FUNGICIDE AS GROWTH REGULATOR APPLICATION EFFECT ON WINTER OILSEED RAPE (*BRASSCIA NAPUS* L.) AUTUMN GROWTH

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ABSTRACT. *Plant growth regulation during autumn is one of the instruments for oilseed rape growers to improve plant readiness for winter. Influence on plant biometrical parameters by fungicide as growth regulator application allows affect one of the significant risk factors for successful growing of winter oilseed rape – winterhardiness. The aim of our research, started in autumn 2007 and continued up to autumn 2010 in Research and Study farm 'Vecauce' of Latvia University of Agriculture, was to investigate the influence of fungicide (Juventus 90 s.c. – metconazole, 90 g L^{-1}; dose: 0.5 L ha^{-1}) as growth regulator application depending on sowing date (five dates) and sowing rate (four rates) in autumn on two type winter rape cultivars' (line 'Californium' and hybrid 'Excalibur') autumn plant development. Results showed that fungicide application affected oilseed rape plant biometric parameters during autumn, but effect depended on conditions in research year, as well as used cultivar. Sowing time also had influence on increase or decrease of some plant biometrical parameters. Parameters affected significantly ($P < 0.05$) on average by fungicide application were: total plant mass significantly increased in year 2009 for 'Californium', decreased in years 2007 and 2010 for 'Excalibur'; height of growth point decreased for 'Californium' in year 2007 and 2010, but increased in 2008, but that of 'Excalibur' decreased in years 2007, 2009 and 2010; root neck diameter decreased only in years 2007 and 2010 for 'Excalibur'; number of leaves increased in all trial years except year 2010 for both varieties; root length increased in years 2008 and 2009 for 'Excalibur'. Root mass changes in result of fungicide application were insignificant in all trial years. Fungicide application effect depended also on sowing date, but in majority cases were not related to sowing rate.*

Keywords: *winter oilseed rape, sowing date and rate, growth regulator, plant biometric indices.*

Introduction

Wintering of oilseed rape depends on the plant development stage at the end of vegetation period, but plant development could be affected by the growing manner including used cultivar, application of growth regulators and agro-climatic factors. Before the winter period, rapeseed plant should create reasonable plant mass and has to develop definite plant parameters for root-neck diameter, height of growth point above the soil level, and number of leaves. Overgrowing risk exists because of very early sowings and warm autumns. Growth regulation is one of the possibilities to control plant growth during autumn.

Cell division and cell elongation of shoots are usually controlled by the application of growth regulators resulting altered yield structure and reduced plant height, as well as reduced leaf area and increased root/shoot ratio (Bruns *et al.*, 1990; Fisahn, Hofner, 1995). Some researchers from Lithuania in other conditions reported (Gaveliene *et al*., 2002; Miliuviene *et al*., 2004) that application of growth regulator increases number of leaves per plant and root-neck diameter, and decreases height of growth-point of winter rape, thus favouring winterhardiness of the crop. Moreover, growth regulators are used to improve plant survival during winter, to limit development of oilseed rape plants especially with high N-regimes and early sowing date, as well as to increase cold tolerance due to reduction in stem length. Growth regulator application is often combined with use of fungicides application. Moreover, side effects of fungicides are used to regulate plant growth. During shooting application of growth regulators decreases plant height and improves plant stability to prevent lodging and influences yield structure where effectiveness depends on cultivar (Rao *et al*., 1991; Gans *et al*., 2000).

The aim of our research, started in autumn 2007 and continued up to autumn 2010 in Research and Study farm 'Vecauce' of Latvia University of Agriculture, was to investigate the influence of fungicide (Juventus 90 s.c. – metconazole, 90 g L^{-1}; dose: 0.5 L ha^{-1}) as growth regulator application depending on sowing date (five dates) and sowing rate (four rates) in autumn on two type winter rape varieties' (line 'Californium' and hybrid 'Excalibur') autumn plant development.

Materials and methods

The experiments were carried out on winter oilseed rape (*Brassica napus* ssp. oleifera) plants. Four year (starting from 2007/2008 to 2010/2011) investigations 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 type winter rape varieties (line 'Californium' and hybrid 'Excalibur', both bred by Monsanto Crop Science) was carried out; the paper is focused on fungicide as growth regulator application effect on plant autumn growth results for all four seasons (2007, 2008, 2009, 2010). The following factors were investigated:

Factor A − sowing date: starting on 1st August with ten day interval to 10th September (five sowing dates in total). Sowing was done close (with one or two days deviation) to established dates in some occasion because of inappropriate (mainly too moist) soil conditions for sowing. Data of three first sowing dates are represented in this paper because it was without agronomical rationale to apply growth regulator for small plants sown on 1st and 10th September.

Factor B – fungicide application (B1 – control, without fungicide; B2 – fungicide applied as growth regulator). Fungicide application scheme: 0.5 L ha^{-1} dose of fungicide Juventus 90 s.c. (metconazole, 90 g L^{-1}) was applied at the 4-6 leaves stage:

- on rape sown on 1st August – 30th August 2007, 8th September 2008 and 2009, 9th September 2010;
- on rape sown on10th August – 12th September 2007, 13th September 2008, 22th September 2009, 24th September 2010;
- on rape sown on 20th August – 27th September 2007, 8th October 2008, 30th September 2009, 7th October 2010.

Factor C – sowing rate (C1-120, C2-100, C3-80, C4-60 germinating seeds per m^2 – 'Californium'; C1-80, C2-60, C3-40, C4-20 germinate able seeds per m^2 – 'Excalibur').

Soil at the trials' site was strongly altered by cultivation (ANt) in 2007 and 2010 and sod-gleyic (GLg) (Taxonomy…, 2009) in 2008 and 2009 loam with 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}; organic matter 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 little different soil conditions in the trial 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} 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.

At the end of autumn vegetation 10-plant samples were taken randomly for each plot for biometrical analysis.

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. ANOVA two-factor with replications (within each sowing date), and three-factor (factors A, B and C – mentioned above) analysis of variance were used for processing the experimental data of each separate variety. Effect of variety on plant growth characterising parameters is not mathematically evaluated.

Meteorological data were collected from automatically working meteorological station approximately 1 km from trial site. Meteorological conditions were considerably different in each trial year and that caused differences between plant biometrical indices through all trial years. October 2009 and 2010 characterizes with very low mean air temperatures. August 2009 and September 2008 was relatively dry, but August 2010 was extremely wet (Fig. 1). The heat accumulated by oilseed rape plants over autumns in trial years was also sufficiently different depending on year; growing degree days (GDD) (Bonhomme, 2000) for characterization of warmth conditions were calculated using formula (1):

$$GDD = \frac{(T_{\max} + T_{\min})}{2} - T_{base} \quad (1)$$

where T_{max}- average daily maximum temperature; T_{min} – average daily minimum temperature; T_{base} –base temperature (5^0C).

Growing Degree Days (GDD), from first sowing date − 1st August up to the end of vegetative growth was as follows: 567 GDD in 2007, 440 GDD in 2008, 428 GDD in 2009 and 478 GDD in year 2010. First decade of August was critical for amount of precipitation in all four trial years (see Figure 1); in year 2008 and 2009 lack of precipitation was observed even in ten day period before 1st sowing date that explains slow seed germination and later plant development (Figure1).

Vegetative period (mean temperature below 5^0C for at least 3 days) ended on 4th November in 2007 and 2008 and did renew for eight to five days period up to 4th December; at 1st November in 2009; at 7th November in 2010.

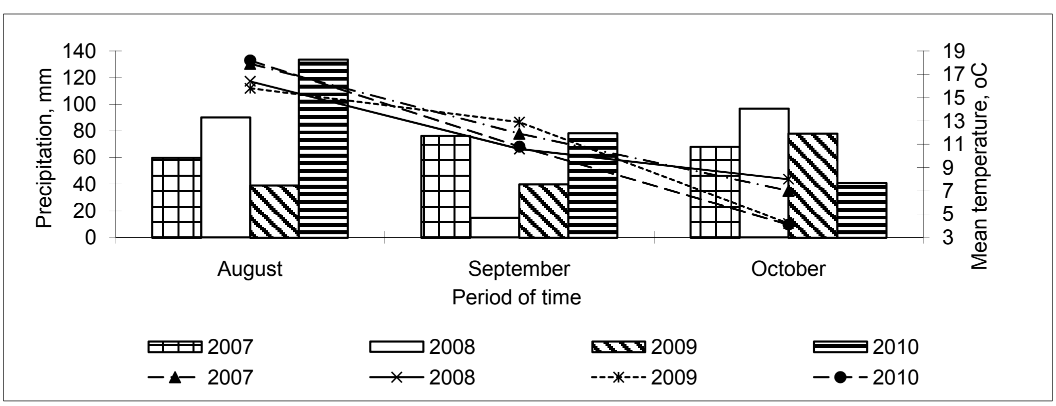

Figure 1. Mean air temperature and precipitation in RSF 'Vecauce' in autumn 2007 to 2010.

Results and discussion

Fungicide application effect depending on sowing date

Fungicide Juventus 90 (as growth regulator) was applied only for plots sown on first three sowing dates when rape plants achieved 4–6 true leaf stage. Rape sown on fourth (1 September) and fifth (10 September) sowing dates did not achieve necessary stage for fungicide application at the first ten-day period of October in all trial years. From the four-year trial results (2007− 2010) we can conclude that winter oilseed rape biometrical parameters were influenced by fungicide application in autumn period and fungicide application effect depended also on sowing date.

First sowing date – 1st August is declared as early sowing date for winter oilseed rape in Latvia conditions because of overgrowth possibility that causes risk for overwintering (Gaveliene *et al*., 1998). Plant growth regulation is expected to give more effect on plant biometrical parameters in such early sowings. At the same time, plant mass depended on used cultivar and conditions of trial year: 'Excalibur' (hybrid F1) formed bigger plants if compared to 'Californium' (line) (Table 1). Average (per all sowing dates and treatments) plant mass was the 18.3−32.9 g for 'Californium' depending on the year, and 39.9−67.6 g for 'Excalibur'; the smallest plants were formed in autumn 2010, when conditions were cooler if compared to long-term average data (long-term date is obtained from regional Hydro Meteorological Station 'Dobele'). Plant mass was affected by fungicide treatment in all trial years (Table 1) and we mainly obtained the expected result: plant mass decreased, but on average per all sowing dates significant ($P < 0.05$) this decrease was only for cultivar 'Excalibur' in autumns 2007 and 2010. Still fungicide application timing for oilseed rape plants is preventive because of different autumn meteorological conditions (including GDD amount). We find also one exception from the tendency to decrease plant mass – on average per all sowing dates plant mass in result of fungicide treatment increased for 'Californium' in 2009. Although leaves caused the bigger proportion of total plant mass in all trial years, root mass of 'Californium' influenced by fungicide application increased significantly ($P < 0.05$) in 2009 and as a result – total plant mass increased. If we look on separate sowing dates, then significant ($P < 0.05$) plant mass increase was observed also for 'Californium' sown on the 1st sowing date of 2009 and 2010 (Table 1). Plants of 'Californium' (see Table 1) were small in both years (2009 and 2010; biggest plants did not exceed 44. 9 g in 2009) and did not look overgrown.

Other important biometrical indices for plant autumn growth are height of growth point (should be less than 30 mm) and root neck diameter (should reach 8 to 10 mm). Height of growth point was highest in plots sown on 1st August in all trial years (Table 2).

Table 1. Fungicide effect on average plant mass (g) depending on sowing date in years 2007−2010

Variety	Sowing date	2007		2008		2009		2010	
		B1†	B2‡	B1†	B2‡	B1†	B2‡	B1†	B2‡
Californium	1st August	39.2	31.9	40.8	39.9	30.9	44.9*	20.4	23.9*
	10th August	40.2	37.0	42.3	37.7	24.1	26.9	29.3	23.6
	20th August	21.0	18.6	18.8	17.9	23.6	20.7	7.6	4.7
Excalibur	1st August	90.4	67.0*	55.8	58.9	56.3	61.8	61.8	46.4
	10th August	82.0	72.9	55.8	47.9	54.4	58.4	55.8	49.6*
	20th August	56.1	37.0*	25.5	28.6	53.4	46.2	14.9	10.9

B1†− control; B2‡ − fungicide treated plants; *$P < 0.05$, when B1 and B2 are compared within the same sowing date in specific year.

Table 2. Fungicide effect on height (mm) of growth point above soil depending on sowing date in years 2007−2010

Variety	Sowing date	2007		2008		2009		2010	
		B1†	B2‡	B1†	B2‡	B1†	B2‡	B1†	B2‡
Californium	1st August	43.0	31.2*	13.9	13.1	19.0	16.5*	26.4	25.3
	10th August	21.6	19.1	12.4	13.3	15.6	13.1*	12.3	10.2*
	20th August	12.2	9.5	9.2	11.1*	11.8	14.6	6.0	5.3
Excalibur	1st August	66.4	38.9*	20.1	20.2	32.7	23.7*	45.8	35.1*
	10th August	35.5	24.4*	14.3	13.3	26.7	27.1	20.5	17.2*
	20th August	19.5	15.0*	11.2	11.2	20.6	15.9*	9.4	8.2

B1†− control; B2‡ − fungicide treated plants; *$P < 0.05$, when B1 and B2 are compared within the same sowing date in specific year.

Table 3. Average per all sowing dates and rates root neck diameter (mm) of varieties 'Californium' and 'Excalibur' depending on fungicide as growth regulator application in years 2007−2010

Variety	2007		2008		2009		2010	
	B1†	B2‡	B1†	B2‡	B1†	B2‡	B1†	B2‡
Californium	6.95	6.92	6.96	7.32	6.26	6.00	5.38	5.14
Excalibur	9.85	8.90*	8.44	8.44	8.75	8.71	7.35	6.99*

B1†− control; B2‡ − fungicide treated plants; *$P < 0.05$, when B1 and B2 are compared within the same specific year.

Cultivar 'Excalibur' formed higher average height of growth point if compared to 'Californium' and accordingly risky value for height of growth point (above 30 mm) more frequently was observed for 'Excalibur' (plants sown on 1st August 2007, 2009, 2010, and on 10th August 2007). For 'Californium' growth point above 30 mm was noted only for plants sown on 1st August 2007. Application of fungicide decreased height of growth point in all mentioned cases substantially (*P < 0.05*). Totallly, decrease of growth point was observed in 18 cases from 24 per trial period (Table 2); again some exceptions with increase of growth point in result of fungicide application were observed (Table 2). Mainly our results are similar to those obtained by V. Gaveliene *et al.* (2002) and L. Miliuviene *et al.* (2004) who reported that application of growth regulators decreases height of growth point. We obtained similar results also in our previous investigations with only one sowing time (20th August), but using more varieties and different fungicides (Bankina *et al.*, 2010). Relatively high proportion (η%) of fungicide application influence on height of growth point was noted from three investigated factors (sowing time, sowing rate, fungicide application) (Table 3).

Root neck diameter below 10 mm is considered as acceptable for oilseed rape growing in conditions with milder winters, example – Central Europe (Becka *et al.*, 2004). Other researchers found that application of growth regulators can increase root neck diameter (Miliuviene *et al.,* 2004), but our results did not show such a preferable result. Effect of growth regulation on average root neck diameter of 'Californium' was unsubstantial in all trial years; effect of growth regulation on root neck diameter of 'Excalibur' F1 on average was also unsubstantial in 2008 and 2009, but mathematically substantial decrease of average rot neck diameter (in opposite to desirable effect) was observed in 2007 and 2010 (Table 3). Decrease of 'Excalibur's' root neck diameter in 2010 (by 0.36 mm) from agronomical point of view is immaterial. More and significant effect on root neck diameter was shown by sowing time and used cultivar (hybrid formed bigger root neck diameter if compared with line, Table 3). This is in accordance with our previous research (Bankina *et al.*, 2010). Differences from results of other researchers can be caused by used growth regulator, varieties and conditions of trial.

Number of leaves per plant increased in result of fungicide application in all trial years on all three sowing dates and for both cultivars. 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, Bankina *et al.*, 2010) and such result is in accordance with expected. Substantial (*P < 0.05*) increase was observed for both cultivars in 2007, 2008, 2009, but only tendency of leaves' increase as result of fungicide application was noted in 2010.

For good overwintering well-developed root is necessary for oilseed rape plants. Other researchers (Gaveliene *et al.*, 2002; Miliuviene *et al.*, 2004) reported that application of growth regulators can increase fresh root mass. Our previous results also showed such tendency (Balodis *et al*., 2007a; Bankina *et al*., 2010). Opposite results were obtained from pot experiments, when significant influence on root biomass was not obtained by any of the plant growth regulators (Bruns *et al*, 1990). Cases with non-significant effect of fungicide Juventus 90 on fresh root mass prevailed per four trial years for both cultivars and three sowing dates in our experiments, but tendency of fresh root mass increase was noted in 15 cases from 24. Root length changes of 'Californium' in result of fungicide application also was non-significant, but tendency of root length increase was observed in 8 cases from 12. Substantial (*P* < 0.05) average root length increase of 'Excalibur' was noted in 2008 and 2009, but changes in 2007 and 2010 were also mainly non-significant.

Fungicide application effect depending on sowing rate

As different sowing rates were used for both varieties, we have analysed also fungicide effect depending on sowing rate. Sowing rate is the first cause of different plant densities (Balodis, Gaile, 2010), but depending on plant density different values of rape plant biometric indices can be formed. D. Becka et al. (2004) reported that more leaves, less height of growth point and greater diameter of root neck are the result of lower crop density.

Fungicide application effect on fresh plant mass was similar for all sowing rates – when tendency was observed to decrease plant mass – it was similar at all sowing rates: 2007, 2008, and 2010. Plant mass increased at all sowing rates of 'Californium' in 2009, but that of 'Excalibur' in 2009 decreased at lower rates (20 and 40 germinate able seeds per 1 m^2), but increased at higher rates (60 and 80 germinate able seeds per 1 m^2). Effect of fungicide application on fresh plant mass depending on sowing rate in majority cases was insignificant.

Average height of growth point with some exceptions decreased at each sowing rate for both varieties. Significant (*P* < 0.05) decrease was observed for 'Californium' in year 2007 at each sowing rate and in 2009 at sowing rates 100, 80 and 60 germinate able seeds per 1 m^2 (Table 4). The tendency to decrease height of growth point was observed also for 'Excalibur' at all sowing rates in all trial years, but decrease was significant (*P < 0.05*) in years 2007 and 2010, but in 2009 – at sowing rates 80 and 20 germinate able seeds per 1 m^2.

Our results showed that fungicide application had no significant (*P* > 0.05) effect on average root neck diameter for 'Californium' in all trial years at all sowing rates. Though interesting was observation that in years 2007 and 2008 tendency of root neck diameter increase was observed at seven from eight cases, but the opposite situation was observed in years 2009 and 2010 when root neck diameter slightly and insignificantly decreased. Tendency to decrease root neck diameter in result of fungicide application was observed for 'Excalibur' in 13 cases from 16.

The tendency of leaves' number increase in result of fungicide application was observed in majority cases in trial years, when different sowing rates were used, but significant increase was observed at 14 cases from 32. Relationship with specifically used sowing rate was not noted: significant increase of rape leaves per plant in result of fungicide as growth regulator application was observed at least for one time at each sowing rate. Only a tendency was observed that at lower sowing rates more leaves increased at the result of growth regulation if compared to higher sowing rates for variety 'Californium' in all trial years (example for 'Californium' in 2009: B1C1 (without fungicide, sowing rate 120 germinating seeds per 1 m^2) – 5.4 leaves; B2C1 (fungicide was applied, sowing rate 120 germinating seeds per 1 m^2) – 6.4 leaves; B1C4 (without fungicide, sowing rate 60 germinating seeds per 1 m^2) – 6.7 leaves; B2C4 (fungicide was applied, sowing rate 60 germinating seeds per 1 m^2) – 8.1 leaves). Such tendency was not noted for 'Excalibur'.

Table 4. Fungicide application effect on average per all sowing dates height of growth point (mm) depending on sowing rate of variety 'Californium' in autumn 2007−2010

	2007		2008		2009		2010	
Sowing rate (C)	B1†	B2‡	B1†	B2‡	B1†	B2‡	B1†	B2‡
C1 120	25.4	21.0*	11.5	12.1	14.4	15.0	14.4	13.5
C2 100	26.6	20.6*	12.8	12.2	15.7	12.2*	15.2	13.4
C3 80	25.0	20.1*	11.3	12.3	16.0	17.9*	14.9	12.8
C4 60	25.4	18.1*	11.7	13.4*	15.7	13.7*	15.0	14.8
$LSD_{0.05BC}$	3.63		1.28		1.74		2.36	

B1†− control; B2‡ − fungicide treated plants **P < 0.05*, when B1 and B2 are compared within the same sowing rate in specific year.

Effect of fungicide application on root length at different sowing rates in majority cases was insignificant, but a tendency was observed that root length increased (in 21 cases from 32). Fungicide as growth regulator also had insignificant effect on root mass at different sowing rates. Only two exceptions were observed: significantly root mass increased for 'Californium' in the result of fungicide application when sown at the rates of 120 and 80 germinate able seeds per 1 m^2 in 2009.

Judging from obtained results, one can say that sowing rate as initial reason of plant density did not cause particular effect of fungicide application. Increase or decrease of values of plant biometric indices in the result of fungicide application was caused rather by used cultivar, sowing date, meteorological conditions at particular sowing date and in specific year or other factors. May be more relationship between exact plant density and direction (increase or decrease of plant parameter) of fungicide application effect can be detected, but it can be clarified in next investigations.

Conclusions

1. Fungicide as growth regulator (Juventus 90 s.c. – metconazole, 90 g L^{-1}) application affected rape plant biometric parameters during autumn, but influence was not equipollent and not always conform to results obtained in other investigations.
2. More marked fungicide effect on values of plant biometric parameters was observed when they were analysed at three different sowing dates. Tendency was observed that plant mass and height of growth point decreased in fungicide treated plots, but result depended from conditions in trial year and variety. Number of leaves in result of fungicide application increased significantly (*P < 0.05*) in 2007, 2008 and 2009, but only tendency of leaves' increase was observed in 2010. Results of root length and mass, and root neck diameter changes at three different sowing times depending on fungicide as growth regulation application were controversial.
3. Sowing rate as initial reason of plant density did not cause particular effect of fungicide application influence on plant biometric parameters. Fungicide application effect on rape plants' sown at different sowing rates in majority cases was insignificant (*P > 0.05*).

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