OILSEED RAPE (*BRASSICA NAPUS* SSP. OLEIFERA) SEED YIELD DEPENDING ON SEVERAL AGRO-ECOLOGICAL FACTORS

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Abstract
Most significant growing manner tool to gain high seed yield is the understanding about influence of different factors that have important role on winter oilseed rape growing. The lack of knowledge and research on different agro-ecological factors about oilseed rape growing is observed in Latvia. The aim of our research, started in the season of 2007/2008 and continued up to the season of 2010/2011 in Research and Study farm "Vecauce" of Latvia University of Agriculture, was to investigate the influence of agro-ecological factors (sowing date and rate, and fungicide as growth regulator) on seed yield of two types of winter rape cultivars. The observed seed yield results are analyzed in this paper. Rape was sown on five dates, starting with 1 August with ten days intervals. Specific four sowing rates were used in years 2007/2008 and 2008/2009: 120, 100, 80, and 60 germinate able seeds per m^2 for 'Californium' (line) and 80, 60, 40 and 20 germinate able seeds per m^2 for 'Excalibur' (hybrid). Equal sowing rates for both varieties were used in 2009/2010 and 2010/2011: from 120 to 20 germinate able seeds per m^2 with interval of 20 seeds per m^2. Fungicide as growth regulator (Juventus 90 s.c. (metconazole, 90 g L^{-1}) dose: 0.5 L ha^{-1}) was applied for rape plants at 4-6 leaves stage for crop sown on first three sowing dates. The highest average yield from all trial years was observed for variety 'Californium' sown on 10 August, and for variety 'Excalibur' F1 – sown on 20 August. Winter oilseed rape seed yield was significantly ($p<0.05$) affected by sowing date. The influence of sowing rate on yield was variable. Fungicide application significantly ($p<0.05$) increased the seed yield of 'Californium' in all trial years, but yield of 'Excalibur' – in three out of four trial years: 2008, 2010 and 2011.
Key words: winter oilseed rape, sowing date, sowing rate, fungicide as growth regulator, yield.

Introduction

Use of renewable energy resources is one of the core preconditions of sustainable development of rural areas. It is possible to obtain bioenergy from oilseed rape and agricultural by-products. Winter oilseed rape (*Brassica napus* ssp. oleifera) seeds are raw material for biodiesel production in Latvia. Winter form of crop is preferred because of the possibility of obtaining higher seed yield. Oilseed rape plant development could be affected by the growing manner including used cultivar, sowing date, application of growth regulators and agro-climatic factors. S.V. Angadi et al. (2003) reported that reducing plant population by half from 80 to 40 plants m^{-2} did not reduce seed yield when the reduced plant population was uniformly distributed. He also has recognized that oilseed rape exhibits plasticity to maintain seed yield across a wide range of populations. However, seed yield was generally increased, when sowing rate was increased and seed yield responses to the high rates of sowing or fertilizer only occurred where both inputs were at the highest level, indicating that the optimum level of one was dependent upon the level of the other input (Brandt et al., 2007). Optimal sowing date is still looked for in among the oilseed rape researchers and growers. Results up to now show that the impact of sowing date affected emergence, seedling vigour and yield (Gusta et al., 2004; O'Donavan et al., 2005). Sowing date influenced crop dry weight, crop height, branches, pod number and, after all, seed yield (Luthman and Dixon, 1987). Yield response to sowing date did not differ among similar types of cultivars in some experiments with canola (Clayton et al., 2004). O. Christen (1999) highlights that there is little variation in the date of sowing winter oilseed rape in Germany and the UK. The range is from the middle of August in the northern part of Germany and the UK, to the middle of September in southern Germany. He also reports that increasing the sowing rate does not compensate for late autumn drilling. Optimal sowing date for winter oilseed rape has to be determined in Latvia because of growing manner development and due to climate change.

Growth regulation with triazoles in autumn firstly provides a fungicide treatment, the effect of which on early Phoma (*Leptospheria* spp.) infections should not be underestimated. Secondly as well as growth regulation, combined with good nutrient application with potash and boron increases winter hardiness. Researches show that triazole is increasing the seed yield of rape depending on application timing (autumn or spring), and the increase was: from 0.04 to 0.55 t ha^{-1} respectively (Pits et al., 2008).

Substantial data about winter oilseed rape sowing date and rate, and fungicide application effect in autumn on winter oilseed rape yield in agro-ecological conditions of Latvia so far are little documented. Seed yield evaluation is part of our complicated research

Table 1

Soil parameters at trial site depending on year

Parameter	Year			
	2008	2009	2010	2011
pH KCl	7.4	7.2	7.2	6.7
available K, mg kg^{-1}	194	169	141	104
available P, mg kg^{-1}	115	100	111	111
humus content, g kg^{-1}	38	30	22	27

Source: made by the authors

on winter oilseed rape plant growth parameters. The aim of currently described section of our research was to investigate the influence of agro-ecological factors (sowing date and rate, and fungicide as growth regulator application) on two-type winter rape cultivars seed yield. Meteorological conditions as a factor are partly discussed. Part of data about this research has been already discussed in seminars and conferences, and described (Balodis and Gaile, 2010) using research data about yields in 2008, 2009 and 2010. After completion of the research in 2011 and data collection, analyses and conclusions are added in the current paper.

Materials and Methods

To achieve the defined aim, the four year (starting from 2007/2008 to 2010/2011) experiments were carried out in the Research and Study farm "Vecauce" (latitude: N 56º 28´, longitude: E 22º 53´) of Latvia University of Agriculture. A three-factor field trial was established using two types of winter rape (*Brassica napus* ssp. oleifera) cultivars (line 'Californium' and hybrid 'Excalibur' both bred by Monsanto Crop Science – DEKALB). The following factors were investigated:

Factor A – sowing date: A1 -1^{st} – called 1^{st} August, A2 - 2^{nd} – called 10^{th} August, A3 - 3^{rd} – called 20^{th} August, A4 - 4^{th} – called 1^{st} September, A5 - 5^{th} – called 10^{th} September.

Factor B – sowing rate (B1-120, B2-100, B3-80, B4-60 germinable seeds per m^2 – 'Californium'; B1-80, B2-60, B3-40, B4-20 germinate able seeds per m^2 – 'Excalibur' in 2007/2008 and in 2008/2009. In seasons 2009/2010 and 2010/2011, sowing rates were supplemented to equals - B1-120, B2-100, B3-80, B4-60, B5-40, B6-20 germinable seeds per m^2 for both varieties.

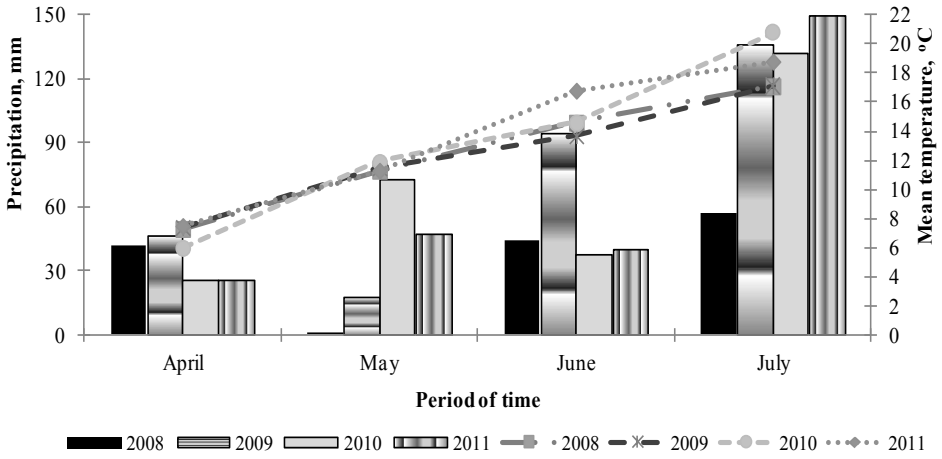
Factor C – fungicide application (C1 – control, without fungicide; C2 - fungicide applied as growth regulator). Fungicide application scheme: 0.5 L ha^{-1} of fungicide Juventus 90 s.c. (metconazole, 90 g L^{-1}) was applied at the 4-6 leaves stage:

- on rape sown on 1^{st} August –30^{th} August 2007, 8^{th} September 2008 and 2009, 9^{th} September 2010;
- on rape sown on 10^{th} August – 12^{th} September 2007, 13^{th} September 2008, 22^{nd} September 2009, 24^{th} September 2010;
- on rape sown on 20^{th} August – 27^{th} September 2007, 8^{th} October 2008, 30^{th} September 2009, 7^{th} October 2010.

Soil at the trials' site was strongly altered by cultivation in 2008 and 2011 and soil-gleyic in 2009 and 2010. Soil parameters were slightly different depending on year (Table 1).

Traditional soil tillage with mould-board ploughing was used, rototilling was performed 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 and soil properties. Top-dressing with nitrogen fertilizer at the rate of 70 kg ha^{-1} of N (ammonium nitrate) - at the start of vegetation, plus 70 kg ha^{-1} of N (ammonium sulphate) - at the stage of well developed rosette, was applied. Sowing was done close (with one or two days deviation) to established dates; deviations in some occasions occured because of inappropriate (mainly too moist) soil conditions for sowing. Weeds were controlled using herbicide Butisan Star s.c. (metasachlor, 333 g L^{-1} + kvinmerac, 83 g L^{-1}), 2.5 L ha^{-1} in 2007-2009, and 3.0 L ha^{-1} in autumn 2010. Herbicide was applied when the oilseed rape was fully germinated in plots of first three sowing dates in 2007 and 2008, and directly after sowing in 2009 and 2010 for all trial. For plots of 4^{th} and 5^{th} sowing date, 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). To decrease the possible impact of *Sclerotinia* stem rot (*Sclerotinia sclerotiorum*) incidence, fungicide Cantus d.g. (boscalid, 500 g kg^{-1}) 0.5 kg ha^{-1} was used during full flowering (GS 65). Two-factor analysis of variance was used for processing the experimental data.

Summarizing meteorological conditions of research years, it is clearly obvious that autumn meteorological conditions were different depending on year and had a significant impact on plant autumn development. Serious research results about plant autumn growth depending on meteorological conditions have already been published (Balodis, Gaile, 2011). Unusually very long autumns and warm winters were observed



Source: made by the authors

Figure 1. **Amount of precipitation and mean air temperatures in RSF "Vecauce" in vegetation periods 2008 -2011.**

in research years 2007/2008 and 2008/2009. October 2009 and 2010 characterizes with very low mean air temperatures. Comparatively harder winters with lower mean temperatures and much thicker and stable snow cover were observed in years 2009/2010 and 2010/2011.

Winter conditions had critical influence to plant survival on spring in all years. Meteorological conditions in trial year's autumns were considerably different. October 2009 and 2010 characterizes with very low mean air temperatures. Unusually long-lasting autumns and warm winters (2007/2008 and 2008/2009) were observed for both research years. Vegetative growth period from April to July (full ripening period) were also different on temperatures and precipitation (Fig. 1).

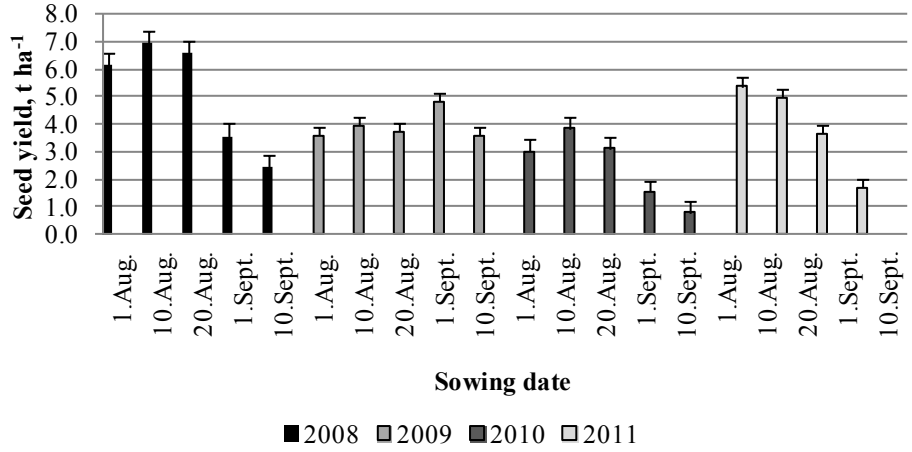
Weather conditions in April were quite similar in all trial years, and vegetation started on 1st of April in 2008 and 2010, 3rd of April in 2009, and on 5th of April in 2011. An extremely dry May was observed in years 2008 and 2009, but oil-seed rape plants used the moisture reserves suspended in soil during winter, and growth and development of crop occurred without irregularities. Precipitation in June was close to long–term observations (51 mm), with much higher precipitation in year 2009. Extraordinarily, but precipitations in July in three out of four trial years were much higher than long–term observations (75 mm). Heat wave during July in year 2010 was noted, but that with high precipitation was very favourable conditions for oilseed rape yield formation.

Results and Discussion

Sowing date influence. From the four-year results (2008-2011), it was evident that winter rape seed yield was influenced by the sowing date, which agrees with other research results (Boelcke et al., 1991), as well as by the sowing rate and fungicide application in autumn period. Meteorological conditions in autumn and summer season were different in each trial year. Significant impact ($p<0.05$) of sowing date was observed on the seed yield in all trial years for both varieties – 'Californium' and 'Excalibur'. On average (when the following sowing rates were used: 120 to 60 germinable seeds per m^2 – 'Californium'; 80 to 20 germinate able seeds per m^2 – 'Excalibur') highest seed yields were observed in year 2008, because of appropriate meteorological conditions in autumn despite the comparatively dry summer (see Figure 1). As winter 2010/2011 was unfavourable for small, immature plants (sown on 10th of September), the plants did not survive at all. Highest yields for each cultivar were achieved in different sowing dates. Average highest seed yield for line variety 'Californium' was obtained from plots sown on 2nd sowing date (10th of August) on years 2008 and 2010, in 4th sowing date (1st of September) in year 2009, and on 1st sowing date (1st of August) in year 2011 (Fig. 2).

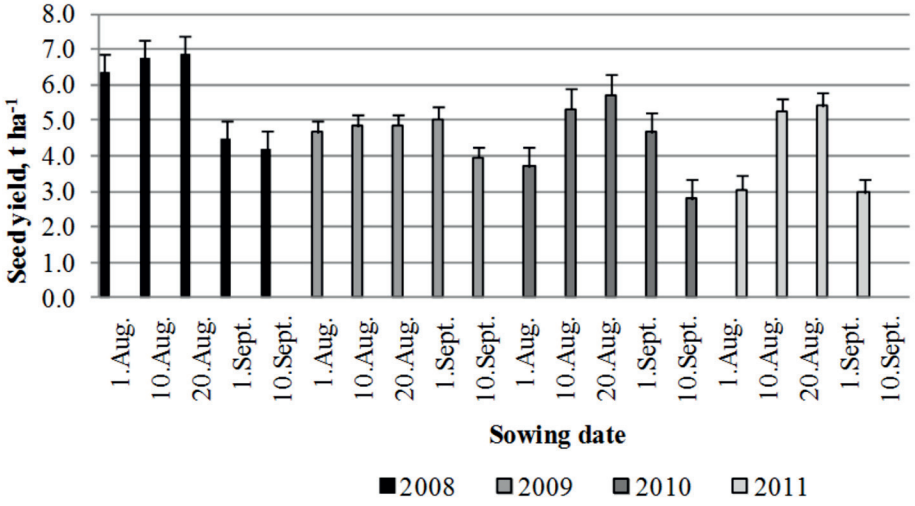
There were no significant differences in seed yield of 'Californium' when sown on 10th and 20th of August in 2008 and when sown on 1st and 20th of August and 10th of September in 2009. Also no significant difference was observed between the seed yields, obtained from plots sown on 10th and 20th of August in year 2009. In 2010 significant yield differences were not observed between plots on 1st and 20th of August, but in 2011 all yield differences depending on the sowing date were significant (Fig. 2).

Hybrid cultivar 'Excalibur' (Fig. 3) yielded the most on 3rd sowing date (20th of August) in years 2008, 2010 and 2011, but on 4th sowing date (1st of September) in year 2009. There were no significant differences in the seed yields for 'Excalibur' sown on 10th and 20th of August and 1st and 10th of September in year 2008, between that sown on 10th and 20th of August in 2010 and 2011. Interesting that seed yields in some



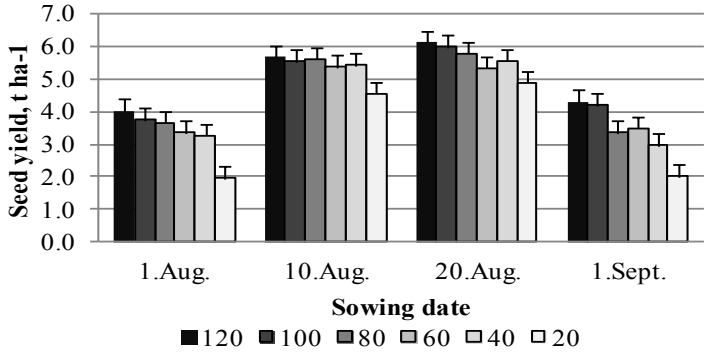
Source: made by the authors

Figure 2. **The effect of sowing date on winter oilseed rape seed yield for variety 'Californium' in years 2008-2011 (p<0.05).**



Source: made by the authors

Figure 3. **The effect of sowing date on winter oilseed rape seed yield for variety 'Excalibur' in years 2008-2011.**



Source: made by the authors

Figure 4. **The effect of sowing rate on winter oilseed rape seed yield of cultivar 'Excalibur' in year 2011 (plots sown on 10th September did not overwinter).**

cases were similar in plots sown on 1st of August and 10th of August (Fig. 3). Also it is clearly observed that seed yield from plots sown on 1st of September 2009 was not significantly higher than that obtained from plots sown on previous two sowing dates (10th and 20th of August), which is in accordance with hybridization benefit of hybrid cultivars which are more suitable for later sowing. Also 'Excalibur' sown later yielded better if compared with 'Californium' (Figs. 2 and 3).

From four trial years it is difficult to define the optimal sowing date, because of variable results, but if results are expressed on average from all trial years then the highest yield was observed for cultivar 'Californium' (line) sown on 10th August and for cultivar 'Excalibur' (F1) – sown on 20th August.

Sowing rate effect. Plant density (sowing rate – factor B) has a significant role in yield formation for winter oilseed rape (Sierts et al., 1987; Butkute et al., 2006). It is similar to our results of sowing rate effect on seed yield. The highest seed yields were gained with relatively highest sowing rates (actual plant densities at harvest are not considered in current paper) in our experiment. For 'Californium' on average 120 germinable seeds per m^2 yielded most in all trial years and 80 germinable seeds per m^2 in years 2008 and 2009, but for 'Excalibur' it is interesting that on average 120 germinable seeds per m^2 yielded the most in years 2010 and 2011 (Fig. 4), when equal sowing rates were used (see section Materials and Methods).

Results with 'Excalibur' showed that sowing rate and plant density have to be more analyzed as a very important yield formation factor and yield structural element, e.g., in 2011,the importance of sowing rate was more marked in sowing dates which influenced the yield mostly - 1st of August and 1st of September. Plants sown on 1st of August showed tendency to overgrow - exceeded plant biometrical parameters for successful wintering were noted. However, sowing rate had insignificant ($p>0.05$) impact on seed yield in two out of four years – 2008 and 2011 for 'Californium', and in year 2010 for 'Excalibur'.

Fungicides effect. The four-year trial results (2008-2011) we suggest that winter oilseed rape seed yield was influenced by fungicide application in autumn period, and the effect of fungicide application in its turn depended on sowing date and sowing rate. Seed yields were positively affected because fungicide application probably improved plant overwintering and also decreased disease incidence level in autumn period. Such observations agree with the literature data (Leach et al., 1994; Butkute et al., 2006). We have already analysed the fungicide application effect on plant biometrical indicators in our previous research (Balodis, Gaile, 2011a). Higher yields caused by fungicide application for each variety were achieved in different sowing dates, and in few cases fungicide application had no positive effect on the seed yield (Table 2). Plant growth regulation is expected to give a greater effect on plant biometrical parameters which causes seed yield increase mostly in early sowing dates – 1st of August in our experiment. The seed yield was affected by fungicide treatment in all trial years, and mainly we obtained the expected result that seed yield increased. Nevertheless, an exception was noted when rape was sown on 1st of August in 2009 for both varieties and for 'Excalibur' sown on 10th of August in years 2009, 2010 and 2011, and on 20th of August in 2009, 2011 (Table 2). Fungicide application had a statistically significant impact on the average seed yield in all trial years for both varieties; an exception was for 'Excalibur' in year 2009, but still tendency of yield increase was observed in two sowing dates (Table 2).

Interesting that fungicide positively affected the seed yield for 'Excalibur' that was sown as early as on 1st of August because that sowing date is untimely or overly early for a hybrid cultivar. So that discovers oilseed rape growers much larger variability to get higher seed yields, because use of a hybrid variety in combination with growth regulation

Table 2.

Fungicide effect on average seed yield (t ha^{-1}) depending on sowing date in years 2008-2011

Variety	Sowing date	2008		2009		2010		2011	
		C1†	C2‡	C1†	C2‡	C1†	C2‡	C1†	C2‡
Californium	1st August	6.16	7.15	3.61	3.49*	3.02	4.11	5.37	5.54*
	10th August	6.93	7.87	3.97	4.17	3.85	3.80*	4.97	5.27
	20th August	6.60	7.37	3.75	4.37	3.14	3.59	3.67	4.08
Excalibur	1st August	6.38	6.77	4.66*	4.25*	3.71	5.66	3.06	4.39
	10th August	6.97	7.75	4.83*	4.85*	5.33	5.04*	5.25	5.13*
	20th August	6.38	6.77	4.86*	5.59*	5.71	6.65	5.40	5.43*

C1†- control; C2‡ - fungicide treated plants; *$p>0.05$, when C1 and C2 are compared within the same sowing date in a definite year;

Source: made by the authors

possibilities gained higher yields in three out of four trial years.

Conclusions

Significant impact ($p<0.05$) of sowing date was observed on the seed yield in all trial years for both varieties – line type 'Californium' and hybrid type 'Excalibur'. Highest yields for each variety were achieved in different sowing dates, but on average from all trial years the highest yield was observed for 'Californium' sown on 10th August and for 'Excalibur' F1 – sown on 20th August.

The highest seed yields were gained with highest sowing rates. In the present experiment, plots sown at rate of 120 germinate able seeds per m^2 on average yielded the most in all trial years for 'Californium' and for 'Excalibur' - in 2010 and 2011, but 80 germinable seeds per m^2 in years 2008 and 2009 for 'Excalibur'. Sowing rate and plant density have to be analyzed more in detail as very important yield formation factors and yield structural elements.

Higher yields caused by fungicide as growth regulator application in autumn for each variety were achieved when sown in different sowing dates, but mainly when sown until 20th of August. Later sown rape did not reach the sufficient development stage for fungicide application. In some cases fungicide application had no positive effect on seed yield. Positive effect of fungicide application has to be analysed in combination with plant biometrical parameters in autumn and overwintering results.

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