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Agronomic Effect and Economic Efficiency of Long-Term Mineral Fertilization with Optimal Norm of Nitrogen Fertilization with Different PK Norms and Ratios on Wheat Productivity

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Abstract

A stationary field trial (Haplic Chernozems) initiated in 1967 with a two-field crop rotation of wheat and maize investigated the economic efficiency of continuous nitrogen, phosphorus and potassium fertilization with different norms and ratios on wheat production. Variety Dragana was tested in this trial; it was grown with combining 4 nitrogen and phosphorus norms – 0, 60, 120 and 180 kg ha-1 and three potassium norms – 0, 60 and 120 kg ha-1. The investigation encompassed the period 2010– 2013. The meteorological conditions during the years of wheat growing had a strong effect on the economic efficiency of mineral fertilization with macro elements, regardless of the norms and ratios between them. During years unfavorable for wheat production there was a market positive role of continuous NPK fertilization at ratios 1:1:0; 1:1:1 and 1:1.5:1. Total income was directly dependent on the obtained agronomic effect and the realization price of the ready produce. According to the type of the fertilization variant during the years of investigation, it varied from 1441.4 BGN ha^{-1} (2011) to 3620.8 BGN ha^{-1} (2013). As a result from the long application of mineral fertilizers at different norms and ratios between the macro elements based on the production potential of variety Dragana for the period 2010 – 20013 it was established that under the conditions of slightly leached chernozem fertilization with N12P6K6 was economically most advisable. It ensured higher mean profit even in comparison to independent application of nitrogen (120 kg ha^{-1}). During all years of investigation a return of 1 BGN of direct expenses for buying of fertilizers was established.

Averaged for the period these expenses were highest for the combinations between the macro elements from the nitrogen norm 120 kg/ha and reached a mean value of 3.43 BGN income per 1 BGN investment for fertilizers in systematic fertilization with N120P60K60.

Averaged for the period, the economic analysis was in favor of the independent nitrogen fertilization regardless of the size of the fertilization norm and the noticed tendencies. In this case, however, we are considering the economic evaluation of an open and highly dynamic system which includes two biological components: soil and plant, which are strongly affected by the meteorological conditions and market price of the produce, without accounting for grain quality. When considering the negative effect of independent nitrogen fertilization on soil fertility, the economically more profitable application of independent nitrogen fertilization should give way to the most suitable norms and ratios between the main macro elements. Averaged for the period, regardless of the market character of buying prices even at the high fertilization norms, high rentability was registered - from 9.13 % (N120P180K120) to 68.01 % (N120P60K60).

Key words: Wheat, Fertilization with different NPK norms and ratios, Economic analysis

Introduction

The agronomic efficiency and economic efficacy of mineral fertilization depends on the optimization of the fertilizer norms and the ratios between the nutrients, the soil fertility, the meteorological conditions, the level of the applied technologies for growing of the crops, etc. The evaluation of these indices is possible only in stationary precise agro technological trials. In her long-term investigations on two wheat cultivars, Bezostaya 1 and Sadovo 1, Petrova (1984) recommends to apply in practice nitrogen and phosphorus fertilization with 120-140 N kg ha-1 and 100-120 kg P2O5 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 P2O5 ha-1). The next increase

of the nitrogen norm (above 140 N kg ha-1) and of the phosphorus norm (above 120 kg P2O5 ha-1) is not justifiable because the total produce is not increasing while the expenses are getting significantly greater.

Under conditions of leached chernozem, the independent and combines effect of a number of agronomy factors (soil tillage, sowing date, sowing norm, fertilization, varietal specificity, etc.) on the economic efficiency of wheat production was also established (Kassimov, 1989). The investigation has found out that fertilization can contribute to increase of the net income with up to 20.4 BGN ha-1. 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.

Undoubtedly, 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 a certain fertilization system (Özberk et al., 2006; Nankov, 2007; Hristova, 2011). 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. Such fertilization can in the course of time expand and intensify its negative effects on the environment, decreasing the soil fertility of the arable lands, generally speaking.

Tonev et al. (2004), working on the problem of the economic efficiency of mineral fertilization of wheat grown after leguminous predecessors, found out that the coefficient of the percent of the nitrogen fertilization can vary within a wide range – from 0.083 to 0.115. The authors also pointed out that regardless of the previous crop and previous nitrogen norm, the direct fertilization of wheat with 0-160 kg N ha-1 increased the expenses for growing the crop with averagely 20 %.

This investigation is aimed at determining the agronomic effect and the economic efficiency of the long-term introduction of the nitrogen norm of 120 kg ha-1, which is optimal for the region of South Dobrudzha, in combination with various norms and ratios of phosphorus and potassium, on the production of wheat cultivar Dragana.

Materials and Methods

Twenty-seven bread wheat cultivars were investigated at four locations in Bulgaria during 2006 – 2008. Grain yield and all productivity elements were studied and analyzed. The methods and approaches were described in the first communication (Tsenov et al., 2013). In this study the data are interpreted with a view of the response of each specific cultivar according to the above traits, as well as its plasticity and stability against the background of the entire investigated group of cultivars. For a more objective approach, when analyzing the effect of the individual traits on grain yield, to each specific cultivar the method of Smiryaev et al., (1992) was applied, modified by Georgiev et al., (2013). It consists in calculating the complex value for each genotype (complex assessment value) which allows determining the place (rank) of each genotype in the investigated group, which is our ultimate aim. The approach involved the calculation of the relative value of the genotype according to the mean value of the group for each individual trait; then these values were summed up to form an assessment that allowed evaluating the genotype against the background of the other genotypes. To make sure this approach was appropriate, we corrected in our database the values of the complex evaluation (CE) by traits with the actual correlations each of them has with grain yield. Thus the corrected complex assessment value was obtained. The correctness of the approach was checked by calculating the correlations between the two values of CE and the values of the traits themselves for the entire group of cultivars. The cultivars' plasticity and stability against the background of the investigated locations was presented by the computer program GGE biplot 6.5 (Yan et al., 2000).

Results

The trial was initiated in 1967 by Prof. Maria Petrova in the experimental field of Dobrudzha Agricultural Institute (Haplic Chernozems, WRBSR, Rome, 2006) by the net square method using the full scheme of the design (4 x 4 x 3 = 48) in five replications, the size of the trial plot being 63 m2, and of the harvest plot - 25 m2. Four nitrogen and phosphorus norms were tested - 0, 60, 120 and 180 kg/ha, as well as three potassium norms - 0, 60 и 120 kg ha-1. The trial involved an additional variant - N180P180K180 kg ha-1; thus the number of the tested variants of independent and combined mineral fertilization was 49.

The mineral fertilization was done with conventional fertilizer products – ammonium nitrate, triple super phosphate and potassium chloride. The phosphorus and potassium fertilizers

were introduced after harvesting of maize. Soil tillage involved 3-5 applications of disking depending on the year conditions with the aim of developing maximum favorable conditions for performance of sowing. The sowing norm was determined on the basis of 550 germinating seeds/m2. The nitrogen fertilizer was introduced at the beginning of permanent spring vegetation with the above norms.

For this investigation, only fertilizer variants were selected which included the norm 120 kg ha-1 of the three main macro elements applied independently, as well as selected combinations of this nitrogen norm with phosphorus and potassium, which were significant for the practice and were of purely scientific interest (Table 1).

Table1. Selected fertilizer norms and ratios between the main macro elements

Fertilization norms, kg/da	Ratios N:P:K	Fertilization norms, kg/ha	Ratios N:P:K	Fertilization norms, kg/ha	Ratios N:P:K
$N_0P_0K_0$	0:0:0	$N_{120}P_{60}K_0$	1:0,5:0	$N_{120}P_{60}K_{60}$	1:0,5:0,5
$N_{120}P_0K_0$	1:0:0	$N_{120}P_{120}K_0$	1:1:0	$N_{120}P_{60}K_{120}$	1:0,5:1
$N_0P_{120}K_0$	0:1:0	$N_{120}P_{180}K_0$	1:1,5:0	$N_{120}P_{120}K_{60}$	1:1:0,5
$N_0P_0K_{120}$	0:0:1	$N_{120}P_0K_{60}$	1:0:0,5	$N_{120}P_{120}K_{120}$	1:1:1
$N_0P_{120}K_{120}$	0:1:1	$N_{120}P_0K_{120}$	1:0:1	$N_{120}P_{180}K_{60}$	1:1,5:0,5
				$N_{120}P_{180}K_{120}$	1:1,5:1

The long-term investigations carried out in this trial by Petrova (1984), Gospodinov (1981), Kirchev and Nankova (1999) revealed that the nitrogen norm of 120 kg N/ha was most justifiable from an agronomic point of view, i.e. from the point of view of the quantity and quality of the produced grain. The calculation of the ratios between the macro elements in the Table 2 was based on step 120.

Harvesting of wheat was done with plot micro combine. Yield was equalized to 13 % moisture.

Mathematical processing of the obtained results on the productivity of the cultivars was done with software Excel и SPSS 16.

During the years of conducting the trial, the following cultivars were sown: Bezostaya 1 (1967-1970), Avrora (1971-1973), Sadovo 1 (1974-1980), Vratsa (1981-1982); Pliska (1983-2000); Enola (2001-2009) and Dragana – from 2010 till now.

The economic efficiency of wheat production was realized through determining of the indices: direct expenses for production, expenses for fertilizers and their introduction, total income, revenue and profitability norm. For this purpose, a technological card was elaborated for each of the tested fertilization variants. Prices provided from the accounting department of DAI – General Toshevo were used, which were valid for each of the investigated years.

The period of investigation encompassed 4 years: from 2010 to 2013. The years in which the investigation was carried out with regard to the sums and the distribution of vegetation rainfalls and the dynamics of temperatures differed both from one another and from the long-term ones. The main elements from the meteorological characteristics of the investigated period had significant deviations from the mean values of the period 1953 – 2010 (Figure 1).

The precipitation sums during the growing season of wheat in 2010 and 1012 were above the mean long-term values with 73.3% and 15.6%. For harvest years 2011 and 2013 respective amounts of rainfalls with 3.5 % and 11.9 % lower were registered (Figure 1). The distribution of rainfalls by every one of the months for the period of autumn and winter vegetation in harvest years 2010, 2012 and 2013 was above the mean value of the 60-year period with 80.2 %, 22.5 % и 8.1% In 2011 the sum of autumn and winter rainfalls was with 10.6 % below the mean long-term value.

At the beginning of permanent spring vegetation, year 2010 (April) was with lower amount of rainfalls in comparison to the rest of the years, but the extremely high sum of autumn-and-winter rainfalls in combination with the rainfalls in May, June and July made this year the most humid during the entire 1953-2013 period. The precipitation sum for the growing season of wheat in harvest year 2010 was 759.2 mm; with this sum it significantly exceeded the mean long-term value. The amount of vegetation rainfalls in harvest year 2013 was lower in comparison to the rest of the years of investigation, but they were comparatively more evenly distributed (Figure 2).

During the 4-year period of investigation, only year 2011 had mean annual temperature approximating the mean 60-year value (10.6o C). The rest of the years were characterized with

mean temperatures from 11.6o C to 12.0o C (Figure 3). In this situation the mean temperatures during the growing season of wheat varied from 8.5o C (2011) to 10.4o C (2013), the level of the mean long tem value being 8.9o C. The periods of early spring vegetation, of intensive dry matter accumulation and especially of grain filling occurred under higher temperatures in 2012 and 2013.

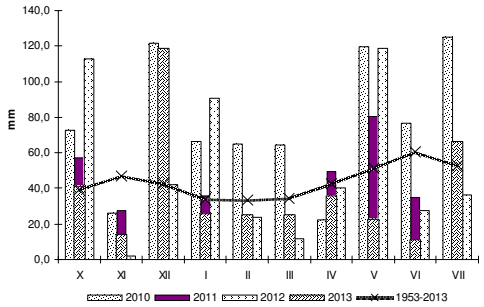

Figure1. Mean monthly rainfalls by years of investigation

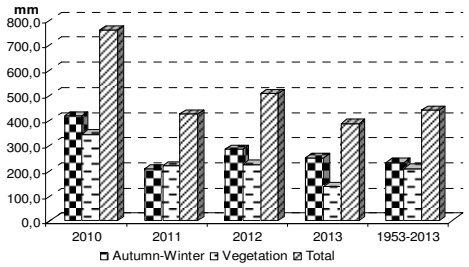

Figure2. Sum of rainfalls during autumn-and-winter period, spring vegetation and total for the growing season of wheat

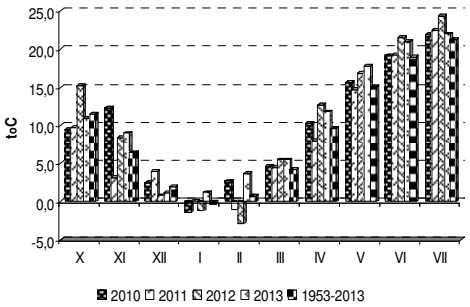

Figure3. Mean monthly temperatures by years of investigation

Results

The mathematical analysis of the obtained results on the productivity of the cultivar and the agronomic effect of mineral fertilization showed maximum levels of significance for the tested fertilization variants by years of investigation (Table 2). Averaged for the investigated period, the two factors, year and fertilizer variant, as well as their interaction, also had high level of significance.

The strength of the independent effect of the two factors on wheat productivity was very well and almost proportionally expressed (Figure 4). The tendency toward some preponderance of the effect of the meteorological factor of the investigated years over the effect of mineral fertilization was confirmed. In our case this preponderance was with 1.37 % in absolute values. The combined interaction of the two factors was also strongly expressed and amounted to 14.43 %.

Table2. Analysis of variances of the obtained yields and agronomical effect from mineral fertilization

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
	Yields				
2010	696752,021	15	46450,135	8,808	,000
2011	1051191,082	15	70079,405	16,783	,000
2012	1669588,958	15	111305,931	66,671	,000
2013	8703401,444	15	580226,763	48,315	,000
Years (2010-2013) (1)	24075523,141	3	8025174,380	1387,961	,000
Fertilizer variants (2010-2013) (2)	9026256,458	15	601750,431	104,073	,000
1 X 2	3094677,048	45	68770,601	11,894	,000
	Agronomical affect				
2010	696752,021	15	46450,135	12,599	,000
2011	1051192,549	15	70079,503	26,804	,000
2012	1669588,958	15	111305,931	141,816	,000
2013	8703401,444	15	580226,763	109,413	,000
Years 2010-2013	9320888,374	3	3106962,791	1003,130	,000
Fertilizer variants (2010-2013)	9026258,501	15	601750,567	194,284	,000
1 X 2	3094676,471	45	68770,588	22,204	,000

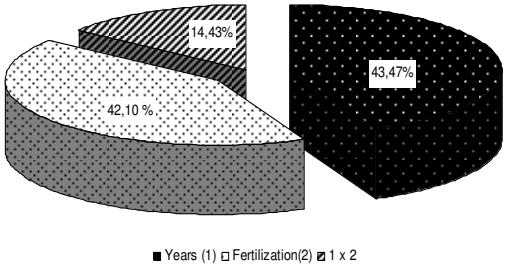

Figure4. Strength of the factors' effect

The obtained yields over the years of investigation using different combinations of the nitrogen norm of 120 kg N ha-1 at different norms and ratios with phosphorus and potassium varied significantly according to the type of fertilizer combination (Table 3). The first thing worth mentioning is the high productivity of wheat in the check variant, which was due, on the one hand, to the high natural fertility of the slightly leached chernozem soil, and on the other – to the strict observance of all agronomy practices of growing the crop. During the 46-year history of the trial, only in harvest year 2003 the yield from the check variant was below 1000 kg ha-1 (Nankova, 2007).

The independent nitrogen fertilization with 120 kg N ha-1 increased yields with 1.5 to 2.7 times, while the independent phosphorus and potassium fertilization lead to slight increase according to the check. All three nitrogen-phosphorus combinations at ratio N:P = 1:0.5, 1:1 and 1:1.5 had over the years of the investigation effect on the size of yield; with the exception of year 2010 better results were obtained at ratio N:P=1:1 from 120 kg ha-1 for the two elements. By the size of yield, the nitrogen-potassium combinations conceded to the nitrogen-phosphorus combinations; in years 2011, 2012 and 2013 the mineral fertilization at ratio N:P:K = 1:0:1 contributed to higher yields in comparison to the ratio N:P:K=1:0:0.5

Table3. Yields by years of investigation according to the norms of mineral fertilization, kg ha^{-1}

№	Variants	2010	2011	2012	2013
1	$N_0P_0K_0$	2346 a	2369 a	2139 a	5013 a
2	$N_{120}P_0K_0$	4002 b	4332 cd	5356 b	12983 bc
3	$N_0P_{120}K_0$	2457 a	2883 a	2115 a	5376 a
4	$N_0P_0K_{120}$	2347 a	2543 a	2264 a	5280 a
5	$N_0P_{120}K_{120}$	2421 a	2990 ab	2499 a	5637 a
6	$N_{120}P_{60}K_0$	4782 bcd	5497 efgh	6096 c	14003 cde
7	$N_{120}P_{120}K_0$	4344 bcd	5679 fgh	6147 c	13486 bcd
8	$N_{120}P_{180}K_0$	5203 d	4831 de	5298 b	13440 bcd
9	$N_{120}P_0K_0$	4382 bcd	3737 bc	5131 b	12276 b
10	$N_{120}P_0K_{120}$	4105 bc	5464 efgh	5951 c	13228 bc
11	$N_{120}P_{60}K_{60}$	5103 d	5341 efg	6239 c	14139 cde
12	$N_{120}P_{60}K_{120}$	4891 bcd	5174 ef	5992 c	13888 cde
13	$N_{120}P_{120}K_{60}$	4799 bcd	5731 fgh	6225 c	13789 cde
14	$N_{120}P_{120}K_{120}$	5072 cd	5511 efgh	5899 c	14937 e
15	$N_{120}P_{180}K_{60}$	4683 bcd	6282 h	6236 c	13905 cde
16	$N_{120}P_{180}K_{120}$	4822 bcd	6074 gh	6218 c	14668 de

The independent nitrogen fertilization with 120 kg N ha-1 increased yields with 1.5 to 2.7 times, while the independent phosphorus and potassium fertilization lead to slight increase according to the check. All three nitrogen-phosphorus combinations at ratio N:P = 1:0.5, 1:1 and 1:1.5 had over the years of the investigation effect on the size of yield; with the exception of year 2010 better results were obtained at ratio N:P=1:1 from 120 kg ha-1 for the two elements. By the size of yield, the nitrogen-potassium combinations conceded to the nitrogen-phosphorus combinations; in years 2011, 2012 and 2013 the mineral fertilization at ratio N:P:K = 1:0:1 contributed to higher yields in comparison to the ratio N:P:K=1:0:0.5

The combination of the three macro elements also had positive effect on wheat productivity, leading during the individual years to various exceeding of yield over the independent fertilization with 120 kg N ha-1. Within each year, the Waller-Duncan test clearly differentiated the yields and showed the differences, the similarities and the sameness between the tested fertilizer variants.

The lowest differentiation in the values of obtained yields was found in 2012 when 9 of the tested 16 fertilizer combinations fell within the group of highest order "c" where the variation was from 5899 kg ha-1 (N120P120K120) to 6236 kg ha-1 (N120P180K60). Highest differentiation between the yields was determined in harvest year 2011 (8 groups) with highest yield of 6282 kg ha-1 at N120P180K60. Harvest years 2010, 2011 and 2012 were characterized with comparatively similar mean yields - 4110 kg ha-1, 4420 kg ha-1 and 4990 kg ha-1, respectively. In harvest year 2013 the mean yield from the tested fertilizer variants was 11629 kg ha-1. The exceptional combination of a complex of meteorological elements and agronomy factors, including the cultivar as such, were at the basis of the highest till the present moment yields since the initiation of the trial in 1967.

The mean yields during the period 2010 – 2013 revealed the exceptional role of the combinations between the nutrients for the higher productivity of the cultivar (Figure 5). As a result from the independent fertilization this productivity increased with 121.80 % in comparison to the check variant. Under independent phosphorus fertilization this increase was with 20.33 %, and under independent potassium fertilization – only with 7.69 %. The combination between these two macro elements increased productivity with 20.44 % according to the check. All fertilizer combinations involving nitrogen, by pairs, and at the full combination between the three macro elements, increased the productivity of cultivar Dragana up to 2.65 times according to the check. Thus the highest increase was achieved in three variants: N120P120K0 – with 155.69 %; N120P120K120–with 163.31 % and N120P180K120 – with 164. 91%.

In these variants the highest increase according to the mean productivity under the independent nitrogen fertilization was registered, with 15.27 %, 18.71 % and 19.43 %, respectively. The mean results clearly showed the role of involving potassium from the norm 120 kg K2O ha-1 which was mainly due to the obtained results in 2013. Among all fertilizer combinations, only the variant N120P60K0 had yield 98.11% from the yield obtained under independent nitrogen fertilization.

The agronomy effect from the independent nitrogen fertilization varied over the years from 1656 kg ha-1 (2010) to 7970 kg ha-1 (2013). Lowest values of this index were obtained under independent phosphorus and potassium fertilization (Table 4). Even in 2012 the yield obtained from the independent phosphorus fertilization was a little below the yield from the check variant.

The different fertilizer variants lead during the individual years to maximum values of the agronomy effect: 2010 – N120P180K0 – 2857 kg ha-1; 2011 - N120P180K60 – 3913 kg ha-1; 2012 - N120P60K60 – 4100 kg ha-1 and 2013 – N120P120K120 – 9924 kg ha-1.

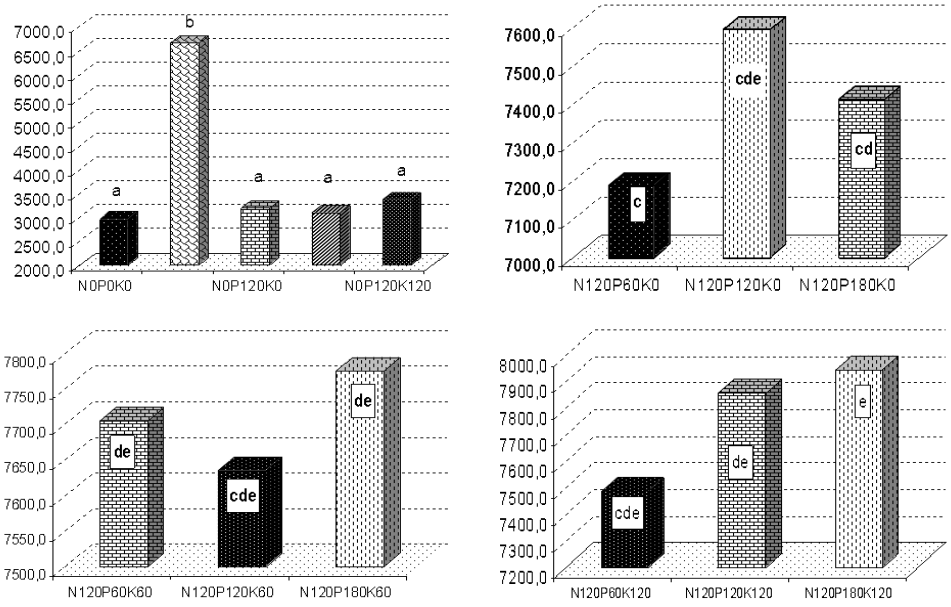

Figure5. Mean yields from cultivar Dragana during 2010-2013 depending on mineral fertilization with N120 under different phosphorus and potassium combinations, kg ha-1

Table4. Agronomy effect by year depending on the mineral fertilization norms, kg ha^{-1} (Waller-Duncan N=4)

№	Variants	2010	2011	2012	2013
1	$N_0P_0K_0$	,0000 a	,0000 a	,0000 a	,0000 a
2	$N_{120}P_0K_0$	1656 b	1963 bc	3217 c	7970 bc
3	$N_0P_{120}K_0$	111 a	514 a	-23 a	363 a
4	$N_0P_0K_{120}$	0,818 a	174 a	125 ab	274 a
5	$N_0P_{120}K_{120}$	75 a	621 a	360 b	624 a
6	$N_{120}P_{60}K_0$	2436 bcde	3128 ef	3957 d	8990 de
7	$N_{120}P_{120}K_0$	1997 bcd	3310 efg	4009 d	8473 cd
8	$N_{120}P_{180}K_0$	2857 e	2461 cd	3159 c	8427 cd
9	$N_{120}P_0K_0$	2035 bcd	1368 b	2992 c	7263 b
10	$N_{120}P_0K_{120}$	0,818 a	3094 def	3812 d	8214 cd
11	$N_{120}P_{60}K_{60}$	2757 de	2972 de	4100 d	9126 def
12	$N_{120}P_{60}K_{120}$	2544 cde	2805 de	3853 d	8874 cde
13	$N_{120}P_{120}K_{60}$	2453 bcde	3362 efg	4086 d	8775 cde
14	$N_{120}P_{120}K_{120}$	2725 de	3142 ef	3760 d	9924 f
15	$N_{120}P_{180}K_{60}$	2336 bcde	3913 g	4097 d	8891 de
16	$N_{120}P_{180}K_{120}$	2476 cde	3705 fg	4079 d	9655 ef

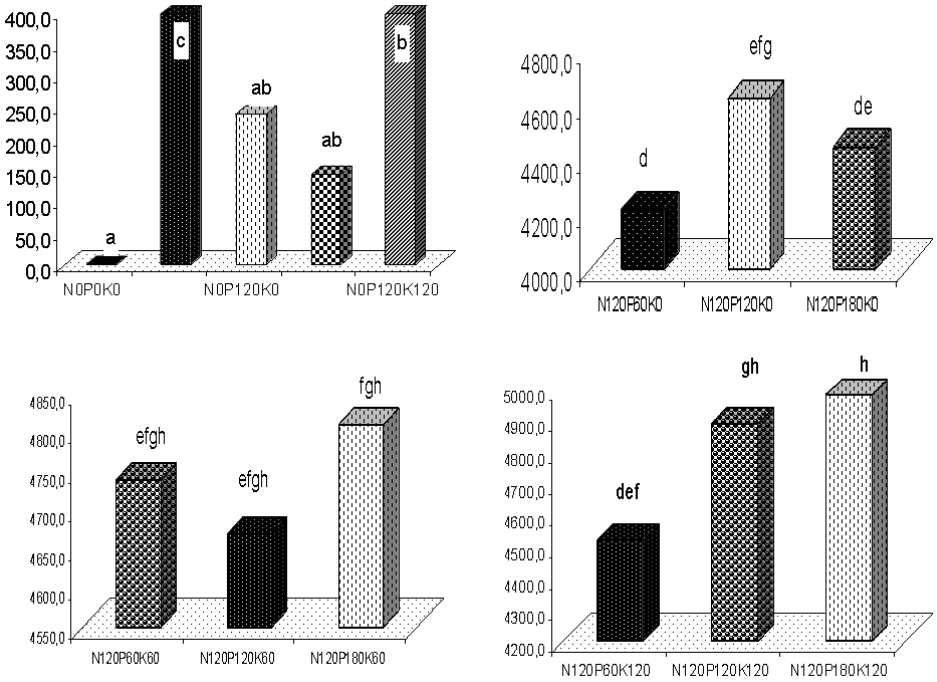

Figure 6. Mean agronomy effect from cultivar Dragana during 2010-2013 according to mineral fertilization with N_{120} in different combinations with phosphorus and potassium, kg ha^{-1}

From 2010 to 2013 the mean values of the agronomy effect gradually increased from 1882 kg ha-1 to 7056 kg ha-1. Averaged for the tested fertilizer variants and the years of investigation, the agronomy effect from the applied mineral fertilization was 3541 kg ha-1. Under independent introduction of the nutrients from norm 120 kg ha-1, the effect of nitrogen was highest - 3614 kg ha-1 (Figure 6). The systematic addition of 120 kg P2O5 ha-1 increased the values of the agronomy effect to 4619 kg ha-1, which was the highest addition among the tested nitrogen-phosphorus and nitrogen-potassium combinations.

The combination of the three macro elements maintained the mean addition above 4000 kg ha-1. Highest values of the agronomy effect were obtained at ratios N:P:K = 1:1:1 – 4846 kg ha-1 (N120P120K120) and N:P:K=1:1.5:1 – 4893 kg ha-1 (N120P180K120).

During the years of investigation, as well as averaged for the period, high and significant positive correlations were found between productivity and the agronomic effect as a result from mineral fertilization (Table 5)

Table5. Correlation coefficients between grain yield and the agronomic effect of mineral fertilization by years of investigation

Grain	Years	Agronomic effect
yield	2010	,993**
	2011	,992**
	2012	,987**
	2013	,992**

The optimization of the size of expenses for agricultural production is very important for the higher sustainability and competitiveness of production. The specificity of agricultural production, which involves the effect of biotic and abiotic factors, inevitably reflects on the production expenses, the financial and economic result and the marketing of grain.

In our investigations the direct expenses for production are the focus of our attention. It is also necessary to add that the economic analysis does not include the subsidies and rents due to the specificity of the production at Dobrudzha Agricultural Institute – General Toshevo.

The expenses in the check variants during the analyzed years were the expression of all expenses, except for those for fertilizers, and indicated that the highest expenses were made in 2013 due to the higher prices of fuel, herbicides, etc (Figure 7). During the investigated period 2010 – 2013, the expenses for production in the variant without mineral fertilization amounted to a mean of 479.6 BGN ha-1 and increased almost twice at the different fertilizer combinations with the three macro elements, reaching 1221.5 BGN ha-1.

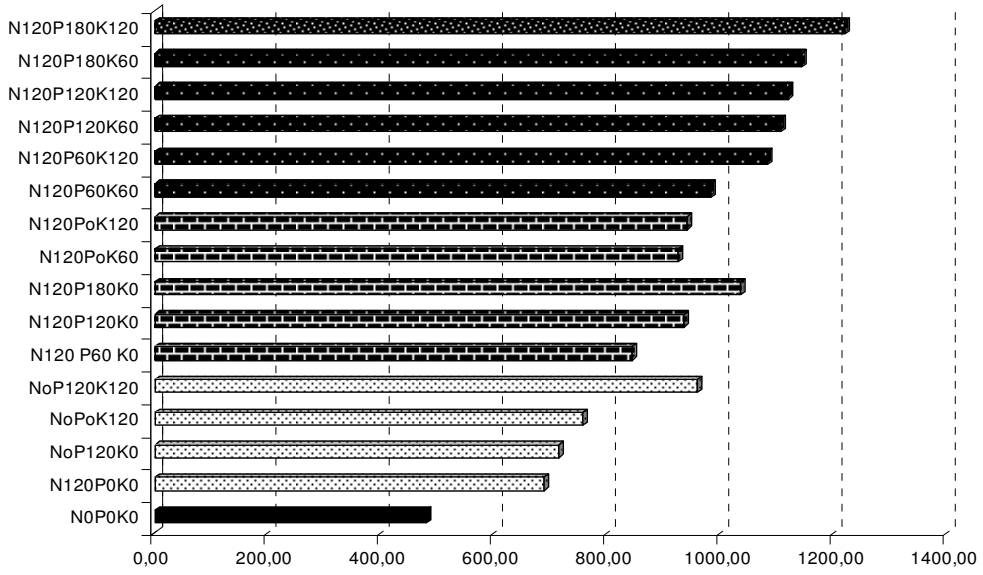

Figure7. Direct expenses for production of wheat averaged for the period 2010-2013 according to the fertilization norm, BGN ha-1

The expenses for fertilizers and their introduction are among the highest expenses for the production of this crop. During the individual years, even at the same fertilizer variants, the expenses varied within a rather wide range mainly due to the increasing prices of the fertilizers. The prices of the phosphorus and potassium fertilizers marked highest values in 2012, and of the nitrogen fertilizers – in 2013.

Averaged for the investigated period, in the tested variants the percent of expenses for fertilizers and their application amounted to 50.03 % of all direct expenses made. At independent introduction of each of the macro elements from norm 120 kg/ha, nitrogen fertilization had the lowest percent from the expenses for fertilizers, and phosphorus and potassium fertilization – the highest, a variant without practical significance (Figure 8). In the double combinations (NP and NK), the percent of the expenses at systematic introduction of N120P180K0 was highest.

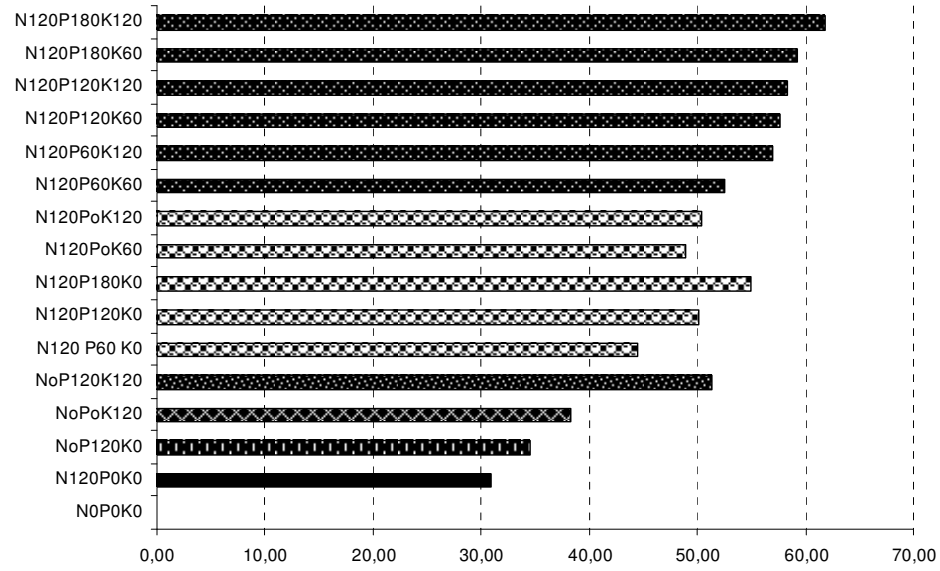

Figure8. Mean percent of the expenses for fertilization from the total expenses for production of wheat according to the fertilization norms, %

Beside the variation by years, there was variation in the percent of expenses for providing the respective nutrition regimes in the different fertilizer variants from 0 % in the check variant to 61.78 % averaged for 2010 – 2013 under systematic introduction of N120P180K120. In this very variant, the percent of the expenses for fertilizers and their introduction was highest in 2010 – 67.1 %, which was also the highest within this investigation.

Averaged for the period 2010 – 2013 in the group of variants with independent introduction of the macro elements at the analyzed norm of 120 kg ha-1, as well as at the combination N0P120K120, the highest size of the total profit was that of the independent nitrogen fertilization – 2304.6 BGN ha-1 (Figure 9).

In the double combinations between the macro elements, the size of the total profit was highest at N120P120K0 – 2631.9 BGN ha-1. This variant maintained a comparatively high level of total profit during the investigated years and reached a maximum in 2013 – 4201.0 BGN ha-1.

From the point of view of obtaining good and stable production results combined with cares for restoration of the exhausted soil reserves of nutrients, the combinations between the three macro elements deserve serious attention in the economic analysis as well. In the group of fertilizer combinations where the nitrogen from norm 120 kg ha-1 was combined with various norms of phosphorus and potassium, the size of the total profit, averaged for the investigated period, varied from 2599.5 BGN ha-1 (N120P60K120) to 2742.4 BGN ha-1 (N120P180K120).

The applied norms of fertilization also had significant effect on the dynamics of the obtained profit by years. A tendency was observed toward approximately equal and higher profit in the fertilization variants involving all three macro elements in the fertilization norm in comparison to the independent introduction of nitrogen. Averaged for the investigated period, the nitrogen norm of 120 kg N ha-1, introduced independently or in various norms and ratios with phosphorus and potassium, ensured 2 to 3 times higher profit from wheat production in comparison to the check variant (Figure 10). The variants with independent introduction of phosphorus and potassium and the combination between them realized significantly lower profits in comparison to the check and were extremely unsuitable for practice.

Averaged for the period, among the NP combinations, the systematic introduction of N120P120K0 had the highest mean size of profit – 1667.3 BGN ha-1, exceeding the profit from the independent application of nitrogen from the same norm with 4.7 %. For the combination N120P60K0 this exceeding was with only 1.6 %, and in the variant with prevalence of phosphorus over nitrogen (1:1.5), the size of profit was 94.2 % from the profit under independent nitrogen fertilization.

In the NK combinations, the variant N120P0K60 ensured a mean profit of 1633.9 BGN/ha thus exceeding the profit from the independent nitrogen fertilization with 2.6%. The other similar combination - N120P0K120 was with

a mean profit of 1255.3 BGN ha-1, which was 78.8% from the profit of the independent nitrogen fertilization. Averaged for the investigated period, the profitability norm in the check variant was 123.92 % (Figure 11). In the variant with independent introduction of the three macro elements, highest values of the index were determined after independent nitrogen fertilization with 120 kg N ha-1 – 211.80 %, which was the highest value of the profitability norm within this investigation.

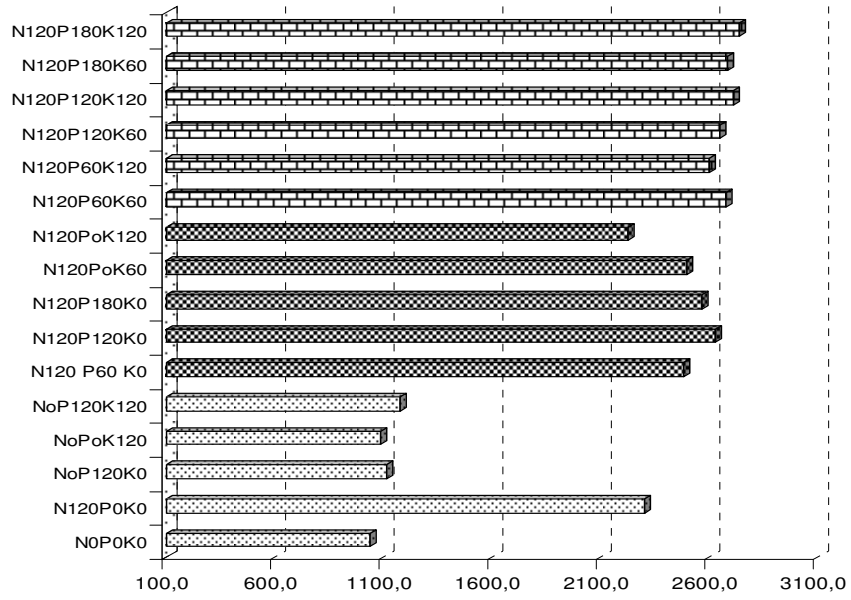

Figure9. Total profit averaged for the period 2010-2013 according to the mineral fertilization norms, BGN ha^{-1}.

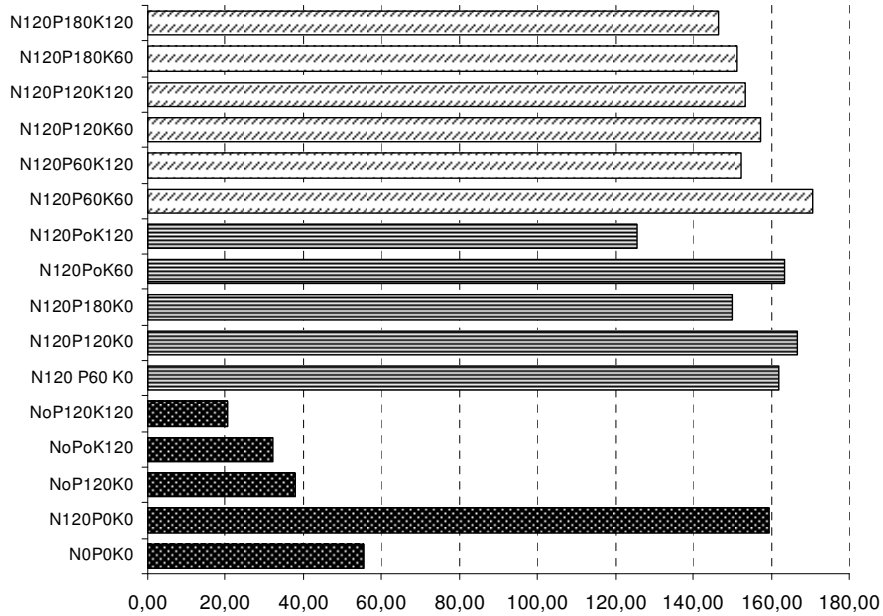

Figure10. Mean values of profit during 2010-2013 depending on the fertilization norm,

Among the nitrogen and phosphorus combinations valuable for practice from an agronomic point of view, highest mean profitability norm was determined after systematic application of N120P60K0 – 178.37 %. The profitability norm decreased with the higher norm of phosphorus in this fertilizer combination. Regardless of the fact that in the double combinations between the nutrients the highest value of the profitability norm was determined in the variant with N120P0K60 – 181.87%, the nitrogen-and-potassium combinations were not significant for the practice in this region.

When combining all three macro elements at different norms and ratios, two variants with considerable importance for practice were with the highest mean norm of profitability: N120P60K60 – 168.01% and N120P120K60 – 140.49%.

It is worth mentioning the fact that on the whole the economic analysis is in favor of the independent nitrogen fertilization regardless of the size of the fertilizer norm and the noticed tendencies. In this case, however, we are considering the economic evaluation of an open and highly dynamic system which includes two biological components, soil and plant, which are strongly influenced by the meteorological conditions of the year of production and the market price of the respective produce.

Another fact should also be mentioned – the economic evaluation does not include the quality of the produce. Furthermore, the buying-in prices of grain are rather low to cover the outrunning prices of the resources necessary for the production of wheat. It becomes evident from this investigation that only the expenses for fertilizers when combining the nitrogen norm of 120 kg ha-1 with different norms and ratios of phosphorus and potassium amount from 30.97 % to 61.79 % of all expenses made.

Without touching the issue of the negative effect of the independent nitrogen fertilization on soil fertility, we think that the seemingly better data from the economic analysis on the independent nitrogen fertilization should concede to the best norms and ratios between the main macro elements from an agronomic point of view. What is more, in the recent years, regardless of the inadequate buying-in prices of the wheat grain, even at the high fertilizer combinations a high norm of profitability was determined (about 60-70 %) of the total invested expenses for production of wheat under the conditions of this experiment.

Not always the high productivity and the respective agronomic effect are in direct proportional correlation with the economic efficiency of production. The analysis of the 4-year results clearly confirmed this fact (Figure 12). Averaged for the investigated period, the efficiency of the applied variants of mineral fertilization was highest under systematic long-term introduction of N120P180K120, while the profit from the obtained produce, as a complex economic indicator was highest under fertilization with N120P60K60.

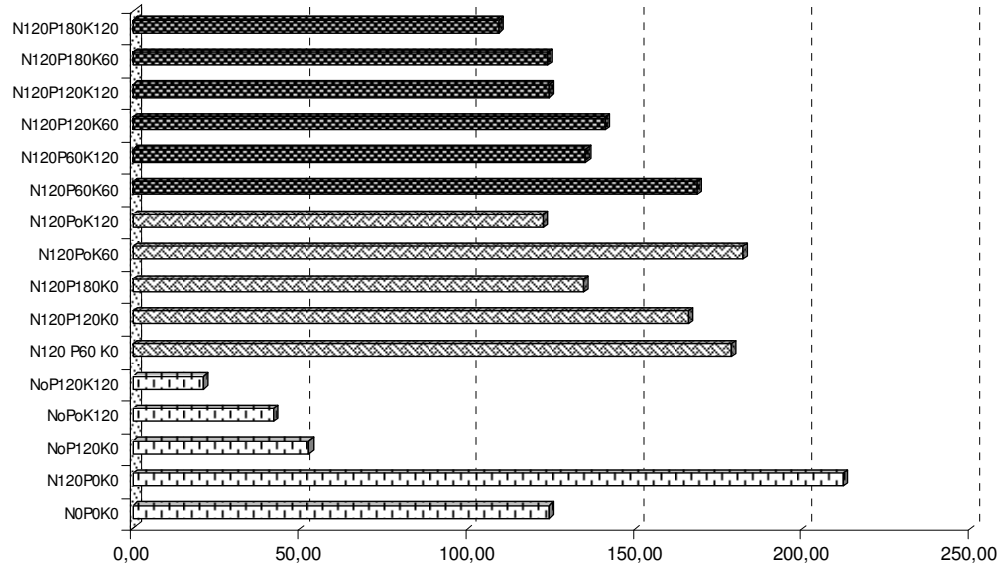

Figure11. Mean profitability norm of wheat production during 2010-2013 depending on the fertilization norm, %.

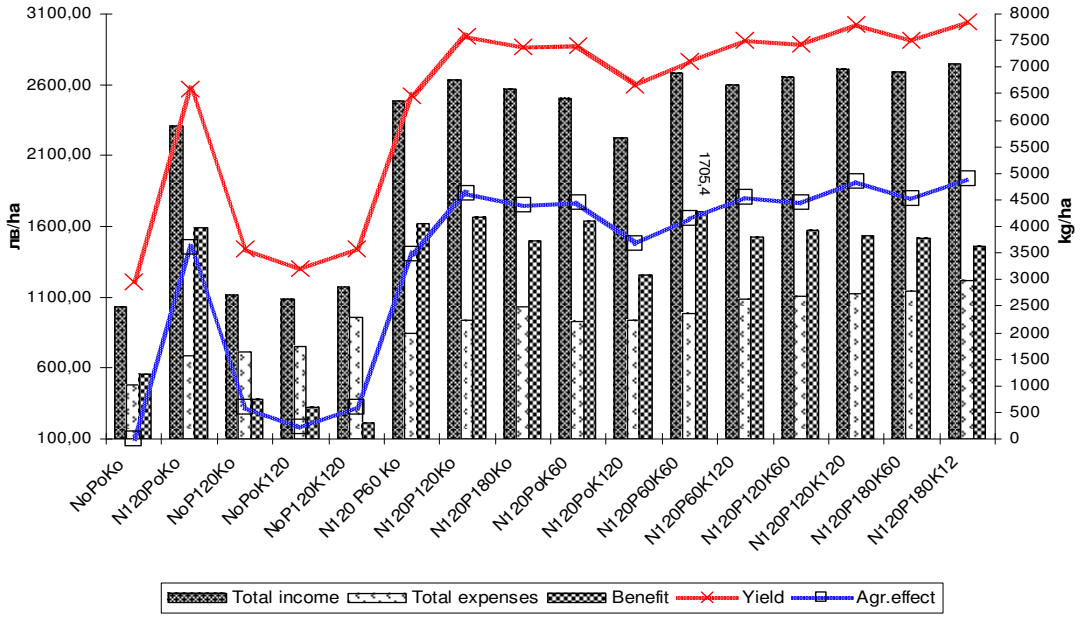

Figure12. Productivity, agronomic effect and economic efficiency as a result from the tested norms of systematic mineral fertilization, kg ha^{-1} and BGN/ha^{-1}

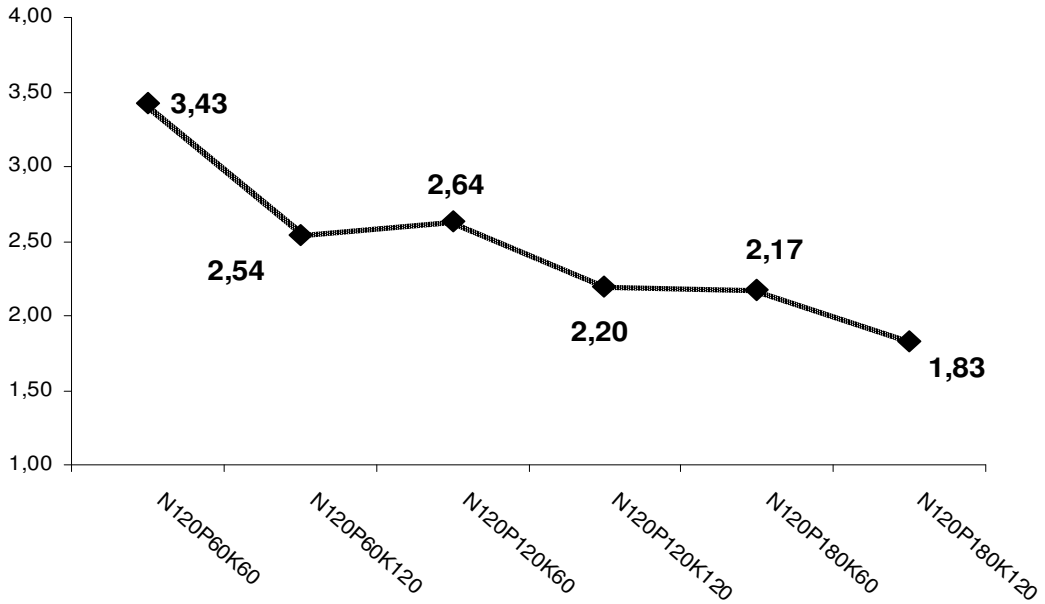

Figure13. Return on unit of expenses for fertilization depending on the type of NPK combination, time

These data were confirmed also by the obtained results on the expenses made for fertilization. A unit expense for mineral fertilization at the different fertilizer combinations contributed to its return, the size of which was strongly influenced by the meteorological conditions of the year of investigation and the ratio between the main macro elements. Indisputably, averaged for the period, the independent nitrogen fertilization with c 120 kg N ha-1 had the highest return on expenses – with an average of 6.71 times. In the combinations nitrogen-phosphorus and nitrogen-potassium, the return on expenses varied from 1.04 (N120P0K120) to 3.53 (N120P180K0) and 3.66 (N120P60K0).

At the full combination of the three macro elements, the variant with systematic introduction of N120P60K60 was with maximum return on a

unit of expenses for fertilization – 3.43 times (Figure 13).

Conclusions

The independent introduction of the main macro elements from norm 120 kg/ha contributed over years to a stable addition to the yield from cultivar Dragana according to the check variant. The mean yield from the untreated check was 2967 kg ha-1 and reflected the high natural fertility of the soil in the trial field (Haplic Chernozems). The obtained mean agronomic effect was highest after introduction of nitrogen - 3614 kg ha-1. After independent phosphorus and potassium fertilization it was 603 kg ha-1 and 228 kg ha-1, respectively.

The cultivar showed maximum mean productivity in the fertilizer combinations N:P:K=1:1:0, N:P:K=1:1:1 and N:P:K=1:1.5:1, where the increase according to the check variant was with 155,7%, 163,3% and 164,9%, respectively. In these three fertilizer combinations (N120P120K0, N120P120K120, N120P180K120) the highest increase according to the independent nitrogen fertilization with 120 kg ha-1 was achieved.

The agronomic effect from the independent nitrogen fertilization varied over the years from 1656 kg ha-1 (2010) to 7970 kg/ha (2013).The highest values of the agronomic effect were obtained at ratios N:P:K=1:1:1 – 4846 kg ha-1 (N120P120K120) and N:P:K=1:1.5:1 – 4893 kg ha-1 (N120P180K120).

The complex of meteorological conditions during the period of investigation was favorable for the development, productivity and agronomic efficiency of cultivar Dragana in harvest year 2013. During the years of investigation and averaged for the period, high significant and positive correlations were found between productivity and the agronomic effect as a result from mineral fertilization.

The economic efficiency of the production of the cultivar was directly dependent on the achieved agronomic effect, the realization price of the end produce and the production expenses. Depending on the type of the fertilizer variant during the years of investigation, the total income varied from 762.8 BGN ha^{-1} (N0P0K120 - 2011) to 4481.2 BGN ha^{-1} (N120P120K120 - 2013).

Among all considered combinations of the nitrogen norm of 120 kg N ha-1 with phosphorus and potassium, the systematic fertilization with N120P60K60 was with the highest profit (1705.4 BGN ha^{-1}), satisfactorily high norm of profitability (over 60%) and high return on unit expenses for fertilization (3.43). The profit in this variant exceeded the profit from the independent nitrogen fertilization with 7.1 %. A similar tendency of high values of the main indicators of economic efficiency was observed under systematic fertilization with N120P120K0, where the exceeding of the mean profit over the independent nitrogen fertilization was with 4.7 %. The size of the profit in the variants with highest productivity and agronomic effect, N120P120K120 and N120P180K120, conceded to the profit from the independent fertilization with nitrogen at 120 kg ha-1 and was 96.35% and 91.90% from it, respectively.

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