Nematol. medit. (1991) *19*: 37-40

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EFFECT OF TEMPERATURE ON JUVENILE EMERGENCE OF SPANISH POPULATIONS OF *HETERODERA AVENAE*

by
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Summary. Hatching tests with Spanish populations of *Heterodera avenae* using cysts in distilled water kept in soil at 15 cm depth, showed juvenile emergence beginning in the autumn at 15-20°C, without needing a cold stimulus. Maximum emergence coincided with temperatures of 5-10.5°C and emergence stopped in spring as temperature approached 15°C. Percentage of emergence was about 90-100% for 8-17% of the individuals, and ≥60% for 14-28% of them.

The influence of temperature on the hatching of eggs and the emergence of second stage juveniles of *Heterodera avenae* Woll, has been reported by many workers under laboratory and field conditions. In Canada and Northern European countries, emergence begins when temperatures reach 15-20°C in the spring (Winslow, 1955; Hesling, 1957; Davies, 1962; Fushtey and Johnson, 1966; Fisher, 1981). In countries with hot summers, emergence begins when the temperature decreases in the autumn. In India the optimum temperature for juvenile emergence has been estimated as 15-20°C by Bhatti and Malhan (1982) and 20-22°C by Swarup and Gill (1972) and Mathur *et al.* (1974). Banyer and Fisher (1971) found two periods in the hatching of eggs of Australian populations of *H. avenae*, one period of juvenile development and another one concerned with eclosion, the optimum temperatures being 10 and 20°C respectively; maximum hatching was at 15°C. In France, Rivoal (1979) found optimum hatching temperatures of 10-15°C for the northern and 5°C for the southern ecotypes, although significant emergence occured at 15-20°C and 10-15°C respectively.

This paper describes work carried out with Spanish populations to determine the influence of temperature on emergence of *H. avenae* juvenile, as well as observations on the fertility of cysts and percentage of emergence of juveniles in water.

Materials and methods

Populations of *H. avenae* were obtained from five locations in three provinces of cereal growing areas with different climatic characteristics (Table I) and transferred to Madrid where experiments were done over three consecutive years. Every year, soil from three of these populations was sown with wheat cv. Anza, susceptible to *H. avenae*. Cysts were extracted in mid July in each year using a Fenwick can. Newly formed cysts were selected and kept in distilled water at 20°C until the end of September. In the first year of the experiment 20 cysts were selected and 30 in the following ones. The cysts were individually introduced into a glass tube containing distilled water,

Table I - *Geographic situation and temperatures of the original areas of the populations studied.*

Location (Province)	Year	Latitude	Temperature °C					
			Dec-Jan			Jul-Aug		
			Max.	Min.	Mean	Max.	Min.	Mean
1 Bello (Teruel)	1983-84	40° 55' N	7.8	−2.5	2.6	28.9	10.8	19.8
2 Concud (Teruel)	1984-86	40° 22' N	9.1	−1.5	3.8	29.4	12.1	20.8
3 Alcalá de Guadaira (Sevilla)	1983-85	37° 22' N	15.7	4.8	10.3	35.7	18.0	26.9
4 Carmona (Sevilla)	1985-86	37° 30' N	12.2	5.2	8.7	33.1	20.4	26.8
5 La Higueruela (Toledo)	1983-86	40° 30' N	11.5	1.2	6.4	32.6	15.1	23.8

closed with a cork and placed in a hole in the soil at a depth of 15 cm. The upper part was closed by a uralite plate and covered with a soil layer. Every ten days the water suspension from each tube was poured into a Petri dish and the juveniles that had emerged from the cyst were counted. The cysts were then transfered to fresh tubes and again put into the soil as before (Rivoal, 1986).

During the season a number of cysts were lost, due to the breaking of the cyst wall. After eight months, the remaining cysts were squashed and the unhatched juveniles judged to be viable because of their straight shape and contrasting contents, were counted.

Temperatures were recorded with a thermograph, and mean temperatures were calculated for six hourly periods.

Data were transformed to log (X + 1) (Sokal and Rholf, 1979) and statistical analyses were carried out for the differences between populations for mean values of abundance.

Results

In each of the three years emergence of second stage juveniles (Fig. 1) began at the end of October or beginning of November when calculated mean temperatures were 15-20°C (depending on the year), then increased to reach a maximum at 5-10°C in December till February, thereafter decreasing and finally ceasing in April as mean temperatures approached 15°C. However, a slight increase of emergence was observed for the population from Toledo in March or April corresponding with an increase of temperature up to 10-15°C, in 1983-84 and 1985-86.

Table II shows the results of statistical analysis for the total number of juveniles emerged from each population over the three years. Maximum emergence was in January and February for the populations from Teruel and in November-January for that from Sevilla, while no clear differences in emergence during the period November-

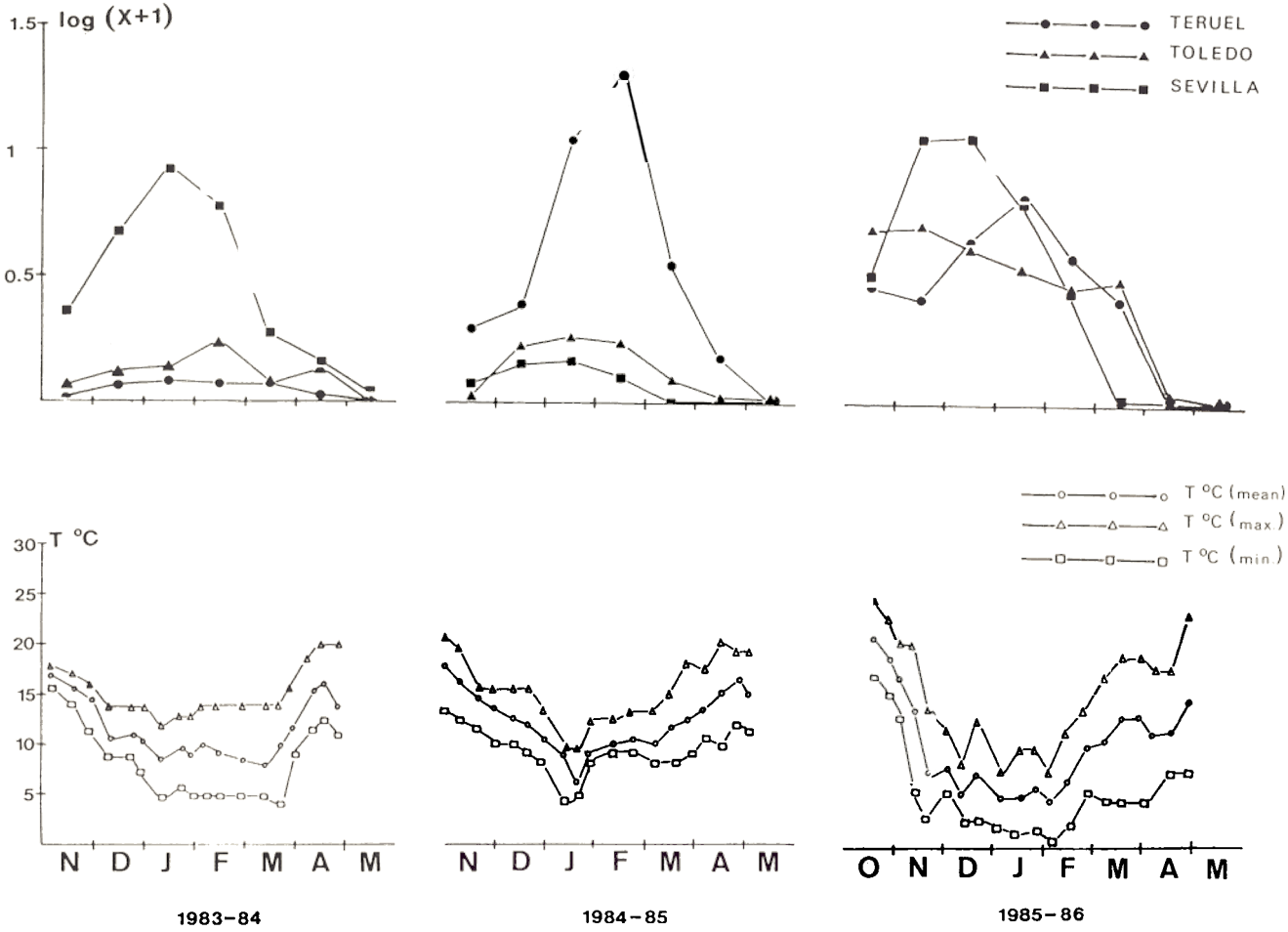

Fig. 1 - Monthly juvenile emergence distribution for Teruel, Toledo and Sevilla populations with respect to temperature variation over the three years.

March were discernible with the population from Toledo. In all cases were no significant differences in the number of juveniles during the period of maximum emergence, but the emergence during this period differs significantly ($p < 0.01$) from the rest of the season. Therefore, mean values of abundance were taken for each of the periods of maximum emergence and compared statistically. Abundance differed ($p < 0.01$) between each two populations (Table II and Fig. 2).

Mean temperatures during these periods were also com-

TABLE II - *Juvenile emergence of* Heterodera avenae *over the three years (n = replicates; L_1 = higher confidence limit; L_2 = lower confidence limit; X = mean values). Results of Student's t Test.*

	Teruel				Sevilla				Toledo			
		L_1	L_2	$\bar{X}$		L_1	L_2	$\bar{X}$		L_1	L_2	
October	86	1.55	2.69	2.07 ab	90	1.74	3.16	2.36 ad	89	2.19	4.17	3.01 a
November	208	1.70	2.25	1.97 a	220	2.75	4.17	3.40 ac	211	2.04	3.98	2.88 a
December	222	2.19	3.03	2.55b	237	3.47	5.02	4.22 bc	224	1.82	2.51	2.15 ab
January	217	4.07	6.46	5.14 c	234	3.16	4.79	3.93 c	219	1.82	2.51	2.13 ab
February	190	4.26	7.41	5.57 c	206	2.29	3.47	2.84 a	189	1.70	2.34	2.01 b
March	178	1.90	2.75	2.30 abd	202	1.66	2.09	1.87 d	191	1.55	2.04	1.80 b
April	194	1.17	1.41	1.30 e	228	1.05	1.20	1.12 e	214	1.07	1.23	1.15 c
May	170	1.00	1.05	1.02 f	198	1.04	1.05	1.04 f	185	1.00	1.01	1.00 d

Means expresed as log (X + 1) in the same columns followed by the same letter do not differ significantly for p. 0,05

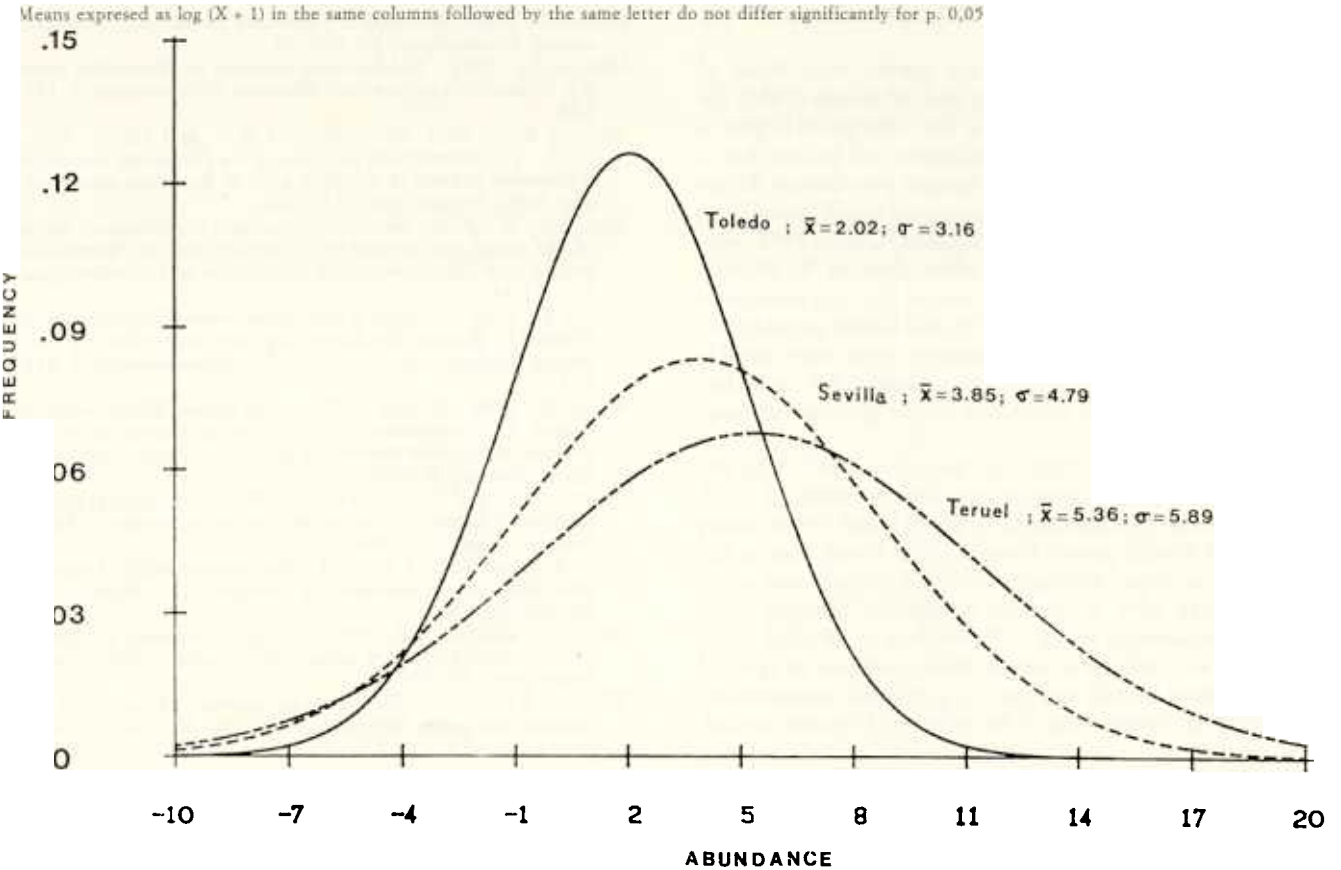

Fig. 2 - Distribution of the means of juvenile emergence in the maximum abundance periods for the populations considered.

pared. Maximum abundance for the Teruel population coincided with a mean temperature of 8.5°C, significantly different ($p<0.05$) from the populations from Sevilla (10.3°C) and Toledo (10.4°C).

Mean values of percentage of emergence, considering the three years, were ≥ 60% for 13.75% of the specimens from Toledo, 26.25% for those from Sevilla and 27.50% for the ones from Teruel, and an emergence of 90-100% was observed in 7.5% of the individuals from Toledo, 16.5% from Sevilla and 15% from Teruel.

Discussion

The results demonstrate that, although differences in the periods of maximum emergence and in mean temperatures during these periods have been observed among populations from different areas, these differences are not sufficient to consider them as different ecotypes as the pattern of emergence is similar in all of the populations, i.e. emergence begins in the autumn, increases during the winter and ceases at the beginning of the spring. The maximum emergence of the Teruel populations at a lower temperature (8.5°C) than with the Sevilla and Toledo populations (10.3 and 10.4°C) is associated with the lower winter temperatures in the Teruel region compared with the other areas.

From the comparison of our results with those of Rivoal (1979) for French races and of Greco (1981) for Italian populations, we conclude that emergence begins at the same time as in Italian populations and before that in southern French ecotype Fr1. Spanish populations do not need a cold period to initiate emergence which is similar to Australian (Meagher, 1970) and Italian (Greco, 1981) populations. Maximum hatching takes place at 5- 10.5°C, which represents a larger range than in Fr1, but emergence stops at about 15°C similar to Fr1 and Italian populations.

Percentages of juvenile emergence were very variable between years and populations, probably due to differences in cyst age and sometimes to the presence of fungi inside the cysts.

Emergence of 90-100% has been found in 7.5-16.5% of cysts of Spanish populations, and ≥ 60% in 13.7-27.5%, while in experiments with Fr1 and Fr4 ecotypes over a 15 month period Rivoal (1979) found that in the southern ecotype, emergence (in this period) was never greater than 60% in the best conditions. Similary, with Italian populations about 57% hatched in distilled water at 10°C and only 15% out of doors; however in cysts of the northern French ecotype, at a suitable temperature, hatching led to emptying of the cysts in a 15 month period.

The bioecological behaviour of Spanish populations is of a Mediterranean type, but with some characteristics of those from Northern European countries. As discussed previously (Romero and Valdeolivas, 1990) this can be explained by the special situation of the Iberian Peninsula, exposed to both Mediterranean and Atlantic influences.

The authors thanks Dr. J. Rey for his help in drawing the graphics.

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ccepted for publication on 21 November 1990.