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ROOT-KNOT NEMATODES IN THE SUDAN AND THEIR CHEMICAL CONTROL

by
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Root-knot nematodes (*Meloidogyne* spp.) occur widely spread in river silt along the Nile bank and in light volcanic and alluvial soils of the Sudan (Yassin *et al.*, 1970; El Amin and Siddiqi, 1970). Although they may infest many crop and weed plants, their economic damage is most often confined to tobacco and some of the vegetable crops especially tomato. This article deals with the geographical distribution and host range of the various species, some biological aspects of important pathogens, chemical control of the most important species in tomato and the performance of resistant tomato lines under local conditions.

I. *Geographical distribution*:

A survey was undertaken by the author for several years throughout various localities in the Sudan (Yassin *et al.*, 1970). Three species of *Meloidogyne* were isolated from the roots of 10 plant species. A list of the three species, their host range and distribution within the various localities, is given in Table I.

Meloidogyne arenaria (Neal) Chitw. occurred in all three major localities surveyed. The highest infestation level, resulting in almost complete destruction of the crop, was encountered in tomato in southern Sudan.

M. incognita (Kofoid *et* Withe) Chitw. was isolated from the roots of six crop plants grown in all three localities. It was, however, more destructive on egg plant in southern Sudan.

M. javanica (Treub) Chitw. appeared to be the most prevalent species both in central and western Sudan, though not reported from southern Sudan, and is perhaps the most economically important of the three. It was isolated from the roots of eight crop plants and one weed. The highest damage, however, was found on tomato in central Sudan and tobacco in western Sudan, where approximately 70% or more of the tobacco crop was severely affected. Species of root-knot nematode, not identified, but which resulted in conspicuous root-galling, were isolated from the roots of certain crop, weed and ornamental plants grown mainly in central Sudan. (Table I).

II. *Life cycle of* M. javanica *in tomato*:

Single egg masses of *M. javanica* were isolated from the roots of tomato grown on the Blue Nile river side near Wad Medani. The eggs were placed in syracuse dishes containing tap water. They were then introduced into 40 10 cm pots containing 4-6 week-old tomato seedlings (var. local) grown in a mixture of sterilized 1:1 (v/v) sand and river silt. The pots were regularly watered and kept in an outdoor bamboo-wire-netting house. During the experimental period of January-March, temperatures ranged between 19°-27° C (minimum) and 28°-44° C (maximum). At intervals of 3-7 days, tomato plants were removed from 3-5 pots, the roots carefully washed and examined for nematode infestation. It was sometimes necessary to stain the nematodes within the root tissue. This was accomplished by dipping infested roots or root bits into warm lactophenol acid fuchsin for a few minutes, washing off the excess stain, and then placing the stained roots in pure lactophenol over-night or longer (McBeth *et al.*, 1941).

Fully developed root galls occurred about four weeks after inoculation. Fully developed females, however, did not usually form before eight weeks or so; and gravid females about ten weeks after inoculation. Thus, the life cycle of *M. javanica* from egg to egg in tomato (var. local) under the experimental conditions may take up to 70 days to complete. These data are similar to that found by Oteifa and El Gindi (1956) in the AR Egypt.

Table I - *Check list of root-knot nematodes in the Sudan.*

Nematode species	Infested plant species * and locality
Meloidogyne arenaria (Neal) Chitwood	Dolichos bean (*Lablab vulgaris* Savi)[1]
	* Tomato (*Lycopersicon esculentum* Mill.)[3]
	French bean (*Phaseolus vulgaris* L.)[2]
	Egg plant (*Solanum melongena* L.)[1]
M. incognita (Kofoid *et* White) Chitwood	Jew's mallow (*Chorchorus olitorius* L.)[1]
	Squash (*Cucurbita maxima* Duch.)[1]
	Dolichos bean[1]
	Tomato[1]
	French bean[2]
	* Egg plant[3]
M. javanica (Treub) Chitwood	Jew's mallow[1]
	Squash[1]
	Carrot (*Daucus carota* L.)[2]
	Okra (*Hibiscus esculentus* L.)[1]
	Dolichos bean[1]
	* Tomato[1]
	* Tobacco (*Nicotiana tabacum* L.) var. White Gold[1-2]
	Sida alba L.[1]
	Egg plant[1]
Unidentified	*Agreatum* sp.[1]
	Amaranthus sp.[1]
	Calotropis procera R. Br.[1]
	Pepper (*Capsicum annuum* L.)[1]
	Fennel (*Foeniculum vulgare* Mill.)[1]
	Lettuce (*Lactuca sativa* L.)[2]
	Guava (*Psidium guajava* L.)[1]
	Phyllanthus sp.[1]
	Euphorbia atropurpurea Bronss.[1]

[1] Central Sudan: (Blue Nile and part of Khartoum Province).
[2] Western Sudan: (Darfur and part of Kordofan Province).
[3] Southern Sudan: (Wau district).
* Economic infestation.

III. *Chemical control of* M. javanica *in tomato*:

These tests were undertaken in 1970-71, 71-72 and 72-73 seasons on the local variety of tomato from the Gezira. A total of ten nematicides (Table II) were tested.

1970/71: An initial experiment was established on a heavily infected *M. javanica* soil at the Blue Nile river side near Wad Medani. Treatments included Methomyl (5% a.i.) (20 kg/ha), Methomyl w.p. (90% a.i.) (600 g/ha), Thionazin G (10% a.i.) (20 kg/ha), DBCP (75% a.i.) (10 l/ha), Terracur G (10% a.i.) (100 kg/ha) and Dazomet (98% a.i.) (10 kg/ha). Each treatment contained four replicates (5 x 3 m/rep.) placed in a randomized block design. The given dosage rates refer to active ingredients. All of the chemicals, except Methomyl 90% were applied to wet soil at a depth of 15-20 cm and at 50 cm intervals along the row, ten days before planting of tomato seedlings. DBCP emulsion (1:20 by V in water) was injected into the soil. A Methomyl 90% water suspension was sprayed onto the foliage about 4-6 weeks after planting. Conventional cultural practices were adopted in the cultivation of tomato and the seedlings planted singly at a spacing of approximately 50 cm on 100 cm-wide ridges. At maturity data were taken as follows: (A) fruit yield, kg/plant, (B) plant size (radius and height, in cm), and (C) root galling index (RI), using the following grades after Zeck (1971): (O) no root infection, (1) presence of a few small galls throughout the root system, (2) presence of numerous small galls, (3) numerous small galls growing together but function of the root not yet seriously affected, (4) numerous small galls plus some big galls, (5), (6) and (7) about ¼, ½ and ¾ of the root system, respectively, hampered due to the heavy galling, (8) no healthy roots left but the plant still green, (9) the completely galled root system is rotting and the plant showing yellowing and drying of the foliage, i.e. signs of death and (10) shoot and root completely dead. The results are summarized in Table II.

All six chemicals applied resulted in some improvement in the plant growth. The best chemicals were Terracur and Methomyl. In no case, however, was the increase in plant size significantly better than the controls. On the other hand, Terracur, Methomyl 5% G, DBCP and Dazomet application resulted in significant increase in yields as compared to the control. In addition to better plant growth and highest yield both Terracur and Methomyl 5% G also resulted in highly significant decrease of root galling. Conversely, both Methomyl 90% w.p. and Thionazin resulted in little or no decrease in RI with, however, some accompanying decreased yield; which is difficult to explain since some improvement in plant growth had occurred (Table II).

Table II - *Effect of selected nematicides against the local race of* Meloidogyne javanica *from the Gezira on the local variety of tomato.*

	Treatments (1)	Mean yield (kg/plant)	Mean plant size in cm (rad. x ht)	Root galling index
1970-71	Terracur	0.66 **	25 × 75	4.4 **
	Methomyl 5% G	0.41 **	27 × 72	2.5 **
	DBCP	0.51 **	21 × 68	6.3 *
	Dazomet	0.39 **	23 × 66	5.6 *
	Thionazin	0.22	24 × 69	6.9
	Methomyl 90% wp	0.19	25 × 66	7.5
	Control	0.23	21 × 62	7.9
	S.E.	0.089		
1971-72 (Average of 2 plots)	Metham Sodium	0.69 **	21 × 55 *	3.0 **
	D-D	0.60 *	19 × 44	2.5 **
	Terracur	0.60 *	21 × 53	3.0 **
	DBCP	0.57 *	18 × 47	4.0 **
	Oxamyl	0.67 **	18 × 48	5.6
	Methomyl 5% G	0.65 **	19 × 51	5.0 *
	Prophos	0.60 *	18 × 45	5.0 *
	Control	0.32	18 × 47	6.0
	S.E.	0.074		
1972-73	Metham Sodium	0.33 ***	22 × 56 **	1.0 **
	Prophos	0.11 **	15 × 38 **	1.5 **
	DBCP	0.15 **	11 × 31	2.5 *
	D-D	0.09 **	13 × 35 **	2.5 *
	Methomyl 5% G	0.08 **	8 × 25	2.0 *
	Oxamyl	0.09	14 × 34 *	2.8
	Terracur	0.06	12 × 32	2.8
	Control	0.04	9 × 27	2.8
	S.E.	0.028		

*, **, *** P = 0.05, 0.01 and 0.001 respectively. (1) for dosage see the test.

1971/72: Chemicals included were those that showed promise for increased yield and-or reduced RI in the previous seasons plus others in common use. D-D (100 l/ha), Methomyl 5% G (20 kg/ha), Prophos (100 kg/ha), DBCP (10 l/ha), Oxamyl (60 l/ha), Metham Sodium (200 l/ha) and Terracur (100 kg/ha), were thus compared with a control in an experimental plot with natural infestation of *M. javanica* on a site at the Blue Nile river side. Methods of application, experimental lay-out and experimental procedures were as stated earlier. D-D and Metham Sodium were applied by means of an injector gun. Also, as before, the stated dosage rates refer to active ingredients. Results of fruit yield, plant measurements and RI are given in Table II.

All chemicals tested resulted in a two to three fold increase in yield over the control plots. On the other hand, only Metham Sodium, D-D, Terracur and DBCP resulted in highly significant decrease of RI (2.5-4 compared to 6.3). Metham Sodium, however, was the only chemical that resulted in significant increase in plant size. In addition, the chemical produced highest yield and most reduction in RI. Plants from plots treated with Metham Sodium showed an average root-knot infestation of 3 while those from the control plots showed up to 6. Although Oxamyl was next best in regard to yield (0.67 kg/plant), no significant decrease of RI resulted from its application. This may be accounted for, at least partially, in terms of its insecticidal property.

1972/73: The 1971/72 experiment was repeated, however, another plot which showed less infestation of *M. javanica* was used. Results are also given in Table II. Five of the seven treatments produced highly significant increase in yield of tomato fruit. The treatments included Metham Sodium, Prophos, DBCP, D-D and Methomyl 5% G. OF these, only Metham Sodium and Prophos showed correspondingly highly significant increase of the plant size and highly significant decrease of RI, as well, compared to the control (1.0 and 1.5 respectively compared to 2.8). As in the previous season, Metham Sodium again gave best nematode control as evidenced by yield and plant growth. An 8 fold increase in tomato fruit yield and 75% reduction in root galling resulted from its application. In case of Prophos, DBCP, D-D and Methomyl the increase in yield ranged between two and four fold and reduction in RI of up to about 50%.

IV. *The performance of resistant tomato lines under local conditions*:

A total of mine nematode-resistant tomato varieties, imported as seeds from various parts of the world, were included in these tests. These were, Anahu, VFN-8, and VFN-Bush (California), Marsol, Motabo, Nonita, Piersol and Rossol (France) and Ronita (Italy). The local variety from the Gezira was also included for comparison. Six to eight week-old seedlings of these varieties were planted in alternate rows each and replicated three times in a plot on a site at the Blue Nile river side naturally infested with *M. javanica*. At maturity, fruit yield assessments were made as before. Also, the roots were dug out, washed and analysed for root-knot infestation (Zeck, 1971). Plants of all the nine imported varieties showed no root-knot infestation (RI = O) as compared to those of the local variety which showed up to 4 RI. In addition to their freedom from root-knot, some of the varieties, e.g., VFN-8, Rossol and Ronita out-yielded the local. Thus, while yield from these ranged between 0.41 and 0.49 kg/plants, that from the local was 0.37.

Since infestation in the field plot was only moderate, the experiment was repeated in a glass-house. Plants of all the varieties were directly seeded in naturally infested soil placed in petrol tins. Infested roots were added to this soil also as means of amplifying the infestation. Before incorporation the roots were masherated in a blendor to release the infctive larvae, which were then added in suspension to the tins. After about 16 weeks the contents of the tins were removed, the roots washed and similarly analysed for root-knot attack. Again, as in the field test, plants of all the nine varieties showed no root galling. Conversely, a high proportion of those of the local variety showed up to 8-9 RI (severe galling resulting in almost complete root damage and impaired shoot growth).

Discussion and conclusions

According to Luc (1968), climates with pronounced seasonal changes are more favourable for the prevalence of *M. javanica* in any one locality. On the other hand, *M. incognita* is favoured by a more tropical less variable climate. This may be true to a certain degree in the Sudan. Results of the geographical distribution of the various species reported herein (Table I) showed that *M. incognita* was among the dominant species in the southern Sudan where the climate is more tropical than further north. Conversely, in the northern sector, *M. javanica* was the major one. The geographical zones of these two species, however, are not always sharply defined.

For example, both species together with *M. arenaria*, were isolated from the roots of dolichos bean plants grown at one site on the Blue Nile river side near Wad Medani (Table I). *M. arenaria* was also found in southern Sudan (Table I), and El Amin and Siddiqi (1970) have further reported a sub-species, namely *M. arenaria thamesi*, from the southeastern part of the northern sector. This, however, may be an atypical form of *M. incognita* (Luc, 1968). In the neighbouring and some African countries, e.g. AR Egypt, Kenya, Madagascar, Senegal and Tanzania, species similar to those reported herein from the Sudan are also known to exist and, again, *M. javanica* being the dominant one (Houssny and Oteifa, 1956; Luc, 1968; Whitehead, 1959). On the other hand, in the Ivory Coast and Upper Volta, with more tropical climates, *M. incognita* prevails (Luc, 1968).

The inconsistencies sometimes encountered in the results of nematicidal applications against *M. javanica* in tomato (Table II), e.g. the relatively poor behaviour of Terracur in 1972/73, may be associated with the poor standards of husbandry in the privately owned plots. Despite this, however, some of the chemicals proved rather promising. Metham Sodium, for example, controlled the nematode best over the two seasons. About two to eight-fold increase in yield of tomato and 50 to 75% decrease in root knot infestation resulted from its application. Since, however, it also gave good control of weeds in the experimental plots, the given increase in yield cannot be accounted for merely in terms of nematode control. At the existing formulation, Metham Sodium requires a relatively large volume of water, about five times its volume, for its application. This may be taken into account when selecting nematicides in localities with water shortage problems; e.g. in western Sudan. D-D, Methomyl 5% G, DBCP and Terracur were also among the promising nematicides throughout the 2-3 seasons period of test. They resulted in about 2-4 fold increase in yield and up to approximately 50% reduction in root-knot infestation. DBCP ranked slightly better than the others in these respects.

Provided varieties of tomato resistant to root-knot are of relatively high yield caliber, e.g. VFN-8, Rossol and Ronita, and also meet other commercial standards. They can, therefore, replace the local or other susceptible varieties in places known to be severely damaged by root-knot nematodes, e.g. Wau and Zalingei districts in southern and western Sudan, respectively.

SUMMARY

Three species of *Meloidogyne, M. arenaria* (Neal) Chitw., *M. incognita* (Kofoid *et* White) Chitw. and *M. javanica* (Treub) Chitw., occurred widely distributed in light volcanic, or alluvial, and in river silt soils throughout the Sudan. The most important was *M. javanica* which caused in devastating damage to tomato and tobacco in the northern sector. *M. incognita*, the second in importance, was more prevalent in the southern sector. None of the 3 species occured in the Gezira heavy clay. A total of 10 nematicides were tested against *M. javanica* in tomato fields. The most effective were respectively Metham Sodium, DBCP, Methomyl, D-D and Terracur. Over a two-fold increase in tomato fruit yield coupled with more than 50% reduction in root galling resulted from the application of these chemicals. All nine resistant tomato lines, imported from various parts of the world, remained free of infestation by the local race of *M. javanica*. Some of the factors governing the geographical distribution of the three species and the chemical control of *M. javanica* are discussed.

RIASSUNTO

Nematodi galligeni in Sudan e la relativa lotta chimica.

Tre specie di *Meloidogyne, M. arenaria* (Neal) Chitw., *M. incognita* (Kofoid *et* White) Chitw. e *M. javanica* (Treub) Chitw., sono state trovate largamente distribuite in terreni leggeri vulcanici, alluvionali e limosi nel Sudan. La specie più importante è *M. javanica* che causa danni rilevanti alle colture di Pomodoro e di Tabacco nelle zone settentrionali. *M. incognita*, seconda per importanza, è invece prevalente nelle zone meridionali. Nessuna delle tre specie è stata rinvenuta nei terreni argillosi di Gezira. Dieci nematocidi sono stati saggiati contro *M. javanica* in campi di Pomodoro. I più efficaci sono risultati essere rispettivamente, Metham Sodium, DBCP, Methomyl, D-D e Terracur. L'applicazione di questi prodotti ha raddoppiato la produzione di pomodori e ha ridotto del 50% il grado di infestazione delle radici. Nove varietà di pomodoro, importate da diverse parti del mondo, sono risultate immuni agli attacchi della popolazione locale di *M. javanica*. Vengono inoltre discussi i fattori che influenzano la distribuzione geografica delle tre specie di *Meloidogyne* e la lotta chimica contro *M. javanica*.

RÉSUMÉ

Les nématodes qui causent des galles au Sudan et leur contrôle chimique.

Trois espèces de *Meloidogyne, M. arenaria* (Neal) Chitw., *M. incognita* (Kofoid *et* White) Chitw. et *M. javanica* (Treub) Chitw., ont été trouvées largement distribuées dans des terrains légers volcaniques, alluviaux et boneux du Sudan. La plus importante est *M. javanica* qui cause des grands dommages sur tomate et tabac dans les zones du Nord. *M. incognita*, la seconde par importance, est, au contraire, prépondérante dans les zones du Sud. Aucune des trois espèces n'a pas été trouvée dans les sols argileux de Gezira. Dix nématicides ont été expérimentés contre *M. javanica* dans des champs de tomate. Les plus efficaces ont été le Metham Sodium, le DBCP, le Méthomyl, le D-D et le Terracur. L'application de ces produits a doublé la production de tomate et a réduit de 50% les galles sur les racines. Les neuf variétés de tomates importées de plusieurs pays n'ont pas été infectées par la population locale de *M. javanica*. Les facteurs qui influent sur la distribution géographique des trois espèces et le contrôle chimique de *M. javanica* sont commentés.

LITERATURE CITED

EL AMIN E. M. and SIDDIQI M. R., 1970 - Incidence of plant parasitic nematodes in the northern Fung area, the Sudan. *Pl. Prot. Bull. FAO, 18*: 102-106.

HOUSSNY H. H. and OTEIFA B. A., 1956 - Preliminary field tests for evaluating some tomato varieties for resistance to root-knot nematodes, *Meloidogyne* spp. *Pl. Dis. Reptr., 40*: 974-976.

LUC M., 1968 - Nematological problems in the former French African tropical territories and Madagascar. In *Tropical Nematology*, Edit. G. C. Smart e V. G. Perry, Univ. Fla Press, Gainesville: 93-112.

MCBETH C. W., TAYLOR A. L. and SMITH A. L., 1941 - Note on staining nematodes in root tissue. *Proc. helm. Soc. Wash., 8*: 26.

OTEIFA B. A. and EL GINDI D. M., 1956 - Studies on root-knot nematodes, *Meloidogyne* spp., in Giza, Egypt. II - Development behaviour of the root-knot nematode, *Meloidogyne javanica. Bull. N° 101, Faculty of Agric., Cairo University, Cairo*, 10 pp.

WHITEHEAD A. G., 1959 - « Plant nematology ». *Rec. Res. E. Afr. Agric. for Res. Org.* Year 1958, 109 pp.

YASSIN A. M., LOOF P. A. A. and OOSTENBRINK M., 1970 - Plant parasitic nematodes in the Sudan. *Nematologica, 16*: 567-571.

ZECK W. M., 1971 - A rating scheme for field evaluation of root-knot nematode infestations. *Bayer PflSchutz. Nachr., 1*: 141-144.

Accepted for publication on 18 September 1974.