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Agronomic Characters of Hulless Barley Collection

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Abstract **— The research was conducted in 2011-2013 in the northern forest-steppe of the Tyumen region. The vegetation period of hulless barley samples ranged from 63 to 80 days. The samples with the length of stages – seedling-heading – 38-42 days and heading-ripening – 29-33 days produced the yield higher than the standard Omsk bare-grain 1 by 2.9-60.6%. The largest number of samples (56.6%) formed the eighth group where protein content was 15.1-17.0%; 30.2% of the samples appeared to be in the ninth group (17.1-20.1%), and 13.2% – in the seventh (14.0-14.9%). The highest average 1000 grain weight was observed in barley samples of the ninth group (42.8 g). The samples of the eighth group showed a lower characteristic value (40.3 g) while the samples of the seventh group where protein content was 14.0-14.9% had the lowest value (39.9 g). The average starch content in the samples of all groups was at the level of 58.8-60.5%. The limits of starch variations in barley samples were higher in the seventh group with high protein content. In the same group, the variation range of a trait was much higher (14.2%). The grain-unit g/cm^3 increased on average from 6.5 (seventh group) to 6.7 (ninth group). The largest variation range was in the eighth group (2.0). A reliable positive correlation with yielding properties was found in the group with very high protein content (17.1–20.1%). The highest correlation coefficients were found by interrelations with: protein content (r=0.400), 1000 grain weight (r=0.687) and grain-unit g/cm^3 (r=0.656). A reliable negatively-associated relationship was found between the starch content and the yield (r=-0.382). The following samples showed high resistance to stem rust (Puccinia graminis Pers), namely: Local (k-3115, Tajikistan), Local (k-3170, Tajikistan), Local (k-3772, Dagestan), Local (k-19709, Denmark), Local (to-21747, Dagestan). By lodging resistance at the level of 9 points, the following samples were distinguished, namely: Local (k-3038, Turkmenistan), Local (k-3165, Tajikistan), Local (k-3938, Mongolia), Buck CDC (k-30173, Canada). In the ninth group with high protein content (17.1–20.1) the local sample from Tajikistan (K-3770) formed standard starch content (60.8%). The local cultivars from Iran (k-3082) and Georgia (k-838) had the highest 1000 grain weight (52.7-55.5 g).**

Keywords — hulless barley, protein, starch, grain-unit.

I. INTRODUCTION

The problem of creating new varieties of crops is quite challenging nowadays. Applying new varieties is the milestone in the innovation strategy aimed at the development of crop production in the country [1] including the Northern Urals. To create new varieties it is of great importance to study the source material, particularly, barley.

Barley is an adaptive variety that has been cultivated in Siberia for many years. It has a high ability to make use of natural and climatic resources to ensure high productivity. Due to its biological characteristics (short growing season, drought tolerance), barley can produce yields higher than other crops can, despite the lack of heat and moisture in certain years [2].

Recently, along with chaffy varieties that have been cultivated long since, recognized varieties of hulless barley have appeared in the country. Grain of such varieties is much more nutritious, since they have a high protein load, grain hardness, grain-unit, essential and non-essential amino acids, and vitamins. The increase in the number of acres planted to these particular varieties is hampered by insufficiently high grain productivity. In addition, strong lodging and stem rust may be prominent. In this regard, there is a need to create and

apply new highly productive varieties of hulless barley with high feed and nutritional qualities [3, 4]. For these purposes great importance is given to the study of source material.

The success of creating new varieties, including barley, is largely predetermined by the source material that can be represented as samples of the collection of the All-Russian Research Institute of Plant Industry (VIR), and the material of other breeding institutions [5].

The purpose of research was to select economically valuable samples based on yield capacity, length of the growing season, grain quality, stem rust resistance and stem lodging.

II. SUBJECTS AND METHODS

The experiments were carried out in the Northern forest-steppe of the Tyumen region in the study area of the Northern Trans-Ural State Agricultural University in the period of 2011-2013.

The weather conditions during the study years differed both in the amount of precipitation and in the air temperature. In 2011, there was a moisture deficit in May and heavy precipitation in June. In 2012, there was an acute moisture deficit with high temperatures in May, June and July. In 2013, there was a moisture deficit in June and heavy precipitation in July.

The soil is leached chernozem, clayey loamy formed on cover loam with traits typical of the forest-steppe zone of the Trans-Urals. The bulk density in a layer of 0-50 cm ranges from 1.07 to 1.40 g /cm3. The humus content in the layer of 0-20 cm is 9.05-9.00%. When getting deeper there is a gradual decrease to 2%. The degree of base saturation varies in profile within limits of 89-92%. The water reserves corresponding to the smallest capacity in a layer of 0-50 cm reach 185 mm [6]. Low nitrogen status, medium and high – of phosphorus and high potassium status against the calculated amount of nitrogen fertilizers applied contributed to obtaining the cultivar yield and lines of chaffy barley up to 4 t/ha, hulless barley – up to 2.5 t/ha. The forerunner was annual grasses. The experiment was carried out in accordance with the VIR method [7], a plot area was 1-2 m^2, the standard was placed through 20 collection samples.

54 botanical accessions of hulless barley including nudum, coeleste, trifurcatum, violaceum, brevisetum, neogenes, himalayense were defined as the material for study. They were taken from the VIR collection and other NRUs. Omsk bare-grain accession 1 recognized in the region was used as a standard.

The content of protein and starch was determined in the Department of Biochemistry and Molecular Biology of Vavilov All-Russian Research Institute of Plant Industry (St. Petersburg) [8].

Stem rust resistance (Puccinia graminis Pers), stem lodging was performed according to the VIR method [7] on a 9-point scale.

III. RESULTS

The set of collection samples under study was characterized by different length of the growing season. In general, over the years of research, the growing season varied from 63 to 80 days. Subject to meteorological conditions, the length of the growing season varied significantly over the years. Thus, in 2011 it was 69-100 days, in 2012 – 50 - 62 days and in 2013 – 63 - 80 days (Table 1).

TABLE I. VARYING VEGETATION PERIOD FOR HULLESS BARLEY (2011-2013)

Year	Attribute	Length of seedling–heading period, days		
		seedling-heading	heading-ripening	seedling-ripening
2011	Variation range, days	33-74	25-50	69-100
	Variation ratio, %	19,7	15,0	8,2
2012	Variation range, days	25-43	15-25	50-62
	Variation ratio, %	10,7	10,4	4,5
2013	Variation range, days	30-48	30-40	70-82
	Variation ratio, %	9,4	6,0	3,4
Average	Variation range, days	29-54	25-36	63-80
	Variation ratio, %	13,3	7,7	5,1

Resulting from the research conducted, the samples with the length of seedling–heading period of 38-42 days and heading- ripening period of 29-33 days were singled out. It is with this ratio of the interfacial periods that the yield is higher than the standard by 2.9-60.6% (Table 2).

TABLE II. HIGH-YIELDING HULLESS BARLEY ACCESSIONS WITH THE LENGTH OF VEGETATION PERIOD OF 68-75 DAYS, 2011-2013

No. in VIR catalog	Accession	Provenance	Length of seedling–heading period, days			Yield capacity,g/m^2
			seedling-heading	heading-ripening	seedling-ripening	
30919	Omsk bare-grain 1	Omsk region	39	33	72	307
3423	Local	China	40	35	75	316
30034	Shonkin	USA	41	28	69	493
30036	Condor	Canada	41	30	71	331
30167	CDC Richard	Canada	38	30	68	355
30358	C.I. 11080 Lan	Peru	42	29	71	378
HCP_{05} (n=54)			2,1	0,9	1,4	40,6

The grain of cultivated hulless barley generally has lower protein content than the grain of wheat. During the analysis of the samples taken from the experimental plots of the agro-

climatic zones of the Tyumen region, Professor R.I. Belkina (1981-1983) determined that the average protein content in recognized wheat varieties was 16.3%, while in barley varieties it made up 12.8%. To increase the nutritional value of feed, it is proposed to use hulless barley [9].

To range barley samples according to the protein content, groups used by the international CMEA classification system for the genus Hordeum L [10] were taken as the basis, namely: 1 – very low (less than 8.1%); 2 – very low (8.1–9.0%); 3 – low (9.1-10.0%); 4 – low (10.1-12.0%); 5 – medium (12.1-13.0%); 6 – medium (13.1-14.0%); 7 – high (14.1-15.0%); 8 – high (15.1-17.0%); 9 – very high (more than 17%).

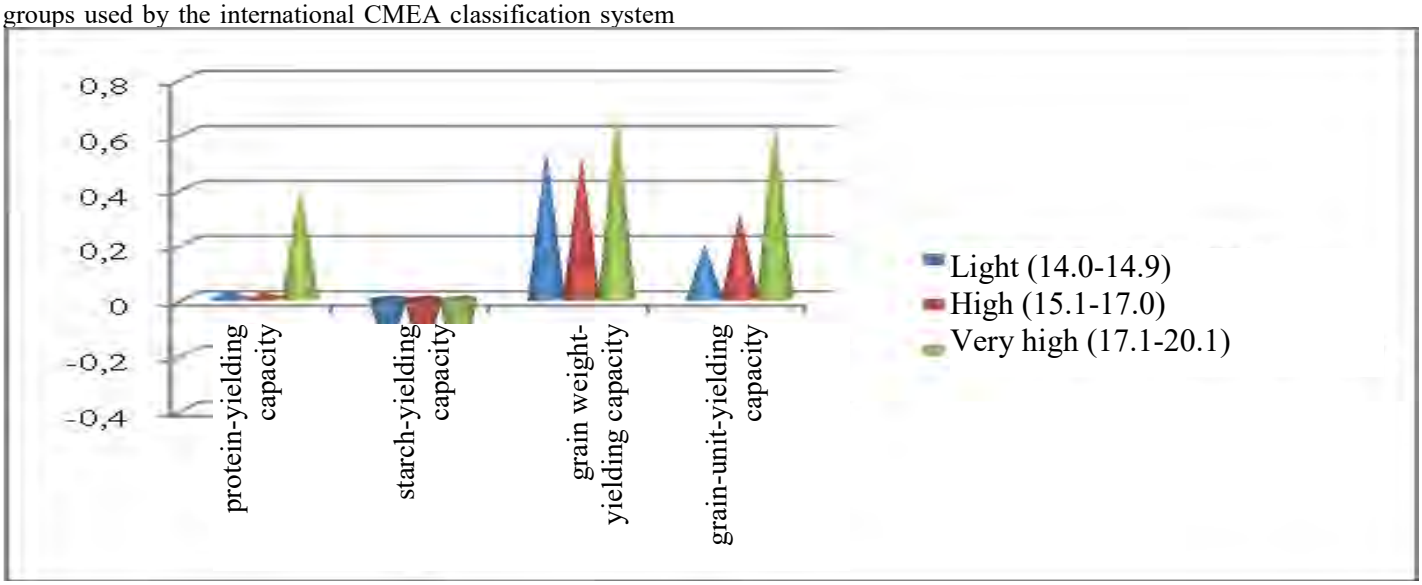

Fig. 1. Crop yield - grain quality relation based on protein content, %

As shown by the data in Table 3, the largest number of samples (56.6%) belonged to the eighth group where the protein content was 15.1-17.0%; 30.2% of the samples formed the ninth group (17.1-20.1%), and 13.2% – the seventh (14.0-14.9%).

TABLE III. QUALITY OF BARLEY SAMPLES DIFFERENT IN PROTEIN CONTENT, 2011-2013

Group No	Character value	Number of accessions	1000 grain weight, g		Starch, %		Grain-unit, g/sm^3	
			Average	Range	Average	Range	Average	Range
7	High 14,0-14,9	7	39,9	31,3-45,5	59,5	59,5-63,1	6,5	5,3-7,1
8	High 15,1-17,0	31	40,3	27,7-51,9	60,5	58,3-62,9	6,6	5,2-7,2
9	Very high 17,1-20,1	16	42,8	29,4-55,5	58,8	57,0-60,8	6,7	5,6-7,4

The highest average 1000 grain weight was observed in barley samples of the ninth group (42.8 g). In samples of the eighth group, the characteristic value is lower – 40.3 g, and in samples of the seventh group where the protein content is 14.0-14.9%, the indice is lowest – 39.9 g. The variation range of 1000 grain weight is more significant in the groups with very high protein content. The variation range of the character was in groups: 14.2 g, 24.2 g, 26.1 g, which indicates its significant increase in the groups with a protein content of 17.1 to 20.1%.

The average starch content in all groups is at the level of 58.8-60.5%. The variation range of starch content in barley samples is more significant in the seventh group with high protein content. In the same group, the variation range of the character is much higher – 14.2%. In the eighth and ninth groups, this figure is lower – 4.6%; 3.8%, respectively.

The grain-unit g/cm^3 increased on average from 6.5 (seventh group) to 6.7 (ninth group). The largest variation range was identified in the eighth group (2.0). In other groups, this indice was at the level of 1.8 g/cm^3.

A reliable positive correlation with yield (Fig. 1) was found in the group with very high protein content (17.1-20.1%), the highest correlation coefficient was determined by interrelations with: protein content (r = 0.400), 1000 grain wight (r = 0,687) and the grain-unit g/cm^3 (r = 0,656). A significant negative relationship was found between the starch content and yield (r = -0.382). In the group with high protein content of 14.0–14.9% and 15.1–17.0, a reliably positive correlation was with 1000 grain weight r = 0.548 and r = 0.520, respectively. The same relationship was found between yield and grain-unit g/cm^3 (r = 0.313) in the high protein group at the level of 15.1-17.0. In other groups, other indices were insignificant.

For northern regions of Russia, there is a need to create early maturing barley cultivars prone to lodging and standing crop, due to excessive moisture during ripening and harvest,

tolerant to the most harmful diseases (loose smut, shot hole, powdery mildew, stem rust) that produce annual high yields [11].

In 2012, due to dry summer, no cases of stem rust (Puccinia graminis Pers) had been reported but for some episodic manifestation of this disease. The following accessions showed high pathogenic resilience (Table 4): Local (k-3115, Tajikistan), Local (k-3170, Tajikistan), Local (k-3772, Dagestan), Local (k-19709, Denmark), Local (K-21747, Dagestan).

TABLE IV. SOURCES OF STEM RUST AND SHOT HOLE RESILIENCE, 2011-2013

No. in VIR catalog	Accession	Provenance	Stem rust, point	Shot hole, point
30919	Omsk bare-grain 1	Omsk region	7,7	6,3
3115	Local	Tajikistan	9	7
3170	Local	Tajikistan	9	7
3772	Local	Dagestan	9	7
21747	Local	Dagestan	9	7
3423	Local	China	9	7
30034	Shonkin	USA	9	7
30358	C.I. 11080 Lan	Peru	9	7
30440	23007	Denmark	9	7

Plant lodging can significantly reduce the yield, preventing the accumulation of nutrients in the grain. The relationship of lodging resistance with plant productivity was noted by K.V. Azarin, A.V. Usatov, N.S. Kolokolova, O.A. Usatova, A.V. Alabushev, P.I. Kostylev [1], N.A. Surin, N.V. Zobova, N.E. Lyakhova [2], N.I. Aniskov, N.A. Kalashnik, D.V. Garis [3]. A number of works provide information on the relationship of lodging resistance of grain crops with plant height, anatomical structure of the stem and other characters [4, 11].

TABLE V. LODGING RESISTANCE AND YEILDING CAPACITY OF DIFFERENT-LENGTH BARLEY ACCESSIONS IN VIR CATALOG, 2011-2013

Group	Number of specimens, pcs	Plant height, cm	Lodging resistance, point	Yielding capacity, g/m^2
Very low (41-60 cm)	29	55,0	9-7	191
Short growing (61-70 cm)	22	65,2	***9-7***	***273***
Medium low (71-80 cm)	2	74,7	7-5	252
Medium tall (81-95 cm)	1	84,0	7-5	212

All analyzed collection samples, according to the international CMEA classification system for the genus Hordeum L [10], were divided by plant height into 4 groups (Table 5), namely: very low (41-60 cm), short growing (61-70 cm), medium low (71- 80 cm), medium tall (81-95 cm).

Negative relationships between plant height and lodging resistance at the medium level were found in the groups: very low ($r = –0.42 \pm 0.10$) and short growing ($r = –0.47 \pm 0.10$).

The group of short growing samples was distinguished by the highest yield and lodging resistance.

The following samples were distinguished by resistance to lodging: Local (k-3038, Turkmenistan), Local (k-3165, Tajikistan), Local (k-3938, Mongolia), Buck CDC (k-30173, Canada).

Taking into account the high protein content in barley grains intended for feeding purposes, it was advisable to present the characteristics of samples with very high protein content (over 17, 1% protein) and other attributes. Table 6 shows the samples of the ninth group. All of them have significantly higher protein content compared to that in Omsk bare-grain 1 (exceeding by 2.3-5.3%).

TABLE VI. CHARACTERISTIC OF HIGH-PROTEIN SPECIMENS IN VIR CATALOG, 2011-2013

No. in VIR catalog	Accession	Provenance	Protein, %	Starch, %	1000 grain weight, g
30919	Omsk bare-grain 1	Omsk region	14,8	60,8	47,5
838	Local	Georgia	17,7	60,1	55,5
2767	Komehadaka	Japan	17,3	59,2	30,5
3038	Local	Turkmenistan	19,0	57,6	42,0
3082	Local	Iran	17,7	58,7	52,7
3115	Local	Tajikistan	17,4	58,7	44,2
3165	Local	Tajikistan	17,2	60,1	35,9
3170	Local	Tajikistan	17,1	60,8	39,2
3423	Local*	China	17,3	57,7	44,7
3938	Local	Mongolia	20,1	57,0	29,4
21747	Local	Dagestan	17,9	59,3	51,5
27171	E.E.E.N46	Bolivia	18,3	56,1	32,0
27176	CM67-V-Sask 1800C	Bolivia	18,2	57,3	33,6
27730	95683/76	Germany (till 1991)	17,8	59,9	45,3
30250	Nue grosse	Sweden	17,7	58,8	55,1
30284	Namoi	Australia	19,5	57,9	43,9
31125	Nudum 95	Chelyabinsk region	20,0	57,0	49,8

Local sample from Tajikistan (k-3770) had the starch content at the standard level (60.8%). Local varieties from Iran (k-3082) and Georgia (k-838) had the highest 1000 grain weight (52.7-55.5).

IV. CONCLUSION

1. Over the years of research conducted in conditions of the Northern forest-steppe of the Tyumen region, the vegetation period of hulless barley samples varied from 63 to 80 days. The samples with the length of stages: seedling-heading – 38-42 days and heading-ripening – 29-33 days produced the yield higher than the standard Omsk bare-grain 1 by 2.9-60.6%.
2. The largest number of samples (56.6%) formed the eighth group where protein content was 15.1-17.0%; 30.2% of the samples appeared to be in the ninth group (17.1-20.1%), and 13.2% – in the seventh (14.0-14.9%).
3. The highest average 1000 grain weight was observed in barley samples of the ninth group (42.8 g). The samples of the eighth group showed a lower characteristic value (40.3 g) while the samples of the seventh group where protein content was 14.0-14.9% had the lowest value (39.9 g).
4. The average starch content in samples of all groups was at the level of 58.8-60.5%. The limits of starch variations in barley samples were higher in the seventh group with high protein content. In the same group, the variation range of a character was much higher (14.2%).
5. The grain-unit g/cm3 increased on average from 6.5 (seventh group) to 6.7 (ninth group). The largest variation range was in the eighth group (2.0).
6. A reliable positive correlation with yielding properties was found in the group with very high protein content (17.1–20.1%). The highest correlation coefficients were found by interrelations with: protein content (r=0.400), 1000 grain weight (r=0.687) and grain-unit g/cm3 (r=0.656). A reliable negatively-associated relationship was found between the starch content and the yield (r=-0.382).
7. The following samples showed high resistance to stem rust (Puccinia graminis Pers), namely: Local (k-3115, Tajikistan), Local (k-3170, Tajikistan), Local (k-3772, Dagestan), Local (k-19709, Denmark), Local (to-21747, Dagestan).
8. By lodging resistance at the level of 9 points, the following samples were distinguished, namely: Local (k-3038, Turkmenistan), Local (k-3165, Tajikistan), Local (k-3938, Mongolia), Buck CDC (k-30173, Canada).
9. In the ninth group with high protein content (17.1–20.1) the local sample from Tajikistan (K-3770) formed standard starch content (60.8%). The local cultivars from Iran (k-3082) and Georgia (k-838) had the highest 1000 grain weight (52.7-55.5 g).

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