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Influence of crop management on formation of yield components of winter oilseed rape

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Abstract: The habitus of oilseed rape and its yield component values can be strongly affected by the structure of its stand. Field experiments took place in Central Bohemia in years 2013–2015 aiming at determining the influence of row-spacing (12.5, 25, 35 and 45 cm) on the yield components. Chosen parameters (the number of plants per unit area, the number of pods per plant, the number of seeds per pod and yield) were evaluated at the monitored stands (30 seeds/m^2 sowing rate, cv. DK Exquisite). The study confirmed the statistical significance of the influence of row-spacing on some winter oilseed rape yield components. Widening of the row-spacing has led to a decrease in the number of pods per plant and the number of plants per unit area and an increase in the number of seeds per pod parameter. 1000 seed weight was not affected. This study did not confirm a positive effect of sowing oilseed rape in rows wider than 12.5 cm. Therefore, such an agronomical decision cannot be recommended as a way to achieve higher seed yield.

Keywords: *Brassica napus* L. var. *napus*; rapeseed; oilseed crop; plant density; intraspecific competition; stand structure

Oilseed rape (*Brassica napus* L. var. *napus*, rapeseed or OSR) is currently the most frequently grown oilseed crop in both Europe and the Czech Republic (Eurostat 2018, Sálusová 2018). On global scale, oilseed rape is the second most frequently grown oil crop after soy (FAOSTAT 2018). The current standard planting technology of OSR in the Czech Republic uses rows 12.5 cm wide, with seeding rates at 40 to 60 seeds/m^2 (SPZO 2015). Vosshenrich and Dölger (2011) consider the optimal row-spacing to be 18 cm with a sowing rate of 30 seeds/m^2.

Frequency of rape crops established with wider rows has been spreading in the Czech Republic over the last few years. The rows expand to the width of 35 cm, while using the Horsch Focus technology, or to 45 cm, using a sugar beet seeding drill. The wider rows are also often used in the strip tillage system that commonly uses row-spacing from 35 cm to 75 cm (Hermann et al. 2012, Brant et al. 2016). Baranyk and Fábry (2007) stated that although oilseed rape has good compensation capacity, it can be utilized only in the case of even plant distribution over a given area. Former studies revealed that agronomic practices such as manipulation with row arrangement and plant density widely affect the OSR yield (Boelcke et al. 1991, Leach et al. 1999, Diepenbrock 2000, Bilgili et al. 2003, Johnson and Hanson 2003, Rathke et al. 2005). Row-spacing represents an important agricultural factor and has a large effect on the seed yield and the yield components of individual plants (Diepenbrock 2000).

Increasing the row-spacing of winter oilseed rape influences the development of its root system and its habitus. Brant et al. (2016) proved that increasing the row-spacing of winter oilseed rape from 12.5 cm to 45 cm (40 seeds/m^2) led to the development of roots towards the interline and a restriction of its branching in the axis of the row. Hermann et al. (2012) verified the influence of the sowing date and the sowing rate on the development of OSR with

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rows 37.5 cm wide. In comparison with the sowing rate of 40 and 60 seeds/m^2, a lower sowing rate (20 seeds/m^2) with earlier sowing (20th August) resulted in deeper root development, better rooting of the upper layer of the soil and more roots growing to the sides of the line. Later sowing (16th September) did not show this trend.

Many studies focusing on the influence of row-spacing on oilseed rape yield formation were conducted. Diepenbrock (2000) lists among the primary yield components of oilseed rape the number of plants per square meter, the number of pods per plant, the number of seeds per pod and 1000 seed weight. According to former studies, different row-spacing highly influences all the given yield components except for the 1000 seed weight (Morrison et al. 1996, Habekotté 1997, Diepenbrock 2000, Ozer 2003). However, previous studies are often inconsistent in their results. Results gained by Różyło and Pałys (2014) showed a declining trend in the seed yield and biomass yield (pods and straw weight) when increasing the row-spacing. Morrison et al. (1990), Ozer (2003), Yazdifar and Valiollah (2009), Uzun et al. (2012) or Wang et al. (2015) observed similar results. Waseem et al. (2014) reached a different conclusion, i.e. that the highest seed yield was achieved with the widest rows (60 cm). The studies by Oad et al. (2001) and Masood et al. (2003) came to similar conclusions. Such diversity in results may arise from soil, seed and climate differences (Uzun 2012). On the other hand, the variability in results induces the necessity to be interested in the topic just on regional level. The main reason for that is the locally limited interest of growers. In different regions farmers should profit from different recommendations.

With regard to inconsistent results of former studies and above mentioned necessity of local verification of possible technologies of establishing oilseed rape crop it was decided to elaborate a study in order to create a recommendation for Czech farmers how to achieve higher seed yield. This study aims to assess to what extent different methods of sowing affect the formation of oilseed rape (*Brassica napus* L. var. *napus*) yield components. More specifically, the main focus is on the relation between width of sowing lines and number of seeds per pod and number of pods per plant.

MATERIAL AND METHODS

Experimental sites. Half-operational field experiments were carried out in three consecutive growing seasons (2012/2013, 2013/2014, 2014/2015). Experimental sites were located in Central Bohemia. These locations are situated in an area with sandy-loam soils and the climate in this region is classified as mildly warm and relatively dry. The altitude ranges from 300 to 400 m a.s.l. The average temperature is about 8°C and the average precipitation is 480 mm. Balanced fields were selected to secure similar field conditions for all plots on the basis of regularly conducted soil sampling. As a previous crop spring barley was used in all three years. Table 1 documents the GPS position of the experimental fields, the dates of sowing of oilseed rape in the evaluated years and basic chemical properties of the soil.

Experimental design. Basic tillage and preparation for sowing were identical for all the experimental treatments in all evaluated years. After finishing harvest of the previous crop, minimal tillage was done into depth of 12 cm and subsequently repeated into the depth of 20 cm. A comparison of the treatments tested in this study can be found in Table 2. Four different row widths were used, i.e. 12.5, 25, 35 and 45 cm. The treatment with row-spacing of 12.5 cm represents a control variant, because that is most

Table 1. Position of experimental sites, dates of sowing in three years (2012–2015), pH and concentration of phosphorus (P) and potassium (K) in soil recorded at the dates of sowing (analysed according to Mehlich III)

Number and indication of the experimental site	Position (GPS coordinates)	Date of sowing	pH	P	K
				(mg/kg)	
ES1	50.220800, 13.963558	25/08/2012	6.4	164	482
ES2	50.013149, 13.749051	25/08/2012	6.0	25	139
ES3	50.215852, 14.024361	02/09/2013	6.5	71	409
ES4	50.227493, 13.983735	02/09/2013	5.1	59	374
ES5	50.206762, 13.996448	24/08/2014	6.7	107	370
ES6	50.192732, 13.978257	24/08/2014	7.0	161	419

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Table 2. Description of the compared treatments differing in row widths and used seeding drills. The seeding rate (30 seed/m^2) and cultivar (DK Exquisite) were the same for all treatments in all three seasons (2012–2014)

Treatment	Row width (cm)	Seeding drill	Manufacturer
V1	12.5	Rapid A800	Väderstad, Sweden
V2	25	Rapid A800	Väderstad, Sweden
V3	35	Focus 6TD	Horsch, Germany
V4	45	Meka	Monosem, France

frequently used technology in the Czech Republic. In all treatments the same cultivar (DK Exquisite, Dekalb company) and the same seeding rate (30 seeds per m^2) were used. The size of each plot was 1800 m^2 (width 12 m, length 150 m, minimal area of crop for harvest: 1000 m^2) and it was the same for each treatment and all three growing seasons. Each plot was split into three pseudo-repetitions and all pseudo-repetitions were used for measuring of biometrical characteristics of plants. The stands were subsequently treated with identical methods. Fertilization and pesticides were applied according to the indication and needs of the crop. The machines that distributed fertilizers and even pesticides were always moving at the right angle to the direction of rows so that no treatment got any advantage or disadvantage.

Measurement, sampling and harvest. Samples of plants and pods were collected between BBCH 75 and 79 (BBCH rated by Meier (1997)). In each pseudo-repetition, 20 plant samples were collected – at random and in a diagonal direction. Samples were then sorted by size and every other sample was used for evaluation of the number of branches (primary branches and a terminal) per plant and pods per branch. Thus, 10 plants from each pseudo-repetition were analysed, i.e. in total 30 plants in each treatment. Subsequently, pods were collected from every other plant (5 plants in each pseudo-repetition, 15 in each treatment), stored separately in boxes (one box for each plant) and naturally dried. Once fully dried, pods from each box were sorted by size and 15 of them were randomly selected so that all sizes were represented. The chosen pods were used for counting the number of seeds per pod. Plots were harvested using a standard combine harvester and a sample of 1 kg was taken from each pseudo-repetition. These were used to determine the 1000 seed weight. After the harvest, the number of plants per square meter was evaluated by counting the number of plants five times diagonally on each pseudo-repetition using a template with surface area of 1 m^2.

Values of the calculated yield were determined based on the following algorithm:

$$\mathrm{CY} = \frac{\mathrm{NoPl} \times \mathrm{NoPo} \times \mathrm{NoSe} \times \mathrm{TSW}}{1000}$$

Where: CY – value of the calculated yield (g/m^2); NoPl – average number of plants per area unit (plants/m^2); NoPo – average number of pods per plant (pieces/plant); NoSe – average number of seeds per pod (pieces/plant); TSW – 1000 seeds weight (g).

Statistical analysis. Analyses were performed using a correlation analysis and one-way ANOVA (Scheffe's – honestly significant difference – test, $\alpha = 0.05$) were performed using the Statgraphics® Plus programme, ver. 4.0 (Statgraphics, Warrenton, USA). Correlations in Figures 1 and 2 were determined using the data shown in Tables 4 and 5, which represents average values for every treatment got from years 2013–2015.

RESULTS AND DISCUSSION

The yield components, i.e. the number specifying plant density, the number of branches per plant, the number of pods per branch, the number of seeds per pod, and the 1000-seed weight were evaluated in this experiment. Table 3 shows the average of these parameters for all experimental sites in the years 2013–2015.

Number of plants per unit area. Despite the fact that the same seeding rate was used, different numbers of plants per square meter were observed upon the harvest. The final population was the largest in the 12.5 cm row-spacing, followed by 25, 35 and 45 cm (Table 3). Vann et al. (2016) and Sierts et al. (1987) found similar results where a greater reduction in plant stand occurred in the wider row-spacing when the same targeted plant density was planted across row-spacing. Sierts et al. (1987) attributed these results to intraspecific competition.

Number of pods per plant. The average value of this parameter was 303.63 with 720 samples of plants evaluated altogether. The lowest observed value was 54 and the highest value was 994 pods per plant. Table 4 shows data from every year of the experiment and every experimental site separately. Statistical significance of the influence of row-spacing on the

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Table 3. Average values of evaluated yield components in years 2013–2015

Treatment	Row-spacing (cm)	Plant density (plants/m²)	Number of pods per branch (pieces)	Number of branches per plant (pieces)	Number of pods per plant (pieces)	Number of seeds per pod (pieces)	1000-seeds weight (g)
V1	12.5	28.38^b	42.37^b	7.87^ab	330.52^b	17.58^a	5.41^a
V2	25	26.60^ab	38.13^a	8.27^b	314.09^ab	18.76^b	5.53^a
V3	35	24.66^a	37.42^a	7.80^ab	289.92^a	19.78^c	5.70^a
V4	45	24.16^a	37.71^a	7.38^a	279.95^a	19.89^c	5.85^a

ANOVA (Scheffe's tests); the means listed in the individual columns differ significantly from one another ($P < 0.05$) when they are accompanied by distinct letters

number of pods per plant parameter was confirmed only in one case, but the declining trend is evident in all locations (Figure 1). A significant decrease in the number of pods per plant in wider rows becomes evident when average data for all locations and years are used as shown in Table 3. Data from our study are inconsistent with former studies by Wang et al. (2015), Uzun et al. (2012), Ozer (2003) and others. These authors reported that oilseed rape produced more pods per plant with wider row-spacing.

Number of seeds per pod. The number of seeds per pod was statistically affected by different row-spacing in all years of experiment (Table 5). 10 800 pods were processed and the average number of seeds per pod was 19.00 with the minimum at 1.00 and the maximum at 49.00. The V1 treatment exhibited the lowest average value with the number of seeds per pod at 17.58. The number of seeds per pod grew significantly with increasing row-spacing and the highest row-spacing produced the highest value (Figure 2). These findings indicate that higher row-spacing gave rise to a higher

Table 4. Average numbers of pods and seeds per plant in the evaluated experimental site in years 2013–2015

Row-spacing (cm)	2013		2014		2015	
	ES1	ES2	ES3	ES4	ES5	ES6
Number of pods per plant (pieces)						
12.5	278^a	338^a	337^a	296^a	364^b	372^a
25	272^a	326^a	307^a	286^a	343^ab	351^a
35	261^a	277^a	283^a	277^a	317^ab	325^a
45	246^a	288^a	342^a	265^a	271^a	267^a
Number of seeds per pod (pieces)						
12.5	16.4^a	18.8^b	17.9^a	16.4^a	17.9^a	18.0^a
25	18.0^b	20.9^c	18.7^ab	17.3^ab	18.7^a	19.0^ab
35	19.2^bc	19.7^b	20.2^c	18.6^bc	21.1^b	19.9^b
45	20.0^c	17.6^a	20.1^bc	19.2^c	21.2^b	21.3^c

ANOVA (Scheffe's tests); the means listed in the individual columns differ significantly from one another ($P < 0.05$) when they are accompanied by distinct letters

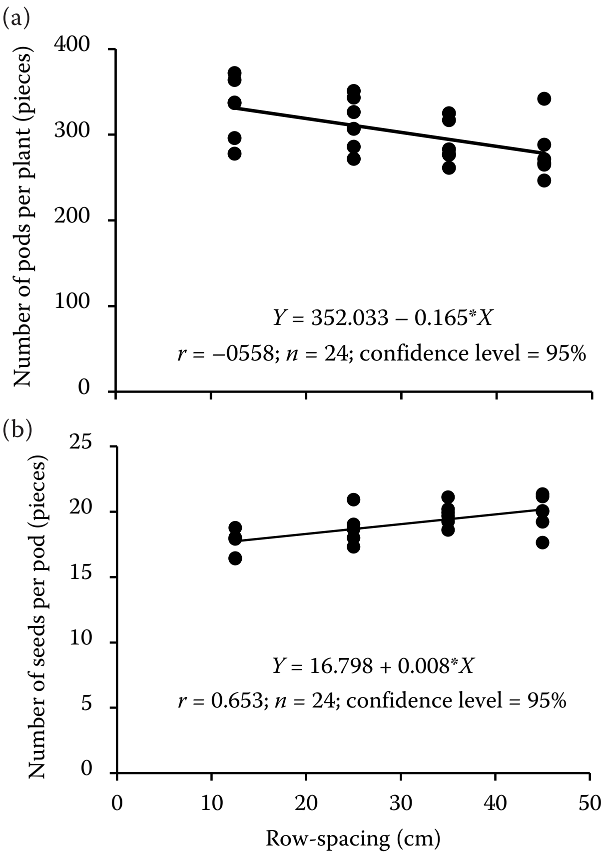

Figure 1. The influence of row-spacing on the number of (a) pods and (b) seeds per plant. Average values of number of pods per plant on the rated localities in years 2013–2015 are used as a dependent variable. r – correlation coefficient; n – number of variables

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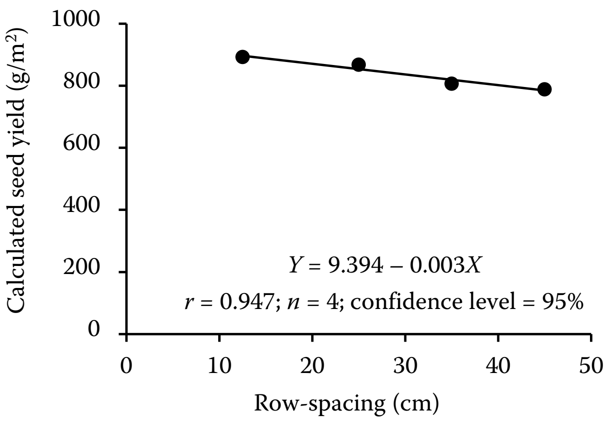

Figure 3. Calculated seed yield on the basis of the data of the yield components (plant per unit area, pods per plant, seeds per pod and 1000 seed weight) according to row-spacing

seeds per pod value. Such findings are consistent with the results of the experiments by Oad (2001), Ozer (2003) and Uzun (2012).

1000 seed weight. Similar to the studies by Wang et al. (2015), Ozer (2003) or Morrison et al. (1990), the data collected in the three years of our experiment indicated that no significant differences between individual treatments of row-spacing occurred with regard to the 1000-seed weight (Table 3). Diepenbrock (2000) stated that seed weight depends on environment conditions less than other components of the yield. Nevertheless, the average values showed an increasing trend of the parameter on wider rows. The average value of this parameter was 5.63 g with the minimum at 4.46 g and maximum at 6.89 g.

Calculated seed yield. Values of the calculated yield arose from the average data of yield components, specifically the number of plants per unit area, the number of pods per plant, the number of seeds per pod and the 1000 seed weight. Data values estimated the calculated seed yield to about 800 grams per square meter. Such value corresponds to the calculated seed yield in the study by Kuchtová and Vašák (2004). As only a small sample size was used for this test, the data remain only indicative. Although the highest value of the number of seeds per pod (Figure 2) and the 1000-seed weight were achieved with the widest rows, such an increase could not offset the decline in the other parameters, i.e. the number of plants per unit area and the number of pods per plant (Figure 2). Besides, the seed yield shows a slightly declining trend in wider row-spacing, as indicated in Figure 3. Such findings correspond to the studies by Różyło and Pałys (2014), Ozer (2003), Morrison et al. (1990). Kuai et al. (2015) came to similar results. In their study, the seed yield decreased significantly with increasing row-spacing, although most numbers of yield components increased.

This study did not confirm a positive effect of sowing oilseed rape in rows wider than 12.5 cm on increase of values of important yield factors. Therefore such an agronomical decision cannot be recommended in general (at least to Czech growers) as a way to achieve higher seed yield.

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