Journal of Botanical Research
https://ojs.bilpublishing.com/index.php/jbr

ARTICLE

Effects of Growth Type, Sowing Date, and Sowing Rate on the Canopy Architecture, Protein Yields, and Oil Yields of Winter Oilseed Rape (*Brassica napus* L.)

Karolina Ratajczak* **Hanna Sulewska** **Grażyna Szymańska**

Department of Agronomy, Poznan University of Life Sciences, Poland

ARTICLE INFO

Article history
Received: 31 October 2018
Accepted: 4 January 2019
Published Online: 30 April 2019

Keywords:
Cultivars
Semi-dwarf hybrid
Open-pollinated
Sowing time
Sowing density

ABSTRACT

A split-split-plot design was used to evaluate the effects of sowing dates and sowing rates on three winter rape cultivars, including 'PR45D03', a semi-dwarf hybrid, 'PR46W31', a traditional hybrid, and 'Californium', an open-pollinated cultivar. August 25 was the optimal sowing date for maximizing protein and oil yields across all three cultivars. Of the cultivars, the traditional hybrid, 'PR46W31', produced the highest protein and oil yields on that date. The yields of the semi-dwarf hybrid, 'PR45D03', were greater than those of the open-pollinated cultivar, 'Californium', when these were sown later than the optimal date. Protein and oil yields did not differ significantly among different seeding densities.

1. Introduction

Sowing date and sowing density combined account for 80% of the variation in the yielding potential in winter rape (*Brassica napus* L.) [6, 19]. Advances in winter rape breeding and genetic engineering techniques have made cultivar development the least expensive element of improving yields [1,18]. According to Bartkowiak-Broda [4], the cultivar was the most important factor in determining the volume and quality of seed yield produced by oilseed rape. Intensive breeding programs have increased the number of winter oilseed rape cultivars, including hybrids, that are being registered in Poland. The biology and yielding of hybrid cultivars with a semi-dwarf habit have yet to be thoroughly investigated. Many studies have been conducted to investigate the effect of sowing date on agronomic traits, but few of these have been on semi-dwarf hybrids. According to Al-Ahmad [1], the effect of sowing date needs to be tested in these cultivars, as late sowing may be better tolerated by tall cultivars. Cultivation recommendations for sowing date and sowing rate for new oilseed rape cultivars need to be verified. The aim of this study was to determine the effect of sowing date and sowing rate on the dynamics of winter rape growth and development, as well as on yield-forming aspects of the plant habit in various cultivars of winter rape, including an open-pollinated cultivar, a traditional hybrid, and semi-dwarf hybrid.

2. Material and Methods

Field trials with winter oilseed rape (*Brassica napus* L.)

**Corresponding Author:*
Karolina Ratajczak,
Department of Agronomy, Poznan University of Life Sciences, Poland;
Email: karolina.ratajczak@up.poznan.pl

 DOI: https://doi.org/10.30564/jrb.v1i1.245

were conducted during two successive growing seasons, 2008-2009 and 2009-2010, at the Złotniki Experimental Station (N 52° 29.193'; E 16° 20.569') in Poland. The trials were conducted using a split-split-plot design with four field replications and three experimental treatment factors, including sowing date, winter rape cultivar, and sowing rate. Sowing dates were August 14, August 25, September 4, September 15; winter rape cultivars were 'PR45D03' (semi-dwarf hybrid), 'PR46W31' (hybrid F1), and 'Californium' (open-pollinated); sowing rates were 30 seeds·m^{-2}, 40 seeds·m^{-2}, 50 seeds·m^{-2}, and 60 seeds·m^{-2}.

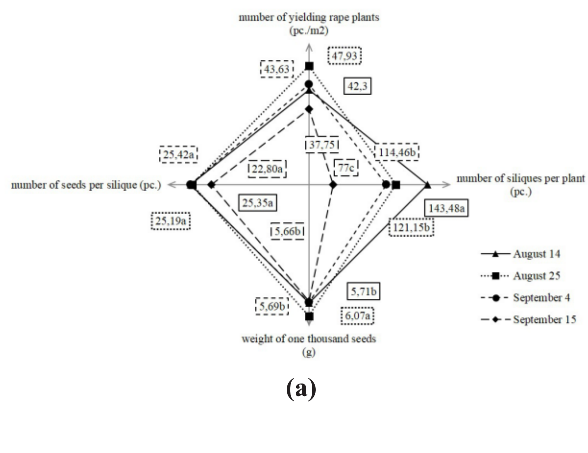
The experimental plots were 14 m^2 and were located on sandy luvisol soils deposited over light clay [12] . A four-row, single-seed Monosem drill was used to sow seeds in 4 rows with an inter-row spacing of 0.35 m. Nitrogen fertilizer was applied in August, prior to sowing, at a rate of 25 kg·ha^{-1}. Nitrogen fertilizer was again applied at a total rate of 112 kg·ha^{-1} in two doses in March and April of 2009. Phosphorus and potassium fertilizers were applied at the rate of 21.8 kg·ha^{-1} and 103.75 kg·ha^{-1}, respectively, and determination of these rates was based on analyses of available forms of both nutrients in the soil's A-horizon. The plots were sprayed with the herbicide Butisan Star 416 SC at a rate of 3 l·ha^{-1} after oilseed rape sowing; the herbicide Fusilade Forte 150 EC was applied at a rate of 1 l·ha^{-1} after plant emergence; the herbicide Galera 334 SL was applied at a rate of 0.35 l·ha^{-1} in the spring of 2009. During each growing season plants were sprayed with insecticides three times: Fastac 100 EC was applied at a rate of 0.12 l·ha^{-1} in April 2009, Karate Zeon 50 CS was applied at a rate of 0.12 l·ha^{-1} in April 2009 and in May 2010, and Nurelle D 550 EC was applied at a rate of 0.6l·ha^{-1} in April 2009 and 2010. Fungicides were applied twice during each growing season; Horizon 250 EW was applied at a rate of 0.7 l·ha^{-1} after plant emergence, and Pictor 400 SC was applied at a rate of 0.5 l·ha^{-1} at the onset of flowering. To ensure uniformity of plant maturation and to prevent shattering in early July, Spodnam DC and Roundup Energy 450 SL desiccant were applied at a rates of 1 l·ha^{-1} and 3 l·ha^{-1}, respectively.

At the stage of seed ripening (BBCH 80-82), a total of 50 siliques per plant, including 25 each from the main and lateral shoots, were collected. The mean number of set seeds in siliques and the number of siliques harvested from an area unit were calculated. After harvest the 1000 seed weight and the weight of 1 hectolitre of seeds were determined using an electronic meter of seed density per storage volume (DRAMINSKI GMDM Electronics in Agriculture, Poland). Protein and oil were determined in the Plant Breeding Laboratory in Strzelce, department Małyszyn, using near-infrared spectroscopy in a NIRSystems 6500 spectrometer (FOSS NIRSystems Inc., Silver Spring, MD).

Yield parameters and biometric measurements were analyzed using analysis of variance (ANOVA) in the Statistica (ver. 10) software package. A principal components analysis (PCA) was used to identify regularities the multi-dimensional analysis.

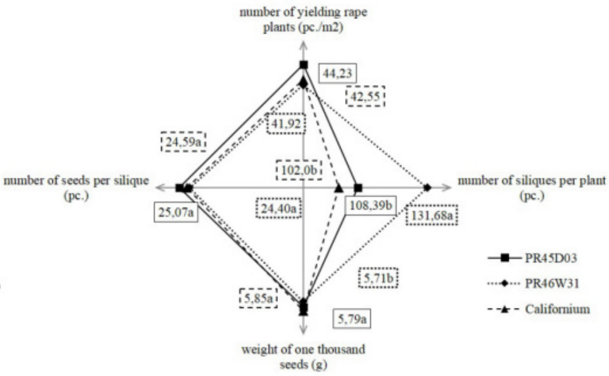
3. Results

The highest average numbers of plants per unit area were obtained when seeds were sown on August 25. Sowing 10 days earlier decreased the number of yielding plants by 5.6 plants per 1 m^2, while a sowing 10 and 20 days later decreased the number of yielding plants by 4.3 and 10.2 plants per 1 m^2 (Figure 1a). The semi-dwarf hybrid 'PR45D03' produced the greatest number of plants per unit area (Figure 1b). The highest number of yielding plants were obtained at the greatest sowing density, 60 seeds·m^{-2} (Figure 1c). Plants sown at the earlier date (14.08.) set the greatest number of siliques per plant. Later sowing dates reduced this number by 22.3, 29.0 and 66.5 for the dates of August 25, September 4 and September 15, respectively (Figure 3a). The hybrid cultivar with the traditional growth habit formed 170.3 more seeds per plant than the semi-dwarf morphotype. The number of siliques formed per plant decreased with increasing sowing density. The greatest number of siliques was set by plants sown at a density of 30 plants·m^{-2} (Figure 1c). Plants sown at the latest date, September 15, formed fewer seeds per silique, although these differences were not confirmed statistically (Figure 1a). Among the tested cultivars, the semi-dwarf hybrid 'PR45D03' formed the highest number of seeds per silique. Differences in the numbers of seeds per silique were small relative to the cultivars 'PR46W31' and 'Californium', amounting to 0,67 and 0,48 seeds (Figure 1b). The greatest thousand seed weight was produced by the open-pollinated cultivar 'Californium'. Increased seeding density reduced 1000 seed weight by an average of 5,81 (30 pc.·m^{-2}) – 5,75 (50 pc.·m^{-2}).

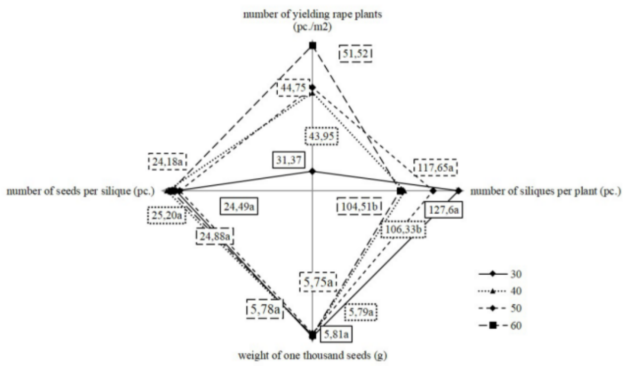


(a)

DOI: https://doi.org/10.30564/jrb.v1i1.245



(b)



(c)

Figure 1. Yield components in winter oilseed rape depending on: (a) sowing date, (b) cultivar, and (c) sowing density.

Note: Means within a columns followed by the same letter are not significantly different according to Tukey's test ($P \leq 0.05$);

The results of an ANOVA for oil and protein yields are presented in Table 1. The highest yields of total protein (1166.1 kg·ha^{-1}) and oil (2203.2 kg·ha^{-1}) were obtained from plants sown at August 25. Sowing after August 25 significantly decreased the yields of protein and oil in each cultivar. Sowing on September 4 reduced protein and oil yields by 255.3 kg·ha^{-1} and 518.1 kg·ha^{-1}, respectively. Sowing on September 15 further reduced protein and oil yields by 616.9 kg·ha^{-1} and 1,267.1 kg·ha^{-1}, respectively, compared to plants sown on August 25. The traditional hybrid, 'PR46W31, produced significantly higher yields of protein and oil than other varieties. The semi-dwarf hybrid protein and oil yields were not significantly different than those produced by the open-pollinated variety, 'Californium'. Protein and oil yields changed were significantly dependent on sowing date and cultivar. The highest protein and oil yields were obtained for all cultivars when sown on August 25. A large decrease in the protein and oil yields occurred in all cultivars when plants were sown later than the optimal sowing date. Delaying sowing from August 25 to September 15 caused the largest reductions in protein and oil yields in the semi dwarf hybrid, 'PR45D03', and plants of this cultivar produced 525.7 kg·ha^{-1} (49.2%) less protein and 1155.3 kg·ha^{-1} (55.1%) less oil when sown on September 15 compared those sown on August 25. Protein yield was significantly increased by increasing the seeding density from 30 to 40 pc.·m^{-2}, and an increase to a sowing density to 60 pc.·m^{-2} caused a non-significant increase in protein yield (Table 1). The oil yield produced at a seeding density of 30 pc.·m^{-2} (1,627.6 kg·ha^{-1}) was significantly lower than the yield produced at higher seeding densities. Higher seeding densities produced oil yields ranging from 1712.7 (40 pc.·m^{-2}) to 1737.3 kg·ha^{-1} (50 pc.·m^{-2}).

Table 1. Protein and oil yields (kg•ha^{-1}) depending on sowing date, cultivar and sowing rate

Treatment		**Protein yield**			
		'PR45D03'	**'PR46W31'**	**'Californium'**	**Average**
	August 14 14.08.	920,77 ^{cd}	1115,71 ^{abc}	1013,56 ^{bcd}	1016.7 B
	August 25 25.08.	1067,98 ^{abcd}	1280,60 ^{a}	1149,67 ^{ab}	1166.1 A
	September 4 4.09.	900,68 ^{cd}	971,91 ^{bcd}	859,70 ^{e}	910.8 C
	September 15 15.09.	542,25 ^{f}	588,70 ^{f}	516,52 ^{f}	549.2 D
	Average	857.9 B	989.2 A	884.9 B	
Sowing date		**Oil yield**			
		'PR45D03'	**'PR46W31'**	**'Californium'**	**Average**
	August 14 14.08.	1834,23 ^{bcde}	2193,32 ^{ab}	1917,88 ^{bcde}	1981.8 B
	August 25 25.08.	2096,04 ^{abcd}	2355,26 ^{a}	2158,32 ^{abc}	2203.2 A
	September 4 4.09.	1700,70 ^{de}	1772,88 ^{cde}	1581,82 ^{e}	1685.1 C
	September 15 15.09.	940,76 ^{f}	1021,19 ^{f}	846,27 ^{f}	936.1 D
	Average	1642.9 B	1835.7 A	1626.1 B	
		Protein yield		**Oil yield**	
Sowing rate (pc.·m^{-2})	30 pc·m^{-2}	869.0 ^{b}		1627.6 ^{b}	
	40 pc·m^{-2}	916.8 ^{a}		1712.7 ^{a}	
	50 pc·m^{-2}	928.2 ^{a}		1737.3 ^{a}	
	60 pc·m^{-2}	928.7 ^{a}		1728.6 ^{a}	

Note: Means within a columns followed by the same letter are not significantly different according to Tukey's test ($P \leq 0.05$)

The coefficients of variation calculated for the protein and oil yields of all tested varieties showed that both of the earlier sowing dates (August 14 and 25) guaranteed stable yields compared to later sowing dates (September 04 and 15) (Table 2). The increase in yield variability (CV%) on delayed sowing dates was mainly due to the significant decrease of minimum yields.

Table 2. Statistical characteristics of protein and oil yields

Sowing date	Variety	CV (%)	SD	Values	
				Min	Max
Protein yield					
14.08.	PR45D03	8.3	76.1	816.3	1006.8
	PR46W31	3.3	37.3	1043.3	1157.5
	Californium	10.8	109.4	877.4	1145.5
25.08.	PR45D03	8.7	93.1	926.7	1166.4
	PR46W31	3.1	39.5	1230.9	1346.8
	Californium	6.8	78.8	1004.2	1235.6
04.09.	PR45D03	30.3	272.6	491.1	1202.3
	PR46W31	27.5	267.4	600.6	1244.7
	Californium	26.5	228.0	576.1	1104.0
15.09.	PR45D03	70.6	365.5	126.7	928.5
	PR46W31	78.7	497.9	99.7	1157.5
	Californium	82.0	425.8	83.4	966.6
Oil yield					
14.08.	PR45D03	8.4	155.0	1645.1	2014.2
	PR46W31	3.3	71.9	2075.7	2283.5
	Californium	8.8	168.7	1666.9	2081.7
25.08.	PR45D03	10.9	230.0	1776.6	2325.6
	PR46W31	6.7	157.1	2197.8	2556.8
	Californium	3.8	82.7	2024.5	2247.2
04.09.	PR45D03	30.0	511.0	946.1	2269.9
	PR46W31	26.0	461.1	1137.4	2222.0
	Californium	28.7	454.1	1048.1	2074.3
15.09.	PR45D03	72.0	677.7	215.5	1809.2
	PR46W31	76.2	778.7	181.2	1871.6
	Californium	81.0	685.5	140.9	1614.5

The relationships between seed yield volume and its components was determined for individual cultivars in terms of the selected sowing dates (Figure 2). Regardless of the selected sowing date, a strong relationship was observed between yields and the number of siliques per 1 m^2 in both the semi-dwarf and traditional hybrid. However, yield was correlated more strongly with the number of seeds per silique in plants sown on the last sowing date, September 15. Moreover, a significant negative correlation was found between yield and 1000 seed weight in traditional hybrid sown on August 14 and 25. It is only an apparent contradiction, however, since the basic yield components affect not only seed yield, but also one another. This is frequently manifested in the fact that an increase in the value of one of the components, e.g. silique number, is correlated with a reduction of another, such as the number of seeds per silique or the 1000 seed weight. Similarly, an increase in the number of seeds per fruit is frequently correlated with reduced weight per seed.

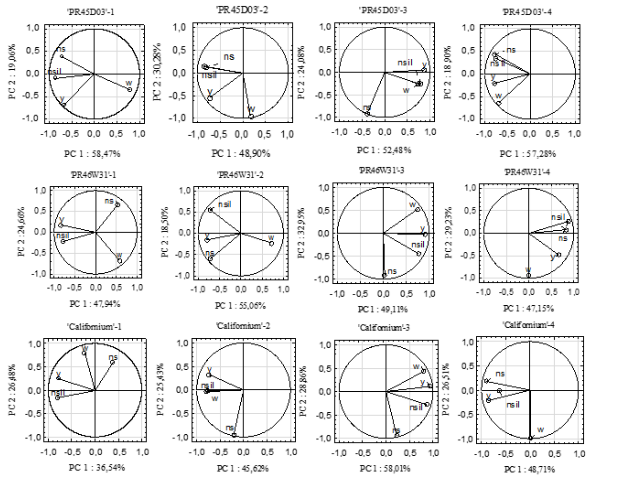


Figure 2. Principal component analysis of individual sowing dates in analyzed cultivar types

Note: (y – yield; nsil - number of siliques per plant (pc.·m^{-2}); ns - number of seeds per silique (pc.); w - weight of one thousand seeds (g); 1-August 14, 2-August 25, 3-September 4, 4- September 15)

Yields in the open-pollinated cultivar were also positively correlated with the number of siliques per m^2 were solely correlated with the number of seeds per silique on the last sowing date. Yields in that cultivar was also significantly positively correlated with the 1000 seed weight on August 25 and September 4. The dependence established using a regression analysis between seed yield and sowing date was parabolic (Figure 3). Our analysis predicts that sowing cv. 'PR45D03' 9.3 days after the early sowing date, August 14, would maximize its yields and produce 48.3 dt·ha^{-1}. Sowing the traditional hybrid, 'PR46W31', 6.9 days after August 14 (August 22) would maximize its yield and produce 54.8 dt·ha^{-1}. Sowing the open-pollinated cv, 'Californium', 7.5 days after August 14 would maximize its yields and produce 49.8 dt·ha^{-1}.

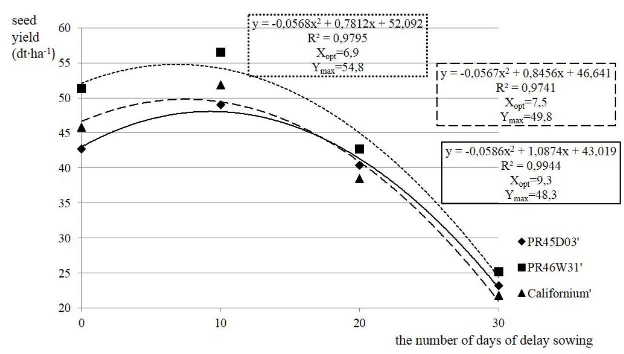


Figure 3. Seed yield (dt·ha^{-1}) of analyzed cultivars depending on sowing date.

  DOI: https://doi.org/10.30564/jrb.v1i1.245

4. Discussion

Recent publications [7, 13] have emphasized the importance of choosing optimal sowing dates to maximize winter rape seed yields while limiting the risk of culture failure [3]. Many authors have stressed that late sowing dates reduce the number of siliques per plant [2], reduce plant height, reduce the number of seeds per silique [14], reduce the number of tillers per plant [15], and reduce seed yield and oil quality [8]. Sowing 10 days earlier relative to the optimal date for the specific climatic and soil conditions of the experiments increased the number of siliques per plant but did not affect other yield components. It should be stressed that sowing rape at the optimal date increased the number of yielding plants and the thousand seed weight, which in turn determined yielding.

We found that traditional hybrids produced significantly more siliques per plant and had greater seed fill per silique than the open-pollinated cultivar, 'Californium', but the 1000 seed weight in the hybrid cultivars was lower than in open-pollinated cultivar. These findings are in agreement with previous studies by Jankowski and Budzyński [9] and Kotecki et al. [10] . In contrast to the assumption of Seeger and Filser [17], the cultivar Artus, a hybrid with the traditional habit, formed significantly more seeds, 749.7 seeds per plant, than the cultivar 'PR45D03'.

Despite considerable breeding progress, both the new and old cultivars exhibit similar responses to sowing dates. All cultivated genotypes, i.e. open-pollinated, complex hybrid, and restoration, exhibited the same trend and scope of response to a delay in sowing date, despite the morphologically differences observed among plants in the autumn[6]. Jankowski and Budzyński[9] also found no differences in the responses among open-pollinated, complex hybrid, and restoration cultivars to delayed sowing.

Plant densities of 60–70 plants·m^{-2} are generally considered to be optimal for cultivating rapeseed hybrids in Europe[16], and Wielebski and Wójtowicz [20] recommended an optimal sowing rate, irrespective of the cultivar, of 80 seeds·m^{-2}, and a reduced sowing rate contributed to an increased number of siliques per plant and a higher 1000 seed weight. Our study confirmed that oil and protein yield did not differ significantly among a seeding rates of 40, 50, and 60 seeds·m^{-2}, and this finding is consistent with Kwiatkowski et al. [11], who claimed reducing the seed sowing rate to 40 seeds per 1 m^2 did not increase weed infestation or reduce yield. Dehkordi and Soleymani [5] confirmed that maximum oil yield occurred at a seeding rate of 40 plants·m^{-2} and found that increasing the seeding density to 80 and 120 plants·m^{-2} caused significant reductions in oil yield, equal to 28.2 and 16.5 kg·ha^{-1}, respectively.

5. Conclusion

(1) The optimal sowing date for all the tested oilseed rape cultivars was August 25. The hybrid cultivar 'PR46W31' sown on that date exhibited the highest protein and oil yields, and in these respects outproduced cv. 'PR45D03' by 221.6 and 259.2 kg·ha^{-1}, respectively, and outproduced the open-pollinated cv. 'Californium' by 130.9 and 196.9 kg·ha^{-1}, respectively. The regression analysis indicates that the cultivars 'PR46W31', 'Californium', and 'PR45D03' can be expected to produce maximized yields when sown on August 22, August 23, and August 24, respectively.

(2) The semi-dwarf hybrid showed a greater tolerance to delayed sowing compared to the open-pollinated cultivar, and this was confirmed by the dependencies of the main yield components. This cultivar was the only tested cultivar in which yield was strongly correlated with the number of siliques per m^2, even for plants sown later than the optimal date.

(3) The yields of protein and oil did not differ significantly among plants seeded at densities of 40, 50, 60 pc·m^{-2}.

Reference

[1] Al-Ahmad H, Dwyer J, Moloney M, et al. Mitigation of establishment of *Brassica napus* transgene in volunteers using a tandem construct containing a selectively unfit gene. Plant Biotechnol J 2006, 4, 1: 7-21. http://10.1111/j.1467-7652.2005.00152.x

[2] Asgari A, Moradie-Dalini A. Evaluation, yield components and vegetative characters of rapeseed cultivars in different planting date. Seed and Plant J 2008, 23: 419-430.

[3] Baghdadi H, Taspinar S, Yousefi M, et al. Influence of different sowing dates on grain yield of canola (*Brassica napus* L.) cultivars in Qazvin area. Intl. J Agric: Res & Rev 2012, 2: 1092-1096.

[4]Bartkowiak – Broda I. Kierunki hodowli i nasiennictwo. Technologia Produkcji Rzepaku. Praca zbiorowa pod redakcją Muśnickiego i in. „Wieś Jutra", Warszawa 2005, 52-61 (in Polish)

[5] Dehkordi N K, Soleymani A. Effect of Plant Populations on Content of Nitrogen, Phosphorous, Potassium and Oil Yield of Different Rapeseed Cultivars. Journal of Research in Agricultural Science 2012,8, 2: 153-156.

[6] Budzyński W, Zając T. Oil crops – cultivation and application. PWRiL, Poznań 2010 (in Polish)

[7] Fink NS, Conley Christmas E. An evaluation of the effects of planting date and seeding rate on the yield of winter canola grown at three different geographic

areas. The ASA-CSSA-SSSA International Annual Meetings, 2006.

[8] Hocking PJ. Effect of sowing time on nitrate and total nitrogen concentration in field-grown canola (*Brassica napus* L.) and implications for plant analysis. J Plant Nutrition 2001, 24, 1: 43-59.
http://dx.doi.org/10.1081/PLN-100000311

[9] Jankowski J, Budzyński W. Response of different cultivars of winter rape to sowing date and sowing rate. II. Seed yield and its components. Oilseed Crops XXVIII 2007, 2: 195-207. (in Polish)

[10] Kotecki A, Malarz W, Kozak M, Pogorzelec A. The effect of plant distribution in the stand on the development and yielding of hybrid and open-pollinated cultivars of rape. I. Plant morphology and seed yield. Zeszyty Naukowe Uniwersytetu Przyrodniczego we Wrocławiu, Rolnictwo XC 2007, 553: 7-40. (in Polish)

[11] Kwiatkowski C A, Gawęda D, Drabowicz M, et al. Effect of diverse fertilization, row spacing and sowing rate on weed infestation and yield of winter oilseed rape. Acta Scientiarum Polonorum. Agricultura 2012, 11, 4: 53-63.

[12] Marcinek J., Komisarek J., Bednarek R., et al. Systematyka gleb Polski. Roczniki gleboznawcze, 2011, 62, 3. (in Polish)

[13] Martin VL. Planting date effect on winter canola production in Kansas, the ACSSASSSA, International Annual Meeting 2006. www.ksre.ksu.edu/water quality /KSNMHatch.html

[14] Nanda R, Bhargava SC, Tomar DPS et al. Phenological development of Brassica campestris, B. juncea, B. napus, and B. carinata grown in controlled environments and from 14 sowing dates in the field. Field Crops Res 1999, 46, 1-3: 93-103.
http://dx.doi.org/10.1016/0378-4290(95)00090-9

[15] Ozer H. Sowing date and nitrogen rate effects on growth, yield and yield components of two summer rapeseed cultivars. European J Agronomy 2003, 19, 3: 453-463.
http://dx.doi.org/10.1016/S1161-0301(02)00136-3

[16] Rathke G W, Behrens T, Diepenbrock W. Integrated nitrogen management strategies to improve seed yield, oil content and nitrogen efficiency of winter oilseed rape (*Brassica napus* L.): A review. Agr. Ecosyst. Environ 2006,117: 80–108.

[17] Seeger J, Filser J. Can dwarfed oilseed rape (*Brassica napus* L.) measure up to tall cultivars? GM-Crop Cultivation-Ecological Effects on a Landscape Scale. Theorie in der Ökologie 17. Frankfurt, Peter Lang 2013, 53-56.

[18] Snowdon RJ, Friedt W. Molecular markers in Brassica oilseed breeding: current status and future possibilities. Plant Breeding 2004, 123: 1-8.
http://10.1111/j.1439-0523.2003.00968.x

[19] Turhan H, Gül KM, Egesel ÖC et al. Effect of sowing time on grain yield, oil content, and fatty acids in rapeseed (*Brassica napus* subsp. oleifera). Turk J Agric For 2011, 35: 225-234.
http://doi:10.3906/tar-1002-717

[20] Wielebski F, Wójtowicz M. Wpływ gęstości siewu na cechy morfologiczne i elementy struktury plonu odmian populacyjnych i mieszańcowych rzepaku ozimego. Rośliny Oleiste XXII 2001, 349-362 (in Polish).

  DOI: https://doi.org/10.30564/jrb.v1i1.245