IMPACT OF SOME AGROECOLOGICAL FACTORS ON WINTER OILSEED RAPE (*BRASSICA NAPUS* L.) PLANT DENSITY

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Abstract. Winter rape (*Brassica napus* L.) significance among field crops is unchangeable for last decade in Latvia. Rape plant development in autumn, plant wintering and plant yielding is partly influenced by plant density. The aim of our research, started in autumn 2007 in the Research and Study farm "Vecauce", was to investigate the influence of agroecological factors (sowing date, sowing rate and fungicide (as growth regulator in autumn) application) on two type (line and F_1) winter rape varieties' plant density in autumn, in spring and at harvesting. Plant density in autumn, in spring and during harvesting was determined also by meteorological parameters as air temperature and precipitation. Oilseed rape field germination was observed from 84% sown on 1st of August in 2007 till 67% sown on 1st of August in 2008. A significant impact ($p<0.05$) of the sowing rate was noted for plant winterhardiness (in points) for variety 'Californium' in both years: 2008 and 2009. Fungicide application effect on plant survival during winter was observed for treatments with greater plants density. A very little average plant number decrease per m^2 during summer growth period was noted for all treatments in both years - within 1 to 4% in some cases. The tendency was observed that final plant density at harvest if greater sowing rates had been used, was never high on average for 'Californium' from 75 plants per 1 m^2 (120 germinable seeds per m^2) to 60 plants per 1 m^2 (100 germinable seeds per m^2) in 2009. Correlations between plant density at harvest time and seed yield were found.
Key words: winter rape, sowing date and rate, growth regulator, plant density changes.

Introduction

Significance of rape (*Brassica napus* L.) among field crops in Latvia is stable, and its proportion has increased during the last 15 years. The area under rape during very last years has shown some stabilization: 99 600 ha in 2007, 83 000 ha in 2008, and 93 900 ha in 2009. On-going rapeseed export and capacity increase of Latvia biofuel factories' production is a guarantee for stable rape growing development in Latvia. Latvia, especially central region, has suitable soils and meteorological conditions for winter rape cultivation. The area sown with winter rape is increasing (from 43% in 2005 to 66% in 2007 from the total rape sowing area) in central Latvia region - Zemgale (Central Statistical Bureau of Latvia).

Plant survival during winter and adverse spring is one of the key factors for successful growing of winter oil-seed rape. Wintering of rape depends on two aspects: (1) meteorological conditions for rape growth during autumn before wintering and (2) the plant development stage in the autumn, which could be affected by the growing manner including used cultivar, and agro-meteorological factors.

Rape seed germination is affected by soil moisture and temperature (Kondra et al., 1983; Rapacz, 1998a; Rapacz et al., 1998; Diepenbrock, 2000). Soil moisture is critical as it affects how quickly water penetrates the seed. Dry and cold seedbed will result in reduced and delayed germination, reduced rate of seedling emergence and may inhibit germination altogether until a rain occurs. Important rape plant development functions such as evapotranspiration, photosynthesis, water and nutrient absorption and other biological and chemical activities are regulated by temperature (Rapacz, 1998b). Rape is a relatively cool season crop, in that its best growth occurs above 12 °C and below 30 °C (optimal from 18 °C to 22 °C). Also water is essential for plant growth. The amounts and duration of rainfall cannot be controlled and may be a limiting factor to crop growth unless irrigation is applied, and too much or too little water at any particular growth stage reduces yield potential (Good et al., 1993). Other factors such as light (day length), nutrition and variety also play a role to plant development in autumn, but they generally are of secondary importance (Thomas, 2003).

The above mentioned factors can affect rape plant development and plant density in autumn. Plant density has the greatest effect on seed yield and the yield components of individual plants. Optimum crop density for successful wintering is reported 30 to 70 plants m^{-2} (Leach et al., 1999; Velicka, 2003). Our previous research showed that application of a growth regulator affected the number of leaves per plant and the root-neck diameter, and decreased the height of growth-point of winter rape, thus favouring winterhardiness of the crop (Balodis et al., 2008; Balodis et al., 2009).

In agro-ecological conditions of Latvia, data on winter rape plant density changes from autumn through winter and the following summer growth period is little documented.

The aim of currently described section of our research was to investigate the influence of agroecological factors (sowing date, sowing rate and fungicide (as growth regulator in autumn) application as well as moisture supply and temperature) on two type winter rape varieties' plant density changes from sowing till harvesting.

Materials and Methods

The investigations were carried out on winter oilseed rape (*Brassica napus* ssp. oleifera) plants. Three- factor field trials using two type winter rape cultivars (line 'Californium' and hybrid 'Excalibur') were carried out in the Research and Study farm 'Vecauce' of Latvia University of Agriculture starting from 2007/2008 and continuing till 2009/2010; the paper is focused on plant density results for seasons 2007/2008 and 2008/2009.

Factor A - sowing date:

1st – called 1st August (exactly 2nd August – 2007; 1st August – 2008),

2nd – called 10th August (exactly 10th August – 2007; 11th August – 2008),

3rd – called 20th August (exactly 20th August – 2007; 21st August – 2008),

4th – called 1st September (exactly 31st August – 2007; 30th August – 2008),

5th – called 10th September (exactly 10th September – 2007; 9th September – 2008).

Factor B – fungicide application (B1 – control, without fungicide; B2 - fungicide applied as growth regulator). Fungicide application scheme: dose (0.5 L ha^{-1}) of fungicide juventus 90 s.c. (metconasol 90 g L^{-1}) was applied at the 4-6 leaves stage (for rape sown on 1st August - on 30th August 2007, on 8th September 2008; sown on 10th August – on 12th September 2007, on 13th September in 2008; sown on 20th August – 27th September 2007, on 8th October in 2008); no fungicide was applied to rape sown on fourth and fifth sowing dates, because rape plants did not achieve the necessary stage for fungicide application for growth regulation at the first ten-day period of October.

Factor C – four different sowing rates for each cultivar: 120, 100, 80, and 60 germinable seeds per 1 m^2 – 'Californium'; 80, 60, 40, and 20 germinable seeds per 1 m^2 – 'Excalibur'. A treated seed was used.

Soil at the trials' site was strongly altered by cultivation loam with pH KCl = 7.2 to 7.4; content of available for plants K was 169 to 194 mg kg^{-1} and P - 100 to 115 mg kg^{-1}; humus content - 32 to 38 g kg^{-1}. Pre-crop was cereal mixture for silage in both years. Herbicide raundap gold s.c. (gliphosate 450 g L^{-1}), 3.0 L ha^{-1}, was used two weeks before traditional soil tillage with mould-board ploughing. Rototilling was used before sowing. The crop was fertilized with a complex mineral fertilizer at the rate of N 12 to 28 kg ha^{-1}, P 18 to 30 kg ha^{-1}, and K 79 to 103 kg ha^{-1} before sowing depending on a year. Sowing was done according to the previously described design. Weeds were controlled using herbicide butisan star s.c. (metasachlor 333 g L^{-1} + kvinmerac 83 g L^{-1}), 2.5 L ha^{-1}, when the rape was fully germinated in plots of first three sowing dates in 2007 and 2008. For plots of 4th and 5th sowing date, the herbicide was not used in autumn 2007 (lontrel 300 s.c. (clopiralid 300 g L^{-1})), 0.5 L ha^{-1}, was used in spring 2008), but in autumn 2008 butisan star s.c. was used directly after sowing at previously mentioned rate.

Rape plant density was determined by counting plants in autumn after full emergence had occurred, in spring after renewal of vegetative growth, and exactly after harvesting in one constant 0.5 m^2 area of each plot. Winterhardiness of plants was evaluated using two approaches:

1) condition of plants in plots was visually evaluated in autumn and then – again visually - in spring. Visual assessment of every plot according to methodology used in the official test of 'Value for cultivation and use', was given:
   - 9 points (100% of plants survived),
   - 7 points (up to 25% of plants dead),
   - 5 points (up to 50% of plants dead),
   - 3 points (up to 75% of plants dead),
   - 1 point (100% of plants dead);
2) winterhardiness was calculated as percentage of survived plants from those counted in autumn.

ANOVA procedures were used for processing the experimental data. Also correlation analysis was used.

Mean air temperatures in August and September 2007 (17.9 °C and 11.9 °C respectively) were higher than in 2008 (16.4 °C and 10.6 °C). Air temperature only in the first ten-day period of September 2008 was higher than that in 2007 (14.1 °C and 11.2 °C respectively, Figure 1.)

Precipitation in autumn 2007 was apportioned, and soil moisture was appropriate for successful seed germination. The period before 1st August was rich in precipitation thus ensuring soil moisture for seed germination also for the next sowing time. Second ten-day period of September was warm and rainy, which had an effect on good seedling germination even for late sown (10th of September) plants (Figure 1).

Different was autumn 2008, when the first significant rain for seed germination was recorded only on 14th August that negatively affected seed germination of rape sown on 1st August. Also the ten-day period before 1st sowing time was extremely dry (Figure 1). A long-lasting rain was recorded from 21st August to 29th August (totally 45.6 mm), which made some difficulties for successful rape drilling on 3rd sowing date. Weather in September 2008 was cool and dry (only 1 mm of rainfall in the second decade, and totally 14 mm of rainfall per month). Summarizing meteorological conditions of both autumns of the research years, it can be said that meteorological conditions were considerably different. Unusually long-lasting autumns and warm winters (2007/2008 and 2008/2009) were observed for both research years.

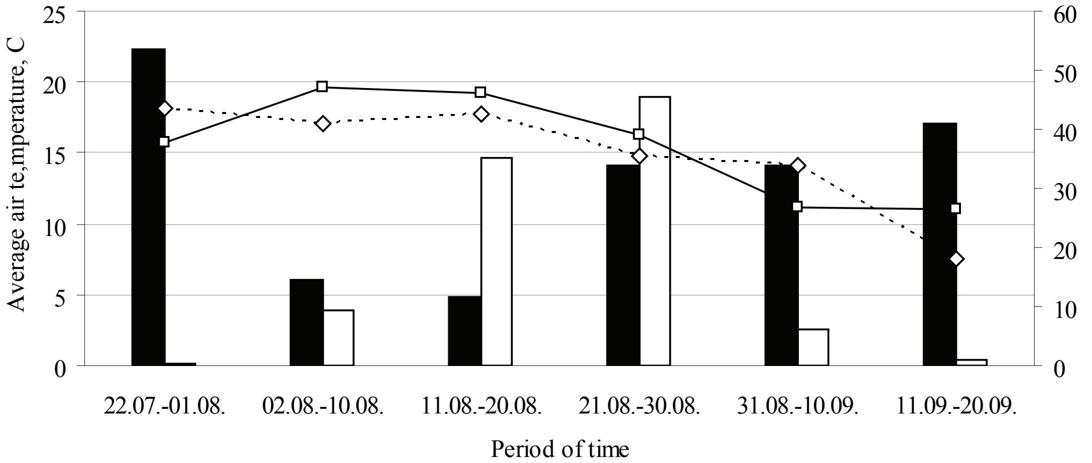

Figure 1. The average air temperature and precipitation in RSF 'Vecauce' in autumn 2007 and 2008 (■ - precipitation in 2007; □ - precipitation in 2008; —— - average air temperature in 2007; – – – - average air temperature in 2008).

Frosts and particular temperature fluctuations that can damage plant growth in spring were not observed in both trial years. Plant damage (central bud and leaves) during winter 2007/2008 was damaged by wild doe for rape sown in first two sowing dates; the level of plant injury did not cause additional plant death in spring 2008. Pools were observed in plots on 1st and 2nd sowing date in spring 2009, which influenced plant survival during winter. Summer for both trial years was without untypical meteorological conditions that could cause greater plant death during summer vegetation.

Results and Discussion

Oilseed rape germination and development during autumn

The emergence of seedlings depends on moisture, temperature, and the seedbed quality. Our observations showed that appropriate soil moisture and productive precipitations were very significant for successful seed field-germination. Oilseed rape sown in the year 2007 had more even field germination (from 98% sown on 20th of August to 84% sown on 1st of August) (Figure 2); exception was rape sown on 1st of September 2007 – 63%. Rapeseed field germination was highly influenced by soil moisture, especially in 2008 when it was affected by drought in the beginning of August when soil humidity was insufficient. Rainfall period in the third decade of August affected drilling quality on 3rd (in 2008) and 4th (in 2007) sowing dates. For those sowing dates rape germination was influenced mainly by drilling quality (which in turn was affected by excessive soil moisture) in both trial years. Better average field germination was observed in the second (10th August) and third (20th August) sown plots in both trial years. Overly high field germination was observed on the 3rd sowing date (10th August) – 105% - and on the 4th (1st September) sowing date in 2008 – 114%. That could be the result of excellent seedbed quality, soil moisture, and temperature conditions, but in addition the reason could be inaccurate germination test result in combination with some technical inaccuracy of the seeder. Our results agree with Diepenbrock (2000) that percentage germination of rapeseed in a standard test is correlating poorly with field performance. Kondra et al. (1983) found that seed germination of rape seed at different temperatures varies a little, which also agrees with our observations of moisture importance for seed germination.

Research results from Canada (Thomas, 2003) have shown that temperature is one of the most important environmental factors regulating growth and development of rape. Our results confirm that rape plant development is considerably different in each trial year. Our previous research results (in detail described in Balodis et al., 2009) showed that sowing date was the main factor which had a strong and significant impact on biometrical parameters of rape plants in autumn. Mainly is early sowing connected with a higher temperature during plant autumn development (Figure 1). Early sowings are often characterised by profuse autumn growth which sets the base for excessive canopy growth in spring. Sowing later can reduce canopy size in spring, but unsuitable late sowing results in small plants which are most vulnerable during wintering. An earlier sowing date significantly increased height of growth point, root neck diameter, plant and root mass, and main root length ($p<0.05$) for both cultivars.

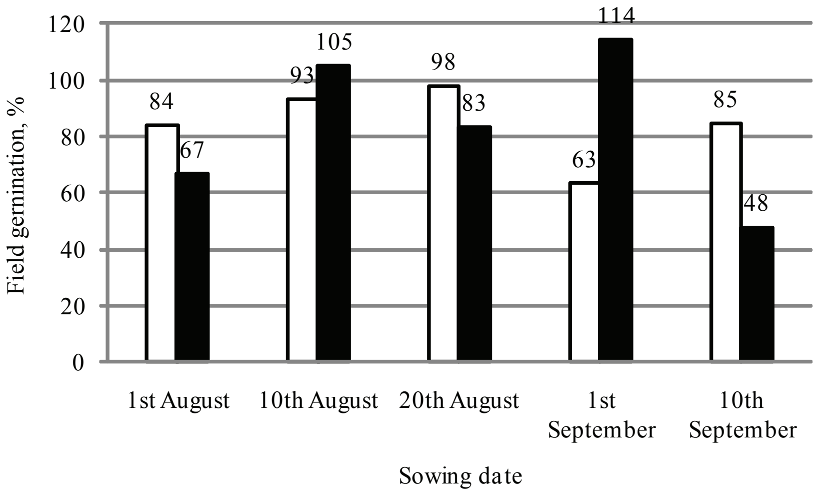

Figure 2. Average (per all sowing rates and both cultivars) winter rape seed field germination depending on the sowing date in 2007/2008 and 2008/2009, % from sown germinable seeds (□ - 2007, ■ - 2008).

Analyses of winter rape growing in Lithuania have shown a highly significant relationship between the leaf area and the air temperature expressed as growing degree-days (GDD) (Sidlauskas et al., 1999). GDD parameters that characterize winter rape autumn growth have to be studied deeper in future also in Latvia's conditions.

Lithuanian researchers found that air temperature was of particular significance in the determination of the leaf area. At 552 °C GDD, only the area of 5 primary leaves reached a plateau, which means that the maximum leaf size was obtained. Marked differences to leaf area were observed between the sowing dates. Due to higher air temperature, earlier sown plants developed a bigger leaf area (Sidlauskas et al., 1999).

The day length closer to the end of the vegetative growth decreases in Latvia (from 16 h 14 min on 1st August to 13 h 12 min on 10th September), which influences plant ability to accumulate necessary chemical and physical components for successful wintering and vigorous spring growth. Day length differences also ensures sharply different plant development during autumn (Thomas, 2003).

Oilseed rape plant density in spring and its winterhardiness

Winter oilseed rape winterhardiness or survival of plants till spring is the most important characteristic for the cultivar used in such conditions as in Latvia where winters with sharp temperature fluctuations, black frost and other adverse factors may occur. Possibility to improve rape wintering using any growth regulation in autumn is little documented in Latvia. Some references in the literature show (Gaveliene et al., 2005) that use of growth regulators (auxin analogues) can improve wintering of winter oilseed rape. Also our previous study results showed that fungicide treatment affected winterhardiness which was evaluated in points (1st approach of winterhardiness evaluation) in some winters (Balodis et al., 2008). Winterhardiness evaluated in points was observed within 8 to 9 points in spring of 2008 and 2009 which were excellent wintering results. Fungicide treatment did not increased ($p>0.05$) winterhardiness (in points) in both years for both cultivars. A significant impact ($p<0.05$) of the sowing rate was noted only for winterhardiness (in points) of 'Californium' in both trial years.

Two-year experimental results showed contrary results of winterhardiness depending on the evaluation method. After winter 2007/2008, a essential correlation between the results of the visual method (evaluation in points) and the survived plants calculated as percentage from those established in plots in previous autumn was not observed ($r= 0.112<r_{0.05}=0.444$ for 'Californium', n=20; $r=/-0.083/<r_{0.05}=0.444$ for 'Excalibur', n=20; $r=0.087<r_{0.05}=0.310$ for both cultivars together, n=40). A correlation was found between the same parameters in the year 2008/2009 ($r= 0.597>r_{0.05}=0.444$ for 'Californium', n=20; $r= 0.473>r_{0.05}=0.310$ for both cultivars, n=40), but was not observed for 'Excalibur' $r=0.431<r_{0.05}=0.444$, n=20. It should be pointed out that the manner of observing winterhardiness has to be improved and discussed in winter rape growing sphere in Latvia. Winters were untypically warm and winterhardiness (in points) was similar in both years; however, another growth factors influenced yield results between the years.

From the two-year results (2007/2008-2008/2009) it was evident that plant death during winter was higher when higher was plant density in autumn or when initially higher sowing rate was used. Total average number of perished plants per winter was noted from 31 plants (30% from the plant number in autumn) for cultivar 'Californium' when sown at the rate of 120 germinable seeds per 1 m^2 in the year 2008 till totally survived plants for cultivar 'Excalibur' when sown at the rate of 20 germinable seeds per 1 m^2 in the year 2008 year, but 26 plants (28% from plant number in autumn) for cultivar 'Californium' when

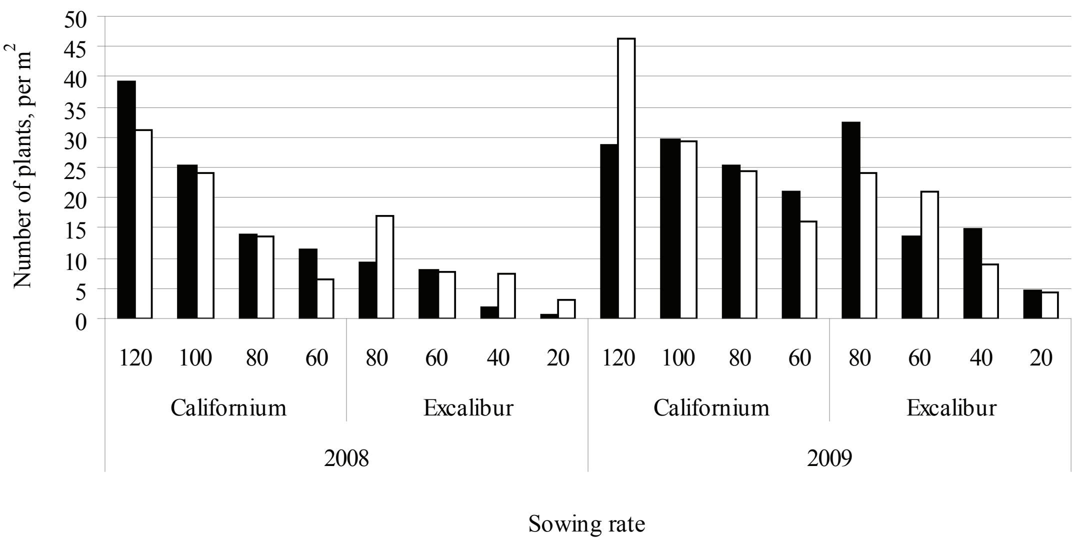

Figure 3. The impact of fungicide application on the average number of dead plants from three sowing dates (1st August; 10th August; 20th August) during winters 2007/2008 and 2008/2009 (■ - control without fungicide; □ - application of fungicide juventus 90).

sown at the rate of 120 germinable seeds per 1 m^2 in the year 2009 till 3 plants (18% from the plant number in autumn) for cultivar 'Excalibur' when sown at the rate of 20 germinable seeds per 1 m^2 in the year 2009. Fungicide application as growth regulator in autumn improved rape plant vitality during winter and in the subsequent spring. An important fungicide application effect on plant survival was observed for plots with greater density (see 'Californium' in 2007/2008 and 2008/2009, Figure 3); exception was 'Californium' with the sowing rate of 120 germinable seeds per m^2 in 2008/2009, which was influenced by pools on the plots. Air temperatures were appropriate for autumn growth and hardening for winter period. Also M. Rapacz and F. Janowiak (1998) reported that lower day temperatures in autumn considerably improved the frost resistance of plants. Winter conditions in 2008/2009 were similar to those of 2007/2008, but the wet and cold spring of 2009 was worse for plant survival if compared to the winter of 2007/2008 and spring of 2008. Due to this on average more plants perished during the winter of 2008/2009.

A very little decrease in average plant number per 1 m^2 during summer growth period was observed for all sowing dates in both years - mainly it was within 0% to 4% with only some exceptions: for 'Californium' 24% plant decrease in 2008 when 100 germinable seeds per m^2 were sown in on the 5th sowing date (2007), and for 'Excalibur' 19% plant decrease during summer 2009 when 60 germinable seeds per m^2 were sown on the 1st sowing date (2008). An effect of sowing date effect on plant decrease during summer was not observed. On the one hand, it is completely clear that in our two-year experiments mainly winter conditions decreased plant density per 1 m^2, but, on the other hand, the winter oilseed rape sowing rate is an important factor that can stabilize on optimal plant density for high seed yields.

Oil-seed rape plant density at harvest time, and yield

Sufficient total plant density at harvest time is the most important base for high winter rape seed yields. Hence, in spite of other meteorological and agronomical factors, winter rape yield can be affected also by the used sowing rate. The tendency was observed that the final rape plant density when higher sowing rates were used was not particularly high - on average for 'Californium' from 75 plants per 1 m^2 (120 germinable seeds per m^2 were sown) to 60 plants per 1 m^2 (100 germinable seeds per m^2 were sown) in 2009 (Table 1). A tendency was noted that average plant density more decreased at earliest and latest sowing dates (Table 1). Also 1st of September is considered to be a little too late sowing date for Latvia, however, the average plant density at harvest was highest for this sowing time in 2009, which was affected by the unexpected extra germination (explained in subsection *Oilseed rape germination and development during autumn*) (Table 1). Final plant densities obtained in our experiment were optimal for a good yield that is reported to be 30 to 70 plants m^{-2} (Leach et al., 1999; Velicka, 2003). An exception is 'Excalibur', when sown only 20 germinable seeds per 1 m^2. There are also other factors like sowing rate that can influence the rape seed yield. Our field experiment results showed that the sowing rate affected the plant density at harvest time significantly ($p<0.05$) for 'Californium' and 'Excalibur' in 2008 and 2009. Results from Germany show that there is not significant seed yield increase for much higher sowing rates than the optimal, but importance of optimal and appropriate sowing rates for different sowing dates is also emphasized (Шпаар, 2007). After all, correlations had been found between the plant density at harvest time and the sowing rate ('Californium' - $r=0.616>r_{0.05}=0.444$, 'Excalibur' –

Table 1

The influence of sowing date and sowing rate on winter rape plant density during harvesting of fungicide - untreated cultivars 'Californium' and 'Excalibur' in the years 2008 and 2009, plants per 1 m^2

Sowing date	'Californium', sowing rate, germinable seeds per 1 m^2								
	120		100		80		60		Average
	2008	2009	2008	2009	2008	2009	2008	2009	
01-Aug	77	26	66	27	43	14	42	11	38
10-Aug	71	74	61	57	46	42	39	46	54
20-Aug	79	85	75	65	72	40	45	33	62
01-Sep	41	139	44	114	42	77	26	54	67
10-Sep	45	51	46	40	31	25	31	20	36
Average	62	75	58	60	47	39	36	33	x
Sowing date	'Excalibur', sowing rate, germinable seeds per m^2								
	80		60		40		20		Average
	2008	2009	2008	2009	2008	2009	2008	2009	
01-Aug	57	27	54	27	35	12	17	8	30
10-Aug	51	63	44	39	38	22	24	17	37
20-Aug	60	73	54	45	35	29	18	9	40
01-Sep	41	98	44	52	42	39	26	20	45
10-Sep	45	51	46	40	31	25	31	20	36
Average	51	62	48	41	36	25	23	15	x

$r=0.870>r_{0.05}=0.444$ in 2008; 'Californium' - $r=0.515>r_{0.05}=0.444$, 'Excalibur' - $r=0.792>r_{0.05}=0.444$ in 2009, n=20).

Still, there are no fixed optimal sowing rates in Latvia's conditions, but our previous research about winter rape yield structural elements in 2008 showed correlation between the plant density at harvest time and the seed yield ('Californium' - $r=0.689>r_{0.05}=0.444$; 'Excalibur' - $r=0.600>r_{0.05}=0.444$, n=20, Balodis et al; 2009.), which agrees with W. Diepenbrock (2000) and R. Velicka (2003). It was found that the effect of fungicide as growth application (in autumn) on the total plant density at harvest time was not significant in both trial years ($p<0.05$).

Highest rape seed yields in 2008 were observed for 'Californium', at the sowing rate of 100 germinable seeds per m^2 (7.19 t ha^{-1}), and for 'Excalibur', at the sowing rate of 80 germinable seeds per m^2 (7.42 t ha^{-1}), sown on 10th and 20th August respectively. Similar in one aspect was the year 2009 when higher seed yields were provided by the same sowing rates for each cultivar ('Californium' - 4.94 t ha^{-1}, and 'Excalibur' – 5.49 t ha^{-1}), but both were sown on 1st September. The sowing rate as an initial reason of plant density at harvest significantly ($p<0.05$) affected the seed yield in 2008 for both cultivars (for 'Excalibur' by 15%, and for 'Californium' by 9%), and for 'Excalibur' by 38% in 2009. An interesting tendency was found that for almost all sowing dates the highest seed yields were noted when the highest sowing rates were used, exceptions were 'Californium' with the sowing rate of 100 germinable seeds per 1 m^2 sown on 1st and 20th August 2007, and 'Excalibur' with the sowing rate of 60 germinable seeds per 1 m^2 sown on 1st September 2007. Affirmation that plant density is an important element that influences the seed yield, was confirmed by the correlations found between plant density at harvest time and seed yield ('Californium' - $r=0.662>r_{0.05}=0.444$, not found for 'Excalibur' in 2008; 'Californium' - $r=0.829>r_{0.05}=0.444$, and for 'Excalibur' - $r=0.637>r_{0.05}=0.444$ in 2009, n=20). If this research is continued at least for the next two years it will be possible to find out the most suitable sowing rate for each sowing date in particular conditions.

Conclusions

1. Our research results confirmed that oilseed rape field germination was mainly affected by soil moisture and productive precipitation. On average, field germination was observed from 84% to 98% with some exceptions when adverse conditions - mainly lack of moisture or too much moisture - occurred.
2. Main periods in which most decrease of initially by sowing rate designed plant number was observed, were field-germination and wintering. More plants perished during winter when higher was plant density in autumn or in its turn – when initially higher sowing rate was used. A tendency that fungicide application (as growth regulator in

autumn) can affect plant survival during winter was noted for treatments with greater plant density. The effect of fungicide application on total plant density at harvest time was not significant in both trial years.
3. Excellent winterhardiness results were noted (from 8 to 9 points) in both trial years when it was evaluated visually in points, but only some correlations between this result (winterhardiness in points) and exact percentage of the survived plants during winter were found. Besides, high rapeseed yields were obtained in spite of contradictory winterhardiness results. Winterhardiness assessment manner has to be improved and discussed in Latvia.
4. Final plant density at harvest is an important factor that influences the seed yield. If this research is continued at least for the next two years it will be possible to find out the most suitable sowing rate for each sowing date in particular conditions.

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