Relative susceptibility and tolerance of thirteen Egyptian wheat cultivars to the cereal cyst nematode (*Heterodera avenae* Woll.)

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**ABSTRACT**

Relative susceptibility and tolerance of thirteen Egyptian wheat cultivars to the cereal cyst nematode *Heterodera avenae* were determined under greenhouse conditions. Resistance/susceptibility was assessed as relative susceptibility (RS) to the standard susceptible control cultivar Sakha-93. The results showed that *H. avenae* infected and well reproduced on all tested cultivars, so all of them were designated as susceptible cultivars. Cultivars Misr-1, Misr-2, Misr-3 and Shandaweel were highly susceptible to *H. avenae*, as their (RS) were more than 92%. Data also indicated that cultivars Sakha-8, Sakha-93, Sakha-95, Shandaweel and Giza-168 were ranked as less tolerant according to their tolerance index. Other wheat cultivars, Giza-171, Misr-1, Misr-2, Misr-3, Seds-1, Seds-12, Seds-13 and Seds-14 were ranked as intolerant (sensitive) cultivars, as their tolerance indices were more than one.

**Keywords:** Wheat, *Heterodera avenae*, susceptibility, tolerance, Egypt.

**Introduction**

The cereal cyst nematode *Heterodera avenae* Woll. is considered one of the major disease agents of wheat throughout the world (Nicol and Rivoal, 2008). It has been early detected in Europe and Canada, now it is disseminated in most wheat-growing areas of the world within temperate, semi-arid, tropical and subtropical regions including Australia, Canada, USA, Israel, Japan and many European countries (Holdeman & Watson, 1977; Meagher, 1977), as well as India (Sharma & Swarup, 1984), China (Peng et al., 2007), many countries within North Africa and Western Asia including Morocco, Tunisia, Libya and Pakistan (Sikora, 1988), Iran (Ahmadi and Maafi, 2014), Turkey (Abidou et al., 2005), Algeria (Mokabli et al., 2001), Saudi Arabia (Ibrahim et al., 1999).

Yield losses due to this nematode were 15-20% on wheat in Pakistan (Maqbool, 1988), 40-92% in Saudi Arabia (Ibrahim et al., 1999), 23-50% in Australia (Meagher, 1972), and 24% in Oregon in Pacific North West (Smiley et al., 2005). The annual loss in wheat yield was equivalent to USD 70 million in Australia, USD 4.5 million in Europe, USD 9.6 in India (CAB International, 1999), and USD 3.4 million in the Western USA (Smiley, 2009).

In Egypt, the cereal cyst nematode *H. avenae* was first recorded on wheat and barley in Beheira province, northwestern Egypt (Ibrahim et al., 1986). It was also recorded on wheat in a survey conducted in Alexandria and Beheira provinces (Ibrahim and Handoo, 2007). Recently it was recognized in Ismailia province northeastern Egypt (Baklawa et al., 2012a; Korayem & Mohamed, 2015). The reduction in grain yield ranged between 24-40% at initial population of 20 juveniles /ml soil in pot experiment (Baklawa et al., 2012b), it also was 31.5% at nematode density of 8 juveniles (in average) per 1 g soil under field conditions (Korayem, 2019).

In many of the countries where *H. avenae* occurs like Egypt, wheat is considered one of the major food staple, thus the control of this nematode is of considerable importance to improve the production and livelihood of the farming communities. The use of resistant cultivars which leads to a reduction of nematode populations offers one of the most effective control methods with minimum cost or equipment (Nicol & Rivoal, 2008). Resistance is defined as the ability of a cultivar to suppress or prevent reproduction of the nematode. In contrast, when the nematode is capable of multiplying the
variety is considered susceptible. Ideally resistance should be combined with tolerance. Tolerance is defined as the ability of a plant to withstand or recover from nematode invasion and to yield well in comparison with non-infected plants (Trudgill, 1991). In contrast, when the yield is greatly reduced by the nematode, the variety is considered intolerant (sensitive). Grain yield is used to define tolerance in wheat. Resistance and tolerance are genetically independent and both are required to prevent or to reduce the damage to future plantings (resistance) as well as for optimal performance in existing plantings (tolerance) (Smiley et al., 2013). The aim of this study is to evaluate different Egyptian wheat cultivars for their resistance / tolerance to the wheat cyst nematode *Heterodera avenae*.

Materials and Methods

Nematode populations:
Population of *Heterodera avenae* was collected from a wheat-growing area heavily infected with nematodes from Ismailia province. This population was previously classified as pathotype Ha13 (Baklawa et al., 2012a). Nematode cysts were extracted from soil according to method of Shepherd (1970). Nematode cysts were dried at room temperature (20 ± 2°C) and kept at 7°C until further use. Ten cysts were squashed according to Seinhorst and Den Ouden (1966) and the total numbers of eggs and second stage juveniles (J$_2$) per cyst were counted. The average of eggs and J$_2$ was 100 per cyst.

Plant materials:
Thirteen wheat cultivars i.e. Seds-1, Seds-12, Seds-13, Seds-14, Misr-1, Misr-2, Misr-3, Sakha-8, Sakha-95 Sakha-93, Giza-168, Giza-171, and Shandaweel used in the study, were obtained from the Crop Research Institute, Ministry of Agriculture, Egypt.

Experimental set-up:
The experiment was done in plastic pots (13 cm diam) containing one kg loamy soil. Cysts of *H.avenae* populations were added to the soil to give initial population density of 4 juveniles per g soil. Then seeds of wheat cultivars previously mentioned were grown in pots. Each pot contained 5 seedlings of the respective cultivar and three pots were used as replicates for each cultivar. For each cultivar, three pots of non-infected soil served as control. Pots were arranged in a greenhouse at 20 ± 5°C fertilized with NPK (20:20:20) fertilizer and watered as necessary with tap water.

Data collection and analysis:
About five months after planting, the final nematode population (Pf) were determined in each pot. Cysts were extracted from soil using the floatation technique and squashed as previously mentioned, and the number of eggs and juveniles were recorded. Resistance was assessed as relative susceptibility (RS) to the standard susceptible control cultivar sakha-93 which was ranked as susceptible host to *H. avenae* (Baklawa et al., 2012b). RS= (Pf on the test cultivar/Pf on susceptible control “Sakha-93”)* 100, where Pf = final population density of eggs +J$_2$ / g soil. A rating system based on the relative susceptibility (RS) was used to characterize the host response of different wheat cultivars. Cultivars with RS less than 5% were considered resistant, cultivars with RS between 6-20% were considered moderately resistant, cultivars with 21-50% RS were considered moderately susceptible, while cultivars with RS more than 51% were considered as susceptible (Lüke, 1976).

The grain yield per pot was recorded to determine the damage potential of *H. avenae* on wheat cultivars. The percentages of reduction in grain yield were calculated as follows: Red(%)= (GC – GI/GC)* 100, where Red(%)= percentage of reduction, GC= grain yield of control, GI= grain of infected plant. The tolerance index (TI) of a cultivar was calculated as follows: TI= (GC- GI/GC)* 100 / Pf, where TI = tolerance index, GC and GI = grain yield of control and infected plants, respectively, Pf= final population density (eggs + j$_2$/1 g soil). Wheat cultivar with TI less than 0.5 considered tolerant, cultivar with TI between 0.5-1.0 considered less tolerant, what cultivar with TI more than one was considered sensitive to *H. avenae* (Dixon et al., 1990).
Results

Relative susceptibility of thirteen wheat cultivar to *H. avenae*

Final population densities of *H. avenae* and relative susceptibility of tested wheat cultivars are presented in table (1). Data indicated that all tested cultivars were designated as susceptible cultivars, as their relative susceptibility (RS) was more than 51%. High relative susceptibilities were recorded in cultivars Misr-1, Misr-2, Misr-3 and Sakha-95 as RS were 92.0%, 101.0%, 97.0% and 92.0%, respectively. Other wheat cultivars had RS ranged between 55.2-67.2%.

Table 1: Final population densities of *H. avenae* and relative susceptibility of thirteen wheat cultivars

| Wheat cultivar | Pf  | RS   | Suitability rank |
|----------------|-----|------|------------------|
| Giza-168       | 11.1| 55.2 | S                |
| Giza-171       | 13.1| 65.2 | S                |
| Misr-1         | 18.5| 92.0 | S                |
| Misr-2         | 20.3| 101.0| S                |
| Misr-3         | 19.5| 97.0 | S                |
| Sakha-8        | 16.5| 82.1 | S                |
| Sakha-93       | 20.1| 100.0| S                |
| Sakha-95       | 18.5| 92.0 | S                |
| Shandaweel     | 13.5| 67.2 | S                |
| Seds-1         | 12.5| 62.2 | S                |
| Seds-12        | 13.1| 65.2 | S                |
| Seds-13        | 13.2| 65.7 | S                |
| Seds-14        | 12.4| 61.7 | S                |

Pf=final population density (eggs + juveniles / 1 g soil)
RS= Relative susceptibility % = Pf on test cultivar /Pf on susceptible control (Sakha-93)* 100.
Rank: R= resistant (0-5% RS), MR=moderately, resistant (6-20% RS), MS=moderately, susceptible (21-50% RS), S=susceptible, (more than 51%), according to Lüeke (1976).

Effect of *H. avenae* on wheat yield

Grain yield of thirteen wheat cultivars are presented in table (2). The response of wheat cultivars to the nematode infection was differed. The reduction in grain yield ranged between 6.3% to 21.1%. High reductions 20.0, 20.5 and 21.1% were occurred at cultivars Misr-1, Misr-2 and Misr-3, respectively, while less reduction 6.3% was occurred in Giza-168 cultivar, reduction in grain yield of other cultivars ranged between 11.1%-15.0%.

Table 2: Effect of *H. avenae* on grain yield of different wheat cultivars

| Wheat cultivar | Mean of grain yield / pot (g) | % Reduction |
|----------------|-------------------------------|-------------|
|                | Healthy | Infected |                  |
| Giza-168       | 6.4     | 6.0      | 6.3              |
| Giza-171       | 6.8     | 5.9      | 13.2             |
| Misr-1         | 6.0     | 4.8      | 20.0             |
| Misr-2         | 6.8     | 5.4      | 20.5             |
| Misr-3         | 7.6     | 6.0      | 21.1             |
| Sakha-8        | 6.0     | 5.2      | 13.3             |
| Sakha-93       | 8.0     | 6.8      | 15.0             |
| Sakha-95       | 7.2     | 6.4      | 11.1             |
| Shandaweel     | 3.6     | 3.2      | 11.1             |
| Seds-1         | 6.0     | 5.2      | 13.3             |
| Seds-12        | 5.6     | 0.8      | 14.3             |
| Seds-13        | 6.0     | 1.2      | 13.3             |
| Seds-14        | 6.4     | 5.6      | 12.5             |

% Reduction = percentage of reduction in grain yield of infected compared to control (healthy)

Tolerance of wheat cultivars to *H. avenae*

Tolerant index (TI) of wheat cultivars is presented in table (3). Data showed that wheat cultivars sakha-8, sakha-93 sakha-95, Shandaweel and Giza – 168 had TI ranged between 0.5-1, and they were ranked as less tolerant according to Dixon *et al.*, (1990). The rest of wheat cultivars had TI
ranged between 1.01-1.09, so they ranked as sensitive (intolerant), they were Giza-171, Misr-1, Misr-2, Misr-3, Seds-1, Seds-12, Seds-13 and Seds14.

**Table 3:** Tolerance index of wheat cultivars to *H. avenae*  

| Wheat cultivar | Tolerance index | Tolerance rank  |
|----------------|-----------------|----------------|
| Giza-168       | 0.57            | Less tolerant  |
| Giza-171       | 1.01            | Sensitive      |
| Misr-1         | 1.08            | Sensitive      |
| Misr-2         | 1.01            | Sensitive      |
| Misr-3         | 1.08            | Sensitive      |
| Sakha-8        | 0.8             | Less tolerant  |
| Sakha-93       | 0.75            | Less tolerant  |
| Sakha-95       | 0.60            | Less tolerant  |
| Shandaweel     | 0.82            | Less tolerant  |
| Seds-1         | 1.06            | Sensitive      |
| Seds-12        | 1.09            | Sensitive      |
| Seds-13        | 1.01            | Sensitive      |
| Seds-14        | 1.01            | Sensitive      |

* Data are adapted from tables 1 and 2. Tolerance index (TI)= Percentage reduction in grain yield of cultivars/Pf  
Tolerance ranking: tolerant (TI from 0-0.5), less tolerant (TI from 0.5-1) and sensitive (TI >1).

**Discussion**

Our study re-confirmed that the cereal cyst nematode *Heterodera avenae* is one of the major disease agents of wheat worldwide, considered a major limiting factor of wheat in some regions of the world. So, the control of this nematode is very essential to improve the income of the farming communities (Yadav et al., 2002; Nicol & Rivoal, 2008). Many different control options such as chemical, cultural, genetic (resistance/ tolerance) and biological control are now available, the use of resistant/tolerant cultivars offers one of the most effective control methods environmentally safe, applicable with minimum cost or equipment (Nicol & Rivoal, 2008).

Our data showed that all tested Egyptian wheat cultivars were ranked as susceptible cultivars to *H. avenae* infection, moreover all of them were assessed as intolerant or less tolerant cultivars. Therefore to initiate breeding program for resistance to *H. avenae*, the most urgent need is to search for sources of resistance to *H. avenae* among Egyptian wheat germplasm or to introduce resistant germplasm from another cereal. Resistance gene Cre3 from the cereal cultivar *Aegilops tauschii* and gene Cre6 from *Ae. ventricosa* 5Nv provide resistance against pathotype Ha13 (Eastwood et al., 1991; Ogbonnaya et al., 2001).

In order that plant resistance to be effective and durable, more knowledge is needed on the virulent populations. The virulence of populations can be determined by their ability to overcome resistance genes, such virulent population may be classified as pathotypes. The differentiation of pathotypes can be done using an International Test Assortment of barley, oat and wheat cultivars with respective resistance genes. (Cook and Rivoal, 1998; Nicol, 2002; Smiley et al., 2011).

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