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## Breeding of Naked Oats Having High-Quality Grain

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**Abstract**—Ecologically plastic naked oat Bekas, which combines high productivity (up to 5.63 t/ha) and grain quality (protein content up to 19.7%; fat content up to 6.7%; starch content up to 54.61%; test weight up to 712 g/L; kernel yield 95–98%; grain yield from sheaf up to 42.3%), was created using selective sampling under different natural conditions: the Northeast Agricultural Research Institute and Falenki Breeding Station (Kirov region), as well as Samara Agricultural Research Institute (Samara region). The grain is large—1000 grain mass is 26.9–29.1 g, grain size is 7–9 × 2.5–3.5 mm, and 2–6 grains are in a spikelet. The new variety is resistant to falling out, to helminthosporium leaf blotch and to crown rust in natural infectious background; it is tolerant to fruit fly.

**Keywords:** oats, crossing, productivity, resistance

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### INTRODUCTION

Food security is determined by the provision of a country with high quality grain suitable for both animal feeding and producing food products for various purposes, children-oriented, dietary and functional, which are beneficial for human health. In this regard, naked oats occupies a special place among other crops [1, 2]. The cultivation of scarious oats is widespread in Russia and in the world and naked oats is a new crop. It is characterized by a higher content of protein, starch, fat, and minerals in the grain [3] with a substantially reduced (by three times) content of fiber [1] and higher protein digestibility.

Glutelins predominate in the protein complex of grain in the varieties of naked oats (47.3–50.4%), while the content of prolamin is low (13–16%). Naked varieties differ from scarious by a fewer number of alcohol-soluble proteins, indicating a better balance on the amino acid composition [4]. With increasing yield, the content of starch in grains of naked varieties increases and the portions of protein and fat are reduced. Oats' fat has a high caloric value and a favorable ratio of fatty acids: low content of linolenic acid (18 : 3) and high content of oleic (18 : 1) and linoleic (18 : 2) acids. The yield of starch from oatmeal is high, 48.5–61.0%, suggesting its use in the production of starch [5]. Water-soluble fibers  $\beta$ -glucans is an important component determining the nutritional

value of oats grain. Their content in the whole oats grain is 38–61 g/kg of grain [6].

Despite all the advantages of the crop, naked oats has not been widely used in the production. This is mainly due to lower yield than that of scarious oats, the presence of a certain amount of scarious grains (0.2–2.2%) and a pubescent kernel, which is undesirable when grain is processed in cereal production or used as forage [1, 3, 5].

In Russia, there is a shortage of naked oats' seeds and an insufficient number of varieties approved for production. The State Register for 2015 included 115 varieties of oats, of which only there were 11 varieties of naked oats [7]. In some regions of the European part of the country, there is no zoned varieties of this type of oats (North, Northwest, Central, North Caucasus, Middle Volga, Lower Volga), while the assortment is limited in other regions: varieties Vyatka and Pesheron (Agricultural Research Institute of the Northeast), Tyumensky golozerny (Agricultural Research Institute of Northern Trans-Urals), Vlyadyka (Belarus) are approved for use in the production in the Volga–Vyatka region, Vyatsky for the Central Black Earth region, seven varieties are approved for the Urals, Siberia, and the Far East, six of them for the West Siberian region. According to the website <http://rosselhocenter.com/ofitsialnye-dokumenty>, 766984 tons of oat seeds were sown in Russia in 2014, of which only 3560 tons of seeds were those of naked oats.

The wide variety of soil and climatic conditions of our country determines the need for breeding complementary eco-specialized varieties allocated during the ecological variety testing and their use in production. It facilitates the screening for adaptive and plastic genotypes and the address transfer of new varieties on the state variety trial in proposed zoning areas. Therefore, the selection of naked oats for increased yield and grain quality in different environmental locations is of current interest.

The aim of the study was to create a new plastic variety of naked oats for the production of high quality food and fodder grain.

## MATERIALS AND METHODS

The studies were conducted in 2000–2015 in two ecological points of the Kirov region at the Agricultural Research Institute of the Northeast (Kirov, the central zone of the region), in 2010–2015 in Falenki Breeding Station (Falenki village, northeastern part of the central zone), and in 2014–2015 in the Samara region at Samara Agricultural Research Institute (Bezenchuk city) in accordance with the procedure of the state variety trials [8].

The climate of the Kirov region is temperate continental with long, snowy, and cold winter and moderately warm summer. On average, there are 20–35 dry days during the warm period, in some years there are 30–60 days without rain in a row. The sum of active temperatures (above 10°C) in an area where the study was conducted is 1700–1900°C, the duration of active plant growth is 116–120 days; dry winds, drought, and irregular rainfall are marked during the growing season. The conditions of vegetation in the period of stem elongation–flowering–filling varied during the years of research from arid (2010, 2013, hydrothermal coefficient (HC) = 0.4–0.6) to excessively wet (2006, HC = 2.2), the most favorable years were 2011 and 2014 (HC = 1.3–1.4). Soils in the area are podzolic and sod-podzolic with high acidity, low humus content, and low power of humus horizon [9]. Samara region in the study area has a continental climate with cold winter with little snow and dry hot summer [10]. The frost-free period is 149 days. The sum of active temperatures is 2600–2800°C. The average amount of precipitation for May–August is 167 mm. In some years, there is no rain for a month or more. HC from May to August is 0.71. Soil is terrace ordinary black earth with low humus content and moderately heavy loam.

## RESULTS AND DISCUSSION

Modern breeding has a wide range of methods to create new forms of plants, but the recombinative selection based on the use of hybridization and subsequent selection is the most effective [11, 12]. The breeding of new naked oat variety Bekas (breeding

no. 41h04) included the hybridization of scarious oat variety Faust (Russia, the maternal form) that was tolerant to edaphic stress (alyumotoksichnost acidic sod-podzolic soils) and drought and naked variety Nuprime (France) that was used in 2000 to increase the number of valuable recombinants. In 2004, 28 elite plants of naked oat that met the parameters of the model of selectable naked oat variety: large filled panicle, filled grain, strong and resistant to lodging stem, and field resistance to environmental stress factors of different nature were selected from the F<sub>4</sub> hybrid population no. 40-00. In 2005–2008, the breeding line 41h04 was selected among the elites in the breeding kennels for its productivity, the duration of the growing season, the structure of productivity, and morphology. Hybrid and breeding kernels were located on a naked cultivated fallow (the content of P<sub>2</sub>O<sub>5</sub>–292–356; K<sub>2</sub>O–248–265 mg/kg of soil; humus–2.51–2.91%) to improve the efficiency of selection and screen for the most productive large-kerneled forms. Annual negative mass selection for panicle (during the period of flowering–maturation) in the field and for grain in the laboratory, corresponding to the world and domestic practice [12], was performed to stabilize the “naked” trait.

Parallel competitive test (2010–2015) was carried out at the final stage of breeding in different environmental conditions (Kirov and Samara oblasts) to select lines that are adaptive to a range of abiotic and biotic environmental factors. Selective screening in different ecological points and in different years allowed us to create a middle-grade naked oat variety Bekas, combining high productivity, plant productivity, and grain quality with ecological plasticity. The average yield of new variety for the years of competitive tests in the Agricultural Research Institute of the Northeast was 4.11 t/ha, 4.0 t/ha in Falenki Breeding Station, and 2.29 t/ha in the Samara Agricultural Research Institute (Table 1). The yield of naked oat variety Bekas was significantly affected by the climate of the Samara region, characterized by sharp fluctuations in temperature during the day, dry air, high solar insolation, and the lack of precipitation and its uneven distribution during the growing season.

The territory of the Samara Agricultural Research Institute experimental field is characterized by aridity in 45–50% of years, 15% of which are acutely dry years (HC ≤ 0.3) [10]. Minimum yield of 1.6 t/ha was received in 2015, even lower values were reported by the scientists of the Agricultural Research Institute of the Northeast and Falenki breeding station on the background of drought in 2010 and 2013.

A new variety formed a high quality grain under conditions of both Volga and Volga–Vyatka region. The highest indicators—19.7% for protein content, 6.7% for fat, and 709–713 g/L—for grain unit were observed in Samara Agricultural Research Institute, where the manifestation of naked grain was full (Table 2).

**Table 1.** Yield (t/ha) of naked oats variety Bekas under different environmental conditions

Variety	RI of Northeast, 2008–2015		Falenki BS, 2010–2015		Samara RI, 2014–2015	
	min–max	average	min–max	average	min–max	average
Bekas	2.75–5.63	4.11	1.30–5.07	4.00	1.60–2.98	2.29
Vyatsky, standard	2.15–4.90	3.60	1.3–4.78	3.48	1.48–2.74	2.11

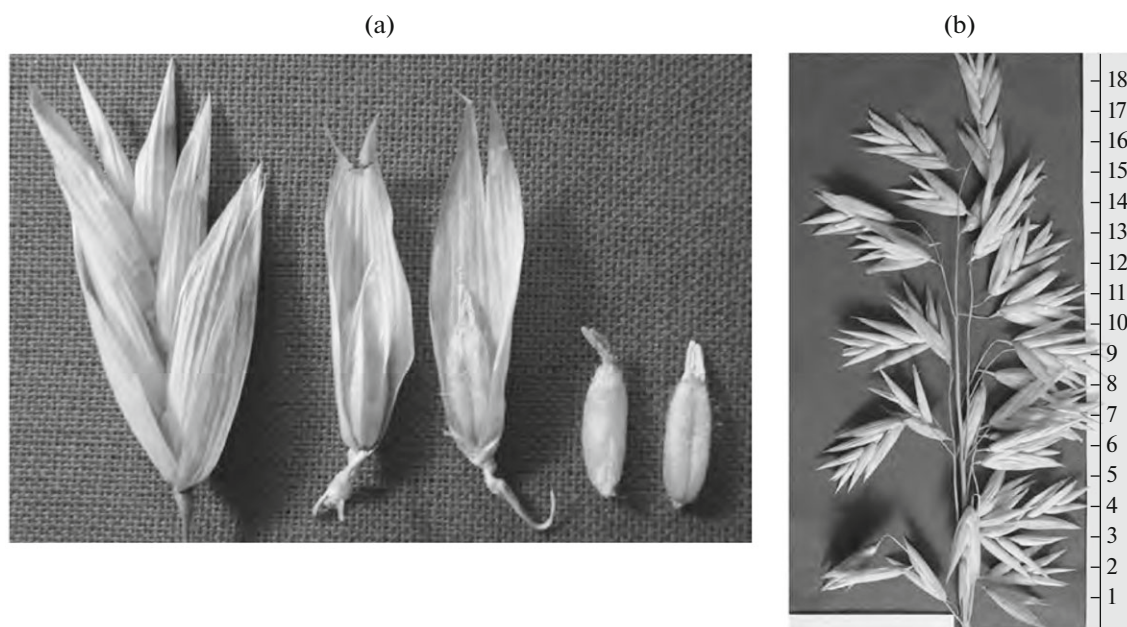
**Table 2.** Characterization of naked oats variety Bekas on a number of economically valuable traits under different environmental conditions

Indicator	RI of Northeast, 2012–2015	Samara RI, 2014–2015
Grain yield ( $K_{ec}$ ), %	36.8–42.3	19.9–26.1
Productive tillering capacity	1.5–2.5	2.2–4.5
Number of grains in panicle, pcs.	36–50	15–26
Weight of 1000 kernels, g	26.9–31.2	28.4–28.8
Grain unit, g/L	661–685	709–713
Content in the grain, %:		
kernel	95–97	95–97
fat	4.62–5.05	6.5–6.7
protein	15.11–17.13	17.6–19.7
starch	45.97–54.61	49.8–54.3

Currently, the requirements for the naked oats supplied for processing are to be developed. Natural weight and the content of grains in the kernel are among the main characteristics for the grain of scarious oats for food production. According to GOST 28673-90, grain unit of class I scarious oats produced for food purposes should be at least 550 g/L, the content of grains in the kernel is

not less than 65%. Grain yield of naked oats Bekas is 95–98%. As a result, the yield of naked oats and scarious oats per unit area are the same. The absence of the lamina simplifies the production of food concentrates and increases the yield of finished products.

Attention should be paid to the grain shape and color when the oats is used for processing. In scarious

**Fig. 1.** (a) Spikelet and grain and (b) panicle of naked oats variety Bekas.

oats, it should be large, filled, and white or yellow. Grain of naked oats variety Bekas is pale (white) and lies freely between the lemmas (*inermis* variety) (Fig. 1a). Weevil is half long and large: the grain size is  $7-9 \times 2.5-3.5$  mm, weight of 1000 kernels is 26.9–31.2 g, and grain base is moderately pubescent. The panicle of the new variety multiflorous semibranchy yellow-white, having a length of 13–20 cm, from 2 to 6 grains are formed in the spikelets of a panicle (Fig. 1b).

The presence of starch in the grain and high fiber content, which consist principally of nonstarch polysaccharides [6], are an important characteristic of the food quality of oats grain. Their content in the grain of Bekas oats is 9.1% (3.3%– $\beta$ -glucans, 5.8%–araboxylans). It is known that  $\beta$ -glucan is a physiologically important dietary component of the grain, which lowers the level of cholesterol in the blood.

Variety Bekas has a number of properties that are valuable for cultivation: resistance to shattering and germination on the vine at overripe, spring frosts, red–brown spot and frit fly (plant death is 1.01–1.45 and 1.85–2.46% at damage), and crown rust. The new variety provides high forage productivity due to good foliage. Under favorable conditions, the collection of high quality dry mass (10.59% protein content, 2.07% fat, 26.34% fiber, 0.65 oat feed unit (OFU)) reaches 9.5 t/ha. The new variety can provide economically significant grain yield due to unfertile stems when the main panicles are sterile as a result of drought.

Thus, new plastic variety of naked oats Bekas was created, using intraspecific hybridization, individual and multiple mass negative selection in field and laboratory conditions, and screening in various environmental locations, for the production of high quality grain suitable for food and fodder purposes.

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