Yield components of winter oilseed rape regard to plant population

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Abstract: The aim of this study was to analyze the yield components of winter oilseed rape depending on the plant population in 2017/2018 growing season. Three plant populatios were considered in the study: 20, 40 and 60 plants m^{-2}. At harvest several yield components were determined: plant height (cm), plant mass (g), height of the first fertile branch (cm), number of fertile lateral branches, number of pods per plant, length of the pod (cm), number of seeds per pod, mass of seeds per pod (g), number of seeds per plant, 1000 grain mass (g) and yield of seeds per plant (g). At the plant population of 40 plants m^{-2} the plants were the highest (153.4 cm), with the highest plant mass (295.3 g) and the number of lateral fertile branches (5.6 branches per plant). Furthermore, the plants from 40 plants m^{-2} had the highest number of pods per plant (716 pieces), the longest pods (6.5 cm) with the largest number of seeds per pod (21.0) and the number of seeds per plant (15 036 seeds). The highest and significant correlation coeficient was found between number of pods per plant and plant mass (r=0.890***) and than between the number of lateral branches and number of pods per plant (r=0.850***). Linear regression showed that for every centimeter increment of pod length the number of seeds increase for 4.8 seeds at 20 and 40 plants m^{-2} and for 5.5 seeds per pod at 60 plants m^{-2}. Furthermore, regression analysis showed that for every centimeter pod length increment the seeds mass per pod increase on average of all plant population for 0.02 g.

Keywords: winter oilseed rape, 2017/2018, plant population, yield components

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Introduction

According to FAOStat data (2018) in the world production of oilseed rape form 2012 to 2016 was on about 35 mil. ha with seed yield of 2.0 t ha^{-1}, whereas in the Europe there was about 25% of world sown area, and it counts on average 8.6 mil. ha with seed of yield 2.9 t ha^{-1} (Table 1). The greater producers in the EU are France, Germany and United Kingdom, while in the world great producers are Canada, China, India and Australia. In Republic of Croatia the average production area of winter oilseed rape was 21 948 ha and seed yield 2.8 t ha^{-1} (Statistical Yearbook of the Republic of Croatia 2017). The importance of rape has thus increased in recent years and today it is cultivated on every continent. Nowadays the cultivation of oilseed rape have a great importance due to its usage as vegetable oil in human diet, but also for the biodiesel production as a renewable source, as a catch crop for green manuring and as a forage crop: nutrition in the form of rape cake and meal (Pepó, 2013; Carré and Pouzet, 2014; Lääniste et al. 2016; Nath et al. 2016; Zając et al., 2016; Novoselec et al. 2018).

Table 1. Production of oilseed rape in the world from 2012 to 2016 (FAOStat, 2018)

	Harvested area (ha)	Seed yield (t ha^{-1})
The greater producers in the Europe		
Europe total	*8 619 138*	*2.9*
France	1 520 668	3.3
Germany	1 355 440	3.9
Russian Federation	993 076	1.1
Poland	873 228	2.9
Ukraine	705 758	2.5
Great Britain	675 303	3.4
The greater producers in the world		
World total	*35 175 387*	*2.0*
Canada	8 322 800	2.1
China	7 537 637	1.9
India	6 085 748	1.2
Australia	2 726 891	1.3

The number of plants per unit area is one of the most important yield components in plant production (Ma et al., 2014; Masarirambi et al., 2012; Pepó and Murányi, 2014; Varga et al., 2015; Li et al., 2017; Varga et al., 2017; Vinze, 2017). According to Balodis and Gaile (2016) plant population in relation to the sowing rate particularly affects the number of pods per plant and seed number per pod. The optimum density or plant population results in mature plants that are sufficiently crowded to efficiently use resources such as water, nutrients, and sunlight, yet not so crowded that some plants die or are unproductive. Thus, the distribution of plants

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per unit area is of great importance for yield stability. There are several factors that have influence on the realized plant population like soil properties, seed quality, field germination, sowing time, plant morphology, diseases, pests, seedbeed preparation etc. (Sidlauskas et al., 2003; Kristek et al., 2015; Balodis and Gaile 2016; Kovacevic et al., 2017; Zebec et al., 2017).

The optimum time for sowing winter oilseed rape in Croatia is from 25th August to 10th September. It is therefore sown at 12.5 cm or 25 cm distance between the rows and at the depth from 1.5 cm to 2.5 cm. The recommended seed rate for winter sown oilseed rape in the Croatia is 2.5 – 5 kg ha^{-1}. In Europe oilseed rape is usually sown as winter crop at sown rate around 70 seeds m^{-2} (Roques and Berry, 2016). It can be also sown as a spring crop, when it is sown in higher density as 150 seeds m^{-2} (Lääniste et al. 2016) or 100 – 110 seeds m^{-2} (Leach et al., 1999) for hybrids.

The optimum plant population for oilseed rape hybrids is 30 – 50 plants m^{-2} at harvest (Pospišil, 2013.). On the one hand, in lower plant populations oilseed rape form greater lateral branches, which can somewhat compenstate the lack of plants. On the other hand, larger number of plants per m^{-2} can couse decrease in the steam diameter, thus plants are more sensible to lie down. Leach et al. (1999) indicate that the yield of winter oilseed rape increases if 50-60 plants m^{-2} is achieved. Authors suggested that the productivity of the plant at lower plant population is compensated by increasing the leaf area, multiple lateral fertile branches and with more pods per plant. On the contraty, authors stated that in large plant population, no significant increase in yields was found becouse of the greater possibility of disease in oilseed rape crops. Mendham et al. (1981) shown that plant populations of 20–30 plants m^{-2} produce yields comparable to crops with 70–80 plants m^{-2}, in some instances a crop with only 9–10 plants m^{-2} produced acceptable yields if the plants were healthy and evenly distributed. Diepenbrock (2000) reported that plant population had the greatest effect on yield components of individual plants.

There is a lack of research available on winter oilseed rape yield components in the conditions of Croatia, especially regard to plant population. It is therefore, essential to understand how individual plants interact with each other and the environment and to possibly come up with the ideal crop density levels to optimize yields. The aim of this study was to determine the winter oilseed rape yield components regard to different plant populations in 2017/2018 vegetation.

Material and methods

Field trail was set up in Eastern Croatia (location Beravci) on Family farm «Ivica Anđelić». Winter oilseed rape was sown on 5th September 2017 (hybrid Hybrirock, KWS). One month after sowing (5th November 2017) when plants had about 5-6 leaves, the plant population correction was made to get three different densities: 20, 40 and 60 plants m^{-2}. Each plant population was established in plot size 10 m x 3 m. There were total 171 kg ha^{-1} N, 67 kg ha^{-1} P i 87 kg ha^{-1} K added with fertilization (Table 2). All protection against weeds and pests was made properly.

During the vegetation, the number of leaves per plant were determined in 7 dates (from 5th November 2017 to 5th April 2018). In 2017 the number of leaves represent the average number of leaves per plant counted on 30 individual plants, whereas in 2018 the number of leaves per plant represent the average number of 45 individual plants. Thus, the number of leaves were determined on 270 individual plants.

Besides leaves counting, during vegetation the realized plant population was determined three times for every treatment in 4 replications. The harvest was on 11th June 2018 and therefore from the every plant population (20, 40 and 60 plants m^{-2}) the 15 individual plants were harvested manually. Therefore, the yield components were

Table 2. Fertilization of winter oilseed rape for 2017/2018 vegetation year

Fertilizer	Amount (kg ha^{-1})	N	P_2O_5	K_2O
	5th July 2017 (with soil tillage)			
NPK 0-20-30	200	-	40	60
UREA	100	46	-	-
	5th September 2017 (with sowing)			
NPK 15-15-15	180	27	27	27
	1st March and 12th April 2018 (top dressing)			
KAN	180	49	-	-
KAN	180	49	-	-
	Total	***171***	***67***	***87***

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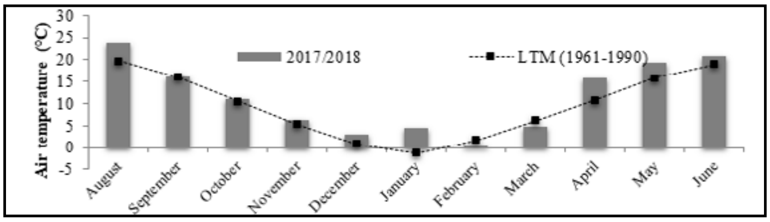

Figure 1. The mean air temperature (°C) in 2017/2018 winter oilseed rape vegetation as compared to the long term mean (LTM = 1961-1990) for Meteorological station Slavonski Brod (Croatian Meteorological and Hydrological Service, 2018)

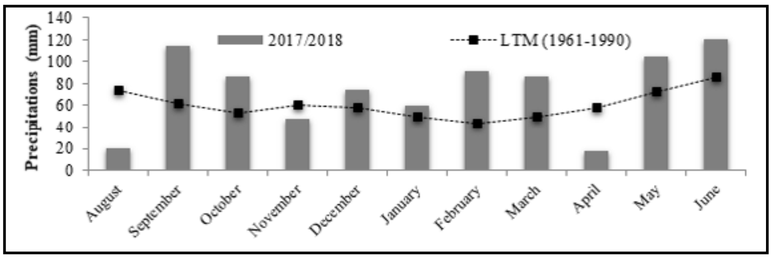

*Figure 2.*The total monthly precipitation (mm) in 2017/2018 winter oilseed rape vegetation as compared to the long term mean (LTM = 1961-1990) for Meteorological station Slavonski Brod (Croatian Meteorological and Hydrological Service, 2018)

determined on 45 individual plants. The plants were marked and afterwards the plant hight (cm), the plant hight to first fertile branche (cm), total number of pods per plant were measured. From every plant 100 individual pods were separated in the paper bag, and than on every pod several measurments were made: the pods length (cm), the number of seeds per pod and mass of seeds per pod. Total of 4500 individual pods were analyzed. Afterwards, the number of seeds per plant, the 1000 grain mass and the yield of seeds per plant (g per plant) were determined.

During vegetation period, form August 2017 to June 2018 (Figure 1) the average air temeprature was 1.9°C higher as compared to the long-term mean (LTM, 1961-1990) (Croatian Meteorological and Hydrological Service, 2018). The winter period was not so cold, so the plants were not destroyed. Even though, in January the mean air memperature was for 4.5°C which was higher for 5.7°C comparing to LTM. During vegetation, there were total 824.1 mm precipitation (Figure 2), which was for 156.8 mm higher as compared to the LTM (667.3 mm). In spring 2018 there was 173.8% higher rainfall in March, and than the lack of rainfall in April (17.7 mm), but towards to winter oilseed rape maturation, in May and June there were higher rainfall and warm air temperatures, thus the harvest of winter oil seed rape and other winter crops in Croatia started about 20 days earlyer than usual.

The diferences between the mean values were calculated in SAS 9.4. with one way ANOVA as plant population as the main factor.

Results

In order to determine the phase of growth for winter period, the number of leaves per plant were determined (Figure 3). Thus, the rosette was in the optimum phase for winter period. Also after winter period there was not extreme decrease of planed plant population (Table 3). The mean plant hight was 138.8 cm (Table 4)

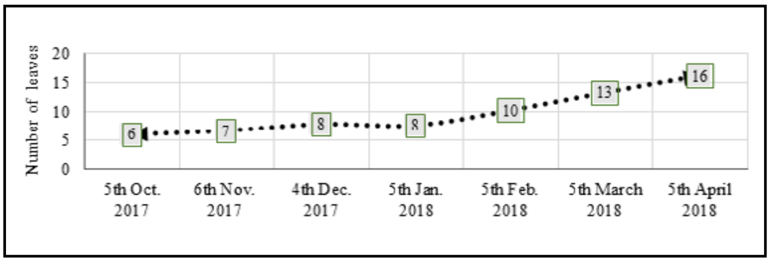

*Figure 2.*The average number of leaves per oilseed rape plant in 2017/2018 vegetation

Table 3. Realized winter oilseed rape plant population

Planed plant population	Date					
	5th November 2017		5th March 2018		11th June 2018	
	Realized plants m^{-2}	% of planed	Realized plants m^{-2}	% of planed	Realized plants m^{-2}	% of planed
20 plants m^{-2}	19	95	18	90	18	90
40 plants m^{-2}	39	98	39	98	39	98
60 plants m^{-2}	59	98	58	97	57	95

Table 4. The plant hight (cm), plant mass (g), hight to first fertile branches (cm), the number of lateral branches of winter oilseed rape at different plant population

	Plant hight (cm)	Plant mass (g)	Hight to first fertile branches (cm)	Number of lateral branches
20 plants m^{-2}	123.7 ^{c}	112.0 ^{b}	28.4 ^{a}	3.5 ^{b}
40 plants m^{-2}	153.4 ^{a}	295.3 ^{a}	21.0 ^{b}	5.6 ^{a}
60 plants m^{-2}	139.1 ^{b}	167.9 ^{b}	19.1 ^{b}	4.4 ^{b}
Average	***138.8***	***191.8***	***22.9***	***4.5***

*The differences between the means within the column are marked with different letter (**abc**) at p<0.05*

Table 5. The number of pods per plant, the pods length (cm), number of seeds per pod and mass of seed per pod (g) of winter oilseed rape at different plant population

	Number of pods per plant	Pods length (cm)	Number of seeds per pod	Mass of seed per pod (g)
20 plants m^{-2}	339 ^{b}	6.2 ^{b}	20.4 ^{a}	0.09 ^{a}
40 plants m^{-2}	716 ^{a}	6.5 ^{a}	21.0 ^{a}	0.10 ^{a}
60 plants m^{-2}	462 ^{b}	6.4 ^{ab}	20.3 ^{a}	0.10 ^{a}
Average	***506***	***6.4***	***20.6***	***0.10***

*The differences between the means within the column are marked with different letter (**abc**) at p<0.05*

Table 6. The number of seeds per plant, 1000 grain mass (g) and yield of seeds per plant (g) of winter oilseed rape at different plant population

	Number of seeds per plant	1000 grain mass (g)	Seed yield per plant (g)
20 plants m^{-2}	6 916 ^{b}	4.71 ^{a}	35.0 ^{b}
40 plants m^{-2}	15 036 ^{a}	4.65 ^{a}	85.2 ^{a}
60 plants m^{-2}	9 379 ^{b}	4.85 ^{a}	45.0 ^{b}
Average	***10 423***	***4.74***	***55.1***

*The differences between the means within the column are marked with different letter (**abc**) at p<0.05*

and it varyed from 123.7 cm (20 plants m^{-2}) to 153.4 cm (40 plants m^{-2}). The highest plant mass (295.3 g) had the plants at 40 plants m^{-2}, and there there were no statistically differences determined for plant mass between 20 and 60 plants m^{-2}. The plants formed 4.5 lateral branches and the mean hight of first fertile branche was 22.9 cm.

At plant population of 40 plants m^{-2} plants formed the higher number of pods per plant (Table 5), but also, at 40 plants m^{-2} the number of seeds per plant and seed yield per plant (Table 6) were the highest, which was significant (p<0.05) in comparison with number of pods per plant, number of seeds per plant and seed yield per plant at 20 and 60 plants m^{-2} where the differences was not significant. The average length od pods was 6.4 cm with 20.6 seeds which weighted on average 0.10 g (Table 5). The 1000 grains mass was not significant different between plant population.

In order to determine the relationship between the yield components the Pearson's correlation coeficient was calculated (Table 7). Significant and positive correlation for plant population and plant hight was found (r = 0.385**) and significant but negative correlation was between plant population and the hight to first fertile branch (r = -0.372*). Other yield components (the number of lateral branches, the number of pods per plant, plant mass, pod length, number of seeds per pod, mass of seeds per pod and

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Table 7. The Pearson's correlation coeficient between yield components of winter oilseed rape (N = 45)

	PP	PH	BH	NB	NP	PM	PL	NSP	MS	PS
PP	-									
PH	0.385**	-								
BH	-0.372*	-0.300*	-							
NB	0.229ns	0.625***	-0.465***	-						
NP	0.156ns	0.662***	-0.481***	0.850***	-					
PM	0.179ns	0.666***	-0.467***	0.782***	0.890***	-				
PL	0.246ns	0.500***	-0.378**	0.561***	0.508***	0.415**	-			
NSP	0.001ns	0.247ns	-0.251ns	0.296*	0.335*	0.199ns	0.755***	-		
MS	-0.075ns	0.368*	-0.369*	0.542***	0.619***	0.631***	0.448**	0.481***	-	
PS	-0.073ns	0.373*	-0.368*	0.545***	0.619***	0.631***	0.454**	0.488***	0.757***	-

p< 0.001 ***; p<0.01 **; p<0.05 *; **ns** – not significant)

PP – plant population; **PH** – plant hight; **BH** – hight to first fertile brnch; **NB** – number of lateral branches; **NP** – number of pods per plant; **PM** – plant mass; **PL** – pod length; **NSP** – number of seeds per pod; **MS** – mass of seeds per pod; **SY** – seed yield per plant

seed yield per plant) did not have significant relationship with winter oilseed rape plant population. For other winter oilseed rape yield components, the highest and significant correlation coeficient was found between number of pods per plant and plant mass (r = 0.890***) and than between the number of lateral branches and number of pods per plant (r = 0.850 ***).

Linear regression was also calculated for pod length and number of seeds per pod and pod length and mass of seeds per pod (Figure 4). According to linear regression analysis the equations showed quite similar relationship between the pod length and number of seeds per pod at every plant population. Thus, it was found that for every centimeter increment of pod length the number of seeds increase for about 4.8 seeds at 20 and 40 plants m^{-2} and for about 5.5 seeds per pod at 60 plants m^{-2}. In regression analysis of the mass of seeds per pod (g) and pod length (cm) it was found that for every centimeter pod length increment the mass of seeds per pod increase for 0.02 or 0.03 g.

Discussion

In the period from August 2017 to June 2018, temperatures were higher by 1.9°C than the long term mean (9.6°C) and during this period the precipitation amount was 156.8 mm higher than the long term mean (667.3 mm). The weather conditions were suitable for the development of oilseed rape. According to the data obtained in this study, the planed plant population was not drastically reduced to harvest. It is important to note that in the winter period form December 2017 to March 2018 was not extremely cold and did not affect the plant's population reduction. Zając et al. (2013) state that as a result of very cold winter, oilseed rape plants developed a larger number of lateral branches to compensate for reduced plant population. In this study, high temperatures in April and May led to earlier harvest of oilseed rape, which was about 20 days before the optimal harvest dates (3rd decade of the June).

The plant population is a very important factor winter oilseed rape production. Pospišil et al. (2014) and Diepenbrock (2000) stated that the plant population had the greatest influence on the seed yield and the yield component of winter oilseed rape. Zhang et al. (2012) found that the number of pods per plant and the number of seeds per pod are the most varied yield component of winter of oilseed rape.

The basic yield components of oilseed rape seed are the number of plants per unit area (m^2), the number of pods per plant, the number of seeds per pod and the mass of 1000 seeds. Even though Momoh and Zhou (2001) and Clarke and Simpson (1978) found that in small plant population oilseed rape will increase the number of lateral branches, in this study on

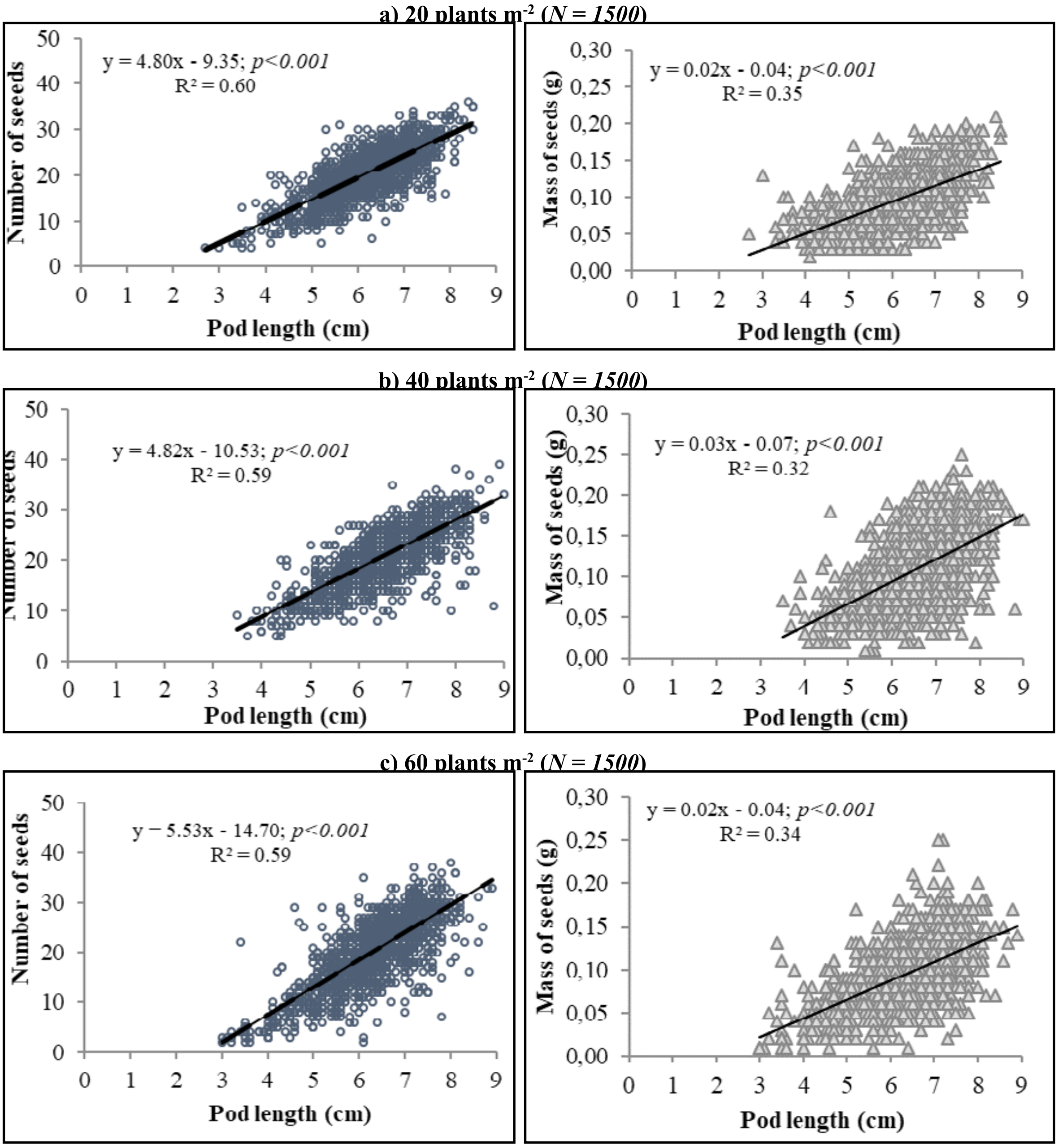

Figure 4. The linear regression of pod length (cm) and number of seeds per pod and pod length (cm) and mass of seeds per pod (g) of winter oilseed rape at three different plant population

the contrary, the smallest plant population (20 plants m^{-2}) did not resulted with highest number of lateral branches (3.5 lateral branches). In our study some relationships between several yield components (parameters of an individual plant productivity) were observed. The number of pods per plant depends on the number of developed pods and aborted pods, which vary depending on different pollination conditions. Abiotic stress like high temperatures during flowering can also affect the number of pods per plant. Angadi et al. (2000) reported that high temperatures at flowering affected yield formation more than high temperature at pod development and that in such conditions *Brassica* sp. could have more pods per plant, but with less seeds due to seed abortion was also more common. According to Pospišil (2013) the number of pods per plant in our agroecological conditions could varyed from 100 to 600. In our experiment the highest number of pods per plant was 716 in plant population of 40 plants m^{-2} and at 20 and 60 plants m^{-2} it was decreased by 52.7% and 35.5%, respecively. Balodis and

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Gaile (2016) stated that the differences in the oilseed rape yield component "pods per plant" showed plant ability to compensate seed yield in cases when plant density was lower, such as due to decreased sowing rate and poor wintering. So, in our experiment this was not confirmed. Based on three year experiment in Croatia, Pospišil et al. (2014) found that the number of pods per pant varyed from 140 (cultivar Ricco, 2009/10 season) to 528 (hybrid Turan, 2011/12 season).

Correlations are important for the breeder in order to associate all the possible valuable features in the newly created genotypes. It was interesting to find that plant hight was positive and extremely significant correlated with the number of lateral fertile branches, number of seeds per plant and pod length (Table 7). Zhang and Zhou (2006) reported that number of seed per pod and 1000 seed mass were positively correlated with seed yield per plant plant. Besides correlatios, the regression analysis can explain prediction and connection between the yield components. Zając et al. (2011) found a high coefficient of determination R^2 = 0.945 between the seed mass per oilseed rape pod and the total mass of the pod, but also authors found that the length of the pod was very poorly correlated with seed mass. This is quite similar to our results, which showed a small coefficient of determination ($R^2 = 0.32$ to $R^2 = 0.35$) between pods lenght and seeds mass per pod.

Zając et al. (2011) reported that mean number of seeds per pod is around 19 and that it should be considered that location of particular pod on a plant was also important; more seeds per pod were found in the middle part of plant in comparison with upper and lower parts. Authors stated that the seed number per pod can increase up to 27 seeds on the main stem, in relation to pod location on the plant. Even though it would be interested, in our study, the location of pods on a plant was not observed, but there were no significant difference for aveage number (20.6) of seeds per pod regard to plant population (Table 5). The opposite findings were in Li et al. (2017) study, where with increasing winter oilseed rape plant population, decreased number of seeds per pod. Pospišil et al. (2014) emphasize the genotype differences in number of seeds per pod and between 11 hybrids and 5 cultivars, the cultivar Ricco had the highest number of seeds per pod in two seasons, 30,00 in 2010/11 and 33,41 in 2011/12.

Our study did not shown the significant influence of plant population on 1000 grain mass. This is simmilar to Li et al. (2017) found that with increasing winter oilseed rape plant population there were no significant influence on 1000 grain mass. In study with different nitrogen fertilizer rate, Spitek and Pospišil (2017) did not found significant difference in 1000 grain mass (on average 5.65 g).

Our trial results showed the highest significant ($p<0.05$) seed yield per plant of 85.2 g at 40 plants m^{-2} in comparison with other plant populations (Table 6). Similar results was obtained in the study of Nasiri et al. (2017). Authors include 6 different oilseed rape genotypes (Ahmadi, Okapi, Opera, L72, Karaj1 and SW102) and found that the seed yield at 60 and 80 plants m^{-2} in all varieties was significantly reduced compared to the 40 plants m^{-2}. In the study of different plant population (30, 40, 50 and 60 seeds m^{-2}) by Ratajczak et al. (2017) indicate that the lowest seed yield was obtained at 30 m^{-2} seeds (38.9 dt ha^{-1}), while there was no statistically justified differences between yield of seeds of other sowing density and the yield ranged from 41.0 dt ha^{-1} (40 seeds m^{-2}) to 41.4 dt ha^{-1} (60 seeds m^{-2}). Zhang et al. (2012) also found yield decrement with increasing plant population and they statted that the highest seed yield per plant was at 36 plants m^{-2}.

Conclusion

In this study field trail was set up to analyze the yield components of winter oilseed rape depending on the plant population (20, 40 and 60 plants m^{-2}) in 2017/2018 year. It is obvious in our experiment that, generally the best results were found at 40 plants m^{-2}. Thus, there were the highest plants developed (153.4 cm per plant) with the largest plant mass (295.3 g per plant) and furthermore, plants formed the most fertile side branches (5.6 branches per plant) and the largest number of pods per plant (716 pieces). Also, plants had the longest pods length (6.5 cm) and therefore the largest number of seeds per pod (average 21.0). The highest seed yield per plant of 85.2 g was found at 40 plants m^{-2}, which was 58.9% and 47.2% higher compared to 20 and 60 plants m^{-2}, respectively. Even though this results showed only one oilseed rape season, our results coincides with the recommendations that the winter oilseed rape hybrids should be sown within 30 to 50 plants m^{-2}.

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References

Angadi, S.V., Cutforth, H.W., Miller, P.R., McConkey, B.G., Entz, M.H., Brandt, S.A., Volkmar, K.M. (2000): Response of three *Brassica* species to high temperature stress during reproductive growth. Canadian Journal of Plant Science, **80**: 4. 693-701. https://doi.org/10.4141/P99-152

Balodis, O., Gaile, Z. (2016): Sowing date and rate effect on winter oilseed rape (*Brassica napus* L.) yield components' formation. Proceedings of the Latvian Academy of Sciences. Section B, **70**: 6 (705). 384–392. doi: 10.1515/prolas-2016-0058

Carré, P., Pouzet, A. (2014): Rapeseed – Tremendous potential for added value generation? Oilseeds and fats, Crops and Lipids, **21**: 1. D102: 1-12. doi:10.1038/srep12574

Clarke, J.M., Simpson, G.M. (1978): Influence of irrigation and seeding rates on yield and yield components of *Brassica napus* cv. Tower. Can. J. Plant Sci. **58**: 731-737. https://doi.org/10.4141/cjps78-108

Croatian Meteorological and Hydrological Service, 2018 (http://meteo.hr/index.php, accessed on 11th October 2018).

Diepenbrock, W. (2000): Yield analysis of winter oilseed rape (*Brassica napus* L.): A review. Field Crops Research, **67**: 35-49. doi: 10.1016/S0378-4290(00)00082-4

FAOStat, Food and Agriculture Organization of the United Nations (2017) http://www.fao.org/faostat/en/#data/QC (accessed on 10th May 2018).

Kovacevic, V., Antunovic, M., Varga, I., Iljkic, D., Jovic, J. (2017): Response of soybean and barley to Fertdolomite application on acid soil. Columella – Journal of Agricultural and Environmental Sciences. **4**: 2. 7-15. DOI: 10.18380/SZIE.COLUM.2017.4.2.7

Kristek, A., Kristek, S., Varga, I., Drmić, Z. (2015): Results of sugar beet production depending on the hybrids selection and the number of fungicide application (*in Croatian*). Poljoprivreda/Agriculture, **21**: 2. 15-22. DOI: http://dx.doi.org/10.18047/poljo.21.2.3

Lääniste, P., Eremeev, V., Mäeorg, E., Jõudu, J. (2016): Effect of sowing date on oil, protein and glucosinolate concentration of winter oilseed rape (*Brassica napus* L.). Agronomy Research **14**(S2). 1384–1395.

Leach, J. E., Stevenson, H. J., Rainbow, A. J., Mullen, L. A. (1999): Effects of high plant populations on the growth and yield of winter oilseed rape (*Brassica napus*). The Journal of Agricultural Science, **132**: 2. 173-180.

Li, M., Shahbaz Naeem, M., Ali, S., Zhang, L., Liu, L., Ma, N., Zhang C. (2017): Leaf Senescence, Root Morphology, and Seed Yield of Winter Oilseed Rape (*Brassica napus* L.) at Varying Plant Densities. BioMed Research International, 2017, Article ID 8581072. https://doi.org/10.1155/2017/8581072

Ma, N., Yuan, J., Li, M., Li, J., Zhang, L., Liu, L., Naeem, M.S., Zhang, C. (2014): Ideotype population exploration: growth, photosynthesis, and yield components at different planting densities in winter oilseed rape (*Brassica napus* L.). PloS one, **9**: 12: e114232. doi: 10.1371/journal.pone.0114232.

Masarirambi, M.T., Mandisodza, F.C., Mashingaidze, A.B., Bhebhe, E. (2012): Influence of plant population and seed tuber size on growth and yield components of potato (*Solanum tuberosum*). Int. J. Agric. Biol., **14**: 545–549.

Mendham, N., Shipway, P., Scott, R. (1981): The effects of seed size, autumn nitrogen and plant population density on the response to delayed sowing in winter oil-seed rape (*Brassica napus*). The Journal of Agricultural Science, **96**: 2. 417-428. https://doi.org/10.1017/S0021859600066181

Momoh, E.J.J., Zhou, W. (2001): Growth and yield responses to plant density and stage of transplanting in winter oilseed rape (*Brassica napus* L.). Journal of Agronomy and Crop Science, **186**: 4. 253-259. https://doi.org/10.1046/j.1439-037x.2001.00476.x

Nasiri, A., Samdaliri, M., Rad, A. S., Shahsavari, N., Kale, A. M., Jabbari, H. (2017): Effect of plant density on yield and physiological characteristics of six canola cultivars. Journal of Scientific Agriculture, **1**. 249-253. DOI: https://doi.org/10.25081/jsa.2017.v1.819

Nath, U.K., Kim, H.-T., Khatun, K., Park, J.-I., Kang, K.-K., Nou, I-S. (2016): Modification of Fatty Acid Profiles of Rapeseed (*Brassica napus* L.) Oil for Using as Food, Industrial Feed-Stock and Biodiesel. Plant Breed. Biotech, **4**: 2. 123-134. DOI: https://doi.org/10.9787/PBB.2016.4.2.123

Novoselec, J., Klir, Ž., Domaćinović, M., Lončarić, Z., Antunović, Z. (2018): Biofortification of feedstuffs with microelements in animal nutrition. Poljoprivreda/Agriculture, **24**: 1. 25-34. DOI: 10.18047/poljo.24.1.4

 DOI: 10.18380/SZIE.COLUM.2018.5.2.33

Pepó, P. (2013): Effects of nutrient supply and sowing time on the yield and pathological traits of winter oilseed rape. Acta Agronomica Hungarica, **61**: 3. 195–205.

Pepó, P., Murányi, E. (2014): Plant density impact on grain yield of maize (*Zea mays* L.) hybrids on chernozem soil of the Eastern Hungary. Columella - Journal of Agricultural and Environmental Sciences, **1**: 2. 95-100. DOI: 10.1556/AAgr.61.2013.3.3

Pospišil, M. (2013): Ratarstvo II. dio – industrijsko bilje. Zrinski. Čakovec.

Pospišil, M., Brčić, M., Pospišil, A., Butorac, J. (2014): Yield and yield components of investigated rapeseed hybrids and cultivars (*in Croatian*). Poljoprivreda/Agriculture, **20**: 1. 3-9.

Ratajczak, K., Sulewska, H., Szymańska, G. (2017): New winter oilseed rape varieties – seed quality and morphological traits depending on sowing date and rate. Plant Production Science, **20**: 3. 262-272. https://doi.org/10.1080/1343943X.2017.1304809

Roques, S., Berry, P. (2016): The yield response of oilseed rape to plant population density. The Journal of Agricultural Science, **154**: 2. 305-320. https://doi.org/10.1017/S0021859614001373

Sidlauskas, G., Bernotas, S. (2003): Some factors affecting seed yield of spring oilseed rape (*Brassica napus* L.). Agronomy Research, **1**: 2. 229-243.

Spitek, J., Pospišil, M. (2017): Influence of nitrogen and sulfur rate in topdressing upon the yield and yield components of rapeseed (*in Croatian*). Glasnik Zaštite Bilja, **40**: 4. 76-81.

Statistical Yearbook of the Republic of Croatia 2017.

Varga, I., Kristek, A., Antunović, M. (2015): Growth analysis of sugar beet in different sowing density during vegetation. Poljoprivreda/Agriculture, **21**: 1: 28-34. https://doi.org/10.18047/poljo.21.1.5

Varga, I., Antunović, M., Iljkić, D. (2017): Vliv rozdílného hnojení dusíkem na růst kořene cukrové řepy (*in Czech*). Listy cukrov. řepař., **133**: 4. 138-141.

Vinze, É. (2017): The effect of sowing date and plant density on yield elements of different winter oilseed rape (*Brassica napus* var. *napus* f. *biennis* L.) genotypes. Columella – Journal of Agricultural and Environmental Sciences, **4**: 1. 21-25. DOI: 10.18380/SZIE.COLUM.2017.4.1.suppl

Zając, T., Oleksy, A., Synowiec, A., Klimek-Kopyra, A. (2011). Comparison of morphological traits, productivity and canopy architecture of winter oilseed rape (*Brassica napus* L.) and white mustard (*Sinapis alba* L.). Journal of Applied Botany and Food Quality, **84**. 183-191.

Zając, T., Kulig, B., Oleksy, A., Stokłosa, A., Styrc, N., Pyziak, K. (2013): Development and yield of morphologically different groups of winter oilseed rape canopy I. Productivity and morphology of plants. Acta Sci. Pol., Agricultura, **12**: 1. 45-56.

Zając, T., Klimek-Kopyra, A., Oleksy, A., Lorenc-Kozik, A., Ratajczak, K. (2016): Analysis of yield and plant traits of oilseed rape (*Brassica napus* L.) cultivated in temperate region in light of the possibilities of sowing in arid areas. DOI: 10.5586/aa.1696

Zebec, V., Semialjac, Z., Marković, M., Tadić, V., Radić, D., Rastija, D. (2017): Influence of physical and chemical properties of different soil types on optimal soil moisture for tillage (*in Croatian*). Poljoprivreda/Agriculture, **23**: 2. 10-18. DOI: 10.18047/poljo.23.2.2

Zhang, G., Zou, W. (2006): Genetic analyses of agronomic and seed quality traits of synthetic oilseed *Brassica napus* produced from interspecific hybridization of *B. campestris* and *B. oleracea*. J Genet., **85**: 1. 45-51.

Zhang, S., Liao, X., Zhang, C., Xu, H. (2012): Influences of plant density on the seed yield and oil content of winter oilseed rape (*Brassica napus* L.). Industrial Crops and Products, **40**: 27-32.