RESENA—REVIEW

NEMATODE PROBLEMS OF BULBS, WITH SPECIAL REFERENCE TO *DITYLENCHUS DIPSACI*†

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ABSTRACT

Tenente, R. C. V. 1996. Nematode problems of bulbs, with special reference to *Ditylenchus dipsaci.* Nematropica 26:91-99.

Nematode diseases have increased greatly in economic importance in vegetable and ornamental bulb crops. Nematodes are important parasites of gladiolus, narcissus, tulip, onion, and garlic, and to a lesser extent on leek, spring onion, iris, hyacinth, and lily. The main nematode genera affecting bulb crops throughout the world are *Ditylenchus, Heterodera, Longidorus, Meloidogyne, Paratylenchus, Pratylenchus* and *Paratrichodorus.* Some of these nematodes are quarantined in various countries and regions due to their wide host range, potential for damage to economically important crops, or because their geographic ranges are restricted. Once established, eradication of these nematodes is almost impossible. Nematode species are often introduced into uninfested land on seeds or bulbs, and once introduced, they are difficult to control. *Ditylenchus dipsaci* has many attributes which make it particularly difficult to manage.

Key words: Allium cepa, Allium sativum, Ditylenchus dipsaci, garlic, nematodes, onion.

RESUMEN

Tenente, R. C. V. 1996. Problemas nematológicos en bulbos, con énfasis especial en *Ditylenchus dipsaci.* Nematrópica 26:91-99.

Las enfermedades de nematodos han incrementado su importancia económica en cultivos hortícolas y ornamentales de bulbo. Son importantes en gladiolas, narcisos, tulipanes, cebollas, y ajos. Son menos importantes en otros cultivos de bulbo como puerros jacintos y lirios. Los principales generos que afectan cultivos de bulbo en el mundo son *Ditylenchus, Heterodera, Longidorus, Meloidogyne, Paratylenchus, Pratylenchus,* y *Paratrichodorus.* Algunos estan cuarentenados en varios países y regiones debido a su amplia gama de hospedantes, potencial para dañar cultivos de importancia económica o porque estan restringidos geográficamente. Una vez establecidos, los nematodos son practicamente imposibles de erradicar. Sus especies son introducidas a áreas libres atraves de semillas o bulbos contaminados. Una vez establecidos son difíles de controlar. *D. dipsaci* posee varios atributos que lo hacen particularmente dificil de manejar.

Palabras clave: ajo, *Allium cepa, Allium sativum,* cebolla, *Ditylenchus dipsaci,* nematodos.

INTRODUCTION

Vegetable bulbs such as onion (*Allium cepa* L.) or garlic (*A. sativum* L.) are part of the diet of most humans, although the amount consumed varies among countries around the world. Bulb production (vegetable and ornamental) in virtually every

†Symposium presentation at 24th Annual Meeting of ONTA in the Canary Islands.

part of the world is affected by nematode pests (Luc *et al.*, 1990). Nematode diseases of bulb crops have increased greatly in economic importance and sometimes have developed to near catastrophic proportions. For example, the stem and bulb nematode, *Ditylenchus dipsaci* (Kuhn) Filipjev, is the most important bulb nematode pest (Thorne, 1961; Hooper, 1972). It is still an agricultural menace nearly as great as it was in the 1920's, when the nematode nearly destroyed the narcissus (*Narcissus* spp.) industry in Britain (Hague, 1972).

There are many genera of nematodes parasitic on bulbs, and several are widely distributed throughout the world's varied climatic and topographic areas. These include *Ditylenchus, Heterodera, Longidorus, Meloidogyne, Paratrichodorus, Paratylenchus,* and *Pratylenchus.* Individual species tend to be more restricted in their distribution, e.g. *Paratrichodorus allius* on onion in Oregon (U.S.A.) (Luc *et al.*, 1990) (Table 1). *Ditylenchus dipsaci* has been known for about a century as one of the most harmful species of parasitic nematodes on bulbs (Decker, 1981; Hooper, 1972; Yuksel, 1960). This nematode is a migratory endoparasite that parasitizes a wide range of plants of economic importance including bulb crops such as garlic, onion, hyacinth (*Hyacinthus* spp.), narcissus, and tulip (*Tulipa* spp.) (Goodey *et al.*, 1965; Thorne, 1961; Hague, 1972; Webster, 1972; Charchar *et al.*, 1980; Costa Manso *et al.*, 1994). This species of nematode has a very wide geographical distribution. It is found in Europe (Eriksson, 1974), Africa (Lamberti *et al.*, 1975), the American continent (Tenente & Manso, 1987), Australasia (Goodey, 1931), and Asia (Nattras, 1950) (Table 2).

Ritzema-Bos first established the presence of biological races of *D. dipsaci* in 1892 (Thorne, 1961). These morphologically identical host races differ in their host ranges. There is controversy over the number of *D. dipsaci*, 11 being recognized by Seinhorst (1957), 21 by Hesling (1966a), and 15 cited by Gubina (1988).

Local populations within a race may vary in their pathogenicity and host range, and this increases the complexity of identifying biological races. Differences among isolates have been found in onion (Edwards and Taylor, 1963; Sayre and Mountain, 1962), narcissus (Hesling, 1966b; Hodson, 1926; Wilson, 1943), and garlic races (Pimentel and Huang, 1985). These biological races differ in the degree to which they show segregation or interbreeding and recombination of characters controlling host preference. Thus, races of *D. dipsaci* can interbreed and their progeny can have different host preferences (Sturhan, 1971; Webster, 1967). Sturhan (1971) reported that the host preference of the hybrid populations resulting from interbreeding among 11 biological races differed from those of the parental types. Webster (1967) reported that continuous backcrossing and a slow rate of reproduction in the resulting progeny could account for the variation in host preference of the biological races of *D. dipsaci.* These observations suggested that physiological differences among *D. dipsaci* are insufficient to assure the designation of these races by a "type" host (Sturhan, 1971). This is consistent with the report by Viglierchio (1971) that an extremely polyphagous race from garlic was able to reproduce on a number of plant tissues. It is clear, however, that races differ among countries in their frequency of occurrence and in their geographical variation, due to their origin or their acclimatization to a host after being introduced to a new area.

Each biological race of *D. dipsaci* varies in its degree of host specificity. Some have wide host ranges, like the strawberry, sugar beet, rye, and oat races; others such as the red clover, white clover, and hyacinth races

Table 1. Parasitic nematodes associated with onion and garlic.

Host Plant	Nematodes
Allium cepa (onion)	*Aphelenchoides* sp., *Aphelenchus* sp., *A. avenae, Basiria* sp., *Belonolaimus gracillis, Ditylenchus* sp., *D. destructor, D. dipsaci, Helicotylenchus* sp., *H. dihystera, H. microlobus, Heterodera* sp., *Macroposthonia onoensis, Meloidogyne* sp., *M. arenaria, M. exigua, M. hapla, M. incognita, M. acrita, M. javanica, M. thamesi, Paratrichodorus allius, Paratylenchus projectus, Pratylenchus brachyurus, P. coffeae, P. zeae, Scutellonema bradys, Radopholus similis, Tylenchorhynchus* sp., *T. robustus, Tylenchus* sp., *T. coffeae.*
Allium sativum (garlic)	*Aphelenchoides* sp., *A. besseyi, A. ritzemabosi, Criconemoides* sp., *C. lobatum, Ditylenchus dipsaci, Helicotylenchus africanus, H. cavenessi, H. dihystera, H. erythrinae, H. multicinctus, H. pseudorobustus, H. talonus, Hemicycliophora* sp., *Macroposthonia onoensis, Meloidogyne* sp., *M. incognita, Pratylenchus* sp., *P. brachyurus, P. penetrans, P. zeae, Psilenchus* sp., *Rotylenchulus reniformis, Tylenchus* sp., *Xiphinema* sp., *X. brasiliensis.*

References: Manso *et al.*, 1994; Goodey *et al.*, 1965; Gubina, 1988; Luc *et al.*, 1990; Tenente *et al.*, 1981.

are highly host-specific. The spectrum of hosts of the separate races is quite wide, and certain species of crops and wild growing plants are host to several races. For example, onion has been recorded by various researchers as being a host to 14 races (onion, rye, oat, sugar beet, potato, strawberry, red clover, white clover, lucerne, hyacinth, tulip, narcissus, phlox, teasel). The onion race is often regarded as being among the most polyphagous and is a parasite of different species of the genus *Allium* and occasionally damages other crops. The host range for populations of the onion race has been reported by many other researchers (Edwards and Taylor, 1963; Petrova cited by Gubina (1988); Sayre and Mountain, 1962; Seinhorst, 1957; Windrich, 1970). Nevertheless, many nematologists continue to use a list of differential host plants to identify the races of *D. dipsaci.* Two lists of differential host plants have been proposed, one by Seinhorst (1956) and the more recently one by Metlistky cited by Gubina (1988).

The existence of intraspecific diversity in *D. dipsaci* according to host range and the degree of pathogenicity to specific crops is an important factor in its control. Furthermore, several species of *Ditylenchus* have attributes that make their control quite difficult. These include the presence of an anhydrobiotic preadult stage, rapid reproduction, and an ability to reproduce repeatedly on the same host leading to rapid population increase (Kostuk, 1965). *Ditylenchus dipsaci* is often introduced into uninfested sites on seed (Brown, 1957; Caubel *et al.*, 1985; Green and Sime, 1979; Hooper, 1971; 1984) or in other material used for propagation such as bulbs (Anonymous 1982; 1983a; 1983b; Brown, 1978; Cucchi *et al.*, 1967; Huang and Uesugi, 1981; Johnson and Lear, 1965; Tenente, 1985), and is subsequently spread by movement of soil (Jones and Jones, 1984; Seinhorst, 1956), infested foliage (Atkinson and Sykes, 1981), or run-off water (Brown, 1957). Therefore, prevention of dispersal relies initially on ensuring that such propagation material is free of *D. dipsaci.* Currently, this is assisted by plant quarantine activities that many countries have for this purpose (Warwick *et al.*, 1983). For example in Brazil, all flower bulbs, onion, clover (*Trifolium* spp.), and lucerne (*Meloidogyne sativa*) seeds which are imported or intended for export must be certified free

Table 2. Geographical distribution of several races of *Ditylenchus dipsaci.*

Host Race	Countries
Garlic	Argentina, Algeria, Brazil, Chile, Great Britain, Mexico, Peru, Spain, U.S.A., USSR, Venezuela
Hyacinth	Algeria, Denmark, France, Great Britain, Netherlands, Switzerland, U.S.A., USSR
Narcissus	Canada, Denmark, Great Britain, Netherlands, Switzerland, U.S.A.
Onion	Argentina, Belgium, Brazil, Bulgaria, Canada, Czechoslovakia, France, Germany, Great Britain, India, Ireland, Italy, Mexico, Netherlands, Poland, U.S.A., USSR, Yugoslavia
Teasel	Algeria, France, Germany, Great Britain, Italy, Netherlands, U.S.A., USSR
Tulip	Canada, Great Britain, Ireland, Netherlands, Switzerland

References: Gubina, 1988; Hague, 1972; Hooper, 1972; Luc *et al.*, 1990; Tenente, 1991; Tenente & Manso, 1987.

from *D. dipsaci.* Successful quarantine depends upon many factors, but the time lost by delay during quarantine is well rewarded by saving of time and money spent in the control and attempted eradication of the parasite in a newly infested area.

The control of *Ditylenchus* spp. in seed and bulbs includes all methods known in plant protection including agrotechnical (e.g. seed cleaning), chemical, physical, and biological measures. It is general practice to use methyl bromide fumigation to eradicate *D. dipsaci* from seed of shallot (*Allium cepa* L. var. *ascalonicum*), onion, red clover (*Trifolium pratense*), and lucerne (Hague, 1968; Jones and Jones, 1984; Powell, 1974). However, Hooper (1984) verified that some nematodes of the bean race survived the treatment and seed germination was decreased. In addition, susceptibility to nematicides may be reduced in anhydrobiotic individuals (Gubina, 1988; Kostuk, 1968). Similarly, hot water treatment of flower bulbs is recommended for narcissus, iris (*Iris* spp.) and onion bulbs (Decker, 1981; Gubina, 1988; Hague and Kondrollochis, 1969). Reduction of germination in this propagating material was observed (Gubina, 1988) when it was treated by hot water. Even when garlic was processed with hot-water treatment for one hr, the treatment did not ensure 100% mortality of *D. dipsaci.*

In the field, the wide host range of *D. dipsaci* limits the value of crop rotation as a method of control. There are several references to a suitable time interval between host crops, which varies from 2 to 9 years (Anonymous, 1978; 1983a; 1983b; Hooper, 1984; Lewis and Mai, 1960; Wilson and French, 1975). Even if a sufficient interval is allowed between host crops, the weed hosts of *D. dipsaci* are numerous, and it is generally believed these can maintain nematode populations (Anonymous, 1978; 1978; 1979b; 1983a; 1983b; Clayden and Hooper, 1981; Goodey *et al.*, 1965; Hooper and Southey, 1978; Jones and Jones, 1984; Wilson & French, 1975). Although weed hosts may support *D. dipsaci* during the growing season, they cannot be entirely responsible for the perennial survival of soil populations. The oat race of *D. dipsaci* has been found to persist for 3-4 years in herbicide-treated microplots in the absence of a host crop (Wilson and French, 1975) and overwinter survival of this race in soil has been recorded often (Hooper, 1984). Also, he suggested that persistence in soil is possibly much longer than 10 years. Observations on the survival of *D. dipsaci* indicated that 9 years without host crop was necessary before the bean race was eliminated from soil (Hooper, 1984). A shorter period of survival of *D. dipsaci* has been found for the garlic race (Pimentel and Huang, 1985), which took less than 2 years to eliminate when no host was present. The number of garlic race nematodes "surviving" showed a rapid decrease after 12 months, with only 2% recovered from an initial population of 500/200 ml of soil. Infested soil stored under outdoor conditions showed higher numbers at sampling one year later but declined to zero 18 months after storing the infested soil. These results showed that number of the *D. dipsaci* garlic race surviving decrease rapidly, and this decrease tended to be quicker at 20°C and outdoors in spring time. The garlic race survived longest at 5°C (Tenente, 1991; Tenente and Evans, 1989).

Fluctuations in the soil density of *D. dipsaci* are commonly reported and large ranges occur, but the explanations for this are varied. Sayre and Mountain (1962) believed that the optimum conditions for survival of the onion race were low soil moisture and a temperature near or below freezing. In contrast, Lewis and Mai (1960) found that the mortality of this species was high in soil that froze during the winter and suggested that this accounted for a decline in the density of nematodes in the surface 15 cm of soil. They further suggested that autumn and spring fluctuations in nematode numbers resulted from partial downward and upward migration of the nematode. However, mortality in the different soils was not quantified, and it has been suggested that a higher mortality in sandy soil is due to greater extremes of desiccation (Wallace, 1961, 1962).

Discrepancies concerning survival periods for *D. dipsaci* may be related to host race, since differing survival abilities have been recorded for the carrot (Goodey, 1931, 1947), hyacinth, narcissus (Gubina, 1988), and oat races (Robertson, 1955). Survival of nematodes may be affected not only by temperature but by the interaction of other factors from the environment. Humidity and temperature are factors that greatly influence the survival of this nematode when they act together (Miyagawa and Lear, 1970; Palo, 1962; Seinhorst, 1957). When humidity decreases, almost all development ceases, and nematodes may pass into anabiosis (Kostuk, 1968; Sayre and Hwang, 1975). *Ditylenchus dipsaci* shows an outstanding ability to survive anhydrobiosis. Few other species of nematodes are capable of withstanding such severe desiccation as *D. dipsaci*, and most are forms which parasitise the aerial parts of plants (Ellenby, 1969).

In cases of extreme environmental dryness, nematodes can form aggregates ("eelworm wool") in response to the adverse conditions. Excess of humidity may induce clustering, and this was observed in *D. dipsaci* at 100% relative humidity *in vitro* (Ellenby and Gilbert, 1957). Similar aggregations were seen in infected onion (Gubina, 1988). Aggregates of nematodes live much longer than isolated individuals (Webster, 1964). Humidity has been shown to affect nematodes in soil by decreasing their ability to invade plants (Cassini and Caubel, 1969; Pimentel and Huang, 1985; Sayre and Mountain, 1962; Seinhorst, 1957; Wallace, 1962). However, humidity is not a factor that affects nematodes in isolation. In nature, humidity and temperature are closely-linked physical factors in soil, especially at extremes of both.

Survival in the anhydrobiotic state was studied by Ellenby (1969) who found that survival depended upon the rate of drying. Anhydrobiosis is less important for *D. dipsaci* in temperate soils because dry conditions rarely last long, and it has been shown that repeated cycles of desiccation and rehydration may reduce the longevity of fourth-stage juveniles of *D. dipsaci* (Evans and Perry, 1976). Such factors which influence the ability of anhydrobiotic nematodes to survive have been considered by many researchers as one aspect of nematode dormancy (Cooper and Van Gundy, 1971; Evans and Perry, 1976; Wombersley, 1987). They suggest that dehydration leads to a decreased metabolic rate of this nematode, called quiescence. If the desiccation continues and metabolism of the parasite decreases to an undetectable level, then the individuals reach the state of cryptobiosis (Barret, 1982; Cooper and Van Gundy, 1971; Evans and Perry, 1976; Van Gundy, 1965).

Diapause is another form of dormancy in which ontogenetic and/or somatic development is stopped by endogenous factors or signals received from the environment. Diapause is a strategy for survival for long periods (months or years) and may persist even when environmental conditions become favorable for short periods (Evans, 1987; Evans and Perry, 1976). Diapause may be seen in most individuals of each generation and has only been established in a few species of plant-parasitic nematodes, in which it is probably induced by environmental conditions. Diapause in plant nematodes appears linked to the necessity of tolerating extremes of temperature (de Guiran, 1980; Hominick, 1979; Hominick *et al.*, 1985). Diapause in *D. dipsaci* juveniles has been suggested because more nematodes were recovered in summer from soil after chilling than when extracted immediately without chilling (Saigusa and Yamamoto, 1972). This suggested that many live nematodes were unable to respond rapidly to favorable conditions. Other reports indicated that juveniles of *D. dipsaci* extracted from narcissus and garlic had increased infectivity to onion plants after chilling (Tenente and Evans, 1989, 1992, 1993a, 1993b, 1994; Webster, 1964).

Some reports (Saigusa and Yamamoto, 1972; Webster, 1964) strongly imply that, in addition to the well-known ability of preadult *D. dipsaci* to enter cryptobiosis, some aspects of *D. dipsaci* survival may involve diapause (Evans, 1987; Evans and Perry, 1976). Research data (Tenente and Evans, 1989, 1990, 1993a, 1993b) frequently record an increase in nematodes recovered from soil in summer after a period of chilling, suggesting that hydration of preadults in soil may be synchronized with the availability of suitable host plants. This suggests that diapause might act on the preadult stage and initiate in response to chilling of nematodes.

Knowledge about *D. dipsaci* and other important parasites of bulbs (Table 1) provides an awareness of the importance of using quarantine procedures in plant introduction and reducing risks of introducing these parasites into some countries or areas within a country. Such precautions can minimize or avoid losses in the production of ornamental and vegetable bulb crops for the welfare of farmers and the agricultural economy.

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Received: *15.IX.1995*

Recibido:

Accepted for publication: *2.III.1996*

Aceptado para publicación: