Assesment of rice yield quality in Kuban in connection with grain damage in the form of dark spots

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Abstract. The problem of rice damage by "black spotting" in the field during maturation is acute in all rice-growing countries. In the work, it was necessary to study the spread of shield bugs on rice crops in the Krasnodar region, the intensity of damage to rice crops in various areas according to the method of assessing damage to the rice crop, differentiation of varieties by tolerance to damage. Surveys of rice crops were carried out during various periods of the growing season in order to identify insect pests with piercing-sucking mouthparts in the Krasnoarmeysky, Abinsky, Slavyansky, Kalininsky districts of Krasnodar region and Prikubansky district of Krasnodar in 2020-2023 and a comparative assessment of the intensity of damage to rice grains in the form of dark spots by region is given. The highest intensity of grain damage was noted in Krasnoarmeysky district. Preliminary results on the tolerance of varieties to grain damage by stink bugs during the rice growing season were obtained and preliminary differentiation of varieties was carried out. The most tolerant varieties were Abinsky, Vector, and Strombus, and therefore these varieties are recommended to be grown in areas with the most intense damage to crops by stink bugs. Methodological methods have been developed for studying the “black spotting” of rice, which consist of selecting samples of rice varieties in industrial crops in areas of its cultivation, characterizing the content of damaged grains and assessing the influence of the intensity of damage on the physical properties of the yield. **Key words:** rice, pekty rice, grain quality, methodology of grain quality research.

1 Introduction

Damage to grain by pests and pathogenic microorganisms leads to a decrease in quality and limits the formation of stable rice yields. In the Krasnodar region, damage to the pericarp of grain by "black spotting" during maturation has been noted over the past twenty years. Thus, the nutritional properties of the rice grain are reduced.

Spots on grain appear as a result of insects pricking the grain and the development of pathogenic microflora at the site of damage.

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In rice-growing countries, various representatives of stink bugs have been identified as pests: Oebalus pugnax F., Oebalus poecilus, Oebalus insularis, Hypatropis inermis, Eysarcoris ventralis, etc. [2]. Oebalus poecilus [2] is widespread in Brazil; Leptocorisa chinensis and Nezara viridula are widespread in Japan [3]. The rice bug O. pugnax (Hemiptera: Pentatomidae) is a major pest of rice in the southern United States of America. Depending on the infestation of stink bugs, different intensity of damage to varieties in crops was shown. The variety Cheniere was more damaged than Kaybonnet in crops by O. Pugnax, and the number of larvae surviving to adulthood did not differ between rice varieties[4]. In the Sochi district, Abkhazia and Georgia, a massive proliferation of stink bugs was noted in 2015 [5, 6].

One of the possible pests of rice crops is the brown marmorated stink bug. The marble bug is a pest of annual and perennial crops. In 2017, in Northern Italy, for the first time, damage to rice grains in panicles by a marble bug was noted [7]. Reports on the appearance of the shield bug Hypatropis inermis on crops of high-altitude rice (Cambará variety) in Novo Progresso, state of Pará, in Brazil (7 °07′45,71 °w.55°23′21,13″z.d.) were made for the first time in 2010-2011. [8]. Activity of Oebalus poecilus in Rio Grande do Sul in Brazil is limited to the period from November to March and four generations can develop in each rice growing season, at which point the population can reach economically harmful levels. Rice planted late, however, escapes attack as diapause occurs in early March. The results suggest that delaying and limiting the timing of rice planting can be an effective pest management tactic as it results in asynchrony between the pest and the crop.

The White-spotted shield bug, Eysarcoris ventralis (Westwood) (Pentatomidae), is considered one of the main pests damaging rice worldwide. It was first recorded in Iran on weeds, grapes, alfalfa and wheat. In 2017, 2018, in Gilan province (Northern Iran), when examining rice crops for the presence of pests, a large number of adult individuals were found on rice panicles feeding on grains. The appearance of spots and empty grains was noted as a result of punctures of rice grains by adults and nymphs [9].

In the southern regions of Russia, in the crops of vegetable, fruit, berry crops, soybeans, a sharp increase in the number of harmful beetles Nezara viridula (L.) (vegetable beetle shield) was noted at the beginning of the two thousandth years. In the second half of the 20th century, the beetle, one of the first among the pentatomids, began to spread from north Africa and as it progressed, the harmfulness on crops increased [10]. The increase in the number of pentatomid shield beetles and the expansion of their distribution range are associated with the distinctive features of their vital activity and global climate warming. Adaptive features include the absence of natural enemies in the territory of settlement, polyphagy, high ability to migrate in the imago stage and adaptation to environmental conditions. Climate change may lead to increased fertility of stink bugs and an increase in the number of generations per season. Possible introduction as a result of intensified movement of goods and people is also important [10].

Damage to rice crops by stink bugs leads to the appearance of dark spots, a decrease in grain weight, germination, an increase in shrinked grains, empty grains, chalkiness, and grain fragmentation. If the grain is damaged during the milky ripeness stage, the number of empty grains in the panicle can increase up to 83% and even more during the milky phase [11, 12]. When damaged, grains become infected with various pathogens, including fungi. In damage by O. Poecilus and O. Ypsilongriseus, differences were shown among varieties [13]. In an experiment in Stoneville, MS, in 2010 and 2011, it was shown that when rice was damaged by the rice stink bug, Oebalus pugnax (F.) during the flowering stage, grain yield decreased, and during the milky ripeness stage, yield quality decreased [11].

The harmfulness of pentamamids as a result of an increase in the number of pests leads to a significant negative impact on agricultural yields, especially significant in the absence of timely protective measures. The main method of controlling O. pugnax is the use of

chemical insecticides. Thus, the use of silicon fertilizers leads to an increase in the development time of the larva and a reduction in the survival rate of both larvae and adults by almost 40%, which reduces the productivity of O. pugnax [4]. Due to the fact that the number of shield bugs in natural ecosystems is high and there is a tendency to a rapid increase not only in numbers, but also in harmfulness, practical measures to protect crops, including rice, include measures for effective pest control of shield bugs.

In the work, it was necessary to study the spread of shield bugs on rice crops in the Krasnodar region, the intensity of damage to rice crops in various areas according to the method of assessing damage to the rice crop, differentiation of varieties by tolerance to damage.

2 Research Method

For the research, the varieties of the FNC selection of rice grown in farms of various districts of the Krasnodar Territory (Krasnoarmeysky district, Abinsky, Seversky, Slavyansky, Kalininsky, Krasnoarmeysky districts of the Krasnodar Territory, Prikubansky district of Krasnodar) in 2020-2023 were taken. The seeds were provided by the UNU collection (A unique scientific installation) "Collection of genetic resources of rice, vegetables and melons". Grain samples were taken during the full ripeness phase.

The effect of nitrogen nutrition on grain damage in the form of dark spots was studied on rice crops in the Abinsk region. The soils of the site in the Abinsky district (valley agricultural landscape) are represented by a complex of meadow-chernozem medium–sized heavy loamy soils; the thickness of the humus horizon is 75 cm, the humus content is 5.1%, the reaction of the soil solution in the arable horizon is neutral - pH 6.8-7.2. The content of gross nitrogen is 0.22-0.26%, total phosphorus is 0.18-0.20%. The content of easily hydrolyzable nitrogen is 8.7-10.3 mg/100 g; mobile phosphorus is 9.3-12.2 mg/100 g. Mineral fertilizers were added to the top dressing in the amount of: 1 variant of the experiment - $N_{60}P_{90}K_{60}$, 2 variant of the experiment $N_{120}P_{90}K_{60}$. Technological signs of quality : the mass of 1000 absolutely dry grains (weight 1000 a. s. z.) or the grain size was determined according to GOST 10842-89, fracturing was determined on a DSZ-3 diaphanoscope.

In August, 2020-2023, on agricultural crops with Rapan rice variety at the Federal Rice Research Center on an area of 8 hectares and in rice farms of the Krasnoarmeysky district on an area of 44 hectares on Rapan, Khazar, Utes, Prestige, Romance, Voskhod, Pole 5, Rubicon, Dialog, Frigate, Favorit, Trio, Zlata, Acoustic Pirouette. The method of accounting for the number of relatively large, well-marked insects on cereals with dense herbage was used twice, starting from the phase of milk ripeness. The insect population was accounted for by "mowing" with a standard entomological net with a hoop with a diameter of 30 cm, a wooden handle with a length of 1.2 m, and a net bag with a length of 70 cm. The mathematical processing of the data was carried out by methods of descriptive statistics and correlation and regression analysis.

3 Results and Discussion

Research on the problem of pekty rice was started in 2013 at the Rice Research Center (Krasnodar). In 2012 and 2013, shipments of grain with black spot damage of up to 20-30% were noted in the Kuban, which led to a sharp decrease in the profitability of rice production. In the future, the intensity of grain damage decreased and was on average within the range of 0-1.5%.

The number of stink bugs was acconted in August 2020–2023 on rice crops of Federal Scientific Rice Centre (Krasnodar), on farms in Abinsky, Seversky, Kalininsky, Slavyansky, Krasnoarmeysky districts (Table 1). Individuals of the green or green vegetable bug (Nezara viridula Linnaeus, 1758), the brown marmorated bug (Halyomorpha halys Stål, 1855), and the berry bug (Dolycoris baccarum Linnaeus, 1758) were taken into account.

Table 1. Population density of stink bugs in rice crops, ind./m^2

District	2020	2021	2022	2023	Mean value for 2020-2023
Krasnodar	0,03	0,04	0,06	0,01	0,04
Seversky	0,00	0,01	0,01	0,02	0,01
Kalininsky	0,00	0,03	0,03	0,02	0,02
Abinsky	0,03	0,05	0,04	0,05	0,04
Slavyansky	0,07	0,08	0,08	0,06	0,07
Krasnoarmeysky	0,23	0,30	0,40	0,15	0,27

The population density of stink bugs in rice crops was assessed as insignificant (from 0.01 to 0.30 ind./m^2). When calculating the average population density of rice crops, a tendency was noted for higher rates of damage to rice grains in the Slavyansky and Krasnoarmeysky districts: in Krasnoarmeysky district there are 0.23, 0.25, 0.26 and 0.23 ind./m^2 more than in the Abinsky, Kalininsky, Seversky districts and Krasnodar.

Rice grain grown in the Krasnodar was characterized by relatively low damage, up to 0.5%, in 2020–2023. In 2020–2022 in contrast to Federal Scientific Rice Centre in 2020 and 2022 in rice crops in the Krasnoarmeysky region, rice damage could reach 2.0...6.5% and 5.3% in 2023 (varieties Olimp, Favorit, Veles). In Seversky district too. A slight intensity of damage was noted in 2020 - up to 0.8% of damaged grains in samples of harvested grain in Seversky and Abinsky districts. In 2022, in Slavyansky and Kalininsky districts, the content of damaged grains did not exceed 1.8% until 2022, however, in 2023, it was at the level of the Seversky and Abinsky districts, but lower than in the Krasnoarmeysky (6.5%). Based on this criterion, districts can be distributed taking into account the years 2020-2023 in order of increasing in the following series: Krasnodar, Seversky, Kalininsky, Abinsky, Slavyansky, and Krasnoarmeysky (Table 2).

Table 2. Content of damaged grains in rice crops, grown in districts of Krasnodar region, %

District	2020	2021	2022	2023	Mean value for 2020-2023
Krasnodar	0,1-0,3	0,1-0,5	0,1-0,5	0,1-0,2	0,24
Seversky	0,1-0,2	0,1-0,5	0,1-0,6	0,1-1,6	0,41
Kalininsky	0,2-1,5	0,3-1,7	0,0-1,3	0,1-1,5	0,83
Abinsky	0,3-0,8	0,2-2,0	0,1-1,5	0,5-2,0	0,93
Slavyansky	0,2-1,5	0,5-1,7	0,5-1,8	0,3-2,5	1,13
Krasnoarmeysky	0,5-2,0	0,6-1,2	1,0-6,5	0,5-5,3	2,2

Grain damage by "black spotting" for varietal rice crops was studied in connection with the wide assortment of varieties sown in the Kuban (Table 3). In 2022, the varieties Olympus, Courage, Rapan, Apollo were more damaged, in 2023 - Rapan, Olympus.

Table 3. Intensity of Damage to rice varieties in 2020-2023

Year	2020	2021	2022	2023
Limits of grain damage	2,0 %	2,0…3,0 %	2,0…6,5 %	2,0-8,0
Variety	Rapan, Favorit	Olimp, Kurazh, Apollon, Rapan, Utes, Fregat, Rubikon	Olimp, Kurazh, Rapan, Apollon, Favorit, Sonet	Rapan, Olimp

The assumption of tolerance of rice varieties to damage in the form of dark spots in the field was first put forward by Ferreira E. (Brazil, 2002). The presence of a weak connection between the rice genotype and the intensity of grain damage is confirmed by the analysis of the results obtained in 2020-2023. Based on these data, rice varieties were grouped according to the intensity of grain damage by "black spotting" (Table 4).

Table 4. Groups of rice varieties by the intensity of damage to crops (2020-2023)

1 group	2 group	3 group
Abinsky	Orfey	Olimp
Vector	Absolut	Kurazh
Strombus	Utes	Apollon
	Fregat	Rapan
	Rubikon	Sonet
	Rodos	
	Trio	
	Classic	

Absolutely resistant rice varieties to damage by "black spotting" were not found. The lowest damage rates were in 2020-2023 or separately in each year for the rice varieties Abinsky, Vector, Strombus. Every year, on rice farms, increased damage rates were noted for the varieties Olimpus, Kurazh, Apollon, Rapan, and Sonet. The nature of the varying intensity of damage to rice grains by "black spotting" is still unknown. It should be borne in mind that the results were obtained against the background of low damage rates in 2020-2023 they may change with a sharp increase in the intensity of grain damage under the prevailing conditions of the growing season. The authors consider it possible that some morphological grain traits typical for the variety may influence the degree and intensity of damage to the grain in the field as a result of a sting by stink bugs. Research in this area is relevant due to the possible identification of a breeding significant trait that determines the quality of rice yield.

The effect of nitrogen nutrition on grain damage in the form of dark spots was studied under growing conditions at 60 and 120 kg of active nitrogen substances per hectare (Table 5).

Table 5. Impact of nitrogen fertilizers on grain damage in the form of dark spots in field conditions

Variety	Content of damaged grains, %							
	2020		2021		2022		2023	
	60 kg a.i./ha	120 kg a.i./ha	60 kg a.i./ha	120 kg a.i./ha	60 kg a.i./ha	120 kg a.i./ha	60 kg a.i./ha	120 kg a.i./ha
Rapan	0,0	0,0	0,0	1,0	2,2	2,0	2,3	1,5
Olimp	0,8	0,0	0,0	1,0	2,2	2,5	2,5	1,4
Orfey	-	-	-	-	1,5	0,8	1,9	1,6
Forsage	-	-	-	-	1,5	1,7	2,0	2,0
Regul 2	-	-	-	-	0,5	0,5	0,8	0,8
LSD_{05}	-	-	-	-	0,10	0,11	0,12	0,12

The ambiguous influence of mineral fertilizers on the variability of the trait “grain damage in the form of dark spots” is shown. Based on the results obtained, the calculated values of the Student's t-test for unrelated populations (≤ 1.1) were lower than the critical values of the Student's t-test (2.306), at a significance level of $\alpha = 0.05$, the differences between the options with doses of nitrogen fertilizers are insignificant.

Thus, in a field experiment, when establishing a possible connection between the development of the disease and the doses of nitrogen fertilizers (urea), it was revealed that there was no connection between the studied factors and the susceptibility of rice grains to the pathogen. At the same time, the distribution of affected grains among experimental options was random.

The problem of damage to rice grains by "black spotting" in rice-growing countries is of an urgent nature. In the rice-growing region of Russia (Krasnodar Territory), a sharp increase in grain damage in the form of dark spots is periodic. In 2012 and 2013, high intensity of rice damage was observed in all districts. Subsequently, the intensity of grain damage was at a low level, although in some areas, for a number of varieties, the intensity of grain damage by "black spotting" reached 8%. In this regard, it was considered necessary to equip rice farming with a modern tool for assessing the harmfulness of “black spotting” in rice in order to predict its spread, take measures to level the phenomenon and create conditions to ensure the quality of the rice grain.

As a result of the work carried out to identify “black spotting”, approaches to the methodology for assessing the intensity of damage to rice crops were formulated.

In winter, green stink bugs or green vegetable bugs, brown marmorated stink bugs, berry stink bugs and others are found in dry litter. Stink bugs are active throughout the warm period of the year; the first individuals can be recorded as early as April and May; they go into hibernation when the temperature drops - in September and October. Stink bugs reproduce in spring and summer, from May to July, when the air temperature rises to at least +18 °C. From the eggs, after 7-25 days, depending on the type and air temperature, larvae appear, similar to adults, without wings.

After molting five times, they reach adulthood in about a month and a half. Already from the beginning of the growing season, bugs have been infesting wheat, barley, garden and vegetable crops. After harvesting, stink bugs move to rice crops. It is proposed to monitor the early crops for bug infestation before sowing rice (April, May, June) in order to predict the intensity of the manifestation of “black spotting” on rice crops. At the same time, starting from the phase of milk ripeness, use the method of accounting for the number of relatively large, well-visible insects on cereals with dense herbage twice. The count of the number of insects is carried out by “mowing” with a standard entomological net with a wooden handle according to the recommendation of Sobolev A.S., 1961. On rice crops - at the end of July (July 25-31) and in August, during the initial period of grain filling, from the beginning of flowering and until 20-25 days from the beginning of flowering. Depending on the sowing period and variety, it is recommended to carry out surveys at least 2 times during August. It is necessary to note the relationship between phenological stages and categories of insects: during the rice cycle, the spread of “adults” of bugs (mid-vegetative phase of rice); “nymphs” - as a rule, more common from the end of the growing season; “adults + nymphs” from the beginning of flowering, since they were most concentrated near the edge of the crop. The spatiotemporal dynamics of surveys includes the study of bugs according to the phases of rice development on crops, which are included in monitoring in accordance with the capabilities of the farm.

It is recommended to use Rosselkhoznadzor data when monitoring and forecasting the spread of stink bugs. For example, in 2023, Rosselkhoznadzor provided information on the flight of the bug (*Eurygaster integriceps*) from wintering grounds on April 22-23, the subsequent flight to wheat crops, the hatching of the first larvae in the second ten days of

May and their density on the crops. *Eurygaster integriceps* is a potential pest of rice crops according to the results of a study by foreign researchers. After harvesting wheat, the pest can migrate to rice crops.

In terms of assessing damage to rice in the field, it is recommended to carry out grain sampling on the 10th (milk ripeness) and 30th (waxy ripeness) day of ripening. The assessment of the content of damaged grains is carried out according to the method developed at Federal Scientific Rice Centre based on the percentage of damaged grains in the grain mass. The results of more than 1% damaged grains on the 10th day of ripening suggest a high intensity of grain damage at the time of harvest.

It is recommended to assess the impact of rice damage in the form of dark spots based on technological grain quality traits: size, vitreosity, grain fracturing, grain yield (Table 6).

Table 6. Technological quality traits of rice varieties grown in Abinsky district in 2022

Variety	Mass of 1000 absolutely dry grains, g	Vitreousity, %	Fracturing, %	Total milling yield, %	Head rice content, %	Content of damaged grains, %
Rapan 2	23,0	85	13	66,7	94,9	2,0
Favorit	27,3	78	12	65,8	86,6	3,0
VNIIR 6910	31,3	77	13	65,0	90,2	2,0
VNIIR 7042	28,5	85	5	67,0	93,7	3,0
VNIIR 7070	29,8	77	3	66,0	95,0	2,0
LSD_{05}	0,11	1,3	1,5	0,51	0,83	-

Increased rates of grain damage in the form of dark spots (2.0-3.0%) may lead to a decrease in vitreousity and milling yield during grinding - 12-13% for a number of varieties. Indicators of technological signs of grain quality make it possible to predict the quality of rice products, assess the consumer advantages of cereals in connection with damage, determine the approximate percentage of reduction in profitability of production of grain products based on the intensity of crop damage in the form of "black spotting" of grain.

4 Conclusions

To predict and level out the negative consequences of a decrease in the quality of rice yield in Krasnodar region, it is advisable to regularly monitor the occurrence of “black spot” in rice. Perhaps bedbugs have always been present in the fields of vegetating rice since the early 2000s, but their numbers were regulated by the presence of natural parasites of the bedbugs themselves and the agro-climatic conditions of the region. The characteristics of rice varieties in production are also of great importance for the degree of damage by "black spotting". The study identified groups of varieties that were significantly susceptible to damage under field conditions and relatively tolerant. As a result of a study of the intensity of pekty rice manifestation, it was shown that rice varieties grown in Abinsky, Seversky and Kalininsky districts were characterized by the least damage; damage rates were higher by 1-2% in Slavyansky and Krasnoarmeysky districts.

According to the degree of increasing intensity of damage to rice grains, the districts can be arranged in the following row: Kalininsky, Slavyansky, Krasnodar and Abinsky,

Seversky, Krasnoarmeysky, which may be due to the proximity of traditional food bases for stink bugs, the peculiarities of agricultural technology for cultivating crops, varietal composition, and specific weather conditions.

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