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DEVELOPMENT AND YIELD OF MORPHOLOGICALLY DIFFERENT GROUPS OF WINTER OILSEED RAPE CANOPY I. PRODUCTIVITY AND MORPHOLOGY OF PLANTS

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Abstract. The research aim was to evaluate the productivity of two winter oilseed rape cultivars, Adam and Poznaniak, in three localities in the south of Poland: Głubczyce, Pawłowice and Prusy. The scope of comparisons was broaden through a detailed biometrical analysis of plants and the spectral properties (GAI, LAI and SPAD) of canopy, which determine oilseed rape productivity. At the optimal plant density of two hybrid cultivars of winter oilseed rape: Adam and Poznaniak, three groups of plants differing morphologically and productively were identified. Strongly branching winter oilseed rape of large biomass determined the final density only in 27.2%, but it had the biggest share in seed yield per area unit, reaching 52.5%. The share of small plants of oilseed rape in the canopy reached 37.6%, but they played a minor role in the creation of seed yield. High dynamics of development ratio of winter oilseed rape plants and canopy led to the increased height of plants which, however, was accompanied by a lower number of branches and siliques and a diminished diameter of main shoot and lateral branches.

Key words: *Brassica napus*, GAI, hybrid, NDVI, siliques, SPAD

INTRODUCTION

In the colder zone of temperate climate of Europe, winter oilseed rape (WOR) is the leading species among oil plants in economic terms. As a result of heavy winters, healthy plants develop a higher number of lateral branches in order to compensate the reduced density of the canopy [Diepenbrock 2000, Wielebski 2007a]. Despite a constant occurrence of these losses, which sometimes may be severe, winter form of rape

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dominates in Poland due to higher yields of by about 40-45 %, as compared to spring form [Budzyński 2010].

Multiple factors influence the dominance of winter forms of rape in the group of oil plants production, because of the systematic increase in fat content and seed yield of new hybrid cultivars [Berry and Spink 2006]. Budzyński [2010] reports that the seed yield of WOR registered in the experiments carried out in Poland according to the Post--Registration Variety Testing System was 4.67 $t \cdot ha^{-1}$. In the vegetative seasons promoting the good yielding of WOR, a record harvest was obtained in the strict field experiments, e.g. Jankowski and Budzyński [2007] point out that in 2005 in Warmia region (Poland) the seed yield of hybrid cv. Kronos reached the level of 7.17 $t \cdot ha^{-1}$. In 2004 Wielebski [2007b] obtained the seed yield of 7.51 $t \cdot ha^{-1}$ from the MR 153 line in the conditions of Wielkopolska region (Poland). Unfortunately, as evidenced by Kaczmarek *et al*. [2003], a varied genotype-environmental reaction of WOR cultivars, depends on the soil and weather conditions in a particular location and growing season, which indicates the desirability of determining the productivity of this plant cultivars in several areas.

In the studies conducted so far, the seed yield and its components for both winter and spring form of oilseed rape were analyzed with the relatively high degree of generality, probably due to the laborious measurements and also the tendency of siliques for cracking. As a result of these assumptions, a limited number of plant and silique samples, disregarding the morphological and production status of single plants, was analyzed. The objective of this study was a comparative analysis of productivity of the diversified group of WOR hybrid cultivars grown in localities differing in agro--climatic and habitat conditions. The present study aimed at assessing the morphological differentiation and features of winter oilseed rape plants and siliques in the canopy from the three different localities.

MATERIAL AND METHODS

In the years 2010-2011 a multisite field experiment was conducted in three localities in Poland: Głubczyce (50°12' N; 17°50' E) – the Experimental Station for Cultivar Testing (Opole region); Pawłowice (50°28' N; 18°31' E) – the Experimental Station for Cultivar Testing (Silesia region) and Prusy (50°07' N; 20°05' E) – the Experimental Station of the University of Agriculture in Krakow (Małopolska region). A selection of the experimental location aimed to determine the production potential of two hybrid (F1) cultivars of WOR, i.e. Poznaniak and Adam in the conditions of southern Poland. In Głubczyce and Prusy the experiment was set up on the degraded chernozem, situated on loess, while in Pawłowice, on podzolized soil formed from boulder clay. The soil concentrations of major nutrients: P, K and Mg, fertilizer doses, pesticides and other agro-technical data are presented in Table 1. Dressed WOR seeds were sown in the number of 60 germinating pieces per 1 m^2. Row spacing in Głubczyce and Pawłowice was 30 cm, in Prusy 28 cm.

The indicators of vegetation determined at the characteristic phases of WOR plants development comprised: green area index (GAI) in the rape canopy measured using Sunscan Delta-T (SunScan Canopy Analysis System SS1-COM-R4), the normalized difference vegetation index (NDVI) measured using GreenSeker (N-Tech Companies) and the relative chlorophyll content (SPAD) assessed using Minolta SPAD 502DL

(Konica Minolta). Measurements were performed on the following dates: 11 April (BBCH 35-51), 27 April (BBCH 57-61), 20 May (BBCH 64-65) and 15 June (BBCH 69-71).

Before harvesting, the deflection rate of rape canopy was estimated, which is the ratio of plants' height before harvest to their height at the stage of technical maturity. The number of plants was determined in two two-meters-long rows to assess the number of plants on the row length mentioned above and their production category: small, medium and large, based on the number of lateral branches: small – 1 to 4, medium – 5 to 7 and large ≥ 8 branches. Plants harvested from the field were dried in a ventilated room for one month. The following assessments were carried out for the individual siliques: a single silique weight, seed weight per silique and seed number per silique.

The obtained data were statistically analyzed using three way ANOVA, Statistica® 9.0 [StatSoft 2009]. Tables and figures in the text present the main effects and selected, significant interactions. The significance of differences was determined by Tukey's test.

RESULTS

The location of experiments affected the thermal conditions and precipitation for WOR during the growing period (Table 2). As expected, the best thermal conditions for the growth of WOR prevailed in Głubczyce (Opole region), which was manifested by the greatest height of the plants. Thermal conditions were getting worse with cultivation moving east of the country, which is well reflected by the analysis of the average air temperatures for individual months in the growing period of WOR, in the villages of Pawłowice and Prusy. On the other hand, the total rainfall for each month of the growing season was the highest in Prusy and the lowest in Głubczyce, which is the inverse of the thermal situation. In Pawłowice the average temperature and rainfall amount was in between values noted for Głubczyce and Prusy. September 2010 and April 2011 were particularly wet months in this village. It can be assumed that rainfall noted in Prusy in these months might have intensified mineral nitrogen leaching deep into the soil profile, or even to groundwater, which probably influenced the reduced plant height, which resulted in a tendency for lower yields. In all localities rainfall in July was excessively high, which prolonged the vegetation of WOR, as well as an increased tendency of siliques to rupture, and also hampered harvest of mature plants.

In Głubczyce WOR plants started the growth earlier and were growing more rapidly, resulting in higher values of green area index (GAI), which refers to the assimilation area of canopy (Table 3). In the other localities GAI was significantly lower. On the date of the second measurement the increase of assimilation area was the largest for WOR canopy in Głubczyce, where GAI increased by about 2.52 $m^2 \cdot m^{-2}$, in comparison with the first assessment date. In the other localities, i.e. Prusy and Pawłowice, GAI increased in the same period and amounted to respectively: 2.35 and 1.13 $m^2 \cdot m^{-2}$. The probable reason for this situation was heavy rainfall in April, especially in Prusy, as shown in Table 1. The measurements carried out on 20 May in Głubczyce showed GAI value of 7.65 $m^2 \cdot m^{-2}$, which was significantly higher in comparison with the other localities. In mid-June a significant reduction in GAI was noted, which stabilized at a balanced level. Both WOR cultivars developed GAI on similar levels – without significant differences, however, cv. Poznaniak showed a tendency for a slightly higher GAI (Table 3).

Table 1. Basic agro-technical data for localities of experiments

Specification	Locality		
	Głubczyce	Pawłowice	Prusy
Forecrop	Spring barley	Winter wheat	Winter wheat
Plant density, seeds·m^{-2}	60	60	60
Sowing date	04.09.2010	04.09.2010	26.08.2010
Beginning of flowering	30.04.2011	28.04.2011	02.05.2011
End of flowering	28.05.2011	24.05.2011	30.05.2011
Harvest date	19.07.2011	29.07.2011	02.08.2011
Levels of fertilizers N; P; K; S, kg·ha^{-1}	150; 67.5; 142.5; 42.3	217.5; 54; 114; 54	200; 100; 281; 70
P	25.0 very high	19.2 high	17.1 high
K	19.4 medium	20.7 medium	13.5 low
Mg	15.3 very high	11.5 high	14.2 very high
pH	6.5 slightly acid	6.3 slightly acid	6.2 slightly acid
Herbicides (dates of spraying)	Butisan Star 416 SC – 2.5 L·ha^{-1} (6.09.10) Supero 05 EC – 1.2 L·ha^{-1} (22.09.10)	Butisan Star 416 SC – 3.0 L·ha^{-1} (4.09.10)	Butisan Star 416 SC – 3 L·ha^{-1} (4.10.10) Fusilade Forte 150 EC – 0.8 L·ha^{-1} (4.10.10) Galera 334 SL – 0.35 L·ha^{-1} (15.04.11)
Insecticides (dates of spraying)	Dursban 480 EC – 0.75 L·ha^{-1} (22.09.10) Decis 2.5 EC – 0.25 L·ha^{-1} (22.09.10) Decis 2.5 EC – 0.3 L·ha^{-1} (4.04.11) Dursban 480 EC – 0.6 L·ha^{-1} (16.04.11) Karate Zeon 050 CS – 0.15 L·ha^{-1} (9.05.11)	Fury 100 EW – 0.1 L·ha^{-1} (8.10.10) Mospilan 20 SP – 0.1 kg·ha^{-1} (22.04.11) Patriot 100 EC – 0.08 L·ha^{-1} (28.03.11)	Caramba 60 SL + Talstar 100 EC – 1.25 + 0.1 L·ha^{-1} (19.04.11) Talstar 100 EC – 0.1 L·ha^{-1} (29.04.11) Mospilan 20 SP – 0.1 kg·ha^{-1} (18.05.11)
Desiccant (dates of spraying)	Reglone 200 SL – 2.5 L·ha^{-1} (13.07.11)	–	Basta 150 SL – 2.5 L·ha^{-1} (15.07.11)

Table 2. Weather course during winter oilseed rape growth in south Poland localities

Locality	Months												$\Sigma - \bar{x}$ August–July	$\Sigma - \bar{x}$ April–July
	August	September	October	November	December	January	February	March	April	May	June	July		
Temperature, ºC														
Głubczyce	18.5	11.6	5.6	6.1	-4.7	-0.1	-2	4.4	11.1	14.3	18.7	17.8	8.4	15.5
Pawłowice	18.6	12.2	5.8	6.3	-5.1	-0.7	-2.5	3.6	10.4	13.6	18.3	17.6	8.2	15
Prusy	18.7	12.2	5.5	5.9	-5.3	-0.9	-3	3.8	10.2	13.7	17.8	17.6	8	14.8
Rainfall, mm														
Głubczyce	35.9	32	6.6	19.9	8.1	27.6	10.6	34.0	23.6	43.1	33.5	159	434	259
Pawłowice	96.4	97.9	3.3	72.7	43.8	25.1	11.8	25.6	21.4	57.4	42.8	111	609	233
Prusy	128	132	9.8	47.8	35	26.8	6.9	17.9	77.9	60.7	44.4	194	781	377

Table 3. Changes in green area index ($m^2 \cdot m^{-2}$) (GAI), Normalized Difference Vegetation Index (NDVI) and relative chlorophyll content (SPAD) values of WOR canopy and plants during growth

Treatment	Calendar dates of measurement			
	11.04	28.04	20.05	15.06
		GAI		
Głubczyce	2.78	5.30	7.65	2.80
Pawłowice	0.83	3.18	4.05	2.43
Prusy	1.00	2.13	4.16	2.84
$LSD_{0.05}$	0.651	0.734	0.515	ns
Adam	1.40	3.25	5.25	2.78
Poznaniak	1.67	3.82	5.33	2.60
$LSD_{0.05}$	ns	ns	ns	ns
		NDVI		
Głubczyce	0.664	0.673	0.216	0.588
Pawłowice	0.523	0.676	0.437	0.530
Prusy	0.553	0.671	0.307	0.545
$LSD_{0.05}$	0.1114	ns	0.0454	0.0260
Adam	0.552	0.671	0.308	0.553
Poznaniak	0.575	0.676	0.326	0.552
$LSD_{0.05}$	ns	ns	ns	ns
		SPAD		
Głubczyce	49.3	55.8	50.4	48.3
Pawłowice	50.9	52.3	53.6	48.8
Prusy	50.8	61.6	55.3	45.3
$LSD_{0.05}$	n.s.	6.05	n.s.	n.s.
Adam	49.8	60.5	53.6	47.5
Poznaniak	51.4	60.1	55.4	46.4
$LSD_{0.05}$	ns	ns	ns	ns

ns – non-significant differences

NDVI index measured after 10 April ranged between 0.52-0.66 and showed similar trends as GAI indicator discussed above (Table 3). It was much higher in Głubczyce than in other places, but at the end of budding and at the beginning of flowering its diversity was significantly lower (0.67-0.68). A notable reduction in the value of this index during canopy flowering is commonly known, whereas the observed values of this index may signify a higher intensity of WOR flowering in Głubczyce (low value of GAI). In mid-June (phase of green siliques) the value of NDVI index increased, as compared to the flowering season, and the highest value was observed in the last decade of April in the canopy in Głubczyce. With the exception of the last period, cv. Poznaniak was characterized by slightly larger values of NDVI index (Table 3). Significant differences in leaf greenness index/relative chlorophyll content (SPAD) were observed at late stages of budding/beginning of flowering, which resulted from an increase in nitrogen content in leaves after the second dose of nitrogen fertilization. The greatest value of SPAD indicator (61.6) was registered in Prusy, which seems to be appropriate because of the relatively small size of the canopy area and similar doses of nitrogen applied in all localities. On the next measurement dates, SPAD index systematically declined, due to the dilution of nitrogen in the growing mass of plants reaching the lowest value in Prusy in mid-June (45.3) (Table 3).

Data presented in Table 4 show that the density of WOR cultivars in the compared localities was proper, since it fluctuated around 40 plants per 1 m^2. Small plants were the most frequent in WOR, whereas the large ones were the least frequent, however the obtained differences were insignificant. Both WOR cultivars were similar in height, however this feature varied significantly between localities, because significantly higher plants formed under conditions of Głubczyce (Table 4). The compared cultivars developed similar numbers of branches. WOR plants in Pawłowice developed slightly more branches. Groups of winter rape plants differed significantly in terms of the branch number. In Głubczyce tall plants had fewer branches and lower mass, which was probably caused by an increased competition of individuals for space and light in the canopy because of very high canopy GAI, as shown in detail in Table 3.

Table 4. Comparison of plant density (PD), height and productivity of single WOR plant depending on cultivar, locality and identified plant groups, including their percentage share in seed yield per 1 m^2 area

Factor and interaction	Treatment	Plant and canopy features						Share (%) of plant groups in the yield per 1 m^2
		PD* $pcs \cdot m^{-2}$	H cm	NOB pcs	CD	PM g DM	SY g	
Cultivars	Poznaniak	38.9	142.7	6.2	88.03	40.5	18.3	–
	Adam	41.9	142.3	6.3	93.24	45.2	20.3	
	$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	
Localities	Głubczyce	40.6	155.2	5.7	82.37	34.4	16.3	
	Pawłowice	41.6	136.8	6.8	96.42	49.2	23.1	
	Prusy	39.0	135.5	6.3	93.94	45.0	18.4	
	$LSD_{0.05}$	ns	11.98	ns	6.58	ns	ns	
Plant groups	small	15.2	139.3	3.5	–	15.7	6.49	14.5
	medium	14.2	141.7	6.2	–	36.2	16.70	33.0
	large	11.0	146.5	9.2	–	76.0	34.68	52.5
	$LSD_{0.05}$	ns	ns	1.24	–	6.64	10.86	12.81
Interaction:								
localities × cultivars		*	*	ns	ns	*	*	–
localities × plant groups		ns	ns	ns	–	*	*	ns
cultivars × plant groups		ns	ns	ns	–	*	*	ns

PD – Plant density, H – Height, NOB – Number of Branches, CD – Canopy Deflection, PM – Plant Mass, SY – Seed Yield
* interaction is significant at $P \leq 0.05$
ns – non-significant differences

Large WOR plants prevailingly contributed to the yield, since they determined it in about 52.5% (Table 4), which was especially for Pawłowice (Fig. 1B). The opposite situation was visible for a group of WOR plants, defined as small. They had a significant share in the canopy density, yet they played a minor role in its yielding. Although, on average, both cultivars had a similar seed yield (Table 4, Fig. 1C), interaction has revealed, that cv. Adam yielded significantly higher in Głubczyce (Fig. 1A).

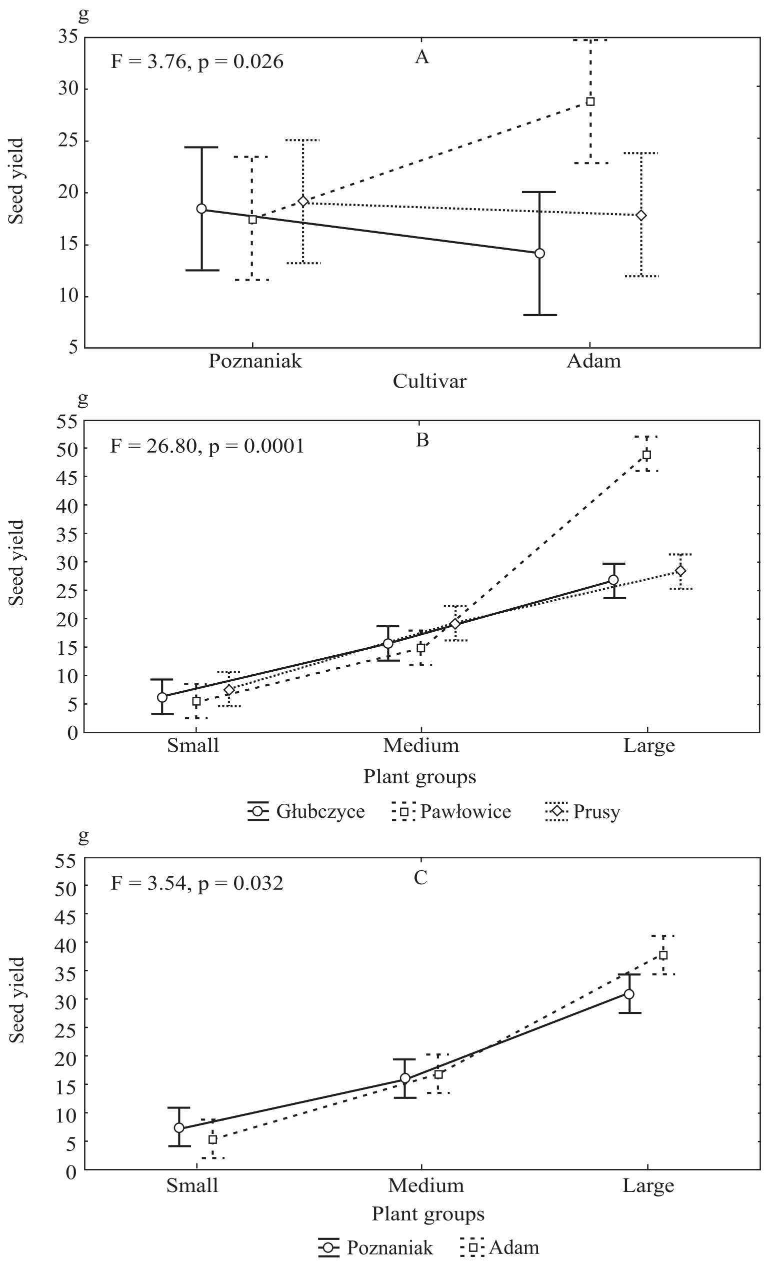

Fig. 1. Interaction between the factors studied

A single silique weight of compared WOR cultivars was not significantly different (Table 5). Agro-climatic factors in the tested localities were also insignificant, although in Pawłowice and Prusy, with climate and soil conditions less favorable for oilseed rape, the weight of single silique as well as mass of rape seeds were slightly higher. Direct a comparison of the mass of siliques showed that within the compared groups of plants, this feature showed significant differences, arising from the developmental and productive status of the individual plant in the canopy (Table 5). The seed mass of WOR cultivars was very high, especially in Pawłowice, which improved the seed yield. Within the WOR groups of plants – small, medium and large, the number of siliques per individual plant was as a ratio of 1:2:4, respectively. Large plants developed larger siliques of larger mass. Significantly varied traits, related to the production of siliques per a single WOR plant, show a different contribution of an individual plant to the canopy yielding (Table 5).

Table 5. Characteristic of WOR siliques depending on cultivar, locality and identified groups of plants

Factor and interaction	Treatment	Siliques traits				
		SSM, mg	SM, mg	SMS, mg	NSP, pcs	MSP, g
Cultivar	Poznaniak	180.1	6.56	110.9	169.7	30.2
	Adam	168.9	6.37	103.4	177.9	32.7
	$LSD_{0.05}$	ns	ns	ns	ns	ns
Locality	Głubczyce	158.1	5.88	100.8	163.3	26.1
	Pawłowice	179.4	7.23	107.8	191.2	37.2
	Prusy	185.9	6.27	112.8	166.8	31.1
	$LSD_{0.05}$	ns	ns	ns	ns	ns
Plant groups	small	148.6	6.68	87.4	73.6	11.0
	medium	174.6	6.27	110.3	156.8	26.4
	large	200.3	6.44	123.8	291	56.9
	$LSD_{0.05}$	26.43	ns	18.40	55.01	16.03
Interaction:						
localities × cultivars		*	ns	ns	ns	ns
localities × plant groups		ns	ns	ns	*	ns
cultivars × plant groups		ns	ns	ns	ns	ns

SSM – Single Silique Mass, SM – Seed Mass, SMS – Seed Mass per Silique, NSP – Number of Siliques per Plant, MSP – Mass of Siliques per Plant
ns – non-significant differences

DISCUSSION

The paper demonstrated that the productive potential of new WOR hybrid cultivars: Adam and Poznaniak was approximate, whereas analyzed morphological features and productivity of individual plants, regarded on the cultivar level, generally proved to be non-significant. The effect of habitat conditions of the localities were neither strong nor significant creators of variability in the range of compared features and measures. On the other hand, a considerable significance of compared morphological and productive features was observed for single winter oilseed rape plants. It was demonstrated for the first time for winter oilseed rape that individuals of markedly diversified productivity occur in the canopy, following the seed yield structure components, which may be regarded as evident intervarietal variability, evidencing a flexible adaptation of this species to conditions of growth in a canopy. It should be emphasized that oilseed rape plant density per area unit before harvest, oscillating about 40 pieces per 1 m^2, may be regarded as optimal for hybrid varieties [Shuije *et al*. 2012]. In these conditions, the number of branches formed by plants called small, medium and large proved a specific indicator of individual plant productive potential. In the opinion of many authors [Sieling and Christen 1997, Liersch *et al*. 2004, Rathke *et al*. 2006, Jankowski and Budzyński 2007, Wielebski 2009], quantitative features of new rapeseed cultivars affecting potentially high seed and oil yield per area unit are strongly modified by environmental conditions of their cultivation site, changeable in time (growth years) and space of production (soil, forecrop, fertilization, protection). Jankowski and Budzyński [2007] reported that a good yield of winter oilseed rape was obtained in the years favouring good wintering of plants, particularly those from early sowing. Previous experiments with winter oilseed rape demonstrated the occurrence of plants considerably different as to the number of formed lateral branches, but also as to the effect of big and very big siliques on seed yield per single plant [Zając *et al*. 2011]. Plant groups singled out from the phytocenoses of oilseed rape cultivars formed siliques of significantly diversified weight but a single seed weight was analogous, which proves that siliques originating from large plants were setting more seeds, whereas this strong tendency was observed for medium plants. Sieling and Christen [1997] assessed components of single winter oilseed rape plant yield based on seed yield from the main shoot, from the group of lower lateral shoots marked 1-3 and from the other lateral shoots marked 4 and above, with no precise numbers. It has been known for some time that winter oilseed rape, as the leading form of oil plants, reveals a diversified productivity, determined by biological properties of the cultivars, but also considerably corrected by habitat, soil and agro-technical conditions of the cultivation site, as evidenced by the vegetation indices. Objective presentation of different productive potential of separated rape plant groups was justified because they significantly determined the values of rape structure components, morphological features and harvest index. Presented data fill in a gap concerning productivity of a single winter oilseed rape plant, which was strongly connected with the degree of branching. A methodological imperative assumed in this work justifies research on rape population focused on the role of an individual and not only the analysis of population based on averaged data, as has been the standard so far. An important indicator of WOR canopy productivity is green area index (GAI). Behrens and Diepenbrock [2006] reported canopy green area on the level of 5 $m^2 \cdot m^{-2}$ in 2003 and 6 $m^2 \cdot m^{-2}$ in 2004 for winter oilseed rape fertilized with nitrogen dosed 210 $kg \cdot ha^{-1}$. On the other hand, Justes *et al.* [2000] estimated rape green area as 5.5 $m^2 \cdot m^{-2}$ at nitrogen fertilization of 270 $kg \cdot ha^{-1}$. Muller *et al.* [2008] estimated similar values of GAI for winter oilseed rape canopy, about 5 $m^2 \cdot m^{-2}$ at joint application of 200 kg $N \cdot ha^{-1}$. It should be stressed that the data were acquired in the area of central or northern Germany, where climatic conditions for winter rapeseed oil cultivation are better than in Poland. Therefore, the obtained results of authors' own investigations referring to GAI size in the localities of southern Poland should be regarded as proper and even on a record level, which means that rape canopy in this locality was exceptionally well developed and absorbed most of available PAR.

CONCLUSIONS

Under conditions of optimal hybrid plant cultivar density, during ontogenesis, three groups of plants could be separated in the winter oilseed rape canopy. They had visibly diversified morphological features and different productivity. Although large and strongly branched WOR plants determined the final density only in 27%, they had the largest share in the seed yield per area unit, because they determined it in 52.5%. The opposite was noted for the rape plant group described as small, which had a high share – 37.6% in canopy density, but played a minor role in the seed yield, reaching 14.5%. Soil and agro-climatic conditions of the localities diversified the productive potential of WOR canopy. In south-western Poland (Głubczyce) plants developed dynamically, resulting in a very high values of green area index. The result of a considerable development dynamics of plants and the canopy of winter oilseed rape in this locality was a bigger height of plants, however accompanied by a lower number of branches and siliques and a lower diameter of the main shoot and lateral branches.

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ROZWÓJ I PLONOWANIE ZRÓŻNICOWANEGO MORFOLOGICZNIE ŁANU RZEPAKU OZIMEGO
I. PRODUKCYJNOŚĆ I CECHY MORFOLOGICZNE ROŚLIN

Streszczenie. Celem badań, przeprowadzonych w trzech miejscowościach Polski południowej: Głubczycach, Pawłowicach i Prusach, była ocena produkcyjności dwóch odmian mieszańcowych rzepaku ozimego: Poznaniak i Adam. Zasięg porównań poszerzono o szczegółową analizę cech biometrycznych roślin i właściwości spektralnych (GAI, LAI i SPAD) łanu rzepaku ozimego, determinujących produkcyjność. W warunkach optymalnej obsady roślin mieszańcowych odmian: Adam i Poznaniak w łanie rzepaku ozimego wydzieliły się trzy grupy roślin o zróżnicowanych cechach morfologicznych i produkcyjności. Silnie rozgałęzione rośliny rzepaku ozimego, o dużej biomasie, chociaż decydowały tylko w 27,2% o końcowym zagęszczeniu, to miały największy wkład w plon nasion z jednostki powierzchni, ponieważ partycypowały w niego w 52,5%. Przeciwstawna sytuacja znamionowała grupę roślin rzepaku, określaną jako małe, które chociaż miały znaczny udział – 37,6% w zagęszczeniu łanu, to jednak w plonie nasion odgrywały niewielką rolę. W rejonie Głubczyc rośliny rzepaku dynamicznie rozwijały się, skutkiem czego były bardzo wysokie wartości zielonej powierzchni asymilacyjnej. Duża dynamika rozwojowa roślin i łanu odmian rzepaku ozimego w tej miejscowości wpływała na zwiększoną wysokość roślin, której towarzyszyła jednak mniejsza liczba rozgałęzień i łuszczyn oraz zmniejszona średnica pędów – głównego i bocznych.

Słowa kluczowe: *Brassica napus*, GAI, łuszczyny, NDVI, odmiana mieszańcowa, SPAD

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