Nematology in 2000 AD

New Delhi

May 28, 1988

Organised by

Prof. Gopal Swarup Felicitation Committee

IARI, New Delhi-110012

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FOREWORD

It was in December, 1986 at the time of National Conference--Plant Parasitic Nematodes of India that students, friends and well-wishers of Prof Gopal Swarup expressed a desire to celebrate his sixtieth birthday in an appropriate manner Dr. Swarup's contributions in the development of this discipline in India are well known to majority of the scientists engaged in plant pathological or nematological investigations. Consequently a felicitation committee with Drs. D.J. Raski, Abrar M. Khan, A.R. Seshadri, S.K. Prasad as patrons and 8 others as members, was constituted and was entrusted with the job. The Committee decided to publish an advanced treatise on cyst forming nematodes, a subject on which Dr. Swarup concentrated the most, and to organise a symposium on 'Nematology in the year 2000 A.D. as I see it'. The Committee was overjoyed to have received the overwhelming response from the nematologists from all over the country. Besides several young and experienced researchers from India, a few nematologists from abroad have also given their consent to contribute a chapter for the proposed book. We earnestly feel that the book will be issued by the first quarter of next year. As the retirement of Dr. Swarup from active research work is also indicative of the beginning of a new era in nematological investigations in this country, it was considered appropriate to invite only younger researchers to put forth their views about the coming events in various aspects of nematology. I assure the participants that the Committee will, both dutifully and earnestly, fulfil the task it has undertaken on its shoulders

(C.L. SETHI)

NEMATOLOGY IN THE YEAR 2000 A. D. AS I SEE IT IN RELATION TO DRYLAND FARMING

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Over the years, the presence of nematological problems has gradually become more and more apparent, especially in developed nations. This trend is gaining momentum in developing countries as well. It is now known that nematode diseases take their toll in crop production all over the world. A recent survey indicated that monetary losses due to diseases caused by nematode on a world-wide basis exceed $ 100 billion annually (Sasser and Freckman, 1987). Though extensive in occurrence, diseases caused by nematodes lead to great loss in tropical crop production. The reasons for this are probably many and diverse. Favourable soil temperatures for nematode activity and development during most parts of the year, longer growing seasons, cultivation of susceptible crops continuously year after year, occurrence of many damaging species in the tropics, and lack of general awareness about these diseases are some of the reasons for most of the damage. In some crops, such as banana, coconut, and vegetables, the damage is usually spectacular, while in pulses, oilseeds, and many other crops in dryland agriculture, the damage is less dramatic, but sure and cumulative, resulting in reduced crop productivity. Crop yields in the drylands are as such poor due to a lack of soil moisture and nutrients. The presence of insect pests, nematodes, and other diseases further reduce the potential yields.

About 75% of the cultivated area in India is rainfed and approximately 45% of the total crop production comes from these drylands (Singh, 1983). Despite a projected increase in irrigated area by the year 2000, the dependance on dryland agriculture for food will be significant. These areas not only grow much of our millet and pulses but are major suppliers of cotton and groundnut. If India is to provide adequate food for a projected population of one billion people by the year 2000, the contribution of this area to crop production will have to be increased from the current 45% to 60%.

In order to produce more food, we will have to protect our crops from pests and diseases. The diseases caused by nematodes are known to be complex and

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are serious problems in dryland agriculture. Sandy and warm soils in the arid zone are very favourable to diseases caused by nematodes, especially in areas cultivated almost continuously. By overcoming, or at least by reducing these diseases, more food can become available to the increasing population. In other words, nematode control can play a crucial role in reducing the existing gap between food and population. Sorghum and pearl millet are the important cereals while groundnut, pigeonpea, and chickpea are the important legumes in the drylands. Ninety per cent of sorghum, pearl millet, groundnut, pigeonpea, and chickpea, are grown without irrigation. In this paper, I will confine myself to the nematode-caused diseases of these crops.

Current knowledge on the nematode problems in drylands of India

Groundnut : More than 27 species of plant parasitic nematodes have been recorded to be associated with groundnut in the different states of India (Sharma, 1985). The root-knot disease caused by *Meloidogyne arenaria*, and the pod-lesion diseases caused by *Pratylenchus* spp and the *Tylenchorhynchus* spp are important. Limited surveys have indicated that the root-knot disease is severe in the western states of Gujarat and Maharashtra, particularly in the Saurashtra region of Gujarat. Yield losses due to this disease in this area may range from 20% to 90%. Pathogenicity tests in pots at different locations have shown that an initial population level of 1–3 larvae per cm^3 of soil can adversely affect the plant growth and yield. Farmers do not use any nematicides or other control measures, but the practice of summer plowing is thought to reduce the disease intensity. The pod-lesion diseases are so far known to occur in localized areas of two southern states —Andhra Pradesh and Tamil Nadu. The sources of resistance against these diseases have been identified. The populations of *M. arenaria* are suspected to interact with important fungal diseases, however, the role played by the nematodes in the etiology of these diseases is not clear.

Pigeonpea : More than 39 species of the plant-parasitic nematodes have been associated with this crop (Sharma, 1985). The pigeonpea cyst nematode (*Heterodera cajani*), the reniform nematode (*Rotylenchulus reniformis*), and the root-knot nematodes (*M. incognita* and *M. javanica*) are considered important in different states. Greenhouse experiments at many locations using different populations indicated that an initial population level of <1 *H. cajani*, 1–2 *R. reniformis*, and 1–2 *M. incognita* per cm^3 of soil could significantly reduce the plant growth. *H. cajani* infection in the field can delay the flowering and maturity of the crop. It seems reasonable that the yield might be getting affected at or above these population levels in the fields. These species can enhance the fusarium-wilt incidence in the wilt-susceptible lines (Sharma and Nene, 1986). There are indications that root-knot nematodes may break the resistance of the wilt-resistant cultivars (Sharma, 1985a). A large number of pigeonpea genotypes have been recorded as resistant, in greenhouse tests, particularly to the root-knot nematodes.

Chickpea : Of the 29 species recorded to be associated with chickpea (Sharma, 1985), the root-knot nematodes, *Meloidogyne* spp (*M. incognita, M. javanica*), the reniform nematode (*R. reniformis*), and the root-lesion nematode (*Pratylenchus* spp) are considered important. An initial population level of 1 *M. incognita* or *M. javanica*, and 2 *R. reniformis* per cm^3 of soil can cause significant growth reduction. Presence of these nematodes enhances the severity of fungal diseases caused by *Fusarium* and *Rhizoctonia*. The root-knot nematodes can break the resistance to *F. oxysporum* (Upadhyay and Dwivedi, 1987).

Sorghum : There are 46 species of plant parasitic nematodes reported to be associated with this crop (Sharma, 1985). Diseases caused by the species of the stunt nematodes (*Tylenchorhynchus* spp) and the lesion nematodes (*Pratylenchus* spp) are suspected to be important in the states of Andhra Pradesh, Bihar, Gujarat, Karnataka, and Maharashtra. Information on the nematode-caused diseases of sorghum is very limited. However, an initial population level of 2–5 *Pratylenchus* sp per cm^3 of soil can be detrimental to plant growth. In Bihar, a population level of 2 *Hoplolaimus* sp. per cm^3 soil at planting may adversely affect the plant growth and the nematode is suspected to interact with species of *Alternaria, Curvularia*, and *Helminthosporium*.

Pearl millet : Work done on nematode-caused diseases of pearl millet is very limited. Of the 34 reported species (Sharma, 1985), *Tylenchorhynchus* spp and *Pratylenchus* spp appear to be important particularly in parts of Gujarat and Rajasthan. A population level of 1–2 nematodes of *T. vulgaris*, *Pratylenchus* sp, and *Hoplolaimus* sp may cause significant reduction in crop growth. *Hoplolaimus* sp is suspected to interact with *Helminthosporium* sp, *Alternaria* sp, and *Curvularia* sp.

The extent and pace with which work on nematode-caused diseases of crops has developed in relation to other sciences may not be very encouraging; however, keeping in view the limited available resources, the progress made is appreciable. It is well understood that plant-parasitic nematodes act as energy sinks in the crop-production systems and make the energy input versus output ratio inefficient. On the basis of limited surveys (approximately $<10\%$ of the total area under each of the crops has so far been surveyed), attempts have been made to identify the major nematode problems and their crop-loss potential.

Our approach in the nineties and thereafter

In the next decade and in 2000 A. D., we must focus our attention on some of the important aspects of agricultural nematology and strengthen our knowledge on the identified nematode problems besides surveying further crop areas and discovering new nematode diseases.

General awareness of nematode diseases : First of all, we need to create general awareness about the importance of nematode diseases in the dryland agriculture. Presently very few agriculturists are sufficiently conscious of the need to recognize and combat the diseases caused by these tiny creatures because their damage is usually difficult to differentiate from damage caused by other more familiar biotic and abiotic agents. Poor growth and declining yields of crops commonly observed in the semi-arid tropics are generally attributed to decreasing soil fertility, when in fact nematodes may be the major offenders. The extension nematologists, the principal communication link between the growers and research nematologists, will play a very significant role in taking the message from nematology laboratories to farmers' fields by conducting demonstrations, testing the adaptability of technologies developed at the agricultural stations, and convincing the growers that awareness and timely management of nematode diseases is of economic advantage, as well as informing nematologists about the new and changing problems to help direct the ongoing research programs. The nematologists must educate the small and large farmers of the important nematode problems of different crops. Distribution of simplified, colorful literature on the diseases and their control, use of mass media (radio, television, and video films) to reach a wider audience, and the publication of simple and not very technical articles on local nematode diseases in popular magazines will be useful. Extension services should help farmers in the diagnosis of nematode diseases and advise different options available to avoid crop damage. Establishment of nematode-assay services, where simplified (computerized) nematode and disease diagnostic schemes are available, in each district will be very helpful.

Crop-loss estimation and prediction of damage : Information on the capabilities of different nematode species to inflict economic losses is mainly limited to the effects of the root-knot and few other nematodes on vegetative growth of crops. This is the area that needs most attention now. We have hitherto talked of the presence of high and low nematode populations and somehow deduced that yields must be getting adversely affected. Major attention on estimation of crop losses by important nematode-caused diseases at different locations is inevitable to project the importance of nematode-caused diseases as constraints in crop production. However, quantification of crop responses and estimation of yield losses by nematode diseases is as much an art as a science because many factors influence the relationships between population densities of nematodes and crop responses. These factors prohibit an accurate characterization of loss. Development and use of damage-predicting models, based on the relationships between preplant, midseason, and harvest-time nematode densities and the crop damage will undoubtedly help in understanding these problems. These models will be helpful in advising the growers, on the basis of information available on the damage thresholds and nematode-hazard indices, as to which crops or crop varieties can be grown and which control method could be adopted. Development of regional crop-loss data base on the basis of crop-loss data collected over different spatial units (villages, tehsils, districts) will provide information on the prevalence and severity of diseases and related losses. This program will be useful in keeping administrators, policymakers, researchers, and farmers aware of the status of diseases caused by nematodes. Use of computer technology will be of great help in maintenance of the databases. Newly developed computer-video image systems have much potential in relating nematode crop performance to nematode numbers. Foliage-disease symptoms of plants have been quantified by use of microcomputer-digitized video-image analyses (Lendou and Webb, 1983). Digital sensing techniques for counting nematode eggs or galls on roots and mapping of nematode damage by aerial infrared photography will be useful in this pursuit (Sanwald, 1979).

Apart from direct damage to crops, some nematodes act as virus vectors. There are 20 virus diseases known to be transmitted by several species of dorylaimid nematodes. In addition, many nematode species involve themselves in diseases caused by fungi, bacteria, and viruses, and indirectly contribute to the losses attributed to the other better-known pathogens. The contribution of nematodes to yield losses in the complex diseases needs to be clearly projected.

Management strategies: Management of diseases caused by nematodes includes chemical and nonchemical methods to mitigate losses. Use of nematicides though effective, has not been very successful because of the high cost of the nematicides and the relative low value of the crops. Perhaps that is why nematicides form a small portion ($<2.5\%$) of the total pesticides market (Premachandran, 1986). Attempts should be made to develop nematicides of plant origin and antimetabolites that are capable of stimulating or inhibiting egg hatch or interfering with establishment in host tissue (Sethi and Gaur, 1986). Chemicals and phytoalexins that have implications in the nematode control (Varaprasad and Swarup, 1986), synthetic pheromones to disrupt nematode reproduction (Bone, 1987), and chemicals that directly interfere with nematode chemoreceptors (Jansson, 1987) should be exploited for nematode-population management. However, keeping in view the pollution and possible health hazards due to application of nematicides, we need to give priority to other areas of research in management of diseases caused by nematode such as physical methods of control, host-plant resistance, identification of cropping sequences and rotations.

Soil solarization. Use of solar heat for nematode disease control holds a definite promise especially in the regions of tropics where maximum daily air temperatures in summer usually exceeds 40°C. The solar heat can be trapped and conserved using transparent polythene mulch (solarization). In summer, soil solarization controls effectively diseases caused by nematodes (Sharma and Nene, 1985; Sharma, 1985a) as well as many other soilborne diseases. It induces microbial processes that can contribute to the control of pathogens (Katan, 1981). Heating soil with solar energy is an environmentally safe and effective method. It would be interesting to couple solarization with different control measures such as application of neem cake and other amendments to see if there are any interactive longer-lasting effects on the control of nematode diseases. Planting of resistant cultivars or nonhosts after solarization can result in long-term control (Katan *et al.* 1983). This agrotechnology has a great potential as a component of integrated pest and disease management systems. More research is required to improve the present state of solarization technology.

Host-plant resistance : So far major research emphasis has been on the evaluation of germplasm lines in pots mainly against the root-knot nematodes and this exercise has resulted in the identification of some sources of resistance. There are more than 400 lines of chickpea and pigeonpea that may be consisdered as 'probable sources of resistance' to the root-knot nematodes (Sharma, 1987). Unfortunately, no effort has been made to test these lines at different locations in the hot-spot areas to confirm the resistance and to make use of these sources of resistance in breeding programs. I believe that these will remain unused till the importance of nematode diseases as a serious production constraint is realized by the growers as well as policymakers. A breeder will not hesitate to spend his time to breed for nematode recistance if he is convinced of the importance of nematode-caused diseases as yield reducers and the reliablity of screening techniques. So far, the screening work has been restricted to the pot studies in the greenhouses. We should try to shift to less cumbersome field-screening methods in uniformly nematode-sick fields. This will facilitate screening a large number of lines at a time. Plant breeders should be involved in this work from the beginning and a nematologist should become an important component in the crop-improvement programs. It is likely that a continuous search in different regions may lead to the discovery of durable sources of resistance. Application of biotechnology and genetic engineering can open new horizons in front of nematologists and plant breeders with an opportunity to modify host germplasms. *In vitro* procedures involving embryo rescue, cloning, and hybrid plant production are likely to play a significant role as a supplement to conventional plant-breeding techniques. One of the classical examples of embryo-rescue technique in nematode resistance is the synthesis of tomato cultivars resistant to the root-knot nematodes. A cross between susceptible cultivated tomato species (*Lycopersicon esculentum*) and highly resistant wild species (*L. peruvianum*) yields a hybrid in which the endosperm does not develop and the embryo aborts. This problem was solved by culturing the hybrid embryo on tissue-culture medium. The protoplast fusion technique involving interspecific crosses have been implemented to evolve root-knot nematode resistant egg plants (Fassuliotis and Bhatt, 1982). With the advent of new techniques in molecular biology and genetic engineering, the nematologists will be immensely benefitted by the advances in biotechnology by synthesizing genotypes with desirable resistance against important nematode diseases. Bioregulation of nematode pests through disruption of host recognition phenomenon appears to have exciting possibilities (Dasgupta and Ganguly, 1986).

Cropping systems : Experiences around the world have shown that the greatest contribution is made by fertilizers in improving yields in both irrigated and unirrigated agriculture. The drylands are not only thirsty but hungry as well (Kanwar, 1985). With the enhanced use of fertilizers and rain-water management technology, a greater portion of the drylands will be under intensive cropping systems such as mixed cropping (intercropping), sequential cropping, etc. There are published evidences that specific cropping systems can modify the incidence of nematode diseases. For example, if a crop in rainy season is a good host of a particular nematode, the carry-over nematode population will have high and adverse effects on a susceptible post-rainy season crop. On the contrary, if the rainy season crop is poor or nonhost, the spillover influence on the post-rainy season susceptible crop can be clearly seen. The nematode effect on a crop can be greatly influenced by companion crops in the same field. It has been found that there is considerably less severe galling by *M. incognita* on potato (*Solanum tuberosum*) roots intercropped with onion (*Allium* sp) and maize (*Zea mays*) compared with the galling found on potato alone (Raymundo, 1983). Our knowledge about the influence of cropping systems on the control of nematode diseases is very limited. Increased interest in cropping systems as a means of nematode control, if there is no sufficient resistance available, will be helpful.

Nematodes appear to have special abilities to survive under the harsh and dry conditions. Even fragile-looking larvae of *R. reniformis*, *Helicotylenchus retusus*, and *Hoplolaimus seinhorsti* can survive for more than 1 year in dry Alfisols and Vertisols without any host. Understanding of their survival strategies will be helpful in designing our multifaceted management approach.

Conclusions

The pressure to produce more food will be tremendous on drylands in 2000 A.D. This may be achieved by replacing the low-yielding land races with high-yielding genotypes, increasing fertilizer inputs, proper water management, and intensive cropping systems. These practices, by and large, will result in an increase in nematode-caused disease problems.

1. Nematologists can play a very important role in increasing the food production in the drylands by increasing the awareness of growers about the nematode diseases and their control. Extension nematologists and subject-matter specialists will play a vital role in this crusade to transfer the technologies generated to the growers.

2. In addition to traditional methodologies in nematology, the incoming younger generation of nematologists will require a broadbased training in application of computer technology and biotechnology.

3. The thrust areas for research nematologists will be development of

   a. location-specific disease forecasting models;

   b. very simple (computerized) nematode and disease-identification schemes

c. crop-loss database systems for nematode-caused diseases of important crops; and

d. disease-management systems, based on readily available solar heat and resistant-variety-based cropping systems.

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