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EFFECTS OF CEREAL CYST NEMATODE ON GROWTH AND PHYSIOLOGICAL ASPECTS OF WHEAT UNDER FIELD CONDITIONS

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Abstract

Effect of *Heterodera avenae* the cereal cyst nematode (CCN) on growth and physiological aspects of wheat cv. Yecora Rojo were studied under field conditions at Al-Kharj, near Riyadh, Saudi Arabia. *H. avenae* at increasing initial population densities of 00, 75, 225 cysts / 250 cm^3 soil, reduced the number of tillers / plant and suppressed the fresh and dry weight of shoot as well as leaf area but increased the water content of shoot at heading and dough stages. However, fresh and dry weight of root increased with nematode infection at heading stage and decreased at dough stage but an opposite trend was found with the water content of roots. Root : shoot ratio increased with nematode infection at heading stage. At dough stage, plant height, total chlorophyll content and intercepted light by leaves were suppressed but temperature of plant canopy increased compared to the non-infected controls. Nematode infection caused a significant decrease in the concentrations of N, Fe, Mn, and Cu in shoots at dough stage but increased the concentration of Zn in the grains as compared to the control.

Wheat (*Triticum aestivum* L.) is one of the most important field crops grown in Saudi Arabia. *Heterodera avenae* Wollenweber 1924 the cereal cyst nematode (CCN) has been found to suppress the growth of root and shoot with consequent reduction in the yield of wheat in different parts of the world (Amir & Sinclair, 1996; Sabova *et al.*, 1981; Youssif, 1987). In Saudi Arabia, *H. avenae* also has been found to attack wheat in different regions in the country with almost all the locally grown wheat cultivars susceptible to this nematode (Al-Hazmi, 1992; Al-Hazmi *et al.*, 1994; Osman *et al.*, 1994; Youssif, 1987). The nematode has been found to cause more than 90% yield loss in some wheat fields in Al-Kharj region (unpublished data).

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Plants affected by *H. avenae* show symptoms of reduced tillering, discoloration and narrowing of leaves, as well as stunting of plants which resemble the symptoms of water - stress deficit (Holdman & Watson, 1977; Kort, 1972). However information on the effects of *H. avenae* on physiology growth parameter water status and the canopy temperature of wheat plants are very limited or lacking. A reduction of leaf transpiration rate in wheat as a result of *H. avenae* infection has also been reported (Amir & Sinclair, 1996). The effects of different initial population densities of *H. avenae* on some growth and physiological aspects of wheat under field conditions are presented in this paper

Materials and Methods

A wheat grown field (50 ha), naturally infested with *H. avenae* in Al-Kharj region, near Riyadh was chosen for this study. Three sites with three different population densities of 00,75 and 225 cysts / 250 cm^3 soil (Krusberg *et al.*, 1994) were selected and five experimental plots each of 1 m^2 were defined at each site. Wheat cultivar "Yecora Rojo" was sown and all the agronomical practices normally used in the region were followed.

Number of tillers / plant, fresh and dry weight of root and shoot, root: shoot ratio, leaf area and water content of root and shoot were determined at heading and dough stages of growth (82 & 123 days after sowing, respectively). Plant height, total chlorophyll content, plant canopy temperature, as well as the amount of intercepted light by the canopy were measured at dough stage. Concentrations of N,P,K,Fe,Mn, Zn and Cu were determined in the shoots at dough stage and in grains at harvest i.e., 154 days after sowing using the atomic absorption spectrophotometer and Kjeldahl method described by Chapman & Pratt (1961).

Plant canopy temperature was measured with an infrared thermometer (Model 110, Everest Interscience, Tustin, CA) with a narrow field of view (3 deg.), detecting radiation in the 8-14μ waveband. The infrared thermometer was operated with the emissifity set at 0.98 and was compared frequently to an Everest black-body standard. The measurements were made at noon time of a clear day (Wanjura & Upchurch, 1991).

Intercepted light by wheat canopy was measured with the quantum sensor (photometer) in the photosynthetically active radiation (PAR) waveband. The mean intercepted light by canopy was calculated as the difference between light flux density above and below the canopy at the noon time of a clear day (Sivakumar & Virmani, 1984; Wilson, 1981).

Total chlorophyll content in the wheat leaves of nematode - infected and non - infected plants, was extracted by direct immersion of 0.2 g fresh leaves into 10 ml of N,N-dimethylformamide (DMF) solvent. After storage in dark for 24-48 hr at 4°C, the extracts were examined by a spectrophotometer at 647 and 664.5 nm (Moran & Porath, 1980) and calculations were made according to Ross (1974).

Water contents of shoot and root were determined according to the standard weight method and plant leaf area was measured using the COR LI- 300A area meter (LI - COR inc., Lincoln, NE).

The data were analysed by analysis of Variance and means were separated with the protected LSD. Percentage data were transformed to the angular transformation prior to ANOVA, whenever needed.

Results and Discussion

This study shows that the wheat cultivar "Yecora Rojo" is a very susceptible and intolerant host for *H. avenae* which corroborate well with the reports of Al-Hazmi *et al.*, (1994) and Osman *et al.*, (1994). No cysts were found on the roots of wheat plants grown in the control plots, whereas, number of cysts developed on the roots of wheat plants increased as the nematode initial densities increased (data no shown). *H. avenae* reduced ($P \leq 0.05$) the number of tillers / plant, leaf area and suppressed the fresh and dry weight of shoot at heading and dough stages of growth (Table 1). *Heterodera avenae* also suppressed tillering, shoot weight and leaf area. Similar results have also been reported by Holdman & Watson (1977), Kort (1972), Osman *et al.*, (1994) and Youssif (1987). Fresh and dry weight of root increased, with the nematode infection, at heading, but decreased ($P \leq 0.05$) at dough stage. Consequently, root:shoot ratio increased ($P \leq 0.05$) at heading stage as the nematode initial densities increased, but was not significantly affected at dough stage (Table 1). The initial increase might be due to the abnormal branching of infected roots as an attempt of the plant to compensate for root infection (Holdman & Watson, 1977) whereas suppression in roots growth, at dough stage could be due to increased invasion of roots by the nematode juveniles and also the later death of a great portion of infected roots (Amir & Sinclair, 1996; Youssif, 1987).

Table 1. Effect of *Heterodera avenae*, the cereal cyst nematode on some growth parameters of wheat under field conditions.

Initial density (Pi) (Cysts/250 cm^3 soil)	Number of tillers per plant	Shoot wt./plant (g)		Root wt./plant (g)		Root: Shoot Ratio
		Fresh	Dry	Fresh	Dry	
			Heading stage			
00	3.0 a	8.00 a	1.44 a	1.74 a	0.26 a	0.20 a
75	1.6 b	2.14 b	0.42 b	2.03 a	0.29 a	0.87 a
225	1.0 b	1.66 b	0.25 c	2.82 b	1.14 b	3.65 b
			Dough stage			
00	2.8 a	18.46 a	6.98 a	2.51 a	1.32 a	0.20 a
75	2.6 a	10.45 b	3.55 b	1.66 b	0.94 b	0.26 a
225	1.0 b	1.81 c	0.70 c	0.61 c	0.18 c	0.27 a

Values are means of five replicates. Means in a column, for ach stage, followed by the same letter are not different ($P \leq 0.05$) according to Fisher's Protected LSD.

Increasing initial densities of the nematode increased the water content of shoot at both stages of growth (Table 2) with an increase in the temperature of plant canopy ($P \leq 0.05$) at dough stage (Table 3). Water content of shoots increased in the nematode - infected plants. This is possibly due to a reduction of stomatal conductance which could reduce the leaf transpiration rate (Amir & Sinclair, 1996) and hence reduce the evaporative cooling of leaves leading to a higher plant temperature (Kirkpatrick *et al.*, 1995). Water content of the infected roots was reduced ($P \leq 0.05$) at heading, but increased ($P \leq 0.05$) at dough stage (Table 2), which might be due to the disruption of the xylem, accumulation of dry matter and the high fibration of infected roots (Dorhout *et al.*, 1991; Shephered & Huck, 1989).

Table 2. Effect of *Heterodera avenae*, the cereal cyst nematode on leaf area and water content of wheat under field conditions.

Initial density (Pi) (Cyst/250 cm^3 soil)	Leaf area (cm^2/plant)	Water content (%)* Shoot	Water content (%)* Root
		Heading stage	
00	121.58 a	81.94 a	85.58 a
75	39.90 b	80.26 a	87.60 a
225	28.46 b	84.84 b	61.14 b
		Dough stage	
00	40.68 a	56.88 a	48.02 a
75	32.40 a	60.06 a	45.78 a
225	9.53 b	62.38 a	69.96 b

Values are means of five replicates. Means in a column, for each stage, followed by the same letter are not different ($P \leq 0.05$) according to Fisher's Protected LSD.

* Untransformed data; data were subjected to the angular transformation prior to ANOVA.

Table 3. Effect of *Heterodera avenae*, the cereal cyst nematode on plant height, total chlorophyll content, plant canopy temperature and intercepted light at dough stage of wheat field conditions.

Initial density (Pi) (cysts/250 cm^3 soil)	Plant height (cm)	Total chlorophyll content (mg/g fresh weight)	amount of intercepted light (%)*	Plant canopy temperature (°C)
00	70.6 a	0.540 a	89.40 a	24.82 a
75	45.8 b	0.177 b	65.00 b	27.18 b
225	29.6 c	0.105 b	32.00 c	27.60 b

Values are means of five replicates. Means in a column followed by the same letter are not different ($P \leq 0.05$) according to Fisher's Protected LSD.

* Untransformed data; data were subjected to the angular transformation prior to ANOVA.

At dough stage, plant height, total chlorophyll content and intercepted light by leaves were suppressed ($P \leq 0.05$) with nematode infection (Table 3). It has been reported that as initial population density of *Pratylenchus thornei* Sher & Allen increased, there was a corresponding decrease in the growth, total chlorophyll content and photosynthetic rate of *Mentha citrata* leaves (Haseeb & Shukla, 1995).

Nematode infection caused a significant decrease ($P \leq 0.05$) in the concentrations of N,Fe,Mn and Cu in wheat shoots at dough stage, but increased the concentration of Zn in the grains at harvest as compared to the controls (Table 4). In a previous study, Haseeb *et al.*, (1993) found that *Meloidogyne incognita* (Kofoid & White) Chitwood reduced the concentrations of Mn and Cu in the shoots of *Hyoscyamus albus*.

Table 4. Effect of *Heterodera avenae*, the cereal cyst nematode on total concentrations of N,P,K and certain microelements in wheat shoots and grains under field conditions.

Initial density (Pi)	Total concentration of elements						
(cysts/250 cm^3 soil)	N (%)	P (%)	K (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
			Shoots (at dough stage)				
00	2.71 a	0.282 a	0.867 a	292.0 a	50.8 a	41.2 a	27.2 a
75	1.85 b	0.275 a	0.882 a	263.2 b	46.0 a	43.2 a	24.0 a
225	1.53 b	0.244 a	1.008 a	248.8 b	28.0 b	37.6 a	18.0 b
			Grains (at harvest)				
00	1.77 a	0.25 a	0.28 a	153.9 a	43.60 a	48.80 a	10.40 a
75	1.90 a	0.24 a	0.41 a	164.0 a	42.31 a	58.47 b	10.92 a
225	2.07 a	0.24 a	0.41 a	152.9 a	39.52 a	55.43 b	8.95 a

Values are means of five replicates. Means in a column, for each stage, followed by the same letter are not different ($P \leq 0.05$) according to Fisher's Protected LSD.

These adverse growth and physiological effects of *H. avenae* on wheat are undoubtedly reflected on quantity and quality of yield. In the present study the crop losses of wheat yield reached up to 90% in some of the infested sites (unpublished data). The present report describe the effects of *H. avenae* on certain growth and physiological aspects of wheat under field conditions. There is need to carry out more studies and determine the effects of this nematode on photosynthesis, transpiration and other physiological processes.

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