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YIELDING OF NEW QUALITY VARIETIES OF WINTER WHEAT CULTIVATED IN ORGANIC FARMING

Summary

The aim of this study was to evaluate the yielding of selected quality varieties of winter wheat grown in organic farming in different regions of Poland. The field trials were performed in the years 2014-2015. The analyses included grain yield, its structure, nitrogen nutritional status and presence and intensity of fungal diseases. The results showed that, regardless of locality, Sailor, KWS Ozon and Muszelka gave the largest and the most stable yields. The mass of 1000 grains was the main factor responsible for this. Arkadia, Ostroga and spelt wheat Rokosz varieties gave the smallest yields. There was a lack of correlation between the yields and the nitrogen nutritional status of tested varieties. The results indicate the need to develop new critical nitrogen concentrations better tailored to the specifics of organic farming.
***Key words**: winter wheat, varieties, organic farming, nitrogen nutritional status, yield components*

PLONOWANIE NOWYCH JAKOŚCIOWYCH ODMIAN PSZENICY OZIMEJ UPRAWIANYCH W WARUNKACH PRODUKCJI EKOLOGICZNEJ

Streszczenie

W latach 2014 - 2015 przeprowadzono badania polowe, których celem była ocena plonowania wybranych jakościowych odmian pszenicy ozimej uprawianych w gospodarstwach ekologicznych w różnych rejonach kraju. Zakres badań obejmował plon ziarna i cechy jego struktury, stan odżywienia roślin w azot oraz występowanie i nasilenie chorób grzybowych. Wyniki badań pozwoliły na wskazanie niezależnie od warunków siedliskowych odmian, które charakteryzowały się dużymi i stabilnymi w latach plonami ziarna, były to: Sailor, KWS Ozon, Muszelka. Cechą charakterystyczną struktury plonu decydującą o większej wydajności w tej grupie była głównie masa 1000 ziaren. Do grupy odmian o najmniejszej wydajności zaliczono odmiany: Arkadia, Ostroga oraz pszenicy orkisz Rokosz. Stwierdzono brak zależność pomiędzy uzyskanymi plonami a stanem odżywienia badanych odmian w azot. Wynik ten wskazuje na potrzebę wypracowania w warunkach produkcji ekologicznej nowych zawartości krytycznych azotu lepiej dopasowanych do specyfiki tego systemu.
***Słowa kluczowe**: pszenica ozima, odmiana, rolnictwo ekologiczne, stan odżywienia w azot, struktura plonu*

1. Introduction

Selection of appropriate varieties is a key element of agricultural practice in organic crop production. This allows a better use of habitat potential, prevent from pests and shape the crop quality [2, 3, 6, 9].

Many years of research conducted at IUNG - PIB in Pulawy on the reaction of cereal varieties cultivated in organic farming indicate significant differences in their yielding, particularly large for winter cereals [8, 9]. The research conducted at IUNG-PIB in Pulawy and in another research centers shows that cereals grown in organic system compared to conventional intensive cultivation yielded lower by about 30-35%, and in the years with strong pressure of the yield limiting factors (e.g. a high intensity of fungal diseases) this difference reached 50%. The results also indicate that the varieties that meet the selection criteria for organic farming allow to reduce the risk of large yield declines, achieve lower variability in years and grain of good quality [8, 9, 10, 11, 13].

According to organic requirements the farmer is obliged to use organic seed material. However in practice, most farmers in Poland use conventional seed material, what is especially noticeable for cereals. It is estimated that more than 95% of organic producers use conventional seed material [13, 15, 16]. The reason of this situation consists in, among others, the lack of organic breeding programs, a small supply of seeds from organic farms and insufficient supply of varieties.

Due to the lack of varieties adapted to organic farming, their selection from the national registry is key for achieving stable yields of suitable quality [9, 11].

The aim of the study was to compare the yields of several varieties of winter wheat grown in organic farms and an indication of varieties best suited to organic production. An additional objective was to evaluate the usefulness of NNI (Nitrogen Nutrient Index) to assess the nitrogen status of winter wheat grown in organic system.

2. Materials and methods

The research was conducted in 2014 and 2015 in three organic farms located in different regions of Poland, i.e: IUNG-PIB Experimental Station Kępa in Osiny (lubelskie voivodeship), Agricultural Advisory Centre Brwinów farm in Chwałowice (mazowieckie voivodeship), private organic farm in Chomentowo (podlaskie voivodeship). The characteristics of the natural conditions in these three different localities are given in Table 1.

In each location 11 varieties of winter wheat were tested. They belonged to two technology groups: A - a group of quality wheat (Arkadia, Bamberka, Julius, Ostroga, Sailor, Skagen, Smuga) and B - a group of bread wheat (Banderola, Jantarka, KWS Ozon, Muszelka). In addition, a first registered variety of spelt winter wheat – Rokosz was included in this comparison.

Table 1. Characteristics of the natural conditions of selected farms
Tab. 1. Charakterystyka warunków siedliskowych doświadczeń z pszenicą ozimą

Specification		Farm (location)		
		Osiny (lubelskie)	Chwałowice (mazowieckie)	Chomentowo (podlaskie)
Soil suitability complex		very good rye	good wheat	very good rye
Soil type		lessive	brown soil	leached soil
Soil fertility: Humus [%]		1,4	1,7	1,6
P_2O_5	[mg*100 g^{-1} soil]	8,6	23,4	6,4
K_2O		10,0	22,3	5,3
Mg		9,1	13,1	13,6
pH KCl		5,9	6,2	6,6
Forecrop		clover-grass mixture	mixture of cereals	clover-grass mixture

Source: own work / *Źródło*: opracowanie własne

The selection of varieties was based on the results of COBORU and IUNG-PIB research [4, 10, 11]. The tested varieties were of a very good quality, had higher than average resistance to fungal pathogens and different morphology of stalk and ears. These characteristics were essential in the context of their competitiveness in relation to weeds and resistance to fungal pathogens, especially of Fusarium genus [4]. For all used varieties the same seeding density (4.5 million grains/ha) was applied. The one-factor experiments were established in a randomized block design with 4 replications. Plot size ranged between 30 to 35 m^2. Analysis of variance with Tukey's half-intervals at significance level of α=0,05 was used to assess the impact of tested factors. Grain yield, characteristics of its structure, the nitrogen nutritional status and intensity of fungal diseases were analyzed. 40 plants in 4 replicates for each variety were taken to analyze the intensity of leaf diseases. The percentage of surface of leaf blades infested by a particular disease was determined. Assessment of the disease intensity on leaves was done in accordance with recommendations of EPPO [7]. The assessment of diseases infestation was done in the early and soft dough stage (BBCH 77-85). To evaluate the nitrogen status Nitrogen Nutrient Index was used [17, 19]. Nitrogen nutritional status was evaluated in two growth stages: in the stem elongation stage (BBCH 32-35) and inflorescence emergence and heading (BBCH 50-59).

The index of the NNI is defined as follows [12]:

$$NNI = N\ measured / N\ critical,$$

where:
N measured is a nitrogen content (%) in a sample,
N critical is a critical nitrogen content (%).
Critical nitrogen concentrations were calculated by the following regression equation proposed for Polish conditions by Fotyma and Pecio [8]:

$$Y = 4{,}56\ (W)^{-0.483},$$

where:
Y is a critical nitrogen content (%),
W is a dry matter yield in t*ha^{-1}.

For crops optimally provided with nitrogen value of this index is 1.

3. Results and Discussion

Weather conditions

In 2013/2014 season in all localities intensive precipitation before sowing negatively affected the pre-sowing preparation of fields, sowing and crop emergence. In Osiny and Chwałowice from May to August precipitation sums exceeded several times the multi-year averages (tab. 2). In such conditions development of fungal diseases of leaves and spikes were observed. 2014/2015 season was characterized by a deficiency of rainfall. In the summer months a deficit of rainfall, depending on the locality, ranged from 1/3 to 1/5 of the long-term averages. This situation was particularly severe in Chomentowo in podlaskie voivodeship, where the dry season lasted from May to the end of the growing season. Lack of rainfall during the period from June to the end of the growing season limited the incidence of fungal diseases, one of the main factors limiting the yield of cereals in organic production.

Yielding of varieties

A large variation of yielding in particular seasons and localities was noted. The reaction of varieties in specific habitats was significantly modified by precipitation sum and incidence of fungal diseases and weed infestation (tab. 3, 4).
In 2014, the highest yields were noted in Chwałowice where soils are of a very good quality. In this place the yields ranged from 6,30 to 8,41 t*ha^{-1}. The highest yields were noted for Skagen (8,41 t*ha^{-1}), Julius (8,18 t*ha^{-1}) and Bamberka (8,16 t*ha^{-1}) variety. A characteristic feature of Skagen and Julius varieties consists in an ability to develop a dense canopy of 490-530 ears per m^2 and for Bamberka variety a large mass of 1000 grains that amounted to 51 g. In Osiny due to sparse canopy severe weed infestation was observed (weeds mass amounted to 265 g*m^{-2}). As a consequence the yields of all varieties were worse (tab. 3). In Osiny Smuga variety gave the largest yields on the level of 5,27 t*ha^{-1}, which, compared to other varieties, developed relatively dense canopy with 326 ears per m^2 and large 1000 grain mass that amounted to 42,9 g. In Chomentowo KWS Ozon, Sailor, Smuga, Banderola and Muszelka varieties gave the largest yields. High productivity of Sailor variety was due to dense canopy of 460 ears per m^2 and large 1000 grain weight that amounted to 39,1 g. In a case of Smuga and Banderola varieties the grain plumpness to the greatest extent determined the yield. It amounted respectively to 38,9 g and 38,6 g. In Chomentowo Osroga, Arkadia and Rokosz varieties yielded the worst. They produced the smallest grain plumpness of the mass ranged from 33,4 to 35,3 g.

Table 2. Average monthly temperature (°C) and sum of rainfalls (mm) during the growing season of winter wheat (2013-2015)
Tab. 2. Średnie miesięczne temperatury (°C) powietrza oraz sumy opadów (mm) w wybranych miesiącach okresu wegetacji pszenicy ozimej (2013-2015)

Weather measures	Location	Year	Months					
			IX	X	V	VI	VII	VIII
Temperature	Chomentowo	2013/2014	11,4	9,7	13,5	15,1	20,6	17,7
		2014/2015	14,3	8,9	12,7	16,9	19,4	22,2
		from years 1969/95	12,0	7,0	12,6	15,7	17,1	16,3
	Chwałowice	2013/2014	12,1	10,3	14,0	14,7	20,7	18,0
		2014/2015	14,7	9,3	13,0	17,3	20,1	22,4
		from years 2006/15	13,2	8,4	13,8	16,4	18,6	18,0
	Osiny	2013/2014	11,8	10,2	13,4	15,7	20,6	18,4
		2014/2015	14,7	10,0	12,6	16,8	19,8	22,4
		from years 1950/2000	13,3	8,4	13,8	17,1	18,6	17,8
Rainfalls	Chomentowo	2013/2014	150	12	42	74	56	63
		2014/2015	17	7	46	25	40	10
		from years 1969/95	56	47	57	71	87	71
	Chwałowice	2013/2014	86	7	181	47	158	198
		2014/2015	44	36	142	46	32	14
		from years 2006/15	42	40	111	78	137	66
	Osiny	2013/2014	58	8	171	99	56	106
		2014/2015	16	19	109	29	52	4,3
		from years 1950/2000	53	39	55	71	78	67

Source: own work / *Źródło:* opracowanie własne

In 2015, the highest yields were recorded in Osiny. They were higher than those achieved in 2014 average up to 3,3 t*ha^{-1}, and ranged from 6,11 to 8,70 t*ha^{-1} (tab. 3). This result should be associated with very good weather conditions characterized by less than in other localities moisture deficit and the low intensity of incidence of fungal pathogens. In such conditions, most varieties yielded on a similar level, and the differences in yields were statistically insignificant. In Chwałowice (mazowieckie voivodeship) the average yields of tested varieties amounted to 6,08 t*ha^{-1} and were lower than in 2014 by t*ha^{-1}. Declines of yields in this locality should be associated with weed infestation (weed mass amounted to 73 g*m^{-2}) that influenced canopy density and the grain plumpness. The highest yields in the locality were noted for Muszelka (8,70 t*ha^{-1}) and KWS Ozon (8,18 t*ha^{-1}) variety, and the smallest for Arkadia (6,11 t*ha^{-1}) and spelt wheat Rokosz (6,35 t*ha^{-1}). In Chomentowo Bamberka (5,71 t*ha^{-1}) and Skagen (5,63 t*ha^{-1}) varieties were in a group with the largest productivity. A characteristic feature of Bamberka were manifested by a large grain plumpness – 44,5 g and for Skagen - dense canopy of 432 ears per m^2. In Chomentowo, as in Osiny, Arkadia and Rokosz gave the smallest yields.

Detailed analysis of productivity and frequency of the largest and the smallest yields in all localities allowed to classify varieties into two groups. In the group with high and stable yields were: Muszelka, KWS Ozon and Sailor. The group of varieties that yielded the worst included: Arkadia, Ostroga and spelt wheat Rokosz. These varieties, mainly spelt wheat, produced grain of smaller plumpness and were more infested by fungal pathogens present on the leaves (tab. 3, 4). The obtained results showing the ability of winter wheat to produce large 1000 grains weight and its significance for yielding in conditions of organic farming were confirmed by other authors [3, 6, 10, 13].

The incidence of fungal diseases

In the analyzed period increased infestation of winter wheat by fungal pathogens was recorded in 2014. In this year *Septoria spp.* and *Puccinia striiformis* dominated. The largest area of leaves with symptoms of septoria disease was recorded for Arkadia - 44%, Jantarka - 33%, Smuga and spelt wheat Rokosz - 22%. Whereas greater susceptibility to infection by *Puccinia striiformis* (damage at the level of 12-23% of the leaf surface) was observed for Rokosz, Ostroga and Arkadia varieties. Wheat leaf damage by other pathogens was low and in a case of *Drechslera tritici-repentis* amounted on average to approximately 5% and 2% for *Puccinia recondita*. The severity of *Drechslera tritici-repentis* was observed to a greater extent only for KWS Ozon variety - 11%, however it was not an important factor in reducing the grain yield (tab. 3, 4).

In 2015 weather conditions were not good to the incidence of fungal pathogens. In all locations *Puccinia striiformis* was observed in the highest intensity. It caused the greatest damage to the leaves of Arkadia - 21% and Muszelka - 19%. In a case of other varieties more susceptible to this pathogen, as in 2014, was Rokosz - 11% and Ostroga - 11% varieties (tab. 4). Other fungal pathogens of wheat leaves were recorded in lower intensity. In a case of septoria disease more symptoms, as in 2014, were observed on spelt wheat Rokosz - 13%, and for wheat leaf rust on Skagen variety - 11%. The presence of *Puccinia striiformis* was negligible and the differences in incidence of this pathogen between varieties were not statistically significant (tab. 4). For wheat pathogens occurring in greater intensity (*Septoria spp.* and *Puccinia striiformis*), there was no significant interaction of variety and the locality. This shows a similar reaction of varieties on infections caused by these pathogens.

Nitrogen nutritional status of tested varieties

Nitrogen nutritional status, evaluated by NNI test in two growth stages - BBCH 32-35 and 50-59, was deficient for all tested varieties (Fig. 1). These results are consistent with those obtained by the authors in previous studies [14, 16]. Most varieties were characterized by better nitrogen nutritional status in BBCH 32-35 growth stage than in BBCH 50-59. In 2014, only a Julius variety, and in 2015 Ostroga, Skagen, Smuga and spelt wheat Rokosz, showed a smaller deficit of nitrogen in BBCH 32-35 stage than in BBCH 50-59. The smaller deficit of nitrogen for most of varieties in BBCH 50-59 growth stage in 2015 than in 2014 should be associated with better availability of this nutrient. In 2015 wheat might uptake N in later growth stages due to better rainfall distribution, smaller severity of fungal diseases and smaller weeds infestation (Fig. 1). In 2014 the least deficient nitrogen nutritional status in BBCH 32-35 stage was observed for Bamberka, Smuga and Ostroga varieties, whereas the most deficient for Julius variety. In BBCH 50-59 stage this variety had the best nitrogen nutritional status, and the biggest deficiency was noted for Skagen, Ostroga and Rokosz varieties. In 2015 in BBCH 32-35 stage, as in 2014, Bamberka, Ostroga, Arkadia and Sailor had better nitrogen nutritional status. In the BBCH 50-59 stage the most favorable nutritional status in N was recorded for Ostroga and Skagen varieties, whereas Jantarka, Julius, Muszelka and Ozon varieties showed the biggest deficiency of N. The results indicate that some varieties as Bamberka and Ostroga were characterized in both years by a better nutritional status in the early growth stages.

In literature it is showed large differences in N uptake by wheat varieties and the importance of this feature in conditions of organic farming [1, 16]. It should be emphasized, however, that the nitrogen nutritional status of the tested cultivars evaluated by NNI test did not correspond with the yields. Different results showing a positive correlation between yield and nitrogen nutritional status was obtained in the conventional system [1, 5, 18]. These results indicate that critical nitrogen nutrient concentrations determined for NNI index in intensive conventional farming are not appropriate for organic farming and there is a need to develop these concentrations specifically for conditions of this system.

Table 3. The grain yield of winter wheat and the components of yield structure – 2014-2015
Tab. 3. Plon ziarna pszenicy ozimej i elementy jego struktury – w latach 2014-2015

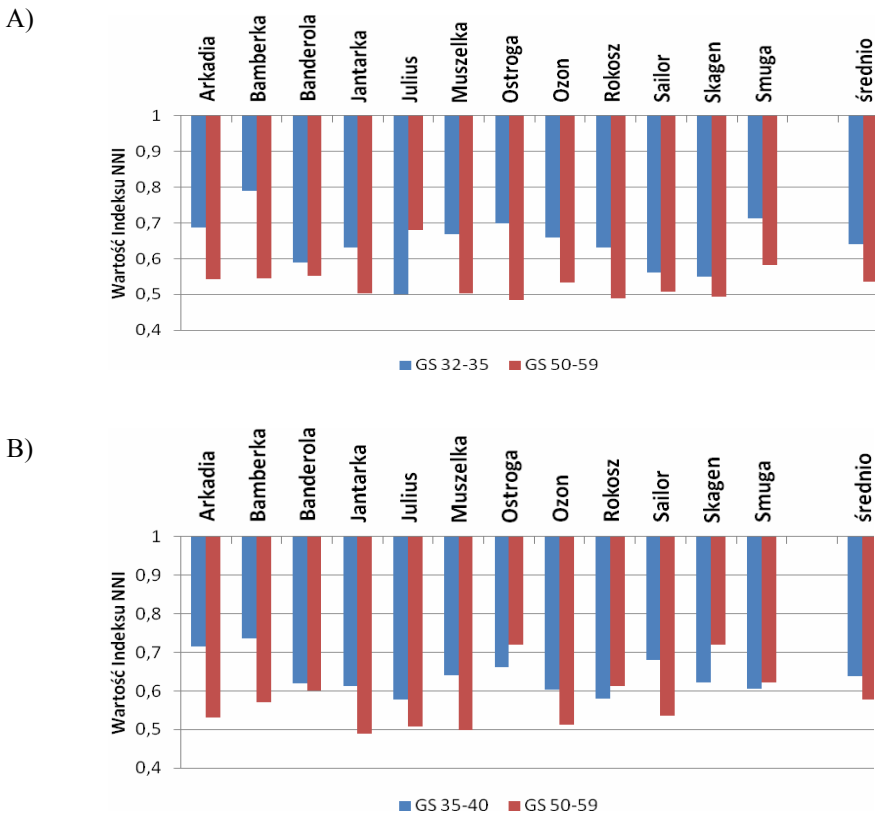
Variety	Osiny			Chomentowo			Chwałowice		
	Yield [t*ha^{-1}]	Number of ears [szt.*m^{-2}]	1000 grains weight [g]	Yield [t*ha^{-1}]	Number of ears [szt.*m^{-2}]	1000 grains weight [g]	Yield [t*ha^{-1}]	Number of ears [szt.*m^{-2}]	1000 grains weight [g]
2014									
Arkadia	3,92	293	39,3	4,04	415	35,3	7,61	422	47,8
Bamberka	3,60	282	42,9	4,86	402	43,2	8,16	426	51,0
Banderola	4,31	270	44,1	5,43	418	38,6	7,16	413	49,4
Janarka	4,54	285	41,8	5,16	472	37,5	6,66	383	47,0
Julius	4,64	282	39,2	4,57	428	34,6	8,18	528	46,0
KWS Ozon	3,27	236	40,8	5,65	402	35,2	7,61	447	53,3
Muszelka	4,43	314	42,0	5,40	469	36,4	6,60	453	46,3
Ostroga	4,62	351	42,4	3,94	444	33,4	6,30	468	47,1
Rokosz	3,78	346	38,5	4,24	418	33,4	6,88	428	37,7
Sailor	4,25	264	42,1	5,63	460	39,1	7,58	396	48,4
Skagen	4,71	320	41,5	4,69	458	39,9	8,41	491	47,8
Smuga	5,27	326	42,9	5,59	414	38,9	7,27	495	48,6
Mean	**4,28**	**297**	**41,4**	**4,93**	**433**	**37,1**	**7,37**	**446**	**47,5**
$LSD_{0,05}$	1,26	84	1,9	0,22	72	0,7	0,10	57	2,1
Weed infestation in total (g*m^{-2})	265			26			51		
2015									
Arkadia	6,11	482	38,3	4,39	397	40,8	5,52	373	43,6
Bamberka	7,99	474	45,1	5,70	353	44,5	6,25	375	49,0
Banderola	8,07	515	46,2	4,78	332	39,8	6,10	325	48,1
Janarka	7,86	462	45,7	5,31	408	40,3	5,89	328	47,4
Julius	7,83	528	39,9	4,58	364	38,6	6,58	382	47,7
KWS Ozon	8,18	440	43,0	4,94	375	43,2	6,77	370	49,5
Muszelka	8,70	510	43,4	4,96	434	40,8	6,83	394	47,0
Ostroga	7,22	483	41,6	4,75	400	41,7	5,58	355	44,3
Rokosz *	6,35	531	41,5	3,57	417	39,0	4,94	366	41,5
Sailor	7,91	489	41,7	5,01	356	39,9	6,60	393	45,5
Skagen	7,52	474	39,4	5,63	432	38,4	6,37	347	46,2
Smuga	7,62	460	45,6	4,75	391	40,4	5,53	346	43,9
Mean	**7,61**	**487**	**42,6**	**4,86**	**388**	**40,6**	**6,08**	**362**	**46,1**
$LSD_{0,05}$	0,53	75	2,3	0,23	63	1,8	0,98	43	2,5
Weed infestation in total (g*m^{-2})	27			9			73		

Source: own work / *Źródło:* opracowanie własne

Table 4. Infestation of winter wheat leaves (F-F2) by fungal pathogens - the average from three locations (BBCH 77-83)
Tab. 4. Porażenie liści(F-F2) pszenicy ozimej przez patogeny grzybowe - średnia z trzech lokalizacji (faza mleczno-woskowa ziarna BBCH 77-83)

Variety	The leaves with disease symptoms in %			
	Puccinia recondita	*Septoria spp.*	*Puccinia striiformis*	*Drechslera tritici-repentis*
2014				
Arkadia	1,8	44,2	11,5	3,2
Bamberka	2,5	13,8	0,2	4,1
Banderola	3,3	18,9	0,2	2,9
Jantarka	1,4	33,2	8,4	1,6
Julius	2,2	12,1	0,2	7,5
Muszelka	0,7	16,4	3,6	8,2
Ostroga	1,0	12,1	19,6	2,8
Ozon	2,1	12,2	0,2	10,8
Rokosz	1,6	22,5	23,4	2,2
Sailor	2,8	16,3	0,2	5,5
Skagen	3,2	7,7	0,1	4,4
Smuga	4,9	27,7	0,6	8,4
$LSD_{0,05}$	3,4	12,7	8,8	4,0
2015				
Arkadia	6,0	6,2	21,4	0,4
Bamberka	6,6	1,8	0,4	1,7
Banderola	4,0	1,0	4,0	2,1
Jantarka	2,8	2,2	4,7	2,5
Julius	4,2	0,6	0,1	1,0
Muszelka	3,1	1,3	18,6	3,3
Ostroga	5,6	0,8	10,2	1,8
Ozon	2,9	0,5	0,0	1,0
Rokosz	6,4	13,0	11,4	2,5
Sailor	3,7	2,6	0,6	3,5
Skagen	11,2	0,1	0,0	0,6
Smuga	6,0	1,0	1,7	5,9
$LSD_{0,05}$	4,4	6,6	14,7	2,9

Source: own work / *Źródło:* opracowanie własne



Source: own work / *Źródło:* opracowanie własne

Fig. 1. The value of the NNI index for the winter wheat varieties grown in organic system in 2014 (A) and 2015 (B)
Rys. 1. Wartość Indeksu NNI dla dwunastu odmian pszenicy ozimej w systemie ekologicznym w latach 2014 (A) i 2015 (B)

4. Conclusion

Among the tested winter wheat varieties Muszelka, KWS Ozon and Sailor were in the group with the largest and stable yielding in all localities. These varieties were characterized by a larger weight of 1000 grains and higher resistance to infection by *Septoria spp.* and *Puccinia striiformis*.

Muszelka, KWS Ozon and Sailor, on average, yielded at the level of 6,1 $t \cdot ha^{-1}$. It was mainly due to large grain plumpness, which for KWS Ozon was on the level of 44,2 g, and for Muszelka and Sailor 42,7 g. Additionally Muszelka variety was characterized by a high density of canopy with 430 $ears \cdot m^{-2}$ on average.

Spelt wheat Rokosz in all locations yielded the lowest achieving 4,96 $t \cdot ha^{-1}$ of husked grain. Spelt wheat formed a dense canopy of 418 ears per m^2 with low weight of 1000 grains – 38,6 g at the same time. Higher susceptibility to fungal diseases, mainly septoria and rust was the main yield limiting factor for Rokosz variety.

Arkadia and Ostroga were in the group of varieties with the lowest yields. These varieties obtained an average yield in all locations at the level of 5,3 $t \cdot ha^{-1}$. The lower productivity of these varieties was due to worse grain plumpness, amounting on average for Arkadia – to 40,9 g, and for Ostroga variety – to 41,8 g. Both varieties were more affected by *Septoria spp.* and *Puccinia striiformis*.

There was no correlation between the yields obtained and the nitrogen nutritional status of the tested varieties as evaluated by NNI test. This observation points to the need to develop critical nitrogen concentrations in the conditions of organic farming.

5. References

[1] Anderson W.K., Seymour M., D'Antuono M.F.: Evidence for differences between cultivars in responsiveness of wheat to applied nitrogen. Austrialian Journal of Agricultural Research, 1991, 42: 363-377.

[2] Baresel J.P., Zimmermann G., Reents, H.J.: Effects of genotypes and environment on N uptake and N partition in organically grown winter wheat (Triticum aestivum L.) in Germany. Euphytica, 2008, 163: 347-354.

[3] Cesevičienė J., Leistrumaitė A., Paplauskienė V.: Grain yield and quality of winter wheat varieties in organic agriculture. Agronomy Research, 2009, 7: 217-223.

[4] COBORU, Porejestrowe doświadczalnictwo odmianowe. Charakterystyka odmian. 2014. http://www.coboru.pl/DR/charaktodmiany.aspx.

[5] Dawson J.C., Huggins D.R., Jones S.S.: Characterizing nitrogen use efficiency in natural and agricultural ecosystems to improve the performance of cereal crops in low-input and organic agricultural systems. Field Crops Research, 2008, 107: 89-101.

[6] Eisele J.A., Köpke U.: Choice of cultivars in organic farming: new criteria for winter wheat ideotypes. Pflanzenbauwissenschaften, 1997, 1(1): 19-24.

[7] EPPO: Guidelines for the efficacy evaluation of plant protection products. Standards, vol.1:187-195, 1999.

[8] Fotyma E., Pecio A.: Zależność pomiędzy zawartością azotu a nagromadzaniem suchej masy przez zboża. Pam. Puł. 1999, 114: 93-100.

[9] Jończyk K.: Problemy agrotechniki w rolnictwie ekologicznym. Studia i Raporty IUNG-PIB, 2010, z. 26.

[10] Jończyk K. Reakcja wybranych odmian pszenicy ozimej na uprawę w różnych systemach produkcji roślinnej. Pam. Puł., 2012, 130/1: 339-345.

[11] Kuś J., Jończyk K., Stalenga J, Feledyn-Szewczyk B., Mróz A.: Plonowanie wybranych odmian pszenicy ozimej w uprawie ekologicznej i konwencjonalnej. Journal of Research and Applications in Agricultural Engineering, 2010, 55(3): 219-223.

[12] Lemaire G., Gastal F. 1997. N uptake and distribution in plant canopies. In: Lemaire G. (ed.) Diagnosis of the nitrogen in crops. Springer-Verlag Berlin Heidelberg: 3-43.

[13] Lammerts van Bueren E.T., Jones S.S.,Tamm L., Murphy K.M., Myers J.R., Leifert C., Messmer M.M.: The need to breed crop varieties suitable for organic farming, using wheat, tomato and broccoli as examples: A review. NJAS Wageningen, Journal of Life Sciences, 2011, 58: 193-205.

[14] Lenc L., Kuś J., Sadowski Cz.: Fuzarioza kłosów i ziarna pszenicy ozimej (*Fusarium* spp.) w różnych systemach uprawy. Journal of Research and Applications in Agricultural Engineering, 56 (4): 32-37.

[15] Löschenberger F., Fleck A., Grausgruber H., Hetzendorfer H., Hof G., Lafferty J., Marn M., Neumayer A., Pfaffinger G., Birschitzky J.: Breeding for organic agriculture: the example of winter wheat in Austria. Euphytica, 2008, 163: 469-480.

[16] Murphy K.M., Campbell K.G., Lyon S.R., Jones S.S.: Evidence of varietal adaptation to organic farming systems. Field Crops Research, 2007, 102: 172-177.

[17] Stalenga J. Applicability of different indices to evaluate nutrient status of winter wheat in the organic system. Journal of Plant Nutrition, 2007, 30: 351-365.

[18] Stalenga J.: Zastosowanie testu SPAD do oceny stanu odżywienia azotem pszenicy ozimej w różnych systemach produkcji roślinnej. Nawozy i Nawożenie, 2002, 2 (11): 137-144.

Stalenga J.: Plonowanie, stan odżywienia oraz efektywność wykorzystania składników nawozowych (NPK) przez dawne i współczesne odmiany pszenicy ozimej uprawiane w ekologicznym systemie produkcji roślinnej. Journal of Research and Applications in Agricultural Engineering, 2009, 54 (4): 106-119.