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## Stem Eelworm Attacking Carrots

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In July, 1952, carrots growing in the Chatteris area of the Isle of Ely were found to be attacked by *Ditylenchus dipsaci*. The preceding crop had been wheat and for the previous twenty years the crop rotation of the field had been carrots, potatoes and wheat with an occasional crop of celery. There have been two previous records of stem eelworm attack on carrots in this country, both from the Chatteris area, the first in 1931 and the second in 1941. These occurred on fields which, both before and since the attacks, have grown carrots frequently. The outbreak was very severe in 1941 and caused slight damage in later years but appears since to have died out. All three outbreaks were on different fields on different farms although within the radius of about one mile. The fields are separated either by a railway line or a wide ditch as well as a series of minor ditches, and it is difficult to see any connection between the outbreaks.

The leaf bases were swollen and puffy and the infestation often extended downwards into the top of the root. Both the leaf bases and the crown were paler than normal and, as the attack progressed, they became brown and decayed. The attack was not noticed by the farmer until the crop was being harvested when the tops of affected carrots broke off leaving the roots in the ground. For this reason the extent of the damage could not be clearly seen but it appeared that the attack was most severe in the lowest part of the field. These symptoms were essentially the same as those described and figured by T. Goodey (1931).

Attacked carrots were replanted at Rothamsted and in the following year several produced flowering stems. Many of these were deformed and twisted with some stunting and swelling. In some plants the stem and bracts just beneath the umbel were swollen and had brownish lesions. Later the seed from these heads was collected and dried. In

the spring of 1954 this seed was sown but although 89 seeds were planted not a single infested carrot resulted. Seedborne infestation therefore remains unproven.

Infested carrots were chopped up and used to inoculate pots of J. I. compost in which were grown carrots, potatoes, celery, parsley, parsnips and garden peas. The carrots in the inoculated pots died after a few weeks whereas those in the uninfested control pot grew normally. Four potatoes were planted, one being a control which grew to a height of 14 inches, whilst the plants in the inoculated pots were severely damaged and averaged  $8\frac{1}{2}$  inches high. The leaflets were malformed and twisted and there were puffy and cracked brownish areas on the backs of the leaves. Stems and petioles had gall-like swellings which developed into lesions. Some shoots had the terminal bud destroyed so that they yellowed and died prematurely. In others, the death of the terminal bud caused laterals to develop. When the pots were turned out, all the new tubers were clean, except one, in which a small lesion contained a few adults, larvae and eggs of *D. dipsaci*. A slight attack developed on the celery as somewhat misshapen and crinkly leaflets and there were swellings on the petioles. In one plant considerable dwarfing occurred as a result of the infestation. Neither parsley nor parsnips were attacked but garden peas were dwarfed and swollen with numerous eelworms in the tissue.

The farmer kindly allowed us in April, 1953, to put down an experiment on the field, which in that year was growing potatoes. Four replicated blocks of plots, each of four rows, 12 ft. long, of the following 12 plants were sown: Parsnips, celery, parsley, kidney beans, garden peas, field beans (*Vicia faba*), broad red clover, late-flowering red clover, lucerne (variety Du Puits), oats (variety S. 147), sugar beet and mangolds. A row of carrots was sown between each plot and along each edge. The plants were examined from time to time and, as late as the beginning of August, apart from a few celery plants which had lesions containing eelworms at the leaf bases, all the other plants appeared healthy and were growing excellently. The field beans were over 4 ft. high and, although apparently healthy, one plant was found with a long blister-like lesion on the stem about 18 ins. above the ground. Examination showed the lesion to be full of stem eelworm. Another examination in early September brought to light many more lesions on bean stems and a few more celery plants were found attacked including one or two with small, isolated, petiolar lesions. On this occasion many carrots were dug and some of these were found to be typically attacked.

The other test plants and the potatoes adjoining the experiment were apparently quite free from eelworm attack.

The presence of blister-like lesions on the bean stems suggested that the race of *D. dipsaci* might be the giant one (Goodey 1941). In 1954 a pot experiment was set up to test this supposition and also to make certain that the eelworms attacking carrots and beans in the field at Chatteris were identical. For ease of reference the population from this field will be called "race 'X'." Pots of carrots and broad beans (*V. faba*) were inoculated with about 10,000 eelworms each, extracted from beans infested with race 'X' and compared with a similar series inoculated with the same numbers of the giant race extracted from infested bean material obtained from Portugal. In addition, some pots of oats (var. Golden Rain) were inoculated with race 'X.' The results were as follows :

#### RACE 'X.'

##### Carrots.

Malformation and lesions on the leaf bases. Ultimately the eelworms invaded the tops of some of the roots.

##### Broad Beans (*V. faba*).

Blister-like lesions on the lower parts of the stems and broken black lesions at the stem bases.

##### Oats.

Typical symptoms of tulip root.

#### GIANT RACE.

##### Carrots.

These remained clean throughout the experiment.

##### Broad Beans (*V. faba*).

Blister-like lesions on the lower parts of the stems though one lesion was 15 ins. above the ground. One plant was very dwarfed and malformed. A few had broken black lesions at the stem bases.

Infested material from this experiment was teased out in water and samples of adult eelworms picked up, relaxed by gentle heat and then fixed in 5 per cent. formalin. Measurements were obtained from camera lucida drawings and these are set out in Table I.

## DISCUSSION.

Certain conclusions can be drawn about the population of stem eelworm (Race 'X') which was found attacking carrots near Chatteris. The evidence from the measurement data and the fact that the giant race did not attack carrots indicates that race 'X' is not identical with the giant race. The fact that eelworms from infested bean material obtained from the carrot field transferred to carrots confirms that race 'X' is not a mixed population. The damage to the stem bases of *Vicia faba* was typical of the oat race but the production of blister-like lesions generally higher up the stem was not characteristic. Large numbers of eelworms were to be found immediately below the epidermis in the region of these lesions. White cottony masses of eelworms were easily visible in this position when the epidermis was peeled off. The giant race also behaves in this way. Typical tulip-root symptoms were produced on oats grown in pots whereas those on the field site showed no signs of attack. The two oat varieties used, S.147 on the field site and Golden Rain in pots are both very susceptible to the oat race. The eelworms from these pot-infested oats were slightly longer than race 'X' from carrots and beans and since they were reproducing quite well it is obvious that oats were a favourable host under these conditions. Table II sets out a comparison of the body lengths of samples of the giant race from *V. faba* and race 'X' from *V. faba* and oats, with similar data from T. Goodey (1941). The close agreement between the two series is remarkable.

Under pot conditions carrots, celery, *V. faba*, garden peas, oats and potatoes were attacked. In the field, however, only carrots, celery, *V. faba* and one specimen of fools parsley (*Aethusa cynapium*) were found attacked, although the same series of plants was grown as well as a number of others.

The inconsistencies between the two sets of results need to be explained. In pots, carrot seedlings were wiped out in the 1952 experiments so that, compared with the field experiment where only a small percentage of the carrots was attacked, it seems reasonable to assume that the level of infestation was much higher in the pots. The same line of argument may be applied to the question of the oats, garden peas and potatoes but it is not clear why these crops remained apparently completely free from eelworm attack in the field. Celery and *V. faba* were attacked both in pots and in the field.

Potatoes are not a recognised host of the oat race and attack on celery has not been reported before in this country. Peas have been reported as attacked by stem eelworm on several occasions and in 1952 one of us (J. B. G.) successfully transferred an infestation from peas to oats, setting up typical tulip-root. Although *V. faba* and parsnip are

TABLE I.

Summary of data on carrot population of *D. dipsaci* (Race "X") compared with data on giant race.

Race	Source	Host	Sex	Standard			a.	b.	c.	V%
				L.	deviation	n.				
"X"	Chatteris	Carrot	♀	1.37	0.258	12	44.0	7.35	—	80.5
"X"	Chatteris	Oats	♀	1.52	0.090	12	43.8	7.22	—	80.7
"X"	Chatteris	<i>V. faba</i>	♀	1.36	0.098	12	36.3	6.83	—	81.0
Giant	Portugal	<i>V. faba</i>	♀	1.86	0.129	7	53.4	7.74	—	81.4
"X"	Chatteris	Carrot	♂	1.27	0.024	12	45.3	6.75	14.4	
"X"	Chatteris	Oats	♂	1.49	0.024	12	50.4	6.78	15.6	
"X"	Chatteris	<i>V. faba</i>	♂	1.33	0.167	12	41.2	6.44	14.2	
Giant	Portugal	<i>V. faba</i>	♂	1.63	0.021	3	50.0	7.21	18.4	

NOTE.—L = length in mm.; a = length/greatest width; b = length/length of oesophagus; c = length/tail length; V% = position of vulva as % of length.

TABLE II.

Comparison of mean lengths (mm.) of *D. dipsaci* obtained in this work, with those from T. Goodey (1941).

Origin of data	Race	Host	Female			Male		
			L.	Stan. dev.	n.	L.	Stan. dev.	n.
This work	"X"	Oat	1.52	0.090	12	1.49	0.024	12
T.G.	Oat	Oat	1.49	0.076	50	1.38	0.087	50
This work	"X"	<i>V. faba</i>	1.36	0.098	12	1.33	0.167	12
T.G.	Oat	<i>V. faba</i>	1.38	0.141	82	1.33	0.096	85
This work	Giant	<i>V. faba</i>	1.86	0.129	7	1.63	0.021	3
T.G.	Giant	<i>V. faba</i>	1.97	0.156	35	1.73	0.151	37

recognised hosts of the oat race, symptoms on *V. faba* were not entirely characteristic and parsnips remained unattacked both in pots and in the field. It seems probable, therefore, that although it would attack oats and beans, the race 'X' population was not covered by the term 'oat race' of stem eelworm.

Carrots were grown on the field again in 1955 and were severely damaged in the same areas as previously. As a check a few short rows of oats (Sun II) were sown in one of the affected areas. These oats grew normally in the first few weeks but tulip-root symptoms appeared on a very small percentage of the later tillers. The eelworms were breeding in these tillers and numerous eggs were present. This slight and late development of tulip-root in the oats, taken together with the previous observations on oats inoculated with this population of stem eelworm, adds further weight to the suggestion that the 'X' race of *D. dipsaci* is not one covered by the term 'oat race' of stem eelworm.

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