THE OHIO STATE UNIVERSITY EXTENSION

FACT SHEET

Agriculture and Natural Resources

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# The Role of Soil Protozoa and Nematodes

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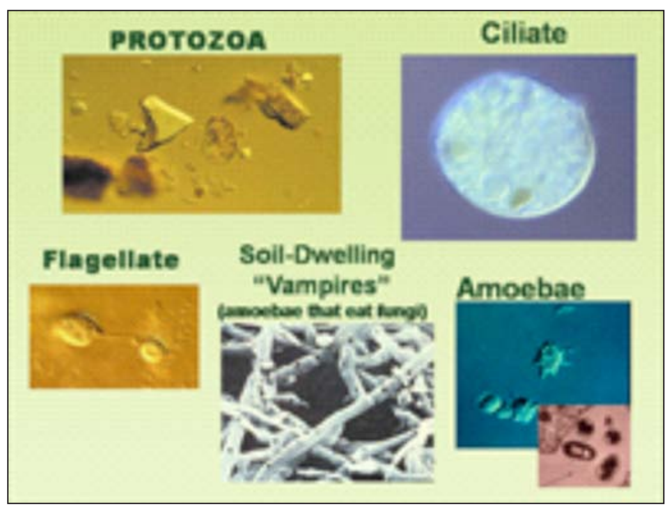
## Protozoa Introduction

Protozoa are single-celled animals that feed primarily on bacteria, but also eat other protozoa, soluble organic matter, and sometimes fungi. They are several times larger than bacteria, ranging from 1/5000 to 1/50 of an inch (5 to 500 $\mu$m) in diameter. Both protozoa and nematodes are aquatic and live and move in soil water films and water-filled pores of soil aggregates.

Protozoa are classified into three groups based on their shape:

1. Species of Mastigophora or *flagellates* are the smallest (5 to 20 $\mu$m) and use one to four whip-like flagella to move. Flagellates feed primarily on bacteria and are the most numerous of soil protozoa.
2. Ciliophora or *ciliates* are the largest (10 to 80 $\mu$m) protozoa and the least numerous and move by means of hair-like cilia. The cilia use vibrating hairs to move. Ciliates use the fine cilia along their bodies like oars to move rapidly through the soil. They eat the other two types of protozoa, as well as bacteria. Cilates may consume as many as ten thousand bacteria per day.
3. Sarcodina or *amoebae* also can be quite large and move by means of a temporary foot or "pseudopod." Amoebas reside in the rhizosphere and at the root surface where they graze on bacteria populations. There are two types of amoebas: testate and naked. Testate amoebas are encased in a rigid chitin shell or testa, while naked amoebas lack a rigid shell. Naked amoebas can change shape and explore tiny pore spaces making them valuable for soil nutrient recycling.

Protozoa are found in greatest abundance near the surface of the soil, particularly in the upper 15 cm (six inches). The life cycle of many protozoa consists of an active or trophozoite phase where the animal feeds and multiplies and a resting or cyst stage where the cell produces a thick coating. In the cyst stage, many species can withstand harsh environmental conditions and persist for many years until environmental conditions improve.




Photos by Elaine L. Ingram, Oregon State University, and USDA Natural Resource Conservation Service Soil Biology Primer.

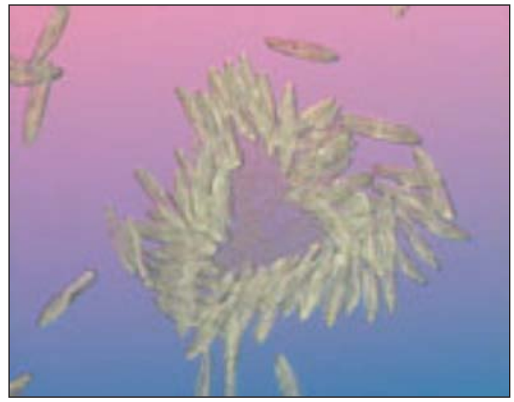
## Role of Protozoa

Protozoa play an important role in mineralizing nutrients, making them available for use by plants and other soil organisms. Protozoa (and nematodes) have a lower concentration of carbon (C) and nitrogen (N) in their cells than the bacteria they eat. (The ratio of C:N for protozoa is 10:1 or much more than 3:1 to 10:1 for bacteria.) Bacteria eaten by protozoa contain too much N for the amount of C protozoa need. They release the excess N in the form of ammonium ($NH_4^+$). This usually occurs near the root system of a plant. Bacteria and other organisms rapidly take up most of the ammonium, but some is used by the plant. See Understanding Soil Microbes and Nutrient Recycling.

Another role that protozoa play is in regulating bacteria and algae populations. Single protozoa (paramecium) can consume as many as 5 million bacteria in one day. The protozoa help maintain an ecological balance in the soil. When they graze on bacteria, protozoa stimulate growth of the bacterial population and decomposition rates and soil aggregation. Protozoa grazing can be thought of like pruning a tree—a small amount enhances growth, too much reduces growth or will modify the mix of species in the bacterial community. Protozoa are also an important food source for other soil organisms and help to suppress disease by competing with or feeding on pathogens. Protozoa feed selectively so they influence the bacteria composition and bacteria population in the rhizosphere.

Living roots release many types of organic materials into the rhizosphere within 50 μm of the surface of the root. The rhizosphere typically contains 1,000 to 2,000 times more microorganisms than the typical soil without roots.

Protozoa need bacteria and algae to eat and water in which to move, so moisture plays a big role in determining which types of protozoa will be active and present. Like bacteria, protozoa are particularly active in the rhizosphere next to roots. Typical numbers of protozoa in soil vary widely, from a thousand per teaspoon in low fertility soils to a million per teaspoon in some highly fertile soils. Mastigophora or flagellates tend to dominate in drier soils while Ciliophora or cilates are abundant only if the soil moisture level is high.



Cilate protozoa surrounding bacteria. Fotosearch Waukesha, WI.

In bacterial-dominated soils like cultivated soils, flagellates and amoebae predominate. In general, high clay-content soils contain a higher number of smaller protozoa (flagellates and naked amoebae), while coarser textured soils and undisturbed or no-till soils contain more large flagellates, testate amoebae, and ciliates. Protozoa and bacterial-feeding nematodes compete for their common food resource, which is bacteria. Some soils have high numbers of either nematodes or protozoa, but not both.

## Nematode Introduction

Nematodes or roundworms are non-segmented worms with tapered ends typically 1/500 of an inch (50 μm) in diameter and 1/20 of an inch (1 mm) in length. They have a head, and a tail with a well developed central nervous and fertility system with a complete digestive system, so they are considered the most primitive animal. They are small enough to fit in most soil pores and soil aggregates. They are classified in the animal phylum Nemata and are best known for causing infectious disease in plants and animals, but they also play an important role in soil and crop ecology. Nematodes are aquatic organisms so they require adequate soil moisture to move in the soil.

A few species are responsible for plant diseases but far less is known about the majority of the nematode community that plays beneficial roles in soil. Many beneficial nematodes serve as biological pest control agents in managed systems and others regulate the natural ecosystem and soil nutrient cycling. Some feed on the plants and algae (first trophic level); others are grazers that feed on bacteria and fungi (second trophic level); and some feed on other nematodes (higher trophic levels). A variety of nematodes function at several trophic levels of the soil food web. Nematodes are most abundant in the surface soil horizon.

## Role of Nematodes

Nematodes use either a stylet or tooth to puncture and suck out cell contents or ingest cells whole. Nematodes can be divided into five broad groups based on their diet with the first four groups being free living:

1. *Bacterial-feeders* consume bacteria through a stoma, a large open channel.
2. *Fungal-feeders* feed by puncturing the cell wall of fungi using a small slender stylet to suck out the internal contents.
3. *Predatory nematodes* eat all types of nematodes and protozoa using a stylet. They eat smaller microorganisms whole or attach themselves to the cuticle of larger nematodes, scraping away until the prey's internal body parts can be extracted.
4. *Omnivores* eat a variety of organisms including bacteria, fungus, protozoa, other nematodes and roots and may have a different diet at each life stage.
5. *Root-feeders* are plant parasites feeding on roots, and thus are not free-living in the soil because they live either inside or outside the plant root, depending on the plant root for a food source.

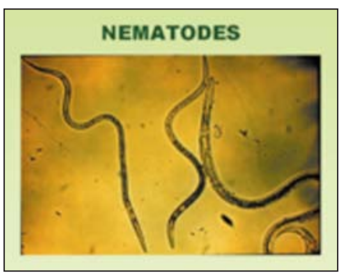



Photo by Elaine L. Ingram, Oregon State University

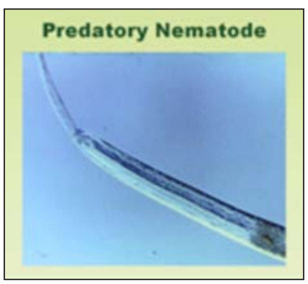
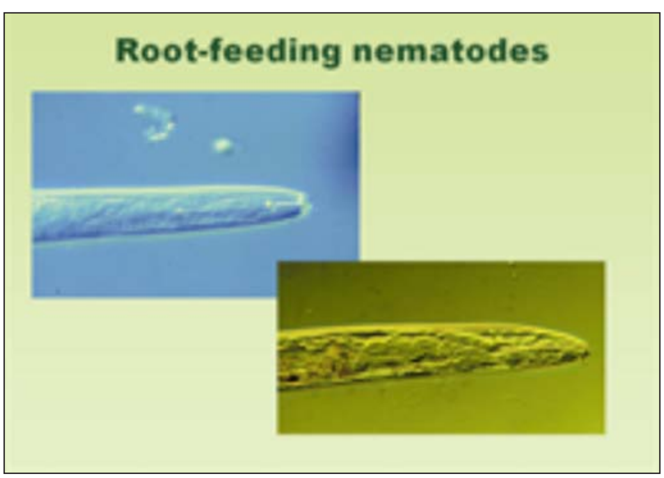



Photo by Elaine L. Ingram, Oregon State University.




Upper left photo by Kathy Merrifeld. Lower right photo by Elaine L. Ingram, Oregon State University.

Like protozoa, nematodes are important in mineralizing, or releasing, nutrients in plant-available forms. When nematodes eat bacteria or fungi, ammonium ($NH_4^+$) is released because bacteria and fungi contain much more N than the nematodes require. At low nematode densities, feeding by nematodes stimulates the growth rate of bacteria populations. For example, low grazing may stimulate bacteria growth and increase nutrient release. Small or low root consumption by nematodes may stimulate plant root growth like branch pruning, increasing root biomass. See fact sheet: Understanding Soil Microbes and Nutrient Recycling for decomposition of organic residues.

Nematode grazing may control the balance between bacteria and fungi, and the species composition of the microbial community. Nematodes help distribute bacteria and fungi through the soil and along roots by carrying live and dormant microbes on their surfaces and in their digestive systems. Some nematodes cause disease while other nematodes consume disease-causing organisms, such as root-feeding nematodes, or prevent their access to roots and some nematodes may be potential bio-control agents.

Nematodes are concentrated near their prey groups. Bacterial-feeders abound near roots where bacteria congregate; fungal-feeders are near fungal biomass; root-feeders are concentrated around roots of stressed or susceptible plants. Predatory nematodes are more likely to be abundant in soils with high numbers of nematodes. Because of their size, nematodes tend to be more common in coarser-textured soils. Nematodes move in water films in large (>1/500 inch or 50 $\mu$m) pore spaces and in uncultivated soils with mesopores (30 to 100 $\mu$m). Nematodes are considered mesofauna because they are larger in size (0.1 to 2 mm) than the microfauna (protozoa, <0.1 mm). Nematodes and protozoa are food for higher level predators including predatory nematodes, soil microarthropods, and soil insects. They are also parasitized by bacteria and fungi.

Agricultural soils generally support less than 100 nematodes in each teaspoon (dry gram) of soil. Grasslands may contain 50 to 500 nematodes, and forest soils generally hold several hundred per teaspoon. The proportion of bacterial-feeding and fungal-feeding nematodes is related to the amount of bacteria and fungi in the soil. Less disturbed soils contain more predatory nematodes, suggesting that predatory nematodes are highly sensitive to a wide range of disturbances. In addition to their diversity, nematodes may be useful indicators because their populations are relatively stable in response to changes in moisture and temperature (in contrast to bacteria). Because they are quite small and live in water films, changes in nematode populations reflect changes in soil microenvironments. So they are a useful indicator for soil quality and soil health.

## Managing Parasitic Nematodes

Michigan State research shows that the nematode community structure varies among different cropping systems. Parasitic nematodes are consided harmful to plants. The highest concentration was found in conventional tillage systems with progressively lower concentrations in integrated fertilizer, integrated compost and the lowest in transitional organic systems. The ratio of non-parasitic to parasitic nematodes may be an indication of ecosystem soil health with organic systems having better soil health.

Most conventional farms maximize crop yields using purchased inputs and this frequently limits biological diversity and results in extensive food supplies for parasitic nematodes with few predators and few factors to limit their population. Ecologically managed farming systems are designed to foster biological diversity and nematode problems are rare in these systems when there is a balance of prey and predators.

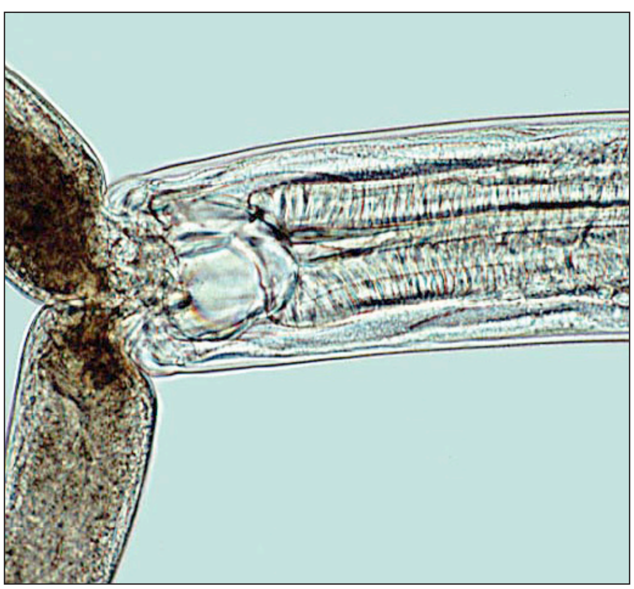
Nematode management involves monitoring nematode populations and using other information like cropping history, soil texture, soil nutrient levels, and other factors to limit parasitic nematodes and enhance beneficial predator nematodes. There are four main stategies to control nematodes: avoidance-exclusion, containment-elimination, control, or do nothing.

Avoidance-exclusion is the best way to prevent nematode problems because it is easier to prevent a nematode problem rather than trying to manage an established problem. Some nematode management tactics include: designing a field crop ecosystem for enhanced biodiversity, crop rotation, using nematode free seed or transplants, enhancing limiting factors, control soil erosion, keeping farm equipment nematode free, and maintaining good sanitation.

Containment-elimination is used once nematodes become established and it is important to prevent them from spreading to other sites. This can be achieved partially by reducing harmful nematode population densities and using avoidance-exclusion to prevent spread to new locations. It usually is not possible to eliminate a nematode species from a system once it becomes established.

When a nematode's population density exceeds the crop's threshold, some type of control is used. Nematode control reduces the population to a level that is below the disease threshold and attempts to maintain this equilibrium. Nematode control tactics include: manipulating soil structure, the soil water content, and soil humus content; using organic amendments; rotating with non-host crops; releasing natural enemies; introducing bionematicides; enhancing existing limiting factors, and using synthetic chemical nematicides.

Sometimes doing nothing is the appropriate response. For example, when a parasitic nematode population is



Predator nematode consuming a parasitic nematode. Photo used with permission from Jonathan Eisenback www.mactode.com.

Lesion nematode penetrating a root. Used with permission from Ulrich Zunke, www.mactode.com.

declining and it looks like the population will continue to decline, then doing nothing is the most appropriate strategy.

Using cover crops with no-till is an example of how to reduce parasitic nematode populations. Root exudates from a variety of crops influence nematode abundance and behavior. Nematodes are more abundant in the rhizosphere than in the root-free soil. Root exudates can influence nematode cysts or egg hatching, with some plants inducing hatching. For example, some cover crops like annual ryegrass, cereal rye, and oilseed radish induce soybean cyst nematode hatching in the fall, reducing parasitic nematode populations by 80 to 90 percent. When the female cyst dies, her body becomes a cyst that protects the eggs in the absence of a suitable host for as long as ten years. Grasses result in fewer soybean cyst nematodes surviving in the spring because grasses are not a suitable host like soybeans and the soybean cyst nematode dies out over the winter. Nematode larva concentrations are usually the highest near the elongating root tip because the root exudates are food for nematodes or attract bacteria, which are food for the nematodes.

Researchers have observed that brassicas (e.g., rapeseed, mustard) have a nematode-supressive effect that benefit crops in a rotation. This "mustard effect" is attributed to glucosinolate compounds contained in brassica residues that suppress nematodes by interfering with their reproductive cycle.

## Summary

Protozoa and nematodes consume other microbes in the soil and release the N as ammonia, which becomes available to plants. Protozoa consume primarily bacteria and other protozoa and help to regulate bacteria densities, composition, and populations. Protozoa and bacteria tend to be more numerous than nematodes in cultivated or tilled soils. Nematodes feed on bacteria, fungus, protozoa, and other nematodes, but some are root feeders. Stable soil ecosystems using no-till or a cover crop, pasture, or hay fields tend to have more fungus and nematodes, which are sensitive to environmental disturbances.

## Acknowledgment

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## References

Alexander, Martin, 1991, Introduction to Soil Microbiology, 2nd Edition, Krieger Publishing Company, Malabar, Florida.

Archulate, R. 2009. *Soil Quality Basics*, Lesson 1, Activity 3, Soil Quality Assessment and Applications for Field Staff, United States Department of Agriculture, Natural Resource Conservation Service, ver 7.2009.

Cavigelli, M.A., S.R. Deming, L.K. Probyn, and R.R. Harwood (eds.). 1998. *Michigan Field Crop Ecology: Managing biological processes for productivity and environmental quality*. Michigan State University Extension Bulletin E-2646.

Magdoff, F., and H. van Es. 2001. *Building Soils for Better Crops*. 2nd ed. Sustainable Agriculture Network. Beltsville, MD. www.sare.org/publications/soils.htm.

Nester, E.W., D.G. Anderson, E.C.E. Robert, Jr., and M.T. Nester. 2007. Microbiology: A Human Perspective. Edited by Nicole Young. McGraw-Hill Publishing.

Sylvia, D.M., P.G. Hartel, J.J. Fuhrmann, and D.A. Zuberer. 2005. *Principle and Application of Soil Microbiology*. 2nd ed. Edited by David M. Sylva, Pearson Prentice Hall.

Tugel, A.J., A.M. Lewandowski, and D. Happe-vonArb, eds. 2000. *Soil Biology Primer*, Chapter 5: Soil Protozoa and Chapter 6: Nematodes. Ankeny, IA: Soil and Water Conservation Society. See http://soils.usda.gov/sqi/concepts/soil_biology.

## Related Publications

- Using Cover Crops to Improve Soil and Water Quality
- Sustainable Crop Rotations with Cover Crops
- The Biology of Soil Compaction
- Using Cover Crops to Convert to No-till
- Understanding Soil Microbes and Nutrient Recycling
- The Role of Soil Bacteria
- The Role of Soil Fungus
- Homegrown Nitrogen