



Correlation Between Initial Nematode Population Density and Crop Losses Caused by *Heterodera avenae* in Wheat

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted to find out the effect of different inoculums levels (0, 2, 4, 8 and 16 cyst/plant) *H. avenae* on wheat. Among different inoculums level, highest females/5 g root (32.75), cysts per 200 cc soil (43.07) and juveniles per 200 cc soil (358.75) were recorded in 16 cyst/plant whereas lowest were recorded in 2 cyst/plant. Maximum shoot length (79.85 cm), shoot weight (28.84 g), root length (32.10 cm), root weight (7.71 g), fodder yield (23.72) and grain yield (15.81) were recorded in uninoculated plants (0 cyst/plant) whereas minimum was at 16 cyst/plant. Significant reduction in plant growth characters were observed at and above 4 cyst/plant. Hence, experimental result revealed threshold level of 4 cyst per plant on wheat.

Keywords: Nematode; crop; *Heterodera avenae*; wheat.

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1. INTRODUCTION

Wheat (*Triticum spp.*) ranks among the world's most important staple crop serving as a primary food source for over one-third of the global population due to its adaptability and nutritional value particularly its carbohydrate and protein content (Curtis et al., 2002). With extensive cultivation across diverse agro-ecological zones, wheat significantly contributes to food security, especially in regions with high per capita wheat consumption (FAO, 2021). However, wheat productivity is increasingly threatened by soil-borne pathogens, notably nematodes such as *Heterodera avenae* (cereal cyst nematode), which can cause severe damage to crop yields (Smiley et al., 2005). *Heterodera avenae* is a key pest in wheat-growing areas worldwide, affecting plant root systems, reducing nutrient uptake, and ultimately resulting in stunted growth and lower yields (Nicol et al., 2011). In regions with intensive wheat production, infestations by *H. avenae* can lead to substantial economic losses (Rivoal and Cook, 1993). As the initial population density of nematodes often influences the extent of crop losses, understanding this correlation is essential for effective management strategies.

2. METHODOLOGY

An experiment was carried out to find out the effect of different levels of *H. avenae* on plant growth of wheat and nematode multiplication. Experiment was laid out in completely randomized design with five treatments and six replications. Earthen clays pots were filled and two seeds of wheat (RAJ-4037) sown in each pot. Single plant was maintained after 15 days of sowing. Thereafter, plant roots were exposed by gently removing upper soil around base of the plant 2, 4, 8, and 16 cyst/plant were inoculated. The pot was watered regularly and rotated in order to avoid effect of sun and shade. Utmost care was taken for better crop growth. After 120 days of sowing, the plants were uprooted and following observations viz: shoot length (cm), shoot weight (g), root length (cm), root weight (g), number of females/5g root, number of cysts per 200 cc soil, final larvae population/200cc soil, fodder yield/plant (g) and grain yield/plant (g) were recorded.

3. RESULTS AND DISCUSSION

3.1 Plant Growth Parameter

3.1.1 Shoot length

Result exhibited that as the inoculum level increased from 2 to 16 cysts/ plant corresponding

decreased in crop growth was noticed. Among different inoculum levels, minimum shoot length was recorded (40.29 cm) in 16 cysts/plant. It was obtained to be 79.17 cm, 69.38 cm and 56.65 cm in 2, 4 and 8 cysts per plant, respectively. These treatments were significantly differed from each other. The results of uninoculated plant (79.85 cm) and 2 cyst (79.17 cm) per plant was statistically found at par with each other with regard to shoot length.

3.1.2 Shoot weight

Results revealed remarkable changes in shoot weight at different inoculums levels. Maximum shoot weight observed (28.84 g) in uninoculated plant followed by 28.79 g, 25.72 g and 15.59 g in 2, 4 and 8 cysts/plant, respectively. Minimum shoot weight (10.19 g) was recorded in 16 cysts per plant. These treatments significantly differed from each other. The results of uninoculated plant found at par with 2 cyst/plant.

3.1.3 Root length

Results expressed that root length of wheat slightly decreased and difference were found at par from each other with 0 and 2 cyst level. Root length was reduced significantly at 4 cyst (28.11), 8 cyst (26.86) and 16 cyst (21.56) of cereal cyst nematode. Highest reduction in root length was recorded at an inoculums of 16 cyst level.

3.1.4 Root weight

Result indicated that the root weight was obtained 7.71g in uninoculated and slightly decreased at 2 cyst (6.78g) per plant. Root weight was significantly reduced at an inoculums level of 4 cyst level (5.98) and such reduction were maximum at 16 cyst (4.36) followed by 8 cyst level (5.38). The root weight was recorded highest at 0 cyst and lowest at 16 cyst level.

3.1.5 Fodder yield/plant (g)

Result exhibited the differences among fodder yield at different inoculum levels. The highest fodder yield/plant (g) was obtained 23.72 g in uninoculated plants and gradually decrease at i.e., 2 cyst per plant (22.69 g). Significant reduction in fodder yield was observed at and beyond 4 cyst per plant. The fodder yield was observed 21.34 g, 19.76 g and 18.68 g at 4 cyst, 8 cyst and 16 cyst, respectively. Results significantly differ from each other. It was recorded highest at 0 cyst and lowest at 16 cyst.

Table 1. Effect of different inoculum levels of cereal cyst nematode, *Heteroderaavenae* on plant growth parameters of wheat

Treatments	Shoot length (cm)			Shoot weight (g)			Root length (cm)			Root weight (g)			Fodder yield/plant (g)			Grain yield/plant (g)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T ₁ 0 cyst /plant	78.65	81.06	79.85	28.27	29.41	28.84	32.87	31.34	32.10	8.09	7.34	7.71	23.57	23.86	23.72	15.72	15.91	15.81
T ₂ 2 cyst /plant	78.36	79.98	79.17	28.27	29.30	28.79	32.48	30.88	31.68	7.16	6.40	6.78	22.77	22.62	22.69	15.18	15.08	15.13
T ₃ 4cyst /plant	68.59	70.17	69.38	24.78	26.66	25.72	27.17	29.05	28.11	5.69	6.27	5.98	21.51	21.18	21.34	14.34	14.12	14.23
T ₄ 8cyst /plant	56.32	56.97	56.65	14.75	16.42	15.59	26.21	27.50	26.86	5.15	5.61	5.38	19.89	19.63	19.76	13.26	13.09	13.17
T ₅ 16 cyst /plant	39.96	40.62	40.29	9.66	10.72	10.19	21.25	21.87	21.56	4.01	4.72	4.36	19.00	18.35	18.68	12.67	12.23	12.45
SEm±	0.378	0.416	0.281	0.320	0.287	0.215	0.320	0.331	0.230	0.214	0.211	0.150	0.389	0.349	0.261	0.249	0.260	0.180
CD at 5%	1.102	1.212	0.799	0.931	0.835	0.610	0.933	0.965	0.654	0.625	0.614	0.427	1.132	1.018	0.742	0.725	0.757	0.511

Data are the average value of six replications

Table 2. Effect of different inoculum levels of cereal cyst nematode, *Heteroderaavenae* on nematode reproduction parameters on wheat

Treatments	No. of females /5g root			No. of cysts /200cc soil			Final larvae population /200cc soil		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
T ₁ 0 cyst /plant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T ₂ 2 cyst /plant	10.17	11.83	11.00	16.50	17.50	17.00	120.83	134.00	127.42
T ₃ 4cyst /plant	14.00	15.33	14.67	18.50	19.50	19.00	143.33	151.67	147.50
T ₄ 8cyst /plant	16.00	17.67	16.84	21.67	23.67	22.67	232.33	281.67	257.00
T ₅ 16 cyst /plant	30.83	34.67	32.75	42.50	43.65	43.07	345.83	371.67	358.75
SEm±	0.252	0.304	0.197	0.447	0.427	0.309	3.911	3.750	2.709
CD at 5%	0.734	0.886	0.561	1.303	1.244	0.878	11.391	10.922	7.695

3.1.6 Grain yield/plant (g)

Result revealed significant differences among grain yield at different inoculum levels. Maximum grain yield/plant was recorded (15.81g) in uninoculated plants and slightly decrease at lower inoculum level *i.e.*, 2 cyst per plant (15.13 g). Result showed significant reduction in grain yield at and beyond 4 cyst per plant. The grain yield was noticed 14.23 g, 13.17 g and 12.45 g at 4 cyst, 8 cyst and 16 cyst, respectively. It was recorded maximum at 0 cyst (uninoculated plant) and minimum at 16 cyst.

3.2 Nematode Reproduction

3.2.1 Number of females/5g root

Results indicated gradual increase in number of females/5 g root with increase in inoculum levels. Among inoculum levels, minimum number of females/5 g root observed with 2 cyst/plant inoculum level (11.00) followed by 14.67 and 16.84 at 4 and 8 cyst per plant, respectively. These treatments significantly differed from each other. Highest numbers of females/5g root (32.75) were recorded in the inoculum level of 16 cysts /plant.

3.2.2 Number of cysts per 200 cc soil

Result showed that as the inoculum level increased from 2 to 16 cysts/plant corresponding increased in the number of cysts/200 cc soil was recorded. Lowest cysts/200 cc soil were (17.00) obtained at inoculums of 2 cysts subsequently 19.00 and 22.67 at 4, 8 cysts/plant inoculum level, respectively. However, maximum cysts/200 cc soil (43.07) were observed in 16 cysts/plant. All different inoculum levels significantly changed from each other.

3.2.3 Final larvae population/200 cc soil

Result revealed that final larvae population/200 cc soil significantly increased as the inoculum level increased from 2 to 16 cysts/plant. Among treatments, lowest nematode larvae population/200 cc soil (127.42) was found at 2 cysts/plant inoculum level subsequently 147.50 and 257.00 at 4 and 8 cysts/plant larvae per 200 cc soil, respectively. Highest nematode population (358.75) was recorded with 16 cysts/plant. All treatments significantly differed from each other.

Results observed in present investigation similar to the findings of number of earlier reports. Gill

and Swarup (1971) studied the critical damage level of wheat and barley and found that at 10,000 larvae/500 g soil shoot length and weight as well as root length and weight are badly affected. They further reported that at a level of two or more larvae/g soil, the growth and development of the crop is influenced and at a level of 20 or more larvae/g soil, it is significantly reduced. Meagher and Brown (1974) reported that as the inoculum level of *H. avenae* in the soil increases, the yield of wheat crop reduces. Hajihassani et al., (2010) reported that initial population of *H. filipjevi* significantly reduced several growth parameters of wheat compared with the untreated control. Korayemet al., (2015) reported a 21.6% reduction in grain yield in wheat plants infected with *Heterodera avenae* compared to healthy plants. When infected plants received a double dose of nitrogen, the yield loss was reduced to 15.9%. Yadav et al., (2022) conducted a pathogen city trial on wheat with *Heterodera avenae*, inoculating different cyst levels (0, 2, 4, 8, 12, 16 cysts per plant). Plant growth improved up to 2 cysts per plant but significantly decreased at 4 cysts and above. The threshold level of *H. avenae* on wheat was determined to be 4 cysts per plant. As the inoculum level (0 to 16 cyst per plant) of cereal cyst nematode increases, plant growth parameters decrease, due to several factors. The nematodes feed on plant roots, depriving the plant of essential nutrients and causing significant root damage which impairs the plant's ability to absorb water and minerals uptake. This root disruption leads to reduced growth while the plant also experiences stress and hormonal imbalances, diverting energy from development to defense. The cumulative effect of these factors results in stunted growth, reduced biomass, and lower yield as the nematode population rises.

Results exhibited that the nematode population increased progressively with an increase in inoculum levels 2, 4, 8 and 16 cyst per plant. It was observed that the minimum number of females/5g root recorded at 2 cyst (11.00) level and maximum (32.75) at 16 cyst levels. Females were observed at 14.67 (4 cyst) and 16.84 (8 cyst) per plant. Similar trend was also noticed with respect to number of cyst/200 cc soil and number of larvae/200cc soil. The results of present investigation are in accordance with the findings of Shahina and Maqbool (1990) who found that the infectivity of *H. zae* on maize increased with increased in inoculum level. Meena et al., (2009) who conducted a study for pathogen city test and

observed that 100 J2/ plant is an economic threshold level of pigeon pea cyst nematode and this inoculum level causes considerable losses to red gram. Meena et al. (2016) studied the effect of varied inoculum i.e, 0, 2000, 4000, 8000 *H. zaeae* larvae/pot on plant growth and multiplication of maize cyst nematode, *H.zaeae* on maize. The experimental findings showed that cyst/plant, cyst and nematode larvae/100 cc soil increased with the increase in inoculum level of *H. zaeae* on maize. This may be due to the fact that as the inoculum increase, more nematode juveniles reached to the feeding site to the host plant and ultimately more nematode infection takes place.

Pathogen city trial showed that the inoculum level of 4 cyst / plant significantly reduced plant growth parameters of wheat. Hence, this inoculum level may be considered as economic threshold level of cereal cyst nematode, *H. avenae* on wheat.

4. CONCLUSION

Pathogenicity trial showed that plant growth characters gradually decreased with the increase in inoculum level and significantly reduced at an above 4 cyst level. The threshold level of cereal cyst nematode, *H. avenae* was observed 4 cyst per plant on wheat.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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