Autumn growth and development of different winter oilseed rape variety types at three input levels

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ABSTRACT

The autumn growth and development was studied in three types of winter oilseed rape varieties (line, hybrid and genetically modified hybrid) at three technologies (intensity, standard and low input). Technologies were different by soil preparation before sowing, sowing rate, chemical treatment levels, growth regulation and fertilisation. It is evident from the autumn period 1999–2002, that the yield of biomass and roots in the autumn period was influenced by the technology and year conditions (water soil condition). The occurrence of surface soil clods influenced negatively the creation of root and aboveground biomass irrespective of the soil cultivation (ploughing or cultivation without ploughing). Also the excessive soil moisture negatively influenced the root and aboveground biomass and increased the differences among variants. The low input variant was substantially worse than intensity and standard. The dry mass of aboveground and root biomass was statistically different ($\alpha = 0.05$) in the intensive and standard variant in comparison with the variant without ploughing (low input). No statistically significant differences were found in the mass of aboveground and root biomass ($\alpha = 0.05$). The percentage of dry mass in aboveground and root biomass was statistically significantly higher ($\alpha = 0.05$) in intensity of growth regulator application tebuconazole (Horizon 250EW) + chlormequat-chloride (Retacel Extra R68) compared with standard and low input. The diameter of root neck, length of roots and number of leaves was statistically the highest ($\alpha = 0.05$) in the intensive variant. Statistically the values differed from the standard and low input variants. Substantially lower differences were found in the varieties in the same characters. GM hybrid showed a lower heterosis effect and the studied characters did not reach the level of unmodified hybrid level.

Keywords: winter rapeseed; varieties; genetic modification; technology; intensity; standard; low input; biomass

The area of GM crops has been increasing since 1996 (1.7 mil. ha). GM crops were grown in 16 countries in the world (mostly in USA – 39 mil. ha, Argentina – 13.5 mil. ha, Canada – 3.5 mil. ha and China – 2.1 mil. ha) on the area 58.7 mil. ha (i.e. an increase from the year 2001 by 12%). Oilseed rape (canola) was the fourth most grown GM crop (after soya bean, cotton and maize) on the area of 3 mil. ha (the increase since 1996 – 97%, since 2001 – 10%, resp.) (ISAAA 2003).

The necessary condition for a good overwintering and high yields is the autumn growth and development of rapeseed plants. Before the winter period, rapeseed plants should create a sufficient aboveground and root mass and the reduce water content in tissues. Other important characters are: the root-neck diameter, height of growth apex, number and length of leaves, length of root (Vašák et al. 1997, Diepenbrock 2000)

MATERIAL AND METHODS

Experiments with three different variety types of winter oilseed rape were established in the Research Station of Czech University of Agriculture in Červený Újezd (405 above sea level, mean annual temperature 7.7°C; sum of precipitations 549 mm, during the vegetation period [April–September] 13.9°C and 361 mm) line variety – Lirajet (in 2001/2002 – Navajo), hybrid variety – Pronto (in 2001/2002 – Embleme) and genetically modified (GM) hybrid – tolerant to glufosinate (Liberty Link). Experiments were established at three different technologies, i.e. intensity with the expected yield 4 t/ha, standard with yield 3 t/ha and low input with yield 2.5 t/ha. The technologies differ mainly in the soil preparation before sowing, sowing rate, fertilization (mainly nitrogen) and chemical treatment (Table 1).

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Table 1. Main differences in agrotechnique in individual technologies

		Intensive	Standard	Low input
Autumn	soil preparation	ploughing (20–22 cm)	ploughing (18–20 cm)	stubble ploughing
	fertilization P, K, Mg	yes	yes	no
	sowing rate (seeds/m^2)	60	80	80
	fertilization N (before sowing + during vegetation period)	30 + 20	0 + 20	no
	herbicide*	Butisan Star	Lasso Microtech + Command 4EC	Lasso Microtech + Command 4EC
	insecticide + fungicide	yes	no	no
	growth regulator	Horizon 250EW+ Retacel Extra R68	Retacel Extra R68	no
Spring	nitrogen total/number of doses	210/4	150/3	150/2
	growth regulator	Caramba	no	no
	stimulation TSM	Atonik	Relan (Rexan)	no
	foliar fertilizer	Campofort B	no	no
	fungicide	yes	no	no
	insecticide against pod pests	yes	no	no
	ripening regulation	yes	yes	no

*GM variety – application of Liberty herbicide

The plants were sampled at the end of autumn vegetation (8.11.1999, 8.11.2000 a 12.11.2001) from 1 m row in each replicate. The length of roots, number and length of leaves, diameter of root neck and the height of epicotyle were measured. After that the fresh green aboveground mass and roots were weighed. After drying at 105°C the dry mass of aboveground biomass and roots was established. The area on replicate was 79.2 m^2 (harvesting plot 22 m^2). The course of the weather (temperatures and precipitation's) is given in Tables 2 and 3.

The entire request at CR and EU legislative with GMO and environmental conditions were complied. The whole experimental area was sown by 8 m wide protective strips (early and late flowering varieties) which were completely destroyed after flowering. Space isolation was in the distance of 400 m from other stands of Brassica crops. All the harvested seed in GMO wrapping was processed as bio-fuel and the meal was burned or composted.

Analysis of variance of multiple classification was used for the result evaluation and *LSD* method at 95% for a more detail evaluation. Results were processed in the programme Statgraphics Plus version 4.

RESULTS AND DISCUSSION

Production of aboveground and root biomass in autumn

From the three-year results (1999–2002), it is evident that the yield of leaf biomass and roots was in the autumn period influenced by the technology and year of growing (moisture soil conditions) (Table 4). In the vegetation year 1999/2000 the limiting factor were clods inhibiting the plant emergence in all the variants. This year the clod number (greater than 4 cm) per m^2 was 30.5 at the intensive, 23.8 at the standard and 8.6 at the low input variants. The differences between the intensity (higher values) and low input systems were 4.9 g/m^2 (i.e. 23%) in the mass of above-ground mass and 0.3 g/m^2 (i.e. 9%) in the root dry mass. In 2001/2002 due to the late sowing (one day after the agrotechnical term – i.e. 6th September) and very high soil moisture the emergence was worse. The low input variant was the worst. The differences in the intensity and low input variants were substantially higher. The differences in aboveground dry biomass was 81.4 g/m^2 (i.e. 78%) in the root

Table 2. Percentages of the precipitation normal in the autumn period (August–December), in Červený Újezd (evaluated according to WMO method, Kožnarová and Klabzuba 2002)

Month	Precipitation normal (mm)	Percentage of precipitation normal					
		1999		2000		2001	
August	68	31	vbn	63	bn	158	an
September	46	119	n	49	bn	152	an
October	39	63	n	146	an	61	n
November	34	86	n	93	n	110	n
December	32	83	n	34	vbn	112	n

ebn – extraordinary below normal, vbn – very below normal, bn – below normal, n – normal, an – above normal, van – very above normal, ean – extraordinary above normal

Table 3. Deviation of the temperature normal in the autumn period (August–December), in Červený Újezd (evaluated according to WMO method, Kožnarová and Klabzuba 2002)

Month	Temperature normal (°C)	Deviation of temperature normal (°C)					
		1999		2000		2001	
August	16.8	0.7	n	2.0	van	2.2	van
September	13.7	3.3	van	0.1	n	–2.0	bn
October	8.2	0.5	n	2.5	van	3.5	ean
November	2.5	–0.5	n	2.7	van	–0.1	n
December	–0.8	0.9	n	1.3	n	–1.5	n

ebn – extraordinary below normal, vbn – very below normal, bn – below normal, n – normal, an – above normal, van – very above normal, ean – extraordinary above normal.

dry mass 8.6 g/m^2 (i.e. 77%). Briefly, the occurrence of surface clods had a negative influence on the root and aboveground biomass creation in all variants (1999/00), i.e. regardless of the soil cultivation (ploughing or minimalization). In the case of the excessive soil moisture there appeared to be a reduction of variant differences, i.e. the variant without ploughing (low input) was substantially worse than the intensity and standard.

Aboveground biomass

The mean aboveground dry biomass was (1999–2002) 102.0 g/m^2 in the intensive variant, 99.0 g/m^2 in the standard and 72.5 g/m^2 in low input variant (Table 4). Figure 1 shows that the mass in the intensive and standard variant is statistically different compared with the low input one, but it does not reach the levels cited in literature. Diepenbrock and Grosse (1995) present as the optimum 200 g/m^2 of aboveground dry mass in the autumn period. Vincenc and Vašák (2000) – creation of 200–250 g/m^2 of aboveground dry biomass. Sova (1999) found similar differences among technologies. The intensive technology created 142 g of aboveground dry biomass per m^2, standard 112 g/m^2 and low input 60 g/m^2. Differences appeared also in the aboveground dry mass percentage. In the intensive variant the aboveground dry mass was 14.1% and was statistically different (D_{min} = 0.734266, α = 0.05) from the low input (13.0%) and standard (12.8%) variants. The higher dry mass content was the result of growth regulators application in the intensity variant (Horizon 250EW + Retacel Extra R68), increasing the percentage of dry mass.

There were no statistically significant differences (Figure 2) among varieties. The mean value of hybrid varieties (modified and unmodified) was 7.3 g (i.e. 7.8%) higher due to heterosis in comparison with the mean of line variety. Grosse et al. (1992, cit. Diepenbrock 2000) compared the aboveground biomass in hybrids and their parental lines during the vegetation period. Hybrids created more aboveground dry biomass in comparison with their parents in the autumn period by 11%, during the

Table 4. Comparison of aboveground and root dry biomass (g/m^2) in autumn, precise experiments in Červený Újezd 1999/2000, 2000/2001, 2001/2002

	Intensive				Standard				Low input			
	1999/2000	2000/2001	2001/2002	mean	1999/2000	2000/2001	2001/2002	mean	1999/2000	2000/2001	2001/2002	mean
Number of plants/m^2*	45	36	54	45	49	54	97	67	38	45	55	46
Dry mass of above-ground biomass (g/m^2)	21.6	180.3	104	102.0	14.7	197.2	85.1	99.0	16.7	178.3	22.6	72.5
	a	b	c	D_{min} 21.3763	a	b	c	D_{min} 28.2387	a	b	a	D_{min} 30.7945
Dry mass of roots (g/m^2)	3.4	46.7	11.1	20.4	2.5	45.4	10	19.3	3.1	35.9	2.5	13.8
	a	b	c	D_{min} 7.34998	a	b	a	D_{min} 9.00077	a	b	a	D_{min} 6.61932

*the number of plants/m^2 is higher in 2001/2002 due to the seed emergence from the soil

The same letters in one row-variants are not significantly different (*LSD*, 95% probability), the different letters in one row-variants are significantly different (*LSD*, 95% probability)

flowering period by 8% and after flowering by 25%. There was no statistically significant difference (D_{min} = 0.734266, α = 0.05) among varieties in the aboveground dry biomass content (GM hybrid = 13.7%, hybrid = 13.2% and line = 13.1%).

Root biomass

The mean root dry mass reached in 1999–2002 in the intensive variant 20.4 g/m^2, in the standard variant 19.3 g/m^2 and in the low input variant 13.8 g/m^2. It is evident (Figure 3) that this mass was statistically different in the intensive and standard variants, compared with the low input variant. Vincenc and Vašák (2000) present the optimum 30 g/m^2 of root dry mass in the autumn period. Sova (1999) presents the same results – intensive 24 g/m^2, standard 18 g/m^2 and low input 10 g/m^2. In the intensive variant (Horizon 250EW + Retacel Extra R68) rapeseed had statistically significant (D_{min} = 0.691318, α = 0.05) higher root dry content (18.5%) in comparison with low input (17.5%) and standard (17.4%) variants. According to Mikšík (2000) the root dry mass content before the beginning of winter season one of the most important characters. The higher the root and root neck mass content the better the preparation of plants for overwintering.

There were no statistically significant differences (Figure 4) among varieties. The highest root dry mass was 19.5 g/m^2 in the genetically modified hybrid variety, 17.4 g/m^2 in the line and 16.6 g/m^2 in the hybrid unmodified variety. There were no statistically significant differences (D_{min} = 0.691318, α = 0.05) in the percentage of root dry mass content (hybrid = 18.0%, line = 17.8% and GM hybrid = 17.7%).

Indices of oilseed rape growth and development in autumn

Significant differences were found among individual variants in the growth and development of plants (Table 5). The plants in the intensive variant had the evident root neck (4.9 mm). The root neck in the standard variant was 3.6 mm in diameter and in the low input 3.4 mm. These two diameters were significantly different from the intensive variant. The number of leaves 7.6 per plant was significantly different in comparison with standard and low input – both 5.9. The higher number of leaves was the result of lower seed rate, plants had enough space and there did not exist a strong intraspecific competition. The highest differences among variants were observed in the length of roots. The influence of soil preparation was strongly evident.

Figure 1. Comparison of aboveground dry biomass (g/m^2) in autumn – in individual variants, precise experiments in Červený Újezd, mean 1999–2002

Method: 95.0 percent LSD

Variant	Count	LS Mean	Homogeneous Groups
3 - low input	36	72.5444	X
2 - standard	36	98.9722	X
1 - intensive	36	101.967	X

D_{min} = 16.7647

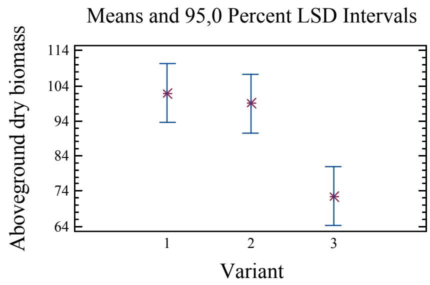


Figure 2. Comparison of aboveground dry biomass (g/m^2) in autumn – in individual varieties, precise experiments in Červený Újezd, mean 1999–2002

Method: 95.0 percent LSD

Variety	Count	LS Mean	Homogeneous Groups
2 - line	36	86.275	X
1 - hybrid	36	92.2861	X
3 - GM hybrid	36	94.9222	X

D_{min} = 16.7647

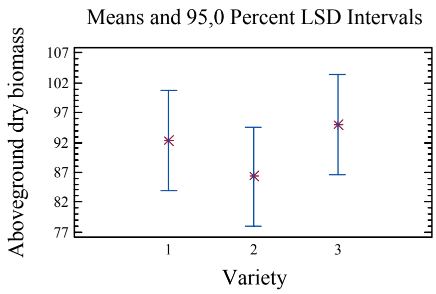


Figure 3. Comparison of root dry mass (g/m^2) in autumn – in individual variants, precise experiments in Červený Újezd, mean 1999–2002

Method: 95.0 percent LSD

Variant	Count	LS Mean	Homogeneous Groups
3 - low input	36	13.8583	X
2 - standard	36	19.3222	X
1 - intensive	36	20.4222	X

D_{min} = 4.40843

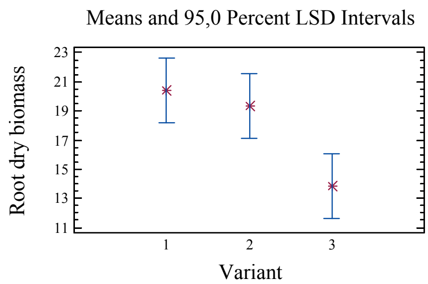
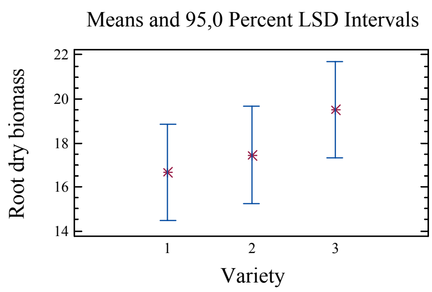


Figure 4. Comparison of root dry mass (g/m^2) in autumn – in individual varieties, precise experiments in Červený Újezd, mean 1999–2002

Method: 95.0 percent LSD

Variety	Count	LS Mean	Homogeneous Groups
1 - hybrid	36	16.6472	X
2 - line	36	17.4417	X
3 - GM hybrid	36	19.5139	X

D_{min} = 4.40843



The longest roots were observed in intensive variant (ploughing 20–22 cm) – 13.1 cm, then standard (ploughing 18–20 cm) – 12.7 cm and the shortest roots in low input variant (surface ploughing till 15 cm) – 10.6 cm. The differences are statistically significant (α = 0.05). The length of roots was also influenced by moisture soil conditions. In the more arid years the roots were longer (1999 – 10.8 cm, 2000 – 16.8 cm) compared with the humid year 2001 – 8.8 cm. The differences are statistically

Table 5. Comparison of indices of oilseed rape growth and development in autumn – in individual variants, precise experiments in Červený Újezd, mean 1999–2002

Variants	Mean of root neck		Length of leaves		Length of roots		Number of leaves	
	mm	statistics	cm	statistics	cm	statistics	no.	statistics
Intensive	4.9	a	16.5	a	13.1	a	7.6	a
Standard	3.6	b	17.1	a	12.7	b	5.9	b
Low input	3.4	b	14.4	b	10.6	c	5.9	b
D_{min}	0.254995		0.66759		0.427072		0.259233	

The same letters in one column – variants are not significantly different (*LSD*, 95% probability), the different letters in one column – variants are significantly different (*LSD*, 95% probability)

Table 6. Comparison of indices of oilseed rape growth and development in autumn – in individual varieties, precise experiments in Červený Újezd, mean 1999–2002

Varieties	Mean of root neck		Length of leaves		Length of roots		Number of leaves	
	mm	statistics	cm	statistics	cm	statistics	no.	statistics
Hybrid	4.0	a	16.7	a	12.4	a	6.7	a
Line	4.0	a	16.1	a	12.2	a	6.4	b
GM hybrid	3.9	a	15.2	b	11.8	b	6.3	b
D_{min}	0.253757		0.664349		0.424999		0.257974	

The same letters in one column – variants are not significantly different (*LSD*, 95% probability), the different letters in one column – variants are significantly different (*LSD*, 95% probability)

significant (D_{min} = 0.428102, α = 0.05). Kjellstöm and Kirchmann (1994) proved that the roots in more arid and warmer years are longer and thinner than in humid and cold years. The length of leaves was influenced by the morphoregulationary activity of growth regulators (Horizon 250 EW and Retacel Extra R68) and by the higher number of weak plants with shorten leaves (in the variant low input 14.4 cm). The combination of Horizon 250 EW and Retacel Extra R68 (0.5 + 2 l/ha) retarded the length of leaves in intensity (16.5 cm) while the Retacel Extra R68 itself (standard) had a minimum influence on the leaves (17.1 cm).

Substantially minor differences were proved in these characters among varieties. In the unmodified hybrid variety the effect of heterosis caused the higher growth and vitality compared with the line. It is interesting that in the GM hybrid variety the effect of heterosis was substantially lower. In the studied characters the GM hybrid was in a lower level compared with the unmodified hybrid and in some cases even with the line (Table 6).

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ABSTRACT

Podzimní růst a vývoj odlišných typů odrůd ozimé řepky při třech úrovních pěstování

Sledovali jsme podzimní růst a vývoj rostlin u tří typů odrůd ozimé řepky (linie, hybrid a GM hybrid) při třech pěstitelských úrovních (intenzivní, standardní, low input). Pěstitelské technologie se lišily přípravou půdy před setím, výsevkem, úrovní chemické ochrany, regulací růstu a hnojením. Z tříletých výsledků (1999–2002) je patrné, že výnos biomasy listů a kořenů na podzim je ovlivněn technologií pěstování a ročníkem (vláhovými podmínkami v půdě). Výskyt hrud na povrchu se negativně projevuje na tvorbě kořenové a nadzemní biomasy bez ohledu na zpracování půdy (orba nebo bezorebné zpracování). Také nadměrná půdní vlhkost negativně působí na nadzemní a kořenovou biomasu a zvyšuje rozdíly mezi variantami. Bezorebná varianta (low input) byla podstatně horší než orební příprava (intenzivní a standardní). Hmotnost sušiny nadzemní i kořenové biomasy byla u intenzivní a standardní varianty statisticky odlišná (α = 0,05) v porovnání s bezorebnou variantou low input. Mezi odrůdami nebyly u hmotnosti nadzemní a kořenové biomasy zjištěny statisticky průkazné rozdíly (α = 0,05). Procentuální obsah sušiny u nadzemní i kořenové biomasy byl statisticky průkazně vyšší (α = 0,05) u intenzivní varianty s aplikací růstových regulátorů tebuconazole (Horizon 250EW) + chlormequat-chloride (Retacel Extra R68) v porovnání s variantou standardní a low input. Průměr kořenového krčku, délka kořenů i počet listů byl u intenzivní varianty nejvyšší a statisticky (α = 0,05) se tyto hodnoty odlišovaly od varianty standardní a low input. Mezi odrůdami byly v těchto znacích zjištěny podstatně menší rozdíly. U GM hybridu se heterozní efekt projevil slaběji a sledované znaky nedosáhly úrovně hodnot hybridu nemodifikovaného.

Klíčová slova: ozimá řepka; odrůdy; genetické modifikace; technologie pěstování; intenzita; standard; low input; biomasa

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