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Evaluation of the effect of infection with *Aphelenchoides besseyi* on yield elements in rice varieties and lines

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Abstract

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The study was conducted during the period 2019-2021 under field conditions and artificial infection with *Aphelenchoides besseyi* Christie (rice white tip nematode). Four varieties and two lines of rice were tested. The lowest percentage of plants showing symptoms of „white tip" is the variety CRLB 1. The variety Cameo is highly susceptible to infection with a higher number of nematodes in the seeds. Artificial infection leads to a decrease in the values of the panicle length, the total number of grains per panicle, the weight of one panicle, the weight of the grain in a panicle and the weight of 1000 grains in plants showing symptoms. In the varieties Osmanchik 97, Cameo and line №19 a larger decrease in the yield by elements was found.

Keywords: rice; *Aphelenchoides besseyi*; yield elements

Introduction

Rice (*Oryza sativa* L.) is one of the most important cereals cultivated worldwide, constituting the basic food for large number of human beings, sustaining two-thirds of the world population (Zhou et al., 2002). According to studies by the International Rice Research Institute (IRRI), Philippines, production should increase by about 1% per year, not only due to the growing demands of the population on food, but also due to adverse climatic conditions (Muhammad et al., 2013; Zhao & Fitzgerald, 2013).

There are many factors that determine rice productivity (Horie et al., 2005; Park et al., 2018; Zhao & Fitzgerald, 2013; Zhao et al., 2020). The attack by pests also has a significant influence in this regard. Nematodes are economically significant pests in a number of major crops, and in many cases have a major impact on the quantity and quality of production. From the species of the genus *Aphelenchoides* with the widest distribution and economic importance in rice worldwide (Yu Xin et al., 2015), including in our country (Yonchev, 2010; Samaliev & Stoyanov, 2007; Valcheva et al., 2017) is *Aphelenchoides besseyi*. Temperature and humidity are suitable for the development of rice white tip nematode almost throughout the growing season, and in practice the monoculture cultivation of rice is one of the main reasons for its reproduction and increasing population density.

Aphelenchoides besseyi is an ecto- or endoparasite that feeds on above-ground parts of host plants. This nematode has spread worldwide and caused extensive losses in global rice production. Symptoms caused by *A. besseyi* generally display the characteristic white tip of the top leaves, small grains, and erect panicles (Feng et al., 2021).

Yield losses in rice caused by *Aphelenchoides besseyi* vary depending on the variety, year of cultivation, temperature, level of applied agricultural techniques and other variable factors (Tulek & Cobanoglu, 2010; Tülek, 2016). In infected crops, yield reductions of up to 30–70% have been reported (Prot, 1992; Lin et al., 2004; Tulek & Cobanoglu, 2010; Mohammad et al., 2013).

The aim of the present study was to determine the level of infection by *Aphelenchoides besseyi* and its influence on structural elements of yield in introduced varieties and Bulgarian lines rice.

Material and Methods

Plant material and experimental design

The study was conducted at Maritsa Vegetable Crops Research Institute, Plovdiv during the period 2019-2021 under field conditions. Rice varieties Osmanchik 97 and Gala originating from Turkey, the Italian varieties Cameo and CRLB 1 and the Bulgarian lines №19 and №77 were tested. The experiments were conducted as split plots in a completely randomized block design with 3 replications (artificially infected plants and uninfected control) with plot sizes of 2 m^2. During the vegetation the standard agrotechnics for rice cultivation in Bulgaria was applied.

Nematode extraction

A modified Baermann method (Hooper, 1986) was used to isolate *Aphelenchoides besseyi*. Before the analysis of randomly selected grains from panicles with „white tip“ symptom collected from the previous year, the flower glume was removed and used for nematode extraction. Each sample was kept in water for 48 hours. The nematodes in two aliquant parts of 1 ml water suspension from each extract were counted in counting dishes. Using a stereomicroscope, the average value of both aliquant parts was calculated referring to 100 seeds.

Rice plants were inoculated at tillering stages with 500 nematodes/plant.

Evaluation of the reaction

The „white tip“ symptoms on the leaves were reported 6 to 8 weeks after inoculation and the percentage of plants showing symptoms by the varieties was determined. The nematode population density was calculated at the end of the growing season by counting the number of nematodes in 100 seeds. The resistance of rice varieties/lines to *A. besseyi* was assessed by counting the number of nematodes in the plants and the development of white tip symptoms, using a disease index scale (Popova et al., 1994).

The resistance rated as follows:

0 – No „white tip“ symptoms and nematodes;
1 – There are no „white tip“ symptoms and the number of nematodes is 1–10 per plant;
3 – There are no symptoms of „white tip“ and number of nematodes> 10 per plant;
5 – Presence of „white tip“ symptoms and a large number of nematodes”.

The average index of infection of each variety was calculated by the formula:

$$P = \frac{\sum(B \times n)}{N},$$

where Σ (B × n) – Sum of the number of plants (n) and the corresponding infection index (B); N – total number of infected plants.

Each tested variety/line was classified based on the average index of infection: 0 – immune, 0.1–1.0 – highly resistant, 1.1–3.0 – moderately resistant, 3.1–4.0 – moderately susceptible, 4.1–5.0 – highly susceptible.

In the phase of full maturity, 10 panicles were collected from each replication. The recorded indicators were: panicle length (cm), weight of one panicle (g), weight of grain in panicle (g), total number of grains per panicle and weight of 1000 grains (g). The percentage of yield reduction by components was also determined.

The weight loss of the panicle (panicle length, grain weight per panicle, total number of grains per panicle, weight of 1000 grains) used to calculate yield reduction is determined as follows:

Decrease in panicle weight 1 (%): reduction of panicle weight with symptoms of „white tip“ in the infected plot compared to panicles in control plots.

Decrease in panicle weight 2 (%): decrease in panicle weight without symptoms „white tip “in infected “plots compared to panicles in control plots.

The formulas used to calculate yield losses are as follows:

– Decrease in yield 1 for plants with „white tip“symptoms (%)
  % of plants showing symptoms x decrease in panicle weight 1(%)/100;
– Decrease in yield 2 for plants without „white tip “symptoms (%)
  % of plants without symptoms x decrease in panicle weight 2 (%)/100;
– Total yield loss (%) = Yield decrease 1 (%) + Yield decrease 2 (%).

Results and Discussion

The tested cultivars/lines showed different symptoms after infection with *Aphelenchoides besseyi*. In variety Gala and line №19 the plants shown typical „white tip“. The varieties Osmanchik 97 and Cameo and line №77 show a mixed type of reaction: white tip of the leaves of the central stem and the brothers, the panicles are partly exerted with immature and empty grains, deformed and twisted leaves. In variety CRLB 1, without symptoms but infested plants were found in two of the experimental years (Table 1).

Results that infection with *Aphelenchoides besseyi* causes different symptoms in different varieties were obtained from Jamali & Mousanejad (2011), Yu Xin et al. (2015), Tülek (2016).

The data for the determined percentage of plants with and without symptoms and the resistance of the tested samples are presented in Table 1. The highest percentage of plants with symptoms in all three experimental years was recorded in the Italian variety Cameo. Among the tested varieties and lines there are no immune ones. The Turkish varieties Osmanchik 97 and Gala show moderately susceptibility, three genotypes were moderately resistant, and variety Cameo reacts as moderately and highly susceptible (Table 1).

The data from the biometric measurements regarding the structural elements of the yield of infected plants showing symptoms, those without symptoms, as well as the control variant are presented in Table 2. Plants inoculated with *Aphelenchoides besseyi* and showing symptoms have lower

Table 1. Results of evaluation of rice varieties and lines for resistance to *Aphelenchoides besseyi*

Variety/Line	2019			2020			2021		
	Plants showing symptoms, %	Average index of infection	Resistance*	Plants showing symptoms, %	Average index of infection	Resistance *	Plants showing symptoms, %	Average index of infection	Resistance *
Osmanchik 97	40	3.8	MS	40	3.6	MS	35	3.5	MS
Cameo	60	3.4	MS	55	3.2	MS	75	4.1	HS
Line №19	45	2.6	MR	25	2.4	MR	10	2.3	MR
CRLB 1	10	2.4	MR	0	2.0	MR	0	2.0	MR
Line №77	25	1.7	MR	20	1.6	MR	10	1.5	MR
Gala	35	3.2	MS	25	3.3	MS	20	3.5	MS

*HR – highly resistant, MR – moderately resistant, MS – moderately susceptible, HS – highly susceptible

Table 2. Biometric measurements of yield components (average for the period)

Variety/Line	Indexes				
	Panicle length, cm	Weight of one panicle, g	Weight of grain in panicle, g	Total number of grains per panicle	Weight of 1000 grains, g
Osmanchik 97					
With symptoms	14.1	4.29	4.12	150	32.1
Without symptoms	15.6	5.51	5.28	164	34.5
Control	16.0	5.71	5.48	166	36.1
Cameo					
With symptoms	18.5	3.77	3.61	93	38.9
Without symptoms	19.2	3.91	3.74	98	40.9
Control	19.5	4.12	3.99	103	44.7
Line №19					
With symptoms	14.7	5.38	5.16	201	28.8
Without symptoms	15.8	4.39	5.56	197	30.4
Control	16.4	5.85	6.17	228	31.7
CRLB 1					
With symptoms	19.3	2.68	2.49	94	27.5
Without symptoms	19.8	2.80	2.66	106	27.9
Control	20.3	2.98	2.86	112	28.6
Line №77					
With symptoms	15.6	5.83	5.61	175	35.1
Without symptoms	16.5	6.28	6.02	175	36.9
Control	17.0	6.71	6.45	185	38.0
Gala					
With symptoms	14.5	4.44	4.28	144	34.4
Without symptoms	15.3	5.27	5.04	151	35.1
Control	15.8	5.46	5.29	157	35.8

Table 3. Decrease in yield by components (average for the period)

Indexes	Variety/Line					
	Osmanchik 97	Cameo	Line №19	CRLB1	Line №77	Gala
Panicle length						
Yield reduction in plants with symptoms, %	4.7	2.72	2.34	0.29	1.21	2.07
Yield reduction in plants without symptoms, %	1.71	0.50	3.20	1.76	2.51	2.13
Total yield reduction, %	6.41	3.22	5.54	2.05	3.72	4.20
Weight of one panicle						
Yield reduction in plants with symptoms, %	9.53	5.89	3.04	0.09	1.96	4.63
Yield reduction in plants without symptoms, %	2.3	1.88	7.82	1.47	5.68	2.41
Total yield reduction, %	11.83	7.77	10.86	1.56	7.64	7.04
Weight of grain in panicle						
Yield reduction in plants with symptoms, %	9.54	5.93	2.97	0.86	1.96	4.73
Yield reduction in plants without symptoms, %	2.43	1.83	8.63	3.09	5.88	3.31
Total yield reduction, %	11.97	7.76	11.60	3.95	7.84	8.04
Total number of grains						
Yield reduction in plants with symptoms, %	3.48	6.15	1.63	1.28	0.59	1.91
Yield reduction in plants without symptoms, %	0.75	1.54	9.78	0.96	1.85	2.82
Total yield reduction, %	4.23	7.69	11.41	2.24	2.44	4.73
Weight of 1000 grains						
Yield reduction in plants with symptoms, %	4.19	8.81	2.34	0.07	1.39	0.98
Yield reduction in plants without symptoms, %	2.82	2.70	2.87	0.13	2.21	1.37
Total yield reduction, %	7.01	11.51	5.21	0.20	3.60	2.35

values of the defined indicators of those in the control variants. The individual components were affected to varying degrees. The size of the panicle decreased by 4.9% to 11.9%. The panicle weight was reduced by 8.1% to 24.9% compared to the control, the weight of the grain in the panicle was from 9.5% to 24.8%, for the total number of grains they are from 5.4% to 16.1% and for the weight of 1000 grains – from 3.8% to 11.1%.

Our data confirm the results of studies by Yu Xin et al. (2015), Tülek et al. (2015), Valcheva et al. (2017), Lisnawita & Safni (2019) that nematode infection causes a decrease in the quantity of the studied indicators.

The determined percentage of yield reduction by component is presented in Table 3. Of the studied indicators, the nematode infection leads to a greater decrease in the values of the weight of one panicle and the weight of the grain in the panicle by an average of 7.78% and 8.53%.

Infection with rice nematode in varieties Osmanchik 97 and Cameo and in line №19 leads to a higher percentage of yield loss.

In Osmanchik 97, where 35–40% of the plants showed the symptom of „white tips", the panicle was shortened by an average of 6.41%, the weight of one panicle, the grain in it and the weight of 1000 grains were reduced by 11.83%, 11.97% and 7.01%, respectively.

With a greater total decrease in yield in four of its components is also line №19 – panicle length (5.54%), weight of one panicle (10.86%), weight of grain in a panicle (11.6%) and total number of grains (11.41%).

The infection decreases in larger sizes and the values of the indicators in the variety Cameo. Yield losses in relation to the total number of grains in the panicle reach 7.69%, and the reduction in the weights of 1000 grains amounts to 11.51%.

Conclusion

In the study of the varietal response to the rice tip nematode *Aphelenchoides besseyi* with the lowest percentage of plants showing symptoms, the variety CRLB 1.

The variety Cameo is highly susceptible to infection with a higher number of nematodes in the seeds.

Artificial infestation resulted in decreased values of panicle length, total number of grains per panicle, weight per panicle, weight of grain per panicle and weight per 1000 grains in plants showing symptoms.

In the varieties Osmanchik 97, Cameo and line №19 a larger decrease in the yield by components was stablished.

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