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# Nitrogen uptake and expense in durum wheat depending on genotype and nitrogen fertilization

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***Abstract.*** *Nitrogen uptake and expense of durum wheat were studied under the conditions of fertilized field experiment on soil type Pellic vertisol. The seven genotypes - Progress, Vazhod, Victoria, Predel, Deana, Zvezdica and Elbrus selected at the Institute of Field Crops – Chirpan, Bulgaria, were grown in two field crops rotation of cotton and durum wheat under rainfed conditions for a period of three vegetations in years 2011-2013. The spring treatments of nitrogen as $NH_4NO_3$ were as follows: $N_0$, $N_{60}$, $N_{120}$ and $N_{180}$. The total N uptake in the above ground biomass of durum wheat increased with the amount of applied nitrogen and during climatically favorable years reached 220 kg N.ha$^{-1}$. A tendency was found that the new genotypes uptook more N, compared to varieties Progress and Vazhod. The N expense of the new cultivars Predel and Zvezdica showed the highest amount of N per 1 ton of grain, 40.7 and 41.1 kg, respectively. Strong positive correlation was found between N fertilization and N uptake and expense for 1 ton of grain. The regression model indicated that N uptake with the grain and straw and N expense depending on N fertilization occurred with delay. With N fertilization of durum wheat at rates of up to 180 kg N.ha$^{-1}$ each kilogram of applied N fertilizer increased the average expected N uptake with 7 kg.ha$^{-1}$ and N expense with 0.66 kg.ton$^{-1}$ grain.*

**Keywords:** durum wheat, genotype, nitrogen, uptake, expense

## Introduction

Productivity and quality of crops, including durum wheat, varies to wide extent depending on the agroecological conditions (Dexter and Marchylo, 2000; Dechev and Panayotova, 2010; Panayotova et al., 2013), cultivar and crop-rotation (López-Bellido, 2001; Panayotova and Dechev, 2003; Panayotova, 2006; Gerdzhikova, 2014, 2015), cultivation technology (Petrova, 2009; Lalev et al., 2010), fertilization and soil fertility (Kostadinova and Panayotova, 2003; Stoyanova and Petkova, 2010; Panayotova and Kostadinova, 2015), etc. Optimizing the mineral nutrition is one of the most important conventions for favorable growth and production of the plants, for satisfying their need of nutrient elements, for increasing the soil richness (Schillingb et al., 2003).

Durum wheat needs nitrogen during the entire vegetation period. Nitrogen fertilization should be well balanced with phosphorus and potassium in the soil. Modern cultivars of durum wheat have high productive potential but realize it after high investments in production. In the breeding process, the specifics of output forms in terms of mineral nutrition are rarely taken into account for the effective and efficient use of nutrients.

Wheat genotypes have different adaptability to varying levels of fertilization (Ivanov, 1993; Le Gouis et al., 2000). Their productivity is related mainly to the accumulation of nitrogen and phosphorus (Marschner, 1997; Przulj and Momcilovic, 2001a, 2001b; Prystupa et al., 2004; Alvaro et al., 2008). In full maturity, more than 80% of nitrogen and phosphorus are localized in the grain, and less than 20% of potassium. Various authors develop and use parameters associated with accumulation, distribution and remobilization of above-ground biomass, nitrogen and phosphorus (Cox et al., 1985a,b;1986; Papakosta and Gagianas 1991; Papakosta, 1994; Przulj and Momcilovic, 2001c; Abeledo et al., 2008; Ercolia et al., 2008; Dordas, 2009;).

It was generally believed that cultivars differ in responsiveness to accumulation of nitrogen in the vegetative parts. Some authors established the effectiveness of fertilization on varieties of different genetic potential in the differentiated soil fertility (Dhugga and Waines, 1989; Deshmukh et al., 1990; Panayotova and Yanev, 2001). The nitrogen content in the grain and straw increased with increasing the nitrogen rate and in rich soil fertility (Rharrabti et al., 2003). The main objective of breeding is to create varieties of high productivity and stability. Fertilized plants utilize about 53% more nitrogen into the grain compared to unfertilized (Dhugga and Waines, 1989; Ricciardi, 2001; Abeledo et al., 2008).

The interest among researchers and farmers for more effective genotypes of cereals is increasing worldwide in connection with the energy crisis and use of non-renewable resources in the production of nitrogen and phosphorous fertilizers (Ortiz-Monasterio et al., 2001; Guarda et al., 2004; LaPerche et al., 2006; Hirel et al., 2007; Li et al., 2008) and creating a strategy for growing with higher utilization efficiency (Raun et al., 2002; Shanahan et al., 2008; Foulkes et al., 2009) and adaptation at low levels of nitrogen and phosphorus in the soil (Lawlor, 2002; Goulding, 2004).

The nitrogen and phosphorus uptake in plants depends mainly on the formed dry mass (Panaiotova, 2004; Ozturk et al., 2005; Panayotova et al., 2006). The nitrogen content in grain is more closely related to dry matter accumulation after flowering stage than phosphorus. Therefore, the nitrogen content in grain is more closely related to the environmental conditions, while the phosphorus content in the grain – to the genetic characteristics.

The prevailing scientific opinion states that the uptake of nitrogen in wheat is predominantly before flowering. Thus, over 80%

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of the total nitrogen content in maturity is presented in flowering plants (Papakosta and Gagianas, 1991) and accumulated nitrogen before flowering may amount to more than 75-90% of the final content of nitrogen in grain (Cox et al., 1985a, b; Heitholt et al., 1990). The accumulation of nitrogen until flowering is lower at temporary nitrogen deficiency in tillering and/or stem elongation, as a result of insufficient nitrogen fertilization (Lambers et al., 1982). The extent of nitrogen accumulation is determined by the relationship between the capacity of plants to absorb and remobilise nitrogen (Fageria and Baligar, 2005).

There are different opinions about the effects of fertilization and genotype on HI and NHI and the ratio NHI / HI depends to a greater extent on the influence of growing conditions on growth and yield formation. The yields of grain and grain protein depend on the content of nitrogen and carbohydrates in the grain and it is necessary for the study of wheat genotypic specificity to take into account both parts - nitrogen and carbohydrates. In this way, the two indices - nitrogen (NHI) and yield (HI) are included in the formation of grain protein yield (Cox et al., 1986). The content of mineral nitrogen and mobile phosphates in soil and fertilization influence the percentage of nitrogen and phosphorus in plants and uptake with the above-ground mass (Bauer et al. 1987).

In Bulgaria, the genotypic specificity of mineral nutrition is studied primarily with common wheat (Ivanov et al., 1993; Rachovski et al., 2005) and still lacks sufficient scientific information about the new varieties of durum wheat. There is no scientific data on indicators related to the assimilation of nitrogen for the newly established durum wheat varieties.

The aim of this study was to investigate nitrogen uptake and expense of durum wheat depending on genotype and nitrogen fertilization on soil type *Pellic vertisol*.

## Material and methods

The experiment was conducted in 2011 – 2013 on the field of the Cotton and Durum Wheat Research Institute in Chirpan, Bulgaria, under rainfed conditions. Split-plot randomised design with a yield plot of 10 $m^2$ in four replications was used. The cropping pattern is winter durum wheat (*Tr. durum* Desf.) – cotton.

The influence of nitrogen rates 0, 60, 120 and 180 $kg.ha^{-1}$ on the durum wheat cultivars Progress, Vazhod, Victoria, Predel, Deana, Zvezdica and Elbrus was studied. The unfertilized cultivar Progress was accepted as control.

Before sowing all the plots were fertilized with a rate of 80 kg $P_2O_5.ha^{-1}$ as triple superphosphate. Nitrogen as ammonium nitrate was applied on durum wheat by hand two times: one third - at sowing, and the rest as a top dressing at the end of wheat tillering stage.

The seeds were sown on 25-30 October and the sowing rate for each genotype was 450 germinated seeds per $m^2$. Weeds were controlled with herbicides between the tillering and shoot elongation stages. There were no pathogens and pests above the threshold of harm during the durum wheat vegetation in the three growing years and chemical spraying was not used. The harvest took place with plot harvester.

The total yield of grain and straw (t $.ha^{-1}$), the total nitrogen uptake ($kg.ha^{-1}$) as a product of nitrogen concentration (%) multiplied by the yields of grain and straw from durum wheat varieties and nitrogen input for the preparation of 1 ton of grain were determined. The nitrogen harvest index (%) at maturity was defined as the ratio between the nitrogen amount in grain to the total nitrogen amount in the above ground biomass in maturity. In regard with the meteorological conditions, unfavorable influence on grain was registered for the high temperatures during the period April-June in the three years of the experiment and for the heavy precipitation in May-June in 2012 and 2013 (Figures 1 and 2). During the winter period no critical negative temperatures and no frost damage to the crops were registered.

The data was statistically analyzed with the ANOVA procedure within the SPSS statistical program and Duncan's multiple range test (P = 0.05) to find significant differences among means. Correlation and regression analyses were applied for assessment of interaction between genotypes and nitrogen rates for the studied parameters.


**Figure 1.** Air temperatures during the vegetation period of durum wheat, 2011 – 2013

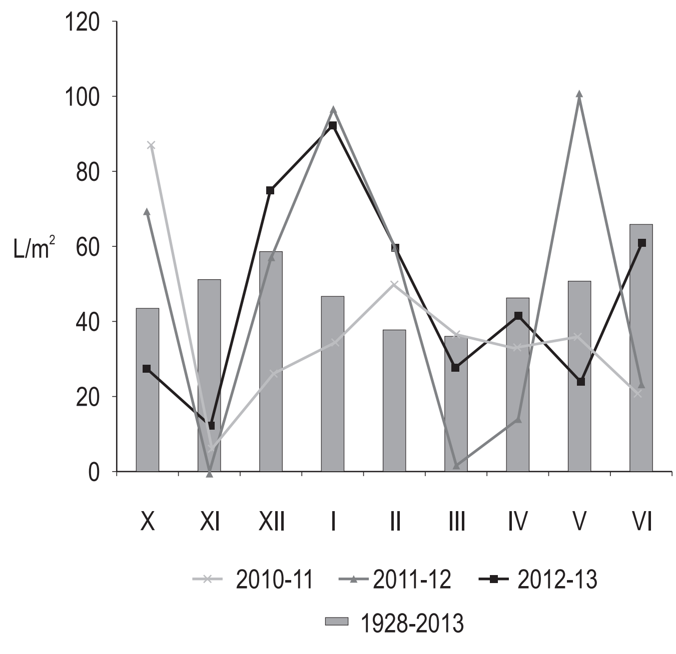


**Figure 2.** Sum of rainfall during the vegetation of durum wheat, 2011 – 2013

## Results and discussion

The soil type at the experimental field was *Pellic vertisols* (FAO) and generally refers to the so called Mediterranean chernozems. The soil type is one of the richest, most widely spread and significant in Bulgaria. It is suitable for growing most field crops and has potential for high yield. It has a high-powered humus horizon (70–80 cm), with a compact zone of the profile (united horizon). By humus content it belongs to the mean humus soils. It is characterized by high humidity capacity, caused by high percentage of clay minerals, heavy mechanical composition, weak water-permeability, bulk weight of the arable soil layer 1.2-1.3 $g.cm^{-3}$, specific gravity of 2.4-2.6 and low total porosity, neutral soil reaction, total N in the arable layer 0.095-0.14 % and low content of total phosphorus (0.05-0.11 %), poorly to medium supplied with mineral nitrogen, poorly supplied with available phosphorus and well supplied with available potassium (Table 1).

Average for the period 2011-2013, the differences in grain yield of durum wheat between the studied nitrogen levels were significant (Table 2). Without fertilization the varieties formed an average grain yield of 3.77 $t.ha^{-1}$. N fertilization was investigated and showed an increase in the average yield to standard $N_{120}$ - 4.80 $t.ha^{-1}$, with 27 %

**Table 1.** Soil properties in 0-40 cm soil layer of *Pellic Vertisols*, Chirpan

| Depth (cm) | pH | Mineral N (mg/kg soil) | | | $P_2O_5$ (mg/100 g) | $K_2O$ (mg/100 g) |
|---|---|---|---|---|---|---|
| | | $NH_4$-N | $NO_3$-N | $N_{min}$ | | |
| Average 0-20 | 6.3 | 25.80 | 15.40 | 41.20 | 3.2 | 19.8 |
| Average 20-40 | 6.5 | 20.02 | 10.01 | 30.03 | 2.8 | 17.8 |

**Table 2.** Grain yield depending on nitrogen fertilization and cultivar, $t.ha^{-1}$

| Factors | 2011 | 2012 | 2013 | Average | |
|---|---|---|---|---|---|
| | | | | $t.ha^{-1}$ | % |
| A. Fertilization | | | | | |
| $N_0$ | $4.12^{d}$ | $3.09^{b}$ | $4.09^{b}$ | $3.77^{c}$ | 100 |
| $N_{60}$ | $4.71^{c}$ | $3.36^{b}$ | $4.50^{ab}$ | $4.19^{b}$ | 111 |
| $N_{120}$ | $5.63^{a}$ | $3.84^{a}$ | $4.93^{a}$ | $4.80^{a}$ | 127 |
| $N_{180}$ | $5.20^{b}$ | $4.27^{a}$ | $4.40^{ab}$ | $4.62^{a}$ | 123 |
| B. Genotype | | | | | |
| Progress (control) | $4.76^{ns}$ | $3.38^{ns}$ | $3.84^{b}$ | $3.99^{ns}$ | 100 |
| Vazhod | 5.02 | 3.36 | $4.27^{ab}$ | 4.22 | 106 |
| Victoria | 5.09 | 3.41 | $4.40^{ab}$ | 4.30 | 108 |
| Predel | 4.90 | 3.28 | $4.26^{ab}$ | 4.15 | 104 |
| Deana | 4.74 | 4.14 | $4.52^{ab}$ | 4.47 | 112 |
| Zvezdica | 4.64 | 3.78 | $4.30^{ab}$ | 4.24 | 106 |
| Elbrus | 5.25 | 4.11 | $4.79^{a}$ | 4.72 | 118 |

**Table 3.** Yield of grain + straw depending on nitrogen fertilization and cultivar, $t.ha^{-1}$

| Factors | 2011 | 2012 | 2013 | Average |
|---|---|---|---|---|
| A. Fertilization | | | | |
| $N_0$ | $9.96^{c}$ | $8.76^{c}$ | $10.86^{c}$ | $9.86^{c}$ |
| $N_{60}$ | $11.97^{b}$ | $9.60^{c}$ | $12.08^{b}$ | $11.21^{b}$ |
| $N_{120}$ | $14.38^{a}$ | $11.18^{b}$ | $13.88^{a}$ | $13.15^{a}$ |
| $N_{180}$ | $14.44^{a}$ | $12.39^{a}$ | $13.38^{a}$ | $13.40^{a}$ |
| B. Genotype | | | | |
| Progress (control) | $12.73^{ns}$ | $10.38^{ns}$ | $10.55^{b}$ | $11.22^{ns}$ |
| Vazhod | 12.47 | 9.83 | $11.92^{ab}$ | 11.41 |
| Victoria | 13.54 | 9.93 | $13.13^{a}$ | 12.20 |
| Predel | 12.96 | 9.72 | $13.09^{a}$ | 11.92 |
| Deana | 11.77 | 11.87 | $13.03^{a}$ | 12.22 |
| Zvezdica | 11.98 | 10.59 | $13.37^{a}$ | 11.98 |
| Elbrus | 13.34 | 11.06 | $12.75^{a}$ | 12.38 |

**Table 4.** Total N uptake (kg $N.ha^{-1}$) depending on nitrogen fertilization, genotype and year

| Factors | 2011 | 2012 | 2013 | Average |
|---|---|---|---|---|
| A. Fertilization | | | | |
| $N_0$ | $131.8^{c}$ | $91.5^{d}$ | $127.4^{b}$ | $116.9^{c}$ |
| $N_{60}$ | $172.7^{b}$ | $110.7^{c}$ | $151.5^{b}$ | $145.0^{b}$ |
| $N_{120}$ | $221.4^{a}$ | $145.3^{b}$ | $192.9^{a}$ | $186.5^{a}$ |
| $N_{180}$ | $222.4^{a}$ | $171.0^{a}$ | $191.6^{a}$ | $195.0^{a}$ |
| B. Genotype | | | | |
| Progress (control) | $173.3^{ns}$ | $115.6^{ns}$ | $125.6^{b}$ | $138.2^{ns}$ |
| Vazhod | 170.5 | 110.6 | $144.6^{ab}$ | 141.9 |
| Victoria | 194.2 | 119.4 | $169.1^{ab}$ | 160.9 |
| Predel | 209.7 | 130.9 | $187.9^{a}$ | 176.2 |
| Deana | 167.4 | 139.8 | $164.7^{ab}$ | 157.3 |
| Zvezdica | 196.1 | 148.1 | $189.5^{a}$ | 177.9 |
| Elbrus | 198.4 | 143.2 | $179.5^{a}$ | 173.7 |
| C. Year | $187.1^{a}$ | $129.7^{c}$ | $165.8^{b}$ | |

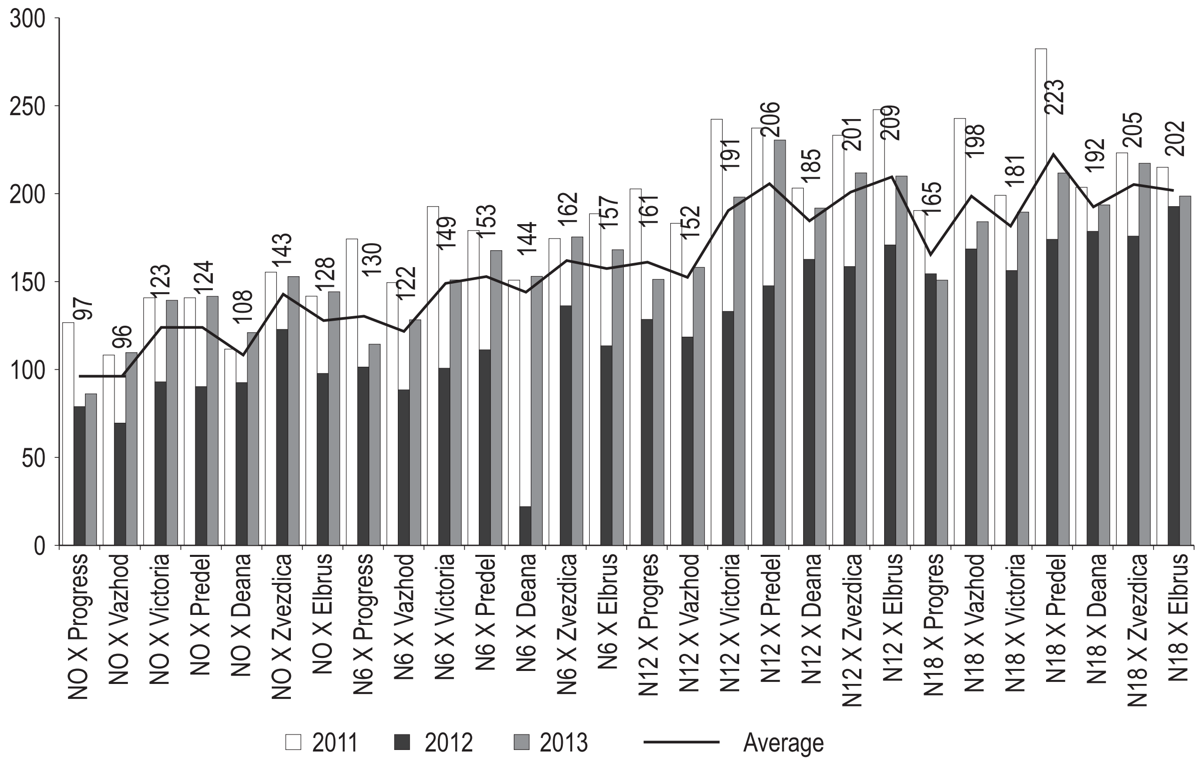


**Figure 3.** Total N uptake (kg $N.ha^{-1}$) at interaction of nitrogen and genotype

over the unfertilized control. High nitrogen rates $N_{180}$ showed a tendency to decrease the yield with 0.18 $t.ha^{-1}$ compared to moderate fertilization with $N_{120}$. The results corresponded to the data by Panayotova and Dechev (2003), who also established the highest productivity of durum wheat varieties at fertilization with 120 kg $N.ha^{-1}$.

The differences between the average grain yields of the varieties in the period were not proven. The cultivar Progress was characterized with the lowest yield – 3.99 $t.ha^{-1}$, and the new varieties Elbrus and Deana formed the highest grain productivity, 4.72 and 4.47 $t.ha^{-1}$, respectively. Average for the period with tested four nitrogen levels these two varieties exceeded the standard Progress by 18% and 12%. The relative yield of Predel was the lowest – 4% above Progress.

For the period cultivar Progress without nitrogen fertilization formed the lowest yield 3.26 $t.ha^{-1}$ at the interaction of N x cultivar. Cultivar Elbrus fertilized with $N_{120}$ was marked with the highest average values for grain yield - 5.21 $t.ha^{-1}$ and at $N_{180}$ - 4.99 $t.ha^{-1}$, which exceeded by 60% and 53% the unfertilized standard Progress and substantially exceeded all the other interactions.

The average total yield of grain and straw without fertilization was 9.86 $t.ha^{-1}$ (Table 3). The economic yield for the period was

**Table 5.** Nitrogen harvest index (%) depending on nitrogen fertilization, genotype and year

| Factors | 2011 | 2012 | 2013 | Average |
|---|---|---|---|---|
| A. Fertilization | | | | |
| $N_0$ | 71.7$^{a}$ | 70.40$^{a}$ | 70.78$^{a}$ | 71.10$^{a}$ |
| $N_{60}$ | 62.2$^{c}$ | 65.64$^{b}$ | 66.77$^{ab}$ | 64.67$^{b}$ |
| $N_{120}$ | 68.5$^{ab}$ | 65.44$^{b}$ | 66.05$^{b}$ | 66.87$^{b}$ |
| $N_{180}$ | 66.2$^{bc}$ | 65.20$^{b}$ | 62.74$^{b}$ | 64.77$^{b}$ |
| B. Genotype | | | | |
| Progress (control) | 69.95$^{ns}$ | 69.36$^{a}$ | 66.45$^{abc}$ | 68.71$^{ab}$ |
| Vazhod | 69.98 | 68.30$^{ab}$ | 70.35$^{a}$ | 69.65$^{a}$ |
| Victoria | 66.76 | 67.36$^{ab}$ | 68.29$^{ab}$ | 67.37$^{ab}$ |
| Predel | 64.56 | 62.13$^{b}$ | 63.32$^{bc}$ | 63.49$^{ab}$ |
| Deana | 68.90 | 68.09$^{ab}$ | 67.61$^{abc}$ | 68.21$^{ab}$ |
| Zvezdica | 62.29 | 63.63$^{ab}$ | 61.52$^{c}$ | 62.41$^{b}$ |
| Elbrus | 67.79 | 67.82 $^{ab}$ | 68.56$^{ab}$ | 68.12$^{ab}$ |
| C. Year | 67.2$^{ns}$ | 66.7 | 66.7 | |

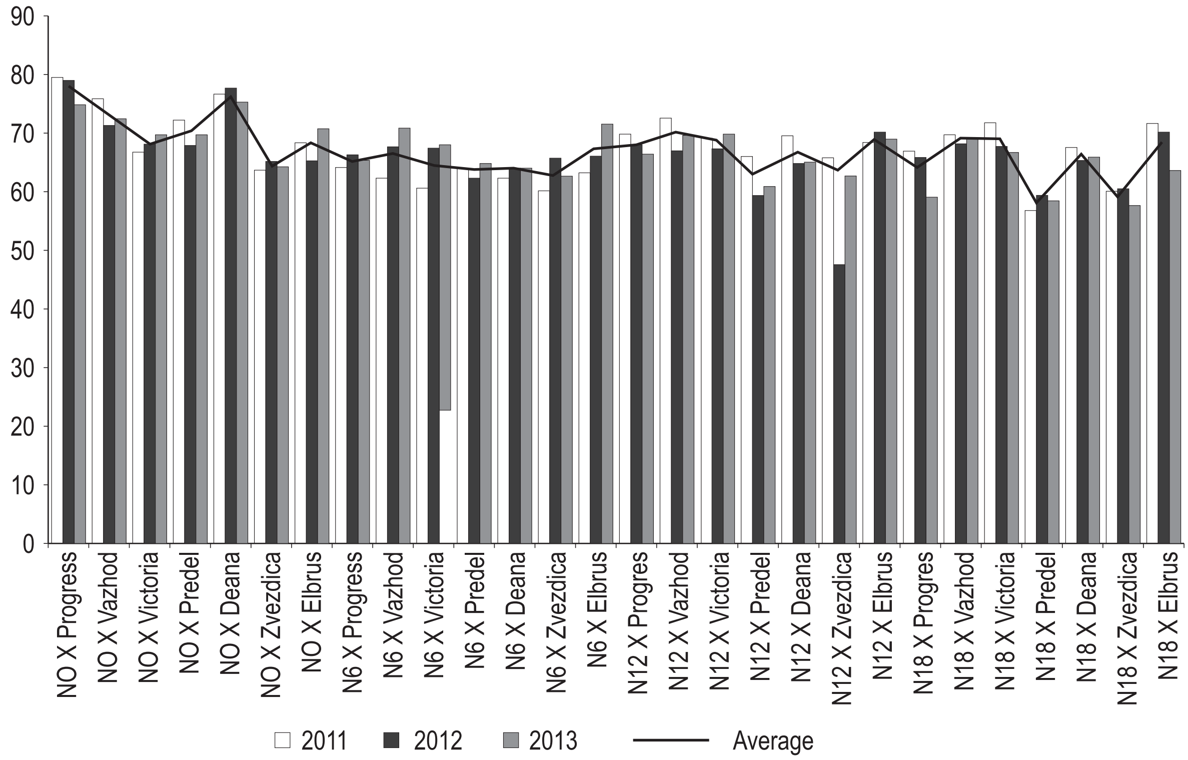


**Figure 4.** Nitrogen harvest index (%) at interaction of the factors nitrogen fertilization and variety

enhanced by increasing the nitrogen rate. The highest values were reported at the rate of $N_{180}$ - 1.34 t.ha$^{-1}$, which were proven to exceed the unfertilized by 36% and the low rate of $N_{60}$ by 20%. At the high rate of $N_{180}$ the economic yield was not proven to increase by 2% compared to $N_{120}$. The highest biological yield for the period was reported during the harvest of 2011 at 180 kg N.ha$^{-1}$ - 1.44 t.ha$^{-1}$.

The differences between the average yields of grain + straw of durum wheat varieties were not proven. The new cultivars Elbrus and Deana formed the highest above-ground yield - 12.38 and 12.22 t.ha$^{-1}$, respectively, and Progress was with the lowest yield - 11.22 t.ha$^{-1}$.

At the interaction of N fertilization x cultivar, the highest values were expressed by cultivar Predel x $N_{180}$ - 14.19 t.ha$^{-1}$. At $N_0$ x Progress was formed above-ground biological yield of 9.16 t.ha$^{-1}$, while $N_0$ x Elbrus - 10.61 t.ha$^{-1}$, which showed that Elbrus was more productive at low nitrogen nutrition compared to Progress.

The total nitrogen uptake in the above-ground biomass of the studied cultivars increased by increasing the amount of imported nitrogen (Table 4). Accumulated nitrogen at 180 kg.ha$^{-1}$ reached 195.0 kg.ha$^{-1}$ and was proven to exceed the nitrogen uptake at $N_0$ and $N_{60}$, by 67% and 34 % respectively, and the difference with rate $N_{120}$ was insignificant.

A trend was established showing that the new cultivars uptake

**Table 6.** Nitrogen expense for 1 ton of grain depending on N fertilization, cultivar and year

| Main factors | 2011 | 2012 | 2013 | Average |
|---|---|---|---|---|
| A. Fertilization | | | | |
| $N_0$ | 32.0$^c$ | 29.6$^b$ | 31.2$^c$ | 30.9$^b$ |
| $N_{60}$ | 36.8$^{bc}$ | 33.0$^b$ | 33.9$^c$ | 34.6$^b$ |
| $N_{120}$ | 39.3$^{ab}$ | 37.8$^a$ | 39.0$^b$ | 38.7$^a$ |
| $N_{180}$ | 42.8$^a$ | 40.2$^a$ | 43.6$^a$ | 42.2$^a$ |
| B. Genotype | | | | |
| Progress (control) | 36.2$^{ns}$ | 33.7$^{ns}$ | 36.8$^{ab}$ | 35.5$^{ns}$ |
| Vazhod | 33.4 | 32.0 | 32.5$^b$ | 32.6 |
| Victoria | 37.9 | 34.7 | 35.7$^{ab}$ | 36.1 |
| Predel | 42.1 | 39.3 | 40.6$^{ab}$ | 40.7 |
| Deana | 34.9 | 33.3 | 34.9$^{ab}$ | 34.4 |
| Zvezdica | 42.1 | 39.0 | 42.1$^a$ | 41.1 |
| Elbrus | 37.4 | 34.2 | 36.1$^{ab}$ | 35.9 |
| C. Year | 37.7$^{ns}$ | 35.2 | 36.9 | |

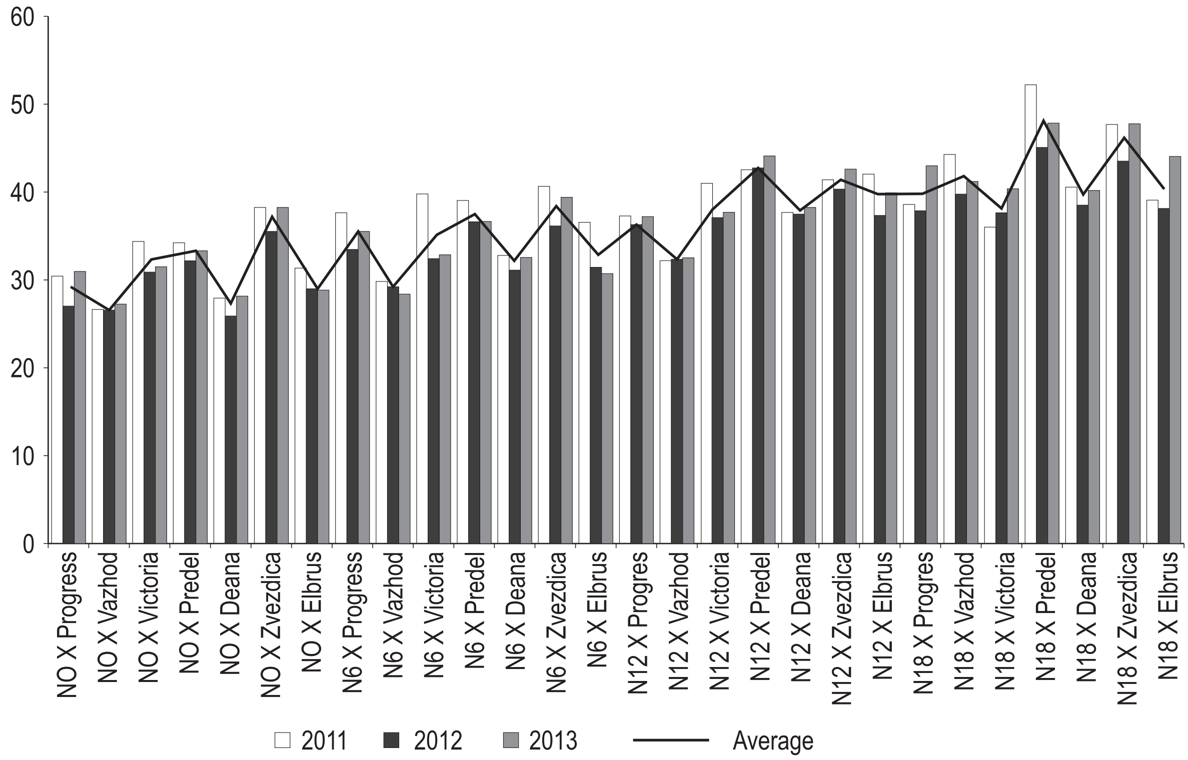


**Figure 5.** Nitrogen expense for 1 ton of grain at interaction of nitrogen fertilization and variety

more nitrogen compared to Progress and Vazhod. Progress uptook the least nitrogen with above-ground biomass - 138.2 kg.ha$^{-1}$, Zvezdica uptook the most nitrogen - 177.9 kg.ha$^{-1}$, but the differences between cultivars were not proven. All new cultivars - Zvezdica, Predel, Elbrus and Deana uptook more nitrogen (over 160 kg.ha$^{-1}$) compared to Progress and Vazhod. In 2011 the cultivars uptook the most nitrogen with the total yield - 187.1 kg.ha$^{-1}$, proven for more than 44% of uptake in 2012 and 13% over the one in 2013.

At the interaction of nitrogen rate x cultivar the total nitrogen uptake of above-ground biomass showed the highest values for Predel and Elbrus, fertilized with 120 to 180 kg N.ha$^{-1}$. In favorable climatic years, such as 2011, the uptake of Predel x $N_{180}$ reached 222.4 kg N.ha$^{-1}$ (Figure 3).

Average for the period, nitrogen fertilization decreased the nitrogen harvest index from 71.1% at $N_0$ to 64.77% at $N_{180}$ (Table 5). The cultivars distributed from 62.41% of the total nitrogen in grain in maturity for Zvezdica to 69.65% for Vazhod. Differences only between these two cultivars were proven mathematically. The year factor did not affect this indicator and the values of different years were close and with no proven difference. The highest value of the indicator for all the interactions was obtained by the unfertilized cultivar Progress - 77.89%, and the lowest NHI was for Predel, fertilized with 180 kg N.ha$^{-1}$ – 57.74% (Figure 4). Except for the newest Elbrus at $N_{60}$ all other new varieties fall behind the older

**Table 7.** Correlations between total N uptake, N expense, NHI and nitrogen fertilization

| Parameters | 2011 | 2012 | 2013 | 2011-2013 |
|---|---|---|---|---|
| Total nitrogen uptake | 0.823** | 0.888** | 0.734** | 0.859** |
| N expense | 0.689** | 0.810** | 0.817** | 0.789** |
| NHI | -0.212 | -0.415* | -0.610* | -0.433* |

Progress (65.03 %) and Vazhod (66.39%). In 2011 and 2013 at $N_{120}$, Vazhod had the highest NHI, 72.51% and 69.43%, respectively, and in 2012 it gave way to Elbrus (69.89%) and Victoria (67.20%). Average for the period, at the high rate of 180 kg.ha$^{-1}$, NHI was the highest for Vazhod - 69.05%.

The main indicator for evaluating the effectiveness of fertilization is the N expense per unit of production. The N expense for 1 ton of grain grew together with level of nitrogen nutrition from 30.9 kg at $N_0$ to 42.2 kg for wheat fertilized with $N_{180}$, whereas Vazhod consumed the least amount of N - 32.6 kg (Table 6). To form 1 ton of grain of Progress, Vazhod, Deana and Elbrus with no fertilization 26.8-29.9 kg N were used or less than Victoria, Predel and Zvezdica (Figure 5). At the low rate of $N_{60}$ only Vazhod consumed less than 30 kg N. At the rate of 120 kg N.ha$^{-1}$ cultivars Predel, Zvezdica and Elbrus needed 40 kg of nitrogen per 1 ton of grain, i.e. they were less effective from agrochemical point of view. At the high rate of $N_{180}$ the most nitrogen was used by Predel and Zvezdica, 48.5 and 46.5 kg, respectively.

A strong positive correlation was established between nitrogen fertilization and N uptake and expense for 1 ton of durum wheat grain, whereas the relation between nitrogen fertilization and nitrogen harvest index was negative (Table 7).

The dependencies of total N uptake and N expense for 1 ton of grain with the applied nitrogen fertilization for durum wheat were not rectilinear (Table 8). As a result of the conducted regression analysis, the modeled relationships were presented with equations of the second degree, and high values of the determination coefficient ($R^2$) were established. The regression model showed that increasing the uptake of nitrogen with grain and straw, as well as N expense depending on nitrogen fertilization occurred with delay during the three harvest years and average for the period. With nitrogen fertilization at rates up to 180 kg N.ha$^{-1}$ every kilogram of applied nitrogen increased the average expected uptake of nitrogen with 7 kg.ha$^{-1}$, and N expense - with 0.66 kg.ha$^{-1}$.

**Table 8.** Regression relations of total nitrogen uptake and N expense with nitrogen fertilization

| Year | | $R^2$ |
|---|---|---|
| Total nitrogen uptake | | |
| 2011 | $y = 129.2 + 10.3x - 0.274x^2$ | 0.728 |
| 2012 | $y = 90.4 + 3.7x - 0.05x^2$ | 0.790 |
| 2013 | $y = 124.4+ 7.1x - 0.17x^2$ | 0.568 |
| 2011-2013 | $y = 114.7 + 7.0x - 0.14x^2$ | 0.756 |
| N expense | | |
| 2011 | $y = 32.1 + 0.73x - 0.009x^2$ | 0.478 |
| 2012 | $y = 29.4 + 0.71x - 0.007x^2$ | 0.658 |
| 2013 | $y = 31.2 + 0.46x - 0.014x^2$ | 0.662 |
| 2011-2013 | $y = 30.8 + 0.66x - 0.001x^2$ | 0.623 |

## Conclusion

The total N uptake with above-ground biomass of durum wheat increased with the amount of applied nitrogen and in favorable years it reached 22 kg N.ha$^{-1}$. A trend was established that the new genotypes uptake more nitrogen compared to Progress and Vazhod. Nitrogen fertilization decreased the nitrogen harvest index from 71.1% for $N_0$ to 64.8% at $N_{180}$. The cultivars distributed from 62.4% of total nitrogen in grain, average for the period for Zvezdica, to 69.6% for Vazhod and the year factor had no proven impact on this indicator. Nitrogen expense for formation of 1 ton of durum wheat grain increased with the level of nitrogen nutrition from 30.9 kg at $N_0$ to 42.2 kg for fertilization with $N_{180}$ and Vazhod used the least N - 32.6 kg. The new cultivars Predel and Zvezdica used the highest amount of nitrogen for 1 ton of grain, 40.7 and 41.1 kg, respectively. A strong positive correlation was established between nitrogen fertilization and N uptake and N expense to form 1 ton of grain. The regression model indicated that N uptake with grain and straw, as well as N expense depending on nitrogen fertilization occurred with delay. At nitrogen fertilization of durum wheat at rates up to 180 kg N.ha$^{-1}$, every kilogram of applied nitrogen increased the average N uptake with 7 kg.ha$^{-1}$ and N expense – with 0.66 kg ha$^{-1}$.

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