Nematodes: The Ignored Precedence

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FIGURE 1. Electron micrograph of soybean cyst nematode (*Heterodera sp.*) and egg (Image courtesy: wikipedia.org 2006)

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SUMMARY

Nematodes are cylindrical, multicellular, microscopic, sessile organisms that are ubiquitous in nature and possess characteristics of ideal bio-indicators. Of the estimated 5,00,000 species only 1 percent is identified and the rest are yet to be explored. Only a handful of nematode species are detrimental to plants and animals while rest attributes to many beneficial environmental impacts seen and unseen. Free living nematode *C. elegans* contributed significantly to research of organ development and programmed cell death. Nematode species *Odontophora villoti, Parasphaerolaimus paradoxus, Trichotheristus mirabilis, Theristus pertenuis* etc. act as biological indicators to disturbances like ecological disturbances like heavy metals, hydrocarbon pollution, organic enrichment, xenobiotics, and combinations. The nematodes are known to impact the process of nutrient cycling while maintaining the soil health by breaking down the organic matter in the food web. Predacious nematodes in soil parasitizes various pathogens and pests that are detrimental to the crops. In the hue and cry of sustainability entomopathogenic nematodes are promisingly widely used as biological insecticides in sustainable pest management programs. So nematodes are a major bane to the society and its full potential to synergize mankind is to be explored.

INTERODUCTION

Nematodes, the most abundant microscopic multicelluar organisms on earth, are ubiquitous and reside mostly on the upper zone of the soil. Adapted to almost all environments, nematodes are reported from snowy mountain peaks to hot water springs and from hot deserts to depth of the oceans. Vedic literature (6000-4000 B.C.) refers to nematodes in the *Rig, Yajur and Atharv veda* under the Sanskrit name Krimin or Kurmi meaning 'worm'. A popular quote by N.A. Cobb (1915) who is considered to be the father of American Nematology explains,

"If all the matter in this universe except the nematodes were swept away, our world would still be recognizable, and if, as disembodied spirits, we could then investigate it, we should find its mountains, hills, valleys, rivers, lakes and oceans represented by a film of nematodes".

One handful of soil contains about 10^3 numbers of nematodes and they are also known to survive for many years in quiescent phase in the absence of congenial environmental conditions. The important self explanatory groups are plant parasitic nematodes, fungi feeding nematodes, bacteria-feeding nematodes, predatory nematodes and omnivorous nematodes. Only about 25,000 of the estimated 500,000 nematode species are known till date and 15% of the known species are only considered to be harmful to agricultural crops. Recent studies have mainly highlighted the harmful impact of plant parasitic nematodes on crops but it is to be believed that nematodes are more a boon to the society than a curse (Figure 1).

Caenorhabditis elegans: A wonder organism

C. elegans a free living nematode of the order Rhabditida is a very popular model system for studying developmental biology as it has some of the organ systems same as larger animals. The genome of the wonder nematode *C. elegans* is completely sequenced and is similar to humans (40% homologous). It was the first multicellular organism to have its whole genome sequenced, and as of 2019, is the only organism to have its connectome (neuronal "wiring diagram") complete. Till date John Sulston, Sidney Brenner, and Robert Horvitz for their discovery in genetic regulation of organ development and programmed cell death, Andrew Fire and Graig Mello for RNAi interference study and Martin Chalfie for the discovery of development of the green fluorescent protein in *Caenorhabditis elegans* have received Nobel prize in the year 2002, 2006 and 2008 respectively. The nematode is being recently studied for recombinational repair of DNA damages that arise, especially under stressful conditions. Industrially also the nematode *C. elegans* contributes to study of behavioral response to nicotine parallel to humans which include acute response, tolerance, withdrawal, and sensitization. Benefitting the beauty industry the nematode is used to study ageing. The nematode bagged accolades when it survived space Shuttle Columbia disaster in February 2003 and later in 2009 a space research project to explore the effects of zero gravity on muscle development and physiology of *C. elegans* was launched. Out of many advantages the nematodes are easy to culture and can be conveniently stored for longer periods which automatically entitle

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them as important genetic tool for research.

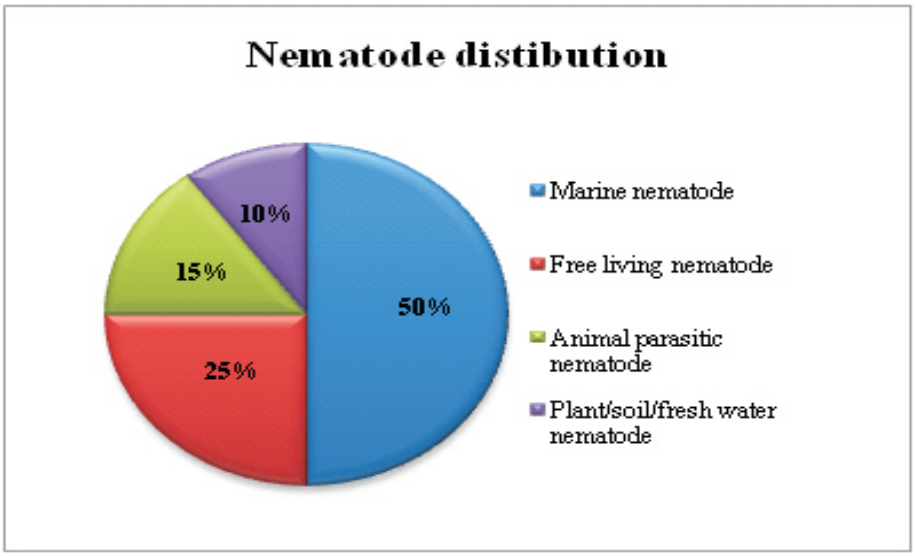

FIGURE 2. Pie chart documenting the nematode distribution

Turbatrix aceti: Vinegar nematode

Also known as industrial nematode *Turbatrix aceti* are free-living nematodes that feed on a microbial culture called mother of vinegar (used to create vinegar) and may be found in unfiltered vinegar. The nematodes can withstand a wide range of pH of 1.6 to 11. The nematode is extremely tolerant to harsh conditions and can be explored for the prospective of biocontrol agents.

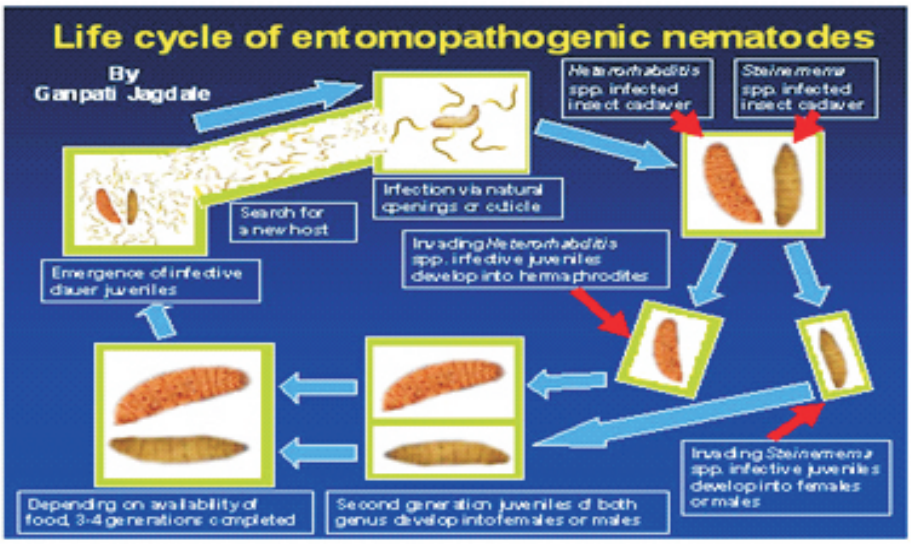

FIGURE 3. Life cycle of entomopathogenic nematodes (epns), (image courtesy: nematodeinformation.com 2008)

Nematodes used As bioindicators

Many nematodes are used as pollution indicators because they are ubiquitous possessing permeable cuticle, which allows them to respond to a wide range of pollutants. They also fulfill the markers of ecological indicator as highly diversified, elevated community stability, self-recovery to chemical and biological disturbances, ability to maintain the integrity of nutrient cycling and cost effective. Free-living marine nematodes have been used successfully as indicators of biological health and ocean pollution of heavy metals and hydrocarbon (PAH) for at least past 40 years. The ecological disturbances like heavy metals, hydrocarbon pollution, organic enrichment, xenobiotics, and combinations of these pollutants are indicative by the nematode taxa *Odontophora villoti, Parasphaerolaimus paradoxus, Trichotheristus mirabilis, Theristus pertenuis*, and members of the family *Encheliidae* which are extremely sensitive upon exposure. *Araeolaimus bioculatus* issensitive to mercuric and chromium concentrations and genera led by *Pomponema, Halalaimus, Setosabatieria, Paracanthonchus, Richtersia, Desmoscolex, and Xyala* are sensitive to combinations of hydrocarbons and heavy metals (Cr, Cu, and Ni) and more general organic enrichment and chemical pollution.

Role of beneficial nematodes in soil

Free living nematodes reflect and impact the biodiversity of soil ecosystems and soil health while contributing significantly to soil sustainability. They are actively involved in nutrient cycling and the breakdown of organic matter in food webs which is a crucial requirement in agriculture. It is experimentally exhibited that nitrogen is available in the ammonium form at about 8% to 19% when bacterivores and fungivores nematodes are present in both conventional and integrated farming systems respectively. The four main species of stimulatory nematodes—*Diplolaimelloides meyli, Diplolaimelloides oschei, Diplolaimella dievengatensis,* and *Panagrolaimus paetzoldi* are known to speed up the decomposition process by stimulating the microbial community. Besides, the order Rhabditida eg. *Acrobeles spp. Rhabditis sp., Acrobeliodes sp., Caenorhabditis elegans, Panagrolaimus subelongatus* and many more have significant role in the decomposition of organic matter. Nematodes through direct excretion of ammonia maintain the soil carbon to nitrogen ratio and stabilizes the soil environment. Nematodes additionally possess proteins in their cells that are involved in the release of metal ions and the detoxification of organic xenobiotics. Nematode completes your life cycle in soil (Figure 2).

Nematodes as enemy of pests

Entomopathogenic nematodes (nematodes pathogenic to insects) occur naturally in soil environments. The nematodes of nine families (*Allantonematidae, Diplogasteridae, Heterorhabditidae, Mermithidae, Neotylenchidae, Rhabditidae, Sphaerulariidae, Steinernematidae*, and *Tetradonematidae*) attack insects pest, kill, sterilize, or alter host development. The nematode species of two families (Heterorhabditidae and Steinernematidae) have been effectively and widely used as biological insecticides in sustainable pest management programs. Often considered non-toxic to humans, relatively specific to their target pests, and applicable with standard pesticide equipment are some of the advantages of the EPN. Both *Heterorhabditis* and *Steinernema* genus are mutualistically associated with bacteria of the genera *Photorhabdus* and *Xenorhabdus* respectively, that in association causes septicemia of the exposed pest within 24-48 hrs.

Romanomermis iyengari

(Mermithidae) is one of several species of entomopathogenic nematodes which parasitize and kill mosquito larvae. *R. iyengari, R. culicivorax* and *R. nielsoni* parasitizes Anophilis, Culex and Aedes mosquito respectively. The *Rhabditida* nematode, same family as *C. elegans*, is also known to parasitize and kill slugs and snails (Table- 1)

(Nitrous oxide and Sulphur), eutrophication and many more are already knocking the doors of menace. Timely intervention is the only impactful solution to it or else it may soon lead to human life degrading factors like plastic, global warming and deteriorated air quality. The free living and marine nematodes and their bio indicative character are to be mined and channelized for successfully arming them to the soil, growing green manure crops as cover crops, covering soil with organic mulch, and conservation tillage practices. This improves population densities of beneficial free-living nematodes in the soil. Nematodes cause nearly US$157 billion worth of food and agricultural loss which by soil amendments such as chitin, paper waste, and pine bark were found to reduce numbers of plant-parasitic nematodes and

Crops (targeted)	Pest common name	Pest scientific name	Effective nematodes
Artichokes	Artichoke plume moth	*Platyptilia carduidactyla*	Sc
Vegetables	Armyworm	Lep: Noctuidae	Sc, Sf, Sr
Ornamentals	Banana moth	*Opogona sacchari*	Hb, Sc
Bananas	Banana root borer	*Cosmopolites sordidus*	Sc, Sf, Sg
Turf	Billbug	*Sphenophorus* spp. (Col: Curculionidae)	Hb, Sc
Turf, vegetables	Black cutworm	*Agrotisipsilon*	Sc
Berries, ornamentals	Black vine weevil	*Otiorhynchussulcatus*	Hb, Hd, Hm, Hmeg, Sc, Sg
Fruit trees, ornamentals	Borer	*Synanthedon* spp. and other sesiids	Hb, Sc, Sf
Home yard, turf	Cat flea	*Ctenocephalides felis*	Sc
Citrus, ornamentals	Citrus root weevil	*Pachnaeus* spp. (Col: Curculionidae)	Sr, Hb
Pome fruit	Codling moth	*Cydiapomonella*	Sc, Sf
Vegetables	Corn earworm	*Helicoverpazea*	Sc, Sf, Sr
Vegetables	Corn rootworm	*Diabrotica* spp.	Hb, Sc
Cranberries	Cranberry girdler	*Chrysoteuchiatopiaria*	Sc
Turf	Crane fly	Dip: Tipulidae	Sc
Citrus, ornamentals	Diaprepes root weevil	*Diaprepesabbreviatus*	Hb, Sr
Mushrooms	Fungus gnat	Dip: Sciaridae	Sf, Hb
Grapes	Grape root borer	*Vitaceapolistiformis*	Hz, Hb
Iris	Iris borer	*Macronoctuaonusta*	Hb, Sc
Forest plantings	Large pine weevil	*Hylobiusabietis*	Hd, Sc
Vegetables, ornamentals	Leafminer	*Liriomyza* spp. (Dip: Agromyzidae)	Sc, Sf
Turf	Mole cricket	*Scapteriscus* spp.	Sc, Sr, Sscap
Nut and fruit trees	Navel orangeworm	*Amyeloistransitella*	Sc
Fruit trees	Plum curculio	*Conotrachelus nenuphar*	Sr
Turf, ornamentals	Scarab grub[c]	Col: Scarabaeidae	Hb, Sc, Sg, Ss, Hz
Ornamentals	Shore fly	*Scatella* spp.	Sc, Sf
Berries strawberry	Root weevil	*Otiorhynchusovatus*	Hm
Bee hives	Small hive beetle	*Aethinatumida*	Hi, Sr
Sweet potato	Sweetpotato weevil	*Cylasformicarius*	Hb, Sc, Sf

TABLE 1. Commercial use of Entomopathogenic nematode (EPN) of genus *Steinernema* and *Heterorhabditis* as bio insecticide.

Future thrusts

Nematodes have also recently been used for soil health assessment, aided by developments in analytical and identification methods. The environment is significantly exposed to many visible and invisible disturbances and the looming pollution threats like micro plastic, air pollution against detecting and signaling of the major disturbances in the ecology. The population is increasing folds and the supply of quality food is facing an uphill task especially when the soil quality is taking a deteriorating toll due to the overburdening of chemicals. The saving of the soil from such adversities is also a concern which can be tackled by adding organic amendments increase the free living nematodes as much as five folds. Entomopathogenic nematodes can be explored and tested against various insect pest of crops to mitigate crop loss.

CONCLUSION

Due to limited research nematodes are considered to be degraders, but the organism's exact potential is yet to be furnished. Only 15 % of the total nematode community is harmful to plants but one single *C. elegans* produced about 3 noble prizes and more than 10000 species of free living nematodes are yet to be under nomenclature. This opens up vast windows of opportunities' for researchers to many unsolved theories. On the other hand breakthrough in multiplication of free-living nematodes in soil will also help in nutrient mineral stabilization. This will lead to sustainable and stable soil ecology for the future generations. There is a challenge for understanding appropriate prospects of free living nematodes as biological indicators but the recent findings encourage the phenomenon's and the major lead of nematodes in identifying the ecological stress.

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