Selection

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RESULTS AND PROSPECTS OF SELECTION OF NAKED OAT VARIETIES IN THE CONDITIONS OF THE NORTHERN STEPPE OF UKRAINE

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The results and prospects of naked oat selection in the conditions of the Northern Steppe of Ukraine were highlighted. The problems and main directions of new initial material creating were determined. The high-yielding, large-grain genotypes (thousand grain weight was to 25.3–29.1 g) such as Abel, Rhea, Nuprime, Plater, Adam, Biloruskyi, Pushkinskyi, Hosha, Kriepysh resistant to abiotic factors, and used in hybridization allowed to create a new hybrid combinations of naked oats.

We established that the cultivars differed significantly from each other in the spikelets and grains number per plant, but these features not often affected the plant productivity. Thus, it is proved that the set of features such as number of spikelets in the panicle, number of grains in the spikelet and the grain size determines the plant productivity.

The best initial forms of naked oats by biological and economic features were specified.

The characteristics of the new initial material were highlighted, and the results of breeding work were presented. The naked oat cultivars were selected in the control nursery: Ск 1024/10, Рс 72/09, Сс 732/10, their grain yield (2.59–2.66 t/ha) exceeded significantly the standard variety (by 0, 35–0.42 t/ha) on average for 3 years.

The most productive cultivars by protein content (15.9–16.2 %) were Pc 72/09, CC 1136/09, Cc 732/10 and Cn 234/10.

The average yield (2.58 t/ha) of Rodonit naked oat variety exceeded the Skarb Ukrainy national standard variety by 0.33 t/ha or by 14.7 % according to the three-year competitive variety test. Since 2019, Rodonit has been under state variety testing. The protein content of 16.1 % and the starch of 49.0 % were in the grain, and the number of chaffy caryopsises did not exceed 3.0 %. The growing season of Rodonit variety was 91 days which was three days longer than the standard variety.

Key words: *oat, variety, hybridization, selection, yield, hybrid combinations.*

The necessity of acceleration and improvement of breeding process, its implementation at modern level and targeted production of new naked oat genotypes with specified properties poses a task for breeders to optimize the technology for creation of competitive varieties. In this regard, the problem of assessing and using the existing genetic potential of naked oats, and creating a new initial material is one of the main tasks of selection of this culture.

The yield potential of naked oats is 4.5–5.0 t/ha, and it can approach to 6.0 t/ha in some regions. The thousand grain weight (TGW) of naked oat varieties (26–30 g) is slightly lower compared to hulled genotypes, as a result the productivity of these plants is lower [1, 2]. However, the groats output of naked oat varieties is 99.2 %, and hulled oat varieties – only 71.5 %. The grain yield of naked oats per 1 ha was obtained 4891 kg, hulled oats – 4867 kg [3]. Naked oat outperforms any cereal crops in terms of protein quantity and quality. The protein content in its grain reaches of 16.6–18.0 %, which is by 38–60 % more compared to hulled oat. Naked varieties differ from hulled varieties by a smaller amount of alcohol-soluble proteins, which indicates a better balance of their amino acid composition [4, 5].

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The N1 major dominant gene and several modifiers with incomplete dominance are controlling the oat baldness. The prospects of selection for this oat form are associated with the genome plasticity, which leads to the transfer of genes from hulled to naked form, the reducing of hulled forms segregation, and the combining in one variety of valuable traits and properties [6, 7].

The initial material determines significantly the success of breeding work and the parameters of created varieties. The current complication level of selection tasks requires fundamentally new approaches for the initial material selecting. The knowledge of genetic structure, recombination ability and phytopathological characteristics is necessary for the involvement of cultivars in crossing [8, 9]. The State Register of plant varieties suitable for distribution in Ukraine for 2019 includes 40 oat varieties, of which 7 are naked [10]. The range of oat varieties for growing in the Steppe zone of Ukraine is represented only by hulled forms. Taking into account the above-mentioned information, the assessment and definition of genotypes with the required economically valuable traits, which needed for significantly accelerating and improving the breeding work of naked oat for growing in the Steppe zone of Ukraine, are the necessary and actual tasks.

Aim. The assessment and selection of genotypes with economically valuable traits for the creation of naked oat varieties well adapted to the Steppe zone.

Methods. The oat varieties of both foreign and domestic selection were involved in the breeding work for initial material creating. Forms with economically valuable traits and properties that meet the requirements of selection at the current development of agricultural production, were identified by the study of the gene pool. The Diietychnyi, Dioskurii (Verkhniatska Research Breeding Station IBCSB, NAAS of Ukraine), Tembr, Visyt (Nosivska Breeding and Experimental Station of the V. M. Remeslo Myronivska Institute Wheat, NAAS of Ukraine), Abel (Czech Republic), Rhea and Nuprime (France), Plater and Adam (Poland), Biloruskyi and Kriepysh (Belarus), Pushkinskyi and Hosha (Russia) varieties are deserved attention among the studied varieties. In order obtain a hybrid material with the required characteristics and properties these cultivars played the role of both maternal and paternal forms in crossing.

The research was implemented at the Synelnykove Breeding and Research Station of the State Institution Institute of Grain Crops of NAAS during 2016–2018.

The breeding and hybrid nurseries and initial material nurseries of oat were placed in a stationary experiment on the crop rotation with winter wheat after black fallow as a predecessor. Breeding and hybrid nurseries were sown by means of seeder SSFK-7 with 45 cm row width, the plot area was 1.8 sq. m.

The intraspecific hybridization by the Shyshlov's method [11] followed by individual selection in nurseries was carried out to creating a new initial material of oats.

We conducted the phenological observations in nurseries during the growing season, and analyzed the duration of the interphase periods and the general growing season of oats, resistance to lodging, shattering, drought, disease according to existing recommendations and methods [12–16]. Also we selected 50 plants during the complete maturity of grain from breeding and hybrid nurseries for analysis of economically valuable traits. The obtained research results were statistically processed by dispersive and correlation analyses in accordance with Dospekhov's method [17].

During the growing season in 2016, weather conditions were relatively favorable for plant growth and development. Significant precipitation and moderate temperatures ensured the seasonable even sprouts.

In May, the weather was mostly warm with frequent precipitation of varying intensity, which led to significant soil moistening and had a positive effect on the plant generative organs formation. In June, the average air temperature was 20.7 °C (long-term average was 19.1 °C). In June, the precipitation was only 35.7 mm (long-term average was 59 mm). In July, there was quite warm, sometimes hot weather. Average daily temperatures ranged from 18.3 to 24.4 °C. The precipitation was only 19.8 mm. Such weather conditions negatively affected the caryopsis formation; as a result the TGW was much lower than in other years.

In 2017, oat seeding was on March 28–29 at the optimal time. The weather conditions

were conducive for the even sprouts. In the second ten days period of April, temperature conditions corresponded to long-term averages. During this period, precipitation was above normal limit, which significantly improved the moisture supply of plants. But later, during May and the first ten-day period of June, there was no productive precipitation. However, in the second and third ten-day periods of June the precipitation positive effected on plant growth and development.

In 2018, oats were sown on April 11–12. In March, the precipitation which totaled to three monthly norms stimulated the even sprouts. During seeding, the temperature was significantly higher (by 3–4 °C) compared to the long-term average. In April, a temperature regime was steady exceeded (by 1–9 °C). The precipitation average in April was 47 % monthly norm.

In May and June, dry and relatively warm weather prevailed. At this time, the average daily air temperatures exceeded the norm by 4.7–10.0 and 3–11 °C, respectively, and varied between 17.8–27.0 °C. On average, about 74 % monthly precipitation fell in May and June. In the first and second ten-day periods of July there was a moderate temperature with insignificant precipitation. Taking into account the above, the weather conditions 2018 were not favorable for the formation of significant oat grain yield.

Results. The using of the world gene pool collection of oats, and the determination of the sources and donors of breeding valuable traits have great significance for effective breeding work into initial material obtaining. The investigation of morphological features and plant productivity elements is an important condition in the creating of the initial material of naked varieties.

During 2016–2018, the 29,590 castrated flowers were pollinated, of which 3,610 seeds were obtained. The percentage of setting of hybrid seeds varied from 2.2 to 21.8 %.

The high-yielding, large-grain genotypes (TGW was to 25.3–29.1 g) resistant to abiotic factors, such as Abel, Rhea, Nuprime, Plater, Adam, Biloruskyi, Pushkinskyi, Hosha, Kriepysh were used in hybridization. They allowed the creating a new hybrid combinations of naked oats, which we assessed in breeding nursery.

At the beginning of the breeding process, the initial material was quite diverse. The first generation of naked oat hybrids was compared to the parental forms. We conducted the individual selection on the basis of economically valuable traits for F2 naked oat hybrids, and the selections to identify both heterozygous families and homozygous lines for F3 and next generations.

We selected elite plants among heterozygous oat populations of different generations on such indicators as plant height, length and type of panicle, number of spikelets in panicle, number of grains in panicle, grain weight per panicle and one plant, TGW, productive tillering.

The main directions of breeding and genetic improvement of the initial material of naked oats were to increase grain yield and improve its quality (protein, fat, starch, etc.), increase the TGW, reduce kernel hairiness and number of segregated chaffy kernels. Also we paid special attention to the grain size uniformity, the elimination of germination at the root, the breeding for resistance and tolerance to diseases and pests, the optimization of the morphological type of plant. The 10–12 thousand elite plants of naked cultivars with a breeding value for further work were annually selected.

Analysis of yield structure elements revealed a number of perspective hybrid combinations of naked oats for further selection.

The most perspective hybrid combinations were created by means of the Plater, Bilaruskyi, Abel, Kriepysh varieties. Table 1 shows the characteristics of the yield structure elements of the best naked oats cultivars in breeding nursery.

The panicle length of the main stem depends on the variety genotype and weather conditions of the year. The significant difference between the studied varieties was not found. The panicle length varied from 22.6 to 25.4 cm.

The oat yield includes the individual structural elements of both panicles and plants as a whole. The cultivars significantly differed in the number of spikelets and grains formed by plants, but these characteristics did not always significantly affect the productivity of one plant. With different numbers of spikelets and grains of the cultivars obtained from F_5 hybrid combinations (Kriepysh x Biloruskyi 445/12) and F_6

(Plater x Vandrivnyk) x Adam 1101/11), the grain weight from one plant was 4.66 and 4.59 g, respectively. That is, it should be noted that the panicle productivity is determined by a set of traits: spikelets number in the panicle, grains number per spikelet and grain size.

1. Yield structure elements for best hybrid combinations of naked oats according to the breeding nursery data (2017)

Cultivars	Panicle length, cm	Spikelet number per plant, pcs.	Grain number per plant, pcs.	Grain weight per plant, g	Thousand grain weight, g
F_5 Kriepysh x Biloruskyi 445/12	25.4 ± 2.1	53.2 ± 13.8	165.5 ± 33.6	4.66 ± 0.9	29.2 ± 0.31
F_6 Biloruskyi x Hosha 1031/11	23.9 ± 2.7	59.8 ± 13.1	185.5 ± 21.2	4.57 ± 1.8	26.6 ± 0.26
F_6 Rhea x Abel 822/11	23.2 ± 3.4	64.3 ± 7.9	178.6 ± 21.4	4.13 ± 1.6	25.1 ± 0.28
F_6 Plater x Abel 412/11	23.1 ± 2.6	63.6 ± 13.4	213.4 ± 31.2	5.12 ± 2.4	26.0 ± 0.19
F_5 Plater x Kriepysh 716/12	22.6 ± 2.2	88.1 ± 22.8	174.6 ± 24.3	4.74 ± 1.9	28.2 ± 0.21
F_6 (Plater x Vandrivnyk) x Adam 1101/11	24.1 ± 3.2	96.6 ± 2.5	193.3 ± 22.1	4.59 ± 1.2	25.7 ± 0.22

Thus, the TGW of F_5 Kriepysh x Biloruskyi 445/12 hybrid combination was 29.2 g, while F_6 [(Plater x Vandrivnyk) x Adam 1101/11] – only 25.7 g. Regarding the grain weight per plant (4. 57–5.12 g), the most productive genotypes were F_6 Plater x Abel 412/11, F_5 Plater x Kriepysh 716/12, F_5 Kriepysh x Biloruskyi 445/12.

Individual selection from heterozygous hybrid populations was performed on the basis of variability and inheritance analysis of quantitative and qualitative traits.

Table 2 shows the variational and statistical characteristics of the main economically valuable traits of the most perspective naked oats hybrid combinations in the breeding nursery. These samples were quite productive; the grain weight per plant for different hybrid combinations was 4.8–5.6 g. The variation coeffi-

2. Variation and statistical characteristics of main economically valuable traits of the best hybrid combinations of naked oats (control nursery, in 2018)

Feature	Variation parameters	Hybrid combination			
		F_5 (Nadiinyi x Kriepysh)	F_5 (Ariadna x Rhea)	F_6 (Hosha x Pushkinskyi)	F_6 (Vandrivnyk x Hosha)
Spikelet number per plant, pcs.	$X \pm S_x$	93.0 ± 2.1	83.8 ± 2.5	93.3 ± 2.5	93.2 ± 2.5
	Lim (min–max)	73.6–103.2	68.4–92.3	76.0–101.2	78.1–104.1
	V, %	26.7	26.2	26.5	28.1
Grain number per plant, pcs.	$X \pm S_x$	185.4 ± 4.2	177.3 ± 2.8	186.5 ± 2.4	192.4 ± 2.3
	Lim (min–max)	144.5–211.2	151.6–202.5	158.1–195.7	168.4–208.2
	V, %	26.3	28.8	29.8	27.4
Grain weight per plant, g	$X \pm S_x$	5.6 ± 0.41	5.5 ± 0.87	4.8 ± 0.62	5.3 ± 0.87
	Lim (min–max)	5.2–6.7	3.8–5.9	4.1–5.6	4.8–5.7
	V, %	26.1	27.2	29.2	29.8
Thousand grain weight, g	$X \pm S_x$	29.2 ± 0.28	30.0 ± 0.41	25.8 ± 0.31	27.5 ± 0.34
	Lim (min–max)	29.3–31.3	29.1–32.6	22.5–26.4	25.1–29.2
	V, %	8.5	8.8	8.6	8.8

cient of this indicator ranged from 26.1 to 29.8 %, which indicates a significant genetic potential of naked oats. The F_5 (Nadiinyi x Kriepysh), F_5 (Ariadna x Rhea) and F_6 (Vandrivnyk x Hosha) hybrid combinations had the greatest values of grain weight per plant.

As noted earlier, plant productivity depends on grain size. In 2018, the large-grained cultivars were selected from F_5 (Nadiinyi x Kriepysh) and F_5 (Ariadna x Rhea) hybrid combinations with TGW of 29.2 and 30.0 g, respectively.

The 26 cultivars of different morphological types of naked oats were investigated in the control nursery. The hull content of the hulled oats was 22–26 %; this indicator reached almost 35 % and more in dry hot weather. The naked oat productivity compared with hulled oats was lower by 35–45 %, and some varieties even by 55 %, but the difference between these forms was only 5–15 % in consideration of the non-nutritive part (hull). The Ск 1024/10, Рс 72/09, Сс 732/10 naked oat cultivars were distinguished in the control nursery, the grain yield average for 3 years was 2.59–2.66 t/ha and by 0.35–0, 42 t/ha exceeded of the standard variety (Table 3).

3. Yield of the most perspective naked oat cultivars (control nursery, in 2016–2018)

Cultivars	Grain yield, t/ha			Average
	2016	2017	2018	
Skarb Ukrainy (standard)	2.24	2.31	2.18	2.24
Ск 1024/10	2.66	2.73	2.59	2.66
Сс 732/10	2.54	2.66	2.57	2.59
Рс 72/09	2.69	2.74	2.51	2.65
СС 1136/09	2.47	2.56	2.39	2.47
Сп 547/10	2.37	2.48	2.32	2.39
Сп 234/10	2.32	2.43	2.25	2.33
$LSD_{05,}$ t/ha	0.19	0.23	0.21	0.21

In terms of nutritional and feed value, the most valuable indicators of oat grain quality were protein and fat content and amino acid composition. The primary objective of breeders is oat varieties creating both with high yield potential, and with improved nutritional qualities. It is known that oat groats is valuable due to its nutritional value and caloric content. Oat groats proteins are well assimilable, rich in essential amino acids. They contain large amounts of lysine, arginine and tryptophan. The starch is significant part of oat grain. The compound starch grains were contained in the endosperm.

The important indicators of grain quality are TGW and grain volume weight. The TGW indicates the nutrient reserves, seedling emergence and viability of seeds [18]. The high grain volume weight is marked by well-filled grains and significant percentage of the kernel. Table 4 shows the grain quality indicators of the most perspective cultivars of naked oats..

4. Indicators of grain quality of the most perspective naked oat cultivars (control nursery, average for 2017–2018)

Cultivars	Grain content,% (calculated on Dry Matter Basis)			Thousand grain weight, g	Grain volume weight, g/l
	protein	fiber	starch		
Ск 1024/10	15.2	4.2	47.1	29.8	681
Сс 732/10	15.9	3.6	45.7	27.6	658
Рс 72/09	16.0	3.4	48.1	29.4	678
СС 1136/09	16.2	2.7	48.6	27.9	659
Сп 547/10	15.3	3.5	46.8	28.3	667
Сп 234/10	15.9	3.1	46.9	28.8	677

The Pc 72/09, CC 1136/09, Cc 732/10 and Cп 234/10 cultivars differed in protein content. The protein content in their grain ranged from 15.9 to 16.2 %. The yield (2.58 t/ha) of Rodonit naked oat variety exceeded the Skarb Ukrainy national standard variety by 0.33 t/ha or by 14.7 % according to the three-year competitive variety test. Since 2019, Rodonit has been under state variety testing. (Refer to Table 5). The protein content in the grain was 16.1 %, the starch – 49.0 %, and the number of chaffy caryopsises did not exceed 3.0 %. The growing season of new variety was 91 days which was three days longer than the standard variety.

5. Comparative analysis of Rodonit naked oat variety and the standard variety (competitive variety testing, average for 2016–2018.)

Varieties	Grain yield, t/ha	Thousand grain weight, g	Grain volume weight, g/l	Protein content, %	Growing season, days
Skarb Ukrainy, (standard)	2.25	27.1	657	14.2	88
Rodonit	2.58	30.2	683	16.1	91

Conclusions. Thus, Rodonit naked oat variety was transferred for state variety testing. The evaluation and selection of genotypes with appropriate economically valuable traits for creating of naked oats well adapted to the Steppe zone conditions were performed. In the future, Cк 1024/10, Pc 72/09, Cc 732/10 naked oat cultivars will be included in the breeding program for new high-yielding naked varieties with the targeted economically valuable traits.

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