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Growing Wheat (*Trititcum aestivum* L.) by the Methods of Organic Agriculture Under the Conditions of Dobrudzha Region, Bulgaria

G. Milev, N. Nankov, I. Iliev, A. Ivanova, M. Nankova
Dobrudzha Agricultural Institute – General Toshevo 9520, Bulgaria
Corresponding autor: milev2013@abv.bg

Abstract

During 2011 – 2013 a field experiment with wheat (*Trititcum aestivum L.*) was carried out in the trial field of Dobrudzha Agricultural Institute. The aim of the investigation was to determine what are the possibilities of growing common wheat in a main wheat production region (Dobrudzha, north-east Bulgaria) using the methods of organic agriculture. The results from the biological growing were compared to the respective results obtained by the conventional method. The following agronomy factors were investigated in both variants of production: three sowing dates (early, optimal and late) x three cultivars (Enola, Aglika and Galateya) x three sowing norms (550, 650 and 750 seeds m^{-2}). In the conventional part of the experiment, suitable fertilizers and pesticides were applied. Wheat was rotated with fodder pea, grain maize and fallow. The soil in the trial field was slightly leached chernozem (*Luvic phaeozem*) with very good physical and chemical characteristics. The trial was designed according to the split-split plot method in four replications. Wheat productivity in both ways of production was significantly influenced by the tested agronomy factors. Averaged for the investigated period, the yield obtained in the conventional production exceeded the biological method with 11.94 %. The early sowing date was an important prerequisite for higher yields under organic growing. The sowing density was the factor with most variable effect on wheat productivity. Cultivar Aglika demonstrated highest mean productivity under both ways of production. The year conditions had significant effect on grain yield in both methods of growing.

Key words: wheat, organic agriculture, grain yield

Introduction

The system of organic agriculture originated in Western Europe and the USA in the 1980's as an alternative to the excessive use of synthetic chemicals (pesticides, fertilizers, consumables, etc.) in the agriculture of the developed countries and the related harmful effect on the environment and the human health (Bio agriculture, 2011; Dimitrov and Karov, 2004; Steiner, 2001).

The organic system of agriculture is, according to the definition of Kus and Fotyma (1992), a system which excludes the use of mineral fertilizers, pesticides and growth regulators. It is characterized with a closed cycle of the type "soil – plant – productive animal", the ecological purposes being predominant over the economic ones.

A typical and irrevocable feature of organic agriculture is its strict regulation by a number of legal acts called "regulatory acts" of both world and national institutions (IFOAM*, National plan for development of organic agriculture in Bulgaria during 2007 – 2013; Regulation 22 of the Ministry of Agriculture and Forestry, State Gazette 68/03.08.2001).

At the end of the first decade of the 21st century, organic agriculture in Bulgaria was represented mainly by the products of apiculture, the production of herbs, essential oils, cosmetics, and to a lesser extent – some animal products (Production, distribution and consumption of bio products in Bulgaria, 2009). Such major crops for Bulgaria as wheat, maize and sunflower are still not grown by the rules of organic agriculture.

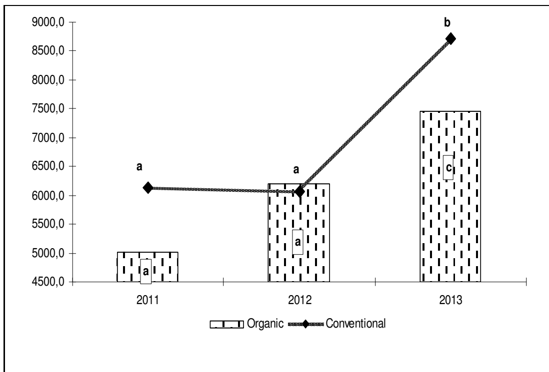
The agronomy methods for growing of a crop, for example wheat under conditions of organic agriculture, are decisive for its successful harvesting (Boone, 1999; Burnett and Clarke, 2002).

Table 1. Analysis of the variances of the investigated indices (values of parameter *p*) (*Tests of Between-Subjects Effects*)

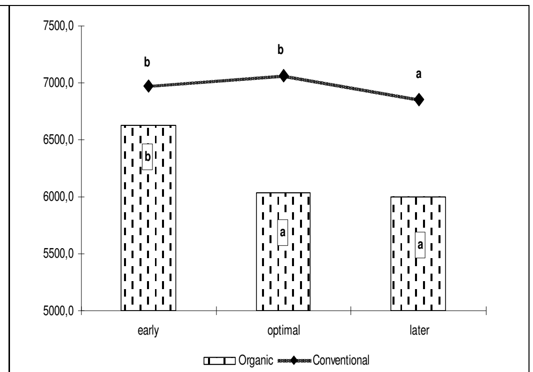
Factors	Indices	Significance	
		Organic production	Conventional production
Years (1)	Yield	.000	.000
	Absolute weight	.000	.000
	Test weight	.000	.000
Sowing date (2)	Yield	.000	.000
	Absolute weight	.000	.000
	Test weight	.000	.000
Cultivar (3)	Yield	.000	.000
	Absolute weight	.000	.000
	Test weight	.000	.000
Sowing densities (4)	Yield	$.233^{NS}$	.009
	Absolute weight	$.196^{NS}$	$.418^{NS}$
	Test weight	$.326^{NS}$	.000
1 x 2	Yield	.000	.000
	Absolute weight	.000	$.019^{NS}$
	Test weight	.000	.000
1 x 3	Yield	.000	.000
	Absolute weight	.000	.000
	Test weight	.000	.000
1 x 4	Yield	$.102^{NS}$	$.271^{NS}$
	Absolute weight	$.221^{NS}$	$.135^{NS}$
	Test weight	.000	.000
2 x 3	Yield	.000	.000
	Absolute weight	.002	.000
	Test weight	.000	.000
2 x 4	Yield	$.133^{NS}$	$.271^{NS}$
	Absolute weight	$.068^{NS}$	$.135^{NS}$
	Test weight	.000	.000
3 x 4	Yield	.004	.000
	Absolute weight	.000	.001
	Test weight	$.014^{NS}$	.000
1 x 2 x 3	Yield	.000	.000
	Absolute weight	.000	.000
	Test weight	.000	.000
1 x 2 x 4	Yield	$.039^{NS}$	.006
	Absolute weight	$.070^{NS}$	.000
	Test weight	.000	.000
1 x 3 x 4	Yield	.011	.000
	Absolute weight	$.048^{NS}$	$.116^{NS}$
	Test weight	.000	.000
2 x 3 x 4	Yield	$.113^{NS}$	.000
	Absolute weight	$.064^{NS}$	$.459^{NS}$
	Test weight	.000	.000
1 x 2 x 3 x 4	Yield	$.674^{NS}$	.006
	Absolute weight	.004	.000
	Test weight	.000	.000

Table 2. Productivity of wheat under organic and conventional production averaged for three years, kg ha^{-1}

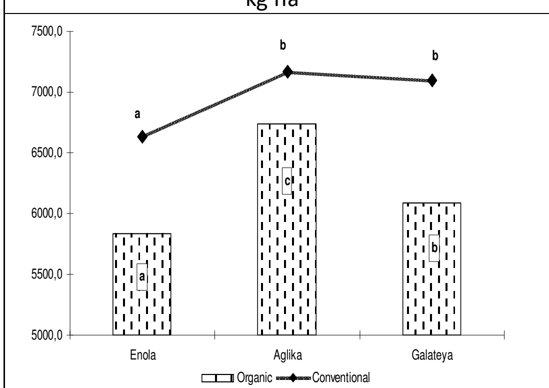
Cultivar	Sowing norm g.s. m^{-2}	Sowing date					
		Early		Optimal		Late	
		Organic	Conventional	Organic	Conventional	Organic	Conventional
	550	6287	6157	5162	7176	5224	6312
Enola	650	6285	5869	5167	6546	5860	6979
	750	6648	6990	5554	6782	6271	6857
Averaged for the sowing date		*6407*	*6339*	*5294*	*6835*	*5785*	*6716*
	550	7115	7228	6973	7258	6504	7023
Aglika	650	6672	7153	6976	7551	6772	7105
	750	6793	6890	6089	7322	6757	6959
Averaged for the sowing date		*6860*	*7091*	*6679*	*7377*	*6678*	*7029*
	550	6576	7616	5805	6544	5458	6529
Galateya	650	6852	7487	6346	7195	5444	7147
	750	6396	7405	6288	7167	5635	6777
Averaged for the sowing date		*6608*	*7502*	*6146*	*6969*	*5512*	*6818*



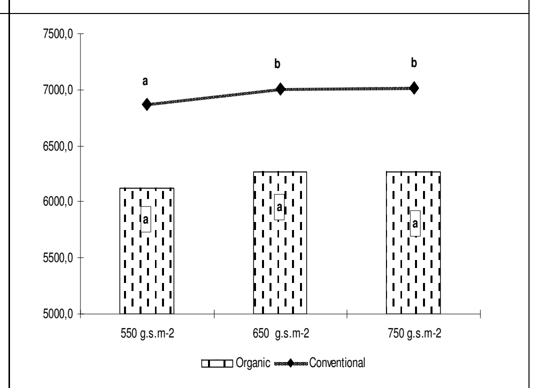
Yield according to the year of investigation, kg ha^{-1}



Yield according to the sowing date, kg ha^{-1}



Yield according to the cultivar, kg ha^{-1}



Yield according to the sowing density, kg ha^{-1}

Figure 1. Effect of the agronomy factors on the mean productivity of wheat according to the mode of production

Table 3. Mass of 1000 seeds under organic and conventional production averaged for three years, g

Cultivar	Sowing norm g.s. m^{-2}	Sowing dates					
		Early		Optimal		Late	
		Organic	Conventional	Organic	Conventional	Organic	Conventional
Enola	550	43.90	44.87	43.96	43.30	44.12	43.59
	650	43.34	44.28	43.92	43.49	42.86	44.08
	750	42.88	43.82	43.79	42.73	42.06	43.20
Averaged for the sowing date		*43.37*	*44.32*	*43.89*	*43.17*	*43.01*	*43.62*
Aglika	550	43.23	43.46	43.23	43.20	43.12	41.38
	650	43.56	42.41	42.71	42.54	42.29	42.04
	750	43.17	42.41	42.26	43.66	42.62	41.41
Averaged for the sowing date		*43.32*	*42.76*	*42.73*	*43.13*	*42.68*	*41.61*
Galateya	550	46.01	45.31	47.34	45.07	46.57	44.18
	650	46.74	45.47	48.28	45.63	47.41	44.98
	750	47.84	45.61	47.99	45.89	46.43	44.68
Averaged for the sowing date		*46.87*	*45.46*	*47.87*	*45.53*	*46.80*	*44.61*

Weeds, diseases and pests have been pointed out as the main limiting factors when growing this crop with the methods of organic agriculture.

The deficiency of nutrients has to be compensated by some other means, too, since the use of chemical fertilizers is not allowed.

Under these conditions of limitations it is very important to choose a suitable cultivar which is resistant to diseases and is sufficiently capable of competing with the weed vegetation for moisture and nutrients. In this respect some characteristics of the wheat cultivars such as high tillering capacity, drought resistance, plasticity with regard to the planting date, economic utilization of nutrients, requirements to the previous crop, etc., are a useful prerequisite for the possibility to grow a certain cultivar under conditions of organic agriculture.

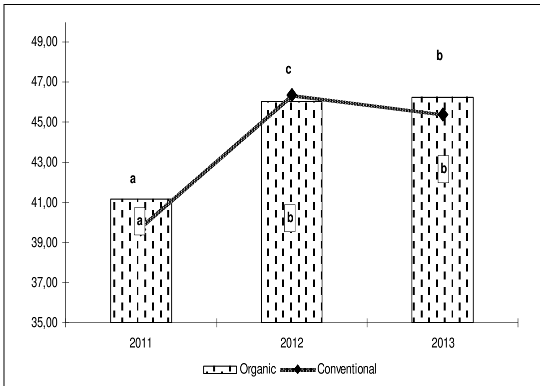
Planning a suitable crop rotation, which involves the crop subjected to organic cultivation, is crucial for overcoming of the negative consequences mentioned above (Dzhumalieva et al., 1986). The crops involved in the crop rotation can considerably help to overcome the problems with weeds, diseases and deficiencies of nutrients. Using a field in fallow, which is however maintained in good agronomic condition, is a frequent practice in the organic agriculture system.

For growing of wheat in Bulgaria, shallow pre-sowing soil tillage is usually recommended which ensure homogeneity of the soil layer to the depth of planting (Simeonov, 1956; Klochkov, 1983; Kassimov, 1989). In parallel with this, the above authors are explicit that in case of infestation with perennial weeds, especially in the earlier predecessors, deeper tillage with turning of the surface layer should be applied, for example pre-sowing plowing. This conclusion is especially important for the organic mode of production in which infestation of the fields with weeds is inevitable, excluding chemical control.

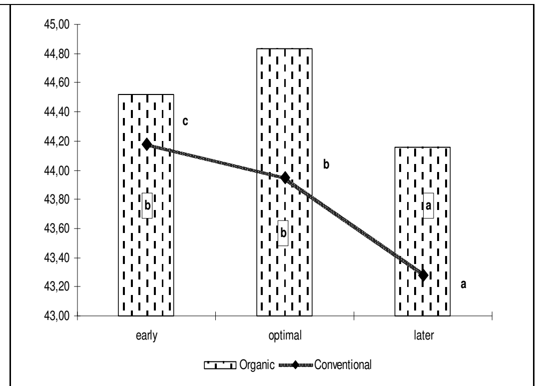
Kassimov (1982 and 1989) considered the sowing date and norm as a complex related to the characteristics of the different cultivars (with higher or lower tillering capacity) and determined that the beginning of October is the optimal sowing date of common wheat in the region of Dobrudzha. The purposeful sowing date is often aimed at non-coincidence of the developmental stages of the crop and the weeds, while the sowing norm is set at competing with the number of weed plants.

Determining the optimal levels of these two factors in organic agriculture is however related not only to their direct effect on yield but also to the formation of a sufficiently dense crop that can perform auto control on weeding. Therefore the optimal levels of the factors norm and sowing in the organic agriculture are determined from another point of view, since they can turn out to be different from those of the conventional production.

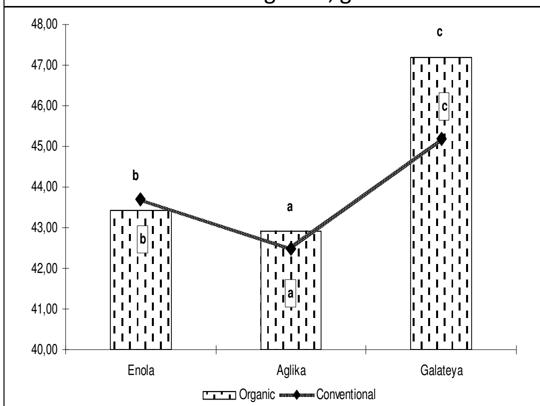
With a view of answering the questions considered above and related to the organic mode of production, a field experiment with wheat was carried out at DAI – General Toshevo, North-East Bulgaria; the aim of the experiment was to find out what is the effect of some agronomy factors on the formation of a wheat crop grown under conditions of organic agriculture.



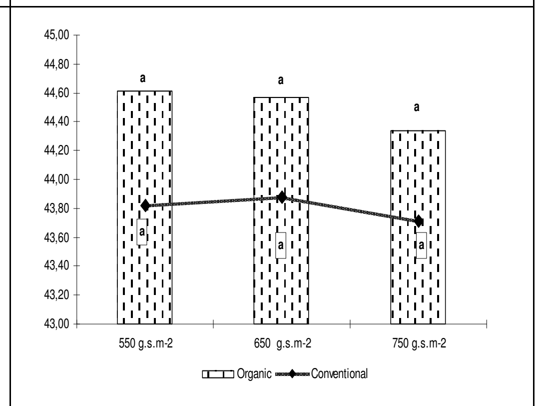
Absolute weight according to the year of investigation, g



Absolute weight according to the sowing date, g



Absolute weight according to the cultivar, g



Absolute weight according to the sowing density,g

Figure 2. Effect of the agronomy factors on the mean values of wheat grain size (mass of 1000 seeds) according to the mode of production

Material and methods

During 2010 – 2012 in the trial field of DAI – General Toshevo, a field experiment with wheat was carried out by the split plot method. The experiment was performed in a field which has not been treated with fertilizers and pesticides since 2001, i.e. the area was purposefully prepared for organic agriculture. The organic and the conventional parts of the experiment consisted in 4-field crop rotation (pea, wheat, maize, lying fallow).

The mineral fertilization of each crop in the conventional part of the experiment was as follows: pea – $N_{60}P_{80}K_{60}$; maize – $N_{120}P_{60}K_{0}$; wheat – $N_{120}P_{120}K_{60}$. The norms are given as active substances kg ha^{-1}. The technology for growing of the wheat and the other crops was traditional (Klochkov et al., 1988).

Cultivars Enola, Aglika and Galateya were tested in the experiment as conditional representatives of three main wheat types. The first cultivar is highly productive, the second possesses high grain quality, and the third has high tillering capacity. These cultivars were sown on three dates: early (20th – 25th September), optimal (10th – 15th October), and late (10th – 15th November). The sowing norms were 550, 650 and 750 germinating seeds m^{-2}.

No pesticides or other substances not allowed in organic agriculture were applied in the organic part of the trial. The wheat seeds in this part of the experiment were from the previous harvest year.

The meteorological conditions during the individual years, more specifically precipitation, differed significantly. The autumn-and-winter rainfalls were most abundant during 2011 – 2012: 283.3 mm, and the vegetation rainfalls (April – June) – in 2011. The sum of precipitation was highest in 2012 - 469 mm.

The obtained results were processed statistically using the software SPSS 13.

Table 4. Test weight of wheat under organic and conventional production averaged for three years, кg

Cultivar	Sowing norm g.s./m^{-2}	Sowing dates					
		Early		Optimal		Late	
		Organic	Conventional	Organic	Conventional	Organic	Conventional
Enola	550	81.52	80.77	82.19	80.94	81.18	80.44
	650	81.88	80.81	82.01	80.96	81.37	80.52
	750	82.10	80.98	81.97	80.80	81.07	80.11
Averaged for the sowing date		*81.83*	*80.85*	*82.06*	*80.90*	*81.20*	*80.36*
Aglika	550	81.68	81.11	82.07	81.77	81.60	81.06
	650	81.48	81.62	82.13	81.93	81.53	80.86
	750	81.51	81.49	82.00	82.29	81.81	81.09
Averaged for the sowing date		*81.56*	*81.41*	*82.07*	*82.00*	*81.65*	*81.00*
Galateya	550	81.91	81.74	81.57	81.07	81.36	80.97
	650	81.82	81.89	81.63	81.48	81.33	81.17
	750	81.99	81.12	81.77	81.24	81.16	81.29
Averaged for the sowing date		*81.91*	*81.59*	*81.66*	*81.26*	*81.28*	*81.14*

Results and Discussion

The dispersion analysis of the results during 2011-2013 showed that the year of investigation, the sowing date and the choice of cultivar influenced significantly the crop's productivity regardless of the mode of production (Table 1). The independent action of the factor crop density did not cause significant variations in the productivity under organic production. Most of the interactions involving this factor had insignificant effect on grain yield. Under conventional production, the investigated agronomy factors had significant effect on wheat productivity in greater number of cases in comparison to organic production.

During the years of investigation, the differentiation in the productivity under organic production was more clearly expressed in comparison to conventional production (Figure 1). The results clearly show that the conditions of harvest year 2013 were a prerequisite for higher productivity in comparison to the rest of the investigated years. In 2011 and 2013 the results undoubtedly indicated that conventional production allowed higher yields in comparison to the organic, while in 2012 a significant difference in the mean productivity under the two modes of production was not found.

The data for the investigated period, averaged by cultivars, sowing dates and sowing densities, clearly demonstrated the effect of these factors on the productivity of wheat (Table 2).

Absolute kernel weight, averaged for the period, varied from 41.38 g (Aglika, conventional production, late sowing with 550 g.s. m^{-2}) to 47.84 g (Galateya, organic production, early sowing with 750 g.s. m^{-2}) (Table 3). The analysis of dispersions under conventional production showed that the values of this index were influenced insignificantly by the direct effect of the factor sowing density.

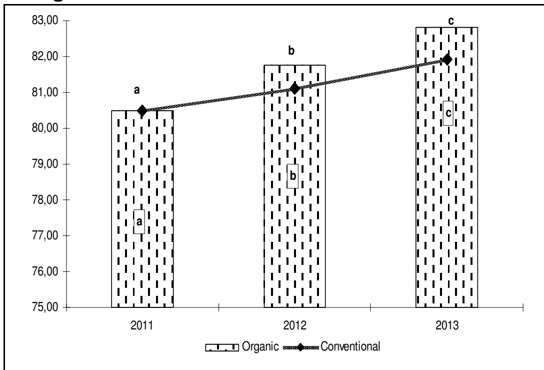
The greater part of the interactions involving this factor were also statistically insignificant. There was a significant interaction with the factor cultivar; significant was the complete interaction between the four factors as well. The factor year played a determining role for the grain size, followed by the factor "genotype". Among all types of interactions between the factors, the combination between these two factors on the values of absolute grain weight was most significant. This tendency was valid for the organic production as well; in this case the strength of the effect of the factor cultivar was considerably better expressed than in conventional production.

In 2012, higher values of grain size were obtained under both modes of production, without significant variations between them (Figure 2). The smallest grain was obtained in 2011; under organic production it was with higher values of the index in comparison to conventional production.

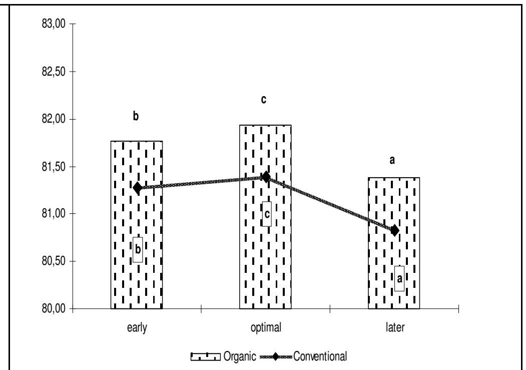
The sowing date definitely had a better expressed effect on grain size under conventional production in comparison to organic.

Lowest mean values of absolute grain weight were obtained at the late sowing date, conventional production conceding to organic. Among the three investigated cultivars, cultivar Galateya had the largest grain under organic production. It was followed by cultivar Enola. In cultivars Enola and Aglika, averaged for the period of investigation, the mode of production did not have a significant effect on this index.

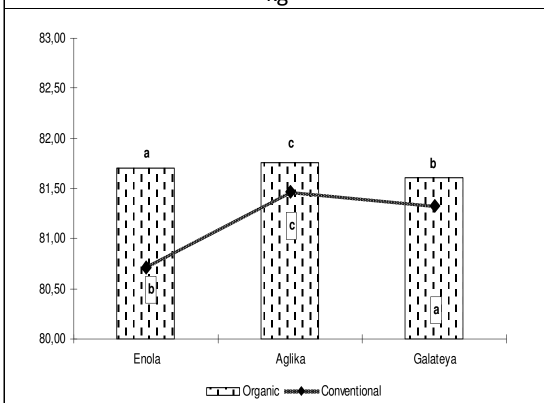
The sowing density did not have effect on the mean values of the index under both modes of production. Regardless of this fact, a tendency was observed toward larger grain under organic production in comparison to conventional.



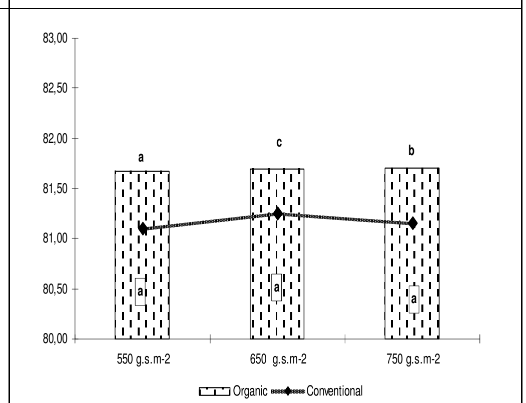
Test weight according to the year of investigation, kg



Test weight according to the sowing date, kg



Test weight according to the cultivar, kg



Test weight according to the sowing density, kg

Figure 3. Effect of the agronomy factors on the mean values of test weight of wheat grain according to the mode of production

Test weight of grain varied significantly depending on the tested factors of the trial (Table 4). Its mean values were from 80.11 kg (Enola, conventional production, late sowing date with 750 g.s. m^{-2}) to 82.13 kg (Aglika, organic production, optimal sowing date with 650 g.s. m^{-2}). The analysis of dispersions under biological production revealed that that the direct and combined interaction of the factors was statistically significant, with the exception of the factor sowing density. The factors year, sowing date and their interaction had highest strength of effect on the values of the index.

Under conventional production, the effect of the factors and their interaction was also statistically significant. According to their direct effect, the factors can be arranged as follows: Year > Cultivar > Sowing date > Sowing density. The most significant interactions of the factors were Year x Cultivar, Year x Sowing date, and Year x Sowing date x Cultivar.

The role of the years of investigation was very well differentiated under both modes of production (Figure 3). The obtained grain had highest test weight in 2013. The grain produced during the unfavorable year 2011 had lowest test weight, the established variations between the two modes of production not being significant. During the rest of the years a tendency was observed toward grain with higher test weight under organic production in comparison to conventional production.

The sowing date also had significant effect on the values of the index and although these values varied within a comparatively narrow range, the Waller-Duncan test differentiated them to a maximum degree. This factor also outlined a tendency toward grain with higher test weight under organic production in comparison to the conventional. The late sowing date decreased the values of this index in wheat.

Regardless of the mode of production, the grain of cultivar Aglika had highest test weight, followed by cultivars Galateya and Enola. The variation in the values depending on the mode of production was best expressed in cultivar Enola, in which test weigh under organic production was higher than the test weigh under conventional production. In the other two cultivars, averaged for the investigated period, it was not significant.

Under organic production, the role of the sowing density was insignificant. Regardless of the significance of the variations under conventional production, the values of the index varied within a narrow range. Highest mean values were found at sowing density 650 g.s. m^{-2}.

Conclusions

Averaged for the investigated period, the yields obtained under organic production conceded to the yields under conventional production with 11.94 %.

The early sowing date was an important prerequisite for higher yields under organic production. The late sowing date led to lower productivity of the crop, which was better expressed under organic production.

Highest mean productivity under both modes of production was demonstrated by cultivar Aglika.

The sowing density was the factor with most variable effect on wheat productivity; its effect was not significant statistically under organic production.

Highest variations in the values of the index 1000 kernel weight depending on the mode of production were found in cultivar Galateya, while in the other two cultivars the differences were not significant.

Test weight of grain showed a tendency toward higher values under organic production in comparison to the conventional technology of growing of the crop.

***Aknowlegements**:*
The authors wish to express their gratitude to the technical team who carried out the field work during the trial. Since 2013 the topic presented in this paper is being developed as a PhD thesis.

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