Correlation of technological indicators of grain and milled rice quality of new varieties depending on climate condition

R R Dzhamirze, N V Ostapenko and N N Chinchenko

Federal State Budgetary Scientific Institution «All-Russian Rice Research Institute», 3 Belozerny, Krasnodar, 350921, Russia

E-mail: dzhamirze01022010@yandex.ru

Abstract. Rice is the staple food of many nations of the world, as it gives the greatest amount of grain per unit area. The most important task in developing a new high-yielding variety is to increase the technological indicators of grain and milled rice quality, or at least to keep them at the optimal level (standard-check variety). Rice for food purposes is used in the form of cereals, as an admixture to bread or confectionery, in the production of flakes, puffy grains. This is due to the demand for high-quality rice with excellent taste and culinary qualities in a dynamic market.

This article presents the results of three-year studies on the formation of technological indicators of grain and milled rice quality with different heat supply during the growing season. It is established that the accumulation of heat in 2016-2018 exceeded the average long-term data (783 °C) - 1054, 1089 and 1238 °C, respectively. Under these conditions, the varieties VNIIR 10244, VNIIR 10276 and VNIIR 10279 with a mass of 1000 grains - 29.3; 30.5 and 30.4 g, respectively were selected, significantly exceeding the standard (27.8 g). Vitreousness in all varieties was at a high level - 89.7-97.7%. Filming over the years of research varied on average from 17.7 to 21.4%. The fracture of the presented varieties was 4.7-32.3%. The varieties VNIIR 10275, VNIIR 10278 and VNIIR 10828 showed the maximum resistance to grain cracking - 9.7; 9.3 and 4.7%. Total milling yield in almost all genotypes was at the level of variety Flagman (st), with the exception of VNIIR 10278 (72.7%), which significantly exceeded the standard. By head rice content the variety VNIIR 10282 turned out to be significantly higher than the standard, and the rest within the LSD 0.05. The correlation of technological indicators of grain and milled rice quality with the heat supply of the growing season were revealed. It was established that the varieties VNIIR 10279 and VNIIR 10282 by head rice content weakly correlate with heat supply. There are also varieties (VNIIR 10275, VNIIR 10276, VNIIR 10277 and VNIIR 10282) with a weak connection of a mass of 1000 grains and the sum of effective temperatures (0.60; 0.18; 0.27 and 0.36, respectively). This fact suggests a weak variability of these traits in new rice varieties with heat accumulation, which determines their genetic nature and the possibility of forming a high-quality yield.

1. Introduction

In terms of gross grain collection around the world, rice stands in the same place as wheat, ranking second in terms of acreage. According to available estimates, the contribution of breeding to increasing crop yields over the past decades is estimated at 30–70%, and taking into account possible climate changes, the role of breeding will increase [1; 2].

Milled rice has high nutritional properties. Considering that whole grain of rice is eaten, very high demands are made on the milled rice quality. These include - the total milling yield and head rice content, the mass of 1000 grains, vitreousness, fracturing, filminess, color, shape and grain size. However, over
time, due to certain factors - biotic and abiotic (drought, high daily average air temperatures, heavy rains during harvesting, damage by pests and diseases, etc.), as well as anthropogenic (lack of primary seed production and variety renewal), the same variety gives grain of different quality and nutritional value. Therefore, the concept of rice quality is diverse [3].

Development and introduction of productive varieties with high technological indicators of grain and milled rice quality are facilitated by the combination of certain conditions that prevent the expansion of foreign varieties to the domestic market of seeds and milled rice. This explains the purpose and relevance of our research on breeding of high-yielding rice varieties with excellent grain and milled rice quality that meet the modern requirements of production workers, as well as the processing industry.

2. Materials and methods of research
As the object of the study 9 varieties from the competitive test of medium-ripening group served, developed by the classical method of hybridization and individual selection from the resulting hybrid combinations. Genotypes were studied for 2-3 years in the conditions of breeding (BN) and control (CN) nurseries in order to identify the best of them. Over the next three years, they were further evaluated in competitive testing (CVT) to identify a promising variety that reliably exceeded the standard for a set of economically valuable traits for its transfer to state variety testing (SVT).

For sowing CVT plots, a Wintersteiger Ploteed seed drill was used. The accounting area of the plots is 20 m², the repetition is fourfold, the placement is randomized repetition, the standard is rice variety Flagman, the general background of mineral nutrition is N10P60K40.

Research work was carried out in accordance with GOST 15.101.80 "The order of research work" and techniques developed in All-Russian Rice Research Institute [4; 5].

Agroclimatic conditions of production department of ARRRI in 2016-2018. Sowing dates – 01.05-05.05, initial flooding - 05.05-08.05.

In competitive varietal testing, the dates of prophylactic treatments and the occurrence of phenological phases of emergence and full ripeness were noted. During the growing season, the plots were evaluated visually on the field according to plants density, lodging resistance, disease and pest damage, uniformity of crops. After the field rejection from the plots planned for harvesting, we took model sheaves of 10–15 plants for biometric analysis.

Technological characteristics of grain and milled rice were determined according to GOST 10843-76, GOST 10987-76 and “Methodological guidelines for assessing the quality of rice grains” [6].

The results obtained were processed by the method of dispersive and statistical analyzes [7], and to determine the closeness of the relationship between traits of grain and milled rice quality with heat accumulation, correlation analysis (r) was used [8].

3. Results and discussion
To identify and study the nature of the relationship between the sum of temperatures above 15 ° C and the technological indicators of grain and milled rice quality in the presented rice genotypes, we examined the dynamics of temperature accumulation and calculated the heat supply of the vegetation period during 2016-2018 (figure 1).

Analysis of the three-year data showed that the temperature during the study was generally favorable for rice. In 2016, the increase in the sum of effective temperatures above 15 ° C in the first two decades of May was ahead of the average annual one. From the third decade of May to the end of the second decade of June, the heat supply was below the average long-term indicators. From the third decade of June to the second decade of September inclusive, the sum of effective temperatures above 15 ° C increased at an accelerating rate, reaching 1054 ° C, which is 277 ° C higher than the average annual. During this period of favorable air temperatures, the main development phases of rice take place: booting, emergence, all phases of grain filling up to full ripening of medium-ripening rice varieties.
Figure 1. Temperature regime during the research period, 2016-2018.

In 2017, the sum of effective temperatures above 15 °C in the first two decades of May was ahead of the average annual. From the third decade of May to the end of the second decade of June, heat supply was below the average annual rates, which probably caused an increase in the vegetation period. From the third decade of June to the third decade of September, inclusive, the heat supply during the growing season grew at an accelerating pace, reaching 1089 °C, which is 306 °C higher than the average annual.

The sum of effective air temperatures above 15 °C during the whole vegetation period of rice of 2018 (May – September) significantly exceeded the average annual one. By the end of September, the difference from the average annual was 455 °C.

In general, the heat regime for the three years of research was positive and did not have critical deviations from the mean annual values, but the individuality of each year contributed to the specific reaction of the varieties under study (table 1).

Table 1. Technological indicators of grain and milled rice of new varieties, CVT 2016-2018.

| №  | Variety       | Mass of 1000 grains, g | Vitreousness, % | Filminess, % | Fracture, % | Total milled rice, % | Head rice content, % |
|----|---------------|------------------------|-----------------|--------------|-------------|----------------------|----------------------|
| 1  | Flagman (st)  | 27,8                   | 89,7            | 18,7         | 32,3        | 71,6                 | 85,8                 |
| 2  | VNIIR 10244   | 29,3                   | 90,0            | 17,7         | 18,7        | 71,4                 | 88,5                 |
A mass of 1000 grains is the most important characteristic characterizing a variety, and is also a reliable criterion for the variety to belong to a certain group by grain size (small grain, medium grain and large grain). Most of the presented varieties can be classified as medium grain - with a mass of 1000 grains 24.8-28.1 g. But varieties VNIIR 10244, VNIIR 10276 and VNIIR 10279 with a mass of 1000 grains - 29.3; 30.5 and 30.4 g significantly exceeded the standard for this indicator, and they can be characterized as large grain.

Vitreousness is one of the important indicators of rice grain quality, an increase in which is accompanied by an increase in the technological characteristics and cooking properties of milled rice. Vitreous rice is primarily in demand by consumers.

This trait is characterized by constancy and little variability over the years. In our studies, vitreousness ranged from 89.7-97.7%. Significant differences were noted in varieties VNIIR 10275 and VNIIR 10282 - 97.7 and 96.7%, respectively.

The percentage of flowering and spikelet scales in the grain mass of the presented varieties was 17.7-21.4% on average over three years. In general, the filminess of the varieties studied in the CVT was at the optimal level (17-20%), with the exception of VNIIR 10282 with the maximum value of the trait - 21.4%.

Fracture is a negative trait, as a rule, negatively affecting the head rice content. Cracks caused by weather fluctuations, overmature standing and other conditions penetrate to different depths and destroy the endosperm of the rice core. After peeling and grinding such kernels turn into a crushed product. Fracture in our studies ranged from 4.7 to 32.3%. The varieties VNIIR 10275, VNIIR 10278 and VNIIR 10282 showed the maximum resistance to cracking - 9.7; 9.3 and 4.7%, respectively, and may be of some value to breeders. All varieties significantly exceeded the standard for resistance to cracking of grain. The high fracture of variety Flagman (st) - 32.3% may be due to the lower elasticity, elasticity and mechanical strength of the grain as a whole during the study period.

Total milled rice and head rice content are complex indicators of technological rice qualities. The total milled rice on average over three years varied by varieties from 69.1% (VNIIR 10275) to 72.7% (VNIIR 10278). VNIIR 10278 has a significant excess of the standard for this attribute. Milling yield from the other varieties for three years varied at the level of the standard.

Head rice content is one of the main technological indicators of milled rice quality, characterizing the economic efficiency of rice varieties during the processing. The value of the trait by varieties in the experiment was 82.0-93.5% on average, which is at the level of the standard (LSD$_{5}$ = 9.64), with the exception of VNIIR 10282, which significantly exceeded it - 97.8%.

The genetic diversity of the material under study is provided by the diversity and closeness of the relationship of traits characterizing the variety. To determine the interaction of the genetic systems of rice varieties under study and the closeness of their connection with the temperature regime of the vegetation period in CVT conditions, we carried out a correlation analysis (table 2).

![Table 2](http://example.com/table2.png)

| Trait                              | Flagman (st) | VNIIR 10244 | VNIIR 10275 | VNIIR 10276 | VNIIR 10277 | VNIIR 10278 | VNIIR 10279 | VNIIR 10282 |
|------------------------------------|--------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Sum of t $^\circ C > 15$, $^\circ C$ | 1127.2       | 1127.2      | 1127.2      | 1127.2      | 1127.2      | 1127.2      | 1127.2      | 1127.2      |
| Mass of 1000 grains, g             | 0.94         | 0.99        | 0.60        | 0.18        | 0.27        | -0.96       | 0.90        | 0.36        |
| Vitreousness, %                    | -0.96        | -0.99       | -0.98       | -0.81       | 0.06        | -0.76       | -0.76       | -0.65       |
On the data of the correlation analysis, we compared milled rice quality of a standard variety against the sum of effective temperatures (SET) and the varieties under study.

In variety Flagman, two indicators had a strong negative correlation with temperature: vitreousness and fracture. That is, as the sum of effective temperatures increases, their values decrease. And if the reduction vector for vitreousness is bad, it is good for fracture. The filminess and total milled rice showed no dependence on the temperature gradient. And head rice content and the mass of 1000 grains are strongly positively associated with SET in this variety.

VNIIR 10244 is similar to the standard for the dependence of almost all studied quality traits on the sum of effective temperatures, except for total milled rice. In the new variety, total milled rice has a high positive correlation with the temperature gradient.

The remaining varieties in the experiment had each individual special reaction to temperature.

In VNIIR 10275, VNIIR 10276, VNIIR 10277 and VNIIR 10282, the mass of 1000 grains shows a low or very weak correlation with the SET.

Vitreousness in almost all new varieties (except for VNIIR 10277) negatively and largely responded to the increase in the SET.

The value of the correlation coefficient of filminess for varieties ranged from -0.41 (VNIIR 10244) to 0.99 (VNIIR 10275). In the same way as Flagman (almost neutral), 4 varieties reacted to the increase of SET in the experiment: VNIIR 10244, VNIIR 10276, VNIIR 10277 and VNIIR 10279. Previous studies of filminess in a large number of old rice varieties indicate its indifference [9]. On the new varieties we see the same thing, obviously, one cannot judge the reaction of the variety by this indicator.

Researchers have previously noted that fracture is characterized by strong variability depending on the variety and growing zone [9]. In our experiment, in all varieties, the dependence of fracture on the SET level is strong negative, except for variety VNIIR 10282 (r = -0.64 is medium).

Total milled rice, depending on the variety and the cultivation zone, is characterized by relatively small variability (V = 2.3–11.3%) [9]. Four varieties in the experiment have a neutral or weak dependence of total milled rice on an SET (r = -0.36 to 0.53) (at the level of the standard). Three varieties strongly and positively increase total milled rice with an increase in SET (VNIIR 10244, VNIIR 10277 and VNIIR 10279). As already noted, the experiment took place over a period of three years with the growth of SET.

The most important indicator for the breeder is “head rice content”. In our experiment, we see a high positive correlation in five varieties (r = 0.85–0.99) from SET, at the standard level. Such a correlation can be interpreted as follows: with an increase in the sum of effective temperatures, the head rice content will increase. But then with a decrease in SET, we will get a decrease in head rice content.

In our opinion, the varieties showing a weak or medium correlation with a temperature gradient such as VNIIR 10279 and VNIIR 10282 (r = 0.40; r = 0.75) are more interesting. They have high head rice content, and it is to be hoped that they will not experience dramatic changes in quality with variations in SET.

If we consider all the coefficients of correlation in this way, it can be seen that VNIIR 10282 is a variety with a predominantly neutral or weak response to the SET of all quality indicators.

4. Conclusion

Thus, the correlation of quality traits and changes in the sum of effective temperatures can serve as a criterion for selecting varieties in CVT. By analogy with the standard variety Flagman, the variety VNIIR 10244 can be selected; neutral reaction to the change in SET in all quality indicators - VNIIR 10282; high indices of head rice content and low or medium correlation with temperature gradient - VNIIR 10279 and VNIIR 10282.
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