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Variability of the agronomic characters in different types of cultivars of winter oilseed rape (*Brassica napus* L.)

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Abstract. Winter oilseed rape cultivars (open-pollinated variety, four composite hybrids, one restored hybrid and the CMS *ogura* line) were tested during two crop seasons of 2002/2003 and 2003/2004 in field trials at two locations in western Poland. The objectives of the present study were: to determine the variability of yield and the most important phenotypic traits of different types of winter oilseed rape cultivars and to analyse the genotypic variability of this cultivars by environment interactions. The growing seasons differed especially in terms of water supply. Seed yield, yield components and some quality traits (oil content and total glucosinolate content) were recorded. The tested cultivars showed substantial differences in terms of yield and other investigated traits. Analysis of variance indicated that the main effects of cultivar and locations were significant for all the traits of the study. Very high heritability estimates were obtained for seed yield (0.90–0.98), yield components (length of silique, number of seeds per silique and weight of 1000 seeds), and also for oil and glucosinolate contents. The correlation coefficients between the investigated traits displayed strong positive relationships between seed yield and the number of seeds per silique, chlorophyll content, and the length of flowering period. The results confirmed the higher productivity of hybrid cultivars, as well as their better adaptability to variable environmental conditions, especially drought.

keywords: *Brassica napus*, cultivar, yield and yield component, quality trait, coefficient of variability, heritability

INTRODUCTION

Research related to the improvement of winter oilseed rape quality and yield capability has led to increased worldwide production of this plant. Winter oilseed rape is the leading oilseed crop both in Poland and across the European Union. In Europe (28 EU members countries) today, oilseed rape is grown over a total area of 6.7 Mha (2014) and produces over 24.3 Mt of seeds. The major producers of rapeseed seeds in the EU in 2014 are: France 5.5 Mt, Germany 6.3 Mt, and United Kingdom 2.4 Mt ha. Poland also has a significant production level – around 3.2 Mt, and so ranks third or fourth in the EU, depending on the year (FAOSTAT, 2016).

Increased worldwide oilseed rape production was not only achieved by increasing the growing area, but also by the introduction of the latest generation of high-yielding open pollinated and hybrid cultivars. Oilseed rape hybrids, due to the heterosis effect, produce high and stable seeds and oil yield. Oilseed rape hybrid cultivars in Poland account for about 30% of the area under the crop and the area is still increasing. In Germany, for example, hybrid cultivars represent more than 50% of the total oilseed rape growing area in 2009 (Wittkop et al., 2009) which now exceeds 90% of the cultivated area (BDP, Meilensteine im deutschen Rapsanbau, 2017).

The Polish National List of Agricultural Plant Varieties (www.coboru.pl) includes 121 winter oilseed rape cultivars; 42 are open pollinated cultivars and 79 hybrids and 30 spring oilseed rape cultivars (15 open pollinated cultivars and 15 F_1 hybrids). The cultivars are characterized by different levels of yield, yield components, and quality parameters – such as oil, protein, glucosinolate contents and the fatty acid composition of seeds. Apart from cultivar-specific factors, environmental conditions have the most significant influence on seed yield, their components and seed quality (Seyis et al., 2006; Girke et al., 2012; Nowosad et al., 2016).

The aim of this study was to determine the variability of yield and the most important phenotypic traits of different types of winter oilseed rape cultivars.

MATERIALS AND METHODS

Plant material and field trials

Seven different types of winter oilseed rape cultivars were investigated for seed yield and different phenoty-

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pic traits. These cultivars were: the 'Lisek' open-pollinated variety (Deutsche Saatveredelung GmbH, Lippstadt); 'Samourai' – a CMS *ogura* line of the Samourai cultivar (the maternal line of the composite hybrids v. Synergy and four Polish composite hybrids, Serasem); four Polish composite hybrids – 'Kaszub', 'Pomorzanin', 'Lubusz', and 'Mazur' (Plant Breeding Company Strzelce Ltd. Group PBAI); and one restored hybrid 'Kronos' (NorddeutschePflanzenzucht, Hans-Georg Lembke KG, Hohenlieth). The plants of the CMS *ogura* line, 'Samourai', were pollinated on neighbouring plots with male fertile plants. The varieties were tested in the growing seasons of 2002/2003 and 2003/2004. Field trials were performed in four replicates of a randomized block design at the Wielichowo – Zielęcin Experimental Station (52°10'N, 16°23'E) and at the Borowo Division of the Strzelce Plant Breeding Company Ltd (52°07'N, 16°46'E) (Greater Poland, Poland). As shown in Tables 1 and 2, the two locations differed slightly in their climatic conditions, soil types and previous crops. Experimental cultivars were grown on 10 m^2 plots, at a density of 80 plants per m^2. Each plot consisted of four rows with 0.30 m between rows and approximately 0.20 m between plants within rows. Sowing dates were between the 24th and 28th of August.

Table 1. Soil properties in the two trial locations, Borowo and Zielęcin in crop seasons 2002/2003 and 2003/2004.

Location/Year	Soil quality class	Soil pH	Previous crop
Borowo 2002/2003	IIIa	6.3	wheat
Borowo 2003/2004	IIIa	6.1	triticale
Zielęcin 2002/2003	IVa	6.3	barley
Zielęcin 2003/2004	IVa	5.4	barley

Yield and yield component determination, phenotypic traits

The following factors were measured during the crop season: earliness, beginning, end and length of flowering period. 10 days before harvest, 25 siliques from each plot were collected to determine silique length and the number of seeds per silique. After the harvest, the seed yields from each replicate plot were determined: weight of 1000 seeds, oil content and total glucosinolate content. Analyses of glucosinolates were performed via gas chromatography of the silyl derivatives of desulfoglucosinolates (PN ISO 9167-1:1999). Oil content in seeds was analyzed using the Nuclear Magnetic Resonance method (NMR Newport Instruments Ltd.) (Krzymanski, 1970).

Statistical analysis

The Shapiro-Wilk normality test (Shapiro and Wilk, 1965) was used to establish the normal distributions of the all phenotypic traits: seed yield [dt ha^{-1}], length of silique [cm], number of seeds per silique, weight of 1000 seeds [g], chlorophyll content [unit SPAD], beginning of flowering [day of year], end of flowering [day of year], length of flowering [days], oil content [%], and total glucosinolate content [μmol g^{-1} of seeds]. A three-way analysis of variance was carried out to determine the effects of cultivars, years and locations and the interactions: cultivars × years, cultivars × locations, years × locations and cultivars × years × locations – on the variability of studied traits. Coefficients of variation (cv) (Kozak et al., 2013) and the broad-sense heritability coefficients (h^2) (Falconer and Mackay, 1996) were calculated for observed traits for each year and location. Mean values of observed traits for cultivars-locations-years combinations was presented on the parallel coordinate plots (Bocianowski et al., 2015). The applied canonical variate analysis (CVA) makes it possible to reduce the number of traits (dimensions) describing the objects (combinations of genotypes, locations and years) and illustrates the distribution of object means on the plane (Seidler-Łożykowska and Bocianowski, 2012). All statistical analyses were performed using the GenStat v. 17 statistical software package.

RESULTS AND DISCUSSION

The two vegetation seasons during which the experiment was performed differed from each other especially for water supply. In 2003, there was a severe drought from March to the end of September. The sum of rainfall in the spring of 2003 (108 mm in Borowo; 139 mm in Zielęcin) was markedly lower than during the same period in 2004 (176 mm in Borowo; 218 mm in Zielęcin). Average rainfall for the same period in the years 1954–2002 was 177 mm in Borowo and 190 mm in Zielęcin (Table 2).

Analysis of variance indicated that the main effects of cultivar and location were significant for all the traits of the study, including yield and the traits directly influencing the quantity of seed yield as well as quality traits (Table 3). This is certainly due to the different genotypes of the investigated cultivars, as well as the different climatic and environmental conditions, as shown in tables 1 and 2. The main effects of year as well as year × location interaction were significant for all traits except silique length (Table 3), whereas the effects of cultivar × year interaction were significant for all traits except silique length and the number of seeds per silique (Table 3). This effect is probably due to the shortage of water in the critical period in the 2002/2003 vegetation season. The effects of cultivar × location interaction were significant for silique length, chlorophyll content as well as the beginning, end and length of flowering (Table 3), whereas the effects of cultivar × year × location interaction were significant only for the beginning, end and length of flowering as well as for the weight of 1000 seeds, chlorophyll content and oil content (Table 3). Chen et al. (2014) showed significant differences

Table 2. Meteorological conditions at Borowo and Zielęcin during the vegetation season of winter oilseed rape in 2002/2003 – 2003/2004 and over an extended period.

Basic weather parameters	Borowo			Zielęcin		
	2002/2003	2003/2004	1954–2002	2002/2003	2003/2004	1954–2002
Mean temperature [°C]						
annual	8.9	8.5	8.8	9.0	10.0	8.9
critical season of autumn#	7.4	7.3	8.0	8.0	8.0	8.9
critical season of spring###	15.9	13.7	14.9	16.0	15.0	14.6
Precipitation [mm]						
in whole vegetation season	481	497	538	601	419	594
in critical season of autumn#	178	84	103	168	64	114
in critical season of winter##	90	170	141	116	157	164
in critical season of spring###	108	176	177	139	218	190
Precipitation in % of a many years background						
in whole vegetation season	89	72	100	101	71	100
in critical season of autumn#	173	82	100	147	56	100
in critical season of winter##	64	121	100	71	96	100
in critical season of spring###	61	99	100	73	115	100

months: September, October, first and second decades of November
months: third decade of November, December, January, February and March
months: April, May, June and first decade of July

Table 3. Mean squares from analysis of variance (ANOVA) for observed traits of winter oilseed rape (*Brassica napus* L.).

Source of variation	Cultivar (C)	Year (Y)	Location (L)	C×Y	C×L	Y×L	C×Y×L	Residual
Degrees of freedom	6	1	1	6	6	1	6	132
Seed yield	958.06***	136964.85***	1434.19***	700.19***	8.68	2389.88***	5.32	43.54
Length of silique	3.78***	0.60	2.54***	0.32	1.35***	0.35	0.28	0.22
Number of seeds per silique	114.91***	41.31**	284.36***	12.02	6.60	257.30***	8.02	5.70
Weight of 1000 seeds	1.72***	0.72*	3.80***	2.02***	0.20	28.38***	0.33**	0.11
Chlorophyll content	10691***	600250***	130416***	3378**	4635***	158005***	2612*	886.00
Beginning of flowering	57.85***	624.10***	308.03***	6.06***	16.53***	55.23***	4.25***	0.96
End of flowering	27.20***	74.26***	878.91***	15.35***	6.78**	425.76***	7.89***	1.90
Length of flowering	9.57***	267.81***	2242.51***	17.28***	11.71***	778.81***	4.49*	1.55
Oil content	7.08***	34.67***	4.65*	4.30***	1.01	303.27***	2.29*	0.95
Total glucosinolate content	171.15***	748.23***	72.09***	107.18***	3.16	193.16***	3.09	4.57

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

between the environments (two years) and yield and agronomic traits of rapeseed such as: weight of 1000 seeds, number of siliques per plant, seeds per silique, plant height, oil content and glucosinolate content (Chen et al., 2017).

Table 4 shows the phenotypic variation (mean value, coefficient of variation and heritability *sensu lato*) for all measured traits at two locations over the two years of field trials. The results of field trials demonstrated the impact of weather conditions on the seed yield and other phenotypic traits of all investigated types of winter oilseed rape varieties. The average seed yield of seven cultivars at two locations was higher in the crop season of 2003/2004 (68.5 dt ha^{-1} at Borowo; 54.8 dt ha^{-1} at Zielęcin) than in 2002/2003 (22.7 dt ha^{-1} at Borowo; 40.1 dt ha^{-1} at Zielęcin) (Table 4). Two hybrid cultivars – restored Kronos (54.41 dt ha^{-1}) and composite hybrid Lubusz (55.66 dt ha^{-1}) – showed the highest average yield (Table 4, Fig. 1). In contrast, the CMS *ogura* line Samourai showed the lowest seed yield at all tested localities (27.07 dt ha^{-1}). This indicates that, in rapeseed, self-pollination is just as important as allogamous pollina-

Table 4. Mean value, coefficient of variation (cv) and heritability (h^2) for phenotypic traits of investigated cultivars.

Trait		Kaszub	Kronos	Lisek	Lubusz	Mazur	Pomo-rzanin	Samourai	$\bar{x}$	cv	h^2
Seed yield [dt ha^{-1}]	B3	25.6	31.2	25.4	25.2	24.3	24.5	7.1	22.7	38	0.98
	B4	68.24	76.18	68.2	82.35	75.72	70.53	49.71	68.49	19.4	0.9
	Z3	45	47.9	43	45	42.5	48.5	19.1	40.1	31.1	0.94
	Z4	57.19	62.34	56	70.09	61.91	57.08	32.36	54.77	27.4	0.91
Length of silique [cm]	B3	9.13	8.88	8.34	8.48	8.68	9.05	7.87	8.55	6.82	0.87
	B4	8.25	8.35	8.28	7.95	8.84	8.84	8.11	8.33	5.68	0.75
	Z3	8.16	8.88	8.6	8.1	8.18	8.24	7.21	8.21	8.5	0.92
	Z4	7.85	9.04	8.29	8.25	7.93	8.23	7.43	8.18	9.35	0.84
Number of seeds per silique	B3	27.03	27.61	25.1	26.27	23.72	25.03	21.31	25.01	11.1	0.91
	B4	25.88	30.85	29.5	29.5	28.55	28.95	26.06	28.56	9.35	0.83
	Z3	24.35	28.41	26.7	22.25	24.1	25.7	21.05	24.88	13.6	0.9
	Z4	20.93	27.27	24.3	24.9	21.12	22.15	20.66	23.36	16.5	0.8
Weight of 1000 seeds [g]	B3	5.3	4.78	5.01	5.08	5.66	5.46	6.16	5.34	9.86	0.98
	B4	4.76	4.1	4.23	4.54	5.46	4.58	3.82	4.36	15.3	0.85
	Z3	4.97	4.3	4.66	4.83	5.09	4.8	5.24	4.8	7.85	0.94
	Z4	5.89	5.48	5.44	5.35	5.78	6.03	5.14	5.52	7.3	0.85
Chlorophyll content [unit SPAD]	B3	651.0	680.2	670.3	738.5	661.0	715.0	651.5	676.9	5.04	0.92
	B4	711.8	702.4	730.4	791.5	761.0	744.2	746.0	736.6	5.14	0.84
	Z3	673.0	645.8	645.5	674.5	727.5	757.5	648.5	671.2	6.16	0.97
	Z4	896.5	842.1	839.0	868.5	874.8	863.8	849.9	856.5	5.19	0.53
Beginning of flowering [day of year]	B3	119.8	122.9	124.0	118.5	120.0	122.0	119.6	121.3	1.78	0.96
	B4	114.5	119.1	118.9	114.2	115.5	115.8	113.0	116.2	2.15	0.99
	Z3	122.0	123.6	124.3	122.0	123.0	122.8	108.4	120.2	14.62	0.42
	Z4	118.0	121.0	121.1	123.0	118.2	119.5	119.2	120.1	1.68	0.87
End of flowering [day of year]	B3	140.2	142.1	144.3	140.5	139.5	142.5	138.8	141.3	1.57	0.95
	B4	143.0	143.3	143.8	142.8	143.0	143.5	142.9	143.2	0.73	0.41
	Z3	138.2	141.5	141.8	138.0	139.5	138.8	138.9	139.9	1.49	0.85
	Z4	133.2	135.5	135.9	139.0	133.2	134.0	135.1	135.3	1.63	0.86
Length of flowering [days]	B3	20.5	19.3	20.3	22.0	19.5	20.5	19.1	20.0	7.39	0.75
	B4	28.5	24.1	24.8	28.5	27.5	27.8	29.9	27.0	9.18	0.96
	Z3	16.3	17.9	17.5	16.0	16.5	16.0	16.8	16.9	8.45	0.64
	Z4	15.3	14.4	14.8	16.0	15.0	14.5	15.9	15.1	8.14	0.65
Oil content [%]	B3	45.28	45.16	44.51	45.05	44.20	45.03	43.12	44.52	2.88	0.76
	B4	49.45	47.41	46.94	49.45	48.45	48.18	48.89	48.20	2.51	0.89
	Z3	47.65	47.36	46.50	47.43	47.25	47.67	45.77	46.93	2.06	0.86
	Z4	45.17	45.29	44.85	46.38	45.30	45.00	44.46	45.10	2.65	0.57
Total glucosinolates content [μmol g^{-1} of seeds]	B3	19.38	12.08	13.15	16.48	15.20	18.15	24.14	16.79	27.77	0.98
	B4	15.47	8.38	9.01	9.85	11.78	13.27	8.78	10.27	26.33	0.94
	Z3	13.53	9.45	10.07	13.15	13.30	13.45	20.02	13.25	32.91	0.95
	Z4	15.60	8.60	9.99	10.45	12.68	13.18	11.09	11.12	30.05	0.78

B3 – Borowo 2003, B4 – Borowo 2004, Z3 – Zielęcin 2003, Z4 – Zielęcin 2004

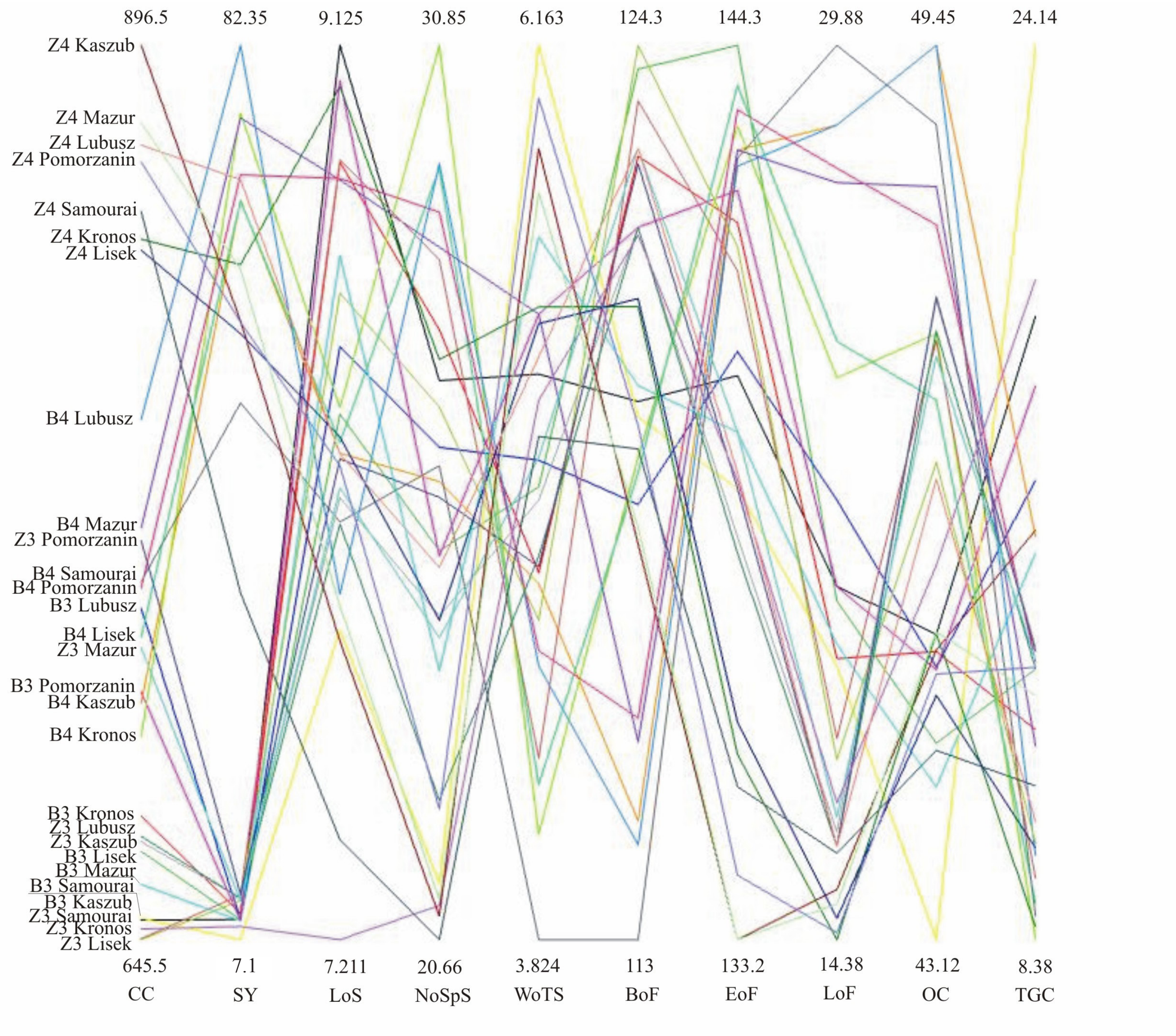

Figure 1. Parallel coordinate plots (PCPs) for 28 cultivars-locations-years combinations and ten traits of winter oilseed rape (CC – chlorophyll content, SY – seed yield, LoS – length of silique, NoSpS – number of seeds per silique, WoTS – weight of 1000 seeds, BoF – beginning of flowering, EoF – end of flowering, LoF – length of flowering, OC – oil content, TGC – total glucosinolates content; B3 – Borowo 2003, B4 – Borowo 2004, Z3 – Zielęcin 2003, Z4 – Zielęcin 2004).

tion, while CMS *ogura* Samourai plants were pollinated only by pollen from neigbouring plots. The seed yields of the composite hybrids Kaszub, Lubusz, Mazur and Pomorzanin greatly exceeded the yield of their parental line, CMS *ogura* Samourai (Fig. 2). Seed yield was conspicuous for its medium coefficient of variability (19.40–37.98), but a very high heritability *sensu lato* (0.90–0.98). The results indicate that the yield of cultivars was determined by genotype and, to a small extent, by the environmental conditions. Würschum et al. (2012) estimated the heritabilities for grain yield in the population of 391 elite rapeseed lines at 0.78. For the seed quality traits, in 518 *B. napus* inbreed lines the heritabilities ranged from 0.86 for oil content to 0.96 for glucosinoalte content (Körber et al., 2012). Gehringer et al. (2007) and Nowosad et al. (2016) showed that F_1 hybrids display a comparatively wider adaptability to adverse soil and climatic conditions than open pollinating lines, with a high yield potential and yield stability in general. Budewig and Léon (2003) confirm that hybrids, as a group, offer higher and more stable yields than open-pollinated cultivars.

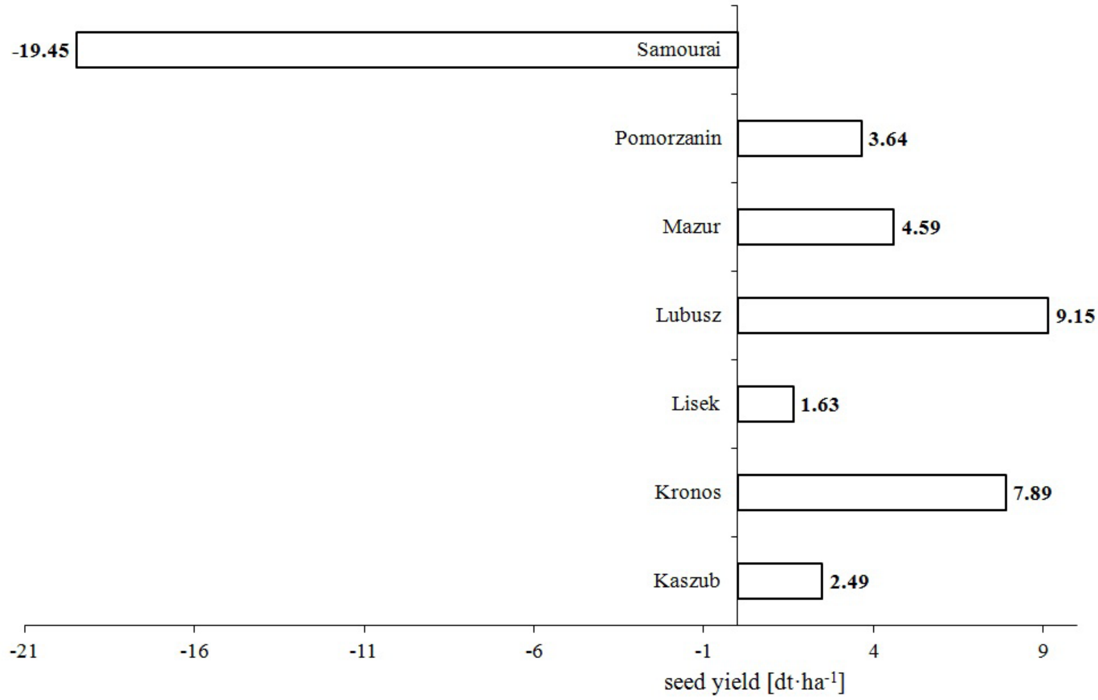

Figure 2. Mean effects of environmental conditions on the seed yield of particular winter oilseed rape cultivars.

Increases in yield are the result of increases in the number of siliques per plant, number of seeds per silique and less frequently the weight of 1000 seeds. The silique is an organ which produces yield and is also a major photosynthesis organ (Zhang et al., 2011). The silique traits, such as silique length, seeds per silique, and seed weight, are the fundamental factors determining rapeseed yield. Statistical analysis revealed differences in terms of yield components – i.e. number of seeds per silique and weight of 1000 seeds at two localities Borowo et Zielęcin. The mean silique length ranged from 8.18 (Zielęcin 2004) to 8.55 (Borowo 2003) with a low coefficient of variability: 9.35 and 6.82, respectively (Table 4). The restored hybrid Kronos demonstrated the longest siliques with the highest number of seeds per silique in all locations. In both years, all tested cultivars demonstrated high coefficients of heritability for silique length, number of seeds per silique and the weight of 1000 seeds. Zhang et al. (2011) found a high coefficient of heritability for seeds per silique (82.5%), silique length (76.9%) and seed weight (87.5%) in a doubled haploid mapping population. Radoev et al. (2008) and Chen et al. (2011) indicate that seeds per silique and seed weight traits depend on silique development, and the development of siliques is influenced by many abiotic factors, such as temperature, light and nutrients.

The highest chlorophyll levels in the leaves of tested cultivars were recorded in the 2003/2004 growing season at Zielęcin – an average of 856.5, but the coefficient of heritability for this trait was the lowest, 0.53. The investigated composite hybrids and the CMS *ogura* line Samurai had similar dates for the beginning and the end of flowering. In all environments, the earliest was the CMS *ogura* line Samourai. The length of the flowering period was greater in both growing seasons at Borowo – respectively 27 and 20 days, as compared to 15.1 and 16.9 days at Zielęcin (Table 4).

Oilseed rape seeds contain valuable nutritional and anti-nutritional compounds. Mature oilseed rape seeds are rich in oil (45–50%), but oil-free meal contains a number of anti-nutritive components, such as glucosinolates, sinapine esters and crude fibre. Hence, breeding efforts towards increased overall seed quality must focus not only on the improvement of oil content and quality, but also on the reduction of anti-nutritive factors (Wittkop et al. 2009). The experimental cultivars varied in their oil and total glucosinolates levels. The composite hybrid Kaszub demonstrated the highest oil levels 49.45% at Borowo 2003/2004, but 45.28% in the dry season (Table 4). The breeding progress for oil content can further be exploited through the development of hybrids from high-oil lines as the hybrid component. Total glucosinolate content ranged from 8.38 (Kronos in Borowo 2004) to 24.14 $\mu mol \cdot g^{-1}$ of seeds (CMS *ogura* line Samourai in Borowo 2003). The coefficient of heritability for the most important quality traits varied for oil content from 0.57 to 0.89 and for total glucosinolate content from 0.78 to 0.98. In the population of 391 elite rapeseed lines, heritability ranged from 0.80 for oil content to 0.93 for glucosinolate content (Würschum et al., 2012). Nowosad et al. (2017) reported that the genotype and environments main effects as well as genotype by environment interaction had the strongest effect on oil content expression in western Poland. Friedt and Snowdon (2009), Liersch et al. (2013) suggest that the majority of seed components significantly depend on both genetic and environmental factors, with a large influence derived from temperature, water and nutrient supply.

The correlation coefficients (Table 5) between the investigated traits display strong positive relationships between seed yield and the number of seeds per silique, chlorophyll content, and the length of flowering period. Also, oil content depends on seed yield and the length of flowering period. Ozer et al. (1999) and Marjanović-Jeromela et al. (2008) calculated positive correlation between seed oil content and seed yield per plant.

The multidimensional analysis of the tested traits compared winter oilseed rape cultivars-locations-years combinations in respect of ten traits (Fig. 3). The first and second canonical varieties elucidated 56.45% and 26.93%, respec-

Table 5. The correlation coefficients between the investigated traits of winter oilseed rape.

Trait	Seed yield	Length of silique	Number of seeds per pod	Weight of 1000 seeds	Chlorophyll content	Beginning of flowering	End of flowering	Length of flowering	Oil content
Length of silique	0.01	1							
Number of seeds per pod	0.30***	0.66***	1						
Weight of 1000 seeds	-0.16*	-0.11	-0.53***	1					
Chlorophyll content	0.59***	-0.13	-0.18*	0.27***	1				
Beginning of flowering	-0.59***	0.14	-0.09	0.16*	-0.30***	1			
End of flowering	-0.03	0.24**	0.52***	-0.57***	-0.59***	-0.07	1		
Length of flowering	0.36***	0.07	0.43***	-0.51***	-0.22**	-0.69***	0.75***	1	
Oil content	0.38***	0.15	0.46***	-0.59***	-0.07	-0.39***	0.38***	0.52***	1
Total glucosinolates content	-0.45***	-0.21**	-0.42***	0.51***	-0.30***	0.05	-0.12	-0.12	-0.34***

* P<0.05, ** P<0.01, *** P<0.001

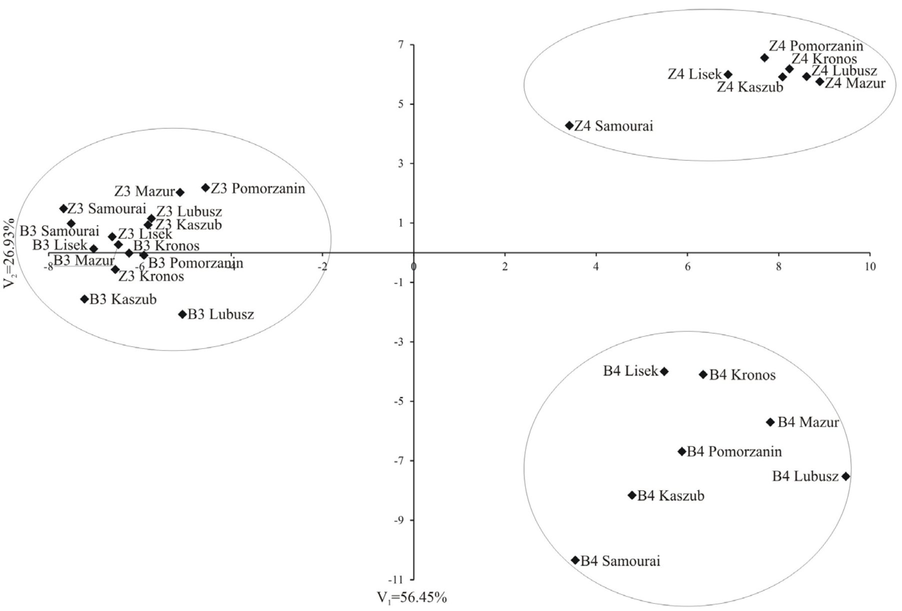

Figure 3. Configuration of winter oilseed rape cultivars-locations-years combinations in the space of two canonical varieties calculated for the ten observed traits (B3 – Borowo 2003, B4 – Borowo 2004, Z3 – Zielęcin 2003, Z4 – Zielęcin 2004).

tively, of multivariate variability of objects (Fig. 3). CVA allowed distinction into three groups of objects. The first group contain cultivars in Zielęcin 2004; second group – cultivars in Borowo 2004; and third group – cultivars observed in 2003 in both locations (Fig. 3).

Winter oilseed rape hybrids achieve a yield advantage of only around 6% to 15% over open-pollinated cultivars (in official plot trials in Germany by Basunanda et al., 2010). For example, in Germany the 10-year mean yield advantage of hybrid in practical winter oilseed rape production is currently around 11% (data from Kleffmann Group/Norddeutsche Pflanzenzucht H.-G. Lembke KG by Basunanda et al., 2010).

Cultivars with higher adaptable ability to changeable environmental conditions were characterized higher ability to compensate losses of plants by branch and silique production, higher nitrogen use efficacy and higher effect of number and weight of seeds per silique on seed yield. Environmental conditions affected yield components as a results of plant development directly-satisfying temperature and water needs (Wójtowicz, 2013). Our results confirm the higher productivity of hybrid cultivars, as well as their better adaptability to variable environmental conditions, especially drought.

Research on genotypic and environmental interaction, abiotic stress response (particularly to drought), adaptation to changing agronomic conditions and nitrogen use efficiency are currently one of the most important research directions on rapeseed in many scientific centers in Europe and in the world (Faralli et al., 2015; Crnobarac et al., 2015; Hegewald and Christen, 2015).

CONCLUSIONS

1. The statistical analysis of variance showed significant differences of the investigated cultivars and expression of cultivars in locations and years of studies for all the traits of the study.
2. The very high coefficient of heritability for seed yield, yield components and quality traits such as oil content and total glucosinolate content were obtained.
3. In our study, hybrid cultivars demonstrated higher adaptive ability to changeable environmental conditions and reaction on stress factor (especially drought). This information may be useful for oilseed rape breeding programs.

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