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ORIGINAL RESEARCH PAPER

Weed suppression and yield of thirteen spring wheat (*Triticum aestivum* L.) varieties grown in an organic system

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Abstract

The aim of this study was to determine the relationships between morphological features, canopy parameters, weed infestation, and grain yield of spring wheat varieties. The study was conducted in the period 2011–2013, on fields managed organically at the Experimental Station of The Institute of Soil Science and Plant Cultivation – State Research Institute, Osiny, Poland. Thirteen spring wheat varieties were sown in a randomized complete block design with four replications. Weed density and dry matter production were estimated as well biometric features of the wheat varieties at tillering (BBCH 22–24) and dough (BBCH 85–87) stages. The analyses of variance showed that the year had a stronger effect than varieties on the level of weed infestation. Pearson's correlation analysis indicated that weed number was influenced by the height of wheat plants and their aboveground biomass at the tillering stage and additionally by number of tillers at the dough stage. A significant correlation ($r = -0.328$, siginfficant at $p < 0.05$) was shown between the number of weeds and wheat grain yield. Different morphological features and canopy parameters influenced the competitive abilities of the spring wheat varieties tested. A cluster analysis detected one set of varieties with the largest ('Bombona', 'Brawura', 'Hewilla', 'Kandela', 'Katoda', 'Łagwa', and 'Żura') and another with the smallest ('Monsun', 'Ostka Smolicka', and 'Parabola') competitive abilities against weeds. The main outcome of the research is information for farmers as to which varieties are highly competitive against weeds and also high yielding. Among the varieties with the highest competitiveness, *Triticum aestivum* 'Żura' was the highest yielder (3.82 t ha^{-1} on average), whereas 'Bombona' yielded only at an average level (3.03 t ha^{-1}). The suppressive ability of spring wheat varieties against weeds and yield potential should be both taken into account in the selection of varieties suitable for an organic farming system where weed control is absent.

Keywords

competitiveness; morphological features; wheat; selection of varieties; weed infestation; organic farming

Introduction

The area of agricultural lands dedicated to an organic farming system has shown continuous growth in a number of European countries [1]. In this specific system, the use of synthetic fertilizers and chemical plant protection measures are forbidden according to legal regulations [2]. Weed management incorporates agricultural practices which create a balance between cultivated crops and weeds. These practices include crop rotation, choice of species and varieties, soil tillage, organic fertilization, date and density of sowing as well as direct mechanical, biological, and physical methods of weed control [3,4].

The choice of cereal varieties suited to the specific conditions of organic agriculture requires a different approach to that used in a conventional, high input system [5,6]. This is because there are fewer opportunities in organic production to compensate for yield decrease caused by diseases, low nutrient levels, and weeds [7]. Breeders typically work under weed-free conditions and develop cultivars for specific environments without taking into consideration their competitive ability against weeds. It is estimated that >95% of organic production is based on crop varieties that were bred for the conventional high-input sector [8]. The lack of information on the performance of modern cereal varieties under organic conditions is a limitation for this production [9].

Cereal varieties vary in their competitiveness against weeds [10–12] and those with a high degree of competitive ability, especially against aggressive weeds, are highly beneficial in organic farming and other low-input farming systems because they protect against the build-up of weed infestation and proliferation of the weed seed bank [3,5]. A review of world literature indicates that the competitiveness of cereal varieties depends on crop density and intrinsic morphological and growth features, such as rate of growth, length of stems, tillering rate, surface and angle of leaf attachment on the wheat plant as well as any allelopathic properties [13–17]. Competitive ability is usually not attributed to a single characteristic, but it involves the interaction of a series of desirable traits [7]. Studies that aim to find the variety that is highly competitive against weeds are very useful in the improvement of organic, low-input and integrated crop production systems [18,19].

The aim of this study was to determine the relationship between the features of 13 spring wheat varieties included in the "Common catalogue of varieties of agricultural plant species" [20] and their competitive potential against weeds and grain yield.

Material and methods

Site characteristics, experimental design, and agronomic practices

The study was conducted in 2011–2013 in the Experimental Station of the Institute of Soil Science and Plant Cultivation – State Research Institute in Puławy, Poland (51°28′ N, 22°04′ E), on fields managed organically since 1994. The experiment was located on a Luvisol soil type [21], with a texture of loamy sand, characterized by a slightly acid reaction (pH_{KCl} = 5.6), an average phosphorus content (43.6 mg kg^{-1} P), a low potassium level (63.1 mg kg^{-1} K), and a humus content of 1.6%. The organic system in place comprises five fields with an area of 1 ha. Crops are cultivated in rotation: potato, spring wheat, clovers and grasses (first year and second year), winter wheat and a catch crop (mustard). Within the field of spring wheat (*Triticum aestivum* L.), a one-factor experiment was established with different varieties, arranged in a randomized complete block design with four replications. The area of each replicate plot for sowing and harvest was 100 m^2. The 13 spring wheat varieties selected for cultivation were all included in the "Common catalogue of varieties of agricultural plant species" [20], and differed in their morphological features: 'Bombona', 'Brawura', 'Hewilla', 'Kandela', 'Katoda', 'Ługwa', 'Monsun', 'Ostka Smolicka', 'Parabola', 'Trappe', 'Tybalt', 'Werbena', and 'Żura'. Pre-sowing treatments were performed in accordance with good agricultural practice and sowing was at the optimum time for the region (April 11, 2011, April 5, 2012, and April 15, 2013). Sowing rates were the same for each variety – 450 grains m^{-2}. The row spacing was 12 cm and the planting depth 3.5 cm. According to organic agriculture ruling, mineral fertilizers and other agrochemicals were not used [2]. Harvests were made on August 12, 2011, August 4, 2012, and August 6, 2013.

Meteorological conditions

The experimental site is located in a moderately continental climatic zone. Annual total precipitation was 586 mm, with a mean air temperature of 7.5°C (data for the years 1950–2010, Agrometeorological Station, Puławy). The climatic data for the research period are presented in Tab. 1. In both 2011 and 2012, inadequate rainfall was observed

Tab. 1 Monthly average air temperature and total precipitation in 2011–2013.

Weather measures	Years	Months			
		April	May	June	July
Temperature (°C)	2011	10.5	13.8	18.4	18.2
	2012	9.6	15.3	17.1	20.8
	2013	8.2	15.1	18.2	19.4
	mean from 1951–2010	7.9	13.5	16.8	18.5
Precipitation (mm)	2011	22.8	67.8	57.7	247.8
	2012	35.6	39.1	78.0	77.4
	2013	46.1	105.0	113.4	50.2
	mean from 1951–2010	40.0	57.0	70.0	85.0

in the spring. However, meteorological conditions in spring 2013 were favorable for wheat growth and development. Only drought in July significantly influenced nutrient uptake which resulted in a lower grain yield.

Sampling and estimation of traits

The number of weeds and their dry matter production were assessed twice in the growing seasons: at the tillering stage (BBCH 22–24) and in the dough stage for spring wheat (BBCH 85–87) [22], using the weight-counting method, on an area of 0.5 × 1 m in each plot [23]. Weeds were cut at soil level, sorted by hand and assigned to species according to the method of Rutkowski [24]. Thirty wheat plants were removed by hand from the same area colonized by weeds to assess their density and total aboveground biomass as well as their height and number of tillers. Dry matter production of weeds and wheat was determined after drying at 40°C for 7 days. Grain yield was evaluated for the whole plot area after harvesting using a special small harvester, calculated as t ha^{-1} at 15% moisture content.

Statistical analysis

Two-factor ANOVA for a completely randomized model with interaction was used, where varieties and years were main effects (13 varieties × 3 years). The significance of any differences between treatments was verified by Tukey's test at $p \leq 0.05$. Where no significant interaction between Variety × Year was demonstrated at the 95% confidence level, letters are attached to means of main factors in the relevant tables presented in the "Results" section. Where there were significant interactions, the differences between varieties were analyzed separately for each year, and letters attached in the "Results" tables relate to treatments. In order to estimate how the features of spring wheat varieties influence the parameters of weed infestation, Pearson's correlation coefficients were computed between the number of weeds and their dry matter production, morphological features, and canopy parameters. A cluster analysis using the furthest neighbor method was performed in order to classify the samples into groups with similar characteristics. Calculations were performed using Statgraphic Plus version 2.1 software.

The structure of weed communities was also analyzed using two ecological indices: Shannon's diversity index: $H' = -\sum p_i \ln p_i$ [25] and Simpson's dominance index: $SI = \sum p_i^2$ [26], where p_i is the probability of species occurrence in the sample. In order to classify the samples (varieties) based on their weed species composition, detrended correspondence analysis (DCA) was used, as this is recommended for preliminary ordering of floristic samples [27]. The results of these ordinations are presented graphically on separate diagrams for samples and species. These analyses were performed using Canoco 4.5 [28].

Results

Assessment of the competitiveness of spring wheat varieties at the tillering stage

No significant differences were demonstrated in the number of weeds between the varieties tested (Tab. 2). A significant interaction Variety × Year in weed dry matter

Tab. 2 Number of weeds and their dry matter in spring wheat varieties at the tillering stage.

Varieties	Number of weeds (plants m^{-2})				Dry matter of weeds (g m^{-2})		
	2011	2012	2013	mean	2011	2012	2013
'Bombona'	80.0	161.5	115.0	118.8 ^{a}	8.6 ^{a}	8.3 ^{a}	1.8 ^{a}
'Brawura'	138.0	157.5	155.5	150.3 ^{a}	33.1 ^{b}	8.4 ^{a}	2.3 ^{a}
'Hewilla'	102.0	158.5	160.5	140.3 ^{a}	17.5 ^{ab}	10.8 ^{a}	4.1 ^{a}
'Kandela'	90.0	154.0	145.5	129.8 ^{a}	13.9 ^{a}	14.1 ^{a}	4.6 ^{a}
'Katoda'	86.0	132.0	130.0	116.0 ^{a}	11.8 ^{a}	11.8 ^{a}	4.2 ^{a}
'Łagwa'	86.7	147.0	164.5	132.7 ^{a}	10.0 ^{a}	9.9 ^{a}	6.3 ^{a}
'Monsun'	102.7	157.0	141.5	133.7 ^{a}	16.9 ^{ab}	11.0 ^{a}	4.7 ^{a}
'Ostka Sm.'	94.7	156.0	135.5	128.7 ^{a}	10.3 ^{a}	12.0 ^{a}	3.0 ^{a}
'Parabola'	98.0	156.5	159.0	137.8 ^{a}	9.9 ^{a}	10.4 ^{a}	3.6 ^{a}
'Trappe'	104.7	177.0	154.5	145.4 ^{a}	18.1 ^{ab}	18.6 ^{a}	2.5 ^{a}
'Tybalt'	108.7	150.0	138.0	132.2 ^{a}	32.9 ^{b}	16.4 ^{a}	2.2 ^{a}
'Werbena'	71.3	176.5	186.5	144.8 ^{a}	18.2 ^{ab}	14.5 ^{a}	4.7 ^{a}
'Żura'	97.3	151.0	142.5	130.3 ^{a}	13.0 ^{a}	8.5 ^{a}	5.2 ^{a}
Mean	96.9 ^{A}	156.5 ^{B}	148.4 ^{B}	-	16.5	11.9	3.8

Different letters behind the mean values indicate significant differences ($p \le 0.05$). For significant model effects, a post hoc Tukey HSD test was performed to compare mean values.

production was however detected. In 2011, 'Brawura' and 'Tybalt' were characterized by the lowest competitiveness against weeds reflected in a two times higher weed biomass yield than the mean value of all varieties.

The analysis of morphological features and canopy parameters showed significant differences in height, number of tillers, plant density, and dry matter yield of the wheat varieties at the tillering stage. The highest number of tillers per plant was observed for 'Tybalt' in every year and the lowest for 'Katoda' in 2011 and 'Hewilla' and 'Żura' in the other years (Tab. 3). Cultivars 'Żura', 'Parabola', 'Brawura', and 'Hewilla' were the tallest at this stage, whereas 'Tybalt', 'Bombona', and 'Ostka Smolicka' were the lowest growing. Cultivar 'Bombona' was characterized by the highest density of wheat plants in 2011 and this parameter influenced its competitiveness against weeds (Tab. 4). A large number of plants per unit area was also noted for 'Trappe', but it was not correlated with its suppressive ability (Tab. 4, Tab. 5, and Tab. 10). The lowest wheat plant density and dry matter production were found for 'Hewilla' in 2011. Significant varietal differences in the accumulation of biomass were recorded in 2011 (Tab. 4).

Different morphological features and canopy parameters influenced the competitive abilities of the 13 spring wheat varieties at the tillering stage. Cluster analysis divided varieties into three groups with different suppressive abilities against weeds (Tab. 5). Seven varieties belonging to the first group: 'Bombona', 'Kandela', 'Katoda', 'Łagwa', 'Monsun', 'Ostka Smolicka', and 'Tybalt', characterized by the lowest number of weeds and a high number of tillers and wheat plant density. The second cluster grouped three varieties: 'Hewilla', 'Parabola', and 'Żura', which had the maximum height and dry matter production of wheat and the lowest dry matter yield of weeds. The third cluster included the varieties with the highest level of weed infestation, high wheat plant density, and intermediate values of other features ('Brawura', 'Trappe', and 'Werbena'). Correlation analysis for all varieties together showed that for the parameters tested, height and wheat dry matter production mainly determined the weed number at the tillering stage ($r = -0.378$ and $r = -393$, respectively; significant at $p < 0.05$) (Tab. 11).

Tab. 3 The selected morphological features of spring wheat varieties at the tillering stage.

Varieties	Number of tillers per plant			Height (cm)		
	2011	2012	2013	2011	2012	2013
'Bombona'	3.03 [ab]	3.13 [ab]	2.57 [ab]	46.13 [bc]	32.42 [ab]	21.73 [a]
'Brawura'	3.03 [ab]	2.81 [ab]	2.41 [ab]	61.85 [d]	42.78 [cd]	27.03 [c]
'Hewilla'	2.86 [ab]	2.74 [a]	2.21 [a]	60.78 [d]	40.43 [bcd]	25.40 [abc]
'Kandela'	3.02 [ab]	3.45 [ab]	2.39 [ab]	44.98 [ab]	36.03 [abc]	24.81 [abc]
'Katoda'	2.67 [a]	3.34 [ab]	2.65 [ab]	51.22 [c]	36.85 [a–d]	22.99 [ab]
'Ługwa'	2.73 [ab]	2.89 [ab]	2.26 [ab]	48.03 [bc]	33.82 [ab]	24.52 [abc]
'Monsun'	2.78 [ab]	2.86 [ab]	2.54 [ab]	47.98 [bc]	36.51 [abc]	23.88 [abc]
'Ostka Sm.'	3.07 [ab]	3.06 [ab]	2.38 [ab]	51.21 [c]	35.60 [abc]	21.74 [a]
'Parabola'	2.96 [ab]	2.73 [a]	2.53 [ab]	61.23 [d]	44.86 [d]	25.40 [abc]
'Trappe'	3.14 [ab]	3.46 [ab]	2.44 [ab]	45.54 [ab]	35.12 [abc]	22.15 [ab]
'Tybalt'	3.49 [b]	3.58 [b]	2.86 [b]	40.54 [a]	31.61 [a]	24.41 [abc]
'Werbena'	2.78 [ab]	3.18 [ab]	2.40 [ab]	49.60 [bc]	40.15 [bcd]	22.86 [ab]
'Żura'	2.74 [ab]	2.72 [a]	2.14 [a]	64.26 [d]	43.01 [cd]	25.78 [bc]
Mean	2.95	3.07	2.44	51.80	37.63	24.05

The same notes apply as in Tab. 2.

Tab. 4 The selected canopy parameters of spring wheat varieties at the tillering stage.

Varieties	Density of wheat plants (plants m^{-2})			Dry matter of wheat (g m^{-2})		
	2011	2012	2013	2011	2012	2013
'Bombona'	275 [b]	263 [a]	230 [a]	268.6 [abc]	160.8 [a]	37.3 [a]
'Brawura'	230 [ab]	242 [a]	241 [a]	317.4 [c]	163.6 [a]	45.6 [a]
'Hewilla'	200 [a]	228 [a]	210 [a]	316.0 [c]	174.5 [a]	35.6 [a]
'Kandela'	247 [ab]	219 [a]	241 [a]	232.2 [ab]	145.2 [a]	39.9 [a]
'Katoda'	260 [b]	228 [a]	225 [a]	304.8 [c]	157.5 [a]	41.3 [a]
'Ługwa'	242 [ab]	219 [a]	226 [a]	284.7 [bc]	144.6 [a]	44.0 [a]
'Monsun'	247 [ab]	253 [a]	200 [a]	279.2 [bc]	171.9 [a]	39.9 [a]
'Ostka Sm.'	247 [ab]	231 [a]	212 [a]	289.1 [c]	145.9 [a]	35.0 [a]
'Parabola'	223 [ab]	226 [a]	210 [a]	275.4 [bc]	164.2 [a]	38.0 [a]
'Trappe'	268 [b]	247 [a]	223 [a]	283.3 [bc]	155.0 [a]	43.6 [a]
'Tybalt'	241 [ab]	230 [a]	200 [a]	216.8 [a]	127.7 [a]	33.8 [a]
'Werbena'	224 [ab]	238 [a]	207 [a]	292.8 [c]	183.4 [a]	32.7 [a]
'Żura'	220 [ab]	250 [a]	200 [a]	306.0 [c]	181.9 [a]	41.7 [a]
Mean	240	237	219	282.0	159.7	39.1

The same notes apply as in Tab. 2.

Tab. 5 Cluster analysis of spring wheat varieties at the tillering stage (mean for years 2011–2013).

Cluster	Parameters*						Varieties
	NW	DMW	NT	H	WD	WDM	
1	127.4	10.2	2.89	35.1	235.0	152.4	'Bombona', 'Kandela', 'Katoda', 'Łagwa', 'Monsun', 'Ostka Smolicka', 'Tybalt'
2	136.1	9.2	2.62	43.5	220.7	170.4	'Hewilla', 'Parabola', 'Żura'
3	146.8	13.4	2.85	38.6	235.6	168.6	'Brawura', 'Trappe', 'Werbena'

* NW – number of weeds (plants m^{-2}); DMW – dry matter of weeds (g m^{-2}); NT – number of tillers per plant; H – height (cm); WD – wheat density (plants m^{-2}); WDM – wheat dry matter (g m^{-2}).

Assessment of the competitiveness of the spring wheat varieties at the dough stage

At the dough stage, no significant differences between varieties were detected in the number of weeds, but were in their dry matter yield (Tab. 6). Weed dry matter in the most suppressive variety, 'Bombona', was 32% lower than the mean for all varieties, whereas it was 35–37% higher in the case of the least suppressive varieties, 'Monsun' and 'Trappe'.

Cultivars 'Parabola' and 'Monsun' showed the highest number of weeds and largest dry matter production, which was reflected in the results of the cluster analysis (Tab. 6 and Tab. 9). It should be emphasized that the year had a stronger effect on the weed number ($F = 40.18$) than did cultivar ($F = 0.59$). Similarly, weed dry matter was more influenced by the year ($F = 6.03$) than by cultivar ($F = 1.50$). Cultivars 'Hewilla' and 'Brawura' had the longest stems (Tab. 7) and highest dry matter of aboveground parts (Tab. 8). The greatest density of wheat plants per unit area was recorded for 'Brawura', 'Bombona', and 'Katoda' and the smallest for 'Tybalt'. The shortest varieties were 'Werbena' and 'Tybalt'. Cultivar 'Parabola' grew the smallest number of tillers (Tab. 7) and at the same time had low competitiveness in relation to weeds, which was confirmed by the results of the cluster analysis (Tab. 9).

Cultivars 'Monsun', 'Ostka Smolicka', and 'Tybalt' were the strongest competitors against weed infestation at the tillering stage (Tab. 5), but during the growing season their suppressive abilities decreased (Tab. 9). The results of the cluster analysis confirmed a high competitive potential of 'Bombona' during the whole growth season and also the increasing competitiveness of 'Brawura'. At the tillering stage, 'Brawura' was one of the most weedy varieties, although at the dough stage its competitiveness had increased significantly, which placed it among the most competitive varieties against weeds, with 'Bombona', 'Hewilla', 'Kandela', 'Katoda', 'Łagwa', and 'Żura' (Tab. 9).

At the dough stage, the total number of species in weed communities ranged from 26 in 'Łagwa' to 35 in the 'Monsun' canopy (Tab. 10). For all varieties, short-lived (annual) species dominated (92% of total weed abundance), such as *Chenopodium album* L., *Stellaria media* (L.) Vill., and *Viola arvensis* Murray. Perennial species (8% of total weed number) were dominated by *Plantago major* L. The diversity of the weed flora, as measured by Shannon's diversity index, was high and ranged from 2.32 ('Werbena') to 2.50 ('Bombona'). Low values of Simpson's dominance index (<0.3) suggested that there was no significant dominance by any of the species in the weed communities (Tab. 10).

In order to determine the relationship between varieties and the presence of certain species of weeds in the wheat canopy, ordination analysis using the DCA technique was used (Fig. 1). The smaller the distances between points on the diagram, the greater the similarity of species composition of the weed communities. Our data showed the greatest similarity of weed flora in plots of 'Bombona', 'Hewilla', and 'Katoda' as well as 'Łagwa', 'Trappe', and 'Brawura' (Fig. 1a). The most weedy 'Parabola', 'Monsun', and 'Ostka Smolicka' showed differences in species composition, as evidenced by the distance of points on the ordination diagram. Many weed species grouped in the middle of the

Tab. 6 Number of weeds and their dry matter in spring wheat varieties at the dough stage.

Varieties	Number of weeds (plants m^{-2})				Dry matter of weeds (g m^{-2})			
	2011	2012	2013	mean	2011	2012	2013	mean
'Bombona'	84.5	36.0	104.0	74.8 [a]	46.2	26.1	18.1	30.1 [a]
'Brawura'	80.0	49.0	125.5	84.8 [a]	37.7	37.5	27.9	34.4 [ab]
'Hewilla'	71.5	50.5	114.0	78.7 [a]	29.5	45.4	36.4	37.1 [ab]
'Kandela'	60.5	74.5	85.0	73.3 [a]	39.1	37.6	28.4	35.0 [ab]
'Katoda'	68.0	63.0	100.5	77.2 [a]	37.1	57.1	12.3	35.5 [ab]
'Łagwa'	68.0	64.0	92.0	74.7 [a]	38.8	50.9	28.8	39.5 [ab]
'Monsun'	85.5	58.0	134.0	92.5 [a]	55.4	72.6	50.0	59.3 [b]
'Ostka Sm.'	78.0	76.0	100.5	84.8 [a]	46.3	67.6	33.5	49.1 [ab]
'Parabola'	67.0	52.5	172.0	97.2 [a]	58.6	47.1	59.3	55.0 [ab]
'Trappe'	98.5	37.5	101.5	79.2 [a]	92.3	65.8	22.1	60.1 [b]
'Tybalt'	61.5	67.0	124.5	84.3 [a]	29.8	60.4	37.1	42.4 [ab]
'Werbena'	80.0	66.5	114.5	87.0 [a]	46.0	54.8	45.4	48.7 [ab]
'Żura'	58.5	42.5	121.5	74.2 [a]	36.0	61.5	39.8	45.8 [ab]
Mean	74.0 [A]	56.7 [B]	114.6 [C]	-	45.6 [A]	52.7 [A]	33.8 [B]	-

The same notes apply as in Tab. 2.

Tab. 7 The selected morphological features of spring wheat varieties at the dough stage.

Varieties	Number of tillers per plant			Height (cm)		
	2011	2012	2013	2011	2012	2013
'Bombona'	1.53 [ab]	1.51 [a]	1.26 [a]	88.17 [bc]	85.06 [b–e]	77.18 [def]
'Brawura'	1.53 [ab]	1.59 [a]	1.23 [a]	89.95 [bc]	91.40 [e]	81.14 [f]
'Hewilla'	1.54 [ab]	1.58 [a]	1.23 [a]	96.65 [c]	92.09 [e]	78.51 [ef]
'Kandela'	1.57 [ab]	1.55 [a]	1.18 [a]	77.19 [ab]	77.23 [abc]	70.89 [bcd]
'Katoda'	1.60 [ab]	1.67 [a]	1.27 [a]	91.08 [bc]	85.77 [cde]	79.49 [ef]
'Łagwa'	1.44 [ab]	1.47 [a]	1.27 [a]	80.83 [abc]	81.28 [a–d]	73.15 [b–e]
'Monsun'	1.45 [ab]	1.35 [a]	1.13 [a]	84.63 [abc]	75.78 [ab]	70.09 [bc]
'Ostka Sm.'	1.35 [ab]	1.32 [a]	1.11 [a]	91.18 [bc]	79.49 [abc]	75.33 [c–f]
'Parabola'	1.21 [a]	1.37 [a]	1.16 [a]	86.56 [abc]	81.52 [a–d]	74.83 [b–f]
'Trappe'	1.72 [b]	1.63 [a]	1.23 [a]	80.34 [abc]	79.44 [abc]	70.48 [bcd]
'Tybalt'	1.63 [ab]	1.35 [a]	1.31 [a]	76.67 [ab]	71.79 [a]	68.48 [b]
'Werbena'	1.53 [ab]	1.61 [a]	1.09 [a]	70.88 [a]	71.94 [a]	59.88 [a]
'Żura'	1.33 [ab]	1.63 [a]	1.23 [a]	86.33 [abc]	89.83 [de]	76.04 [c–f]
Mean	1.49	1.51	1.21	84.65	81.74	73.50

The same notes apply as in Tab. 2.

Tab. 8 The selected canopy parameters of spring wheat varieties at the dough stage.

Varieties	Density of wheat plants (plants m^{-2})				Dry matter of wheat (g m^{-2})		
	2011	2012	2013	mean	2011	2012	2013
'Bombona'	223	260	226	236 ^{a}	663.2 ^{a}	798.6 ^{abc}	562.4 ^{ab}
'Brawura'	223	240	240	234 ^{a}	769.6 ^{a}	1128.0 ^{c}	682.1 ^{b}
'Hewilla'	199	227	207	211 ^{a}	800.5 ^{a}	1066.1 ^{bc}	472.6 ^{ab}
'Kandela'	206	219	240	222 ^{a}	680.6 ^{a}	869.2 ^{abc}	689.1 ^{b}
'Katoda'	247	227	221	232 ^{a}	793.1 ^{a}	898.8 ^{abc}	612.4 ^{b}
'Ługwa'	229	217	217	221 ^{a}	637.0 ^{a}	846.1 ^{abc}	488.6 ^{ab}
'Monsun'	202	228	203	211 ^{a}	637.6 ^{a}	791.2 ^{abc}	534.3 ^{ab}
'Ostka Sm.'	238	230	210	227 ^{a}	807.0 ^{a}	806.4 ^{abc}	518.9 ^{ab}
'Parabola'	220	208	207	212 ^{a}	788.6 ^{a}	796.6 ^{abc}	552.5 ^{ab}
'Trappe'	224	200	217	214 ^{a}	720.0 ^{a}	832.4 ^{abc}	547.0 ^{ab}
'Tybalt'	183	211	199	198 ^{a}	561.7 ^{a}	771.8 ^{ab}	604.8 ^{b}
'Werbena'	223	202	190	205 ^{a}	608.0 ^{a}	614.5 ^{a}	315.8 ^{a}
'Żura'	219	227	216	221 ^{a}	577.1 ^{a}	1046.9 ^{bc}	507.0 ^{ab}
Mean	218 ^{A}	223 ^{A}	215 ^{A}	-	695.7	866.6	545.2

The same notes apply as in Tab. 2.

Tab. 9 Cluster analysis of spring wheat varieties at the dough stage (mean for years 2011–2013).

Cluster	Parameters						Varieties
	NW	DMW	NT	H	WD	WDM	
1	76.8	36.8	1.44	83.3	225.2	742.3	'Bombona', 'Brawura', 'Hewilla', 'Kandela', 'Katoda', 'Ługwa', 'Żura'
2	83.5	50.4	1.46	72.2	205.6	619.5	'Trappe', 'Tybalt', 'Werbena'
3	91.5	54.5	1.27	79.9	216.7	692.6	'Monsun', 'Ostka Smolicka', 'Parabola'

The same notes apply as in Tab. 5.

diagram, which shows that they occurred in all varietal plots and were not specific for any of them (Fig. 1b). Species coming off the diagrams were characteristic for some varieties, for example, *Arctium lappa* L. for 'Tybalt', *Erigeron annuus* L. Pers. for 'Werbena', and *Anchusa arvensis* (L.) M. Bieb. for 'Brawura'. *Erigeron annus* (L.) Pers., together with *Soligago gigantea* Aiton and *Conyza canadensis* (L.) Cronquist are all invasive alien species.

According to the results of the cluster analysis, varieties with the lowest weed infestation were the tallest and had the greatest density of their canopies and dry matter of wheat as well as a large number of tillers (Cluster 1) (Tab. 9). The most weedy varieties, 'Monsun', 'Ostka Smolicka', and 'Parabola, had the lowest number of tillers (Cluster 3). Three varieties, 'Trappe', 'Tybalt', and 'Werbena', with a medium level of infestation of weeds, were grouped together in Cluster 2 and were characterized by the highest number of tillers per plant, but the lowest plant heights, lowest wheat plant density and dry matter production.

Tab. 10 Weed species composition and number (plants m^{-2}) in spring wheat cultivated in an organic system (dough stage, mean from 2011–2013).

No.	Weed species	Varieties													Mean
		'Bombona'	'Brawura'	'Hewilla'	'Katoda'	'Kandela'	'Łagwa'	'Monsun'	'Ostka Sm.'	'Parabola'	'Trappe'	'Tybalt'	'Werbena'	'Żura'	
	I. Annual and biennial weeds														
1	*Chenopodium album* L.	22.0	25.5	26.0	24.3	25.7	21.3	30.5	26.2	30.3	26.3	28.2	31.5	25.7	26.4
2	*Viola arvensis* Murray	9.2	12.3	10.3	8.8	10.7	10.2	12.0	12.0	8.3	12.5	9.8	12.5	6.5	10.4
3	*Stellaria media* (L.) Vill.	10.7	10.7	10.0	9.3	9.7	9.7	9.5	9.7	15.7	9.3	10.5	9.8	7.2	10.1
4	*Thlaspi arvense* L.	1.7	3.0	3.5	6.5	3.3	6.5	5.2	6.2	0.5	5.2	4.8	7.3	4.8	4.5
5	*Capsella bursa-pastoris* (L.) Medik.	3.3	4.0	4.3	1.5	1.5	1.3	5.3	1.3	7.5	1.3	1.5	1.3	7.2	3.2
6	*Matricaria maritima* L. ssp. *inodora* (L.) Dostál	2.2	2.3	1.8	4.2	2.8	2.5	2.7	2.5	4.5	2.3	3.2	1.3	1.2	2.6
7	*Galinsoga parviflora* Cav.	1.5	1.3	1.3	0.7	3.8	3.3	1.3	4.2	3.8	0.7	4.7	4.5	2.0	2.6
8	*Fallopia convolvulus* (L.) Á. Löve	3.0	2.0	3.3	1.7	2.2	2.0	3.7	2.0	2.7	2.5	1.3	1.7	2.5	2.3
9	*Vicia hirsuta* L. (Gray)	1.0	2.7	0.7	1.8	1.3	2.3	2.0	4.8	1.8	2.2	1.8	0.3	2.7	2.0
10	*Galium aparine* L.	0.8	1.2	1.2	0.5	1.3	2.0	1.0	1.7	1.3	1.5	3.0	2.5	2.8	1.6
11	*Anthemis arvensis* L.	1.0	1.8	1.7	1.2	1.2	1.5	1.2	3.0	1.0	1.7	0.5	0.7	1.0	1.3
12	*Veronica persica* Poir.	2.2	1.2	1.2	1.5	0.0	0.8	1.0	1.0	1.7	1.3	0.2	1.0	1.0	1.1
13	*Lapsana communis* L.	0.3	0.5	0.7	0.2	1.2	1.5	1.2	1.5	3.0	1.2	0.0	1.8	1.0	1.1
14	*Myosotis arvensis* (L.) Hill	1.3	1.5	1.0	0.8	1.7	0.2	0.3	1.3	0.7	1.5	1.3	0.3	0.5	1.0
15	*Lamium purpureum* L.	2.2	0.5	0.8	0.3	0.2	0.8	0.5	0.3	0.7	1.5	0.7	0.3	0.8	0.7
16	*Melandrium album* (Mill.) Garcke	1.3	0.2	0.3	1.2	1.0	0.2	0.5	0.8	0.8	0.7	0.3	0.8	0.2	0.6
17	*Papaver rhoeas* L.	0.5	0.5	0.2	0.5	0.3	0.7	0.5	0.3	0.8	0.5	0.8	0.7	0.7	0.5
18	*Echinochloa crus-galli* (L.) P. Beauv.	-	-	0.2	-	0.2	0.0	1.2	0.5	2.7	-	1.2	0.8	-	0.5
19	*Polygonum aviculare* L.	0.5	-	0.3	0.5	0.0	0.2	0.5	0.7	0.7	1.3	-	0.2	0.2	0.4

Tab. 10 Continued

No.	Weed species	Varieties													Mean
		'Bombona'	'Brawura'	'Hewilla'	'Katoda'	'Kandela'	'Łagwa'	'Monsun'	'Ostka Sm.'	'Parabola'	'Trappe'	'Tybalt'	'Werbena'	'Żura'	
20	*Geranium pusillum* Burm. f. ex L.	0.7	0.3	0.3	-	0.8	0.5	-	0.2	0.3	-	0.7	0.3	0.7	0.4
21	*Galeopsis tetrahit* L.	0.2	-	-	0.3	0.5	0.3	0.5	-	0.2	0.5	0.5	-	1.2	0.3
22	*Conyza canadensis* (L.) Cronquist	0.2	0.2	0.5	0.2	0.7	0.3	1.3	-	0.2	0.2	0.0	0.2	0.3	0.3
23	*Centaurea cyanus* L.	0.2	-	-	0.3	0.2	0.7	0.2	0.3	-	-	0.2	-	-	0.2
24	*Amaranthus retroflexus* L.	-	0.2	-	-	-	-	1.5	-	0.2	-	-	-	-	0.1
25	*Polygonum persicaria* L.	0.0	0.2	-	0.2	-	-	1.2	-	-	-	0.2	-	-	0.1
26	*Setaria pumila* (Poir.) Roem. & Schult.	0.2	-	0.2	0.2	0.3	-	0.5	-	-	-	-	0.2	-	0.1
27	*Consolida regalis* Gray	-	0.2	0.2	-	-	0.3	-	-	-	0.3	-	-	-	0.1
28	*Erigeron annuus* (L.) Pers.	-	-	-	-	-	-	-	-	-	-	-	0.8	-	0.1
29	*Daucus carota* L.	-	-	-	-	0.3	-	0.2	-	-	-	-	-	0.2	0.1
30	*Arctium lappa* L.	-	-	-	-	-	-	-	-	-	-	0.7	-	-	0.1
31	*Euphorbia helioscopia* L.	-	-	-	-	-	-	-	0.3	0.2	-	-	-	0.2	0.1
32	*Solanum nigrum* L. emend. Mill.	-	-	-	-	-	-	-	-	0.2	-	-	-	0.3	0.0
33	*Gnaphalium uliginosum* L.	0.2	-	-	0.3	-	-	-	-	-	-	-	-	-	0.0
34	*Apera spica*-venti (L.) P. Beauv.	-	-	0.2	-	0.2	-	-	0.2	-	-	-	-	-	0.0
35	*Erodium cicutarium* (L.) L.'Her	-	-	-	-	0.2	-	-	-	-	0.2	-	-	-	0.0
36	*Anagallis arvensis* L.	-	-	-	-	-	-	-	-	0.2	-	0.2	-	-	0.0
37	*Anchusa arvensis* (L.) M. Bieb.	-	0.3	-	-	-	-	-	-	-	-	-	-	-	0.0
38	*Fumaria officinalis* L.	-	-	-	-	0.2	-	-	-	-	-	0.2	-	-	0.0
Number of annual or/and biennial weeds (I)		66.2	72.5	70.2	67.0	71.3	69.2	85.3	81.0	89.8	74.7	76.3	81.0	70.7	75.0

Tab. 10 Continued

No.	Weed species	Varieties													Mean
		'Bombona'	'Brawura'	'Hewilla'	'Katoda'	'Kandela'	'Łagwa'	'Monsun'	'Ostka Sm.'	'Parabola'	'Trappe'	'Tybalt'	'Werbena'	'Żura'	
II. Perennial weeds															
39	*Plantago major* L.	5.8	9.8	7.0	7.8	1.8	0.3	3.0	0.5	4.3	3.2	5.3	2.5	1.7	4.1
40	*Cirsium arvense* (L.) Scop.	0.7	2.2	0.7	2.2	0.2	3.2	1.3	2.5	1.3	0.8	1.2	1.5	0.5	1.4
41	*Sonchus arvensis* L.	1.8	0.2	-	-	-	2.0	0.3	-	-	-	-	0.3	0.5	0.4
42	*Elymus repens* (L.) Gould	-	-	-	-	-	-	1.0	-	1.0	-	-	-	-	0.2
43	*Convolvulus arvensis* L.	-	-	0.3	-	-	-	0.5	0.3	0.5	-	0.2	0.7	0.2	0.2
44	*Equisetum arvense* L.	-	-	-	-	-	-	-	0.5	-	-	1.3	0.7	0.7	0.2
45	*Solidago gigantea* Aiton	-	0.2	0.3	-	-	-	0.3	-	0.2	-	-	-	-	0.1
46	*Plantago lanceolata* L.	0.3	-	-	-	-	-	0.2	-	-	-	-	0.2	-	0.1
47	*Mentha arvensis* L.	-	-	0.2	-	-	-	0.3	-	-	0.2	-	-	-	0.1
48	*Urtica dioica* L.	-	-	-	0.2	-	-	0.2	-	-	0.3	-	0.2	-	0.1
Number of perennial weeds (II)		8.7	12.3	8.5	10.2	2.0	5.5	7.2	3.8	7.3	4.5	8.0	6.0	3.5	6.7
Total I + II		74.8	84.8	78.7	77.2	73.3	74.7	92.5	84.8	97.2	79.2	84.3	87.0	74.2	81.7
Number of species		28	27	29	27	28	26	35	27	31	26	28	30	29	48
Shannon's diversity index		2.50	2.36	2.36	2.37	2.33	2.48	2.56	2.44	2.47	2.38	2.40	2.32	2.45	2.53
Simpson's dominance index		0.14	0.15	0.16	0.15	0.17	0.13	0.15	0.14	0.15	0.16	0.16	0.18	0.16	0.15

The value 0.0 means that the species was found in a number less than 0.1 plant m^{-2}; "-" – the species did not occur.

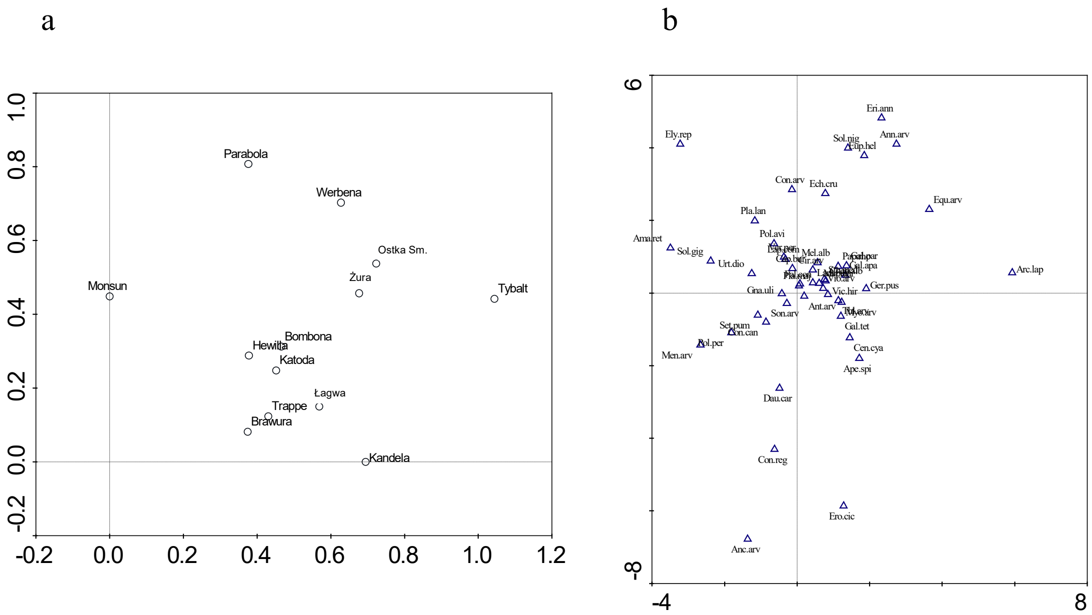

Fig. 1 Ordination diagram of samples (**a**) and species (**b**) in relation to first and second axes of DCA (dough stage; means from 2011–2013).

The results of the correlation analysis indicated that at the tillering stage, the dry matter and height of wheat plants had the greatest impact on the number of weeds, whereas at the dough stage, the number of tillers also influenced the degree of weed infestation (Tab. 11). Weak, but significant correlation between number of weeds and wheat grain yield was found ($r = -0.213$ at the tillering stage and $r = -0.328$ at the dough stage; both significant at $p < 0.05$).

Tab. 11 Correlation coefficients (r) between weed infestation, some morphological features and canopy parameters for spring wheat varieties in an organic system ($N = 156$).

Parameters	NW	DMW	NT	H	WD	WMD	GY
NW		−0.001	−0.035	−0.378*	0.039	−0.393*	−0.213*
DMW	0.152		0.469*	0.533*	0.115	0.586*	0.309*
NT	−0.267*	0.088		0.339*	0.182*	0.431*	0.444*
H	−0.309*	−0.034	0.459*		0.073	0.927*	0.644*
WD	−0.112	−0.057	−0.097	0.187*		0.259*	0.127
WMD	−0.338*	0.089	0.498*	0.606*	0.356*		0.693*
GY	−0.328*	0.032	0.569*	0.560*	0.005	0.500*	

Light grey cells – dough stage; white cells – tillering stage. NW – number of weeds (plants m^{-2}); DMW – dry matter of weeds (g m^{-2}); NT – number of tillers per plant; H – height (cm); WD – wheat density (plants m^{-2}); WDM – wheat dry matter (g m^{-2}). * Significant correlation at $p \leq 0.05$.

A significant positive correlation between wheat plant height, number of tillers, wheat dry matter, and grain yield was demonstrated. Among varieties with high competitive abilities,'Żura', 'Kandela', and 'Katoda' had significantly the highest yield (3.74–3.82 t ha^{-1}), whilst 'Bombona' produced only a medium yield (3.03 t ha^{-1}; Tab. 9 and Tab. 12). The lowest yielding varieties, 'Werbena' and 'Tybalt', had only medium-level competitive ability against weeds. Our results showed that the year of the trial had a stronger effect

Tab. 12 The grain yield (t ha^{-1}) of spring wheat varieties cultivated in an organic system.

Varieties	Years of research			Mean
	2011	2012	2013	
'Bombona'	3.32	3.31	2.46	3.03 ^{ab}
'Brawura'	3.68	3.60	2.31	3.20 ^{ab}
'Hewilla'	4.18	4.08	2.19	3.48 ^{ab}
'Kandela'	4.22	4.32	2.70	3.74 ^{b}
'Katoda'	4.06	4.47	2.71	3.74 ^{b}
'Ławga'	4.00	4.14	2.43	3.52 ^{ab}
'Monsun'	3.91	3.40	2.99	3.43 ^{ab}
'Ostka Sm.'	3.82	3.66	2.27	3.25 ^{ab}
'Parabola'	3.86	3.91	2.89	3.55 ^{ab}
'Trappe'	3.78	4.10	2.02	3.30 ^{ab}
'Tybalt'	3.57	2.40	2.75	2.91 ^{a}
'Werbena'	3.88	3.00	1.68	2.85 ^{a}
'Żura'	4.45	3.99	3.01	3.82 ^{b}
Mean	3.90 ^{A}	3.72 ^{A}	2.49 ^{B}	-

The same notes apply as in Tab. 2.

on grain yield (F = 90.14) than did variety (F = 3.54) . Significantly lower yields of all varieties in 2013 were due to a prolonged drought in July which probably influenced nutrient uptake (Tab. 1 and Tab. 12).

Discussion

In our study, greater differences in weed infestation of spring wheat were established between years than between varieties, which confirmed the results of earlier research conducted on winter wheat varieties [17]. The results of the cluster analysis indicated that 'Bombona', 'Hewilla', 'Brawura', 'Kandela', 'Katoda', 'Ławga', and 'Żura' are strongly competitive against weeds, which was reflected in the lowest number and dry matter production of weeds at the end of the growing season (77 plants m^{-2} and 37 g m^{-2} respectively, on average). These varieties were the tallest and they were characterized by the best establishment and dry matter in aboveground parts. Conversely, 'Monsun', 'Ostka Smolicka', and 'Parabola' had the lowest competitive abilities, which resulted in the highest level of weed infestation (91 plants m^{-2} and 54 g m^{-2} respectively, on average). The degree of infestation was influenced by the dry matter elaborated and the height of the wheat at the tillering stage and additionally by the number of tillers at the dough stage. The study of winter wheat varieties conducted on the same experimental fields similarly indicated that dry matter of wheat, plant density, and the height had the greatest impact on weed number and biomass [17]. The correlations between varietal morphological features and weed abundance were stronger for winter wheat than for spring wheat which was also confirmed in research by Deveikyte et al. [29].

Different features determined the competitiveness of spring wheat varieties. In 'Bombona', the density of plants could be the most important factor. In many studies, plant height has been shown to be a significant or even the only factor for cereal competitiveness [10,29,30]. In contrast, other researchers have indicated that plant height is of minor importance [31,32]. In a study by O'Donovan et al. [15], differences in seedling establishment of wheat and barley varieties tended to influence competitive ability against wild oat (*Avena fatua* L.) more than did plant height. Lemerle et al. [12] also reported that there was no evidence of any relationship between morphological traits and suppression of weeds, which emphasizes the complex nature of competitiveness and the still poor understanding of the mechanisms underlying crop/weed interactions. According to Lammerts van Bueren et al. [8] traits important for weed suppression are fluid and often depend on site-specific environmental conditions, and also on the winter or spring growth habit in wheat. In the case of some varieties, a complex of features influences competitive ability but none of them dominate; indeed, other traits such as, e.g., allelopathic effects may be involved [8,14,30,33].

A weak, significant correlation was established between the number of weeds and wheat grain yield (r = −0.328 at the dough stage; significant at p < 0.05). A greater influence of weed infestation on grain yield was observed in the study of winter wheat varieties conducted on the same experimental fields [4]. The height and tillering of the varieties tested were positively correlated with grain yield, which suggests that the competitive ability does not impact on yield. In our research, highly competitive varieties yielded moderate (3.03 t ha^{-1}) to the highest values (3.82 t ha^{-1}). Similarly, in studies by Hoad et al. [5], some highly competitive cultivars gave only modest yields. In a study on spring barley varieties by Leistrumaite et al. [1], the yield correlated with the number of productive tillers (r = 0.63) and plant height (r = 0.53). Hucl [34] reported yield gains of 7–9% in "competitive" compared to "non-competitive" spring wheat varieties. For winter wheat, the highest grain-producing cultivars included three medium height cultivars [35], but Murphy et al. [30] report no evidence of a causal relationship between ability in weed suppression and grain yield of spring wheat. According to Lemerle et al. [12] competitive ability and yield potential must therefore be treated as separate traits for selection.

The grain yield of wheat in an organic system could be affected not only by weeds but also by nitrogen status and other nutrient deficiencies as well as, for example, fungal leaf diseases [4]. In this study, significantly lower grain yield of all spring wheat varieties in 2013 was caused by drought in July which probably affected the nutrient uptake. However, it was shown that on a fertile soil and after a suitable pre-cropping, it is possible to produce high yields of cereals in an organic system [9,36]. In the studies of Feledyn-Szewczyk et al. [4], spring wheat yielded 34% lower in an organic system than in a conventional one and varietal differences were apparent. Any information about the performance of cereal cultivars in an organic system could also be useful for low-input, integrated and conventional farming in order to achieve the economic and environmental goals [9,18].

Conclusions

Based on the results reported here, the following conclusions can be drawn:

- The year of an experiment had a stronger effect on weed abundance than did variety in spring wheat.
- Weed infestation was influenced by the height of plants and their dry matter at the tillering stage, and additionally by the number of tillers at the dough stage.
- Different morphological features and canopy parameters influenced the competitive abilities of the spring wheat varieties tested. A group of varieties was found to have the highest ('Bombona', 'Brawura', 'Hewilla', 'Kandela', 'Katoda', 'Łagwa', and 'Żura') and another the lowest ('Monsun', 'Ostka Smolicka', and 'Parabola') competitive ability against weeds at the dough stage.
- A significant correlation was detected between the number of weeds and wheat grain yield ($r = -0.328$ at the dough stage; significant at $p < 0.05$). Among the varieties with the highest competitiveness, 'Żura', 'Kandela', and 'Katoda' yielded the most (3.74–3.82 t ha^{-1}), whereas 'Bombona' gave only a moderate yield (3.03 t ha^{-1} on average).
- Both the competitiveness of spring wheat varieties against weeds and the yield potential should be taken into account in the selection of varieties for an organic farming system.

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Zdolności konkurencyjne w stosunku do chwastów oraz plonowanie 13 odmian pszenicy jarej (*Triticum vulgare* L.) uprawianych w systemie ekologicznym

Streszczenie

Celem badań była ocena zależności między cechami morfologicznymi, parametrami łanu a zachwaszczeniem i plonowaniem odmian pszenicy jarej (*Triticum vulgare* L.). Badania zostały przeprowadzone w latach 2011–2013, na polach uprawianych w systemie ekologicznym, w Zakładzie Doświadczalnym Instytutu Uprawy Nawożenia i Gleboznawstwa – Państwowego Instytutu Badawczego w Osinach, Polska (51°28′ N, 22°04′ E). Trzynaście odmian pszenicy jarej wysiewano w układzie całkowitej randomizacji w 4 powtórzeniach. Liczebność chwastów i ich sucha masa, jak również cechy biometryczne odmian pszenicy były oceniane w fazie krzewienia (BBCH 22–24) i dojrzałości (BBCH 85–87). Na podstawie analizy wariancji stwierdzono, że rok badań w większym stopniu wpływał na poziom zachwaszczenia niż odmiana. Analiza korelacji Pearsona wykazała, że liczba chwastów zależała od wysokości odmian pszenicy i masy części nadziemnych łanu w fazie krzewienia oraz dodatkowo rozkrzewienia w fazie dojrzałości. Stwierdzono istotną korelację między liczbą chwastów i plonem ziarna pszenicy ($r = -0.328$, $p < 0.05$). Różne cechy morfologiczne i parametry łanu wpływały na zdolności konkurencyjne testowanych odmian pszenicy jarej. Analiza skupień podzieliła odmiany na grupę o największych ('Bombona', 'Brawura', 'Hewilla', 'Kandela', 'Katoda', 'Łagwa', 'Żura') i najmniejszych ('Monsun', 'Ostka Smolicka', 'Parabola') zdolnościach konkurencyjnych w stosunku do chwastów. Głównym osiągnięciem badań jest informacja dla rolników, które odmiany pszenicy jarej cechują się dużą konkurencyjnością w stosunku do chwastów i jednocześnie plonują na wysokim poziomie. Wśród odmian o największej konkurencyjności w stosunku do chwastów najwyżej plonowała odmiana 'Żura' (średnio 3.82 t ha^{-1}), natomiast 'Bombona' plonowała na średnim poziomie (3.03 t ha^{-1}). Zarówno zdolności supresyjne odmian pszenicy jarej w stosunku do chwastów, jak i potencjał plonowania powinny być brane pod uwagę przy doborze odmian do rolnictwa ekologicznego.