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Effect of cereal cyst nematode *Heterodera avenae* (Tylenchida: Heteroderidae) on yield of some spring wheat varieties in Adana Province, Turkey

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Abstract: Cereal cyst nematode *Heterodera avenae* is found predominantly in the spring wheat-growing areas in Adana Province in the eastern Mediterranean region of Turkey. The impact of *H. avenae* on wheat yield has been observed but not quantified. This study was conducted to determine the effect of *H. avenae* on the yield of 6 wheat varieties in the 2011/2012 and 2012/2013 growing seasons in the naturally infested fields of Adana. According to our results, *H. avenae* significantly suppressed grain yield of the wheat varieties, ranging from 4.3% to 25.7%. Negative or positive linear regressions between the reproduction factor of *H. avenae* and grain yield of the wheat cultivars depended on the variety. Regression analysis of the data revealed that reproduction factors of *H. avenae* were positively correlated with grain yield in cultivars Adana-99, Ceyhan-99, and Silverstar, whereas reproduction factors were negatively correlated with the Karatopak, Osmaniyem, and Seri-82 cultivars.

Key words: Cereal cyst nematode, *Heterodera avenae*, yield loss, wheat

1. Introduction

Wheat (*Triticum* spp.) is one of the most important field crops in Turkey, where spring and winter wheat cultivars are grown mostly under nonirrigated conditions. The eastern Mediterranean region is considered the main spring wheat production area with 2×10^6 t of wheat production in Turkey (www.turkstat.gov.tr).

Plant-parasitic nematodes are one of the leading biotic constraints on cereal production in Turkey. The cereal cyst nematode (CCN) complex (Stone and Hill, 1982) is the most significant group of plant-parasitic nematodes for wheat and barley in the world (Sikora, 1988). CCN consists of 12 valid species (Subbotin et al., 1999; Handoo, 2002), 3 of which, *Heterodera avenae* Wollenweber, *H. filipjevi* (Madzhidov) Stone, and *H. latipons*, are considered the most economically important (Nicol et al., 2002; Tanha Maafi et al., 2003).

Heterodera avenae is found in temperate wheat-producing regions throughout the world, including North and South Africa (Mokabli et al., 2002), Australia (Kort, 1972), Europe (Sikora, 1988; Rivoal and Cook, 1993), the Middle East (Ibrahim et al., 1999), and North America (Smiley, 1994). The yield reduction of wheat caused by *H. avenae* is 15%–20% in Pakistan (Maqbool, 1988), 40%–90% in Saudi Arabia (Ibrahim et al., 1999), and 23%–50% in Australia (Nicol et al., 2002). In Turkey, *H. avenae* is found in the spring wheat-growing areas in Adana Province in the eastern Mediterranean region (Subbotin et al., 2003; İmren et al., 2012). However, the impact of *H. avenae* on wheat yield has been observed but not quantified.

The relationship between the population density of *H. avenae* and the grain yield of wheat is important in determining the economic impact of the nematode on this crop (Ibrahim et al., 1999) and, therefore, provides essential data for nematode management. Such information is very important for the control of *H. avenae* on wheat in the eastern Mediterranean region of Turkey. Therefore, the objective of this work was to determine the effect of *H. avenae* reproduction on wheat yield under field conditions in Adana Province in the eastern Mediterranean region.

2. Material and methods

2.1. Field experiment setup

Field trials were carried out in Adana Province (Karlık-Sarıçam, 39°24′13″N, 32°37′14″E) in the eastern Mediterranean region of Turkey during the 2011/2012 and 2012/2013 wheat-growing seasons. Wheat fields naturally infested with *H. avenae* were selected before the growing season (Imren et al., 2012). The soil in these fields was mostly clayey.

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Experiments were established using 6 varieties of wheat. Four local spring wheat varieties, Adana-99, Ceyhan-99, Karatopak, and Osmaniyem, and 2 control lines, Seri-82 (susceptible) and Silverstar (tolerant), were tested in nematicide-treated and nontreated plots. The soil was prepared in the area and each field was divided into 72 experimental plots, each 4.2 m^2 in size and spaced 0.5 m apart.

In the experiment, 36 plots were treated with the nematicide Aldicarb (Temik 15 G) and 36 were not treated. The application rate for the nematicide was 4.2 kg a.i./ha; wheat seeds were mixed with the nematicide before sowing. Within the experiments, treatments were replicated 6 times according to a randomized block design. During the 2 wheat-growing seasons, all cultural practices that are commonly used by the local growers were followed. Weeds, aphids, and *Puccinia striiformis* were present in the experimental plots. An herbicide, insecticide, and fungicide were used to control weeds, aphids, and *Puccinia striiformis*, respectively. In addition, weeds that emerged after herbicide application were controlled by hand-weeding.

2.2. Nematode densities

For the determination of the initial population (Pi) and final population (Pf) of nematodes, 10 subsamples were taken from each plot at a depth of 20–30 cm at the beginning and at the end of the growing season. The soil samples were taken using a diamond sampling design (zigzag sampling). Cysts were extracted from 4 subsamples of 250 g each using a Fenwick can (Shepherd, 1986) and only full cysts were counted.

Cysts were crushed in a tissue grinder in 50 mL of tap water and eggs and second-stage juveniles in 3 aliquots of 1 mL each were counted under a stereomicroscope. Pi and Pf were expressed as number of eggs and second-stage juveniles per gram of soil, and reproduction factors (Rf) were also calculated (Scholz, 2001).

2.3. Yield determination

At the end of the 2011/2102 and 2012/2013 growing seasons, all plants from the experimental plots were harvested in late May. The wheat in each plot was threshed with a small combine. The grain yield per plot was recorded as kg/ha. Mean yields per treatment were then calculated and assessments of the percentages of yield reduction were done based on the values of the nontreated plots.

2.4. Statistical analysis

All data were subjected to analysis of variance and means were compared using the protected least significant difference (LSD) at the 5% level. Regression analyses were also performed to describe the relationship between the reproduction factor of the nematodes (Rf = Pf/Pi) and the grain yield of each wheat cultivar.

3. Results

The grain yields of all varieties in plots treated with Aldicarb were significantly higher ($P < 0.001$) than those of the nontreated plots. *Heterodera avenae* in the nontreated plots caused reductions in grain yield of all varieties that were significantly different from each other. Furthermore, the grain yield reductions of Seri-82, Osmaniyem, and Karatopak appeared to be greater than those of the other 3 varieties. The percentage reductions in wheat yield of the varieties ranged between 4.36% and 25.7% averaged over the 2 growing seasons (Table).

Regression analysis of the data revealed that reproduction factors of *H. avenae* were positively correlated with the grain yield of Adana-99, Ceyhan-99, and Silverstar (Figure 1), whereas reproduction factors were negatively correlated with the grain yield of Karatopak, Osmaniyem, and Seri-82 (Figure 2).

4. Discussion

This study indicates that *H. avenae* has a great potential to reduce wheat yield in Adana Province in Turkey. In the plots treated with the nematicide, grain yields were higher than those of the nontreated plots; furthermore, reproduction rates of the nematode were in the range of 0.26–0.46 in the treated plots, suggesting that the nematode occurred in the experimental plots and was controlled by the nematicide application.

Reductions in grain yield of the different wheat varieties were calculated by comparing yield in the nontreated plots and the treated plots. In this study, reductions in grain yield of wheat varieties varied between 4.3% and 25.7% over the 2 growing seasons. In other studies, yield losses in wheat caused by *H. avenae* were reported to be between 15% and 20% in Pakistan (Maqbool, 1988), 40% and 90% in Saudi Arabia (Ibrahim et al., 1999), and 23% and 50% in Australia (Nicol et al., 2002). Thus, our work demonstrates that the damage from *H. avenae* is lower in Turkey than in the other countries mentioned above. The reproduction rates of the nematode observed in the present study were also lower than those observed in the above-mentioned countries because the reproduction of *H. avenae* is affected by soil texture (Namouchi-Kachouri et al., 2009). It was suggested that yield losses caused by *H. avenae* were up to 80% in sandy soils (Namouchi-Kachouri et al., 2009) but up to only 49.5% in clayey soil (Hassan et al., 2010). In the present study, the soil texture of the experimental area was mostly clayey (60%), and the yield reduction is comparable to those of the previous studies done on similar soil.

According to the regression analysis, Adana-99, Ceyhan-99, and Silverstar showed better performance based on grain yields. The reproduction factors of *H. avenae* in Adana-99 and Ceyhan-99 were positively correlated with grain yield, as was that of Silverstar, which

Table. The effects of different densities and reproduction factors of *Heterodera avenae* on the grain yield of wheat varieties under field conditions across the 2011/2012 and 2012/2013 growing seasons[1,2].

Treatment	Varieties	Initial nematode density (Pi)[3]	Wheat Yield		Final nematode density (Pf)[3]	Reproduction factor (Rf = Pf/Pi)
			kg/ha	% reduction		
Treated	Silverstar	35.2	5060a		9.6	0.27
	Seri-82	27.7	4183b		12.8	0.46
	Ceyhan-99	28.3	5024a		10.5	0.37
	Osmaniyem	29.4	3991b		9.5	0.32
	Karatopak	27.1	3493b		8.9	0.32
	Adana-99	34.2	6037a		9.1	0.26
Not treated	Silverstar	35.1	4840ab	4.34	91.20	2.65
	Seri-82	36.1	3108c	25.70	104.60	2.90
	Ceyhan-99	30.2	4540ab	9.63	103.80	3.44
	Osmaniyem	32.6	3093d	22.50	96.17	2.95
	Karatopak	30.8	2927d	16.21	95.40	3.10
	Adana-99	34.5	5620a	6.9	110.20	3.20

[1]Values are means of 6 replicates. Means with the same letter in the same column are not significantly different at P = 0.05 using the LSD test.
[2]All values show the average of both years with 6 replicates.
[3]Pi and Pf = number of eggs and second-stage juveniles per gram of soil in each plot, respectively.

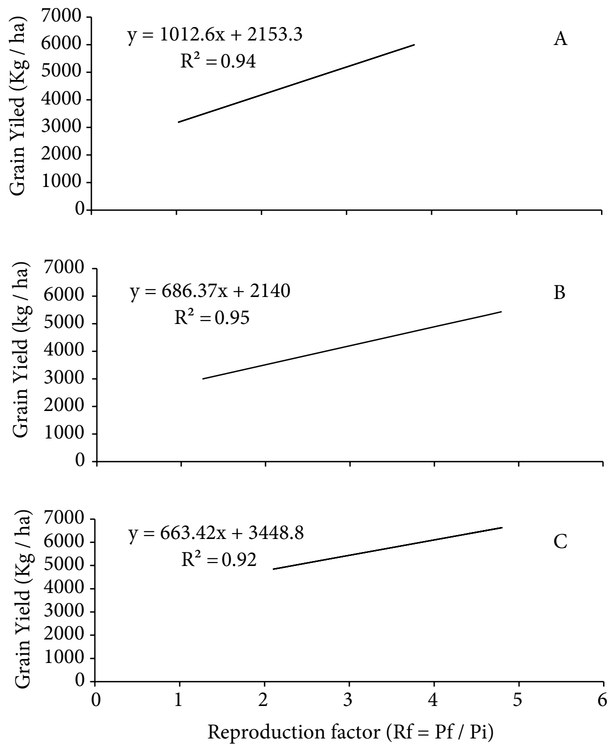

Figure 1. Positive linear regressions between grain yield and the reproduction factor of *Heterodera avenae* in 3 wheat varieties. All values of R^2 were significant at P < 0.001. All values show the average of both years with 6 replicates. A = Silverstar, B = Ceyhan-99, C = Adana-99.

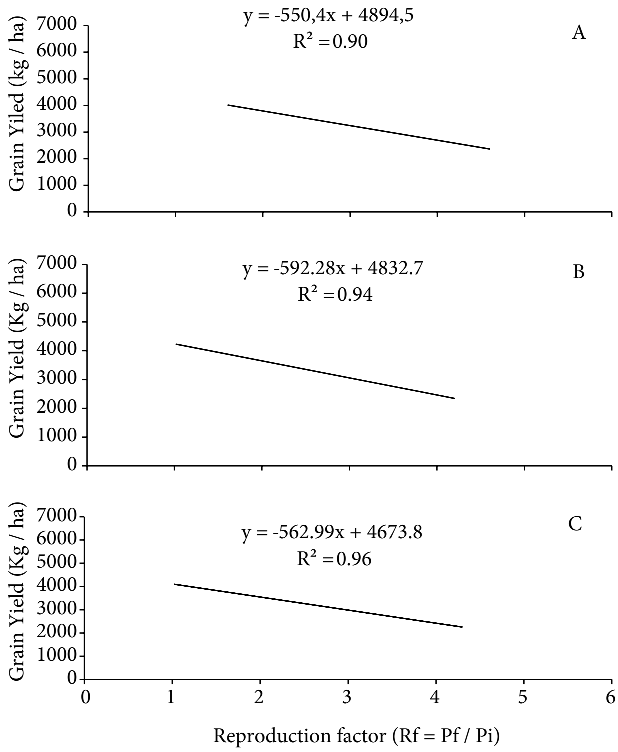

Figure 2. Negative linear regressions between grain yield and the reproduction factor of *Heterodera avenae* in 3 wheat varieties. All values of R^2 were significant at P < 0.001. All values show the average of both years with 6 replicates. A = Seri-82, B = Osmaniyem, C = Karatopak.

is a known tolerant variety. This means that Adana-99 and Ceyhan-99 could be accepted as tolerant varieties. Toktay et al. (2012) found that Adana-99 and Ceyhan-99 are moderately resistant to *Pratylenchus thornei* under laboratory conditions. Additionally, İmren et al. (2013) found that Adana-99 is moderately resistant to *H. avenae* in in vitro conditions. It has been suggested that Adana-99 could be used in wheat breeding programs to develop a variety resistant to *H. avenae*.

Our results show that *H. avenae* is potentially significant for yield losses in Adana Province in Turkey. It is necessary to develop or introduce resistant or tolerant cultivars as well as use chemical and biological control methods to develop effective integrated control strategies to protect cereal crops.

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