WINTER OILSEED RAPE (*BRASSICA NAPUS* L.) AUTUMN GROWTH

Oskars Balodis, Zinta Gaile
Latvia University of Agriculture
balodis.oskars@inbox.lv

Abstract

Lack of data about effect of meteorological conditions, sowing date, sowing rate, fungicide as growth regulator application and other agroecological factors on rape autumn growth is observed in Latvia. The aim of our research, started in autumn 2007 and continued up to autumn 2010 in 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 as well as meteorological conditions on autumn plant growth of two types of winter rape varieties. Winter rape biometrical parameters were estimated, and meteorological parameters (hydrothermal coefficient (HTC) and growing degree days (GDD)) were calculated. Four year results showed that winter oilseed rape seed germination was affected by precipitation and air temperature around the sowing time. Calculated GDD correlated with plant biometrical parameters during trial years. HTC showed moisture effect on rape emergence time. Sowing date was important factor which 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, and main root length significantly for both cultivars in four trial years. Such agro-ecological factor as sowing rate (plant density) affected plant biometrical parameters only in some trial years. Plant weight was significantly influenced by sowing rate for both cultivars if sowing rates were equal. Other important parameter – height of growth point – was not significantly influenced by sowing rate for both cultivars when similar sowing rates were used in all years; exception was year 2009 for 'Californium'.
Key words: winter rape, sowing date and rate, growing degree days, hydro-thermal coefficient.

Introduction

Winter oilseed rape (*Brassica napus* L.) has become one of the basic crops in modern crop farming in Europe and Latvia. No decrease in oilseed rape cropping area has been observed during the last twelve years, and area under rape reached 109 400 ha in Latvia. Latvia, especially its central region, has suitable soils and meteorological conditions for winter rape cultivation. Proportion 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; at the same time, if winter is hard, spring oilseed rape proportion from the total area can again increase (winter rape – 61% in 2010 from the total area sown with rape according to data of Central Statistical Bureau of Latvia). For good rape wintering, meteorological conditions in autumn as well as technology used are important factors.

Meteorologist M. Rummukainen (2010) mentions that drought is becoming a factor to be considered also in the Nordic and Baltic Sea region. Various climate extremes also seem to change. Some examples are frequency of intensive precipitation, cold spells, and heat waves. Therefore analyzing winter oilseed rape and also other winter crop growth during autumn effect of meteorological condition on plant development has to be more carefully analyzed. Hydrothermal coefficient (HTC) is one of the tools for interpretation of meteorological conditions' effect on plant development used in wheat and other crops and even in forestry. HTC till now is less used for oilseed rape growing issue interpretation (Ozolincius et al., 2005; Povilaitis and Lazauskas, 2010).

Rape seed germination and early development mainly is affected by soil moisture and temperature. Important rape plant development functions such as evapotranspiration, photosynthesis, water and nutrient absorption and other biological and chemical activities are regulated by temperature (Rapacz, 1998; Diepenbrock, 2000). Temperature effect on rape plant development can be interpreted as Growing Degree Days (GDD) and Corn Heat Units (CHU); both measures of heat accumulated by a crop over a period of time. GDD are much simpler to calculate and prove a good estimation of accumulated heat for most cool season crops like oilseed rape and wheat (Bonhomme, 2000). GDD calculation is more popular in Canada and United States, but less popular in Europe. To evaluate the risks of sowing time selection, the 'typical' GDD for specific area should be known. Such information about 'typical' GDD in rape growing areas of Latvia is not found while enough climate data websites are available for Canada with GDD maps. Some researches about winter oilseed rape autumn development with specific accent on GDD in a region close to Latvia are found (Sidlauskas and Rife, 1999; Laaniste et al., 2007).

Growth, development and seed yield of winter oilseed rape are closely related to sowing date and plant (sowing) density. A number of environmental factors interact with optimal sowing like soil temperature and moisture level affecting germination (BBCH 00–09) and seedbed preparation. Some objectives must be taken into account when choosing a sowing date: (1) ensuring that high-quality germination and emergence are possible; (2) optimizing the weight and number of the harvested plant parts; and (3) timing the cycle so as to limit the incidence of periods unfavourable to the crop (various stresses, parasites, frost, drought, etc.) (Fleury, 1986 cited by Rathe et al., 2006).

Plant density has been observed to have a huge influence on growth, development and seed yield of winter oilseed rape (Leach et al., 1999; Diepenbrock, 2000). Stand establishment generally varies depending on different important circumstances, such as soil condition and water availability during germination as well as weather conditions (Mendham et al., 1981). Optimal plant density varies depending on oilseed rape growing region. Optimal plant density is about 80–150 plants m^{-2} before winter and 60–80 plants m^{-2} at the beginning of spring, respectively. Lower seeding densities (60–70 seeds m^{-2}) are required for hybrids, as mentioned by W. Sauermann (1995) (cited by Diepenbrock, 2000) in Germany, but optimum crop density for successful wintering in Nordic states is reported to be 30 to 70 plants m^{-2} (Velicka, 2003). Required optimal densities are changing in length of time together with availability of more knowledge of rape yield formation.

In agro-ecological conditions of Latvia, data on winter rape plant autumn development is little documented. The aim of currently described section of our research was to investigate the influence of agricultural practice (sowing date and sowing rate) and meteorological conditions on autumn plant development two types of winter rape varieties. Part of research was described already in 2009 (Balodis and Gaile, 2009) using data about plant biometrical parameters in 2007 and 2008. Now research is complete, and new data, analyses and conclusions are added in the current paper.

Materials and Methods

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. Three-factor field trial using two types of winter rape (*Brassica napus* ssp. oleifera) cultivars (line 'Californium' and hybrid 'Excalibur') was carried out. The paper is focused on plant autumn growth results for all four seasons. The following factors were investigated:

Factor A – sowing date:
1st – called 1st August,
2nd – called 10th August,
3rd – called 20th August,
4th – called 1st September,
5th – called 10th September.

Factor B – sowing rate (120, 100, 80, 60 germinable seeds per m^2 – 'Californium'; 80, 60, 40, 20 germinate able seeds per m^2 – 'Excalibur' in 2007/2008 and in 2008/2009). In seasons 2009/2010 and 2010/2011, the sowing rates were supplemented to equals – 120, 100, 80, 60, 40, 20 germinable seeds per m^2 for both cultivars.

Soil at the trial site was strongly altered by cultivation in 2007 and 2010, and by soil-gleyic in 2008 and 2009; grading composition was loam; pH KCl = 6.7 to 7.4; content of available for plants K was 103 to 194 mg kg^{-1}, and P – 100 to 136 mg kg^{-1}; humus content – 25 to 38 g kg^{-1}. Pre-crop was cereal mixture for silage in all years. Traditional soil tillage with mould-board ploughing was used, 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}, except autumn and in 2010 when 3.0 L ha^{-1} were applied. The herbicide was applied 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 and in all plots in 2009 and 2010 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, 10-plant samples were taken randomly from each plot for biometrical analysis. Number of leaves per plant (No), leaves', plant and roots' 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 first, second and third sowing date and all plants sown on 4th and 5th date were taken for from 1.0 m^2 dry matter content analyses. Dry matter of leaves was determined by drying at temperature of 105 °C for 2 hours (ISO 6496: 1999). The dry matter yield of rape leaves per m^2 was calculated according to plant number per 1 m^2.

To describe conditions of autumn growth, meteorological parameters were analyzed. Meteorological data were collected from automatically working meteorological station approximately 1 km from trial site. Hydrothermal coefficient (HTC) was calculated using (1) formula of G. Selianinov:

$$HTC = \frac{R \times 10}{\sum t} \quad (1)$$

where R – is the sum of precipitation (mm) during (ten-day) period;
$\sum t$ – the sum of the average daily temperatures during the same period.

The growing degree days (GDD) were calculated using (2) formula:

$$GDD = \frac{(T_{\max} + T_{\min})}{2} - T_{base} \quad (2)$$

where T_{max} – daily maximum temperature;
T_{min} – daily minimum temperature;
T_{base} – base temperature (5 ºC).

ANOVA procedures were used for processing the experimental data.

Meteorological conditions in the autumn of all trial years were considerably different. October 2009 and 2010 was characterized by very low mean air temperatures. August 2009 and September 2008 were relatively dry, but wet August 2010 was extremely.

Vegetative period (mean temperature below 5 ºC for at least 3 days) ended on 4th of November in 2007; and 2008 and renewed for eight to five days period up to 4th

December; at 1st of November in 2009; (two-week period in the middle of the October registered with very low temperatures); at 7th of November in 2010.

Results and Discussion

Oilseed rape autumn growth depending on meteorological conditions

Winter oilseed rape seed germination (BBCH 09) length in days was different depending on the sowing year and the sowing time because of different soil moisture. A more even seed germination was observed in autumn 2007 (seeds germinated in 8 to 10 days). The longest germination time was observed in plots sown on 1st August in 2008 and 2009 (15 and 16 days), and in plots sown on 10th September in 2008, 2009 and 2010 (14 to 17 days).

Our observations showed that appropriate soil moisture and productive precipitations were very significant for successful field-germination of seed. Water stress expressed as hydrothermal coefficient gives clear explanation about seed germination speed. Dependence on soil moisture, especially at the beginning of August when mean air temperature is high and soil surface dries quickly, is critical for seed germination. The first decade in August was critical (HTC below 1.0) because of amount of precipitation in all four trial years; even in years 2008 and 2009 lack of precipitation was observed in the ten-day period before 1st sowing date, which that explains the slow seed germination (Fig. 1).

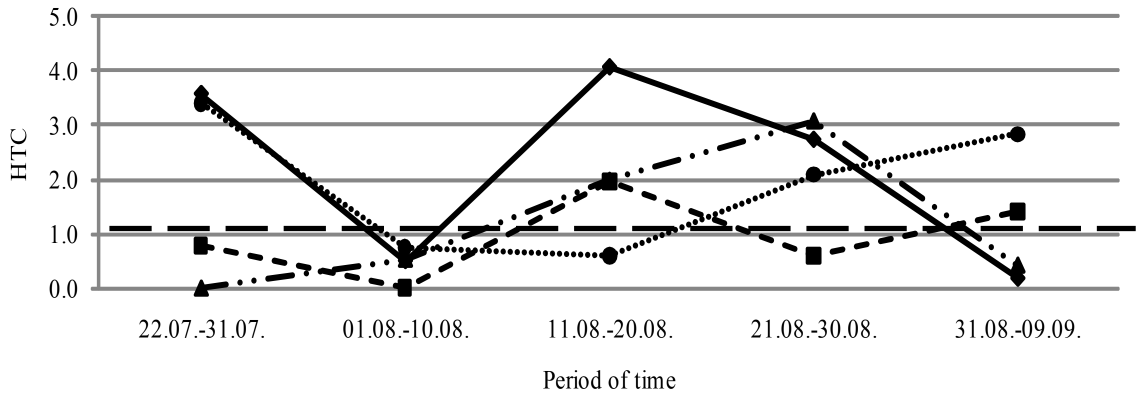

Figure 1. Water stress expressed as hydrothermal coefficient in RSF 'Vecauce' in autumn 2007, 2008, 2009 and 2010. (▬ - year 2010; ▬ · · · - year 2009; – – - year 2008; ····· - year 2007; ▬ ▬ - threshold).

The role of temperature in seed germination increases with later sowing date. Longer time for seed germination was dependent on the air and soil temperature, which agrees with data of R.E. Blackshaw (1991) who emphasizes the role of moisture and temperature role for seed germination – in dry and hot conditions seed germination was delayed for three days, but in cool conditions – for up to six days. On the last sowing date, in the first decade of September, the importance of precipitation decreased because of a lower air temperature that reduced water evaporation; however seed germination still had connection to HTC values (see Fig. 1) when longest seed germination was observed in 2010 (17 days, HTC 0.2) and fastest germination – in 2007 (9 days, HTC 2.8). Difference in germination length between the cultivars was not observed.

Oilseed rape plants require a specific number of GDD to develop from growth stage to growth stage between emergence, flowering and maturity. Also the specific amount of GDD has to be accumulated before oilseed rate wintering. In our experiment GDD had various values because of different meteorological conditions in all trial years. Four years' data indicated that sowing time on 1st August (478 GDD till the end of vegetation period as four-year average) was risky because the rapeseed plants tended to overgrow, especially in autumn 2007 (567 GDD) when the height of root column, which is the most vulnerable part of the rapeseed plant, reached up to 5 cm above the soil surface. This agrees with Laaniste et al. (2007) who reported overgrown plants in Estonian conditions when 515 GDD were accumulated. On the other hand, if sowing was performed later than 1st September, especially in years 2009 (60 GDD) and 2010 (38 GDD), only 3-4 small leaves formed which were exposed to the danger for winter-kill. The autumn development of oilseed rape plants may affect not only their wintering and subsequent vegetative renewal in spring, but also the yield. A number of leaves was affected by accumulated GDD in three trial autumns (2008, 2009, and 2010 – Fig. 2) only for hybrid cultivar 'Excalibur'. The plant produced a sufficient number of leaves for successful wintering (five leaves according to Velicka et al., 2006).

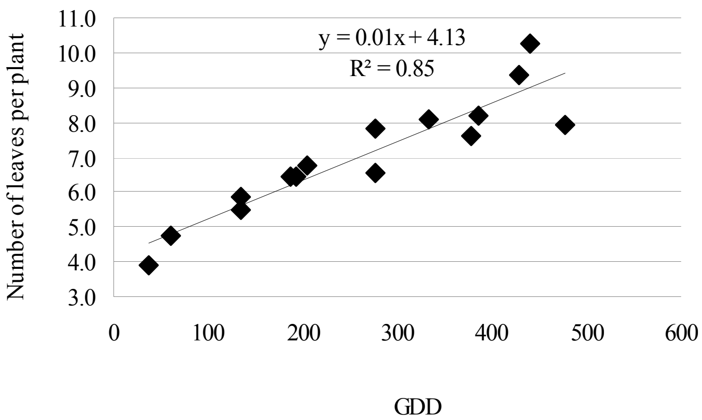

Figure 2. The relationship between GDD (x) and number of leaves per plant (y) for 'Excalibur' in years 2008, 2009, and 2010 ($p<0.05$).

More important is leaf area expansion before wintering, as declared by G. Sidlauskas and C. Rife (1999). They admitted that only 5 leaves reached the maximum leaf area during autumn vegetative growth (the plant received 552 GDD until the end of vegetative period). In our trial it was observed that especially in the last sowing dates the plant leaves did not reach full expansion and leaf area was dramatically lower, which was proved by calculating the last dry mass (DM) from 1 m^2 (Fig. 3). A significant relationship between GDD and root neck diameter was observed for both cultivars in all trial years ($y = 0.0153 + 0.4783x$ and $R^2=0.89$ for 'Californium'; $y = 0.0204x + 0.6800$ and $R^2=0.93$ for 'Excalibur'). A significant ($p<0.05$) linear relationship was also observed between GDD and height of growth point, root mass and length.

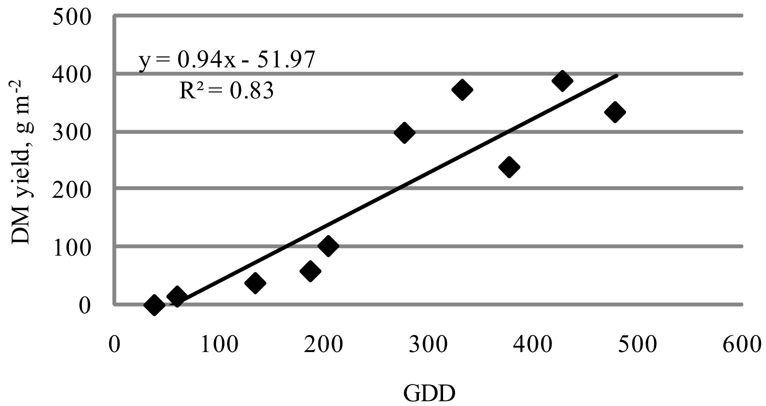

Figure 3. The relationship between GDD (x) and DM mass of oilseed rape leaves (y) at the end of autumn growth for 'Excalibur' in years 2009 and 2010.

Plant DM mass of leaves per 1 m^2 at the end of vegetation in five sowing dates had strong relationship with GDD, which underlines to the importance of GDD in plant preparation for successful wintering (Fig. 3). Correlation between GDD for 'Californium' was not statistically significant ($p>0.05$). The trend (Fig. 2) shows relationship that DM of aboveground vegetation depends mostly on the accumulation of GDD which agrees with G. Sidlauskas and C. Rife (1999). Also GDD relationships with plant fresh mass, plant leaf number, and root mass were observed in our experiment. More investigations should be performed on GDD impact on winter rape dry mass indices of different plant parts.

Effect of sowing date

Important plant parameters (plant fresh mass, height of growth point, root neck diameter, number of leaves per plant, shoot mass and length) that characterize plant autumn development were measured each experimental year. From the four-year results (2007-2010) it is evident that winter rape biometrical parameters were influenced by the sowing date, rate and fungicide application in autumn period, as well as by used cultivar. Sowing date had the most important and significant ($p<0.05$) impact on plant parameters if compared with sowing rate (density). A significant ($p<0.05$) impact of sowing date on all measured winter rape parameters in autumn 2007, 2008, 2009 and

2010 was noted. The proportion of sowing date influence (η%) on plant parameters showed that in all experimental years greater effect of the sowing date was on the height of growth point and root neck diameter (Table 1).

Table 1

Proportion (η%) of sowing date influence ($p<0.05$) on winter oilseed rape plant parameters of cultivars 'Californium' and 'Excalibur' in autumns 2007 – 2010

Evaluated parameters	2007		2008		2009		2010	
	C†	E‡	C†	E‡	C†	E‡	C†	E‡
Height of growth point	92	95	84	90	93	90	95	95
Root neck diameter	82	81	89	89	89	78	94	86
Plant mass	70	55	71	79	72	53	83	63
Number of leaves	70	66	43	58	73	34	79	59
Root mass	77	66	84	87	80	63	87	69
Root length	82	68	82	94	73	90	88	92

C† – line cultivar 'Californium; E‡ – hybrid cultivar 'Excalibur'

Four-year experiments showed that extremely high growth point was determined for early sownrape (e.g. 1st August; 43.0 mm for 'Californium', 66.4 mm for 'Excalibur' in 2007), and lowest height of growth point was observed on the last sowing date (e.g. 10th September; 2.0 mm for 'Californium', 2.2 mm for 'Excalibur' in 2010). 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); however but experience shows that plants with higher plant parameter values which could be theoretically risky for overwintering have survived well in specific conditions. In our experiment plants tended to overgrow in year 2007 because of the height of growth point reached up above the soil surface, which is risky for overwintering according to Laaniste (2007). In experimental years with equal sowing rates for both cultivars (2009 and 2010), higher average height of growth point was observed for 'Excalibur' (e.g., 1st August – 44.8 mm in 2010 and 33.6 mm in 2009). Four-year experiment gives evidence that height of growth point decreased in later sowing dates and was especially affected by meteorological conditions in a specific autumn. Also lower height of growth point was observed for line-type cultivar if compared to hybrid cultivar.

Plant leaf number (leaf area is even more important) is also a parameter that influences plant survival during autumn and affects the seed yield (because of more plant branching). Results of Estonian researchers (Laaniste et al., 2007) indicate that plants before wintering reach 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. Sowing date significantly ($p<0.05$) affected the number of leaves per plant for both cultivars in all trial years (Table 1). In 2009-2010 (equal sowing rates were used for both cultivars), also a tendency was observed that hybrid cultivar 'Excalibur' developed more leaves than line cultivar 'Californium'.

Table 2

Average number of leaves depending on the sowing date in years 2009 and 2010

Sowing date	Californium		Excalibur	
	2009	2010	2009	2010
1st August	7.6	7.2	8.9	7.2
10th August	6.5	7.5	6.9	7.6
20th August	6.5	5.7	7.0	6.5
1st September	5.1	4.9	6.2	5.5
10th September	3.7	3.4	4.8	3.8
$RS_{0.05}$	0.42	0.37	0.76	0.46

Significant differences in the number of leaves were not noted between the plants sown on 10th and 20th August 2009, but in the year 2010 – between 1st and 10th August (Table 2). It is with certainty evident than in late sowing dates of 2009 and 2010 the number of leaves was lower than in years 2007 and 2008 (e.g., sown on 10th of September– on average 4.5 leaves for 'Californium', and leaves 5.5 for 'Excalibur' in 2007; 5.4 leaves for 'Californium', and 5.9 leaves for 'Excalibur' in 2008). Importance of number of leaves difference between plants sown in different dates could affect plant wintering and has to be analyzed with wintering issue in spring.

Sowing date affected also the root neck diameter significantly ($p<0.05$) for both varieties in all trial years, and sowing date impact on this parameter was within η – 78.1% for 'Excalibur' in 2009 and η – 94.3% for 'Californium' in 2010 (Table 1). Root neck diameter decreased with later sowing date (on average from all trial years, from 7.2 mm in plants sown on 1st August to 1.8 mm in plants sown on – 10th September for 'Californium'; 9.8 mm for plants sown on 1st August to 2.3 mm – 10th September for 'Excalibur'). Root neck diameter of plants sown on last two sowing dates was less than 5 mm in all trial years, which might be risky for good rape wintering according to Velicka et al. (2006). The same tendency was observed also for root neck diameter. This parameter in of hybrid cultivar 'Excalibur' was greater than in line cultivar 'Californium', which was especially marked in the year 2010 then October was very cool and 'Excalibur' developed larger root neck diameter in the last two sowing dates (3.0 mm in plants sown on 1st September, and 1.4 mm in plants sown on 1st September for 'Excalibur', and 1.8 mm and 1.2 mm for 'Californium' respectively).

Average fresh plant weight from all trial years was from 90.4 g in plants sown on 1st August 2007 to 0.8 g in plants sown on 10th September 2010 for 'Excalibur and', 42.3 g in plants sown on 19th August on 2008 to 0.5 g in plants sown 0n 10th September 2010 for 'Californium'. Plant weight parameter showed a very similar tendency, and also the values of plant weight were similar in years 2009 and 2010 (equal sowing rates for both cultivars). Root weight and root length also were significantly ($p<0.05$) influenced by the sowing date for both cultivars in all trial years. The same tendency was observed that root weight and root length decreased in later sowing dates: average root weight from all years: was within 5.3 g in plants sown on 1st August and 0.1 g in plants sown on 10th September for 'Californium, and with in 12.7 g in plants sown on 1st August and 0.2 g in plants sown on 10th September for 'Excalibur'; average length was within 20.9 cm in plants sown on 1st August and 9.2 cm in plants sown on 10th September for 'Californium, and within 23.8 cm in plants sown on 1st August and 10.6 cm in plants sown on 10th September for 'Excalibur'.

Effect of sowing rate

Plant development parameter in autumn – plant weight – was significantly ($p<0.05$) influenced by sowing rate in some cases (for 'Excalibur' in years 2007, 2009, and 2010; for 'Californium' only in years 2009 and 2010). Use of equal sowing rates for both cultivars in 2009 and 2010 allows discussing sowing rate (plant density) impact on plant weight with more certainty. Plant weight using sowing rate of 120 germinable seeds per 1 m^2 was nearly three times smaller than using 20 germinable seeds per 1 m^2 for both cultivars (Fig. 4). Also plant weight was significantly ($p<0.05$) influenced by sowing rate in years 2009 and 2010 (Fig. 4) for both cultivars.

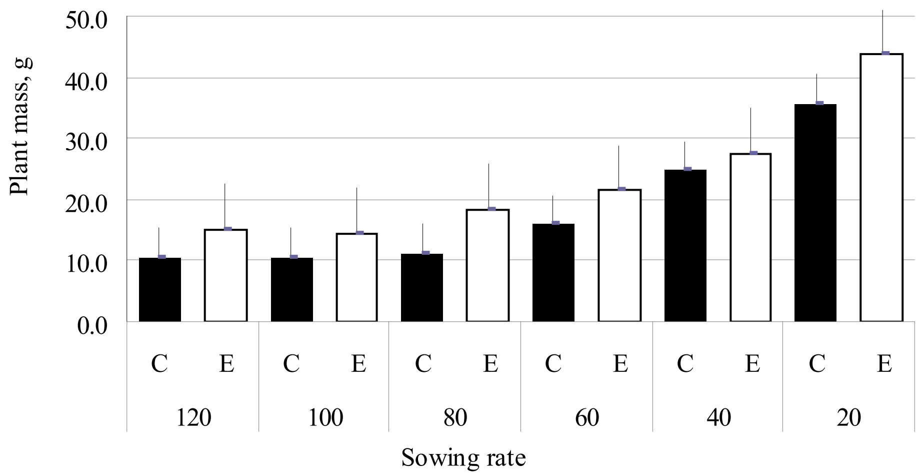

Figure 4. Sowing rate influence on winter rape plant mass of cultivars 'Californium' and 'Excalibur' in autumn 2010 (■ – 'Californium' (C); □ –'Excalibur'(E)).

Four-year results showed that height of growth point was not significantly influenced the by sowing rate for both cultivars when equal sowing rates were used, the exception was year 2009 for 'Californium' when sowing rate showed significant ($p<0.01$) impact on height of growth point using rates from 20 up to 120 germinable seeds per 1 m^2.

Sowing rate significantly ($p<0.05$) influenced winter oilseed rape root weight and root neck diameter for cultivar 'Californium' in the years 2009 and 2010 (when low sowing rates were used) and for 'Excalibur' in 2007, and in 2009 as well as 2010 when also high sowing rates were used. Root length was not significantly ($p>0.05$) influenced by the sowing rate in all trial years for both cultivars.

Conclusion

1. Four-year results showed that winter oilseed rape seed germination was affected by the amount of precipitation and air temperature around the sowing time. Seed germination was delayed for some days during drought (HTC<1) on some sowing dates in several trial years. The accumulated GDD during autumn vegetation correlated with plant biometrical parameters during trial years.
2. Sowing date was an important factor which had a strong and significant impact on rape plant development in autumn. Sowing on earlier dates significantly increased the height of growth point, root neck diameter, plant and root mass, and main root length for both cultivars (line and hybrid) in four trial years.
3. Sowing rate (plant density) affected plant biometrical parameters only in some trial years. Plant weight was significantly influenced by the sowing rate for both cultivars when sowing rates were equal. The height of growth point was not significantly influenced by sowing rate for both cultivars even if equal sowing rates were used in all years; exception was year 2009 for 'Californium'.

Acknowledgements

The study was supported by ESF Project 2009/0225/1DP/1.1.2.1.2/09/IPIA/VIAA/129.

References

1. Balodis O., Gaile Z. (2009) Influence of agroecological factors on winter oilseed rape *(Brassica napus* L.) Autumn growth. In: Gaile Z., Ciproviča I., Kaķītis A., et al. (eds) Research for Rural Development – 2009. *International Scientific Conference Proceedings*, Jelgava, LLU, pp. 36-43.
2. Becka D., Vasak J., Kroutil P., Stranc P. (2004) Autumn growth development of different winter oilseed rape variety types at three input levels. *Plant and Soil Environment*, 50, pp. 168-174.
3. Blackshaw R.E. (1991) Soil temperature and moisture effects on downy brome vs. winter canola, wheat and rye emergence. *Crop Science*, 31, pp. 1034-1040.
4. Bonhomme R. (2000) Bases and limits to using 'degree day' units. *European Journal of Agronomy*, 13, pp. 1-10.
5. Diepenbrock W. (2000) Yield analysis of winter oilseed rape (*Brassica napus* L.): a review. *Field Crop Reaserch*, 67, pp. 35-49.
6. Laaniste P., Joudu J., Eremeev V., Maeorg E. (2007) Sowing date influence on winter oilseed rape overwintering in Estonia. *Acta Agriculturae Scandinavica. Section B-Soil and Plant Science*, 57, pp. 342-348.
7. Leach J.E., Stevenson H.J., Rainbow A.J., Mullen L.A. (1999) Effects of high plant population on growth of winter oilseed rape (*Brassica napus*). *Journal of Agriculture Science,* 132, pp. 173-180.
8. Mendham N.J., Shipway P.A., Scott R.K. (1981) The effect of delayed sowing and weather on growth, development and yield of winter oil-seed rape (*Brassica napus*). *Journal of Agriculture Science*, Cambridge, 96, pp. 389-416.
9. Povilaitis V., Lazauskas S. (2010) Winter wheat productivity in relation to water availability and growing intensity. *Žemdirbystė–Agriculture*, 97 (3), pp. 59-68.
10. Ozolincius R., Stakenas V., Serafinaviciute B. (2005) Meteorological factors and air pollution in Lithuanian forests: possible effects on tree condition. *Enviromental pollution*, 137 (3), pp. 587-595.
11. Rapacz M. (1998) The effects of day and night temperature during early growth of winter oilseed rape (*Brassica napus* L. var. *oleifera* cv. *Gorczanski*) seedlings on their morphology and cold acclimation responses. *Acta Physiologiae Planitarium*, 20 (1), pp. 67-72.
12. Rathke G.-W., Behrens T., Diepenbrock W. (2006) Integrated nitrogen management strategies to improve seed yield, oil content and nitrogen efficiency of winter oilseed rape (*Brassica napus* L.): a review. Agriculture, Ecosystems and Environment, No.117, pp. 80-108.
13. Rummukainen M. (2010) Climate outlook for the Baltic sea region. *NJF report* 6. (1.) pp. 12-13.
14. Sidlauskas G., Rife C. (1999) Environmental and agronomic factors affect on the growth of rape leaves in autumn. *Proceedings of 10th International Rape Congress, Canbera, Australia, 1999*. Available at: www.regional.org.au/au/gcirc/index/references.htm, 2 March 2011.
15. Velicka R. (2003) *Rape:* Summary of the monograph, presented for habilitation confer. Lithuanian University of Agriculture, Kaunas, 78 p.
16. Velicka R., Marcinkeviciene A., Raudonis S., Rimkeviciene M. (2006) Integrated evaluation of rape readiness for overwintering. *Acta Agriculturae Scandinavica Section B-Soil and Plant Science*, 56, pp. 110-116.