Bio-Ecological Assessment of the Cereal Cyst Nematode (Heterodera Avenae) in the North West of Algeria

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Abstract

This study assesses the presence and population density of the cereal cyst nematode, Heterodera avenae, in cereal soils of the Relizane province in northwestern Algeria. Through a six-month sampling campaign, nematode cysts were extracted, counted, and analyzed morpho-biometrically using the Fenwick method. The results revealed a 40% prevalence rate, with low population densities ranging between 1 and 3 cysts per 500g of soil. Morphological and biometric measurements confirmed the identity of H. avenae. Environmental factors such as drought and cultural practices appear to influence population dynamics. These findings provide essential baseline data for the development of integrated pest management strategies in cereal production in Algeria.

Keywords: *Heterodera avenae, cereal cyst nematode, nematology, soil ecology, pest management.*

INTRODUCTION

Cereals are the primary food source for most of humanity. In Mediterranean countries, cereal cultivation, primarily that of winter wheat, holds significant importance in agriculture. In addition to these economic constraints, phytosanitary issues are also a concern, particularly fungal diseases, birds, insects, and nematodes that affect cereals. Many species of nematodes are phytophagous (plant-feeding), and some have been known for over a century. Cereal crops are not free from nematodes. The most dangerous among them can cause sporadic damage, such as Pratylenchus spp. (migratory endoparasites in roots), as well as more complex parasitism, like the endocauline species Anguina tritici (Chitwood) and Ditylenchus dipsaci (Kühn) Filipjev, and the sedentary endoracinary species Meloidogyne naasi Franklin and Heterodera avenae Wollenweber (Kort, 1972).The cereal cyst nematode, Heterodera avenae, is the most damaging and widespread species within a complex of over ten species in the family Heteroderidae, characterized by a marked sexual dimorphism in adults (Rivoal et al., 1985). An obligatory parasite of cultivated and wild grasses, it is endemic in cereal-growing regions of Northern and Southern Europe, as well as North Africa (Ritter, 1982). In Algeria, its presence was first reported by Scotto La Massèse in 1975. Subsequent work, particularly by Lamberti, highlighted localized but significant losses attributable to this parasite. Historically, Heterodera avenae has opened a vast field of international research, with numerous studies revealing a remarkable adaptation of populations to cereal crop cycles. Today, the nematological threat is evolving. Climate change, with milder winters and hotter summers, is influencing crop phenology and the nematode's life cycle, potentially expanding its range and increasing the number of generations per season (Smiley et al., 2022). Concurrently, the intensification of cereal systems and the simplification of crop rotations, often favoring host crops like wheat and barley, create favorable conditions for the accumulation of very high cyst densities in the soil, exacerbating the risks of yield losses (Dababat et al., 2022).

In this context, the present study aims to assess the presence and population density of Heterodera avenae in the main cereal-growing regions of Algeria and to analyze the influence of some agronomic and environmental factors on its distribution.

The objective is to identify at-risk areas and to provide essential preliminary data for the establishment of integrated management programs. The results of this research will contribute to a better understanding of the bio-ecology of this nematode in the region and to the protection of local cereal crops.

MATERIALS AND METHODS

This study was conducted using a rigorous methodology to assess the presence, density, and morphobiometric characteristics of the nematode Heterodera avenae in the Relizane province. The methods used for sampling, extraction, counting, and cyst analysis are described below.

- Conducting a nematological analysis of soil samples for the study area.
- Conducting a nematological analysis of weed samples (soil - roots) for the study area.
- Taking morphometric measurements of the cysts and anatomical notes at the level of the female genital opening and knead it to determine the type or types of nematodes that are cysts for each region

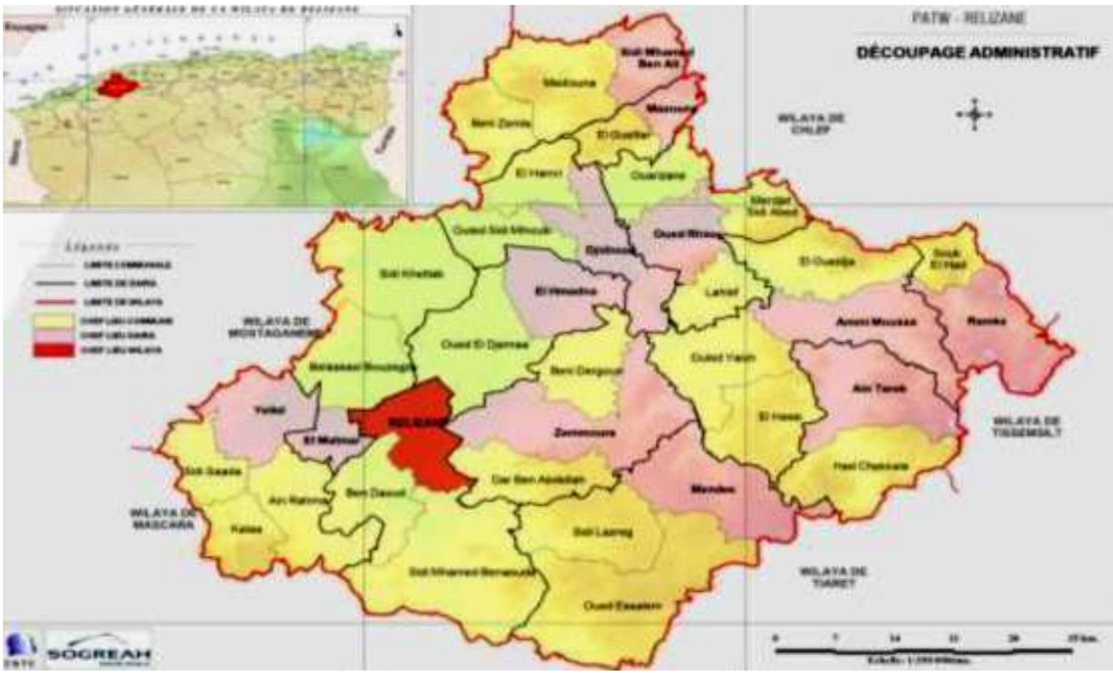

Figure 1. *Geographical location of the study area (Relizane province). (PATW, 2014)*

Study Area

The study was conducted in the Relizane province, an area covering 4,872.32 km² located in northwestern Algeria (Fig. 1). This province, established through the 1984 administrative division, is strategically positioned as a hub for socio-economic exchange and a transit point between western and coastal Algeria and the rest of the country. It is geographically bordered by the provinces of Mostaganem and Chlef to

the north, Mascara and Tiaret to the south, Mascara and Mostaganem to the west, and Chlef, Tiaret, and Tissemsilet to the east.
From a geomorphological perspective, Relizane Province comprises three main physical regions:
- The Mountain Zone: Characterized by rugged terrain with elevations ranging between 600 and 1,200 meters.
- The Hill and High Plains Zone: Covering 55% of the total area, with average elevations of 200 to 400 meters. This zone is prone to erosion and gullying.
- The Low Plains: Including the Lower Cheliff and Mina plains.

The climate of Relizane Province is continental, with cold winters and hot, humid summers. It is mildly semi-arid in the north, mildly arid in the plains and foothills, and hot semi-arid in the mountainous Ouarsenis region. The average annual rainfall is approximately 350 mm, although it has been closer to 300 mm over the past decade due to drought. The local economy relies primarily on agriculture and livestock farming, with agricultural land accounting for 62% of the province's total area, of which 11% is irrigated. Agricultural production is diverse, including cereals, pulses, arboriculture, market gardening, and industrial crops.

Plant Sampling

Knowledge of the cyst nematode Heterodera avenae and its parasitic method, coupled with the fact that cereal crops are annual with fibrous root systems, constitutes the direct cornerstone for choosing the sampling and collection method for this study. We followed the Zigzag method (Fig. 2). This method involves collecting small samples from 20 points in a field not exceeding 4 hectares in area, at a depth of 20-25 cm. The number of small samples collected varies with the total area of the field. These samples are then mixed, and a composite sample of 1 kg to 1.5 kg is taken. This composite sample is placed in a labelled plastic bag containing all necessary information (crop type, field area, current crop, previous crop, sampling date, etc.), as described by Righi (2003).

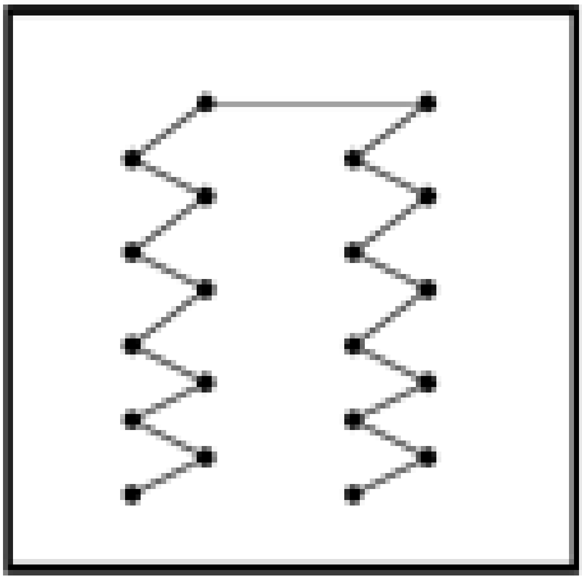

Figure 2. *Sampling method (zigzag) in a 4-hectare cereal field (Righi, 2003)*

The samples were sent to the laboratory for analysis and processed as follows:

Sample Preparation

Upon arrival at the laboratory, the samples underwent a two-step preparation process:

Soil Drying

The soil samples were air-dried by spreading them out and leaving them to dry for 5 to 7 days. This process also allowed for the removal of stones and plant debris. **Storage**

Once dried, the samples were transferred to paper bags and labeled with relevant information (plant type, date, and location of collection) for storage prior to analysis.

Cyst Enumeration and Density Calculation

Extracted cysts were observed under a stereomicroscope. For efficient enumeration, cysts in a Petri dish (area = 57 cm^2) were counted within five randomly selected 1 cm^2 squares. The average number of cysts per cm^2 was then extrapolated to estimate the total number of cysts per 500 g of soil. infestation levels were classified into four degrees: • Degree 1: 50 - 300 cysts/500g soil

- Degree 2: 300 - 600 cysts/500g soil
- Degree 3: 600 - 900 cysts/500g soil
- Degree 4: > 900 cysts/500g soil

Morphometric and Species Identification

For morphometric analysis, 15 cysts from each sampling location were examined under an optical microscope equipped with a micrometer. Key morphological characteristics were measured:

- Cyst length (from base to neck)
- Cyst width (at the widest point)
- Neck length

Species identification within the Heterodera avenae complex was based on these morphometric data and the anatomical features of the vulval cone.

Data Analysis

The study analyzed the relationship between infestation degree and various agronomic factors, including previous crop (cereal, legume, or fallow) and soil type (sandy, clayey, sandy-clay). The distribution and density of cysts were also mapped across the different communes.

RESULTS AND DISCUSSION Nematological Analysis of Soil Samples Assessment of Heterodera avenae Infestation General Infestation Status

Nematological analysis of 40 cereal fields across 11 communes in the Relizane wilaya confirmed a 100% infestation rate by cyst nematodes of the Heterodera complex. The results, detailed in Table 1, demonstrate that all sampled fields were infested to varying degrees of severity. Oat fields exhibited the highest cyst densities, with 30% of fields falling into Degree 4 (>900 cysts/500g soil), followed by soft wheat (25%) and barley (11.76%). Durum wheat had the highest proportion of fields (26.66%) in Degree 3 (600-900 cysts/500g soil). All crops showed a significant baseline infestation, with 40-50% of fields categorized under Degree 1 (<300 cysts/500g soil).

Infestation Status in Relation to Previous Crop

Agricultural practices in the studied region were dominated by cereal monoculture, with limited rotation involving legumes or fallow periods. The impact of the previous crop on subsequent nematode population density is a critical finding (Table 02). Fields where cereals were the preceding crop showed the most severe infestations. This was particularly evident for oats, soft wheat, and barley, where high cyst densities (Degree 4) were recorded in 30%, 25%, and 11.76% of such fields, respectively. This pattern underscores the role of continuous cereal cultivation in fostering the multiplication of H. avenae, a host-specific pathogen. Conversely, fields previously cultivated with legumes or left fallow demonstrated lower cyst densities. However, it is notable that fallow fields still maintained considerable cyst levels. This persistence is likely due to the presence of wild grass species, which act as alternate hosts for the nematode, allowing the population to be maintained even in the absence of a commercial crop (Fig 3). These results emphasize the paramount importance of crop rotation in integrated nematode management strategies. The failure to control weeds during fallow periods negates the benefits of leaving land uncultivated, as the nematode population is sustained by alternative grass hosts.

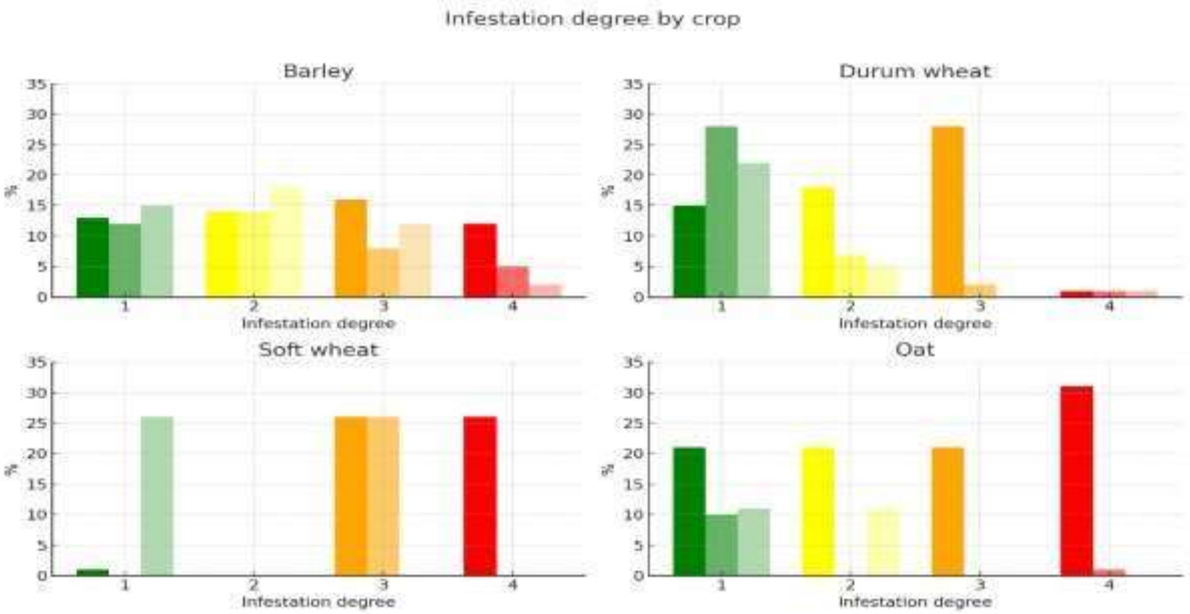

Figure 3. Degree of field infestation of crops by cyst nematode in relation to the preceding crop.

Infestation in Relation to Soil Type

Soil texture significantly influenced the degree of nematode infestation (Table 03). Sandy-clay and clay loam soils were found to be most conducive to cyst development and high population densities.Purely sandy soils showed the lowest infestation levels, with only 12% of fields in Degree 1 and no fields in higher degrees. In contrast, clay and sandy-clay soils supported higher population densities across all degrees, including Degree 4. This is likely attributable to better moisture retention and more favorable conditions for root development in these soils, which in turn support nematode reproduction, survival, and movement.

Geographical Distribution of Infestation by Municipality

All surveyed communes were infested with cyst nematodes, although the prevalence and severity of infestation varied significantly. Municipality such as Mendes, Relizane, and Mediouna recorded the highest cyst densities, with some fields exceeding 900 cysts/500g of soil. The variation in infestation levels among communes can be attributed to a combination of agroecological factors, including local climatic conditions, predominant soil types, historical cropping patterns (continuous cereal vs. rotation), and weed management practices. Communes with large-scale, long-term cereal monoculture exhibited the most severe infestations. Table 04 further classifies the fields based on the proposed infestation degree scale, providing a clear overview of the severity distribution across the different communes. The concentration of Degree 3 and 4 infestations in specific municipality highlights areas that require immediate attention and the implementation of control strategies.

Morpho-Biometric Study of Cysts

Morphometric analysis revealed significant variability in cyst dimensions (length, width, and neck length) across the different municipalty and agricultural regions. This variability is a strong indicator that the populations studied do not consist of a single species. This morphological diversity, corroborated by microscopic observations of the vulval cone region, suggests the presence of at least two species within the Heterodera avenae complex, notably H. avenae and H. latipons. These species were often found in mixed populations within the same field. The observed differences could also be influenced by environmental conditions (e.g., temperature, moisture stress) and host suitability, which affect nematode development and the ultimate size of the female and subsequent cyst. Furthermore, the age structure of the cyst population in the soil (old vs. newly formed cysts) may contribute to the recorded biometric variability. Subsequent municipalty-specific biometric data support these conclusions and align with previous studies conducted in other cereal-growing regions of Algeria (Kaci, 1996; Berkane, 2007; Righi, 2016), which also reported the presence of a complex of species rather than a single entity.

GENERAL CONCLUSION

This study confirms the widespread and severe infestation of cereal crops by cyst nematodes, primarily Heterodera avenae, throughout the Relizane wilaya. The universal infestation (100% of sampled fields) underscores this pathogen as a major, though often overlooked, constraint to cereal production in the region. The positive correlation between cereal monoculture and high nematode densities aligns with global findings on the ecology of obligate plant parasites (Rivoal and Cook, 1993; Nicol, 2002). The persistence of significant cyst populations in fallow fields is a critical observation, highlighting the role of poor weed management, articularly of grass species, in perpetuating the problem. This necessitates a reevaluation of fallow as a control strategy unless coupled with effective weed eradication. The influence of soil type on infestation severity suggests that management recommendations could be tailored to specific agro-pedological units. Farmers in areas with clay and sandy-clay soils should be particularly vigilant. The morpho-biometric results are perhaps the most significant finding, indicating the presence of a species complex. The potential coexistence of H. avenae, H. latipons, and possibly H. hordecalis (as indicated in the thesis abstract) has important implications for disease management. Different species and pathotypes can exhibit varying virulence, host ranges, and responses to control measures, including resistance genes in cereals and hatch stimulation triggers (Rivoal et al., 2001). Therefore, future management strategies, including the deployment of resistant varieties, must be informed by a precise understanding of the specific specific composition and pathotype structure within each region.

In conclusion, the high infestation levels demand the implementation of integrated pest management (IPM) strategies. These should include:

- Mandatory crop rotation with non-host crops (e.g., legumes like chickpea).
- Strict weed control, especially during fallow periods, to eliminate alternate hosts.
- Use of resistant or tolerant varieties where available, with consideration for potential pathotype diversity.
- Soil sampling and monitoring to identify hotspot areas and make informed decisions.

This study provides a foundational map of nematode distribution and intensity in Relizane, which is essential for researchers, extension services, and policymakers to prioritize efforts and develop targeted control programs to safeguard Algeria's strategic cereal production.

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Annex 1 : Tables

Table 1. Field infection status.

Crop	Number of Fields	% Infected Fields	% Fields by Infestation Degree			
			1	2	3	
			46.66			
						4
Durum Wheat	11	100%		26.66	22.66	0
Soft Wheat	5	100%	50	25	0	25
Barley	18	100%	41.17	29.41	17.64	11.76
Oats	6	100%	40	30	0	30
Total	40	100%	44	22	20	14

Note: Degree 1: 50 to 300 cysts / 500 g soil; Degree 2: 300 to 600 cysts / 500 g soil; Degree 3: 600 to 900 cysts / 500 g soil; Degree 4: > 900 cysts / 500 g soil

Degree 1: from 50 to 300 cysts / 500 g of soil
Degree 2: from 300 to 600 cysts / 500 g of soil
Degree 3: from 600 to 900 cysts / 500 g of soil
Degree 4: more than 900 cysts / 500 g of soil

Table 2. Effect of previous crop on the degree of Heterodera avenae infestation (%).

Durum Wheat	11	0	13.33	26.66	0	26.66	6.66	0	0	6.66	20	0	0
Soft Wheat	5	0	0	25	25	25	0	0	0	0	0	0	0
Barley	18	11.76	11.76	17.64	11.76	11.76	5.88	0	0	17.64	11.76	0	0
Oats	6	20	20	20	30	0	10	0	0	10	10	0	0

Table 3. Degree of infestation according to soil type (%).

Soil Type	Infestation Degree			
	1	2	3	4
Sandy	12	0	0	0
Sandy-Clayey	16	10	8	10
Clayey	8	12	12	4

Annex 2 : Figures

Figure. 4. FENWICK's device (1940).

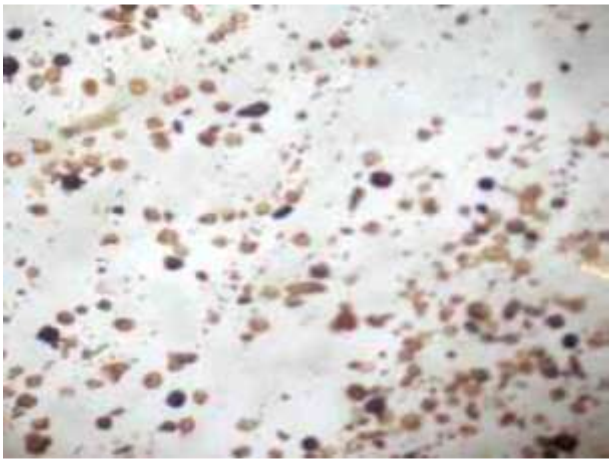

Figure 5. Sample of extracted cysts observed under a binocular magnifier.

Figure 6. Counting of nematode cysts (Binocular Magnifier).