ISSN 1392-3196
Žemdirbystė / Zemdirbyste / Agriculture, vol. 94, No. 4 (2007), p. 88–98
UDK 633.16:631.526.32:631.559:581.19

THE SINGLE GRAIN TRAITS FOR THE EVALUATION OF SPRING MALTING BARLEY BREEDING LINES

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Abstract

During the period 2001–2004 grain yield, quality, and single grain traits of spring barley (*Hordeum vulgare* L.) varieties (n = 36) and breeding lines (n = 41) were investigated at the Lithuanian Institute of Agriculture. The yield mean of breeding lines group was 4.78 t ha^{-1} and that of barley varieties 4.68 t ha^{-1}. The breeding lines developed at LIA significantly surpassed barley varieties mean by the 1000 grain weight and single grain traits: nitrogen and starch content. Ratio of C_{starch}:N per single grain for breeding lines mean tended to be too low compared with that for varieties. Number of grain per area unit as well as the single grain quality traits: nitrogen, starch content per single grain and ratio of C_{starch}:N could be an additional informative indices in malting barley breeding. Under Lithuania's weather and growing conditions the requirement for at least 95.6 million grain per ha^{-1}, single grain N content of not higher than 1050–1100 micrograms, ratio of C_{starch}:N not lower than 11.9 should be pursued in malting barley breeding programme. The valuable breeding lines (7422-3 and 7661-1) with the high extract content demonstrated C_{starch}:N ratio per single grain up to 12.2–12.6.

Key words: *Hordeum vulgare* L., nitrogen, starch, carbon and nitrogen ratio, grain number per area.

Introduction

The grain quality characters of spring barley can vary substantially due to genetic characteristics, growing technologies, and environmental conditions /Bertholdsson, 1999; Tamm, Tamm, 2002; /. Moderate supply of mineral nitrogen (N) has the most important impact on malting barley yield and especially on grain quality /Qi et al., 2006/. The supply of plants with plenty of mineral nitrogen induces accumulation of protein, however protein content has a negative relation with malt extract content /Moral et al., 1998/. Reduction in ear size increased grain N concentration under all environmental conditions /Dreccer et al., 1997/. Therefore, N content per single grain can be related with the number of grain per plot area. Single grain N concentration can be a response to nitrogen source-sink ratio during grain fill.

Over 30 characters are used for evaluation of malting grain, malt, wort and beer quality[1]. The protein content and grain fraction 2.5 mm are the mainly observed quality characters, which are in close relation to extract yield /Moral et al., 1998; Zhang et al., 2001; Bertholdsson, 2004; Qi et al., 2006/. According to the State Standard LST 1591[2] protein content should be below 11.5 %. Protein content for the first class grain is 9.5–11.0 %, for the second class 11.1–11.5 %. The variation of protein content in barley grain is high. The investigations in Jogeva Plant Breeding Institute showed that protein content of 57 malting barley cultivars varied from 9.9 to 14.4 % /Tamm, Tamm, 2002/. Therefore, breeders look for indications to reveal tendencies of barley breeding lines to accumulate protein in grain.

About two thirds of malt extractive substances are formed from starch hydrolysis products. The weather conditions have a considerable impact on the starch synthesis and accumulation per grain as well as on the grading output /Tamm, Tamm, 2002/. Experiments on the malting cultivar 'Trumpf' revealed, that when weather during grain maturing period is sunny the grain is thin and contains more protein than grain which matured over damp and cloudy weather conditions /Molina-Cano et al., 2001/. The grain of the same variety but different in size could also differ in chemical composition. However, the variation of concentration of chemical substances in grain of different varieties is larger than that of different size grain of the same variety /Elfverson et al., 1999/. Unevenness of the stand, radiation per plant, nitrogen and water availabilities as well as cultivars vegetative and reproductive plasticity can strongly affect grain number per plant and per area and photosynthesis /Andrade et al., 2002; Andrade, Abbate, 2005/. Consequently in malting barley breeding it is important to measure yield potential, elements of yield structure, the total protein, starch content as well as grain number per plot and the single grain traits: nitrogen, starch (or carbon calculated from the starch data) content, ratio of C_{starch}:N.

The aim of this study is to evaluate spring barley varieties and LIA breeding lines' grain yield and quality characters: grain number per area, nitrogen, starch (or carbon calculated from starch data) content per single grain, and ratio of C_{starch}:N per single grain.

Materials and Methods

The experiment was set up at the Lithuanian Institute of Agriculture (LIA) during the period 2001-2004. The spring barley varieties (cultivars) of foreign origin and LIA bred, and LIA new breeding lines were tested. The soil of the experimental site was *Endocalcari-Epihypogleyic Cambisol* (CMg-p-w-can) light loam. According to conventional Lithuanian soil assessment method the soil pH was 6.0–7.0, medium in organic matter (2.5–2.7 %), plant available phosphorus (P_2O_5 190–250 mg kg^{-1}) and potassium (K_2O 200–260 mg kg^{-1}). Clay content 24–27 %. The annual $N_{90}P_{60}$ K_{60} fertiliser rate was applied. Barley was grown according the technology used in LIA for breeding. The plots were harvested by a Winterstaiger harvester. Combine-harvested grain from each plot was dried and sampled for analyses. One thousand grain weight (TGW) (ISO 580), total grain protein (total nitrogen by Kjeldahl multiplied by 6.25, ICC 105/2), grading output

[1] Analytica-EBC, 1998. European brewery convention

[2] LST 1591:2000. Miežiai. Supirkimo ir tiekimo reikalavimai

(fraction on 2.5 x 20 mm sieve), total starch content (by hydrochloric acid dissolution, ICC 123/1) were determined. Extract content was determined according to EBC recommendation, adjusted to hand-technology. Yield data were adjusted to 15 % moisture content. Grain quality characters were calculated for dry grain. Number of grain ha^{-1} was calculated from the data of combine-harvested grain yield and TGW. Indices for single grain were calculated from chemical matters total percentage, grain yield and data of TGW.

The data were statistically processed by software packages STAT and ANOVA /Tarakanovas, Raudonius, 2003/ and mean and standard error of the mean were introduced. Averaged data of groups formed of 36 cultivars and 41 breeding lines grown every experimental year were compared. Relationships between malting barley characters were determined and coefficients of linear correlation were presented. The null hypothesis was rejected at the levels of $P \leq 0.05$ (*) or $P \leq 0.01$ (**).

Results and Discussion

Weather conditions. In 2001 the weather conditions were moderate for barley growth (Table 1). The weather during post-anthesis period was wet, therefore the spread of diseases was noticeable. Grain yield varied from 4.0 to 5.0 t ha^{-1}. In 2002 during barley growing period the weather was warm and dry. The tillering was poor and barley formed only 1–2 productive stems per plant. The incidence of insects, mainly aphids, was high, therefore barley stands were sprayed three times. Grain yield was from 4.0 to 5.5 t ha^{-1}. In 2003 barley matured early, approximately at the same time as winter wheat did. Grain yield was from 4.5 to 5.5 t ha^{-1}. The most favourable weather conditions for spring barley growth were in 2004. Grain yield was high: from 5.5 to 6.5 t ha^{-1}. It is obvious that the variation of the weather conditions affected grain yield and quality. As a result, it was relevant for the investigation, that the single grain data were calculated for malting barley which grew and matured at different weather conditions.

Table 1. The weather conditions during the spring barley growing season in Dotnuva
1 lentelė. *Meteorologinės sąlygos miežių vegetacijos metu Dotnuvoje*

Month *Mėnuo*	Long-term mean (1924–2004) *Ilgametis vidurkis*	Year *Metai*			
		2001	2002	2003	2004
Mean air temperature C^0 / Vidutinė oro temperatūra C^0					
April / *Balandis*	5.7	8.0	7.9	5.4	7.6
May / *Gegužė*	12.2	12.8	15.4	13.6	11.2
June / *Birželis*	15.4	14.4	16.8	15.5	14.2
July / *Liepa*	17.6	21.0	20.3	20.6	16.9
August / *Rugpjūtis*	16.6	17.6	20.3	17.3	18.1
Mean / *Vidurkis*	13.5	14.8	16.1	14.5	13.6
Total precipitation mm / *Kritulių suma mm*					
April / *Balandis*	37.7	34.7	21.6	37.6	11.1
May / *Gegužė*	52.1	34.6	25.5	36.3	27.8
June / *Birželis*	61.9	52.8	53.2	54.9	44.2
July / *Liepa*	73.4	102.5	35.7	54.6	81.6
August / *Rugpjūtis*	73.5	59.1	29.1	66.5	94.5
Total / *Suma*	298.6	283.7	165.1	249.9	259.2

Variation of grain quality. The investigations of spring barley varieties and breeding lines carried out during 2001–2004 showed that yield and grain quality traits of the breeding lines were more stable than those of the varieties (Table 2). The values of coefficients of variation for routine indices: grading data, TGW, hectolitre weight, total protein, starch, extract content varied considerably for the cultivars (from 3.3 to 15.8)

Table 2. The variation of yield and grain quality traits of spring barley varieties and breeding lines

2 lentelė. *Vasarinių miežių veislių ir selekcinių linijų derliaus ir grūdų kokybės rodiklių variacija*

Dotnuva, 2001–2004

Trait *Rodiklis*	Varieties n = 36 *Veislės n = 36*			Breeding lines n = 41 *Selekcinės linijos n = 41*		
	Mean *Vidurkis*	Standard error of the mean *Vidurkio standartinė paklaida*	Coefficient of variation % *Variacijos koeficientas %*	Mean *Vidurkis*	Standard error of the mean *Vidurkio standartinė paklaida*	Coefficient of variation % *Variacijos koeficientas %*
Grain yield t ha^{-1} *Grūdų derlius t ha^{-1}*	4.68	0.124	15.8	4.78	0.058	7.7
>2,5 mm grain % *>2,5 mm grūdų %*	87.0	1.37	9.4	88.1	0.820	6.0
>2,5 mm grain t ha^{-1} *>2,5 mm grūdų t ha^{-1}*	4.10	0.142	20.8	4.21	0.070	10.6
1000 grain weight g *1000-čio grūdų masė g*	48.90	0.695	8.5	50.82	0.669	8.4
Hectolitre weight g 1^{-1} *Natūrinis svoris g 1^{-1}*	682.8	4.54	4.0	684.7	4.50	4.2
Protein g kg^{-1} *Baltymai g kg^{-1}*	134.0	2.27	10.2	136.1	1.35	6.3
Starch g kg^{-1} *Krakmolas g kg^{-1}*	569.0	4.29	4.5	562.6	3.02	3.4
Extract content % *Ekstraktingumas %*	77.58	0.427	3.3	77.00	0.216	1.8
Grain number mio ha^{-1} *Grūdų skaičius mlj ha^{-1}*	95.90	2.270	14.2	94.62	1.600	10.8
N per grain µg *Grūde N µg*	1047.0	20.76	11.9	1105.1	15.31	8.9
Starch per grain µg *Grūde krakmolo µg*	27826	450	9.7	28583	388	8.7
C starch per grain µg *Grūde krakmolo C*	12355	200	9.7	12691	172	8.7
Ratio C_{starch}:N units *Grūde $C_{krakmolo}$:N vnt.*	11.94	0.271	13.6	11.54	0.156	8.7

and for breeding lines (from 1.8 to 8.4). The values of variation coefficients for the indices such as coarse grain yield per hectare, grain number per area, protein, starch content per single grain and their ratio were rather similar. For breeding lines they differed from 8.7 to 10.8. The variation of these values for cultivars was higher (from 9.7 to 20.8), therefore these indices should be evaluated during breeding process.

The data of routine analyses showed, that there was a slight superiority of breeding lines compared with the average mean of varieties for grain yield, hectolitre weight; the required for malting barley lower protein and higher starch content in average was more frequent in barley varieties; the extract content of breeding lines was slightly lower than cultivars mean too. Regrettably, the differences were of higher than 0.05 probability level, therefore only the tendencies could be discussed. The differences in grain quality between the breeding lines and varieties groups could be a result of growing conditions, such as different number of grain per area due to differences in N supply during grain fill period or due to peculiarities of senescence process and therefore different N content per grain. The breeding lines had a slightly lesser number of grain per plot, but significantly higher TGW. It could be due to the provision with nitrogen as well as due to varietal characteristics. Nitrogen stress reduced kernel number of maize /Andrade et al., 2002/. When the number of grain is fewer, the kernels have better nitrogen and carbon assimilates supply and can accumulate more N and carbon per grain. The derivative dimension – ratio of C (calculated from starch) and N content in single grain in average for varieties was 11.94 and lower for breeding lines 11.54. The difference was very close to the 0.05 probability limit. Therefore the ratio of C and N, as well as N content per single grain could be an additional indicator for evaluation of spring barley malting quality attributes.

The grain of spring barley varieties recommended for forage (‘Aidas’, ‘Ūla’, ‘Aura’, ‘Luokė’) and for malting had different ratio of C_{starch}:N per single grain (Table 3). The ratio mean for Lithuanian malting barley ‘Auksiniai 3’ and ‘Alsa’ was from 10.90 to 11.98 and that for foreign cultivars much higher (from 12.18 to 13.10). Therefore a breeder has to increase this ratio. Also the total and course grain yield in LIA breeding lines should be increased. The high protein content of native cultivars could be a result of lower grain number per hectare. When grain number was low a plant was able to supply them with higher content of protein synthesis products. Therefore N content per single grain of native cultivars was higher, and ratio C_{starch}:N per single grain was lower.

Ratio C_{starch}:N per single grain varied from year to year. In separate year the ratio C_{starch}:N for malting barley cultivars ‘Barke’, ‘Passadena’ and ‘Scarlet’ varied from 11.0 to 11.8 on 2001, from 10.4 to11.3 on 2002, from 13.1 to 13.5 on 2003 and from 14.0 to 15.8 on 2004. The ratio for malting variety ‘Sebastian’ in 2004 (when it was first planted in LIA breeding plots) was 14.9. The ratio for LIA bred varieties was lower than that for foreign ones. So, the highest ratio was for cultivars ‘Luokė’ and ‘Auksiniai 3’ (12.3 and 11.9 respectively) in 2001, for ‘Ūla’, ‘Luokė’ and ‘Auksiniai 3’ (10.1-10.8) in 2002, for ‘Luokė’ and ‘Auksiniai 3’ (12.2 and 12.9) in 2003, for ‘Luokė’ and ‘Auksiniai 3’ (14.3 and 13.0) in 2004. Presumably, ratio C_{starch}:N per single grain of malting barley may be one of the early indications of malting qualities. This ratio for foreign cultivars was more uniform (we evaluated 36 of them) compared with that for LIA-bred cultivars. For

Table 3. The comparison of spring barley varieties yield and grain quality*
3 lentelė. *Vasarinių miežių veislių derlingumo ir grūdų kokybės palyginimas**
Dotnuva, 2001–2004

Variety *Veislė*	Grain t ha^{-1} *Grūdų* *t ha^{-1}*	>2,5 mm grain t ha^{-1} *>2,5 mm grūdų* *t ha^{-1}*	Grain mio ha^{-1} *Grūdų* *mlj ha^{-1}*	Protein g kg^{-1} *Baltymų* *g kg^{-1}*	Per single grain N µg *Grūde* *N µg*	Ratio per single grain C_{starch}:N *Grūde* *$C_{krakmolo}$:N*	Extract content % *Ekstrak-tingumas* *%*
Aidas (LT)	4.12 0.176	3.03 0.376	91.30 2.51	141.8 4.8	1023 53.23	10.98 0.480	74.93 0.911
Ūla (LT)	4.53 0.111	4.06 0.140	85.95 5.92	136.8 4.6	1162 49.8	11.55 0.51	75.93 0.480
Aura (LT)	4.74 0.358	4.27 0.420	96.65 6.99	142.3 8.1	1114 55.3	10.95 0.802	76.20 0.730
Luokė (LT)	4.57 0.199	4.01 0.291	92.78 5.74	128.3 6.3	1020 82.5	12.30 0.791	75.58 0.592
Auksiniai 3 (LT)	3.92 0.029	3.48 0.090	86.0 3.90	136.5 5.7	998 42.9	11.98 0.672	78.48 0.558
Alsa (LT)	4.59 0.141	4.06 0.138	97.23 5.03	141.8 7.6	1073 60.7	10.90 0.853	76.60 0.776
Barke (DE)	5.44 0.730	4.72 0.786	103.78 11.25	129.8 5.5	1079 67.0	12.75 0.777	80.98 0.593
Passadena (DE)	4.93 0.370	4.19 0.342	96.85 6.93	121.0 6.0	967 57.0	13.10 1.018	76.63 0.590
Scarlet (DE)	5.12 0.161	4.83 0.163	106.18 4.78	133.0 6.4	1028 56.3	12.18 0.827	81.08 0.569

* Mean and standard error of the mean
* *Vidurkis ir vidurkio standartinė paklaida*

foreign cultivars in 2001 these values varied from 11.2 to 11.8, in 2002 10.4–11.3, in 2003 13.1–13.5, in 2004. 14.0–15.8. For LIA-bred cultivars they were 9.6–12.3; 9.0–10.8; 11.7–12.9 and 11.6–14.3. The variability of this ratio should be low /Triboi, Triboi-Blondel, 2002/. The low variation shows the genetic ability of the variety to balance supply of N and products of photosynthesis assimilation during grain maturing period. 'Auksiniai 3' was closer to foreign malting varieties by ratio C_{starch}:N per single grain than the other LIA-bred cultivars. We conclude that ratio C_{starch}:N per single grain for new malting barley lines must be close to that of modern foreign malting varieties. According to the ratio C_{starch}:N per single grain most suitable for malting purposes would be breeding lines 7422-3, 7661-1 and 7967-2 (Table 4).

The content of N per grain was low for 7661-1, 7442-3 and 7967-2 lines. The number of grain per plot for breeding lines should be higher. However, the extract content of the breeding lines had to be higher. Therefore, number of grain per plot, N content in single grain and ratio of C content calculated from starch and N (C_{starch}:N) should be involved in a group of routine characters for malting quality indication. According to 2001–2004 data the desirable values of malting barley indicators would be

as follows: more than 95.6 mio ha^{-1} grain, not more than 1047–1105 N µg per single grain and the ratio C_{starch}:N per single grain not less than 11.9

Table 4. The variation of yield and grain quality* of spring barley breeding lines
4 lentelė. *Vasarinių miežių selekcinių linijų derlingumo ir grūdų kokybės* variacija*
Dotnuva, 2001–2004

Breeding line *Selekcinė linija*	Grain t ha^{-1} *Grūdų t ha^{-1}*	>2,5 mm grain t ha^{-1} *>2,5 mm grūdų t ha^{-1}*	Grain mio ha^{-1} *Grūdų mlj ha^{-1}*	Protein g kg^{-1} *Baltymų g kg^{-1}*	Per single grain N *Grūde* N µg	Per single grain C_{starch}:N *Grūde* $C_{krakmolo}$:N	Extract content % *Ekstrak-tingumas %*
6804-62**	4.84 0.400	4.26 0.510	94.3 9.05	133.0 6.41	1097 63.8	11.83 0.411	76.03 0.521
7007-24**	4.81 0.371	3.85 0.411	99.6 9.35	145.7 3.34	1134 63.4	10.20 0.455	74.77 0.382
6915-6**	4.88 0.343	4.49 0.392	93.2 8.97	144.0 2.04	1214 55.6	10.63 0.187	76.87 0.640
6915-12**	4.82 0.350	4.18 0.476	95.93 6.64	138.7 6.56	1114 47.2	11.10 0.662	76.30 0.261
7222-3**	4.69 0.158	4.32 0.081	85.47 6.95	133.3 3.81	1176 30.0	11.63 0.485	76.87 0.581
7224-2**	4.45 0.024	4.10 0.044	87.67 4.09	139.3 2.04	1134 43.5	11.17 0.290	77.60 0.124
7322-6	4.81 0.094	4.41 0.078	96.20 4.87	137.5 1.83	1109 58.8	11.45 0.204	77.18 0.400
7101-1	4.94 0.132	4.45 0.119	94.23 3.97	134.3 4.70	1127 35.2	11.65 0.555	76.73 0.440
7422-3	4.85 0.151	4.14 0.153	100.58 4.20	131.3 3.12	1015 43.1	12.60 0.442	79.28 0.452
7661-1	4.79 0.176	4.28 0.189	98.13 5.43	130.3 2.71	1024 53.9	12.18 0.438	78.65 0.232
7695-4	4.74 0.177	3.94 0.167	95.3 4.48	129.0 5.57	1028 38.1	12.13 0.645	75.90 0.530
7709-2**	4.62 0.129	4.10 0.185	91.17 2.74	143.3 5.76	1162 32.0	11.10 0.496	77.40 0.402
7967-2	4.94 0.356	4.06 0.226	106.4 13.08	121.0 8.56	914 104.7	13.67 1.130	77.27 0.501

* Mean and standard error of the mean / *Vidurkis ir vidurkio standartinė paklaida*
** Data averaged over 2001–2003 / *2001–2003 metų vidutiniai duomenys*

Correlation of grain quality traits. To verify if the grain number per area, N and starch content per single grain can be valuable indicators in malting barley breeding process, linear correlations between these and routine indices were calculated (Table 5).

The significant correlations among traits in varieties group in a few cases were insignificant for breeding lines group. So, close correlation among grain number per area and course grain output was determined in cultivars group, but it was non-significant in

breeding lines group. The correlations between grain number and protein, starch, extract content were significant for cultivars group but they were non-significant for breeding lines group. The correlation among grain number and N content per grain was determined only for varieties group. These discrepancies can result from the fact that insufficient attention was addressed to the plasticity of new lines. The coefficient of variation of grain number for breeding lines group was lower than that for varieties group.

Table 5. Intercorrelation among the main traits of malting barley varieties and breeding lines

5 lentelė. *Vasarinių miežių veislių ir selekcinių linijų grūdų kokybės rodiklių tarpusavio koreliacija*

Dotnuva, 2001–2004

Trait *Rodiklis*	Varieties group *Veislių grupė*				Breeding lines group *Selekcinių linijų grupė*			
	Grain mio ha^{-1} *Grūdų mlj ha^{-1}*	N per grain µg *Grūde N µg*	Starch per grain µg *Grūde krakmolo µg*	C_{starch}:N per grain *Grūde $C_{krakmolo}$:N*	Grain mio ha^{-1} *Grūdų mlj ha^{-1}*	N per grain µg *Grūde N µg*	Starch per grain µg *Grūde krakmolo µg*	C_{starch}:N per grain *Grūde $C_{krakmolo}$:N*
Yield t ha^{-1} *Derlius t ha^{-1}*	0.840**	ns	0.538**	0.466**	0.608**	ns	ns	ns
>2.5 mm grain % *>2,5 mm grūdų %*	ns	0.330*	0.541**	ns	-0.316*	0.529**	0.503**	ns
>2.5 mm grain t ha^{-1} *>2,5 mm grūdų t ha^{-1}*	0.680**	ns	0.635**	0.390*	ns	0.409**	0.338*	ns
TGW g *1000 grūdų masė g*	ns	0.555**	0.886**	ns	-0.736**	0.739**	0.921**	ns
Hectolitre weight g l^{-1} *Natūrinis svoris g l^{-1}*	ns	0.523**	0.472**	ns	-0.422**	0.604**	0.658**	ns
Protein g kg^{-1} Baltymai g kg^{-1}	-0.378*	0.696**	-0.493**	-0.966**	ns	0.404**	-0.499**	-0.938**
Starch g kg^{-1} *Krakmolas g kg^{-1}*	0.381*	-0.552**	0.479**	0.816**	ns	-0.463**	ns	0.756**
Extract % *Ekstraktingumas %*	0.504**	-0.355*	0.366**	0.568**	ns	ns	0.426**	0.564**
Grain mio ha^{-1} *Grūdų mlj ha^{-1}*	1	-0.440**	ns	0.414*	1	-0.496**	-0.679**	ns
N per grain µg *Grūde N µg*	-0.442**	1	ns	-0.711**	-0.496**	1	0.533**	-0.495**
Starch per grain µg *Grūde krakmolo* µg	ns	ns	1	0.507**	-0.679**	0.533**	1	-0.468**
C_{starch}:N per grain *Grūde $C_{krakmolo}$:N*	0.414*	-0.711**	0.507**	1	ns	-0.495**	-0.468**	1

Ratio C_{starch}:N decreased when a higher N content per single grain was accumulated. The correlation of ratio C_{starch}:N in single grain with malt extractability was moderate, but closer than that between malt extractability and protein or starch content per grain. When the number of grain per area increases, the supply of nitrogen substances for a single grain can be reduced. Therefore the correlation between ratio C_{starch}:N and grain number was positive, but only for varieties group. The higher C_{starch}:N ratio could be an indicator of barley malting quality. When stand density is higher a shading regime changes and starch accumulation in barley grain could be higher. Thus the number of grain per area as well as single grain traits should be one of the targets for breeders. However, the opinion, that the single kernel method may be used by the breeder as a quality criterion for new barley varieties to test their spike development was expressed in earlier publication /Angelino et al., 1997/.

Nitrogen content per single grain shows the level of nitrogen support for plants during grain maturing period /Triboi, Triboi-Blondel, 2002/. In our investigations the correlation between the grain yield and N content per grain was non-significant for both experimental groups. The grain N concentration which is necessary to achieve maximum grain weight is below that which maximizes grain N accumulation /Dreccer et al., 1997/. However there can be no significant interaction between nitrogen treatment and cultivar /Qi et al., 2006/. Therefore the N content per single grain as indicator of nitrogen supply in malting barley breeding process, its correlation with barley senescence during grain feeling should be investigated with future studies.

Conclusions

1. The breeding lines developed at LIA significantly surpassed barley varieties mean by the 1000 grain weight and nitrogen and starch content per single grain. Ratio of C_{starch}:N per single grain for breeding lines tended to be lower compared with that for varieties.

2. The single grain quality traits: nitrogen, starch content per single grain, ratio of C_{starch}:N as well as number of grain per area could be informative indices in malting barley breeding. Under Lithuania's weather and growing conditions the requirement for at least of 95.6 million grain per ha^{-1}, single grain N content of not higher than 1050-1100 micrograms, ratio of C_{starch}:N not lower than 11.9 should be pursued in malting barley breeding programme. The breeding lines 7422-3 and 7661-1 with the high extract content demonstrated high C_{starch}:N ratio (up to 12.2-12.6).

3. Nitrogen content per single grain and grain number per ha^{-1} could be used as indirect indices for evaluation of nitrogen supply for spring barley breeding lines grain during grain maturing period.

Received 01 08 2007
Accepted 16 09 2007

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ISSN 1392-3196
Žemdirbystė, t. 94, Nr. 4 (2007), p. 88–98
UDK 633.16:631.526.32:631.559:581.19

VIENO GRŪDO RODIKLIAI VERTINANT VASARINIŲ SALYKLINIŲ MIEŽIŲ SELEKCINES LINIJAS

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Santrauka

Lietuvos žemdirbystės institute Dotnuvoje 2001–2004 metais konkursiniuose bandymuose ištirta vasarinių miežių (*Hordeum vulgare* L.) veislių (n = 36) ir sukurtų perspektyvių selekcinių linijų (n = 41) derlingumas ir grūdų savybės. Selekcinių linijų derlingumo vidurkis buvo 4,78 t ha^{-1}, veislių – 4,68 t ha^{-1}. LŽI sukurtų linijų vidutinės 1000-čio grūdų masės ir azoto bei krakmolo kiekio viename grūde vertės buvo iš esmės didesnės už vidutines veislių grupės vertes. Išvestinis dydis – krakmolo anglies ir azoto santykis viename grūde selekcinių linijų buvo mažokas, palyginti su veislių grupe. Kokybiniai vieno grūdo rodikliai: azoto, krakmolo (anglies) kiekis ir tarpusavio santykis bei grūdų skaičius ploto vienete yra papildomi rodikliai, reikalingi miežių salyklinių savybių charakteristikai selekcijos procese. Lietuvos meteorologinėmis ir agrotechnikos sąlygomis selekciniuose laukeliuose salyklinius miežius reikėtų auginti siekiant kad būtų ne mažiau kaip 95,6 milijono grūdų hektare, viename grūde ne daugiau kaip 1050–1100 mikrogramų azoto ir santykis $C_{krakmolo}$: N ne žemesnis kaip 11,9. Perspektyvių LŽI selekcinių linijų (7422-3 ir 7661-1), pasižyminčių geru ekstraktingumu, $C_{krakmolo}$: N santykis viename grūde buvo 12,2-12,6 vieneto.

Reikšminiai žodžiai: *Hordeum vulgare* L., azotas, krakmolas, anglies ir azoto santykis, grūdų skaičius plote.