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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

Atanas Atanasov*, Margarita Nankova
Agricultural Academy – Sofia, Dobrudzha Agricultural Institute – General Toshevo, Bulgaria
*E-mail: *nasko_9004@abv.bg*

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Abstract

The aim of this study was to evaluate, based on the yield and the physical properties of grain, the response of five *Tr. aestivum* L. varieties developed at Dobrudzha Agricultural Institute grown under transition to organic production (TOP) and under conventional production (CP) during 2018 – 2020. Under TOP, decisive for productivity were the type of previous crop and the conditions for development in the specific year. The higher productivity of cultivars Kosara (3903.9 kg/ha), Rada and Kalina was advantageous under organic production. The CP of wheat exceeded by yield the TOP grown wheat with 2178.5 kg/ha (64.38 %), and in years with unfavorable conditions – with more than 80 %. Under CP, mineral fertilization was a yield-determining factor. The highest mean yield from the tested varieties was obtained under fertilization with $N_{180}P_{60}K_{60}$ - 7189.8 kg/ha. Cultivar Rada was with the highest productivity under conventional growing (6143.9 kg/ha). Under both ways of production, cultivars Dragana and Pchelina had higher values of test weight. The previous crops pea and oil seed rape had favorable effect on the values of this parameter, while fertilization with $N_{180}P_{60}K_{60}$ decreased them. Thousand kernel weight under both ways of production was highest in cultivar Kalina, followed by Dragana and Rada. In contrast to test weight, grain with highest 1000 kernel weight was obtained under the highest norm of mineral fertilization and after previous crop oilseed rape.

The level of all tested correlations was considerably higher under the TOP in comparison to the CP for mass production of wheat.

Key words: common winter wheat; transition to organic production; conventional production, fertilization; previous crop

INTRODUCTION

In the modern world, common wheat is of primary importance as human food and is widespread on almost all geographical latitudes (Rodomiro at al., 2008). The formation of the proper varietal agrotechnology in accordance with the specific ecological conditions of the region can significantly increase the yield and quality of production (Ilieva, 2011).

The organic agriculture is the most popular type of sustainable agriculture worldwide and has the reputation of being environment-friendly among the producers, the EU member countries, the USA and a number of countries in Central and Eastern Europe (Dochev et al., 2019).

It is well known, that one of the limiting factors on the yield from the agricultural crops, which are grown under organic production, is soil fertility (Yakimov, 2013; Nankova et al., 2021). By alternating the crops in a suitable crop rotation (legumes), its optimization is possible (Atanasova et. al., 2013). The stressors – abiotic (parameters of the main meteorological elements) and biotic (weeds, diseases and pests), are the major factors determining the size of yield (Vulchev & Valcheva, 2005; Stoimenov et al., 2007; Bozhanova et al., 2009; Mihova et al., 2010).

The use of mineral fertilizers has contributed to the increase of the yields from the main agricultural crops worldwide with over 50 % (Tsenov et al., 2021). The mineral fertilization, in combination with other agronomy practices, not only as norms but also as ratios between the nutrition elements, has a positive effect on the tolerance of the crops under abiotic stress (Nankov & Nankova, 2007; Glogova & Nankov, 2019).

In the recent years, systematic investigations are carried out in Bulgaria to evaluate the effect of the climate change on the agricultural crops (Ivanov, 2008). These investigations found out that drought and weather warming are taking place, which is in accordance with the global tendencies (drought increase and climate warming) (Slavov & Moteva, 2006; Bavaru & Bercu, 2012). This new reality is related to higher mean annual temperatures, amplitude anomalies and uneven distribution of rainfalls (Knight et al., 2004; Atanasova et al., 2009, Kostov & Cleemput, 2019). The quality of wheat grain can be improved by breeding and by proper agronomy practices (Panayotova & Kostadinova, 2004; Nankova et. al., 2020). This imposes the necessity to introduce varieties with high productivity and adaptability to the environment (Ivanova et al., 2023). The production of healthy and quality products in combination with the sharp decrease of the complex pressure on the environment is directly related to the organic way of production, which has high standards of control and stringency. In a thorough study of Uhr et al., 2017 it is pointed out that our breeding has the important task of developing varieties for organic production.

The aim of this study was to determine the effect of the meteorological conditions, the level of the nutrition regime and the type of previous crop on the productivity and physical properties of the grain of common winter wheat under transitional growing to organic production and under conventional production on slightly leached chernozem soil in the region of Dobrudzha.

MATERIAL AND METHODS

The study was carried out in the experimental field of Dobrudzha Agricultural Institute – General Toshevo on slightly leached chernozem (*Haplic Chernozems*) during 2018-2020. The experiment was designed according to the split plot method, with a block design of the levels of the nutrition regime. The size of the plot was 12 m^2, with four replications of the variants. Five common winter wheat varieties were subjected to investigation (*Dragana, Rada, Pchelina, Kosara and Kalina*), which were developed at Dobrudzha Agricultural Institute. These varieties are medium early and are characterized by very good winter and cold resistance and drought tolerance.

Cultivars Dragana, Rada, Kosara and Kalina belong to quality group B; their grain is of medium increased strength. Cultivar Pchelina has excellent technological and bread-making properties (quality group A) and is fully resistant to brown rust. Under conventional production (CP), the varieties were sown within the dates optimal for the region at sowing norm 550 germinating seeds/ m^2, and under transition to organic production (TOP) – at norm 650 germinating seeds/ m^2. The sowing norm was determined on the basis of the laboratory germination of the sowing material and the 1000 kernel weight. The study involved four previous crops (oilseed rape, pea, sunflower, grain maize) and three levels of mineral fertilization depending on the type of previous crop: after pea in kg/ha – $N_{30}P_{60}K_{60}$ (CP-T_1), $N_{60}P_{60}K_{60}$ (CP-T_2) and $N_{90}P_{60}K_{60}$ (CP-T_3), and after the other previous crops – $N_{60}P_{60}K_{60}$ (CP-T_1), $N_{120}P_{60}K_{60}$ (CP-T_2) and $N_{180}P_{60}K_{60}$ (CP-T_3) with check variant $N_0P_0K_0$ (CP-T_0) and transition to organic production $N_0P_0K_0$ (TOP). Under conventional production, mechanized phosphorus and potassium fertilization was applied before the primary soil tillage. Nitrogen fertilization was manually applied at the beginning of steady spring vegetative growth by single introduction of the above norms. The following conventional mineral fertilizers were used: ammonia nitrate (NH_4NO_3), 33-34% N, triple superphosphate (46% P_2O_5) and potassium chloride (KCl), 60% K_2O. Soil tillage included single disking (10-12 cm) after harvesting of the previous crop, and after primary fertilization, multiple disking was done to achieve optimal sowing conditions.

Under conventional production, weed control was carried out with a vegetation herbicide. In the variants with transition to organic production, the tested varieties did not receive any mineral or organic fertilizers and stimulants eligible for organic production, nor any pesticides. Harvesting was done at full maturity with a plot harvester.

The following parameters were investigated:

- Grain yield (GY, kg/ha)
- Thousand kernel weight (TKW, g)
- Test weight (TW, kg/100 l)

The statistical analysis and the effects of the individual factors were estimated using Microsoft Excel 2013 and SPSS 2013. Data were processed by applying ANOVA, Waller-Duncan test and correlation analysis.

The investigated period was characterized by exceptionally high dynamics of the main meteorological elements during the individual stages of the crop development (Figure 1). Among the three investigated years, 2017-2018 was with the highest sum of autumn-winter precipitation (357.6 mm). This fact affected positively the further development of the plants since there was a serious drought during April-June, which was the period critical for wheat development. The precipitation during booting stage (April) was 4.9 mm. The stages of heading and grain filling also occurred under extremely low available moisture reserves in soil: 30.9 mm in May and 9.8 mm in June.

With regard to temperatures, each of the wheat development stages during the investigated years was characterized by higher temperatures in comparison to the long-term climatic norm (1953-2017). Highest temperature conditions for autumn and winter vegetative growth were observed in harvest year 2020 – 3.4°C above the climatic norm. The mean temperatures during the vegetative growth of wheat were respectively 11.8°C (2018), 11.4 °C (2019), 12.2 °C (2020) as compared to the climatic norm 10.2 °C. harvest years 2019 and 2020 were with lower autumn and winter precipitation (significantly below the climatic norm) in comparison to the sum of rainfalls in 2018. The lowest value of the total precipitation sum for the entire period of vegetative growth of wheat was determined in harvest year 2019. It is interesting to mention that in this year the rainfalls from steady spring vegetative growth to harvest were comparatively proportionally distributed.

The dynamics of rainfall in harvest year 2020 make it the year with the lowest October-March precipitation sum in comparison to the rest of the studied period. Furthermore, the precipitation sum in April was critically low (5.8 mm), while in June the precipitation sum was 192.2 mm.

With regard to temperature, each of the wheat development stages during the years of study was characterized by higher temperatures than the long-term climatic norm (1953-2017).

The warmest conditions for autumn-winter vegetative growth (October – March) were observed

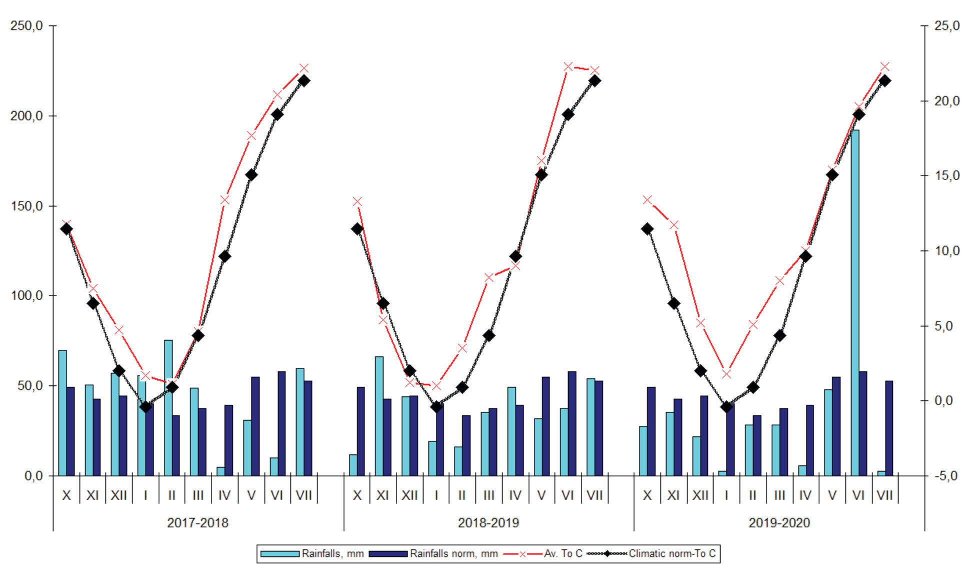


Figure 1. Temperatures and precipitation during the period of study

in harvest year 2020 - 3.4 °C above the climatic norm. The mean temperature during the vegetative growth of wheat was 11.8°C (2018), 11.4 °C (2019), and 12.2 °C (2020) respectively, the climatic norm being 10.2 °C.

RESULTS AND DISCUSSION

In the transition to organic production (TOP), the analysis of variances demonstrated the significance of the effect of the agronomy factors on the studied traits (Table 1). The significance of their independent effect on the values of the tested traits was expressed to a maximum degree. In the parameters of the grain physical properties, the interaction between the factors was also with a maximum level of statistical significance.

During the investigated period, the combined interaction of the cultivar and the previous crop, as well as the complete interaction between the factors on the size of yield was significant, though to a lesser degree. Under the conditions of transition to organic production, a difference in the strength of effect of the tested factors was found. Under this type of production, the influence of the previous crop (48.09%) was determining for the yield size and was much better expressed than the influence of the year conditions (30.21%). The values of the grain physical properties were definitely most affected by the meteorological factor. This effect was better expressed in test weight of grain (62.82 %) in comparison to 1000 kernel weight (51.04 %). The factor cultivar was next in strength of effect. Its effect on the values of grain size was almost twice as high as that of test weight.

Wheat productivity under conventional production (CP) was dependent to a highest degree on the mineral fertilization (Table 2). Averaged for the investigated period, the strength of the independent effect of this factor was 47.36%. Among all interactions, most significant were those with the previous crop (4.62%) and its combination with the effect of the year and the previous crop (4.31%). Second in strength according to its effect on wheat yield was the meteorological factor, followed by the type of previous crop (11.80 %).

It is worth mentioning that the strength of the effects of the factor cultivar under TOP and CP was identical, averaged for the tested period. These values were with high level of significance, but the effect was considerably lower than the effect of the rest of the factors. Considering their combined interactions under CP, wheat yield was affected most by the combinations year x previous crop (9.88%), fertilization x previous crop (4.62%) and year x fertilization x previous crop (4.31%).The influence of the previous crop in combination with the meteorological conditions of the year was even better expressed under organic production - 16.46 %. These results are a confirmation that mineral fertilization is one of the most powerful tested agronomy factors, which determine the size of yield (Freeman et al., 2007; Nankova et al., 2012; Racz et al., 2015; Atanasov et al., 2019; Tsvey et al., 2021; Singh et al., 2021).

The values of the physical properties of grain outlined divergent tendencies depending on the tested

Table 1. Variance analysis of factor interaction for yield and grain physical properties in the transition to organic production (TOP)

Source	df	Grain yield			Test weight			1000 kernel weight		
		Mean Square	Sig.	%	Mean Square	Sig.	%	Mean Square	Sig.	%
Years (Y)	2	940007,07	0,00	30,21	431,49	0,00	62,82	1373,14	0,00	51,04
Cultivars (C)	4	16471,84	0,00	1,06	58,45	0,00	17,02	496,23	0,00	36,89
Predecessors (P)	3	997526,25	0,00	48,09	12,58	0,00	2,75	52,19	0,00	2,91
Y * C	8	10740,70	0,00	1,38	13,74	0,00	8,00	7,63	0,00	1,14
Y * P	6	170712,18	0,00	16,46	6,99	0,00	3,05	33,41	0,00	3,73
C * P	12	5430,39	0,01	1,05	1,24	0,00	1,08	4,49	0,00	1,00
Y * C * P	24	4538,82	0,01	1,75	3,02	0,00	5,27	7,40	0,00	3,30

Table 2. Variance analysis of factor interactions for yield and grain physical properties under conventional production (CP)

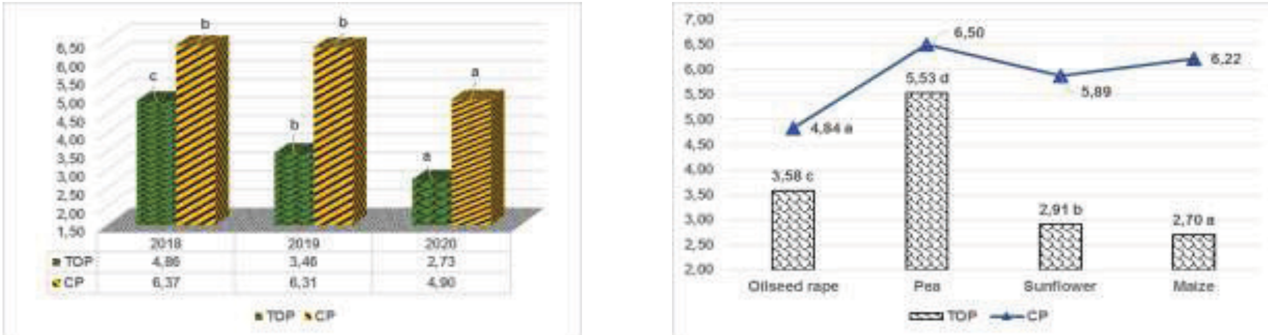
Source	df	Grain yield			Test weight			1000 kernel weight		
		Mean Square	Sig.	%	Mean Square	Sig.	%	Mean Square	Sig.	%
Years (Y)	2	2218422,8	0,000	13,79	2078,3	0,000	64,59	2571,6	0,000	28,71
Fertilization (F)	3	5079698,2	0,000	47,36	106,1	0,000	4,95	190,6	0,000	3,19
Cultivars (C)	4	87710,2	0,000	1,09	173,1	0,000	10,76	2049,0	0,000	45,76
Predesessors (P)	3	1265039,8	0,000	11,80	56,0	0,000	2,61	158,8	0,000	2,66
Y * F	6	177967,7	0,000	3,32	20,5	0,000	1,91	59,3	0,000	1,99
Y * C	8	55716,4	0,000	1,39	63,8	0,000	7,93	111,9	0,000	5,00
F * C	12	9006,1	0,000	0,34	3,3	0,000	0,62	15,8	0,000	1,06
Y * F * C	24	6486,4	0,000	0,48	3,4	0,000	1,25	11,3	0,000	1,51
Y * P	6	529567,6	0,000	9,88	14,3	0,000	1,33	72,7	0,000	2,43
F * P	9	165275,1	0,000	4,62	3,1	0,000	0,43	4,4	0,000	0,22
Y * F * P	18	77025,2	0,000	4,31	2,9	0,000	0,81	29,5	0,000	2,97
C * P	12	3371,5	0,007	0,13	3,4	0,000	0,64	11,5	0,000	0,77
Y * C * P	24	4406,6	0,000	0,33	2,9	0,000	1,10	6,9	0,000	0,92
F * C * P	36	3599,2	0,000	0,40	0,7	0,000	0,38	5,2	0,000	1,05
Y * F * C * P	72	3441,4	0,000	0,77	0,6	0,000	0,70	4,4	0,000	1,75

agronomy factors under conventional production. The independent effect of the year conditions had the highest influence on test weight (64.59%), followed by the effect of the cultivar (10.76 %). The cultivar, on the contrary, had the strongest effect on the grain size (45.76 %), followed by the effect of the year conditions (28.71%). Regardless of the values of η %, all possible combinations between the factors had maximum levels of significance on the physical properties of grain. The combinations year x cultivar, year x fertilization, year x previous crop and year x fertilization x cultivar were with greater strength of their effects for both parameters. The full combined interaction of the factors had greater influence on 1000 kernel weight in comparison to test weight.

Similar results have been reported in other publications on common wheat (Giorgio et al., 1992; Ivanova et. al., 2007; Ivanova & Tsenov, 2009), durum wheat (Ivanova & Tsenov, 2010, Nouri, 2011,) and barley (Mihova et. al., 2010; Ivanova & Mihova, 2012).

The year conditions caused serious dynamics in the expression of the productivity potential of the common wheat cultivars (Figure 2). Lowest mean yields under both production systems were formed in 2020. The unfavorable combination of the meteorological elements in that year in addition to the low autumn and winter precipitation sum lead to only 56.15% of the yields obtained in 2018, on the average, under TOP, and to 76.92% under CP. Thus, the obtained averaged productivity under CP was with 64.38% higher than the productivity under organic production. In years with favorable conditions for growing of wheat (2018), the mean yield under conventional production was with 31.02% above the yield under organic production. Under conditions of different types of stress during the vegetative growth of plants, the difference between the two systems of production increased with 82.65% (2019) and 79.49% (2020), respectively, in favor of CP. In a study by Uhr & Ivanov (2015), this difference was 15.5 %, on average for their study.

The presented results from the experiment revealed that the type of previous crop had the highest effect on the productivity of wheat, grown under transition to organic production. Undisputable was the advantage of pea as the best previous crop, followed by oilseed rape. The differentiation in the values of yield depending on the type of previous



Depending on the year

Depending on the previous crop

Figure 2. Mean productivity of wheat depending on the year of study and the type of previous crop under transition to organic production and under conventional production, t/ha

crop was strongly expressed. The difference in the size of the yields after the most and the least favorable previous crops (pea and maize, respectively) amounted to 2.83 t/ha, averaged for the period of study.

Under conventional production of wheat, averaged for the period, significant displacements in the suitability of the previous crops for positive effect on yield occurred. Pea maintained is leading position with regard to its effect on the size of yield. The complex of agronomy practices in CP considerably increased the suitability of maize and sunflower as previous crops in comparison to oilseed rape. This way of production significantly decreased the differences between the mean yields depending on the type of previous crop. In our experiment, the difference between the highest and the lowest average yield under CP was 1.66 t/ha, which was 58.61 % from the difference determined under TOP (2.83 t/ha).

The conventional system for production of wheat requires considering the effect of the main factor, which distinguished it most significantly from TOP – mineral fertilization (Figure. 3). The levels of the nutrition regime in soil in the CP and TOP check variants were similar due to the fact that no mineral fertilization was applied, as confirmed by the agrochemical analyses carried out (Nankova et al, 2021). The only agronomy differences between these variants were the size of the sowing norm and the lack and respectively use of chemical control of weeds. The obtained mean yields from these two variants showed considerable similarity in the response of the crop; in the variant CP-T_0, 127.9 kg/ha more grain was obtained than in TOP.

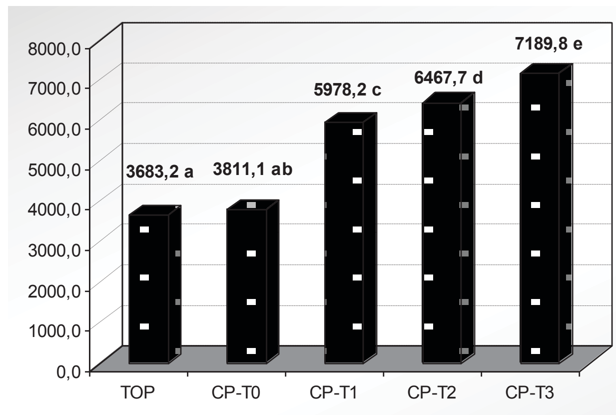


Figure 3. Effect of the nutrition regime level under TOP and CP, t/ha

The mineral fertilization with increasing norms (according to the previous crop), averaged for the period, gradually increased productivity. Against the background of phosphorus-potassium fertilization, the use of nitrogen at ratio between the elements N:P:K=3:1:1 contributed to a mean yield of 7.19 t/ha. This yield exceeded the yield obtained under TOP with 95.21 %, and CP-T_0 - with 88.65 %.

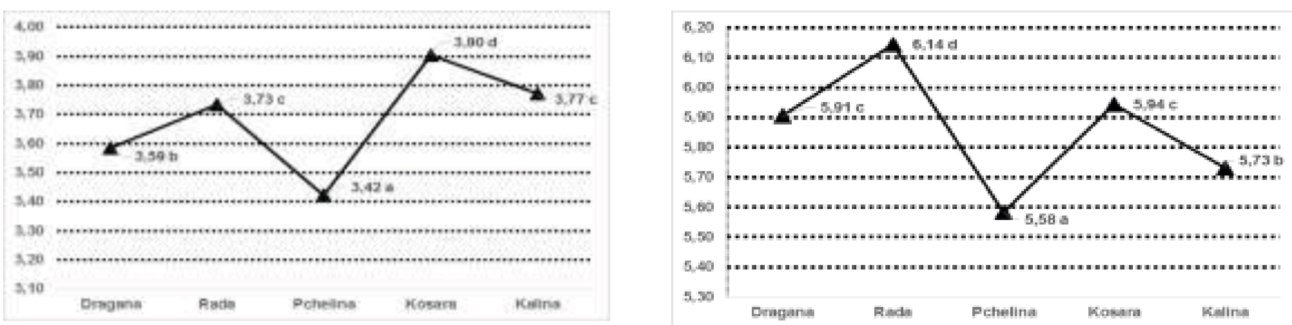
Against the background of these nutrition regimes, the tested wheat cultivars realized their maximum potential under the specific conditions of the investigation (Figure 4). Under the TOP variants, the mean productivity potential varied from 3.42 t/ha (Pchelina) to 3.90 t/ha (Kosara). A reaction similar to that of Kosara was demonstrated by cultivars Rada and Kalina. This result is a prerequisite for a certain advantage of these cultivars when grown under organic production.

The conventional system of production ensured higher productivity than TOP with an average of 2.18 t/ha. Although with a considerable increase of the mean yield under CP in comparison to TOP (62.20 %), cultivar Pchelina again showed lower productivity than the rest of the cultivars. In cultivar Kalina, this increase was with 51.97 %. According to the Waller-Dunkan test, cultivars Dragana and Kosara demonstrated the same response to the CP growing conditions, i.e. they fell in the same group. These two cultivars, however, increased their productivity in comparison to TOP to different degree – with 64.67 % and 52.27 %, respectively. A leader by mean productivity under the conventional system for production was cultivar Rada: 6.14 t/ha and increase of its yield in comparison to TOP with 64.57 %.

Test weight is a parameter characterizing the grain's density. The mean values of this physical property of grain varied significantly over years depending on the way of production (Samodova, 2019).

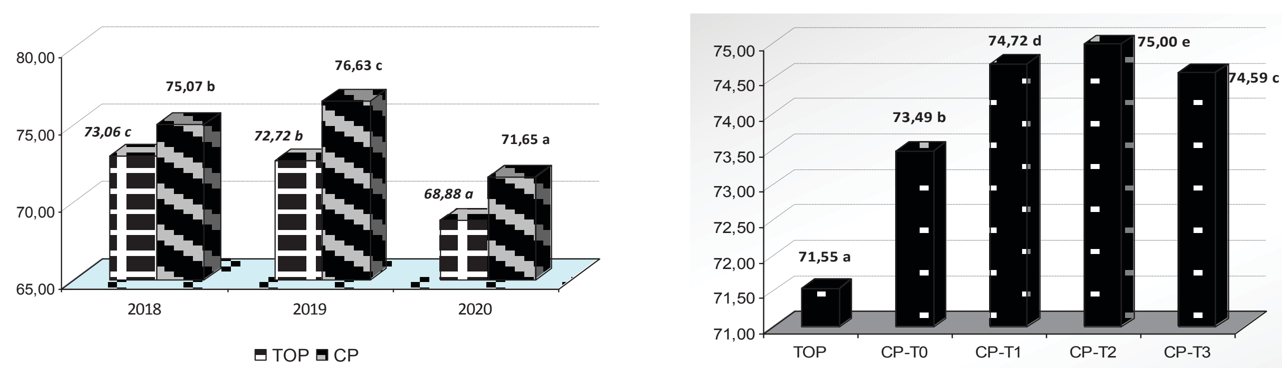
Under TOP conditions, the highest values of this parameter were determined in 2018 – 73.06 kg/100 l. Similar to yield, year 2020 was unfavorable for test weight values, too (Figure 5). The obtained grain was with test weight 94.28 % from the value in 2018. In fact, this was the parameter, which was most influenced by the complex interaction of the main meteorological components.

Under conventional production, the lowest values were again obtained in 2020. They, however, exceeded the TOP values with 4.02 %. Most favorable for this parameter were the conditions of 2019, when, averaged for the conditions of the conventional part of the experiment, 76.63 kg/100 l test weight



TOP CP

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



Depending on the year Depending on the nutrition regime

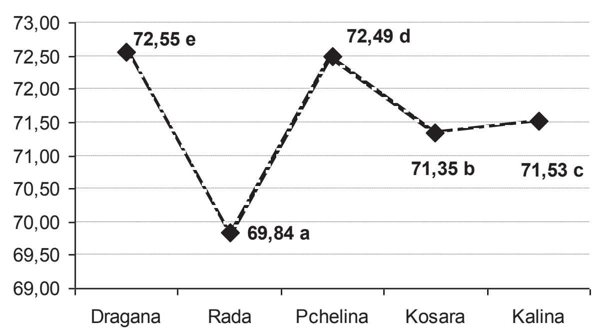
Figure 5. Test weight of wheat depending on the year of study and the nutrition regime levels under transition to organic production and under conventional production, kg/100 l

of grain was obtained, and the exceeding according to TOP was with 5.38 %.

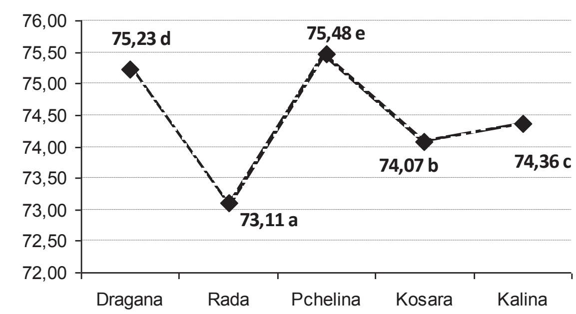
Regardless of the considerable dynamics in the values of test weight depending on the year conditions, the grain from the wheat grown under CP was with 4.05 % heavier than the grain grown under TOP conditions. Mineral fertilization, though with lesser strength of effect, provoked higher test weight values, reaching a maximum at ratio N:P:K=2:1:1 ($N_{120}P_{60}K_{60}$), where the mean value of the parameter was 75.00 kg/100 l. The further increase of the norm of mineral fertilization tended to decrease the values of this parameter. The response of the cultivars grown in the check variant of CP resulted in test weight higher with 1.94 points in comparison to the mean values under TOP.

The experiment also demonstrated the much higher significance of the genotype factor for the test weight values in comparison to mineral fertilization (Figure 6). Cultivars Dragana and Pchelina maintained their leading positions under both ways of agricultural production, while cultivar Rada was characterized by the lowest values of this parameter. Although Rada was with the lowest test weight values, this cultivar increased the values of the parameter to a higher degree (with 3.27 points) under CP in comparison to TOP. Averaged for the varieties selected for this study, CP contributed to obtaining test weight of grain with 2.90 points higher in comparison to TOP.

We found out that the influence of the tested previous crops on test weight of grain had significant effect, but less expressed strength under both ways of wheat production. Regardless of this, the complex of tested factors had a significant and positive effect on the values of grain density (Figure 7).

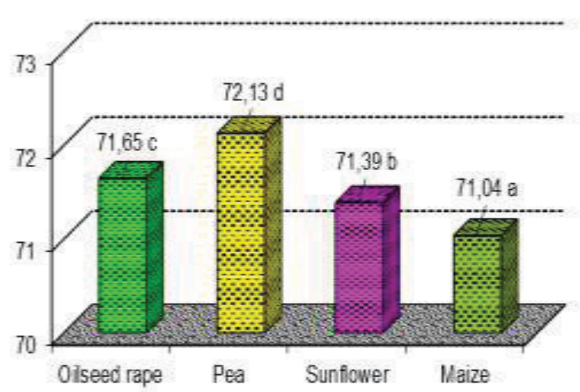


TOP

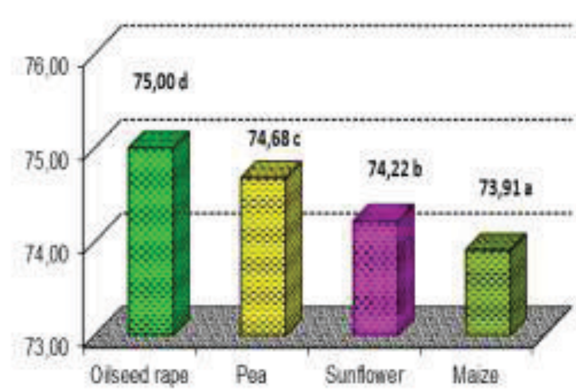


CP

Figure 6. Test weight of wheat depending on the type of cultivar under transition to organic production and under conventional production, kg/100 l



TOP



CP

Figure 7. Test weight of wheat depending on the type of previous crop under TOP and CP, kg/100 l

Under both ways of growing, wheat had lowed test weight when grown after previous crop sunflower, and particularly after maize.

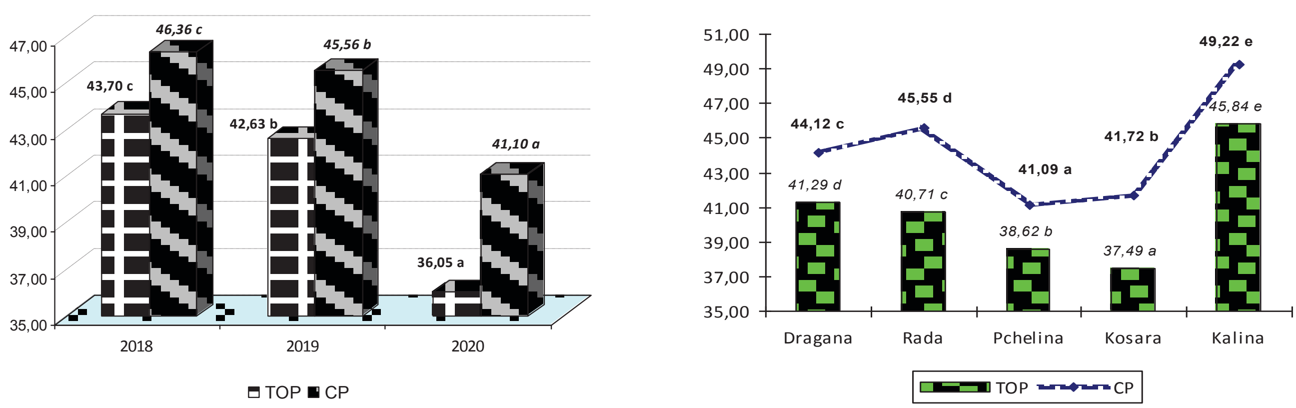
Undoubtedly, after previous crop pea, the conditions for development and nutrition of the crop were much better than after the other predecessors. Under TOP, this previous crop is the best opportunity to obtain heavier grain, followed by previous crop oilseed rape. Under conventional production, oilseed rape turned out to be the predecessor, after which the obtained grain was with the highest test weight values in comparison to the other previous crops.

Thousand kernel weight (TKW) is an important trait characterizing the physical properties of wheat grain; it is also a trade characteristics (Delibaltova et al., 2014). It is variety-specific and is determined genetically, but is also influenced by the conditions of the environment: year and the agronomy practices applied for growing (Figure 8). In growing under TOP, the complex of meteorological conditions over years was of primary importance. Similar to the other parameters, the values obtained for grain size were highest in 2018. There was a sharp decrease in the mean values of this parameter in 2020 – with 7.65 g. Against this background, the wheat grown under TOP was with considerably larger grain – an average of 3.55 g (8.70 %). The conventional production system, under the highly unfavorable conditions of 2020, contributed to grain size higher with 5.05 g (14.01 %) in comparison to TOP.

Being genetically determined, the cultivar had a decisive strength of effect on the values of TKW under CP. The differentiation in the values of this parameter depending on the peculiarities of the cultivar was well expressed under both ways for crop production (Figure 9). Cultivar Kalina was with the largest grain regardless of the way of production. Cultivars Pchelina and Kosara maintained the two bottom positions in the ranking according to the values of this parameter. Lowest was the amplitude of variation of TKW depending on the ways of production in cultivar Pchelina: 2.47 g (from 38.62 g under TOP to 41.09 g under CP). The used agronomy practices under the studied ways of production were at the basis of the highest variations of the values of this parameter in cultivars Rada (4.84 g) and Kosara (4.23 g).

Under CP, the differentiation in the values of the grain size according to the type of previous crop was expressed slightly, and the variation was from 39.96 g (maize) to 41.74 g (oilseed rape). Growing of wheat under CP, which is typical for this region, had a significant positive effect on grain size. The mean increase was with 3.55 g and was observed in growing of wheat after all previous crops, being best expressed in the variants with previous crop sunflower. On the whole, the highest values were of the grain from the cultivars grown after oilseed rape. There was a tendency of smaller grain size towards maize depending on the type of previous crop under both ways of production.

Comparing the two variants without use of mineral fertilizers (TOP and CP-T_0), we determined a significant advantage of the conventional production of wheat, typical for this region on the mean values of the parameter. Grain size increased with averagely 2.31 g according to the mean values ob-



Year Cultivar

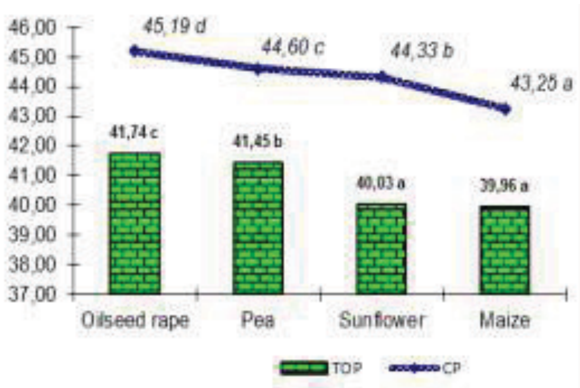
Figure 8. 1000 kernel weight depending on the year of study and the type of cultivar under TOP and CP, g

tained from TOP. This was largely due to the quality weed control carried out.

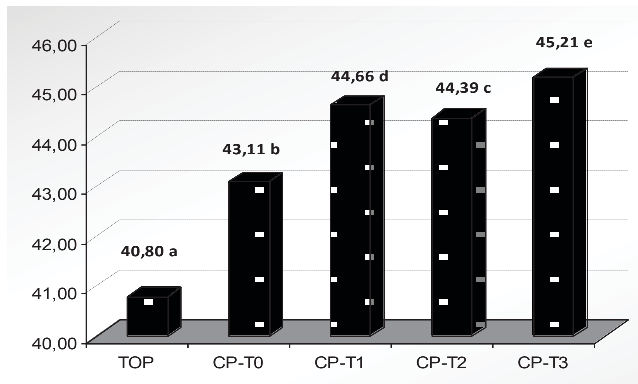
The complex mineral fertilization with increasing norms between the three macro elements from norm 60 kg/ha active matter at ratios N:P:K= 1:1:1; 2:1:1 and 3:1:1 contributed significantly to the higher mean values of TKW. During the period of study, these values were highest at fertilization with $N_{180}P_{60}K_{60}$.

Over years, the correlations between the tested factors under the two systems for production of wheat were characterized with well expressed dynamics (Table 3). In the year with conditions most favorable for the development of the crop during the investigated period (2018), statistically significant interactions between the parameters under TOP were not found. Under CP, significant but low were the correlations Yield-TW and TW-TKW. In 2019, all studied correlations under TOP were significant. The correlation TW-TKW was with the highest value of R (0.611^{**}).

The same correlation under CP was the only one with mathematical significance but with values



Previous crop



Level of nutrition regime

Figure 9. 1000 kernel weight depending on the previous crop and the levels of nutrition regime under TOP and CP, g

Table 3. Correlations between the tested parameters

Indices	Grain yield		TW		TKW	
	TOP	CP	TOP	CP	TOP	CP
			2018 **n=80/320**			
Grain yields	1	1	0.158	0.385(**)	0.037	-0.082
HW	0.158	0.385(**)	1	1	-0.004	0.163(**)
TKW	0.037	-0.082	-0.004	0.163(**)	1	1
			2019 **n=80/320**			
Grain yields	1	1	,497(**)	,045	0.460(**)	0.104
HW	0.497(**)	0.045	1	1	0.611(**)	0.381(**)
TKW	0.460(**)	0.104	0.611(**)	0.381(**)	1	1
			2020 **n=80/320**			
Grain yields	1	1	-0.216	0.124(*)	0.382(**)	0.398(**)
HW	-0.216	0.124(*)	1	1	-0.406(**)	-0.307(**)
TKW	0.382(**)	0.398(**)	-0.406(**)	-0.307(**)	1	1
			2018-2020 n=240/960			
Grain yields	1	1	0.479(**)	0.381(**)	0.467(**)	0.289(**)
HW	0.479(**)	0.381(**)	1	1	0.628(**)	0.409(**)
TKW	0.467(**)	0.289(**)	0.628(**)	0.409(**)	1	1

considerably lower than the values under TOP. The extremely unfavorable (with regard to meteorology) year 2020 was with a low positive correlation Yield-TKW (0.382**) and high negative correlation TKW-TW (-0.406**) under transition to organic agriculture. The latter correlation was significant under conventional production, too, but the R values were lower. Under CP, low positive correlations Yield-TW and Yield-TKW were determined as well.

Averaged for the period 2018 – 2020, all determined correlations were positive and significant. The level of these correlations was significantly higher under transition to organic production in comparison to the conventional technology for mass production of wheat.

Similar positive correlations between TW and TKW were reported also by Stoyanov (2013).

CONCLUSIONS

Under transition to organic production, decisive for wheat productivity were the type of previous crop and the conditions of the year. The higher productivity of cultivars Kosara (3.90 t/ha), Rada and Kalina gave them an advantage under organic production. The conventional way of growing wheat exceeded the transition to organic production with regard to wheat yield with 2.18 t/ha (64.38 %), and in years with unfavorable conditions – with over 80 %.

Under conventional production, mineral fertilization was a yield-determining factor. The highest mean yield from the tested cultivars was obtained after fertilization with $N_{180}P_{60}K_{60}$ – 7.19 t/ha. The mean yield from the cultivars grown under transition to organic production was with only 127.9 kg/ha lower than the check variant ($N_0P_0K_0$) under CP.

The physical properties of grain were definitely affected most by the year conditions and the type of cultivar. Under both ways of production, cultivars Dragana and Pchelina had higher values of test weight.

Thousand kernel weight under both ways of production was highest in cultivar Kalina, followed by Dragana and Rada. The values of this parameter were highest after previous crop oilseed rape.

The level of correlations between different parameters was considerably higher under transition to organic production as compared to the conventional technology for mass production of wheat.

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