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Kinetics of recovery from anhydrobiosis in *Pratylenchus thornei*, *Merlinius brevidens* and *Heterodera avenae* from dry field soils and dry roots of the host plant

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Summary – The behaviour of *Pratylenchus thornei, Merlinius brevidens* and *Heterodera avenae* in a distinctively dry soil environment of Southern Spain has been studied after the summer season. Six times of recovery, up to 135 hours of rehydration plus migration, let to recover more than 95 % of the *Merlinius* population. But for *Pratylenchus*, which seems to be the predominant and most important nematode species there, after a wheat var. yecora, a quantitative recovery of 95 % or more of its true population density is only reached after twelve times, 279 hours, as far as all the remaining wheat roots are considered and processed. Those *Pratylenchus* that survive within dry wheat roots seem to be the cause of some until now unexplained losses of wheat yield. *Heterodera avenae* seems to play a secondary role in this dry soil environment.

Résumé – *Cinétique de la récupération, après anhydrobiose, de* Pratylenchus thornei, Merlinius brevidens *et* Heterodera avenae *à partir de sols secs ou de racines sèches de la plante hôte – Le comportement de *Pratylenchus thornei, Merlinius brevidens* et *Heterodera avenae* dans un sol particulièrement sec du sud de l'Espagne a été étudié, après la saison d'été. Six périodes de récupération, allant jusqu'à 135 h de réhydratation suivie de migration, permettent de récupérer plus de 95 % de la population de *Merlinius*. Mais pour *P. thornei* – qui semble l'espèce dominante et la plus importante dans la zone considérée – la récupération au taux de 95 %, après culture de blé var. yecora, n'est atteinte qu'après douze périodes, et 279 h, pour autant que toutes les racines présentes dans le sol soient elles aussi traitées. Les *Pratylenchus* survivant dans les racines desséchées du blé semblent être la cause de pertes de récolte encore inexpliquées atteignant cette culture. *Heterodera avenae* ne paraît jouer qu'un rôle secondaire dans ces sols secs.

Key-words : Anhydrobiosis, quantitative recovery *Pratylenchus, Merlinius, Heterodera,* nematode.

Losses of yield suffered by cultivars of wheat suitable for some Southern Spain soils, which form a distinctive environment with periods of extreme water stress along the plant life cycle, could not be explained either by those water stresses or by the presence of low population levels of *Heterodera avenae* Wollenweber, 1924. Initial levels of population of *Pratylenchus thornei* Sher & Allen, 1953 and *Merlinius brevidens* (Allen, 1955) Sidiqqi, 1970, also present in those soils, estimated by a modification of Oostenbrink's technique (Tobar, 1962, 1963), based on nematode weight, size and its capability of migration in a standard time of 15 hours, were far from those considered close to their accepted level of damage.

Previously, *Tylenchorhynchus sulcatus* from a nearby area had been found able to withstand quick desiccation. After two-and-a-half months in dried sand, 41 % of the population was recovered within 15 hours of rehydration and migration (Tobar & Gallardo, 1976). Later, from a total population of 1430 *Tylenchorhynchus* sp. recovered from naturally dried soil within 39 hours of rehydration and migration, 610 (42.7 %) came from the 15-39 hours period (Tobar & Salmerón, 1985).

Maize roots remaining in the soil after harvest had been seen to provide a dry season habitat for *Pratylenchus* spp. (Egunjobi & Bolaji, 1979). It has been established that *Pratylenchus zeae* enters anhydrobiosis while in the roots of maize (Swanepoel *et al.*, 1987). *Pratylenchus mediterraneus* had been found able to withstand desiccation for up to 7-8 months, keeping its infectivity towards its hosts (Glazer & Orion, 1983).

The results mentioned and the information given in a review about arrested development in plant parasitic nematodes (Antoniou, 1989) suggested that nematode levels may have been underestimated owing to the possible existence of a particular stage of anhydrobiosis in soil (particularly in the roots remaining from the previous crop, not usually taken into account after the dry season), evolved by those indigenous nematodes to survive in their hostile environment.

This work has been carried out to study the behaviour of the most important nematode species of the soil environment involved at the beginning of the growing season and to evaluate the role exerted in the soil by the remaining roots of wheat, one main plant crop.

Material and methods

Soil type Ecija 1 (a vertic soil with a sandy loam texture) was taken from five locations of a non-irrigated area of the province of Sevilla, characterized by periods of extreme water stress throughout the life cycle of its crops, mainly wheat and sunflower. The soil, as large hard dry fragments, obtained after harvest by deep ploughing when it still held some moisture, was sampled after the summer dry season, just before the first autumn rains. The previous crops of the last growing season had been wheat var. yecora (fields 1-2) and sunflower var. sungro 386 (fields 3-5).

Soil samples were broken into crumbs, and four representative subsamples of 120 g for each of the five fields were moistened and processed by differential sedimentation in water in an elutriator, sieving of the supernatant through four 53 μm sieves (Tobar, 1963) and active migration of the nematodes through a filter to clean tap water (Tobar, 1962). Migration (rehydration plus migration) was allowed to proceed along times 1-30 (15 h and 29 additional periods of 24 h). At time 30 there had not been any nematode revovery for three times from any of the replicates. After each time the water embedded in the nematode filters was changed and these were replaced in a fresh volume of tap water to stimulate the nematode activity.

All the dry wheat-root fragments from 120 g subsamples of soil from field 2 (that with the largest *P. thornei* density), slightly washed before their processing, were placed uncut on nematode filters in tap water and the active nematodes recovered, as those from soil, but for 109 times (15 h and 108 additional periods of 24 h). There was no nematode recovery for times 107-109.

Cumulative *Pratylenchus thornei* and *Merlinius brevidens* numbers up to time 6, as a percentage of their total recoveries, transformed into angles, were studied by analysis of the variance (nematode species, fields and replicates) and, for the 5 % level of probability significant F value of the interaction species × fields, differences between nematode counts were compared with the least significant difference.

Results and discussion

Recovery of filiform nematodes from dry soil

At time 6 of rehydration and migration, 95 % or more (means, 95.8 %-98.3 %; individual values, 94.7 %-99.4 %) of the *P. thornei* populations from fields 3-5 were recovered from soil. Roots of the previous crop, sunflower var. sungro 386, which were already decomposed, had not had any influence on the nematode behaviour. On the other hand, recoveries at time 6 for fields 1 and 2 only reached mean values of 89.9 % (82.9 %-92.8 %) and 84.6 % (80.8 %-90.0 %) of the population, respectively. Roots of the previous crop, wheat var. yecora, remaining in the soil, had provided a good dry-season habitat for this nematode, as maize roots did for

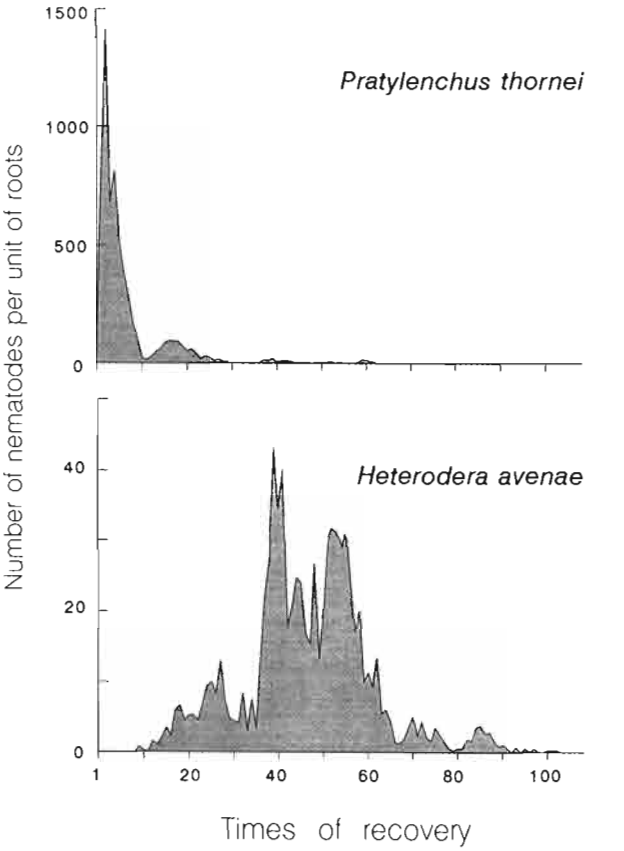

Fig. 1. *Numbers of nematodes per unit of roots (those remaining in 120 g of soil from field 2; 0.1106-0.2948 g, mean 0.22 g). Time 1, 15 hours; times 2-109, periods of 24 hours. Values are the mean of four replicates.*

Pratylenchus spp. (Egunjobi & Bolaji, 1979) and *P. zeae* (Swanepoel *et al.*, 1987). The revovery of *P. thornei* from soil was significantly more efficient, at time 6, for fields 3-5 than for fields 1 and 2. The 95 % or more of the population was recovered from soil of these two fields at the end of time 12. This delay was thought to be due to the possible and significant presence of small, practically unseen or non-looked for, pieces of wheat roots that might have gone through the upper sieve of the elutriator, which usually retains the gross particles of sand and the plant debris, and might finally have been located in part on the nematode filter, gradually liberating nematodes to the clean tap water.

At time 6 of rehydration and migration, more than 95 % (means, 98.1 %-100.0 %; individual values, 97 %-100 %) of the *M. brevidens* populations from fields 1-5 were recovered from soil.

Recovery of nematodes from dry roots (Fig. 1)

Pratylenchus thornei

At time 6, the recovery of *P. thornei* from all the wheat roots of 120 g subsamples of soil from field 2 had only

reached 68.8 % (60.2 %-81.3 %) of the nematode population. The nematode recovery at time 12 reached 83.4 % (80.1 %-90.0 %). A pronounced second boost of 12.6 % (8.0 %-15.8 %) of the population, at times 13-30, and subsequent smaller ones, might be due to a delay for recovery from anhydrobiosis in eggs and their hatching within the wheat roots on the nematode filter. The total recovery up to time 30 was 96.0 % (94.7 %-98.0 %). When dry soil was under investigation *Pratylenchus* recoveries from roots did not occur beyond 95 % or more of its living population for the next season from time 6 onwards, as has already been seen. The roots remaining on the nematode filter surrounded by median soil particles and soil debris decay more rapidly than those previously washed, as seems to occur within moist field soil.

The main nematode recovery at times 7-12 seems to explain the already discussed delay in *P. thornei* recovery from fields 1 and 2 soils. Nevertheless, part of the fine root pieces remained on the coarse mesh of the upper sieve of the elutriator and adhered to the inner wall of its funnel, and they were later taken off by washing.

In soil from field 2, a large amount of the *P. thornei* population was located within the remaining roots of wheat. This fact might tie in with the unexplained losses of wheat yield commented on in the introduction.

Heterodera avenae

At time 10, juveniles of *H. avenae* started to appear among the individuals of *P. thornei,* reaching their largest density at times 37-59 and decreasing their numbers afterwards until time 103, with no recovery at all at times 104-109 (Fig. 1).

These juveniles were proved to come from 18 (7-35) young cysts of *H. avenae* adhered to the wheat roots, cysts that seemed to need some time to mature and/or their juveniles to recover from anhydrobiosis. The number of juveniles migrated to the clean tap water was 822 (5-1827) and 761 (0-1986) remained encysted.

A marked delay was shown in the emergence of the juveniles in the distinctively dry soil environment studied. This delay might mean that the *H. avenae* juveniles are free and able to infest new host roots when these are already occupied by *P. thornei,* which seems the predominant and most important nematode species there.

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