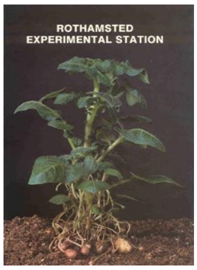
ROTHAMSTED RESEARCH

Rothamsted Experimental Station Report for 1983

Full Table of Content



Observations on Stem Nematode, *Ditylenchus dipsaci*, Attacking Field Beans, *Vicia faba*

D. J. Hooper

D. J. Hooper (1984) *Observations on Stem Nematode, Ditylenchus dipsaci, Attacking Field Beans, Vicia faba ;* Rothamsted Experimental Station Report For 1983, pp 239 - 260 **- DOI: https://doi.org/10.23637/ERADOC-1-34112**

Observations on stem nematode, *Ditylenchus dipsaci*, attacking field beans, *Vicia faba*

D. J. HOOPER

Abstract

The incidence of stem nematode, *Ditylenchus dipsaci*, on field beans, *Vicia faba*, has been monitored since 1965 on the Rothamsted Experimental Station farms at Rothamsted and Woburn. Observations have shown that both the oat race and giant race of *D. dipsaci* infest winter and spring cultivars of field beans and that infested seed is sometimes produced. Seed-borne infestations have introduced *D. dipsaci* to many sites on the Rothamsted farms. Some commercial field bean stocks were found to be infested and all the commercial cultivars generally available were found to be susceptible to both races of *D. dipsaci* as were 99 other breeding lines/cultivars that were tested against the giant race and 48 tested against the oat race. A simple 'beaker test' was adopted to check for seed-borne infestations.

Seed-borne infestations usually have little effect on the vigour of the first bean crop but they are a very important factor in the introduction of *D. dipsaci* to uninfested land and its buildup in the soil. Subsequent bean crops usually become much infested from the soil and there may be crop loss. The growing of beans on some parts of the Rothamsted farms has been discontinued because of severe infestations of *D. dipsaci*. This was particularly so on Broadbalk where the second bean crop, following seed-borne introduction of *D. dipsaci*, was devastated by the giant race although there was a 2-year break of non-host crops in the rotation.

The giant race is generally more damaging to beans than the oat race and produces more infested seed. In a field trial at Rothamsted, plots with 81% of the bean stems infested with the oat race had their seed yield decreased by 26% and of the seed produced 3% was infested; plots with 99% of the stems infested with the giant race had their yield decreased by 58% and 67% of the seed produced was infested.

The survival of *D. dipsaci* in the soil was studied at two sites at Rothamsted and on one at Woburn. Observations on the giant race, at both farms, showed that 8 to 10 years under non-host crops were necessary before beans could be grown again without much risk of infection. The oat race persisted at Rothamsted for over 9 years and incidental observations at other experimental sites on the farms indicate that the oat race, which has a wide host range including many weeds, persists almost indefinitely.

Field experiments at Rothamsted showed that seed- and soil-borne infestations of *D. dipsaci* on spring beans were controlled by in-row treatment at the time of sowing with aldicarb at 4–5 kg a.i. ha^{-1} (rows 50 cm apart). Thiabendazole was very effective against *D. dipsaci* on beans in pot tests but less so in a field trial. Heat treatment of seed to control *D. dipsaci* was not successful.

Pot tests and field observations indicate that the giant race has a much more limited host range than the oat race.

The monitoring of bean crops on the Rothamsted and Woburn farms and the checking of seed for presence of *D. dipsaci* has helped to avoid the use of infested sites and the spread of the nematode to uninfested areas. However, many sites on the Rothamsted and Woburn farms are infested and cropping with field beans should be as infrequent as possible; likewise on other farms where *D. dipsaci* is known to occur. A national inspection scheme is required to prevent stem nematode being dispersed in commercial seed stocks.

https://doi.org/10.23637/ERADOC-1-23

Introduction

The stem nematode, *Ditylenchus dipsaci* (Kühn, 1857) Filipjev, 1936, is a bisexual species with vermiform juveniles and adults. It is a migratory endoparasite of stems and bulbs. Eggs, up to 500 from each female, are deposited in plant tissues. There are four juvenile stages; the second stage emerges from the egg and the life cycle under favourable conditions takes 3–4 weeks. Juveniles and young adults, particularly the preadult fourth stage, can withstand desiccation and when well infested plant tissues dry out the nematodes clump together to form 'wool'. In the desiccated state, *D. dipsaci* is often dispersed with seed or debris of host plants and can survive dry for many years. *D. dipsaci* is one of the most devastating plant parasitic nematodes, especially in temperate regions; it occurs in several biological races some of which have a limited host range (Hooper, 1972). Two races have been found on beans on the Rothamsted farms; the oat race which has a wide host range of crops and weeds and the giant race, so called because the adults are about half as long again as those of other races. The giant race is not known to attack crops other than faba bean and seems to have few weed hosts; it is more prevalent in the Mediterranean region.

Stem nematode caused considerable crop loss to oats and beans on small plots on Little Knott I in 1965 and infestations were also found that year on other oat and bean crops on the Rothamsted farm (Table 1). Consequently, in subsequent years all oat and bean crops on the Rothamsted and Woburn farms were inspected for incidence of *D. dipsaci*. Where possible, individual plots of experiments were examined so that some indication could be given to sponsors as to whether *D. dipsaci,* if present, was likely to affect results. Non-experimental bean crops were also examined so that future cropping could avoid infested areas. In 1967 it was realized that *D. dipsaci* was being dispersed on bean seed and so the farm was advised which crops should be saved for seed and any new stocks bought in were also examined for *D. dipsaci*. Bean plots were usually examined in July or early August and a detailed report sent each year to the Field Plots Committee.

Symptoms on infested plants

The oat race of the stem nematode can seriously damage susceptible oat cultivars. Infested oat plants are stunted, swollen at the base and the extra secondary tillers that are produced are also often stunted and distorted; such symptoms are often referred to as 'tulip root'. Badly infested areas in a crop appear stunted with rather pale leaves. Heavily infested bean seedlings may show some distortion or necrosis of the leaf tissues and possibly of the stem tissue but light infestations of oat or giant race are easily overlooked. In the older plant, by the time the pods have set, oat race infestations are usually indicated by an even reddish brown coloration of the stems typically starting at the base and often stopping at a leaf node (Plate 1). Heavy infestations of oat race tend to result in very thin, occasionally distorted, stems and plant height and yield are decreased; infestations in the pod region sometimes result in infested seed. The giant race, which does not attack oats, generally causes more severe symptoms on beans than the oat race. Diseased stems are usually a darker brown than those infested by the oat race and also blistered, stunted and distorted (Plate 2). There is typically a characteristic S-shaped bend in the lower stem where the plants tend to break off prematurely. Infestations often reach the pod-bearing region and heavily infested pods are small and distorted and often contain well infested seed. Sometimes the top of the plant is swollen, stunted and distorted to give a characteristic 'mop top' appearance (Plate 3). The browning of diseased stems is readily noticed in spring beans especially in

https://doi.org/10.23637/ERADOC-1-23

PLATE 1. Field bean stems infested with the oat race of *Ditylenchus dipsaci* which causes a browning of the stem tissues mainly in the lower half of the plant.

https://doi.org/10.23637/ERADOC-1-23

TABLE 1

ROTHAMSTED FARM—Incidence of stem nematode, Ditylenchus dipsaci, *on oats* (O) *and beans* (B) *1965–1982.* °=oat race; •=giant race; ° or • light, scattered infestation, °° or •• scattered infestation with locally severe patches; °°° or ••• general infestation.

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Agdell															B•	B•	B••	B••
Barnfield			B°°	B°°°	B°°°	B°°°	B°°°	B°°°•	B°°°•	B°°°•	B°°°••	B°°°••						
Broadbalk 2				B•			B••						B•••					
4						B•			B•									
7								B••			B•••			B•••				
Delafield														B•				
Delharding															B•			
Drapers										B•								
Fosters Ley Arable		O°°													B°°			
Fosters O & E II						B°		B°°°	*B°°°*	*B°°*	*B°°*		*B°°*	*B°°*	*B°*	*B°°*	*B°°*	B°
Fosters O & E III											B°	B°						
Fosters O & E IV		O°°°												B°°°				
Fosters O & E V		O°						B°•										
Fosters O & E VI		O°°°					B°°	B°°•	B°°•	B°°••	B°•••							
Fosters West															B•			
Garden Fields†			B°	O°°														
Garden Plots				B°°		B°°	B°°	B°°•		B•					B••			
Geescroft																B°		
Great Field I			B°°°			B°°		B°°•			B°°		B°°•					
Great Field II	B°•			B°°°			B°°°•	B°°•					B°°°••					
Great Harpenden I	B°		B°°	B°°	B°°	B°	B°	B°•				B°•		B°°	B°°•		B°°•	B°°
Great Harpenden II										B•				B•				
Great Knott I														B•				
Great Knott II									B°°•							B°°		
Great Knott III	B°			B°°				B°°•										
Highfield Drive											B°°							
Highfield III O & E									B°°•••	B°°•••	B°°•••	B°•	B°••		B°••		B••	B••
Highfield IV			B°				B°°°											
Highfield VI O & E																		B•
Hoosfield	B°°° O°°°		B°°°	B°°			B°°	B°°•	B•	B°°	B°•	B°•	B°°	B°••				
Little Hoos															B°°•			
Little Knott I	B°• O°°	B°°° O°°°	B°°°						B°	B•	B•				B••			
Long Hoos I & II										B•				B••				
Long Hoos III			B°°°		B°°°												B°°	
Long Hoos IV					B••						B•••		B••					

Long Hoos V	$B^{\circ\circ\circ}$						$B^{\circ\circ}$ O°	$B^{\circ}_{\cdot}$	$B^{\circ\circ\circ}$						$B^{\circ\circ}_{\cdot}$		
Long Hoos VI							B°						$B^{\circ\circ}$				
Pastures						B.			B.				B.				
Pennells Piece	B° $O^{\circ\circ}$	B° O°	B°	$B^{\circ\circ}$	B°	B°	B°	$B^{\circ}_{\cdot}$	$B^{\circ\circ}$								
Stubbings				B.						B.							
Summerdells I & II E				B.	B..	B...			*B..*	*B..*	*B.*		*B.*		*B..*	$B^{\circ\circ}$	
Summerdells II W								B..							B..		
White Horse I						B.				B.						$B^{\circ\circ}$	
Whittlocks			$B^{\circ\circ\circ}$							$B^{\circ\circ}_{\cdot}$							$B^{\circ\circ\circ}_{\cdot}$

† Ex allotments adjacent Barnfield.
B=survival of *D. dipsaci* expts.

TABLE 2

WOBURN FARM—Incidence of stem nematode, Ditylenchus dipsaci, *on Spring Beans 1968–1982.*

$^{\circ}$=Oat race; *=Giant race; $^{\circ}$ or * light, scattered, infestation; $^{\circ\circ}$ or ** scattered infestation plus locally more severe patches; *** general infestation.

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Broad Mead II & III						$B^{\circ\circ}$									
Broad Mead IV		$B^{\circ\circ}$		$B^{\circ\circ}$											
Butt Close		$B^{\circ\circ}$	B°	B°	B°	B°		B°	B°						
Butt Furlong			B^{*}		B°	B^{**}	B^{**}								
Far Field I							B^{*}			B^{***}					
Far Field II											B^{**}				
Great Hill Bottom					B^{*}						B^{**}				
Horsepool Field					B^{*}			B^{***}							
Horsepool Lane Close							B^{*}								
Lansome I	B^{*}	B^{**}													
Lansome II			B^{*}	B^{**}	B^{**}	B^{***}									
Lansome III			B^{*}			B^{*}									
Road Piece	B^{**}											B^{*}			
Stackyard B			B^{*}												
Warren Field I		$B^{\circ\circ}$				$B^{\circ***}$									
Warren Field II		$B^{\circ\circ}$		$B^{\circ\circ}$	$B^{\circ**}$	(B^{***})	(B^{**})	(B^{**})	(B^{*})	(B^{*})	(B^{**})	(B^{*})		(B^{*})	
White Horse					B^{*}			B^{***}	B^{*}	B^{***}					

( ) Survival of *D. dipsaci* Expt.

https://doi.org/10.23637/ERADOC-1-23

PLATE 2. Field bean stems infested with the giant race of *Ditylenchus dipsaci* which causes a browning of stem tissues and stunting and distortion of the plants.

https://doi.org/10.23637/ERADOC-1-23

PLATE 3. 'Mop top' symptoms in field beans: stunting and distortion of the upper parts of the plants due to heavy infestation by the giant race of *Ditylenchus dipsaci*.

https://doi.org/10.23637/ERADOC-1-23

about mid July to early August and more easily when many of the lower leaves have fallen off; later, the symptoms tend to become masked by the general browning of stems caused by senescence. Symptoms on winter beans tend to become masked by the browning of stems caused by chocolate spot or rust and so it is better to examine winter crops somewhat earlier, at about the beginning of June. However the distortion caused by the giant race can be detected to some extent in older plants.

Measurements of oat race and giant race of *D. dipsaci*

Although the symptoms on infested bean plants suggest which race is involved, measuring adult or fourth-stage juveniles gives a surer indication. Measurements of the body length of specimens from oats and beans from various localities are given in Table 3. Specimens are killed with heat and mounted in TAF fixative. The mean length of the oat race populations ranges from 1.2 to 1.4 mm for males and females although the occasional female reaches 1.6 mm; whereas for the giant race the mean length of populations ranges from 1.5 to 1.7 mm but some individuals may be as short as 1.2 mm. Hence there is an overlap in the size range of the two races; however, it seems safe to assume that individual adults less than 1.2 mm long are oat race and those more than 1.6 mm are giant race. At least ten individuals should be measured to obtain a mean value. Measurements of fourth-stage juveniles, the predominant stage in dry tissue, on seed and in soil, indicate that the mean length of oat race is just under 1 mm whereas the giant race is just over 1 mm but the difference between them is small; also the situation can be confused by the presence of third stage juveniles of either race.

Incidence of stem nematode on Rothamsted farms

Infestations of *D. dipsaci* on oats or beans on the farms at Rothamsted and Woburn from 1965 to 1982 are indicated in Tables 1 and 2. From 1965 to 1971 infestations were mainly of the oat race; where susceptible oats and beans were grown in close rotation on a site they both built up nematode populations which were damaging to each other; this was seen in the rotations included in the Intensive Winter Barley Experiment on Hoosfield (old four course site) and Intensive Spring Barley Experiment on Little Knott I. From 1967 damage to oats was largely avoided by growing resistant cultivars. In 1967 infestations were found on beans on some sites which had not included oats or beans in recent rotations, particularly Barnfield and Whittlocks, suggesting that *D. dipsaci* was being distributed with bean seed. Examination of seeds from winter beans (cv. Pedigree) on Hoosfield and spring beans (cv. Maris Bead) on Great Field and Whittlocks showed that some seeds were heavily infested with *D. dipsaci*. As Rothamsted sometimes saves its own seed for sowing, home produced seed was partly responsible for the spread of this nematode to fresh sites. However, various batches of seed bought in for sowing were also infested. A stock of Maris Bead bought in 1966 for the Macroplot Experiment in Great Field I was apparently infested and gave an infested crop which was saved for seed and which spread the oat race of *D. dipsaci* to previously uninfested areas. In 1968 a stock of cv. Tarvin introduced the giant race to other uninfested sites particularly Summerdells I and IIE at Rothamsted and to Lansome I at Woburn and another stock of cv. Maris Bead infested Broadbalk Section 2. Unfortunately, infested seed (cv. Maris Bead) from the 1971 crop in Great Field II was sown in 1972 on most of the sites at Rothamsted and Woburn. This resulted in light but widespread infestations of the giant race in most of the bean crops including those on previously uninfested sites such as Broadbalk Section 7 and three fields at Woburn as well as to sites already infested with the oat race. Although Broadbalk Section 7 had a

https://doi.org/10.23637/ERADOC-1-23

TABLE 3

Ditylenchus dipsaci: *Body length measurements (μm, ±SE) of adults and fourth stage juveniles (n=20). Specimens killed by heat and mounted in TAF fixative*

Host	Population	Females	Males	J4 ex soil
		Oat Race		
Beans	Little Knott, 1973	1229±17·1 1035–1346	1191±16·4 1018–1311	
Beans	Long Hoos III, 1981	1315±14·6 1180–1404	1241±18·3 1080–1368	
Beans	Fosters O & E II, 1981	1404±20·1 1232–1546	1301±19·8 1053–1434	941±9·1 856–998
Oat	Fosters O & E VI, 1976	1423±16·3 1267–1571	1284±20·9 1125–1464	950±18·1 819–1104
Onion	Great Field, 1976	1435±24·1 1214–1566	1319±24·5 1121–1495	
		Giant race		
Beans	Hoosfield, 1976	1597±16·9 1495–1780	1519±15·6 1424–1727	
Beans	Great Harpenden, 1976	1664±19·3 1584–1889	1520±16·9 1210–1744	1030±10·4 922–1129
Beans	Broadbalk, 1973	1691±27·0 1484–1967	1578±13·9 1466–1708	1064±19·0 820–1180
Beans	Whittlocks, Woburn, 1981	1715±19·3 1590–1971	1644±16·9 1523–1837	

(J4=fourth-stage juveniles)

three course rotation, which included the non-hosts potatoes and wheat, the next bean crop in 1975 was well infested and in 1978 there was so much crop loss due to *D. dipsaci* that it was no longer practicable to keep beans in the rotation. Also, with so many of the bean sites infested it was difficult in subsequent years to find crops suitable for seed and there was further, slight, seed-borne dispersal of the giant race in 1974 and 1979. Seed stocks in 1980, 1981 and 1982 seem to have been uninfested as no new infestations were found.

The number of plants attacked by the giant race in the next bean crop following that with seed-borne infestations, even with a gap of non-host crops, was alarming. In addition to Broadbalk Section 7, the bean crop on Horsepool and White Horse fields at Woburn in 1975 were heavily infested following seed-borne introduction in 1972. Likewise beans on Far Field I, Woburn were attacked in 1977 from a seed-borne infestation in 1974.

Where the giant race was introduced to sites already infested with the oat race, cropping with beans gradually increased the proportion of giant race. This was seen particularly on Fosters O & E VI where oats in 1966 and beans in 1971 and 1972 were well infested with the oat race. There was some seed-borne introduction of the giant race to the 1972 bean crop which gradually increased in beans in 1973, 1974 and 1975, nearly all the plants in the 1975 crop having giant race symptoms. However, susceptible oats sown on that site in 1976 became well infested, showing that the oat race persisted to some extent.

Seed-borne infestations. Infestations of oat race usually have little effect on the appearance of the seed although heavy infestations may cause some darkening and cracking of the testa. Giant race infestations often cause a blackening and cracking of the testa and, because they often give rise to small distorted pods, heavily infested seed samples often have more pod debris than usual. Poor quality, small, shrivelled seeds

https://doi.org/10.23637/ERADOC-1-23

tend to be more heavily infested than larger seeds. The dried *D. dipsaci*, mainly fourth-stage juveniles, may be stuck on to the testa, wedged in the slit in the hilum or in cracks on the testa. When the testa is removed, infested seed often has patches of nematodes in depressions in the cotyledons either side of the radicle and the cotyledons may show necrosis. More than 10000 *D. dipsaci* have been recovered from one seed (Hooper, 1971). It seems to be a feature of infested seeds, especially where the giant race is concerned, that some are very heavily infested but others not at all.

Examination of seed for presence of stem nematode. Because anhydrobiotic fourth-stage juveniles infesting bean seed become active on soaking in water, the following 'beaker test' has been adopted for screening bean stocks for stem nematode.

Up to four 150 g random subsamples of seed are taken from each bulk sample. As seeds with blemished testa tend to be more heavily infested, an extra subsample of such seeds can be selected from the remainder of the sample. Broken seeds should be removed from subsamples as they release starch grains which make subsequent examination of the water extract more difficult.

Each subsample is soaked overnight in about 400 ml of tap water in a wide base 1 litre beaker. The contents are then agitated and the water poured into a separate clean beaker ('A'), the subsample is rinsed with 100 ml water which is then added to the beaker 'A'. The extract in 'A' is allowed to settle for at least 4 h and then the water is decanted carefully leaving 50–60 ml of extract in the bottom of the beaker. The extract is poured into a suitable counting dish and examined under a stereoscopic microscope at about 25× magnification. Extracts should be examined immediately as they become cloudy with storage. Most of the *D. dipsaci* recovered will be fourth-stage juveniles and, due to lack of oxygen, they tend to be motionless but often revive in fresh, aerated water. Alternatively, an indication of their viability can be obtained by cutting specimens with a needle when the body contents burst from live specimens, whereas dead ones break cleanly. Some adults may also be recovered and, though usually dead, can be mounted and body length measured to obtain an indication as to whether the oat or giant race is present.

Bacterial feeding nematodes seem to be rare in bean seed samples but if encountered can be distinguished from *D. dipsaci* by the absence of a mouth stylet.

The Seinhorst mist-extraction system (see Flegg & Hooper, 1970) can be used to obtain *D. dipsaci* from bean seed. Although it has the advantage of yielding clean, active nematodes, the dead adults may not be recovered. Great care is also required in cleaning the sieves and trays used, to prevent contamination between samples.

Seed-borne infestations of *D. dipsaci* in commercial stocks. Over the period 1968 to 1973, eight out of 15 seed samples from seed producers/merchants were infested with *D. dipsaci*. In 1974, mainly as a result of the Rothamsted farm trying to obtain uninfested seed, 49 batches of commercial seed were examined of which 26 were infested. In some later years the National Institute of Agricultural Botany provided samples of seed stocks submitted for certification which gave some indication of the degree of infestation in commercial stocks (Table 4). It would seem that 1974 (seed produced in 1973) was a particularly bad year for infestations. The subsequent decline could be due partly to the very dry summer of 1976 when infestations were much less than expected on the Rothamsted farms. Also in recent years some seed producers have been checking seed and prospective sites for *D. dipsaci*. Nonetheless, infestations still occur in some stocks. Cultivars found infested over the period 1968–82 included Blaze, Bulldog, Cockfield, Daffa, Danas, Franks Ackerperle, Herra, Herz Freya, Maris Bead, Maris Beagle, Maxime, Minden, Minor, Ostlers, Pedigree, Tarvin and Throws

https://doi.org/10.23637/ERADOC-1-23

TABLE 4

Incidence of stem nematode in commercial stocks

*Year examined	No. samples examined	No. samples infested	Percentage infested
1974	49	26	53
1975	45	10	22
1976	0	—	—
1977	36	0	0
1978	53	2	4
1979	49	5	10
1980	48	5	10
1981	48	5	10
1982	48	3	6

*Samples examined would usually have been produced in the previous year

M.S.; of 109 Maris Bead samples examined during that period, 32 were infested. Any infestation of the national bean seed stock has serious consequences because of the persistence of this pest once introduced to field sites.

Effect of stem nematode on bean crops

Observations on chance infestations of farm plots indicated that the seed yield of plants heavily infested with either the giant race or oat race was much decreased.

In 1973 an experiment was set up (R/CS/116, Highfield O & E III) to study in detail the effect of the two races on yield and seed-borne infestation. The design was three randomized blocks of six plots, each plot was 9·15 by 4·2 m with 2·14 m fallow sideland and 3·05 m fallow headland. The remainder of the site was cropped with beans. There was one replicate of each treatment but two untreated plots in each block. Plots were laid out the previous autumn and infested bean straw from Fosters O & E II (mainly oat race 'O') or Garden Plots 5 (mainly giant race 'G') was rotavated in at one (O1, G1) or two (O2, G2) bales of straw per plot, one bale per plot being equivalent to normal straw yield (3·1 t ha^{-1}). Minden seed, nematode free, was sown on 12 March 1973, eight rows per plot. Plots were assessed for infested stems at the end of July by examining the third and sixth row of each. Pods were hand harvested in August from every other plant in one of the centre rows of each plot and 100 seeds from each plot sample were examined individually by soaking in water overnight. The plots were managed and harvested according to standard farm practice. Phorate granules, 1·2 kg ha^{-1}, were applied on two occasions to control aphids.

The results, Table 5, confirm chance observations on the farms that the giant race is more damaging than the oat race and causes more infested seed to be produced. The G2 rate killed off some seedlings and there were fewer stems on those plots. In spite of the

TABLE 5

Effects of stem nematode on spring beans

Nematode	Stems per plot row	Infested stems (%)	Infested seed (%)	Seed yield (t ha^{-1})
None	212	4·9	2·5	2·92
01	211	81·7	1·3	3·06
02	211	80·8	3·0	2·17
G1	191	100·0	63·0	1·43
G2	169	99·9	67·0	1·24
SED		4·3	3·29	0·097

https://doi.org/10.23637/ERADOC-1-23

headlands and sidelands some untreated plots became infested, one in particular having 24% of its stems infested.

Survival of stem nematode

Incidence of *D. dipsaci* on farm sites indicated that infestations were persisting in the soil for several years without a host crop. This was studied further with observation plots on three sites: Summerdells II E Rothamsted, giant race on beans in 1970; Fosters O & E II Rothamsted, oat race on beans in 1972; Warren Field II Woburn, mainly giant race on beans 1972. The sites at Rothamsted are on a flinty, silty clay loam and that at Woburn on a sandy clay loam. Two blocks of ten plots were set up at each site in 1973. Each plot was 9·15 m by 2·14 m with 2·14 m sidelands and 5·19 m headlands. A different plot on each block was cropped with spring beans (nematode-free seed) each year with four rows of beans per plot. Non-bean plots were cropped with non-host crops of wheat or barley and the crops were managed according to standard farm practice. Stems in the two centre rows of each bean plot were examined in July or August for presence of *D. dipsaci*. The results are given in Table 6.

On Summerdells II E, where infestations of *D. dipsaci* were less to begin with than on the other two sites, the whole site was cropped with spring beans in 1979. Then, some infestations were found in plots previously cropped with beans in 1973 or later but none on plots without beans since 1970. There were slight infestations remaining in 1977 from the 1970 beans and infestations were picked up in 1979 from the 1973 infested plots indicating that some giant race on this site were surviving for 6–7 years. However, lack of infestation in 1978 and 1979 on plots without beans since 1970 suggests that *D. dipsaci* had died out on this site after 8 years. Elsewhere on Summerdells II in 1979, a non experimental crop of beans had some heavily infested patches on the western part of the site (infested beans 1972) but very few on the eastern part (infested beans 1970). No giant race infested stems were found on Summerdells I in 1980 in spite of very heavy infestations there in 1970.

All plots of the other two sites were cropped with spring beans in 1981. At Warren Field II there was slight infestation (giant race) in 1979 but none in 1980; also in 1981

TABLE 6

Survival of stem nematode

	Summerdells Giant race infested beans 1970		Warren Field Giant race infested beans 1972		Fosters O & E II Oat race infested beans 1972	
Year	A	B (1979)	A	B (1981)	A	B (1981)
1973	19·0	24·4	100	0·0	82·8	36·6
1974	1·1	23·0	58·5	0·0	34·0	34·0
1975	5·8	5·0	55·5	0·25	62·0	40·6
1976	0·0	0·1	11·5	0·0	0·0	28·6
1977	0·8	31·5	3·2	0·7	24·5	62·0
1978	0·0	0·0	58·7	22·5	53·5	82·3
1979	0·0	0·0	2·1	0·9	2·4	47·3
1980	—	—	0·0	0·0	0·0	18·6
1981	—	—	0·0	0·0	11·4	11·4

A Infested bean stems (%) in year indicated, non-host crops in intervening years. Mean of two plots each year.

B Infested bean stems (%), on same plots as in year indicated, when whole site cropped with beans in 1979 or 1981.

https://doi.org/10.23637/ERADOC-1-23

only plots that had beans in 1975 or later had infested plants. Infestations in 1978 were more than expected but the same plots were the most infested in 1981. The indications are that at Rothamsted and Woburn, once moderate to heavy infestations of giant race have been established in the soil, it will take 8–10 years without crop or weed hosts for the infestation to die out.

On Fosters O & E II, oat race, there was some indication that the infestation had died out in 1980 there being very little (2·4% of stems) the previous year. Lack of infestation on this site in 1976 and at Summerdells was probably due to extremely dry conditions throughout the growing season when there were fewer infestations than expected on other parts of the farm. However when all the site was cropped with beans in 1981, all four plots, which had not had beans since 1972, had some infestation. Also to the south side of the plots there was a general infestation in the adjoining bean crop although that area had not had a host crop since 1972. The oat race is known to have a very wide weed host range and chickweed (*Stellaria* spp.) is a particularly good host. Although the cereal crops were virtually weed free there are periods during the late summer and over the winter when there is some weed growth which could act as a reservoir for *D. dipsaci*. Thus on this site, although the degree of infestation had decreased, some infestation was present after 9 years. Observations on other sites on the farm indicate a long survival time for soil infestations of the oat race. Observations on the crops and seeds used indicated that there were no new introductions of the oat race on the Rothamsted farms since 1967 and so infestations noted since then are apparently soil-borne and some of them seem to have persisted for a long time; on one plot on Long Hoos V where winter beans were well infested in 1965 beans were also well infested in 1973; on Great Knott II beans were moderately infested in 1973 and 1980 and on Summerdells I a patch of oat race in beans in 1980 seems to have persisted from the bean crop of 1970, despite non-host crops in intervening years, although the infestation was not noticed in 1970 because of a very heavy infestation of the giant race. There were also other unexpectedly heavy and widespread infestations of the oat race on beans particularly on plot 49 of the Ley Arable on Fosters in 1979 and Fosters O & E IV in 1978. Plot 49 had susceptible oats in 1964, then non-hosts, mainly wheat, until oats cv. Manod in 1977. Manod was listed by the NIAB as being resistant to *D. dipsaci* but, although the plants do not develop tulip root symptoms, Whitehead *et al.* (1981) have shown that soil populations of *D. dipsaci* increase under this cultivar and so it would seem to be tolerant rather than resistant. On Fosters O & E IV Manod oats were grown in 1969 and again in 1977 with intervening years of wheat except for 1 year fallow, and presumably the oats maintained the *D. dipsaci* population which damaged beans in 1978. Even so, 1969–77 is a long period without a known host crop but weeds may have been reservoir hosts.

Thus the indications are that soil infestations of the oat race on the Rothamsted farm persist for at least 8–10 years, possibly much longer, and still cause moderate infestation in beans.

The soil populations of *D. dipsaci* on the survival observation plots were also assessed during the final year when plots were all cropped with beans. Fifteen 20×2·4 cm soil cores were taken from each plot, the cores were broken down and mixed together and two 200 ml (by displacement in water) replicates from each plot extracted by the Seinhorst two-flask technique and the resulting extract was cleaned by centrifugation (see Flegg & Hooper, 1970). Generally very few (less than 30 litre^{-1}), if any, were recovered and there was no correlation between the sparse numbers recovered and the plot treatments. The soil populations of plots 1, 9 and 18 of Broadbalk Section 2 (beans moderately infested with giant race in 1977) and Section 7 (beans heavily infested with giant race in 1978) have been monitored since December 1978 using the above sampling and extraction technique. The results are given in Table 7. The infestation of Section 2

https://doi.org/10.23637/ERADOC-1-23

TABLE 7

Broadbalk—Survival of Ditylenchus dipsaci, *giant race*

Number of *D. dipsaci* l^{-1} soil (by displacement in water) (±SE) n=6

	Dec 1978	May 1979	May 1980	May 1981	May 1982
Section 2 (Beans moderately infested with *D. dipsaci* 1977)	113 (36·1)	47 (17·9)	135 (45·8)	18 (6·0)	3 (1·7)
Crop	Fallow after W. wheat	Fallow	Potatoes	W. wheat	Fallow
Section 7 (Beans heavily infested with *D. dipsaci* 1978)	12278 (1599·4)	12010 (1835·7)	9813 (2708·4)	1658 (375·6)	628 (85·3)
Crop	W. wheat after Beans	W. wheat	Fallow	Potatoes	W. wheat

was barely detected in May 1982 whereas in Section 7, where the numbers had been generally much greater, *D. dipsaci* were still plentiful in 1982.

Use of chemicals to control stem nematode

Incidental observations on experimental plots which happened to be sited on infested sites indicated that of various chemicals used to control pests, aldicarb seemed to be the only one having a marked effect on the incidence of infestations of *D. dipsaci* in bean stems and then only when it was used at a high rate of 10 kg a.i. ha^{-1}, broadcast and mixed with the soil. Beans are usually grown in rather widely spaced rows (50 cm) so, to decrease the amount of chemical used, in-row rather than broadcast treatment was tried to control seed-borne and soil-borne infestations of *D. dipsaci*.

Aldicarb—treatment of seed-borne infestation. In 1974 (R/BE/7; Garden Plots 7) in-row treatments were applied to infested seed (cv. Minor) at the time of sowing. The seed, infested with the giant race of *D. dipsaci*, was sown into open drills. Aldicarb granules (10% a.i.) were then applied on top of the seed using a land-wheel driven single-hopper microband granule applicator. The drills were then closed by light harrowing and rolling. There were four randomized blocks of four plots, each plot was 1·52×9·14 m with three rows of beans along each plot. Aldicarb was applied at 1·0, 2·0 and 4·0 kg a.i. ha^{-1}. Plant stems were assessed visually for incidence of *D. dipsaci* in July; 150 g of combine-harvested seed from each plot were extracted for *D. dipsaci* by the beaker method. Individual seeds, 300 per plot, were also checked for presence of *D. dipsaci*. The results are given in Table 8. The top rate of aldicarb decreased greatly, but

TABLE 8

Ditylenchus dipsaci: *seed-borne infestation, in-row treatment with aldicarb at time of sowing spring beans*

					SED
Aldicarb kg a.i. ha^{-1}	0	1	2	4	
Infested bean stems (%)	65	41	35	12	
Infested seed (%)	10	3	1	0	
D. dipsaci per 150 g seed	671	2847	234	27	
Grain yield t ha^{-1}	4·52	4·48	4·53	4·68	0·377

https://doi.org/10.23637/ERADOC-1-23

did not eradicate, stem infestation but seed infestation was prevented. Although 65% of the stems in the control plots were infested the degree of infestation was not enough to affect grain yield.

Aldicarb—treatment of soil-borne infestation. In 1975 (R/BE/7; Fosters O & E VI) in-row treatments were applied to seed (cv. Maris Bead) at the time of sowing (25 April) in land infested with *D. dipsaci* giant race. There were four randomized blocks of four plots; each plot was 2·54×9·14 m with five rows of beans along each plot. Aldicarb was applied in the rows, as described above, at 1·0, 2·0 or 4·0 kg a.i. ha^{-1}. Plant stems were assessed visually for incidence of *D. dipsaci* early in August. Seed produced from each plot was also checked for presence of *D. dipsaci*. The results are given in Table 9. The top rate of aldicarb almost eliminated stem infestation and no infested seed was produced. The increase in grain yield was not necessarily due to control of *D. dipsaci* as weevil-transmitted viruses were also much decreased (Cockbain & Bowen, 1976). The generally low grain yields were probably due to late sowing and a rather dry summer.

TABLE 9

Ditylenchus dipsaci: *soil-borne infestation, in-row treatment with aldicarb at time of sowing spring beans*

					SED
Aldicarb kg a.i. ha^{-1}	0	1	2	4	
Infested bean stems (%)	87	41	15	1	
Infested seed (%)	4	4	0	0	
D. dipsaci per 150 g seed	47	4	0	0	
Grain yield t ha^{-1}	1·08	1·69	1·87	2·03	0·106

Effects of thiabendazole. Thiabendazole is known to have some nematicidal activity (McCleod, 1973) but, in contrast to aldicarb, has a low mammalian toxicity.

In 1975 pot tests of thiabendazole as a wettable powder and a water soluble formulation were made against the giant race of *D. dipsaci* on spring beans. Each 25 cm diameter pot, with 5·5 litre soil, was sown with seven beans and inoculated with 75000 *D. dipsaci*. There was a three-fold replication and the seeds were covered with a 5 cm layer of soil containing either of the above formulations to give 0, 60, 120, 240 or 480 mg a.i. per pot. Stems in untreated pots became heavily infested and distorted and some stems in pots treated with 60 or 120 mg were lightly infested; none was infested in pots treated with 240 or 480 mg of either formulation but the highest rate was toxic to the beans causing abnormally thin and short stems to develop. In 1976 thiabendazole as a wettable powder or granular formulation (240 mg a.i. in 5·5 litre of soil) controlled *D. dipsaci* on beans when applied at planting time to soil inoculated with *D. dipsaci* (75000 per pot). When the same dose was applied as a drench to soil growing heavily infested five week-old seedlings, many of the plants recovered and were freed from infestation indicating that thiabendazole had some systemic effect.

Thiabendazole and aldicarb—field plot trial. In 1977 (R/BE/5, Highfield O & E III) thiabendazole was tested on field plots for its ability to control a soil-borne infestation, mainly giant race, of *D. dipsaci*. The experiment was sown in three randomized blocks of eight plots each plot being 2·54×9·14 m with five rows of beans along each plot. Many germinating seeds were destroyed by pigeons; the inadvertent omission of weedkiller led to serious weed infestation and damage from these two causes was so severe that one of the blocks had to be abandoned. Hence there was two-fold replication of the treatments plus four untreated plots. Thiabendazole was applied

https://doi.org/10.23637/ERADOC-1-23

TABLE 10

Thiabendazole and aldicarb and stem nematode on field beans

	Untreated	Treated: Thiabendazole: Granules kg a.i. ha^{-1}			Treated: Thiabendazole: Seed treatment g a.i. kg^{-1} seed		Treated: Aldicarb Granules kg a.i. ha^{-1}
		3	6	12	12	24	5
Stem height (cm)	55	55	64	63	70	67	85
SE±	1·8	1·2	3·5	4·6	0·7	3·8	3·3
Infested stems (%)	52	71	28	61	35	40	0
SE±	4·5	4·5	14·5	2·1	7·1	14·1	0·0
Infested seed (%)	12	14	12	8	8	11	0
SE±	2·3	4·5	2·3	3·3	2·8	3·3	0·0
Seed yield (t ha^{-1}) SED±0·265	0·44	0·50	0·74	0·72	1·04	0·88	1·61

either as fine granules (5% a.i.) to open bean rows at time of sowing at 3, 6 and 12 kg a.i. ha^{-1} or as a seed dressing using 60% a.i. wettable powder at 12 and 24 g a.i. kg^{-1} seed. The seed (4·5 kg) was dressed in a 'Rotostat' machine using 45 ml of 3% methyl cellulose sticker. For comparative purposes, aldicarb granules (10% a.i.) at 5 kg a.i. ha^{-1} was also included in the row treatments. The thiabendazole and aldicarb granules were applied at the time of sowing to open rows as previously described. The plots were sown on 19 April and harvested on 29 September. Stem height and numbers of stems infested with *D. dipsaci* were recorded in August. The seed infestation was assessed in seed from hand-harvested pods. The results are given in Table 10. In contrast to the pot tests, thiabendazole as granules or seed dressing had little effect on the infestation of *D. dipsaci* on bean stems or seed but there was some growth and yield response, especially from dressed seed, which may have been due to control of root-rot fungi rather than *D. dipsaci*. The aldicarb granules were much more effective, preventing stem and seed infestation by *D. dipsaci*, although the much higher seed yield may have been due to the control of weevils as well as nematodes.

Effect of heat treatment on bean seed infested with *D. dipsaci*.

Batches of spring bean seed from three different sites infested with the giant race of *D. dipsaci* were heated in a hot air oven at 60°C for 1, 2 or 4 days or at 80°C for 30 min or 1 h. The moisture content of two batches of seed was 9·1% and 7·3% respectively. At least 100 seeds were used for each treatment. None of these treatments had any obvious effect on the nematodes; just as many *D. dipsaci* revived, when soaked in water, from the treated seeds as from the untreated controls. However all the above treatments at 60°C decreased seed germination by at least 40%, sometimes much more; treatment at 80°C decreased germination by 6–45%. (In collaboration with Dr A. J. Cockbain, Plant Pathology Department)

Tests for faba beans resistant to stem nematode

Cultivars of some crops, particularly oats, red clover and lucerne, are resistant to *D. dipsaci*. With this in mind it was decided to test for resistance a range of faba bean cultivars, breeding lines and hybrids. Seed was kindly supplied by the Welsh Plant Breeding Station and the Plant Breeding Institute, Cambridge. It was found that an

https://doi.org/10.23637/ERADOC-1-23

inoculum of 75 000 *D. dipsaci* fourth-stage juveniles, per 25 cm diam. pot (5·5 litre soil) would usually severely damage known susceptible bean cultivars but not often kill them. Where sufficient seed was available, seven seeds were sown per pot with two pots per batch of seed. The nematode inoculum was added at sowing and the seeds then covered with about 8 cm soil. A steam-sterilized potting loam was used. The nematode inoculum was obtained by mist extraction (Flegg & Hooper, 1970) of infested bean seed, straw or oat straw and the nematode suspension added to each pot in about 75 ml of water. As each batch of test seeds was set up, a known susceptible cultivar was also included to indicate the effectiveness of the nematode inoculum. The pots were set up in the spring, plunged outside in sand and watered as necessary. They were covered with polythene sheeting until the seedlings were about 3 cm high to prevent drying out and bird damage. Germination was checked and the stems produced were usually assessed for nematode damage in July or August; some stem tissue was also checked in the laboratory for presence of *D. dipsaci*. Over the years 1975–78, 99 different faba bean selections were tested against the giant race and 48 against the oat race of *D. dipsaci*. No selections were completely resistant. In the pot tests the primary shoot would sometimes be killed off by nematode invasion; secondary tillers eventually produced would often be much less infested than stems from other primary shoots in the same pot which had survived the initial invasion. Such lightly infested secondary tillers give the impression of resistance but they are in fact the result of greater susceptibility of the primary shoot. This reaction depended partly on the selection tested and on the degree of infestation. Secondary tillers may escape infestation to some extent because they start nearer the soil surface and, as they arise from an established root system, their growth tends to be quicker than primary shoots. Sometimes the initial invasion killed the entire plant.

The following commercial cultivars were found susceptible to the giant and oat race of *D. dipsaci*: Ascott, Banner, Bulldog, Blaze, Daffa, Danas, Franks Ackerperle, Herra, Maris Bead, Maris Beagle, Maris Beaver, Minden, Stella, Tarvin and Throws M.S. When combined with the list of cultivars which had infested seed (p. 248) all the recommended commercial cultivars available up to 1982 seem to be susceptible to *D. dipsaci*.

Sturhan (1975) reported that the broad bean cv. Staygreen was somewhat resistant to one population of the giant race of *D. dipsaci*. However Staygreen and the cv. Beryl, Primo, Three Fold White and Wierboon were severely infested by the Rothamsted populations of the oat race and giant race of *D. dipsaci*.

Relationship between age of faba bean plants and infestation with *D. dipsaci*

In a pot experiment, field beans cv. Minden were sown at weekly intervals over 7 weeks (9 March to 20 April) in the spring and all pots were inoculated with the giant race of *D. dipsaci* at the time of the last sowing. The seeds were sown in 25 cm diam. pots, seven seeds per pot. The pots were inoculated with 100 000 or 200 000 *D. dipsaci* fourth-stage juveniles poured on to the soil surface in 100 ml water, there being three replicates for each rate each week. The pots were plunged in sand outside and watered as necessary. The degree of infestation was assessed in mid August when the length of stem showing symptoms of nematode infestation was recorded against the total stem length. The incidence of secondary tillers and distortion at the top of the plant was noted. The results are given in Table 11. The degree of infestation decreased with increased age of plants at inoculation and pots inoculated before the plants had emerged had the most severely infested stems in which some tops were distorted giving a 'mop top' appearance as has also been seen sporadically on infested field sites; such plants tend to produce

https://doi.org/10.23637/ERADOC-1-23

TABLE 11

Relationships between age of field bean plants and infestation by D. dipsaci

Inoculum rate	Time (weeks) from sowing to inoculation	Plant height (cm) at inoculation	Stem length (%) infested	Secondary tillers per 3 pots	Distorted tops per 3 pots
A	0	0	65	8	4
B			83	11	5
A	1	0	83	1	5
B			76	5	8
A	2	6	39	0	2
B			56	0	3
A	3	8	43	0	0
B			63	0	3
A	4	16	21	0	0
B			36	0	0
A	5	23	17	0	0
B			7	0	0
A	6	30	0	0	0
B			4	0	0

A=100000, B=200000 *D. dipsaci* (giant race) per pot (5·5 litre soil)

much infested seed. The same pots also produced plants with extra tillers due to the killing off of the primary shoot by heavy infestations of *D. dipsaci*; not all tillers so produced were infested. It is interesting that 6-week-old plants could still become infested but this was only at the base of the stems. These results corroborate other pot and field observations in that cool, moist, conditions at time of sowing, hence slow emergence, tend to result in more heavily infested plants. The susceptibility of more mature plants indicates that chemical treatments would need to be persistent to control late infestations.

Host range tests with populations of *Ditylenchus dipsaci* from Rothamsted Farm

Some other crops were tested for their susceptibility to the oat race population from Fosters O & E VI and to the giant race from Great Field II. The crops tested and the results are given in Table 12. Seeds were sown in 17·5 or 25 cm diam. pots using a steam sterilized potting soil. The inoculum was obtained by mist extraction of bean seed, straw or oat straw and the water suspension of nematodes added to the seed at time of sowing. The rate of inoculum, mainly fourth-stage juveniles, varied between 50000 and 100000 *D. dipsaci* per pot; a pot of susceptible field beans was sown and inoculated at the time each test batch was set up to check on the effectiveness of the inoculum. Pots were set up in the spring and kept outside in a sand plunge and watered as necessary.

Lupinus albus was severely distorted by the oat race but there was very little reproduction by *D. dipsaci* and eventually the plants recovered. Peas are generally susceptible to the oat race but they seem to be less affected by the Rothamsted giant race which reproduced very little, if at all, in the cultivars tested. However, a giant race population from beans in Shropshire stunted early growth of peas (cv. Kelvedon Wonder and Progreta) and although the stems eventually grew away and produced pods there were some *D. dipsaci* reproducing in the stems up to harvest time. This population also invaded and stunted oilseed rape seedlings (cv. Giant Broadleaf, Jet Neuf) but no *D. dipsaci* were recovered from the plants later in the season. Although the Rothamsted giant race reproduced slightly in onion sets (Hooper, 1971), from an infection started by injection into the hollow leaves, there was usually little

https://doi.org/10.23637/ERADOC-1-23

TABLE 12

Susceptibility of some crops to the oat race and giant race of Ditylenchus dipsaci *from Rothamsted Farm*

Common name	Latin name	Cultivar	Oat race	Giant race
Carrots	*Daucus carota* L.	Amsterdam	++	0
Celery	*Apium dulce* Mill.	Giant White	–	0
Lucerne	*Medicago sativa* L.	Europe	–	0
Lupin	*Lupinus albus* L.	Kievski	++	0
	Lupinus angustifolius L.		0	0
Maize	*Zea mays* L.	Aztec	–	0
		Early King	0	0
		Maris Carmine	++	0
		Pioneer	0	0
Navy beans	*Phaseolus vulgaris* L.		–	0
Oat	*Avena sativa* L.	Maris Osprey	+++	0
		Condor	+++	0
Oilseed rape	*Brassica napus* L. v. *arvensis* (Lam.)	Gulle	–	0
	Thellung	Victor	–	0
Onion	*Allium cepa* L.	Bedfordshire-Champion	+++	0, +
		Superba	+++	0
Pea	*Pisum sativum* L.	Kelvedon Wonder	++	+
		Progress	++	+
		(leafless)	++	–
Red clover	*Trifolium pratense* L.	(S123)	–	0
Sugar beet	*Beta vulgaris* L.		++	0
White clover	*Trifolium repens* L.	(S100)	–	0
Wild oat	*Avena fatua* L.		+++	0

–=not tested
0=tested but no effect
+=slight plant distortion and/or necrosis; some *D. dipsaci* present but little reproduction.
++=moderate distortion and/or necrosis; *D. dipsaci* reproducing in tissues.
+++=severe distortion and/or necrosis; many *D. dipsaci* reproducing in tissues

reproduction in onions raised from seed sown in infested soil and where there was some infestation, once out of four tests, there were few nematodes in the tissues and little reproduction.

Wild oats (*Avena fatua* L.) growing amongst winter beans (cv. Maris Beagle) in Cambridgeshire were well infested with the oat race of *D. dipsaci*, as were the beans, and some of the oat plants were showing tulip root symptoms. The Rothamsted oat race population also reproduced in *A. fatua* which could be an important reservoir host.

The negative results obtained with the crops listed, although an indication of their probable non-host status, should be treated with caution as various factors such as temperature and moisture can affect plant susceptibility. This is illustrated by the results with maize which was tested on three different occasions but only once did an infestation become established; then reproduction of *D. dipsaci* was limited but the plants were badly stunted and distorted as described by Caubel (1973).

During the pot tests some plants of the weed Broad-leaved Willow-herb (*Epilobium montanum* L.) became well infested with the oat race of *D. dipsaci* and showed stem and petiole distortion. This seems to be a new host record for *D. dipsaci*.

Discussion

The ease with which *D. dipsaci* can be spread on field bean seed and its rapid buildup in a host crop are well illustrated by the observations made on the Rothamsted farms. Although seed-borne infestations may not have much effect on the yield of the first

https://doi.org/10.23637/ERADOC-1-23

crop, the population released into the soil at the end of the season can be enough to damage the next host crop especially if grown within the next 3 or 4 years. However, the observations on the survival sites indicate that some 9 years without a host crop are necessary before the giant race dies out in soil and that the oat race survives for more than 9 years. These long survival times are in accord with Seinhorst (1957) who found that *D. dipsaci* persisted indefinitely in heavy soils and Wilson and French (1975) who found that the oat race survived for up to 7 years and that weeds were an important factor in survival.

The first record of *D. dipsaci* infesting field beans (Ritzema Bos, 1892) confirmed observations by the English naturalist Miss E. Ormerod on field beans which had been badly attacked following oats on a farm near Luton. The same publication also noted that in 1866 Miss Ormerod had been advised by a farmer in Ayrshire that oats following beans were severely attacked by 'tulip root'. Thus it was shown early on that oats or beans could build up populations of *D. dipsaci* which could be damaging to the other, following, crop. However it was not realised until much later (Dierks & Klewitz, 1962; Hooper, 1971) that *D. dipsaci* could be dispersed with the seed of field beans and also broad beans (Green & Sime, 1979). The oat race is common throughout Europe but local populations may vary in their pathogenicity and host range (Seinhorst, 1957; Sturhan, 1969; Caubel, 1971).

The giant race of *D. dipsaci* is a serious pest of faba beans in the Mediterranean region and was first recorded on broad beans in North Africa (Debray & Maupas, 1896). It was recorded in Britain on broad beans (Goodey, 1941) but it is only in recent years that it has been noticed on field beans in cooler parts of Europe (Hooper, 1971; Sturhan, 1975; Brzeski, 1978). The giant race at Rothamsted seems to survive the winter just as well as the oat race but is generally much more damaging to field beans and results in more infested seed.

The oat race is known to have a very wide weed host-range which, as noted by Wilson and French (1975), plays a part in its survival in soil whereas red or white dead nettle (*Lamium purpureum* L. and *L. album* L.) are the only weed hosts (Clayden & Hooper, 1981) known for the giant race in Britain. Of 12 common weeds examined from a bean field heavily infested with the giant race in Shropshire, red dead nettle was the only one found infested. It is interesting that another dead nettle, *L. amplexicaule* L., is a weed host for the giant race in Syria (Weltzien & Weltzien, 1980). It is possible that there is more than one giant race of *D. dipsaci*; Sturhan (1975) found that populations differed in host range and D'Addabbo Gallo *et al.* (1982) studied two different tetraploid populations.

Although aldicarb at 4–5 kg a.i. ha^{-1} controlled seed- and soil-borne infestations of *D. dipsaci* in spring-sown beans, the cost of such treatment would not be feasible on a crop sown for feed. However, it might be worthwhile for an important seed stock especially as such treatment would also control weevils, aphids and virus. It may be more difficult to control infestations in winter-sown beans. An attempt to control a soil-borne giant race infestation in winter beans in a fertilizer experiment on Agdell (81/R/AG/6) was unsuccessful. Aldicarb was applied with the bean seed at 4 kg a.i. ha^{-1} in November 1980, but plants were well infested with the giant race the following summer. Pot tests have shown the *D. dipsaci* can invade well-established spring bean plants so it is possible that winter bean plants would be invaded in the spring when the effects of aldicarb would have decreased.

It is general practice to use methyl bromide fumigation to eradicate *D. dipsaci* from seeds of onion, red clover and lucerne. Powell (1974) found that although methyl bromide gave some control it required 2500 mg h $litre^{-1}$ (2·5× the normal commercial treatment) to kill most of the *D. dipsaci* on heavily infested seed. However some *D.*

https://doi.org/10.23637/ERADOC-1-23

dipsaci survived the treatment and seed germination was decreased. Thus there is some doubt as to whether fumigation is feasible on a commercial scale.

From discussions with farmers who grow beans, it seems to be their practice to buy in a bean stock from the produce of which they save seed for their own sowing in subsequent years. Thus if they are unfortunate enough to buy an infested stock much of their farm could become infested as has happened on the Rothamsted farms. Although there is a MAFF certification scheme, which includes a check for *Ascochyta fabae,* such certified seed can be heavily infested with *D. dipsaci*. Partly in response to exhibits at Rothamsted Subject Days and Rothamsted exhibits elsewhere some seed producers and merchants are now having seed and sites checked for *D. dipsaci*. However, a national detection scheme would be more effective and it could be incorporated into the existing certification scheme by using the 'beaker test' which is quick and simple and would detect most significantly infested stocks.

Acknowledgements

I thank the various people who over the years have assisted in the annual survey of field beans on the Rothamsted and Woburn farms. The cooperation of J. R. Moffatt, R. Moffitt and J. Wilson in the conduct of field experiments and the advice and encouragement from J. McEwen are much appreciated. A. G. Whitehead advised on, and provided machinery for, the chemical treatment of field plots. Mr A. G. Richards, Rothwell Plant Health Ltd, Lincoln, kindly supplied formulations of thiabendazole. Dr D. A. Lawes of the Welsh Plant Breeding Station, Aberystwyth and Dr D. A. Bond of the Plant Breeding Institute, Cambridge, supplied various faba bean lines for testing against *D. dipsaci*. Mr G. R. A. Crofton of the National Institute of Agricultural Botany, Cambridge and Mr A. J. Biddle of the Processors 'Growers' Research Organization, Thornhaugh have supplied seed samples and information. In particular I thank Mrs Janet Cowland for help with surveys and seed inspection and the preparation of this manuscript.

REFERENCES

BRZESKI, M. W. (1978) *Ditylenchus dipsaci* (Kühn) w nasioach bobu. *Roczniki Nauk Rolniczych, E* **8,** 71–74.

CAUBEL, G. (1971) Le problème du nématode des tiges et des bulbes en France. In: *Les nématodes des cultures.* [Journées françaises d'études et d'information, Paris, 3–5 Novembre, 1971] Paris, France: Association de Coordination Technique Agricole (ACTA), pp. 193–256.

CAUBEL, G. (1973) Problèmes nématologiques du mais en France: connaissances actuelles, possibilités d'intervention. *Phytiatrie-Phytopharmacie* **22,** 39–48.

CLAYDEN, I. & HOOPER, D. J. (1981) New weed hosts for the giant race of *Ditylenchus dipsaci* (Kühn) Filipjev. *Plant Pathology* **30,** 251–252.

COCKBAIN, A. J. & BOWEN, R. (1976) Effects of insecticides on virus spread and yield. *Rothamsted Experimental Station. Report for 1975,* Part 1, 262.

D'ADDABBO GALLO, M., MORONE DE LUCIA, M. R., GRIMALDI DE ZIO, S. & LAMBERTI, F. (1982) Caryo-phenotype relationships in *Ditylenchus dipsaci. Nematologia Mediterranea* **10,** 39–47.

DEBRAY, F. & MAUPAS, E. (1896) Le *Tylenchus devastatrix* Kühn et la maladie vermiculaire des fèves en Algerie. *L'Algerie agricole,* pp. 1–55.

DIERKS, R. & KLEWITZ, R. (1962) Zür Samenübertragbarkeit einer Ackerbohnen vorkommenden Herkunft des Stengelälchens *Ditylenchus dipsaci* (Kühn). *Nematologica* **7,** 155–163.

FLEGG, J. J. M. & HOOPER, D. J. (1970) Extraction of free living stages from soil. In: *Laboratory methods for work with plant and soil nematodes.* Ed. J. F. Southey. MAFF Technical Bulletin 2, London: HMSO, pp. 5–22.

GOODEY, T. (1941) Observations on a giant race of the stem eelworm, *Anguillulina dipsaci,* attacking broad beans, *Vicia faba* L. *Journal of Helminthology* **19,** 114–122.

GREEN, C. D. & SIME, S. (1979) The dispersal of *Ditylenchus dipsaci* with vegetable seeds. *Annals of Applied Biology* **92,** 263–270.

HOOPER, D. J. (1971) Stem eelworm *(Ditylenchus dipsaci),* a seed and soil-borne pathogen of field beans *(Vicia faba). Plant Pathology* **20,** 25–27.

https://doi.org/10.23637/ERADOC-1-23

HOOPER, D. J. (1972) *Ditylenchus dipsaci.* C.I.H. descriptions of plant-parasitic nematodes. Set 1, no. 14, 4pp. Farnham Royal: Commonwealth Agricultural Bureaux.

MCLEOD, R. W. (1973) Suppression of *Aphelenchoides composticola* and *Ditylenchus myceliophagus* on *Agaricus bisporus* by thiabendazole and benomyl. *Nematologica* **19,** 236–247.

POWELL, D. F. (1974) Fumigation of field beans against *Ditylenchus dipsaci.* *Plant Pathology* **23,** 110–113.

RITZEMA BOS, J. (1892) L'anguillule de la tige (*Tylenchus devastatrix* Kühn) et les maladies des plantes dues à ce nématode. *Archives du Musee Teyler* Ser. II, **3,** 545–588.

SEINHORST, J. W. (1956) Population studies on stem eelworms *(Ditylenchus dipsaci).* *Nematologica* **1,** 159–164.

SEINHORST, J. W. (1957) Some aspects of the biology and ecology of stem eelworms. *Nematologica* **2,** (Supplement), 355S–361S.

STURHAN, D. (1969) Das Rassenproblem bei *Ditylenchus dipsaci.* *Mitteilungen aus der Biologischen Bundesanstalt für Land- und Forstwirtschaft Berlin-Dahlem* **136,** 87–98.

STURHAN, D. (1975) Untersuchung von *Vicia faba*—sorten auf Resistenz gegenüber Stengelälchen *(Ditylenchus dipsaci).* *Mededelingen van de Faculteit Landbouwwetenschappen Rijksuniversiteit Gent.* **40,** 443–450.

WELTZIEN, M. & WELTZIEN, H. (1980) *Lamium amplexicaule* L. as host of the stem nematode *Ditylenchus dipsaci* in Syria. *Faba Bean Information Service Newsletter* No. 2, 50.

WHITEHEAD, A. G., TITE, D. J., BROMILOW, R. H., FRASER, J. & NICHOLS, A. (1981) Stem nematodes *(Ditylenchus dipsaci).* *Rothamsted Experimental Station. Report for 1980,* Part 1, 152.

WILSON, W. R. & FRENCH, N. (1975) Population studies of stem eelworm *(Ditylenchus dipsaci)* in microplots, field plots and fields in the north of England under different crop rotations. *Plant Pathology* **24,** 176–183.

https://doi.org/10.23637/ERADOC-1-23