A Preliminary note on the Root-gall Nematode *Heterodera radicicola* Muller and its Economic importance in South India.

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Among animals other than insects capable of causing losses to the agriculturist, the group of Nematodes or Round Worms is of no mean importance. Besides including numerous forms capable of causing diseases in livestock, the group contains several species known to be seriously destructive to plants of economic importance. Few among them can, however, claim that front rank in notoriety which the Root-knot Eelworm—*Heterodera radicicola* Muller justly occupies by reason firstly of the world-wide distribution it enjoys being present in tropic and temperate climes alike, and secondly, of its cosmopolitan tastes in having one of the widest known range of food plants.

History of the Disease. Ever since its discovery in the middle of the 19th century this Eel-worm has been recorded from various countries causing damage to numerous crops. Eminent scientists have made a serious study of this worm with a view to find out possibilities of bringing it under control and the results of their labours have been carefully set forth but it is doubtful if those measures will be applicable in the conditions obtaining in this country. With all its notoriety as a destructive organism and its wide range of distribution it is to be regretted that it has not received the attention it deserves at the hands of the economic biologists of our country. Apart from an invetigation of an attack of this worm on Tea by Dr. Barber which was published in the form of a Bulletin in 1905, noting worth nothing seems to have been done in Madras either in regard to observations as to its distribution and damage or measures of control. The question of this rootknot worm was brought to serious prominence recently in connection with its suspected complicity in the reported deterioration of Betel-vine cultivation in the neighbourhood of Coimbatore. This led to a thorough examination of the roots of the Betel vine as also of the roots of other plants found growing in and near the garden. Reports received from other parts of the Presidency as to certain obscure diseases

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noticed on various crops on examination proved in some cases to be due to the attacks of this underground pest. The main purpose of this paper is to draw the attention of the workers in this field to the economic aspect of the problem and the writer lays no claim to any complete investigation as to the lifehistory, economic importance, or control measures of this serious pest. But as its title clearly implies, it is an account of certain observations of interest made in the course of examination of infested plants collected in and around Coimbatore and received from other parts of the Presidency.

Lines of investigation. The methods of study adopted for a preliminary enquiry are confined to simple observations of different host plants infested at various stages, the microscopic examination of worms at different degrees of growth and a study of the nature and symptoms of attack of the disease. Inoculations were also made in a few cases in plants grown in sterilized soil in pots for studying its life cycle. The work done is confessedly too insufficient to warrant any attempt at giving a complete account of its lifehistory or measures of control.

Symptoms of attack. The symptoms of attack are not always sufficiently well defined or clear to enable one to spot out the affected plants. Apparently in many cases of attack by Eelworms the crop does not seem to have suffered very much in consequence nor does the yield appear to be appreciably diminished which might be one of the reasons why the study of this has not been taken up seriously here. But the decrease in yield and the loss as a result of infestation must in some cases, be really great and may work up to a great percentage. The external signs, if any, are limited to a stunted or dwarfed appearance of plants or the wilting of them to a greater or less extent which very often is attributed to drought. Sometimes the leaves turn slightly yellowish and on the whole present an unhealthy appearance as in certain turmeric plants and the crop may completely fail as was reported in the case of *Coleus parviflorus* (Koorkai-Mal) by the Farm Manager, Tenmalai and the disease in this particular instance was reported to go by a local name Mundringa. In some cases plants in an area may dry up showing a patch of diseased plants as was seen in the case of Daincha in Central Farm Coimbatore. But in most cases no marked colour variation is discernible though a trained eye may detect infested plants in that these show a lighter shade of green than others. On the other hand it is the roots when dug up that show surprising structural changes. It is often found to be marked with enlargements or swellings of curious shapes. These can be easily distinguished from the swellings of bacterial tubercles of leguminous plants. These malformations or

abnormal elevations are in many cases rounded but in bad cases may have their surfaces cracked and grooved. The dimensions of these galls may vary very much from less than 1 inch in diameter to 1 or $1\frac{1}{2}$ inches as have been observed in the case of brinjal roots. In extreme and long standing cases of attack some discolouration is noticeable in that these galls may have dirty black patches of rotten portions. These outgrowths are in fact the galls formed by the presence of this root-gall nematode. A short account of the life history of the pest part of which is based on personal observations, is given here, as it would give a clearer idea of the nature of the pest.

Lifehistory. When an ordinary swelling or gall mentioned above is cut across and examined with a lens, one may find a number of the characteristic flask-shaped or pear-shaped structures whitish and glistening. Sometimes if the section cuts through one of these bodies in an advanced state of development a number of eggs of small size (in some of which the young worm can be seen coiled) embedded in a gelatinous mass, some of which just hatched out into small worms may be observed. If one of these curiously shaped bodies is removed from the tissue by the point of a needle and teased under microscope numerous fat globules may be found in case the worm is yet young. The external form and other characters of this female cyst are really interesting.

These female cysts may be found in abundance as already mentioned in any portion of the root gall. When isolated on a slide with a drop of distilled water under a binocular microscope the flask shape with a projecting neck can be easily identified. The projecting neck can be recognised as the head end and the small mouth with the characteristic minute spine or "Spear" can be noted. This mouth spine is very characteristic of all Eelworms that are plant parasites and any form devoid of this may be easily told as not injurious to plants. This spine can be worked backwards and forwards to cut through the tissue of the plant. In the enlarged space the female reproductive organs are seen prominently developed. The ova or eggs develop here and when nature are less than 0.0 mm. approximately in seize and are very numerous. The exact number has not been noted (but is said to vary between three to four hundred). These eggs hatch out into small thread-like worms with a comparatively bluntly pointed head end and narrow tail end roughly about a quarter of a mm in length. The exsertile spine is, if carefully examined, visible even at this stage. These larvae are said to make their way outside or into a fresh portion of the root or root-let with

the help of this mouth spine and the irritation thus caused leads to the formation of a gall. After it has effected a lodging in the tissue it is said to enlarge and form a cyst and both the sexes are alike up to this stage. The male, after this stage, is said to moult inside the cyst and after some transformations issues out in the form of an active Eelworm. In the case of the female the cyst continues to enlarge until it assumes the characteristic flask shape.

Inoculation. In order to find out the length of the life cycle and verify other factors in the lifehistory, a series of inoculation experiments was started in 1923 and continued this year also. As eelworms were seen attacking betel vine it was thought convenient to conduct these on betel vines grown in pots. With this object in view on 17-11-23 two pots of betel vine grown in sterilized soil in pots were selected for experiments one of which was inoculated with Heterodera specimens taken out from infected betel vine roots obtained from Singanallur and the other was kept as control. On 29-11-23 another set of two pots with vines was selected. One of these was inoculated with worms from *coleus parviflorus* (Kurkai in Mal.) and the other was kept as control. In all these the inoculations were done as follows. A careful search to see if there were any galls on the roots was made at the outset to assure that the plants experimented upon are uninfested. The worms (young ones just hatched out) were separated in watch glass containing a small quantity of distilled water and introduced on the roots of betel vine after carefully removing the soil. The roots of these plants (inoculated and control) were examined periodically for a period of three months and more and no galls or even traces of Eelworms were found. As no galls could be observed it was concluded that inoculations were unsuccessful and a further fresh set of experiments was started. On 15-4-1924 two young betel vines grown in wooden boxes (one side of which was covered with glass) were selected for inoculations. One of these was inoculated with Eelworms taken out from cauliflower and the other was kept as control. The inoculations here were conducted in a slightly different way. The worms were isolated in all stages from cauliflower in a watch glass having a little distilled water. These were carefully introduced onto the roots as also a bit of infested root of cauliflower. These were examined only on 16th June 1924 and showed plenty of nodules of root galls (only the inoculated one) (size 1 mm to 5 mm) especially on tender portions of roots. When teased under microscope plenty of female cyst were found. As the plant was not examined earlier the conclusion as regards length of life cycle is very indefinite. But two things are obvious from these that the lifecycle of thisworm is less than two months (15th March 1924 to 16th June 1924) and that cauliflower worms could be successfully bred on betel vine.

Distribution and Host plants. The hordes of insects injurious to vegetation can be easily seen along with the havoc wrought on it, but the tiny microscopic eelworms that inhabit the subterranean portions of plants are difficult to be demonstrated as destructive to valuable crops. It is the vegetable gardens as will be seen from a list of plants affected that suffer most on account of this pest. Broadly speaking its distribution can be said to be world wide. But here from its occurrence in various places in the presidency such as Tenmalai, Travancore, Salem, Coimbatore, Taliparamba (Malabar) Erode etc., it can safely be inferred that the worm is fairly well distributed in the southern part of the presidency. Many are the plants that are susceptible to the attack of this worm and the following are a few that have been noted to be badly infested in S. India.

Scientific name.	*Popular name.*	*Locality.*	*Collector.*
Solanum melongena.	Egg plant (Brinjal)	Coimbatore.	P. N. K.
Lycopersicum esculentum.	Tomato.	Coimbatore.	,,
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Capsicum annum.	Chillies.	Coimbatore.	C. K. S.
Nicotiana Tabacum.	Tobacco.	...	P. N. K.
Canna indica.	Indian shot.	...	,,
Curcuma longa.	Turmeric.	Salem & Erode.	R. N.
Brassica oleracea (var)	Cauliflower.	Coimbatore.	P. N. K.
Brassica oleracea	Cabbage.	...	,,
Brassica oleracea	Knol Kohl.	...	,,
Apium graveolens	Celery.	...	,,
Daucus carota.	Carrot.	...	,,
Beta vulgaris.	Beet.	...	,,
Piper betle.	Betel vine	...	Y. R. Rao.
Piper nigrum.	Pepper vine.	Taliparamba. (Malabar)	,,
Sesbania grandiflora	Agathi.	Coimbatore.	P. N. K.
Sesbania aegyptiaca.	Daincha.	...	C. S. K.
Hibiscus esculentus.	Okra. (Bendai)	Tenmalai. (Travancore.)	F. M.
		Hagari Bellary Dt.	Y.R. Rao.
Hibiscus cannabinus.	Gogu.	Madras.	,,
Coleus parviflorus.	Kurkai (Mal)	Tenmalai.	F. M.
Dioscorea.		do.	,,
Cucumis sativus.	Cucumber.	do.	,,
Camellia Thea.	Tea.	Devala.	C. A. Barber.

Possible control measures. It is evident from the endoparasitic nature of the pest that no cut and dried measure for combating the pest can be laid down. The difficulty is felt all the greater since no

control methods have been experimented upon here. But the following measures tried elsewhere may suggest the lines on which its control may be based. In the case of a bad infestation all plants may be dug up and destroyed by burning and the land kept free of all vegetation for one or two years. They may probably reduce the degree of infestation when cultivated next. On a field such an application of chemicals cannot be recommended though many insecticides such as carbon-bi-sulphide, Formalin solutions or Sodium cyanide dissolved in water have been suggested. The ideal procedure as every one would admit is to produce non-susceptible or resistant strains of plants. Rotation of crops and clean cultivation need no special mention as they are but too often over emphasised. If one method above all should be tried on a field scale it is that of growing trap crops (as suggested by the German Scientist Kuehn). The method is to trap the worms by growing by the side of an infested valuable crop or in the infested soil before the crop is grown, some very susceptible plants and destroying them in time before the worms leave the trap crop. If necessary the process of growing trap crops may be repeated so as to ensure satisfaction. For Heterodera it has been noted that cruciferous crops are more susceptible and as such these can be tried as trap crops. For this purpose a correct determination of the length of the life cycle of the worm is quite essential and the catch plants should be pulled out and destroyed before the worms inhabiting the roots show a tendency to leave the roots.

In conclusion it may be stated that further investigation for finding out the exact duration of its life cycle and experiments in regard to its control by means of trap crops are proposed to be conducted side by side with the search for host plants to note the range and extent of its distribution. This opportunity is taken to acknowledge my indebtedness to M. R. Ry., Rao Sahib Y. Ramachandra Rao, M.A., F.E.S., Ag., Government Entomologist for the encouragement given in the pursuit of this problem.