DAMAGE POTENTIAL AND REPRODUCTION OF *HETERODERA AVENAE* ON WHEAT UNDER SYRIAN FIELD CONDITIONS

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Summary. Three trials were conducted to asses the effects of three levels of initial population densities (*Pi*) of *Heterodera avenae* (15.3, 27.6, 40.4 eggs and juveniles/g soil) on growth and yield of two wheat cultivars ('Sham 3' of durum wheat and 'Sham 6' of bread wheat) and nematode reproduction, under field conditions in North East Syria, during the growing season 2006-2007. Reduction of yield components of both wheat cultivars increased with the increase of *Pi* of *H. avenae* and reached maxima of 56.6% and 49.6% in grain yield and 49.5% and 44.6% in straw yield in durum and bread wheat, respectively, at the greatest initial population density of 40.4 eggs and juveniles/g soil. A similar trend was observed for the reduction of plant height in both cultivars. Durum wheat was more sensitive than bread wheat to the nematode. Significant negative linear regressions were observed between *Pi* of *H. avenae* and yield components of both wheat cultivars. Final population densities (*Pf*) of *H. avenae* were positively correlated with *Pi*, whereas reproduction factors (*Rf*) were negatively correlated with *Pi* on both wheat cultivars.

Keywords: Cereal cyst nematode, nematode dynamics, yield loss.

Wheat (*Triticum* spp.) is one of the most important field crops in Syria, where different cultivars (durum and bread) are grown under irrigated and non-irrigated conditions throughout most of the country but most intensively in North East Syria, Al-Hassakeh Governorate. In 2007, the area under wheat cultivation in Syria was 1,485,991 ha yielding 2,139,380 t (Anonymous, 2007).

The cereal cyst nematode (CCN), *Heterodera avenae* Woll., is distributed worldwide and has been reported as the most damaging nematode on wheat, especially in semi-arid regions, where it can increase drought stress (Rivoal and Cook, 1993; Nicol, 2002). In Syria, *H. avenae* has also been found to attack wheat and barley in many regions, with soil population densities that in some fields can be as large as 85 eggs and juveniles/g soil (Hassan, 2008), which suggests a high economic impact on host crops. Yield losses caused by *H. avenae* to wheat are reported to be in the range 15-20% in Pakistan (Maqbool, 1988), 40-90% in Saudi Arabia (Ibrahim *et al.*, 1999) and up to 90% at about 60 eggs/g soil in Tunisia (Namouchi-Kachouri *et al.*, 2009).

The relationship between the initial population density (*Pi*) of CCN and growth and yield of wheat is very important in determining the economic impact of the nematode on this crop (Ibrahim *et al.*, 1999) and, therefore, is basic information for any tactic to manage the nematode. Such information was lacking for *H. avenae* on wheat under Syrian field conditions. Therefore, the objective of this work was to estimate the impact of three initial population densities of *H. avenae* on yield components of wheat and nematode reproduction under field conditions of North East Syria. However, in the field it is difficult to compare the yield of infested plots with that of non-infested ones as it may not be possible to identify suitable plots. As nematicides are known to be effective for the control of nematodes, including cereal cyst nematodes (Meagher *et al.*, 1978; Nicol, 2002; Smiley *et al.*, 2005), comparison of non-treated with treated plots, as in our experiment, is also useful in the assessment of yield losses caused by nematodes.

MATERIALS AND METHODS

The experiment was arranged in the third agro-ecological zone, Al-Hassakeh governorate, North East Syria, with an average annual rainfall of 283 mm during the growing season. Three fields of wheat (400 m^2 each), naturally infested with different densities of *H. avenae*, were selected during the 2006/2007 growing season. These fields were selected because preliminary samplings demonstrated that other nematodes known to affect wheat in the Mediterranean region, such as *H. latipons* Franklin, *H. filipjevi* (Madzhidov) Stelter, *Pratylenchus neglectus* (Rensch) Filipjev *et* Schuurmans Stekhoven), *P. thornei* Sher *et* Allen and *Meloidogyne artiellia* Franklin, which are rather common in Syria, were not present. The soil in these fields was clayey, with pH 7.5, EC 0.85-0.91 mm/s, 1.1% organic matter, 60% clay, 11% silt, and 30% sand. The soil was prepared as usually done in the area and each field was divided into sixteen experimental plots, each of 20 m^2 and spaced 0.5 m apart.

Composite soil samples, each of five or ten sub-samples taken to a depth of 20-30 cm, were colleted from each plot at the beginning of the growing season, to determine *Pi*s, and also after harvest to assess final population densities (*Pf*s). Each soil sample was thoroughly mixed, any clods broken and air dried. Cysts were extracted from four sub-samples of 200 g with a Fenwick can (Southey, 1986), separated from soil debris and counted. Thereafter, cysts were crushed in a tissue grinder in 50 ml of tap water and eggs and second-stage juveniles in three 1-ml aliquots were counted under a stereo-microscope. *Pi*s and *Pf*s were expressed as numbers of eggs and second-stage juveniles/g soil and reproduction factors (*Rf*s) were also calculated (Scholz, 2001).

The three fields were found to be infested with means of 15.3, 27.6 or 40.4 eggs and juveniles/g soil. In each field, eight plots were treated with the nematicide Vydate (granules containing 10% of the a.i. oxamyl) and eight were left untreated. The nematicide was applied one day before sowing at the rate of 1.5 g/m^2 (of the commercial product), evenly distributed on the surface of the plot and then incorporated into the top 15 cm soil. On 11 December 2006, of the treated and untreated plots, four were sown by hand with the cv. Sham 6 of durum wheat [*Triticum turgidum* L. subsp. *durum* (Desf.) Husn.] and four with the cv. Sham 3 of bread wheat (*Triticum aestivum* L.), each at the rate of 18 g seeds/m^2. Within each field, treatments were replicated four times according to a randomized block design. During the growing season, all cultural practices commonly used in the region were followed.

At harvest (13 May 2007), the height of 10 plants per plot was measured and averages per plot and treatment were calculated. All plants of a plot were removed manually. After threshing with a small plot combine (Wintersteiger), grain yield (kg/ha), straw yield (kg/ha) and weight of 1000 kernels (g) per plot were recorded, averages per treatments determined and reduction percentages of non-treated plots compared to treated plots of the same *Pi* were calculated.

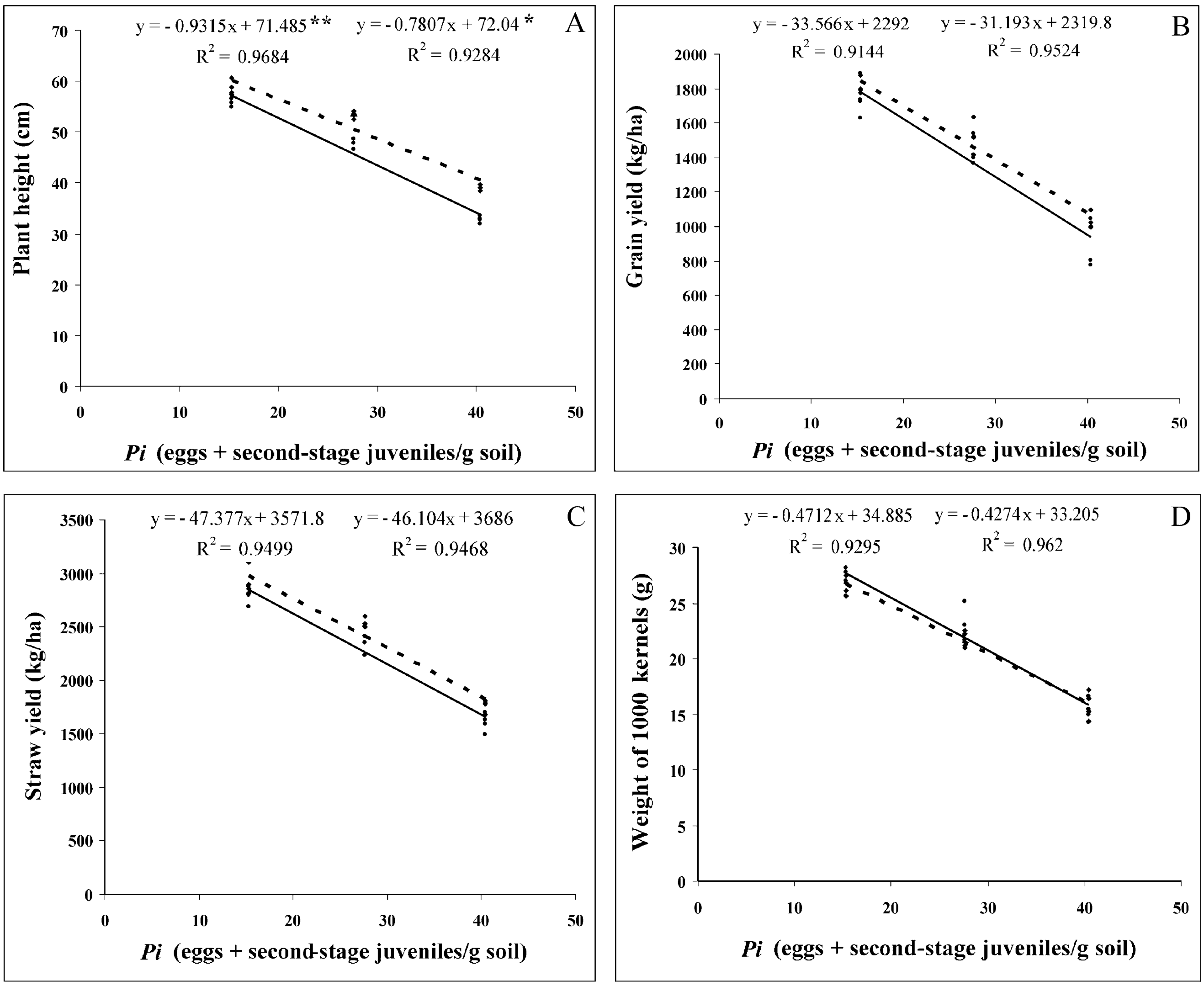

Fig. 1. Relationship between initial population densities (*Pi*) of *H. avenae* and yield components of durum wheat (cv. Sham 3——) and bread wheat (cv. Sham 6 ------), A: Plant height; B: Grain yield; C: Straw yield; D: Weight of 1000 kernels. (All values of R^2 were always significant at $P<0.001$).
*: The right regression equation is for bread wheat.
**: The left regression equation is for durum wheat.

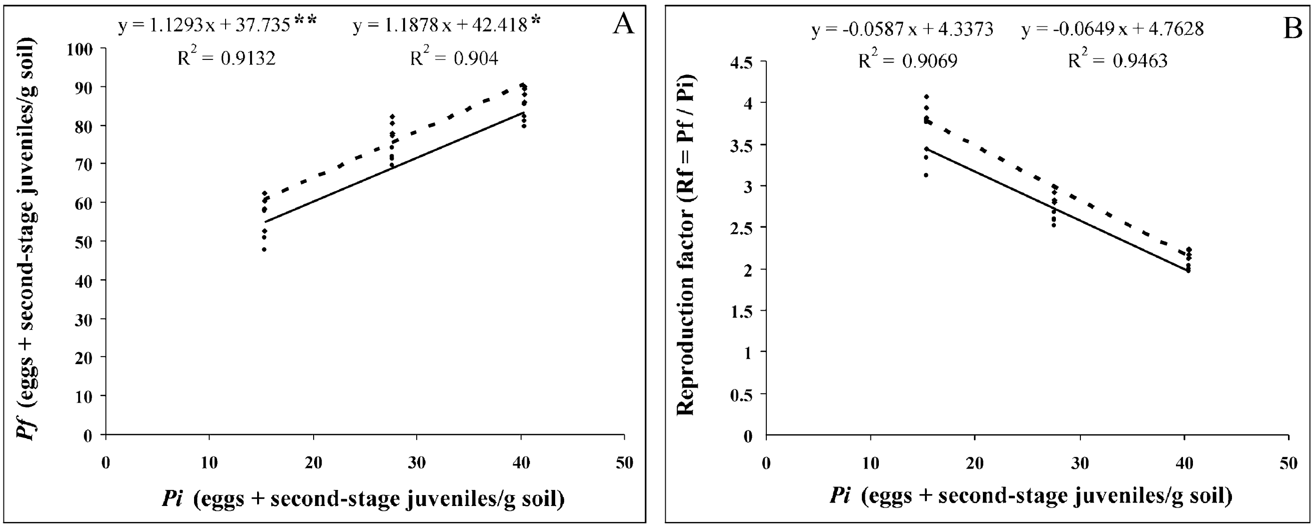

Fig. 2. Relationship between initial population densities (*Pi*) of *H. avenae* and A: Final population densities (*Pf*); B: Nematode reproduction factor (*Rf*) on durum wheat (cv. Sham 3 ——) and bread wheat (cv. Sham 6 ------). (Both values of R^2 were significant at P<0.001).
*: The right regression equation is for bread wheat.
**: The left regression equation is for durum wheat.

All data were subjected to analysis of variance and means compared with the protected LSD at the 5% level. Regression analyses were also performed to describe the relationship between *Pi* and yield components of each wheat cultivar, *Pf* and *Rf*.

RESULTS

Yield components of durum and bread wheat in plots treated with Vydate were significantly higher (P <0.001) than in untreated plots and similar in the three differently infested fields. In the untreated plots, yield components of both wheat cultivars were larger at the smallest initial population density (15.3 eggs and second-stage juveniles/g soil) and decreased with the increase of the initial population densities (to 27.6 and 40.4 eggs and second-stage juveniles/g soil) (Tables I and II).

The different densities of *H. avenae* in the three fields caused reductions in yield components of both Sham 3 (hard wheat) and Sham 6 (bread wheat) that were significantly different (P <0.001) from each other. Also, yield reduction of hard wheat appeared to be greater than that of bread wheat at all *Pi*s. At the smallest *Pi* (15.3 eggs and second-stage juveniles/g soil), reductions were of 10.6% and 9.8% for plant height, 16.7% and 11.7% for grain yield, 12.6% and 8.8% for straw yield and 14.6% and 14.7% for the weight of 1000 kernels in durum and bread wheat, respectively (Tables I and II). Reductions of 23.7% and 17.7% in plant height, 30.7% and 25.6% in grain yield, 25.6% and 20.6% in straw yield and 27.5% and 26.5% in weight of 1000 kernels in durum and bread wheat, respectively, were observed in the field infested with 27.6 eggs and second-stage juveniles/g soil, (Tables I and II). The greatest reductions were observed at the largest *Pi* (40.4 eggs and second-stage juveniles/g soil) and were 48.1% and 39.6% in plant height, 56.6% and 49.6% in grain yield, 49.5% and 44.6% in straw yield and 51.6 and 46.5% in weight of 1000 kernels of durum and bread wheat, respectively (Tables I and II).

At harvest, the population densities of *H. avenae* had decreased in all treated plots while they increased in all non-treated plots and were larger the larger the nematode populations at sowing. Also, final population densities in plots sown to durum wheat (cv. Sham 3) were always greater than those in plots sown to bread wheat (cv. Sham 6). As a consequence, the reproduction factor (*Rf*) had the same trend (Tables I and II).

Regression analysis showed that all yield components were negatively correlated with *Pi* of *H. avenae* (Fig. 1A, B, C, D). In the untreated plots, the final population densities of the nematode (*Pf*) were positively correlated with *Pi* on both cultivars (Fig. 2A), while the reproduction factor (*Rf*) was negatively correlated with *Pi* (Fig. 2B) with values of R^2 always highly significant (P <0.001) (range 0.904-0.9684).

DISCUSSION

Our study indicated that *H. avenae* has potential to decrease growth and yield of wheat in Syria. In the plots treated with the nematicide Vydate, growth and yield of wheat were similar at all *Pi*s and the reproduction rates of the nematode were in the range 0.15-0.27, thus suggesting that the nematicide controlled the nematode to

Table I. Effects of different densities and reproduction of *Heterodera avenae* on yield components of durum wheat (cv. Sham 3) under field conditions during the growing season 2006/2007.[1]

Treatment	Initial nematode density (*Pi*)[2]	Plant height		Weight of 1000 kernels		Grain yield		Straw yield		Final nematode density (*Pf*)[2]	Reproduction factor (*Rf = Pf/Pi*)
		(cm)	% reduction	(g)	% reduction	(kg/ha)	% reduction	(kg/ha)	% reduction		
Treated	15.3	62.8 a		31.7 a		2096 a		3193 a		4.2	0.27
	27.6	62.8 a		31.7 a		2065 a		3189 a		5.4	0.20
	40.4	62.6 a		31.6 a		2086 a		3178 a		6.2	0.15
Non-treated	15.3	56.1 b	10.6	27.1 b	14.6	1746 b	16.7	2791 b	12.6	58.4	3.82
	27.6	47.9 c	23.7	23 c	27.5	1430 c	30.7	2374 c	25.7	79.5	2.88
	40.4	32.8 d	48.1	15.3 d	51.6	904 d	56.6	1604 d	49.5	88.3	2.19
$LSD_{0.05}$	-	1.915		1.336		108.1		132.2			

[1] Values are means of four replicates. Means in a column followed by the same letter are not different (P <0.001) according to Fisher's protected LSD.
[2] *Pi* and *Pf* = Number of eggs and second-stage juveniles/g soil in each field.

Table II. Effects of different densities and reproduction of *H. avenae* on yield components of bread wheat (cv. Sham 6) under field conditions during the growing season 2006/2007.[1]

Treatment	Initial nematode density (*Pi*)[2]	Plant height		Weight of 1000 kernels		Grain yield		Straw yield		Final nematode density (*Pf*)[2]	Reproduction factor (*Rf = Pf/Pi*)
		(cm)	% reduction	(g)	% reduction	(kg/ha)	% reduction	(kg/ha)	% reduction		
Treated	15.3	65 a		29.7 a		2051 a		3200 a		3.7	0.24
	27.6	64.9 a		29.6 a		2046.2 a		3193 a		5	0.18
	40.4	64.7 a		29.5 a		2041.4 a		3186 a		6.5	0.16
Non-treated	15.3	58.6 b	9.8	26.5 b	10.7	1810.2 b	11.7	2919 b	8.8	53.6	3.5
	27.6	53.4 c	17.7	21.7 c	26.5	1522.4 c	25.6	2534 c	20.6	71.7	2.6
	40.4	39.1 d	39.6	15.8 d	46.6	1028.5 d	49.6	1764 d	44.6	82	2.03
$LSD_{0.05}$	-	1.922		1.555		77.64		78.6		-	-

[1] Values are means of four replicates. Means in a column followed by the same letter are not different (P <0.001) according to Fisher's protected LSD.
[2] *Pi* and *Pf* = Number of eggs and second-stage juveniles/g soil in each field.

a great extent. As reduction percentages of wheat yield at the different infestation levels were calculated by comparing yield in non-treated plots with that in treated plots, the observed yield reductions can be considered representative of the severity of the nematode in Syria. Reduction of yield components were dependent on *Pi* levels and were significant even at the smallest *Pi* (15.3 eggs and second-stage juveniles/g soil), thus indicating that this population density is well above the tolerance limit of wheat to the nematode, which, under similar climatic conditions (in Tunisia), has been reported to be of 1.3 eggs/g soil (Namouchi-Kachouri *et al*., 2009). Both durum wheat cv. Sham 3 and bread wheat cv. Sham 6 were very susceptible to *H. avenae*. However, the reduction ratios of yield components caused by *H. avenae* to durum wheat (Sham 3) were larger than those observed on bread wheat (Sham 6). Similar results were found by Scholz (2001) with *H. latipons*.

The impact of *H. avenae* on wheat in Syria appears to be less severe than in other countries. In our experiments, yield reductions of bread and durum wheat were 11.7-16.7%, 25.6-30.7% and 49.6-56.6% at 15.3, 27.6 and 40.4 eggs and second-stage juveniles/g soil, respectively. At similar *Pi*s, in Australia, yield reductions caused by *H. avenae* (now *H. australis* Subbotin, Sturhan, Rumpenhorst *et* Moens) were estimated at 55, 58, and 62% (Meagher and Brown, 1974), in Saudi Arabia (Ibrahim *et al*., 1999), under irrigated conditions (second year), at 40, 67 and 80%, and in Tunisia (Namouchi-Kachouri *et al*., 2009), yield losses of durum wheat were estimated at 42, 60 and 80%. Although different wheat cultivars may account for the observed differences by independent authors, it is most probable that soil texture, especially clay content, may have been the most important factor in determining the lower yield losses observed in Syria. In our country, the soil was clayey (60% clay content), while it was sandy loam in Australia, loamy sand (14% clay) in Saudi Arabia, and sandy or loamy in Tunisia.

The negative correlation between *Pi* and yield components reported in our study has also been demonstrated in many previous studies (Fisher, 1987; Al-Yahya *et al*., 1998; Al-Hazmi *et al*., 1999; Ibrahim *et al*.,1999 ; Smiley *et al*., 2005; Namouchi-Kachouri *et al*., 2009). In untreated plots, *H. avenae* reproduced well on both wheat cultivars (durum and bread), and *Pf* increased as *Pi* increased, but *Rf* values were negatively correlated with *Pi*, thus confirming previous findings (Rivoal and Sarr, 1988; Magi, 1989). However, the reproduction rates of the nematode observed in our study were also less than those observed in the above-mentioned countries (Ibrahim *et al*., 1999), probably because of already mentioned factors and of the soil texture. Namouchi-Kachouri *et al*. (2009) demonstrated that reproduction of *H. avenae* is affected by soil texture.

Our study shows that *H. avenae* is a real threat to wheat production in Al-Hassakeh governorate, North East Syria, due to the high levels of infestation by *H. avenae* common in the area and caused by the prevalence of cereal monoculture (Hassan, 2008). Furthermore, synchronization between hatching of cereal cyst nematode and the sowing period of wheat, as has been found under Mediterranean conditions, would result in heavy early infection and severe crop losses (Rivoal, 1982). This suggests the need to develop or introduce resistant, or at least tolerant, cultivars as well as to develop effective integrated control strategies to protect cereal crops.

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Accepted for publication on 26 March 2010.