22%), i.e. the applied phosphorus rates have one-way effect. The interaction of N x P is very strong (54.51%), which statistically indicates that grain yield increases by combined fertilization with increasing nitrogen and phosphorus rates. Insignificant is the interaction P x Year, and N x Year is proven at p ≤ 0.01.

Concerning the independent action of nitrogen (Figure 3), it was found on average for the experiment that the high N₁₆₀ rate stimulated the formation of the highest yield - 3.84 t.ha⁻¹, followed by N₁₂₀ - 3.41 t.ha⁻¹.

The best effect on yield had the main action of phosphorus rate P₁₂₀, but the differences with the effect of the other tested phosphorus rates were insignificant (Figure 4).

The harvest index (HI) is an important factor for effective plant production (Swaidner et al., 1994; Parry and Reynolds, 2007). For the trial period, the average harvest index is good - 0.353, the highest harvest index being in 2014 - 0.356, with lower values in 2012 - 0.353 (Table 4). With the non-fertilized control, the harvest index for the period is 0.359 on average. The application of the low nitrogen rate N₈₀ results in unproved increase by 0.56% compared to non-fertilized. At moderate and high nitrogen rate (N₁₂₀ and N₁₆₀), the harvest index of the yield for variety Predel decreases compared to the control by 2.51 and 5.57%, respectively. With N₈₀ fertilization in 2014, the lowest value was recorded - 0.326. In combined

**Table 2. Grain yield of durum wheat variety Predel to nitrogen-phosphorous fertilization, 2012-2014, t.ha⁻¹**

<table>
<thead>
<tr>
<th>Fertilization</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t.ha⁻¹</td>
<td>%</td>
<td>t.ha⁻¹</td>
<td>%</td>
</tr>
<tr>
<td>N₈₀, P₈₀, K₈₀</td>
<td>2.62</td>
<td>100.0</td>
<td>2.16</td>
<td>100.0</td>
</tr>
<tr>
<td>N₈₀</td>
<td>3.48</td>
<td>133.1</td>
<td>3.48</td>
<td>161.2</td>
</tr>
<tr>
<td>N₁₂₀</td>
<td>3.86</td>
<td>147.8</td>
<td>3.94</td>
<td>182.3</td>
</tr>
<tr>
<td>N₁₆₀</td>
<td>3.92</td>
<td>149.9</td>
<td>3.64</td>
<td>168.5</td>
</tr>
<tr>
<td>P₀</td>
<td>2.80</td>
<td>107.1</td>
<td>2.19</td>
<td>101.7</td>
</tr>
<tr>
<td>N₈₀, P₀</td>
<td>3.80</td>
<td>145.3</td>
<td>3.57</td>
<td>165.2</td>
</tr>
<tr>
<td>N₁₂₀, P₀</td>
<td>4.18</td>
<td>159.7</td>
<td>3.88</td>
<td>179.6</td>
</tr>
<tr>
<td>N₁₆₀, P₀</td>
<td>4.38</td>
<td>167.3</td>
<td>3.73</td>
<td>172.7</td>
</tr>
<tr>
<td>P₁₂₀</td>
<td>2.78</td>
<td>106.5</td>
<td>2.26</td>
<td>104.5</td>
</tr>
<tr>
<td>N₈₀, P₁₂₀</td>
<td>3.79</td>
<td>144.8</td>
<td>3.43</td>
<td>158.9</td>
</tr>
<tr>
<td>N₁₂₀, P₁₂₀</td>
<td>4.26</td>
<td>163.1</td>
<td>3.77</td>
<td>174.5</td>
</tr>
<tr>
<td>N₁₆₀, P₁₂₀</td>
<td>4.50</td>
<td>172.3</td>
<td>3.77</td>
<td>174.6</td>
</tr>
<tr>
<td>Average</td>
<td>3.72</td>
<td>-</td>
<td>3.31</td>
<td>-</td>
</tr>
<tr>
<td>GD</td>
<td>0.319</td>
<td>12.2</td>
<td>0.718</td>
<td>33.3</td>
</tr>
<tr>
<td>GD%</td>
<td>0.429</td>
<td>16.4</td>
<td>1.014</td>
<td>46.9</td>
</tr>
<tr>
<td>GD x 1.1%</td>
<td>0.567</td>
<td>21.7</td>
<td>1.448</td>
<td>67.1</td>
</tr>
<tr>
<td>VC, %</td>
<td>5.97</td>
<td>10.24</td>
<td>8.39</td>
<td>5.60</td>
</tr>
</tbody>
</table>

*** - significant at P ≤ 0.001
Table 3. Analysis of variance for grain yield of durum wheat at fertilization, 2012-2014

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>d.f.</th>
<th>SS</th>
<th>MS, %</th>
<th>S</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>143</td>
<td>572124</td>
<td>100.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bloks</td>
<td>3</td>
<td>11364</td>
<td>1.99***</td>
<td>3788</td>
<td>10.20</td>
</tr>
<tr>
<td>Variants</td>
<td>35</td>
<td>521768</td>
<td>91.20***</td>
<td>14908</td>
<td>40.14</td>
</tr>
<tr>
<td>A - N rate</td>
<td>3</td>
<td>80222</td>
<td>14.02***</td>
<td>26741</td>
<td>72.01</td>
</tr>
<tr>
<td>B - P rate</td>
<td>2</td>
<td>1240</td>
<td>0.22**</td>
<td>620</td>
<td>1.67</td>
</tr>
<tr>
<td>C – Year</td>
<td>2</td>
<td>57128</td>
<td>9.99***</td>
<td>28564</td>
<td>76.92</td>
</tr>
<tr>
<td>A x B</td>
<td>6</td>
<td>311870</td>
<td>54.51***</td>
<td>51978</td>
<td>139.97</td>
</tr>
<tr>
<td>A x C</td>
<td>6</td>
<td>9098</td>
<td>1.59**</td>
<td>1516</td>
<td>4.08</td>
</tr>
<tr>
<td>B x C</td>
<td>4</td>
<td>396</td>
<td>0.07 **</td>
<td>99</td>
<td>0.27</td>
</tr>
<tr>
<td>A x B x C</td>
<td>12</td>
<td>61814</td>
<td>10.80***</td>
<td>5151</td>
<td>13.87</td>
</tr>
<tr>
<td>Error</td>
<td>105</td>
<td>38992</td>
<td>6.81</td>
<td>371</td>
<td></td>
</tr>
</tbody>
</table>

***; ** - significant at P ≤ 0.001 and P ≤ 0.01, respectively

Figure 3. Main effect of nitrogen on grain yield of durum wheat, t/ha

Figure 4. Main effect of phosphorus on grain yield of durum wheat, t/ha

Table 4. Harvest index (HI) of grain yield from durum wheat variety Predel at mineral fertilization, 2012-2014, %

<table>
<thead>
<tr>
<th>Fertilization</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HI</td>
<td>%</td>
<td>HI</td>
<td>%</td>
</tr>
<tr>
<td>N₉₀Pₙ₀Kₙ₀</td>
<td>0.353</td>
<td>100.0</td>
<td>0.370</td>
<td>100.0</td>
</tr>
<tr>
<td>N₈₀</td>
<td>0.362</td>
<td>102.6</td>
<td>0.360</td>
<td>97.3</td>
</tr>
<tr>
<td>N₁₂₀</td>
<td>0.351</td>
<td>99.4</td>
<td>0.358</td>
<td>96.8</td>
</tr>
<tr>
<td>N₁₆₀</td>
<td>0.346</td>
<td>98.0</td>
<td>0.340</td>
<td>91.9</td>
</tr>
<tr>
<td>Pₙ₀</td>
<td>0.341</td>
<td>96.6</td>
<td>0.364</td>
<td>98.4</td>
</tr>
<tr>
<td>N₉₀P₈₀</td>
<td>0.369</td>
<td>104.5</td>
<td>0.365</td>
<td>98.6</td>
</tr>
<tr>
<td>N₁₂₀P₈₀</td>
<td>0.346</td>
<td>98.0</td>
<td>0.354</td>
<td>95.7</td>
</tr>
<tr>
<td>N₁₆₀P₈₀</td>
<td>0.352</td>
<td>99.7</td>
<td>0.347</td>
<td>93.8</td>
</tr>
<tr>
<td>P₁₂₀</td>
<td>0.353</td>
<td>100.0</td>
<td>0.355</td>
<td>95.9</td>
</tr>
<tr>
<td>N₉₀P₁₂₀</td>
<td>0.353</td>
<td>100.0</td>
<td>0.348</td>
<td>94.0</td>
</tr>
<tr>
<td>N₁₂₀P₁₂₀</td>
<td>0.351</td>
<td>99.4</td>
<td>0.358</td>
<td>96.8</td>
</tr>
<tr>
<td>N₁₆₀P₁₂₀</td>
<td>0.357</td>
<td>101.1</td>
<td>0.343</td>
<td>92.7</td>
</tr>
<tr>
<td>Average</td>
<td>0.353</td>
<td>-</td>
<td>0.355</td>
<td>-</td>
</tr>
</tbody>
</table>

GD 5%; 1%; 0.1% = 1.49; 2.02; 2.72
VC, % = 2.48
fertilization with the participation of the high nitrogen rates during the analysed years HI decreases due to formed larger vegetative mass. Good HI results are achieved in fertilization with $P_{120}$ and $N_{80}P_{80}$.

**Conclusion**

At moderate nitrogen fertilization $N_{120}$, grain yield of durum wheat variety Predel grows to a maximum degree, an average of 3.75 t.ha$^{-1}$. At combined fertilization with rate $N_{120}P_{120}$ the highest grain yield was obtained during the trial period - 4.50 t.ha$^{-1}$. Higher yield from the interaction was received in the first year. Independent phosphorus fertilization at moderate and high rates is not an efficient agronomic activity. The harvest index of durum wheat grain variety Predel is 0.353 on average. The greatest effect of all studied factors has the interaction $N \times P$ - 48.79%. In combined fertilization with the participation of the high nitrogen rates during the studied years HI decreases due to the formed larger vegetative mass. Good HI results are formed at fertilization with $P_{120}$ and $N_{80}P_{80}$.

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