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ECONOMIC EVALUATION OF DURUM WHEAT FERTILIZATION IN BULGARIA

GALIA PANAYOTOVA[1*] and SVETLA KOSTADINOVA[2]
[1]Department of Plant Production, Faculty of Agriculture, Trakia University, 6000 Stara Zagora
[2]Department of Agrochemistry and Soil Science, Faculty of Agronomy, Agricultural University, 4000 Plovdiv, Bulgaria

Abstract

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The economic efficiency of durum wheat grain yield under the influence of fertilization in two field trials on Leached vertisol soil type was determined. In the first experiment the reaction of Bulgarian varieties Progress, Vazhod, Victoria, Predel, Deana, Zvezditsa and Elbrus to fertilization at rates of 0, 60, 120, 180 kg N.ha^{-1} was studied. The second long-term fertilizing trial examined the responsiveness of variety Progress towards independent P and combined NP fertilization at rates: N_0P_0, P_{80}, P_{120}, P_{160}, $N_{120}P_{80}$, $N_{120}P_{120}$ and $N_{120}P_{160}$. The results showed that the optimal fertilizer rate for high yield was N_{120}. According to the economic analysis fertilization with 120 kg N.ha^{-1} had good profitability - 127.89%. Appling 180 kgN.ha^{-1} decreased the profitability of production and this rate was not effective. Elbrus variety showed the best economic values for different N levels, followed by variety Deana. Under the conditions of long-term trial, variety Progress demonstrated low efficiency from the combined NP fertilization. The profitability of production at only P fertilization was very low, significantly below the base level of control (-10.65% at P_{160} to 8.57% at P_{80}). Independent phosphorus fertilization was ineffective and economically unjustified.

Key words: durum wheat; fertilization; economic efficiency; profitability

Introduction

The economic profitability of agricultural production requires low cost of raw materials and high yield. Efficiency is very important for every type of agricultural system. The agronomic efficiency and economic efficacy of mineral fertilization depends on the optimization of the fertilizer rates and the ratios between the nutrients. The main advantage of the modern intensive management systems in agriculture is their higher profitability (Tomov et al., 2001; Manolova et al., 2015). The production systems can be profitable while providing environmental benefits by reducing or avoiding the use of chemicals and preventing other agricultural problems like pesticide resistance and soil residues (Pardo et al., 2009). Furthermore, the reduction in agrochemicals can improve the sustainability of the system in the long term.

The genetic potential of varieties is manifested under optimal environmental conditions. The productivity and the economic effect of durum wheat depend on a great degree from the parameters of agro-technological factors, as well as from the rates of mineral fertilization (Schilling et al., 2003; Pacucci et al., 2004).

Tsankova (1996) has established that the economic efficiency of wheat production is highest at fertilization with 80-120 kg N.ha^{-1} when wheat is sown after untreated maize. The tendency toward lower return on expenses with the higher nitrogen norms was even better expressed after nitrogen treatment of the previous crop.

A lot of authors have elaborated on separate aspects of the economic efficiency of wheat fertilization in their investigations based on the agronomic effect of certain fertilization systems (Özberk et al., 2006; Nankov, 2007; Hristova, 2011;

*E-mail: galia_panayotova@abv.bg

Nankov et al., 2014). The use of fertilizers is very capital intensive, but without fertilization it is impossible to organize competitive production.

Not always the maximum possible yield due to increased mineral fertilization is economically effective (López-Bellido and López-Bellido, 2001). In the conditions of free market, the mineral fertilization is applicable only if the crops are reasonable for the farmer. A major problem is finding the cost-effective limit of fertilization. The economic efficiency of fertilizer is expressed mainly in maximizing yield per unit area, i.e. in increasing the additional net income and profitability of production.

Only through nutrients utilization can be obtained an optimal yield with good quality. While the price of grain has decreased, the costs of energy and inputs like chemical fertilizers and herbicides required for farming have increased.

With no less power today, the problem of combining satisfactory results from production of sustainable productivity and quality with results also satisfactory to a maximum degree in economical aspect is an equally serious challenge. Mineral fertilization can lead to negative agronomic results, especially after long-term application at wrong norms and ratios.

Fertilization has practical importance only if the application cost is favorable for the farmer. Effectiveness of investments for fertilization in Bulgaria at the moment is relatively low due to unfavorable ratio of market grain prices and fertilizers. This raises the question to increase profit per unit area, not only to increase yields. The definition of economically effective fertilizing limit under certain conditions is a major issue.

Low fertility entails higher costs for satisfying the plant needs of nutrients. High fertilization costs per unit production are due greatly to the way in which the norms of fertilization are formed (taking into account the available soil reserves of mobile forms of basic nutrients, uptake with plants and creating a good stock of nutrients), i.e. increase the effective soil fertility. Through economic analysis effective rates of crops fertilization are justified to increase the profitability of the production.

In our country, no published results for the economic efficiency of fertilization in the production of Bulgarian durum wheat varieties are recognized after 1990. The comparison with the results of foreign authors is not objective because of the specific soil and climatic conditions of production, the different production costs (prices of materials, fertilizers, pesticides, fuels) and realization prices, the amount of subsidies, taxes, etc.

The aim of this study was to make an economic assessment of the production of durum wheat varieties at different levels of fertilization, grown in the region of Central South Bulgaria.

Material and methods

The economic efficiency of fertilization has been studied in two field fertilizing experiments on durum wheat in rotation with cotton, carried out at the Field Crops Institute – Chirpan (FCI), under rainy conditions.

In the first experiment the responsiveness of Bulgarian durum wheat varieties Progress, Vazhod, Victoria, Predel, Deana, Zvezditsa and Elbrus to the nitrogen fertilization in rates 0, 60, 120, 180 kg $N.ha^{-1}$ was studied. The experimental design consisted of split-plots method in four replications. The harvested size of the plots was 10 m^2.

The second experiment investigated the reaction of durum wheat variety Progress to independent phosphorus and combined nitrogen-phosphorus fertilization, including seven levels of fertilization: N_0P_0; P_{80}; P_{120}; P_{160}; $N_{120}P_{80}$; $N_{120}P_{120}$; $N_{120}P_{160}$. The trial was carried out in four replications. The fertilization of precursor cotton was the same as that of durum wheat.

Nitrogen fertilization in the form of ammonium nitrate was applied broadcast pre-sowing (1/3 of the rate) and the rest 2/3 - as early spring top dressing at the end of the wheat tillering stage - beginning to stem elongation (Feekes stage 4-5). The phosphorus fertilization was done before sowing in the form of triple superphosphate. The results were compared to a non-fertilized variant. The soil type of the experimental field was *Pellic Vertisols* (FAO).

Precipitation and temperatures during the growing period characterized the harvest 2011 and 2013 as favourable for the development of durum wheat and obtaining good yield, and 2012 as less favourable.

A technology for durum wheat developed at the FCI - Chirpan was used to determine the economic efficiency of different fertilization rates. Materials and products were valued at market prices of 2014. The price of ammonium nitrate and triple superphosphate was 600 and 900 $BGN.t^{-1}$, respectively; the grain price was 350 $BGN.t^{-1}$ (1 € = 1.9558 BGN lv.).

The following economic indicators for estimating the efficiency of fertilization were analyzed: total output (TO = Y x PrG) in $BGN.ha^{-1}$, net profit (NP = TO - PrG) in $BGN.ha^{-1}$, cost (C = TC/Y) in $BGN.t^{-1}$, rate of profitability (HP = (NP/TC).100) in %, where: Y is the grain yield ($t.ha^{-1}$), PrG is the grain price ($BGN.t^{-1}$), TC – total production costs ($BGN.ha^{-1}$).

Two ways to measure economic efficiency (based on additional yield and by determining the influence of fertilization

on production efficiency as a whole) can be applied. In this study we applied the second approach (Tonev et al., 2004; Panayotova and Genov, 2005). Excel program was used to update production costs according to the analyzed agronomic factors.

Results and discussion

Optimizing the mineral nutrition is one of the most important conventions for a favorable growth and production of the plants, for ensuring their need of nutrient elements, for increasing the soil richness (Schilling et al., 2003). Often the high fertilization rates lead to obtaining negative results and lead to increase of the economic losses in production. The fertilization of durum wheat grown after cotton should be complied with the fact that a significant part of the nitrogen used for the cotton is not utilized by it, and remains in the soil. The two cultures are successfully developed in crop-rotation and when fertilized, they actively participate in the nutrient utilization (Panayotova, 1998).

The differences in grain yields between the tested nitrogen levels during the period 2011-2013 are significant (Table 1). As a result of natural soil fertility (without fertilization) varieties form an average grain yield of 3.77 t.ha^{-1}. The independent N fertilization, which is often applied in practice, indicates an increase in the average yield to N_{120}, exceeding the unfertilized check with 1.03 t.ha^{-1} or 27%. The high nitrogen rate N_{180} reduces the yield by 4% compared to the moderate N_{120} level, but the difference is not mathematically proven.

The meteorologically favorable 2011 is characterized by the highest grain yield at a nitrogen rate of 120 kg N.ha^{-1} – 5.63 t.ha^{-1}, proven exceed the other fertilization levels. The difference between the yield from the unfertilized field and the fertilizer plants with 60, 120 and 180 kg N.ha^{-1} is 14, 37 and 26% respectively, in favor of nitrogen fertilization.

In 2012 the grain yield increases with increasing of nitrogen rate. The lowest yield was reported at the control – 3.09 t.ha^{-1}, and the difference with the low N_{60} rate was 9% and unproven. The highest yield was obtained at the high rate N_{180} – 4.27 t.ha^{-1}, exceeding the moderate N_{120} level by 0.43 t.ha^{-1}, but the difference in yield between these two fertilizing rates was not proven.

The grain yields achieved in 2013 are in a narrower range, with a proven difference only between the lowest yield obtained in a control - 4.09 t.ha^{-1} and the highest at N_{120} - 4.93 t.ha^{-1}, which is 21% more. Low (N_{60}) and high (N_{180}) nitrogen fertilizing rates tend to increase the grain yield relative to the unfertilized control by 10 and 8%. The yield at lower rate exceeds by 0.10 t.ha^{-1} obtained yield at the high nitrogen rate, but there is no proven difference.

The relative average grain yield at fertilization levels N_{60}, N_{120} and N_{180} increases by 11, 27 and 23%, respectively, compared to the untreated control. This indicates that nitrogen fertilization with 120 kg.ha^{-1} is the limit above which the yield decreases.

The difference in the realized average grain yield during the period 2011-2013 between studied varieties of durum wheat is not proven mathematically.

The variety Progres (standard) is characterized by the lowest yield – 3.99 t.ha^{-1}, and the new varieties Elbrus and Deana form the highest yield of wheat grain, respectively 4.72 t.ha^{-1} and 4.47 t.ha^{-1}. Average for the period at the four N tested levels, these two varieties exceed the standard variety Progres by 18% and 12%, respectively, and the improved relative yield of the variety Predel is the lowest – 4% over the standard. In 2011 and 2012 there was no significant reaction of cultivars and the differences were unproven. In those two years the highest grain yield was realized in the variety Elbrus (5.25 t.ha^{-1} and 4.11 t.ha^{-1}) and the lowest - in the variety Zvezditsa (4.64 t.ha^{-1}) in 2011 and at Predel (3.28 t.ha^{-1}) in 2012. The varieties show proven differences only in 2013, as the highest yielding variety Elbrus (4.79 t.ha^{-1}) exceeds the Progress (3.84 t.ha^{-1}) by 25%.

Average for the period at the interaction of the nitrogen fertilization by variety, the yield of variety Progress without fertilization is the lowest – 3.26 t.ha^{-1}. With the highest average values for grain yield differs the variety Elbrus x N_{120} – 5.21 t.ha^{-1} and Elbrus x N_{180} – 4.99 t.ha^{-1}, which exceed by 60 and 53% unfertilized Progress and exceed all other interactions. During the period, the highest yield is the N_{120} x Victoria and $N_{60\text{-}120}$ x Elbrus in 2013 - by 88-96% above the standard, and the lowest for the Vazhod and Predel at N_0 in 2012 - respectively 9 and 4% less than Progress without fertilization.

Regarding the interaction of the N rate by variety, the favorable 2011 is characterized with the highest grain yield - an average 4.91 t.ha^{-1}, which exceeds the average of 2012 and 2013 by 35 and 10%, respectively, i.e. the conditions have a significant influence.

The yield, although reflecting soil, climate, organizational, economic, social and other factors of production, does not give an independent answer to economic efficiency. The results show that the maximum yield and efficiency do not correspond. The comparison of obtained results with the costs for production gives the answer to these questions.

The total output showed the same trends as the resulting average yields. The increase per unit area was highest after application of fertilizing rate N_{120} - 33.7-59.8% more than the untreated control, while at fertilization with N_{180} the increase was with 27.3-53.1%. The high value was from the Elbrus variety (Table 1).

Table 1
Basic economic parameters for grain yield of durum wheat varieties at different nitrogen rates, average for 2011-2013

N x Variety	Grain yield, $t.ha^{-1}$	Total output, $BGN.ha^{-1}$	Total costs, $BGN.ha^{-1}$	Net profit, $BGN.ha^{-1}$	Cost, $BGN.t^{-1}$	Rate of profitability, %
N_0 x Progress	3.26	1141.0	527.2	613.8	162	116.43
N_0 x Vazhod	3.55	1242.5	527.2	715.2	149	135.68
N_0 x Victoria	3.81	1333.5	527.2	806.3	138	152.94
N_0 x Predel	3.71	1298.5	527.2	771.3	142	146.30
N_0 x Deana	3.96	1386.0	527.2	858.8	133	162.90
N_0 x Zvezditsa	3.82	1337.0	527.2	809.8	138	153.61
N_0 x Elbrus	4.26	1491.0	527.2	963.8	124	182.82
N_{60} x Progress	3.61	1263.5	635.2	628.3	176	98.91
N_{60} x Vazhod	4.15	1452.5	635.2	817.3	153	128.67
N_{60}x Victoria	4.17	1459.5	635.2	824.3	152	129.77
N_{60} x Predel	4.05	1417.5	635.2	782.3	157	123.16
N_{60} x Deana	4.45	1557.5	635.2	922.3	143	145.20
N_{60} x Zvezditsa	4.15	1452.5	635.2	817.3	153	128.67
N_{60} x Elbrus	4.72	1652.0	635.2	1016.8	135	160.08
N_{120} x Progress	4.36	1526.0	737.2	788.8	169	107.00
N_{120} x Vazhod	4.69	1641.5	737.2	904.3	157	122.67
N_{120}x Victoria	4.88	1708.0	737.2	970.8	151	131.69
N_{120} x Predel	4.75	1662.5	737.2	925.3	155	125.52
N_{120} x Deana	4.88	1708.0	737.2	970.8	151	131.69
N_{120} x Zvezditsa	4.83	1690.5	737.2	953.3	153	129.31
N_{120} x Elbrus	5.21	1823.5	737.2	1086.3	141	147.36
N_{180} x Progress	4.15	1452.5	845.2	607.3	204	71.85
N_{180} x Vazhod	4.70	1645.0	845.2	799.8	180	94.63
N_{180} x Victoria	4.76	1666.0	845.2	820.8	178	97.11
N_{180} x Predel	4.55	1592.5	845.2	747.3	186	88.42
N_{180} x Deana	4.80	1680.0	845.2	834.8	176	98.77
N_{180} x Zvezditsa	4.40	1540.0	845.2	694.8	192	82.21
N_{180} x Elbrus	4.99	1746.5	845.2	901.3	169	106.64
Average	4.34	1520.25	686.2	834.05	157.75	125.00

Cost without fertilization was 527.2 $BGN.ha^{-1}$ and increased to 845.2 $BGN.ha^{-1}$ after fertilization with high nitrogen rate. Production costs included material costs, costs for mechanized and transport services. The volume of manual labor in BGN per unit area was negligible, both for control and for all levels of fertilization due to the high level of mechanized cultivation of wheat.

The net profit was highest at the rate of N_{120} - average for the tested seven cultivars was 942.8 $BGN.ha^{-1}$, which was 19.14% over the unfertilized. The maximum value was for Elbrus - 1086.3 $BGN.ha^{-1}$. The proceeds were lowest at a high rate of 180 kg $N.ha^{-1}$ for varieties Progress, Predel, Deana, Zvezditsa and Elbrus, and for the other two varieties Vazhod and Victoria - at variants without fertilization (Figure 1).

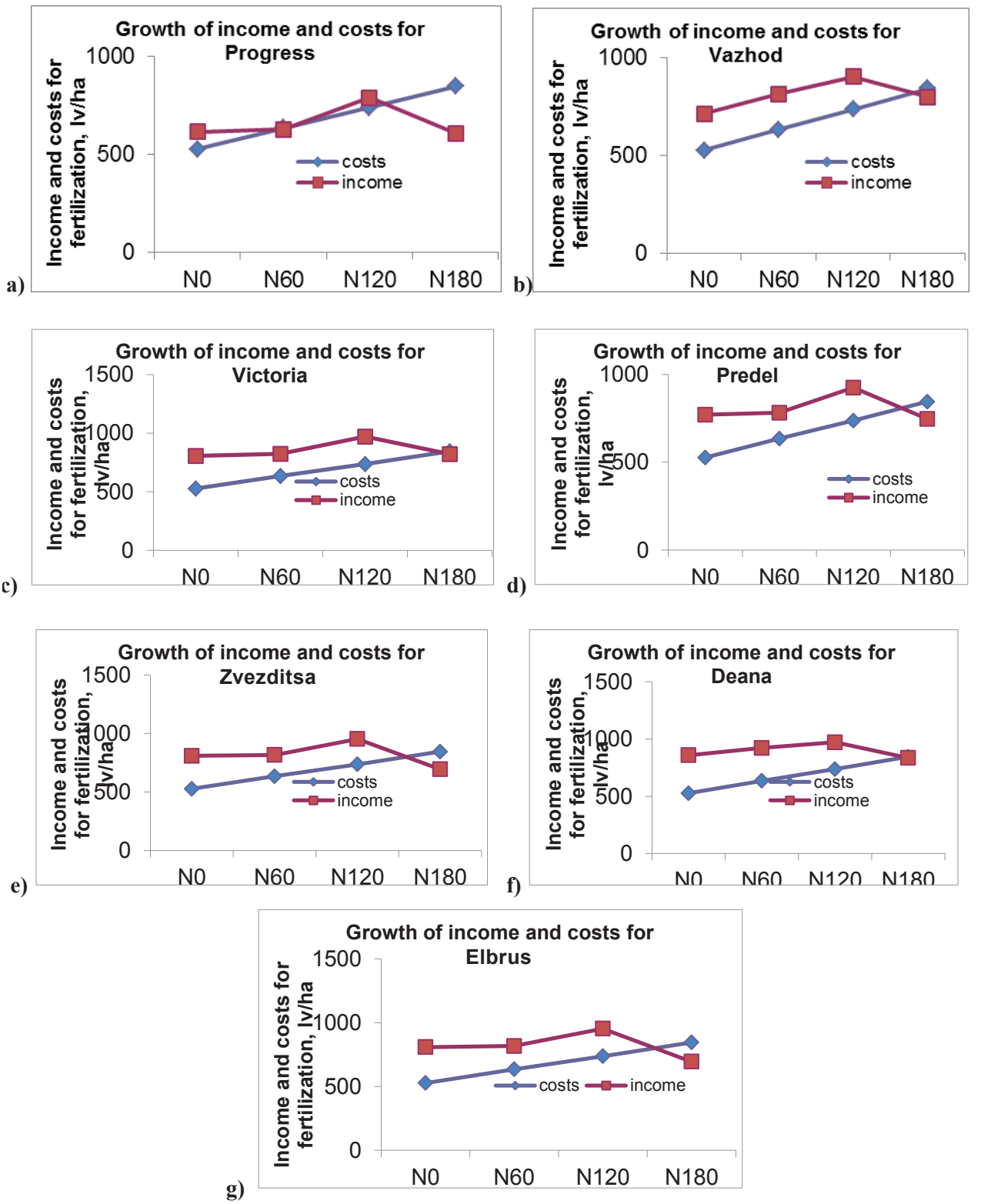

Figure 1. Growth of income and cost for durum wheat cultivars as affected by N fertilization

a) Progress; b) Vazhod: c) Victoria; d) Predel; e) Zvezditsa; f) Deana; g) Elbrus.

The cost per unit of production for different amounts of fertilizers was very well differentiated: 140.8 BGN.t^{-1} without fertilization; increased to 152.7 BGN.t^{-1} for fertilization with N_{60}; 153.8 BGN.t^{-1} for N_{120} and 183.6 BGN.t^{-1} at N_{180}. The Elbrus variety showed the best values at the different nitrogen levels, followed by Deana.

The analysis of return on investment, expressed through rate of profitability in the present study, found that without use of nitrogen fertilization during the three-year period, production was very profitable due to the high yields, especially in 2011. At fertilization with 60, 120 and 180 kg N.ha^{-1}, profitability was 114.92%, 127.89% and 89.52%, respectively. The economic results showed that fertilization with N_{180} resulted in an insufficient change of production profitability (71.85-106.64%) and such agro-technical activity was not recommended.

Petrova (1984) also recommends to apply in practice nitrogen and phosphorus fertilization with 120-140 N kg.ha^{-1} and 100-120 kg P_2O_5.ha^{-1} in spite of the lower norm of profitability in comparison to the lower fertilizer norms of nitrogen (60 N kg.ha^{-1}) and phosphorus (50 kg P_2O_5.ha^{-1}). The next increase of the nitrogen norm (> 140 N kg.ha^{-1}) and of the phosphorus norm (above 120 kg P_2O_5.ha^{-1}) is not justifiable because the total production is not increasing while the expenses are getting significantly greater.

The independent and combined effect of a number of agronomy factors (soil tillage, sowing date, sowing rate, fertilization, varietal specificity, etc.) on the economic efficiency of wheat production was also established by Kassimov (1989). The investigation has found out that fertilization can contribute to increasing the net income with up to 20.4 BGN.ha^{-1}.

During the period 2011-2013, the variants with tested P_{80}, P_{120} and P_{160} fertilization (without nitrogen) have a higher average grain yield respectively with 12, 25 and 14%, compared to the untreated control, but the increase in yield at these fertilization levels is insignificant (Table 2). The results show that the high applied phosphorus rate reduces grain yield. The average yields at combining phosphorous fertilization with N_{120} are proven higher regardless of the phosphorus rate. The grain yield was increased by 116-129% compared to the control.

At combined NP fertilization, the highest values for grain yield in the period were achieved for $N_{120}P_{120}$ – 4.32 t.ha^{-1}, but the differences between the tested rates were not proven. Average for all fertilizing rates, the grain yield is highest in 2012 – 3.31 t.ha^{-1}, followed by 2011 – 3.10 t.ha^{-1}, and the lowest yield is in 2013 – 2.61 t.ha^{-1}, respectively 19 and 27 % lower productivity than the previous two years.

Lalev et al. (2000) also indicate that durum wheat is highly responsive to mineral fertilization and economically effective is fertilization with $N_{120}P_{60}$. The yield is 80.6% higher than unfertilized wheat, the formed net income increases by 139-161% and the cost per unit of production decreases by 14-19%.

The economic analysis of different fertilization systems of the Progress variety in the 3-year period showed low efficiency of combined nitrogen-phosphorous fertilization with values of profitability from 54.40% at $N_{120}P_{120}$ to 61.69 % at $N_{120}P_{80}$ (Table 2). The cost of 1 ton of production was lowest after fertilization with $N_{120}P_{80}$. The profitability of the production at only phosphorous fertilization was extremely low, significantly below the control level, with values ranging from -10.65% at P_{160} to 8.57% at P_{80}. Independent phosphorous fertilization was ineffective and economically unjustified.

Conclusions

The optimal level of fertilization for high yield was N_{120}. The economic analysis indicated that the profitability of durum wheat production is good after fertilization with nitrogen

Table 2
Economical results for durum wheat variety Progress as affected by the fertilizing system, average for 2011-2013

System of fertilization	Grain yield, t.ha^{-1}	Total output, BGN.ha^{-1}	Total costs, BGN.ha^{-1}	Net profit, BGN.ha^{-1}	Cost, BGN.t^{-1}	Rate of profitability, %
N_0P_0	1.89	661.5	527.2	134.3	279	25.48
N_0P_{80}	2.11	738.5	680.2	58.3	322	8.57
N_0P_{120}	2.35	822.5	761.2	61.3	324	8.05
N_0P_{160}	2.15	752.5	842.2	- 89.7	392	-10.65
$N_{120}P_{80}$	4.15	1452.5	898.3	554.2	216	61.69
$N_{120}P_{120}$	4.32	1512.0	979.3	532.7	230	54.40
$N_{120}P_{160}$	4.08	1428.0	898.3	529.7	220	58.97

levels of up to N_{120}. The application of 180 kg $N.ha^{-1}$ significantly decreased the profitability of production and was not an efficient agro-technological activity. The variety Elbrus had the best economic values at the various nitrogen levels, followed by Deana. The Progress variety demonstrated low efficiency of combined nitrogen-phosphorous fertilization under long-term fertilizing conditions. The profitability of the production after fertilization with phosphorous only was extremely low. Independent phosphorous fertilization was ineffective and economically unjustified.

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