Sustainability in Plant and Crop Protection

Sergei A. Subbotin
John J. Chitambar *Editors*

Plant Parasitic Nematodes in Sustainable Agriculture of North America

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Foreword

Nematodes are invertebrate roundworms that inhabit marine, freshwater, and terrestrial environments. They comprise the phylum Nematoda which includes parasites of plants and of animals, including humans, as well as species that feed on bacteria, fungi, algae, and other nematodes. Estimates are that four out of every five multicellular animals on the planet are nematodes. The majority of nematodes are microscopic, but some of the animal parasites are quite large and readily visible to the naked eye. Most soil nematodes are 1 mm or less although some species may be several times that length. They are aquatic organisms, living and moving in the water films that surround the soil particles. They are adapted to moving through the soil pore spaces without having to move the particles or to create burrows.

Nathan Cobb is often described as the "father" of the discipline of Nematology in North America. To illustrate the abundance of soil nematodes, he famously wrote, in 1914, that if the nematodes resident in a single acre of soil near San Antonio, Texas, USA, were to proceed in head-to-tail procession to Washington, D.C., some 2,000 miles away, the first nematode would reach Washington before the rear of the procession left San Antonio! So, select a field of interest and, on a map, draw around it a circle of radius 2,000 miles. Where might the procession of nematodes from an acre of your field extend? And, how many nematodes of average length 1 mm will be in the procession when it reaches its destination? While a first reaction might be one of horror at the magnitude of the nematode-pest problem in the field, if the source is a healthy soil, the majority of species present in the procession are beneficial and contribute to essential ecosystem services. In fact, most nematodes in our environment are not parasites of plants or animals. Nematodes that feed on other organisms are important participants in the cycling of minerals and nutrients in the ecosystem that is fundamental to other biological activities. Consequently, the incidence and abundance of nematode species with different feeding habits and life-history attributes provide useful indicators of environmental quality and soil health.

North America, the geographic purview of this book, is the third largest continent on the planet, stretching from arctic regions in the north to tropical zones in the south. The continent encompasses an enormous diversity of geographic features, soil conditions, and climatic variation and, consequently, supports a concomitantly enormous diversity of agricultural production systems and crop commodities. Specific cadres of pest and disease organisms, well adapted to the local conditions, exploit most of crop commodities in North America and, indeed, in the world. Many species of plant parasitic nematodes are among those pests and, because of their usually belowground habitat and microscopic sizes, are often the last to be diagnosed as the root cause of poor crop performance. Except for the few species that cause plants to exhibit characteristic symptoms, the development and availability of the microscope had enormous impact on our study and knowledge of plant parasitic and other soil nematodes. The diagnostic tools provided by modern molecular methods further enhance our ability to identify nematode species and to diagnose causes of crop damage.

One could argue that the magnitudes of nematode and other pest problems in North America largely are due to the design of cropping systems that are monocultures or at least center on the continuous production of a specific crop type. That lack of diversity in cropping systems is, of course, dictated by climatic, social, and economic factors; it is determined by which crops will grow in an area, whether there is a market demand, and what investments have been made in expensive farm machinery designed for use in specific crops. The limited diversity of crop species or varieties in an area favors pest and disease organisms that are well adapted to local conditions, and it tends to deplete rather than build the nutrient status of the soil. Consequently, agricultural systems become driven and protected through the use of mineral fertilizers and synthetic pesticides, which further disrupt the natural balance of organisms in the ecosystem.

Agricultural sustainability is based on the fusion of agricultural, environmental, and social sciences with evolving advances in technology. Sustainability is a goal that we pursue for the health of our planet and the preservation of living organisms that it supports. Sustainability is, and must be, a moving target, ever changing with environmental shifts and advances in our experiences and understanding. As we pursue the goal, we need to evaluate our past and intended trajectories, where we have come from, where we are now, and where we are trying to go. In this book, you will find documentation of these three components of the journey with regard to the impact and management of plant parasitic nematodes in agricultural systems of North America. You will find details of our understanding of nematodes as pests of plants and the evolution of management tools from those physically and chemically disruptive of the environment to strategies that are less disruptive and more information intensive.

Cumulative experience and evolving technology, both digital and mechanical, provide tools for assessment, analysis, and dissemination of information and advice and for changes in agricultural practices. With the fusion of the component sciences of sustainability comes a renewed realization that everything is connected. At one scale, the physical, chemical, and biological components of our planet are interdependent. At a finer scale, assemblages of organisms are interconnected with each other and with their environment. Through their life processes, as they acquire resources, grow, produce, die, and decompose, their component molecules return to states that are available to other life forms. Those functions that we consider beneficial to the pursuit of sustainability can be termed ecosystem services. The recycling of nutrients through mineralization and the regulation of pest species through predation and parasitism that we term biological control are important ecosystem services. Management practices that disrupt the delicate balances underlying such ecosystem services are non-sustainable.

We are developing a greater understanding of the interconnectedness of soil organisms in agricultural production systems. As a proxy for understanding interconnectedness, there exists on the planet, in soils, water, and plant material, a vast and diverse array of soil nematodes with wide ranges of ecological adaptations, activity, feeding habits, and ecosystem functions. Some of the species are parasites of domestic and wild animals, human, and plants, including agricultural crops. Many others are beneficial in their contributions to ecosystem services, participating in decomposition and mineralization cycles, as predators of pest species or as resources that sustain other predator organisms.

Sustainable management seeks to conserve and enhance the activities of beneficial organisms in the agricultural production system by minimizing physical and chemical disruption of their environment and by providing continued availability of resources. A diversity of plant species in space and time offers a greater array of resources to soil organisms. Cover-crop mixtures present different spatial patterns of root systems and provide resources in different microhabitats for organisms of the soil food web. Therefore, plant diversity supports greater diversity of soil organisms with differing behavior, activity, sizes, and temporal dominances, which must enhance the service capacity of the whole assemblage by accessing different locations, depths, and aggregations of the soil matrix. The assemblage of beneficial organisms provides top-down regulation of pest species in agricultural systems. In the same systems, bottom-up regulation of pest species can be provided by diversifying resource availability in time and space through non-host and resistant varieties, crop rotation, and cover cropping with non-host or even antagonistic plants that are sources of toxic compounds. Of course, the design of such multifactorial, holistic management systems requires information, including rapid and accurate diagnosis of organism habits and functions and the availability of plants with desired attributes. Chemical, physical, and resource disruptions of agricultural systems have major impact on soil organisms. It is important to conserve and enhance healthy systems; it is easier to destroy the systems than it is to rebuild them.

In the descriptions of plant parasitic nematodes in cropping systems documented in these chapters, you will find examples of the evolution of knowledge and tools to facilitate pursuit of the goals of sustainability. You will find documentation of where we came from, where we are now, and where we hope to go. You will read of systems in all phases and stages of sustainable transition. In addition, you will gain understanding of the forces and advances that have allowed and driven these changes.

Department of Entomology and Nematology
University of California,
Davis, CA, USA
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Howard Ferris