Chapter 1. PLANT BREEDING

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COLEOPTILE LENGTH IN LITHUANIAN WINTER WHEAT ADVANCED BREEDING LINES

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Abstract

Research on coleoptile length of Lithuanian winter wheat advanced breeding lines was done at the Lithuanian Institute of Agriculture (LIA) during 2006–2007. Differences in coleoptile length were large among the lines within the tested set. Our experimental evidence showed that genotypes with coleoptiles of medium length (5–7 cm) were dominant among the advanced breeding lines tested. Analysis of maximal coleoptile length showed that most frequent were lines with a coleoptile length of 7.1–8.0 cm (47 %) in 2006. The next year's lines were dominated by the genotypes with a coleoptile length of 8.1–9.0 cm (31 %). There were no promising lines for possible deep sowing in the screened set. The correlation analysis showed that the mean coleoptile length between years correlated strongly (r = 0.76**). These relationships provide a breeder with a possibility to effectively select lines with longer coleoptiles during one year under the environment.

Key words: winter wheat, advanced breeding lines, coleoptile length.

Introduction

Semidwarf and dwarf wheats have the potential to produce high yields when sown and managed under optimal conditions /Sial et al., 2002/. However, yield potential often falls because of poor seedling establishment and low vigour associated with gibberellic acid insensitive height reducing (*Rht*) genes present in these wheats. Changing climate poses new challenges to winter wheat growers and breeders. One of the hardships for seedling establishment is too dry soil surface at sowing time /Richards et al., 2002/.

Seedling establishment of winter wheat has become problematic under Lithuanian conditions in some years. In Lithuania there was no precedent that winter wheat did not germinate at all. But from time to time it is possible to see poorly germinated fields in the autumn. Green patches in the fields are established seedlings. This suggests that adequately wet soil can be achieved if sown a few cm deeper. Successful germination after deeper sowing can be secured if cultivars with long coleoptiles are sown. Another possible means enabling improvement of seedling establishment is irrigation, but technologically and economically it is accessible only in the minority of growing areas.

The most popular and economically beneficial is dry area practice which involves deep sowing of cultivars with long coleoptiles. This trait is also valuable under normally wet soil conditions because it enables the seedlings to germinate from deeper sowing depth /Hakizimana et al., 2000; Hedden, 2003/. Also, yield data for wheats sown into favourable seedbeds indicated no yield penalty for long coleoptile /Rebetzke et al., 1999/. Differences in coleoptile length among genotypes are also specific to other cereals – barley and pearl millet /M'Ragwa et al., 2001; Takahashi et al., 2001/.

Two strategies may be pursued to achieve adult-plant height reduction without negative consequences on reduced coleoptile elongation. One might be used to generate populations void of *Rht-B1b* (formerly *Rht1*) and *Rht-D1b* (formerly *Rht2*) and select phenotypically for minor height-suppressing genes. Removal of these genes in bread wheat near isogenic lines produced only minor increases (less than 28 %) in height, but substantially greater increases (up to 65 %) in coleoptile length /Trethowan et al., 2001/. Independent expression of plant height and coleoptile length in non-*Rht1* or non-*Rht2* populations should allow divergent selection responses for these traits, i.e., shorter height, longer-coleoptile genotypes, in some populations /Rebetzke et al., 1999/. The other strategy might be employed to introduce GA-responsive dwarfing genes, such as *Rht8*, *Rht9* and *Rht12*, that may not reduce coleoptile elongation, though their phenotypic detection may be more challenging /Worland et al., 1994; Worland, Snape, 2001/.

The main problem of selecting cultivars with long coleoptiles is low correlation of coleoptiles length with plant height of semidwarf cultivars without *Rht-B1b* and *Rht-D1b* /Richards et al., 2002/. Tall cultivars in most cases possess long coleoptiles, however these cultivars constitute a minor share of the total range of European winter wheat cultivars /Anonymous, 2005/.

Lithuanian winter wheat breeding material has not been tested for coleoptile length before. It is likely that coleoptile length of Lithuanian winter wheat advanced breeding lines will be shorter compared with the genotypes from arid areas developed specifically for this trait.

Material and Methods

The investigation of coleoptile length of Lithuanian winter wheat advanced breeding lines was done at the Lithuanian Institute of Agriculture (LIA) during 2006–2007. Seed samples of the sowing year were used for testing. In total we screened 87 advanced breeding lines in 2006 and 137 advanced breeding lines in 2007. Fifteen uniform seeds per accession were spaced 1 cm apart and 5 cm from the bottom of a germination towel made from filter paper. Total height of the towel was 20 cm. Towels were rolled loosely and fastened with a rubber band. The wrapped towels were arranged vertically in plastic boxes filled with tap water. The samples were placed in a growth chamber at 100 % relative humidity and 4 ^{o}C for 2 d to interrupt dormancy. Later, the samples were incubated at the same growth chamber at the same humidity and 15 ^{o}C for 7 d, followed by 6 d at 20 ^{o}C. This procedure was conducted four times for all accessions. Coleoptile length was recorded as the distance from the seed to where the first leaf broke through the coleoptile sheath /Bai et al., 2004/.

Cultivars presented in Table 1 were compared by mean, range and standard deviation. Correlation analysis was done to compare the relationships between traits of coleoptile length.

Results and Discussion

Differences in coleoptile length were large among the lines within the tested set. Our experimental evidence showed that genotypes with coleoptiles of medium length (5–7 cm) were dominant among the advanced breeding lines tested (Figure 1). The distribution over two years was similar. The lines from 2006 were dominated (45 %) by the genotypes with a coleoptile length of 6–7 cm. The study of lines from 2007 showed that the genotypes with a coleoptile length of 5–6 and 6–7 cm were the most frequent, 31 % and 30 %, respectively. The mean length of coleoptiles was distributed within 6 groups.

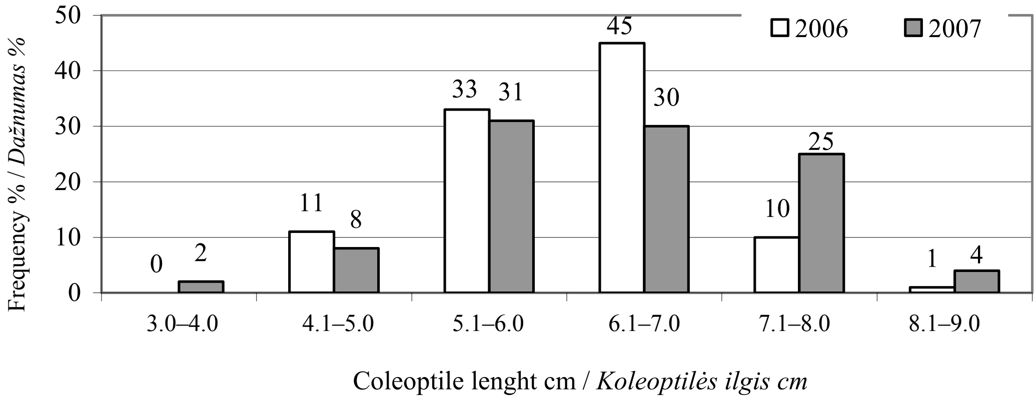

Figure 1. Distribution of the mean coleoptile length of Lithuanian advanced winter wheat breeding lines in 2006–2007
1 paveikslas. *Lietuviškų žieminių kviečių perspektyvių selekcinių linijų koleoptilės vidutinio ilgio pasiskirstymas 2006–2007 m.*

There were no differences in the total mean coleoptile length between years. Some lines (15 %) from 2007 possessed slightly longer coleoptiles.

Analysis of maximal coleoptile length (Figure 2) showed that most frequent were lines with a coleoptile length of 7.1–8.0 cm (47 %) in 2006. Among the next year's lines the dominant genotypes were those with a coleoptile length of 8.1–9.0 cm (31 %). The maximal coleoptile length was distributed within 8 groups. The genotypes of the second year study were characterized by longer coleoptiles.

It is likely that the rapid temperature rise in combination with droughty conditions in the summer of 2005 depressed development of seeds which negatively affected the coleoptile length. The next year, growing season's conditions were more adverse but plants adapted to steady deficiency of water and high temperatures.

Weather-damaged seeds with reductions in falling numbers were associated with small yet significant ($p < 0.05$) reduction in coleoptile length. Differences in coleoptile length among varieties were substantially larger than for effects associated with either grain size or seed source /Botwright et al., 2004/.

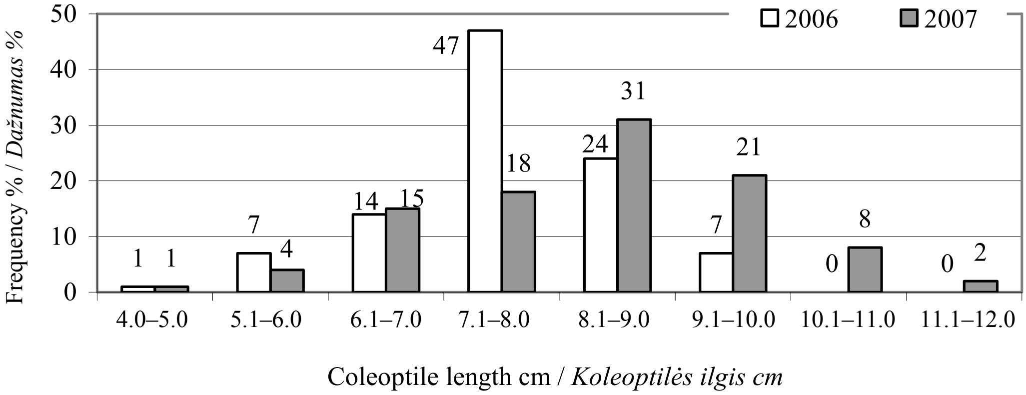

Figure 2. Distribution of the maximal coleoptile length of Lithuanian advanced winter wheat breeding lines in 2006–2007
2 paveikslas. *Lietuviškų žieminių kviečių perspektyvių selekcinių linijų koleoptilės maksimalaus ilgio pasiskirstymas 2006–2007 m.*

The screened lines were the least divergent by minimal coleoptile length; they were distributed within 5 groups (Figure 3). Among the lines with minimal coleoptile length, in both years dominated those with a coleoptile length of 3.1–4.0 cm (about 50 %).

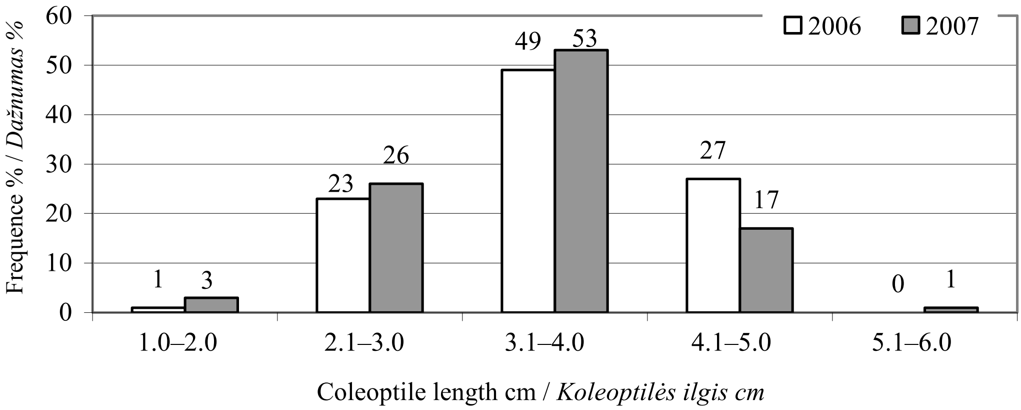

Figure 3. Distribution of the minimal coleoptiles length of Lithuanian advanced winter wheat breeding lines in 2006–2007
3 paveikslas. *Lietuviškų žieminių kviečių perspektyvių selekcinių linijų koleoptilės minimalaus ilgio pasiskirstymas 2006–2007 m.*

The coleoptile minimal length was inadequate for characterization of lines. As we had expected, the mean coleoptile length of our breeding lines was generally shorter than that of purposely selected genotypes from arid areas. The highest mean length was up 9 cm and frequency of such lines over two years was 2.5 %, whereas specially selected genotypes in arid areas have coleoptiles up to 15 cm /Schillinger et al., 1998; Hakizimana et al., 2000; Pereira et al., 2002; Bai et al., 2004/.

Considering the frequency distribution of the mean of coleoptile length we can conclude that to select genotypes with long coleoptiles (≥10 cm) is hardly possible at the moment. There were no promising lines in the screened set for possible deep sowing. However, some lines could be proposed as suitable for a slighly deeper sowing (7–8 cm) than commonly recommended (4–5 cm). By increasing sowing depth by 2–4 cm we could considerably improve emergence in a droughty autumn.

The frequency distribution of maximal coleoptile length suggests some additional advantage because coleoptile length depends on seed size. Cornish and Hindmarsh /1988/ determined that length declined by 0.37 mm per mg reduction in seed weight, although the coleoptile length was mainly influenced by a cultivar. This relationship suggests a chance to improve field emergence by sowing calibrated seed a few cm deeper if cultivars with adequate coleoptile length are not available.

The growth reducing genes *Rht-B1b* and *Rht-D1b* are associated with reduced leaf elongation rate /Schillinger et al., 1998; Ellis et al., 2004; Botwright et al., 2005/. Genotypes possessing long coleoptiles tend to possess longer primary and subsequent leaves. Such traits are useful because they increases wheat competitiveness against weeds.

Among the lines presented in Table 1 the shortest coleoptiles during both years were recorded for the lines, Biscay/Dream (4.4 and 4.5 cm), Dream/Lut.9329 (4.8 and 4.2 cm) and Flair/Lut.9329 (4.6 and 4.9 cm). The lines Astron/Tarso//Yacht (7.9 and 6.0 cm), Astron/Tarso//Mironovskaya 32 (7.9 and 7.6 cm), Pegassos/Residence (8.0 and 8.3 cm), Pegassos/Aspirant (8.0 and 7.3 cm), Astron/Tarso//Mobil (8.2 and 6.5) and Rostovchanka/Sj965210 (8.7 and 7.4 cm) possessed the longest coleoptiles in 2006/2007.

Coleoptile length depended on the height of parental cultivars. The crosses between short cultivars (Biscay, Dream and Lut. 9329) produced lines with short coleoptiles, while tall cultivars (Rostovchanka, Pegassos, Aspirant) in the pedigree positively affected coleoptile length.

The greatest variation in coleoptile length was observed for the lines Hussar/Konsul A//Lut.96-6 (1.5–8.0 cm) and Astron / Tarso // Mironovskaya 32 (2.0–10.0 cm) in 2006 and 2007, respectively.

The correlation analysis showed that the mean coleoptile length correlated strongly ($r = 0.76^{**}$) between years (Table 2). The same was true for the correlation of maximal coleoptile length between years ($r = 0.71^{**}$) Very strong correlation was obtained between the mean and maximal coleoptile length, $r = 0.91^{**}$ and $r = 0.95^{**}$, in 2006 and 2007, respectively. The minimal coleoptile length with other traits correlated weaker ($r = 0.17 – 0.62^{**}$).

Table 1. Length of coleoptile of Lithuanian advanced winter wheat breeding lines in 2006–2007

1 lentelė. *Lietuviškų žieminių kviečių perspektyvių selekcinių linijų koleoptilės ilgis 2006–2007 m.*

Dotnuva, 2006–2007

Catalogue number *Katalogo numeris*	Pedigree *Kilmė*	2006		2007	
		Mean±SD *Vidurkis±SD*	Range *Ribos*	Mean±SD *Vidurkis±SD*	Range *Ribos*
5210--2	Biscay / Dream	4.4±0.13	3.0-5.6	4.5±0.43	3.5-6.5
5060--47	Flair / Lut.9329	4.6±0.31	3.0-6.0	4.9±0.13	3.0-6.5
5202--3	Dream / Lut.9329	4.8±0.23	3.5-7.9	4.2±0.23	1.5-5.5
5202--14	Dream / Lut.9329	4.8±0.35	4.2-6.0	4.5±0.09	2.0-6.0
4390--3	Elena / Lut 956	4.8±0.56	3.0-6.5	6.4±0.64	3.0-8.0
5217--10	Biscay / Pesma	5.4±0.22	3.4-7.2	5.6±0.46	3.0-7.5
5185--36	Pegasos / Biscay	5.9±0.18	3.0-7.5	6.7±0.11	3.5-8.5
5060--15	Flair / Lut.9329	5.9±0.49	3.2-7.7	7.8±0.39	4.0-10.5
4651--1	Astron / Tarso // Yacht	6.0±0.21	3.5-8.0	7.9±0.27	4.5-10.0
5185--33	Pegasos / Biscay	6.0±0.43	3.5-8.0	6.1±0.48	3.0-8.5
4432--2	Flair / Lut 96-2	6.1±0.25	3.5-7.5	6.9±0.31	5.0-9.0
4679--3	Hussar/Konsul A//Lut.96-6	6.2±0.37	1.5-8.0	6.9±0.42	4.0-9.0
5063--77	Flair / Lut 3-96	6.3±0.69	4.0-8.0	7.2±0.30	4.0-8.5
4762--2	Lut 96-3 / Bold	6.4±0.22	4.5-7.5	7.4±0.37	4.0-9.0
5194--5	Pegasos / Aspirant	6.5±0.20	4.4-8.2	7.5±0.54	3.0-10.5
5183--6	Pegasos / Dream	6.5±0.32	4.5-8.5	7.2±0.41	5.0-9.0
5051--27	Flair / Lut.9365	6.5±0.36	4.0-7.8	7.3±0.43	4.0-9.0
5259--13	Bill / Aspirant	6.5±0.51	3.5-8.0	6.0±0.06	3.0-8.5
4644--2	Astron / Tarso // Mobil	6.5±0.71	4.5-9.0	8.2±0.35	5.0-10.5
4642--1	Astron / Tarso // Previa	6.6±0.38	4.0-8.2	7.5±0.63	4.0-11.0
4708--6	Rostovchanka / Lut. 96-3	6.6±0.42	5.0-8.5	7.8±0.32	4.0-10.0
4711--4	Rostovchanka / Chvilia	6.8±0.30	5.0-8.5	7.9±0.46	3.5-10.0
5194--18	Pegasos / Aspirant	6.9±0.20	4.0-8.7	7.2±0.39	5.0-8.6
5185--26	Pegasos / Biscay	7.2±0.35	5.0-8.7	7.2±0.17	5.0-9.0
5194--19	Pegasos / Aspirant	7.3±0.21	4.0-9.3	8.0±0.68	4.0-10.2
4781--3	Rostovcanka / Sj 965210	7.4±0.51	4.7-10	8.7±0.50	5.0-11.5
4780--1	Astron / Tarso // Miron.32	7.6±0.28	5.0-9.0	7.9±0.61	2.0-10.0
5195--35	Pegasos / Residence	7.6±0.46	4.0-9.0	7.7±0.39	2.5-9.5
5195--12	Pegasos / Residence	8.3±0.55	5.0-9.7	8.0±0.27	4.5-10.0

These results revealed that coleoptile length was quite stable over two years. Similar results are usually obtained when calculating stability of plant height for variable years and environments.

Table 2. The correlation between elements of coleoptile length in Lithuanian advanced winter wheat breeding lines
2 lentelė. *Lietuviškų žieminių kviečių perspektyvių selekcinių linijų koleoptilės ilgio elementų koreliacija*

Dotnuva, 2006–2007

Trait / *Požymis*	1	2	3	4	5	6
Minimal coleoptile length in 2006 *Minimalus koleoptilės ilgis 2006 m.*	1.00	0.53*	0.62**	0.17	0.35*	0.39
Maximal coleoptile length in 2006 *Maksimalus koleoptilės ilgis 2006 m.*	----	1.00	0.91**	0.37	0.71**	0.75**
Mean coleoptile length in 2006 *Vidutinis koleoptilės ilgis 2006 m.*	----	----	1.00	0.38	0.72**	0.76**
Minimal coleoptile length in 2007 *Minimalus koleoptilės ilgis 2007 m.*	----	----	----	1.00	0.53*	0.59*
Maximal coleoptile length in 2007 *Maksimalus koleoptilės ilgis 2007 m.*	----	----	----	----	1.00	0.95**
Mean coleoptile length in 2007 *Vidutinis koleoptilės ilgis 2006 m.*	----	----	----	----	----	1.00

* Correlation significant at 95 % probability level / *Ryšys patikimas esant 95 % tikimybės lygiui*
** Correlation significant at 99 % probability level / *Ryšys patikimas esant 99 % tikimybės lygiui*

Transgressive segregation for long coleoptile length produced progenies with coleoptiles significantly longer than the longest coleoptile parent in each population. Genotype x temperature interactions for coleoptile length were small thereby resulting in high line-mean heritabilities for this character. These relationships provide a breeder with a possibility to effectively select lines with long coleoptiles during one year for stable environments /Schillinger et al., 1998; Pereira et al., 2002; Richards et al., 2002; Rebetzke et al., 2004/.

Future breeding efforts should consider introducing genes from long - coleoptile wheat to further increase coleoptile length while maintaining shorter plant height.

Conclusions

1. Genotypes with coleoptiles of medium length (5–7 cm) were dominant among the advanced breeding lines tested. The lines from 2006 were dominated (45 %) by the genotypes with a coleoptile length of 6–7 cm. The study of lines from 2007 showed that the genotypes with a coleoptile length of 5-6 and 6-7 cm were the most frequent, 31 % and 30 %, respectively.

2. Analysis of maximal coleoptile length showed that most frequent were as the lines with a coleoptile of length 7.1–8.0 cm (47 %) in 2006. Among the lines of 2007 year's the dominant genotypes were those with a coleoptile length of 8.1–9.0 cm (31 %).

3. The dominant coleoptile length (about 50 %) among the lines with minimal coleoptile length was 3.1–4.0 cm in both years.

4. Selection of genotypes with long coleoptiles (≥10 cm) is hardly possible at the present moment. There were not found any promising lines in the screened set for possible deep sowing.

5. The shortest coleoptiles during both years were recorded for the lines, Biscay /Dream (4.4 and 4.5 cm), Dream/Lut.9329 (4.8 and 4.2 cm) and Flair/Lut.9329 (4.6 and 4.9 cm) in 2006/2007.

6. The lines, Astron/Tarso//Mironovskaya 32 (7.9 and 7.6 cm), Pegassos / Residence (8.0 and 8.3 cm), Pegassos/Aspirant (8.0 and 7.3 cm), and Rostovchanka/ Sj965210 (8.7 and 7.4 cm) possessed the longest coleoptiles in 2006/2007.

7. The correlation analysis showed that the mean coleoptile length correlated strongly (r = 0.76**) between years. This relationship provides a breeder with a possibility to effectively select lines with long coleoptiles during one year under the stable environments.

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LIETUVIŠKŲ PERSPEKTYVIŲ ŽIEMINIŲ KVIEČIŲ SELEKCINIŲ LINIJŲ KOLEOPTILĖS ILGIS

Ž. Liatukas, V. Ruzgas, K. Razbadauskienė

Santrauka

Lietuvos žemdirbystės institute 2006–2007 m. išmatuotas lietuviškų žieminių kviečių perspektyvių selekcinių linijų koleoptilės ilgis. Tarp tirtų linijų nustatyti dideli koleoptilės ilgio skirtumai. Tyrimų rezultatai rodo, kad tarp tirtų žieminių kviečių perspektyvių selekcinių linijų dominavo genotipai su vidutinio ilgio (5–7 cm) koleoptilėmis. Koleoptilių maksimalaus ilgio analizė rodo, kad 2006 m. dominavo (47 %) linijos su 7,1–8,0 cm ilgio koleoptilėmis, 2007 m. 31 % genotipų koleoptilės buvo 8,1–9,0 cm ilgio. Tarp tirtų linijų nebuvo genotipų, tinkamų giliai sėjai.

Koreliacinė analizė rodo, kad vidutinis koleoptilės ilgis skirtingais metais stipriai koreliavo (r = 0.76**). Kai tyrimai daromi stabilioje aplinkoje, šis priklausomumas suteikia galimybę atrinkti linijas su ilgesnėmis koleoptilėmis per vienerius metus,.

Reikšminiai žodžiai: žieminiai kviečiai, selekcinės linijos, koleoptilės ilgis.