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NEMATODES PARASITIC TO CEREALS AND LEGUMES IN TEMPERATE SEMI-ARID REGIONS

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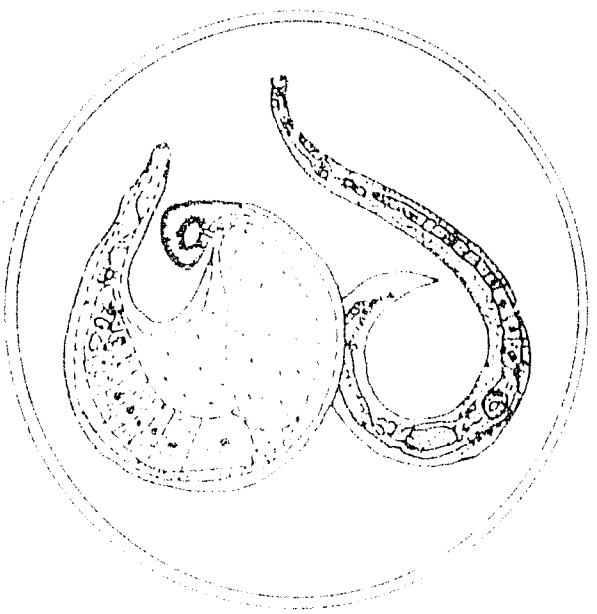

Nematodes Parasitic to Cereals and Legumes in Temperate Semi-Arid Regions

Proceedings of a Workshop held at Larnaca, Cyprus
1 - 5 March 1987

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FOREWORD

Rainfed agriculture has evolved over many centuries in West Asia and North Africa to cope with the problems of farming in an environment characterized by a variable and fragile resource base. It is imperative to increase and sustain overall productivity in this region because of relatively low yields and dependence on large food imports. It is important to analyze causes of low productivity and minimize their effects through research and training.

Plant parasitic nematodes are a severe constraint to agricultural production in developing tropical and semi-tropical countries. Their effects are aggravated when coupled with other abiotic stresses such as drought, heat, poor crop management, and low nutrient availability - common features of the ICARDA region. Very little work has been done on plant parasitic nematodes of cereal, and of food, pasture and forage legumes in the region; primarily due to the lack of support for nematological research on these crops at the national level. However, there are strong indications from the limited work in countries within the region that certain nematodes cause serious losses in yield of these crops and, in some crops, have been shown to cause complete crop failure.

The genesis of this book was a workshop on plant parasitic nematodes in cereal and legume crops in temperate semi-arid regions organized by ICARDA from March 1-5, 1987 in Larnaca, Cyprus which was attended by 25 scientists both from developing and developed countries.

These scientists reviewed and highlighted the nematodes problems on wheat, barley, chickpea, faba bean and forage legumes in the temperate region of West Asia and North Africa. The current knowledge and control methods being employed in other countries were examined in the light of transferability of this information for use in the region. The group also identified priority research activities and areas of cooperation among ICARDA, national programs and other centers of excellence to develop and deploy the most effective control methods against plant parasitic nematodes.

On behalf of ICARDA, I would like to express my deep appreciation to all those who contributed to the workshop and the preparation of this book which I hope will prove a valuable source of information and will lead to an enlarged research network on plant parasitic nematodes.

G.J. Koopman
Acting Director General
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February 1988

A PERSPECTIVE ON NEMATODE PROBLEMS WORLDWIDE

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Introduction

Nematode problems of dry and arid regions will be discussed in detail during this conference by prominent scientists familiar with these areas. We will have to rely heavily on those who have worked in this geographical area to educate us concerning the specific nematode problems and crops involved. By combining our collective experiences, I am confident that before this workshop comes to a close, we can identify the major problem areas and develop a challenging plan of work that will successfully address these problems in an effective manner. The first step is to identify the nematodes and assess the extent of the crop damage they cause. Movement is already being made in this direction by the administration of ICARDA which is addressing the problem head-on as evidenced by this workshop. I am going to give a worldwide overview of nematode problems and resources for dealing with them as a basis for discussing the problems in this particular area of the world. Even though your specific nematode problems may be unique, in a general sense, they are shared by nematologists around the globe.

To accomplish this goal, I would like to address the following points: 1) the general nature of nematodes as plant pathogens or parasites, 2) the importance of plant parasitic nematodes in world

agriculture, 3) a listing of those genera of greatest economic impact on a worldwide basis and for this particular region, 4) availability of resouces (personnel, monetary, published information, resistant germplasm) to cope with the problem, and 5) limitations and constraints experienced by some nematologists.

The source of most of this information, especially that given in items 2,3,4, and 5, is a questionnaire that was sent to 1330 scientists representing the memberships of three major nematological societies-the European Society of Nematologists (ESN), Organization of Tropical American Nematologists (OTAN), and the Society of Nematologists (SON). The questionnaire also was sent to nematologists in developing countries who are collaborating with the Crop Nematode Research and Control Project (CNRCP), with headquarters at North Carolina State University. Because of the large number of scientists who returned the questionnaire (371 from 75 countries), we feel that estimates of crop damage and other statistics presented represent the true situation more accurately than has been done previously.

The Nature of Nematodes as Plant-Pathogens

Nematodes live in the soil, or in plant tissue, and typically do not move great distances. Movement over great distances may occur as a result of man's activities, through infected plant parts, or as contaminants on machinery, crates, bags, or other containers. Nematodes can occur deep in the soil, and many have great capabilities to survive even in the absence of a host.

Species of some genera are rather host-specific, for example

Heterodera glycines which infects mainly soybean. Others, like the root-knot nematode Meloidogyne incognita, have over 1000 hosts. Every part of higher plants (roots, stems, trunk, leaves and inflorescences) is susceptible to attack by one or more species.

Although many nematodes are capable of inflicting severe above-ground damage (stunting, wilting, chlorosis, reduced yields), they most commonly cause direct root damage (galls, lesions, root-pruning, stubby-root), which is indirectly responsible for the above-ground symptoms. In nature nematodes usually act in concert with other pathogens--fungi, bacteria and viruses in causing disease. When such interactions occur, generally it is the nematode that predisposes the root system to infection by other organisms and damage is generally more than the sum total of each pathogen acting alone. Species of at least four genera can transmit viruses from one plant to another.

Root-knot and cyst nematodes, and perhaps other species, have the capacity to develop new strains and races when cultivars resistant to these forms are planted too frequently. Fields are generally infested with several plant parasitic genera and species, making control through the use of resistant cultivars more difficult. These are but a few of the biological characteristics of nematodes and should serve to illustrate the nature of the organisms we are dealing with and some of the complexities that must be considered in developing control strategies.

Importance of Plant-Parasitic Nematodes in World Agriculture

Estimated overall average annual yield loss on the world's major crops

Table 1. Summary of estimated annual yield losses due to damage by plant parasitic nematodes - world basis[1].

Life sustaining crops[2]	Loss (%)	Economically important crops[3]	Loss (%)
Banana	19.7	Cacao	10.5
Barley	6.3	Citrus	14.2
Cassava	8.4	Coffee	15.0
Chickpea	13.7	Cotton	10.7
Coconut	17.1	Cowpea	15.1
Corn	10.2	Eggplant	16.9
Field bean	10.9	Forages	8.2
Millet	11.8	Grape	12.5
Oat	4.2	Guava	10.8
Peanut	12.0	Melons	13.8
Pigeon pea	13.2	Misc./Other	17.3
Potato	12.2	Okra	20.4
Rice	10.0	Ornamentals	11.1
Rye	3.3	Papaya	15.1
Sorghum	6.9	Pepper	12.2
Soybean	10.6	Pineapple	14.9
Sugar beet	10.9	Tea	8.2
Sugar cane	15.3	Tobacco	14.7
Sweet potato	10.2	Tomato	20.6
Wheat	7.0	Yam	17.7
Average	**10.7%**	**Average**	**14.0%**

Overall average 12.3%

1. Information based on worldwide survey of nematologists (371 responses).
2. Crops that stand between man and starvation, according to Dr. S.H. Wittwer of Michigan State University.
3. Additional miscellaneous crops of economic importance, especially for food or export.

due to damage by plant-parasitic nematodes is 12.3% (Table 1). For the 20 crops that stand between man and starvation (Wittwer 1981), an estimated annual yield loss of 10.7% is reported. The 20 crops that represent a miscellaneous group important for food or export value were reported to have an estimated annual yield loss of 14%. Losses for the 40 crops in developed countries average 8.8% compared with 14.6% for developing countries.

Worldwide crop losses due to nematodes on 21 crops, 15 of which are "life sustaining", were estimated at $77 billion annually based on 1984 production figures and prices (Table 2). The United States portion alone is $5.8 billion. These figures are staggering, and the real figure, when all crops throughout the world are considered, probably exceeds $100 billion annually. Based on our survey, it has

Table 2. Estimated annual losses due to nematodes for selected world crops.

Crop	No. of estimates per crop	FAO production estimates (1000 metric tons)[1]	Estimated price per metric ton (US$)[2]	Estimated yield losses due to nematodes (%)[3]	Estimated monetary loss due to nematodes (US$)[4]
Banana	78	2,097	431	19.7	178,049,979
Barley	49	171,635	102	6.3	1,102,926,510
Cassava	25	129,020	90	8.4	975,391,200
Citrus	102	56,100	505	14.2	4,022,931,000
Cocoa	13	1,660	2584	10.5	450,391,200
Coffee	36	5,210	3175	15.0	2,481,262,500
Corn	125	449,255	147	10.2	6,736,129,470
Cotton (lint only)	85	17,794	2160[c]	10.7	4,112,549,280
Field bean	70	19,508	544	10.9	1,156,746,300
Oat	37	43,355	99	4.2	180,270,090
Peanut	69	20,611	416[b]	12.0	1,028,901,120
Potato	141	312,209	152	12.2	5,769,403,696
Rice	64	469,959	342	10.0	16,072,597,800
Sorghum	53	71,698	119	6.9	588,712,270
Soybean	91	89,893	282	10.6	2,687,081,500
Sugar beet	51	293,478	37[a]	10.9	1,183,596,774
Sugar cane	65	935,769	115	15.3	16,464,854,000
Sweet potato	67	117,337	219[b]	10.2	2,621,073,906
Tea	16	2,218	2807	8.2	510,562,300
Tobacco	92	6,205	2996[b]	14.7	2,732,756,460
Wheat	89	521,682	159	7.0	5,806,320,660
				Total	$ 77,698,508,015

1. Figures from 1984 Food & Agriculture Organization Production Yearbook.
2. Based on averages of 1984 Food & Agriculture Organization estimates for major world markets, excpet where indicated.
3. Based on estimates from the 1985 Crop Nematode Research & Control Project worldwide nematode survey of nematologists (371 responses).
4. Product of figures in columns two, three, and four.

a. Based on 1984 commodity price estimate for United States only.
b. Based on 1985 commodity price estimates for United States only.
c. Based on average of 1984 FAO listings for market prices in Liverpool and 1985 US commodity prices.

been estimated that $125 million are spent worldwide for nematology research, teaching and extension. Thus, less than 0.2% of the lost value is being used to address nematode problems. Perhaps, if we can convey the imbalance between crop losses and expenditures to combat these losses to appropriate government officials and to funding agencies worldwide, then more resources may be allocated for research, teaching and extension. Because the highest crop losses due to nematodes occur in developing countries, the dollar value losses are greater there than in developed countries.

Those Genera of Greatest Economic Impact Worldwide

The respondents to the questionnaire were asked to rank the five most damaging genera of plant parasitic nematodes occurring in their country or state. Based on the number of first, second, third, fourth and fifth place votes, a weighted index was calculated by giving first place votes a score of 5; second place votes a score of 4; third place votes a score of 3; fourth place votes a score of 2; and fifth place votes a score of 1. The total weighted votes each nematode genus received is given in parentheses. On a worldwide basis, the ten most important genera of plant parasitic nematodes were reported to be Meloidogyne (1375), Pratylenchus (782), Heterodera (606), Ditylenchus (251), Globodera (244), Tylenchulus (233), Xiphinema (205), Radopholus (170), Rotylenchulus (142), and Helicotylenchus (122). This order of importance of the various genera is fairly representative for most regions of the world. For the countries represented at this meeting, the order of importance of the various genera changes somewhat, although Meloidogyne is still first and Pratylenchus and Heterodera are

still high on the list. In Europe, however, Heterodera (161), Globodera (156), Meloidogyne (100), Ditylenchus (93), Pratylenchus (88), Aphelenchoides (26), Xiphinema (26), Trichodorus (23), Longidorus (17) and Tylenchulus (8) were estimated to be most damaging to plants.

Resources and Services Devoted to Nematology

The current estimated resources devoted to nematology in terms of personnel and financial support are summarized in Table 3. Although many nematologists have adequate financial support for their programs, 65% indicated that they were not satisfied with the support received when compared to other disciplines; 27% were satisfied, and 8% did not respond to this question. In spite of problems with support, a large number of professional societies exist, and many publish their own journals at regular intervals (Table 4).

Table 3. Resources devoted to nematology worldwide[1].

Personnel	
1. Total number of nematologists	1342
2. Total number of students in training (M.S.)	205
3. Total number of students in training (Ph.D.)	169
4. Total number of extension nematologists	142[a]
Support	
5. Average total lump sum (1985 US dollars) devoted to individual programs	$ 93,448[b]
a) average annual resources for developing countries	$ 42,554
b) average annual resources for developed countries	$127,144

1. Information based on worldwide survey of nematologists (371 responses).
a. The number is approximated because many respondents obviously have differing ideas of what an extension nematologist is.
b. Average annual lump sum resources devoted to each individual nematology program (includes salaries, support for graduate students, travel, grants, equipment, supplies, etc.).

Table 4. Professional societies and major journals publishing nematological research.

Professional Society	Journal
Academia Scientiarum Slovaca	Helminthologia
Association of Applied Biologists, Nematology Section	Annals of Applied Biology
Australian Nematologists (informal)	Australian Nematologists' Newsletter
California Plant Nematology Workshop (informal)	No journal
Dutch Circle of Nematologists	Netherland Journal of Plant Pathology (Gewasbescherming)
European Society of Nematologists	Nematologica
Finland Society of Nematologists	No journal
Florida Nematology Forum (section of the Florida Soil & Crop Science Society)	Proc. of the Florida Soil & Crop Science Society
Helminthological Society of India	Indian Journal of Helminthology
Helminthological Society of Washington	Proceedings of the Helminthological Society of Washington
Japanese Nematological Society (section of the Society of Applied Entomology & Zoology)	Japanese Journal of Nematology
Kung v. Nematologen (Netherlands)	No journal
London School of Tropical Medicine, Department of Helminthology	Journal of Helminthology
Louisiana Association of Plant Pathologists and Nematologists	No journal
Mexican Nematologists' Society	No journal
Mississippi Association of Plant Pathologists and Nematologists	No journal
Nematological Society of India	Indian Journal of Nematology
Nematological Society of Southern Africa (NSSA)	Newsletter of the NSSA (published irregularly)
Netherlands Society of Nematologists	No journal
New Zealand Society of Parasitologists	No journal
North Carolina Association of Plant Pathologists & Nematologists	No journal
Organization of Tropical American Nematologists	Nematropica
Pakistan Society of Nematologists	Pakistan Journal of Nematology
Polish Academy of Science, Nematology Group	Zeszyty Problemowe Postepow Nauk Polniczych (occasional publication)
Scottish Nematologists (informal)	No journal
Sociedad Argentina de Nematologia	Boletin de la Sociedad Argentina de Nematologia
Sociedade Brasileira de Nematologia	Nematologia Brasileira
Sociedad Chilena de Nematologia	No journal
Societa Italiana di Nematologia	No journal
Society of Chinese Parasitologists	Acta Zoological Sinica
Society of Nematologists (North America)	Journal of Nematology
Society of Nordic Agricultural Research Workers, Working Group of Nematologists	No journal
Society of Parasitologists (Bulgaria)	Helminthology
Taiwan Society of Nematologists	No journal
No affiliated society	Helminthological Abstracts (B) Plant Nematology
No affiliated society	Nematologia Mediterranea
No affiliated society	Revue de Nematologie

Nematode-tolerant and/or -resistant crop plants available locally in seven geographical regions have been compiled (Table 5). Unavailability seems to be most critical in Africa and Central America. Thirty-one percent of the respondents also reported having access to some type of nematode-free planting stock.

Although many crops were reported to have resistance to nematodes, resistance is usually to only one or two nematode species, and consequently there is a great need for development of additional cultivars with resistance to individual species as well as broad multiple resistance. Efficient use of available cultivars depends upon a knowledge of the plant parasitic nematode species in individual

Table 5. Nematode tolerant or resistant crop plants for which seeds or rootstock are locally available*.

Geographic Regions						
North America	Mexico, Central America & Caribbean	South America	Africa	Europe	Asia	Australia & South Pacific Islands
alfalfa	coffee	alfalfa	bean	alfalfa	almond	alfalfa
apple	plantain	carrot	cowpea	barley	barley	barley
bean	potato	castor bean	tomato	bean	chillies	cereals
cereals	rice	Centrosema	yam	cabbage	citrus	citrus
citrus	tomato	coffee		cereals	cowpea	grapevines
cotton		corn		crucifers	eggplant	oat
cowpea		cotton		forage	grape	peach
cucumber		cowpea		greens	kenaf	potato
fruit & nut trees		crotalaria		oat	peach	tomato
grape		field bean		oil raddish	pine	triticale
peach		Leucaena		peach	potato	wheat
potato		millet		pepper	rice	white clover
Prunus		oat		potato	soybean	
soybean		peach		rape	sweet potato	
strawberry		peanut		red clover	tobacco	
sugar beet		pepper		strawberry	tomato	
sweet potato		plum		sugar beet	watermelon	
tobacco		potato		tomato	wheat	
tomato		sesame		wheat		
		soybean		white clover		
		Stylosanthes				
		sugarcane				
		sweet potato				
		tobacco				
		tomato				
		wheat				

* Information based on worldwide survey of nematologists (371 responses).

fields which means that rapid and reliable nematode identification is essential. It is encouraging to note that 72% of the respondents indicated they had access to diagnostic services that provided nematode identification. However, even with this service, farmers are often reported to experience heavy losses because of the diversity of nematode genera in fields and because new races often emerge after repeated use of resistant cultivars. Thus the number of available resistant cultivars diminishes in relation to their actual usefulness in the suppression of damage. Certainly, we are fortunate to have a number of nematode-resistant cultivars, but we need many, many more. Also, it is important that greater efforts be made to develop cultivars with multiple nematode resistance. The effective use of available resistant cultivars should be maximized by their integration with other nematode management practices.

Limitations and Constraints Experienced by Nematologists

Sixty-four percent of the respondents expressed dissatisfaction with the image of nematology at their institutions. Most of the suggestions to improve this image centered around increased public recognition of nematode damage, development of effective management options, better research programs, and greater funding. The hiring of more nematologists and support staff was deemed critical to image improvement. Apart from the issue of image, many respondents indicated that they felt constrained in their work by lack of facilities and supplies, administrative support, funds, technical assistance, and communication with other nematologists.

Summary

In summary, from a worldwide perspective, nematology is a very important science and it is exceedingly obvious that plant parasitic nematodes constitute a major constraint to agriculture. If crops are to be grown profitably, nematodes must be dealt with just as we deal with other plant diseases, weeds and insects. Although we as nematologists have made significant contributions to our science during the past 25 years, nematode problems warrant considerably more effort and support than they are currently receiving. On the horizon are many challenging and exciting areas of research that will yield high dividends. Tools made available in recent years (scanning electron microscope, gel electrophoresis, computers) have allowed us to make rapid advances in taxonomy and biochemistry of nematodes as well as systems science and data management. Methodology for evaluation of biocontrol agents is rapidly developing, and support for this area of research is likely to increase in the years ahead. New nematode host associations are being discovered each year. A recent example is a Sphaeronema species, a genus closely related to the citrus nematode, found feeding in the roots of declining Fraser fir and red spruce throughout the Southern Appalachian Mountains of western North Carolina and Virginia. Some researchers have attributed the decline of montane boreal forests to acidic deposition and other environmental factors. While much work needs to be done to clarify the etiology of this disease, based on the feeding behaviour of the nematode and the fact that large numbers of nematodes have been recovered from infected roots, this nematode must damage its host and contribute to the disease complex.

Finally, it is encouraging to note the steady growth of our science and the achievements of individual nematologists as reflected on many fronts - excellence in research; teaching and extension; many quality journals; and a large number of new books and manuals. Although our science is relatively young, I believe it is in a healthy state and that future progress will be limited only by lack of resources devoted to it.

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ANALYSIS OF PLANT PARASITIC NEMATODES AFFECTING PASTURE AND FORAGE LEGUMES IN TEMPERATE SEMIARID REGIONS

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Introduction

The development of pasture and forage legume management systems adaptable to the temperate semiarid regions or Mediterranean climate zones is required to significantly increase animal production in North Africa and West Asia. Plant diseases and plant parasitic nematodes, in addition to ecological and agronomic constraints, can negatively influence effective integration of these legumes into the cropping systems.

In an attempt to replace the traditional cereal-fallow rotation practiced in the region, research has been directed toward the incorporation of (1) annual self-regenerating pasture or ley farming with species of Medicago and (2) annually resown forages such as vetch (Vicia sativa), forage pea (Pisum sativum) and chickling (Lathyrus sativus) into the regional cropping system (ICARDA 1985a). A second goal has been an attempt to increase the productivity of nonarable marginal land through management practices.

Plant parasitic nematodes are an important limiting factor in the production of pasture and forage legumes in most temperate areas of the world (Griffin 1984; Eriksson 1972; Sikora and Maas 1987). Vast amounts of literature exist on the economic importance of plant

parasitic nematodes attacking such perennial crops as lucerne (Medicago sativa), red clover (Trifolium pratense) and white clover (T. repens).

Conversely, little is known about the presence, distribution and importance of plant parasitic nematodes on annual medic and clover species or forage legumes adaptable to the temperate semiarid regions of the world. A review of the literature demonstrated that our knowledge is limited to a few publications that reported either, (1) the general presence of nematodes on a particular crop, (2) the description of a new species or (3) the results of screening for resistance to a particular parasite on a limited number of cultivars or breeding lines (Goodey et al. 1965; Helminthological Abst. 1970-1986).

Important Plant Parasitic Nematodes Associated with Crop Loss

Pasture and forage legumes can be severely damaged by cyst nematodes, root-knot nematodes and stem nematodes. Migratory endoparasites and a number of migratory ectoparasites are also known to cause damage. The lack of sufficient published material on the importance of nematodes in the temperate semiarid regions makes any estimation of economic impact impossible.

Economically important plant parasitic nematode genera attack vetch, forage pea, chickling, subterranean clover and annual medics in countries outside the region. Although little is known about the presence of plant parasitic nematodes on these crops in the temperate semiarid zones, many of these nematode species have been detected on other crops in North Africa and West Asia. A number of important parasites have also been reported on these crops from countries within the region.

Nematode species considered to be potential problems in winter season self-regenerating pasture and forage legumes are listed in Tables 1 and 2 respectively.

Table 1. Economically important plant parasitic nematodes associated with medics and clovers*.

Legume host	Nematodes
MEDICAGO	
M. minima	D. dipsaci
M. orbicularis	D. dipsaci, H. glycines
M. scutellata	M. javanica
M. falcata	D. dipsaci, M. hapla
M. polymoropha	D. dipsaci, H. glycines, M. incognita
	M. naasi
M. lupulina	D. dipsaci, M. artiellia, M. hapla
	P. penetrans, M. incognita
TRIFOLIUM	
T. hirtum	M. incognita, M. javanica
T. subterraneum	M. incognita, M. javanica, M. hapla
	P. penetrans, H. daverti
T. alexandrinum	H. daverti, M. javanica, M. incognita
	M. arenaria
T. angustifolium	M. incognita, P. penetrans, H. daverti
T. campestre	M. incognita, H. daverti
T. cherleri	M. incognita
T. spumosum	M. incognita
T. tomentosum	M. incognita

D = Ditylenchus H = Heterodera
P = Pratylenchus M = Meloidogyne

* Species are not listed that have not been examined for susceptibility to plant parasitic nematode.

Stem Nematode (Ditylenchus dipsaci)

Ditylenchus dipsaci is the most important plant parasitic nematode affecting lucerne (M. sativa) and it is an important limiting factor in red clover (T. pratense) and white clover (T. repens) production in many parts of the world (Griffin 1984).

Table 2. Economically important plant parasitic nematodes associated with selected forage legumes*.

Legume host	Nematodes
PISUM	
P. sativum	H. ciceri, D. dipsaci, H. glycines H. goettingiana, H. trifolii, M. artiellia M. incognita, M. javanica, M. arenaria M. hapla, P. penetrans, P. crenatus P. vulnus, Longidorus spp., R. reniformis Trichodorus spp.
LATHYRUS	
L. sativus	D. dipsaci, H. glycines, H. goettingiana H. trifolii, M. incognita
VICIA	
V. sativa	M. artiellia, D. dipsaci, H. glycines H. goettingiana, M. incognita, M. javanica P. penetrans, P. minyus, Longidorus spp.
V. narbonensis	H. glycines, H. trifolii, Meloidogyne spp.
V. ervilia	H. goettingiana, H. trifolii
V. villosa	H. trifolii, H. glycines, D. dipsaci M. incognita, M. artiellia, M. hapla M. naasi, P. penetrans, R. reniformis Trichodorus sp.
V. peregrina	Meloidogyne spp.

D = Ditylenchus
P = Pratylenchus
H = Heterodera
R = Rotylenchulus
M = Meloidgyne

*Species are not listed that have not been examined for susceptibility to plant parasitic nematode.

The nematode is widely distributed throughout the region on faba bean (Vicia faba) (Augustin 1983, 1985). D.dipsaci also reproduces well on a number of weed hosts common throughout the region. The fact that the nematode can be transmitted in seed makes its presence in the region a potentially important problem. The existence of races with the ability to attack other economically important crops increases the level of its importance to cropping system development.

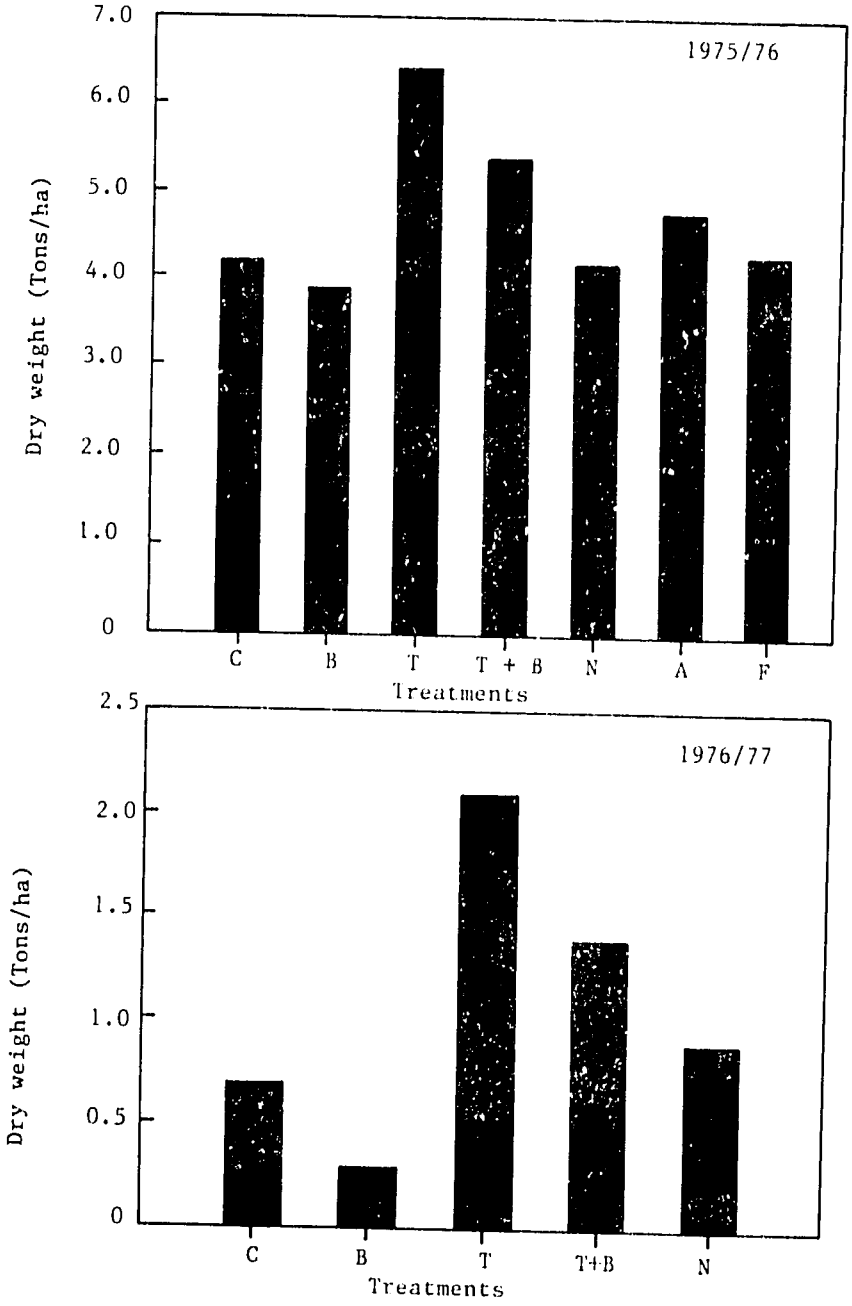
The host range of the giant race of D. dipsaci, which is predominant in the North Africa and West Asia region, has not been sufficiently investigated.

Cyst Nematodes (Heterodera spp.)

The majority of cyst nematodes pathogenic to pasture and forage legumes belong to the Heterodera trifolii - complex (Sikora and Maas 1987). Heterodera trifolii, H. daverti and H. ciceri have been detected in the region. Sikora and Maas (1987) reported the probable existence of an undescribed species of Heterodera from Syria that attacks Medicago sativa, which was originally identified as H. rosii. Heterodera ciceri has been shown to attack vetch, forage pea and chickling in Syria. Resistance has not been detected in screening of a large number of lines of the three crops (Saxena et al 1987). Berseem clover (T. alexandrinum) is severly damaged by H. daverti in Egypt while faba bean is modevately attacked (Personal Comm. Otiefa). Heterodera daverti has been shown to cause severe damage to subterranean clover (T. subterraneum) in Tunisia (Sikora 1977; Nordmeyer et al. 1978). The nematode was present in 20% of the samples collected and was detected in all growing areas examined.

The research conducted on H. daverti in Tunisia clearly demonstrated the influence cyst nematode can exert on subterranean clover grown as self-regenerating pastures (Nordmeyer 1979). Plant growth and yield in tons of dry matter per hectare increased significantly in field studies following nematicide treatments (Fig. 1) It should be noted that T. subterraneum is grown in the humid semiarid climatic zone.

Fig. 1. Influence of some pesticides and a fertilizer on yield of Trifolium subterraneum cv. Clare at 175 and 112 days after sowing in 1975/86 and 1976/77 respectively, at Ras Rajel, Tunisia. C = Control; B = Benlate 2g/kg seed + 4.5g/m^2 at sowing + 3 l(7.5%)/m^2 at 40 days later; T = Temik 10G 5g/m^2 at sowing and 5g/m^2 55 days later; N = Nemacur 5G 15g/m^2 at sowing; A = Aldrex 2P 15g/m^2 at sowing; F = Fertilon Comb. fertilizer 4 kg/ha after sowing + 4 kg/ha in 300 l water as drench after 55 days. Initial population of nematodes (H. daverti) 18 and 12 cysts/100 cm^3 soil in 1975/76 and 1976/77, respectively.



Forage pea, vetch and chickling are hosts of a new species of cyst nematode, H. ciceri described form Syria (Vovlas et al. 1985). Little is known concerning the distribution of this nematode within the region outside of Syria (Greco et al. 1984). The pea cyst nematode (H. goettingiana) has been reported from a number of countries in the region and is widely distributed in Europe where it attacks field and garden peas, faba bean, vetches, and lentil (Jones 1950; Winslow 1954). This nematode could also prove to be a potential pest problem on forage crops.

Heterodera glycines, the soybean cyst nematode, detected in Egypt is a major pest problem in legume production. The nematode is extremely damaging to soybean, lespedeza, some medics and vetch and is known to attack M. orbicularis.

The presence and importance of cyst nematodes on the other medics adapted to the temperate semiarid zones has not been studied.

Root-Knot Nematodes (Meloidogyne spp.)

Pasture and forage legumes are attacked by a number of species of Meloidogyne. Although they are not usually considered serious problems in the temperate zones of the world they could prove to be important in the temperate semiarid zones.

The presence of four of the most important species of Meloidogyne throughout North Africa and West Asia and the known pathogenicity of this group of nematodes to pasture and forage legumes on a worldwide basis dictates the need for research on this group of parasites within the region.

Serious damage to vetches is caused by M. artiellia in Syria (ICARDA 1985). This nematode is found in a number of countries in the region.

Migratory Endo- and Ecto- Parasites

Other genera of plant parasitic nematodes are associated with pasture and forage legumes which could adversely affect production in the region. Species of Pratylenchus, for example, are known to cause yield decline problems on red and white clover. P. thornei has also been detected on vetch, medics, wheat, barley, pea, chickpea, faba bean and chickling in Syria (ICARDA 1984). A number of ectoparasites are also able to damage legumes, but are probably not of economic importance to forage production.

Nematode Biology and Seasonal Effects on Crop Damage

Anhydrobiosis in D. dipsaci allows the nematode to withstand long periods of drying and makes the nematode an important seedborne pest and quarantine problem.

Cyst nematodes can survive up to 10 years in the absence of a host plant. Control measures such as rotation are, therefore, often ineffective. The presence of (1) a diapause in some species, (2) a hatching factor produced by the presence of the host root, (3) resistance to drying that increases survival of nematode inoculum, and (4) the presence of resistance breaking pathotypes are characteristics that complicate effective control of these nematodes.

The fact that nematode multiplication and resulting yield loss are

strongly related by available moisture is well documented. The climatic conditions that exist in the semiarid regions of North Africa and West Asia are ideal for nematode development. Germination of the self-regenerating pasture legumes, after the first rainfall, occurs simultaneously with reactivation of many nematodes from their resting stages (stem nematodes in anabiosis or cysts nematode larvae in the egg). Conditions are, therefore, optimum for both plant growth as well as nematode infection and development. The semiarid climatic conditions which exist during the growing season multiply the detrimental effects nematodes exert on plant growth through a blockage of the vascular system.

Complex Disease Interrelationships

Nematodes are known to interact with a number of soil-borne fungal and bacterial pathogens with a resulting synergistic increase in disease severity.

The results of Nordmeyer and Sikora (1983) demonstrated that losses on T. subterraneum were caused by a synergistic interaction between the cyst nematode H. daverti and two root-rot fungi, Fusarium oxysporum and F. avenaceum. In this the fungal root pathogens significantly increased nematode population densities on the plant. Typical symptoms of decline were only produced when the two organisms were present and fungal infection preceded nematode penetration.

Of extreme importance to legume production are those nematode-plant interactions which negatively affect Rhizobium nodule production (Taha and Raski 1969). Although species of Meloidogyne do not seem to

alter the number or size of nodules, they do disrupt the vascular system, thereby, disturbing the nutrient exchange with the root system.

Severe damage to pea by H. goettingiana was considered due to the suppression of Rhizobium nodulation (Oostenbrink 1955).

Information Transferability

The information accumulated in temperate regions on nematode biology, behaviour, and population dynamics in perennial crops such as lucerne, red and white clover probably has little similarity to what will be encountered on pasture and forage crops in the temperate semiarid climatic zones. However, there are techniques developed which can be used for a resistance screening and biological investigations in nematodes.

Research on the identification of races within the Heterodera trifolii - complex (Sikora and Maas 1987) could be used to avoid problems in the selection of non-host crops for a particular area infested with nematodes in this group. Similar host race tests are available for D. dipsaci and species of Meloidogyne.

The information on the presence of interactions between soil-borne fungi and nematode and techniques for studying these complex interrelationships could be applicable to the research program.

The results obtained to date on the interrelationship between nematodes and Rhizobium are not adequate. Data on the possible effects of this complex association on pasture legumes and forages are lacking. More on-farm research is needed to understand this phenomena.

Outside expertise on the control of seed borne D. dipsaci could be utilized to prevent dissemination of contaminated seed throughout the region, if this nematode proves to be a problem.

Priority Research Areas

The following research areas should be considered:

1. Survey work to determine the presence of important nematode pests in the countries within the region.
2. Field experiments for determination of the level of damage being induced by plant parasitic nematodes.
3. Development of screening programs including the development of screening methods, for resistance to the species considered economically important.
4. Establishment of host range tests with nematode populations of important species already known to exist within the region e.g species of Meloidogyne, Heterodera, and Ditylenchus.
5. Initiation of research to develop cropping systems approaches to integrated control of nematode populations. Study the influence of environmental factors and cultural practices on nematode population dynamics and pathogenicity.
6. Study the importance of disease complex involving nematodes with soil-borne pathogenic fungi and Rhizobium.

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THE IMPORTANCE OF PLANT PARASITIC NEMATODES IN FOOD LEGUME PRODUCTION IN THE MEDITERRANEAN REGION

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Introduction

Food legumes such as faba bean (Vicia faba L.), chickpea (Cicer arietinum L.), lentil (Lens culinaris Medic.), and pea (Pisum sativum L.) are widely cultivated in the Mediterranean region where the climate is characterized by rather mild winters and a concentration of rainfall between November and April. Because of a lack of sufficient water, irrigation is practiced only on a limited area during the dry months. Therefore, the crops are usually sown from November to early March and harvested from May to June. Despite the short growing season and the hot and dry summer season, nematodes have been reported to be major constraints of food legumes in the area. They injure the crops by causing necrosis and disorder in the infested tissues, by interacting with other pathogens, and also by limiting Rhizobium nodulation (Ali et al. 1981). Moreover, plants with impaired root systems suffer more severe water stress in the spring. Information on nematodes infesting food legume crops is scanty and limited to a few countries. The most commonly occurring nematodes are discussed here.

Bulb and Stem Nematode (Ditylenchus dipsaci)

Ditylenchus dipsaci (Kuhn) Filipjev is very common in the Mediterranean

Basin (Lamberti 1981). It has a very wide host range and more than 15 races may occur; the giant race being important on faba bean. This nematode mainly affects faba bean, but also damages pea (Inserra and Vovlas 1979) and lentil. The nematode mainly attacks stems and leaves close to the soil surface causing tissue necrosis. Infested stems of faba bean appear brown and symptoms can be confused with certain fungal diseases. Therefore, extraction of nematodes from infested tissues is required for identification of the causal agent. Infested stems of pea and lentil become dark following nematode infection. Large necrotic areas develop in the leaves, and the leaves may then drop off as the season progresses. In the field these symptoms are obvious by March-April when the crop canopy closes causing the lower parts of the plants to remain wet until late in the morning. Damage is particularly severe if dew, fog, and rain occur frequently. Under these conditions flower abortion as well as pod and seed distortion may occur because of nematode infestation. More than one generation can be completed by the nematode in a growing season, each taking 20-30 days. Therefore, high soil populations of the nematode can be found in the spring. Moreover, the nematode survives in dry seasons as quiescent fourth stage juveniles in stems (especially at the base) and in seeds, the latter responsible for D.dipsaci spread. Grazing infested straw or crop stubble may favour the dispersal of the nematode as it can survive in the animal body during digestion of infested plant organs (Marinari et al. 1971). Augustin (1985) reported, however, that the giant race on faba bean did not survive passage through sheep.

However, the main problem arising from D.dipsaci concerns faba bean. Seed produced in infested fields harbours nematodes and cannot

be exported because plant quarantine regulations of many countries only permit importation of nematode-free faba bean seed.

Cyst Nematodes (*Heterodera* spp.)

Cyst nematodes affecting legumes in the Mediterranean area are not as widespread as the stem nematode, but usually the damage they cause is more evident. They also infest host plants in the winter and develop to the adult stage by the end of winter or early spring. Emergence does not occur from late spring to early autumn.

Heterodera ciceri

The chickpea cyst nematode *H. ciceri* Vovlas, Greco *et* Di Vito is a new species of the *H. trifolii* group recently found (Vovlas *et al*. 1985) in Syria where it causes considerable damage mainly to chickpea and lentil in the north of the country. In the province of Idleb the majority of fields are heavily infested with this nematode. In host range tests with a number of leguminous species, the nematode reproduced well on pea and grasspea and poorly on the other species studied (Greco *et al*. 1986). There is little emergence at 10°C and 25°C and substantial emergence between 15-25°C (Kaloshian *et al*. 1986a). Even though second stage juveniles can invade the root at 8°C no further development occurs at <10°C. Cysts usually develop in 36 days at 20°C after females have reached the yellow stage (Kaloshian *et al*. 1986b). Under field condition in northern Syria, females can be observed on the roots by April. It is assumed that only one generation is completed each growing season on chickpea and lentil. Males, are very common. Symptoms of nematode attack are yellowing of the foliage, poor flowering and podding, extensive necrosis of the roots, and early

senescence of the plants. The symptoms become evident by the end of April and May. The tolerance limit of chickpea to H. cicer was estimated to be about 1 egg/cm^3 soil (Greco et al. unpublished). Complete loss in yield is obtained in fields infested with more than 32 eggs/cm^3 soil. Lentil appears to be more tolerant. There are no reports on the presence of H. ciceri outside Syria.

Heterodera geottingiana

The pea cyst nematode (H. goettingian Liebscher) has been reported as a serious pest of food legumes in Mediterranean countries e.g. Algeria, France, Italy, Libya, Malta, Portugal, Spain (Di Vito and Greco 1986). Faba bean and pea are heavily damaged and the nematode also reproduces well on vetch (Vicia sativa L.) and grasspea (Lathyrus cicera L.). No reproduction has been observed on chickpea and only a few adults were found on lentil (Di Vito et al. 1980) and other legumes. Some wild plant species such as Asperula arvensis L. (Di Vito 1976), Vicia spp. and probably others (Jones 1950; Winslow 1954) are also hosts for the nematode and can maintain nematode population densities at damaging levels when no other host crop is present. Symptoms of nematode attack are evident at flowering and are similar to those reported for H. ciceri. In heavily infested fields total yield loss can be attained. The tolerance limit of peas to H. goettingiana is 3.5-5.3 egg/g soil (Di Vito et al. 1978). Faba bean, however, seems to be less susceptible than pea to the nematode.

If faba bean and pea are sown in early autumn (October) females of H. goettingiana develop by December, when soil temperatures are below 15°C, and large egg masses are produced. Larvae emerge from the egg mass quickly and another generation is initiated (Greco et al. 1986).

In areas where host crops are sown in late autumn or in winter, females are usually formed by early spring when soil temperatures exceed 15°C and no eggs are laid in the gelatinous matrix. Since eggs in new cysts take about two months to emerge, only one generation would occur in late sown crops.

Heterodera trifolii

The clover cyst nematode H. trifolii Goffart is known to affect clovers. Some populations have been reported to be noxious to sugar beet and carnation (Cuany and Dalmasso 1975; Maas and Heijbroek 1982). Among the food legumes, infestation may occur on pea. It has been reported in several Mediterranean countries (Lamberti 1981), but does not seem to be a serious pest of food legumes.

Root-Knot Nematodes (Meloidogyne spp.)

These nematodes are cosmopolitan (Taylor and Sasser 1978) and have also been reported to be noxious to food legumes (Mathur et al. 1969; Nath et al. 1979; Srivastava et al. 1974). Meloidogyne incognita (Kofoid et White) Chitw., M. arenaria (Neal) Chitw. and M. javanica (Treub) Chitw. are widespread in the Mediterranean region (Lamberti 1981). They reproduce well between June and October when soil temperatures are in the range 25-27°C. By the time food legumes are sown (November - March) soil temperatures have dropped to 10-15°C. Nematode development, therefore, is inhibited during this period. When soil temperatures rise in the spring to a level favorable to these species, legumes are in the podding stage or close to harvest and yield loss because of nematode infestation is avoided. Only when legumes are sown in September or October damage is expected, because nematode attacks at

an early growth stage. The surviving plants would recover later, because nematode development is suppressed by the drop in soil temperature.

Meloidogyne hapla Chitw. and M. artiellia Franklin are less dependent on high temperatures for their development. They both occur in the Mediterranean area (Lamberti 1981) and might affect legumes. Meloidogyne artiellia has been reported to cause severe damage to chickpea in Italy (Greco 1984), Spain (Tobar-Jimenez 1973) and especially in Syria where crops in several fields have been completely destroyed by infestations (Greco et al. 1984). Chickpea can be infested by M. artiellia even in the winter season and females with large egg masses can be seen on the roots by early April. Although the eggs may emerge (Ekanayake and Di Vito 1985), usually one generation occurs during the chickpea growing season. Both eggs and second stage juveniles survive during the hot and dry summer season. Galls caused by M. artiellia are characteristically small compared with those of other species of root-knot nematodes and their occurrence within the roots of several host plant species is only evident from the large egg masses which are visible externally.

The nematode has a very wide host range and reproduces well on crucifers, cereals and legumes, with the exception of oat, corn and lentil. Members of other families tested were poor or non hosts for the nematode (Di Vito et al. 1985b).

Despite severe damage caused by root-knot nematodes to food legumes, there is no report on the extent of yield losses in relation to different soil population densities. However, on the basis of

experiments with other host plants in the area (Di Vito et al. 1985a; 1986) it can be assumed that densities exceeding 1 egg/ml soil would also cause considerable damage to food legumes.

Other Nematodes

Lesion nematodes are among the most frequently encountered nematodes in the Mediterranean area. Among them Pratylenchus penetrans (Cobb) Chitwood et Oteifa, P. vulnus Allen et Jensen and P. thornei Sher et Allen may infest faba bean and chickpea. During a survey made in Syria (Greco et al. 1984) P. thornei was found in 74% of root samples of chickpea and also in lentil and faba bean roots. Extensive necrosis occurs on infested roots, but symptoms of lesion nematodes on the above ground parts of chickpea were not as evident. Growth of chickpea was significantly reduced when the crop was sown at population densities of $\geq$ 0.1 eggs/g soil (Walia and Seshadri 1985).

Rotylenchulus reniformis Lingord et Oliveira has also been reported to injure chickpea (Rashid et al. 1973; Mahapatra and Padhi 1986). It occurs in the Mediterranean region but does not seem to appreciably affect legumes.

Many other nematode species are frequently found associated with several crops, including food legumes. Among them species of Paratylenchus, Pratylenchoides, Thylenchorhynchus, Helicotylenchus, Tylenchus and Rotylenchus are very common. Their impact on the growth of these crops is not known.

Control

Because of the destructive habit of most of the nematode species that have been referred to, control measures are required to limit yield losses of legumes. Unfortunately little information exists on 1) nematode soil population density at sowing time which is difficult to determine, 2) the effect of increasing nematode densities on yield and, 3) population dynamics as affected by rates of nematicides which are necessary for effective and economic nematode management.

Soil treatments with fumigant and non fumigant nematicides are generally effective in controlling these nematodes (Di Vito and Lamberti 1976; Whitehead et al. 1979; Singh et al. 1981). They are, however, costly, require specific machinery and well trained personnel, and may cause pollution. Moreover, they may not be available in many countries, or their application can be difficult because of unsuitable soil conditions which prevail when the soil is left fallow. In many countries in the semi-arid zone summers are hot, and the first rain occurs in November or December when soil temperatures are low and crops such as faba bean, pea, and lentil must then be quickly sown. It is only in those areas with irrigation or high rainfall and where pea and faba bean are marketed as expensive fresh pods, that soil treatment with nematicides is practical and economic.

In several areas legumes are grown on marginal land. Low yield prevents economic use of nematicides. Usually M. incognita, M. arenaria and M. javanica do not require specific control measures and by sowing legumes from November onwards the crops escape early nematode infestation. Their build up can also be avoided by rotating legumes

with winter crops.

Control measures are, however, needed to prevent yield losses caused by D. dipsaci, M. artiellia, H. goettingiana, H. ciceri, and Pratylenchus spp.

Because of its wide host range, control of D. dipsaci in faba bean fields by crop rotation is difficult. However, some agronomic practices may prevent the accumulation of moisture at the stem base and hence prevent nematode infestations. Thus, weed control and wide spacing of the plants is recommended for areas in which late winter and early spring tend to be wet. Soil treatments with fumigants (DD; 1, 3D; mixture of DD + methylisothicoyanate) at 200-400 kg/ha or non volatile nematicides (aldicarb, fenamiphos, oxamyl) at 5-20 kg a.i./ha could be used to advantage in nurseries to obtain seed stocks free of nematodes. When faba bean seed stocks are infested, treatments with methyl bromide at CTP of 1000 mg hr/l (Powell 1974), 100 g/m^3 x 18h or 80 g/m^3 x 12h (Caubel et al. 1985) would give satisfactory control of the nematode without affecting germination. Hot water treatment as suggested for flower bulbs (Winfield 1970) could provide the farmer with a relatively easy means of control, but no attempt has been made to ascertain appropriate temperatures and times required for killing nematodes inside infested faba bean seeds.

Control of M. artiellia, Pratylenchus spp. and Rotylenchus reniformis by crop rotation is also difficult because of their wide host ranges. Chickpea is the main host attacked by these nematodes. Lentil, oats, corn, cotton, sugar beet, potato, tomato, lettuce, sunflower, water melon and flax are among the widely cultivated crops

which were found to be poor or non hosts for M. artiellia. Moreover, it seems that P. thornei reproduces better on winter and spring crops than on summer crops, and therefore, the latter can be included in rotation programs to suppress nematode population densities and thus limit yield losses.

Cyst nematodes, on the contrary, have rather narrow host range within the legumnious group. Therefore, their control by crop rotations is feasible and is recommended for infested areas.

Unfortunately there is still insufficient information on the population dynamics in cropping systems of all these nematodes in the Mediterranean region. This information is needed to determine the most suitable rotations for nematode control. For H. goettingiana a decline of 68% during the first year and of 85% after four years has been reported in Southern Italy (Di Vito and Greco 1986), where crop rotations of up to 5 years with cereals and fallow led to an increase in the yield of pea. Probably growing the host crop only every 3 to 5 years would provide satisfactory control of cyst nematodes.

However, several nematodes also develop on weeds and grasses whose control must be considered especially for limiting the reproduction of root-knot, lesion and stem nematodes.

The simplest and most economical way to control plant parasitic nematodes would be by growing resistant cultivars. No faba bean cultivar has so far been found to be resistant to D. dipsaci, but one from Morocco (Sturhan 1980) and cv. Diana (Augustin and Sikora 1984) showed some resistance. Di Vito and Perrino (1978) found a few accessions of the wild species Pisum abyssinicum Brown, P. arvense L.

and P. elatius Ster to be moderately resistant to H. goettingiana. Among chickpea cultivars Mani and Sethi (1985) reported that the genotype N. 501 was resistant and 18 others where moderately resistant to M. incognita. Sharma and Mathur (1985) found the genotype BG 405 to be resistant. In soil infested with M. javanica no galls were observed on 34 out of 275 chickpea cultivars (Handa et al. 1985). No chickpea genotypes have so far been found to be resistant to M. artiellia and H. ciceri.

Other control measures such as biological agents are not effective against these nematodes under field conditions. Mulching the wet soil with thin transparent polyethylene film (solarization) during hot summers has shown promise for the control of several nematode species (Katan 1981; Greco et al. 1985). This method could provide farmers with an easy and simple way of controlling pathogens especially in warm countries, but it is expensive and requires a water supply for irrigation of the fields before mulching.

Conclusions

Because nematodes cause considerable damage to legumes, control measures are necessary to limit yield losses. Nematicides should be used only in areas where economic benefits can be obtained from crop production and in nurseries used for the production of seed stocks free of nematodes.

More emphasis should be put on the use of some agronomic practices. Delayed sowing in areas infested with root-knot nematodes, suitable plant spacing and weed control are suggested. Crop rotation

should be encouraged wherever possible to keep soil nematode populations below damaging levels. However, this requires detailed information on the effect of crop plants on the dynamics of nematode populations under field conditions. Some plant species found to be hosts of a nematode in greenhouse experiments may not be so under field conditions. Further, investigations should be made to ascertain suitable rotations for each nematode species. Cooperative research has been undertaken with ICARDA in Syria to investigate the use of crop rotations for the control of H. ciceri and other nematodes occurring in Syria. It is hoped that similar investigations can be extended elsewhere.

There is no doubt that growing resistant cultivars would be the best way to control nematodes. Unfortunately there are few sources of resistance in legumes to nematodes occurring in the Mediterranean region. Most of the available resistant genotypes have little or no commercial value. Nevertheless this germplasm could be profitably used in a breeding program. Investigations are in progress in cooperation with ICARDA to test the reaction of chickpea germplasm against H. ciceri and M. artiellia. Some genotypes seem promising but their resistance needs confirmation. The most advanced genetic techniques should also be used to induce and transfer resistance to nematodes in food legume cultivars of economic importance.

Research has been undertaken at ICARDA to develop legume cultivars resistant to several pathogens and environmental stresses. It is suggested that these cultivars should be screened for nematode resistance. However, several years are required to obtain resistant cultivars suitable to different environmental condition. Therefore, in

the meantime we think that the adoption of an integrated control program which includes some of the control measures discussed earlier, could be effective and economical against nematodes of food legumes.

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PLANT PARASITIC NEMATODES OF WHEAT AND BARLEY IN TEMPERATE AND TEMPERATE SEMIARID REGIONS - A COMPARATIVE ANALYSIS

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Introduction

The temperate semiarid or mediterranean climatic region of North Africa and West Asia is characterized by winter rainfall alternating with summer drought. Climate, therefore, dictates that dryland agriculture is mainly devoted to the production of temperate crops during the winter season. Wheat and barley are the most important cereal crops in this climatic region. Cereal production there is strongly influenced by social, climatic, agronomic, and biotic factors.

Fungal diseases and insect pests are important constraints in crop production. The development of appropriate control strategies for these problems is a major component of cereal crop improvement programs throughout North Africa and West Asia. Conversely, research on the presence, distribution, and importance of plant parasitic nematodes in cereals has been grossly neglected.

Plant parasitic nematodes are often called "rotation pests" because short rotations permit nematode population buildup beyond economic threshold densities, which results in crop damage. Under long rotations nematode populations usually decrease below these threshold

levels. Short cereal rotations in the temperate semiarid regions favor nematode population development and associated yield loss. Furthermore, other agronomic practices such as soil tillage, and date of planting, can significantly alter population development and the intensity of crop loss.

Nematode populations also are strongly influenced by environmental factors such as temperature, moisture, soil type, nutrient level, and organic matter content. These factors have a strong impact on the nematode-plant interrelationship, which in turn affects disease severity and the development of economically acceptable integrated management systems.

In this analysis, an attempt will be made to: 1) review the present status of wheat and barley production in the temperate regions and temperate semiarid region of North Africa and West Asia, 2) compare environmental factors and agronomic practices prevalent in the two regions, 3) discuss those plant parasitic nematodes considered economically important or of potential importance on wheat and barley, 4) discuss the interrelationships between environment, agronomic practices, and plant parasitic nematode population dynamics and crop loss, and 5) suggest lines of research to determine the true importance of nematodes on wheat and barley in this region.

Most of our knowledge concerning plant parasitic nematodes in cereals is based on research conducted in temperate climates. The majority of research on nematode problems in temperate semiarid climates was conducted in Australia. I have not attempted to review the vast amount of literature on this subject.

Wheat and Barley Production in North Africa and West Asia

The cereal crops of importance to the temperate semiarid regions of North Africa and West Asia are bread wheat, durum wheat and barley. It has been estimated that 70 percent of the land devoted to food crops on an annual basis is planted to cereals. The area planted to these crops and the yields obtained in North Africa and West Asia are given in Table 1 (ICARDA 1986a), and the area planted to these cereals by country are given in Table 2.

High elevation cultivation is common in eight countries in the region. Almost 50% of the wheat area is planted at elevations of $\geq$ 1000 meters. Yields in these areas are low when compared to the other areas.

Temperate Semiarid Environment

The temperate semiarid or Mediterranean climate is a harsh environment. The most important limiting factor in crop production is rainfall, which varies between 250 and 450 mm in the main barley and durum wheat growing areas. Most of the precipitation falls in the cool season from October to May. Large variations in the timing and distribution of rainfall greatly affects crop production. The moisture requirements for the cereal and legume crops in the region are given in Table 3. Approximately 50% of wheat and 75% of barley in these areas receives less than 350 mm of rainfall. Wheat usually is planted in areas with greater rainfall and deeper soils, whereas, barley is grown in drier areas with more shallow soils.

Many of the alkaline soils contain high proportions of calcium carbonate. The calcareous soils in most of the region generally

Table 1. Area and yield of barley, bread wheat, and durum wheat grown in North Africa and West Asia.

Crop	Million hectare	Million tons	Yield (kg/ha)
Bread wheat	23.3	37.1	700-1800
Barley	11.0	11.8	400-1000
Durum wheat	8.5	10.7	600-1200

Table 2. The area planted to wheat and barley in 17 countries in North Africa and West Asia in 1000 ha.

Country	Wheat	Barley
World	23382	91368
North Africa		
Algeria	2400F	800F
Egypt	505	45F
Libya	115F	300F
Morocco	1929	2341
Sudan	282	-
Tunisia	944	379*
West Asia		
Afghanistan	2250F	310F
Cyprus	65F	70F
Iran	8030	1500F
Iraq	2114	700F
Jordan	132F	25F
Lebanon	25F	5F
Pakistan	6403	180
S.Arabia	75F	10F
Syria	1528	1021
Turkey	9300F	2500F
Yemen Arab Republic	50F	70F
Yemen Democratic Republic	14	1

Source: 1977 FAO Production Yearbook, Vol. 31
F = FAO estimate
* = Unofficial figure.

Table 3. Moisture requirements for the ICARDA mandate crops.

Crop	Rainfall in mm per year
Barley Lentil Vetch Chickling	200-350 with periodic drought
Durum wheat Chickpea Medic	300-450
Bread wheat Faba bean Medic	350-600 or irrigated

Table 4. Comparison of environmental conditions in temperate and temperate semiarid regions.

Factor	Temperate	Temperate semiarid
Climate	Cool moist	Cool moist with some drought and then hot dry
Moisture (mm/yr)	$\geq$ 600 mm	200-450+ mm + periodic drought
Rainfall timing	Predictable	Unpredictable
Rainfall distribution	Uniform	Highly erratic
Temperature	0-25 ^{o}C	0-40 ^{o}C
Soil pH	Neutral	Alkaline
Organic matter	$\geq$ 4%	1-3%
Soil fertility	Good	Poor
Available P & N	High	Low

exhibit phosphate deficiency and are poor in available nitrogen. In addition, barley farmers usually do not add fertilizer to the crop (ICARDA 1986). Organic matter concentrations vary between 1 and 3%. These low levels are caused by the utilization of straw for fodder combined with grazing of the remaining stubble. In Table 4 a comparison between the environmental factors affecting crop production in the two climatic regions is shown.

Economically Important Nematodes on Wheat and Barley

Plant parasitic nematodes are recognized as major limiting factors in cereal production in the temperate semiarid regions of Australia (Brown 1984; Rovira 1982), and in the temperate climatic regions of the world (Kort 1972; Griffin 1984). The general distribution of important or potentially important plant parasitic nematodes of wheat and barley in the two climatic regions is given in Table 5.

Cyst Nematodes

Cyst nematodes are considered the most important group of plant parasitic nematodes on wheat and barley on a worldwide basis. The cyst nematodes reported to attack wheat and barley are listed in Table 6. Most of our knowledge on nematodes affecting cereals was obtained from research on Heterodera. avenae. This cyst nematode has been detected in 31 countries and is a major pest of wheat in the temperate regions of Europe and in the temperate semiarid regions of Australia. In southern Australia H. avenae causes losses from 23 to 50% on wheat and up to 20% on barley (Meagher 1972). It has been estimated that two million ha of wheatland are infested with H. avenae in Australia (Brown 1984) with losses in wheat estimated at $AUS 72 million annually (Brown 1981). The nematode was found in 94% of 376 fields examined in England. Population densities ranged from 10 eggs/g soil in 26% of the fields to 40 eggs/g soil in 4% of the fields (Anon. 1975). It has been established that H. avenae causes yield losses of 188 kg/ha on wheat and 75 kg/ha on barley with every increase of 10 eggs/g soil (Dixon 1969). The nematode is common in the cereal production zones throughout Europe.

Table 5. Plant parasitic nematodes of wheat and barley in temperate and temperate semiarid regions.

Nematode	Temperate		Temperate semiarid		
	Europe	N. Am	N. Africa	W. Asia	Australia
WHEAT					
*Anguina tritici**	+	+	+	+	+
Ditylenchus dipsaci	+	+	+	+	+
Heterodera					
avenae	+	+**	+	+	+
latipons	+	+	+	+	–
pakistanensis	–	–	–	+	–
Meloidogyne					
artiellia	+	–	+	–	–
naasi	+	+	–	–	–
Pratylenchus					
neglectus	+	+	+	+	+
penetrans	+	+	+	+	+
thornei	+	+	+	+	+
zeae	–	–	–	+	+
Punctodera punctata	–	+	–	–	–
BARLEY					
*Anguina tritici****	–	–	–	+	–
Ditylenchus dipsaci	–	–	–	–	–
Heterodera					
avenae	+	+**	+	+	+
latipons	+	–	+	–	–
Meloidogyne					
artiellia	+	–	–	+	–
naasi	+	+	–	+	–
Pratylenchus					
penetrans	+	+	+	+	+
neglectus	+	+	+	+	+
zeae	–	–	–	+	–

* *A. tritici* irradicated in most countries with certified seed.
** Reported on oats (Jensen *et al.* 1975).
*** Reported on barley in Iraq (Al-Talib *et al.* 1986).
– Not reported.

Table 6. Cyst nematodes reported from wheat and barley.

Nematode	Host status	
	Wheat	Barley
Heterodera avenae	+	+
H. bifenestra	+	+*
H. hordecalis	+	+
H. latipons	+	+
H. mani	+	+**
H. pakistanensis	+	-
H. zeae	-	+
Punctodera punctata	+	+

* Common in wet soils
** Belongs to a species-complex, some populations infect cereals.

The host range of *H. avenae* is limited to gramineous plants. The cereal hosts of the nematode in descending order of susceptibility are: oats, spring wheat, winter wheat, spring barley, winter barley and rye (Decker 1969). In Australia the highest number of cysts were produced on wheat followed by barley and then oats.

Symptoms of damage on wheat and barley vary from patches of stunted plants to heterogeneous growth over the entire field. In the latter case, crop damage often has been incorrectly attributed to variation in soil structure or poor soil fertility. The root systems of diseased plants are knotted and significantly reduced in size. Tillering is suppressed, leaves are discolored, and plants are stunted. In many cases symptoms resemble with those of nitrogen and phosphorus deficiency (Kort 1972). Damage threshold levels for oats, wheat, and barley in the temperate regions are 0.2, 1.0, and 5 eggs + larvae/g of soil (Andersen 1961; Franklin 1951). In the temperate semiarid regions of Australia yield decreased 20% with 2 eggs/g soil and 40% at 16

eggs/g soil (Meagher and Brown 1974). Threshold levels vary greatly with cultivar and climatic conditions within a geographical area. Between 90 and 105 days after sowing, white cyst development could be observed on the root surface in Australia and India. Completion of the life cycle requires 3 to 4 months and only one generation is produced each season.

Damage is most severe when a condition of optimum soil moisture for seed germination and initial plant growth is followed by drought. Crop loss is amplified because the stunted and abnormal root systems are unable to absorb moisture. Root damage may be increased by the interaction between secondary root-rotting fungi and the nematode (Meagher and Chambers 1971).

Cereal cyst nematode damage is more severe on light and moderate soils, although damage to cereals also occurs on heavy soils. H. avenae was detected in sandy and clay soils in Victoria and South Australia, but not in heavy, poorly structured soils in the same area (Brown 1984). In The Netherlands, however, damage increased when cereal density in the rotation exceeded 60 percent, irrespective of soil type (Kort 1972).

The nematode can be controlled through crop rotation more easily than most other cyst nematodes because of its rapid decline under non-host crops. Whereas crop losses are highest in wheat-fallow and wheat-oat-fallow rotations, yields increased significantly in wheat-legume cropping systems (Meagher 1972; Meagher and Rooney 1966). The best legume crop was a barrel medic. The introduction of annual medic crops into the rotation in North Africa and West Asia could be

advantageous for nematode control. Noteworthy is that the effectiveness of the rotations decreased with increasing levels of gramineous weeds in the legume crops (Meagher and Brown 1974).

Resistant cultivars are the most effective means of nematode control in countries where high densities of cereals are in the rotation, or short rotations and/or monoculture are practiced. Their use results in significant increases in yield and a corresponding reduction in nematode population densities. Resistant cultivars of barley and wheat are available (Williams and Siddiqi 1972). In Denmark about 25% of certified barley is resistant to the nematode (Anderson 1982). However, in Australia the performance of resistant cultivars is often less than that of susceptible cultivars. Resistance in the Australian cultivars reduces the nematode to population levels that would still cause a 15-30% reduction in yield. Unfortunately, this has prevented general acceptance of these cultivars by the growers (Brown 1984). In order to overcome this problem cultivars are needed with both nematode resistance and tolerance (Fisher 1982).

Ten pathotypes of H. avenae have been identified using an international test system containing barley, wheat and oat differentials (Andersen and Andersen 1982). Pathotypes described from Australia and India are often distinctly different from those found in Europe. This demonstrates the presence of extreme variation within the species. However, some resistant cultivars are effective in simultaneously reducing populations of several European pathotypes (Williams and Siddiqi 1972).

Although effective chemical control has been achieved in Australia

(Gurner et al. 1980) with low rates of nematicides, their use is probably uneconomical in the temperate semiarid regions of North Africa and West Asia. Natural levels of biological control detected in fields under oat monoculture may be responsible for significant suppression of the nematode population (Kerry et al. 1982). Similar suppression may occur in creal monoculture in North Africa and West Asia.

Heterodera latipons attacks wheat and barley in 4 countries in North Africa and West Asia (Table 7). The nematode was first described in 1969, but has not been studied in detail. Information on host range, biology, and pathogenicity is scarce. Sikora and Oostendorp (1986) observed the nematode on the roots of stunted barley in Syria. They detected populations in soil samples of 1380, [illegible]5, and 1262 eggs + larvae/100 g soil from barley/barley, barley/vetch and barley/fallow rotations, respectively. The nematode could be an important constraint to barley production in the temperate semiarid regions. High populations are to be expected in this region, because of short cereal rotations and monoculture. Nematode suppression of the plants ability to absorb the already limited amount of available moisture would strongly influence yield. Because of the similarity in host range,

Table 7. Detection of Heterodera avenae and H. latipons on cereals in North Africa and West Asia.

Country	H. avenae	H. latipons
Morocco	+	-
Tunisia	+	+
Pakistan	+	-
Cyprus	-	+
Libya	+	+
Syria	-	+

symptomatology, and nematode morphology, many reports of damage attributed to H. avenae were probably due to H. latipons (Kort 1972). The known occurrence of H. avenae and H. latipons on wheat and barley in North Africa and West Asia is given in Table 7.

Although a number of other cyst nematodes parasitize wheat and barley nothing is known of their economic importance.

Seed Gall Nematode

Anguina tritici has been reported on wheat from most of the countries in the region. A population of this nematode also attacks barley in Iraq (Al-Talib et al. 1986).

In Iraq losses in wheat range from 0.03 to 22.9 percent. Ninety percent infestation has been recorded on the cultivar Mexipac (Al-Beldawi et al. 1974). The nematode is also widespread in Pakistan where damage ranges between 2 to 3 percent. Damage by A. tritici may be more severe in high altitude cereal growing regions, where cool temperatures and higher moisture levels favor nematode infection. For example, the nematode is more common in the Jordan cereal growing regions with 400 to 600 mm of rainfall than in the drier regions. Lack of certified seed programs in many of the high altitude growing regions contributes to damage. The nematode can be easily controlled with clean seed technology and is not a problem when certified seed is used. The use of resistance may be an effective alternative where certified seed programs are not available. A number of resistant lines of wheat have been found in the region.

Stem Nematode

Ditylenchus dipsaci is a problem on fall and winter cereal crops growing on heavy soils in high rainfall areas (Griffin 1984). The nematode is economically important on rye, oat, but not on wheat and barley. Furthermore, the race of D. dipsaci which attacks cereals in temperate climates is not common in the temperate semiarid region. The widespread distribution of the "giant race" of D. dipsaci on Vicia faba could be imporatnt if it attacks wheat and barley.

Root-knot Nematodes

Many species of Meloidogyne , common in the temperate semiarid regions, can parasitize wheat and barley. In most cases they are species that favor light soils and the warm temperatures of the summer growing season. They are not generally considered to be problems in winter season cereal production. The following species attack Gramineae in cool climates: M. artiellia, M. chitwoodi, M. naasi, M. microtyla, M. ottersoni. In warm climates M. gaminicola, M. graminis, M. kikuyensis, and M. spartinae are important (Taylor and Sasser 1978). Only M. naasi and M. artiellia cause significant damage to wheat and barley in the winter growing season.

Although M. naasi causes severe losses on barley in temperate regions (Kuiper 1966; Schneider 1967), it is apparently not widespread in the temperate semiarid regions. The nematode, however, damaged durum wheat in 17 percent of the fields sampled in southern Italy (Lamberti 1979) and occurs on barley in Malta (Inserra et al. 1975). Meloidogyne artiellia has a host range that includes crucifers, cereals and legumes (Ritter 1972; Di Vito et al. 1985). The nematode has been

reported from wheat in Greece (Kyrou 1969) and wheat and barley in Syria (Mamluk et al. 1983). M. artiellia reproduces on cereals and severely damages legume crops. Additional research is required to develop functional rotations and pest management programs. Other root-knot nematodes are of unknown or doubtful importance.

Lesion Nematodes

The species of Pratylenchus most commonly associated with wheat and barley in the temperate semiarid regions are: P. neglectus, P. penetrans, and P. thornei. These species have been detected in many countries worldwide including North Africa and West Asia (Table 5).

Pratylenchus thornei causes significant losses in wheat in Mexico (Perez et al. 1970; van Gundy et al. 1974). This species also is found throughout the region and causes damage to wheat in rainfed conditions. Legumes are also good hosts of the nematode (ICARDA 1986). The wide host range of nematode must be considered when developing cropping systems on the cereal-legume basis, because two successive susceptible hosts in a rotation would increase crop damage. The population is reduced significantly through fallow and planting non-host crops.

Influence of Environment and Agronomic Practices on Plant Parasitic Nematodes and Integrated Pest Management Programs

Plant parasitic nematodes are strongly influenced by environmental and agronomic factors. These interrelationships are important to understand the relationship between nematode density and crop loss and in the optimization of integrated control strategies. The development

of an economically acceptable integrated management program for control of plant parasitic nematodes in the temperate semiarid region will depend on optimum utilization of agronomic practices and environmental factors that negatively influence nematode densities. Some farmers in the region have probably unknowingly used a number of these strategies for nematode control.

The use of nematicides, even at low rates, is uneconomical to farmers cultivating small fields in this climatic zone. In addition, constant use of resistant cultivars is likely to increase the chance of pathotype selection e.g. on soybean infested with H. glycines and on potato infested with G. rostochiensis and G. pallida.

Optimum control requires suppression of nematode densities below the economic threshold level. Some potentially important methods in the reigon include: crop rotation with non-host crops, rotation with fallow, development of resistant and tolerant cultivars, stimulation of natural antagonists, enhancement of endotrophic mycorrhizae, timed planting and or harvesting, controlled soil drying. In Table 8 is shown a comparison of control techniques used or recommended for reducing plant parasitic nematodes on wheat and barley.

Moisture and temperature are extremely important to determine the level of crop loss due to nematode infection. High moisture at the time of planting insures optimum larval emergence and root penetration. If soil moisture levels remain high throughout the growing season, the crop normally will not be strongly affected by nematode attack, unless high initial nematode densities exist in the field. If the crop is exposed to drought later in the growing season, as often happens in the

Table 8. Comparison of control techniques used for reducing plant parasitic nematode damage on wheat and barley in the temperate and temperate semiarid regions.

Technique	Temperate	Temperate semiarid
Fallow	Limited	Common
Soil drying	Not practiced	Common
Rotation	Long	Short or none
Planting date	Not practiced	Possible
Resistant cultivars	Common	Limited use
Pathotype tests	Common	Limited use
Inoculum bioassay	Common	Limited
Nematicides	Not used	Limited use
Biological control	Extensively studied	Observed
Integrated control	Common	Limited
Organized survey	Common	Limited
Loss assessment	Conducted	Not examined
Certified seed	Common	Limited

temperate semiarid regions, damage increases signficantly. In the temperate regions of Europe severe damage also is detected when drought conditions appear during the growing season.

Early planting can reduce nematode damage if soil temperature and moisture levels favor seedling growth and are simultaneously unfavorable for nematode emergence and penetration. These environmental factors must be predictable, however, if controlled planting programs are to be of importance.

Some nematodes favor light and others favor heavier soils. Soil type, therefore, can be used to influence the amount of nematode damage. For example, root-knot nematode damage is reduced by planting susceptible crops in areas having predominantly heavy soils.

High soil temperatures and extreme soil drying during the summer months may cause significant levels of nematode mortality. Therefore,

rotations with one or two year fallow may be effective for nematode control. Deep plowing to increase the level of soil drying during the hot dry summer season accelerates nematode control. In addition deep plowing dilutes the nematode inoculum potential after fallow.

In general, good fertility favors the crop and reduces nematode related yield loss. The nematode population is not adversely affected by good soil fertility. On the contrary, nematode population buildup is favored by good growing conditions. There are many antagonists in the soil which can reduce nematode population levels. Vesicular-arbuscular mycorrhizae, which are very common in the low phosphate soils in the temperate semiarid regions may act as important components in natural suppression (Sikora 1981). Fungal parasites, which destroy the female before egg laying is initiated, have been found in many areas of Europe and may be of significance in North Africa and West Asia. The cereal cyst nematode population decreases below the threshold level in oat monocultures because of high parasitism (Kerry et al. 1982). A similar situation may exist in cereal monocultures with H.avenae or H.latipons. Many nematode fungal antagonists require an energy source in the form of organic matter. The low levels of organic matter induced by removal of straw for fodder or through burning plant residues, reduces the effectiveness of this natural suppressive component in the soil. Agronomic practices that increase organic matter levels should be promoted.

The introduction of susceptible crops into rotation could prove problematic if their susceptibility to plant parasitic nematodes is not fully understood. The planting of two susceptible crops in a cereal-legume rotation may induce high nematode levels and yield loss

in one or both crops. This aspect must be considered in selection of non-host cultivars for future rotations. Weeds may act as alternate hosts in fields planted to resistant cultivars or non-host crops. In some cases the nematode populations increase on these hosts.

Conclusions

1. Plant parasitic nematodes are present in the region that are of immediate economic importance to wheat and barley production. The cyst nematodes H. avenae and H. latipons, the seed gall nematode A. tritic, the root-knot nematode M. artiellia and species of the lesion nematode Pratylenchus are important. In addition, other nematodes of unknown distribution and importance, may cause crop loss.
2. The presence and distribution of plant parasitic nematodes, must be determined by extensive survey work.
3. Crop loss assessment trials must be conducted for those nematode species considred to cause economic damage.
4. Host range tests should be conducted using all crops and major weeds common in the growing area.
5. Nematode species that form pathotypes, should be closely examined with test differentials to avoid problems with host resistance breakdown.
6. Screening for host resistance and tolerance should be initiated using known sources of resistance in addition to presently available germplasm.
7. Integrated pest management systems should be developed from research on the influence of environmental and agricultural practices on

nematode population dynamics.

8. Caution is required in attempting to transfer expertise into North Africa and West Asia from other areas of the world. Transferability is complicated by genetic variation present in nematode and crop cultivars (Meagher 1972). Differences in production techniques and environmental conditions in the growing season can siginficantly alter theshold levels and integrated pest management programs.

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A REVIEW OF NEMATOLOGY RESEARCH IN ICARDA

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Introduction

The International Center for Agricultural Research in the Dry Areas (ICARDA) was established in 1977 to undertake research and training activities that would help in increasing the agricultural productivity of the rainfed systems in the dry areas of the West Asia and North Africa region. The Center has been assigned worldwide responsibility for the improvement of barley (Hordeum vulgare), faba bean (Vicia faba), and lentil (Lens culinaris) because of the significance of these crops in this region and in other areas with similar agroecological conditions. In addition, it shares the responsibility with other sister International Agricultural Research Centers for the improvement of wheat and kabuli type chickpea (Cicer arietinum). In these dry areas agriculure is closely linked with animal production, mainly sheep, and therefore research on integrated pasture, forage and livestock improvement is another major activity at the Center.

Although the Center has an access to a region-wide network of research stations in cooperation with the national programs, its principal research station is located at Tel Hadya, northern Syria. Being a part of the fertile crescent, this land, on which ICARDA conducts its major field research, must have been under cultivation

since times immemorial. It was, therefore, of little surprise that problems of plant parasitic nematodes started becoming apparent at the research station soon after the first two cycles of crops were grown here. This paper attempts to briefly review the research work carried out at ICARDA on identifying the nature and magnitude of the problem and on the development of control measures for plant parasitic nematodes affecting cool season food and forage legumes and cereals.

Survey

The first incidence of root-knot and cyst nematodes on forage and food legumes at Center's farm, Tel Hadya, was recorded in the 1981/82 season, and surveys in the nearby areas south-west of Aleppo confirmed their presence in the farmers fields also (Mamluk et al. 1983). The root-knot nematode, Meloidogyne artiellia, Franklin, and the cyst nematode, tentatively identified as Heterodera rossii, Duggan et Brenon, were found on chickpea (Cicer arietinum), vetch (Vicia spp.), peas (Pisum sativum), annual medic (Medicago spp.) and chickling (Lathyrus spp.). However, the heaviest infestation with root-knot nematode was found on vetches. Nematodes found on forage legume crops during the survey work done in 1981-83 are reported by Mamluk (1983). During the seasons 1981/82-1983/84 all experimental fields at Tel Hadya were examined for the presence of nematodes. Root-knot and cyst nematodes were found on legume and cereal crops, whereas root-lesion nematodes (Pratylenchus thornei) were found only on legume crops.

Soil and plant samples were collected mostly from fields of chickpea (44), and of lentil (2), faba bean (4), alfalfa (3), and vetch

from northern Syria in 1982/83. Twelve nematode genera occurred in soil and root samples. Heterodera, Meloidogyne, Pratylenchus, Ditylenchus, Aphelenchoides, Pratylenchoides, Helicotylenchus, Tylenchorhynchus and Xiphinema; the first five being of more economic importance (ICARDA 1984). Surveys during the 1983/84 season in the same area as also in the central and sourthern part of Syria confirmed that cyst nematode was most widespread and destructive in spring sown chickpea fields, while root-knot and root lesion nematodes were seen sporadically, only on winter sown chickpea. Surveys in 1984/85 showed the same picture with cyst nematode being most widespread in spring sown chickpea (ICARDA 1985b).

Surveys done in the major faba bean production areas in Syria, Cyprus and Egypt by a Ph.D. scholar during 1981/82 revealed that about 45.9% of the surveyed fields in Syria were infested with stem and bulb nematode, Ditylenchus dipsaci (Kuhn), Filipjev. Fields in the western part of the country showed higher infestation. No infestation was found in the warmer, drier faba bean cultivation areas of Deir Ezzor, Raqqa and Hassake. Also high (53%) was the level of seed infestation in samples collected from farmers in Syria (Augustin 1985). In Cyprus, 31.6% of the surveyed fields were infested by the stem nematodes--mostly in the western part of the country. In Egypt, no stem nematode was found in the 45 fields surveyed (Augustin 1985).

The seed gall nematode, Anguina tritici, has been detected in wheat seed samples from northern Syria (ICARDA 1985a).

Both root-knot and cyst nematodes were found on barley and wheat on samples collected from different ICARDA sub-sites in northern Syria

(Sikora and Oostendorp 1986). The population density of the cyst nematode in barley fields was far above the known damage threshold level, whereas on wheat only low numbers of cysts were found. Root-knot nematodes were found at low level in one barley sample and only in one site. Root-lesion nematodes were found in 5% of the wheat and barley samples, but population density was not considered to be of economic importance. Presence of cyst nematodes in all sites investigated may suggest that these nematodes are probabely widely distributed in the ICARDA region.

Studies on Nematodes Affecting Food Legumes

As is evident from the above surveys cyst, root-knot, root-lesion and stem nematodes are the major parasitic nematodes affecting one or more of the three food legumes of principal concern to ICARDA. Hence more detailed studies were undertaken on these from 1982/83 season onward.

1. Cyst nematode (*Heterodera* sp.)

Host range of chickpea cyst nematode (*Heterodera* sp.) was studied in the 1983/84 and 1984/85 seasons respectively, using 46 and 50 crop species, and it was observed that the range was confined to *Leguminosae* such as chickpea, lentil and pea and only a few females were observed on carnation. Wild species of chickpea were also good hosts for cyst nematode (ICARDA 1984, 1985b). Because of rather narrow host range of the chickpea cyst nematode, it should be possible to control it by using appropriate crop rotations.

Biology of chickpea cyst nematode was studied at Bari, Italy in

1984/85 and at Bari and ICARDA in 1985/86. It was observed that Heterodera sp. can complete its life cycle in about 40 days at 20°C and second stage of juveniles emerge easily from cysts at 15-25°C (ICARDA 1985b). Second stage juveniles of (Heterodera sp. invade roots of chickpea soon after plants emerge both in winter and spring sown plots (ICARDA 1986). Only one generation per year occurs.

Light and scanning electron microscopy studies and studies on the host range of the cyst nematode infesting chickpea in Syria have shown that the nematode is a new species, Heterodera ciceri sp. n. (Vovlas et al. 1985).

Relationship between population densities of Heterodera ciceri and yield of winter and spring sown chickpea and winter sown lentil have been studied (ICARDA 1985b, 1986). Chickpea tolerates populations of $\leq$ 1 egg/cm of soil but yields are reduced by 50% or completely lost when populations of the nematodes are 16 egg/cm^3 of soil or exceed 64 egg/cm^3 soil, respectively. Lentil is less susceptible to H. ciceri and a tolerance limit of 2.5 eggs/cm^3 soil and maximum losses of 50% have been observed. The nematode reproduced better on chickpea than on lentil.

Screening technique for host resistance for cyst nematode has been developed (ICARDA 1984). Using this technique, preliminary screening of 300 lines of chickpea in 1983/84 and of 253 lines in the 1984/85 season in the greenhouse at Tel Hadya showed large genotypic differences in susceptibility. Advanced screening in the same season confirmed good tolerance in 11 lines (ICARDA 1985b). Further screening of 269 lines of chickpea in 1985/86, however, did

not give satisfactory results because of interference with root-rot and wilt disease pathogens; hence their screening will be repeated (ICARDA 1986).

A total of 175 lines of lentil were screened in 1984/85, but no resistance was found. Hence more lines will be screened in future.

2. Root-knot nematode (*Meloidogyne artiellia*):

Host range studies, using 53 crop species, showed that *M. artiellia* reproduced very well on *Leguminosae*, *Cruciferae*, and *Graminaceae*. Most of the species belonging to *Solanaceae*, *Umbelliferae*, *Cheopodiaceae*, *Cucurbitaceae* and *Malvaceae* were poor or non-hosts of the nematode. All members of *Compositae*, *Liliaceae*, *Linaceae* and *Rosaceae* were non-hosts. Among the *Leguminosae* and *Graminaceae*, cowpea, lupin and maize were non-hosts and bean, lentil, soybean, sanfoin and oat were poor hosts of the nematode and could be included with profit in a rotation program aiming at reducing the losses from this nematode (ICARDA 1985b).

Studies on biology of *M. artiellia* revealed that the nematode invaded roots of chickpea in winter and females and egg masses of the nematodes were observed by early and late March, respectively. No diapause of *M. artiellia* eggs was observed and the nematodes survived during dry and hot summer months both as eggs or juveniles, and 20% of the nematode population at harvest still occurred the following autumn (ICARDA 1986).

Screening of 341 lines of chickpea including wild species for resistance to root-knot nematode in Italy revealed no genetic

variation in 1984/85 (ICARDA 1985b). Another 110 lines were screened during the 1985/86 season, and 19 lines were identified as resistant and 8 moderately resistant (ICARDA 1966). These 27 lines will be retested for their reaction.

3. Root-lesion nematode (*Pratylenchus thornei*):

Host range of this nematode was studied in 1983/84 using 46 crop species, and it was observed that both legumes and cereals were affected by the nematode, and faba bean, pea, lentil were good hosts (ICARDA 1984).

Field screening of 100 lines of chickpea for root-lesion nematode resistance indicated most of the lines to be susceptible (ICARDA 1984).

Soil application of aldicarb (Temik -10G) reduced populations of root-lesion nematode and root necrosis in faba bean and chickpea (ICARDA 1985b). However, some phytotoxicity was observed on chickpea when 10kg a.i. aldicarb was applied per hectare. Application of 10 kg a.i. aldicarb/ha in two or three splits reduced the phytotoxicity (ICARDA 1986). Soil solarization also reduced the infestation (ICARDA 1986).

4. Stem and bulb nematode (*Ditylenchus dipsaci*):

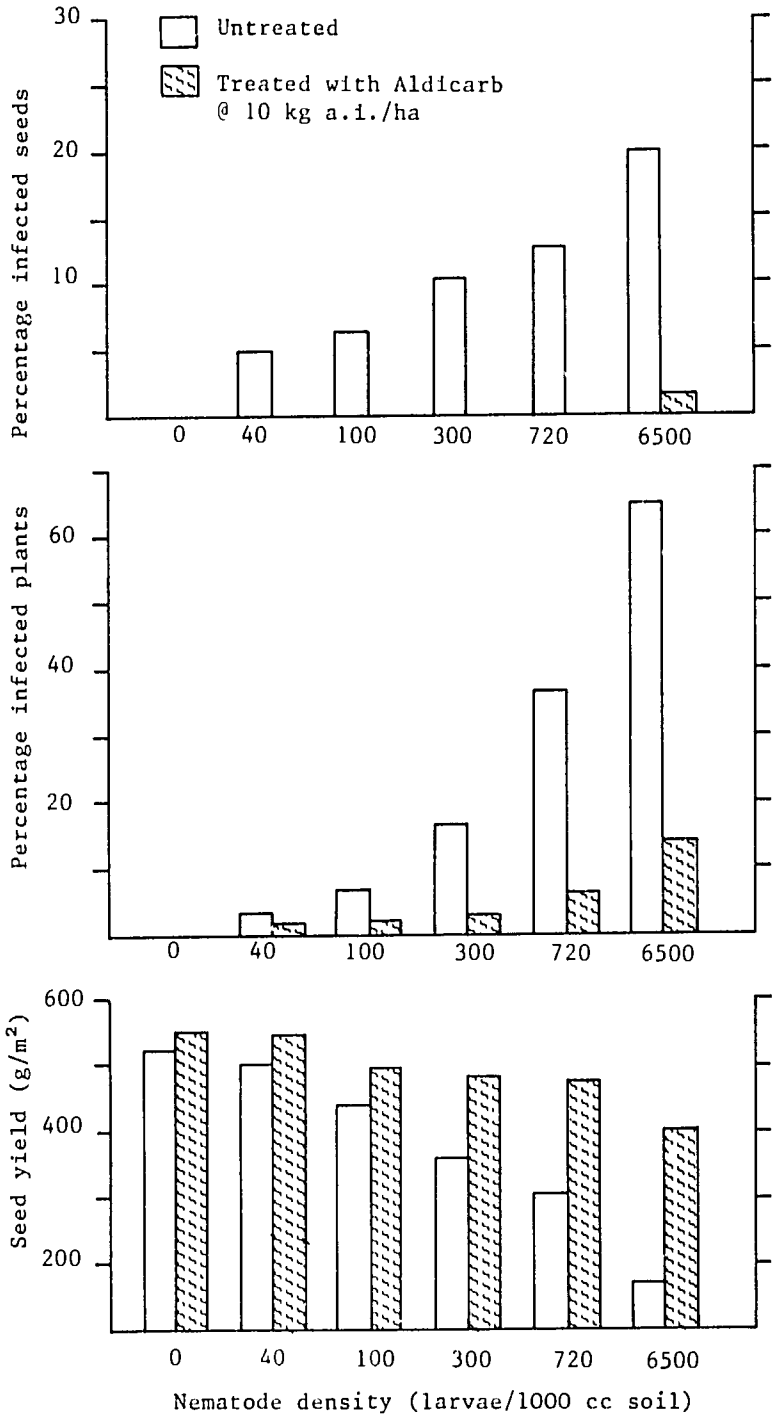
This nematode is an important seed and soil borne pathogen (Green 1979) throughout the faba bean production region in Europe, North Africa and Middle East. The nematode has been, therefore, under

study from the very start of the Center. Our studies have shown that reduction in faba bean yield up to 67% could be obtained in fields in Syria. The 'giant race' predominates (Hanounik and Sikora 1980) which is generally more destructive (Hooper and Brown 1975). Although the use of clean seed affects the survival and dissemination of stem nematodes, effective control can be achieved only if host-resistance and chemicals (Hanounik 1983; Hanounik et al. 1986) are used in combination with other sanitary control measures, particularly when population levels of D. dipsaci present in the field are high. Therefore, our efforts concentrated on identifying useful sources of resistance and developing practical chemical control measures against this nematode.

Evaluation of ICARDA's pure line collection of faba bean in 1981 and 1982 in the artificially infested soil, in the field at Lattakia sub-site in northern Syria led to the identification of 12 lines resistant to stem nematode (ICARDA 1982). Confirmation was done in field screening in Tunisia in 1984 (Hanounik et al. 1986).

Effect of aldicarb (Temik-10G) on yield and nematode infestation of seed of faba bean, grown at different population densitites of D. dipsaci in the field, was studied at Lattakia sub-site of ICARDA. Results (Fig. 1) showed that yield reduced significantly as the population density of D. dipsaci increased beyond 40 larvae/1000 cm^3 soil. Aldicarb application significantly increased yield at all the levels of nematode population, and gave nematode-free seed at all populations except at the highest level of infestation (6500 larvae/1000 cm^3 of soil). Plants grown in untreated plots, however, yielded infested seeds even at the lowest

Fig. 1. Effect of aldicarb (Temik-10G) on yield and nematode infestation of seed of faba bean grown at different population densities of Ditylenchus dipsaci in field at Lattakia, north Syria.



population density. Thus aldicarb can be used to reduce losses due to stem nematode and produce nematode free seed to prevent nematode dissemination.

Studies on Nematodes Affecting Forage Legumes

Root-knot and cyst nematodes were observed to cause considerable damage to leguminous forage crops, such as forage vetches, forage peas and chickling in 1983/84. Herbage yields were reduced because of loss in plant populations. Studies were, therefore, initiated to screen existing forage crop genotypes for resistance to these nemtodes.

One hundred strains of forage pea and 81 of vetches including common vetch (Vicia sativa) wooly pod vetch (Vicia villosa ssp. dasycarpa) and narbon vetch (Vicia narbonensis) were examined for their susceptibility to cyst and root-knot nematodes in 1984-85 in a field at Tel Hadya heavily infested with both nematodes. Nematode population was monitored by taking soil samples before planting and during crop growth (Table 1). Random samples of plants were taken to isolate the nematodes and determine the degree of root infestation. Root symptoms were root-knots, excessive branching and injured root tips in case of root-knot nematode attack. The common symptoms of cyst nematode were the presence of female nematodes in varying stages of development and cysts attached on to the roots. Nodulation was affected adversely.

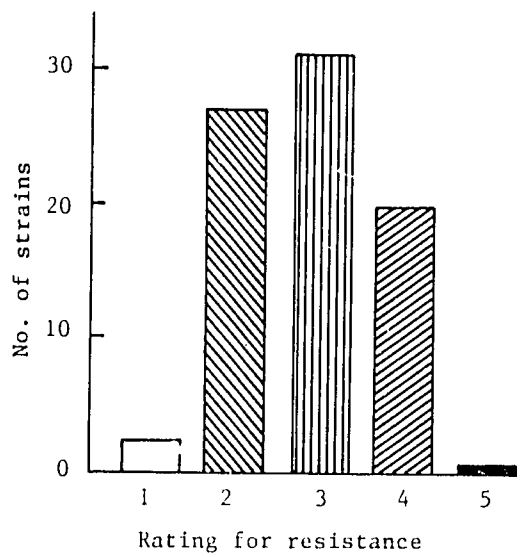
Preliminary observations from this study confirmed that forage vetches are severely attacked by both cyst and root-knot nematode. Three vetches (common vetch selection 2005, 1432 and wooly pod vetch acc. 683) were resistant to root-knot nematode (Fig. 2), 27 were

Table 1. Number of cyst and root-knot nematodes present in soil samples on five sampling dates, Tel Hadya.

Sampling date	Cyst nematode[1)]	Root-knot nematode[2)]
30.11.1984	29	495
3. 3. 1985	33	231
4. 4. 1985	34	783
6. 5. 1985	35	1275
14.6. 1985	33	

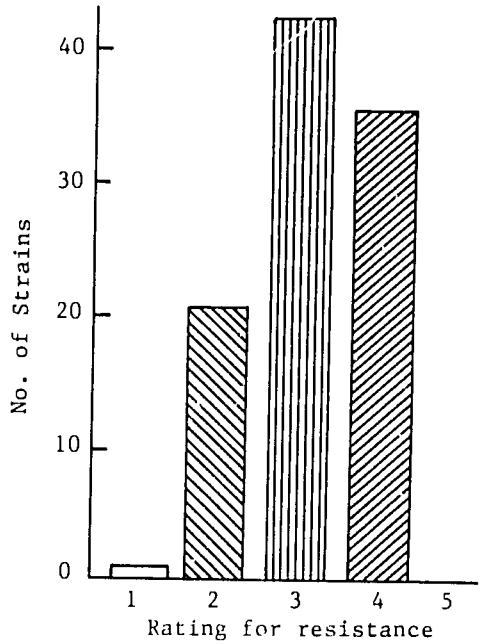
1) Cysts per 200 g soil
2) Root-knot larvae per 500 g soil.

Fig. 2. Variability in resistance to root-knot nematode among 81 strains of vetch, based on the following scores 1 = resistant: no galls or very light galling; 2 = tolerant: light galling; 3 = moderately susceptible: moderate galling; 4 = susceptible: heavy galling; 5 = very susceptible: very heavy galling.



tolerant and the remaining 51 were moderately susceptible to very susceptible. Resistance to root-knot nematode increases the value of wooly pod vetch which has also resistance to broom rape (Orobanche sp.). The local common vetch was moderately susceptible to root-knot nematode.

Fig. 3. Variability in resistance to cyst nematode among 100 strains of forage peas, based on the following score: 1 = resistant; 5 = very susceptible.



In forage peas, the mean number of cysts per gram of roots was high (471) with a big range from 9 (in selection 61) to 3021 (in selection 571). In the field screening some strains were resistant or tolerant (Fig. 3).

1. Root-knot nematode in vetches:

In order to verify the results of field screening of 1984/85, the screening for root-knot nematode resistance was repeated in 1985/86 using 30 selections of vetch both in the field with natural infestation, as well as, in the greenhouse using artificial infection. Nematode population in the field was again high

Table 2. Mean number of cyst and root-knot nematodes present in soil of field A18 on six sampling dates, Tel Hadya.

Samlping date	Cyst nematode[1)]	Root-knot nematode[2)]
6. 11.1985	160	600
31.12.1985	220	1120
30. 1. 1986	200	1116
3. 3.1986	210	2660
8. 4.1986	185	2720
5. 5.1986	165	2270
Mean	190	1748
LSD (P<0.05)	19.0	394

1) Cysts per kg soil.
2) Root-knot larvae per kg soil.

(Table 2), even higher than in 1984/85. The greenhouse screening was done by artificially infecting the soil with 2000 eggs/kg soil.

The results confirmed the observation that wooly pod vetch (sel. 683) is highly resistant under both field and greenhouse conditions to root-knot nematode. Narbon vetch (acc. 67), and 13 of the 28 common vetch strains showed tolerance, while 15 of the common vetch strains failed to repeat their performance of the previous season.

2. Resistance to cyst nematode in forage peas:

Twenty two lines of forage peas were selected from the initial field screening in 1984/85. These were further assessed in 1985/86 in artificially infested soil in the greenhouse (400 cysts/kg soil). At the beginning of flowering the roots were washed and assessed for the presence of cysts. The greenhouse screening did not reveal any selection which could be rated as resistant. Selection 61, did not

repeat its resistant performance. However, there were five selections showing good tolerance and this group included selection 61.

3. Resistance of two chickling species (Lathyrus spp.) to cyst nematode:

Screening of chickling for resistance to cyst nematode began in 1985/86. Sixteen promising selections were screened in a field highly infested with cyst nematode, and under artificial infection in the greenhouse. Under field conditions the mean number of cysts/g root varied from 13 to 218 (average 146). Chickling species Lathyrus ochrus (selection 185) was resistant under field condition and tolerant in the greenhouse screening. Two other selections of L. ochrus (384 and 385) were also tolerant. The rest were either moderately susceptible or susceptible.

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CROP LOSS ASSESSMENT IN NEMATOLOGY

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Introduction

Crop loss is defined as the difference between attainable yield and actual yield (Chiarappa 1971). Attainable yield is difficult to determine, and depends on many cultural, environmental, and pest factors. Usually, yields obtained in protected or treated plots are considered attainable in a given agricultural system. Actual yield is more easily defined as that obtained under prevailing pest pressure, or with no protection. Crop losses due to nematodes would be that portion of the difference directly or indirectly attributable to the presence of nematodes.

Assessment of the extent of these losses is a unique combination of art and science, with the sources of various estimates ranging from informed guesses to replicated experiments with elaborate statistical sampling procedures. Determination of losses may be done on macro and micro scales. Macro assessments consist of large-scale geographic surveys, where the goal is to estimate losses for entire countries, or regions (Sasser and Freckman 1987 - In press). Micro assessments consist of the determination of damage functions in individual fields or in other experimental units (greenhouse pots, microplots, or small field plots).

The uses for information from macro and micro scale assessments are quite different as well. Micro information is most useful in the formulation of management models and for providing advisory services to growers. Macro scale data may be used by institutions and government leaders for the allocation of resources and the determination of research priorities. Both functions are extremely important to the continued health and growth of our science. Farmers need accurate management recommendations as options are decreased and profit margins grow ever thinner. The importance of crop loss assessment on a large scale was well stated by Lyman (1918) as follows:

> "How can we expect practical men to be properly impressed with the importance of our work and to vote large sums of money for its support when in place of facts we have only vague guesses to give them..."

The two aspects of assessment, macro and micro, are closely linked, in that large scale surveys are usually concerned with determining nematode occurrence and population levels, whereas micro-scale damage functions must be used to translate nematode population counts into estimates of crop damage. Usually the experimental phase should precede survey work, since the information obtained from nematode surveys would be of little use until damage functions were available. Some surveys, however, attempt to assess crop losses directly from authoritative best-guesses. In these studies there may be no back-up experimental work, and the guesses must stand on their own as unverified estimates of crop losses. In this presentation, surveys will be considered first, followed by a discussion of methods for determining nematode damage functions.

Nematode/Crop Loss Surveys

Several approaches to collecting information are useful for large-scale assessment work. Authorities in target areas can be asked to estimate crop damages, and the results can be averaged to ascertain general crop loss figures. An example of this type of survey has been presented earlier by Sasser in this meeting. Another approach, which may be more successful on a smaller scale, is to send surveys directly to growers for estimation of losses. This technique assumes a fairly literate and informed farming population, and works only for obvious, easily identified pest problems, such as root-knot and cyst nematodes. However, a predominant charactersitic of plant-parasitic nematodes has been that they are the unseen enemy, causing subtle crop losses by damaging below-ground plant parts. In many agricultural systems which sustain significant losses to nematodes, the only way to detect nematode involvement is by assaying the soil and plant roots for the presence of parasitic species.

Assaying large geographical areas for nematodes has been done primarily to detect and categorize the distribution of nematode problems. The techniques useful in this type of assessment, have been discussed by Bridge at this meeting. Ideally, however, the next step is to conduct large scale surveys aimed at determining the incidence and population densities (extensity and intensity in epidemiological terms) of parasitic species previously determined to be important. It is not enough to know that the nematodes are there. We also must know to what extent and in what numbers they are occurring in order to make reasonable predictions of crop losses. In some ways, we are fortunate in nematology, in that crop-losses are heavily dependent on the number

of nematodes present in the soil at planting. Assessing potential crop losses becomes largely a matter of counting nematodes. We do not need to assess disease levels directly (and probably could not, for most plant-parasitic nematodes), and we need not be concerned with large influxes of inoculum from other fields and areas, as is the case for foliar plant diseases.

Determining the intensity of a nematode infestation over an entire country, or region, is a formidable task, but this task may be reduced to manageable proportions by the adroit use of statistical sampling designs. Particularly important is the use of a priori information: that is, the existing knowledge and experience of local authorities. All parts of a country, or region, do not have an equal likelihood of having a particular nematode species. Cropping patterns, soil types, and previous nematode surveys all can be used as a priori information to design efficient sampling schemes. Obviously, it makes no sense to sample non-agricultural areas and areas where there are no known host crops grown for the target nematodes. Additionally, some soil types may favor heavy infestations. Usually, the nematode species is of interest only because problems already have been identified in certain agricultural areas.

Statistical sampling methods have been developed to increase the efficiency of large-scale surveys. Efficient distribution of samples is critical, since resources are usually quite limited for this type of work. Very large geographical areas must be represented with relatively few samples. A commonly used technique for increasing sample efficiencies is called sampling with probability proportional to size (PPS). In this technique, a specified number of samples are

alloted to certain geographical areas according to the magnitude of some known variable. For instance, the total hectares of wheat grown in each area can be used to allot samples in an efficient manner. If wheat is the primary host crop of interest, then it makes no sense to sample soils where wheat is not grown. Likewise, the total hectares per area can be used to apportion more samples to those areas which are most intensively cultivated in wheat. This method of apportioning a limited number of samples can be further refiend by the use of certain agricultural techniques (selection with unequal probabilities). Appropriate use of these techniques is well documented and provides statistically reliable methods for deploying limited resources to obtain the most efficient, minimally-baised estimates of nematode population densities (Cochran 1977).

After a certain number of samples has been alloted for an area, the fields to be sampled must be selected. Usually, this selection is made randomly, from a listing of all growers in the area. Care should be taken to ensure that no bias enters into the sample selection. For instance, it is common for researchers to select growers that are well known, or large growers. Often, these farmers are successful because they are better crop managers, and the pest situation in their fields is not representative of the typical farmer.

The method of collecting soil samples for nematode assay should be standardized throughout the survey, in accordance with recommended sampling procedures (Barker 1985b). Care also should be taken in handling and storing the samples until processing. Appropriate extraction methods should be used for the target nematode species and life stages (Barker 1985a). Baermann techniques are commonly used, but

are not appropriate for sedentary nematodes, or non-motile life stages of active nematodes (cysts and eggs). Special extraction methods must be used for these nematodes, which may exclude other species. Bioassays should also be considered where they can provide reliable quantitative estimates of nematode density. In irrigated desert systems, or where a definite dry season occurs between growing seasons, plant-parasitic nematodes may be undetectable before planting, even though the soil is heavily infested. However, a bioassay can accurately indicate nematode densities by allowing surviving life-stages to infest an appropriate host.

Every step of the assessment process must be standardized and done in the most efficient manner possible to provide accurate estimates of crop losses over a large geographical area. There will never seem to be sufficient time or resources to do a complete survey. For this reason, resources must be used to assay for the most important nematode species in the most important crops. Only by working closely with local scientists and using their experience and knowledge, can an accurate crop loss assessment be obtained with a reasonable effort.

Experimental Determination of Nematode Damage Functions

In order to make use of nematode population assays to estimate crop losses, there must be some way to relate crop performance to nematode numbers. Usually, this is done with a mathematical expression called a nematode damage function, which relates crop yield to preplant nematode numbers. Preplant counts are emphasized, since all available management options for limiting losses due to nematodes must be

deployed prior to planting the crop. Mid-season counts may be more strongly related to crop performance, but would be of little practical significance, since there is nothing the farmer can do at mid-season to avoid losses due to nematodes.

Greenhouse pots: Experimental methods for derivation of nematode damage functions include the use of greenhouse pots, microplots, and small field plots. Regardless of which methods are used, the aim is to implement as large a range of nematode densities as possible in the soil, and then measure crop performance. Where greenhouse pots are used, a known amount of nematode inoculum is prepared and added to sterile soil/sand mixtures at differing rates. The rates must be selected judiciously, since the goal is to determine nematode damage from zero to maximum damage. Typically, large amounts of nematode inoculum must be prepared, and this may be difficult for some nematode species. Some nematodes, typically large ectoparasitic species, may not infest host plants and reproduce in the greenhouse. Many plant-parasitic nematodes have not been given the attention they deserve, simply because they cannot be cultured easily in pots.

After nematode inoculum has been mixed into the soil of individual pots, in a replicated, randomized design, an appropriate host plant is planted in each pot. Non-inoculated controls are included, and performance of the plants is measured for each pot. Yield may be measured in terms of the usual marketable product, if the crop will mature properly in greenhouse pots, or fresh and dry weights of shoots and roots may be measured. The length of time plants are allowed to grow may affect yield responses. It is best if plants are allowed to mature, but this may not be possible in relatively small pots.

Greenhouse methods are best suited for establishing the host status of a wide range of plant species and cultivars. However, information obtained in greenhouse pots is not a reliable indicator of crop performance in actual field situations, and will not usually provide a suitable base for the formulation of applied management models. The controlled environment of a greenhouse does not accurately represent crop stresses experienced in a farmer's field. In addition, greenhouse methods may not be feasible for all important nematode species, due to difficulties in culturing the nematodes in pots and in the production of inoculum.

Microplots: Ideally, nematode damage should be assessed in naturally-infested field plots, in order to represent accurately losses experienced by farmers. Field work, however, can be quite labor intensive, time consuming, expensive, and risky. An intermediate step between the greenhouse and field has been the use of microplots. Microplots are small (1-2 m diameter), fiberglass-enclosed (to a depth of 1 m with an open bottom) plots established in a systematic fashion in a research field. The plots are usually fumigated before use and then infested with varying rates of nematode inoculum in a randomized design. The selected host is planted in each microplot and allowed to grow to maturity. Crop yields are measured in each plot. Additionally, nematode population dynamics can be monitored by assaying soil samples from the microplots at regular intervals.

Using microplots to determine nematode damage functions has some of the advantages of using field plots and some of the disadvantages of using greenhouse pots. Nematode inoculum must be produced to infest the microplots, and the inoculum is required in even larger quantities

than for greenhouse pots. For many nematode species, it is not possible to produce enough inoculum to infest microplots at high enough densities for determination of the maximum crop loss potential. It may be possible, however, to allow inoculum to build up naturally by planting a suitable host in preceding growing cycles. This also allows the soil environment to return to a more natural biological equilibrium after fumigation. Additionally, different soil types can be placed in microplots located at the same site, which allows determination of the impact of soil characteristics on nematode damage functions. The fiberglass enclosures alter water relationships to some extent, but generally, microplots provide a more accurate representation of crop losses experienced in farmers' fields than do greenhouse methods.

The use of microplots for determination of nematode-crop relationships has been discussed in greater detail elsewhere (Barker 1985c). Both greenhouse and microplot methods provide useful information, and where feasible, should be used in preliminary investigations of crop loss relationships. A researcher certainly would want to establish the host status and damage potential in a nematode-host combination before embarking on large-scale field tests. The field, however, is the ultimate laboratory for the determination of crop loss functions.

Small field plots: Nematode damage functions can be derived in naturally-infested fields by establishing relatively small (24 m^2) plots in a rectangular grid and monitoring nematode populations and crop yields in each plot. Again, the emphasis is on relating crop yields to preplant nematode densities, so very few variables must be monitored. There are different approaches to the use of field plots.

Some researchers set up and manage plots essentially as large microplots without barriers. That is, they establish plots separated by buffer areas, fumigate them, and artificially infest them with selected nematodes. Crops are then planted and managed artificially with manual small-plot techniques. A better approach for crop loss assessment is to establish plots in a large field which is planted and managed by common farming techniques. This process is labor intensive, but not very complex or expensive to set up and monitor. Ideally, farmers' fields may be used, which means that crop cultivation is not the responsibility of the researcher. Plots also can be established on research farms where appropriate.

The first step is to find a number of fields heavily infested with the target nematode species. This should not be very difficult if the nematode is a significant pest to begin with. Next, the fields are pre-sampled to determine areas of high and low infestation. Immediately after planting, grids of plots (64-100 plots per grid) are marked in each field with the grid overlapping an area of high infestation and an area of low infestation. Appropriate placement of the grids ensures that a broad range of nematode densities will occur naturally in the plots. This range is necessary to determine the entire nematode damage function, from zero to maximum damage. Typically, plant-parasitic nematodes have a very clustered spatial pattern in infested fields, so it is not difficult to obtain a wide range of densities among small plots. In fact, a primary diagnostic characteristic of nematode damage is that it occurs in discrete patches. These patches can be used to aid in the correct placement of research plots, if a field is identified during the preceding growing season.

Where sufficient diversity in nematode densities was not obtained in field plots, various management techniques may be applied to enhance natural variability. Differing crop rotations can be used in separate areas of a field, or some areas may be left fallow while others are planted with a good host. As a last resort, some areas may be treated with nematicides, while others are left untreated. This is not a desirable way to manipulate nematode densities, since most nematicides affect other pests, and may affect yield directly in unpredictable ways. It is essential that measured differences in yield represent nematode activity, and not the effects of controlling other pests or biochemical stimulation of plant growth.

Other than obtaining an appropriate range of nematode densities, there should be little difficulty in implementing field methods for determining nematode damage functions. Soil samples can be collected for nematode assay as plots are marked, and plots can be assayed again at harvest for analysis of population dynamics. In between, there should be no disruption of normal farming practices, which essentially means that the farmer maintains the plots. At maturity, each plot must be harvested individually, which may disrupt the farming operation and should be coordinated carefully with the grower. Methods for using small field plots in crop loss assessment and cropping systems analysis for improving management decisions have been described in detail elsewhere (Noe 1986).

Research grids should be replicated at a number of sites, and over a number of growing seasons, in order to obtain estimates of "typical" crop losses in "typical" growing seasons, as well as estimates of variability in nematode damage functions due to differing soil types

and environmental stresses. This design may require establishing a large number of plots, but only nematode counts and yield estimates need to be collected from each plot. From this data, statistical procedures can be used to determine crop loss functions which represent actual damages incurred by local farmers under existing management practices. Nothing else will provide scientists, administrators, and farmers with the information they need for improved decision-making.

Nematode damage functions: After collecting experimental data to be used in estimating nematode damage functions, appropriate statistical methods and mathematical models to describe the functions must be selected. A typical damage curve begins with a somewhat level phase, followed by an area of rapid decline in yield with increasing nematode numbers. Eventually, the rate of decrease in yield levels off, becoming asymptotic at some point. The minimum yield may be fairly large, or may be zero, but at some point the curve must level off. Several mathematical models have been proposed to represent this type of curve. A formula by Seinhorst (1965) has been most commonly used to represent the relationship of yields to nematode densities. This function begins with a straight line, representing unmeasurable losses at low densities, followed by a rapidly-declining negative exponential curve which levels off at minimum yield. Other models include linear fits to log-transformed data and various inverse-logistic curves. Within the framework of sampling and experimental error inherent in field work, there is little justification to recommend one particular mathematical function over another. The researcher should select the model that works best in his situation.

Summary, with a Look toward Further Uses of Crop Loss Assessments

Well designed surveys, individual field assays, and experimental quantitative work in determining nematode-host relationships will provide a wealth of information for agricultural scientists and decision-makers. Large scale surveys combined with damage functions and economic data give estimates of total monetary losses due to nematodes. This information can be used as a guide to allocation of limited resources in research and extension. Eventually, regular monitoring of pest losses can be implemented by using the personnel networks and quantitative data developed during initial crop loss assessments. Although such grand scale programs may not be feasible at this time, future technologies may bring them into the realm of possibility. Already, aerial infrared photography has been used sccessfully to detect losses due to cyst nematodes (Yuhara 1975). Satellite remote sensing, combined with computer analyses and interpretations may provide large scale crop loss assays for a number of important pests. However, even if such methods become feasible, they will still rely on a sound basis of experimental data on nematode-host relationships.

Nematode damage functions also can be combined with data on population dynamics and with economic and cultural information to create computer simulations of long-term cropping systems (Noe 1986). Through the use of linear programing and other optimization techniques, these simulations can be used to provide management recomendations for the best possible economic control of losses due to nematodes. When linked to nematode assay laboratories for farmers, these studies will become the foundations of future extension advisory systems.

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SCREENING POTATOES FOR RESISTANCE TO ROOT-KNOT NEMATODES *MELOIDOGYNE* SPP. AND POTATO CYST NEMATODES *GLOBODERA* SPP.

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Introduction

Resistant reaction of potato roots or tubers to nematodes is based on the ability of the nematodes to reproduce or develop specific symptoms on them. Accurate identification of resistance is dependent upon the efficiency and reliability of the screening methods.

As a vegetatively propagated crop, potato tubers and rooted stem cuttings are the main sources of testing material. However, in a resistance breeding program, a large number of true potato seeds are developed. These seeds are genetically different and, therefore, may have varying degrees of resistance. In order to avoid confusion, I will attempt to present the various screening methods used in the search for resistance to root-knot and potato cyst nematodes.

Screening for Resistance to *Meloidogyne* spp.

Screening potatoes for resistance to *Meloidogyne* spp. involves utilization of seed tubers, rooted stem cuttings, and true potato seeds. It is of paramount importance to note that the resistance to

Meloidogyne spp. in roots and tubers is different and independent from one another. It is also important to note that although various screening criteria are known, in most cases, they are primarily based on the ability of the nematodes to reproduce or develop symptoms on roots. Unfortunately, some important aspects of plant resistance, such as the quantity and quality of root systmes, have been overlooked in many screening procedures. I would, therefore, like to emphasize these important aspects of plant behavior during the resistant screening process. We have efficiently utilized this sort of information in our breeding and screening for resistance to root-knot nematodes. Our indexing of root galling and nematode reproduction is directly correlated with the quantity and quality of the root systems. Utilizing this correlation procedure, we have been able to exclude a large number of plants with false resistant expression but poor quality and very low quantity of root system from our breeding program. Therefore, our high selection pressure will exclude those plants which would have low yields despite their apparent resistance to nematodes.

A. Types of testing:

In testing potatoes for resistance to nematodes, we may consider an initial greenhouse test followed by a field test to obtain additional information such as yield, etc.

1. Greenhouse test:

a. Potato tubers. Whole or cut well-sprouted potato tubers are planted in 8-10 cm diameter clay or plastic pots containing sterilized potting soil. These pots containing tubers may be inoculated at planting or when the plants have emerged and

grown to a height of 5-10 cm. It is recommended that inoculation with nematodes takes place during the latter stage. To provide a uniformity in the screening process, it is suggested that each pot be inoculated with 4000 eggs. After a two-month growth period, roots are removed from the soil, examined, and the reactions of roots to nematodes are recorded.

b. Rooted stem-cuttings. Rooted stem-cuttings are transplanted in 8-10 cm diameter clay or plastic pots containing sterilized potting soil. After 7 days or when the plants are established, they are inoculated as described above.

c. True potato seeds. True potato seeds are treated with 1500 ppm Giberellic acid for 24 hrs to promote germination. After this period they may be washed and kept until a later date or planted immediately in trays containing a sterilized mixture of sand and peat moss (1:1). Care should be taken to avoid planting the seeds deep in the medium. When the plants are 5-10 cm in height, they are transplanted to 50-100 cc plastic cups containing sterilized potting soil and allowed to grow 7-14 days or until they are well established. They are then inoculated as described above.

2. Field test

Field experimentation provides additional data on the resistance of tubers as well as the yield. In this case plants are allowed to grow almost to maturity. Care should be taken to select a uniformly and highly infested field for such screening. At least

5 tubers or stem cuttings of each clone are to be used per row and the rows are replicated 5 times throughout the field. Young transplanted seedlings may also be used but in this case there is no replication.

B. Suggested procedures for obtaining and applying root-knot nematode inoculum

1. Inoculation with *Meloidogyne* eggs

a. Meterials:

1. Clorox (5.25% NaOCl) or similar commercial sodium hypochlorite solution.
2. 200-mesh and 500-mesh stainless steel sieves, standard height, 3 inches (7.5 cm) or more in diameter e.g. Tyler sieves (W.S. Tyler, Inc., Mentor, Ohio 44060).
3. A jar or similar container with large orifice and tight seal.

b. Procedures for obtaining egg (International *Meloidogyne* Project.)

1. Wash the soil from galled roots of a plant harvested 45-55 days after inoculation. If older plants are used, make sure that the roots are not in an advanced stage of deterioration. Eggs from roots of an older plant will be less uniform in development than if a younger plant is used.
2. Excise the roots and wash well. The cleaner the root system, the easier it will be to collect the eggs by the sieving process. If the root system is large, process only half at a time.

3. Prepare a 10 or 20% Clorox solution (v/v), (0.525% or 1.05% sodium hypochlorite, respectively). A 20% NaOCl solution frees more eggs at a faster rate.

4. Place the washed roots in a jar, add 200 ml NaOCl solution and seal the top. Vigorously shake jar for 4 mins.

5. After shaking, quickly pass the NaOCl solution through the sieves, a 200-mesh sieve nested in a 500-mesh sieve. Once the original NaOCl solution has been sieved, fill the jar containing the roots with water and set aside. After the NaOCl solution has been passed through the sieves, remove the 200-mesh sieve and hold the 500-mesh sieve (containing eggs) under a slow stream of cold tap water to remove residual NaOCl. Rinse eggs from 500-mesh sieve into a 2-liter beaker.

c. Inoculum application: Suspension of eggs can be applied on the surface or in indentations or holes made in soil around the growing plants to provide unifomity, each pot should be inoculated with 4000 eggs in 4-5 ml water. After inoculation irrigate the pot lightly to assure survival and even distribution.

2. Inoculation with chopped, galled *Meloidogyne*-infected roots.

If there are no facilities to obtain eggs, *Meloidogyne* infected roots can be used as inoculm. Utilize this method as the last resort. There are two types of application methods:

a. Apply 0.5 - 1.0 g (depending on the quantity of egg masses

present) chopped, galled roots in the depressions made around the seedling or plant roots at inoculation time. Cover with soil and irrigate.

b. Throughly mix the correct amount of inoculum with the potting soil prior to planting.

C. Resistance evaluation

For determination of resistance, the following scale of root galling index and nematode reproduction is recommended. In utilizing this scale, one must consider the quality and quantity of roots and score the various levels of resistance accordingly.

1. Root infection and galling index

1 = Immune = no root galling and/or nematode reproduction

2 = Resistant = trace of root galling and/or trace of nematode reproduction

3 = Moderately susceptible = moderate root galling and/or moderate nematode reprodution

4 = Susceptible = severe root galling and/or a high nematode reproduction

5 = Very susceptible = very severe root galling and/or a very high nematode reproduction.

Plants showing a root galling of 1 or 2 should be tested again to avoid the possibility of escape.

2. Tuber infection index

Reaction of tubers to root-knot nematode is rated as follows:

1 = Resistant = no external galling and/or no evidence of nematode presence inside tubers

2 = Modertately resistant = no external galling but evidence of nematode presence inside tubers

3 = Susceptible = external galling and deformation of tubers.

In addition to the above, field data may be obtained using a a rating system of 1 to 5 (1 = no tuber galling or deformation, 5 = 100% tuber galling or deformation per plant) to indicate percent visible tuber infection per plant.

Screening for Resistance to Cyst Nematodes, *Globodera pallida* and *G. rostochiensis*

Although several methods of screening for resistance are used by different investigators, basically these methods measure similar parameters. In an effort to increase the efficiency of our screening process, various methods were evaluated and a modification of these methods was adopted . It is believed that utilization of the following methodology would enhance the accuracy of the screening process as the procedures can be readily adopted as a routine process without the need of sophisticated equipment, etc.

A. Inoculum source

There are several races of the two species of potato cyst nematodes. In order to have meaningful information, it is of paramount importance to determine the races of the nematodes used in the screening process. Once this information is available, soil samples

are to be processed to extract cysts. Through the use of sieves or simple visual screening process, cysts of equal size are to be selected. Normally cysts retained on a 35 mesh (500 mm) sieve would be desirable for utilization in the screening. The total viability is determined by crushing 25 or 30 cysts in a given amount of water and the number of eggs and juveniles per cyst is calculated. The infective viability is determined by placing 25-30 cysts in root exudates of a susceptible potato and allowing the eggs to hatch for a period of 4 weeks. Periodic changes of root exudates are to be made to avoid fungal buildup. The infective viability usually constitutes 60-70% of the total viability. The differences of infective viability and total viability is denominated as the residual viability (30-40%). Those in the last group would eventually emerge at the same proportions as above with additional and further stimulation by fresh root exudates.

In the screening process carried out in pots, cysts with a known total viability are used.

B. Resistance evaluation

After treating the seeds with 1500 ppm Giberellic acid for 24 hrs, they are washed and dried for future use.

1. Individual seedling testing

Seedlings of 5-10 cm height are transplanted to 50-100cc plastic cups as described in the screening process for *Meloidogyne* spp. Sufficient cysts are added at transplanting or 15 days after transplanting to provide a concentration of 20 eggs/g soil and

plants are allowed to grow for 8-10 weeks. After this period cups are inverted and the root-balls are carefully removed for observation of the developing females. The following scale is used to determine the reaction of plants to nematodes:

Resistant (R) = 0-5 developing females/root-ball

Partially resistant (PR) = 6-15 developing females/root-ball

Moderately susceptible (MS) = 16-50 developing females/root-ball

Highly susceptible (S) = > 50 developing females/root-ball.

All the plants with a root-ball exhibiting more than 5 females are discarded and those with less than 5 females are allowed to mature. Number of cysts per cup is determined. Once again utilizing the above classification scheme, only tubers of plants with less than 5 cysts are retained for further testing.

2. Tuber testing

Well sprouted tubers are planted in 7-10 cm diameter pots and sufficient cysts are added at planting to provide an inoculum concentration of 20 eggs or juveniles/g soil. All the procedures for evaluation and selection are carried out as described above for individual seedling test.

In both the individual seedling and individual tuber test, the process is repeated for the second time utilizing the progenies of the individual seedling test to provide replications. It is recommended that the first and second tuber tests as well as the progenies of the first individual seedling test have no less than 3 and, if possible, 5 or more replications per treatment. Nematode multiplication rates (Pf/Pi) are

calculated for those exhibiting less than 5 females during the first observation after 10 weeks of exposure to nematodes.

3. Mass seedling testing

The objective of this test is to evaluate and select families having the highest frequency of segregation for resistance. For this test rectangular tray-like recepticles having the capacity of accommodating the growth of up to 40 seedlings are used. Trays are filled to 3/4 capacity with sterilized desirable potting soil (sand- peat moss mixture). Sufficient cysts are added to provide a final concentration of 20 eggs/g soil. Seeds are sowed and covered with a thin layer of the same soil mixture. Plants are allowed to grow for 8-10 weeks after germination or until the gravid female nematodes can be observed on roots. In order to determine the rate of nematode growth, a recepticle of the same size having small equal-sized rectangles cut out at the bottom to facilitate root observation, called as "the observation tray", is used. The complete soil and root masses are removed and placed in the observation tray. Roots are examined from under and through the cut out rectangles and the number of females are recorded. Utilizing this method, families with the lowest frequency of females/root can be selected for further testing. To facilitate handling, plastic trays are recommended for this test.

4. Petri plate testing

This is a very sensitive method of screening with a very high accuracy. It is recommended for use only after the first two pot

tests have indicated the resistance of a given cultivar or clone. It consists of placing a well washed and surface sterilized piece of a selected tuber with a well developed sprout on the corner of a petri plate containing 2% water agar. Plates are then kept vertically at 20°C to allow the roots to grow on the agar surface. These roots are inoculated by placing 5 freshly hatched juveniles at the root tip. The points of inoculations are marked on the plate to facilitate further observation. After 39 days the roots are checked for the growth of females and evaluated by utilizing the following formula:

$$\text{Development of nematode} = \frac{\text{No developed females X 100}}{\text{No. juveniles inoculated}}$$

5. Field testing

Response of the selected clones after the initial greenhouse tests is evaluated under field conditions to assess their agronomic characteristics as well as behaviour under naturally infested conditions. Data such as tolerance to nematode infection can also be collected. Nematode multiplication rate (Pf/Pi) is measured by obtaining the initial and final cyst and egg populations.

The screening procedures, methodologies, and criteria described above are summarized in Table 1. These are results of several years of intensive studies at the International Potato Center.

The information presented above was also discussed earlier in two separate meetings and planning conferences held by the Latin American nematologists working on potatoes and a meeting of

Table 1. Test procedures, criteria and scale of resistance reaction used for screening potato germplasm for cyst nematodes at the International Potato Center, Lima, Peru.[1]

Test	Criteria	Parameter	Scale	Reaction
Pot test (tuber and/ or seedling test)	Visual observation for female nematode formation	No. of young females on root-ball	0-5 6-15 16-50 >50	R PR MS S
	Estimating final population of cysts (C) and/or eggs (e)	Cyst multiplication rate (cPf/cPi)	1.0 1.0-1.3 1.3-2.0 >2.0	R PR MS S
		Egg multiplication rate (ePf/ePi)	1.0 1.0 1.0-3.7 >3.7	R PR MS S
	Reproduction in relation to susceptible host	Suscpetibility index: $\frac{\text{Pf of tested clone}}{\text{Pf of susceptible clone}} \times 100$	0.0 1.0-12.5 12.5-25.0 >25	R PR MS S
Petri plate test	No. of developed females	Female index: $\frac{\text{No. developed females}}{\text{No. juveniles inoculated}} \times 100$	0.0 7.0	R PR
Field test	Visual observation of females and consideration of root development	No. of females on roots	none = 0 1-20 = 1 20-50 = 2 >50 = 3	R PR MS S

R = resistant; PR = partially resistant; MS = moderately susceptible; S = susceptible.
1/ Courtesy of Dr. J. Franco and Ing. A. Gonzales.

the same nature was held for the Asian scientists in the Philippines in an attempt to unify the methodologies used by various investigators. After thorough discussions, the methodologies described above were unanimously accepted by all the scientists involved. An accomplishment of this task is believed to be the first of its kind in plant nematology. It is hoped that such criteria or their modifications can also be applied to other crops and nematodes.

SEEKING NEMATODE RESISTANT FOOD CROPS

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Introduction

Out of sight- out of mind. And certainly out of consideration is all too often the role for soil-borne nematodes when the reason for a crop yield decline is being sought. The cunning ability of nematodes for a slow, step-by-step development, often with frequent pauses, into a destructive force borders on treachery in that the farmer was unaware of the trap he had helped construct by growing susceptible crops on the same land too frequently.

With each turn of the planet, the nematodes parasitic on plants are assuming greater importance as their accelerated spread by man joins with the expansion of old crops into new areas; as the use of good land intensifies; as more efficient farming is required to meet the competition from other farmers and other crops, local and foreign; as marginal land is increasingly used by minimum-input smallholder farmers; and as consumer demands rise. In general, the greatest losses caused by nematodes occur on soils that have been under cultivation for long periods and where ignorance, economic pressure for continuous cash crop production or land scarcity has resulted in a limited or no rotation system. These and other considerations command a supply of better crops for farmer's economic well-being and community welfare.

Enter the Nematologist

That the problem exists has been acknowledged to some extent by the hiring of a nematologist. His role is to control the nematodes. However, control is relative to the crops being grown and the nematodes in the soil and satisfactory economic control may change with the price of the marketable produce. In general, the more primative the agriculture the more losses are accepted as good yields are not expected and output does not have to cover high input costs. The means for controlling nematodes are many and diverse. Their selection and implementation will depend on local farm and farmer situations.

All control principles are based on the imposition of certain stress factors on nematode populations. The imposed stress or stresses affect the nematode's ability to feed, reproduce and survive as a population. The nematode populations are limited or even reduced by some cultural practices. This generally happens over various periods of time in comparison to a time-saving quick kill by the use of heat or chemicals. Control is also realized where cultural practices prevent the nematode population's initial increase to damage causing levels.

The various methods for controlling nematodes can be placed in categories such as cultural, physical, chemical and, biological control and legal restrictions. Where they are available, nematode resistant crops are highly complementary to a successful crop rotation scheme. The cost of development of a resistant cultivar is generally borne by government or other agency and the benefits are passed on to the farmer. The recent restrictions on the manufacture and use of some effective nematicides has made breeding for resistance to nematode

parasitism an attractive alternative. The high potential for good future returns on funds invested in nematode resistant cultivar development justifies its inclusion in the objectives of a crop improvement program through plant breeding.

Inbred resistance is effective, economical and an environmentally safe means of reducing or eliminating losses caused by nematodes. The use of resistant plants enables the grower to control nematode diseases without increasing production costs through the use of chemicals with their associated machinery and labor costs. Nematode resistant lines can be vitally important where low value crops and perennial horticultural crops are grown. Inputs such as water and fertilizers are used more efficiently as a healthy root system enters its maximum volume of soil. Resistant cultivars also widen the scope for crop rotations to include previously excluded crops or more frequent growing of the preferred cash crop or in subsistence agriculture the survival crop.

The Nematologist as Planner, Organizer and Salesman.

Ideally, the search for genes resistant to nematodes and the development of economically nematode-resistant cultivars is a team effort of a nematologist, plant breeder and an agronomist, each fulfilling their role in the breeding program. As the nematology input is a luxury in the current view of agricultural research, the services of an entomologist and pathologist is assumed. The overall importance of the nematode problem must be emphasized or "sold" to the administrators with facts, demonstrations and verbal explanation.

Facility Design

Facilities for the growng of plants and maintaining nematode cultures need to be designed or adapted from present structures. As nematode cultures can conveniently be kept in pots, a greenhouse or screenhouse can be quite satisfactory. A simple shadehouse made from locally available materials could be functional. Pots should be spaced to avoid cross contamination by splashing from water dripping through the shade cover during rains.

Nematode Problem Overview

Before the nematologist can assist in the breeding program, the nematodes need to be identified and their race determined. The prevalence and the distribution of the various species and races need to be known. An assessment of their economic importance needs to be made so that a knowledgeable assignment of priorities can be made. In this respect microplots can be of great utility.

Inoculum Development and Maintenance

Inoculum in large quantities of a single species, and perhaps of race is necessary. The species cultured must be maintained in a pure form free from other species. Suitable precautions can be taken to reduce the chances of contamination by separating the pots containing the cultures with a distance or a physical barrier.

It is necessary to consider each species or race separately in testing the crop germplasm. If a mixture of populations is used as

inoculum for screening plants, resistant material may be discarded if it displays resistance to only one of the species and not to the other. The germplasm could be of value in areas where only one species prevails. Also when screening plants, there should be a single plant per pot. Two or more plants per pot are not necessarily parasitized equally although they may have the same genetic background and are being attacked by the same nematode.

The pure cultures are best started from a number of specimens that have been positively identified. This will broaden the genetic base of the inoculum and be closer to that of the general field populations. If the specimens have not been identified, a single eggmass from a root-knot female or a cyst can be applied to a suitable host plant in a pot of sterilized soil. After a few weeks the successful inoculations will provide abundant material for species identification. When identifications have been made the nematodes can be multiplied and maintained on the host plants. A sufficient number of reinoculations to new host plants in sterilized soil should be made to assure a constant supply of parasites. Susceptible tomato or cucumber plants make host plants for a rapid increase of root-knot nematode eggs. However, Carica papaya is a slower growing and long-lived plant and useful for maintaining cultures over an extended period of time. When a few eggs are required for rapid increase on tomato, only a few roots need to be removed from the pot.

Test plants in which a host-parasite relationship does not become established should be retested with a number of replicates to confirm the incompatibility. Culture purity should be routinely checked to assure that a mixing of species or populations did not occur.

For the root-knot nematodes species determination is based on morphological characters. Examination under a light microscope should be with a particular attention to morphology of the perineal pattern, stylet and head region. An excellent supporting document has been produced by Eisenback et al. (1981). This illustrated publication highlights the essential characters of the species. A study of the specimens with the aid of this publication will quickly build the worker's confidence in root-knot nematode identification of M. incognita, M. arenaria, M. javanica and M. hopla.

The four species accounted for more than 95% of the root-knot nematodes identified from agricultural soils around the world. Four host races of M. incognita and two of M. arenaria were identified using the Differential Host Test. Until experience dictates otherwise, this means that a cultivar bred for resistance against a specific species and race would have broad utility on other continents (Sasser and Carter 1985; Taylor and Sasser 1978).

Inoculum Preparation

The use of freed eggs of the root-knot nematode as inoculum is convenient and an accurate quantity is easily determined. The collecting and freeing of eggs from plant roots is easily and quickly done. The sodium hypochlorite technique of Hussey and Barker (1973) requires minimum equipment. Plant roots are made free of soil by gentle washing with water. A very sandy soil used as the potting medium aids in this. The roots are placed in a suitable container with a tight fitting lid. Depending on the quantity of roots involved, plastic jars of 500 ml to 4 liters in size are convenient to use. The

500 ml size jars fit in the modified fingers of an automatic wrist-action shaker. A shaker is convenient and helps standardize procedures when a series of plant roots are to be examined. The commercial bleach (NaOCl) is used at a concentration of 20%. With the 500 ml jar, 100 ml of solution is used to shake with the roots for maximum of four minutes. The solution is poured through a coarse screen to trap the larger pieces of debris while the nematode eggs are caught on a 500-mesh sieve. The roots are rinsed with tap water two or three times before being discarded. If a 500-mesh sieve is not available, the sodium hypochlorite solution containing the eggs can be diluted in a large volume of water and the eggs allowed to settle, in large plastic wash tub. The surplus water is decanted and the number of eggs per liter of water calculated. The eggs can then be pipetted onto the soil around the test plant with small beaker or vial. The water containing eggs should be stirred frequently to maintain a uniform water-egg mixture.

Soil infested with the nematode or infected roots can be used as the inoculum source but the inoculum level is difficult to determine. Second-stage juveniles collected from galled roots in a mist chamber would provide infective nematodes of a relatively well known age if collected routinely. Woody roots will yield juveniles over a much longer time span than herbaceous roots like tomato or cucumber. Roots of the cotton plant have produced juveniles in a mist chamber for periods up to six weeks.

Screening the Plants for Resistance

Fassuliotis (1979) provides a review of the techniques for screening

plant germplasm in the laboratory, greenhouse and field. Unless a highly sophisticated approach is required, the plant in a pot in a greenhouse provides good results. The researcher has control over the germplasm planted, the nematode inoculum, the quantity of inoculum and the length of incubation. Depending on plant size and type, an inoculum of 2,000 to 10,000 eggs per pot should be satisfactory. Seedlings inoculated on emergence, would receive a quantity of inoculum at the lower end of the scale. Plants derived from slips or rhizomes should be allowed to form roots before being inoculated. Whatever the quantity of inoculum used, all plants in the test should be inoculated with the same number of eggs or juveniles. Cowpea seedlings inoculated with 5,000 eggs per pot at emergence and grown in a hot greenhouse died while those inoculated with 2,000 eggs per pot grew well until the test was terminated. Screening can be done at ambient temperatures but a soil temperature maintained between 22 to 25°C will identify incompatibility between host and parasite that might not be detected at a higher soil temperature (Dropkin 1969; Fassuliotis et al. 1970; Jatala and Russell 1972). Plants with a well known susceptible reaction should be grown as a control with each new batch of inoculum used.

Growth Habit of the Plant

If the plant being screened for resistance to nematodes can withstand the shock of uprooting, it can be replanted after examination of roots. For crops that have a low survival rate on replanting, the double potting method is useful. With this method two pots are used one above the other. The seed is planted in the upper pot and the roots are

given time to grow through the bottom of the pot into the soil of the lower pot. The roots in the lower pot are inoculated and later severed and rated for infection and rate of nematode reproduction.

Germplasm identified for resistance should be retested to confirm the results and tested against other parasitic nematodes in the target area of concern. Groundnut tested in southwestern Nigeria was shown to have good resistance against the root-knot, root-lesion and spiral nematodes.

The Rating Schemes for Resistance Reporting

LaPage (1937) lists three criteria of nematode resistance in animals which seem equally relevant to nematode resistance in plants- 1) a failure of the nematode to live inside the host or its early death in it; 2) a decrease in the parasite's production of eggs and juveniles; and 3) an inhibition of the parasite's growth or development, so that the adults require longer to mature and do not live so long when they are mature, sometimes being stunted and smaller.

Taylor and Sasser (1978) provide a brief definition in that resistance is the character or characters of a plant that inhibit nematode reproduction. A detailed discussion is presented by Canto-Saenz (1985) on terms used to describe the plant response to nematode parasitism. Canto-Saenz proposed that suitability designations be based on the two criteria of the plant as an efficient host (rate of reproduction) and damage to the plant (harm caused by the nematode as a parasite). Sasser et al. (1984) accepted the proposal of Canto-Saenz (Table 1) and proposed a quantitative rating system based

Table 1. The host suitability designations proposed by Canto-Saenz (1985).

Nematode reporduction	Damage to host plant	
	Statistically significant	Not significant
Efficient	Susceptible	Tolerant
Inefficient	Hypersusceptible	Resistant

Table 2. A quantitative scheme for assignment of host suitability designations.

Gall index for plant damage	The R factor host efficiency[1]	The designation for degree of resistance
≤ 2	≤ 1	resistant
≤ 2	> 1	tolerant
> 2	≤ 1	hypersusceptible
> 2	> 1	susceptible

[1] Reproduction factor: $R = P_f/P_i$, where P_i = the initial inoculum level and P_f = the final number of eggs.

on the gall index as an indicator of plant damage and nematode reproduction as determined by Oostenbrink's (1966) reproduction factor.

A gall index greater than 2 but an efficient host would be designated as susceptible or hypersusceptible (for the redundant "intolerant" term) for an inefficient host. A gall index of 2 or less and an inefficient host would be designated resistant or if an efficient host as tolerant (Table 2). Table 2 should be used with caution when screening germplasm looking for resistant material for the plant breeder. A plant giving a host efficiency factor of 1 would still be producing about 5,000 eggs per plant if that was the inoculum level. In recommending resistant parent material to the plant breeder,

the rate of reproduction should probably be 50 eggs or less per plant unless the gene pool is very small or more resistant parent material just cannot be found.

Sasser et al. (1984) proposed that root galling be substituted in the initial screening tests for the statistically significant nematode damage to the plant as in Table 1. This is probably satisfactory and expedient for the first screening of germplasm and the follow-up confirmation screening. Before more resources are committed to using the promising material as a resistant parent, the plant-damage factor caused by nematode parasitism should be determined under field conditions. The replicated use of microplots would provide satisfactory results on yield returns. Microplots are a good compromise between a pot in the greenhouse and large plots in the field with their inherent uneven distribution of nematodes. In microplots the soils can be made typical for the target area, unwanted nematodes can be eradicated by using a nematicide, the desired nematode population can be introduced and increased to a high level on an efficient host plant and the costs would be less than field plots. The proper field testing of the improved crop cultivar would be further down the line in the breeding program and promising but unsuitable material would be dropped from, or improved before being advanced in, the breeding program.

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ANALYSIS OF METHODS FOR DETERMINING PRESENCE, DISTRIBUTION AND IMPORTANCE OF NEMATODES ON A REGIONAL BASIS

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Introduction

A great deal of our understanding of the distribution of nematodes is largely derived from haphazard and unrelated sampling of soils and plant material. Methodical and extensive surveys have been a rare occurrence and even these have only provided a fraction of the true picture on nematode distribution. Countries with a comparatively long history of nematological expertise still remain in ignorance of many important nematode problems with wide gaps in their knowledge of the distribution of most nematodes. The exceptions tend to be with those nematodes which are known to cause serious crop losses and have become subject to regulatory procedures where farmers are encouraged, or legally obliged, to determine their presence or absence in field soils, e.g. with the potato cyst nematodes in Europe.

Determining the distribution of nematodes on a regional basis is an ongoing and long-term procedure; it is a gradual accumulation of knowledge resulting from limited or extensive investigations and surveys by individual scientists over many years. When a particular nematode becomes recognized as an important pest, when the means of

sampling and extraction are established, and when clearly identifiable symptoms of damage become known, there is a self-generating impetus within agricultural groups to determine the presence or absence of the pest in local areas. This is especially so when farmers hear of a 'new' pest that could be affecting their crops as they will be asking/demanding from the advisory services, commercial firms and scientists answers to their own yield losses.

In countries where knowledge of nematode problems is still in its infancy but where Ministries or Institutions such as ICARDA have the foresight to recognize the importance of nematodes, there is the obvious need to provide as much information on nematodes in the shortest possible time. This, therefore, necessitates survey work by nematologists.

Nematode Surveys

Most plant nematological investigations in a country are first initiated by general or 'preliminary' surveys which unearth nematodes of possible economic importance. This has happened in many countries throughtout the region and, once interest and funding is forthcoming, it normally leads to an increase in nematologists, followed by more detailed surveys and experimental work to determine the distribution, host range and actual damage potential of the nematodes. An example is with the preliminary surveys of nematodes in Syria by Greco et al. (1984) and others (Bellar & Kebabeh 1983; Mamluk et al. 1983) which showed that a Heterodera sp. commonly occurred with chickpea and other crops. This led to the identification of the nematodes as a new species, Heterodera ciceri (Vovlas et al. 1985), its definite

association with yield losses and recognizable field symptoms, and its host range (Greco et al. 1986).

Work of this nature raises a number of questions. Are these surveys the most effective way of determining the information required on the presence, distribution and importance of nematodes? Is there a more scientific and efficient means of providing the answers? If not, how can the surveys be improved to provide more rapid and accurate answers within the limitations that exist? Are there other techniques which can be employed which help in this determination?

Difficulties Encountered in Nematode Surveys

Plant nematology has many disadvantages compared to other crop protection disciplines mainly related to the fact that we deal with microscopic symptoms of damage. We are rarely provided with information by non-nematologists on the presence of nematodes to help us in building up a distribution picture of the pests. Thus, virtually all work on distribution mapping has to be done by scientists with nematological experitise. It follows, therefore, that the main factors which limit the amount of information that can be gathered on all aspects of plant nematodes are the availability of : 1. field nematologists; 2. nematode taxonomists; and 3. nematology laboratory facilities.

Even in a situation where nematologists are available, results from surveys are often insufficient to provide answers to questions on the distribution and importance of nematodes. This can be because of the discrepancies between workers on sampling and survey methods, identification of species, damaging population levels, associated

nematode damage (i.e. whether entirely or partially due to nematodes) and yield loss. It has been said that "the chances of detecting nematodes in soil samples are poor because they are distributed patchily and the techniques of extraction are imperfect" (Jones 1969). To achieve a reasonable amount of success in surveys, the type of survey and the methods employed need to be carefully considered in advance.

Types of Survey

As there are many different ways of conducting a survey, each one giving different results, the reasons for doing the work and the information already available should dictate the type of survey chosen, so as to supply answers to the questions which are posed. These questions can be many and varied:

What nematodes are present in field soil?
What nematodes occur with a particular crop?
What crops are affected by a known nematode?
Which nematodes are causing damage to the crop(s)?
Are nematodes the cause of crop decline?
Are nematodes present at damaging threshold levels?

Etc.

In general, the more answers required, the more detailed and laborious the survey, but one type of survey, or one survey alone, will rarely give all the answers.

The type of nematode surveys can be broadly placed into three categories: 1. exploratory; 2. diagnostic; 3. advisory and regulatory.

Exploratory surveys

The exploratory or preliminary survey is the one most commonly chosen by nematologists to begin investigations on nematodes. It is also the method favoured by taxonomists in their search for new species. It normally consists of a random sampling of soil only, or soil and plant material. The survey can encompass a farm, area, country or region, and can cover one or many crops.

This type of survey is the simplest means of obtaining data on the presence and distribution of some of the nematodes and usually produces a list of representative nematode groups in the area surveyed. If the list includes species or genera of known pathogenicity to the crops sampled, it can be an indicator of their importance as pests and further surveys can be initiated.

The main drawback of the exploratory survey is that information on the association between nematodes and yield decline or crop damage is generally not included in the work and the status of nematodes as damaging pests remains unknown. Usually, only one or two standard extraction techniques are used which often fail to extract certain species. This is often the case when soil alone is sampled.

The exploratory survey will produce an impressive list of nematode species and genera of considerable interest to nematologists but, if the original intention of the survey was to determine the presence and distribution of economically important plant nematodes, it will have failed and further surveys will be required.

Diagnostic surveys

Surveys intended to directly determine the role of nematodes in crop

damage need to be more selective and detailed. Unlike exploratory surveys, they are best done in co-operation with advisory services, other agricultural scientists and farmers. The crop or areas sampled have to be more clearly defined and the survey requires more planning.

Instead of random sampling, the areas are selected on the basis of the plants being diseased or in yield decline. The selection can be done by the nematologist or on information provided by the advisory/extension services and/or farmers. The nematode data obtained after processing samples is combined with field observations made at the time of sampling and observations of plant tissues prior to extraction or after staining. Additional and very useful information can also be obtained by comparative sampling of healthy plants of the same crop growing in close vicinity to the diseased plants.

The accumulated data from the above can often provde a clear picture of the involvement of nematode species and populations in poor or diseased plant growth and associated malformed or necrotic tissues. Further information provided by the farmers or agriculturists who have intimate knowledge of the crop and disease, its history and spread, should be sufficient to make a firm diagnosis on the importance of the nematodes in crop production.

This type of survey has many advantages in obtaining the relevant information on the distribution and importance of nematodes on a crop-by-crop basis. Its disadvantages are that it is more time consuming, requires expert knowledge of the crops investigated, and nematodes not producing crop damage at the time of sampling can be missed from the survey.

Advisory and regulatory surveys

Nematode sampling and survey work specifically designed to advise farmers on the means of controlling nematodes by cultural, chemical and other methods assumes that the basic information on the presence, distribution and importance of nematodes is already available. It is mainly concerned with determining population damaging threshold levels, detailed local occurrence and host status of crops grown on land infested with the nematodes.

The other form of advisory and regulatory survey work involves determining presence or absence of a particular nematode. The phytosanitary regulations of many countries require land to be certified 'free' from certain nematodes (e.g. the potato cyst nematodes) on the basis of soil sampling of standard methods (Southey 1986). Detecting low populations of nematodes is notoriously difficult; a negative result may only mean that a nematode has not been found by the techniques used. The probability that an infestation will be detected depends on the quantity of soil examined and, to a lesser degree, on the number of points from which the sample is derived (Southey 1974).

Techniques Used in Surveys

The techniques used in exploratory and diagnostic survey work will depend on the equipment, facilities and staff available and are often governed by the preferences of individual nematologists. Determining the presence, distribution and importance of nematodes is mainly done by standard or direct techniques involving the sampling and processing of soil and plant material. Other, indirect or remote sensing,

techniques such as aerial photography are also available to help in this determination.

Direct techniques

The many, well documented techniques for sampling and processing soil and plant material all have a part to play in survey work, each one having its advantages and disadvantages. In general, enlightened use of even the simplest techniques will provide some pertinent information on the presence of most nematodes.

Field samples

Assessment of nematodes in fields can be done by taking and analyzing individual samples or by taking a large number of samples from similar plants and bulking before extraction and further processing. The sample size - that is the number of samples and size of areas sampled - and the sampling patterns are only critical for determination of nematode populations in advisory and regulatory surveys. For this work, the number of samples recommended is very variable, although a figure of 20-25/ha is usually given (e.g. Carbonell & Angulo 1979) and, in general systematic sampling gives more reliable results than random sampling. Time of sampling can be critical; obviously fewer nematodes will be found outside the growing season. The most representative picture of nematodes parasitic on crop plants will be obtained by sampling from mid-to end of the growing season, but before plant senescence.

Soils

No special implement is required for collecting soil samples as they can be taken with whatever local digging tool comes to hand. Most nematodes will occur around the plant root zone at depths of 5-30cm, with few occurring in the surface layers.

The many extraction methods that can be used to separate nematodes from soil are mainly based on the following techniques: Baermann funnel; flotation, sedimentation and sieving; elutriation, centrifugal flotation; and flotation, flocculation and sieving. All are fully described by Hooper (1986a). As Hooper states "most nematogolical laboratories and nematologists have their own modifications of these basic techniques; consequently, extraction efficiency will vary within, as well as between, methods and this should be taken into account when comparing results". In my own experience, simple dish and tray modifications of the Baermann funnel technique will extract at least some specimens of most nematode genera and a better idea of populations of certain genera can be obtained by additional extraction techniques, e.g. sieving methods for larger nematodes and sugar centrifugation for criconematids. Although the above techniques will not extract immobile sedentary females, they will extract the juveniles of most e.g. Meloidogyne, Tylenchulus, Rotylenchulus, Heterodera, thus determining their presence. Root examination will then be required and special extraction techniques adopted for such nematodes as Heterodera and Globodera cysts (see Shepherd 1986).

Roots

The type and amount of roots sampled can be important. It is

preferable to take all roots from actively growing plants with comparatively small root systems, but this is not always possible. The techniques used for assessing nematodes in roots will depend on whether the nematodes are active or sedentary. Active or migratory nematodes can be extracted by Baermann-type systems, root incubation, maceration-filtration, or mist extraction. Sedentary nematodes can be separated from root tissues by maceration-sieving, and maceration-centrifugal flotation techniques (see: Hooper 1986b). If a simple extraction method is used, e.g. chopped roots placed on Baermann-type system or root incubation, and combined with staining of roots (Hooper 1986c), most, if not all, types of nematodes present in roots will be found. Staining also gives additional information on the direct association between presence of nematodes and tissue damage.

Direct assessment of visible root damage symptoms induced by nematodes can be a great help in estimating actual crop damage and nematode infestation levels. This is especially so with root-galling nematodes. e.g. Meloidogyne spp. A quantitative analysis of the extent of galling can be expressed as the percentage of roots galled, number of galls, size of galls, or types of roots galled. Similarly with the migratory endoparasites, e.g. Pratylenchus, Radopholus, the amount of visible necrosis or browning can be determined again on a percentage basis.

Foilage

Most leaf, stem and seed nematodes are active and can be extracted by methods used for root nematode extraction, particularly Baermann-funnel, maceration-filtration, or mist extraction techniques. The main

consideration is the parts of the plant chosen to ensure that the nematodes known, or likely, to occur are extracted. Populations are normally quantified on numbers of nematodes per weight of stems and leaves, and weight or numbers of seeds.

Direct assessment of damage symptoms is also possible, either in the field or laboratory, i.e. the numbers of plants with seed galls or number of seed galls per head caused by Anguina tritici; leaf twisting, stem and inflorescence distortion and necrosis caused by species of Anguina, Aphelenchoides and Ditylenchus.

Other samples

In addition to direct sampling of soils and plant material from fields, accurate assessments of the presence and severity of certain nematodes can be obtained by sampling good produce in local markets and seed stores. This is a valuable method for assessing nematodes in many crops that we are not concerned with here (e.g. root-galling, lesion and other nematodes on root and tuber crops) but can effectively be used to determine presence and percentage infestation of nematodes such as Anguina tritici in cereal seed stores and grain markets (Paruthi & Bhatti 1985) and Ditylenchus dipsaci on faba bean.

Indirect or Remote Sensing Technique

The standard or direct field sampling techniques to determine presence and distribution of nematodes are laborious and time-consuming, and there is an element of luck involved when there are no recognisable or obvious symptoms of damage associated with nematodes. Is it possible,

therefore, to use indirect or remote sensing techniques to identify field infestation by nematodes?

Aerial photographs taken from aircraft, balloons and satellites, and multispectral scanning data have been used to measure fungal and viral disease incidence in many agricultural systems (Sharp et al. 1985; Swain & Davis 1978). Aerial photography, using both normal and infra-red film, has also been employed to determine the presence of nematodes or extent of nematode damage (Arnett 1976; Caubel el al. 1975; Caubel et al. 1978; Caubel et al. 1978a; Cocks et al. 1976; Norman & Fritz 1965; Orion et al. 1982; Sanwald 1979; Yuhara 1975).

Photographs taken with normal colour film will show differences in density of plant growth and the colour of foliage, if these differences are marked. Colour infra-red or false-colour intra-red film, on the other hand, can detect slight differences between healthy and infested plants not easily detectable to the naked eye and it is this method that has mainly been used. Detection of plants infested with nematodes works on the principle that healthy vegetation reflects far more infra-red than do unhealthy plants of the same species (Cock et al. 1976). In fields known to be infested with nematodes, aerial photographs can measure the rate of spread of nematodes from year to year in relation to crop damage (Cocks et al. 1976; Orion et al. 1982) but are less valuable in discovering new areas of infestation (Cocks et al. 1976).

Compilation of Results and Distribution Mapping

Processing plant material collected in surveys, correctly identifying all the nematode genera and species, and collating the information

takes a great deal of time and effort, even from comparatively small surveys. The results from each survey, if the nematologist is persistent, will be a list of nematodes on crops from a clearly defined area of a country. Sometimes this work is published but often the nematologist, overwhelmed with the amount of data collected or facing difficulties with identification, will only complete and publish part of the work or even retain all the information in the laboratory files. It follows, therefore, that to prevent wastage of effort, the nematologist attempting a survey should have the commitment, resources and availability of taxonomic expertise to fully compelete the work and compile and publish the data.

The other difficulty that arises is in the compilation of accumulated survey data from different sources to produce accurate and useful information on the distribution of nematodes on a country or regional basis. An answer to this problem by European nematologists was the establishment of the European Plant-Parasitic Nematode Survey (EPPNS), formally recognized in 1980, with financial support from the European Science Foundation. The aim of the survey was to initiate collaboration among European national centres to produce computer-based maps of the distribution of individual nematode species. Many European countries had accumulated data from various national surveys; others initiated projects which included the collection of survey data (Topham et al. 1983). The survey and distribution mapping has been co-ordinated by the Scottish Crop Research Institute, U.K. All data sent from the different countries have been analysed by computer to determine species associations within countries and to assess distribution patterns, using standard computer software packages such as SPSS, GENSTAT and CLUSTAN. Nematode distribution atlases from

computer maps have been produced for 14 countries and EPPNS has now developed a new computer-generated outline basemap of Europe to map European nematodes on a continental basis (Anon. 1986), an example of which is the 'European Atlas of the Longidoridae and Trichodoridae'.

This elaborate distribution mapping of nematodes obviously needs computer equipment, operators, finanical funding and the participation of many national research centres. However, even this, the most extensive collection of survey data that has ever been attempted, is still limited by the amount and type of information that is input to the system. The distribution maps that are produced, although of considerable usefulness, do not always give all the answers, such as the extent of crop damage. Gaps in this knowledge and in the knowledge of the distribution of nematodes in other regions will still need to be filled by committed and informed nematologists working at the crop roots.

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PRESENCE AND ROLE OF PLANT PARASITIC NEMATODES IN CEREALS AND FOOD AND FORAGE LEGUMES IN CYPRUS

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Introduction

Cyprus, an island with an area of 9,500 km^2 is basically an agricultural country, its agricultural exports being the most essential source of nationl income. Its climatic conditions throughout the year favour early production of vegetables and other fruits, especially citrus and potatoes. The annual mean precipitation is around 470 mm while the yearly average air temperature is approximately 19°C (Max. 24, Min. 14). Most of the island's irrigated land is planted with high value cash crops like citrus, vegetables and deciduous fruit trees yielding annually US$ 210 million, while in the rainfed area where cereals, forage crops, olive trees and vines are grown, the value of production reaches around US$ 84 million (Anon. 1984).

As far as nematological problems are concerned, these, in some conditions are serious, causing substantial yield losses. For instance high soil temperatures (23-27°C), in the summer season, favour the development and reproduction of the destructive root-knot nematode, Meloidogyne sp., which attacks many summer-grown vegetables causing great losses (Philis 1971; 1974; 1976) while during spring and autumn the potato cyst nematode, Globodera rostochiensis, attacks potatoes reducing yields considerably (Philis 1981). From a survey carried out during 1976 it was shown that a complex of plant parasitic nematode

groups may be found on the island. More work, however, is needed to get a complete picture concerning the presence and distribution of these pests on the island.

During the last fifteen years our main nematological concern was the identification and chemical control of the most important parasitic nematodes found on citrus, bananas, tomatoes, egg plants and carrots. It is only recently that work concerning important biological aspects of nematodes and other essential related topics was implemented. An example of this was the study concerning the phenological control of the potato cyst nematode (Philis 1986).

Nematodes Associated with Cereals and Forage Crops

Due to other priority needs the presence and distribution of parasitic nematodes on cereals and other forage crops on the island was not given adequate attention. Our knowledge concerning these crops and their relationship with nematodes is very scanty (Table 1). The need, therefore, to learn more about these crops and their behaviour in nematode-infested fields is, indeed, enormous.

From a limited sampling at one of the traditional barley growing areas of the island (Athienou), it was found that most of the root and soil samples collected contained the mediterranean cereal cyst nematode (Heterodera latipons Franklin) and Pratylenchus sp.. Nematode infested fields had patches of chlorotic and stunted plants while root penetration of infested plants in the deeper layers of soil was very poor. Careful examination of infested feeder roots revealed all stages of nematode development.

Table 1. Area, production and the nematodes of some of the important cool season cereals and legume crops grown in Cyprus.

Crop	Area (ha)	Value of production (US$ million)	Nematode involved
Wheat	6.500	1.0 (grain)	NA[1]
Barley	50.000	8.4 (grain)	Heterodera latipons
Vetch	2.500	0.3 (grain)	Paratylenchus (microdorus)
Faba bean	1.100	0.7 (grain)	Ditylenchus dipsaci
Green fodder	25.000	1.8 (grazing) 3.0 (hay-making) 2.5 (straw)	NA

1/ NA = no information is available.

An important rainfed forage crop on the island is Vicia sativa L. with an annual value of production reaching US$ 8.2 million (grain, straw, grazing). In an incidental soil sampling in an agronomical experiment, where plant growth was drastically reduced, it was found that the soil around the roots of young plants contained high numbers of the pin-nematode Paratylenchus (microdorus group). Attempts to correlate nematode populations with plant growth showed a negative correlation, suggesting that the nematode is pathogenic.

Also, repeated studies on faba bean (Vicia faba L.) have shown that the nematode Ditylenchus dipsaci Filipjev is present on the island attacking the crop seriously, causing in many instances, total yield loss. The incidence of nematode damage is largely confined to the west part of the island, most probably due to favourable weather and other conditions (Augustin 1983).

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LOSS ESTIMATION FOR WINTER SEASON CEREAL AND LEGUME CROPS DUE TO PLANT PARASITIC NEMATODES AND COMPLEX DISEASES IN EGYPT

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Introduction

In 1982, Agricultural Production of Egypt was L.E. 4.9 billion (Anon. 1983). Production of crops (field, vegetable, fruit, ornamental, medicinal, and aromatic crop plants) represented 70.6% of this value, i.e., L.E. 3.47 billion. Actual cultivated area in Egypt is 5.9 million feddans (2.45 feddans = 1 ha). Due to the production of crops in winter, summer, and nili (late summer) planting seasons the productive area has now reached 11.2 million feddans.

In Egypt, plant parasitic nematodes and complex diseases involving nematodes and other organisms are causing significant crop yield losses due to the continuous cropping of fields. Estimates for crop losses from plant parasitic nematodes and complex diseases are high. Losses for summer and nili crops are much higher than those for winter crops as plant suffers from aridity stress in addition to the pathogenic stresses.

Objectives of the present paper are to 1) review the published nematology research on winter cereal and legume crops in Egypt, 2) estimate annual crop losses (1986), and 3) describe present and proposed control measures.

Winter Cereals

The main winter cereals in Egypt are wheat and barley. Both crops are planted in the Nile-Delta and along the Nile-Valley using a 30,000 km of network of irrigation canals.

Oteifa (1964) recorded the main plant parasitic nematodes in the Egyptian fields. Yassin (1977) studied the infection of wheat roots by Meloidogyne javanica inoculation. Nematode parasitism caused hypertrophied, multinucleated cells, dense vaculated cytoplasm and malformation of the stelar region of wheat roots, resulting in suppression of growth. Eissa and Moussa (1982) reported a 20-36% increase in wheat yield following nematicide treatment to control the root lesion and the stunt nematodes.

Cereal losses

Table 1 lists the area planted to wheat and barley in 1984, 1985, and 1986. Plant parasitic nematodes and complex soil diseases were not thoroughly studied under winter cereals in Egypt. Losses in wheat are higher than in barley, because of the short growth period of barley, and the frequent irrigation of wheat. For wheat a 10% grain loss and for barley a 5% grain loss was estimated to result in total losses of 137205 tons and 7,386 tons, respectively amounting to L.E. 42,108,566 for wheat and L.E. 630,531 for barley.

Methods of control

Integrated pest management techniques have not yet been developed for winter cereals in Egypt. Crop rotation is followed in Egypt in the

Table 1. Loss estimation for winter season cereal and legume crops due to plant parasitic nematode and complex diseases in Egypt, 1986.

Crop	Average 1984/1986 Area (Feddan)	Yield (Tons/F.)	Estimated losses for 1986 % Yield	Tons	Value (L.E.)
I. Field Crops:					
Wheat	1190114	1.573	10(5-35)	187205	42108566
Barley	127022	1.163	5(0-15)	7386	1630532
Berseem clover	2982473		10(0-25)		60937700
Faba bean	275258	1.037	15(5-25)	42816	19620949
Lentil	19546	0.648	20(10-30)	2533	2477592
Chickpea	20700	0.665	15(10-30)	2065	2339309
Fenugreek	27750	0.786	5(0-15)	1091	599816
Lupin	12559	0.741	5(0-15)	465	376189
Sub-total	4655422			243561	130090652
II. Vegetable Crops (1985):					
Fresh faba bean	790	3.30	15(5-25)	391	58658
Fresh common bean	8283	3.19	15(5-25)	2963	824390
Dry bean	710	1.25	15(5-25)	133	102506
Fresh pea	19734	3.99	15(5-25)	11811	2752979
Dry pea	4269	0.82	15(5-25)	525	283547
Sub-total	33786			15823	4022080
Grand Total	4689208			399384	134112733

Calculated as cash value of 1981 for berseem seeds, and fresh forage (one, two, three, four, or five cuts annually).
1 Feddan = 0.40 ha; L.E. = Egyptian Pound.

sense that agricultural land is continuously planted, round the year with one crop or the other. Nematicidal and/or fungicidal seed coating could be of significance to improve wheat and barley production under irrigation in Egypt. This technique could protect seeds from sparrows and rodents after planting, and protect seedlings from early diseases, mites, insects and/or nematodes. Residues of pesticides in the harvested crop would be minimum as the applied dose is small. This technology serves also the purpose of rationalized pesticide use.

Winter Legumes

The main winter legumes in Egypt are berseem clover, Trifolium alexandrium (forage crop), faba bean, fenugreek, chickpea, pea, lentil, lupin and bean in a descending order for the area of cultivation. Berseem clover and faba bean are grown throughout Egypt. Fenugreek is grown mainly in Sharkia governorate, mid-Egypt (Giza, Beni-Seuf, Fayoum and Minia) and upper-Egypt (Assiut, Sohag, Kena and Asswan). Chickpea is grown in Sharkia, Ismailia, Behaira, Minia and upper-Egypt. Lupin is grown in Sharkia, Ismailia, and mid- and upper-Egypt. Lentil is grown mainly in upper-Egypt. Winter legumes for vegetables are grown all over Egypt.

Oteifa (1964) pioneered the studies on nematodes in Egypt recording plant parasitic nematodes of leguminous and other field crops. Kassab (1974) and Taha et al. (1974) reported that root-knot nematode infestation caused decrease in nitrogen accummulation in legume-foliage, up to 55.3% in lupin, 47.4% in faba bean, 80.8% in peas and 89.5% in berseem clover. Osman and Kheir (1978) proved that Meloidogyne javanica reduced faba bean foliage weight up to 41.2% and root weight up to 39.6%. Yousif (1979) reported that M. incognita infestation in faba bean, lupin, pea, and berseem clover did not disturb Rhizobium nodular tissues. Nematode gall size and giant cell wall thickness were greater in faba bean than in lupin and peas. Berseem clover was least affected.

Susceptibility of some legumes to plant parasitic nematodes was also studied by Ibrahim et al. (1980) and Moussa et al. (1981). They mainly investigated susceptibility of common beans and cowpea to root-knot nematodes. Masoud (1971, 1980) investigated the effect of

plant parasitic nematodes in berseem clover. Mohamed (1981) reported that the foliar diseases of winter legumes in Egypt are less significant than complex root diseases in the soil. Abd El-Massih et al. (1982) reported the presence of the nematode genera, Meloidogyne, Tylenchorhynchus, Pratylenchus, Helicotylenchus and Rotylenchulus in descending order of population density in faba bean, berseem clover, common bean, peas, fenugreek and lupin. Abd-Elgawad (1986) proved high susceptibility of berseem clover cultivars to M. javanica, M. incognita race 3 and M. arenaria. Control of plant parasitic nematodes of legumes resulted in 16.6 - 62% yield increases (Moussa et al. 1982; Eissa and Abdel-Azim 1981).

Legume losses

Table 1 presents the area and yield losses of winter legumes due to the plant parasitic nematode and complex soil diseases in Egypt. In berseem clover, losses are the highest followed by faba bean, peas, lentil, chickpea, common bean, fenugreek and lupin. Total value of winter legume losses exceeds L.E. 90 million.

Methods of control

Crop rotation is the main control system followed in Egypt. Nematicidal chemicals were used only for experimental purposes. The presence of tolerance, resistance, or susceptibiity to nematode pests in Egyptian cultivars and germplasm were not studied for the majority of winter legumes. Seed dressing with nematicidal and/or fungicidal chemicals could improve legumes production at present until the resistant cultivars are available to the farmers.

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PLANT PARASITIC NEMATODES ON CEREALS AND LEGUMES IN IRAQ

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Introduction

Nematology research work is being carried out in Iraq as a part of the general research program to solve the most important nematode problems limiting the production of vegetable, field and fruit crops, and also to seek short and long term economic control measures to minimize the losses caused by these pests either by cultural or chemical methods (Al-Beldawi et al. 1974, 1975, 1985; Al-Safie 1985; Al-Talib et al. 1986; Katcho et al. 1976).

Nematode Studies in Cereals

Work on cereals, especially wheat and barley includes surveys on nematode diseases, occurrence and distribution, economic importance and screening for resistance to nematodes.

Wheat is one of the most important cereal crops in Iraq. There are about 2 million hectares planted with this crop, and 70% of the planted area is concentrated in the northern region of Iraq. Yield production per capita is very low because of several reasons such as adverse environmental factors (low rainfall) and diseases (rusts, septoria and nematodes)

Wheat seed gall nematode, Anguina tritici (Steinbuch) Chitwood, an important pest in Iraq, was first recorded on wheat in 1921. In 1974, a general survey showed that A. tritici was found throughout the wheat growing area. The highest percentage of infection (22.9) was recorded in Anbar province on Mexipac wheat. In other areas infection ranged between 0.03-22.9%. The survey conducted in 1979 showed that the percentage of infection increased to 45% on Mexipac in Nineveh province.

In 1985, a barley field in Sheikhan area (40 km north of Mosul) in the northern region of Iraq was found to be heavily infected (90%) with seed gall nematode A. tritici. This was the highest damage so far reported in Iraq, and perhaps in the world, caused by gall nematode in wheat.

Screening of wheat and barley varieties for resistance to A. tritici

In 1975, in a greenhouse experiment, a number of wheat and barley cultivars were screened for resistance to A. tritici. Results indicated that all barley cultivars tested and one wheat (Saber beg) cultivar were free of infection.

In 1986, A. tritici from barley was tested in pot experiment on 6 barley and 7 wheat cultivars. The results revealed that all tested barley cultivars were susceptible to this nematode while the wheat cultivars were free of infestation.

Other research studies on A. tritici from wheat indicated that the percentage of infection increased with increasing level of inoculum to 24 galls/pot, and conversely, infection decreased with increasing inoculum up to 40 galls/pot.

Inoculation with either wheat galls or juvenile suspension at the time of sowing gave significantly higher infection than inoculation after seed germination.

Differences in number of juveniles per gall ranged from as low as 19140 juveniles/gall recorded in the cultivar Italia, and a high of 40620 juveniles/gall in the cultivar Alyeba.

The decrease in yield caused by A. tritici on wheat was 30.2% in Mexipac and 0.02% in Nori-70, while Saber beg was not affected because of its resistance to the disease.

Other research studies revealed that the simultaneous presence of the fungus Dilophospora alopecuri (Fr.) Fr. with A. tritici, in the soil, increased the severity of the disease and caused the symptoms to appear on spikes as well as leaves.

Nematode Studies in Legumes

Root-knot nematodes, Meloidogyne spp., are the most destructive group of nematodes known at present in Iraq. Four species namely M. javanica, M. incognita (Race 1 and 2), M. arenaria (R_1) and M. hapla have been found attacking more than 100 host plants. Meloidogyne javanica was the most common species, being found on 97.57% of the plants examined.

A survey of faba bean (Vicia faba L.), bean (Phaseolus vulgaris L.) and cowpea (Vigna sinensis Endle ex. Hassak) growing areas showed that there were two species of root-knot nematodes, M. javanica and M. incognita associated with these crops.

Future Research Objectives

The major objectives of the future research are as follows:

1. To determine the species and biotypes of root-knot and seed-gall nematodes.
2. Screen wheat, barley and legume varieties for resistance to pathogenic nematodes.
3. Study host range/status of various crops to pathogenic nematodes of cereals and legumes.
4. Investigate the nature and extent of damage of nematodes affecting legumes and cereals.
5. Evaluate various management practices and cropping systems for suppression of nematode populations to maximize yield production.
6. To determine the effect of pathogenic nematodes-fungi/bacteria interactions on the host and disease development.

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PLANT PARASITIC NEMATODES ASSOCIATED WITH CEREAL AND FORAGE CROPS IN JORDAN

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Introduction

Statistical data of 1985 (Anon. 1986a) indicated that nearly 255,000 ha were under cultivation in Jordan of which 150,000, 50,000 and 55,000 ha were planted to field crops, vegetable crops and fruit trees, respectively. The irrigated lands comprised about 23.5% of the total cultivated area, while the rest was planted to crops and orchards under rainfed conditions. It is further estimated that 2.7%, 75% and 75% of the respective areas are allocated to irrigated field crops, vegetables and fruit trees.

A great diversity of climatic conditions prevail in Jordan; ranging from a semi-temperate climate on the elevated highlands to semi-tropical in the Jordan Valley, and from arid regions along the desert periphery to semi-humid on the tops of high mountains overlooking the Jordan Rift Valley.

Investigations and preliminary research in the area of phytonematology began in the mid-1960's. Applied research was initiated in the early 1970's. Research on plant nematology, because of limited specialized man-power and facilities, was at first addressed to solving nematode problems of important cash crops, especially

irrigated vegetables. Among the nematode problems of cereals and forage crops that received attention were the wheat seed gall nematode, Anguina tritici, and the stem nematode of faba bean, Ditylenchus dipsaci.

However, nematodes associated with cereal and forage crops were either mentioned in the general surveys (Abu-Gharbieh & Hammou 1970; Abu-Gharbieh & Hashim 1974-76; Bridge 1978; Hashim 1979a and Sudah 1967) or listed in compilations of earlier findings (Hashim 1979a; Mamluk et al. 1984) or were subject of actual investigations (Abu-Gharbieh 1964; Abu-Gharbieh & Tamimi 1982; Hashim 1979b).

Plant Parasitic Nematodes Associated with Crops

1. Wheat (Triticum durum Desf. and T. aestivum L.)

Wheat in Jordan is generally grown under rainfed condition, where an annual average (1981-1985) of 86,000 ha produce around 60,000 MT (Anon. 1986a). Meanwhile, an average area of only 19,000 ha (producing nearly 22,000 MT) is planted under irrigation, half of which in the Jordan Valley (Anon. 1986a). The majority of the area is planted with durum wheat varieties, such as Hourani Nawawi and F-8.

Table 1 lists the nematode species detected through various surveys, and systematically compiled by Mamluk, et al. (1984). The wheat seed gall nematode (Anguina tritici) was first observed in 1965 (Sudah, 1967), and its occurrence determined in a field survey in 1970. Abu-Gharbieh and Tamimi (1982) carried out further investigations and conducted varietal response experiments.

Table 1. Plant parasitic nematodes associated with wheat.

Nematode species	Reference	Regional distribution*
Amplimerlinius macrorus (Goodey) Siddiqi	(7)	ERU
Anguina tritici (Steinbuch) Chitwood	(4, 11)	GA, ERU
Helicotylenchus sp.	(2)	ERU
H. digonicus Perry	(3, 8)	GA
Macroposthonia rustica (Micol.) De Grisse & Loof	(3, 8)	GA
Merlinius brevidens Allen	(7)	ERU
M. nanus (Allen) Siddiqi	(8)	ERU
M. rugosus (Siddiqi) Siddiqi	(8)	ERU
Paratylenchus sp.	(7)	GA
Paratylenchus sp.	(8)	ERU
P. thornei Sher & Allen	(3, 7, 8)	ERU
Tylenchorhynchus sp.	(7)	GA
Xiphinema pachtaicum (Talaganov) Kirjanova	(8)	ERU

* Abbreviations of areas used in this review:
GA = Ghor Area; SW = Side Wadis; ERU = Eastern Rainfed Uplands; EIU = Eastern Irrigated Uplands.

The nematode was found to occur mainly in areas of annual rainfall between 400-600 mm. This comprises areas north of Amman, including Jarash, Irbid and comparable areas in the West Bank. In years of heavy and consistant rains, e.g. 1979/1980 season, high infestation and severe yield reduction occurred.

Abu-Gharbieh and Tamimi (1982) tested the response of six durum wheat varieties (Hourani Nawawi, Deir Alla 2, F-8, Safra Ma'an, Cocorit and Stork); three common bread varieties (Deir Alla 4, Kalynnsona X FAO 215-2 and Sakha); and a triticale (Triticale hexaploide) to the wheat gall nematode. The results showed that the durum varieties were generally susceptible, except for Safra Ma'an which exhibited slight resistance. Hourani Nawawi, which is the

most popular variety, was highly susceptible. Among the common bread wheat varieties, Sakha was highly resistant to the nematode. The triticale was only mildly infected.

Later, Abu-Gharbieh and Al-Banna (unpublished) tested eight varieties of wheat, one triticale and one rye to A. tritici. The bread wheat variety "Spring Wheat Aus. 10894", and the rye variety "South Australian" were resistant, while the wheat var. TIM 56 and the triticale "Ningadhu" exhibited high degrees of tolerance to the nematode.

2. Barley (Hordium vulgare L.)

Barley is generally grown in marginal areas where rainfall is near or just below the lower limits of wheat moisture requirements. An average (1981-1985) of nearly 36,000 ha are planted annually to barley under rainfed condition, with an average production of 58,000 MT (Anon. 1986a). An additional 1,200 ha produce about 4000 MT under irrigation.

Unfortunately, records on plant parasitic nematodes associated with barley are completely lacking. This is undoubtedly due to the absence of extensive survey work on presence and distribution of plant parasitic nematodes on this crop.

3. Lentil (Lens culinaris Medik.)

Lentil is predominantly grown in the northern Irbid governorate, where rainfall is rather high and well distributed throughout the growing season. However, area planted to lentil has diminished

sharply during the last decade due to labour shortage and difficulties in mechanical harvesting of the crop.

The average annual area planted to lentil (1981-1985) was 6,830 ha, with an average production of 4600 MT (Anon 1986). Lentil is grown almost exclusively under rainfed conditions.

The plant parasitic nematodes found associated with lentil in the various surveys are listed in Table 2 (Mamluk *et al*. 1984).

Table 2. Plant parasitic nematodes associated with lentil

Nematode species	References	Regional distribution*
Amplimerlinius macrurus (Goodey) Siddiqi	(3, 7, 8)	ERU
Heterodera goettingiana Liebscher	(3, 7, 8)	ERU
Pratylenchus thornei Sher & Allen	(3, 8)	ERU (frequent)
Trichotylenchus sp.	(7)	ERU
Tylenchorhynchus sp.	(7)	ERU

* See Table 1 for abbreviations

4. Common Vetch (*Vicia sativa* L.)

Vetch is grown mostly in the northern governorate of Irbid, where lentil is usually cultivated. The average annual area planted to vetch during the period 1981-1985 was 4383 ha, with an average production of nearly 3000 MT (Anon. 1986b).

No records are available on plant parasitic nematodes on vetch. This indicates that survey work on this crop has not been conducted.

5. Chickpea (*Cicer arietinum* L.)

Chickpea is grown in Jordan under rainfed conditions both in the southern and northern highlands. The average annual cultivated area for the period 1981-1985 was 2400 ha which produced an average of 1200 MT (Anon. 1986b).

Very little is known about nematodes associated with chickpea, except for *Pratylenchus thornei* Sher and Allen (Abu-Gharbieh and Hashim 1974-78; Hashim 1979) in the eastern rainfed uplands.

6. Faba Bean (*Vicia fabae* L.)

Faba bean is grown in Jordan both as a field crop for proudction of dry seeds and as a vegetable crop for production of green pods. The average annual area planted to faba bean within the period 1981-1985 was 920 to 1245 ha (Anon. 1986b). This crop is grown under irrigation, with nearly 50% of the planted area in the Jordan Valley (Anon. 1986b). The rest is distributed over the irrigated uplands and along certain valleys descending from the eastern uplands to the Jordan Valley.

Faba bean has been studied in more detail for nematode problem than the other crops within this group. Table 3 shows the plant parasitic nematodes found associated with faba bean in Jordan (Mamluk *et al*. 1984).

The "giant race" of *Ditylenchus dipsaci* was first recorded in 1979 by Hashim in a faba bean field in Wadi Shuaib. Later, Abu-Gharbieh (unpublished) found the nematode to be widespread in

Table 3. Plant parasitic nematodes associated with faba bean.

Nematode species	Refs.	Regional distribution*	Remarks
Amplimerilinius sp.	(7)	EIU	Frequent
Ditylenchus dipsaci (Kuehn) Filipjev	(3,9)	GA, SW	Widespread
Helicotylenchus sp.	(3)	GA, SW	Frequent
H. digonicus Perry	(7)	EIU	
H. tunesiensis Siddiqi	(3,8)	EIU	
Heterodera goettingiana Liebscher	(3,7,8)	EIU	Occasional
Meloidogyne sp.	(1)	GA, SW	Frequent
M. javanica (Treub) Chitwood	(3,7)	GA, SW	
Merlinius sp.	(3)	SW	Frequent
M. brevidens Allen	(7)	EIU, SW	
M. nanus (Allen) Siddiqi	(8)	SW	
Metaphelenchus sp.	(3)	GA, SW	Frequent
Pratylenchus sp.	(3)	GA, SW	Frequent
P. thornei Sher & Allen	(7)	GA	
Psilenchus sp.	(2,7)	SW, EIU	Occasional
Rotylenchus sp.	(3)	SW, EIU	
Tylenchorhynchus sp.	(3,8)	SW	

* See Table 1 for abbreviations.

Wadi Shuaib and in the Central Jordan Valley. He further noted that the nematode could be devastating in the spring, particularly in years of heavy rains.

7. Alfalfa (*Medicago sativa* L.) and Clover (*Trifolium* sp.)

Alfalfa and clover are planted in limited scattered areas in the Jordan Valley and elsewhere in the irrigated highlands and side wadis. In 1985, nearly 60 ha of both crops were cultivated under irrigation (Anon. 1986b). The nematodes recorded on alfalfa are presented in Table 4.

Table 4. Plant parasitic nematodes associated with alfalfa.

Nematode species	Reference	Regional distribution*
Aphelenchoides sp.	(2)	EIU
Helicotylenchus sp.	(2)	EIU
Longidorus sp.	(2)	EIU
Meloidogyne sp.	(2, 7)	EIU
Pratylenchus sp.	(2)	EIU
Tylenchorhynchus sp.	(2)	EIU

* EIU = Eastern Irrigated Uplands.

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NEMATODE STATUS ON FOOD LEGUMES AND CEREALS IN MOROCCO

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Introduction

In Morocco, faba bean (Vicia faba), french bean (Phaseolus vulgaris), lentil (Lens culinaris), chickpea (Cicer arietinum), field pea (Pisum sativum), soybean (Glycine max) and peanut (Arachis hypogaea) are the main food legumes. Cereals are represented by wheat (Triticum aestivum and T. durum), barley (Hordeum vulgare), corn (Zea mays) and rice (Oryza sativa).

Even though these crops are of high economic and social value, most of the nematode studies have been conducted todate on vegetables, citrus, banana and stone fruits (Agdar et al. 1980, Ammati 1978). These crops are considered important cash crops, especially tomato and citrus, and a major source of foreign exchange.

Concerning food legumes and cereals, only preliminary studies on faba bean and a survey on barley and wheat were conducted in Morocco. The principal results from these studies and recommendations dealing with this area of research are presented in this report.

Nematode Status on Faba Bean

Faba bean is the main food legume and is cultivated throughout Morocco.

Ditylenchus dipsaci is the only important species identified sofar, on this crop (Anon. 1978). Among 246 seed samples collected from all over the country, 80% were infected. Losses per annum were estimated at 7,500 to 15,000 tons (total production per year is around 250,000 tons). Seeds are considered the major means of disperal of this nematode. Under Moroccan conditions, specific symptoms of D. dipsaci are not discernible at the seedling stage. Symptoms of nematode damage are usually seen at flowering.

Further work was devoted to identification of the biological races occurring in Morocco and the length of their life cycles. This study showed that the prevalent pathotype is the giant race (1800 u is the length of adult) and 30 days (at 15°C) is the span of its life cycle (Ait Ighal 1981)). On the basis of these studies, screening of healthy seeds and cropping system are the principal methods recommended to control this species.

Nematode Status on Cereals

A preliminary survey was aimed at identifying the plant parasitic nematodes associated with wheat and barley (Ait Ighil 1981). This survey was conducted in the main areas where these two crops are cultivated. Ten genera of plant parasitic nematodes were identified in the 127 soil samples analyzed (Table 1). Pratylenchus sp. was observed on more than 65% of the wheat and barley samples examined whereas Heterodera avenae was observed only in soil samples from wheat. Studies to identify H. avenae pathotypes in Morocco using different population have not been initiated.

Table 1. List of plant parasitic nematodes encountered in the rhizosphere of wheat and barley in Morocco.

Nematode	Host plant		Regions*
	Wheat	Barley	
Aorolaimus			
A. israeli	"	"	PR, ZA, GH, SA, DO
Boleodorus	"	"	PR
Helicotylenchus			
H. tunisiensis	"	"	PR, ZA, GH, SA, DO
Heterodera			
H. avenae	"		SA, DO
Marcroposthonia	"	"	GH, SA, ZA
Merlinius			
M. brevidens	"	"	PR, ZA, GH, SA
Paratrophurus	"	"	PR
Pratylenchus			
P. neglectus	"	"	ZA, SA
P. penetrans	"	"	PR, SA
P. thornei	"	"	PR, ZA, SA, GH, DO
Tylenchorhynchus	"	"	PR, ZA, SA, GH, DO
Tylenchus	"	"	PR, ZA, SA, GH, DO

* PR: Pre-Rif; ZA: Zaers; GH: Gharb; SA: Sais; DO: Doukkala.

Recommendation

This report shows that nematode problmes on food legumes and cereals has been neglected in Morocco. The following studies are being planned and are considered important for Moroccan economy:

- The surveys on cereals should be extended to other crops such as rice, oat and corn.
- An urgent survey on soybean, peanut, lentil, chickpea and Phaseolus has to be initiated. These crops are cultivated in different areas of Morocco with different cropping systems.
- A germplasm collection of the wild and cultivated species of cereals and the other food legumes should be initiated.

- The exploration of the resistance in different germplasm collections to the main plant parasitic nematode species and other soil born pathogenic fungi (Verticillium, Rhizoctonia and Fusarium) is needed. This screening will act as a basis for the initiation of a breeding program to create resistant varieties for local and international use.
- The study of cropping systems to manage the nematode problem in the country.

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PRESENT STATUS OF RESEARCH ON PLANT PARASITIC NEMATODES IN CEREALS AND FOOD AND FORAGE LEGUMES IN PAKISTAN

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Introduction

Pakistan is predominantly an agricultural country and has large areas of deep soil, favourable topography, suitable climatic conditions and water. These components supported by an extensive canal system allow the production of a variety of food, feed and fibre crops. Total culturable land in the country is 32 million hectares of which about 20 million is being actually cultivated for growing different crops (Table 1). A considerable part of the remaining 12 million hectares could be brought under cultivation after some improvements. The country has a potential of producing nearly 100 million tonnes of food grains annually of which presently only about 20% is being realized.

Table 1. Distribution of total cultivated area of Pakistan under different crops, 1984-85.

Crops	Percent of the total cultivated area
Wheat	36
Rice	12
Cotton	12
Barley	1
Chickpea + other pulses	8
Maize + millet + sorghum	7
Oil seeds	3
Vegetables + fruits	2
Tobacco	0.5
Sugarcane	4.5
Fodder legumes	14

Pakistan's agricultural system is highly complex. Physicgraphically, the country has five distinct zones, viz., (1) mountain and inter-mountain valleys, (2) Potowar plateau and adjacent foothill areas, (3) Indus plain, (4) sandy desert and sand dune area and (5) marsh lands. Climatically, the northern parts fall in the semiarid zones, where the annual rainfall varies from 500 to 1000 mm. Most of the plains and the Baluchistan plateau with annual rainfall of 125-300 and 125-180 mm, respectively, lie in the arid zone. Most of the rainfall is received during the monsoon season i.e., mid-July to mid-September and is well distributed. Some winter rains are also received between December and February. The mean annual minimum and maximum temperatures, respectively, are -5.2 and 36.6^{o}C in northern hilly area; 2.8 and 45.0^{o}C in the semiarid areas; -0.7 and 472°C in the arid zone, and -5.7 and 42°C in Baluchistan.

In Pakistan the nematode problems are serious and complex. The reasons for this are many and varied. The country lies in the tropical region where the climate is suitable for the activity and reproduction of nematodes throughout the year. Sandy and warm soils as found in the arid zone are very favourable for nematode development and infestation. In irrigated areas perennial crops and crops grown in the same field year after year are often heavily attacked by nematodes.

As a result of studies carried out on the nematode problem in Pakistan, the available information on the occurrence, distribution, estimated crop losses due to plant parasitic nematodes and different control systems on wheat, barley, chickpea, bean and forage legumes is given in this presentation.

Wheat and Barley

In Pakistan wheat is a principal crop both in area under cultivation (7.3 million hectares) and in dietary importance. Barley occupies an area of 200,000 ha. Although 45 species of the stylet bearing nematodes (Table 2) have been recorded associated with wheat and barley; most of them have no impact on grain yield (Maqbool 1986). Earcockle caused by Anguina tritici in wheat, cereal cyst nematode (Heterodera avenae) and corn cyst nematode (Heterodera zeae) are major pests of wheat and barley in the country. The earcockle disease occurs in nearly all parts of the country where wheat is cultivated. Tundu disease of wheat caused by the association of earcockle with Coryneabacterium tritici also produces serious losses to the crop in the sub-continent. H. avenae and H. zeae were reported from wheat and barley fields in the North West Frontier Province (Maqbool 1980). These nematodes were then detected later from various fields of Punjab and Sind.

Studies on the economic damage to wheat indicated 2-3% loss in yield due to earcockle and about 15-20% due to H. avenae. In individual fields losses of up to 50% were detected. Although losses caused by H. zeae on barley have not been assessed experimentally, they are often spectacular and frequently exceed 15%.

Control

Infestation caused by A. tritici is generally controlled by removing the galls from healthy seeds. Several methods of control are applied effectively for cereal cyst nematode including (1) crop rotation, (2) use of resistant varieties and (3) chemical control.

Table 2. Stylet bearing nematodes associated with wheat and barley in Pakistan.

Wheat	Barley
Anguina tritici	Aphelenchus avenae
Aphelenchus avenae	Criconemella xenoplax
Basiria incita	Ditylenchus dipsaci
B. minor	Helicotylenchus digonicus
Ditylenchus dipsaci	H. dihystera
Helicotylenchus microdorus	Hirschmanniella oryzae
H. multicinctus	Heterodera avenae
H. egyptiensis	H. zeae
Hirschmanniella gracilis	Hoplolaimus indicus
H. oryzae	Merlinius brevidens
Hemicriconemoides cocophilus	Pratylenchus hamatus
Heterodera avenae	P. projectus
H. zeae	Pratylenchus brachyurus
H. mani	P. crenatus
H. mothi	P. penetrans
H. pakistanensis	P. thornei
Hoplolaimus indicus	Psilenchus hilarulus
H. seinhorsti	Quinisulcius capitatus
Malenchus andrassyi	Tylenchorhynchus brassicae
M. fusiformis	T. annulatus
Merlinius brevidens	T. mashhoodi
M. microdorus	Xiphinema americanum
Neopsilenchus vulgaris	
Pratylenchus brachyurus	
P. penetrans	
P. similis	
P. thornei	
P. zeae	
Psilenchus hilarulus	
Rotylenchus reniformis	
Rotylenchus robustus	
Scutylenchus koreanus	
Tylenchus butteus	
Tylenchorhynchus annulatus	
T. brassicae	
T. cylindricus	
T. mashhoodi	
T. tritici	
Xiphinema intermedium	
X. americanum	

In North West Frontier Province of Pakistan where corn is frequently cultivated, farmers generally grow wheat in the sequence corn-wheat-corn or corn-barley-corn. Disease severity of H. zeae is

therefore high in this area. In the plains of the Punjab improved wheat yields occurred when a 'wheat-cotton- fallow-wheat' or 'barley-cotton-fallow-barley' rotation were used. Keeping the land fallow reduced nematode soil population to the lowest level and produced the greatest subsequent wheat yields. However, fallows are impractical on a long term basis and cotton is not cultivated in most parts of the North West Frontier Province. Tobacco is another important cash crop in the province, but does not help in suppressing nematode populations. Peas, onion, garlic and turnip are winter vegetables cultivated all over Pakistan and are non hosts of H. avenae. These vegetables are effective both in producing an economic return and in reducing H. zeae populations.

The wheat and barley cultivars used are not resistant to H. avenae infection. However, the rate of infection is variable in different varieties.

Nematicides can be used to control H. avenae in wheat. Although it is not economical, its use has shown significant increase in yield. In field trials, carbofuran and aldicarb applications (@ 4 kg ai/ha) have shown 50 and 75% increase in yield, respectively.

Chickpea

Chickpea occupies an important position in Pakistan's agriculture. It is widely cultivated as a cool season annual in the country except in hilly regions where temperatures are continously low. Pakistan ranks second to India in area under chickpea cultivation. The total area

under production is 1.225 million hectares with an average total production of 0.538 million tons.

The chickpea varieties commonly grown in several provinces of Pakistan have been found susceptible to the root-knot nematodes Meloidogyne incognita and M. javanica. Heterodera zeae was also reported from chickpea soil in Peshawar but attachment of cysts to roots were not observed (Maqbool 1980). The other nematodes associated with chickpea include: Tylenchorhynchus annulatus; Helicotylenchus digonicus and Hoplolaimus indicus. Meloidogyne incognita and M. javanica have been found mostly in Sind and Punjab, whereas, T. annulatus, H. digonicus and H. indicus are widely distributed in Sind, Punjab, Baluchistan and NWFP.

Crop loss

Although Meloidogyne is a serious pest, crop loss estimates have been infrequent. However, in several heavily infested fields losses up to 40% have been observed.

Crop rotation

Success has been achieved by rotation with non and poor hosts in greatly reducing the root-knot nematode population level. Population of Meloidogyne digonicus, T. annulatus and H. indicus declined on cotton, wheat and barley in all crop sequences resulting in 10-15% increases in yield in subsequent cropping of chickpea while vegetables favoured nematode population buildup.

Chemical control

Nematicides have been tested for their efficacy at different dosages. Aldicarb and carbofuran at 1 kg ai/ha decreased root-knot index and juvenile population in soil as well as reduced populations of T. annulatus, H. digonicus and H. indicus to a significantly low level from initial populations of 800/100g of soil to 50/100g. Application of these nematicides increased yield up to 20%.

Faba Bean

In surveys of bean fields several important plant parasitic nematodes were isolated. These included Rotylenchus reinformis, M. incognita, M. javanica and Pratylenchus penetrans. However, information on loss in yield due to these nematodes is not available.

At present there is no literature available in the country on control principles against these nematodes in this crop.

Forage Legumes

In Pakistan many varieties of forage legumes are being cultivated. Among these Trifolium spp; Vigna spp; Saphura spp; Medicago sativa; Indigofera oblongifolia and Sesbania sesban are important and cultivated in a number of areas.

Studies have revealed that besides other stylet bearing nematodes M. incognita and M javanica are common in Pakistan (Munir et al. 1986).

Further investigations on loss assessment and control measures are in progress.

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THE STATUS OF RESEARCH ON PLANT NEMATOLOGY IN CEREALS AND FOOD AND FODDER LEGUMES IN THE SUDAN

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Introduction

Since the nematology investigations started in the early sixties, not more than a few nematologists have been engaged in nematological research throughout the Sudan. This is still the case at the present time. In spite of this, strong effort has been made especially regarding species identification and certain biological investigations of major species. Over 70 species of plant parasitic nematodes were detected in and/or around the roots of many cultivated and weed plants in various locations throughout the country (Yassin et al. 1970; El Amin and Siddiqi 1970; Decker et al. 1980). For a comprehensive account of the status of nematological investigations in the Sudan, reference is made to a recent review by the author (Yassin 1986). Cotton and vegetable crops have received a relatively larger attention of the nematologists. This is quite understandable in case of cotton since it has always been the focus of attention as a most widely grown cash crop. In case of vegetable crops nematode problems are more obvious than in the more widely grown cereals and legumes. This is especially true in case of tomato. Thus, the root-lesion nematodes, particularly the new species Pratylenchus sudanensis (Loof and Yassin 1970), have been recognized as potentially hazardous pests to cotton

cultivation in nearly one million hectares in Gazira (Yassin et al. 1970; Yassin 1973). In addition to their role as direct pests, root-lesion nematodes have also been found to act as precursors of fungal induced vascular wilt (Yassin 1974a). Also the root-knot nematode has often constituted a bottle-neck to the production of vegetable crops, especially tomato, at several locations throughout Sudan (Yassin 1974b; 1984).

The major objective of this review is to outline the situation of nematode investigations in cereal as well as leguminous crops, with a view to: a) define the major parasitic species, their distribution, economic importance and control measures; b) outline major deficiencies within such investigations and c) develop a coordinated program of investigations with ICARDA with the objective of drawing an integrated control strategy against major parasitic nematode species in cereal and legume crops.

Plant Parasitic Nematodes in Cereals and Legumes in the Sudan

Several cereals and food and forage legumes are widely cultivated in Sudan. The most important of these are: Triticum aestivum L., Sorghum bicolor Moench, Zea mays L. and Oryza sativa L.; Phaseolus vulgaris L., Arachis hypogaea L., Cajanus cajan, Vicia faba L., Cicer arietinum L. and to a limited extent Lens esculentus Moench and Pisum sativum L.; Lablab niger Medik, Medicago sativa L., and relatively recently introduced fodder beans e.g. Clitoria ternata L. and Phaseolus trilobus L. Nematology investigations in these crops are rather limited. Several species of plant parasitic nematodes, however, have been isolated and identified on these crops at several locations throughout

Sudan. A comprehensive check list is given in Table 1. Among the most important are root-knot nematodes, Meloidogyne javanica Chitwood, M. incognita Chitwood and M. arenaria Chitwood; the root-lesion nematodes, mainly Pratylenchus sudanensis Loof and Yassin and P. neglectus Filipjev and Sh. St.; the stunt nematodes, Tylenchorhynchus dubius Filipjev, T. maximus Allen, T. mashodi Siddiqi and Bashir, T. brevilineatus Williams, Paratrophurus lobatus Loof and Yassin and P. sudanensis Decker, Yassin and El Amin; the lance nematodes, Scutellonema bradys Steiner and Le Hew, S. clathricaudatum Whitehead; the spiral nematode, Helicotylenchus dihystera Sher.; the needle nematode, Longidorus africanus Merry; and the reniform nematode, Rotylenchulus reniformis Linford and Oliveira (see also Table 1). These are covered in some detail in relation to host crop.

Nematode Species associated with the Roots of Cereal Crops

Sorghum millet: Sorghum bicolor is an important crop rotated with cotton in the Gezira ecosystem. Surveys for plant parasitic nematodes in sorghum millet covered major production areas in the north, east and south-east of Sudan. A total of 25 species occurred in the soil or roots of sorghum; most important of which were P. sudanensis, P. neglectus, R. reniformis, and T. dubius (Table 1). Although these species are widely distributed in the fields per se in densities of 100-400 nematodes/200g of soil, few investigations of ecological or biological nature, or possible economic importance in sorghum have been conducted. However, studies have been undertaken with respect to the host-status of P.sudanensis from the Gezira locality. Sorghum acts as a moderate host for the nematode, with a 5-10 fold increase in nematode

densities over the original numbers (Yassin 1973). In addition P. sudanensis was found to exhibit considerable variation in the male/female sex ratio under dwarf milo sorghum. This warrants investigation as to the possible biological races of the nematode (Loof and Yassin, unpublished work).

Wheat: Bread wheat in particular is gaining increasing importance in the Sudan. Wheat ranks next to sorghum millet as a staple food and the area under cultivation extends from the north east to the central region where the Gezira scheme is situated. Like sorghum, it is also an important rotation crop with cotton in the Gezira scheme. In nematological surveys undertaken throughout the main production areas, 12 species of plant parasitic nematodes were identified from the rhizosphere of wheat. The most important of these were species of Paratrophurus lobatus, Tylenchorhynchus maximus and T. mashodi, in densities of 100-300 nematodes/200g soil. Other important nematode species in the rhizosphere of wheat, especially in central Sudan, are unidentified species of Pratylenchus, and Scutellonema (Table 1). Nothing is known of their economic importance or biology.

Maize and rice: These cereal crops are grown to a limited extent and hence limited nematological surveys have been undertaken (Table 1).

Nematode Species associated with Food Legumes

French bean: Though up to 13 species of plant parasitic nematodes were found in association with the roots of french bean (common bean) from various localities in Sudan, only few species seem to be of significance. These are Meloidogyne javanica, M. incognita and M.

arenaria in lighter soils throughout the Sudan. Meloidogyne javanica and M. incognita in particular are known to cause devastating damage in lighter volcanic soils of western Sudan, as well as in the river silt along the Nile bank. Other species of possible economic importance in common bean are species of Tylenchorhynchus and Pratylenchus (Table 1).

Groundnut: This extensively grown leguminous crop seems largely devoid of any significant nematode damage, the only exception is perhaps Tylenchorhynchus spp. in the heavy clay or sandy soils of Western Sudan. This is despite the fact that up to 11 nematode species have been found associated with the root system (Table 1).

Pigeon pea: This deep rooted robust legume has been surveyed for plant parasitic nematodes in central Sudan, where it is commonly grown, and in the south east. Nine plant parasitic nematodes were found associated with its roots, but none seems to affect its growth or yield drastically. In glass-house as well as in field investigations at the Gezira Research Station, it was found to act as one of the best hosts for Pratylenchus sudanensis; with up to a 20-fold increase in nematode densities over the original numbers (Yassin 1973). Inspite of this, pigeon pea seems to exhibit a remarkable degree of tolerance towards this nematode (Saadabi 1985). It is also worth mentioning that duration of the life cycle of nematode on pigeon pea was 28 days (egg to mature female). This means several generations occur during the normal growing season (Yassin and Mohamed 1980).

Faba bean: Despite the fact that faba bean is by far the most important and popular food legume in the Sudan, few nematological surveys have been undertaken on the crop. Its cultivation is largely confined to the northern sector of the Sudan, having a longer and cooler winter

Table 1. A check list of plant parasitic nematodes associated with the roots of cereals, and food and forage crops in the Sudan*.

Crop plant	Nematode species and density	Locality
I. **Cereals:**		
1. *Sorghum bicolor* Moench and *Sorghum* species.	1. *Aphelenchoides parietinus* Steiner	E
	2. *Aphelenchoides* species	E,SE
	3. *Aphelenchus avenae* Bastian	N,E,C
	4. *Ditylenchus myceliophagus* Goodey	N,E,SE,C
	5. *Ditylenchus* species	N
	6. *Helicotylenchus egyptiensis* Tarjan	E
	7. *Helicotylenchus* species	E
	8. *Longidorus* species	N
	9. *Merlinus brevidens* Siddiqi	E,C
	10. *Nothotylenchus* species	C
	11. *Paratrophurus lobatus* Loof & Yassin	N,ES,E
	12. *P. sudanensis* Decker, Yassin & El Amin	E
	13. *Pratylenchus neglectus* Filipj. & Sch. St.	E
	14. *Pratylenchus sudanensis* Loof & Yassin	N,E
	15. *Pratylenchus* species	C,E
	16. *Quinisulcius acti* Siddiqi	
	17. *Rotylenchulus reniformis* Linford & Oliveira	C
	18. *Rotylenchulus* species	C
	19. *Scutellonema clathricaudatum* Whitehead	C,SE
	20. *Scutellonema* species	E,SE,C
	21. *Tylenchorhynchus brevilineatus* Williams	N
	22. *T. cylindricus* Lobb	N,E
	23. *T. dubius* Filipjev.	E
	24. *Tylenchorhynchus* species	N,E
	25. *Tylenchus* species	E
2) *Triticum aestivum* L.	1. *Aphelenchoides tonuis* Steiner & Buhrer	C
	2. *Aphelenchoides* species	E,SE,C
	3. *Aphelenchus avenae* Bastian	C,SE
	4. *Ditylenchus* species	C
	5. *Paratrophurus lobatus* Loof & Yassin	C
	6. *Pratylenchus sudanensis*	C
	7. *Pratylenchus* species	C
	8. *Scutellonema* species	C
	9. *Tylenchorhynchus mashodi* Siddiqi & Bashir	C
	10. *T. maximus* Allen	E
	11. *Tylenchorhynchus* species	C
	12. *Tylenchus* species	C

3) *Oryza sativa* L.	1. *Ditylenchus angustus* Filipjev.	C
	2. *Tylenchurhynchus martini* Fielding	CX
	3. *T. ventrosignatus* Tobar-Jiminez	C
4) *Zea mays* L.	1. *Aphelenchus avenae* Bastian	N
II. Food legumes:		
1) *Phaseolus vulgaris* L.	1. *Aphelenchoides* species	N
	2. *Aphelenchus avenae*	N
	3. *Ditylenchus* species	N
	4. *Longidorus* species	N
	5. *Meloidogyne arenaria* Chitwood	W,C
	6. *M. incognita* Chitwood	W,C
	7. *M. javanica* Chitwood	C
	8. *Paratrophurus lobatus* Loof & Yassin	N
	9. *Paratrophurus* species	N
	10. *Pratylenchus* species	N
	11. *Tylenchorhynchus brevilineatus* Williams	N
	12. *Tylenchorhynchus* species	N
	13. *Tylenchus* species	
2) *Arachis hypogaea* L.	1. *Aphelenchoides subtenius* Steiner & Bahrer	SE,C
	2. *Aphelenchoides* species	C
	3. *Aphelenchus avenae* Bastian	C,E
	4. *Ditylenchus myceliophagus*	E,SE,C
	5. *Ditylenchus* species	C
	6. *Helicotylenchus dihystera* Sher	C
	7. *Paratrophurus* species	S,E
	8. *Pratylenchus* species	C
	9. *Psilenchus* species	C
	10. *Scutellonema bradys* Steiner & Le Hew	C
	11. *Tylenchus* species	E
3) *Cajanus cajan* Mill sp.	1. *Aphelenchoides* species	C
	2. *Aphelenchus avenae* Bastian	C,SE
	3. *Ditylenchus myceliophagus*	C,SE
	4. *Ditylenchus* species	C
	5. *Paratrophurus lobatus* Loof & Yassin	C
	6. *Rotylenchulus reniformis* Linford & Oliveira	SE
	7. *Scutellonema clathricaudtum* Whitehead	C
	8. *Tylenchorhynchus* species	C
	9. *Tylenchus* species	

4) *Vicia faba* L.	1. *Aphelenchus avenae* Bastian	N
	2. *Ditylenchus* species	C
	3. *Longidorus africanus* Merry	C
	4. *Longidorus* species	N
	5. *Pratylenchus* species	N
	6. *Tylenchorhynchus* species	N
5) *Cicer arietinum* L.	1. *Aphelenchoides graminis* Baranowskaja & Hagne	N
	2. *Aphelenchus avenae* Bastian	N
	3. *Ditylenchus myceliophagus*	N
6) *Pisum sativum* L.	1. *Aphelenchus avenae*	N
III. Fodder legumes:		
1) *Lablab niger* Medik	1. *Aphelenchus avenae* Bastian	C,Kht.
	2. *Longidorus siddiqi* Aboul-Eid	C
	3. *Meloidogyne arenaria* Chitwood	C,Kht.
	4. *M. incognita* Chitwood	
	5. *M. javanica* Chitwood	C
	6. *Scutellonema clathricavdatum* Whitehead	C
2) *Medicago sativa* L.	1. *Aphelenchus avenae* Bastian	N
	2. *Longidorus* speices	W
	3. *Tylenchus* species	N
3) *Clitoria ternata* L.	*Pratylenchus sudanensis* Loof & Yassin	C
4) *Phaseolus trilobus* L.	*P. sudanensis*	C

* Taken largely from Decker *et al.* (1980)

Key: E = east, SE = south east, N = north, C = center, W = west, and Kht. = Khartoum.

season. In limited investigations, no detectable nematode problem has been noted. Among the few nematodes identified, are unidentified species of Pratylenchus and Longidorus africanus (Table 1). It is, however, worth noting that L. africanus can inflict conspicuous damage to other crop plants especially in central Sudan by attacking the roots at the growing points and hence resulting in distinctly stunted or stubby root system (Yassin 1974c). Future investigation, therefore, should take this nematode into account. Nematological surveys should also include larger areas of the central region, because faba bean cultivation is being expanded through a joint effort of ICARDA and the Agricultural Research Corporation (ARC) in that region.

Other food legumes (chickpea, lentil and garden pea)

The area under cultivation is relatively limited for these crops in relation to faba bean and groundnut. Limited nematological surveys have been undertaken and no detectable problem has been encountered (Table 1). A joint effort by ICARDA and ARC is also needed in this crop group, particularly in chickpea, not only to cover nematode problems, but also to expand the production in areas with suitable climate and soil.

Nematode Species associated with Forage Legumes

Lubia bean: This leguminous crop was popular and widely grown in the 1960-1980 period, both as a forage and food legume. It was one of the most important crops in the rotation with cotton in the Gezira locality. Due to damage from certain insect pests, especially whitefly and bollworm, to cotton, its cultivation was largely restricted. It is

thus no longer in the Gezira rotation at present. Despite such limitations, it is still quite popular as a fodder crop in the north and central Sudan. This is by virtue of its high tolerance to many pests and diseases, and also because of its rich and highly succulent foliage. Of the six nematode species associated with its roots, only the root-knot nematode constitutes a real hazard, especially in lighter soils. All three root-knot nematode species, M. javanica, M. incognita and M. arenaria, cause extensive root galling making the root more prone to attack by other invading agents e.g. termites. Meloidogyne javanica, is more predominant than the other two species (Yassin 1974b). Lubia bean is also considered an excellent host for P. sudanensis (Yassin 1973).

Medic: This perennial fodder legume is very popular throughout Sudan. The damage due to nematodes has not been detected on the crop, in the limited investiations undertaken in the northern and western Sudan. The most predominant nematode species associated with its root system was species of Longidorus (Table 1).

Other fodder legumes: (Phaseolus trilobus, "Phillipesara", and Clitoria ternate, "butterfly bean"). These were introduced in Sudan long ago but they have not gained much popularity. Nematological surveys in the Gezira locality, however, revealed the presence of Pratylenchus sudanensis in and around the roots of both fodder crops (Saadabi 1985).

General Comments on Preventive and Control Measures against Major Plant Parasitic Species

Root-knot nematodes: The most economical means of controlling this

noxious plant parasitic nematode is by planting crops in heavy clay soils of the Gezira or eastern Sudan (Yassin 1974b). Other means of control can be breeding resistant cultivars and adopting suitable crop rotations.

Root-lesion nematodes: The most effective means of control being practised at present in the Gezira area, is crop rotation. In fact the 4-course rotation adopted in the Gezira area (Cotton-Wheat-Groundnut/Sorghum/Vegetables- and Fallow) is a good safeguard against these noxious migratory endoparasites (Yassin 1973). Two additional control techniques are the practice of deep ploughing recently adopted in the Gezira, and the application of aldicarb (Yassin and Mohamed 1980; Saadabi 1985).

Other nematode species: No clear control or preventive measures against migratory ectoparasites are available. Here again cooperation with ICARDA is important.

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THE STATUS OF PLANT PARASITIC NEMATODES IN CEREALS AND FOOD AND FORAGE LEGUMES IN SYRIA

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Introduction

Cereal and food legumes are considered to be of high economic importance in Syria. Wheat is the major cereal crop followed by barley. Regarding food legumes chickpea ranks first in importance followed by lentil and faba bean (Table 1). One of the major constraints in the production of cereals and food legumes in Syria is the susceptibility of existing varieties to pest and diseases, including nematodes. Documented records of plant parasitic nematodes in Syria are scanty. Mamluk and Faust (1975) reported the occurrence of root-knot nematodes such as Meloidogyne arenaria, M. incognita and M. javanica in cotton and sugar beet in various districts. Tayar

Table 1. Area and production of cereals and food legumes in Syria (1984).

Crops	Cultivated area (ha)	Total production (metric tons)
Wheat	1006955	1067602
Barley	1289133	303483
Chickpea	53316	36787
Lentil	59477	35594
Faba bean	7216	12146

(1970) claimed that a considerable loss in yield of tobacco is caused by M. javanica. The stem nematode Ditylenchus dipsaci was found to severely infest faba bean fields on the coastal areas in Syria (Hanounik and Sikora 1981).

In spite of the limited work that has been done on nematology in Syria, several genera of nematodes are reported on various crops (Table 2).

Table 2. The important parasitic nematodes of cereal, food legumes and forage crops recorded in Syria.

Crops	Nematodes						
	Ditylenchus dipsaci	Helicotylenchus dihystera	Anguina tritici	Heterodera goettingiana	Heterodera ciceri	Pratylenchus thornei	Meloidogyne artiellia
Wheat	+	+	++	-	-	-	
Faba bean	+++	+	-	+			
Chickpea					+++	++	+
Lentil					+++	+	-
Peas					+		+
Vetch					+		+
Roughpeas					+		+
Medics					+		+

+ : Sporadic
++ : Moderate
+++ : Wide spread.

Wheat Nematodes

Stem nematode (Ditylenchus dipsaci): The nematode was found in the stem of wheat in coastal areas (Lamberti 1983).

Spiral nematode (Helicotylenchus dihystera): The nematode was found in the rhizosphere of various plants such as wheat and woody plants in coastal areas (Lamberti 1983).

Seed gall nematode (Anguina tritici): The seed gall nematode was found in wheat seed in the southern part of Syria in 1982 and detected again from diseased seed samples from Aleppo and Idleb districts on the cv Bayyadi in 1984 (Anon. 1982-1986).

Faba Bean Nematodes

Stem nematode (Ditylenchus dipsaci): Joint surveys were conducted by the International Center for Agricultural Research in the Dry Areas (ICARDA) and the Syrian Agriculture Research Center during 1982 to 1986. The stem nematode was widely distributed in faba bean fields in the coastal region and high rainfall areas, causing considerable damage (Anon. 1982-1986; Hanounik and Sikora 1981).

Spiral nematode (Helicotylenchus dihystera): It is wide-spread in coastal areas and was also found in the rhizosphere of faba bean (Lamberti 1983).

Cyst nematode (Heterodera goettingiana): It was found in fields of faba bean in Douma - Rhihan near Damascus.

Chickpea Nematodes

Cyst nematode (Heterodera ciceri): Surveys conducted in northern, central and southern parts of Syria during 1982 to 1986, showed that the cyst nematode was widespread. Infested fields showed poor growth of the plants, leaf yellowing, defoliation indicating that chickpea was infested by this nematode. It was found that the cyst nematode is more common on spring-sown chickpea, and widely prevalent in the farmers' fields especially in the Idleb and Aleppo districts. According to the nematology work conducted at ICARDA, the host range of this nematode is confined to the members of Leguminosae family. Therefore, crop rotation using non-host crops should be practiced to avoid yield losses caused by this nematode (ICARDA 1984, 1985).

Root lesion nematode (Pratylenchus thornei): This nematode was detected in chickpea fields in Syria. Infected chickpea showed reduced growth and many root lesions. The host range of this nematode is large which includes legumes and cereals.

Root-knot nematode (Meloidogyne artiellia): Root-knot nematode is found sporadically in winter-sown chickpea. Infested fields showed patches of yellow and stunted plants. The host range includes members of the families Cruciferae, Leguminosae, and Gramineceae. Others are poor or non-hosts, therefore, crop rotation should provide an efficient way to limit losses in chickpea (ICARDA 1984, 1985).

Forage Crop Nematodes

During the 1981/82 season, 8 field trips were made to the forage crops planted in Syria to evaluate the disease status of these crops. The results showed that root-knot nematode (Meloidogyne sp.) and cyst nematode (Heterodera sp.) were parasitising peas (Pisum sativum), vetch (Vicia sativa), roughpeas (Lathyrus sativus) and medics (Medicago spp.) (Anon. 1982-1986).

Conclusions

This paper presented the major nematode species of legumes and cereals found in Syria. Further studies should be carried out to determine the presence of other species of majro economic importance, their geographical distribution and frequency of occurrence in Syria. There is a need to strengthen nematode research in the Syrian national program.

Investigations were carried out on chickpea nematodes at the International Center for Agricultural Research in the Dry Areas (ICARDA) and Agriculture Research Center in Syria. There is a need to conduct more trials to estimate the economic importance of the nematode problems in lentil, cereals, and forage crops.

Chemical control of parasitic nematodes is not feasible due to low return and the high cost of the treatment. Therefore more attention should be given to crop rotation and introducing resistant varieties to reduce yield loss. This aspect of research should be strengthened.

In order to achieve the above mentioned goals the national program will require support in the form of training, exchanging ideas and providing necessary facilities.

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NEMATOODE PROBLEMS OF WINTER SEASON CEREALS AND FOOD LEGUME CROPS IN THE MEDITERRANEAN REGION

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Introduction

The Mediterranean region includes some 15 countries which are distributed in the continents of Africa, Asia and Europe. The climate of this region is characterized by its mild winter and dry hot summer. In most countries of this region, except Egypt and Sudan, rainfall is adequate during the winter cropping season. Egypt and Sudan depend mainly on their Nile irrigation system network for crop water requirement. Edaphic factors such as pH, fertility and humus content of the soil differ from one country to another.

Important Nematode Pathogens Infecting Winter Season Food Crops in the Region

The following pathogenic nematodes are regarded as important and/or potential economic pests:

Cyst-forming nematodes, Heterodera spp.

These nematodes are no longer confined only to temperate zones, as was at first assumed. As a matter of fact, they can tolerate much wider temperature ranges. In the Mediterranean region, the cereal cyst nematode, *Heterodera avenae* infects both wheat and barley (Lamberti 1978). It is indigenous in many countries of the region and can cause

economic damage irrespective of soil type (Lamberti 1978). H. latipon, a cyst nematode similar to H. avenae, has been found on wheat and barley in certain countries of the region (Franklin 1969). In Egypt, the corn cyst nematode, H. zeae has been recorded on wheat and barley (Oteifa 1978). Faba bean and peas have been reported as hosts of the clover cyst nematode, H. trifolii (Oteifa 1984). The pea cyst nematode, H. gottingiana has been recorded on legume crops in North Africa (Lamberti 1979; Salem 1983).

Root-knot nematodes, Meloidogyne spp.

These nematodes are of widespread occurrence in the region and capable of causing considerable damage to many agricultural crops (Ibrahim 1985). Six species, namely, M. javanica, M. incognita, M. arenaria, M. hapla, M. nassi and M. artiellia have been found to attack wheat, barley, faba bean, lentil, chickpea and pea in certain localities of the region. Certain wheat and barley cultivars are also susceptible to specific biotypes (races) of M. incognita and M. javanica (Oteifa 1983). M. nassi occurs on durum wheat and barley (Lamberti et al. 1975; Lamberti 1978), while M. artiellia has been reported only on wheat (Koliopanos 1978; Philis 1978). Most of the commercial cultivars of faba bean, lentil, chickpea and pea are susceptible to M. incognita (Races 1,2 & 3) and M. javanica (Race 1) (Oteifa and Elgindi 1983). M thamesi and M. hapla have been found on many cultivated plants in Turkey (Yuksel 1983).

Reniform nematodes, Rotylenchulus spp.

Although several species of reniform nematodes now occur, only R. reniformis is considered of economic importance. Due to its

semitropical nature, distribution is rather limited in the region. It is, however, widely-spread in Egypt, where it attacks most of the winter and summer food and fiber crops (Oteifa 1978). Faba bean, lentil, chickpea and pea are susceptible to certain pathotypes of this pest (Oteifa 1984).

Root lesion nematodes, Pratylenchus spp.

Many species of this group have a cosmopolitan regional distribution. While others appear to be restricted to a specific climatic zone. P. thornei and P. crenatus have been reported to attack wheat and barely, respectively . P. neglectus and P. zeae infect both wheat and barely. P. penetrans is a dominant root-rot pathogen of many winter food legumes (Elgindi and Kheir 1976; Webster 1972).

Other pathogenic nematodes

Apart from the nematode species mentioned above there are several others reported to be associated with winter cereals and food legume crops in the region. Certain species of the spiral nematode Helicotylenchus spp.; the stunt nematode Tylenchorhynchus spp.; and the stubby root nematode Trichodorus spp. are of potential economic importance in that many of them cause pronounced damage in certain localities (Webster 1972). The seed gall nematode, Anguina tritici, originally widespread in all wheat growing areas, is now limited to a few countries of the region (Webster 1972).

Major Nematode Problems Encountered in the Region

Direct involvement in crop losses

Direct nematode damage to growing plants is well recognized. The degree of injury, however, depends on the level of soil infestation by the dominating pathogenic nematode species and the prevailing environmental stress conditions, e.g., drought, waterlogging, salinity, inadequate nutrition, etc. Although this workshop deals mainly with the nematode problems of winter season crops, we must be aware of the fact that in the Mediterranean region the prevailing climatic conditions and cropping practices favor buildup of high nematode populations on the subsequent summer crops. Even if a winter crop does not show severe symptoms because of its tolerance to nematode infection, it is regarded as a stock plant upon which large populations of a nematode can build up. High temperatures and longer growing seasons result in more nematode generations per year and thus more crop damage. This is particularly evident with the more damaging species such as M. incognita, M. javanica, R. reniformis, H. zeae, P. penetrans and P. zeae (Kheir et al. 1979; Oteifa 1978).

Involvement in disease complexes

Several reports from the region demonstrate the role of parasitic nematodes in the disease syndrome of infected crops (Oteifa 1978). For example, Meloidogyne spp. are frequently associated with the damping-off fungi (Rhizoctonia and Pythium species) in the expression of root-rot complex disease of food legumes and P. thornei enhances the severity of Verticillium wilt of wheat. Nematode infection lowers the resistance of crop cultivars to vascular wilt diseases caused by soil fungi and bacteria. Disease complexes of this sort present special problemes for control measures which may involve the use of a combination of complementary practices. When developing cultivars with

resistance to wilt organisms, plant breeders should take into consideration the factor of soil pathogenic nematodes. Under field conditions plants develop close association with many organisms.

Involvement in the deterioration of biological nitrogen fixation

Species of nematodes attacking food legumes play a significant role in disturbing nitrogen fixation by nodule-forming bacteria (Kheir et al. 1979; Taha and Raski 1969). They are capable of depressing the number and size of nodules. Some endoparasitic nematodes, e.g., M. javancia infect only nodules and not the roots (Taha et al. 1977). This can cause drastic reductions in the number of nodules on the root system. The limited size of infected nodules is related to the early cessation of meristematic growth as a consequence of nematode infection. Thus concurrent nematode infection reduces the beneficial effects of the nitrogen fixing bacteria. It is noteworthy that nematode buildup on roots of food legume crops causes early destruction of nodules as well as initiating the production of new rootlets which are subject to both rhizobial and nematode infections. Repeated root initiation as a result of nematode infections and the progressive degeneration of bacterial tissue due to the occurrence of nematodes within the nodule are probably responsible for the carbohydrate depletion of legume host plants. It is important however, that rhizosphere environmentl factors along with the host factor itself be considered in the determination of the nematode interaction with nitrogen-fixing bacteria (Burton 1965; Parkinson 1967). This is a subject which needs to be fully explored.

Nematode infestation in newly reclaimed lands

Certain countries in the region are expanding their agricultural areas

through the reclamation of new desert lands. Although soils of these lands are obviously free from pathogenic organisms before reclamation, detectable pathogen infestations are found after a few years of cultivation. Various plant parasitic nematodes gain entrance to such a new areas via the irrigation system and seeds and other planting materials (Oteifa 1978; Oteifa et al. 1970). Once weeds get established they act as a reservoir for many plant parasitic nematodes. Their establishment as serious pests is further favored by light soil texture and high intensity of cropping with winter and summer host crops. Root-knot, root lesion and reniform nematodes become well established due to the provision of a wide host range for their reproduction. Even those of a rather limited host range, like cyst-forming nematodes, succeed to secure establishment on the growing cereals, food legumes and forage crops (Oteifa 1978).

Proposed Priority Research Areas

The following proposed projects are two examples of priority research areas which can be investigated by research scientists from both the national and international perspectives.

Project 1: The occurrence of pathogenic biotypes of nematodes and their implication in control schemes.

The most effective management practice for controlling nematodes is through the use of certain cultural practices, including crop rotation, the use of available resistant crop cultivars, and development of other resistant cultivars. One of the major obstacles, however, towards the establishment of this type of management control program is the

existence of physiological races of these pests. Plants developed for resistance to one race, when planted in soil infested with another race of the same species, may become heavily damaged. On the other hand, the degree of control through crop rotation is based on the level of resistance of the crops included and on the number of years between susceptible crops. Also, populations of other species of nematodes or biotypes of the same nematode species may occur on different succeeding crops. It is necessary, therefore, to initiate research to investigate the physiological and host variation in the economic nematode species occurring in the region. With this knowledge, effective control management programs can be properly designed. The primary objectives of this research should be to:

(i) determine the presence of species and existing biotypes of these nematodes within the region;

(ii) determine the susceptibility and or resistance of the currently grown basic food crops in each locality of the region to the nematode biotypes which are present;

(iii) test imported or introduced sources of resistant germplasm for the development of resistant crop cultivars to the prevailing biotypes; and

(iv) evaluate the host nutrition and environmental factors as related to the extent of pathogenic variations and fecundity of the nematode species.

Project II: Prospects of utilizing biocontrol agents within the integrated nematode management system

Hazards associated with the presently available nematicides for human

beings and animals and agricultural environment, and the lack of new economic and safe agricultural chemicals, accentuate the importance of exploiting the full potential of biocontrol agents in a management program. It is recognized that an integrated pest management and crop protection system is needed in this region. Such a system will substantially contribute to increases in productivity. A permanent policy for crop protection is also essential to ensure that no negative environmental effect will occur. In this respect, biological products, that are composed of natural stabilized plant and mineral extracts which when applied can improve the tolerance of the plant against soil pathogens and render the rhizosphere unfavourable for these pests, are worthy of investigation. The primary objectives of this avenue of biocontrol research would be to:

(i) isolate and identify the soil parasites and predators, e.g., nematode-trapping fungi, predacious nematodes and arthropods that coexist in the rhizosphere with plant pathogenic nematodes;

(ii) quantify these biotic agents in relation to the population dynamics of plant parasitic nematodes;

(iii) assess the antagnostic role of mycorrhizae, especially the vascular- arbuscular forms, against plant parasitic nematodes; and,

(iv) evaluate the efficacy of the recently developed commercial biocontrol products that stimulate the indigenous rhizosphere-inhabiting beneficial organisms which live on the surface of root as it grows through the soil and at the same time releases natural substances that are effective in killing, repelling, or deterring the associated pathogenic nematodes.

With these two approaches information will be generated that will go a long way in increasing crop production and maximizing economic welfare in the region. The quantity and quality of food crops saved as a result of this type of basic and applied research will far outweigh the cost involved in this research. ICARDA should take leadership in this research and develop links with national research organizations in the region to strengthen their research capabilities to cope with crop protection against these noxious pests.

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RECOMMENDATIONS FOR THE ESTABLISHMENT OF A NEMATOLOGY PROGRAM AT ICARDA

Introduction

It is essential to have a nematology program at ICARDA because of the known and likely importance of nematode pests on mandate crops in the region.

Crop production in the region has to be increased because of the relatively low yields and the reliance on imports to the region of essential foodstuffs e.g. grain. Any factors which inhibit the yield have to be fully studied and controlled.

Very little work has been done on plant parasitic nematodes of the cereals, and of food, pasture and forage legumes in the region mainly because of the lack of support for nematological research on these crops at the national level. However, there are strong indications from the limited work done in countries within the region, and also from work in countries outside the region, that certain nematodes cause serious losses in yield of these mandate crops and, in some crops, have been shown to cause complete crop failure. This was clearly demonstrated by results presented in research papers at the ICARDA Nematology Planning Conference in Cyprus (1-5 March 1987).

ICARDA must be able to respond to present and future nematode problems that have, or could, arise as agriculture intensifies and new cropping systems are introduced. The need for information and advice expressed by nematologists in the region could be satisfied by an effective ICARDA nematological program giving guidance and support to national research.

Background Information

On the basis of existing information from the region (see: Proceedings of the Conference), a number of nematodes have been identified as important pests (Table 1). The nematode species of proven economic importance are listed in Table 2.

Table 1. Estimated importance of major nematode groups of the ICARDA mandate crops. Severe (s), moderate (m), low (l), unknown (u) losses.

Nematode groups Crops	Root-knot nematodes	Cyst nematodes	Lesion nematodes	Stem and bulk nematode	Seed gall nematode	Reniformis nematode
Food Legumes:						
Chickpea	s	s	l			l
Faba bean	m	l	l	s		l
Lentil	u	m	l	u		
Pea	m	m	l	u		
Cereals:						
Wheat	u	s	m		m	
Barley	u	s	m		l	
Pasture and Forage:						
Vetch	s	s	l	u		
Forage pea	m	m	l	u		
Chikling	l	s	l	u		
Medics	s	l	l	u		

Table 2. List of economically important plant parasitic nematode species selected on ICARDA's mandate crops.

Root-knot nematodes:
Meloidogyne incognita
M. javanica
M. artiellia
M. arenaria

Cyst nematodes:
Heterodera ciceri
H. latipons
H. avenae
H. goettingiana
H. daverti

Stem and bulb nematode:
Ditylenchus dipsaci

Lesion nematode:
Pratylenchus thornei

Other nematodes that could be important:
other *Meloidogyne* spp.
Pratylenchus spp.
Rotylenchulus reniformis
Possible new species.

Proposed Research Program

The research program can be divided into five interrelated scientific areas. The initiation of research in one or more of these areas, either separately or simultaneously, will be determined by the available information and results from work at ICARDA and in the national centers.

1. Prevalence, Distribution and Identification of Nematodes:

   Standardised sampling, survey, extraction and population density estimation techniques would be developed at ICARDA to determine the prevalence and distribution of important plant nematodes.

   Cooperative research with nematologists in the region would be promoted to relate nematode presence and their population densities to visual crop damage estimates in the fields examined.

   Identification of nematodes considered to be of economic importance would be done in cooperation with National and/or International Nematode Taxonomy Institutes.

2. Crop Loss Assessment and Host Range:

   The host range of important plant parasitic nematodes detected in the region would be studied on the ICARDA mandate crops. Alternate hosts, especially weeds that predominate in the region, would be included where considered important in specific cropping systems.

   Standardised crop loss assessment trials would be done in glasshouses, microplots or field plots for nematodes identified as crop pests.

3. Resistance Screening:

   Nematodes of known importance would be included in existing screening programs.

Standardised inoculation and evaluation techniques would be developed for each nematode crop combination.

Germplasm with known resistance would be obtained through cooperative exchange agreements with National and International gene banks to accelerate development of resistant lines suitable for the region.

4. Population Dynamics and Biology:

Investigations would be initiated to provide information on nematode population changes, reproduction and development of the major nematodes as affected by environmental conditions and cropping systems, that would assist in designing integrated pest management programs.

5. Nematode Management:

Nematode management strategies would be implemented in two stages:

a. immediately, using information that already exists on control possibilities and on nematodes of known economic importance in the region (e.g. Anguina and Heterodera).

b. at a later stage, against the same or other nematodes as additional information on their biology and importance becomes available from the above research areas.

These control strategies would be based on the following:

1. Crop rotation
2. Agronomic practices
3. Crop resistance
4. Nematode-free seed
5. Manipulation of natural antagonists

The use of chemical and biological control methods would also be considered.

Staffing Levels

To initiate ICARDA's commitment to nematological research the minimum staff requirements in the first instance are:

1 Senior Nematologist.

3 Trained Research Assistants - one for each of the crop programs.

Additional necessary manpower resources

Facilities Required

The following will be essential for nematological work:

1. a nematology laboratorty
2. glasshouse space
3. field space
4. additional necessary resources

It is envisaged that, as demands on the nematological expertise increases, further staff and facilities will be required. Additional nematological work at ICARDA can be done by appointing other staff, or by visiting scientists on sabbaticals and by post-graduate students and others on specific outside project money.

Linkages

ICARDA had developed good collaborative linkages with the Institute of Nematology, Bari, Italy and the Institute of Plant Diseases, University of Bonn, Germany. It should encourage and seek linkages and collaborative nematological research programs between ICARDA and the national programs. Expertise available in the National Nematological

Centers in the region (e.g. National nematology Research Center, Karachi, Pakistan; National Research Center, Dokki, Cairo, Egypt) would be of great help in regional networking and should be fully used.

Collaboration should also be expanded with other International Centers outside the region, including CGIAR Institutes; and also with other research centers where appropriate nematological expertise is available (e.g. CSIRO, Australia; CNRCP, N.C.S. Univ., USA; Inst. of Nematology, B.B.A., Munster; CAB Int. Inst. of Parasitology, UK; Dept. of Nematology, Rothamsted; Dept. of Nematology, Wageningen; ORSTROM, Paris, France, and others).

ICARDA Support for National Programs

ICARDA, through its own nematology program, should support ongoing nematological research in national centers in the following areas:

a. Germplasm exchange
b. Experimental planning
c. Statistical analysis
d. Cooperative experimentation
e. Technical or graduate student training
f. Specialised short-term training courses
g. Training of individuals
h. Workshops
i. Literature and information, specific guides
j. Logistic support
k. Strengthening nematology research in national programs
l. Helping to obtain bilateral (or multilateral) funding from donor agencies for national research.

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