RESEARCH ARTICLE

SABRAO Journal of Breeding and Genetics
54 (4) 803-813, 2022
http://doi.org/10.54910/sabrao2022.54.4.11
http://sabraojournal.org/
pISSN 1029-7073; eISSN 2224-8978

RICE GRAIN DARK SPOTS AND THEIR IMPACT ON QUALITY ASSOCIATED TRAITS

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SUMMARY

Rice grain damage due to dark spots was noted more than 10 years ago in Russia. However, this phenomenon has long existed in other rice-growing countries. The factor limiting high rice yields are insect pests and pathogenic microorganisms, the vital activity of which leads to the occurrence of dark spots on the grain shells. This study hopes to assess the effects of dark spots on rice grains of six rice cultivars bred in Russia, i.e., Rapan, Khazar, Romans, Favorit, Trio, and Prestige. The study was carried out in 2020–2021 at the Federal State Budgetary Scientific Institution, Federal Scientific Rice Centre, Krasnodar, Russia. With an increase in the content of damaged grains from 5% to 10% and 20%, the mass of 1000 absolutely dry grains, vitreosity, and head rice content decrease, the filminess increased, and the content of damaged grains negatively affecting the quality traits of rice grains. If the content of damaged grains is up to 5%, grain quality decreases giving no impact of the parameter. The need to predict rice grain yield and quality based on grain damage intensity caused by dark spots ensures the profitability of growing various cultivars in rice production.

Keywords: Rice germplasm, seed dark spots, grain damage, grain yield, grain quality traits

Key findings: Damaged rice grains increase in the grain mass, decrease quality, grain size, vitreosity, and head rice content, and increase filminess. Overall, the content of damaged grains significantly affects the rice grain quality traits.

Communicating Editor: Prof. Naqib Ullah Khan

Manuscript received: August 12, 2022; Accepted: September 14, 2022.

INTRODUCTION

In world agriculture, rice takes second place after wheat in terms of sown area. Milled rice is an essential food product and an integral part of the human diet. Of the volume of various kinds of cereals consumed by Russians in recent years, rice has been 28%–40%. In the Krasnodar region, Russia, the rice yield exceeds 7.0 t/ha, and the gross harvest of paddy rice is about 90,000 t (Zelensky and Zelenskaya, 2022). High yields resulted from the introduction of new rice cultivars, the application of mineral fertilizers, and the use of protection measures against pest and diseases (Zelensky and Zelenskaya, 2022).

Critical factors like insect pests and pathogenic microorganisms affect stable rice yields, and their infestations caused dark spots in rice grain shells. In rice-growing countries, this problem persisted. For the first time in Russia, grain damage due to dark spots noted more than 10 years ago received attention. In 2012, due to climatic conditions, the turtle,

To cite this manuscript: Tumanyan NG, Tkachenko MA, Kumeiko TB, Chizhikova SS (2022). Rice grain dark spots and their impact on quality associated traits. *SABRAO J. Breed. Genet.* 54 (4) 803-813. http://doi.org/10.54910/sabrao2022.54.4.11

bugs, locusts, and meadow moths became active earlier than usual, and a state of emergency was declared in the Russian regions of Volgograd, Saratov, Samara, Astrakhan, Orenburg, Kalmykia, Dagestan, and Stavropol regions. In the Krasnodar region, Russia, in 2012, the significant damage to rice yield rose to 20%–30%, which led to a decrease in rice cultivation profitability (Tumanyan *et al*., 2021).

The damaged rice grain samples were analyzed in microbiological laboratories to identify the problem. These include All-Russian Research Institute of Grain, All-Russian Research Institute of Phytopathology, All-Russian Research Institute of Biological Plant Protection, All-Russian Research Institute of Agricultural Microbiology, All-Russian Rice Research Institute, and the International Rice Research Institute (IRRI). They detected the bacterial and fungal microflora. The Federal Scientific Rice Centre, Krasnodar, Russia recognized the need to evaluate rice breeding materials to monitor the intensity of grain damage in rice farms in the region and predict the occurrence of dark spots due to weather conditions (Chizhikova *et al*., 2014). The amount of bacterial microflora decreased several times after grain harvesting, which agrees with the past literature data (Mudretsova-Viss and Dedyukhina, 2008; Nirmaladevi *et al*., 2015; Rafiq *et al*., 2016).

The pathogenic fungus *Pyrenochaeta oryzae*, the causative agent of rice pyrenochaetosis, was found in milled rice samples (All-Russian Research Institute of Grain, Moscow). A semi-saprophytic bacterium of the genus, *Pantoea agglomerans*, which is constantly present in all plant species, has been isolated (All-Russian Research Institute of Phytopathology, Moscow). The bacteria, presumably of the genus *Xanthomonas*, have also been isolated (VIZR, St. Petersburg). Long-term mycological and bacteriological analyses have been conducted, and as a result, pathogenic fungi were not isolated. However, saprophytic fungi belonging to the genera *Penicillium* sp. and *Aspergillus* sp., causing mold (storage fungi), were found. A complex of semi-saprophytic and saprophytic bacteria of the genus *Erwinia*, consisting of strains with extremely heterogeneous properties, was isolated from milled rice (Federal State Institution 'KRC Rosselkhoznadzor', Krasnodar, Russia). In the study of fungal microflora, fungi of the genus *Alternaria* (70%), genus *Cladosporium* (20%), and the genus *Epicoccus* (10%) were identified (All-Russian Research Institute of Agricultural Microbiology, St. Petersburg).

After a thorough examination of damaged rice seeds, the detected representatives of the fungal microflora included, i.e., *Alternaria tenuis*, *Trichothecium* sp., and *Fusarium moniliforme*, and in small quantities - *Penicillium* sp., *Rhizopus* sp., *Aspergillus flavus* orizae, *Cladosporium* sp., *Phoma* sp., and *Drechslera hawaiiensis* (IRRI, Philippines; Fanyan *et al*., 2002; Kumeiko and Tumanyan, 2020). Grain damage in the form of dark spots leads to a decrease in yield quality in varying degrees (Patel *et al*., 2006; Lang *et al*., 2020; Tumanyan *et al*., 2021). In the United States, Venezuela, Mexico, Brazil, Cuba, and the Caribbean, the main pests responsible for dark spots on caryopsis are *Oebalus pugnax*, *Oebalus insularis* Stål, *Oebalus poecilus*, and *Oebalus ypsilongriseus*, with the intensity of yield damage depending on the distribution of insects (Dallas, 1851; Walker, 1990; Pantoja *et al*., 1995; McPherson and McPherson, 2000; Zachrisson *et al*., 2014).

The small rice stink bug, *Oebalus poecilus* (*Solubea poecila*), a devastating pest of rice crops, belongs to the family, Pentatomidae. The bug smells like rice and it is the main pest of rice crops in many South American countries (Van-Halteren, 1972; Sutherland *et al*., 2002). The bug is of great economic importance to rice farming in Brazil with irrigated, floodplain, and upland farming systems. At the stages of nymphs and adults, they feed mainly on rice grains in all phases of vegetation (milky, waxy, and full ripeness). Damage caused by bugs to crops of high-mountain rice cultivars leads to the occurrence of dark spots, weight loss, germination effect, grain deformation, and an increase in the number of crushed kernels. The beetles increase the grain sterility (83%) in the panicle during the milky stage than in the later stages of rice development. By comparing the degree of damage caused by *O. Poecilus* and *O. Ypsilongriseus*, the differences were shown for rice cultivars (Ferreira *et al*., 2002). The *O. poecilus* are carriers of various fungi (Albuquerque, 1993; Antoniolli and Porto, 1995; Silva *et al*., 2002; Krinski and Foerste, 2017a, b, c; Weber *et al*., 2020). For the first time in 2015, the colonization of the bug, *Hypatropis inermis* (Hemiptera, Pentatomidae), on alpine rice (cultivar Cambará) in Novo Progresso, Pará state, Brazil became known.

Work has been carried out to study the influence of weather on the population dynamics of *O.poecilus*, the main insect pest of rice in South and Central America. Using net traps, from autumn 1999 to spring 2002, *O. poecilus* was shown to feed on grass-alternative hosts in dams surrounding paddy fields. Adult bugs move to the fields in mid-January and mid-August and leave in April and October. Fields typically have four generations per season spaced about four weeks apart. The amount of rainfall was critical to the survival of *O. poecilus* during the off-season, i.e., high rainfall from April to July and from November to January leads to an increase in the number of *O. poecilus* (Sutherland and Baharally, 2003). Thus, they concluded that the density of *Tibraca limbativentris* Stål (stink bug) is critical to the extent of 2-4 bugs per 15 stems for the vegetative stage and 1-2 bugs per 15 stems at the beginning of the reproductive phase (R3/R4). It caused a decrease in rice grain yield and quality in the Brazilian rainforest region of the Southwestern State of Pará, Amazon (Krinski *et al*., 2015; Krinski and Foerster, 2017a, b, c).

Rice stink bug (*Oebalus pugnax*) remains the major pest of rice throughout the entire rice belt in the Southern States of the US, i.e., Mississippi, Arkansas, Louisiana, and Texas. The adult rice stink bug has a yellow to dark brown color and an elongated body shape, sometimes with a yellow triangle. The foremost agricultural pest in the Southern US is this flying insect from the Pentatomidae family, known since 1775. As a result of scientific research in Stoneville and Missouri, the US (Stoneville, MS), the viciousness of the bug *O. pugnax* depends on the stage of development of the rice panicle. Rice yield loss was high during the flowering stage, and grain damage was greatest during the milky and early waxy stages (Awuni *et al*., 2015; Blackman and Stout, 2017).

The *O. insularis* is a rice pest in Central and South America, in the Caribbean (Gomez-Sousa and Meneses-carbonell, 1980; Guharay, 1999; Cherry and Nuesly, 2010). For the first time in 2017 and 2018 in a survey of rice pests in Gilan Province, Northern Iran, the white-spotted bug, *Eysarcoris ventralis* (Westwood, Hem.: Pentatomidae), was found on rice panicles, also recognized as one of the most destructive pests of rice crops, leading to grain sterility and the appearance of a spot around the feeding place. It has also been found on weeds, alfalfa, wheat, and grapes (Jalaeian *et al*., 2019). The comprehensive program for the control of insect pests, including members of the genus *Oebalus*, found that chemicals should not be spayed on them to control them, so as to protect natural populations of parasites and predators. It is necessary to grow rice cultivars that have resistance to nematodes, diseases, and insects by biological control (Shah *et al*., 2015).

Brazil developed new herbal insecticides derived from different species of Annonaceae (Krinski *et al*., 2014). Thus, the Neotropical brown bug *Euschistus heros* (Hemiptera: Pentatomidae), an insect pest of soybeans, was first discovered several years ago in the Mato Grosso State, Brazil. According to the past research, recommendations stressed the use of an alternative to synthetic insecticides for pest control, and it is necessary to use *Hexacladia smithii* Ashmead (Turchen *et al*., 2015). A natural extract with insecticidal properties from *Piper aduncum* (Piperaceae) leaves against stink bugs on soybean has been recommended (Piton *et al*., 2014). However, at present, in many rice-growing countries, including the countries of South America, the control of *Oebalus poecilus* is carried out exclusively with the help of monocrotophos (Ralph and Rivas, 1993).

In Russia, what causes the dark spots' occurrence on rice grains has not yet been resolved. The impact of grain damage on technological quality traits has not yet been sufficiently studied. For this purpose, the study will assess the effect of dark spots on rice grains' most important quality traits, which determine the quantity and quality of rice products.

MATERIALS AND METHODS

Meteorological conditions

The ambient temperature determines the growth rate, development, and productivity of plants. The risk factors in the formation of quality grain yield are the 10-day average air temperature and the sum of average daily temperatures. The sum of effective temperatures required for rice range from 2000°C to 3000°C, when passing to the seedling stage (520°C), and at the onset of the grain filling stage (700°C). A change in these indicators can lead to a significant decrease in rice grain quality. The weather conditions during rice growing periods (2020–2021) differed sharply from each other (Table 1). The sum of effective temperatures in 2020–2021 by the end of the grain filling period (the third day of August) reached 1627°C and 1623°C,

Table 1. The sum of the effective temperatures and average daily air temperatures in April-September 2020, 2021, Belozerny, Krasnodar region, Russia.

Day and month	1	2	3	1	2	3	1	2	3
	April			May			June		
				Sum of effective temperatures					
Average Perennial	-	-	28	78	146	250	345	449	562
2020	6	23	46	107	190	260	376	514	664
2021	13	28	49	103	181	287	365	485	619
				Average daily air temperature					
Average Perennial	8.9	10.9	13.0	15.0	16.8	18.5	19.5	20.4	21.3
2020	9.7	11.4	12.1	16.1	18.3	16.5	21.6	23.8	25.0
2021	10.5	11.4	12.1	15.7	17.9	19.6	17.9	22.0	25.1
	July			August			September		
				Sum of effective temperatures					
Average Perennial	687	819	971	1108	1235	1363	1456	1530	1586
2020	846	999	1175	1339	1481	1627	1780	1900	2016
2021	770	960	1136	1317	1456	1623	1710	1810	1853
				Average daily air temperature					
Average Perennial	22.5	23.2	23.8	23.7	22.7	21.6	19.3	17.4	15.6
2020	28.2	25.4	26.0	26.5	24.2	24.7	25.3	22.0	21.6
2021	25.1	29.0	26.0	28.1	23.9	26.1	18.8	20.1	14.3

respectively, which is significantly higher than the average annual temperatures. A significant increase in the sum of effective temperatures was already noted in June and July. The "average 10-day air temperature" indicator is highly informative, the values of which during said periods were higher than the long-term average of 21.6°C—in 2020 and 2021, the values reached 24.7°C and 26.1°C, respectively. In the initial period of ripening (the first 10 days of August), the maximum average 10-day temperature of 28.1°C was in 2021. The values of the trait were significantly higher than the average long-term temperatures in all days of August. Thus, the weather and climatic conditions for growing rice cultivars, as long-term averages in 2020 and 2021, were different. The accumulation of the sum of effective temperatures in June 2020 was higher than in 2021.

Place of study

The grain harvest of short- and medium-grain rice cultivars was grown in 2020 and 2021 at the Experimental Production Plot of the Federal Scientific Rice Centre, Russia. The experimental plot soil preparation comprised of degraded forest-like and alluvial rocks, predominantly of heavy granulometric composition, rice, and meadow-chernozem, with the most fertile and fairly rich humus horizon, very much like the chernozems in terms of richness. The thickness of the humus horizon ranges from 100 to 130 cm, reaching up to an additional 80 cm, having a humus content in the upper horizon of 3%–4% and gross humus reserves in the A + B horizon from 300 to 450 up to 600 t ha^{-1}. The content of physical clay in the predominant clay cultivars in horizon A was 63%–73%, silt (35%–44%), and dust (45%–58%). In the upper horizon, the gross nitrogen and phosphorus content were 0.14%–0.26% and 0.13%–0.20%, respectively. The capacity of the soil absorbing complex ranged from 25–30 to 35–45 meq 100 g^{-1}, 70%–80% saturated with calcium, less magnesium, and 0.4%–-3.0% sodium. The available mobile elements of mineral nutrition were quite high; in horizon A the pH was 6.6–7.9. The arable horizon of the experimental plot of the Federal Scientific Rice Centre, Russia is characterized by the pH of 7.5, the content of total humus (4.2), easily hydrolyzable nitrogen (7.3 mg 100 g^{-1}), total at 0.22%, mobile phosphorus (2.9 mg 100 g^{-1}), total at 0.25%, and exchangeable potassium (37.4 mg 100 g^{-1}), and total at 1.2% (Kumeiko and Tumanyan, 2019).

Plant material

The research material comprised six rice cultivars, i.e., short- (Rapan, Khazar, Romans) and medium-grain (Favorit, Trio, Prestige) cultivars. The grain yield was obtained in 2020 and 2021 at the experimental plot of FSBSI - Federal Scientific Rice Centre, Russia. From the grain of each cultivar, samples with damaged grains content were formed, i.e., 0%, 3%, 5%, 10%, and 20%. The rice cultivars Khazar, Prestige, and Favorit in 2020, and Prestige and Khazar in 2021 were grown in the ecological cultivar testing of the Federal Scientific Rice

Centre, Russia. For each model sample of all the rice cultivars, indicators of quality traits viz., the grain size, filminess, vitreosity, and head rice content were studied.

Research methodology

The studies were carried out based on the rice quality laboratory using the following methods. The grain was husked on the peeling and grinding plants of Satake (Japan). The mass of 1000 absolutely dry grains was determined using an air-thermal installation ASES 8-2 (Russia) according to GOST 10843-73, filminess (GOST 10843-73), vitreosity using a DSZ-3 Diaphanoscope (Russia) (GOST 10986-76), and head rice content according to GOST ISO 6646-2013. The intensity of damage was assessed by calculating the relative content of rice grains with dark spots on the pericarp and expressed as a percentage according to STO 46429990-025-2016 'High quality milled rice.'

Statistical analysis

The mathematical data compilation and analysis used the Microsoft Excel program.

RESULTS AND DISCUSSION

The task of assessing the impact of the degree of grain damage caused by dark spots was completed through the formation of samples with their different content, and adding 20% content of damaged grains to the studied samples. The evaluation of selected rice cultivar samples with the grain damage revealed a weak degree of damage. The dark spots were also observed at the different locations on the caryopsis, i.e., in the center, near the embryo, on top of the caryopsis, and also on the side in the dorsoventral direction, with different spot sizes (Figure 1).

The weight of 1000 absolutely dry grains (1000 a.d.g.) helped estimate the rice grain size. As a result of evaluating rice cultivars by technological quality traits within groups that differ in the degree of grain damage, it was found that in short-grain cultivars, the 1000-a.d.g. weight of cultivar Rapan varied from 21.7 to 22.3 g in 2020 (Table 2). In the variants of the experiment without damage (0%) and with a minimum degree of damage (1% and 5%), the values of the trait changed within the error. With an increase in the degree of grain damage to 10% and 20%, the mass of 1000 a.d.g. decreased compared with the variant without damage by 0.3% and 0.6%, respectively. In 2021, in the variants of the experiment without and with minimal damage to the grain, the values of the trait did not differ significantly, but with an increase in the degree of damage to 10% and 20%, the weight of 1000 a.d.g. decreased compared with the variant without damage by 0.4% and 0.6%, respectively.

The rice cultivar Khazar had a mass value of 1000 a.d.g. varying that range from 21.4 to 22.2 g in 2020. With an increase in the degree of damage, the mass of 1000 a.d.g. decreased by 0.5% and 0.8%, respectively, at the 10% and 20% damage. In 2021, the values of the trait with a small degree of damage did not differ significantly, but with 10% and 20% damage, the values decreased compared with the variant without damage by 0.4% and 0.6%, respectively. The mass of 1000 a.d.g. in the cultivar Romans varied from 25.9 to 26.5 g in 2020. In the variant without and with a minimum degree of damage, the values changed within the error. In 2021, the mass of 1000 a.d.g. weight decreased by 0.3% and 0.6%, with the 10% and 20% damage, respectively.

Figure 1. Different location of the spots and degree of damage to the rice grains.

Table 2. Mass of 1000 a.d. grains and grain filminess of short-grain rice cultivars due to various damaged grain content in the samples in 2020 and 2021.

Cultivar	Year	Degree of grain damage, %	Mass (m) of 1000 a. d. grains, g	Filminess (fl), %	LSD_{05} m/fl
Rapan	2020	0	22.3	20.2	0.18/0.20
		1	22.3	20.2	
		5	22.2	20.3	
		10	22.0	20.4	
		20	21.7	20.5	
	2021	0	25.8	19.0	0.20/0.19
		1	25.8	19.1	
		5	25.7	19.3	
		10	25.4	19.2	
		20	25.2	19.4	
Khazar	2020	0	22.2	18.8	0.21/0.22
		1	22.3	18.7	
		5	22.2	18.9	
		10	21.7	19.0	
		20	21.4	18.9	
	2021	0	24.2	18.7	0.15/0.21
		1	24.2	18.7	
		5	24.1	18.8	
		10	23.8	18.9	
		20	23.6	18.9	
Romans	2020	0	26.5	17.6	0.30/0.22
		1	26.6	17.5	
		5	26.5	17.6	
		10	26.2	17.8	
		20	25.9	17.7	
	2021	0	27.3	17.3	0.25/0.20
		1	27.4	17.3	
		5	27.3	17.5	
		10	27.0	17.6	
		20	26.8	17.7	

Grain filminess varied from 20.2% to 20.5% for cultivar Rapan, 18.7% to 19.0% for Khazar , and 17.5% to 17.8% for Romans () in 2020. However in 2021, for cultivar Rapan, it ranged from 19.0% to 19.4%, for Khazar - 18.7% to 18.9%, and for Romans - 17.3% to 17.7%. The values of the trait in the variants without (0%) and with minimal (1.5%) damage did not differ significantly in cultivars during the years of research. With an increase in the degree of damage to 10% and 20%, the filminess increased, respectively, by 0.2% and 0.3% in 2020, and 0.2% and 0.4% in 2021 in the cultivar Rapan; by 0.2% and 0.1% in 2020 and 0.2 and 0.2% in 2021 in cultivar Khazar, and by 0.2% and 0.1% in 2020 and 0.3% and 0.4% in 2021 in cultivar Romans.

In the group of medium-grain cultivars, the mass of 1000 a.d.g. varied in 2020, ranging from 29.3 to 30.1 g for cultivar Favorit, 26.6 to 27.1 g for Trio, and 27.5 to 28.2 g for cultivar Prestige, while in 2021, ranging from 31.0 to 31.6 g for Favorit, 27.7 to 28.4 g for Trio, and 28.7 to 29.4 g for Prestige (Table 3). The values of the trait did not differ significantly in the variants without (0%) and with minimal (1.5%) grain damage during the years of research. With an increase in the degree of grain damage to 10% and 20%, the mass of 1000 a.d.g. decreased, compared with the variant without damage, and in 2020 by 0.5 and 0.8 g for cultivar Rapan, by 0.4 and 0.5 g for Trio, and by 0.4 and 0.8 g for Prestige, while in 2021, by 0.4 and 0.6 g for cultivar Rapan, by 0.5 and 0.7 g for Trio, and by 0.4 and 0.7 g for Prestige, respectively.

The filminess did not differ significantly in the variants without (0%) and with a minimum (1.5%) degree of damage to the rice grains. With an increase in the degree of grain damage to 10% and 20%, the values of the trait increased by 0.2% and 0.3%, respectively, in the cultivar Favorit, 0.3% and 0.2% in the cultivar Trio, and 0.4% and 0.5% in the cultivar Prestige in 2020, while by 0.1% and 0.2% for Favorit, 0.3% and 0.3% for Trio,

Table 3. Mass of 1000 a.d. grains and grain filminess of medium-grain rice cultivars due to different damaged grain content in the samples in 2020 and 2021.

Cultivar	Year	Degree of grain damage, %	Mass (m) of 1000 a. d. grains, g	Filminess (fl), %	LSD_{05} m/fl
Favorit	2020	0	30.1	17.8	0.23/0.21
		1	30.0	17.9	
		5	29.9	17.9	
		10	29.6	18.0	
		20	29.3	18.1	
	2021	0	31.6	18.8	0.20/0.22
		1	31.6	18.7	
		5	31.5	18.9	
		10	31.2	18.9	
		20	31.0	19.0	
Trio	2020	0	27.1	18.6	0.21/0.20
		1	27.1	18.6	
		5	27.0	18.8	
		10	26.7	18.9	
		20	26.6	18.8	
	2021	0	28.4	18.6	0.23/0.20
		1	28.3	18.7	
		5	28.2	18.7	
		10	27.9	18.9	
		20	27.7	18.9	
Prestige	2020	0	28.2	17.4	0.25/0.21
		1	28.2	17.5	
		5	28.1	17.6	
		10	27.8	17.8	
		20	27.5	17.9	
	2021	0	29.4	17.0	0.23/0.20
		1	29.5	17.0	
		5	29.3	17.1	
		10	29.0	17.3	
		20	28.7	17.2	

and 0.3% and 0.2% for Prestige in 2021, respectively. The increase in the rice grain filminess was probably associated with a decrease in its size.

Grain vitreosity, which determines the presence of mealy spots, in the group of short-grain rice cultivars, these varied from 89% to 96% for the cultivar Rapan, from 53% to 56% for Khazar, and from 76% to 80% for Romans in 2020, while in 2021, these ranged from 90% to 96% for Rapan, from 48% to 53% for Khazar, and from 83% to 88% for Romans (Table 4). In the experimental variants without (0%) and with minimal (1.5%) damage, the values of the trait changed within the error. With an increase in the degree of grain damage to 10% and 20%, the vitreosity decreased by 4% and 7% for the cultivar Rapan, 2% and 3% for Khazar, and 2% and 4% for Romans in 2020, while in 2021 by 3% and 6% for cultivar Rapan, and 3% and 5% for cultivars Khazar and Romans, compared with the variant without grain damage.

In the group of medium-grain cultivars, vitreosity varied ranging from 60% to 64% for the cultivar Favorit, 82% to 90% for Trio, and 81% to 87% for Prestige in 2020, while in 2021 these ranged from 61% to 66% for Favorit, from 87% to 93% for Trio, and 82% to 90% for Prestige (Table 5). In the variants of the experiment without (0%) and with minimal (1.5%) damage, the values of the trait did not change significantly. With an increase in the degree of grain damage to 10% and 20%, the vitreosity decreased by 3% and 4%, respectively, for the cultivar Favorit, 4% and 8% for Trio, and 3% and 6% for Prestige in 2020, while in 2021, these ranged by 3% and 5% for Favorit, 3% and 6% for Trio, and 4% and 8% for cultivar Prestige.

The indicators of the head rice content, which determine the quality of the rice product, were assessed and recorded as high in all the variants of the experiment for all cultivars. In the group of short-grain rice cultivars, the trait values varied from 85.3% to

Table 4. Vitreosity and head rice content in short-grain rice cultivars due to different content of damaged grain in the samples in 2020 and 2021.

Cultivar	Year	Degree of grain damage, %	Vitreosity (vt.), %	Head rice content (hrc), %	LSD_{05} vt./hrc
Rapan	2020	0	96	90.1	1.4/0.61
		1	95	90.0	
		5	94	88.6	
		10	92	87.1	
		20	89	85.3	
	2021	0	96	95.6	1.7/0.24
		1	96	95.4	
		5	95	93.7	
		10	93	93.9	
		20	90	92.6	
Khazar	2020	0	56	93.4	1.5/0.68
		1	56	93.3	
		5	55	91.5	
		10	54	90.1	
		20	53	88.7	
	2021	0	53	99.2	1.8/0.53
		1	52	98.7	
		5	52	97.4	
		10	50	95.6	
		20	48	94.2	
Romans	2020	0	80	97.5	1.9/0.91
		1	80	97.5	
		5	79	96.2	
		10	78	94.3	
		20	76	93.3	
	2021	0	88	98.7	1.7/0.61
		1	87	98.7	
		5	87	97.3	
		10	85	95.6	
		20	83	94.7	

90.1% for the cultivar Rapan, 88.7% to 93.4% for Khazar, and 93.3% to 97.5% for Romans in 2020, while 90.6% to 95.6% for Rapan, 94.2% to 99.2% for Khazar, and 94.7% to 98.7% for cultivar Romans in 2021. In the variants of the experiment without (0%) and with minimal (1%) damage to the grain, the values of the trait changed within the error. With an increase in the degree of grain damage to 5%, 10%, and 20%, the head rice content decreased, compared with the variant without damage, by 1.5%, 3.0%, and 4.8% for cultivar Rapan, by 1.6%, 3.3%, and 4.7% for Khazar, and by 1.3%, 3.2%, and 4.2% for Romans in 2020, while in 2021, 1.9%, 1.7%, and 3.0% in Rapan, 1.8%, 3.6%, and 5.0% in Khazar, and 1.4%, 3.1%, and 4.0% in rice cultivar Romans, respectively.

In the group of medium-grain cultivars, the content of the whole kernel in rice groats varied from 87.6% to 92.6% for the cultivar Favorit, 90.3% to 95.0% for Trio cultivar, and 71.2% to 76.3% for cultivar Prestige in 2020, while 88.2% to 94.9% for Favorit, 86.4% to 91.4% for Trio, and 70.4% to 75.4% for the cultivar Prestige in 2021. The values of the trait did not differ significantly in the variants of the experiment without (0%) and with minimal (1%) damage to the grain. The content of the whole kernel decreased as the degree of grain damage increased to 5%, 10%, and 20%; by 1.9%, 3.4%, and 5.0% in the cultivar Favorit, by 1.9%, 3.6%, and 4.7% in Trio, and by 1.9%, 3.6%, and 5.1% for the Prestige in 2020, while in 2021 by 2.0%, 5.1%, and 6.7% for Favorit, by 1.8%, 3.6%, and 5.0% for Trio, and by 1.9%, 3.6%, and 5.0% for cultivar Prestige, respectively.

The data obtained on the effect of grain damage in the form of dark spots on the quality of rice products are consistent with the past findings (Krinski and Foerster, 2017a, b, c). The degree of grain damage of *O. poecilus* and *O. ypsilongriseus* differed in unique varieties (Ferreira *et al*., 2002). Past research has also reported a decrease in the quality of rice grains with damage from *O. pugnax* at the Mississippi State University, USA (Awuni *et al*.,

Table 5. Vitreosity and head rice content in medium-grain rice cultivars due to different content of damaged grain in the samples in 2020 and 2021.

Cultivar	Year	Degree of grain damage, %	Vitreosity (vt.), %	Head rice content (hrc), %	LSD_{05} vt./hrc
Favorit	2020	0	64	92.6	1.6/0.97
		1	63	91.7	
		5	63	90.7	
		10	61	89.2	
		20	60	87.6	
	2021	0	66	94.9	1.8/0.90
		1	66	94.0	
		5	65	92.9	
		10	63	89.8	
		20	61	88.2	
Trio	2020	0	90	95.0	1.0/0.48
		1	89	94.6	
		5	89	93.1	
		10	86	91.4	
		20	82	90.3	
	2021	0	93	91.4	1.3/0.82
		1	93	91.2	
		5	92	89.6	
		10	90	87.8	
		20	87	86.4	
Prestige	2020	0	87	76.3	1.5/0.72
		1	86	75.7	
		5	86	74.4	
		10	84	72.7	
		20	81	71.2	
	2021	0	90	75.4	1.8/0.69
		1	90	74.8	
		5	89	73.5	
		10	86	71.8	
		20	82	70.4	

2015). The conducted studies, however, did not allow the identification of differences like the influence of the degree of grain damage in cultivars of different grain shapes (short-grain and medium-grain) and the yield obtained in 2020 and 2021 on grain quality. The trend of a significant decrease in grain quality with an increase in the content of damaged grains up to 5%–20% continued for the yields of 2020 and 2021. In connection with the foregoing, to ensure the profitability of rice production when growing various cultivars, the need to predict the yield quality by the intensity of grain damage caused by dark spots should be given more focus in future studies.

CONCLUSIONS

With an increase in the content of damaged grains from 5% to 10% and 20%, the mass of 1000 a.d. grains, the vitreosity, and the head rice content decreased, while the filminess increased, which showed that the content of damaged grains significantly affects the quality characteristics of rice grains negatively. For adding 5% of damaged grains, the tendency to reduce the grain quality or the absence of the influence of the parameter occurs.

ACKNOWLEDGMENTS

The present research was carried out with the support of the Russian Scientific Foundation and Kuban Scientific Foundation: Project No. 22-26-20098 "Influence of "black spot" on the yield quality of rice cultivars admitted for use on the territory of Krasnodar region, Russia under the grain damage conditions in the field.

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