JOURNAL OF NEMATOLOGY
VOLUME 12 JULY 1980 NUMBER 3

The Development of Nematology on a World Basis[1]

J. N. Sasser and K. Krishnappa[2]

Abstract: Nematology on a world basis has experienced phenomenal growth during the last 25 years. Major influences responsible for this growth are discussed. Education of nematologists has been most evident in only a few developed nations. Some developing countries are now beginning to train nationals as nematologists. Research programs in developed countries are more intensive than in developing nations, largely because of available resources and priorities given to solving nematological problems. Developed nations have been able to take advantage of technological advances almost immediately, whereas in developing nations the lack of resources and constraints imposed by certain social or political conditions has made this difficult. Indications are that emphasis in training nematologists in developed countries may have reached a plateau, while in developing nations provisions for training and research are on the increase. *Key Words:* education, scientific societies and journals, philanthropic agencies.

Some of the major influences which shaped the direction and rate of development of our science on a world basis are discussed here. Because the history of nematology has been treated in a number of excellent reviews (1,2,3,5), we will not emphasize the historical approach to the subject.

We cannot rank the relative role of the various influences on nematology with any degree of accuracy because they are interwoven and difficult to assess objectively. We can, however, enumerate some of those factors which have been important to the development of nematology. Special mention will be made of progress in developing countries and opportunities for assignments in these countries, since the need there is so great.

MAJOR INFLUENCES

Few sciences have grown as rapidly as nematology during the past quarter of a century. This growth has come about primarily because of the cumulative and interacting effects of the forces described here.

Leadership of early pioneering nematologists: The sound and orderly growth of any science depends on the wisdom, dedication, and direction given during its infancy. Certainly, nematology has been fortunate in having leaders of vision, courage, and commitment associated with it during its formative years.

These men and women, working under relatively primitive conditions, had a zeal for knowledge. They were dedicated to an understanding of the truth and to passing this knowledge on to future generations. These early nematologists recognized the need for more of their kind and trained others tutorially. Eventually, programs of study emphasizing nematology were offered by various universities in the United States and other countries. These educational programs led to an accelerated expansion of our science.

It would be difficult to overestimate the importance of higher education in the development of a particular science. A good example is the influence of various agricultural institutions and universities in the development of nematology on a world basis. Although many agencies have played a role in the training of agricultural scientists, not much was done to train nematologists until the late 1940s. We wish to emphasize the role of various universities and institutions within certain countries in the training of nematologists during the past 25 years and to discuss their influence on the development of nematology throughout the world.

Received for publication 5 February 1980.

[1]Symposium paper presented at the annual meeting of the Society of Nematologists, Salt Lake City, Utah, July 23-26, 1979. Paper Number 6310 of the Journal Series of the North Carolina Agricultural Research Service, Raleigh, NC 27650.

[2]Respectively, Professor and Principal Investigator of the International *Meloidogyne* Project, North Carolina State University, Raleigh, NC 27650; and Assistant Professor, University of Agricultural Sciences, Bangalore–560024, India.

Institutions and agencies responsible for the education of nematologists: Graduate education and training of nematologists perhaps has been the greatest single force in the development of nematology on a world basis. Resources devoted to research in any discipline within a country, especially those which are pest related, depend upon recognition of a problem. Once this has been done, tests follow to further verify the relationship between the pest and the disease, to determine the extent of economic loss, and finally, to develop control practices. This pattern has been followed in the case of nematodes in some developed countries and is now taking place to some extent in developing countries. A primary advantage of having a nematologist working in a country is that problems relating to nematology will be recognized. In countries where there are no nematologists, other scientists tend to overlook the damage caused by nematodes. All scientists tend to overemphasize the importance of their own discipline.

An important role of the first nematologist in a country is education of others who can expand his efforts by working on nematological problems in different areas or on other crops.

A large number of institutions have provided training for nematologists at various levels. Advanced education sometimes is given in concentrated programs such as those organized by the International Agricultural Center, Wageningen, The Netherlands. These courses are of about 3 months duration and have been given in The Netherlands, India, and Venezuela (Table 1). Certificates are awarded to those who successfully complete the course.

Universities throughout the world have played a significant role in training nematologists. Information as to the exact number of students graduating from every university is not available. Results of a questionnaire sent to approximately 80 nematologists in developing countries, as well as to nematologists at 28 universities in the United States and at various centers in Europe, give some indication of the countries and institutions which have played a major role in the training of young scientists to be nematologists. A few of these are shown in Table 2.

Availability of textbooks, manuals and other educational materials: Before 1955 there were only four textbooks on plant nematology. Between 1955 and 1965 an additional 21 such books were written. From 1965 to 1980 the number of books and manuals increased by 45, bringing the total now available to more than 60. This has greatly enhanced the effectiveness of teaching programs, and it has been of inestimable value to those engaged in nematological research. The variety of books available range from practical manuals for use by beginners (4) to advanced treatises for use in teaching graduate courses at the university level (6,7).

Organization and activities of the nema-

TABLE 1. International courses in plant nematology organized by the International Agriculture Center, Wageningen, The Netherlands.*

Locations	No. of participants	No. of countries represented
Wageningen	135	48
India	69	6
Venezuela	95	21
Totals	299	75

*Information provided by Dr. J. A. Van Berkum.

TABLE 2. Countries engaged in the training of nemtaologists.*

1st order†	2nd order‡	3rd order‡
Belgium	Australia	Germany
The Netherlands	Brazil	Italy
United Kingdom	Canada	Korea
United States	Egypt	Nigeria
	France	Philippines
	India	Thailand
	Japan	Venezuela
	USSR	

*Ranked according to their estimated relative role.

†Records indicate that more than 300 advanced degrees in nematology have been granted from universities in the United States, more than 150 in the United Kingdom, approximately 16 in the Netherlands, and 14 in Belgium.

‡Information was not available on the number of degrees granted in the countries ranked as 2nd and 3rd order. It is known that strong research programs are underway in each of these countries and that some graduate degrees have been granted. Excellent research and teaching programs are also known to occur in other countries not listed.

tological societies: There are now at least 10 nematological societies throughout the world, and most of these have their own journals (Table 3). Although the teaching of nematology has been the greatest single force in the development of the science, the formation of scientific societies also has had a dramatic impact. Through their annual meetings these societies have facilitated presentation of scholarly work and stimulated discussion through paper sessions, symposia, and colloquia; they have also provided a recognized outlet for publication of research results. The ideas generated from well-planned and well-attended scientific meetings are of inestimable value to all who participate and can be a special source of encouragement to graduate students.

Programs of world and philanthropic agencies: Teaching and scientific societies, although valuable, cannot do all that is needed to develop and promote a field of science. Agencies like the Food and Agriculture Organization of the United Nations (FAO); the European and Mediterranean Plant Protection Organization (EPPO-Paris); United States Agency for International Development (USAID); United Nations Development Program (UNDP); Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM-France); The United States Department of Agriculture (USDA), including the PL-480 program; the Rockefeller Foundation; and the Ford Foundation also play a great role. In some cases, scholarships are provided to students from developing nations to study in Europe or the United States. Nematologists are employed to work abroad for periods of a few months to several years. These scientists may teach courses in the local universities, or they may be involved primarily in assessing nematological problems on major crops in the country or region. Often the scientist from the developed country is assigned a counterpart or local scientist whom he trains and works with on a daily basis. Considerable time and effort is spent in assisting local personnel in designing and equipping laboratories suitable for working with nematodes. Manuals are prepared describing techniques for nematode extraction from the soil or plants and telling how to make slides for microscopic observation and even simple keys for use in identification. These are only a few of the overseas activities supported by agencies interested in the total development of a given country.

Discovery of new pests and developments: During the past quarter of a century a number of important nematode pests have been discovered. Also, new advances in technology have occurred, and the role of nematodes in disease complexes and virus transmission has been elucidated. Although it is not feasible to enumerate all new pests and developments, the following will suffice as examples:

(a) The importance of ectoparasites (*Belonolaimus, Xiphinema, Trichodorus, Paratrichodorus* spp.) has been substantiated.
(b) The soybean cyst nematode (*Heter-*

TABLE 3. Professional societies and major journals publishing nematological research.

Professional societies*	Professional journals†
Helminthological Society of Washington	Proceedings Helminthological Society of Washington
Society of Nematologists	Journal of Nematology
European Society of Nematologists	Nematologica
Mediterranean Nematological Society	Nematologia Mediterranea
Organization of Tropical American Nematologists	Nematropica
The Nematological Society of India	Indian Journal of Nematology
Japanese Nematological Society	Japanese Journal of Nematology
The American Phytopathological Society	Phytopathology

*Three societies—Brazilian Society of Nematology, Nematological Society of Southern Africa, and Societa Italina Di Nematologia—apparently do not have a companion journal.

†There are at least five publications (journals, reviews, or others) in which nematological papers are published which are not identified with any specific scientific society. These include Annals of Applied Biology, Canadian Journal of Plant Science, Helminthological Abstracts—Series B: Plant Nematology, Revue De Nematologie, and Plant Disease (formerly Plant Disease Reporter).

odera glycines) has been revealed as the most important cyst nematode in the United States.

(c) The burrowing nematode (*Radopholus similis*) was discovered on citrus and ornamentals.

(d) *Bursaphelenchus lignicolus* was found on pine.

(e) Nematicides came into widescale use.

(f) Nematode resistant cultivars were developed.

(g) Pathotypes of potato cyst nematodes and races of root-knot nematodes were discovered.

(h) Cytogenetic and biochemical studies of nematodes were made.

(i) Nematode activities were modeled mathematically.

(j) Extraction techniques were improved.

Development of related fields: Nematology has had the benefit of simultaneous developments in cytogenetics, plant breeding, ecology, biochemistry, computer science, photography, scanning electron microscopy, soil physics, and communications as it has grown from an infant science to one of considerable stature. These sciences have aided nematologists greatly in research efforts to understand the nematode and in the development of control strategies.

Professional activities of scientists: Most professional nematologists are engaged in teaching, research, or extension. Many agencies employ nematologists—universities, the United States Department of Agriculture, other ministeries of agriculture, private foundations, international institutes, industries, and many others. Occasionally scientists will be called upon to serve as members of study teams, participate in short courses and special symposia, or to serve as consultants. Sabbatical leaves provide additional opportunities for scholarly work. These assignments may be in the scientist's home country or in other parts of the world where his services are needed. These contributions have been significant in the overall advancement of our knowledge of nematode problems.

Role of industry: Industry has played a vital role in the development of nematology in the United States during the past 25 years. It should be pointed out that the development and use of effective field nematicides in the early 1940s vividly illustrated the importance of nematodes in crop production. This recognition of nematodes as major plant pests gave impetus to financial support for nematological research. Over the years industry has remained active in research and development because of the potential for sales of effective nematicides. Not only has industry provided agriculture with effective and economical nematicides, it has been a compatible partner with educational institutions and government agencies in activities destined to help control nematodes and other pests. Grants-in-aid, educational literature, motion picture films, equipment for applying nematicides, and experimental materials for test purposes all have added to the development of nematology throughout the world.

Interactions: Each of these forces has had a unique influence on the development of nematology on a world basis. However, these forces are interrelated to a great degree, and their interrelationships have had an accelerating and positive influence on the growth of the science of nematology and on the quality of research, teaching, and extension. Much of this interaction occurred naturally without preplanning.

DEVELOPING COUNTRIES

Developing countries have benefited less from these influences than have the developed nations, where personnel and facilities have been available to do research on new pest and disease problems. In developed countries, growers have the resources to take advantage of new technology. Such technology is rare in most developing countries, where resources for research (laboratory equipment, field equipment, library facilities, travel and technical assistance) are limited. In addition to economic constraints, the situation in many developing countries is further complicated by social and political conditions.

In spite of the difficulties, however, much progress has been made in developing countries, and the opportunities for accelerated growth are better now than ever before. Only a few countries remain without nematologists. The presence of one or several nematologists in most developing countries makes it possible for the science

to grow. The important ingredient needed is support and assistance from those of us who work under more favorable conditions. Herein lies our opportunity to help those who work alone under difficult circumstances. Sabbaticals for experienced nematologists, financed by a university or the government, to work in developing countries would help to upgrade and accelerate the rate of progress in those countries. The International *Meloidogyne* Project centered at North Carolina State University[3] has attempted to provide some stimulus for nematologists working as cooperators in this program. Bringing groups together on a regional basis for research and planning conferences has done much to create interest in the science and to give nematologists confidence in their research activities. We need additional similar programs and scientists who can spend several months or a year abroad working side by side with young nematologists. Such experiences in countries where modern technology is not available will help us appreciate the problems encountered by local nematologists in their research and will temper our attitudes and perspectives regarding the seemingly slow progress being made in countries where subsistence agriculture is a way of life.

DISCUSSION

The extent and pace with which nematology has developed in relation to actual needs and to other sciences may not be encouraging. Even so, we must be impressed when we compare nematology now with what it was 25 years ago. Furthermore, it must be recognized that scientists do not have a free hand in designing and carrying out a development scheme in developed countries, much less in other countries. Development of any science is influenced by available resources that can be channeled into any one science.

Advances made in developed countries since the late 1940s undoubtedly were triggered by economic forces brought about by serious losses to certain crops, just as earlier research was prompted by the losses to potato, sugar beet, and other crops. Following World War II the need for agricultural production increased, while the economy in most developed countries was on the incline. Under these conditions, technological advances were welcomed and almost immediately incorporated into agricultural practices. The development and widespread use of nematicides, resistant cultivars, and other control measures are examples. The emphasis given to educating young scientists as nematologists had a tremendous impact on the almost unprecedented growth and development of our science. The rate of growth in most developed countries has now reached a plateau, although the need for additional basic research to cope with new and old problems does not justify reduced emphasis.

Nematological problems in developing countries are just beginning to receive serious attention by the appropriate authorities in these countries. A large number of nationals from developing countries have been trained in Europe or the United States and are now initiating research and teaching programs in their home countries. Extending this information to the small farmer in a package that will be practical and profitable to him is probably the greatest need at this time. A vast amount of information available from developed countries and information recently obtained at the local level could be used now to increase crop production if properly presented to local growers. An educational program will be needed to make growers aware of losses now occurring and to show them how adoption of simple and inexpensive control methods will increase their production and ultimately their quality of life. Thus, considerable emphasis should be placed on such programs; but progress will continue to be slow unless certain local constraints are removed. These include a low priority given to agricultural research by many local governments, socioeconomic problems, and, in some cases, political turmoil.

What then is our role as individual scientists in promoting nematology on a world basis? We should continue very much as we have in the past. Certainly provision should be made for promising young students at home and abroad to receive necessary training. To aid developing countries, we should take advantage of opportunities to work

[3]The International *Meloidogyne* Project is funded by USAID through a contract with North Carolina State University, Raleigh, NC.

abroad and to provide advice through correspondence and literature sharing. Our appreciation, understanding, and encouragement of others are timeless virtues. Our most important role, however, will be our example of hard work, dedication, and desire to see our science grow.

LITERATURE CITED

1. Ayoub, S. M. 1977. Plant Nematology. An Agricultural Training Aid. State of California Department of Food and Agriculture, Division of Plant Industry, Laboratory Services—Nematology, 1220 N. Street, Sacramento, California 95814.

2. Mjuge, S. G. 1977. Historical development of Nematology in Russia. J. Nematol. 9:1-8.

3. Raski, D. J. 1959. Historical Highlights of Nematology. Pp. 384-394 *in* C. S. Holton et al., eds. Plant pathology problems and progress 1908-1958. The University of Wisconsin Press. Madison, Wisconsin.

4. Taylor, A. L. 1967. Introduction to research on plant nematology. F.A.O., Rome.

5. Thorne, G. 1961. Principles of Nematology. McGraw-Hill Book Co., Inc., New York.

6. Zuckerman, B. M., W. F. Mai, and R. A. Rhode, eds. 1971. Plant parasitic nematodes. I. Morphology, anatomy, taxonomy and ecology. Academic Press, New York.

7. Zuckerman, B. M., W. F. Mai, and R. A. Rhode, eds. 1971. Plant parasitic nematodes. II. Cytogenetics, host-parasite interactions and physiology. Academic Press, New York.