Variability of grain and milled rice quality traits of long-grain rice variety

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Abstract. The article presents results of studying 14 families of long-grain rice variety Sharm, divided into two groups. A detailed assessment of technological indicators of grain and milled rice quality in primary seed production nurseries (P-1 and P-2) is given. Variability and correlation of traits is calculated. The experiment was carried out in the period 2016-2018 under the conditions of a field experiment as a control nursery, on the rice irrigation system of FSBSI "FSC of Rice" (Federal State Budgetary Scientific Institution "Federal Scientific Rice Centre"), Krasnodar. In a group of families with typical plants, significant excess of some technological indicators of grain and milled rice quality was revealed in comparison with the original variety Sharm, entered in the state register in 2013: for example, the weight of 1000 grains of the combined families after rejection was 27.6 g; fracturing is significantly lower - 10.2%; also, in terms of the total milling yield, head rice content, significant excess of the combined families was noted - 67; 92.1 and 59.6%. The variability of the considered technological traits is weak and varies within the range of up to 10%, with the exception of fracturing (CV up to 93%), since it is highly susceptible to weather fluctuations. In both groups of families, a close positive correlation was found between the head rice content in the milled rice and its content in the grain (r = 0.981 and 0.989) and a negative average relationship between fracturing and the total milling yield (r = -0.568 and -0.646, respectively). When rejecting families of the variety Sharm in P-1 and P-2, it is recommended to use, in addition to morphological characteristics, the indicator of the mass of 1000 grains and the grain index (l / b).

1 Introduction

In a scientifically grounded technological system for the cultivation of agricultural plants, breeding and seed production occupy a leading place as the most powerful, environmentally friendly levers in increasing the yield and quality of crop production [1, 2].

An important element of rice growing is rice seed production - a system of measures to preserve varietal qualities, grow seeds of high sowing conditions, reproduce them in the required quantities, store and control their quality [3, 4].

The plant density, the uniformity of crops, simultaneous passage of the rice plants through the growing season depends on the quality of the seeds [5]. In this regard, rice seed

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production covers a whole range of tasks, both purely agronomic and organizational, requiring specialists to make timely decisions [6].

Primary seed production after transfering the variety for the State test and before it is entered into the State Register of Breeding Achievements is carried out in specialized research institutes by breeders. The volume of seed material in demand is small, so the work is also complicated by financial issues, since the production of these seeds is not profitable. The work is carried out within the R&D framework. Seed material of new varieties is sent mainly to the SVT sites and is used for environmental and industrial testing. There is a problem of obtaining a small amount of pure seeds for several varieties within three to four years [7].

After being included in the List of varieties approved for use in production, professionals in research institutions and specialized (licensed) farms are engaged in seed production.

The technology of producing seeds of modern varieties, when carrying out a variety change, especially in the primary links, has not been studied enough. And if close attention is paid to the morphological characteristics in the process of primary seed growing of varieties, then the technological traits of grain and milled rice have usually never been studied.

In 1985, Zelensky G.L. had recommended when rejecting lines in rice seed nurseries, along with the typicality of plants and resistance to pests and diseases, to take into account low-changing traits (mass of 1000 grains, length of the main panicle, total number of spikelets in a panicle) and to use methods of statistical analysis to evaluate lines [8, 9].

Our earlier attempts to analyze the technological characteristics of grain and milled rice at the stage of primary seed production have shown their effectiveness. Three families of the variety Lastochka were identified, which showed blast resistance, had relatively low fracturing, a high head rice content and were morphologically typical [10]. In the large-grain rice variety Anait, families with a grain thickness of 2.0-2.1 mm and a mass of 1000 grains of 40-41 g and families with a thickness of 1.8-1.9 mm and a mass of 1000 grains of 34-35 g were distinguished. [7].

In the early-ripening, long-grain rice variety Sharm, in the nurseries of primary seed production, in individual families, a phenotypic trait was observed - the spinous caryopsis, which is unusual for it. After reseeding for three years, its hereditary character was established, which indicates the genetic nature of the phenomenon [11, 12]. At the same time, families did not differ morphologically.

In P-1, P-2 and multiplication nursery grain and milled rice of variety Sharm were technologically assessed by family. The variability of traits over the years was determined.

The material in the experiment was 14 families of the variety Sharm, consisting of two blocks: awnless (families No. 1-7) and with primordial awns (families No. 8-14). The buds of awns appeared in the awnless variety as a result of the unblocking I-An gene [11, 12].

The manifestation of atavistic traits, the genes of which are blocked in the reserve block of the genotype, suggests a re-blocking of genes, which explains the loss of some primitive features by rice, incl. spinousness, pigmentation, etc. It is precisely the overblocking that can explain some genetic processes in the rice population, including the manifestation of atavisms. For example, the I-An gene suppresses the formation of awns. At the plant level, blocked genes constitute the reserve block of the genotype of this rice form. It contains genes responsible for atavistic traits, which usually do not appear during the entire ontogenesis [3].

2 Conditions, material and methods

Weather conditions for the rice growing season in 2016-2018 were generally quite favorable. The climate is moderately continental. The average daily air temperatures over the summer period amounted to about 23 °C, which significantly exceeded the long-term average values, causing the accelerated accumulation of effective air temperatures ($\Sigma > 15$ °C) - about 1200 °C. They favorably contributed to the passage of the tillering phase. However, night temperatures during this period dropped to 12.1-13.6 °C, which increased the duration of the tillering period and allowed, during the differentiation of the growing cone, to form a larger number of spikelets in the embryonic panicle and the productive plant stand [11].

The soils on the territory of the experimental site are represented by semi-hydromorphic analogs of chernozems, with traits of waterlogging in the lower part of the profile. The humus content on average is 3.1% with a low absorption capacity of 33 meq / 100 g and a slightly alkaline reaction of the soil solution - pH = 7.2-7.6.

The material for the research was 14 families of the long-grain rice variety Sharm, divided into two groups according to a number of morphobiological and technological traits.

The experimental part of the work was carried out in 2016-2018. under the conditions of a field experiment on the rice irrigation system of the experimental production department of "Federal Scientific Rice Centre". The setting of the field experiment was carried out as a control nursery (CN) in accordance with GOST 15.101.80 - "Procedure for conducting research work" and the methods developed at Federal Scientific Rice Centre [13], and the method of experimental work on breeding [14]. Sowing dates - I-II decade of May. The predecessor is soybeans, wheat and fallow respectively over the years. The background of mineral nutrition is $N_{120}P_{60}K_{40}$ and additionally fertilizing in the tillering phase with urea - N_{46}.

Primary seed production nursery (P-1) was laid with single-row plots with an area of 0.5 m^2 (length 2.2 m with a row spacing of 22 cm) and sowing 100 grains per plot [14]. Primary seed production nurseries for the second year (P-2) were established in a single replication. Plot area 6.12 m^2 (length 5.10 m, width 1.2 m). The number of rows in the plot is eight, the distance between the rows is 15 cm, the distance between the plots is 40 and 50 cm [13].

The reliability of the data obtained is confirmed by the results of variance, covariance and correlation analyzes [15, 16, 17].

3 Results and discussion

During the long-term cultivation of varieties under the influence of external conditions (high temperatures, solar activity, different heat supply, etc.), phenotypic traits unusual for the variety may appear, which are fixed in the progeny This fact emphasizes the relevance of the issue under study and the need for a deeper study of the reasons for the genotype-environment interaction.

By following the correct primary seed production policy, it is possible to maintain the variety in an unchanged state by removing families with unusual traits from the 1st year nursery. Families remaining in P-1 must be checked the next year in P-2.

Rice researchers refer the mass of 1000 grains to a weakly varying trait [8, 18]. Being one of the main characteristics of the variety, in our experiment it has a low coefficient of variation between families for three years of study CV = 1.47-3.64% (Table 1).

Table 1. Variability of the mass of 1000 grains of variety Sharm, 2016-2018.

№ of awnless family	Year			Mean value	CV, %	№ of family with primordial awns	Year			Mean value	CV, %
	2016	2017	2018				2016	2017	2018		
1	27,9	27,6	26,9	27,47	1,9	8	28,6	28,4	27,8	28,27	1,5
2	27,2	27,5	26,4	27,03	2,1	9	29,8	28,3	27,8	28,63	3,6
3	28,7	27,2	26,9	27,60	3,5	10	30,0	29,2	28,7	29,30	2,2
4	28,2	27,4	26,4	27,33	3,3	11	28,2	27,6	28,5	28,10	1,6
5	28,7	27,6	27,4	27,90	2,5	12	28,7	28,6	27,5	28,27	2,4
6	28,0	28,2	26,6	27,60	3,2	13	28,7	29,6	28,8	29,03	1,7
7	29,3	29,1	28,2	28,87	2,0	14	27,2	27,8	26,7	27,23	2,0
Mean value	28,29	27,80	26,97	27,69		Mean value	28,74	28,50	27,97	28,40	
CV, %	2,41	2,34	2,39			CV, %	3,30	2,51	2,69		
LSD_{05}				0,43		LSD_{05}				0,64	

The mass of 1000 grains in 2016 exceeded the values of the trait of 2017 and 2018. The lowest mass of 1000 grains was formed in 2018. Families were carefully selected according to morphological traits, were harvested by hand, therefore, families can be graded by grain size, based on the absolute values of the mass of 1000 grains. There were no significant differences between families in the variability of the mass of 1000 grains during the study period - CV = 3.3-3.6% is the maximum for the groups.

But if we take the absolute values of the trait, taking into account the LSD05, as a basis for comparison, it is clear that there are significant differences between families. Families № 2 (with a weight of 1000 grains of 27.03 g) and № 7 (28.87 g) are subject to rejection from the first block (awnless). Families № 10 (29.3 g), № 13 (29.03 g), and № 14 (27.23 g) should be excluded from the second block (with primordial awns). The mass of 1000 grains of the noted families is significantly higher or lower than the average for the variety. Both blocks of families differ noticeably among themselves in the mass of 1000 grains: in awnless ones it is 27.7 g, ones with awn primordia - 28.4 g.

The Sharm variety shows insignificant variability in terms of technological parameters of grain and milled rice: mass of 1000 grains, total milling yield, l / b index or grain type ($CV \leq 10\%$), but shows high variability in fracturing (CV = 17.3-93%), which, as a result, does not have a significant effect on the yield and quality of milled rice (Table 2).

Table 2. Fracturing variability in variety Sharm, 2016-2018, %

№ of awnless family	Year			Mean value	CV, %	№ of family with primordial awns	Year			Mean value	CV, %
	2016	2017	2018				2016	2017	2018		
1	14	8	6	9,3	44,6	8	17	9	9	11,7	39,6
2	14	14	3	10,3	61,5	9	14	11	7	10,7	32,9
3	27	6	4	12,3	93,3	10	17	4	7	9,3	72,9
4	15	4	5	8,0	76,0	11	20	13	6	13,0	53,8
5	17	10	7	11,3	45,3	12	23	15	10	16,0	41,0
6	20	11	8	13,0	48,0	13	21	15	17	17,7	17,3
7	18	6	6	10,0	69,3	14	17	13	6	12,0	46,4
Mean value	17,86	8,43	5,57	10,6		Mean value	18,43	11,43	8,86	12,9	
CV, %	25,75	41,02	30,84			CV, %	16,54	34,21	43,93		
LSD_{05}				4,28		LSD_{05}				3,03	

Each family in both studied blocks reacted specifically to the conditions of three years of cultivation. The variation coefficient of fracturing in the group of awnless families is high (CV = 44-93%), and from medium to high in families with primordial awns (CV = 17-73%). This indicates a significant effect of growing conditions on the formation of the rice grain endosperm structure, which can be amorphous or amorphous-crystalline and react differently to the conditions of vegetation, harvesting and post-harvest processing by the formation of cracks [19]. This important indicator characterizing the variety quality was in the absolute value from 3% to 27% for all families. Fracturing varies by year: in 2016 it was higher than in 2017 and 2018. (18; 8-11 and 6-9%). There are also differences between the blocks of families: fracturing in the second block is 2.3% higher.

Family № 13 is distinguished by a relatively low coefficient of variation for the fracturing trait (CV = 17.3%), with the absolute value of the trait being 17.7%. And judging by the average indicator of the physical value of the trait, the best families can be considered № 1, 4 and 10 with a value of 9.3 and 8.0%.

As one can see, the selection of the best families differs with different approaches to rejection. If families are rejected in terms of fracture and only after that they are combined for further reproduction and obtaining original seeds, then the following can be obtained:

- when uniting families № 1 and № 4; fracturing can decrease to 8.65% (with an average of 10.6%), but the total milling yield remains almost unchanged (67.4% and 67.1%) (Table 3), and the head rice content increases slightly (up to 60.7%, against 59.1%) (Table 5);
- when uniting families № 9 and № 10; fracturing can decrease to 10.0% (versus 12.9%), but at the same time the total milling yield (66.8% and 66.75%) and the head rice content change insignificantly (up to 60.2% versus 58.8%).

Table 3. Variability of total milling yield of variety Sharm, 2016-2018, %

№ of awnless family	Year			Mean value	CV, %	№ of family with primordial awns	Year			Mean value	CV, %
	2016	2017	2018				2016	2017	2018		
1	68,2	67,7	65	67,0	2,57	8	68,2	67,7	65,5	67,1	2,14
2	68,5	67,7	65,5	67,2	2,31	9	67,8	67,7	64,7	66,7	2,64
3	68,0	68,2	63,8	66,7	3,73	10	67,5	67,2	66,1	66,9	2,45
4	68,8	68,3	65,5	67,5	2,63	11	67,8	68,6	65,2	67,2	1,98
5	67,9	67,2	65,4	66,8	1,93	12	67,3	67,5	64,4	66,4	1,98
6	67,7	68,0	65,9	67,2	1,69	13	66,9	67,4	64,6	66,3	2,43
7	68,1	67,9	65,4	67,1	2,24	14	67,4	67,0	65,3	66,6	2,32
Mean value	68,17	67,86	65,21	67,08		Mean value	67,56	67,59	65,11	66,75	
CV, %	0,55	0,54	1,04			CV, %	0,62	0,76	0,94		
LSD_{05}				0,58		LSD_{05}				0,53	

Thus, there is no point in rejecting families of the variety Sharm for fracturing, since it (in our experiment) did not have a significant effect on the main indicators of milled rice quality: the total milling yield and the head rice content. At the same time, the fracturing and mass of 1000 grains show significant differences between the blocks of families, and the mass of 1000 grains made it possible to reject families that clearly dropped out of the population.

Index of husked rice grain, i.e. its length to width ratio (l / b), also applies to the main varietal characteristics [20]. l/b variability is small for the 3 years of studies (V=1,7-7,8) (Table 4).

Table 4. Variability of grain index (l/b) of variety Sharm, 2016-2018.

№ of awnless family	Year			Mean value	CV, %	№ of family with primordial awns	Year			Mean value	CV, %
	2016	2017	2018				2016	2017	2018		
1	3,2	3,4	3,4	3,3	3,46	8	3,2	3,5	3,0	3,23	7,78
2	3,3	3,4	3,2	3,3	3,03	9	3,2	3,4	3,1	3,23	4,72
3	3,1	3,2	3,3	3,2	3,12	10	2,8	3,0	3,1	2,97	5,15
4	3,2	3,4	3,3	3,3	3,03	11	3,2	3,4	3,0	3,20	6,25
5	3,2	3,2	3,3	3,2	1,79	12	3,3	3,4	3,3	3,33	1,73
6	3,1	3,2	3,0	3,1	3,23	13	3,4	3,5	3,1	3,33	6,24
7	3,4	3,6	3,5	3,5	2,86	14	3,2	3,4	3,2	3,27	3,54
Mean value	3,21	3,34	3,29	3,28		Mean value	3,19	3,37	3,11	3,22	
CV, %	3,33	4,52	4,79			CV, %	5,85	5,06	3,43		
LSD_{05}				0,09		LSD_{05}				0,14	

Upon a detailed examination of the trait, we observe significant differences: from 3.1 to 3.6 in the first block, and from 2.8 to 3.5 in the second, with LSD_{05} equal to 0.09 and 0.14, respectively. In the block of awnless families, according to the mean value, № 6 and № 7 stand out with l/b = 3.1 and 3.5, and in the block of families with primordial awns, family №10 - l/b = 2.97. They are subject to rejection, because significantly differ from other families. A significant influence of the year of cultivation on the grain size was noted. Longer and thinner grain was formed during the 2017 growing season for all families of the variety.

The grain index (l / b) and the mass of 1000 grains in actual terms in our experiment made it possible to identify families with characteristics atypical for the variety. Taking into account the rejection by these two indicators (l/b and the mass of 1000 grains) in the block of awnless families remain to the union № 1, 3, 4 and 5, in the block of families with the primordial awns - № 8, 9, 11 and 12.

The head rice content in the grain is one of the main technological indicators of the milled rice quality. High absolute values for this trait and their weak variability indicate the ability of the variety to form full-fledged, high-quality and filled grain, in spite of weather fluctuations (Table 5).

Table 5. Variability of head rice content in the grain of variety Sharm, 2016-2018, %

№ of awnless family	Year			Mean value	CV, %	№ of family with primordial awns	Year			Mean value	CV, %
	2016	2017	2018				2016	2017	2018		
1	61,2	62,0	60,9	61,4	0,9	8	55,0	60,5	60,3	58,6	5,3
2	56,5	59,2	59,7	58,5	2,9	9	57,4	57,9	60,1	58,5	2,5
3	52,8	62,9	59,6	58,4	8,8	10	59,8	65	60,5	61,8	4,6
4	56,5	62,1	61,4	60,0	5,1	11	57,5	60,3	60,7	59,5	2,9
5	57,4	59,1	58,6	58,4	1,5	12	51,8	57,4	58,7	56,0	6,6
6	55,1	62,6	60,0	59,2	6,4	13	55,4	59	58,1	57,5	3,3
7	53,5	60,4	60,1	58,0	6,7	14	55,9	62	60,9	59,6	5,5
Mean value	56,1	61,2	60,0	59,1		Mean value	56,1	60,3	59,9	58,8	
CV, %	5,0	2,6	1,5			CV, %	4,5	4,3	1,8		
LSD_{05}				2,16		LSD_{05}				1,71	

To determine the closeness and nature of the interaction of the genetic systems of the studied families of the variety Sharm, expressed by technological traits, we carried out a correlation analysis. Correlation relationships of traits in various combinations indicate the mutual influence of traits on each other (Table 6).

Table 6. Correlation of technological indicators of grain and milled rice quality in families of long-grain variety Sharm

Trait	Mean value	Std. Dev.	Trait			
			1	2	3	4
Awnless families						
Mass of 1000 grains, g	27,7	0,59				
Fracturing, %	10,6	1,73	0,080			
Total milling yield, %	67,1	0,27	-0,237	-0,568		
Head rice content in milled rice, %	88,2	1,72	-0,400	-0,377	0,104	
Head rice content in grain, %	59,1	1,20	-0,431	-0,475	0,297	0,981
Families with primordial awns						
Mass of 1000 grains, g	28,3	0,68				
Fracturing, %	12,9	2,96	0,004			
Total milling yield, %	66,7	0,34	-0,086	-0,646		
Head rice content in milled rice, %	88,1	2,49	0,170	-0,747	0,455	
Head rice content in grain, %	58,7	1,82	0,143	-0,789	0,580	0,989

Note. Trait: 1 – mass of 1000 grains, g;
2 – fracturing, %;
3 – total milling yield, %;
4 – head rice content in milled rice, %;
5 – head rice content in grain, %.

Correlation analysis of technological indicators of grain and milled rice quality in the studied families of the long-grain rice variety Sharm revealed an average negative (inverse) relationship between the total milling yield and fracturing in the group of awnless families - r = -0.568, which is natural. In families with primordial awns, this indicator is -0.646, and there is also a close negative correlation of the head rice content in grain and milled rice with fracturing - r = -0.747 and -0.789, respectively. In both studied groups, a close positive relationship was found between the head rice content in milled rice and its content in the grain - r = 0.981 and 0.989, respectively, since each of them directly determines the value of the other. It should also be noted that the contribution of genetic systems to the formation of these traits is 96 and 98%, respectively.

Analysis of the comparison of the characteristics of the variety Sharm during its transfer to the SVT (2007-2009) and after rejection with the union of the best awnless families, taking into account the technological characteristics of grain and milled rice (2016-2018): we observe an improvement in the indicators in the latter version. A significant decrease in fracturing is noted, with an increase in the total milling yield and the head rice content in grain and milled rice, as well as a slight increase in the mass of 1000 grains (Table 7).

Comparative analysis of the characteristics of the variety Sharm during its transfer to the SVT (2007-2009) and after rejection with the union of the best families with the premordial awns, taking into account the technological characteristics of grain and milled rice (2016-2018): there is a significant decrease in fracturing, with a significant increase the mass of 1000 grains, which indicates a clear discrepancy between their varietal affiliation (Table 7). Our studies for three years show that the morphological changes that have occurred with the variety Sharm in the form of the appearance of awn primordia have deeper consequences: an increase in the mass of 1000 grains. The resulting seed material can be rejected or serve as the basis for developing a new variety.

Table 7. Characteristics of the variety Sharm before transfer to SVT (2007-2009) and after rejection of families in P-1 and P-2 (2016-2018)

Trait	2007-2009	After rejection with union of awnless families (2016-2018)	Change (+;-) in relation to 2007-2009	LSD_{05}	After rejection with union of families with premordial awns (2016-2018)	Change (+;-) in relation to 2007-2009	LSD_{05}
Mass of 1000 grains, g	27,0	27,7	+0,7	0,43	28,3	+1,3	0,64
Length to width ratio (l/b)	3,3	3,3	0,0	0,09	3,25	-0,05	0,14
Fracturing, %	21.0	10,2	-10,8	4,28	12,8	-8,2	3,03
Total milling yield, %	66.0	67,1	+1,0	0,58	66,8	+0,20	0,53
Head rice content in milled rice, %	81,5	92,1	+10,0	8,41	92,0	+7,0	7,13
Head rice content in grain, %	55.0	59,6	+2,16	1,92	58,2	+1,2	1,71

4 Conclusions

In accordance with the above, it should be noted that, as a result of the influence of external conditions, awnless families and families with awn rudiments were distinguished in the population of the long-grain rice variety Sharm. The coefficient of variation of the technological indicators of grain and milled rice in the selected families was insignificant - CV ≤ 10%, with the exception of fracturing - CV = up to 73-93%, respectively, by groups of families. When rejecting families of the variety Sharm in P-1 and P-2, in addition to morphological characteristics, it is necessary to be guided by such traits as the mass of 1000 grains and the grain index (l / b). According to the results of three years of research of awnless families of the variety Sharm on the technological characteristics of grain and milled rice and rejections by the mass of 1000 grains and the grain index in primary seed production nurseries, the best families showed an increase in the mass of 1000 grains, an increase in the resistance of the variety to the process of cracking in rice kernels and, accordingly less crushing of kernels in the manufacture of milled rice. They can be the basis for obtaining original seeds. Families with primordial awns differ significantly from the original characteristics of the variety with a larger mass of 1000 grains and must be removed from the population or can be the basis for developing a new variety.

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