AGRICULTURAL ACADEMY
DOBRUDZHA AGRICULTURAL INSTITUTE
GENERAL TOSHEVO

ATANAS ATANASOV

EFFICIENCY OF NITROGEN UTILIZATION IN MODERN WHEAT VARIETIES (*Triticum aestivum* L.) GROWN UNDER CONDITIONS OF CONVENTIONAL AND TRANSITION TO ORGANIC PRODUCTION

Abstract of Ph.D. Dissertation

For awarding scientific degree of Doctor

SCIENTIFIC SPECIALITY “AGRICULTURE”

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The dissertation materials are available to any interested person at Dobrudzha Agricultural Institute – General Toshevo. The deffence of the Ph.D. thesis will take place on …….. at…….. at Dobrudzha Agricultural institute – General Toshevo at a session of the the specialized scientific jury appointed by order of the Agricultural Academy.

INTRODUCTION

The intensification of agricultural production characterized by a wide range of agronomy prctices (chemical pesticides, mineral fertilizers, intensive soil tillage) is related to decrease of biodiversity, unfavorable effects on the environment and in most cases to results less satisfactory than expected. The climate probles are an additional prerequisite for a multifaceted risk of losses. The management of the agricultural systems under such conditions requires strategic key decisions enhancing agricultural ecosystem services such as nutrient cycling and water regime regulation, without making compromises with the productivity and the quality of the produce.

The past decades were marked by the use of high nitrogen norms. The researches, however, showed that only up to 50 % of the introduced nitrogen is utilized by the plants, and under certain conditions. The extremely high nitrogen norms decrease the yield and increase the losses in the soil ecosystem. This requires precision of the used agronomy practices, particularly the approach to nitrogen fertilization, not only its norm but also the dates of application, the type of source and other specificities. On the other hand, especially important is the response of the crop/variety with regard to the efficiency of the use of this element under specific agrometeorological conditions.

Some countries, due to a number of reasons, maintain traditional agriculture largely based on natural methods and practices. As early as the beginning of the 20th century, Rudolf Steiner founded the Organic-dynamic movement in Germany. Organic agriculture is a system, in which the plants receive nutrients from natural soil resources. This approach can be influenced by climatic factors or soil characteristics, which may cause nutrition stress, which affects the yield and quality of the plants.

It is important to highlight the significance of the efficient utilization of nutrients by the wheat varieties, which are suitable to grow under organic production. Both natural methods and technologies, and nutrition products and plant protection of organic origin are used in modern organic agriculture. This has Pchelinan a long-term global tendency. According to the Green Deal and the Farm to Fork strategy, at least 25 % of the arable land should be allocated to organic production, and the use of chemical products should be reduced under conventional technologies.

This study focuses on growing of common winter wheat varieties under conditions of transition to organic production in comparison to conventional production. The obtained results are important with a view of the data, that will be significant on the way to achieving sustainable agriculture. The understanding of the relationships between the different factors, which affect the productivity and quality of the crop, can contribute to the formulation of more efficient and sustainable agricultural practices to meet the demands of the producers, and of society in general. This is a topical issue both in the agrotechnology and in the breeding of modern wheat cultivars at Dobrudzha Agricultural Institute.

2. GOAL AND TASKS

The main goal of this Ph.D. thesis was to determine the major elements of the nitrogen metabolism in the contemporary Bulgarian wheat cultivars (*T. aestivum L.*) depending on the previous crop, the level of nutrition regime and the way of growin in a 4-field crop rotation.

Accomplishing this goal involved implementing the following tasks:

1. Productivity of common winter wheat cultivars grown in a multiple filed crop rotation in transition to their organic production and under conventional production.
2. Agronomy effect of mineral fertilization on common winter wheat varieties under conventional production.
3. Effect of main agronomy factors on the nitrogen concentration in the organs of all contemporary Bulgarian common winter wheat varieties grown under transition to organic and conventional systems of agricultural production.
4. Effect of main agronomy factors on the nitrogen uptake the the organs of contemporary Bulgarian common winter wheat varieties grown under transition to organic and conventional systems of agricultural production.
5. Parameters of nitrogen metabolism related to nitrogen uptake and productivity of contemporary Bulgarian common winter wheat varieties grown under transition to organic and conventional systems of agricultural production.
6. Physical properties of grain of contemporary Bulgarian common winter wheat varieties grown under transition to organic and conventional systems of agricultural production.
7. Characterization of the parameters of the qualitative parameters of flower from the tested varieties grown under transition to organic and conventional systems of agricultural production.
8. Expense of nitrogen for formation of a unit of agricultural produce of the tested cultivars grown under transition to organic and conventional systems of agricultural production.
9. Correlation between the elements of nitrogen metabolism and the produce formed, physical properties of grain and the breadmaking properties of the tested wheat varieties depending on the system of agricultural production.

3. MATERIAL AND METHODS OF WORK

3.1. Methodological setting of the field trial

3.1.1. Field experiment under conventional production

The aim of the conventional part of the experiment was to follow the effect of abiotic (parameters of the main meteorological elements) and biotic stress (weeds, diseases and pests) on the nitrogen uptake and the indices characterizing the efficiency of nitrogen nutrition in contemporary common winter wheat (*Tr. aestivum L.*) cultivars depending on the norms of mineral fertilization and the previous crop under conditions of slightly leached chernozem soil (Haplic Chernozems) in the experimental field of DAI – General Toshevo. The trial was stationary and was designed by the split plot method in four replications, the size of the harvest plot being 12 m^2 (12 x 1 m).

The soil tillage after harvesting of the previous crops was single disking (10-12 cm) for levelling of the soil surface. It was followed by implementing the layout of the trial and preparation for main mineral fertilization. Then multiple disking was applied to create optimal conditions for sowing. The factors, investigated in the conventional part of the experiment, were the following:

Factor A – mineral fertilization norms for winer cereals. The nitrogen norms varied according to the previous crop (Table 1);

Factor B – previous crops: pea, sunflower, grain maize, oilseed rape;

Factor C – common winter wheat cultivars Dragana, Rada, Pchelina, Kossara and Kalina.

Table. Mineral fertilization norms for winter cereals depending on the previous crop

Factor A	
After pea	After all other previous crops
$N_0P_0K_0$ (T_0)	$N_0P_0K_0$ (T_0)
$N_3P_6K_6$ (T_1),	$N_6P_6K_6$ (T_1),
$N_6P_6K_6$ (T_2),	$N_{12}P_6K_6$ (T_2)
$N_9P_6K_6$ (T_3),	$N_{18}P_6K_6$ (T_3)

The mineral fertilization was done with conventional fertilizers. The phosphorus and potassium fertilizers, triple superphosphate (46% P_2O_5) and potassium chloride (50/60% K_2O), respectively, were introduced prior to main soil tillage. Nitrogen was applied at the beginning of permanent spring vegetative growth of the plants in the form of ammonium nitratre (33-34 % N).

3.1.2. Field experiment under transition to organic production

The aim of this part of the experiment was to follow the effect of abiotic (parameters of the main meteorological elements) and biotic stress (weeds, diseases and pests) on the uptake of nitrogen and the peculiarities in some of its metabolic elements, the productivity and quality of contemporary wheat cultivars grown after different previous croips in transition to organic production.

The factors, investigated in the organic part of the experiment, were the following:

Factor A – previous crops: oilseed rape/рапица; pea/грах, sunflower/слънчоглед, grain maize/царевица

Factor B – common winter wheat cultivars: Dragana/Драгана, Rada/Рада, Pchelina/Пчелина, Kossara/Косара and Kalina/Калина.

In the part of the trial, where the variants with transition to organic production (ТОР/ПБП) were positioned, wheat utilized the natural reserves of nutrients in soil. Here no mineral or organic fertilizers were applied, nor any stimulants eligible for organic production, nor pesticides.

Sowing in both parts of the experiment was within the dates optimal for the region of South Dobrudzha, with sowing norm 550 germinating seeds/m^2 under conventional production and 650 germinating seeds/ m^2 under TOP. The sowing norm under both ways of wheat production was determined on the basis of the laboratory germinating capacity of the planting paterial and 1000 kernel weight (g).

The variants in the conventional part of the experiment included mineral fertilization and control of the weeds. When necessary, disease and pests control was also applied.

With a view of achieving complete accuracy with regart to TOP, all previous crops had their organic and conventional variants.

3.2. Studied parameters

Below are the parameters related to the main goal which were followed in the two trials:

3.2.1. Meteorological observations

- Reading the amount of rainfals during the vegetative growth of plants (over decades) and the amount of winter precipitation;
- Reading air temperature over decades (*T abs. min, T average min, T average, T abs.max, T average max*).

The comparative amalysis of the individual current meteorological elements was done using climatic norms over a long-term period (1953 – 2020).

3.2.2. Biometrical measurements and parameters

a). Biological analysis

- Registering phenological stages in the field experiments;
- Biological yield in the main stages by plant organs;
- structural components of yield – harvest index from total biomass (HITBM), harvest index of grain in spike (HIGS);
- Physical parameters of grain - 1000 kernel weight (g) and test weight (kg/100 dm^3)

б). Agrochemical analyses

The soil analyses were done at the beginning and the end of each harvest year, taking samples from the 0-20 cm and 20-40 cm layers. After setting to air dry condition, the soil samples were prepared according to the specific requirements for each analysis. These included:

- Soil acidicy;
- Available forms of mineral nitrogen;
- Available phosphorus and exchangeable potassium;
- Organic C in soil;
- Total nitrogen in soil (N mg/100 g).

The plant analyses included determining the nitrogen content (N%) over plant organs, using the plants already taken from the frame sampling for biological yield. After determining the quantity of the formed biomass, they were prepared for analysis (by grinding). The nitrogen in the plant organs was determined by the method of Kjeldahl.

The analyses were done at the Laboratory of Agrochemisty at DAI – General Toshevo according to conventional methods for determining of nutrients.

- Determining some parameters of nitrogen metabolism

❖ Elements based on the nitrogen taken up by the plants;
❖ Elements based on the used fertilization norms;
❖ Qualitative characteristics
  - Physical properties of grain;
  - Technological and baking properties of grain.

The preparation of the samples for analysys and their grinding was done with milling equipment MLU-202 to 70 % flour. The analyses for technological and baking properties were done at the Breadmaking Laboratory of DAI – General Toshevo.

The data obtained from the above analyses were feeded to software MS Excel 1997-2003. They were subjected to ANOVA analysis using the general linear model. For determining the significance of the differences between the variants, the analysis of the variances and the correlations (Pearson 1900) between the investigated parameters, the statistical package SPSS 13.0 was applied.

3.3. **General characterization of the soil and climatic conditions of the region**

3.3.1. General climatic characteristics

The Dobrudzha plains and the larger part of Northen Bulgaria belong to the moderate continental zone. The central part of South Dobrudzha is elevated 220 – 310 m above sea level and the relief is slightly undulating. With regard to climate, the region of Dobrudzha belongs to the mid-Eastern climatic region of the Danubean plateau, which is a part of the moderate continental climatic subregion, and to the Northern Black Sea Coast of the Black Sea subregion. Due to climatic factors, atmospheric circulation and the geography of the region, it is refered to the Eastern climatic region of the Danubean plateau from the moderate continental climatic subregion of the European continental climatic zone. The annual precipitation is 500 – 550 mm. In most years, the summer-autumnal dry season is more than 30 days long, and the northernmost part of this region is characterized by steppe climate. The most important climatic characteristics of the Black Sea climatic subregion are comparatively mild and humid winter and hot, comparatively dry and sunny summer. The winter temperatures are primarily influenced by the thermal effects of the large water basins, and the region is open to northern and north-eastern winds, which can reach up to 15-20 m/s in winter.

3.4. **Meteorological characteristics of the years of investigation in relation to common winter wheat development**

The values of the distribution of rainfalls and the temperatures during the vegetative growth of wheat differed considerably over the years of investigation. During 01.10.2017 – 31.03.2018, the rainfalls in the region of DAI – General Toshevo were 357.6 mm/m^2, which was with 113.1 mm/m^2 above the mean long-term norm (Fig.1).

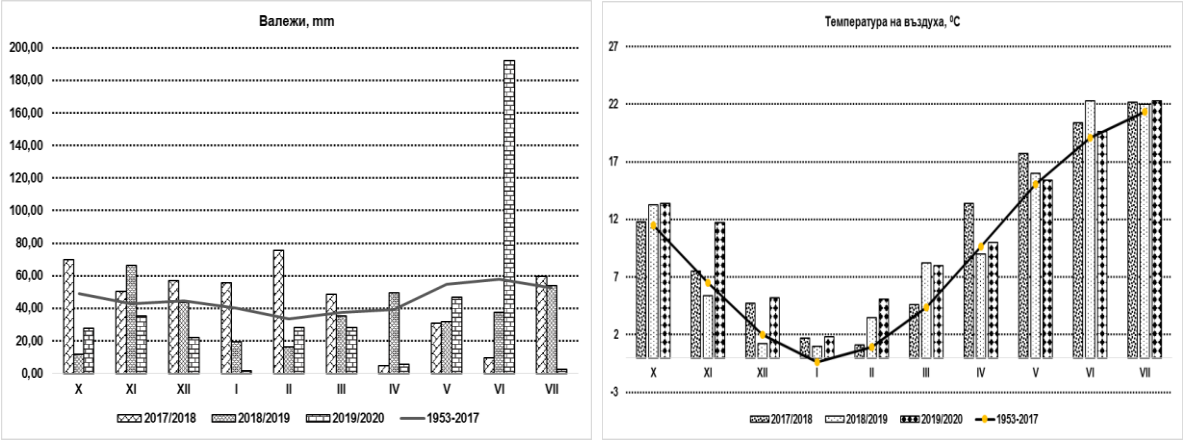


Figure 1. Temperatures and precipitation during the investigated period

The greater differences were determined during the autum-and-winter period. The autumn and winter of harvest year 2018 were with values close to the climatic norm, February being the coldest month (1.1° C). This year was more favorable for the development of the cultivars, especially in the variant with TOP, where the combination of temperatures and rainfalls during the autumn-and-winter period contributed to the fast growth of the plants and the overshadowing of the weed vegetation. The spring was warm and dry. May and June were with air temperatures typical for this region. Meteorologically specific was the spring-and-summer period of 2018. It was characterized by extreme drought in April (4.9 mm) and minimal precipitation during May (30.9 mm), June (9.8 mm) and July (59.6 mm).

The second year of the investigation (2019) was characterized by comparatively warm autumn and temperatures close to the average for the region. The most abundant rainfalls were after sowing, in November (66.2 mm) and December (43.8 mm). January was with the lowest mean diurnal air temperatures of all three years (1°C). The spring, similar to the previous year, was warm, and the air temperatures during the summer months exceeded the climatic norm. During the spring vegetative growth of the plants, the highest amount of rainfalls was registered in June – 59.6 mm. Specific and varied was the picture during the third year of the investigation. It was characterized by long and extreme drought and very low sums of precipitation during the autumn and winter. In October, November and December, the precipitation was 27.6 mm, 35.4 mm and 26.4 mm, respectively, which determined this period as dry. The mean temperatures were above the climatic norm.

Consecutively, the plant development at the initial stages was slower. This was particularly evident in the variants of TOP and T_0 of conventional production. The comparatively mild and warm weather remained unchanged till the end of January, with record-breaking low precipitation of 1.8 mm. The winter can be characterized as very dry, with precipitation maximum in February – 28.1 mm, the coldest month being January (1.9° C). Spring was also warm, and the air temperatures in the early summer were close to the norm. April was dryer than the norm, with precipitation 35.6 mm, in contrast to June (192.2 mm), which exceeded the norm with 130.2 mm, and as a result harvesting was delayed.

Of the three years of the study, the first experimental year (2017–2018) was the most favorable for the growth and development of the plants, followed by 2018–2019, while the third year, 2020, was extremely unfavorable. The complex combination of meteorological elements had a negative effect on the growth, development, yield and quality of wheat.

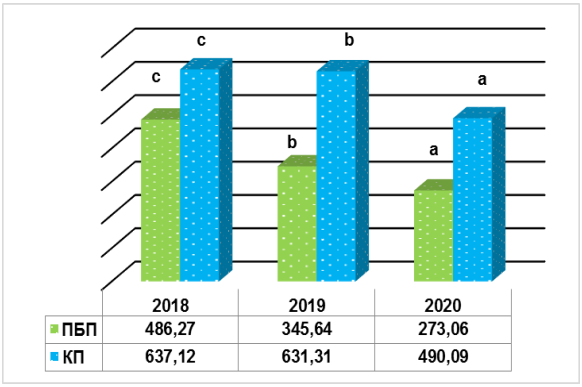
4. RESULTS AND DISCUSSION

4.1. Effect of transition to organic production and conventional wheat cultivation system in a 4-field crop rotation on the productivity of common wheat varieties

4.1.1. Influence of agricultural production systems on the productivity of common wheat

Annual conditions cause serious dynamics in the manifestation of the production potential of common wheat varieties (Fig. 2). The lowest average yields under both agricultural production systems were formed in 2020. The unfavorable combination of meteorological elements in 2020, combined with the low amount of autumn-winter precipitation, lead to an average of 56.15% of the obtained yields in 2018 at TOP, and in CP the same are respectively 76.92%. Thus, the obtained average productivity in CP is 64.38% greater than that obtained in biological production. In years with favorable conditions for growing wheat (2018), the average yield from CP is 31.02% higher than that from organic production. Under the conditions of different stress conditions during the growing season, the difference between the two production systems increases, respectively by 82.65 % (2019) and by 79.49 % (2020) in favor of the conventional system.

From the results presented in the experiment, it became clear that the type of previous crop has the strongest effect on the productivity of wheat grown under TOP. The differentiation in the average yield values depending on the type of previous crop was high. This difference between the most suitable (pea) and the least favorable (maize) amounted to 283.11 kg/dka.



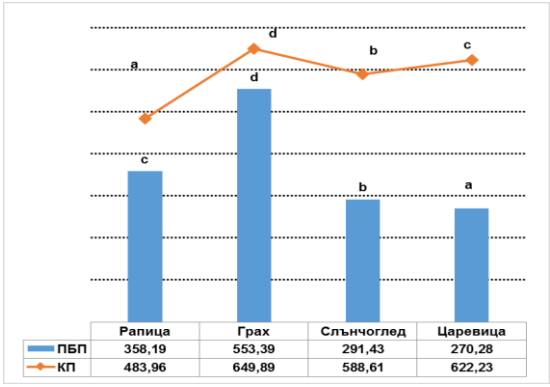


Figure 2. Average productivity of wheat by years of research and depending on the type of previous crop under TOP (ПБП) and CP (КП), kg/dka.

The conventional wheat production system also implies a debate on the influence of the main factor that distinguishes it most significantly from TOP - mineral fertilization (Fig. 3). In the experiment, 5 levels of soil nutrition were applied for both methods of wheat production. In 2 of them (TOP and T_0-CP) there was a uniform approach due to the fact that mineral fertilization was not applied in these cases. The only differences in the agronomy practices between them were in the sowing norms and the corresponding lack of chemical weed control in T_0-CP. The average yields obtained in these two variants showed a substantial similarity, i.e. insignificant difference in the response of the crop. In the variant T_0-CP, 12.79 kg/dka more grain was obtained compared to TOP.

Against the background of phosphorus-potassium fertilization, the introduction of nitrogen in a ratio between the elements N:P:K=3:1:1 lead to an average yield of 718.98 kg/da. It exceeded TOP by 95.21%, and CP-T_0 - by 88.65%.

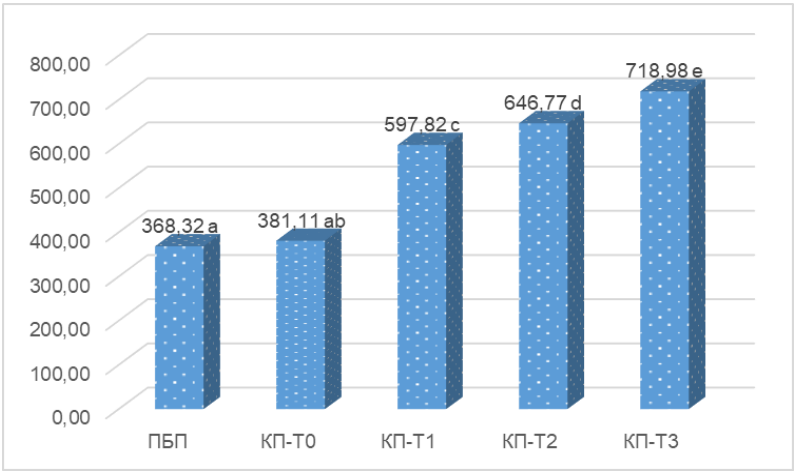


Figure 3. Comparison of the average productivity of wheat depending on the level of the nutritional regime in the experiment (TOP and CP), kg/dka.

With the nutrition regimes thuis applied, the tested wheat varieties realized their maximum potential under the specific conditions of the study (Fig. 4). In the TOP variants, the average productivity potential varied from 342.11 kg/dka (Pchelina) to 390.39 kg/dka (Kossara). A reaction similar to that of cultivar Kossara was demonstrated by cultivars Rada and Kalina. This result is a prerequisite for a certain advantage of these varieties when grown under the conditions of organic production.

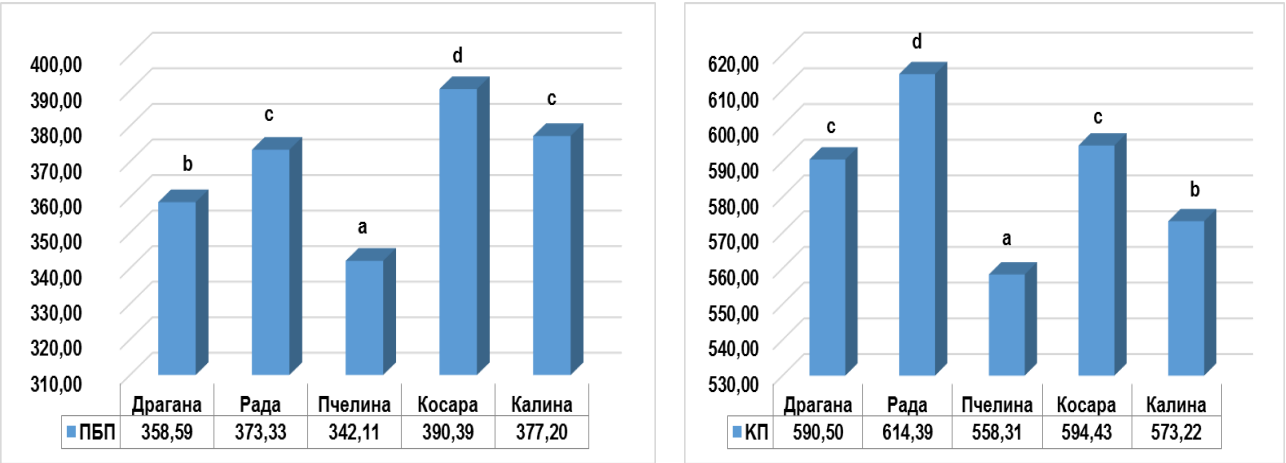


Figure 4. Productivity of wheat depending on the type of cultivar under TOP and CP, kg/dka.

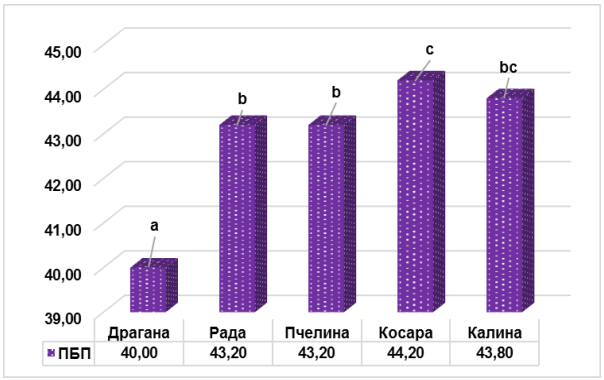
The conventional production system had higher productivity than TOP with an average of 217.85 kg/dka. Although with a significant increase in the average yield under CP compared to TOP (62.20%), cultivar Pchelina was again with lower productivity than the other varieties. In cultivar Kalina, this increase was 51.97%. According to the Waller-Dunkan test, cultivars Dragana and Kosara demonstrated the same reaction when grown under CP, i.e. fell into the same group. However, these two varieties increased their productivity compared to TOP to a different extent - by 64.67% and 52.27%, respectively. The leader in terms of average productivity under the

conventional production system was cultivar Rada - 614.39 kg/dka with an increase of its yield (373.33 kg/dka) under TOP by 64.57%.

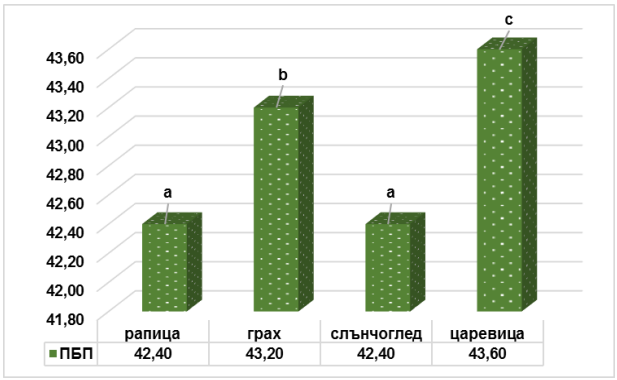
4.1.2. Harvest index under conditions of transition to organic and conventional production

The harvest index (HI) is the relative proportion of the grain to the total shoot biomass. The influence of the variety and the previous crop on the investigated index presented in Figure 5 proved that the effect of the genotype on the values of GHI is the least expressed in cultivar Dragana (40.00 %). The Waller-Duncan test ranked cultivar Kosara (44.20 %) first, followed by Kalina (43.80 %). On average, for the experiment with the highest GHI, the previous crops are corn (43.60 %) and peas (43.10 %), followed by canola and sunflower.

The results obtained at the NGPS, averaged for the period of the study, again highlight cultivar Dragana with lower values of the index (Fig. 6), followed by cultivar Kalina, cultivar Rada being in leading position with 76.32%, followed by Pchelina (75.07%) and Kossara (73.22 %). Averaged for the experiment with the highest value of NGPS, the pervious crop pea (74.26 %) ranked first, followed by grain maize, rape and sunflower.

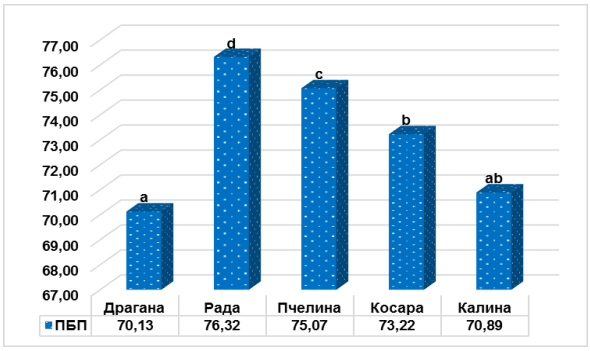


Cultivar

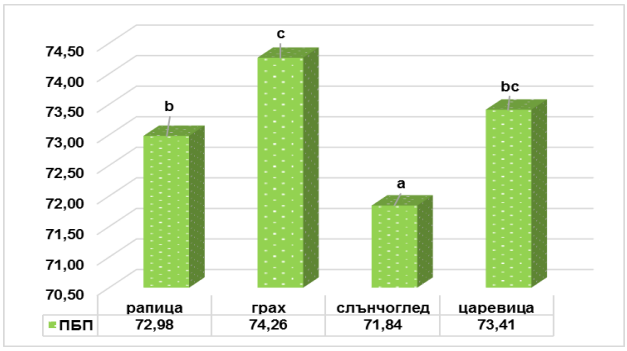


Previous crop

Figure 5. Effect of the cultivar and the previous crop on the harvest index of the total biomass in the transition to organic production, averaged for the investigated period, %



Cultivar

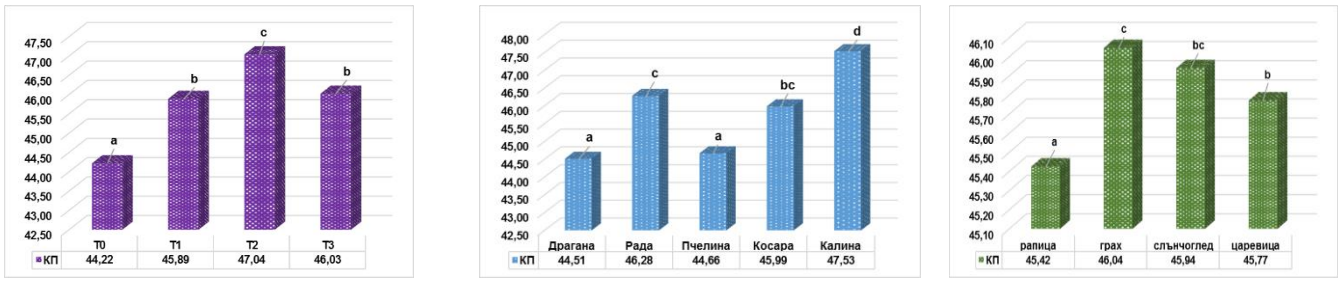


Previous crop

Figure 6. Effect of the cultivar and the previous on the non-grain part in spike (NGPS) under transition to organic production, %

The reaction of GHI in the check variant reflected the lowest values of the index – 44.20% (Fig. 7). The intensive fertilizer rate has a negative effect on the TOP, being equal to the low fertilizer rate and highlighting T_2 (47.02 %) with the highest values, averaged for the period of the study. Cultivars Kalina, Kossara and Rada had the highest GHI, followed by Pchelina and Dragana. The leguminous previous crop ranked first, followed by the root previous crops sunflower and corn, while oilseed rape gave the lowest values, averaged for the studied period under conventional production.

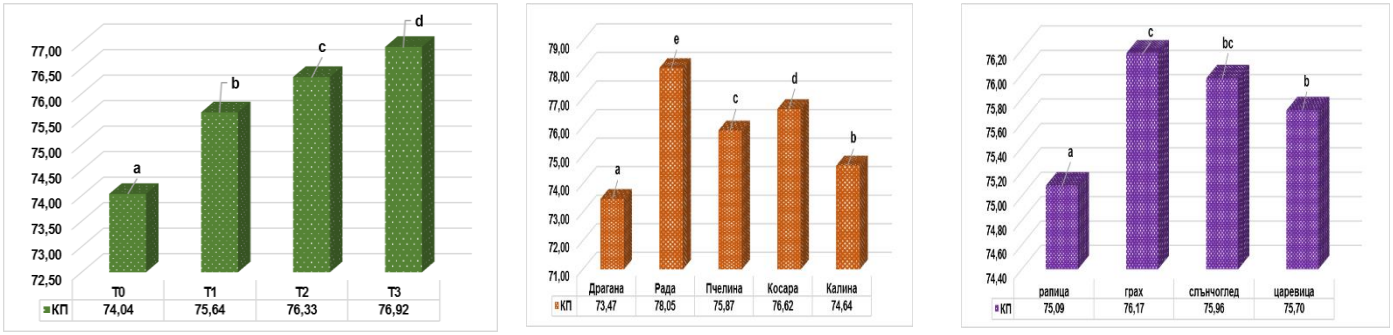
The dynamics of the NGPS, averaged over the period of the study regarding the effect of fertilization is well expressed (Fig. 8). The control variant T_0 had lower results, respectively 74.04% compared to the fertilizer variants, where the maximum of NGPS was reached at the last level of nitrogen fertilization – T3 (76.92%).



Ferilization Cultivar Previous crop

Figure 7. Effect of fertilization, variety and previous crop on the harvest index of the total biomass under conventional production, averaged over the studied period, %

The influence of the genotype was best expressed in Rada (78.05%) and Kossara (76.62%). The lowest values of this index were registered in cultivar Dragana (73.47%). Averaged for the experiment with the highest value of NGPS, previous crop pea ranked first (76.17 %), followed by sunflower and maize.



Ferilization Cultivar Previous crop

Figure 8. Effect of fertilization, cultivar and previous crop on the harvest index under conventional production, averaged over the studied period, %

4.2. Elements of nitrogen metabolism

4.2.1. Elements based on nitrogen uptake by plants

4.2.1.1 Effect of main agronomy factors on the concentration of nitrogen in the organs of modern Bulgarian varieties of common winter wheat grown in transition to biological and conventional systems of agricultural production.

The obtained results for the average values for the period of the study for N% under TOP showed that 2019 provided better conditions for enriching the grain with nitrogen (Fig. 9). In this year, the N% in the leaves was the highest, and that in the NGPS - the lowest. The first year of the study was with the lowest concentrations of nitrogen in leaves, stems and grain.

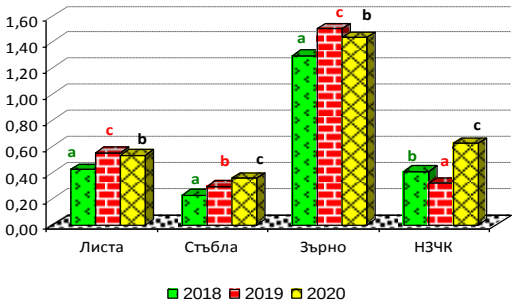
Against this background, the lowest concentrations of nitrogen were found when wheat was grown after oilseed rape, except for N% in the NGPS. After previous crop pea, the nitrogen content of all shoot biomass organs was higher compared to that after the other previous crops. In this sense, according to the average values of N% in the leaves, grain and NGPS, the previous crops were ranked as follows: pea>maize>sunflower>oilseed rape. For nitrogen in the stems, the effect of oilseed rape and sunflower was equalized and resulted in the lowest values for the concentration of nitrogen (N%). The selected ranking of cultivars is also arranged in different ways regarding the concentration of nitrogen in the individual organs. Under TOP conditions, cultivar Pchelina had the highest concentration of nitrogen in the grain, followed by cultivar Rada.

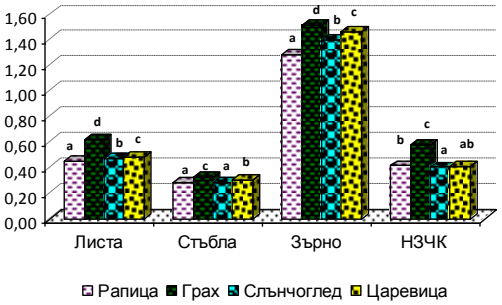
An interesting fact is that cultivar Pchelina remained with the highest concentration of nitrogen in the NGPS, while in Rada that part of the vegetative mass, which was closest to the grain, had the lowest N %. Cultivar Pchelina also had the lowest concentration of nitrogen in the leaves and was eanked second after cultivar refarding N % in the stems.

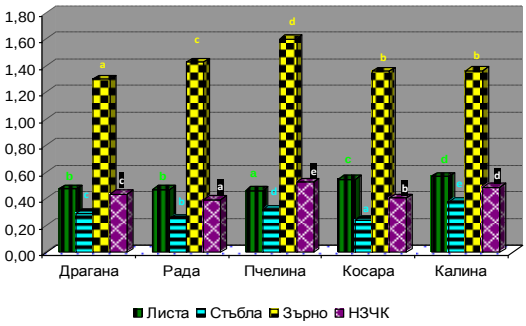
The conventional method of production lead to a higher content of nitrogen in the leaves, stems and grain - respectively by 18.47%, 7.48% and 9.03%. In 2018 and 2020, the N% in the NRC under CP was below the average obtained under the TOP cultivation system and was 87.14% and 95.37% of it, respectively. The same is the reason for a serious shift in the position of the tested previous crops in relation to N%.

It is worth noting that cultivar Rada was characterized by relatively low concentrations of nitrogen in the organs of the vegetative mass, which was probably related to a better flow of assimilates to the grain. The average concentrations of nitrogen in the grain of Kosara, Kalina and Dragana were lower. A significantly higher nitrogen content was found in the leaves and partly in the other organs.

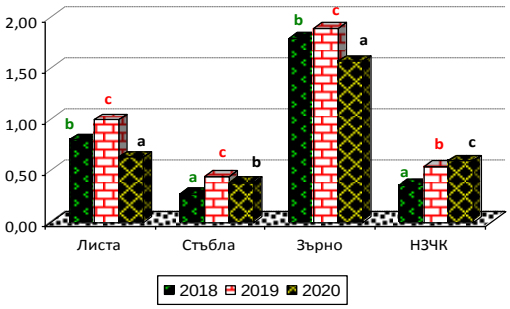
TOP

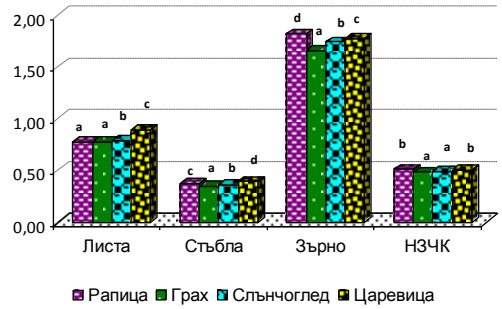


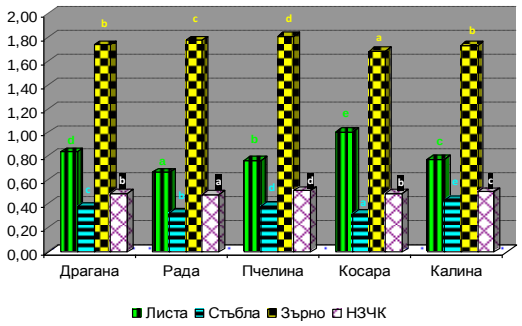




CP







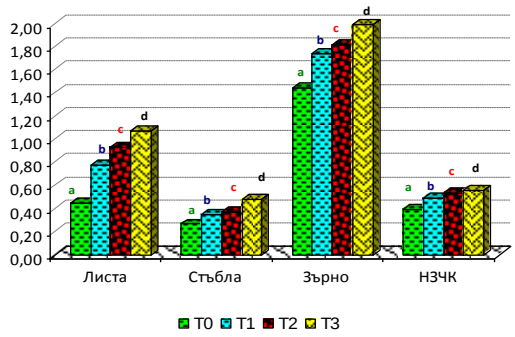


Figure 9. Average data on the concentration of N% depending on the tested factors and methods of wheat production

Since there are two variants in the experiment in which mineral fertilizers are not applied - the transition to organic production (TOP) and the check variant under conventional production

(CP-T0), we also made a comparison between the obtained average values for the concentration of nitrogen for the period 2018- 2020 (Fig. 10).

They revealed that the differences in N% by organs between the variants without applying mineral fertilizers in the two wheat production systems were insignificant. Practically, from the point of view of the agronomy practices used, in TOP the seeding norm was 600 germinating seeds/m2, and under CP it was 550 germinating seeds/m2, and there was also use of herbicide.

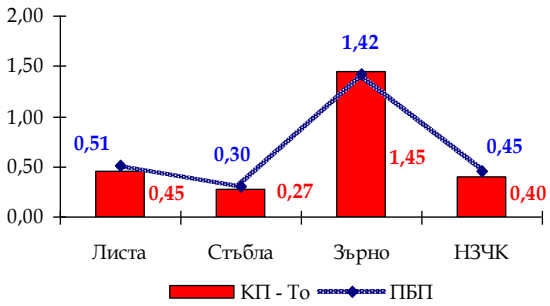


Figure 10. Comparison of nitrogen concentration by organs under TOP and CP-T0, averaged for 2018-2020, %

5.2.1.2. Effect of main agronomy factors on the uptake of nitrogen in the organs of modern Bulgarian varieties of common winter wheat grown in transition to organic and conventional systems of agricultural production.

In absolute values, the differences by year between the two methods of production in the nitrogen uptake in the non-economic part of the produce were clearly expressed (Fig. 11). The biggest differences were found in 2019, when the nitrogen uptake in the vegetative biomass was with 2.690 kg/dka (175.82%) more, compared to PDB. All organs from the non-economic part of the produce contributed to this, and the same was valid for the stems - with 1.189 kg/dka (154.22%). under unfavorable conditions during the wheat growing season, this tendency was also preserved, but the differences between the two methods of production were significantly lower. For example, the difference in the amount of nitrogen in the non-economic part was only 0.861 kg/dka (42.62%) in favor of CP. Again, the stems were the organ where the differences were greatest.

Comparing the results of 2020 to those of 2018, we found out that under very dry conditions, the leaf mass at maturity remained with 2.72 times lower amounts of nitrogen uptake compared to partially favorable conditions in 2018. In these years, the amount of nitrogen in the stems varied insignificantly, while under the conditions of extreme drought, the NGPS retained 1.96 times more nitrogen than in 2018.

The differences in the amounts of nitrogen uptake in the grain and the total shoot biomass followed the above tendencies by year for the nitrogen uptake in the non-economic part of the produce, because they were largely his function. Regardless of the fact that in general the grain took up the most nitrogen in 2019, the biggest difference between the production methods was found in 2018 – 9.169 kg/dka in favor of CP. In 2020, the differences in the nitrogen uptake in the grain and the total shoot biomass were the lowest - respectively 3.618 kg/dka and 4.479 kg/dka.

In the final phase, the amounts of nitrogen locked in the total shoot biomass of the varieties grown under TOP vared within relatively narrow range – 8.957 kg N/dka for cultivar Rada to 7.537

kg N/dka for cultivar Pchelina (Fig. 12). The differentiation between the varieties was better expressed in the organs forming the non-economic part and in the grain.

The reproductive organ had the largest amounts of nitrogen uptake in cultivar Rada - 7.241 kg N/dka. Its reaction was similar to cultivar Kossara. The rest of the varieties showed strong signs of similarity according to this index, but conceded to cultivar Rada.

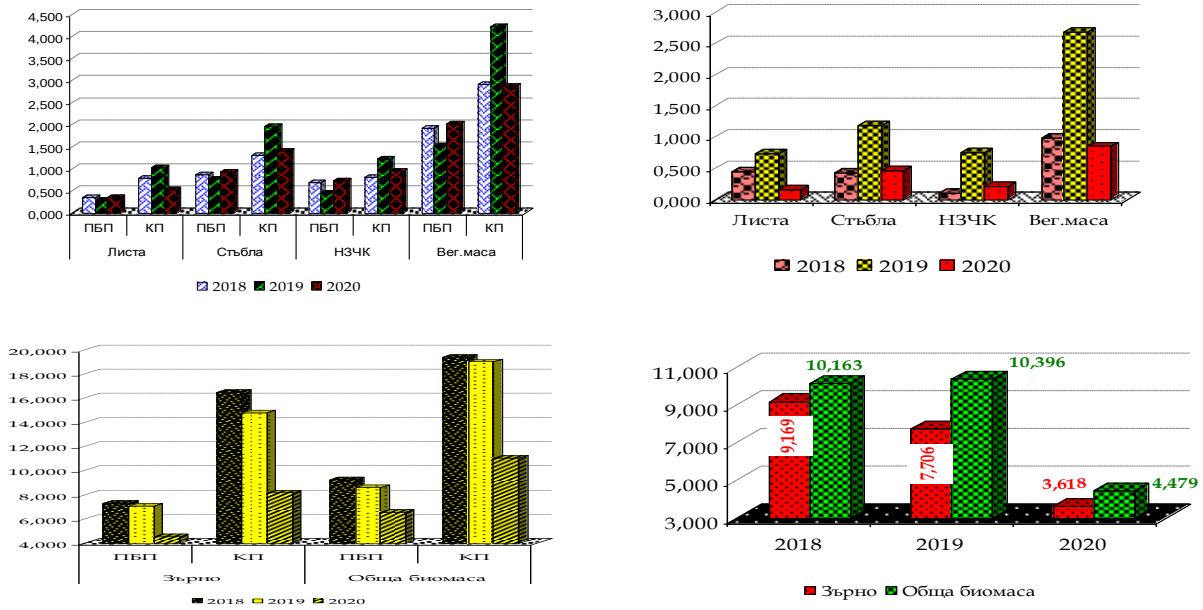
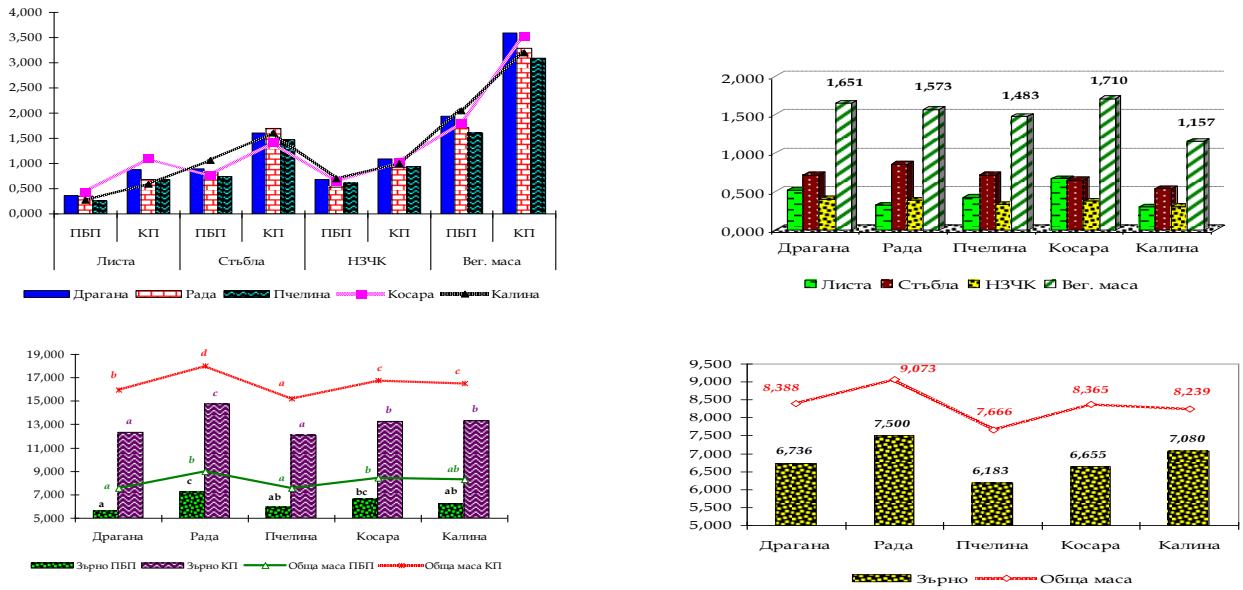


Figure 11. Nitrogen uptake by the organs of the non-economic part, the grain and the total shoot biomass of wheat in the ways of its cultivation by years of research, kg/dka



Nitrogen uptake Difference between TOP and CP

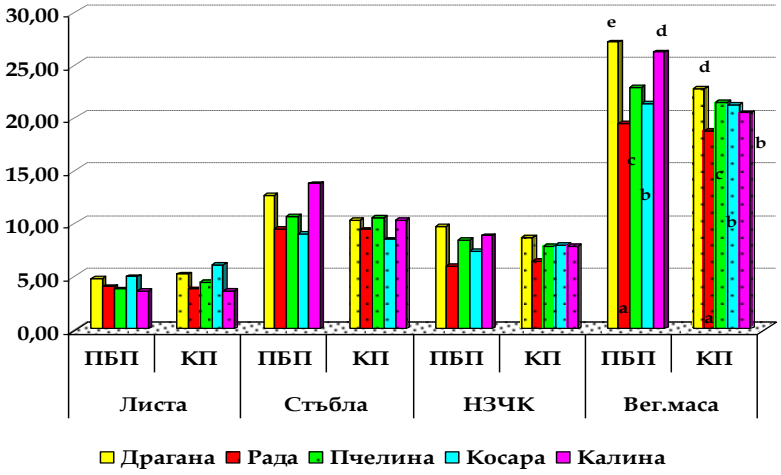
Figure 12. Nitrogen uptake by the organs of the non-economic part, the grain and the total shoot biomass of wheat under the cultivation methods depending on the variety, kg/dka

5.2.1.3. Nitrogen harvest index

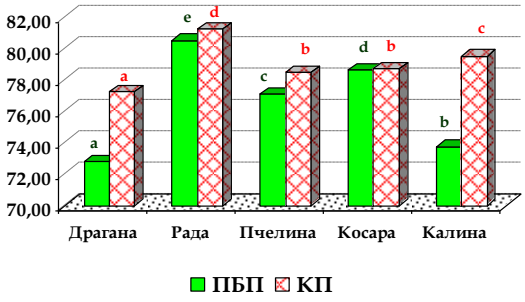
The selected variety composition over the years and on average for the period demonstrated a clear differentiation in the values of NHI by organs compared to the total nitrogen uptake in wheat and under the second method of its production (Fig. 13). Comparing the obtained results, it was evident that under TOP the nitrogen uptake from the vegetative mass to the grain was more difficult, compared to CP. This fact is most pronounced in varieties Dragana and Kalina. The tendency was also observed under CP, as in variety Dragana it affected all examined organs from the non-economic part of the produce.

We established that even under the second method of production, variety Rada had the best uptake of nitrogen from the vegetative mass to the grain, i.e. had the lowest values of NHI of the PHR.

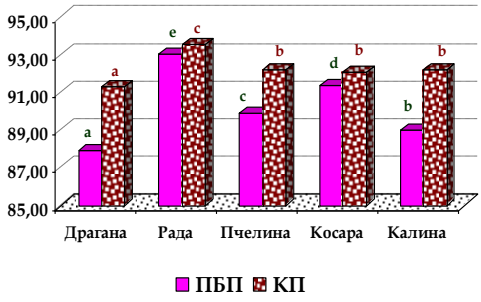
The results unequivocally showed that CP gives better opportunities for nitrogen reutilization compared to growing wheat under TOP. In this regard, the differentiation in the values of the studied index depending on the variety were clearly expressed, especially under TOP.



In the organs of the vegetative mass



The grain



The grain in spike

Figure 13. Nitrogen harvest index by wheat organs depending on the cultivar and the method of production, %

Regardless of the method of production of the crop, the values of the GIA of the grain and that of the grain in spike were the highest in variety Rada. The most significant differentiation between the methods of production was found in cultivars Dragana and Kalina. The only variety with values of GLA of the grain practically not affected by the methods of production was Kosara. Varieties Rada and Kosara had very small differences in the GIA values of the grain in spike, depending on the method of production. In this regard, the greatest differences were found in cultivars Dragana and Kalina, where a large part of the nitrogen remained in the NGPS without being able to be taken up to the grain.

5.2.1.4. Nitrogen utilization efficiency

Nitrogen utilization efficiency (EAU/NUtE - Nitrogen utilization efficiency) depending on the methods of wheat production is a useful characteristics of the yield produced from the nitrogen taken up by the plants. This term in world literature is also known as biomass production efficiency (Biomass production efficiency - BPE).

Averaged for the studied period, a comparison was also made between all options providing a different regime of soil nutrition, regardless of the method of production (Fig. 14). Nitrogen utilization was found to be highest under TOP. In the experiment, there was another variant that reflected the natural level of soil fertility under CP – chack variant T0. The results showed that it was 84.80% of that obtained under TOP in terms of the amount of recycled nitrogen.

The fact of obtaining higher values of the index after previous crop pea was confirmed, as well as the fact that cultivar Rada had the lowest capacity to relocate the total absorbed nitrogen to the grain.

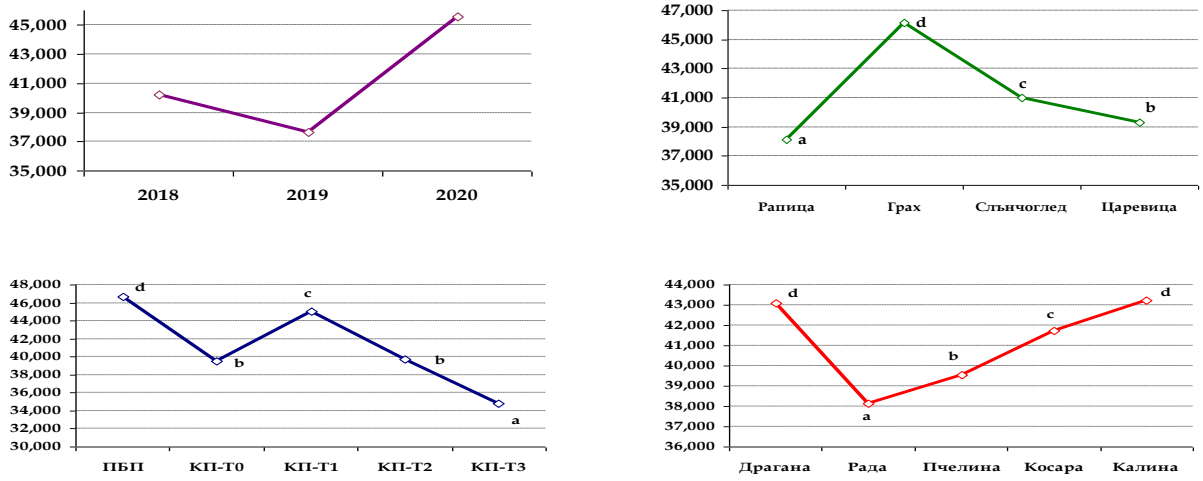


Figure 14. Nitrogen utilization efficiency averaged for the experiment, regardless of the production method for the period 2018-2020, kg.kg-1

4.2.2.1. Yield response to mineral fertilization

The agronomy effect (AE) was determined as the difference between the yield in the check variant for each variety and the results obtained in the corresponding variants with mineral fertilization according to previous crops. In world literature, this index is also called Agronomy Effect and Yield Response. The obtained results revealed a strong interaction between the tested factors (Fig. 15).

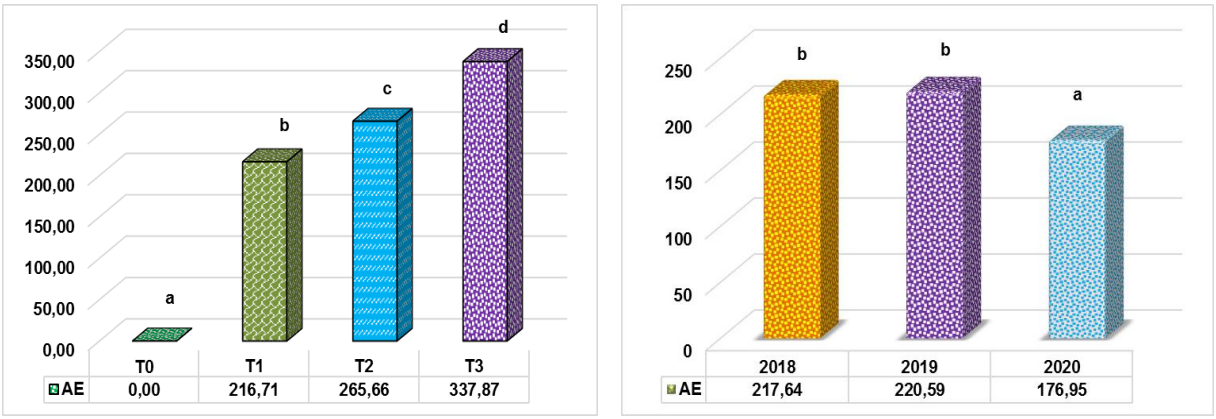


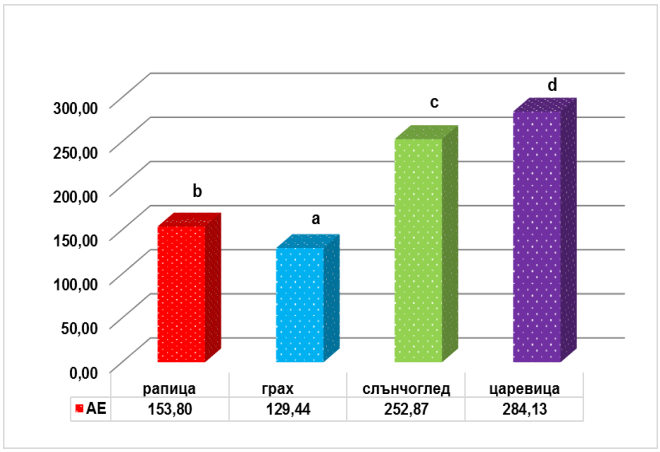
Figure 15. Average values of agronomic effect for common winter wheat, kg/dka

It was established that mineral fertilization had decisive influence on the increase in the yield of the wheat varieties, compared to the natural fertility in the corresponding check variants with little variation in the weather conditions of the investigated period. The size of AE was clearly differentiated depending on the size of the fertilizer norm. It had the highest values under intensive mineral fertilization (ratio N:P:K = 3:1:1) with the highest nitrogen norm for the respective previous crops.

The average productivity of common winter wheat by year varied within a relatively narrow range - from 176.95 kg/dka (2020) to 220.59 kg/dka (2019).

Averaged over the period and at the tested fertilization norms, the cultivars grown after maize had the highest AE (Fig. 16). Sunflower ranked second depending on the influence of the previous crops and displaced oilseed rape as such.

Regarding the AE values averaged over the studied period, cultivar Rada maintained its leading position, followed by Dragana (207.41 kg/dka). The Waller-Duncan test placed varieties Pchelina (202.41 kg/dka) and Kosara (201.28 kg/dka) in one group – b. Variety Kalina, on average, under the conditions of the experiment, had the lowest value of AE.



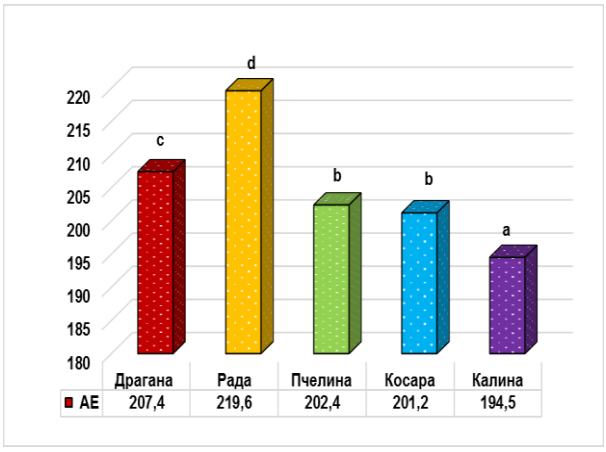


Figure 16. Effect of the previous crop and cultivar on the values of the agronomy effect, kg/dka

4.2.2.2. Partial factor productivity

This is one of the main parameters characterizing nitrogen metabolism, through the size of the nitrogen norm. It gives an idea of the fgrain yield formed when combining the potential soil fertility in a given area and the nitrogen norms used. In world literature it is known as Partial Factor Productivity (PFP).

In all three years of the study, as well as on average for the period, the partial productivity (PP) had the highest values when fertilizing with the low nitrogen norm (Fig. 17). It varied from 146,386 kg.kg in 2019 to 93,605 kg.kg in 2020. The formed nutrient regime in the soil was a result of the natural fertility of slightly leached chernozem combined with nitrogen fertilization of 6 kgN/dka.

The subsequent increase in the nitrogen fertilizer norm lead to a decrease in the values of this index. Averaged for the PE period for this fertilizer option is 68.007 kg.kg, which represents 53.61% of the obtained PE average value at the low nitrogen norm. The use of the optimal for the region nitrogen fertilizer norm of 12 kgN/dka lead to a lower differentiation in the values regarding the influence of the meteorological factor.

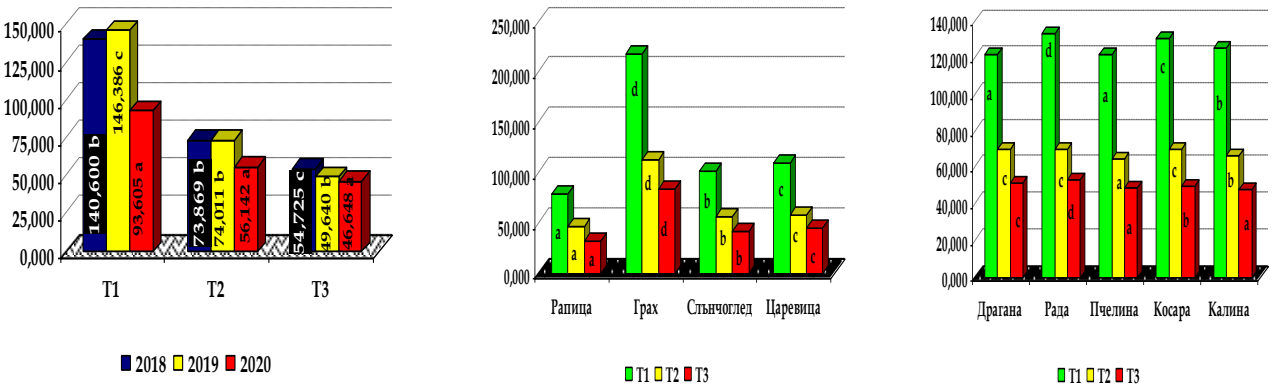


Figure 17. Effect of the factors year, previous crop and cultivar on the values of partial productivity depending on the level of nitrogen fertilization under CP of wheat

The use of aggressive nitrogen norms further reduced PE, with an average for the period of only 50.338 kg.kg, which was 39.68% of the average value for PE when fertilizing with N6P6K6.

The previous crops used in CP of wheat strongly differentiated their influence on the values of CP of nitrogen, depending on the level of nitrogen fertilization. For each of the previous crops, a decrease in the nitrogen ratio was found with the higher nitrogen norms. The values of this index were highest when wheat was grown after pea, followed by previous crop grain maize. The lowest NP of nitrogen after previous crop oilseed rape was only 37.95% of that obtained after previous crop pea.

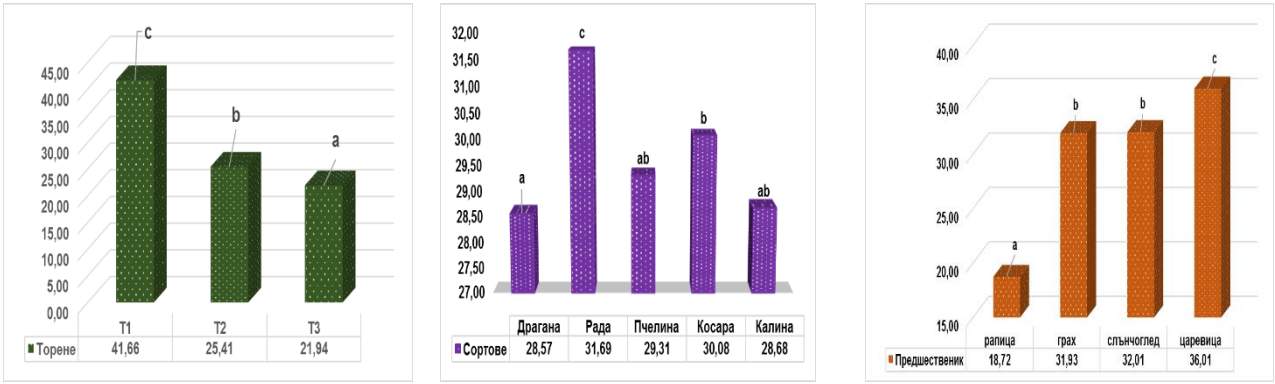
The partial productivity of nitrogen, depending on the tested varieties, had clearly differentiated values. Averaged for the period, it was highest in cultivar Rada - 85,599 kg.kg and lowest – in cultivar Pchelina (78,205 kg.kg). A certain similarity was found between Dragana and Kalina in terms of the results obtained for the nitrogen PNPF.

4.2.2.3. Nitrogen use efficiency at increasing levels of nitrogen fertilization

In essence, the agronomically determined NUE represented the net effect of 1 nitrogen input. It is defined as the difference between the yield of the corresponding fertilizer variant and that of the check variant, divided by the fertilizer rate. This is a highly important index in conventional wheat production.

EIA on grain yield was clearly influenced by fertilization (Fig. 18). The Waller-Duncan test showed a clear differentiation in the values of the index in the first combination T1 - 41.66 kg, redistributing them into 3 independent groups. The differences between T2 and T3 fertilizer norms were insignificant, and increasing fertilization had a negative effect on the index.

The varieties were divided into 3 main groups, after Dragana this trait has the lowest value, and after Rada and Kosara the highest value. In cultivars Kalina (28.68 kg) and Pchelina (29.31 kg), no statistically significant differences were observed, and they were included in one subgroup - ab.



Ferilization Cultivar Previous crop

Figure 18. Effect of factors on the nitrogen use efficiency

Regarding the average productivity of the previous crop, grain maize was in the leading position - 36.01 kg, followed by sunflower (32.01 kg), peas (31.93 kg) and oilseed rape (18.72 kg).

4.2.2.4. Nitrogen uptake efficiency (N_{UP}) under conventional production

Nitrogen uptake efficiency is the amount of available nitrogen in the soil taken up by plants. Essentially, it provides information on the absorbed amount of nitrogen in the total shoot biomass per 1 kg of nitrogen applied through mineral fertilization.

The obtained results averaged over the period showed that years with extremely unfavorable conditions throughout the growing season lead to a decrease in the efficiency of nitrogen accumulation in the shoot biomass by 50% (Fig. 19). Nitrogen fertilization norm were also well differentiated, with the highest NUE values being the low nitrogen rate of 6 kgN/dka (N:P:K=1:1:1). Subsequent increases in the nitrogen norm gave lower results, with a tendency towards some increase at the highest nitrogen norm relative to the optimum for the area. Regarding the role of the previous crop on the efficiency of nitrogen uptake in wheat, the contribution of pea as previous crop (3.033 kg.kg-1) was the highest, followed by maize (2.528 kg.kg-1).

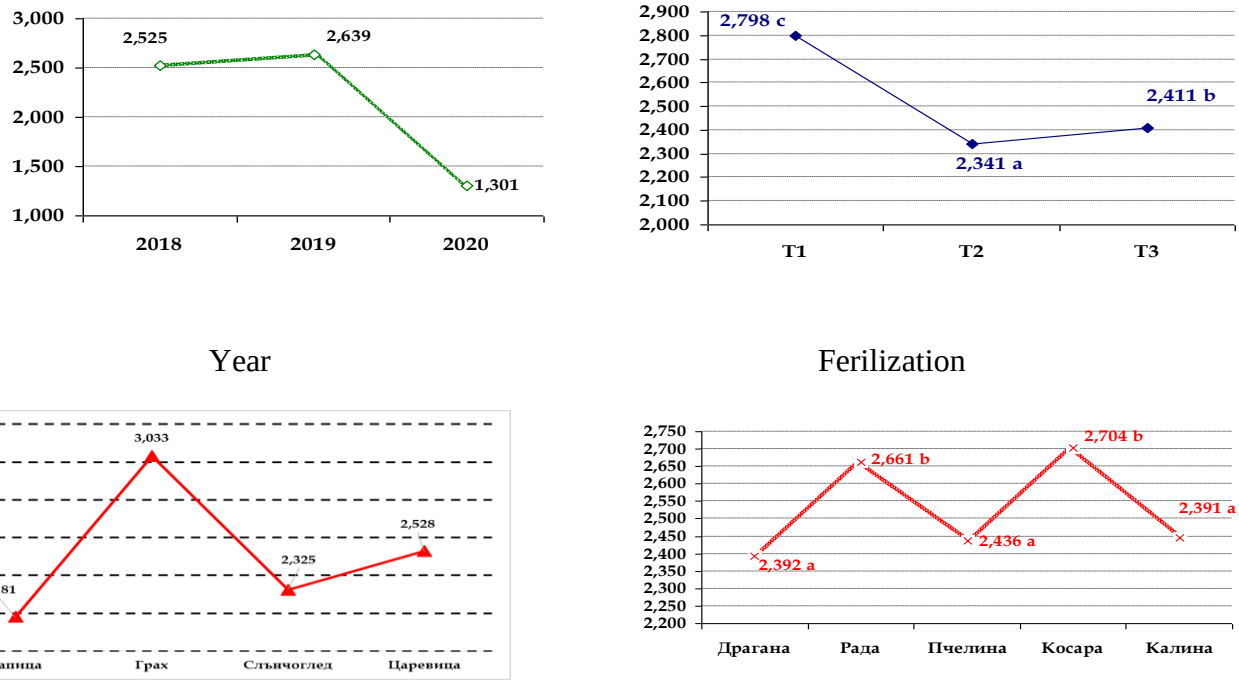


Figure 19. Changes in nitrogen uptake efficiency values, averaged for 2018-2020 depending on the tested factors in the experiment

The most unfavorable in this respect were the two oil seed previous crops, with the NUE values being the lowest after oilseed rape. Of all the tested factors in the experiment, the differentiation was lowest in the factor cultivar. Averaged for the period, the established differences between Dragana, Pchelina and Kalina were insignificant (2.391 kg.kg-1 - 2.436 kg.kg-1). The varieties Kosara and Rada were had significantly higher efficiency of nitrogen uptake.

4.3. Nutrients uptake for 100 kg of grain and the respective non-profitable part of the production

Under TOP, averaged for the period, total nitrogen uptake varied from 1.30 kg to 2.76 kg per 100 kg of grain together with its respective straw. With this method of production, the role of the variety for the uptake of nitrogen in grain was crucial (23.56%), and for NSC - the year (65.77%). Averaged for the period 2018-2020, the total nitrogen uptake was most strongly influenced by the meteorological factor (37.71%). The next most influential factors were the cultivar (17.70%) and the previous crop (11.07%). The full interaction between the tested factors under TOP had the highest average strength of effect on the values of the index -11.37%. The effect of the interaction year x cultivar on the values for the nitrogen uptake was also strongly expressed. The same was the case with grain – 13.12%, for NSC – 9.30% and for the total expense – 9.61%. These results show that growing wheat in a 4-field crop rotation requires very careful choice of a cultivar.

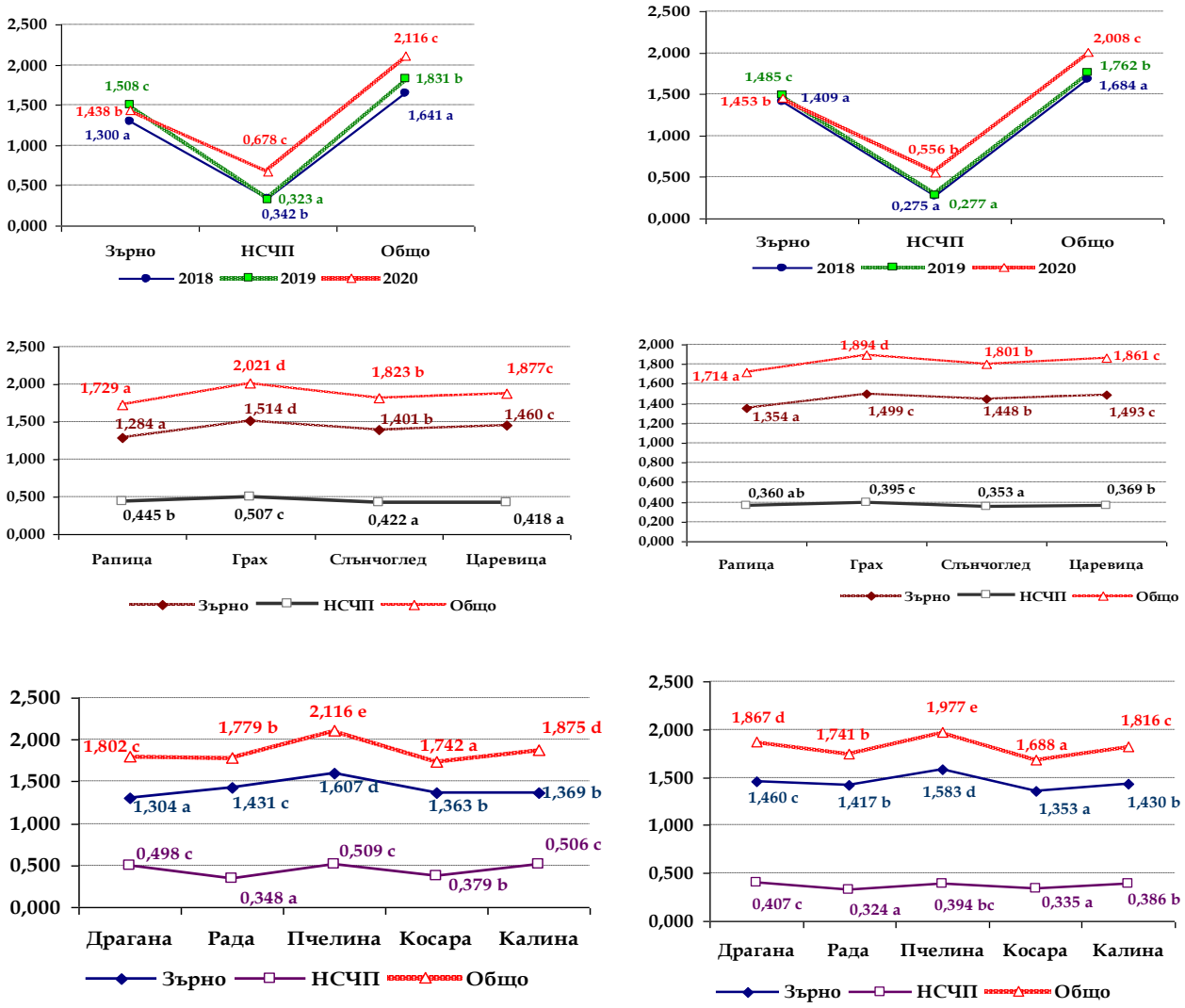
Conventional wheat production is characterized by great dynamics in the values of total nitrogen uptake depending on the nutritional regime of the soil as a result of mineral fertilization. In the check variant, the values ranged from 1.32 kg to 2.68 kg/100 kg and were close to those in the TOP, where there was also no fertilizer used. The increasing norms of nitrogen applied to the soil lead to an increase in the expense per production unit (T1 – from 1.79 to 3.26 kg/100 kg; T2 – from 1.28 to 2.50 kg/100 kg and for T3 – from 1.75 to 3.69 kg/100 kg). In addition to the total total expense, the expense for its components - grain and NSCLC - also increased. There was a tendency towards a determining role of the factor year on the values of this index (T0 – 33.50%; T1 – 19.31%; T2 – 27.59% and T3 – 31.15%). In the control variant and with the low nitrogen norm, the factor cultivar was second in importance. When using the optimal and high nitrogen norm, the influence of the factor previous crop exceeded that of the factor cultivar. From the combined interactions of the previous crops, that of year x previous crop and year x cultivar stood out the most, and in the check variant the latter had an effect of 18.12%, while in the interaction year x cultivar it is 4.17%. With increasing the norm of nitrogen fertilization, dynamics in the values of their strength of effect were established in cultivar Pchelina, but for each individual fertilizer norm, the strength of effect of the indicated interactions was similar.

The results obtained on average for the period showed that more significant differences in the expense per year were found in the values of NSC between the two options without mineral fertilization - TOP and T0 (Fig. 20). The unfavorable conditions of 2020 contributde to a higher total nitrogen uptake for the formation of the a production unit, which was especially evident in NSC.

The previous crops also havd a significant influence on the total uptake of nitrogen, as well as on its components. In TOP after previous crop pea, the cost for the production of 100 kg of grain together with its respective NSCHP was higher compared to that found in CP-T0. A similar tendency was found for the other previous crops.

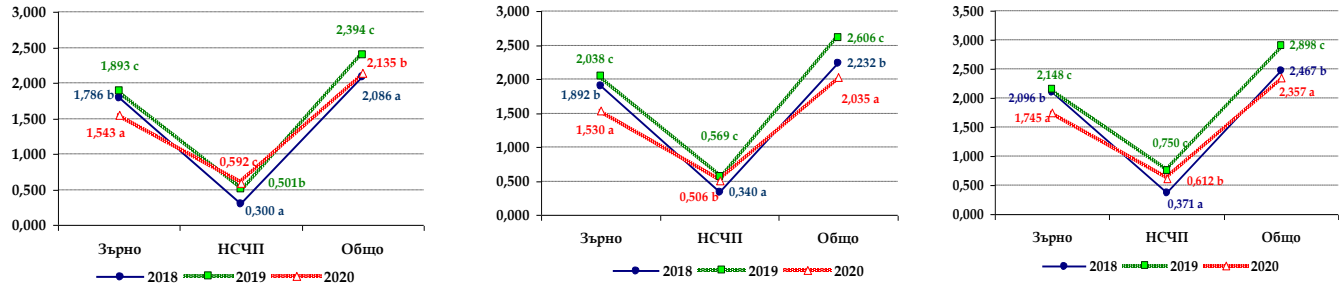
The most significant differences between the two variants without introduction of mineral fertilizers were established for the consumption of NSC, respective to the consumption of 100 kg of grain. Under TOP it was 21.00% higher compared to the average values under CP-T0.

The applied mineral fertilization under CP lead to a gradual increase in the expense in components with an increase in the nitrogen expense - from 1,818 kg (T0) to 2,574 kg (T3) total expense per 100 kg of grain (Fig. 21). Conventional wheat production, according to the values of this index, was ahead of TOP. The total uptake was respectively from 1,863 kg (TOP) to 2,222 kg (CP), which is an increase of 19.29%. With regard to the uptake of grain alone, the increase was by 23.78% (from 1.415 kg to 1.751 kg), and for NSC - by 5.03% (0.448 kg to 0.471 kg).



TOP **CP - T_0**

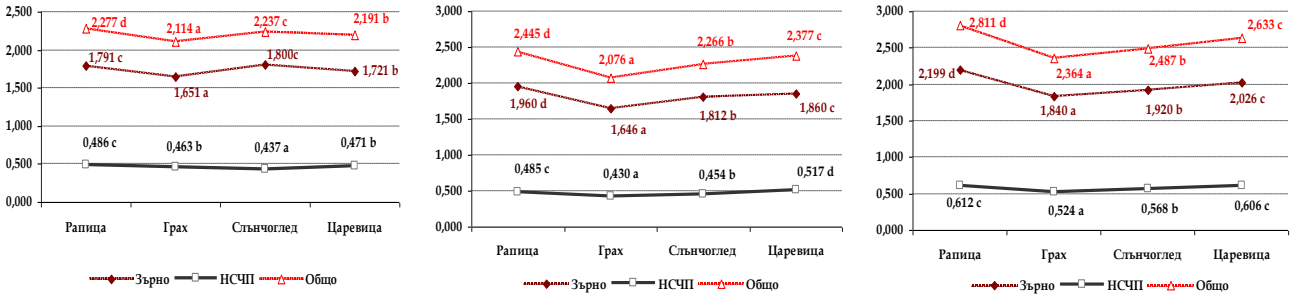
Figure 20. Nitrogen uptake for the formation of 100 kg of grain, its respective non-economic part in the variants with natural fertility (TOP and CP-T_0), kg



T₁ **T₂** **T₃**

Figure 21. Nitrogen uptake for the formation of 100 kg of grain, its respective non-economic part in the variants with increasing norms of nitrogen fertilization depending on the year.

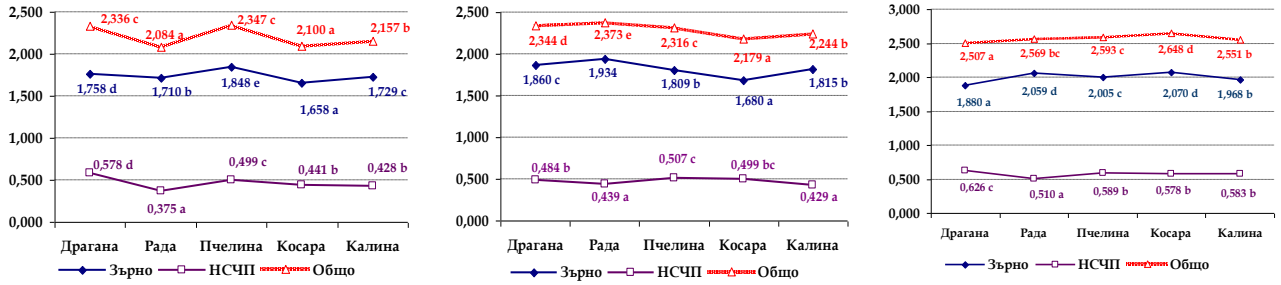
If we take previous crop pea as a standard, the total expense for the formation of 100 kg of grain together with NSC at all nitrogen norms was the highest after after previous crop oilseed rape (Fig. 22). This excess was respectively at T_1 - by 7.71%, T_2 - by 17.77% and at T_3 - by 18.91%. The same tendency was also observed in in previous crop grain maize, but only at the optimal and high nitrogen norms. Averaged for the varieties tested, the values for nitrogen uptake were the lowest when growing wheat after sunflower.



T₁ **T₂** **T₃**

Figure 22. Nitrogen uptake for the formation of 100 kg of grain, its respective non-economic part in the variants with increasing norms of nitrogen fertilization depending on the previous crop.

The reaction of the varieties to the conditions of the experiment showed that under TOP variety Pchelina was with the highest expense for the formation of a production unit (Fig. 23). If we accept variety Rada as a standard, we see that Pchelina exceeded it in terms of this index. This excess was respectively - by 18.94% (at TOP), by 13.56% (CP-T_0), by 12.62% (CP-T_1). The further increase of the nitrogen norm (CP-T_2) according to this index - uptake per 100 kg of grain, leaves all varieties after the variety Rada. Mineral fertilization with the highest nitrogen norm ($N_{18}P_6K_6$) differentiated the varieties according to the values of the index, variety Kosara being with the highest uptake, followed by Rada and all others.



T1 **T2** **T3**

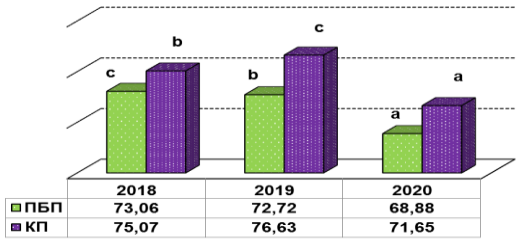
Figure 23. Nitrogen uptake for the formation of 100 kg of grain, its respective non-economic part in the variants with increasing norms of nitrogen fertilization depending on the cultivar

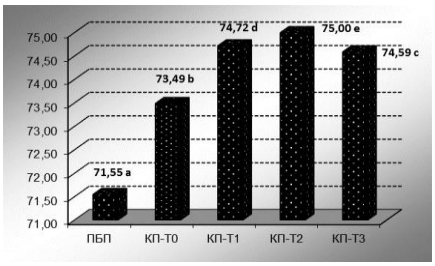
4.4. Effect of the tested systems of agricultural production on the qualitative characteristics of the grain

4.4.1. Effect of the tested systems of agricultural production on the physical characteristics of the grain

4.4.1.1. Test weight

For growing under the conditions of TOP, the highest average values of this index were established in 2018 - 73.06 kg (Fig. 24). Similar to yield, 2020 was also unfavorable for the values of this index. The test weight of the obtained grain was 94.28% of that established in 2018. In fact, this was the indicator most strongly influenced by the complex interaction between the main meteorological components and the variety.





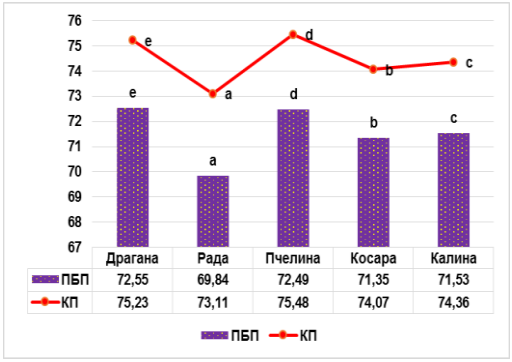
Depending on the year Depending on the nutrition regime

Figure 24. Testweight of wheat depending on the years of study and the levels of the nutrition in transition to organic and conventional production, kg/100 l

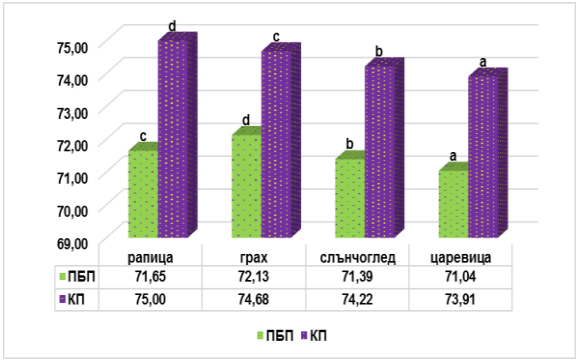
In the case of conventional production, again the lowest average values were obtained in 2020. However, they exceeded the ones obtained under TOP by 4.02%. The most suitable for the index were the conditions of 2019, when, on average, for the conditions of the conventional part of the experiment, 76.63 kg of grain per test weight was obtained, and the excess compared to TOP was 5.38%. Regardless of the significant dynamics in the values of the index depending on the conditions during the years of research, the cultivation of wheat under CP lead to obtaining 4.05% heavier grain compared to cultivation under the conditions of TOP. Mineral fertilization, although not having such a great effect, provoked an increase in its values, the maximum being reached at a ratio of N:P:K=2:1:1 (N12P6K6), where the average value of the index was 75.00 kg. A further increase in the norms of nitrogen fertilization lead to a decrease in the values of the index. The

reaction of the varieties grown in the check variant of CP distinguished them by 1.94 points higher test weight compared to the obtained average values under TOP.

The experiment also showed the much higher significance of the factor genotype for the test weight values compared to mineral fertilization (Fig. 25). Cultivars Dragana and Pchelina retain their leading positions under both methods of agricultural production, while cultivar Rada variety was characterized by the lowest values of the index. Regardless of the fact that cultivar Rada had the lowest average values per testweight, this variety increased the values of the index to a greater extent (by 3.27 points) at CP compared to TOP. Averaged for the varietal structure chosen in this study, CP lead to obtaining grain with 2.90 points higher test weigh compared to TOP.



Cultivar



Previous crop

Figure 25. Test weigh of wheat depending on the type of cultivar and previous crop in transition to organic production and under conventional production, kg/100 l

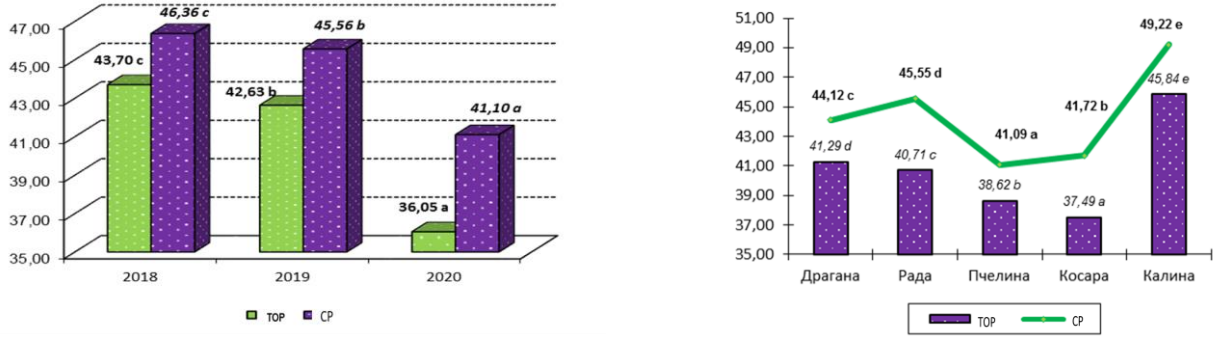
It was established that the role of the tested previous crops on the test weight of the grain had a significant effect, but with a lower strength under both ways of wheat production. Regardless of this fact, the complex of tested factors had a positive and significant effect on the values of grain. Under both methods of cultivation, wheat had lower test weight when grown after sunflower and especially after maize.

Undoubtedly, after previous crop pea, the conditions for the development and nutrition of the crop were much better compared to the other previous crops. This previous crop under TOP is the best option for obtaining a heavier grain, followed by the previous crop oilseed rape. Under conventional production, oilseed rape was the best previous crop, after which the obtained grain had the highest values of test weight compared to the other previous crops.

4.4.1.2. Thousand kernel weight

Absolute weight is the weight of 1000 clean, air-dried seeds, in grams. It is an important quality index that determines the suitability of the wheat grain as seed material and expresses its size and protection.

Under TOP, the complex of meteorological conditions during the years of study were of primary importance (Fig. 26). As for the other indices, the obtained values for grain size were the highest in 2018. There was a drastic decrease in the average values of the uindex in 2020 - by 7.65 g. Against this background, wheat under TOP had a significantly larger grain - on average by 3.55 g (8.70%), averaged for 2019 and 2020. The conventional wheat production system under the extremely unfavorable conditions of 2020 contributed to an increase in grain size by 5.05 g (14.01%) compared to PDB.

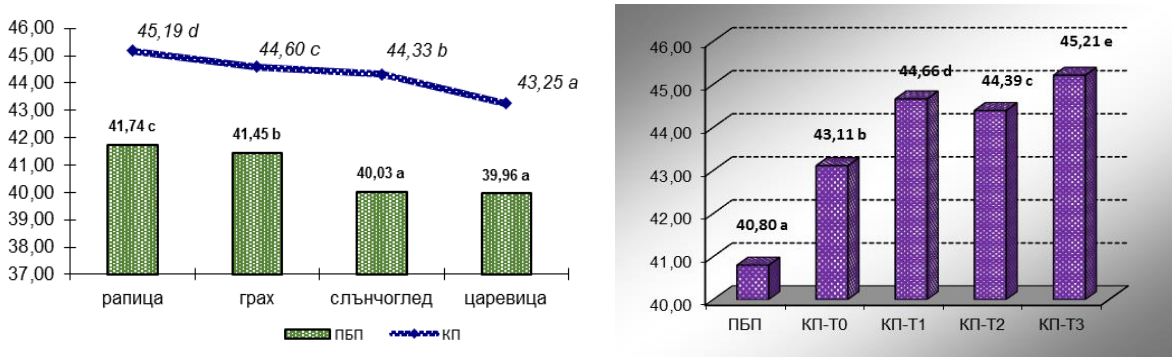


Years of research Cultivar

Figure 26. 1000 kernel weight depending on the years of study and the type of variety in transition to organic production and under conventional production, averaged for the studied period, g

As genetically conditioned, the role of the variety has a determining effect on the values of TKW at CP. The differentiation in the values of this index depending on the characteristics of the variety was very well expressed under both methods of crop production. Cultivar Kalina had the largest grain, regardless of the method of production. Cultivars Pchelina and Kossara ranked last in terms of values of this index. The amplitude of variation in the values of TKW depending on the cultivation methods was the lowest in cultivar - 2.47g (from 38.62 g for TOP to 41.09 g for CP). The agronomy practices used in the investigated production methods were the basis of the greatest variations in the values of the index in cultivars Rada (4.84 g) and Kossara (4.23 g).

Under CP, the differentiation in grain size depending on the type of previous crop was low (Fig. 27), being from 39.96 g (maize) to 41.74 g (oilseed rape). Growing of of wheat under CP had a significant positive effect on the size of the grain. The average increase was 3.55 g and affected the cultivation after all previous crops, being most pronounced in the variants with previous crop sunflower.



Previous crop Level of nutrition regime

Figure 27. Thousand kernel weight depending on the previous crop and the levels of nutrition regime in transition to organic and under conventional production, g

In general, the grain of the varieties grown after oilseed rape was with the highest TKW values. The tendency towards decrease in size of the grain depending on the type of the previous crop in the direction of maize was present under both methods of production.

4.4.2. Characterization of the parameters of the qualitative parameters of flour, dough and bread of the tested varieties grown in transition to organic and conventional systems of agricultural production.

The meteorological conditions during the years of investigation had a strong influence on the dynamics in the values of the studied set of characteristics for the quality of wheat, averaged for the conditions of the experiment (Fig. 28). It is an indisputable fact that 2020, saturated with unfavorable conditions, had a strongly expressed negative influence on the quality of flour and dough. Some of the indixes were several times lower than the values obtained for 2018 and 2019 (RT and ST, min). Protein yield was about 1.5 times lower than in 2018 and 2019, and the softening degree (GO) was 87.42% higher than that determined in 2019. These facts allow defining the conditions during the wheat growing season of 2019 as the most favorable for maximal expression of the potential of wheat in terms of a wide range of quality indices, averaged for the experiment.

The levels of soil nutrition under both systems of agricultural production were a powerful factor for differentiation and increasing the values of the tested quality indices. The under TOP had higher values of sedimentation and wet gluten yield compared to the check variant under CP (T0). Increasing rates of nitrogen fertilization together with increasing the content and yield of protein lead to an increase in ST (1.71 min - TOP to 5.79 min CP-T3); ChKF f.e. (21.15 min - TOP to 68.76 min CP-T3); Sed. (29.08 - TOP to 51.14 min CP-T3); DMG (15.70 - TOP d28.93 min CP-T3), etc. Nitrogen fertilization, however, also lead to an increase in the softening degree values (from 98.72 to 141.43).

The tested varieties had clearly differentiated values of their quality indices, averaged for the experiment. The obtained results showed that in the group of tested varieties Pchelina had the highest protein content (10.09%), ST (4.67 min), Sed. (57.15%) and wet gluten yield (24.50). This variety also had the lowest values of GO. According to the CCF f.e. the variety was slightly inferior to cultivar Dragana, and in terms of protein yield it was practically equal to cultivars Dragana and Kossara. Cultivar Rada (57.87 kg/dka) was definitely the best according to this index (DP).

Cultivars Kossara and Kalina, according to all qualitative indices studied, ranked last after cultivars Pchelina, Rada and Dragana.

Averaged for 2018-2020, maize as a previous crop contributed to increasing the content of DMG, Sed., CHKF f.e., ST min. Together with oilseed rape, these two previous crops contributed to grain with higher protein content. The highest yield of protein was obtained after previous crop pea.

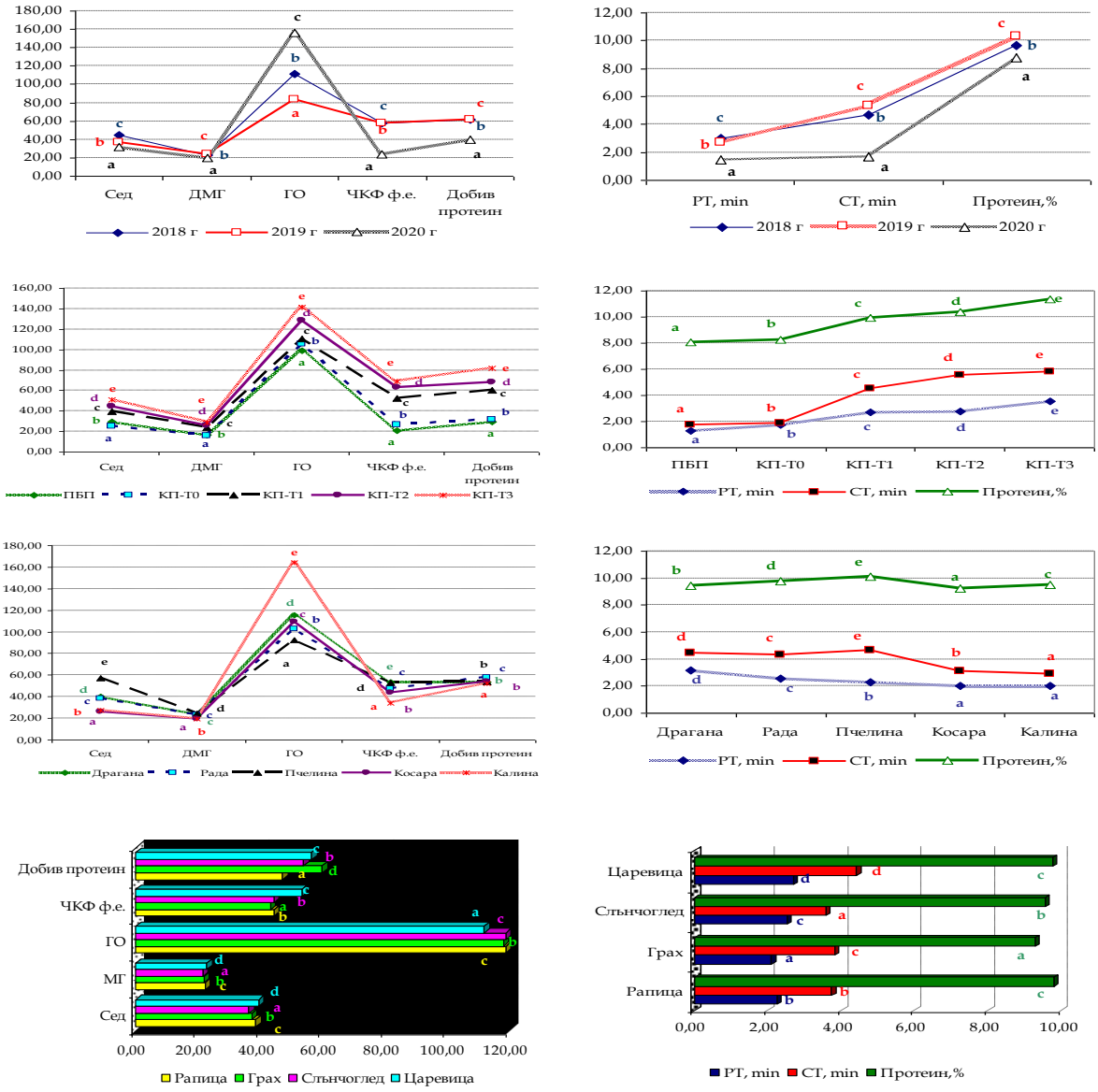


Figure 2. Effect of the agronomy factors in the experiment on the qualitative characteristics of flour and dough under the tested agricultural production systems, averaged for 2018-2020

The volume of bread was also significantly affected by the tested factors (Fig. 29). The average values in 2018 and 2019 exceed those obtained in 2020 by 25.47% and 26.69%, respectively.The average values of this index for the duration of the experiment were the highest for Rada and Dragana, followed by Pchelina. As can be seen from the obtained quality results, cultivar Kalina ranked last.

The values of the studied qualitative characteristics when growing wheat under TOP conceded to those obtained under CP. Averaged for the tested nitrogen standards, CP lead to an increase in protein content by 30.81%; protein yield - by 136.34%; dough stability - by 209.55%; pharinographic value - with 189.76%; stretchability of the dough - by 135.70%; wet gluten yield -

with 59.36%; The sedimentation value of the flour - by 54.47% and the Degree of relaxation of the dough - by 28.35%, compared to the values obtained when growing under TOP. Averaged for the period, the wheat grown under TOP by sedimentation and DMG exceeded the unfertilized check variant under CP, respectively, by 12.83% and 3.86%. For the rest of the quality characteristics, under the conditions without the introduction of nutrients, the advantage of CP over TOP was from 2.35% (protein %) to 35.43% (dough stability).

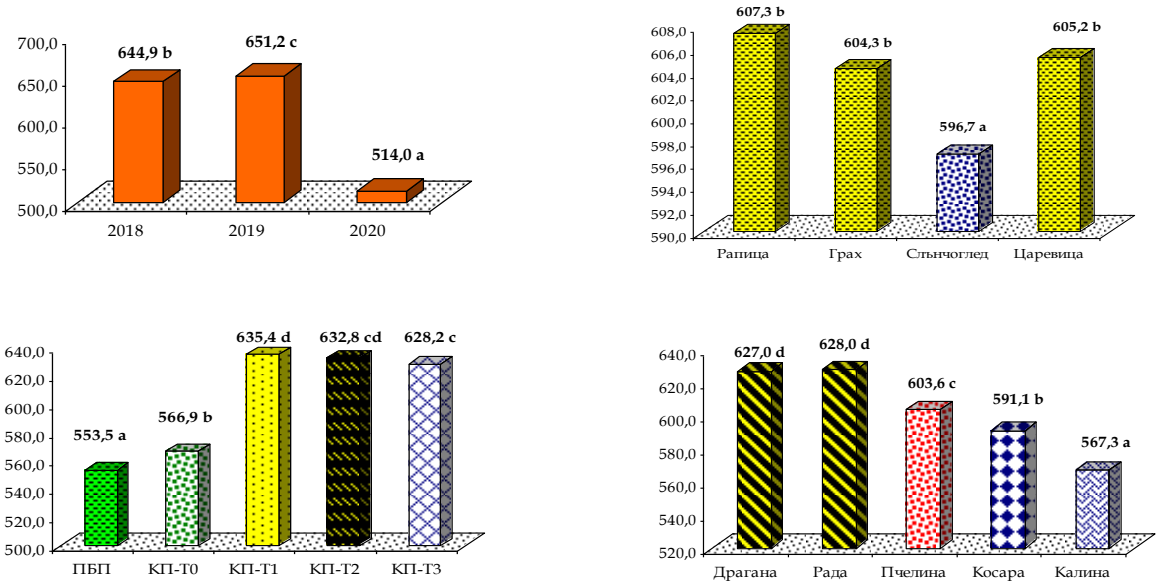


Figure 3. Effect of the agronomy factors of the experiment on the volume of bread under the tested agricultural production systems, averaged for 2018-2020

4.5. Correlation between the tested indices of productivity and quality with the efficiency of 1 kg nitrogen under conventional production of common winter wheat cultivars

The correlation analysis is an important statistical method that examines the relationship between two or more variables. It allows to understand how whether changes in one variable are related to changes in another, and to what extent. Through correlation analysis, we can measure the degree of relationship between two variables using a correlation coefficient. This coefficient can take values between -1 and 1.

In the case of conventional production, the correlation analysis made between the nitrogen concentration of the individual organs and the obtained yield revealed the strongest correlation between the leaves (0.650**) and the grain (0.590**) (Fig. 30). It is noticeable that nitrogen uptake by leaves (-0.240*) is in a low negative correlation with grain yield. On the other hand, yield formed a strong correlation with stems (0.580**) and grain (0.700**) in nitrogen uptake. This also contributed to its stronger correlation with total biomass (0.720**) and nitrogen uptak per 100 kg of grain (0.590**).

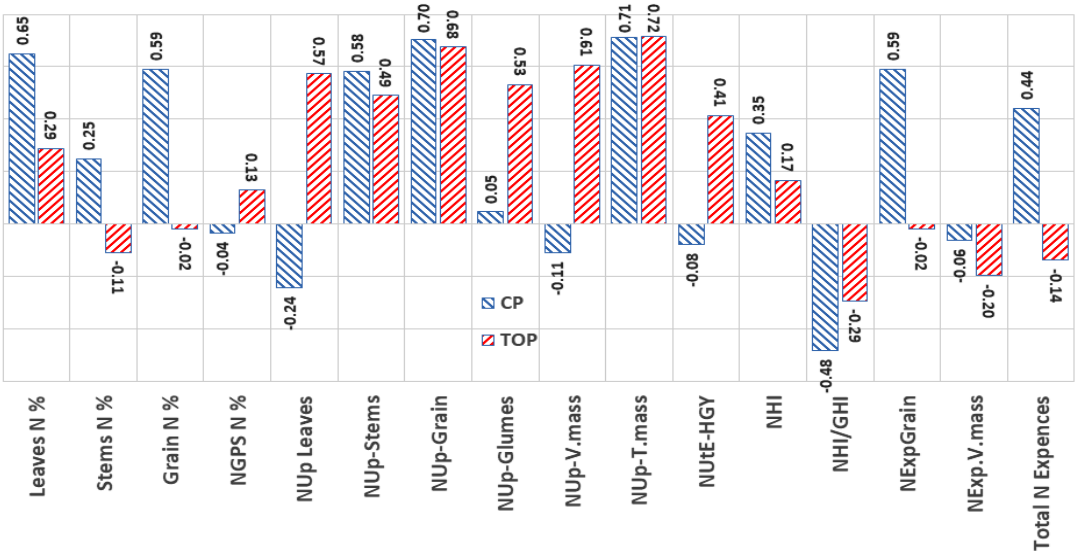


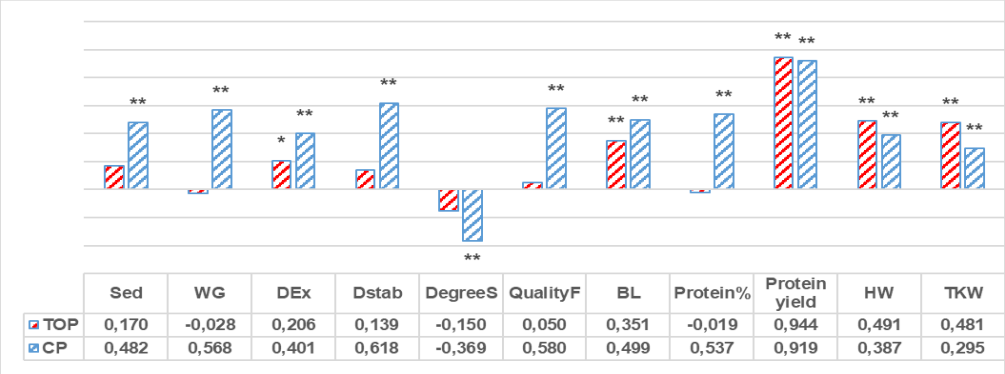
Figure 30. Correlations between the yield and the tested indices in the transition to organic (TOP) and conventional production (CP), averaged over the studied period.

In transition to organic production, the correlations between nitrogen content in wheat organs was insignificant and lead to low correlation with grain yield (0.290). In the rest of the organs, the dispersion was high and no correlations were established in Pchelina. In contrast to conventional production, positive correlations of grain yield with nitrogen uptake were observed in all vegetative organs of wheat, the highest correlation being with total biomass (0.720**). The content per 100 kg with the respective production had no correlation with the grain yield.

Correlations of the yield with the baking and physical properties of the grain were significantly high depending on the system of agricultural production (Fig. 31). For protein yield, there was a high positive correlation for both organic and conventional cultivation, 0.944** and 0.919**, respectively.

This indicates that higher protein yield is directly related to higher grain yield, regardless of the cultivation method. In the transition to conventional production, a moderate positive correlation of yield with test weight (0.491**) and 1000 kernel weight (0.481**) was observed. Under the conditions of conventional production, a positive correlation with the yield of common winter wheat was observed for all indices, except for degree of softening of dough, where a negative correlation was found for both systems of agricultural production, respectively -0.369** and -0.150.

Correlations between grain yield and the parameters of nitrogen metabolism are of particular importance for optimizing agricultural production practices (Fig. 32). Observations show that low and high fertilization rates have a greater correlation between yield and agronomic effect (0.689**, 0.474** and 0.568**). The tendency is similar for the efficient use of nitrogen too, the low rate of fertilization showing a high positive correlation with grain yield (0.718**). The positive correlation with partial nitrogen productivity indicates that low fertilization is associated with higher yield (0.650**).



	Sed	WG	DEx	Dstab	DegreeS	QualityF	BL	Protein%	Protein yield	HW	TKW
TOP	0,170	-0,028	0,206	0,139	-0,150	0,050	0,351	-0,019	0,944	0,491	0,481
CP	0,482	0,568	0,401	0,618	-0,369	0,580	0,499	0,537	0,919	0,387	0,295

Figure 31. Correlations of the yield with the baking and physical properties of grain depending on the system of agricultural production, averaged for the period of study.

Also, the positive correlations between yield and nitrogen utilization efficiency (0.632**, 0.509** and 0.102) highlight the possibility of improving plant nitrogen allocation at low fertilization norms. Despite the benefits of low fertilization, it is important to consider the needs of common winter wheat and implement a balanced approach to optimize production.

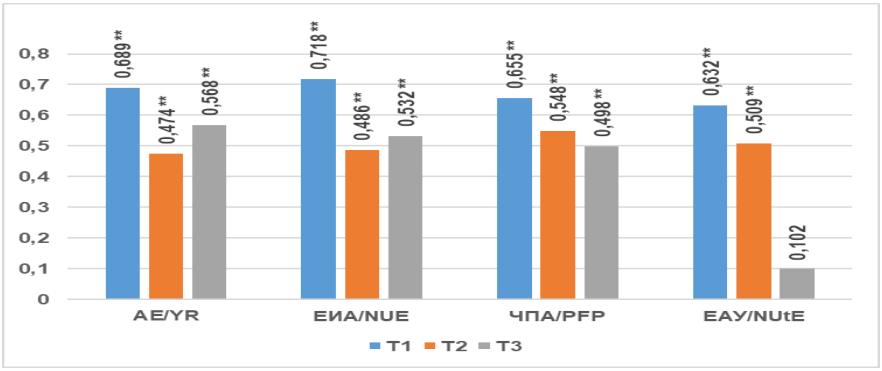


Figure 32. Correlations between yield and parameters of nitrogen metabolism in conventional production by fertilization levels.

CONCLUSIONS

1. In transition to organic production, the decisive factors for wheat productivity were the type of previous crop and the conditions for development of the crop of the year. The higher productivity of cultivars Kosara, Rada and Kalina was an advantageous prerequisite for their organic production. The conventional way of growing wheat exceeded by yield the wheat growin under transition to organic production with 64.38 % (2018-2020), and in the year with unfavorable conditions (2020) – with over 80 %.
2. The harvest indices (from total biomass and spike) under conventional production exceeded the indices determined under transition to organic production with 6.74 % and 3.56 %, respectively. Under the conditions of 2018, the combined interaction between the cultivar and the previous crop was crucial for both indices.
3. The conventional technology of production ensured higher concentration of nitrogen in comparison to transition to organc production. This was also valid for nitrogen uptake in the plant organs of wheat. The excess amount in grain was 111.8 %, in the non-economic part of the produce it was 90.8 %, and in the total shoot biomass formed - 102. 49 %. The increasing norms of nitrogen fertilization reduced the efficiency of nitrogen utilization based on 1 kg applied nitrogen. Cultivars Kosara and Rada were characterized by higher ability for nitrogen untilization, similar effect being determined after previous crop pea, as compared to the other previous crops.
4. The harvest index of nitrogen, as a part of the nitrogen metabolism, decreased from 80.19% (in T_0) to 77.69% (in T_3). The dynamics of the nitrogen index of grain in spike varied from 92.15 % to 92.57 % and was not significantly influenced by the increasing norms of mineral fertilization.
5. The use of the low nitrogen norm in conventional production was characterized by the highest amounts of reutilized nitrogen (45.07 kg.kg-1). The increasing levels of nitrogen fertilization sharply decreased the values characterizing the efficiency of nitrogen utilization; they decreased with an average of 34.85 kg.kg-1 at N18P6K6.
6. The previous crop and the mineral fertilization were decisive for the values of the agronomy effect. The mean value of the index was highest at fertilization with N18P6K6, cultivars Rada and Dragana reaching the highest mean values. Maize as previous crop had the highest contribution to these results.
7. The increasing fertilization norms decreased the partial nitrogen productivity in all years of the investigation. During the entire period of the study, cultivar Rada was with the highest values of this index - 85.60 kg. Cultivars Rada and Kosara were with the highest efficiency of nitrogen urilization. The values of the index were highest at fertilization with N6P6K6 (47 % from the total variation). This was also valid for maize as a previous crop (30 % from the total variation).

8. Conventional production lead to higher expense of nitrogen for formation of a production unit in comparison to transition to organic production with an average of 20 %. The values of this parameter depended on the level of nutrition regime of soil. Regardless of the way of growing wheat, the total expense of nitrogen for formation of 100 kg grain was highest after previous crop oilseed rape. Cultivar Pchelina formed 100 kg grain with higher expense of nitrogen in comparison to the other varieties. When optimal nitrogen fertilization norms were applied, cultivar Rada exceeded all other cultivars by nitrogen expense. The aggressive high nitrogen norms increased the expense for production unit most in cultivar Kosara.
9. In favorable years, the test weight of conventionally grown wheat exceeded the test weight obtained under transition to organic production with 5.38 %. Even under the extreme conditions of 2020, the conventional production demonstrated 4.02 % higher test weight in comparison to the transition to organic production. Cultivars Dragana and Pchelina showed higher values of test weight under both production systems. Thousand kernel weight was influenced most by the cultivar and the year. The conventional production ensured 8.70 % larger grain in comparison to the transition to organic production, cultivar Kalina being the leader under both systems of agricultural production.
10. The level of the nutrition regime of soil was clearly expressed in the formation of some of the qualitative indices (protein content, protein hyield and wet gluten). The degree of softening, protein content and pharinograph value coefficient under conventional growing of wheat were with higher values in comparison to the transition to organic production, with 22.98 %, 48.53 % and 103.85 %, respectively. For all of these indices, the conventional production in the check variant exceeded the values obtained in transition to organic production. The time for dough development and its stability under conventional production were longer with 110.63 % and 159.50 %, respectively, in comparison to the values determined under transition to organic production.
11. High positive correlations were determined of grain yield with protein yield, utilization of nitrogen from grain and total biomass, and the parameters of nitrogen metabolism at fertilization with $N_6P_6K_6$.

CONTRIBUTIONS

Theoretical

1. The changes in the dynamics of productivity, harvest indices and physical properties of grain of cultivars Dragana, Pchelina, Rada, Kossara and Kalina were investigated when grown under conventional and transition to organic production in the region of Dobrudzha.
2. The changes in the nitrogen concentration in the plant parts, the amount of nitrogen taken up in them, the harvest indices of nitrogen and the efficiency of nitrogen reutilization depending on the way of growing were evaluated.
3. The impact of the conventional production of wheat when applying increasing norms of nitrogen fertilization on the agronomy effect, the partial productivity and efficiency of nitrogen uptake and utilization was analyzed.

4. The effect of the different levels of nitrition regime of soil under both systems of agricultural production on the expense of nitrogen for formation of a production unit – the grain and the non-economic part of the produce of the studied cultivars, was characterized.
5. The effect of growing wheat in transition to organic production and under conventional production in a four-field crop rotation on the qualitative charateristics of flour, dough and bread was determined.
6. The correlations of productivity with the elements of nitrogen metabolism and the complex of qualitative characteristics of cultivars Dragana, Rada, Pchelina, Kossara and Kalina grown under conventional and in transition to organic production in the region of Dobrudzha were defined.

Applied

1. The agronomy practices of wheat cultivars Dragana, Rada, Pchelina, Kossara and Kalina when grown in transition to organic production and under traditional technology of production in a 4-field crop rotation were investigated.
2. The productivity potential of the cultivars and the expense for formatiuon of a production unit of grain and its non-economic part depending on the system of agricultural production were determined.
3. The main parameters of the nitrogen metabolism of the wheat cultivars under the conditions of Dobrudzha Agricultiral Institute – General Toshevo were evaluated.
4. The differences in the technological and baking properties of wheat under transition to organic and conventional production and variable meteorological conditions were determined.
5. The correlations of wheat productivity with the efficiency of nitrogen utilization and a complex of qualitative characteristics of the tested cultivars were established.

RESEARCH PUBLICATIONS IN RELATION TO THE PH.D. THESIS

A. Atanasov and M. Nankova (2023). Effect of main agronomy factors on the productivity and physical characteristics of common winter wheat (*Triticum aestivum* L.) grown under conventional and transitional-organic production. Bulgarian Journal of Crop Science, 60(5), 28-39.

A. Atanasov and M. Nankova, (2023). Agronomy effect depending on fertilization and previous crop in some common winter wheat cultivars (*Triticum aestivum* L.). In Journal of Mountain Agriculture on the Balkans 26(5), 196–212