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STUDY OF THE INFESTATION OF DURUM WHEAT WITH CYST NEMATODES OF GENUS "*HETERODERA* " IN TWO LOCALITIES (MEDEA, ALGERIA)

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Abstract

In Algeria, cereal cyst nematodes (CCN) of the genus *Heterodera* are increasingly appearing as important pests. They attack all cereals, including durum wheat, but to varying degrees depending on the region, crop, climate and physical and chemical properties of the soil.
The study of the susceptibility of the durum wheat «waha» variety by cyst nematodes at two experimental sites of different texture under natural conditions and throughout the growing cycle revealed the presence of cysts returning to the genus *Heterodera*. The first site is the most multiplying of these parasites than the second site. These affect the dynamics of nematological population density. These nematodes influence the number of tillers per square meter, the number of ears per square meter and the number of grains per ear at the first site and only the weight of a thousand grains at the second site. But its effect on yield is negligible. These results create relationships that have been crucial and demonstrated by linear regression analysis and the correlation between the variables.

Keywords **:** Algeria; Durum wheat; Cyst nematodes (NC); *Heterodera* sp; soil types, correlation.

Introduction

In Algeria, cereal production has not met the population's needs since 1970 (Smadhi and Zella, 2009), with durum wheat being the main straw cereal grown on 47% of the cereal sole (Haddouche and Mekliche, 2008). As a result, the country imports 1.8 Mt of durum wheat per year. Although the cereal sole hovers around 3 million hectares (Faostat, 2014), 60% of this area is located in a semi-arid climate, where production potential remains low; the cultivation method extensive.

In Algeria, phytoparasitic cyst nematodes of the genus Heterodera are most frequently reported. Among the latter, the species of *Heterodera avenae* causes considerable attacks on durum wheat cultivation.

In Algeria, several researchers have revealed the presence of these nematodes in several cereal areas (Mokabli *et al.,* 2016; Righi *et al.,* 2017). Given the considerable economic importance of the damage caused by these parasites and the lack of information on it in Algeria and particularly in the whole area of Médéa, specifically in the Beni-Slimane region, we performed a preliminary controlled study that proved essential to assess the development of this parasite in two Algerian soils with a different cereal production texture.

Material and Methods

Study area :

The study was conducted from 2016 to 2017 in the pilot farm E.U.R.L. of Si Achour located in the plain of Beni-Slimane, a commune of Beni-Slimane approximately 05 km from the commune of Bouskène and 65 km southeast of the capital of the area of Médéa (fig. 01) at an average altitude of 600 m.

The average annual rainfall is 420 mm with a poor interannual and inter-seasonal distribution, the farm is inserted between the following LAMBERT coordinates :

X= 551,600 m to 555,040 m

Y= 323,250 m to 324,800 m

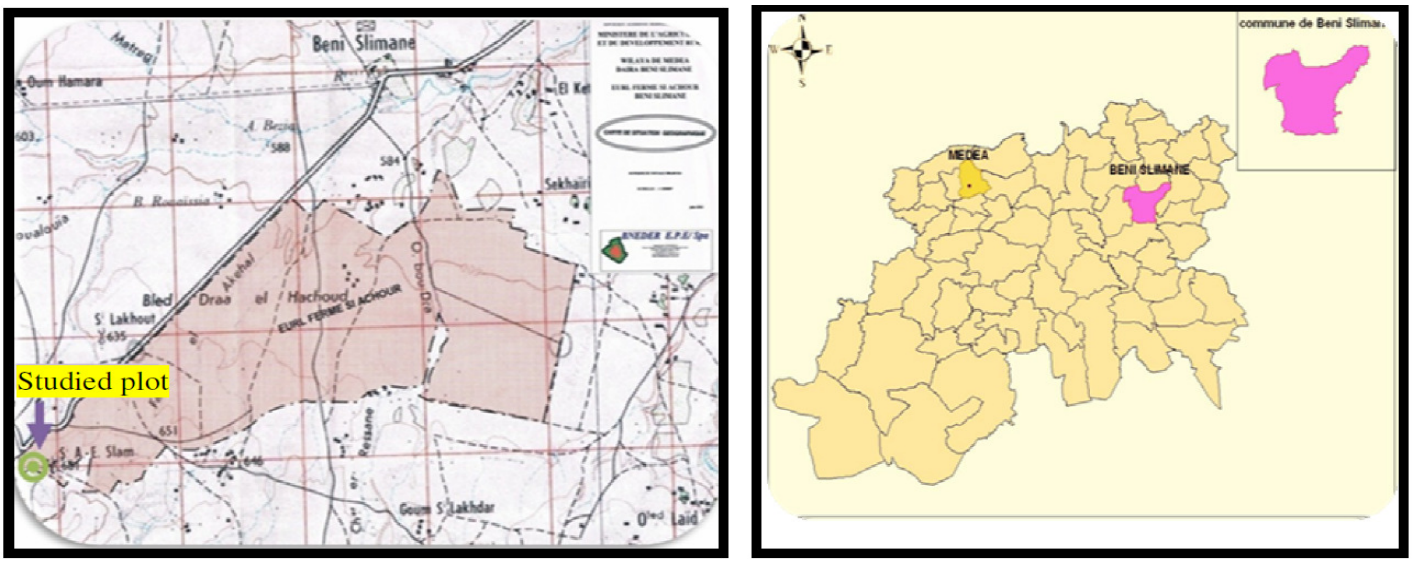

Fig. 1 : Location of the pilot farm Si Achour (Scale: 1/20,000).

Plant material

The plot is cultivated with durum wheat (*Triticum Durum*. Desf), a « Waha » variety with an area of 10 ha, from which we have delimited our experimental plot, which has been estimated at two hectares (02 ha).

Sampling cyst

The experimental design is total randomization with 02 experimental sites. The first is silty clayey soil; the second is calcareous clayey soil. Each of the two experimental sites has 06 replicates, including 18 sampling points. These were collected in 36 samples at a rate of 5.4 kg (for each site, and each phenological stage).

Soil samples were collected near the plants using a probe or trowel at the durum wheat rhizosphere, at a depth of 0 to 30 cm, zigzagging to cover an area of approximately 2 ha or the part of a field that appeared affected. These subsamples were recovered and transferred to a waterproof plastic bag identified in the name of the producer with the address of the sampling site and the date of sampling. The cultural history of the field and soil texture were also recorded for each vegetative stage. These soil samples were then sent to the nematology laboratory of the University of Khemis-Miliana in Ain Defla. All soil samples were homogenized upon receipt and dried at room temperature. A sample weighs on average 300 g of dry soil.

Sampling was performed from the raised stage until the harvest had already begun. Populations of most plant nematodes in soil tend to peak at this time, once the aerial part of the crop has withered or died (Celetti, 2006).

Extraction of Heterodera cyst nematodes

The extraction of cyst nematodes was performed using the classical method described by (Fenwick in 1940), which is based essentially on the density of cysts relative to water. After extraction, the percentage of full cysts is calculated; the juvenile count (L2) was calculated using the counting plate under the binocular magnifying glass. Population sizes were expressed in a number of eggs or infesting larvae /soil dm^3 (N/dm^3) (Wolfgong, 1991).

Data processing and analysis

Three groups of variables were considered in our study: variables considered the host plant, variables related to pests (infestation status) and variables related to the soil parameter to investigate the relationship between the three and their impact, especially on yield components.

The data obtained were entered into the Excel spreadsheet and submitted to the Analysis of Variance (ANOVA). The averages were compared using the Tukey test at the 5% probability threshold.

Results

Physico-chemical characteristics of the soils tested

Results related to texture and chemical characteristics are reported in Tables 1, 2 and 3, and Figures 2 and 3.

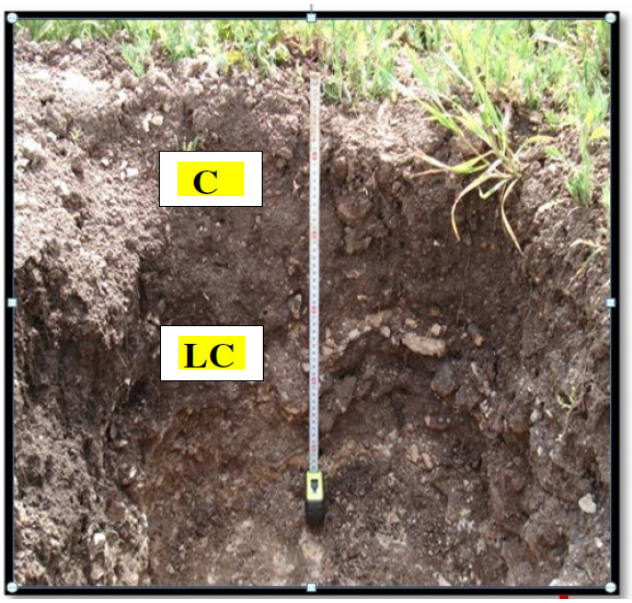

Fig. 2 : Soil profile (A).

Fig. 3 : Soil profile (B).

The abundance of trophic groups of nematodes changes with environmental soil conditions (Sohlenuis, 1980). Several factors favor the development of plant-parasitic nematode populations; climate, cropping system and soil. Algerian soils offer characteristics favorable to the development of nematodes. These factors include texture, pH and organic matter (Hammache, 2010).

Table 1 : Percentage grain size of the profile (A).

Horizon	Granulometry %				
	C	FS	CS	FS	CS
0-40	37	23,6	18	18,9	2,6
40-100	Gravel + rolled stones				
>100	72	23	10	8	2,9

Table 2 : Percentage grain size of the profile (B).

Horizon	Granulometry %				
	C	FS	CS	FS	CS
0 -50	62	8,7	13,3	14	1,6
50-100	77	4,7	10,9	6,5	0,6

- The characteristic profile of these soils (A) is of type LC. The horizon appears brown to dark brown. The structure is lumpy with many small limestone pebbles and crust debris the following upwelling by plowing.
- Profile (B), iron sesquioxide (or manganese) soils-red soils formed under a Mediterranean climate-red soils with a calcium reserve and generally little leached-on alluvium-deep-clayey.

Table 3 : Chemical analysis results for both soil types

Parameters studied	Soil type	
Chemical components	**CC Soil**	**SC Soil**
pH.H_2O	8.09-8.13	8.02-7.80
Ec (µs/cm)	540	412
Limestone (%)	24	2.6
Carbon (%)	0.26	1.09
Organic matter (%)	0.45	1.87

The evolution of the population of *Heterodera* spp.

Concerning the percentage of cysts, it is clear at the emerged stage that the second site with a percentage of solid cysts between 6.6 and 12.5 and a percentage of empty cysts reached 100%, while at the Maturation stage the percentage of empty cysts (ranging from 67.56% to 90.16%) is higher than that of solid cysts (ranging from 9.83% to 40.9%).

Fig. 4 : Percentage of empty and solid cysts of Heterodera according to the points prospected (emerged stage).

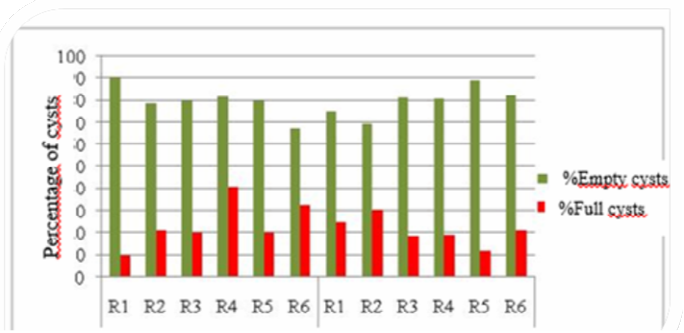

Fig. 5 : Percentage of empty and solid cysts of *Heterodera* according to the points prospected (maturation stage).

However, the averages of infestation levels were calculated only for samples taken at the Maturation stage. They vary from one repetition to another, within the same variety, thus exceeding the threshold of harmfulness which is fixed at 10 L2/g of soil by Mugniéry (1975) cited by Mazouz (2011).

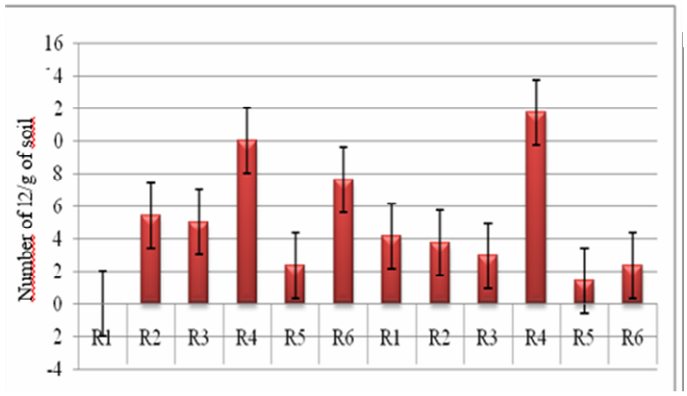

Fig 6 : Average of the infestation levels of Heterodera according to the points surveyed(maturation stage).

Effect of the multiplication of cyst nematodes of the genus Heterodera on the growing season of durum wheat Evaluation of the multiplication rate

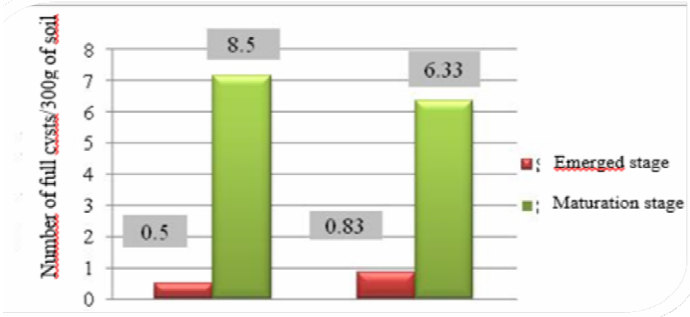

Fig. 7 : Comparison of the infestation rate of the sites studied by the *Heterodera* between the emergence and maturation periods.

Fig. 8 : Comparison of the multiplication rate of the two sites studied by the *Heterodera.*

The exploitation of nematological analysis results from samples taken in the five vegetative stages

Table 6 : Results of the analysis of variance at the 5% threshold for the effect of the variety on the variations in the number of full cysts between the period (emergence to maturation).

Variable	SC Effet	DL Effet	MC Effet	SC Erreur	DL Erreur	MC Erreur	F	P	%cv
Full cyst nematodes (FCN) (Site I)	4	180.200	45.0500	20	43.800	2.1900	20.57	0.0000***	53.49
Full cyst nematodes (FCN) (Site II)	4	132.333	33.0833	20	42.867	2.1433	15.44	0.0000***	51.67

The results of the analysis of variance analysis of the variables studied show that the difference in the mean number of solid cyst nematodes/300g dry soil is very highly significant at the threshold (p· 0,001) with probabilities of 0.0000 at both sites.

Tukey test

Table 7. Results of Tukey's test on the average number of full cyst nematodes.

Cellule	Averages and homogeneous groups, alpha = 0,05 ; dl = 20	
	(Full cysts/300g of dry soil) (Site I)	(Full cysts/300g of dry soil) (Site II)
1	MT 7.1667 A	MT 6.3333 A
2	E 3.5000 B	E 4.1667 A
3	U 2.0000 BC	U 1.5000 B
4	T 0.6667 C	T 1.3333 B
5	L 0.5000 C	L 0.8333 B

The results of the Tukey test for the number of total *Heterodera* cyst nematodes show 03 homogeneous groups (A, B and C) at the first site, and 02 homogeneous groups (A and B) at the second site.

Effect of *Heterodera* spp. on the yield parameters of the « Waha » variety of durum wheat.

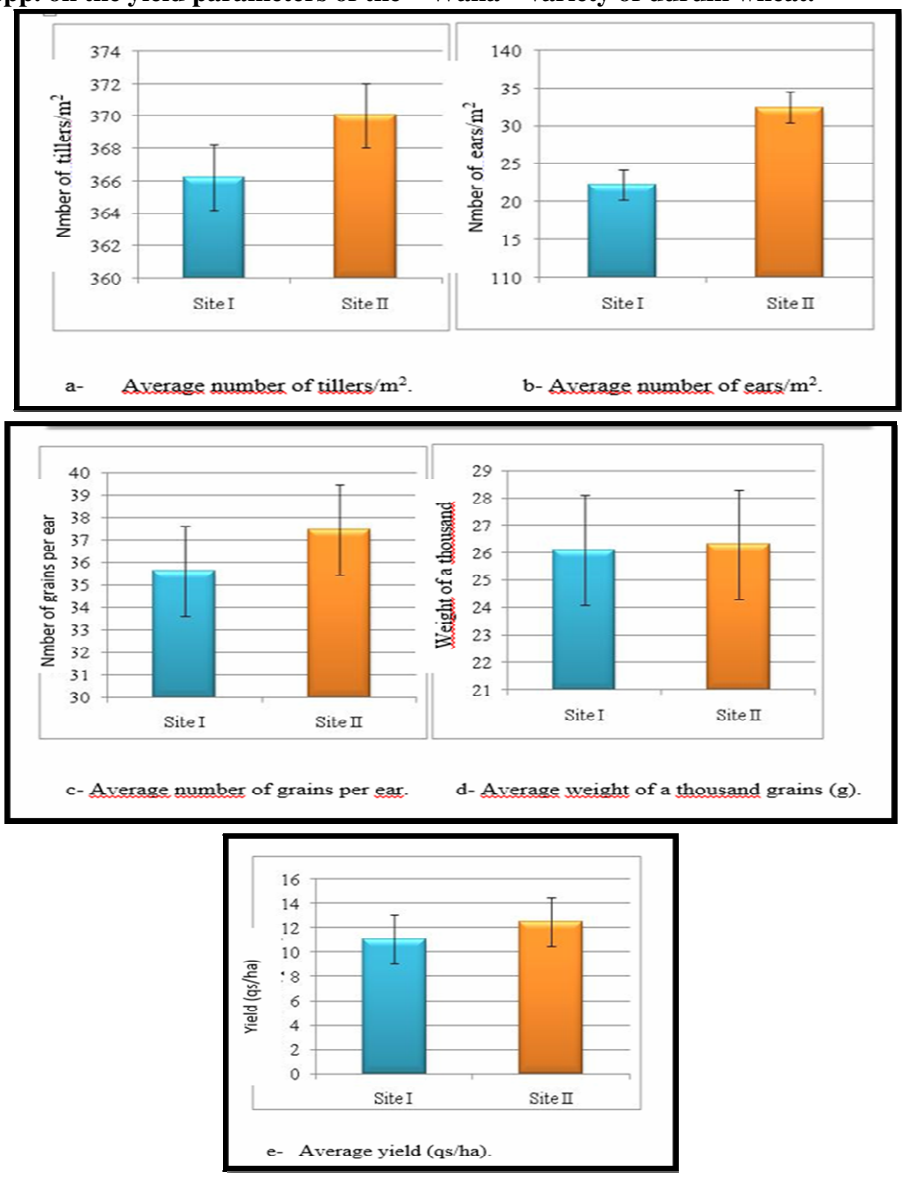

Fig. 9 : Performance components considered on a site-by-site basis.

The correlation matrix of the main parameters studied at the maturation stage of the Waha variety of durum wheat in the first experimental site shows positive and significant correlations were identified, such as the total number of cysts with the number of ECN (0.976) and with the number of ears per square meter (NE/M^2) (0.642); and between the number of solid cyst nematodes with the degree of cyst infestation (DCI) (0.773). Other negative and very highly significant correlations were found, such as the number of ears per square meter with the number of grains/ears (-0.734), and significant with the WTG (0.514), NNKP- NG/Epi (-0.559) and the number of ECN- NG/Ear (-0.492). In the second site, the correlations, some positive and very highly significant to the threshold (p· 0,001) as such as the degree of cyst infestation with the number of FCN (0.745), and between the number of TCN with NKV (0.897). A single negative and very highly significant correlation to the threshold (p<0,001) such as the number of ears per square meter and the number of grains per ear (-0.753).

Table 08 : Correlation matrix obtained from the main parameters studied at the Maturation stage in site I.

Site	Variable	NTCN	NECN	NFCN	DCI	NS/M^2	NE/M^2	NG/E	WTG	YLD
Site I	NTCN	1	,976**	ns	ns	ns	ns	-,492*	ns	ns
	NECN	,976**	1	ns	ns	ns	,649**	-,559*	ns	ns
	NFCN	ns	ns	1	,773**	-,651**	,642**	ns	ns	ns
	DCI	ns	ns	,773**	1	ns	ns	ns	ns	ns
	NS/M^2	ns	ns	ns	-,651**	1	ns	ns	ns	ns
	NE/M^2	ns	,642**	,649**	ns	ns	1	-,734**	-,514*	ns
	NG/E	ns	-,492*	-,559*	ns	ns	-,734**	1	ns	ns
	WTG	ns	ns	ns	ns	ns	-,514*	ns	1	ns
	PRF	ns	ns	ns	ns	ns	ns	ns	ns	1
Site II	NTCN	1	,897**	,604**	ns	ns	ns	ns	ns	ns
	NECN	,897**	1	ns	ns	ns	ns	ns	ns	ns
	NFCN	,604**	ns	1	,745**	ns	ns	ns	ns	ns
	DCI	ns	ns	,745**	1	ns	ns	ns	ns	ns
	NS/M^2	ns	ns	ns	ns	1	ns	ns	ns	ns
	NE/M^2	ns	ns	ns	ns	ns	1	-,753**	ns	ns
	NG/E	ns	ns	ns	ns	ns	-,753**	1	ns	ns
	WTG	ns	ns	ns	ns	ns	ns	ns	1	ns
	YLD	ns	ns	ns	ns	ns	ns	ns	ns	1

Discussion

Soil is a complex environment whose physical, chemical and biological characteristics depend on several factors (soil type, cropping system, and cultural practices) that interact (Chaussod *et al.,* 2007).

Janvier (2007) defines soil as a living, finite and dynamic resource. She explained that soil health results from multiple interactions between Physico-chemical and biological components, including microbial communities, which are essential for the functioning of the soil.

The physics-chemical analysis of the soil makes it possible to determine the quality and soil properties of the two experimental sites, the results of which generally show a clayey silty texture (site I) and a clayey texture (site II), which influences the impermeability and humidity of the soil, thus the increase in salts even the pH is slightly alkaline (between 7.82-8.13). According to Yepsen (1984), cyst nematodes do not hatch well in very acidic soils (pH= 4) or alkaline soils (pH= 8). They prefer soils with a pH close to the neutrality of 6.

However, the increase in the number of solid cysts in the two sites cultivated by the « waha » variety of durum wheat be explained by their sensitivity to these parasites. Similarly, it was found that the variation is small at the first site (silty clay soil) than at a clay soil. The increase in the number of cysts at the first site reflects its strong ability to multiply the larvae of this parasite and transform into females. In Algeria, the sensitivity of the latter has not been studied before. But the effect of resistance variety on populations of nematodes of the genus *Heterodera* has been demonstrated by several authors. According to (Speijer and De Waele, 1997), the selection of resistant hosts represents a promising alternative in controlling nematodes.

It seems that the first site is the most multiplies of these phytophagous nematodes. However, the second site is less sensitive to this parasite. There, it a large difference in the multiplication rate of this parasite (*Heterodera spp*.) between the two experimental sites. It is of wording 14.32 and 7.62 respectively for silty clay and clay soil. These differences have several explanations. Rivoal *et al*., (2001) demonstrated fitness differences between populations in France and West Asia that correspond to the ability of larvae to transform into females. Soil type also plays a key role in the development and multiplication of *H. avenae* (Tard *et al*., 2005).

Generally, the final population Pf increases with the growth of the initial population (*Pi*) even if the intrinsic multiplication rate *Rf* decreases (Magi, 1989).

According to Djical (2003), the development of cyst nematodes is conditioned by an important root system located in the area (0-40 cm). Density is defined as the number of individuals per unit of air.

The results of the egg count of solid cysts from two experimental sites show that the population of the first site has a significant number of significant numbers ranging from 06 solid cysts/300g soil at the emerged stage to 129 at the maturation stage in Site I, and from 15 at the emerged stage to 114 solid cysts/300g soil at the maturation stage of the second site, the number of eggs/cyst ranging from 294.5 eggs/cyst belonging to the first site that is 273.27 eggs/cyst in the second site.

In this study, we found a low average number of ears/m^2 with a highly significant difference in the first site. These results confirm the results of Namouchi *et al*. (2009), which that decreases in wheat production result from changes in yield parameters (number of ears, a number of grains/ear weight of 1000 grains), which are strongly correlated with the initial densities of the nematode. Thus, the degree of infestation has no effect on this variable. Therefore, it is possible that it is a varietal characteristic or linked to other factors (pedo-climatic for example).

Conclusion

As part of a contribution to improving the management of durum wheat, to a better knowledge of the sensitivity of the «waha» variety of durum wheat, the results of this study highlight a difference in the multiplication rate of *Heterodera* by a single variety under natural conditions.

Concerning the study of the effect of this phytophagous nematode on the growth parameters of the durum wheat variety «waha», shows that these parasites have a negative

influence on the number of tillers per square meter, the number of grains per square meter and the weight of a thousand grains.

Since in clayey silty texture is conducive to the development of Heterodera. On the contrary, the clay soil is unfavorable, it has been observed that in the early stages of development of the durum wheat crop some repetitions of this cultivar are free of these parasites, then we have recorded an outbreak in the later stages (run, heading, and ripening). This is due to crop plants, soil temperature, and texture and cropping practices affecting the distribution and abundance of nematode communities and their generic and specific composition. These factors are highly interdependent; their effects be direct and indirect. Similarly, it was revealed that the degree of infestation of the plot studied by the *Heterodera* is closely related to the number of solid cyst nematodes, the degree of infestation and the different phenological stages of the durum wheat crop with a determination coefficient that exceeds 80% (R2) in both the experimental sites, the probability is very highly significant.

It can be concluded that although these two soils are completely different, *Heterodera* populations adapt to them according to the possibilities offered by each of them. This suggests that the potential for infestations in inland plains regions, characterized by clay and clayey-silt soils, is possible if the necessary measures are not taken to avoid soil contamination by cyst nematodes. This impacts the future of agriculture.

Acknowledgments

We would like to thank all the people who contribute to this work.

Abbreviations

R : Repetition
C : Clay,
FS : Fine Silt
CS : Coarse Silt
FS : Fine Sand
CS : Coarse sand
CC : calcareous clayey
SC : Silty clayey
NTCN : Number of Total Cyst Nematodes
NECN : Number of Empty Cyst Nematodes
NFCN : Number of Full Cyst Nematodes
DCI : Degree of Cyst Infestation
NS/M^2 : Number of Slabs Per Square Metre
NE/M^2 : Number of Ears Per Square Metre
NG/ E : Number of Grains Per Ear
WTG : Weight of Thousand Grains
YLD(qs/ha) : Yiled in quintals per hectare

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