INFLUENCE OF AGROECOLOGICAL FACTORS ON WINTER OILSEED RAPE (*BRASSICA NAPUS* L.) AUTUMN GROWTH

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Abstract

Sowing area under oil-seed rape (*Brassica napus* L.) has increased during last decade in Latvia and has become more or less stable since 2007. Lack of research on impact of sowing date, sowing rate, fungicide as growth regulator application and other agroecological factor issues on rape autumn growth is observed. The aim of our research, started in autumn 2007 in Research and Study farm 'Vecauce', was to investigate the influence of applied agroecological factors (five sowing dates, four sowing rates and fungicide (as growth regulator in autumn) application on two type winter rape varieties development in autumn. Winter rape biometrical parameters, dry matter content and dry mass per m^2 of leaves were estimated. Sowing date affected height of growth point, root neck diameter, plant and root mass, main root length significantly ($p<0.05$). Sowing rate affected only some indices significantly in autumn 2007. Fungicide (juventus 90 s.c. - metconasol 90 g L^{-1}) application also affected rape plant biometric parameters during autumn depending on conditions of research year – height of growth point decreased only in year 2007, effect on number of leaves per plant was observed in both trial years, plant weight (2007) and root length (2008) were affected for hybrid variety. Sowing date showed effect on dry matter content in leaves as well as on dry matter mass of leaves per 1 m^2. Fungicide application increased dry mass of leaves per 1 m^2 in two earlier sowing dates. Results are important also for outline of further research directions evaluating significance of above mentioned factors for winter rape wintering in Latvia.

Key words: winter rape, sowing date and rate, growth regulator, plant biometric indices.

Introduction

Latvia, especially the central region, has suitable soil and meteorological conditions for winter rape cultivation. The area for growing rape (*Brassica napus* L.) is increasing in the world. Sowing area under oilseed rape has grown during last 10 years also in Latvia, but last two years have shown some stabilization of it: 99 600 ha in 2007 and 83 000 ha in 2008. Demand for rapeseed used for biofuel is increasing. On-going rapeseed prices were the main reason along with positive effect of rape in crop rotation for increasing area under oilseed rape in Latvia. There is still huge potential to increase rape production capacity to reach 5.75% of bio-fuel from the total amount of transport fuel existing in common national economy, which is the target for 2010 set by EU.

Winter rape growing techniques are quite similar across Europe, with the exception of sowing time, which ranges from 1st August to 10th September (Luthman and Dixon, 1987; Velicka, 2003). Previously investigated data in Lithuania and Latvia indicates that winter rapeseed overwintering depends on plant development stage and biological indicators at the end of the autumn vegetation period (Velicka et al., 2006; Balodis et al., 2007a, 2007b). Quantitative parameters of biological indicators such as number of leaves, height of terminal bud (growth point), diameter of root collar (neck), root length and root mass of rape characterize rape growing in autumn. Before the winter period, rapeseed plant should create a sufficient above ground and root mass, but on the other hand, it should not be overgrown (Becka et al., 2004). Different agroecological factors have an effect on rape autumn growth. The degree of rape development in autumn is described by the number of leaves per plant, diameter of the root collar, dry matter content in the plant, height of stem and other indicators (Luthman and Dixon, 1987; Velicka, 2003; Velicka et al., 2006; Becka et al., 2004; Balodis et al., 2007a, 2007b; Laaniste et al., 2007). Successful overwintering that depends mainly on good autumn growth of rape plants is observed after they develop sufficient amount (6-8) of leaves; therefore, the autumn development of oilseed rape leaves may affect not only their wintering and subsequent vegetative renewal in spring, but also the yield. Collar or root neck diameter has to be 8-10 mm, and distance between terminal bud and ground has to be not more than 3 cm (Diepenbrock, 2000; Velicka et al., 2006). Investigations of dry matter on different winter rape plant parts under field conditions have been carried out by C.G. Kjellstrom and H. Kirchmann (1994), D. Becka et al. (2004) and R. Velicka et al. (2005 and 2006).

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 on two type winter rape varieties' development in autumn.

Materials and Methods

The investigations were carried out on winter oilseed rape (*Brassica napus* ssp. oleifera) plants. Three factor field trials with two type winter rape varieties (line 'Californium' and hybrid 'Excalibur') were carried out in the Research and Study farm 'Vecauce' of Latvia University of Agriculture starting with 2007/2008 and continuing in 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 leaf stage (for rape sown on 1st August – on 30th August 2007, 8th September in 2008; sown on 10th August – on 12th September 2007, 13th September in 2008, sown on 20th August – 27th September 2007, 8th October in 2008); rape sown on fourth and fifth sowing dates did not achieve necessary stage for fungicide application at the first ten-day period of October.

Factor C – sowing rate (120, 100, 80, 60 germinate able seeds per m^2 – 'Californium'; 80, 60, 40, 20 germinate able seeds per m^2 – 'Excalibur').

Soil in the trials' site was strongly altered by cultivation loam with pH_{KCl} = 7.2 to 7.4; content 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. Traditional soil tillage with mould-board ploughing was used. Rototilling was used before sowing. Crop was fertilized with 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 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} after rape was germinated in plots of first three sowing dates in 2007 and 2008. For plots of 4th and 5th sowing date herbicide was not used in autumn 2007, but in 2008 butisan star s.c. was used directly after sowing.

Rape plant density was established by counting plants in one constant 0.5 m^2 area of each plot in autumn.

At the end of autumn vegetation (2007 and 2008) 10-plant samples were taken randomly for each plot for biometrical analysis:

- First sowing date: 29 October 2007; 11 November 2008,
- Second sowing date: 30 October, 2007, fungicide treated in 31 October 2007; 12 November 2008,
- Third sowing date: 2 November, 2007; 13 November, 2008,
- Fourth sowing date: 5 November, 2007; 13 November, 2008,
- Fifth sowing date: 6 November, 2007; 19 November, 2008.

Number of leaves per plant (No), leave, plant, root weight (g), root length (cm), diameter of root neck (mm) and height of growth-point (mm), were measured in laboratory.

Ten-plant samples from plots of the first, the second and the third sowing date and all plants sown on 4th and 5th dates from 1.0 m^2 were taken for dry matter content analyses. Dry matter of leaves was determined by drying at temperature of 105 °C for 2 hours (ISO 6496: 1999). Rape leaves dry matter yield per m^2 was calculated according plant number per 1 m^2.

ANOVA procedures were used for processing the experimental data.

Mean air temperature in August and September 2007 (17.9 °C and 11.9 °C respectively) was higher than in 2008 (16.4 °C and 10.6 °C). Fall of 2007 was enough moist for successful seed germination. Different was autumn 2008, when first significant rain for seed germination was recorded only on 14 August that affected seed germination of rape sown on 1 August. Long rain was recorded from 20 August to 29 August (totally 59 mm) that made some difficulties for successful drilling on the 3rd sowing date. Weather on September 2008 was cool and dry (only 14 mm rainfall). Summarizing meteorological conditions of both autumns of research years, one could say that meteorological conditions were considerably different.

Results and Discussion

Rape seed field germination was influenced by soil moisture, especially germination in 2008 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 in the 3rd (in 2008) and 4th (in 2007) sowing dates. Rape germination was influenced mainly by soil humidity and drilling quality in both trial years. Better average field germination was observed in the second – 10 August and the third – 20 August sowing time plots in both trial years. In plots sown on 1 September in 2007 and sown on 1 August 2008 field germination was considerably different from desirable plant density prescribed in the trial methodology.

From the two-year results (2007-2008), it is evident that winter rape biometrical indices were influenced by the sowing date, rate and fungicide application in autumn period, as well as by used cultivar.

Sowing Date Effect

Two year experiments showed that on average from both years (fungicide untreated) higher growth point was determin_ed for rape sown early (1 August; 28.41 mm for 'Californium', 43.2 mm for 'Excalibur'), lowest height of growth point was observed on the last sowing date (10 September; 4.3 mm for 'Californium', 4.8 mm for 'Excalibur'). Extremely high growth point was noted for both cultivars sown on 1 August 2007 (Fig. 1, 2).

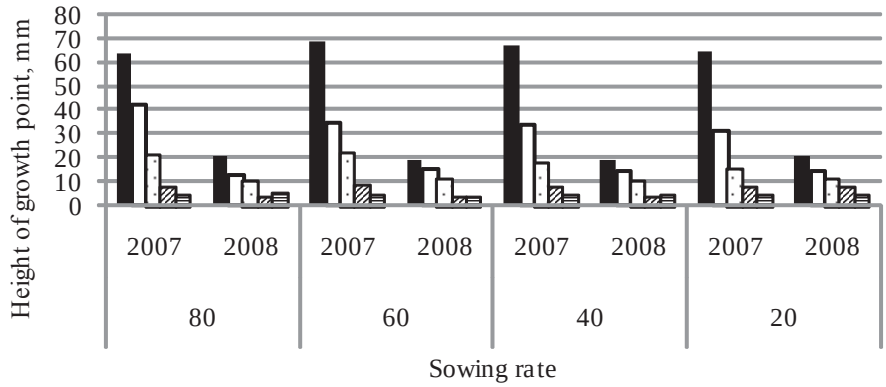

Figure 1. Sowing date and sowing rate influence on winter rape height of growth point of cultivar 'Excalibur' without fungicide application in autumn 2007 and 2008 (mm). Symbols of sowing date: ■ - 1 August; □ - 10 August; ⊡- 20 August; ▨ -1 September; ▤ - 10 September.

Sowing date affected height of growth point significantly (by 85% in 2007 and by 92% in 2008; $p<0.05$) in both trial years for variety 'Californium'. Two year experiments showed that sowing date affected height of growth point significantly (by 95% in 2007 and by 90% in 2008; $p<0.05$) also for variety 'Excalibur'. Optimal height of growth point in our region would not be higher than 30 mm according to results of researchers from Eastern Europe countries (Velicka, 2003; Velicka et al., 2006; Becka et al. 2004; Balodis et al., 2007a, 2007b). In autumn 2007 rape height of grow points were higher than in autumn 2008 that can be explained by different weather conditions, when average air temperature in 2007 was higher than in autumn 2008 during seedling development period. Still, there is a lack of new studies on sowing date effect on biometrical indices of winter rape, but quite lot of information has been found about air and soil temperature impact on winter rape growth during autumn. During August and September temperature decreases; according to Z.P. Kondra et al. (1983) decreased temperature reduces germination rate and as follows – plant density.

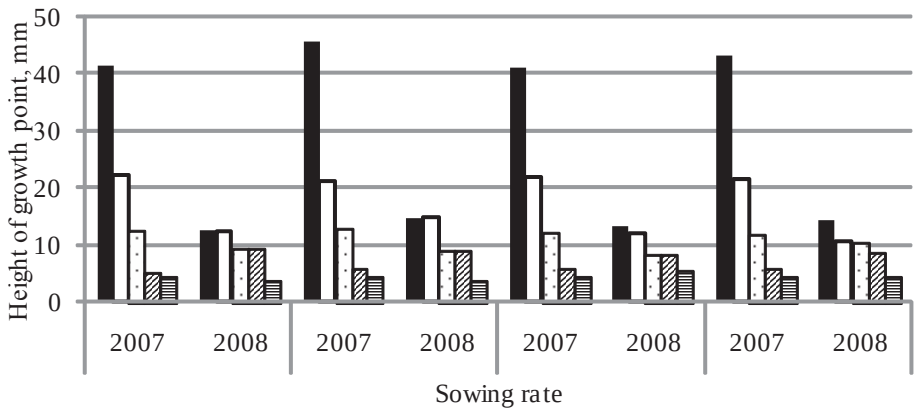

Figure 2. Sowing date and sowing rate influence on winter rape height of growth point of cultivar 'Californium' without fungicide application in autumn 2007 and 2008 (mm). Symbols of sowing date: ■ - 1 August; □ - 10 August; ⊡ - 20 August; ◪ - 1 September; 〓 - 10 September.

W. Diepenbrock (2006) summarizes that plants should reach the 6-8 true leaves stage in autumn before wintering. The number of leaves per plant in both trial years according to this statement was optimal for good wintering of winter rape except plants sown on the last sowing date (10 September) when 5-6 leaves per plant were noted and leaf area (not measured, but observed visually in both years) was smaller (Table 1). Similar observations were noted by Miliuviene et al. (2004) in Lithuania.

Results of Estonian researchers (Laaniste et al., 2007) indicated that plants before wintering reached 9 - 11 leaves if sown at the beginning of August and 3- 4 leaves if sown at the end of August. Accordingly, it was found that the 7-8 leaf stage proved to be the most optimal for successful overwintering. In our study sowing date significantly affected (by 70% for 'Californium' and by 66% for 'Excalibur' in 2007; by 43% for 'Californium' and by 58% for 'Excalibur' in 2008, $p<0.05$) number of leaves per plant for both cultivars in both trial years. For rape plants sown later less number of leaves was noted at the end of vegetation period. It seems that results for plants sown in the first two sowing dates (1 August and 10 August) probably could be affected by sampling method. Some first fully developed true leaves were already dead at the very end of vegetation period, directly before wintering. Methodology of registration of leaves' number per plant has to be more developed in our next studies.

Table 1

Sowing date and sowing rate influence on winter rape number of leaves per plant on fungicide untreated cultivars 'Californium' and 'Excalibur' in autumn 2007 and 2008

Variety	Sowingrate	Year	Sowing date					Average
			01-Aug	10-Aug	20-Aug	01-Sep	10-Sep	
Californium	120	2007	7.0	7.0	6.0	6.0	4.0	6.0
		2008	7.0	7.0	6.0	7.0	5.0	6.4
	100	2007	7.0	6.0	6.0	6.0	4.0	5.8
		2008	8.0	6.0	6.0	7.0	6.0	6.6
	80	2007	7.0	7.0	7.0	6.0	5.0	6.4
		2008	8.0	7.0	5.0	7.0	5.0	6.4
	60	2007	7.0	7.0	7.0	6.0	4.0	6.2
		2008	8.0	6.0	6.0	6.0	5.0	6.2
Average			7.4	6.6	6.1	6.4	4.8	x
Excalibur	80	2007	7.0	8.0	7.0	7.0	6.0	7.0
		2008	10.0	8.0	6.0	6.0	6.0	7.2
	60	2007	8.0	8.0	8.0	7.0	5.0	7.2
		2008	9.0	9.0	7.0	6.0	6.0	7.4
	40	2007	8.0	8.0	9.0	7.0	5.0	7.4
		2008	9.0	9.0	7.0	6.0	6.0	7.4
	20	2007	9.0	9.0	10.0	7.0	5.0	8.0
		2008	13.0	7.0	6.0	7.0	6.0	7.8
Average			9.1	8.3	7.5	6.6	5.6	x

Sowing date affected root neck diameter significantly ($p<0.05$) for both varieties in both trial years. Root neck diameter decreased with later sowing date (on average from both cultivars 9.6 mm for plants sown on 1 August to 2.5 mm – 10 September in 2007; 8.9 mm for plants sown on 1 August to 2.8 mm – 10 September in 2008). Root neck diameter of plants sown on last two sowing dates was less than 5 mm. Researchers from Lithuania found that root neck with diameter less than 5 mm could be risky for good rape wintering (Velicka et al., 2006).

Average (from both cultivars) fresh winter rape plant weight was from 64 g (for rape sown on 1 August to 2 g (for rape plants sown on 10 September) in 2007 and from 49 g (for rape plants sown on1August) to 3.2 g (for rape plants sown on 10 September) sown in 2008. Average root length was higher in 2008 (24.5 cm – rape sown on 1 August; 12.2 cm – rape sown on 10 September) than in 2007 (21.4 cm – rape sown on 1 August to 8.6 cm – rape sown on 10 September). Average root weight was similar in both trial years (10.3 g – rape sown on 1 August to 0.2 g – rape sown on 10 September in 2007, and 10.0 g – rape sown on 1 August to 0.2 g – rape sown on 10 September in 2008).

Higher significant ($p<0.05$) influence of sowing date on winter rape plant weight, root length and root weight was noted for cultivar 'Excalibur' in 2008. Opposite was year 2007 when higher sowing date influence on winter rape plant weight, root length and root weight was noted for cultivar 'Californium' (Fig 3.).

Sowing Rate Effect

According to our two year results, height of growth point was not influenced significantly by sowing rate for both cultivars without fungicide treatment ('Californium': $p=0.921$, 2007; $p=0.247$, 2008; 'Excalibur' $p=0.197$, 2007, $p=0.085$, 2008) (Fig. 1, 2). These results are different from findings of other researchers were the lowest height of growth point was determined in the thinnest crop of rape. High crop density for plants can cause the possibility to spindle (Velicka, 2003; Velicka et al., 2006, Laaniste et al., 2007).

Strong correlation was found between the number of plant leaves and rape crop density in Experimental Station of LUA, 1998-2000 in Lithuania. According to these results more leaves per plant are found in stands with less plant density (Velicka, 2003). Our results shoved that number of leaves per plant was not influenced significantly ($p>0.05$) by sowing rate for cultivar 'Californium' in both years and for cultivar 'Excalibur' in year 2008. Sowing rate and dependant from that plant density significantly affected (by 11%, $p<0.05$) number of leaves per plant for 'Excalibur' in 2007. These results can be affected by method for counting leaves described above (in subsection *'Sowing Date Effect)*

Sowing rate affected root neck diameter, plant weight and root weight significantly ($p<0.05$) for 'Excalibur' in 2007. These parameters were not influenced significantly for another cultivar – 'Californium' by sowing rate.

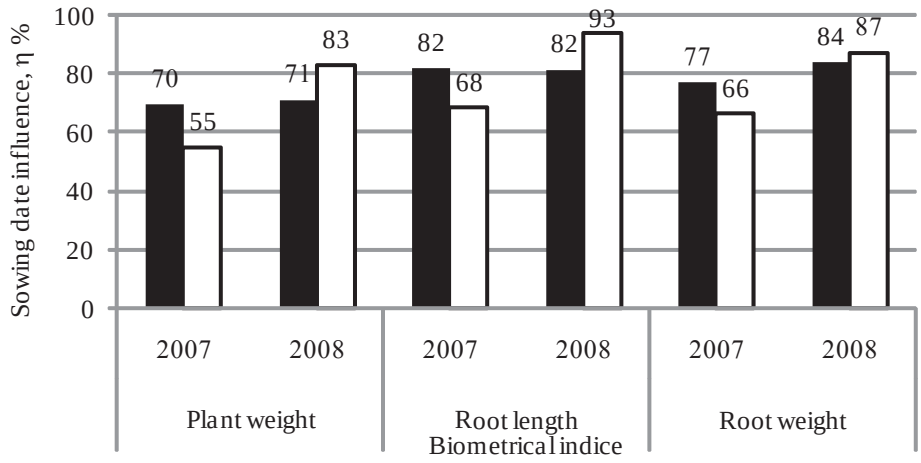

Figure 3. Proportion of sowing date influence on winter rape plant weight, root length and root weight on cultivars 'Californium' and 'Excalibur' in autumn 2007 and 2008, $p<0.05$ (■ - 'Californium'; □ - 'Excalibur').

Fungicide Application Effect

Fungicide (as growth regulator) application was used only for plots sown in the first three dates when rape plants achieved 4-6 true leaf stage. Plants of rape sown in 4th and 5th sowing dates were too small at the first ten-day period of October for fungicide application.

Fungicide application affected significantly (for 'Excalibur' by 16% in 2007, for 'Californium' by 5% in 2007,

by 2% in 2008, $p<0.05$) height of growth point (height of growth point was decreased). This is in accordance with results of other studies (Gaveliene et al., 2002; Balodis et al., 2007a, 2007b). Growth point height decrease by fungicide application was noted for both cultivars sown in very early sowing dates (1 and 10 August), but fungicide application did not decrease this parameter for 'Excalibur' sown on 20 August (the 3rd sowing date) in 2008.

Fungicide application increased number of leaves per plant significantly ($p<0.05$) in both trial years. Also this is in accordance with results of other researchers and our previous investigations (Miliuviene et al., 2004; Gaveliene et al., 2005; Balodis et al., 2007a, 2007b) where more leaves were obtained using fungicide as growth regulator.

Researchers in Lithuania (Gaveliene et al., 1998, Miliuviene et al., 2004) found that use of growth regulators increased significantly the main root diameter and root mass in autumn. Our research showed that root neck diameter and plant weight were affected significantly by fungicide application for 'Excalibur' in 2007, but root length - in 2008.

Dry Matter Content and Dry Mass at the End of Autumn Vegetation Period

Other important indicators of rape vegetative growth in autumn and wintering are chemical composition of root column and crown bud, dry matter content of leaves and dry matter mass per 1 m^2. These parameters along with biometrical indices characterize plant development during autumn growth (Luthman et al., 1987).

Dry matter content in leaves of winter rape was defined in autumn 2008 when active vegetation stopped (11 – 19 November). In our research amount of dry matter was noted from 200 g kg^{-1} in leaves of 'Californium' sown on 1 August (sowing rate - 120 germinate able seeds per 1 m^2) to 80 g kg^{-1} in leaves of 'Californium' sown on 1 September (sowing rate - 80 germinate able seeds per 1 m^2) (Fig. 4). Higher dry matter content was observed in earlier sown winter rape plant leaves, and it decreases during later sown rape. Unexplainable for the present exception was only leaves of plants sown on the last sowing date (10 September) when higher dry matter content was noted (Fig. 4). Velicka et al. (2006) found dry matter content from 190 – 280 g kg^{-1} that is higher if compared with our results. Further investigations about dry matter content of rape plant including leaves should be done in Latvia's conditions.

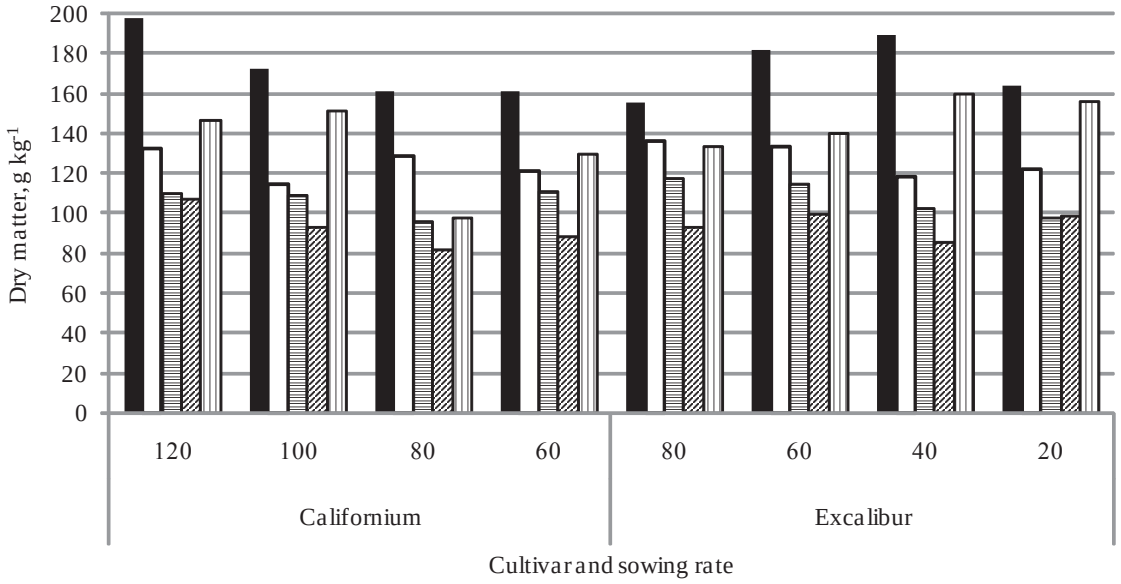

Figure 4. Sowing date and sowing rate influence on winter rape dry matter in leaves in autumn vegetative growth on cultivars 'Californium' and 'Excalibur' in autumn 2008
(■ - 1 August; □ - 10 August; ⊟ - 20 August; ◪ - 1 September; ◫ - 10 September).

Sowing date affected dry matter mass of leaves per 1 m^2 at the end of vegetation period significantly (by 74% - 'Californium' and by 58% - 'Excalibur', $p<0.05$). Also sowing rate affected dry matter mass of leaves per 1 m^2 significantly (by 6% - 'Californium' and by 11% - 'Excalibur', $p<0.05$). Amount of dry mass per 1 m^2 of leaves was noted from 164 g m^{-2} ('Excalibur' sown on 1 August at the rate 80 germinate able seeds per 1 m^2) to

1.5 g m^{-2} ('Californium' sown on 10 September at the rate 80 germinate able seeds per 1 m^2). Dry mass of leaves per 1 m^2 is not the only indice that could characterize winter rape autumn growth. Also dry mass of roots, dry mass of all above-ground biomass and dry mass of whole plant are important indicators (Kjellstrom 1994, Becka et al., 2004, Velicka et al., 2005).

Fungicide application increased dry matter mass of leaves per 1 m^2 significantly ($p<0.05$, $LSD_{0.05} = 8.37$) for cultivar 'Californium' sown on earliest dates (1 and 10 August). No significant impact of fungicide application was observed for rape sown on 20 August (the 3rd sowing date) (Fig. 5). Fungicide application effect on dry matter mass of leaves per 1 m^2 was not found for cultivar 'Excalibur' ($p>0.05$). More investigations should be performed on agro-ecological factors' impact on winter rape dry mass indices in different parts of plant.

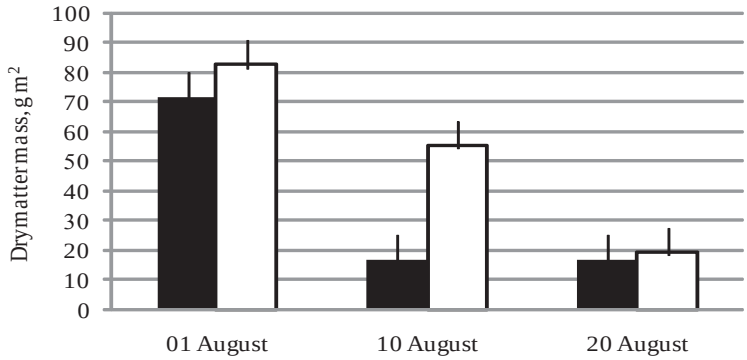

Figure 5. Fungicide application impact on rape dry matter mass per m^2 of leaves in autumn vegetative growth on cultivars 'Californium' in 2008 (■ - control without fungicide; □ - application of fungicide juventus 90).

Conclusions

1. Research results showed that sowing date was the main factor that had strong and significant impact on biometrical parameters of rape plants in autumn. Earlier sowing date increased height of growth point, root neck diameter, plant and root mass, main root length significantly for both cultivars.
2. Sowing rate affected number of leaves per plant, root neck diameter, plant weight and root weight significantly for hybrid cultivar in 2007. Height of growth point was not influenced significantly by sowing rate neither for 'Excalibur' nor 'Californium'.
3. Fungicide as growth regulator (juventus 90 s.c. - metconasol 90 g L^{-1}) application also affected rape plant biometric parameters significantly during autumn: significantly decreased height of growth point in 2007 for both cultivars and for 'Californium' in 2008, increased number of leaves per plant in both trial years, and increased plant weight (in 2007) and root length (2008) only for hybrid cultivar 'Excalibur'.
4. With later sowing date dry matter content in leaves decreased, unexplainable exception was the latest date (10 September) for both cultivars. Sowing date and rate affected dry matter mass of leaves per 1 m^2 significantly for both cultivars. Fungicide application increased dry mass of leaves per m^2 in the first two sowing dates (1 August; 10 August) for cultivar 'Californium', but not for 'Excalibur'.
5. As the winter rape winterhardiness is a risk factor of high significance, investigations on rape development during autumn and its affecting factors should be continued. Described results are important for outlining some further research directions in Latvia.

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