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On the problem of grain damage in the form of dark spots in field conditions when cultivating rice in Krasnodar region

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Abstract. The analysis of grain damage in the form of dark spots of Russian rice varieties grown in Krasnodar region in 2011-2020 has been carried out. Rice grain was damaged during the filling period, mainly in full ripeness. The high degree of damage was the reason for the deterioration of grain quality. The degree of damage varied over the years. 2011 and 2012 were characterized by a high content of damaged grains (up to 3-20%). The degree of damage to rice grain was different in different agar-landscape zones of Krasnodar region: in the Krasnoarmeysky district it was higher than in the Abinsky. On panicles of variety Rapan without stinkbugs, one caryopsis with damage was found, while on panicles with stinkbugs, their number increased to 12.4-20.3%. In variety Kurazh, damage to caryopses in the form of dark spots on panicles with stinkbugs reached 10.1-19.1%. A significant increase in the degree of damage to rice grain stored in storage began in 2011. In 2011, the content of damaged grains increased by more than 1%, in 2012 it reached 8.3% in the Slavyansky district. Since 2013, the degree of damage to rice grain in the field began to decrease. It is concluded that the damage is associated with the pathogenic effect on the plant and the caryopsis of bug insects with a piercing-sucking mouth apparatus. Damage to caryopses was insignificant in 2015-2020.

1 Introduction

The vital activity of insect pests and pathogenic microorganisms is the cause of the appearance of dark spots on the shells of rice grains. In Russia, the problem of dark (black) spots was identified more than 10 years ago. Abroad, in rice-growing countries, it has been known for many decades. In 2012, a state of emergency was declared in the summer in connection with the invasion of locusts, meadow moths and turtle bugs, which earlier became active in some regions of Russia: in the South Urals, in the Volgograd, Rostov, Saratov, Samara, Orenburg and Astrakhan regions, Dagestan, Stavropol Territory and Kalmykia due to weather and climatic conditions. Large volumes of grain from the rice crop grown in Krasnodar region in 2012 were significantly damaged in the field, up to 20-30%, which led to a decrease in the profitability of the industry [1]. Based on the results of studies carried out at the Federal Scientific Rice Centre (Krasnodar), it was concluded that

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it is necessary to monitor the intensity of grain damage in rice farms during rice ripening and predict the appearance of dark spots due to weather conditions [2, 3].

Semi-saprophytic and saprophytic bacteria of the genus Erwinia were isolated from milled rice (FSU "KRC Rosselkhoznadzor", Krasnodar); Molecular research methods have identified clones of the species *Pantoeaananatis* belonging to the genus *Pantoea*. Fungi of the genera *Alternaria* (70%), *Epicoccus* (10%), *Cladosporium* (20%) (All-Russian Research Institute of Agricultural Microbiology, St. Petersburg) were found on rice seeds with dark spots. Also found: *Alternariatenuis, Trichotheciumsp., Fusariummoniliforme, Penicilliumsp., Rhizopussp., Aspergilusflavusorizae, Cladosporiumsp., Phomasp., Drechslerahawaiiensis* (IRRI (International Rice Research Institute), Philippines) [1, 2].

The main species of stink bugs are Oebalus pugnax, Oebalus insularis Stål, Oebalus poecilus (Dallas 1851), and Oebalus ypsilongriseus, found in the United States, Venezuela, Mexico, Brazil, Cuba, and the Caribbean.

The small rice stink bug, Oebalus poecilus (Dallas 1851) (Solubea poecila), of the Pentatomidae family, is the most destructive pest of rice crops that affects rice, barley, oats, corn and wheat, sometimes soybeans, cotton, guava. The bug has a ricey smell. The small rice stink bug Oebalus poecilus is the main pest of rice in Guyana and many other South American countries. In Guyana, the fight against stink bugs consists of spraying rice crops with monocrotophos. Research is underway to find cost effective and safe ways to combat. Attempts have been made to use products derived from the neem tree, which grows in Guyana [4]. The bug is of great economic importance to rice growers in Brazil with irrigated, floodplain and upland farming systems. These pentatomids in the nymph and adult stages feed mainly on developing grains in a rice panicle. Attacks of bugs on crops of high-altitude rice varieties lead to the appearance of seed spots, a decrease in mass, germination, grain deformation, and an increase in the number of chalky and crushed grains. Bugs cause a significantly higher percentage of empty grains (up to 83%) in the milk phase than when they feed on grains during the later phases of panicle development. The same characteristic was observed for grain weight reduction. O. poecilus are also carriers of various fungi [5].

The damage caused in the field by adult bugs Tibraca limbativentris Stål (stinkbug) at different levels of infestation (0, 1, 2 and 4 stink bugs) on three rice plants during three growth stages (V8, V13 and R4 stages) of alpine rice was studied, cultivated in the southwestern state of Pará, Amazon, a rainforest region in Brazil. It was concluded that the density of colonization is critical: 2-4 bugs per 15 stems for the vegetative stage, and 1-2 bugs per 15 stems at the beginning of the reproductive stage (R3 / R4), at which there is a decrease in the yield and quality of rice grain. [6].

The adult stink bug Oebalus pugnax has a coloring from straw to dark brown, elongated body shape, sometimes with a yellow triangle. The rice stink bug is a serious pest of rice crops throughout the rice belt: in the southern United States - Mississippi, Arkansas, Louisiana, Texas. The main pest in the southern United States, a flying insect from the Pentatomidae family, is very mobile and moves en masse through the fields in search of food. Known since 1775. According to the results of a study in Stoneville, Missouri, USA (Stoneville, MS), it was shown that the stage of development of the panicle influenced the harmfulness of the bug Oebalus pugnax (F.). The yield loss was greatest at the bloom stage, while kernel damage was greatest at the milk and soft dough stages [7].

In the rice fields of Florida, Oebalus insularis (Stal) was first seen in 2007. In 2008, 2009, an extensive study was carried out to determine the relative abundance and population biology of O. Insularis (island stinkbug). The stinkbug O. insularis is well known as a rice pest in Central and South America and the Caribbean [8]. A mathematical model was developed for the distribution of Oebalus insularis Stal in rice fields located in the Rio Guárico Irrigation System in Calabozo, Venezuela between 2001 and 2004 [9].

During the development of the Comprehensive Insect Pest Control Program, including Oebalus, it was concluded that chemical spraying should be avoided in order to protect natural populations of parasites and predators. It is necessary to grow host varieties that are resistant to nematodes, diseases and insects using biological control [10].

In 2015, it Was the first reported appearance of the bug Hypatropis inermis (Hemiptera, Pentatomidae) on alpine rice (variety Kambara, Cambará) in Novo Progresso, Pará state, Brazil. Insect pest inventories were carried out from November 2010 to March 2011 using entomological networks and visual search on rice plant stems. Rice crops have been shown to represent feeding and mating sites for this species (Fig 1) [11].

Brazil has developed new plant insecticides as an alternative to chemical protection, such as those derived from various Annonaceae species, which can act as an additional protection tool [12]. For example, the neotropical smelly brown beetle Euschistus heros (F.) (Hemiptera: Pentatomidae), a soybean pest, was first discovered in the state of Mato Grosso in Brazil several years ago. As a result of the research, recommendations were made to use Hexacladia smithii Ashmead (Hymenoptera: Encyrtidae) as an alternative to synthetic insecticides for pest control [13]. A natural extract with the insecticidal properties of their leaves Piper aduncum (Piperaceae) against the stink bug on soybeans has been recommended [14]. The level of parasitism of the eggs of the complex of pests of rice crops of the family Pentatomidae was studied on the variety IDIAP-38 in Panama in the Juan Hombron, Cocle and Chichebre areas. Sampling was carried out between the flowering phase and milk grain in 2012-2016. The level of natural parasitism of Pentatomidae eggs ranged from 8.0 to 85.0%, with the most widespread parasitism being in the stink bug Oebalus insularis (Stal), which in Panama is the main sucking insect of the Pentatomidae complex on rice. The parasites of the eggs of this insect complex in the main rice growing areas in Panama were: Telenomus podisi Ashmead (Hymenoptera: Platygastridae), Trissolcus basalis (Wollaston) and Trissolcus urichi (Crawford) (Hymenoptera: Scelionidae). The average level of parasitism of the parasitoid complex was above 90%, and the most common species was Te. podisi (81.8%) on varieties Conagro-2, Estrella-92, IDIAP-540 [15]. The high frequency of oviposition of the pest Oebalus insularis in Echinochloa colona and Echinochloa crus-pavonis on weeds around rice paddies favored the natural parasitism of Telenomus podisi. Host weeds serve as a natural reservoir of this parasitoid already before rice vegetation, thereby contributing to the sustainability of rice in the agroecosystem (Fig 2) [16]. The results obtained indicated that the so-called rational management of insect pests contributes to the natural parasitism of Pentatomidae species in areas of rice production [17].

Fig. 1. Hypatropis inermis (Hemiptera, Pentatomidae) on alpine rice (variety Kambara, Cambará) in Novo Progresso [11]

Fig. 2. Nymph (a) and an adult (b) Oebalus insularis feeding on echinochloa colon in areas with weeds near rice crops, adjacent to rice crops [16]

2 Materials and methods

The aim of the research was to study the degree of damage to rice grain in the form of dark spots in the field conditions of Krasnodar region in 2010-2020.

The research material were white-grain rice varieties grown at the experimental-production site of the Federal Scientific Rice Centre (EPS, Krasnodar), on the farms of the Abinsky, Slavyansky and Krasnoarmeisky districts, Krasnodar region. At the experimental-production site of Federal Scientific Rice Centre soils are rice, meadow-chernozem, pH of the arable horizon is 7.5, the content of total humus is 4.2, easily hydrolyzable nitrogen is 7.3 mg/100 soil g, total nitrogen is 0.22%; mobile phosphorus 2.9 mg/100 g, total phosphorus 0.25%; exchangeable potassium 37.4 mg / 100 g of soil, total potassium 1.2%. In the Krasnoarmeysky district the soils are rice, meadow-chernozem; the humus content is 2.8-3.7%, the total nitrogen and phosphorus content is 0.20-0.25 and 0.18-0.20%, respectively. The content of easily hydrolyzable nitrogen is 5.2-7.1 mg / 100 g of soil, mobile phosphorus is 2.0-3.3 mg / 100 g, soil pH is 7.0. Sampling was carried out in the phase of complete ripeness of the grain. The rice was husked on a Satake hulling machine and the intensity of damage was determined by the relative content of grains (%) with spots. The soil cover in the Abinsky district is represented by meadow-chernozem medium-thick heavy loamy soils with a humus horizon on average 75 cm thick and a humus content of 5.1% from the reactions of the soil solution in the arable horizon with a pH of 6.8-7.2. Content of gross nitrogen 0.22-0.26%, easily hydrolyzable nitrogen 8.7-10.3 mg / 100 g of soil, total phosphorus 0.18-0.20%, mobile phosphorus 9.3-12.2 mg / 100 g of soil, mobile potassium 43.2-45.8 mg / 100 g of soil.

3 Results and discussion

At grain-receiving enterprises in the last years 2000-2020 grains are found with surface damage in the form of dark spots of various diameters, brown or black (Fig. 3). Research on the problem of the appearance of caryopses with spots on the fruit and seed coats, which appeared in the field, was started in 2013 at the Federal Scientific Rice Centre (All-Russian Rice Research Institute, Krasnodar). In 2012, grain batches were identified with grain damage up to 30%, which led to a sharp decrease in the profitability of rice production. In the 2012 yield, caryopses with large brown-brown spots prevailed, and their content in husked rice was significant.

Fig. 3. Rice grain damage in the form of dark spots (Krasnodar region)

In the field, at the experimental-production site of the Federal Scientific Rice Centre, adults of stinkbugs (third decade of August) were found on panicles of rice varieties Rapan, Kurazh. The adults sat freely on panicles for 3 days (Fig 4).

Fig. 4. Rice panicle at the stage of "milky ripeness". Stinkbugs, adults

After ripening, the panicles were removed by hand and the content of damaged grains in panicles with and without stinkbugs was calculated. The results are shown in Table 1.

Table 1. Content of damaged grains in rice varieties Rapan and Kurazh, (selected on 10.09.2017, experimental-production site of the Federal Scientific Rice Centre, Krasnodar)

Variety	Content of damaged grains, %			
	panicle	no stinkbug	panicle	with stinkbug
Rapan	1	0,6	1	12,4
	2	0,0	2	20,3
Kurazh	1	0,5	1	19,1
	2	0,5	2	10,1

A significant increase in the content of damaged grains was noted in the variety Rapan. If on panicles without stinkbugs one caryopsis with damage was found, then on panicles with stinkbugs their number increased to 12.4-20.3%. In the variety Kurazh, damage to the kernels in the form of dark spots reached 10.1-19.1%. Thus, the data obtained indicate that the infestation of rice crops by stinkbugs provokes a sharp increase in the intensity of damage to grains in the form of dark spots.

The content of damaged grains in the harvested rice grain was studied at large grain receiving points of the Slavyansky and Krasnoarmeysky districts (table 2)

Table 2. The content of damaged grains in rice harvested at grain receiving points of the Krasnodar region

District	Content of damaged grains in rice, %, by years:			
	2010	2011	2012	2013
Slavyansky	1,6	2,8	8,3	2,7
Krasnoarmeysky	1,1	2,1	4,0-4,6	1,6-2,0

A significant increase in the degree of damage to rice grain stored in storage began in 2011. In 2011, the content of damaged grains increased by more than 1%, in 2012 it reached 8.3% in the Slavyansky district. Since 2013, the degree of damage to rice grain in the field began to decrease. The intensity of damage to rice grain in the form of dark spots was studied in the harvest 2012, 2015-2020 on varieties Rapan, Flagman in hulled rice grown at EPS of Federal Scientific Rice Centre. The results are shown in Table 3.

Table 3. The content of damaged grains in the harvest 2012, 2015-2020 (Krasnodar)

Variety	2012	2015	2016	2017	2018	2019	2020
Rapan	3,8	0,8	0,0	0,0	0,0	0 ,1	0,1
Flagman	3,2	0,6	0,0	0,0	0,1	0,1	0,1

The damage to rice caryopses of varieties Rapan and Flagman in 2012 and in 2015 was significant. And since 2016, the content of damaged grains in the harvest was insignificant - up to 0.1%. In rice farms of Krasnoarmeisky, Abinsky, Slavyansky districts in 2013, the degree of grain damage was different (Table 4).

Table 4. The content of damaged grains in rice grown in Krasnoarmeysky (ESPES "Krasnaya"), Abinsky (LLC SHP "Kuban"), Slavyansky (LLC "Kubris") districts, harvest 2013

Variety	Content of damaged grains, %		
	Krasnoarmeysky district	Abinsky district	Slavyansky district
Rapan	3,1	0,8	2,0
Flagman	2,8	0,6	0,6
Diamant	2,1	0,5	1,3
Atlant	1,2	0,6	1,6
Vizit	3,4	0,4	0,9
Victoriya	3,1	0,5	1,3
Renar	3,2	0,7	1,2
Yuzhniy	9,2	1,0	3,1
Sonet	4,5	0,2	1,8
Kurazh	10,6	0,9	3,1

In 2013, the damage to rice grain in the form of dark spots decreased compared to 2012. However, in Krasnoarmeysky district, it continued to be at a high level - from 1.2% in the variety Atlant to 10.6% in Kurazh. In the Slavyansky district, the maximum value of grain damage was also noted for the variety Kurazh - 2.5% higher than for the Flagman. At the maximum level, the grain of the variety Kurazh (0.9%) was also damaged in the Abinsky district. A tendency of comparatively increased values of damage in the form of dark spots in all regions for certain rice varieties - Rapan, Yuzhny, Kurazh was noted. Predicting the quality of the yield produced in Krasnodar region, along with many influencing factors, is associated with the need to assess the degree of grain damage in the form of dark spots in the field. In this part, it is important to study the influence of grains damaged in the form of dark spots on the complex of technological quality traits. In this study, the indicators of the total milling yield and the head rice content were studied for rice samples with different contents of damaged grains. The results are shown in Table 5.

Table 5. The total milling yield and the head rice content when grinding grain with different contents of damaged grains

Variant, content of damaged grains	Total milling yield, %	Head rice content, %
0 %	71,0	97,3
3 %	71,0	97,0
10 %	70,5	94,8
20 %	69,7	91,8
HCP_{05}	0,10	0,46

With an artificial increase in the content of damaged grains in the sample of the variety Flagman to 3%, a slight decrease in the total milling yield and the head rice content was noted. However, with a further increase in the content of damaged grains, there was a significant decrease in the quality of the rice product: the total milling yield decreased by 1.3%, and the head rice content - by 5.5% (20% of damaged grains in the sample). This pattern indicates an increase in the fragility of damaged kernels, which is possibly accompanied by the appearance of microcracks in the kernel.

Thus, the negative impact of the presence of damaged grains in the grain mass on the yield and quality of milled rice was confirmed. Modeling a grain mass with different contents of damaged grains makes it possible to study the effect of damaged grains on the quality of produced rice products.

4 Discussion

According to the data obtained as a result of the study, it is shown that in the conditions of Krasnodar region, rice growers annually encounter the problem of dark spots on a rice grain in the field. The grain damage occurs to varying degrees. The harvest of 2012 was characterized by a high content of damaged grains. Since 2006, when the process of damage was designated as obvious, the Federal Scientific Rice Centre (Krasnodar) conducted research - from direct registration of damaged grains in grain consignments to large-scale research conducted under an agreement with South Rice Union in 2013, 2014. The degree of grain damage in the form of dark spots is definitely lower than in Brazil and other South American countries, lower than in the United States [4, 5, 7, 9]. However, a sharp increase in damage in 2012 indicates that the possibility of reaching threshold values at which the profitability of rice growing sharply falls is also possible in Krasnodar region.

The issues of the species belonging of the most harmful bugs and the time when the bugs were brought to Krasnodar region have not been resolved. Most likely, the pests belong to the genus Oebalus of stinkbugs. It is possible that stinkbugs have always been present in low density in the rice fields, and their number is regulated both by the agro-climatic conditions of the region and by the presence of natural parasites of the stinkbugs themselves, possibly by the genotype of rice varieties in production. It is also possible that the first individuals were introduced in the early 2000s from abroad.

In connection with the relevance of possible outbreaks of reproduction of stinkbugs, field pests of rice grain, the harmful effect of which is to reduce the grain quality, it is necessary to develop control measures for these bugs and measures to combat them.

5 Conclusions

As a result of the studies, it was shown that the degree of intensity of the occurance of caryopses with dark spots in 2011, 2012-2020 and in different regions of rice cultivation is different. The high intensity of damage to rice grain in 2012 was replaced by a relatively insignificant one in subsequent years. The cause of the spots on the caryopsis is the prick-bite of insects belonging to the family of bugs, most likely to the stinkbugs with a piercing-sucking mouth apparatus. As a rule, the content of damaged grains was higher in the Krasnoarmeysky district, compared to experimental-production site of Federal Scientific Rice Centre and Abinsky district. The intensity of grain damage in the form of dark spots may be due to the genotype of the variety and the agro-climatic conditions of rice cultivation, which affect both the developmental biology of stinkbugs and their natural parasitic organisms. Further research is needed to identify the most harmful representative of stinkbugs in Krasnodar region.

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