Leaf area duration of oilseed rape (*Brassica napus* subsp. *napus*) varieties and hybrids and its relationship to selected growth and productivity parameters

Sumárna listová pokryvnosť líniových odrôd a hybridov kapusty repkovej pravej (*Brassica napus* subsp. *napus*) a jej vzťah k vybraným rastovo-produkčným ukazovateľom

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Abstract

The trial with 11 genotypes of winter oilseed rape (*Brassica napus* subsp. *napus*) with different provenance was based on experimental station Borovce near SCAR – RICP Piešťany (Slovak Republic) in autumn 2008 (the Trnavská pahorkatina locality, altitude 167 m, maize growing region). Approximately in weekly intervals, since beginning of April to middle of June 2009, for the purpose of growth analysis, plants of all genotypes were taken. The curves of leaf area development of genotypes were simulated from the data on the size of leaf area using software application. Based on these curves, the integral leaf area (leaf area duration, LAD) was established, calculated as the integral area under the curve showing the course of simulated leaf area during the spring growing season. Hybrids had an average leaf area larger than the line varieties. The highest values of LAD reached line varieties Verona and Viking. LAD values simulated for the spring growing season of individual genotypes correlated closely with dry mass weight reached before siliques ripening period (in the middle of June). The positive correlation between the LAD and the number of deployed siliques was recorded. Ability to keep sufficiently large leaf area over a long period expressed in LAD values was shown as a presumption for high production potential of winter oilseed rape genotypes.

Keywords: oilseed rape, *Brassica napus* subsp. *napus*, genotypes, growth parameters, leaf area duration (LAD)

Abstract in Slovak language

Na jeseň v roku 2008 bol na pozemkoch výskumno-šľachtiteľskej stanice VÚRV Piešťany v Borovciach založený pokus s 11 genotypmi kapusty repkovej pravej, formy ozimnej, rôznej proveniencie (Trnavská pahorkatina, nadmorská výška 167 m, kukuričná výrobná oblasť). Z genotypov boli od začiatku apríla do polovice júna 2009 odoberané rastliny približne v týždňových intervaloch pre účely rastovej analýzy. Z údajov o veľkosti listovej plochy boli modelované krivky vývinu listovej plochy jednotlivých genotypov pomocou softvérovej aplikácie, na základe ktorých bola stanovená integrálna listová plocha LAD (Leaf Area Duration), počítaná ako integrál plochy pod krivkou vyjadrujúcou priebeh modelovanej listovej plochy počas trvania jarného vegetačného obdobia. Hybridy mali v priemere väčšiu listovú plochu ako líniové odrody. Najvyššie hodnoty LAD dosiahli líniové odrody Verona a Viking. Hodnoty LAD modelované pre jarné vegetačné obdobie jednotlivých genotypov úzko korelovali s hmotnosťou sušiny dosiahnutou pred obdobím dozrievania šešúľ (polovica júna). Bola zaznamenaná pozitívna korelácia medzi LAD a počtom nasadených šešúľ. Ukázalo sa, že dostatočne veľká listová plocha schopná udržať sa počas dlhého obdobia vyjadrená v hodnotách LAD predstavuje predpoklad vysokého produkčného potenciálu genotypov kapusty repkovej pravej.

Kľúčové slová: kapusta repková pravá, *Brassica napus* subsp. *napus*, genotypy, rastové parametre, LAD

Detailed abstract in Slovak language

Na jeseň v roku 2008 bol na pozemkoch výskumno-šľachtiteľskej stanice VÚRV Piešťany v Borovciach (Trnavská pahorkatina, nadmorská výška 167 m, kukuričná výrobná oblasť, černozem hnedozemná, obsah humusu 1,8 – 2%, pH 6,35 – 7,2) založený pokus s 11 genotypmi kapusty repkovej pravej, formy ozimnej, rôznej proveniencie: Labrador (líniová odroda, Francúzsko), Maplus (líniová odroda, Nemecko), Oponent (líniová odroda, Česká republika), Slogan (líniová odroda, Nemecko), Verona (líniová odroda, Veľká Británia), Viking (líniová odroda, Nemecko), Baldur (hybrid, Nemecko), Champlain (hybrid, Francúzsko), Dekade (hybrid, Francúzsko), PR 45 D 01 (hybrid, Nemecko/Francúzsko), PR 45 D 03 (hybrid, Nemecko/Francúzsko). Líniové odrody boli vysiate v počte 700 000 klíčivých semien . ha^{-1}, hybridy v počte 500 000 klíčivých semien . ha^{-1}. Na parcelky o rozmeroch 10 m^2 (1,25 x 8 m) v štyroch opakovaniach boli na jeseň pred sejbou aplikované hnojivá v dávke 200 kg N-P-K . ha^{-1}. V marci 2009 boli rastliny prihnojované dusíkom - DASA - v dávke 150 kg .ha^{-1}. V apríli 2009 bol ešte aplikovaný DAM 390 v dávke 150 l.ha^{-1}. V septembri 2008 boli rastliny ošetrované morforegulátorom s fungicídnymi účinkami, herbicídmi a na jar počas vegetácie insekticídmi proti kvetovým a šešuľovým škodcom.

Z genotypov boli od začiatku apríla do polovice júna 2009 odoberané rastliny približne v týždňových intervaloch pre účely rastovej analýzy. Z údajov o veľkosti listovej plochy boli modelované krivky vývinu listovej plochy jednotlivých genotypov pomocou programu Easy Fit Express (Verzia 1.2, Klaus Schitkowski, Nemecko), na základe ktorých bola stanovená integrálna listová plocha LAD (Leaf Area Duration), počítaná ako integrál plochy pod krivkou vyjadrujúcou priebeh modelovanej listovej plochy počas trvania jarného vegetačného obdobia. Podľa vývinu počasia v septembri až novembri (tab. 1) boli na lokalite pokusu splnené nároky kapusty repkovej pravej na vlahu i na teplotu. Zima (december až február) bola ako celok teplá, jar (marec až máj) možno hodnotiť tiež ako teplú až veľmi teplú oproti dlhodobému priemeru. Začiatkom apríla nastúpilo výrazne teplé a suché počasie. Charakteristický exponenciálny nárast veľkosti listovej plochy bol v mesiaci apríl čiastočne zabrzdený mimoriadne suchým počasím (tab. 1). Vývin listovej plochy jednej rastliny kapusty repkovej pravej v priemere za všetky sledované odrody počas vegetácie na jar zobrazuje obr. 1. V jednotlivých fyziologických parametroch (tab. 2) sa prejavila významná odrodová variabilita. Sledované genotypy (obr. 2) sa výrazne líšili v maximálne dosahovanej listovej ploche. Hybrid s najväčšou listovou plochou (PR 45 D01) dosahoval viac než dvojnásobnú plochu 1 rastliny v porovnaní s líniovou odrodou Labrador. Pri porovnaní skupiny hybridov a línií (obr. 3) bola pozorovaná signifikantne vyššia listová plocha 1 rastliny pri hybridoch. Listová plocha hybridov sa štatisticky významne líšila od listovej plochy líniových odrôd. Medzi odrody s najvyšším LAD sa zaradili odrody Dekade, PR 45 D 01, PR 45 D 03 (všetko hybridy), Viking a Verona (líniové odrody, obr. 4). Pri vzájomnom porovnaní skupiny hybridov a skupiny líniových odrôd (obr. 5) nebolo však badať žiaden rozdiel, nakoľko hybridy mali nižší počet rastlín na jednotku plochy. Pri líniových odrodách bola zaregistrovaná väčšia variabilita odrôd – veľmi vysoké aj veľmi nízke LAD. Hodnoty dosiahnutého LAD modelovaného za celé jarné vegetačné obdobie vztiahnuté ku hmotnosti sušiny rastlín stanovenej pri odbere rastlín 13.5.2009, prejavili štatisticky preukaznú závislosť (obr. 6). Štatisticky preukazná bola aj závislosť medzi LAD modelovanom za celé jarné vegetačné obdobie a počtom nasadených šešúľ na 1 rastlinu (obr. 7). Zo závislosti na obr. 7 vyplynulo, že genotypy s vysokými hodnotami dosiahnutého fotosyntetického potenciálu LAD (Dekade, PR 45 D 01, PR 45 D 03, Viking a Verona) sa zároveň vyznačovali vysokým počtom nasadených šešúľ.

Rýchle vytvorenie dostatočne veľkej listovej plochy a jej dlhé udržanie má vplyv na celkovú úroveň vyprodukovanej biomasy. Dostatočná zásoba asimilátov uložených v biomase umožňuje vysoké nasadenie generatívnych orgánov (šešúľ) na rastlinách repky. O celkovej úrode a kvalitatívnych vlastnostiach však rozhoduje aj schopnosť retranslokácie asimilátov do semien a navyše, špecificky pre olejniny, aj kapacita pre zabudovanie uhlíka do reťazcov mastných kyselín v procese biosyntézy oleja. I keď teda vysoké hodnoty LAD nezaručujú automaticky vysokú produktivitu kapusty repkovej pravej, dosiahnutím vyššej efektívnosti využitia žiarenia je vytvorený potenciál, bez ktorého by zvyšovanie úrod nebolo možné.

Kľúčové slová: kapusta repková pravá, *Brassica napus* subsp. *napus*, genotypy, rastové parametre, LAD

Introduction

The rising of winter oilseed rape (*Brassica napus* subsp. *napus*) growing areas is recorded since 1990 year in Slovak republic (from about 30,000 ha in 1990 year to almost 125,000 ha in 2002 year, [24]). In autumn 2008 was 167,586 ha sown to this crop [19]. 23% of Slovakia´s agricultural landscape has very good growing conditions for oilseed rape, 31% has suitable conditions, 14% has less suitable and 32% unsuitable conditions [21]. Under the action of various environmental factors it is necessary to observe growth and yield characters as evaluation criteria in the winter oilseed rape growing [7, 5]. Lack of this information is in literature from Slovak territory.

Knowledge the size of the crop stand assimilation apparatus is one of the basic parameters needed in determining the plant production performance. Using growth analysis method it is possible to determine the actual accumulation by plant dry weight, respectively by crop stand. The method is based on successive taking of plants in a specific time, in determination of dry weight and leaf area of the above ground parts of plants or crop stand [9]. Between parameters derived from growth analysis with the most informative value belongs integral leaf area (LAD – leaf area duration), also called photosynthetic potential, expressing summary leaf cover for the observed period. LAD parameter reflects the ability of plants to create and maintain the green leaf area for the longest time per land area unit. It is calculated as a conjunction of green leaf area size and it´s duration (m^2 day m^{-2}). Therefore we focused in this paper on the assessment of integral leaf area relationship of individual genotypes towards selected growth-yield indicators mainly. These indicators are important for achieving high yields and required seed quality of oilseed rape.

Materials and Methods

The trial with 11 genotypes of winter oilseed rape (*Brassica napus* subsp. *napus*) with different provenance was based on experimental station Borovce near SCAR – RICP Piešťany (Slovak Republic) in autumn 2008 (the Trnavská pahorkatina locality, altitude 167 m, maize growing region). The area of interest is situated in a very warm climate region with annual sum of temperatures 3 000 °C with continental character of climate. The long-term average of temperature is 15.5°C, in vegetation period 9.2°C. Sum of annual precipitation is 593 mm, in vegetation period 358 mm. Soil type is a Luvi-Haplic Chernozem, with 1.8 – 2% content of humus, with pH 6.35 – 7.2 [10, 1]. On 28th of August, 2008, 6 lines and 5 hybrids of winter oilseed rape were sown: Labrador (line variety, France), Maplus (line variety, Germany), Oponent (line variety, Czech Republic), Slogan (line variety, Germany), Verona (line variety, Great Britain), Viking (line variety, Germany), Baldur (hybrid, Germany), Champlain (hybrid, France), Dekade (hybrid, France), PR 45 D 01 (hybrid, Germany/France), PR 45 D 03 (hybrid, Germany/France). Line varieties were sown with amount of 700,000 germinable seeds per 1 ha, hybrids with amount of 500,000 germinable seeds per 1 ha. Plots with area 10 m^2 (1.25 x 8 m) in four replications were fertilised in autumn (pre-sowing fertilising) with 200 kg N-P-K per 1 ha. In March 2009 plants were additionally

fertilised with nitrogen – (DASA) - 150 kg ha^{-1}. In April 2009 was applied DAM 390 (39 kg N in 100 l^{-1} of solution). Plots were treated in autumn by morphoregulator with fungicide effect, with herbicides against weeds. During vegetation period, insecticides against flower and silique pests were used. The harvest was realised on 12th of July, 2009.

Plants were taken approximately in weekly intervals since beginning of April to middle of June 2009 for the purpose of growth analysis in particular days in 2009 year: April, 4th, April, 15th, April, 22nd, May, 4th, May, 13th. Consequently, in May, 21st, May, 27th, June, 3rd and June, 15th not whole plants but siliques only were taken, because of plant leaf area reduction at the end of vegetation. Leaf area was determined by scanning and subsequent image analysis program ImageJ (version 1.31, National Institutes of Health, Bethesda, USA). The curves of leaf area development of genotypes were simulated from the data on the size of leaf area using program Easy Fit Express (version 1.2, Klaus Schitkowski, Germany). Based on these curves, the integral leaf area (Leaf Area Duration, LAD) was established, calculated as the integral area under the curve showing the course of simulated leaf area [22] during the spring growing season of winter oilseed rape genotypes.

Following data were detected: plant height, leaves number, lateral branches number, siliques number, total dry mass weight, total leaves dry mass and total siliques dry mass (grams in average of one plant and calculated into 1 m^2 by actual average number of plants ascertained in spring evaluation per 1 m^2 - data from experimental station in Borovce). According to the methodics [18] further growth parameters were estimated even: LAI, LAR, SLA, SLW, AGR, NAR, RGR, CGR. The investigated parameter values were used to compare differences between individual genotypes. Data were processed using software applications Microsoft Excel and Statistica (StatSoft, Inc). For analysis of observed factors (date, genotype, type of genotypes) the multifactor analysis of variance (ANOVA) was used. Mean values were compared using Duncan LSD test at 95 % probability level with identification of statistically homogenous groups indicated in graphs by small characters (a, b, c, etc.). Statistical significant differences among mean values are displayed in graphs using different characters above data points. The correlation analysis was also realised. Considering extensive data some selected parameters assessment were focused in this paper, only.

Results and discussion

According to the autumn weather development in September – November needs for humidity and temperature of winter oilseed rape on experiment locality Borovce, near Piešťany were fulfilled. Winter (December - February) was warm in average, spring (March - May) was evaluated as warm till very warm compared to long-term average. Since beginning of April markedly warm and dry weather had started. This fact had

impact on abnormally rapid growth vegetation, earlier flowering and earlier onset of pests [12]. Harvest was complicated with rainy weather in July (Table 1).

Photosynthetic efficiency and growth in the crop plants are strongly related to the effect of canopy architecture on the vertical distribution of light within the canopy [16]. Net assimilation rate (NAR) expresses average gain of total dry mass weight per unit of assimilation leaf area. Specific rapid growth rate (RGR) states increase of total dry mass production in time interval (day). Crop growth rate (CGR) presents a speed of dry mass production accrual in certain time period on crop area unit. With leaf area index (LAI) rise (the crop leaves area created per area unit) decreases NAR values and CGR is increasing to the sure limit. Crop stand with insufficient developed leaf area and small number of plants has low LAI value and releases a lot of solar radiation to the soil. Every leaf of crop stand is well irradiated, NAR reaches high

Table 1: The weather running on experimental station Borovce from August 2008 till July 2009.
Tabuľka 1: Priebeh počasia na experimentálnej stanici v Borovciach od augusta 2008 do júla 2009.

Year	2008					2009						
Month	VIII.	IX.	X.	XI.	XII.	I.	II.	III.	IV.	V.	VI.	VII.
Temperature - average (ºC)	20.72	15.27	10.65	6.55	2.27	- 2.03	1.05	5.27	14.45	16.02	18.40	22.44
∑ rainfall (mm)	71.0	50.5	33.1	37.0	29.0	29.9	64.8	58.5	6.0	47.0	58.5	81.0

values. Because of small leaf area (low LAI values) the crop stand productivity expressed by CGR values is low, too [9]. The efficiency of the conversion of intercepted solar radiation into dry matter falls with decreasing of LAI [16]. When number of plant individuals on area is optimal and horizontally and vertically space leaves configuration is optimal too, then absorption of solar radiation is high; crop stand achieves high values of speed accrual of dry mass per area unit - CGR [9]. Table 2 reflects values of selected winter oilseed rape genotypes parameters.

Significant variability was manifested in individual physiological parameters (Table 2). Higher values in CGR parameter were achieved on locality of experiment compared to data published [9]. Moderate levels in a case RGR parameter were found, in accordance with mentioned authors. But higher values in CGR and RGR parameters recognized [4] in experiment by other winter oilseed rape genotypes. Authors [9] reported concrete data at interval 16 – 18 g m^{-2} day^{-1} in CGR (spring and autumn season) and 0.0121 – 0.0945 g g^{-1} day^{-1} in RGR (spring season) in dependence of crop stand density and growing conditions. They showed NAR average value7 – 8 g m^{-2} day^{-1}, or the highest values 9 – 10 g m^{-2} in September and April. Obtained values of NAR in this experiment (table 2) ranged in this interval generally; mostly they were below 7 g m^{-2} day^{-1}. On the other hand, authors [3] acquired higher values

– 6 - 16 g m^{-2} day^{-1} in NAR parameter ranking. It was given by high probability by genotypic differences of assessed winter oilseed rape genotypes. But the number of siliques per plant is decisive for seed yield. This trait is ultimately determined by the survival of branches, buds, flowers and young siliques rather than by potential number of flowers and siliques [2].

There are a number of additional physiological traits that have implications on yield potential and are related to increasing assimilate availability. The first is the ability to reach full ground cover as early as possible after emergence to maximize the interception of radiation [15]. The second is remobilization of soluble carbohydrates (stem reserves) during grain filling [17]. The third is the ability to maintain green leaf area duration "stay green" throughout grain filling [14]. Direct evidence for the contribution of these traits to high yield potential is lacking. Prolonged green leaf area duration (LAD) is another trait with the potential for improving radiation use efficiency [14].

Table 2: Selected growth and yield parameters of winter oilseed rape genotypes
Tabuľka 2: Vybrané rastové a úrodové parametre genotypov kapusty repkovej pravej

Genotype	Provenance of line / hybrid (L / H)	Number of plants per 1 m^2	3.4. - 13.5.2009 NAR ($g.m^2.d.^{-1}$)	RGR ($g.g^{-1}.d.^{-1}$)	CGR ($g.m^{-2}.d.^{-1}$)	Seed yield ($kg.m^{-2}$)
Labrador	L (FRA)	32	4.84	0.0278	29.53	0.468
Slogan	L (GER)	32	3.08	0.0380	26.06	0.346
Maplus	L (GER)	30	7.14	0.0420	31.89	0.365
Champlain	H (FRA)	28	6.93	0.0354	41.76	0.408
Baldur	H (GER)	32	5.53	0.0348	34.64	0.288
Oponent	L (CZ)	38	7.00	0.0412	50.88	0.334
Viking	L (GER)	46	7.81	0.0529	73.19	0.299
PR 45 D 01	H (GER / FRA)	18	3.47	0.0294	24.15	0.316
PR 45 D 03	H (GER / FRA)	30	4.89	0.0449	55.14	0.390
Dekade	H (FRA)	28	5.08	0.0599	37.58	0.445
Verona	L (GB)	42	9.09	0.0593	103.42	0.410

The leaf area development of one winter oilseed rape plant during spring vegetation for all observed genotypes in average shows figure 1. Maximal LAI is generally reached in mid May [8]. The typical exponential rise of leaf area was partly locked by extremely dry weather in April (table 1). Observed genotypes (figure 2) reached substantially different leaf area maximum. Hybrid with the largest leaf area (PR 45 D01) achieved more than double leaf area of one plant in comparison with line variety

Labrador (in graphs, unequal characters above boxes indicate significantly different homogeneous groups). In comparison of hybrids and line varieties evaluated as groups (figure 3), significantly higher leaf area of one plant of hybrids was observed compared to line varieties (P = 0.0002).

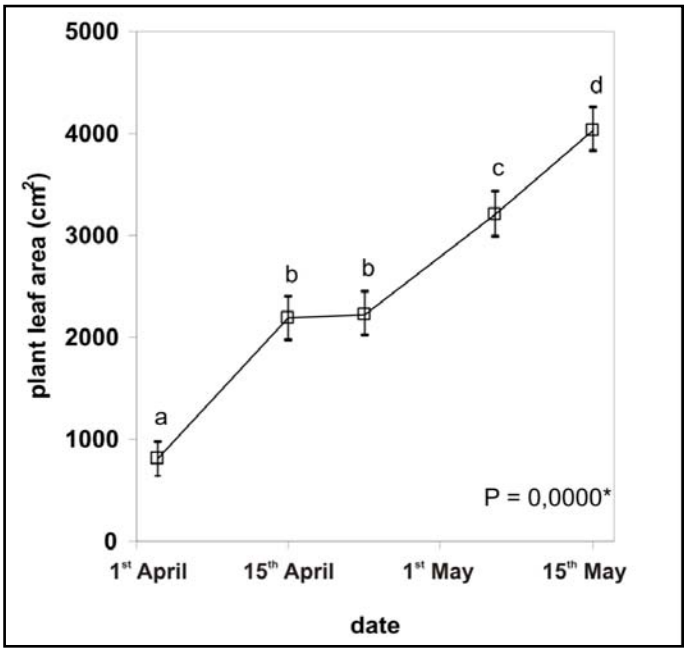

Figure 1: Leaf area development of one winter oilseed rape plant during spring growth vegetation phase (April-May 2009) in average for all genotypes.
Obrázok 1: Vývin listovej plochy jednej rastliny kapusty repkovej pravej, f. ozimná v priebehu jarnej rastovej vegetačnej fázy v priemere za všetky genotypy.

Seasonal changes in LAI and LAD have a marked effect on crop productivity [13]. LAD displayed a strong positive correlation with both dry matter production and grain yield [11]. [20] refers about this correlation, too. The same author also adds that leaf area duration affects yields more than leaf area greatness. Levels of photosynthetic potential (LAD) in our experiment illustrates figure 4. The highest LAD had genotypes Dekade, PR 45 D 01, PR 45 D 03 (hybrids), Viking and Verona (line varieties). In mutual comparison of hybrids and line varieties groups (figure 5) no difference was regarded; because of hybrids had lover number of plants per area unit. Bigger variability was registered in line varieties - very high and very low LAD. The scatter plot of achieved whole season LAD values vs. values of dry mass rated on 13th of May, 2009 (plant sampling) show clear correlation (figure 6). Relatively high dependence between LAD (modelled through the whole spring vegetation period) and number of set siliques per one winter oilseed rape plant shows figure 7. Genotypes with high values of reached photosynthetic potential (Dekade, PR 45 D 01, PR 45 D 03, Viking and Verona) were distinguished with high number of set

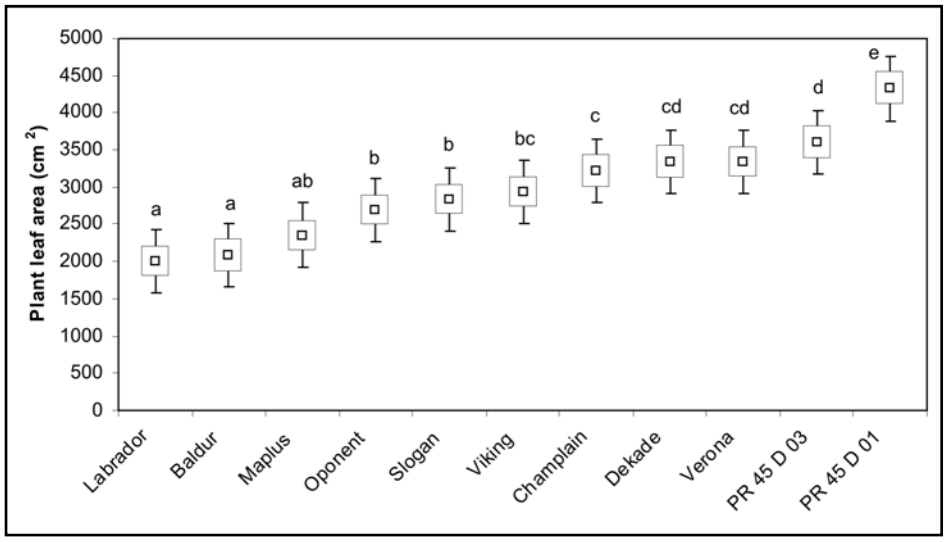

Figure 2: Average leaf area of 1 plant in maximum leaf cover period (from 1st till 2nd decade of May) of observed oilseed rape genotypes (unequal characters above boxes indicate significantly different homogeneous groups according to Duncan LSD test at 95 %).
Obrázok 2: Priemerná listová plocha 1 rastliny v období maximálnej listovej pokryvnosti (1. až 2. dekáda mája) pri sledovaných genotypoch kapusty repkovej pravej (charakteristiky a-e indikujú signifikantne rozdielne homogénne skupiny).

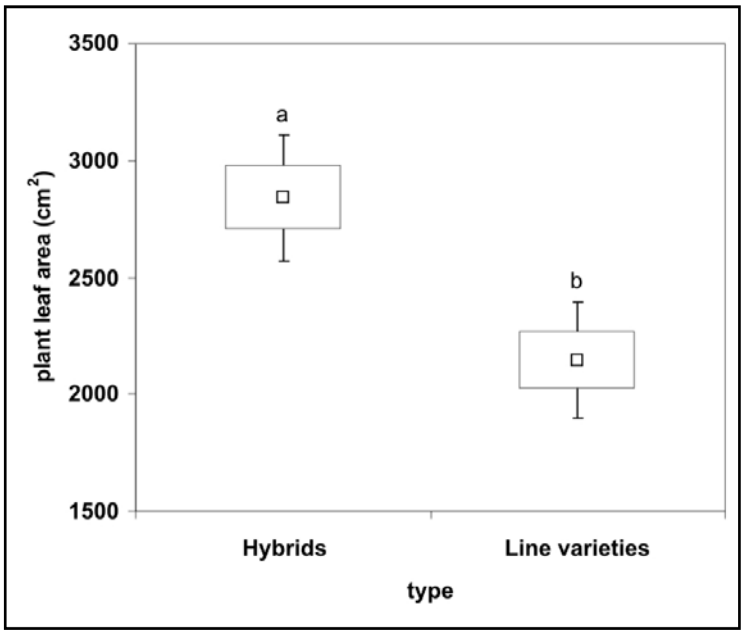

Figure 3: Summary comparison of maximum leaf area of hybrids and line oilseed rape varieties.
Obrázok 3: Sumárne porovnanie maximálnej listovej plochy hybridov a líniových odrôd kapusty repkovej pravej.

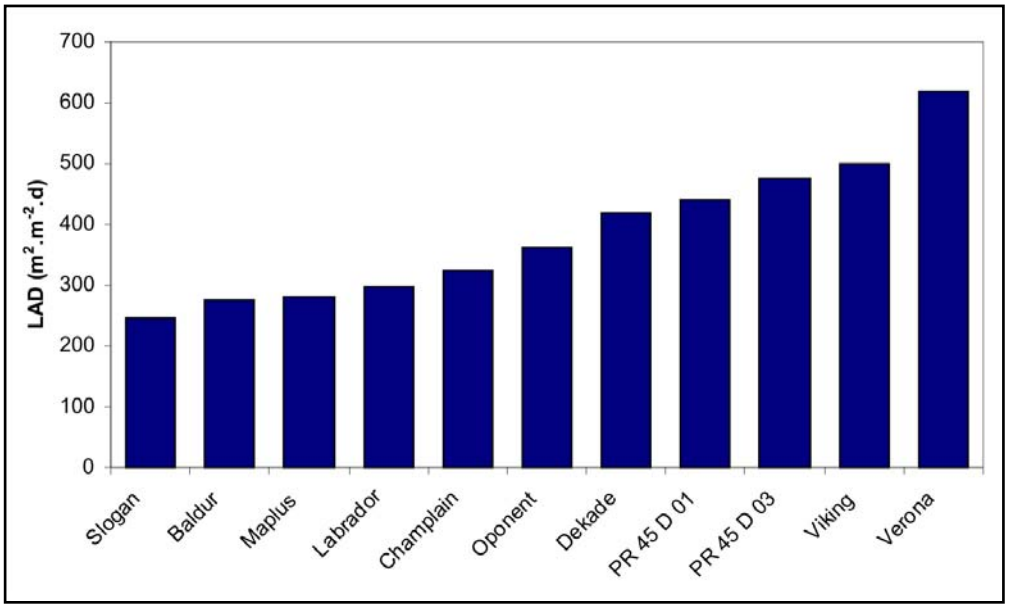

Figure 4: Levels of integral leaf area (LAD) of observed winter oilseed rape genotypes.
Obrázok 4: Hodnoty integrálnej listovej plochy (LAD) sledovaných genotypov kapusty repkovej pravej.

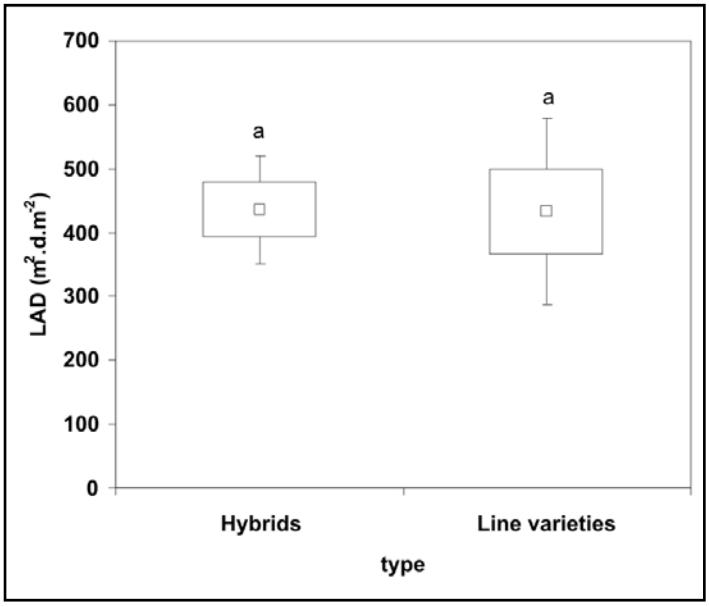

Figure 5: Average values of integral leaf area (LAD) – summary for hybrids and line varieties of winter oilseed rape.

Obrázok 5: Priemerné hodnoty integrálnej listovej plochy (LAD) sumárne za hybridy a líniové odrody kapusty repkovej pravej.

siliques, as it results from ascertained correlation (figure 7). This fact is confirmed also by authors [23] in their findings. They connected higher maxima of leaf area indexes (LAI) with higher number of siliques per plant. This both parameters combined with longer leaf area duration (LAD) led to higher final seed yields. Higher chlorophyll content per leaf area unit can suggest on possible higher LAD [6].

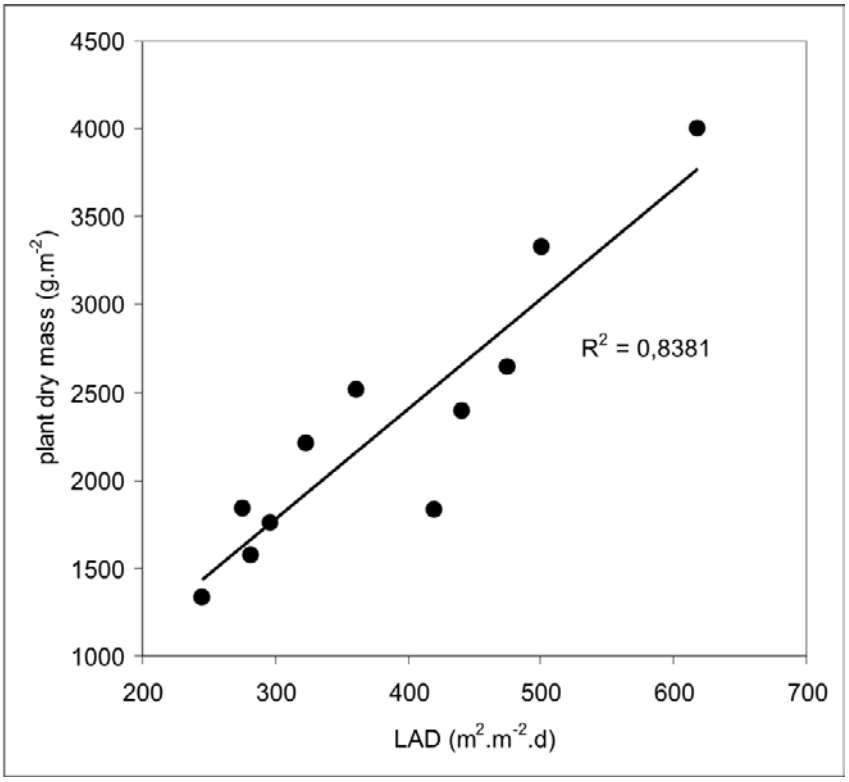

Figure 6: Correlation between integral leaf area (LAD) and plant dry mass weight (plant taking on 13th of May, 2009).
Obrázok 6: Vzťah medzi integrálnou listovou plochou (LAD) a hmotnosťou sušiny (odber 13.5. 2009).

From mentioned findings, we can conclude that rapid creation of sufficiently large leaf area and its long duration has an influence for whole level of produced biomass. It is a primary requirement for formation of field crops yields. Sufficient sink of assimilates located in biomass allows high set of generative organs (siliques) on oilseed rape plants. But ability of assimilates retranslocation into seeds decides about whole yield and its qualitative capabilities. Additionally, very important is a capacity for carbon incorporation into fat acids sequences in oil biosynthesis process, specifically for oil crops. For that reason, high LAD levels can not automatically guarantee high oilseed rape production. But without increase of radiation use efficiency the yield raise would not be possible.

It is worth to remark that high production ability does not necessarily project into high yield or oil quality of winter oilseed rape. The soil tillage quality, protection against weeds and fungal diseases as well as yield loss prevention play important role, too. We can state from this point of view that agrotechnics of soil tillage under oilseed

rape as well as protection and yield loss preclusion was done responsibly and perfectly on based field trial in research – breeding experimental station Borovce near SCAR – RICP Piešťany. These facts allowed to express yield potential of hybrids and line varieties and to reach mostly higher seed yield, even despite of less hospitable weather in April 2009.

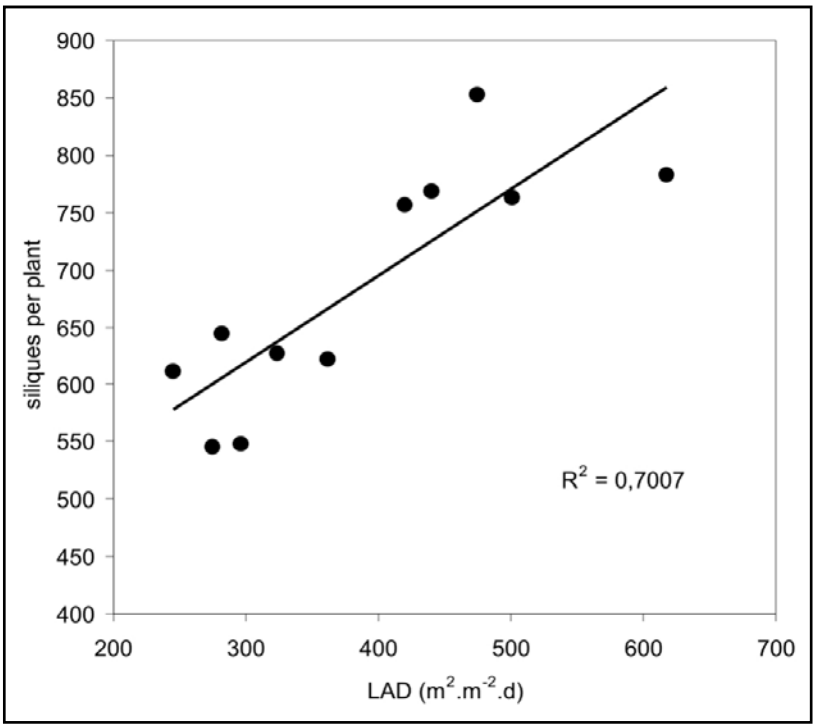

Figure 7: Relationship between integral leaf area (LAD) and observed number of siliques per one winter oilseed rape plant.
Obrázok 7: Vzťah medzi integrálnou listovou plochou (LAD) a stanoveným počtom šešúľ na 1 rastlinu.

Conclusions

- Observed collection of winter oilseed rape genotypes was characterized by significant differences in leaf area per 1 plant, where hybrids had in average larger leaf area than line varieties.

- Because of lower number of plants per area unit of hybrids, differences in leaf area duration (LAD) between hybrids and line varieties were not found. The highest values of LAD achieved line varieties Verona and Viking.

- LAD values modelled for the spring growing season of individual genotypes correlated closely with dry mass reached before ripening period (middle of June).

- The high positive correlation between the LAD and the number of deployed siliques was found.

- Our results suggest that sufficiently large leaf area with long duration of photosynthetic activity characteristic by high LAD values is a presumption for high production potential of winter oilseed rape genotypes.

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References

[1] Babulicová M., Úroda zrna, úrodotvorné prvky a aktuálna zaburinenosť jačmeňa siateho jarného pri rôznej koncentrácii obilnín v osevných postupoch, in: Zborník vedeckých prác SCPV – ÚAE v Michalovciach. SCPV – ÚAE, Michalovce, 2007, pp. 55 – 63.

[2] Diepenbrock W., Yield analysis of winter oilseed rape (*Brassica napus* L.): a review, Field Crop Research (2000) 67: 35-49.

[3] Hunková E., Brestič M., Masarovičová E., Surovčík J., Ferencová J., Využitie rastovej analýzy pre hodnotenie genotypových rozdielov kapusty repkovej pravej (*Brassica napus* subsp. *napus*), in: Nové poznatky z genetiky a šľachtenia poľnohospodárskych rastlín. SCPV – VÚRV Piešťany, 2008, pp. 76-78.

[4] Hunková E., Ferencová J., Brestič M., Živčák M., Masarovičová E., Ekofyziologické prístupy hodnotenia produkčného procesu kapusty repkovej pravej (*Brassica napus* subsp. *napus*), in: Vliv abiotických a biotických stresorů na vlastnosti rostlin 2009. VÚRV, Praha-Ruzyně, 2009, pp. 299-303.

[5] Hunková E., Živčák M., Brestič M., Malovcová Ľ., Vzťah indexu listovej pokryvnosti k produkčnému potenciálu genotypov kapusty repkovej pravej, forma ozimná (*Brassica napus* subsp. *napus*), Acta fytotechnica et zootechnica (2009) 3: 76-80.

[6] Hunková E., Živčák M., Ferencová J., Malovcová Ľ., Brestič M., Dynamika obsahov asimilačných pigmentov vo vybraných genotypoch kapusty repkovej pravej (*Brassica napus*, subsp. *napus*), in: Nové poznatky z genetiky a šľachtenia poľnohospodárskych rastlín. CVRV – VÚRV Piešťany, 2009, pp.72-75.

[7] Jambor M., Vplyv výsevku a termínu sejby na tvorbu úrody vybraných odrôd a hybridov repky ozimnej, Agriculture (Poľnohospodárstvo) (2007) 1: 49-57.

[8] Kappen L., Hammler A., Schultz G., Seasonal Changes in the Photosynthetic Capacity of Winter Rape Plants under Different Nitrogen Regimes Measured in the Field, Journal of Agronomy & Crop Science, (1998) 181: 179-187.

[9] Kostrej A. et al., Ekofyziológia produkčného procesu porastu a plodín, SPU v Nitre, Nitra, 1998. 187 p.

[10] Kováč K., Žák Š., Lehocká Z., Produkčné a kvalitatívne parametre pšenice ozimnej (*Triticum aestivum* L.) pestovanej v integrovanom a low-input systéme, Agriculture (Poľnohospodárstvo) (2005) 3: 113-121.

[11] López-Bellido F. J., López-Bellido R. J., Khalil S. K., López-Bellido L., Effect of Planting Date on Winter Kabuli Chickpea Growth and Yield under Rainfed Mediterranean Conditions, Agronomy Journal (2008) 4: 957-964.

[12] Malovcová Ľ., Sekerková M., Prognóza úrody kapusty repkovej pravej formy ozimnej v SR v r. 2009, CVRV – VÚRV Piešťany, Piešťany, 2009.

[13] Peltonen-Sainio P., Forsman K., Poutala T., Crop Management Effects on Pre- and Post-Anthesis Changes in Leaf Area Index and Leaf Area Duration and their Contribution to Grain Yield Components in Spring Cereals, Journal of Agronomy & Crop Science (1997) 179: 47-61.

[14] Reynolds M. P., Pfeiffer W. H., Applying physiological strategies to improve yield potential, in: Royo C., Nachit M. M., di Fonzo N., Araus J. L. (Eds.), Durum Wheat Improvement in the Mediterranean Region: New Challenges. CIHEAM – Options Méditerranéennes, 2000, pp. 95-103.

[15] Richards R. A., Defining selection criteria to improve yield under drought, Plant Growth Regulation, (1996) 2: 157-166.

[16] Sharifi R. S., Zadeh M. Z., Seiedi M. N., Evaluation of yield and growth indices of canola (*Brassica napus* L.) cultivars in different nitrogen fertilization levels, Journal of Phytology (2009) 6: 475-481.

[17] Stoy V., Photosynthesis, respiration, and carbohydrate accumulation in spring wheat in relation to yield, Physiologia Plantarum (1965) Supplement IV: 1-125.

[18] Šesták Z., Čatský J., et al.: Metody studia fotosyntetické produkce rostlin. Academia, Praha, 1966. 359 p.

[19] Štatistický úrad Slovenskej republiky, Odhad úrody poľnohospodárskych plodín k 15. 8. 2009. Dostupné na internete : http://portal.statistics.sk/showdoc.do?docid=18904

[20] Triboi-Blondel A.-M., Mise en place et fonctionnement des feuilles de colza d´hiver: relations azote-carbone et sénescence, Agronomie (1988) 9: 779-786.

[21] Vilček J., Vhodnosť a kategorizácia pôd pre pestovanie repky olejky formy ozimnej (*Brassica napus* L. var. *arvensis*, forma *biennis*), Acta fytotechnica et zootechnica (2004) 2: 29-33.

[22] Watson D. J., Comparative physiological studies on the growth of field crops. I.: Variation in net assimilation rate and leaf area between species and varieties, and within and between years, Ann. Bot. (1947) 11: 41-76.

[23] Wright G. C., Smith C. J., Woodrofe M. R., The effect of irrigation and nitrogen fertilizer on rapeseed (*Brassica napus*) production in South-Eastern Australia: I. Growth and seed yield, Irrigation Science (1988) 1: 1-13.

[24] Zubal P., Vplyv vybraných agrotechnických faktorov na úrody ozimnej repky olejky, Agriculture (Poľnohospodárstvo) (2003) 12: 597-607.