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Changes in the nitrogen concentration in the organs of winter wheat varieties depending on the agricultural production system

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Abstract: Our aim was to characterize the changes in N% by organs of *Tr. aestivum* L. varieties, grown in transition to organic production (TOP) and conventional production (CP) during the period 2018-2020. The varieties - Dragana, Rada, Pchelina, Kocara and Kalina were grown after predecessors - winter oil rape, spring peas, sunflower and maize for grain. At CP, fertilization was on a PK background of $P_{60}K_{60}$ and after peas 0, 30, 60 and 90 kg N/ha, and after the others - 0, 60, 120 and 180 kg N/ha. In TOP, the leaves N% is influenced to the maximum extent by the type of the predecessor. In CP however, mineral fertilization has a determining role for the dynamics of N% in leaves, stems and grain, while that in the non-grain part of the spike - the conditions of the year. Cultivation after a maize predecessor results in higher N% remaining in the organs of the non-economic part of the crop. At CP, wheat forms a grain with the highest protein content after winter oil rape. As with TOP, the varieties Pchelina and Rada are distinguished by a higher protein content compared to the others. Nitrogen concentration in the organs of wheat grown under CP is higher than the same under TOP. Significant dynamics by year was found in the N% in the leaves, where the excess was respectively 87.85% (2018), 78.89% (2019) and 18.47 (2020). For grain, these values are respectively - 38.15%, 25.40% and 9.03%.

Key words: winter common wheat; N concentration by organs; transition to organic production (TOP); conventional production (CP)

INTRODUCTION

As is known, mineral fertilization is one of the main agrotechnical practices for increasing the productivity of crops in high-productivity agricultural systems. Currently, crop production with the application of mineral fertilization and chemical means of protection against weeds, diseases and enemies is adopted as a conventional production system. Mineral fertilization, particularly high nitrogen rates, is responsible for agriculture-related environmental pollution through leaching or denitrification (Le Gouis et al., 2000). Dealing with both economic and environmental problems is a difficult and responsible task for agricultural science and production.

The agrotechnical practices used in agricultural production such as tillage, crop residue management, nitrogen fertilization and crop rotation affect a number of biological and physical soil properties (Cosor, 2008; Nankova, 2012; Nankova & Filcheva, 2020). Developments on this issue show that the farming systems in the Dobrudja region also affect a number of quality characteristics of the produced products, which is inevitably related to the assimilation of nitrogen (Nankova & Gotzova, 1983; Nankova, 1985; Gospodinov & Nankova, 1988; Nankova, 1994; Nankova & Panayotov, 1995; Nankova & Stoyanova, 1995; Nankova et al., 1998; Atanasov et al., 2019; Doneva et al., 2020).

Limiting the risks of pollution in conventional agricultural production can be achieved by taking into account the characteristics of the relevant agro-ecological region and using varieties whose nitrogen metabolism has a high coefficient of useful action, i.e. maximum use of nitrogen. The selection of such varieties will contribute not only to increasing the effect of the application of all elements of agrotechnics. They are a prerequisite for reducing pollution risks and at the same time can provide optimal financial results for agricultural production. In both directions, nitrogen is a key element, from the application of which we require maximum yield and quality per unit of N input. To obtain high seed protein content and good quality, most of the absorbed nitrogen in the plants must be moved to the grain before maturity (Wang et al., 2012).

Asseng & Van Herwaarden (2003) found that in disturbed water availability, the frequent use of high nitrogen rates reduced the relative contribution of remobilization to grain yield, while in soils with greater water holding capacity, the same increased grain yield.

High-yielding wheat varieties need an increased and regular supply of nitrogen to develop a correspondingly high photosynthetic capacity and to maintain the correct concentration of nitrogen in the leaves so that CO_2 uptake is not affected when large amounts are needed for spike growth during grain filling period (Awaad & Deshesh, 2019). The study by Chu et al. (2023) showed that increasing the number of grains m^2 resulted in reduced grain protein concentrations because the assimilated and transported nitrogen in the ear was diluted with the formation of a larger number of grains.

The utilization of N by plants involves several processes, such as uptake, assimilation, translocation and remobilization (Masclaux-Daubresse et al., 2008). The same occur in plants regardless of the agricultural system of cultivation.

A detailed examination of the nitrogen metabolism processes occurring during vegetation period and especially in grain filling shows that they depend on the ongoing photosynthesis in the leaves and to some extent that in the spikes, as well as on the mobilization of stored water-soluble carbohydrates and nutrients and their forwarding from the stem to the growing grain (Bidinger et al., 1977; Kiniry, 1993; Schnyder, 1993; Blum et al., 1994).

The aim of the study was to characterize the changes in nitrogen concentration in the organs of 5 varieties of *Tr. aestivum* L., selected at the Dobrudzha Agricultural Institute - General Toshevo, grown in transition to organic production (TOP) and conventional production (CP) during the period 2018-2020.

MATERIALS AND METHODS

The investigation was conducted in the Experimental field of Haplic Chernozems (WRB-SR, 2006), during the period 2018-2020. Under a conventional production system (CP), the varieties Dragana, Rada, Pchelina, Kocara and Kalina were tested for 4 predecessor (winter oil rape, spring peas, sunflower and maize for grain).

This system included four levels of nutritional regime, which were tested, differentiated depending on the type of predecessor: after spring peas (0, 30, 60, and 90 kg N/ha), and after the others (0, 60, 120, and 180 kg N/ha), respectively T_0, T_1, T_2, and T_3. Nitrogen fertilization is on a phosphorous-potassium background of 60 kg P_2O_5 and 60 kg K_2O/ha.

After a buffer period of 2018, parallel studies began, in connection with the objectives of the research, on the reaction of the varieties when they were grown in transition to biological production (TOP) of the indicated predecessors against the background of the natural fertility of slightly leached chernozem.

Before wheat harvest, plots (50 x 50 cm) were taken from all tested variants in three replicates. Plants are divided by organs - leaves, stems, grain and non-grain part of spike (NGPS).

For clarification, NGPS includes glums and rachis as part of the total vegetative mass formed by the plants. After determining the amount of mass formed from them, they are prepared for analysis (grinding). The determination of nitrogen in the organs was carried out according to the Kjeldahl method. A Parnas-Wagner distillation apparatus was used for this purpose.

Data were subjected to one-way analyses of variance (ANOVA) using the general linear model in order to calculate the effects of N concentration by organs on the studied parameters. Means were compared by Waller-Duncan's HSD test. A bivariate Pearson correlation procedure was constructed to analyze the relationships between the measured traits. Statistical analyses were performed using the SPSS 18.0 statistical package (SPSS Inc., Chicago, IL, USA).

RESULTS AND DISCUSSIONS

As is known, organic farming is a production system that combines cultural, biological and agrotechnical practices that promote the circulation of resources and ecological balance. This agricultural production system is the basis of biodiversity conservation. The certification of the area for the actual organic/biological agricultural production is preceded by a 3-year period of bioconversion, includes the introduction of organic management and a prohibition on the use of mineral fertilizers and chemical plant protection agents (Wszelaki et al., 2009). In our experiment, these conditions were strictly observed during the period 2014-2017.

On the basis of the statistical processing of the data, the concentration of nitrogen in the organs of wheat is subjected to significant dynamics by years of research (Table 1). The main reason for this fact is the differences in meteorological aspect during the growing season of wheat in the years of study. Their detailed description is presented in a previous study by the authors (Atanasov & Nankova, 2023)

In the first two years, the role of the predecessor has a determining influence on the concentration of nitrogen in the wheat organs, while in 2020 - the genotypic factor has an extremely strong influence in all tested organs. The independent influence of the variety factor in all three years of research has the greatest effect on the nitrogen content in the stems. The transition to organic production resulted in a very pronounced combined variety x predecessor interaction in each of the years. Under conditions of extremely pronounced moisture deficit (2020), the strength of this interaction on nitrogen values is most strongly manifested in grain and NGPS.

Table 1. Variance analysis of factors interaction for nitrogen concentration according to the predecessor and cultivars under transition to organic production (TOP) by organs and years of investigation

Source	Dependent Variable	df	2018			2019			2020		
			F	Sig.	η %*	F	Sig.	η %*	F	Sig.	η %*
Predecessors (1)	Leaves	3	2114.40	0.000	73.55	1156.71	0.000	62.41	24.25	0.000	4.99
	Stems	3	109.93	0.000	43.55	175.44	0.000	23.53	10.01	0.000	2.50
	Grain	3	178.44	0.000	63.94	179.56	0.000	33.11	88.48	0.000	13.25
	NGPS	3	3040.23	0.000	76.65	82.79	0.000	21.40	17.58	0.000	4.92
Cultivars (2)	Leaves	3	167.58	0.000	7.89	256.60	0.000	18.47	257.74	0.000	72.06
	Stems	3	79.17	0.000	41.94	326.99	0.000	58.82	233.48	0.000	78.61
	Grain	3	54.04	0.000	25.82	76.76	0.000	18.88	378.92	0.000	75.61
	NGPS	3	240.07	0.000	8.05	94.13	0.000	32.47	129.53	0.000	47.11
1 x 2	Leaves	9	133.61	0.000	18.56	88.71	0.000	19.12	27.30	0.000	22.95
	Stems	9	8.84	0.000	14.52	32.38	0.000	17.65	18.74	0.000	18.89
	Grain	9	7.14	0.000	10.24	65.14	0.000	48.06	18.61	0.000	11.14
	NGPS	9	151.95	0.000	15.30	45.21	0.000	46.49	43.74	0.000	48.01

**η % - strength of factors effect*

In our experiment in connection with the purpose of research and based on the analysis of the variances of the factors and their interaction, we have established that the concentration of nitrogen in the organs of wheat in the final phase of its development in is subjected to statistically reliable dynamics during the years of research (Table 1). In the first two years, the role of the predecessor has a determining influence on the concentration of nitrogen in the wheat organs, while in 2020 - the genotypic factor has an extremely strong influence in all tested organs. The independent influence of the variety factor in all three years of research has the greatest effect on the nitrogen content in the stems. The transition to organic production resulted in a very pronounced combined variety x predecessor interaction in each of the years. Under conditions of extremely pronounced moisture deficit, the strength of this interaction on nitrogen values is most strongly manifested in grain and NGPS.

The concentration of nitrogen in the leaf mass of the cultivars grown in the TOP varied according to the kind of the predecessor in each of the years of the study (Figure 1).

Average for the tested predecessors in 2018 N% starts from 0.38% (Rada) and reaches 0.46% (Kalina). For this method of production, defi-

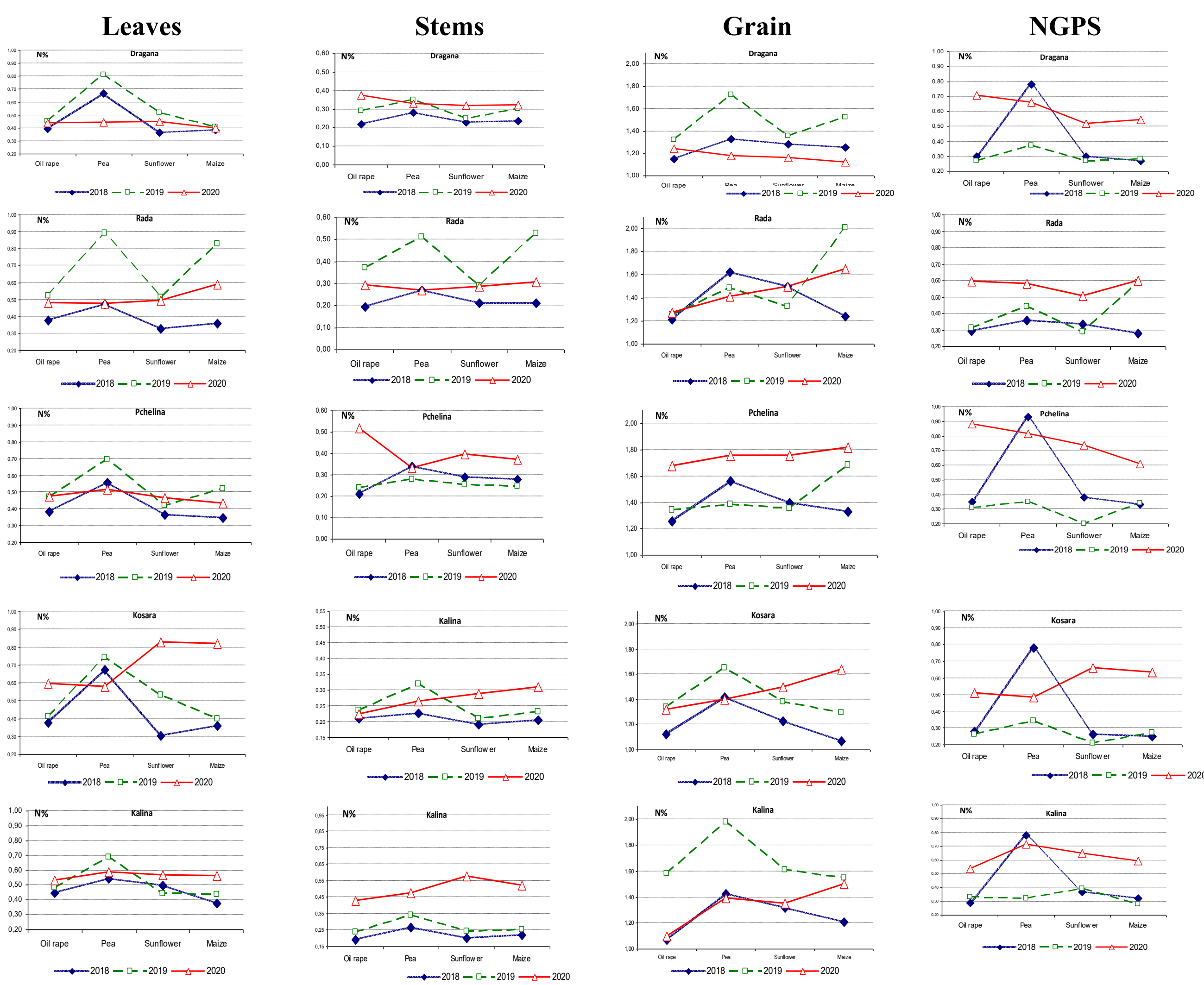

Figure 1. Dynamics of nitrogen concentration in wheat organs according to the predecessor and cultivars under transition to organic production by years of investigation, %

nitely the pea predecessor has the greatest contribution to the fact that the leaf mass at harvest remains with a higher concentration of nitrogen compared to that after the other predecessors. A similar trend was observed in the following years with the difference that the average concentration of nitrogen in the leaves was higher (2019 - 0.56% and 2020 - 0.54%) compared to 2018 (0.43%).

Unlike leaves, stems as an organ at maturity are characterized by lower nitrogen concentrations. By years of the study, the concentration of N% in the leaves was higher than that in the stems by 86.96% (2018); with 86.67% (2019) and with 50.00% (2020). Similar to leaves, N% in stems was also higher in 2019 and 2020 compared to 2018. There was a trend for more N remaining in stems after predecessor pea, but in all three years the differences between predecessors were reliable, but also -weakly expressed compared to the leaves. The stems of the Kalina variety are distinguished by a slight preponderance of N% in the stems compared to the other varieties. Conditions during the growing season of 2018/2019 are most favorable in terms of nitrogen accumulation in the grain. For TOP, pea was again the best predecessor. After it, wheat formed a grain with 9.42% higher nitrogen concentration than the average of the other three predecessors. The reaction of the varieties is well differentiated depending on the type of predecessor, with the formed grain having a lower concentration of nitrogen after oil rape and sunflower. Over the years, the varieties of Bee, followed by Rada, contain more nitrogen in their grain compared to the others. The nitrogen content of NGPS exceeded that of the stems and maintained the trends of the results obtained for the nitrogen content of the grain.

Based on the statistical analysis of the results obtained with the conventional method of production, including a wide range of nitrogen fertilizer rates, we establish a significant redistribution of the influence of each of the factors, as well as the interactions between them (Table 2).

Regardless of the dynamics in the main meteorological elements during the years of research, the statistical reliability of the nitrogen concentration data by organs is at the maximum level. In 2019 and 2020, the independent effect of mineral fertilization definitely has the strongest effect on the concentration of nitrogen in the leaves, and in 2018 - on that in the grain. The strength of the genetic factor in each of the years has the strongest influence on the concentration of nitrogen in the leaves and that of the stems in 2020. Meteorological conditions during the wheat growing season influence the strength of the interaction between the factors and the dynamics in the values of this strength by years. This fact is well expressed in the "predecessor" factor. The strength of the effect of this factor on N% in stems, grain and NGPS in 2019 and 2020 is inferior to that of the "variety" factor. The average values for the concentration of nitrogen in all organs of wheat show an increase in the direction of increasing the rate of nitrogen fertilization (Table 3). The differentiation between fertilizer options is very clear. Only the nitrogen content of the NGPS in 2020 according to the Waller-Duncan test in the variants T_2 and T_3 nitrogen concentrations showed signs of uniformity and also proved to be lower than the average values obtained when fertilizing with 60 kg N/ha at the ratio N:P:K=1:1:1. Throughout the study period, the nitrogen concentration in NGPS was higher than that found in the stems.

The reliability of the influence of the predecessors is clearly expressed within a given year without, however, fixing synchrony in the reaction between the individual organs of the wheat (Table 4). Only in 2018, when grown after rapeseed, in all examined organs, N% had lower values compared to the other predecessors. This fact was also observed in 2019 at N% in the grain when grown after peas. Predecessor maize for grain was characterized by higher leaf and stem nitrogen content in 2018 and 2019 and partly in NGPS. Definitely in 2019 wheat grain after maize predecessor has the highest concentration of nitrogen in the grain. In 2018, practically the same and lowest nitrogen concentration was found in the grain after the predecessors oil rape and peas. A similar response was found in NGPS in 2020 after the predecessors sunflower and maize.

The varieties included in the study are also characterized by significant dynamics in N%

Table 2. Variance analysis of factors interaction for nitrogen concentration according to the predecessor and cultivars under conventional production (CP) by organs and years of investigation

Source	Dependent Variable	df	2018			2019			2020		
			F	Sig.	η %*	F	Sig.	η %*	F	Sig.	η %*
Fertilization (1)	Leaves	3	10044.03	0.000	47.19	7567,99	0.000	58.39	353.22	0.000	31.84
	Stems	3	614.56	0.000	32.13	6512,75	0.000	57.33	302.76	0.000	11.68
	Grain	3	4454.35	0.000	67.99	2364,12	0.000	53.62	630.14	0.000	11.31
	NGPS	3	511.46	0.000	30.50	631,78	0.000	45.19	154.92	0.000	10.03
Predecessors (2)	Leaves	3	2220.97	0.000	10.44	515,52	0.000	3.98	81.44	0.000	7.33
	Stems	3	175.20	0.000	9.16	1039,19	0.000	9.16	423.83	0.000	16.34
	Grain	3	167.80	0.000	2.56	364,93	0.000	8.27	903.49	0.000	16.23
	NGPS	3	184.22	0.000	10.93	56,12	0.000	4.02	404.88	0.000	16.24
Cultivars (3)	Leaves	4	3577.43	0.000	22.41	733,83	0.000	7.55	259.45	0.000	31.19
	Stems	4	108.43	0.000	7.51	281,32	0.000	3.31	715.45	0.000	36.81
	Grain	4	520.03	0.000	10.59	6,61	0.000	0.20	138.05	0.000	3.31
	NGPS	4	101.99	0.000	813	4,79	0.002	0.46	41.73	0.000	3.63
1 x 2	Leaves	9	271.56	0.000	3.83	275,54	0.000	6.38	22.20	0.000	6.00
	Stems	9	50.36	0.000	7.96	245,26	0.000	6.48	86.95	0.000	10.07
	Grain	9	144.24	0.000	6.60	117,05	0.000	7.97	306.80	0.000	16.53
	NGPS	9	23.12	0.000	4.19	36,96	0.000	7.93	90.66	0.000	17.70
1 x 3	Leaves	12	344.43	0.000	6.47	351,64	0.000	10.85	8.90	0.000	3.21
	Stems	12	56.22	0.000	11.71	214,21	0.000	7.54	37.93	0.000	5.84
	Grain	12	27.40	0.000	1.67	110,01	0.000	9.98	531.47	0.000	38.18
	NGPS	12	55.35	0.000	13.21	63,27	0.000	18.11	39.83	0.000	10.39
2 x 3	Leaves	12	240.32	0.000	4.52	103,85	0.000	3.20	25.92	0.000	9.34
	Stems	12	27.14	0.000	5.71	137,59	0.000	4.85	58.16	0.000	8.96
	Grain	12	47.46	0.000	2.90	42,67	0.000	3.87	60.07	0.000	4.31
	NGPS	12	42.31	0.000	10.04	21,49	0.000	6.16	60.93	0.000	15.89
1 x 2 x 3	Leaves	36	91.44	0.000	5.16	104,24	0.000	9.65	10.27	0.000	11.10
	Stems	36	40.99	0.000	25.83	107,39	0.000	11.35	22.20	0.000	10.29
	Grain	36	41.91	0.000	7.68	59.10	0.000	1608	46.99	0.000	10.13
	NGPS	36	32.27	0.000	23.13	21.14	0.000	18.14	20.41	0.000	15.95

**η % - strength of factors effect*

Table 3. Dynamics of nitrogen concentration in wheat organs according to the fertilization norms under conventional production by years of investigation

Fert.	Leaves			Stems			Grain			NGPS		
	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020
T_0	0.419 a	0.423 a	0.507 a	0.231 a	0.245 a	0.337 a	1.409 a	1.485 a	1.455 a	0.316 a	0.335 a	0.544 a
T_1	0.800 b	0.922 b	0.629 b	0.270 b	0.435 b	0.356 b	1.786 b	1.893 b	1.545 b	0.342 b	0.529b	0.628 c
T_2	0.931 c	1.197 c	0.687 c	0.282 c	0.449 c	0.407 c	1.892 c	2.038 c	1.533 b	0.356 c	0.643 c	0.613 b
T_3	1.067 d	1.459 d	0.717 d	0.333 d	0.659 d	0.453 d	2.096 d	2.148 d	1.747 c	0.421 d	0.664d	0.608 b

by organs (Table 5). Thus, for example, the Kosara variety is distinguished by the highest concentration of nitrogen in the leaves and the lowest in the stems during the years of research. In the other varieties, the N% in these organs has been too different over the years.

The most cases of uniformity in the reaction of the varieties was found in N% in the grain. In 2018, Kosara and Kalina varieties have the lowest nitrogen content. In 2019, this fact applies to the Dragana, Rada and Pchelina varieties. This is the year in which the least pronounced differentiation was found in nitrogen values in the grain throughout the study period, while in 2020 the differences between varieties were fully expressed. NGPS also found significant similarities between cultivars in terms of N%, with its concentration being highest in 2020.

On average, for the years of the transition to organic production, for some statistical parameters, a significant scattering of the values for the nitrogen concentration in the wheat organs was found, which is an indication of non-uniformity of the sample data (Table 6). This most strongly applies to nitrogen concentration in NGPS,

Table 4. Dynamics of nitrogen concentration in wheat organs according to the predecessors under conventional production by years of investigation

Pred.	Leaves			Stems			Grain			NGPS		
	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020
Oil rape	0.621 a	1.025 c	0.697 d	0.248 a	0.403 b	0.478 d	1.750 a	1.946 c	1.785 d	0.326 a	0.527 b	0.688 c
Pea	0.876 c	0.855 a	0.614 b	0.287 c	0.385 a	0.379 c	1.762 a	1.725 a	1.494 b	0.391 d	0.494 a	0.578 b
Sunflower	0.802 b	0.986 b	0.594 a	0.281 b	0.466 c	0.341 a	1.874 c	1.914 b	1.450 a	0.355 b	0.548 c	0.563 a
Maize	0.918 d	1.135 d	0.634 c	0.301 d	0.534 d	0.356 b	1798 b	1.979 d	1.551 c	0.363 c	0.601 d	0.563 a

Table 5. Dynamics of nitrogen concentration in wheat organs according to the cultivars under conventional production by years of investigation

Cultivars	Leaves			Stems			Grain			NGPS		
	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020
Dragana	0.868 d	1.064 c	0.593 b	0.286 c	0.442 b	0.417 d	1.736 b	1.878 a	1.607 d	0.331 a	0.536 ab	0.611 b
Rada	0.625 a	0.796 a	0.585 b	0.261 a	0.416 a	0.318 b	1.902 c	1.878 a	1.563 b	0.361 c	0.520 a	0.570 a
Pchelina	0.651 b	1.095 d	0.557 a	0.310 d	0.454 c	0.407 c	1.928 d	1.879 a	1.629 e	0.392 d	0.547 b	0.616 b
Kosara	1.085 e	1.164 e	0.778 d	0.263 a	0.413 a	0.286 a	1.704 a	1.907 b	1.462 a	0.350 b	0.557 b	0.579 a
Kalina	0.791 c	0.884 b	0.661 c	0.275 b	0.510 d	0.513 e	1.708 a	1.913 b	1.588 c	0.359 c	0.553 b	0.613 b

Table 6. Statistical parameters of variation in the concentration of total nitrogen in the organs of wheat for the period 2018-2020 during the transition to organic production (Descriptive Statistics n=120)

Organs	Minimum	Maximum	Mean	Std. Deviation	CV%
Leaves	0.30	0.90	0.5076	0.13796	27.18
Stems	0.18	0.60	0.2978	0.09365	31.45
Grain	1.04	2.03	1.4158	0.21671	15.31
NGPS	0.19	0.94	0.4531	0.19253	42.49

Table 7. Statistical parameters of variation in the concentration of total nitrogen in wheat organs for the period 2018-2020 during conventional production, % (Descriptive Statistics n=480)

Organs	Minimum	Maximum	Mean	Std. Deviation	CV%
Leaves	0.21	2.15	0.8130	0.39376	2.06
Stems	0.14	1.20	0.3714	0.15702	2.37
Grain	0.90	2.80	1.7521	0.35056	5.00
NGPS	0.10	1.06	0.4997	0.16888	2.96

where the coefficient of variation is 42.49%, followed by that for stems - 31.45%.

The conventional method of wheat production on average for the period is distinguished by extremely low and slightly varying values of the coefficients of variation (Table 7).

The results obtained for the average values for the period of the study for N% in TOP show that 2019 provides better conditions for enriching the grain with nitrogen (Figure 2). In this year, N% in leaves is the highest and that in NGPS is the lowest. The first year of the study was distin-

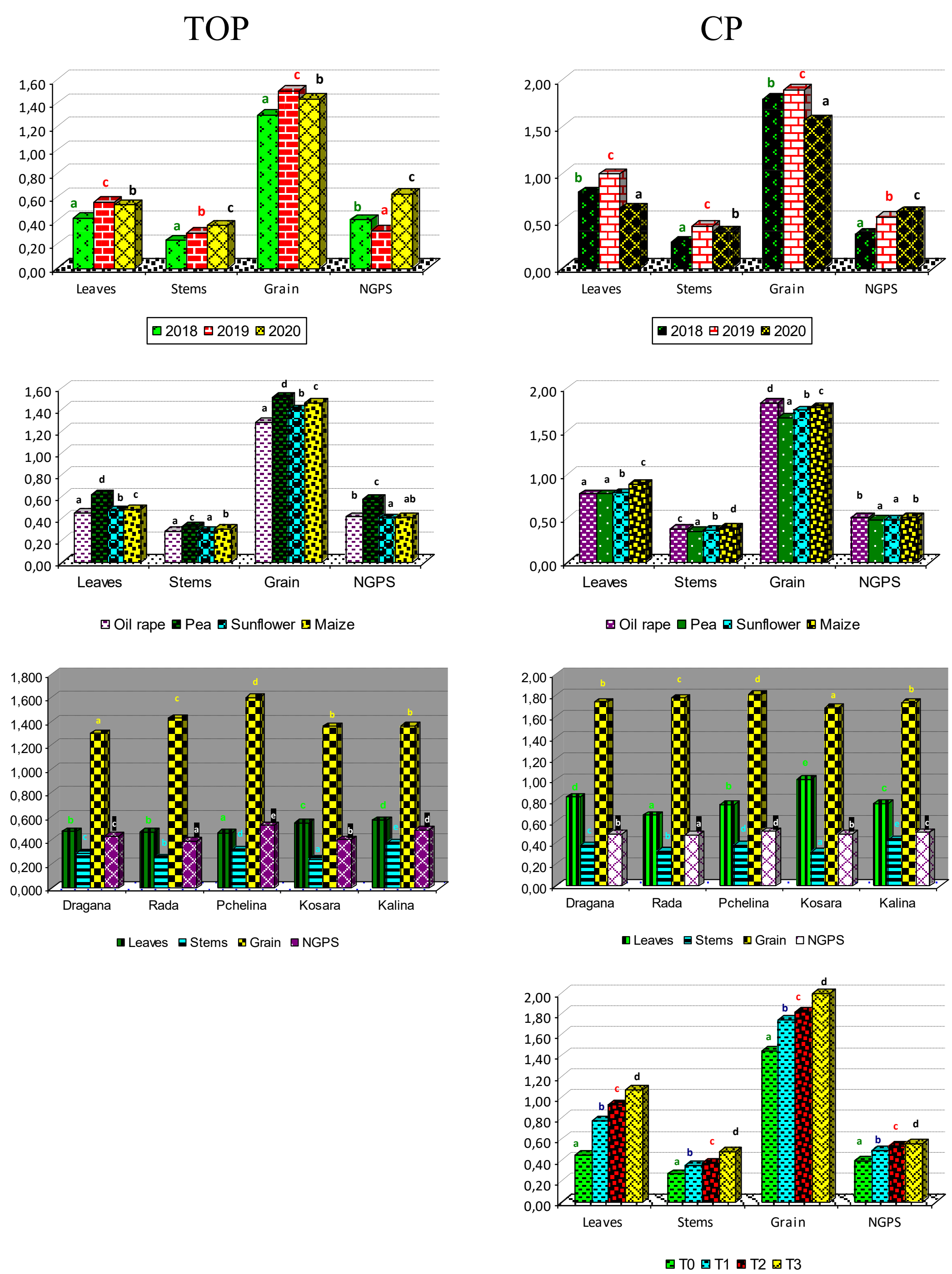

Figure 2. Average data for N% according to investigated factors at TOP and CP systems

guished by the lowest concentrations of nitrogen in leaves, stems and grain.

Against this background, after the cultivation of wheat after oil rape, except for N% in NGPS, the lowest concentrations of nitrogen were found. After the pea predecessor, the nitrogen content of all aboveground biomass organs was higher compared to the other predecessors. In this sense, according to the average values of N% in leaves, grain and NGPS are ranked in the following order: pea>maize>sunflower>oil rape. For nitrogen in the stems, the influence of oil rape and sunflower was roughly the same and resulted in the lowest N%. The selected variety composition is also arranged in different orders regarding the concentration of nitrogen in the individual organs. Under the conditions of TOP, the Pchelina variety is distinguished by the highest concentration of nitrogen in the grain, followed by the Rada variety. An interesting fact is that Pchelina variety remains with the highest nitrogen concentration in NGPS, while in Rada, that part of the vegetative mass closest to the grain has the lowest N%.

The Pchelina variety also has the lowest concentration of nitrogen in the leaves and is in 2nd position after the Kalina variety in terms of N% in the stems. It makes an impression that the Rada variety is characterized by relatively low concentrations of nitrogen in the organs of the vegetative mass, which is probably related to a better outflow of assimilates to the grain. The average concentrations of nitrogen in the grain of Kosara, Kalina and Dragana varieties are lower. The same were found to have a significantly higher nitrogen content in the leaves and partly in the other organs.

The obtained results when growing the varieties on average for the entire research period show that, similar to TOR and with the conventional method of production, wheat organs are distinguished by a greater concentration of nitrogen in 2019 compared to other years. Unlike TOP in conventional production, N% in grain and leaves was the lowest in 2020. In all three years of research, the concentration of nitrogen in the organs of wheat (leaves, stems and grain) grown under CP exceeded the same under TOP cultivation. This preponderance for leaves and grain is most significant in 2018 - with 87.85% and 38.15%, respectively (Table 8). The stems of the culture grown under CP in 2019 have the greatest preponderance over their content under TOP with 49.50%. For the same year, the concentration of nitrogen in NGPS exceeded that found in TOP - by 68.85%. Under the conditions of the 2020 harvest, the obtained average results for N% are the closest in values. The

Table 8. Comparison between the two wheat production systems regarding the average organ N% by years and for the whole period of study

Years	Production systems	Leaves	Stems	Grain	NGPS
2018	TOP	0.43	0.23	1.30	0.41
	CP	0.80	0.28	1.80	0.36
	% CP to TOP	187.85	119.23	138.15	87.14
2019	TOP	0.56	0.30	1.51	0.32
	CP	1.00	0.45	1.89	0.54
	% CP to TOP	178.89	149.50	125.40	168.85
2020	TOP	0.54	0.36	1.44	0.63
	CP	0.64	0.39	1.57	0.60
	% CP to TOP	118.47	107.48	109.03	95.37
2018-2020	TOP	0.51	0.30	1.42	0,.45
	CP	0.81	0.37	1.75	0.50
	% CP to TOP	160.14	124.61	123.75	110.22

conventional method of production still leads to a higher nitrogen content in the leaves, stems and grain - respectively by 18.47%, 7.48% and 9.03%. In 2018 and 2020, N% in NGPS under SR was below the average obtained under TOP cultivation system and was 87.14% and 95.37% of it, respectively.

Conventional production leads to a rather serious shift in the position of the tested predecessors with respect to N%. The grain is an organ that we pay more attention to. In our research, on average, N% is higher compared to TOP - by 23.24%, and on the other hand, it comes out on top in this indicator. According to their influence on the nitrogen content of the grain, the predecessors are arranged in the following order: oil rape> maize> sunflower> pea. NGPS and leaves are distinguished by a more pronounced differentiation in the N% values. In all the organs forming the vegetative mass, the highest values for N% are after maize and the lowest - after a pea predecessor.

The varietal response is also highly pronounced. It is natural that CP leads to an increase of N%. The reaction of the Dragana variety was most pronounced, which increased the concentration of nitrogen in the grain by 33.44% compared to TOP. It was found that the leaves of the Kosara and Dragana cultivars at the end of the growing season remained with a higher nitrogen content than the other cultivars. For the stems, this fact applies to Kalina and Pchelina varieties. This increase is the smallest for the Pchelina variety - by 12.69%. Regardless of this fact, the Pchelina variety in both production systems has the highest concentration of nitrogen in the grain.

The discussion of the obtained results once again confirms the fact that determination of the concentration of nitrogen is an indispensable condition for establishing the parameters of such important processes as the accumulation and redistribution of nitrogen, which determine the yield and quality (Gaju et al., 2011; Yoichiro, 2012). It is widely known that nitrogen accumulated before flowering provides the main source of grain. In wheat, about 50–95% of grain N at harvest comes from remobilization of N stored in vegetative mass and roots before flowering (Kichey et al., 2007). Leaves and stems are the most important sources of N for grain (Critchley, 2001), while roots and NGPS contribute about 10 and 15%, respectively (Dalling, 1985).

Since there are two variants in the experiment in which mineral fertilizers are not imported - the transition to biological production and the control option for conventional production, we also made a comparison between the obtained average values for the nitrogen concentration for the period 2018-2020 (Table 9). The obtained values show that the differences in N% by organs between the variants without the introduction of mineral fertilizers in the two wheat production systems are insignificant. Practically from the point of view of their agrotechnics, in TOP the sowing rate is 650 seeds/m^2, and in CP it is 550 seeds/m^2 and there is an introduction of herbicide.

Correlation dependences between N% in wheat organs in individual years varies widely with different degrees of reliability in both production methods (Table 10).

Under the conditions of 2018 and 2019, all investigated correlations are positive, reliable and with different R values. In 2020, with conventional production, all correlations have lower correlation values compared to previous years. At TOP in 2020, only the correlations between Stems-NGPS and Grain-NGPS are reliable. In 2019, the dependences in the concentration of nitrogen between the organs are most pronounced, particularities in CP.

In all three years, although with different values of the correlations, the nitrogen in the grain is in a well-expressed positive correlation with the nitrogen content in the organs of the vegetative biomass. Regardless of the weather conditions during the years of study and the method of production, the Grain-NGPS correlation is well expressed.

On average for the research period, all investigated correlations between nitrogen content in wheat organs are statistically reliable (Table 11). Nitrogen in the grain is most strongly correlated with nitrogen content in the leaves. In the case of the conventional wheat production system, the values of the correlation coefficients between the grain and the organs forming the vegetative biomass are higher compared to those in TOP.

Table 9. Comparison in N% by organ during cultivation without the introduction of mineral fertilizers (P-T_0 and TOP).

2018-2020	Leaves	Stems	Grain	NGPS
CP - To	0.45	0.27	1.45	0.40
BIO	0.51	0.30	1.42	0.45

CONCLUTIONS

In both agricultural systems for the production of wheat, the concentration of nitrogen in the organs of the crop in the final phase varies significantly depending on the tested factors in the experiment.

In TOP, the nitrogen content of the leaves is influenced to the maximum extent by the type of the predecessor. For the concentration of nitrogen in the stems and the non-grain part of the spike, the meteorological conditions during the years of research are decisive, and for the nitrogen content in the grain/protein - the variety. In

Table 10. Pearson Correlation between N% in wheat organs by year under production systems

Organs	2018		2019		2020	
	TOP	CP	TOP	CP	TOP	CP
Leaves						
Stems	0.414(**)	0.510(**)	0.792(**)	0.674(**)	-0.104	0.304(**)
Grain	0.388(*)	0.491(**)	0.561(**)	0.774(**)	0.216	0.278(**)
NGPS	0.860(**)	0.368(**)	0.709(**)	0.722(**)	-0.021	0.415(**)
Stems						
Leaves	0.414(**)	0.510(**)	0.792(**)	0.674(**)	-0.104	0.304(**)
Grain	0.660(**)	0.577(**)	0.477(**)	0.663(**)	0.081	0.478(**)
NGPS	0.655(**)	0.489(**)	0.783(**)	0.653(**)	0.490(**)	0.648(**)
Grain						
Leaves	0.388(*)	0.491(**)	0.561(**)	0.774(**)	0.216	0.278(**)
Stems	0.660(**)	0.577(**)	0.477(**)	0.663(**)	0.081	0.478(**)
NGPS	0.559(**)	0.536(**)	0.647(**)	0.669(**)	0.470(**)	0.579(**)
NGPS						
Leaves	0.860(**)	0.368(**)	0.709(**)	0.722(**)	-0.021	-0.021
Stems	0.655(**)	0.489(**)	0.783(**)	0.653(**)	0.490(**)	0.490(**)
Grain	0.559(**)	0.536(**)	0.647(**)	0.669(**)	0.470(**)	0.470(**)

Table 11. Pearson correlation between N% in wheat organs under production systems average for 2018-2020

2018-2020	Leaves		Stems		Grain		NGPS	
Fugure	TOP	CP	TOP	CP	TOP	CP	TOP	CP
Leaves	1	1	0.465(**)	0.513(**)	0.500(**)	0.622(**)	0.364(**)	0.393(**)
Stems	0.465(**)	0.513(**)	1	1	0.389(**)	0.481(**)	0.546(**)	0.677(**)
Grain	0.500(**)	0.622(**)	0.389(**)	0.481(**)	1	1	0.295(**)	0.325(**)
NGPS	0.364(**)	0.393(**)	0.546(**)	0.677(**)	0.295(**)	0.325(**)	1	1

2018 and 2019, the grain of the tested varieties had the highest protein content after the predecessor pea, and in 2020 - after maize. In TOP, the varieties Pchelina and Rada are distinguished by a higher protein content compared to the others.

A persistent trend was found for a highly positive correlation of nitrogen concentration in the grain with that in the stems and non-grain part of the spike.

In the case of the conventional production system (CP), the reliability of the influence of the tested factors on the nitrogen concentration cannot be doubted. However, mineral fertilization has a determining role for the dynamics of nitrogen concentration in leaves, stems and grain, while that in the non-grain part of the spike - the conditions of the year.

The influence of the meteorological factor significantly precedes that of the predecessor and the variety. It was established that the concentration of nitrogen in the organs of the vegetative mass is more strongly influenced by the type of variety, while that in the grain - by the type of the predecessor. The organs of wheat are distinguished by the maximum concentration of nitrogen in the variants with the participation of the highest nitrogen rate.

Cultivation of the varieties after a maize predecessor results in higher nitrogen concentrations remaining in the organs of the non-economic part of the crop (vegetation mass). At CP, on average for the studied period, wheat forms a grain with the highest protein content after the predecessor winter oil rape. As with TOP, the varieties Pchelina and Rada are distinguished by a higher protein content compared to the others.

As a result of mineral fertilization, the concentration of nitrogen in the organs of wheat grown under KP is higher than the same under PBP. The most significant dynamics by year was found in the nitrogen content in the leaves, where the excess was respectively 87.85% (2018), 78.89% (2019) and 18.47 (2020). For grain, these values are respectively - 38.15%, 25.40% and 9.03%.

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