Turkish Journal of Agriculture and Forestry
http://journals.tubitak.gov.tr/agriculture/
Research Article
Turk J Agric For
(2015) 39: 958-966

doi:10.3906/tar-1407-120

Reaction of some rice cultivars to the white tip nematode, *Aphelenchoides besseyi*, under field conditions in the Thrace region of Turkey

Adnan TÜLEK[1], **İlker KEPENEKÇİ**[2,*], **Tuğba Hilal ÇİFTCİGİL**[1], **Halil SÜREK**[1], **Kemal AKIN**[1], **Recep KAYA**[1]
[1]Thrace Agricultural Research Institute, Edirne, Turkey
[2]Department of Plant Protection, Faculty of Agriculture, Gaziosmanpaşa University, Taşlıçiftlik, Tokat, Turkey

Received: 21.07.2014 • **Accepted/Published Online:** 06.05.2015 • **Printed:** 30.11.2015

Abstract: The objective of this study was to evaluate the reactions of 41 rice cultivars to *Aphelenchoides besseyi* under field conditions in 2012 at the Thrace Agricultural Research Institute. The experiments were conducted as split plots in a randomized complete block design with 3 replications. An infected plot and an uninfected control plot were the main plots; the cultivars were subplots. As a sign of nematode damage, white tip infection ratio on the rice caused by nematodes was determined in the experiments, and the losses in yield components for the rice cultivars were calculated. There were decreases both in the grain number per panicle (by 38.3%) and in the panicle weight (by 49.7%) in the infected plot with symptoms of white tip nematode. The Ribe cultivar had the highest yield losses due to nematode damage, with 52.1%. The Asahi cultivar, which is a resistant control, had the lowest yield losses with 7.8%. There was a significant positive correlation (r = 0.5068) between the average chlorophyll values (SPAD) in the flag leaf and average white tip ratio (%). Although there was a significant positive correlation (r = 0.7571) between the yield loss and the white tip infection ratio in all cultivars, no significant relation was found between the yield loss and nematode density.

Key words: White tip nematode, *Aphelenchoides besseyi*, rice (*Oryza sativa* L.), varietal reaction, yield component

1. Introduction

White tip nematode, *Aphelenchoides besseyi*, is one of the most widespread nematodes causing economic yield losses in rice-growing areas. White tip nematode is a seed-borne ectoparasite of rice and it has been reported in the majority of the rice-growing countries of Africa; North, Central, and South America; Asia; Europe; and the Pacific. The yield losses caused by this nematode in rice show differences according to rice cultivar, growing year, temperature, cultural practices, and other variable factors. In infested fields, the average yield losses range from 10% to 30%; in fields where all plants have been attacked, yield losses of up to 70% for susceptible cultivars and 20% for resistant cultivars have been reported (Prot, 1992).

Aphelenchoides besseyi is an important nematode pest of rice crops in Turkey. It was first reported in 1995 in the İpsala and Gönen districts of Edirne and Balıkesir provinces, respectively (Öztürk and Enneli, 1997). The yield losses have reached up to 57.9% for susceptible cultivar Halilbey in fields having 77% plants with white tips on the infected flag leaves (Tülek and Çobanoğlu, 2010).

In several countries, control of this nematode has been achieved using nematode-resistant rice cultivars (Qu, 1985). Differences in susceptibility of rice cultivars to *A. besseyi* were previously reported in 1949 and appear to have become widespread since then; resistance (Bridge et al., 1990) or moderate resistance in rice cultivars has been observed in most rice-growing regions (Sivakumar, 1988). It has been reported that certain rice cultivars (Arkansas Fortuna, Asahi, Bluebonnet, Bluebonnet 50, Improved Bluebonnet, Century 231, Fortuna, Hill Long Grain, Nira, Nira 43, Rexoro, Sunbonnet, Texas Patna, Toro, and TP–49) are resistant to white tip in the United States. Century 52, Century Patna 231, and Rexark are fairly resistant (Cralley and Adair, 1949; Todd and Atkins, 1959). In Japan, the Tosan 38 cultivar is very resistant, the Norin 8 and Norin 43 cultivars are resistant, and Norin-Mochi 5 and Natsushimo are fairly resistant (Goto and Fukatsu, 1956). In India, the Gumartia and Chinoor cultivars are nearly immune, and Surmartia is not significantly affected (Dastur, 1936). In Italy, Rinaldo Bersani is resistant, and Carnaroli and Pierrot are fairly resistant (Orsenigo, 1954).

In Russia, an assessment of the resistance of 1003 rice cultivars to *A. besseyi* from different agroecological regions was performed in a glasshouse experiment. Three cultivars were found to be immune (Bluebonnet, Bluebonnet 50, and Starbonnet), 10 were highly resistant, 164 were moderately resistant, and 826 were susceptible or highly

* Correspondence: kepenekci@gmail.com

susceptible to *A. besseyi* (Popova et al., 1994).

Resistance to *A. besseyi* is said to be genetically controlled and carried by the Japanese cultivar Asahi (Nishizawa, 1953), and resistance is one of the best control methods for this nematode. It is important that genetic materials are tested with nematodes. The aim of this study was to determine the levels of *A. besseyi* infestation and its effects on yield components in selected rice cultivars.

2. Materials and methods

2.1. Selection of cultivars used in the experiments

Forty-one cultivars used in varietal reaction studies were selected. Bluebonnet (IRGC-Acc. No. 1799) and Nira 43 (IRGC-Acc. No. 1932) from the United States, Rinaldo Bersani (IRGC-Acc. No. 9468) from Italy, and Asahi (IRGC-Acc. No. 33983) from Japan were used as resistant controls in this experiment. These control varieties were kindly provided by the International Rice Genebank Collection (IRGC) in the Philippines. These rice cultivars have been used in varietal reaction experiments. Nearly all of the rice cultivars used in the experiments belong to the Japonica variety, except for the Bluebonnet, Nira-43, and Aromatik-1 cultivars, which are of the Indica variety.

2.2. Arrangement of experimental design

The experiments were conducted at the Thrace Agricultural Research Institute in Edirne, Turkey. All varieties used in the experiments were sown in the middle of May for all experiments. The varietal reaction studies were performed as two separate experiments.

2.2.1. Determination of white tip ratio (%) in cultivars

The seeds of all varieties used in the experiments were sown by hand in a dry field in a completely randomized block design with 3 replications, with 1 row as 1 m and a space between the rows of 30 cm, with 100 seeds in each row. The seed beds were then watered. To test the cultivars, the seeds were obtained from infected panicles from the previous year. In addition, infected susceptible Beşer cultivar (468 *A. besseyi* 100 seeds^{-1}) was planted in the spaces between the blocks and rows as a spreader. The plants in each row were reaped during the flowering stage, and the ratios of plants (%) with symptoms of white tip in the flag leaf were determined.

On the tillers of the affected plants, the tips of the leaves whiten for a distance of 3 to 5 cm and then die off and shred (Figure 1). The panicles are shorter and often atrophied at the tips. The fertile flowers sometimes produce misshapen grains with low germination potential and delayed date of maximum germination.

2.2.2. Determination of decrease (%) of yield components

The experiments were conducted as split plots in a completely randomized block design with 3 replications, including the treatments (infected plot and uninfected control) as the main plot and cultivars (41 cultivars) as the subplots. The plants were assessed for nematode resistance under field conditions in 2012. Plant seeds were sowed as follows: 3 replications; 1 row is 1 m; the space between rows is 30 cm; there are 100 seeds in each row.

Figure 1. White tip symptoms on flag leaves caused by *Aphelenchoides besseyi*.

Treatment 1: For each cultivar, seeds produced the previous year that were infected with *A. besseyi* were used. In addition, the infected Beşer cultivar (468 *A. besseyi* 100 seeds^{-1}) was planted in spaces between the blocks and lines as a spreader in the experiments. Additionally, 5000 nematodes per square meter were applied 10 days after germination. *A. besseyi* individuals were sprayed onto water-filled rice plots. The average panicle weight (g panicle^{-1}) and average grain number per panicle were determined by collecting 10 panicles from each row at harvest, both having white tip symptoms present and without symptoms on flag leaves. Yield losses were determined according to grain weight loss as a percentage and grain number decrease as a percentage compared with the values in uninfected plots. Nematode analysis was performed on the grains from the bulk (mixture) of the panicles with white tips, with 3 repetitions using 100 seeds for each replication.

Treatment 2: Noninfected (nematode-free) seeds treated with hot water prior to treatment (control) were used in the experiment (Tülek and Çobanoğlu, 2011a). The average panicle weight (g panicle^{-1}) and average grain number (number panicle^{-1}) were determined by collecting 10 panicles from the rows of each cultivar at harvesting. Sterile grains were separated using a 1.75-mm oblong sieve in all experiments.

The weight loss of the grains used for the calculation of yield loss was calculated as described below:

Decrease in panicle weight 1 (%): decrease in panicles' weight with white tip symptoms in the infected plot compared with panicles in the control plots.

Decrease in panicle weight 2 (%): decrease in panicles' weight without white tip symptoms in the infected plots compared with panicles in the control plots.

The formulas used for the calculation of yield losses are as follows.

Yield loss 1: For plants with white tip symptoms, the yield loss was calculated by multiplying the average white tip ratio, which had been previously determined, with the plant ratio of the white tip symptoms, with an average weight decrease (%) (according to control) of the grains of the panicles with white tip symptoms in the infected blocks.

Yield loss 1 (%) = [average white tip ratio (%) × decrease in panicle weight 1 (%)] / 100

Yield loss 2: For plants not exhibiting white tip symptoms, the yield loss was calculated by multiplying the plant ratio without white tip symptoms, which was previously determined, by the average weight decrease (%) (according to control) of the grains of the panicles without white tip symptoms in the infected blocks.

Yield loss 2 (%) = [plant ratio without white tip symptoms (%) × decrease in panicle weight 2 (%)] / 100

Total yield loss (%) = yield loss 1 + yield loss 2

2.3. Determination of presence of hairiness on seeds

In varietal reaction experiments, the relationship between the presence of hairiness on the hulls (lemma and palea) and the formation of white tip was assessed. The presence of hairiness in cultivars was evaluated in existing seeds using a binocular stereo microscope at 7.1× (Leica-MZ 16).

2.4. Determination of chlorophyll content

The indirect chlorophyll content or greenness of the leaves of the cultivars was determined with a Minolta SPAD 502 Chlorophyll Meter (Konica MINOLTA Sensing, Inc., Japan) (Loh et al., 2002). Triplicate SPAD readings were collected from 1 young fully expanded flag leaf from 5 plants per cultivar. A total of 15 measurements were performed with 3 parts from the bottom, middle, and edge of flag leaves from 5 plants for each cultivar during blossoming, when the flag leaf had become mature. The relationship between the white tip symptoms and chlorophyll values was determined using correlation analysis.

2.5. Laboratory analysis

The Baermann funnel method was used to obtain nematodes from the white tips of rice both before sowing and after harvest (Hooper, 1986). The seeds were separated from the hulls (lemma and palea). *A. besseyi* was localized inside the hulls and on the cargo by 97% and 3%, respectively (Tülek and Çobanoğlu, 2011b). Therefore, only the hulls were used for analysis. The samples were stored in water in a conical flask for 48 h, and the bottom-sedimented nematodes were then placed in tubes in volumes of 20 mL. The nematodes in two 1-mL aliquots of water from each extract were counted in counting dishes using a binocular stereo microscope at 32× magnification, and the average of the 2 counts was calculated for 100 paddy seeds. After harvesting, 100 g of paddy rice was removed from each sample and used to determine the milled rice yield (%).

2.6. Statistical analyses

Statistical analyses were performed using the Jump 5.0.1 statistical program. The F-test and Duncan's comparison method were used at 1% and 5% error levels.

3. Results

The analysis of variance for white tip percentage among the rice cultivars revealed significant differences at the $P < 0.01$ level (Table 1). Since Rinaldo Bersani in the infected plots had no panicles with white tip symptoms, and the number of panicles with white tip symptoms in the cultivars Asahi, Nira-43, Bluebonnet, and Aromatik-1 were either low or insufficient for nematode analysis, nematode analyses were done on seeds that were obtained from panicles with no white tip symptoms. According to the results of the analysis, while Nira and Bluebonnet cultivars had no *A. besseyi*, 1 *A. besseyi* 100 seeds^{-1} in Asahi and 5 *A. besseyi* 100 seeds^{-1} were determined in Aromatik-1 rice cultivars. However, there were 120 *A. besseyi* 100 seeds^{-1} in Rinaldo Bersani. In a previous experiment, an average of 741.6 *A. besseyi* was found in the panicles of the Halilbey rice cultivar with white tip symptoms obtained from a field, and an average of 10.9 *A. besseyi* was found in panicles without white tip symptoms (Tülek and Çobanoğlu, 2010). Consequently, in this experiment, the nematode density of the plants without white tip symptoms was not determined.

The highest value of white tip ratio was obtained from the Neğiş cultivar with 85.1%. In the susceptible

Table 1. Analysis of variance for percentage of plants with white tip symptoms on the flag leaf.

Source	DF	Sum of squares	Mean square	F-value
Replication	2	10.8021	5.4010	4.9459
Cultivars	39	428.6422	10.9908	10.0645**
Error	74	80.8108	1.0920	
C. Total	115	512.2571		

**: $P < 0.01$, CV (%): 16.4, $LSD_{0.05}$: 20.65.

Halilbey cultivar, the white tip ratio was 69.5%. The lowest yield loss was from the Asahi cultivar with 7.8%, whereas the highest yield loss was from the Ribe cultivar with 52.1%. In the experiments with the Halilbey cultivar used as a susceptible control, 47.9% yield loss was obtained (Table 2).

In infected plants, the highest decrease in grain number per panicle was in the Kargı cultivar with 54%, the Halilbey cultivar with 51%, and the Neğiş cultivar with 39%. The relationship between the decrease in total yield or in grain weight per panicle and white tip ratio was found statistically significant (r = 0.713) (Figure 2).

Table 2. Decreases in weight of grain per panicle in the infected plot.

Cultivars	Weight P-1#	With WTS	Weight P-2	Without WTS	YL1	YL2	TYL
Sürek	44	40.0	17	60.0	17.5	10	27.6
Yavuz	41	31.0	10	69.0	12.9	7	20.0
Ergene	58	30.4	24	69.6	17.8	16	34.2
Gönen	54	78.3	23	21.7	42.2	5	47.2
Osmancık	56	61.8	16	38.2	34.9	6	40.9
Altınyazı	54	36.7	22	63.3	19.7	14	33.7
Tunca	45	36.8	8	63.2	16.5	5	21.4
Krasnodarsky	36	39.0	14	61.0	14.2	9	23.0
Kızıltan	54	46.1	24	53.9	25.1	13	38.2
Gala	54	65.5	29	34.5	35.6	10	45.7
Karadeniz	52	42.3	29	57.7	22.1	17	38.9
Edirne	44	59.9	14	40.1	26.2	6	31.7
Şumnu	44	26.9	15	73.1	11.9	11	23.2
İpsala	41	26.1	15	73.9	10.8	11	22.1
Kral	43	63.6	12	36.4	27.5	4	32.0
Demir	49	35.4	21	64.6	17.3	13	30.6
Neğiş	50	85.1	17	14.9	42.6	3	45.2
Rocco	48	23.1	22	76.9	11.2	17	28.5
Beşer	47	22.3	30	77.7	10.5	23	34.0
Ece	38	68.8	20	31.2	26.3	6	32.6
Rodinia	55	29.4	25	70.6	16.2	18	33.8
Veneria	43	68.6	18	31.4	29.2	6	34.7
Kırkpınar	52	69.9	24	30.1	36.5	7	43.9
Diyarbakır	48	39.1	18	60.9	18.6	11	29.7
Halilbey	55	69.5	33	30.5	37.9	10	47.9
Kargı	59	44.0	28	56.0	25.8	16	41.6
Plovdiv	48	52.9	21	47.1	25.6	10	35.6
Koral	52	64.8	19	35.2	33.9	7	40.5
Ribe	58	78.4	30	21.6	45.7	6	52.1
Trakya	51	39.1	14	60.9	20.0	9	28.7
Ranbanlli	34	76.9	14	23.1	25.9	3	29.2
Serhat	34	23.7	17	76.3	8.1	13	21.2
Durağan	45	52.3	13	47.7	23.5	6	29.9
7721	45	45.9	13	54.1	20.5	7	27.3
R.Bersani	- *	0.0	26	100.0	-	26	26,0
Asahi	-	1.5	8	98.5	-	7.8	7.8
Nira43	-	1.7	-	98.3	-	-	-
Bluebonnet	-	1.8	-	98.2	-	-	-
Aromatik-1	-	1.8	25	98.2	-	24.6	24.6
Maratelli	62	27.3	36	72.7	17.0	26	43.0
Sarıçeltik	51	9.3	13	90.7	4.8	12	16.6

#: Weight P-1: Decrease in weight of panicle - 1 (%); Weight P-2: Decrease in weight of panicle - 2 (%); Without WTS: Percent of plant without white tip symptoms; With WTS: Percent of plant with white tip symptoms; YL1: Yield loss - 1 (%); YL2: Yield loss - 2 (%); TYL: Total yield loss (%).
*: The evaluation was not performed in cultivars without white tip signs.

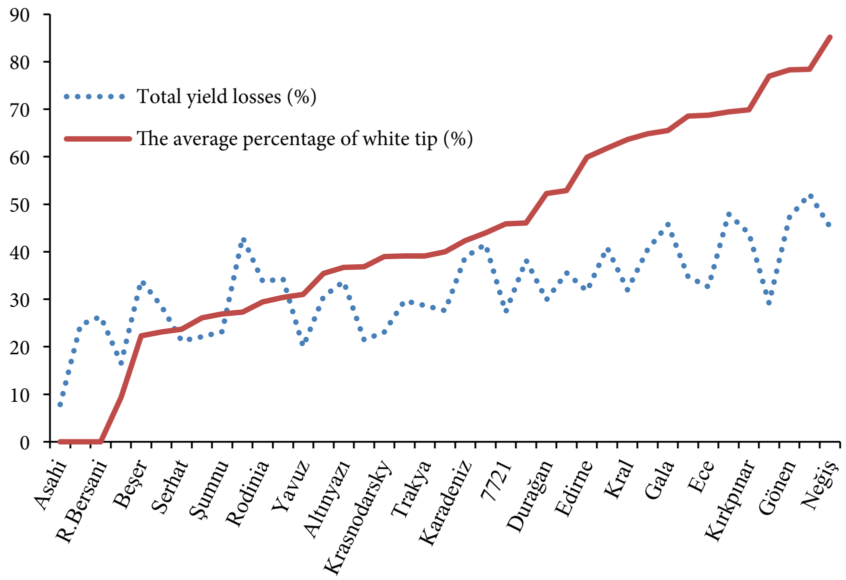

Figure 2. Total yield losses in weight of grain per panicle in the infected plots and its relationship with the percent of plants with white tip symptoms (r = 0.713).

There was a statistically positive correlation (r = 0.82) between the percentage of decrease in grain number per panicle with white tip symptoms and the percentage of decrease in grain weight. There was also a statistically positive correlation (r = 0.71) between the percentage of decrease in grain number per panicle without white tip symptoms and the percentage of decrease in grain weight.

In infected plots, chlorophyll content in the cultivars was investigated. The average chlorophyll content was lowest in the Bluebonnet cultivar (32.2 SPAD) and highest in the Kızıltan cultivar (49.9 SPAD). The chlorophyll content, presence of hairiness, nematode density, and yield losses related to the cultivars are listed in Table 3.

There was a decrease in both the grain number per panicle of 38.3% and in the panicle weight of 49.7% ($P < 0.01$) in the infected plot (signs of white tip present) (Table 4).

According to hierarchic cluster analysis, the position of the cultivars was determined by using the average white tip ratio (%). The chlorophyll content (SPAD), nematode density (*A. besseyi* 100 seeds^{-1}), and yield losses (%) were obtained from data of the varietal reaction studies. The cultivars with similar characteristics were grouped (Figure 3). Similar homogeneous groups were identified mathematically using hierarchic cluster analysis. In the cluster analysis, when measured as a distance, the closest (according to similarity) cultivars were Sürek and Trakya (0.412), and the farthest cultivars were Sürek and Sarıçeltik (4.994). In the cluster analysis, the distance of closeness among cultivars was investigated using 35 cultivars and 4 variables related to these cultivars. As shown in Table 5, the closest variables were detected (4.785) between the average white tip symptoms (%) and the values of yield loss.

In the infected plots, the Rinaldo Bersani, Asahi, Aromatik-1, Nira, and Bluebonnet cultivars were not included in the cluster analysis because there were no white tip symptoms or not enough for nematode analysis. The correlation values for the characteristics are provided in Table 6.

4. Discussion

Traditional Italian cultivars such as Arboria, Baldo, Carnaroli, Vialone Nano, and Volano are more susceptible to nematodes, and these cultivars also have long, broad, and hairy grains. By contrast, nematode susceptibility was rarely detected in the Indica varieties, such as Gladio and Thaibonnet, which have long and hairless grains (Giudici et al., 2003). In this study, cultivars with the highest white tip symptoms and yield loss, such as Neğiş, Kırkpınar, Ece, Ribe, and Halilbey, were found to have long-haired seeds, as well. Huang and Huang (1972) reported that an apicular "tunnel" of approximately 30 µm in diameter, circumscribed by the apiculi of lemma and palea, was the only natural opening to serve as a floral infection court, except during anthesis. Hairs on the glumes possibly retain moisture films on the surface and trigger entrance to the apicular opening. Nematodes are aquatic organisms in nature. In plants, they inhabit the water films around the plant tissue. Parasitic nematodes are biologically active when bathed in moisture films supplied by water in the tissues or body fluids of the host.

When the results were investigated in terms of chlorophyll content, a significant positive correlation (r =

Table 3. Chlorophyll content, nematode density, yield losses, and its relationship with the hairiness of the lemma and palea.

Cultivar	H[1]	C	A.b	TYL
Sürek	Long hair	39.7	265	27.6
Yavuz	Long hair	38.4	273	20.0
Ergene	Long hair	40.0	455	34.2
Gönen	Very long hair	42.0	379	47.2
Osmancık	Long hair	45.2	248	40.9
Altınyazı	Long hair	43.2	175	33.7
Tunca	Hairless	43.0	457	21.4
Krasnodarsky	Long hair	38.6	108	23.0
Kızıltan	Long hair	49.9	627	38.2
Gala	Long hair	46.3	213	45.7
Karadeniz	Long hair	43.1	311	38.9
Edirne	Long hair	42.9	128	31.7
Şumnu	Long hair	39.9	352	23.2
İpsala	Very long hair	43.5	285	22.1
Kral	Long hair	45.5	255	32.0
Demir	Long hair	36.5	367	30.6
Neğiş	Very long hair	37.9	322	45.2
Rocco	Long hair	39.2	313	28.5
Beşer	Long hair	39.2	498	34.0
Ece	Very long hair	43.1	465	32.6
Rodinia	Long hair	38.3	207	33.8
Veneria	Long hair	44.4	322	34.7
Kırkpınar	Very long hair	39.0	145	43.9
Diyarbakır	Long hair	41.0	188	29.7
Halilbey	Long hair	42.8	506	47.9
Kargı	Long hair	40.9	297	41.6
Plovdiv	Long hair	38.3	358	35.6
Koral	Long hair	42.5	75	40.5
Ribe	Long hair	45.2	245	52.1
Trakya	Long hair	39.1	219	28.7
Ranbanlli	Long hair	39.6	214	29.2
Serhat	Long hair	39.2	262	21.2
Durağan	Long hair	42.8	305	29.9
7721	Long hair	38.2	315	27.3
R. Bersani	Long hair	43.4	- *	26.0
Asahi	Short hair	35.7	-	7.8
Nira43	Short hair	32.6	-	-
Bluebonnet	Hairless	32.2	-	-
Aromatik-1	Hairless	40.7	-	24.6
Maratelli	Long hair	41.4	362	43.0
Sarıçeltik	Long hair	33.3	658	16.6

[1]: H: Hairiness on lemma and palea; C: Chlorophyll content (SPAD); A.b: Average number of *Aphelenchoides besseyi* per 100 seeds; TYL: Total yield loss (%).
*: The evaluation was not performed in these cultivars because there were no plants with white tip symptoms or there were not enough for nematode analysis.

Table 4. Population density of *Aphelenchoides besseyi* in rice grains and its influence on yield components in irrigated rice cultivars.

Yield component	I with WTS[1]	NI	D	F-value
Fertile grain number per panicle	63.54 b[2]	102.56 a	38.3	374.9928**
Panicle weight (g)*	1.78 b	3.54 a	49.7	342.6213**
Number of *A. besseyi* per 100 seeds	310.40	0.00	-	205.9164**
Percentage of plants with white tip symptoms (%)	43.90	0.00	-	630.7540**
Yield component	I without WTS	NI	D	F-value
Fertile grain number per panicle	85.8 b	101.90 a	15.8	91.5728*
Panicle weight (g)*	2.75 b	3.48 a	21.0	26.4844*

[1]: I with WTS[1]: Infected plot, panicle with white tip symptoms; I without WTS: Infected plot, panicle without white tip symptoms; NI: Noninfected plot (control); D: Percent decrease.
*: P < 0.05, **: P < 0.01.
[2]: In each row, the means followed by different letters are significantly different according to LSD tests at P = 0.05.

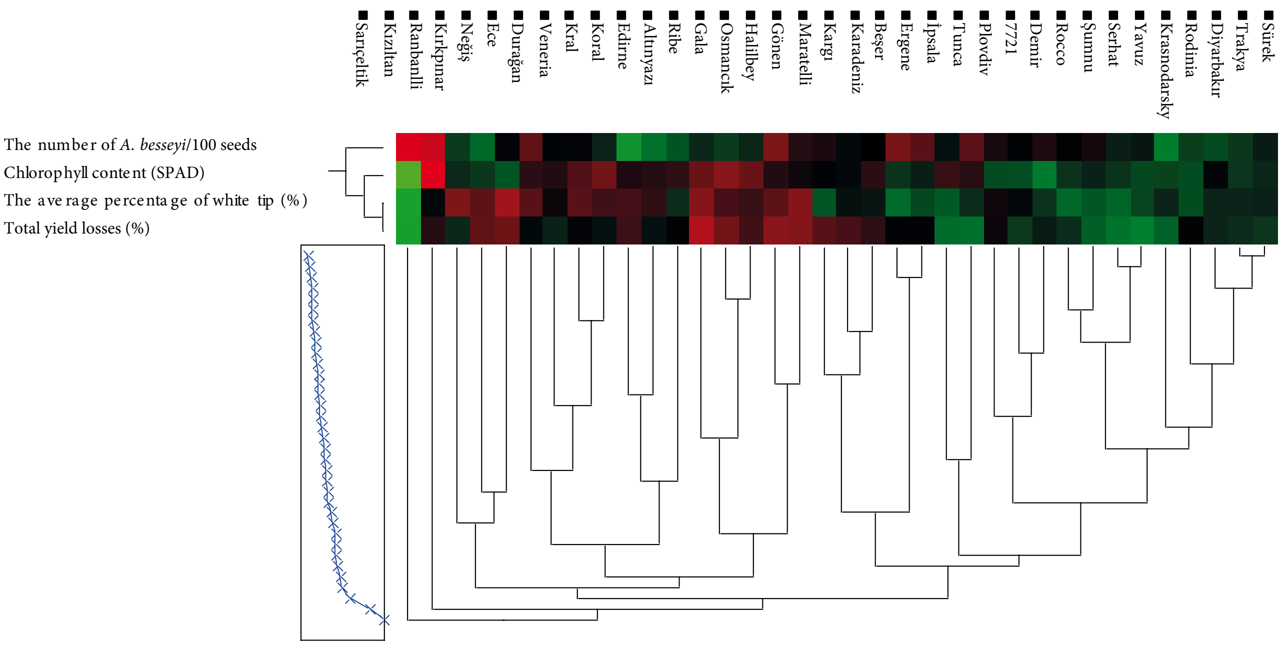

Figure 3. Dendrogram of 35 rice accessions.

Table 5. Hierarchical clusters and the distances between each observation and centroid, with similarity levels of the estimated 4 rice characteristics (variables).

Number of cluster	Distance	Leader	Joiner
3	4.785	The percentage of white tips (%)	Total yield losses (%)
2	6.323	Chlorophyll content (SPAD)	The percentage of white tips (%)
1	8.856	The number of *Aphelenchoides besseyi* 100 seeds^{-1}	Chlorophyll content (SPAD)

Table 6. Correlation coefficients among various quantitative traits of the cultivars.

Traits	A.b[1]	WTS	TYL
Chlorophyll content (SPAD)	–0.0303 NS	0.5068**	0.6394**
The number of *Aphelenchoides besseyi* 100 seeds^{-1}		–0.2558 NS	–0.0751 NS
The percentage of white tip (%)			0.7571**

[1]: A.b: Average number of *A. besseyi* per 100 seeds; WTS: The percentage of white tips (%); TYL: Total yield loss (%). NS: Nonsignificant. *: P < 0.05. **: P < 0.01.

0.5068) at the level of P < 0.01 was found between average chlorophyll content values (SPAD) measured in the flag leaves and average white tip ratio (%). Accordingly, when the chlorophyll content increases, white tip ratio increases as well. Rice cultivars with light green leaves, such as Asahi, Nira-43, and Bluebonnet, have less chlorophyll. By contrast, the Kızıltan cultivar has dark green leaves with higher chlorophyll content, and one of the highest nematode counts per 100 seeds (627 *A. besseyi* 100 seeds^{-1}).

In preliminary studies, the decrease in yield and yield components occurred in both the panicles with white tip symptoms and the panicles without white tip symptoms. The yield loss was severe in the panicles with white tip symptoms. During harvest, to investigate the effect of the white tip nematode on the yield components, the nematode density was determined in the plants with white tip symptoms. In the Halilbey rice cultivar, the nematode density was 741.6 *A. besseyi* 100 seeds^{-1}, the decrease in grain weight per panicle was 60.66%, and the decrease in grain number per panicle was 46.1% (Tülek and Çobanoğlu, 2010). In the Alikazemi cultivar, the nematode density was 650 *A. besseyi* 100 seeds^{-1}, the decrease in grain weight per panicle was 41.9%, and the decrease in grain number per panicle was 69.1% (Jamali et al., 2006). In the Rajbowalia cultivar, the nematode density was 1031 *A. besseyi* 100 seeds^{-1}, the decrease in grain weight per panicle was 59.26%, and the decrease in grain number per panicle was 81.82% (Rahman and Siddique, 1989). The results obtained in this study were in conformity with previous findings.

Among the cultivars that were used in the experiments, there was a decrease of 49.7% (34%–62%) in the panicle weight in plants with white tip symptoms in different nematode densities (75–658 *A. besseyi* 100 seed^{-1}). There was a decrease of 38.3% in fertile seed number.

Rice cultivars with high resistance or tolerance to *A. besseyi* are important for breeding purposes. Nematodes reproduce successfully on tolerant cultivars but do not seriously affect plant productivity. For example, relatively large nematode numbers (50 to 300 per plant) are observed for tolerant plants, although the seed weight is decreased by less than 15% compared to the control; however, in susceptible cultivars, a 30%–70% reduction was reported (Popova et al., 1980) Moreover, in this study, 245 *A. besseyi* caused a 52.1% decrease in the grain weight per panicle in the Ribe cultivar; however, 262 *A. besseyi* caused a 21.2% yield loss in the Serhat cultivar. Considering this fact, Serhat seems to be tolerant to the white tip nematode. Therefore, it is necessary to screen genetic materials rapidly and effectively in response to the rice white tip nematode under field conditions. In this study, the relationship between the white tip symptoms and yield losses in the cultivars was determined. The cultivars with fewer or no white tip symptoms could be used in breeding programs to develop resistant or tolerant varieties to white tip nematode.

Acknowledgment

This study was supported by the Scientific and Technological Research Council of Turkey (TÜBİTAK), both technically and financially (Project No. TOVAG-111O225).

References

Atkins JG, Todd EH (1959). White tip disease of rice. III. Yield test and varietal resistance. Phytopathology 49: 189–191.

Cralley EM, Adair CR (1949). Rice disease in Arkansas in 1948. Plant Disease Reporter 33: 257–259.

Dastur JF (1936). A nematode disease of rice in the Central Provinces. Proceedings of the Indian Academy of Sciences Section B 4: 108–121.

Giudici ML, Villa AM, Callegarin AM, Tamborini L (2003). White tip disease in Italian rice. In: Proceedings of the 3rd International Temperate Rice Conference; 10–13 March 2003; Punta de I'Este, Uruguay.

Goto K, Fukatsu R (1956). Studies on the "white tip" disease of rice. III. Analysis and nature of varietal resistance. Bull Nata Inst Agric Sci Tokyo Ser C No. 6: 123–149 (in Japanese with English summary).

Hooper DJ (1986). Handling, fixing, staining and mounting nematodes. In: Southey JF, editor. Laboratory Methods for Work with Plant and Soil Nematodes. London, UK: Her Majesty's Stationery Office, pp. 59–80.

Huang CS, Huang SP (1972). Bionomics of white-tip nematode, *Aphelenchoides besseyi* in rice florets and developing grains. Bot Bull Acad Sinica 13: 1–10.

Jamali S, Pourjam E, Alizadeh A, Alinia F (2006). Incidence and distribution of *Aphelenchoides besseyi* in rice areas in Iran. J Agr Sci Tech 2: 337–344.

Jamali S, Pourjam E, Safai N (2012). Determining the relationship between population density of white tip nematode and rice yield. J Agr Sci Tech 14: 195–203.

Loh FCW, Grabosky JC, Bassuk NL (2002). Using the SPAD 502 meter to assess chlorophyll and nitrogen content of Benjamin fig and cottonwood leaves. Hort Technology 12: 682–686.

Nishizawa T (1953). Studies on the varietal resistance of rice plant to the rice nematode disease 'senchu shingare byo' (V1). Bulletin of the Kyushu Agricultural Experimental Station 1: 339–349.

Orsenigo M (1954). Suscettibilità di varietà italiane di riso alla malattia della 'white tip'. Annali della Facolta di Agraria Universita Cattolica del S. Cuore, Milano 51: 1–7 (in Italian with English summary).

Öztürk G, Enelli S (1997). Determination of *Aphelenchoides besseyi* Christie (Aphelenchida: Aphelenchoidiae) (the white tip nematode) harmful on rice for the first time in Turkey. Turk J Ento 21: 129–132.

Popova MB, Andryusenko VV, Korsakova LA (1980). Degree of resistance of rice cultivars to the rice leaf nematode. Byulleten' Vsesoyznogo Instituta Gel'mitologii 26: 43–49.

Popova MB, Zelenskii GL, Subbotin SA (1994). An assessment of resistance in cultivars of *Oryza sativa* L. to *Aphelenchoides besseyi* Christie, 1942. Russ J Nematol 2: 41–44.

Prot JC (1992). White tip. In: Webster RK, Gunnel PS, editors. Compendium of Rice Diseases. Davis, CA, USA: A.P.S. Press, University of California, pp. 46–47.

Qu SH (1985). Rice Diseases. Kew, UK: Commonwealth Agricultural Bureau.

Rahman ML, Siddique AM (1989). Occurrence and distribution of white tip disease in deep water rice areas in Bangladesh. Rev Nematol 12: 351–355.

Sivakumar CV (1988). Avoidable yield losses in rice due to *Aphelenchoides besseyi* in Kanyakumari District, Tamil Nadu, India. Indian J Nematol 18: 123–125.

Todd EH, Atkins JG (1959). White tip disease of rice. II. Seed treatment studies. Phytopathology 49: 184–188.

Tülek A, Çobanoğlu S (2010). Distribution of the rice white tip nematode, *Aphelenchoides besseyi*, in rice growing areas in the Thrace region of Turkey. Nematol Medit 38: 215–217.

Tülek A, Çobanoğlu S (2011a). The effect of hot-water treatment on seed vitality and nematode mortality in terms of control of white-tip nematode (*Aphelenchoides besseyi*) on rice (*Oryza sativa* L.). In: Proceedings of the National Seed Congress; 14–17 June 2011; Samsun, Turkey. pp. 348–353.

Tülek A, Çobanoğlu S (2011b). Nematode density and occurrence in paddy seeds infected by rice white-tip nematode (*Aphelenchoides besseyi* Christie) in some rice cultivars. In: Proceedings of the Fourth Plant Protection Congress of Turkey; 28–30 June 2011; Kahramanmaraş, Turkey. p. 179.

Tülek A, Kepenekci İ, Çobanoğlu S, Hekimhan H, Devran Z, Melik B, Elekçioğlu Hİ (2009). A new culturing method for the rice white tip nematode, *Aphelenchoides besseyi* Christie, 1942, on carrot discs. Russ J Nematol 17: 135–136.