УДК 631.527: 633.18

4.1.2. Селекция, семеноводство и биотехнология растений (биологические науки, сельскохозяйственные науки)

СЕЛЕКЦИЯ И ПИЩЕВАЯ ЦЕННОСТЬ КЛЕЙКОГО РИСА (ОБЗОР)

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В рисосеющих странах мира выращивают огромное количество разнотипных сортов риса, крупу которых используют для приготовления различных блюд. Особое место в национальной кухне азиатских стран занимают сорта клейкого (восковидного) риса, в крахмале которого содержится менее 5 % амилозы и отсутствует глютен. Пищевая ценность крупы такого риса усиливается повышенным содержанием олеиновой и линолевой кислот. Содержание амилозы в зерне риса контролируется геном Wx. Восковидность эндосперма клейкого риса обусловлена триплексом рецессивных аллелей wxwxwx. В Российской Федерации согласно ГОСТа 55289–2012 в зерне риса в зависимости от класса не должно быть глютинозных зерен более 0,3-1,0 %. Поэтому создаваемые здесь глютинозные сорта риса имеют ясно выраженный маркерный признак – фиолетовую окраску цветковых чешуй метелки. Это позволяет легко контролировать сортовую чистоту этих сортов, а также исключать засорение ими посевов традиционных сортов риса. Созданные глютинозные сорта риса: короткозерные Виола, Виолетта и длиннозерный Вита прошли производственную, технологическую и кулинарную проверку. В 2022 г. на Госиспытание передан новый сорт клейкого риса Лекарь. Крупа таких сортов рекомендуется для приготовления диетических блюд, а также производства муки при выра-

УДК 631.527: 633.18

4.1.2. Plant breeding, seed production and biotechnology (biological sciences, agricultural sciences)

BREEDING AND NUTRITIONAL VALUE OF STICKY RICE (REVIEW)

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In rice-growing countries around the world, a huge number of different types of rice is grown, the grains of which are used to prepare various dishes. A special place in the national cuisine of Asian countries is occupied by varieties of glutinous (waxy) rice, its starch containing less than 5% amylose and being gluten-free. The nutritional value of such rice cereals is enhanced by the increased content of oleic and linoleic acids. The amylose content in rice grain is controlled by the Wx gene. The waxiness of the endosperm of glutinous rice is caused by a triplex of recessive alleles wxwxwx. Rice grains, depending on the class, should not contain more than 0.3-1.0% glutinous grains according to RF GOST 55289–2012. Therefore, the glutinous rice varieties being created here have a clearly expressed marker trait – the purple color of the flowering scales of the panicle. This makes it easy to control the varietal purity of these varieties, as well as to prevent them from contamination of traditional rice varieties. The created glutinous rice varieties such as short-grain Viola, Violetta and long-grain Vita passed production, technological and culinary testing. In 2022, a new variety of sticky rice, Lekar, was submitted for State Testing. Cereals of these varieties are recommended for the preparation of dietary dishes, as well as the production of flour for baby and medical nutrition. The article presents the genealogy of Russian glutinous varieties and their nutritional value

ботке продуктов детского и лечебного питания. В статье представлена генеалогия российских глютинозных сортов и их пищевая ценность

Ключевые слова: РИС, СЕЛЕКЦИЯ, СОРТ, КЛЕЙКИЙ РИС, АМИЛОЗА, АМИЛОПЕКТИН, ПИЩЕВАЯ ЦЕННОСТЬ

Keywords: RICE, BREEDING, VARIETY, GLUTINOUS RICE, AMYLOSE, AMYLOPECTIN, NUTRITIONAL VALUE

http://dx.doi.org/10.21515/1990-4665-196-016

Rice is the leading crop of irrigated agriculture and the staple food for the majority of the world's population. Most of the world's rice production is consumed by local populations, especially in Asian countries. To prepare cereals there it is required only to husk the grain removing the flower scales. At the same time, the fruit shell (aleurone layer) containing proteins, fats and vitamins is preserved. This cereal is a complete food product. However, the hulled grain is stored for several days only, and then the fats go rancid. Therefore, in order to obtain cereals that will be stored for a long time and commercialized, the rice grains are abraded and polished after husking. The cereal is given a marketable appearance. But during abrading the germ is broken off and the aleurone layer is removed, which leads to a depletion of the chemical composition of the cereal. Disposing of the germ removes chemical contaminants used during rice growing which may have found their way into the grain. Their absence in polished grains has been repeatedly confirmed by special chemical analyzes [12]. This cereal can be used as a dietary product.

Rice grain is 90% starch. Rice starch consists of two classes of glucose polymers – amylopectin and amylose. Amylose is a weakly branched linear molecule, while amylopectin has a much larger polymer unit containing branched bonds [21].

Based on the trait “amylose content” in the endosperm, *Oryza sativa* L. varieties are classified into several groups: glutinous (less than 5%), very low-amylose (from 5 to 9%), low-amylose (from 10 to 19%), medium-amylose (21-25). %), and high-amylose (above 25%) [25]. The amylose content in the groats

of the most rice varieties cultivated in Russia ranges from 15 to 24%, so they are classified as low- and medium-amylose.

Among the varietal diversity in rice growing, a special group includes the varieties and forms of glutinous or waxy (sticky) rice. Glutinous rice has the effect of gluing the grains together during cooking, thus giving it this name. Its grain differs from other varieties of rice in the absence (or insignificant amount) of amylose and a large amount of amylopectin. Amylopectin is responsible for the sticky quality of glutinous rice [28]. Waxy rice does not contain dietary gluten (i.e., it does not contain glutenin or gliadin), so it can be used in gluten-free diets [26]. This rice is safe for people with gluten sensitivity [31].

Waxy rice is considered a high-quality product with a sticky consistency [23]. Due to its unique functional characteristics, waxy rice is widely used in processed foods, drugs, and cosmetics [14, 16]. Many traditional Asian desserts are made from it. Despite the general characteristic of low amylose content, varieties of such rice differ in taste. Study of M.-Y. Kang et al. (2010) of these qualities in eight popular Korean glutinous rice varieties revealed their differences in the physical and chemical properties of the groats, such as digestibility, pasting characteristics, mineral and sugar contents, and amino acid and fatty acid compositions [22].

Glutinous rice is grown over large areas in almost all Asian countries. For example, about 85% of the rice produced in Laos is of this type. In China [33], white non-transparent cereal is obtained from such rice (Fig. 1).

For conservation in the International Rice Genebank (IRGC) 6,530 glutinous rice varieties had been selected in glutinous rice-growing countries by 2013 [30]. In most Asian countries many glutinous rice varieties are ancient; their selection is inextricably linked with the development of the traditional culture of the people of these countries and national cuisine. Their cultivation is confined to local conditions in certain ethnic areas [24]. More modern rice varie-

ties with low amylose content are usually created using traditional breeding methods.

Figure 1 – Regular (amylose) and glutinous (sticky, waxy) rice grains

Genetic studies by foreign researchers have shown that amylose content is controlled by one main gene, Wx, located on chromosome 6 [14]. In this case, the high content of amylose dominates over its low and intermediate content [23]. According to P. He et al. (1999) the inheritance of grain quality in cereal crops is more complex than other agronomic traits due to epistasis, maternal and cytoplasmic effects and the triploid nature of the endosperm [19].

The complex nature of the inheritance of amylose content is confirmed by other studies [28, 29]. V. A. Dzyuba et al. (2015) believe that the structure of the endosperm of the rice grain depends on the concentration and number of dominant and recessive alleles. The triplex of dominant genes WxWxWx forms a glassy endosperm. The presence of at least one recessive allele wx changes the structure of the endosperm towards glutinous-dull. The triplex of recessive alleles wxwxwx forms a glutinous-dull endosperm. Breeders should take this genetic feature into account when creating new glutinous rice varieties [1].

Currently, for the selection of glutinous rice varieties, scientists often use the mutagenesis method, including using the CRISPR/Cas9 system. The devel-

opment of this gene editing system allows rice breeders to control the expression of the Wx gene to obtain rice varieties with desired starch quality traits [18].

The study of molecular methods for controlling the trait “amylose content” by various alleles of the Wx gene showed that marker-assisted selection (MAS) can be used in the future to create starting material with a certain amount of amylose [2].

Improving the nutritional properties of rice groats and increasing its nutritional value is one of the main tasks underlying breeding programs. Numerous studies on the comparative study of regular and glutinous (waxy) rice, conducted in various countries, have shown that there are significant differences between the starch of these rice varieties (Table 1).

Table 1 – Difference between regular and waxy rice starch

Components	Regular (non-waxy) rice starch	Waxy rice starch	Comment
Main components	15-20 % amylose and 80-85 % amylopectin [27]	Low (0-2%) or almost no amylose; high amylopectin content [17]	–
Lipids	0,9-1.3% lipids, consisting of 29-45% fatty acids and 48% phospholipids [36]	Minor content [35]	–
Endosperm transparency	Transparent [27]	Whitish and opaque [35]	–
Starch swelling	Low	High	Starch swelling is a property of amylopectin, while amylose slows down swelling [32]
Gelatinization temperature	High [36]	Low [36]	–
Solubility	Low	High	The higher the amylose content, the lower the solubility [34]
Crystallinity values	Lower	Higher	Amylose content negatively correlates with relative crystallinity [34]
Syneresis (spontaneous decrease in volume with separation of fluid)	Low strength	High strength	Waxy rice starch gel is more resistant to syneresis after a free thawing cycle due to the formation of fewer intermolecular associations [13]
Freeze/Thaw Stability	Low	High	–

In the Russian Federation, sticky rice is called glutinous, which is a translation from Latin: *glutinosus* – glue-like or sticky, and not in the sense of containing gluten. The selection of such varieties at the Federal Research Center for Rice has been carried out since the 1990s using traditional methods. As a result, short-grain varieties Viola, Violetta and long-grain Vita were created [3, 6, 7, 11]. Plants of these varieties have a well-defined marker trait – purple coloration of flower scales (Fig. 2).

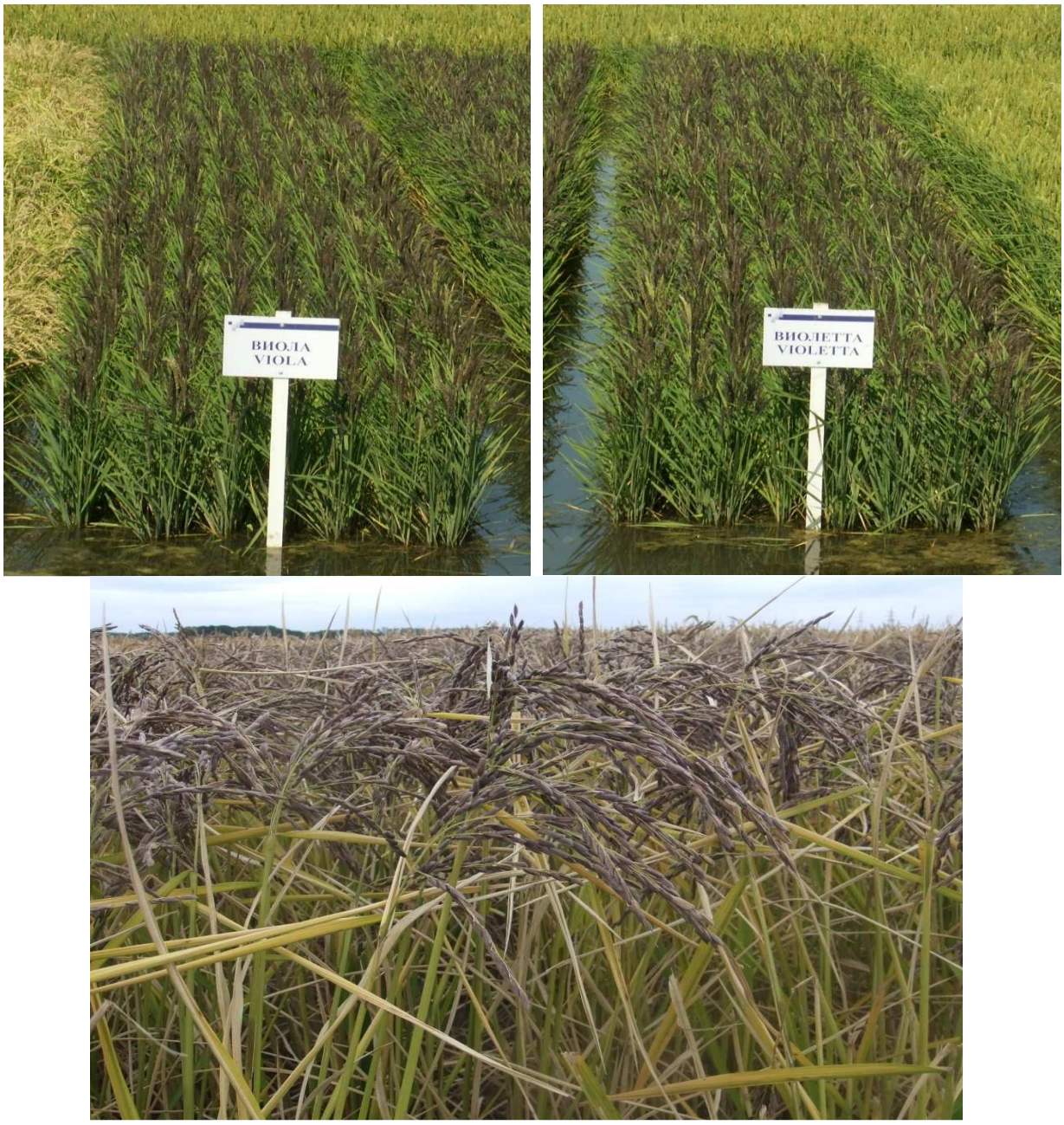

Figure 2 – Glutinous rice varieties: Viola, Violetta, Vita

This makes it easy to distinguish their crops from other cultivated varieties of rice and maintain varietal purity. In the conditions of rice seeding, which is used in the Russian Federation, maintaining varieties in purity is possible only if there are distinctive morphological characteristics of the plants, clearly visible during the period of varietal weeding.

The State Standard of the Russian Federation significantly limits the presence of glutinous rice in the commercial grain of cultivated varieties. Rice grain is divided into four classes depending on quality. In this case, the content of glutinous grains in harvested rice should be no more than: for highest class - 0.3%, first - 0.5%, second and third - 1.0% [10]. The presence of marker traits in Russian glutinous varieties makes it possible to strictly control their inclusion in commercial rice crops.

When studying the fatty acid composition of grains of the glutinous varieties Viola and Violetta, their differences from conventional varieties were revealed [4]. Rice oil is of greatest interest in terms of the content of oleic and linoleic acids, which are found in almost equal concentrations (Table 2).

Table 2 – Characteristics of rice varieties by fatty acid composition, % of the total acid content in hulled rice [4]

Fatty acid	Variety		
	Viola	Violetta	Liman (standard)
Myristic	0,48	0,37	0,22
Palmitic	15,08	15,82	15,83
Palmetooleic	0,11	0,10	0,11
Stearic	1,62	1,49	1,55
Oleic	42,14	39,60	39,54
Linoleic	38,30	40,22	40,27
Linolenic	1,04	1,22	1,31
Arachidic	0,65	0,58	0,61
Eicosenoic	0,47	0,48	0,50
Behenic	0,21	0,17	0,17

As can be seen from Table 2, Viola variety exceeds the standard Liman

variety in oleic acid content by 6.2%. The presence of linolenic acid in the range of 1.0-1.3% increases the biological value of this oil. The content of palmitic acid in the range of 15.0-15.8% is significantly different from many vegetable oils. This indicates the high nutritional value of groats of Viola and Violetta varieties [4].

Russian glutinous varieties Viola and Violetta have been widely tested in production and by nutritionists. Since 2011, at the rice processing plant of the Agro-Alliance company, the production of groats of these varieties has been established, it was supplied to stores under the brand "*YunNat*: rice for children and their parents" in boxes weighing 700 g [5] . The *YunNat* brand offered cereals intended for baby food, as well as for anyone who prefers dietary products. *YunNat* rice has a unique carbohydrate composition. Unlike traditional domestic varieties of rice, its starch consists entirely of easily digestible amylopectin. Due to its molecular structure, this valuable source of nutrition interacts freely with digestive enzymes, is more completely broken down and is easily absorbed even by a child. At the same time, the flow of energy into the body is characterized by a uniform and long-lasting effect. *YunNat* rice was produced in strict accordance with international standards for baby food. It belongs to hypoallergenic (gluten-free) products. It was recommended for children from 3 years of age, especially those actively involved in sports. Unfortunately, in 2020, the Agro-Alliance stopped growing these varieties and the production of glutinous rice.

The main problem in the breeding of glutinous rice in Russia is the limited source material with the genes of the target trait. Thus, among 250 collection samples studied in 2012-2015, only one variety, Kuro-mochi from Japan, did not contain amylose in the grain and belonged to glutinous varieties [9]. However, the Kuro-mochi variety does not have pronounced distinctive morphological characteristics from ordinary rice varieties, such as the Philippine glutinous sample Qu jung Do (IRRI-06537), which has purple flower scales and high resistance to blast disease. That is why Qu jung Do was used for hybridization

with Slavyanets variety as a gluten content donor, despite its late ripening, tallness and poor resistance to lodging. This made it possible to select plants with a violet panicle and a very low amylose content in the hybrid offspring. As a result, well adapted to local conditions Violetta variety was created [5]. It was then used in further breeding work. Based on Violetta, new glutinous varieties Yuzhnaya Noch, Vita and Lekar were bred, which in appearance are easily distinguishable from cultivated amylose rice varieties (Fig. 3).

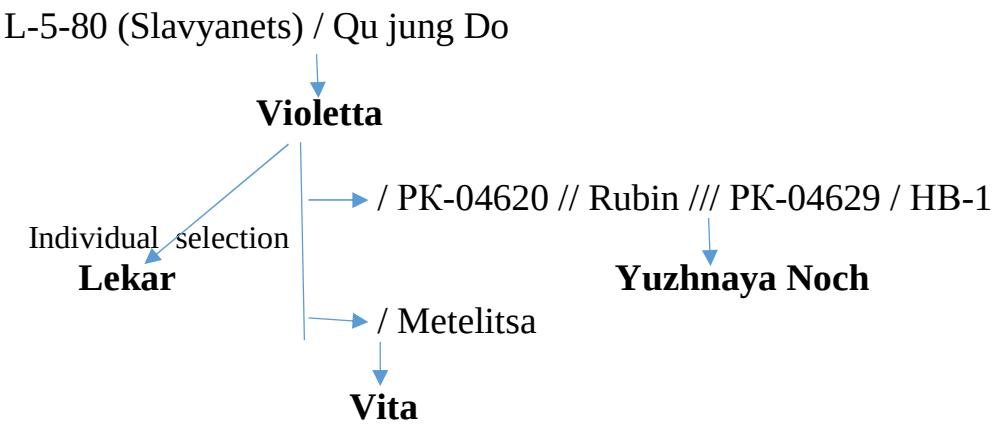

Figure 3 – Genealogy of Russian glutinous rice varieties

The glutinous (sticky) rice variety Lekar was submitted for state testing in 2022 [8]. Its plants have a purple coloration of the flowering scales of the grain and short awns, as a marker feature to distinguish it from ordinary non-glutinous rice, and a white waxy grain, characteristic of other glutinous varieties (Fig. 4).

The groats are white, waxy. It is recommended for use in confectionery production, for preparation of milk porridges, stuffed vegetables, dietary dishes, as well as the production of flour for baby and medical nutrition products.

Plants of the variety Lekar are highly resistant to blast disease and therefore do not require the use of fungicides. The variety is not shedding, but it threshes easily. The variety is suitable for mechanized harvesting.

Figure 4 – Glutinous rice variety Lekar: plants, grains and groats

The average yield in the competitive test over three years was 8.38 t/ha, which was at the level of the standard variety Rapan-2.

For the widespread use of groats of this variety as a medicinal and dietary product, it is necessary to conduct a test in a medical institution under the supervision of experienced doctors, accompanied by laboratory tests.

The Federal Research Center for Rice has begun propagating the variety Lekar to provide seeds for applications for its testing. In 2023, Niris LLC conducted production testing of the variety in field conditions and a preliminary assessment of grain quality.

Conclusions.

1. Sticky or glutinous rice is cultivated in most Asian countries, where it is widely used in national cuisine.

2. The high nutritional value of glutinous rice is ensured by its low amylose content (less than 5%), the absence of gluten and the high concentration of oleic and linoleic acids. Therefore, this rice is often used as a dietary and medicinal product.

3. The waxiness of grain in glutinous rice varieties is controlled by a triplex of recessive genes wxwxwx.

3. In the Russian Federation from 1994 to 2014 glutinous rice varieties have been created: short-grain varieties Viola and Violetta, long-grain Vita. In 2022, a new variety Lekar was submitted for State Testing, the groats of the variety being recommended for the preparation of dietary food, as well as baby and medical nutrition products.

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