54 The stem nematode *Ditylenchus dipsaci* in sugar beet: A species of extremes

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Introduction

The stem nematode *Ditylenchus dipsaci* is a migratory endoparasitic nematode of worldwide importance. In 1857, Julius Kühn was the first to discover *D. dipsaci* infesting the heads of Fuller's teasel, *Dipsacus fullonum*, in Bonn, Germany (Sturhan *et al.*, 2008). *Ditylenchus dipsaci* was long considered as a species with up to 30 different host races with specific host crop spectra (Kühnhold, 2011). However, more recent phylogenetic studies showed that isolates from agricultural plant species, including sugar beet, should be considered as *D. dipsaci* sensu stricto (Subbotin *et al.*, 2005). *Ditylenchus dipsaci* is regulated as a quarantine species in many countries and classified as a regulated non-quarantine pest in the European Union, to avoid further spread of this nematode by infested seeds or planting material. Nevertheless, research on this species is still limited although it is ranked fifth in the top ten list of plant parasitic nematodes (Jones *et al.*, 2013). This leaves plenty of room for new research on developing measures for the integrated management of this nematode.

Economic importance

Economic damage due to *D. dipsaci* mostly occurs in temperate climate zones. It causes significant losses on onion, garlic and ornamental bulbs, because infected crops are unmarketable (Jones *et al.*, 2013). The stem nematode has been reported to cause yield losses as well as an increase of secondary products undesirable for industrial sugar production in sugar beet (Castillo *et al.*, 2007). Yield losses can range between 10% and 60% in Germany and Switzerland, but under optimum conditions for the nematode (cool and moist), 90–100% is possible. However, next to the yield loss, if more than 10% beets show crown rot symptoms the complete harvest will be rejected by the sugar factory (Storelli *et al.*, 2020). Germany and Switzerland consider *D. dipsaci* to be of high economic importance in their main sugar beet production areas. Other countries who reported infections and damage to sugar beet by *D. dipsaci* never reported these high levels of economic damage (Castillo *et al.*, 2007).

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© CAB International 2022. *Integrated Nematode Management: State-of-the-art and visions for the future* (eds R.A. Sikora *et al.*)
DOI: 10.1079/9781789247541.0054

Host range

Ditylenchus dipsaci has an extremely wide host range with around 500 host plants belonging to over 40 plant families. With this spectrum, *D. dipsaci* belongs the group of plant parasitic nematodes with the widest host range worldwide. In addition, the nematode infects blossoms, seeds, stems, leaves as well as tubers, stolons and rhizomes and surpasses the range of damage by the polyphagous species *Aphelenchoides ritzemabosi* and *A. fragariae* (Sturhan *et al.*, 2008).

Distribution

Ditylenchus dipsaci is cosmopolitan with a worldwide distribution, but the main problems are present in temperate regions with significant importance in field and horticultural crops. Several countries, including Spain, Canada, France, England, Hungary, Iran, Morocco, Netherlands, Romania, Serbia and Ukraine have reported infestations and damage on sugar beet by *D. dipsaci* (Castillo *et al.*, 2007). However, only Germany and Switzerland repeatedly report severe damage occurring in their main sugar beet production areas (Kühnhold, 2011; Storelli *et al.*, 2020).

Symptoms of damage

Ditylenchus dipsaci symptoms on sugar beet differ depending on the level of infestation, environmental conditions and the developmental stage of the plant. Early spring symptoms can be swellings and distortions on seedlings (Fig. 54.1). Later in the season, small white callus pustules can appear on the surface of the beet crown (Fig. 54.2). These pustules contain thousands of nematodes per gram tissue and are a clear indicator for high levels of infestation in a given field. Later in the season, crown rot develops without visible symptoms such as yellowing or wilting of leaves (Fig. 54.3). In some cases, *D. dipsaci* infestation can be confused with crown and root rot caused by *Rhizoctonia solani*, which appears on the outside on the upper region of the beet body and at the base of the leaf petioles (Hillnhütter *et al.*, 2011). At harvest time, crown rot symptoms increase until complete decay of the sugar beet plant occurs (Figs 54.4 and 54.5).

Fig. 54.1. Early season symptoms of *Ditylenchus dipsaci* damage in sugar beet seedlings, often appearing after cool and moist conditions in spring. Photograph courtesy of Julius Kühn Institute.

Fig. 54.2. Sugar beet showing callus pustules due to heavy *Ditylenchus dipsaci* infestation during mid-season. Photograph courtesy of Julius Kühn Institute.

Biology and life cycle

Mainly fourth-stage juveniles (J4), the survival stage of *Ditylenchus dipsaci*, penetrate above-ground plant parts early in the growing season and feed upon parenchymatous tissue leading to the breakdown of the middle lamellae of cell walls. By withdrawing cell contents through its stylet, the surrounding cells divide and enlarge, which results in malformation of the affected plant tissue (Jones *et al.*, 2013). Reproduction of *D. dipsaci* is by amphimixis and multiplication rates are very high, as a female of *D. dipsaci*

Fig. 54.3. Crown rot developing inside a sugar beet due to heavy *Ditylenchus dipsaci* infestation during mid-season. Photograph courtesy of Julius Kühn Institute.

Fig. 54.4. Crown rot damage due to *Ditylenchus dipsaci* at the time of harvest. Photograph courtesy of Julius Kühn Institute.

produces up to 500 eggs when the temperature is in the optimum range of 15–20°C. Second-stage juveniles hatch within 2 days and further develop into females within 4–5 days, which can live for more than 10 weeks (Jones *et al.*, 2013). *Ditylenchus dipsaci* is a classic example of a species surviving severe desiccation in a dormant state. At the end of the sugar beet growing season, development stops at the J4 stage. These J4s either leave the rotten beets and move to the soil or coil and clump together in a desiccated state as 'nematode wool' and stay in dried plant debris, where they overwinter (Jones *et al.*, 2013). J4s of *D. dipsaci* have been reported to survive for more than 20 years in this anabiotic state (Sturhan *et al.*, 2008; Jones *et al.*, 2013). This extreme capacity to survive desiccation

Fig. 54.5. Rotten beets due to *Ditylenchus dipsaci* at the time of harvest. Photograph courtesy of Julius Kühn Institute.

and freezing temperatures also helps to withstand nematicides and facilitates dispersal by plant debris and wind. *Ditylenchus dipsaci* has a very low damage threshold level with only 1–2 juveniles per 250 ml of soil. Egg production is linearly related to temperature, with 0.158 eggs per day degree under optimal conditions (Jones *et al.*, 2013). This rapid population growth results in severe crop damage, even when the initial population density is low.

Interactions with other nematodes and pathogens

Plant parasitic nematodes can interact with other plant pathogens in many ways. Mostly, this interaction results in synergism that influences the level of damage to the plant. Growers are confronted with the interaction of *D. dipsaci* and *R. solani*, both causing crown rot symptoms. *R. solani* benefits from *D. dipsaci* and not vice versa, as the nematode provides penetration points for the fungus (Hillnhütter *et al.*, 2011). As *D. dipsaci* is an obligate biotrophic and cannot multiply on rotten plant tissue, high levels of infection by *R. solani* negatively affect nematode reproduction. Field trials demonstrated that sugar beet cultivars tolerant to the sugar beet cyst nematode *Heterodera schachtii* allowed high reproduction rates of *D. dipsaci* with severe crown rot symptoms. When both *H. schachtii* and *D. dipsaci* are present in a field, they do not interfere with each other as they have different distribution patterns (patchy versus broad) and optimum temperature ranges with higher temperatures leading to greater damage by *H. schachtii*. Conversely, *R. solani* tolerant cultivars also showed tolerance to crown rot induced by *D. dipsaci*, but did not mitigate reproduction (Hillnhütter *et al.*, 2011).

Recommended integrated nematode management

The first recommendation after detection of *D. dipsaci* severely damaged sugar beets in a field should be: 'Stop growing sugar beets'. In many cases this is not possible because sugar beet production areas have to be close to the sugar factory and quotas of beets to be delivered are pre-set. However, in this case other recommendations to mitigate yield and quality losses due to *D. dipsaci* can be made as listed below.

- Delayed planting helps to avoid cool and moist conditions in the spring, which will result in reduced damage by *D. dipsaci*, but also affects overall root and sugar yield due to a shortened cropping season.
- Early harvest is recommended when fields have a known history of *D. dipsaci* and crown rot. These beets have to be processed immediately after harvest as the nematode still causes severe levels of root rot when beets are in field storage before processing. However, harvesting early in the season, again, reduces overall root and sugar yield.
- Use of highly tolerant cultivars, which do not develop severe crown rot symptoms even under high *D. dipsaci* pressure. This measure, together with delayed planting gives the best protection against severe losses due to the nematode fungus beet rot complex. It can, however, lead to the lowest yields when conditions for the nematode are unfavourable due to the fact that the cultivars only yield well when nematode damage occurs.
- Crop rotation is difficult to apply due to the extreme wide host range and extreme capability of *D. dipsaci* to survive in soil and on infested plant material for many years. However, several crops such as barley and triticale or non-host intercrops such as ryegrass can be chosen that are poor or non-hosts, suitable to reduce population densities in soil. In addition, good weed control is critical, as weeds are very good hosts for *D. dipsaci* and can help to maintain population densities above the threshold level (Sturhan *et al.*, 2008).

Optimization of nematode management

Farmers often neglect the fact that *D. dipsaci* has an extremely wide host range and can multiply on many crops without causing symptoms of damage or notable yield loss. In addition, a range of common names is used for the same species. Therefore, it is often not realized by the growers that this single species attacks several field and vegetable crops within their crop rotations. To determine the risk of damage before a field is chosen for the production of sugar beet, soil sampling in the autumn before the next sugar beet crop is advised. However, farmers do not use this tool, but rather follow historic or personal preferences to choose their fields, which consequently results in severe losses and rejection of their harvested beets at the sugar factory. Intensive soil sampling should therefore be used, as it is the only measure to detect high-risk fields with population densities above the threshold of 1–2 nematodes per 250 ml of soil. Data from soil sampling should be used to develop a software-based nematode advisory system in support of crop advisers and extension personnel.

Application of nematicides is no longer an option because of the past phase-out of the chemicals in the EU. Furthermore, recent studies demonstrated that *D. dipsaci* showed a low sensitivity to the nematicide fluopyram (Storelli *et al.*, 2020). Although fluopyram applied at planting reduced initial penetration rates under field conditions, it failed to suppress the reproduction of the nematode until harvest. Consequently, development of crown rot symptoms was not reduced (Storelli *et al.*, 2020). This leaves few options for control besides the use of cultivars highly tolerant to secondary infection by *R. solani* and thus to the development of crown rot symptoms.

Future research requirements

There is a need for molecular analysis of soil samples for the nematode because of the low threshold level and difficulty in detecting such population densities (see Chapter 57 in this volume).

Few studies on the molecular basis of the interactions between *Ditylenchus* spp. and host plants have been published (Jones *et al.*, 2013). In particular, little is known about *D. dipsaci* penetration of seedlings and how it interacts with cultivars carrying tolerance to *R. solani*. A better understanding of the factors affecting the successful penetration of the host and the development inside the beet root is required to develop new and effective control options. Genome and transcriptome sequencing will help to better define targets for breeding for resistance or for other means of control. In order to effectively manage *D. dipsaci* in the future, the focus should be on developing a breeding programme for resistant sugar beet cultivars. To date, the classical breeding approaches have not yielded resistant, but only highly tolerant cultivars (Kühnhold *et al.*, 2006; Kühnhold, 2011). However, breeding programmes might focus on different objectives that target reduced attraction to the seedling, penetration and reproduction rates in addition to suppressing crown rot symptoms.

Outlook: anticipating future developments

Farmers and sugar factories will face many problems in the future. The declining market prices for sugar forces companies to concentrate their production on fields close to the factories to minimize costs for transport. These fields, however, are already infested with *D. dipsaci*, which leaves no choice, but to intensify the search for new control measures.

Increasing temperatures due to global warming might benefit sugar beet production as warm and dry conditions in spring or hot and dry conditions in summer will negatively affect the penetration and development of *D. dipsaci* and thereby will reduce crown rot symptoms. However, future breeding programmes must address these conditions in developing new cultivars adapted to the growing region and producing high root and sugar yields. As *D. dipsaci* is a species of the extremes, it might adapt to these conditions and spread to other regions of the world where sugar beet production will be intensified in the future. Strict enforcement of quarantine regulations is therefore necessary to keep *D. dipsaci* out of these regions to avoid future severe economic losses.

References

Castillo, P., Vovlas, N., Azpilicueta, A., Landa, B.B. and Jiménez-Díaz, R.M. (2007) Host-parasite relationships in fall-sown sugar beets infected by the stem and bulb nematode, *Ditylenchus dipsaci*. *Plant Disease* 91, 71–79.

Hillnhütter, C., Albersmeier, A., Berdugo, C.A. and Sikora, R.A. (2011) Synergistic damage by interactions between *Ditylenchus dipsaci* and *Rhizoctonia solani* (AG 2–2IIIB) on sugar beet. *Journal Plant Diseases and Protection* 118, 127–133.

Jones, J.T., Haegeman, A., Danchin, E.G.J., Gaur, H.S., Helder, J., Jones, M.G. K., Kikuchi, T., Manzanilla-López, R., Palomares-Rius, J.E., Wesemael, W.M.L. and Perry, R.N. (2013) Top 10 plant-parasitic nematodes in molecular plant pathology. *Molecular Plant Pathology* 14, 946–961. DOI: https://doi.org/10.1111/mpp.12057.

Kühnhold, V. (2011) Investigation on host-parasite interaction between the stem nematode *Ditylenchus dipsaci* and sugar beet *Beta vulgaris* and their importance for development of alternative integrated management strategies. Doctoral thesis. Rheinische Friedrich-Wilhelms-Universität, Bonn, Germany.

Kühnhold, V., Kiewnick, S. and Sikora, R.A. (2006) Development of an in vivo bioassay to identify sugar beet resistance to the stem nematode *Ditylenchus dipsaci*. *Nematology* 8, 641–645.

Subbotin, S.A., Madani, M., Krall, E., Sturhan, D. and Moens, M. (2005) Molecular diagnostics, taxonomy, and phylogeny of the stem nematode *Ditylenchus dipsaci* species complex based on the sequences of the internal transcribed spacer-rDNA. *Phytopathology* 95, 1308–1315.

Storelli, A., Keiser, A., Eder, R., Jenni, S. and Kiewnick, S. (2020) Evaluation of fluopyram for the control of *Ditylenchus dipsaci* in sugar beet. *Journal of Nematology*, 52(e2020-71), 1–10. DOI: https://doi.org/10.21307/jofnem-2020-071.

Sturhan, D., Hallmann, J. and Niere, B. (2008) A nematological anniversary: 150 years *Ditylenchus dipsaci* (Kühn, 1857). *Nachrichtenblatt des Deutschen Pflanzenschutzdienstes* 60, 261–266.