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Effect of Soil Temperature on Juvenile Emergence of Algerian Populations of *Heterodera Avenae*

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ABSTRACT
A study of the influence of soil temperature on hatching of *Heterodera avenae* over three successive years revealed emergence of 36.4%, 54.4%, 68%, 34.4%, 30.2%, 63%, 65.8% and 36.6% of juveniles for populations of Djendel (Aïn Defla), Dahmouni (Tiaret), El Fedjoudj (Guelma), Oued Smar (Alger), Mouzaïa (Blida), Tighennif (Mascara), Khroub (Constantine) Sidi Amar (Tipaza) respectively. Emergence occurred during the winter period, starting in october or november and ending in april. The data indicate that temperatures from 10°C to 20°C are suitable for hatching, with an optimum of 14.5°C for the populations studied. These populations have hatching patterns typical of the southern European ecotype of *H. avenae*, with winter emergence of juveniles and a summer-autumn diapause.

KEYWORDS: Cereal cyst nematode; *Heterodera avenae* Woll.; Hatching; Soil temperature; Algeria.

INTRODUCTION

The cereal cyst nematode *Heterodera avenae* is widely distributed throughout the temperate cereal-producing regions of the world [26]. This nematode is one of the most harmful phytoparasitic nematodes affecting cereals globally [2], [18], [29], including North Africa [20], [10], [17], [15], where each year, in Algeria, the average area devoted to this crop is 3 million hectares [11].

Also, it is abundant in arid regions such as Saudi Arabi [7]. In Algeria, *H. avenae* was first reported by Scotto La Massese in 1962 and by [9]. More recently, this species was recorded in different cereal-producing regions of Algeria [14], [6], [28], [31].

H. avenae characteristically has two ecotypes differentiated, in relation to the geographic origin of the populations, by the period in which juveniles emerge from eggs [3], [22]. One ecotype from more or less temperate oceanic climates in northern Europe, Great Britain [8] and northern France [21] has a hatching period in springtime. The other from Mediterranean climates, such as Australia [12], the south of France [21] and Italy [4] has more activity in the winter.

In Algeria, a detailed study of hatching processes in controlled conditions, simulating seasonal temperatures changes, showed that the activities of one Algerian ecotype of *H. avenae* depend upon specific temperature conditions breaking one type of diapause, obligatory and in summer for the two populations originating from Oued Smar in a sub-humid coastal plain and from Tiaret in an inland semi-arid plain [14].

In this paper, we have undertaken studies in the field to evaluate the effect of soil temperature on the hatching of eight Algerian populations of *H. avenae*, originating from two different climatic regions: one from the coastal plain and another from the interior plain. Novel information was generated that will be useful to

reduce *H. avenae* damage to wheat in Algeria and other parts of the world.

MATERIALS AND METHODS

Populations of *H. avenae* from eight locations in Algeria were examined (Table 1). The study was carried out in three successive years (2013, 2014 and 2015) at the National Institute of Plant Protection experimental station (Algiers) (36°42'59" N; 3°09'00" E).

Eight soil samples were taken to extract the cysts by the method described by Fenwick (1940) on the device modified by Oostenbrink (1960) [16].

Table 1: Location of populations of *Heterodera avenae* sampled in Algeria, and range and mean of soil temperatures (°C) for January and July for these locations

Town (Province)	Latitude	January			July		
		Max	Min	Mean	Max	Min	Mean
Mouzaïa (Blida)	36°28'N	17,5	5,9	11,7	31,6	19,2	25,4
Sidi Amar (Tipaza)	36°32'N	17,6	5,9	11,7	31,0	19,4	25,2
Oued Smar (Alger)	36°42'N	17,5	6,2	11,8	32,0	19,6	25,8
Djendel (Aïn Defla)	36°13'N	17,0	5,7	11,4	32,0	19,1	25,6
Khroub (Constantine)	36°15'N	13,0	2,3	7,6	34,7	17,8	26,2
El Fedjoudj (Guelma)	36°50'N	16,7	7,3	12,0	30,3	19,4	24,8
Tighennif (Mascara)	35°25'N	15,4	3,9	9,6	36,6	18,6	27,6
Dahmouni (Tiaret)	35°14'N	11,8	1,6	6,7	34,9	17,1	26,0

For each population, 20 cysts were individually placed in tubes with 1 ml of distilled water. Tubes were placed in a hole dug at 30 cm depth in the soil and covered with sod. The soil temperature was recorded with a thermometer placed vertically just close to the tubes containing cysts. The temperatures as daily averages were obtained, which allowed subsequent calculations of weekly averages. The J2 emergence was counted each week.

For identification, the cysts were submitted to the nematology laboratory at Bolu University, Turkey, and each population was determined to be *H. avenae* using PCR-RFLP analysis of the ITS region of ribosomal DNA (unpublished).

Statistical analysis:

To study the variation in outbreaks of *H. avenae* J2 as a function of soil temperature, we used ANOVA with Systat software version 12.0.

Results:

First emergence of J2 was from November to February for the eight *H. avenae* populations in the first year, from October to January in the second year, and from October to December in the third year (Table 2). The beginning of the second and third cycle of emergence occurred at lower temperatures than the first. Hatching was finished by the end of April each year when soil temperature reached 17°C. The analysis of the variance shows a very highly significant difference in the variation of J2 hatching according to soil temperature ($P = 0.000$, $P < 1‰$).

Table 2: First emergence of J2 of *H. avenae* from cyst from eight locations in Algeria buried at 30 cm in field soil

Population		2012/2013	2013/2014	2014/2015
Mouzaia	First emergence (week-month)	2 - Nov	2 - Oct	1 - Oct
	J2/cyst	2.4	3.2	4.1
	Soil temperature (°C)	18.4	14.3	13.4
Sidi Amar	First emergence (week-month)	2 – Jan	1 – Nov	4 - Oct
	J2/cyst	0.4	2.1	3.3
	Soil temperature (°C)	12.9	12	11.2
Oued Smar	First emergence (week-month)	1 – Dec	1 – Nov	4 - Oct
	J2/cyst	1.9	3.7	5.2
	Soil temperature (°C)	14.8	12	11.2
Djendel	First emergence (week-month)	2 – Jan	4 - Oct	1 - Nov
	J2/cyst	0.6	1.9	3.1
	Soil temperature (°C)	12.9	11.1	11
Khroub	First emergence (week-month)	4 – Jan	4 – Dec	3 - Nov
	J2/cyst	1.1	2.2	2.5
	Soil temperature (°C)	13.2	12.4	11.6
El Fedjoudj	First emergence (week-month)	3 – Dec	1 – Dec	2 - Nov
	J2/cyst	1.9	2.7	3.1
	Soil temperature (°C)	15.5	13.2	12.2
Tighennif	First emergence (week-month)	1 – Feb	1 – Jan	4 - Nov
	J2/cyst	3.4	3.1	3.4

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	Soil temperature (°C)	12.8	10.9	11.9
Dahmouni	First emergence (week-month)	3 – Feb	1 – Jan	3 - Dec
	J2/cyst	5.3	3.2	4.5
	Soil temperature (°C)	11.3	10.9	10.9

At the end of the three hatching cycles, proportion of J2 hatch was 65.6%, 69.8%, 63.4%, 63.6%, 32.0%, 34.3%, 37.0% and 45.6% for the populations from Oued Smar (Alger), Mouzaïa (Blida), Sidi Amar (Tipaza), Djendel (Aïn Defla), El Fedjoudj (Guelma), Khroub (Constantine), Tighennif (Mascara), Dahmouni (Tiaret), (north to south), respectively (Fig. 1). For each population, emergence occurred systematically in the winter period with a beginning in October or November and finishing at the end of April.

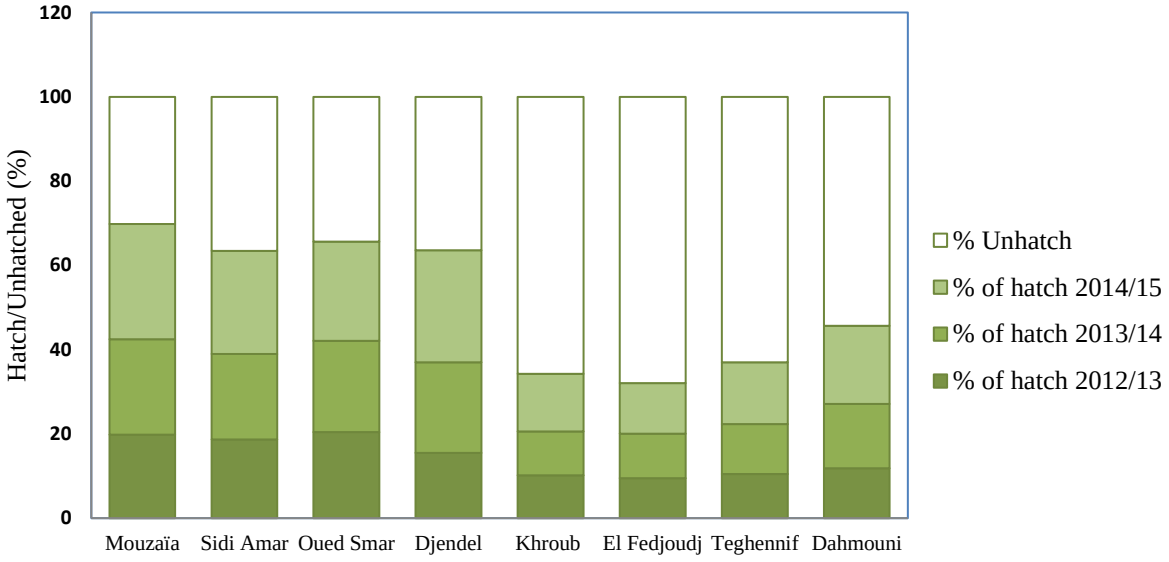

Fig. 1 : Proportion of hatch of eight populations of *Heterodera avenae* in Algeria buried at 30 cm in field soil and monitored over three successive years, 2012/13 (bottom), 2013/2014 (middle), 2014/2015 (middle) and unhatched (top)

Discussion:

Temperature is an important factor that determinates the hatching rate of *H. avenae* [22], [13], [14]. Populations of *H. avenae* that were obtained from different origins revealed the existence of ecotypes that differed in their hatching cycles, which is a result of the induction or suppression of dormancy (diapause) by different temperature conditions [19].

Hatching of *H. avenae* in Mediterranean climates is characterized by J2 emergence from autumn to the beginning of spring, whereas in more temperate climates (cooler, usually with snow), the majority of J2 emerge in spring when soil temperatures rise [22], [23], [24]. Peak populations of *H. avenae* J2 in soils in Oregon occur primarily during the spring [30]. In this study, all populations of *H. avenae* studied showed hatching cycles similar to that of other populations from Mediterranean climates.

Emergence began in October or November, when the soil temperature fell below 17°C. The J2 cease to hatch in April when the soil temperature reached 17°C again. The data indicate that temperatures from 10° to 20°C are suitable for hatching, with an optimum of 14.5°C for the populations studied. For *Heterodera latipons*, hatching occurred in tap water at 10-25°C with an optimum of temperature at 10°C [1].

The Algerian populations were similar to their counterparts of southern Italy [4], [5], Spain [27], [32] and South Australia [12], where hatching occurred during the periods of lower temperatures. In Algeria, hatching was triggered by declining temperature, while increase of temperature (up to 17°C) caused cessation of the hatching cycle for all populations tested.

The work confirmed that Algerian populations of *H. avenae* from the eight locations belong to the Mediterranean ecotype characterized by winter hatching activity. Furthermore, we observed that the proportion of unhatched eggs was considerable (about 30-67%) at the three-year experiment, which indicates cohort of J2

which are able to hatch each year as previously noted by [12] in Australia and [23] in France.

In Algeria, variation of the tolerance of cereal cultivars to *H. avenae* can be explained, in part, by the biology of the nematode. Indeed, durum and bread wheat sown in late autumn are more vulnerable to nematode attack, as their early vegetation coincides exactly with the beginning of J2 emergence.

Such vulnerability of durum wheat to *H. avenae* infestations was observed also in France. In contrast, in northern Europe, spring sown cereals, such as oat or maize, are more vulnerable to this nematode because their growing period coincides with the spring activity of the northern ecotype [25].

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