ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN – POLONIA

VOL. LXIX (2) SECTIO E 2014

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Impact of plant density on the canopy area index and weed infestation depending on different cultivars of winter oilseed rape (*Brassica napus* L., ssp. o*leifera* Metzg.)

Wpływ zagęszczenia roślin na dynamikę rozwoju powierzchni asymilacyjnej łanu i zachwaszczenie różnych odmian rzepaku ozimego (*Brassica napus* L., ssp. o*leifera* Metzg.)

Summary. One way to increase the competitiveness of crop plants against weed infestation is to adjust crop density. Introduction of new ("semi-dwarf") cultivars of winter oilseed rape triggers a need for research in this field. A two-factor experiment evaluated the effect of plant density and winter oilseed rape (WOSR) cultivars on the canopy architecture and weed infestation of a WOSR crop as well as on the correlation between these traits. During the 2010–2012 study period, the average plant density was 38.0; 29.4; and 22.9 plants m^{-2} (three row spacings were used: 33, 44, and 55 cm). The oilseed rape cultivars were as follows: conventional, hybrid and "semi-dwarf" hybrid. Experimental factors did not cause significant differences in the number of weeds and their mass. However, there was a clear trend of decreasing total number of weeds in the span of 33 cm spacing than in the 44 and 55 cm. Hybrid cultivar resulted in increasing of total number of weeds in comparison to the conventional one. The differences in the assimilation area of WOSR plants per unit of ground area were significant between row spacings until the end of the flowering stage and between cultivars until the flower bud development stage. During the growth stages from the beginning of flowering until the end of pod development significant negative correlations were found between the assimilation area and the number of weeds, while the correlations between the assimilation area and the weed weight were insignificant. Insignificant correlations also occurred between the number of oilseed rape plants per unit area and the mass of weeds. The results indicate the possibility of reducing the demand for seed sowing, without requiring additional costs for weed control.

Key words: semi-dwarf cultivar; row spacing, leaf area index, correlations, competitiveness

INTRODUCTION

An essential feature of plants that determines their yields and competitiveness against other species is their leaf area and the rate of its increase. The selection of cultivars that takes into account this feature can be one of weed management methods used in crop protection [Feledyn-Szewczyk 2009].

The maximum productivity of plants growing at optimal density depends on the species, environmental conditions, and agronomic factors. Lower density as a result of a reduced number of plants per unit area can be compensated by increased productivity of a single plant. Some studies designed to evaluate the tolerance of crop plants to the effect of pesticides and to compare crop plant cultivars and the productivity of crops give the number of plants per unit area or the leaf area index (LAI) as the canopy density parameter. Other studies are focused on the actual leaf area as the canopy architecture parameter [Gabrielle *et al.* 1998; Lepiarczyk *et al.* 2005, López-Bellido *et al.* 2005; Jaśkiewicz 2007, Balodis and Gaile 2010; Ciampitti and Vyn 2011; Andruszczak *et al.* 2012; Zhang *et al.* 2012].

The higher LAI is, the larger the leaf area is in relation to the soil surface area and thereby there is a better use of arable area and higher biomass production yield. At the same time, too high values of LAI can mean a worsening of light conditions and CO_2 supply to plants inside the canopy and can increase their susceptibility to pathogen infection. Some reports in the literature include the effect of plant density on WOSR grain yield [Hirose *et al.* 1997; Leach *et al.* 1999; Momoh and Zhou 2001; Seassau *et al.* 2012].

Wrong selection of canopy architecture parameters (too high density of plants) can also cause abnormalities in the pollination of flowers and transport of assimilates to the seeds [Wang *et al.* 2011]. Strongly branching winter oilseed rape of large biomass slightly determines the final density (27.2%), but it has the biggest share in seed yield per area unit (52.5%) [Zając *et al.* 2013].

But there is a lack of reports on the effect of WOSR plant density on the canopy architecture parameters of particular cultivar groups and thus their competitiveness against weeds. A hypothesis was made that it was possible to reduce the number of WOSR plants per unit area by increasing row spacing (not changing in-row density) without a deterioration of the canopy architecture parameters and without increased weed infestation. A reduced requirement for seed material, improved conditions inside the crop and enhanced effectiveness of weed control treatments would be a justification for such a modification of WOSR cultivation technology.

The aim of the present study was to evaluate the weed infestation and the rate of increase in the canopy area index (CAI) of WOSR, depending on the cultivar and plant density of WOSR. Verification of the research hypothesis also required a presentation of fuller characteristics of the crop canopy in the form of a relationship between the rate of shading of WOSR inter rows and weed infestation of the WOSR crop. Therefore, the results of the study were subjected to additional statistical analysis by calculating the coefficient of correlation between CAI and the main weed infestation parameters.

MATERIAL AND METHODS

A field experiment was carried out in the period 2010–2012 at the Experimental Farm in Bezek located near the city of Chełm (N: 51°19' E: 23°25'), belonging to the

University of Life Sciences in Lublin. The experiment was set up in a randomized block design in three replications on mixed rendzina soil developed from chalk rock with the granulometric composition of medium silty loam. This soil was characterized by an alkaline pH (pH in 1 mol KCl was 7.35). Its sorption complex was characterized by a high content of phosphorus and potassium as well as a very low content of magnesium (117.8 – P; 242 – K; and 19 – Mg mg kg^{-1} of soil). The organic carbon content was at a level of 2.47%.

The two-factor experiment evaluated the effect of plant density and OSR cultivars on canopy architecture parameters and yield components as well as on the correlation between these traits. The number of WOSR plants per unit area was controlled by row spacing, which was 33, 44, and 55 cm; this corresponded to the spring average density of 38.0; 29.4 and 22.9 plants m^{-2}. In-row spacing of oilseed rape plants did not change and it was about 8 cm. The oilseed rape cultivars were as follows: A – conventional cultivar "Catana"; B – hybrid cultivar (F1, father line – male fertile) "DK Exquisite"; and C – low-growth ("semi-dwarf") hybrid cultivar (F1, father line – male fertile) (CWH114D) with high winter hardiness (registered in Germany, Czech Rep., Ukraine at all country in EU as "DK Sedona").

After the harvest of winter wheat, phosphorus, potassium and magnesium fertilizers were incorporated (35 kg P ha^{-1} – superphosphate; 50 kg K ha^{-1} – potassium chloride; 18 kg S ha^{-1} and 13.5 kg Mg ha^{-1} – magnesium sulphate) and subsequently pre-sowing ploughing was done. Nitrogen fertilizer was applied (130 kg N ha^{-1} – urea). WOSR was sown in the second half of August (20–25 August).

To control dicotyledonous weeds, the first dose of the herbicide Butisan Star 416 SC was applied at a rate of 1.5 dm^3 ha^{-1} (333 g of metazachlor and 83 g quinmerac in 1 dm^3 of the herbicide) directly after sowing, while the second dose was applied at the same rate 1.5 up to 2 weeks after sowing. At the 3 leaf stage of self-sown cereals and monocotyledonous weeds, Fusilade Forte 150 EC was applied at a rate of 1.0 dm^3 ha^{-1} (125 g fluazifop-p-butyl in 1 litre of the herbicide). Commercials weed control programs used in intensive production of winter rape provide additional spring treatments against secondary weed control. The methodology of this experiment was abandoned with spring herbicide treatments. Individuals weeds that survived the treatments made after sowing and appearing in the autumn and spring are assessed qualitatively and quantitatively.

Weed infestation of the WOSR crop was determined before its harvest (after the end of growth) using the quantitative gravimetric method in an area of 1m^{-2}. The number of weeds, with a breakdown into mono- and dicotyledonous weeds, their species composition and dry weight were determined.

The measurement of assimilation area per unit of ground area were made with a LAI-2000 plant canopy analyzer (Li-Cor Biosciences, Inc., Lincoln, NE). The LAI-2000 is one of the commonly used instruments to measure LAI. The LAI-2000 Canopy Analyzer can by used also to determine the canopy area index (CAI) resulting from radiation measurements made with a made with a "fish-eye" optical sensor [Behrens and Diepenbrock 2006].

The method based on the analysis of optical gap fraction measurements was selected not only due to the ease of its use, but primarily due to the conviction that the stem and pods that contain chlorophyll and shade the canopy are of decisive importance for the results of measurement of the CAI and the final yielding capacity [Fang and Liang 2008].

The evaluation of CAI in the OSR canopy was carried out on five dates: beginning of stem elongation (30–32 scale BBCH – Biologische Bundesanstalt, Bundessortenamt and Chemical Industry); beginning of flower bud development (50–55); beginning of flowering (60–63); end of flowering (67–69) and pod development (76–79).

The fruit of plants belonging to the *Brassicaceae* family is the "silique", but in the literature the term "pod" is used. In order to better understand this paper, the name "pod" is also used in it.

The obtained results were statistically analysed using analysis of variance (ANOVA) and the differences that were proved with an error rate less than or equal to 5% were considered to be significant, while their significance was verified by Tukey's test. Trying to stress the effect of experimental factors that can be determined by man, the results were presented as 3-year means (2010–2012). Correlation coefficients were calculated using Statistica software on the basis of partial results from the 3-year study (the number of cases (N) for each trait was 81) and proven correlations with an error rate less than or equal to 5% were considered to be significant.

RESULTS

Weed infestation of winter oilseed rape

The statistical analysis of the total number of weeds showed that the differences between WOSR cultivars and treatments with different row spacings were insignificant (Tab. 1).

Table 1. Number of weeds per m^{-2} in the WOSR crop (mean for 2010–2012)
Tabela 1. Liczba chwastów na m^{-2} w łanie rzepaku ozimego (średnio dla 2010–2012)

	Row spacing Rozstawa rzędów (cm)	Cultivar – Odmiana			Mean Średnia
		A	B	C	
Dicotyledones	33	15.7	15.0	18.6	16.4
	44	12.7	21.6	18.3	17.5
	55	15.4	16.7	19.8	17.3
	Mean/Średnia	14.6	17.8	18.9	17.1
$LSD_{0.05}$ $NIR_{00,5}$		between cultivars – NS; between rows spacings – NS pomiędzy odmianami – NS; pomiędzy rozstawami rzędów – NS			
Monocotyledones	33	24.0	30.3	23.3	25.9
	44	37.0	45.4	33.4	38.6
	55	39.6	36.6	39.3	38.5
	Mean/Średnia	33.6	37.4	32.0	34.3
$LSD_{0.05}$ $NIR_{00,5}$		between cultivars – NS; between rows spacings – NS pomiędzy odmianami – NS; pomiędzy rozstawami rzędów – NS			
Total Ogółem	33	39.7	45.4	42.0	42.4
	44	49.7	67.0	51.7	56.1
	55	55.1	53.3	59.1	55.8
	Mean/Średnia	48.2	55.2	50.9	51.4
$LSD_{0.05}$ $NIR_{00,5}$		between cultivars – NS; between rows spacings – NS pomiędzy odmianami – NS; pomiędzy rozstawami rzędów – NS			

A – conventional cultivar/ odmiana populacyjna
B – hybrid cultivar (F1, father line)/ odmiana hybrydowa (F1, męskopłodna)
C – hybrid cultivar (F1, father line) with reduced growth ("semi-dwarf")/ odmina hybrydowa (F1, męskopłodna) o zmniejszonym wzroście (półkarłowa)
LSD – the least significant difference/ NIR – najmniejsza istotna różnica
NS – not significant/ różnice nieistotne

However, it is worth drawing attention to a clear trend towards a lower number of monocotyledonous weeds in the plots with the highest plant density of the winter oilseed rape crop (row spacing of 33 cm) compared to the other treatments. Similar trends were observed in the class of dicotyledonous weeds, but they were less noticeable (Tab. 1). It should be stressed that due to the desire to demonstrate WOSR competitiveness against weeds springtime weed control treatments were not performed. That is why most weeds occurring in the lower layer of the crop were in the form of seedlings and young plants and their number was not reflected in weed weight.

The WOSR plots with the conventional cultivar (A) showed a trend towards a lower number of dicotyledonous weeds compared to the plots with the other cultivars. The lowest number of individuals of monocotyledonous weeds was found in the oilseed rape crop of the "semi-dwarf" hybrid cultivar (C). But these differences were statistically insignificant.

Table 2. Dry weight of weeds (g m^{-2}) in the WOSR crop (mean for 2010–2012)
Tabela 2. Powietrznie sucha masa chwastów (g m^{-2}) w łanie rzepaku ozimego (średnio dla 2010–2012)

Row spacing (cm) Rozstawa rzędów	Cultivar/Odmiana			Mean Średnia
	A	B	C	
33	53.7	65.8	60.9	60.1
44	68.7	55.3	64.7	62.9
55	62.4	59.8	70.0	64.1
Mean Średnia	61.6	60.3	65.2	62.4
$LSD_{0.05}$ $NIR_{00,5}$	between cultivars – NS; between rows spacings – NS pomiędzy odmianami – NS pomiędzy rozstawami rzędów – NS			

Explanations as in Table 1/ Objaśnienia jak w tabeli 1

A trend towards lower air-dry weight of weeds was found in the WOSR crop sown at a row spacing of 33 cm compared to the row spacing of 44 and 55 cm (Tab. 2). Slightly higher weed weight was found in the crop of the C cultivar compared to the A and B cultivars. The statistical analysis of these results showed that the differences between both cultivars and treatments with different row spacings were within the margin of statistical error (Tab. 2).

Canopy area index

The differences in CAI between the plots with different row spacings were significant from the beginning of stem elongation (30–32 scale BBCH) until beginning of flowering (60–63). Measurements made at the end of flowering stage (67–69) showed a trend towards higher CAI at a row spacing of 33 cm compared to the row spacing of 44 and 55 cm, but as a result of large standard deviations these differences proved to be statistically insignificant (Tab. 3).

Table 3. Canopy area index (CAI) depending on the winter oilseed rape cultivar, row spacing and growth stage of WOSR (mean for 2010–2012)
Tabela 3. Wskaźnik powierzchni łanu rzepaku ozimego w zależności od odmiany, rozstawy rzędów i fazy rozwojowej (średnia dla 2010–2012)

Growth stage (BBCH) Faza rozwojowa	Row spacing (cm) Rozstawa rzędów	Cultivar/Odmiana			Mean Średnia
		A	B	C	
30-32	33	1.55	2.52	2.18	2.08
	44	1.52	1.96	1.87	1.78
	55	1.27	1.74	1.62	1.54
	mean/średnia	1.45	2.07	1.89	1.80
$LSD_{0.05}$ $NIR_{00,5}$		between cultivars – 0.22; between rows spacings – 0.21 pomiędzy odmianami – 0,22; pomiędzy rozstawami rzędów – 0,21			
50–55	33	1.95	2.57	2.56	2.36
	44	1.70	1.93	2.14	1.92
	55	1.62	1.78	1.75	1.72
	mean/średnia	1.76	2.09	2.15	2,00
$LSD_{0.05}$ $NIR_{00,5}$		between cultivars – 0.39; between rows spacings – 0.37 pomiędzy odmianami – 0,39; pomiędzy rozstawami rzędów – 0,37			
60–63	33	3.51	3.78	3.95	3.75
	44	3.35	3.16	3.60	3.37
	55	3.20	3.43	3.20	3.28
	mean/średnia	3.35	3.47	3.58	3.47
$LSD_{0.05}$ $NIR_{00,5}$		between cultivars – NS; between rows spacings – 0.40 pomiędzy odmianami – NS; pomiędzy rozstawami rzędów – 0,40			
67–69	33	3.57	3.86	4.06	3.83
	44	3.42	3.24	3.82	3.49
	55	3.40	3.51	3.24	3.38
	mean/średnia	3.46	3.54	3.71	3.57
$LSD_{0.05}$ $NIR_{00,5}$		between cultivars – NS; between rows spacings – NS pomiędzy odmianami – NS; pomiędzy rozstawami rzędów – NS			
76–79	33	4.09	4.15	4.48	4.24
	44	4.29	4,06	4.21	4.19
	55	4.12	4.21	3.99	4.11
	mean/średnia	4.17	4.14	4.23	4.18
$LSD_{0.05}$ $NIR_{00,5}$		between cultivars – NS; between rows spacings – NS pomiędzy odmianami – NS; pomiędzy rozstawami rzędów – NS			

Explanations as in Table 1/ Objaśnienia jak w tabeli 1

Coefficients of correlation

The calculated correlation coefficients did not show significant relationships between the weed infestation parameters and number of WOSR plants per unit area. This demonstrates that oilseed rape plant density did not have a significant effect on the number and weight of weeds found in the crop (Tab. 4). On the other hand, significant positive correlations were shown between the number of WOSR plants per unit area and LAI from the beginning of flower bud development (BBCH 50–55) until the end of flowering (BBCH 67–69).

Table 4. Coefficients of correlation between the examined parameters
Tabela 4. Współczynniki korelacji pomiędzy wybranymi cechami

Factors Cechy		Number of WOSR plants per m^{-2} Liczba roślin rzepaku ozimego na 1 m^2	Air dry weight of weeds Powietrznie sucha masa chwastów	Total number of weeds Ogólna liczba chwastów	Number of mono-cotyle-donous weeds Liczba chwastów jednoliścien-nych	Number of dicotyle-donous weeds Liczba chwastów dwuliścien-nych
CAI for growth stage (BBCH) Wskaźnik powierzchni liści dla faz rozwojowych	30–32	0.58*	-0.20	-0.43	-0.45	-0.35
	50–55	0.69*	-0.44	-0.66*	-0.66*	-0.45
	60–63	0.71*	-0.34	-0.67*	-0.63*	-0.35
	67–69	0.55	-0.21	-0.59*	-0.55	-0.30
	76–79	0.48	-0.08	-0.57	-0.48	-0.41
Number of dicotyledonous Liczba chwastów dwuliściennych		0.07	0.31	0.77*	0.58*	**1.00**
Number of monocotyledonous Liczba chwastów jednoliściennych		-0.38	0.65*	0.97*	**1.00**	**0.58***
Total number of weeds Ogólna liczba chwastów		-0.28	0.61*	**1.00**	**0.97***	**0.77***
Dry weight of weeds Sucha mas chwastów		-0.35	**1.00**	**0.61***	**-0.65***	**0.31**

*The significant correlation ($\alpha = 0.05$)/ Korelacje istotne ($\alpha = 0,05$)

Similarly as the number of monocotyledonous weeds, the total number of weeds decreased with an increase in the photosynthetic area index of oilseed rape. The significant negative correlations between these parameters are evidence of such a relationship. However, this was not translated into weed weight, since the correlations between CAI and weed dry weight were statistically insignificant. But weed dry weight showed a significant linear correlation with the number of monocotyledonous weeds and total number of weeds. In turn, the total number of weeds was positively correlated with the number of monocotyledonous weeds

(0.97) and dicotyledonous weeds (0.77) (Tab. 4). This means that monocotyledonous species were the main contributors to weed weight and they constituted a majority in the total number of weeds.

DISCUSSION

WOSR plants in the present study demonstrated the ability to produce a large lateral shoots and produce more assimilation area under a reduced number of plants per unit area. Evidenced by the lack of significant differences in CAI between objects of different row spacing in the stage of development of pods. The large capacity of accommodation of winter oilseed rape to habitat conditions also report Jullien *et al.* [2009]. They showed that rape under nitrogen deficiency significantly increased leaf mass per unit area (leaf mass per area (LMA).

In developing a dynamic model of optimal LAI for winter oilseed rape grown in the provinces of Wuhan, Nanjing, and Jiangsu located in eastern China, Cao *et al.* [2009] found that LAI of oilseed rape reached the highest values at the early flowering stage. In their study, the hybrid cultivar "No.16 Ningyou" showed higher LAI (5.90) than the conventional cultivar "No.9 Zhongshuang" (4.75). The highest LAI at the flowering stage was also found by Momoh and Zhou [2001]. Similarly, Kulig *et al.* [2012] by measuring the rate of green area index (GAI), the highest value of this parameter (6.32) obtained in full flower. No differences were found between the variations in the size of the mark. In their research, LAI at pod development was more than three times lower than at flowering. The differences in the studies of individual authors were probably caused by different LAI measurement or calculation methods. The present experiment showed the highest values of the canopy area index (CAI) of winter oilseed rape (4.11–4.24) at pod development (76–79 BBCH), irrespective of the cultivar and row spacing. On average for the whole measurement period, the hybrid cultivars were characterized by a higher value of CAI compared to the conventional cultivar. The present study used the LAI-2000 plant canopy analyzer which measures soil shading by all plant parts [Welles and Cohen 1996]. At pod development stage in oilseed rape and other plants of the *Brassicaceae* and *Fabaceae* families, not only the leaves contain chlorophyll but also the stem and pods and they are therefore considered to be the photosynthetic area [Andrews and Svec 1975; Atkins *et al.* 1977; Singal *et al.* 1995; Zhou *et al.* 2009; Jun *et al.* 2012].

When reducing the number of plants per unit area, one should account for the risk of increased weed infestation, in particular under agricultural systems in which extensive plant protection and reduced crop rotation are used. The study of Worku and Astatkie [2011] conducted in south-western Ethiopia to determine the effect of interrow width (50; 55; 60; 65; 70 cm) and plant spacing (2.5; 5; 10 cm) in soybean crops showed that these factors significantly modified soybean yield and weed infestation of crops. A statistical analysis of their results showed a negative relationship, albeit with different strength, between planting density and weed infestation. Kwiatkowski *et al.* [2012] after reducing the standard seeding of 70 seeds per 1 m^2 (deploys rows 18 cm) to 40 seeds per 1 m^2 (30 cm row spacing) found an increase in the number and weight of weeds in winter oilseed rape canopy. However, these differences were insignificant. The authors recognize as legitimate the introduction of technology into agricultural practice takes into account the reduced amount of seed sowing (from 4.0 to 2.5 kg ha^{-1}). Our findings confirm those reports. By reducing the number of plants per unit area should expect an increased risk of infestation, but in agricultural systems, where applicable, the correct Riverina danger is small. In the study of Różyło and Pałys [2011], a wider row spacing (33 cm) of WOSR significantly increased the number of monocotyledonous weeds and total number of weeds compared to the spacing of 25 cm. These relationships were not reflected in weed dry weight, since the differences between the treatments with different row spacings were statistically insignificant. The present study did not prove a statistically significant effect of reduced density of winter oilseed rape plants on the number of weeds and dry-weight of their above-ground parts. Various experimental studies have shown that weed weight is a better indicator of competitiveness of weeds against the crop plant than the number of weeds per unit area [Lutman 1992; Sartorato *et al.* 1996; Lutman *et al.* 2000; Lins and Boerboom 2002].

In developing models to predict weed biomass in winter oilseed rape crops, Primot *et al.* [2006] obtained high values of sensitivity and specificity when weed biomass was predicted as a function of sowing date, type of soil tillage, soil mineral nitrogen, crop density, weed density at emergence, and main characteristics of the most abundant weed species. Model performance strongly decreased when input variables related to the weed population were not taken into account. The results of the present study in which weed dry weight was significantly positively correlated with the number of monocotyledonous weeds and with the total number of weeds are a partial confirmation of their conclusions. But the present study did not confirm the correlation between weed weight and the canopy architecture parameters of WOSR (plant density and CAI).

CONCLUSIONS

For stages of development from 50 to 79 (from the beginning to the end of the flowering development siliques) CAI rape smaller due to increased plant spacing has been associated with hypothetical increase in the number of weeds, as evidenced by significant correlation between these parameters. CAI had statistically proven impact on weed infestation of winter rape expressed in the air-dry mass of weeds, since the correlation coefficients between these traits were not significant. This was due to good conditions for germination of weed seeds large amount of spring rape against short circuit rows but the lack of opportunities for growth of weeds in the conditions of high competition from rape.

The results of this study support the hypothesis that it is possible to reduce the number of winter oilseed rape plants per unit area by increasing the row spacing (without changing the density in the row) without a loss of performance and canopy architecture without any significant increase weed. They also point to the possibility of reducing seed standards, thereby reducing the need for seed without the need of extra costs for weed control. The condition of modification technology WOSR must, however, be correct Riverina.

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Streszczenie. Jednym ze sposobów zwiększania konkurencyjności roślin uprawnych w stosunku do chwastów jest regulacja zagęszczenia łanu. Wprowadzanie nowoczesnych półkarłowych odmian rzepaku ozimego wywołuje potrzebę badań nad tym zagadnieniem. W dwuczynnikowym doświadczeniu oceniano oddziaływanie zagęszczenia roślin i odmian rzepaku ozimego na architekturę łanu i jego zachwaszczenie oraz na korelacje pomiędzy tymi cechami. Liczbę roślin rzepaku ozimego na jednostce powierzchni gruntu regulowano rozstawą rzędów, która wynosiła 33, 44 i 55 cm. Odmiany rzepaku to: populacyjna, hybrydowa i hybrydowa półkarłowa. Czynniki doświadczenia nie powodowały statystycznie potwierdzonych różnic w liczbie chwastów i ich powietrznie suchej masie. Zaobserwowano jednak wyraźnie mniejszą ogólną liczbę chwastów w rozstawie 33 cm niż w rozstawie 44 i 55 cm. Zastosowanie odmian hybrydowych natomiast powodowało zwiększenie ogólnej liczby chwastów w porównaniu z odmianą populacyjną. Różnice wskaźnika powierzchni asymilacyjnej łanu rzepaku przypadającej na jednostkę powierzchni były istotne do końca fazy kwitnienia pomiędzy rozstawami rzędów oraz do fazy rozwoju pąków kwiatowych pomiędzy odmianami. W następnych fazach rozwojowych wskaźnik powierzchni łanu rzepaku ozimego był na podobnym poziomie na wszystkich obiektach. Od początku kwitnienia do końca rozwoju łuszczyn korelacje wskaźnik powierzchni łanu rzepaku ozimego z liczbą chwastów były istotnie ujemne, natomiast z masą chwastów były nieistotne. Także korelacje pomiędzy liczbą roślin rzepaku ozimego na jednostce powierzchni a masą chwastów były nieistotne.

Słowa kluczowe: odmiana półkarłowa, rozstawa rzędów, wskaźnik powierzchni łanu, korelacje, konkurencyjność