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Comparison of winter oilseed rape varieties: cold acclimation, seed yield and quality

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Abstract

The purpose of our study was to investigate and compare the acclimatization to wintering, productivity formation, as well as seed yield and quality of different varieties of winter oilseed rape plants. The studied varieties were: very early, medium-resistant to wintering 'Libea', medium-early, resistant to wintering 'Sunday', and medium-early, less than medium resistant to wintering 'Valesca'. The small-plot trials were performed at the Field Research Station of the Institute of Botany. Proline was extracted from the rape root collum and apical bud by using 3% sulfosalicylic acid; the *SLT* software was used for the analysis. Crude fat, crude protein and glucosinolates were analysed by near infrared spectroscopy using NIR Systems model 6500. The fatty acids were extracted from seeds employing the Folch's method. Composition of fatty acids was analysed by gas chromatography.

Comparison of the rape varieties tested during 2007 and 2008 revealed that under favourable germination and growth conditions plants of all tested varieties had developed optimum architecture (6–8 true leaves, root system, formed root collum); during the period of winter hardening the plants had intensively accumulated metabolite proline, which is partly responsible for cold resistance. In the winter oilseed rape hardening period (from BBCH 14–15 up to BBCH 16–17 stage) the amount of proline in the root collum of 'Libea' increased by 52%, of 'Sunday' – by 63%, of 'Valesca' – by 72%, while in the apical bud – by 11, 51 and 58%, respectively. Plants of the tested varieties successfully overwintered, especially 'Valesca' and 'Sunday'. Comparison of the seed yield of the tested rape varieties, which is predetermined by the number of siliquae per plant, number of seeds per silique, seed weight, and meteorological conditions, revealed 'Libea' being somewhat more productive than 'Sunday' and 'Valesca'. Fat yield, which depends not only on seed yield but also on the content of crude fat, was the highest in 'Sunday' seeds.

Genotypic peculiarities partly govern the fatty acids (FA) composition. In 'Sunday' and 'Valesca' seed oil the content of saturated acids, especially of palmitic acid, was considerably lower, while the contents of unsaturated oleic, linoleic and linolenic fatty acids were higher in comparison with the results obtained for 'Libea' seed oil.

Key words: crude fat, proline, fatty acids composition.

Introduction

At present, high quality 00 type winter oilseed rape varieties created in other countries (Sweden, Germany) are grown in Lithuania. However, in our country, in rather complicated meteorological and climatic conditions, the imported varieties cannot realize their productivity potential encoded in the genome. On the other hand, plant species and varieties differ in specific genetic information concerning their growth, development and formation of productivity elements, which is differently used in the course of ontogenesis. For all those reasons, there occur fluctuations in plant growth, seed yield and quality formation in different plant varieties (Butkutė et al., 2000; Flenet, Merrien, 2009; Novickienė et al., 2009). Period of winter oilseed rape plants acclimation, i.e. preparation for the winter is especially important. Individual plants of winter rape should reach the 6^{th} to 8^{th} true-leaf stage, the vegetative point is differentiated but not shot up, the root collum diameter reaches 3−5 mm (Diepenbrock, Grosse, 1995; Gaveliene et al., 2005). However, winterhardiness is not a stable property in rape varieties: it is formed gradually when plants are preparing for winter conditions, enter a new physiological state. The intensive accumulation of saccharides, proteins, proline and other substances irrespective of their chemical origin may be regarded as a cold stress protective measure (Uemura, Steponkus, 2003; Anisimovienė et al., 2004; Verbruggen, Hermans, 2008). Thus, the mentioned morphological and physiological indices play an important role in plants' subsequent periods of acclimation, wintering, growth renewal in spring allowing a more efficient realization of their genetically determined yield potential (Diepenbrock, Grosse, 1995).

Rapeseed oil, compared with other kinds of oil, contains low levels of saturated fatty acids, a high percentage of oleic acid and an optimal ratio of polyunsaturated fatty acids for both nutrition and feeding needs (Hunter, 1990; Butkute, 2004; Butkutė et al., 2006). The chemical composition of rape seeds, including the fatty acids composition, influences the quality of the biodiesel produced from them (Bojanowska, 2006; Bellostas et al., 2007). Therefore, high importance is ascribed to the rapeseed variety from which seed oil is produced, to foresee its purpose of use.

The purpose of the present study was to investigate and compare different winter oilseed rape varieties as regards their autumnal growth, accumulation of the cold stress protective compound proline in different organs, plants' winter survival, seed yield and quality formation.

Material and methods

The experiments on winter oilseed rape (*Brassica napus* L. ssp. *oleifera biennis* Metzg) were carried out in small-plot field trials at the Experimental Bases of the Institute of Botany during 2007−2009. The very early, medium-resistant to wintering 'Libea' developed in Germany and registered in Lithuania in 2002, the medium-early resistant to wintering 'Sunday', produced in Sweden and registered in Lithuania in 2002, and the medium-early less than medium resistant to wintering 'Valesca', produced in Sweden, and registered in Lithuania in 1997 were used as the study objects. The plot sizes were 1 m^{-2} each completed in a randomised block design, and the experiments were performed in four replications. Crop density was 110−120 plants per m^{-2}. Rape was sown 2007 on 15 and 2008 on 18 of August. Rape plants were cultivated according to recommendations for fertilisation and oilseed rape protection (Brazauskienė et al., 2003). Plant fertilization ($N_{120}P_{90}K_{60}$) was performed as follows: P, K and N_{30} were introduced before soil ploughing, and N_{90} was supplied in spring. After sowing, soil was sprayed with a herbicide (Butisan 2.5 l ha^{-1}). During vegetation, oilseed rape plants were sprayed with an insecticide Fastac (0.15 l ha^{-1}).

The morphometrical parameters of plant growth (leaf number, root collum length and diameter, main root length, weight of leaves and roots) were estimated from 20 plants for each variety in autumn, i.e. – in the period of their acclimation to wintering at the stages BBCH 14−15 (control), BBCH 15−16 and BBCH 16−17. Plant growth stages were recorded using the BBCH identification key (Meier, 1997). Root collum and apical bud samples for proline assay were taken from the same plants at the same stages of growth.

Oilseed rape yield structural elements (siliquae number on the terminal and lateral branches, seed number per silique and 1000 seed weight) were assessed in the stage BBCH 97–99. Upon harvesting, the seed weight was determined from each plot at 8.5% moisture content. The fat yield was determined from absolutely dry seed yield and crude fat content (% DM). Dry weight was measured after seed drying at 105ºC.

Free proline content was extracted from homogenised plant material (root collum and apical bud), fixed with dry nitrogen, by using 3% sulfosalicylic acid (Bates et al., 1973). Proline was measured by the wave length 520 nm. Analysis of proline was carried out employing a computerized system.

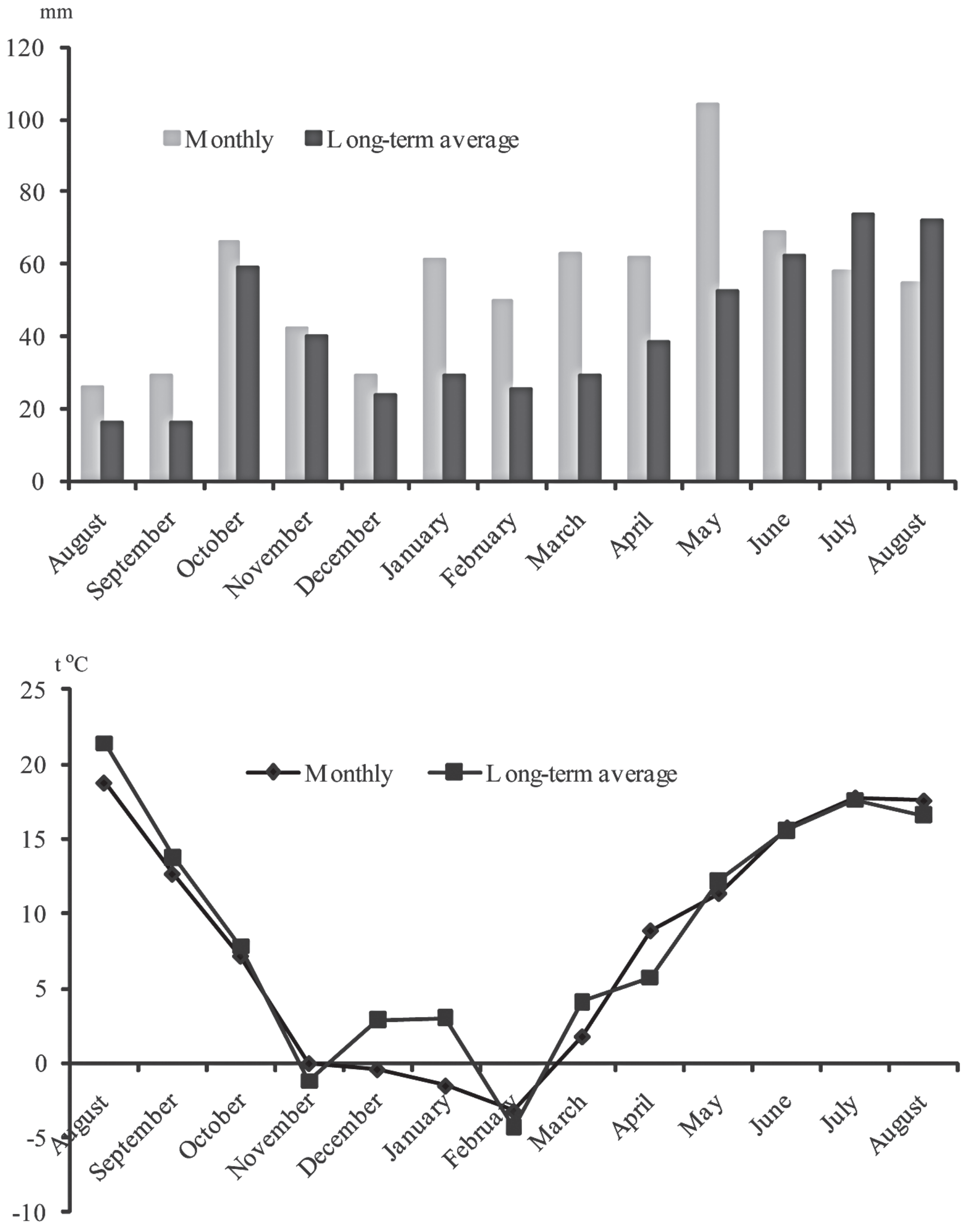
Crude fat (CF), crude protein (CP) and glucosinolates (GLS) were analysed by near infrared spectroscopy using NIR Systems model 6500. Equations for the quality prediction were developed at the Lithuanian Institute of Agriculture (Butkute, 2004). Chemical analysis of seed quality was performed in three replications; biological experiments were repeated in 2007–2008 and 2008–2009.

Lipids for the estimation of fatty acids composition were extracted by Folch's method (Folch et al., 1957). The mixture of fatty acid methylesters (Christopherson, Glass, 1969) was analysed by gas chromatography (GC-2010, "Shimadzu") with a flame ionization detector. Fat acids were identified by their retention times, comparing them with retention times of fatty acids methylesters mixture of known composition (FAME#13cat № 35034, manufactured "Restec"). The content of a fatty acid (% of the total content of fatty acids) was determined using chromatography data of the *GC solution* software. The composition of fatty acids was determined at the Laboratory of Chemistry of the Institute of Animal Science of the Lithuanian Veterinary Academy.

The data were treated statistically. The tables of morphometrical measurements (2007 and 2008 autumn) presented the mean values of four replications and standard errors. The significance of difference was assessed by the Student's test; for yield, significant difference (LSD) was determined at 95% confidence level for mean values of 2008 and 2009 (Tarakanovas, Raudonius, 2003).

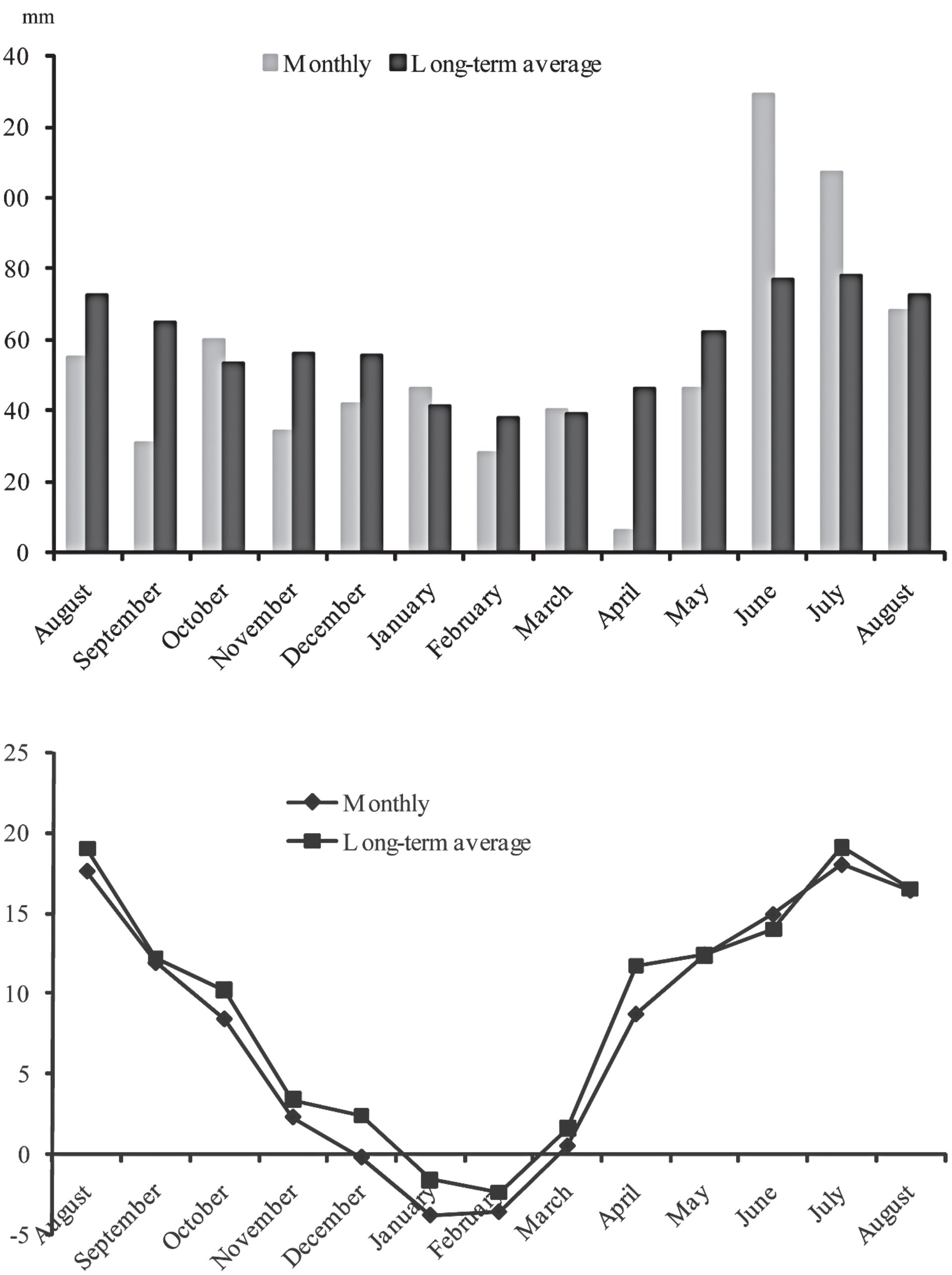
Results and discussion

Winter oilseed rape has become an increasingly important crop in Lithuania's agricultural production, and Lithuania is one of the north-eastern countries in Europe involved in oilseed rape production. To obtain a stable and high-quality seed yield of winter rape in very changeable climatic and meteorological conditions of our country, it is essential to choose a suitable plant variety, to ensure a better development of plants in autumn, i.e. acclimatization to wintering, to prevent damage caused by frosts and temperature fluctuations in winter and early in spring.



Note. Vilnius Hydrometeorological Service under the Ministry of Environment

Figure 1. Monthly mean precipitation and air temperature rate 2007–2008 and long-term average



Note. Vilnius Hydrometeorological Service under the Ministry of Environment

Figure 2. Monthly mean precipitation and air temperature rate 2008–2009 and long-term average

The meteorological conditions of 2007 and 2008 autumn did not differ much from long-term average, although in 2008 the temperature was a few degrees below the long-term average and the precipitation rate of this period fluctuated; especially in August, September and November it was lower than the long-term average (Fig. 1, 2).

Analysis of the growth parameters of winter oilseed rape 'Libea', 'Sunday' and 'Valesca' plants in autumn revealed a slow growth of different plant organs in stage BBCH 14–15 and a more intensive growth in stage BBCH 16–17. The number of leaves in 2007 increased, respectively, by 17, 31 and 19%, in 2008 – 62, 60 and 66%. Root collum diameter in 2007 increased by 13, 15, 11% and in 2008 – by 12, 18, 7% (Table 1).

In 2007 the dry weight of leaves in varieties 'Libea', 'Sunday' and 'Valesca' at stage BBCH 16–17 increased by 35, 15 and 3% in comparison with BBCH 14–15, meanwhile the dry weight of roots – by 4, 43 and 7%, respectively (Table 2). The morphometrical parameters of autumnal growth of different oilseed rape varieties showed that the plants were acclimated, i.e. prepared for wintering.

Table 1. The growth parameters of leaves and roots of different winter oilseed rape varieties

Variety	Leaf number per plant	Main root length mm	Root collum length, diameter mm	
		2007 BBCH 14–15		
'Libea'	6.3 ± 0.33	13.9 ± 0.8	7.0 ± 0.1	3.7 ± 0.2
'Sunday'	6.4 ± 0.40	14.1 ± 0.9	7.1 ± 0.2	3.9± 0.1
'Valesca'	6.3 ± 0.31	14.0 ± 0.9	7.4 ± 0.3	3.7 ± 0.2
		BBCH 16–17		
'Libea'	7.4 ± 0.30	14.8 ± 0.87	7.0 ± 0.14	4.2 ± 0.2
'Sunday'	8.4 ± 0.41	15.8 ± 0.93	7.8 ± 0.23	4.5 ± 0.2
'Valesca'	7.5 ± 0.42	15.2 ± 1.02	7.8 ± 0.28	4.1 ± 0.3
		2008 BBCH 14–15		
'Libea'	4.5 ± 0.4	11.8 ± 1.0	6.0 ± 0.5	4.0 ± 0.3
'Sunday'	4.6 ± 0.4	12.0 ± 1.1	6.3 ± 0.4	3.9 ± 0.2
'Valesca'	4.4 ± 0.3	14.0 ± 0.9	6.5 ± 0.5	4.1 ± 0.4
		BBCH 16–17		
'Libea'	7.3 ± 0.6	13.8 ± 0.6	6.8 ± 0.5	4.5 ± 0.2
'Sunday'	7.4 ± 0.7	13.2 ± 1.2	6.8 ± 0.6	4.6 ± 0.3
'Valesca'	7.3 ± 0.5	14.1 ± 1.3	6.9 ± 0.3	4.4 ± 0.2

Note. Mean ±SE.

Table 2. Weight of leaves and roots of different winter oilseed rape varieties

Variety	Leaf weight g		Root weight g	
	fresh	dry	fresh	dry
		2007 BBCH 14–15		
'Libea'	64.0 ± 1.5	8.3 ± 0.4	11.5 ± 0.2	2.5 ± 0.10
'Sunday'	66.2 ± 2.3	10.4 ± 0.5	16.0 ± 0.3	2.3 ± 0.09
'Valesca'	68.0 ± 1.8	9.7 ± 0.8	15.0 ± 0.4	2.9 ± 0.15
		BBCH 16–17		
'Libea'	65.8 ± 3.5	11.2 ± 0.5	12.4 ± 0.3	2.6 ± 0.2
'Sunday'	68.5 ± 2.6	12.0 ± 1.1	16.9 ± 0.4	3.3 ± 0.9
'Valesca'	70.9 ± 3.9	10.0 ± 0.4	15.5 ± 0.9	3.1 ± 0.2
		2008 BBCH 14–15		
'Libea'	63.2 ± 3.4	6.8 ± 0.5	11.0 ± 1.0	2.7 ± 0.2
'Sunday'	60.4 ± 2.7	9.6 ± 0.7	12.3 ± 1.1	2.9 ± 0.3
'Valesca'	65.4 ± 3.1	8.9 ± 0.9	13.0 ± 0.9	2.8 ± 0.1
		BBCH 16–17		
'Libea'	64.0 ± 3.2	8.2 ± 1.0	11.4 ± 1.0	3.6 ± 0.3
'Sunday'	66.2 ± 3.4	10.4 ± 1.1	15.7 ± 1.2	3.8 ± 0.2
'Valesca'	71.0 ± 3.6	9.6 ± 1.0	15.5 ± 1.2	3.7 ± 0.3

Note. Mean ±SE.

It is known that not only morphometric parameters but also the physiological and biochemical peculiarities of winter oilseed rape plants during acclimatization, i.e. preparation for wintering play an important role. Free proline accumulation is a common physiological response in many plants to a wide range of biotic and abiotic stresses, low temperature included (Verbruggen, Hermans, 2008). Free proline as a biochemical marker for frost tolerance in potato, barley and wheat has been discussed (Dörfling et al., 1990; Petcu, Terbea, 1995), but there are no data on proline accumulation in winter rape plant organs hardened in natural conditions.

We estimated proline as a stress-protective metabolite in dynamics under the natural changes of thermo- and photo induction. Analysis of proline accumulation in root collum and apical bud in plants showed an increase in proline content in all varieties, but to a different extent (Table 3).

Table 3. Free proline accumulation in root collum and in apical bud of different winter oilseed rape varieties during the period of plant adaptation − preparation for wintering, 2008

Variety	Plant growth stages		
	BBCH 14–15	BBCH 15–16	BBCH 16–17
	Oct 06	Oct 21	Nov 16
Proline µM g^{-1} f. w.			
Root collum			
‘Libea’	6.7 ± 0.5	8.6 ± 0.7	10.2 ± 0.8
‘Sunday’	7.2 ± 0.5	10.4 ± 0.8	11.8 ± 0.9
‘Valesca’	6.9 ± 0.5	10.2 ± 0.9	11.9 ± 0.9
Apical bud			
‘Libea’	10.9 ± 0.8	11.8 ± 0.9	12.1 ± 1.0
‘Sunday’	9.5 ± 0.8	11.2 ± 0.9	14.4 ± 1.2
‘Valesca’	10.6 ± 0.8	12.8 ± 1.1	16.8 ± 1.3

In root collum, during the BBCH 14–15 to BBCH 16–17 stages (from Oct 06 to Nov 16), proline content increased in ‘Libea’ by 52%, in ‘Sunday’ by 63% and in ‘Valesca’ by 72%, and in the apical bud proline content increased, by 11, 51 and 58%, respectively. In the rape hardening period, proline more intensively accumulated in root collum than in apical bud, and free proline accumulation was more intensive in ‘Valesca’ and ‘Sunday’. The level of proline (a stress-protective compound) accumulation in plant tissues during their adaptation to cold may be accepted as a biochemical marker of cold tolerance.

The environmental and meteorological conditions have a major influence on rape wintering, vegetation renewal, seed yield and quality (Musnicki et al., 1999). In our experiments, the temperature during winter months was lower than the long-term average, and the precipitation rate did not differ much from the long-term average; however, plants of the test varieties exhibited a satisfactory overwinter survival. The lowest overwinter survival was of var. ‘Libea’ (Table 4).

Table 4. Plant overwinter survival of different winter oilseed rape varieties

Variety	Crop density plants m^{-2}		Overwintered plants %
	in autumn	in spring	
2007–2008			
‘Libea’	96 ± 8.6	71 ± 6.2	74
‘Sunday’	101 ± 7.4	86 ± 5.4	84
‘Valesca’	99 ± 7.8	81 ± 7.2	82
2008–2009			
‘Libea’	94 ± 4.3	62 ± 4.7	64
‘Sunday’	91 ± 6.8	62 ± 5.8	68
‘Valesca’	99 ± 7.1	69 ± 5.8	71

Analysis of productivity elements and seed yield formation showed, that siliquae formation occurred on terminal and lateral branches of all test varieties, however siliquae on the lateral branches of var. 'Libea' formed best, especially in 2008 (Table 5).

It is known that seed yield is a result of a number of complex growth and development processes and not only of the siliquae number per plant but also of the seed number per siliqua and 1000 seed weight. 22–24 seeds per siliqua in average were determined in terminal branches of tested rape varieties, but seed number in lateral branches varied: in 'Libea' being large number of siliquae in lateral branches, the number of seeds per siliqua were less in comparison with 'Sunday' and 'Valesca'. 1000 seed weight differed among the test varieties and was highest in 'Sunday', but seed yield of 'Libea' at 8.5% moisture was a little higher in comparison with 'Sunday' and 'Valesca'. On the other hand, fat yield is an important parameter for variety characteristic. The fat yield was determined from seed yield, and here crude fat content was highly significant. For this reason, the fat yield was higher in 'Sunday' than in 'Libea' and especially in 'Valesca' (Table 6).

Table 5. Siliquae formation on plants of different winter oilseed rape varieties

Variety	Number of siliquae per plant n						
	Terminal branches	Lateral branches					Total
	n	I	II	III	IV	V	
				2008			
'Libea'	44.0 ± 3.8	18.9 ± 1.5	20.3 ± 1.9	20.8 ± 1.7	18.5 ± 1.3	16.9 ± 1.4	138.9
'Sunday'	40.1 ± 3.4	10.5 ± 0.9	15.0 ± 1.4	8.2 ± 0.3	5.3 ± 0.3	4.9 ± 0.2	84.0
'Valesca'	36.3 ± 0.8	8.9 ± 0.5	8.1 ± 0.4	8.7 ± 0.6	9.3 ± 0.8	7.6 ± 0.8	78.9
				2009			
'Libea'	44.4 ± 1.9	15.1 ± 1.2	17.1 ± 1.3	16.1 ± 1.5	15.3 ± 1.3	14.3 ± 0.9	122.3
'Sunday'	35.9 ± 3.4	16.5 ± 0.9	14.3 ± 0.9	8.4 ± 0.9	5.2 ± 0.2	4.2 ± 0.3	84.5
'Valesca'	38.7 ± 1.3	9.4 ± 0.5	9.2 ± 0.8	10.8 ± 0.9	10.2 ± 0.9	10.0 ± 1.0	88.3

Table 6. Seed yield of different winter oilseed rape varieties

Variety	Thousand seed weight g	Seed yield at 8.5% moisture g m^{-2}	Absolutely dry seed yield g m^{-2}	Fat yield g m^{-2}
		2008		
'Libea'	4.13 ± 0.31	331	303	138
'Sunday'	4.24 ± 0.25	325	297	149
'Valesca'	4.00 ± 0.29	329	301	130
		LSD_{05} = 11.2	11.6	9.1
		2009		
'Libea'	4.33 ± 0.27	378	346	154
'Sunday'	5.28 ± 0.32	369	338	170
'Valesca'	4.00 ± 0.28	354	324	140
		LSD_{05} = 11.6	10.9	8.8

The content of crude fat (50.2% DM) and glucosinolates was highest in seeds of 'Sunday' (Table 7), but the content of glucosinolates did not exceed the EU standard for food rapeseed. Seed quality parameters of 'Valesca' corroborated the suggestion about a relationship between crude fat and crude protein: protein accumulation inversely correlated with fat synthesis.

For us, a matter of great concern was to determine not only seed yield and crude fat content in different rape varieties, but also the composition of fatty acids. The obtained results demonstrated a different composition of fatty acids in the winter rapeseed varieties. The content of saturated fatty acids in 'Libea' seed oil was nearly twice as high as that in 'Valesca' and 'Sunday' seed oil. This difference is related to an increased content of palmitic acid (about twice) and stearic acid (by 37 and 17%), respectively. In var. 'Libea' seed oil contained low levels of monosaturated fatty acids (oleic) and polyunsaturated fatty acids (linoleic and linolenic) in comparison with the same fatty acids contents in 'Sunday' and 'Valesca' seed oil (Table 8).

Table 7. Seed quality of different winter oilseed rape varieties

Variety	Crude fat % DM	Crude protein % DM	Glucosinolates μmol g^{-1}
		2008	
'Libea'	45.4 ± 3.2	19.3 ± 0.95	9.8 ± 0.71
'Sunday'	50.1 ± 4.3	18.6 ± 1.20	15.4 ± 0.92
'Valesca'	43.3 ± 3.7	22.8 ± 0.89	10.9 ± 0.74
		2009	
'Libea'	44,6 ± 3.0	17.9 ± 0.93	10.7 ± 0.83
'Sunday'	50.2 ± 3.9	17.8 ± 0.60	15.2 ± 0.88
'Valesca'	43.1 ± 2.8	21.8 ± 0.91	11.1 ± 0.96

Table 8. Fatty acid composition in oil of different winter oilseed rape varieties, 2009

Fatty acid		'Sunday'	'Libea'	'Valesca'
number of carbon atoms		content in oil %		
	Saturated fatty acids			
C 14:0	Myristic	–	0.27 ± 0.08	–
C 16:0	Palmitic	4.65 ± 0.23	9.18 ± 0.41	4.17 ± 0.18
C 18:0	Stearic	1.89 ± 0.12	2.29 ± 0.20	1.45 ± 0.09
C 20:0	Arachidic	0.52 ± 0.04	0.45 ± 0.15	0.49 ± 0.17
C 22:0	Behenic	0.25± 0.02	0.23 ± 0.09	0.25 ± 0.07
Total saturated fatty acids		7.31± 0.10	12.42 ± 0.21	6.36 ± 0.13
	Mono-unsaturated fatty acids			
C 16:1	Palmitoleic	0.27 ± 0.03	0.36 ± 0.02	0.24 ± 0.02
C 17:1	Heptadecenoic	0.23 ± 0.02	0.15 ± 0.01	0.13 ± 0.01
C 18:1	Oleic	64.68 ± 2.50	61.52 ± 1.9	66.26 ± 3.41
C 20:1	Arachidic	0.91 ± 0.08	0.87 ± 0.08	0.94 ± 0.07
Total mono-unsaturated fatty acids		66.09 ± 0.66	62.39 ± 0.5	67.57 ± 0.88
	Poly-unsaturated fatty acids			
C 18:2	Linolic	18.52 ± 1.52	17.52 ± 1.61	18.69 ± 1.7
C 18:3	Linolenic	8.07 ± 0.87	7.16 ± 0.69	7.38 ± 0.55
Total poly-unsaturated fatty acids		26.59 ± 1.20	24.68 ± 1.15	26.07 ± 1.1
Total unsaturated fatty acids		92.68 ± 3.84	87.07 ± 2.72	93.64 ± 3.9
Ratio saturated / unsaturated fatty acids		0.0788	0.1426	0.0679

The total content of mono- and poly-unsaturated fatty acids in the oil of rapeseed cultivars 'Libea', 'Sunday' and 'Valesca' was 87.07, 92.68 and 93.64%, respectively. Our data showed that fatty acids composition and individual fatty acid content depend on the type of varieties. With the standard type, the oleic and linolenic acids range from 60 to 65% and from 8 to 12%, respectively (Flenet, Merrien, 2009). Fatty acids content of tested winter oilseed rape varieties conforms to standard type variety. This rapeseed oil can be used for nutrition and for biodiesel. The content of these mono- and poly-unsaturated fatty acids determines the optimal ratio of linolic to linolenic (n-6/n-3) poly-unsaturated acids, which is associated with a reduced risk of cardiovascular diseases (Hunter, 1990; Bellostas et al., 2007) and the viscosity of fuel (Bojanowska, 2006). Monounsaturated acids in rapeseed oil and oleic acid in particular, are highly valuable for the production of fuels. However, the presence of poly-unsaturated acids in rape-methyl-ester molecules is the cause of their susceptibility to oxidation, which makes them less stable, especially during fuel storage.

On the other hand, cold and/or frost in autumn and in winter and other meteorological conditions that precipitation during the growth season can modify seed yield and quality parameters (Mendham, 1995; Butkutė, 2004; Butkute et al., 2006). The climatic conditions during our experiments (2007−2009) were close to the long-time mean, except from November of 2008 to April 2009. The temperature and precipitation were lower than the long-term mean; however the test plants were prepared for wintering, accumulated a large content of the stress-protective compound proline and survived well the winter, and the vegetation renewal. Besides, in May, June and July the temperature and the amount of precipitation were favourable for seed formation and maturation. Thus the tested rape varieties possess winter hardiness, which is expressed in plants that have not been exposed to low negative temperatures. In the second stage of cold acclimation, the plants are capable of tolerating freezing temperatures (Palta et al., 1998; Burbulis et al., 2008). But in the same growing and technological conditions of experiments, according to morphometrical assessments and proline intensive accumulation in plant organs – apical bud and root collum, important for winterhardiness, and according to the increment of individual fatty acids in rape oil, priority is given to 'Sunday' and 'Valesca'. First of all, our data agree with the opinion that winter rape yield and quality (crude fat, crude protein, glucosinolates and fatty acid composition) depend on the genetic type of a variety (Flenet, Merrien, 2009).

Conclusions

1. Cold acclimation of oilseed rape in natural conditions was related to plant architecture formation and proline content accumulation. During the winter oilseed rape hardening period, the accumulation of free proline in apical bud and especially in root collum was most intensive in the varieties 'Valesca' and 'Sunday'.

2. Crude fat content in rape seed of 'Sunday' was higher by 11 and 15% than in varieties 'Libea' and 'Valesca', and fat yield was also higher.

3. The genotypical peculiarities of the varieties mostly determined the composition of fatty acids in rapeseed oil. In 'Sunday' and 'Valesca' oil, the content of poly-unsaturated and monounsaturated fatty acids, especially oleic acid was higher and the content of saturated fatty acids, especially of palmitic acid, was lower in comparison with 'Libea'.

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References

Anisimovienė N., Novickienė L., Jankauskienė J. Cold acclimation of winter rape: changes in protein composition under the effect of the auxin analogue TA-14 // Žemdirbystė=Agriculture. – 2004, vol. 86, No. 2, p. 30–38

Bates L. S., Waldren R. P., Teare I. D. Rapid determination of free proline for water stress studies // Plant and Soil. – 1973, vol. 39, p. 205–207

Bellostas N., Sorensen H., Sorensen S. Quality of rapeseed oil for non-food (bioenergy), and human and animal nutrition // Bulletin GCIRC. – 2007, No. 24, p. 2–8

Bojanowska M. Fatty acids composition as a criterion for rapeseed application for fuel production // EJPAU. – 2006, vol. 9, No. 4, p. 52. <http://www.ejpau.media.pl//volume9/issue4/art-52.htm> [accessed 05 02 2010]

Brazauskienė I., Bernotas S., Šidlauskas G. Rapsų augintojo atmintinė. Žieminiai rapsai. – Dotnuva, Kėdainių r., 2003. – 46 p.

Burbulis N., Kuprienė R., Blinstrubienė A. Investigation of cold resistance of winter rapeseed *in vitro* // Sodininkystė ir daržininkystė. – 2008, No. 27 (4), p. 223–232

Butkute B. Factors influencing accuracy of NIRS calibrations for the prediction of quality of Lithuania-grown rapeseed // Near Infrared Spectroscopy: proceedings of the 11th International Conference on Near Infrared Spectroscopy. NIR Publications. – Chichester, UK, 2004, p. 405–410

Butkutė B., Šidlauskas G., Brazauskienė I. Seed yield and quality of winter oilseed rape as affected by nitrogen rates, sowing time, and fungicide application // Communications in Soil Science and Plant Analysis. – 2006, vol. 37, p. 2725–2744

Butkutė B., Šidlauskas G., Mašauskienė A., Sliesaravičienė L. Agronominių veiksnių ir augimo sąlygų įtaka žalių baltymų ir žalių riebalų kiekio bei riebalų rūgščių kompozicijos kitimui vasarinių rapsų sėklose [The effect of agronomic factors and growth conditions on protein and fat content in the seed of spring oilseed rape (*Brassica napus* L.) and on the variation of fatty acids (summary)] // Žemdirbystė=Agriculture. – 2000, vol. 70, p. 160–175 (in Lithuanian)

Christopherson S. W., Glass R. L. Preparation of milk fat methylesters by alcoholysis in an essentially non-alcoholic solution // Journal of Diary Science. – 1969, vol. 52, p. 1289–1290

Diepenbrock W., Grosse F. Rapeseed (*Brassica napus* L.) physiology / Advances in plant breeding. 17. Supplements of the Journal Plant Breeding // Beihefte zur Zeitschrift für Pflanzenzüchtung. − Berlin, Vienna, 1995, S. 21–89

Dörffling K. S., Schulemberg G., Lesselich H., Dörffling G. Absicisic acid and proline levels in cold hardened winter wheat leaves in relation to variety-specific differences in freezing resistance // Journal of Agronomy and Crop Science. – 1990, vol. 165, p. 230–239

Flenet F., Merrien A. Main factors influencing energy efficiency for biofuel production and fatty acid composition in winter oilseed rape // GCIRC Bulletin. – 2009, No. 25-1, p. 1–7

Folch J., Less M., Sloanc-Stanley G. H. A simple method for isolation and purification of total lipids from animal tissues // Journal of Biological Chemistry. – 1957, vol. 226, p. 497–509

Gavelienė V., Novickienė L., Miliuvienė L. et al. Possibilities to use growth regulators in winter oilseed rape growing technology. 2. Effects of auxin analogues on the formation of oilseed rape generative organs and plant winterhardiness // Agronomy Research. – 2005, vol. 3, No. 1, p. 9–19
Hunter J. E. n-3 fatty acids from vegetable oils // American Journal of Clinical Nutrition. – 1990, vol. 51, p. 809–814
Meier U. Growth stages of mono- and dicotyledonous plants // BBCH Monograph. – Berlin, 1997. – 622 p.
Mendham N. J. Physiological basis of seed yield and quality in oilseed rape // Rapeseed today and tomorrow: proceedings 9th International Rapeseed Congress. – Cambridge, UK, 1995, vol. 2, p. 485–490
Musnicki C., Tobola P., Musnicka B. Effect of agronomical and environmental factors on the yield quality of winter oilseed rape // Oilseed Crop. – 1999, vol. 20, No. 2, p. 459–470
Novickienė L., Miliuvienė L., Gavelienė V. et al. Rapsų (*Brassica napus* L.) sėklų derlių ir kokybę sąlygojantys veiksniai [A consideration of auxin physiological analogues affecting the seed yield and quality of oilseed rape (*Brassica napus* L.) (summary)] // Vagos. – 2009, vol. 82, No. 35, p. 16–21 (in Lithuanian)
Palta L. A., Zuniga G. E., Alberti M., Corcuera L. J. The role of ABA in freezing tolerance and cold acclimation in barley // Physiologia Plantarum. – 1998, vol. 103, p. 17–23
Petcu E., Terbea M. Proline content and the conductivity test as screening methods for frost tolerance of winter wheat // Bulgarian Journal of Plant Physiology – 1995, vol. 21, No. 4, p. 3–11
Tarakanovas P., Raudonius S., Agronominių tyrimų duomenų statistinė analizė taikant kompiuterines programas *Anova*, *Stat*, *Split-Plot* iš paketo *Selekcija* ir *Irristat*. – Akademija, Kauno r., 2003. – 58 p.
Uemura M., Steponkus L. Modification of the intracellular sugar content alters the incidence of freeze-induced membrane lesions of protoplasts isolated from *Arabidopsis thaliana* leaves // Plant, Cell and Environment. – 2003, vol. 26, p. 1083–1096
Verbruggen N., Hermans Ch. Proline accumulation in plants: a review // Amino Acids. – 2008, vol. 35, p. 753–759

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Žieminio rapso įvairių veislių palyginimas: grūdinimasis, sėklų derlius ir kokybė

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Santrauka

Tyrimų tikslas – ištirti ir palyginti žieminio rapso įvairių veislių pasiruošimą žiemoti, produktyvumo formavimąsi, sėklų derlių bei kokybę. Tirtos veislės: labai ankstyva vidutiniškai žiemojanti 'Libea', vidutinio ankstyvumo gerai žiemojanti 'Sunday', vidutinio vėlyvumo prasčiau nei vidutiniškai žiemojanti 'Valesca'. Mažų laukelių bandymai daryti Botanikos instituto lauko bandymų stotyje. Prolinas buvo išskirtas iš rapso šaknies kaklelio ir viršūninio pumpuro, analizė atlikta taikant kompiuterinę programą *SLT*. Žali riebalai, žali baltymai ir gliukozinolatai buvo nustatyti artimosios srities infraraudonųjų spindulių spektrometru NIRS-6500. Riebalų rūgštys iš sėklų ekstrahuotos Folčo metodu, o jų sudėtis analizuota dujiniu chromatografu.

Palyginus 2007 ir 2008 rudenį tirtas žieminio rapso veisles nustatyta, kad, esant palankioms dygimo ir augimo sąlygoms, visų tirtų veislių augalai suformavo optimalią formą (6–8 tikruosius lapus, šaknų sistemą, šaknies kaklelį) ir grūdinimosi bei pasiruošimo žiemoti laikotarpiu intensyviai kaupė iš dalies atsparumą šalčiui lemiantį metabolitą proliną. Grūdinimosi laikotarpiu (nuo BBCH 14–15 iki BBCH 16–17 tarpsnio) prolino kiekis rapso šaknies kaklelyje veislės 'Libea' padidėjo 52 %, 'Sunday' – 63 %, 'Valesca' – 72 %, o viršūniniame pumpure – atitinkamai 11, 51 ir 58 %. Tyrimų rezultatai parodė, kad tirtų veislių rapsas gerai peržiemojo, ypač veislių 'Valesca' ir 'Sunday'. Palyginus tirtų veislių sėklų derlių, kurį lemia ankštarų kiekis augale, sėklų kiekis ankštaroje, sėklų svoris ir meteorologinės sąlygos, nustatyta, kad sėklų derlius buvo šiek tiek didesnis veislės 'Libea' nei veislių 'Sunday' ir 'Valesca'. Riebalų išeiga, priklausanti ne tik nuo sėklų derliaus, bet ir nuo žalių riebalų procento, buvo didžiausia iš veislės 'Sunday' sėklų.

Veislės genetiniai ypatumai iš dalies lemia riebalų rūgščių (RR) sudėtį. Veislių 'Valesca' ir 'Sunday' sėklų aliejuje nustatytas žymiai mažesnis sočiųjų riebalų rūgščių (SRR), ypač palmitino, kiekis, didesnis mononesočiųjų (MNRR) – oleino – ir polinesočiųjų (PNRR) – linolo bei linoleno – kiekis, palyginti su atitinkamu veislės 'Libea' RR kiekiu.

Reikšminiai žodžiai: prolinas, riebalų rūgščių sudėtis, žali riebalai.