Inaugural Lecture

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A journey through the ‘Nemastonishing’ world of nematodes

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The views expressed in this Inaugural Lecture are not those of the North-West University, but those of the author.

Abstract

Since my first encounter with nematodes, I was intrigued by these extraordinary, microscopic organisms for which Nobel Prizes have been awarded for groundbreaking research. The quote by Carl Sagan: ‘Somewhere, something incredible is waiting to be known' became true a few times during my mesmerizing career in Nematology. I had the privilege of, together with my research teams (colleagues and students), adding novel information to the scientific fraternity regarding plant-parasitic nematodes as well as their non-parasitic counterparts. Most importantly, we were able to assist producers to produce crops sustainably in the presence of low nematode pest population densities under changing climatic conditions. This way marketable produce could be achieved whereby contributions were made to provide food for the nation. Ultimately, the highlight of my scientific career was to act as initiator and chief editor of the book “Nematology in South Africa: A view from the 21st century” whereby nematological research results that were generated by South African nematologists (and international colleagues) since 1982 were published by Springer International. In this Inaugural Lecture I share with those who are interested to ‘walk with me’, the milestones reached during the journey of my career in the discipline of Nematology. This ‘road’ is challenging, but exciting and fulfilling!

Honorable Members of the North-West University Board,
Family,
Friends,
Colleagues and
Students

I dedicate this lecture to my late parents (Piet and Tina Nel) and brother (Hannes Nel)

I compare the journey through my career to peeking through the window of some enchanting shop(s) that I remember as part of my childhood. Embarking on window shopping under the watchful eyes of my late parents and elder siblings was one of the most exciting experiences that made an enormous impression on me as a child. I vividly remember how the butterflies started to flutter in my stomach when we were told that the family will venture into the streets of my hometown, Hartswater in the Northern Cape Province, to do window shopping. When I had to prepare the lecture for my inauguration as professor at the North-West University, I immediately knew that I will start it off with this comparison. Moreover, I cannot refrain from sharing with you the quote ‘Somewhere, something incredible is waiting to be known' by Carl Sagan, since these words became true a few times during my mesmerizing career in Nematology. I also believe that in a continuously changing environment where climate is a major role player in practising agriculture, that lots of secrets will still be revealed by one of our most precious resources, the soil substrate. Nematodes are an integral part of soils since these organisms are aquatic and occur in all soils across the globe.

Now, do you remember when you (as a child) peeked through the window of a confectionary or toy shop? What was your biggest wish at that moment? Did you also, like me, wanted to see more and get nearer to the toys/sweets, or even try to touch it? My career is also about peeking. Yes, peeking through the lenses of a microscope since I joined the microscopic world of nematodes in 1989. This is what I am doing on a daily basis since nematodes are microscopic organisms that are generally not visible to the naked human eye. Using magnification levels of between 10 to 100 times, the most extraordinary view unfolds in front of my eyes every time when I count and study nematodes.

Nematodes are distinguished, extraordinary organisms belonging to five different trophic groups. The trophic group that my research to date mainly focused on is the herbivores/plant-parasitic nematodes that infect different parts/tissues of plants. Their non-parasitic counterparts, bacterivores (feeding on bacteria), fungivores (feeding on fungi), omnivores (feeding on plants and soil-dwelling organisms) and predators (feeding on a wide range of soil-dwelling organisms) are referred to as beneficial nematodes that contribute towards soil quality and are to a lesser degree also being included in my research during the past five years. Within the bacterivores, two nematode species distinguished themselves for their use and contribution towards science. For example, *Caenorhabditis elegans*, has been used as a model organism since 1965. Three Nobel prizes have been awarded (during 2002, 2006 and 2008) to researchers in the disciplines of Physiology and Medicine for genetic studies on this nematode species. The genome of *C. elegans*, for example, was that of the first animal

that was entirely sequenced in 1998. In addition, programmed cell death was discovered in this nematode which has the important application of studying the development of cancer in humans. The other distinguished bacterial-feeding nematode, *Halicephalobus mephisto*, was the first multicellular organism found deep (about 1.3 km) below the earth's surface in salty water in a mine shaft in the Free State Province of South Africa where it survives in extreme conditions.

Except for terrestrial, plant-parasitic and non-parasitic nematodes, those that infect animals (invertebrates and vertebrates) and humans are also of great importance. For example, individuals of *Wuchereria bancrofti, Brugia malayi* and *Brugia timori* migrate and lodge in the lymphatic vessels of humans causing extreme swelling of the body parts. These nematodes are transmitted from human to human via female mosquitos in tropical areas of the world. On the other hand, heart worms (*Dirofilaria immitis*), lodging in the hearts of dogs cause significant mortalities in vertebrate animals. And then entomopathogenic nematodes of the genera *Heterorhabiditis* and *Steinernema* infect invertebrates, specifically insects, and are of particular importance since they are used to control economically important pests.

For the purpose of my research, however, special reference is given from here onwards to the economically important plant-parasitic nematode genera that infect and damage agri- and horticultural crops. Infection by individuals of these genera cause qualitative losses of marketable products such as potato, carrot and beetroot since the produce are downgraded due to the formation of galls, necrotic tissue and other damage. Also,

quantitative losses are caused to grain crops due to infection and parasitism of economically important nematode genera, including root-knot (*Meloidogyne*) and lesion (*Pratylenchus*) nematodes in South Africa in particular, resulting in lower yields and subsequently lower income to producers.

My research and teaching include lecturing of Nematology at Honors level as part of the Sub-program: Integrated Pest Management, mentoring of MSc and PhD students and collaborating with Post-Doctoral Fellows. Research done by myself and my team is funded by local and international institutions, seed and chemical industries, and companies as well as through income from a diagnostic laboratory that is managed under my leadership at the NWU. Research activities related to Nematology are aimed at both commercial and subsistence grain farmers and has a multi-disciplinary and institutional approach. Ultimately, the focus is on practically applied research that aims to provide solutions to producers on how to alleviate nematode damage. However, basic fundamental research forms the basis of all research activities done by our team.

The primary nematode pest genus that our research focuses on is *Meloidogyne* spp. and particularly aspects about the identification, ecology and management of such species. The most abundant and widespread species prevailing in local grain production areas are *Meloidogyne incognita* and *Meloidogyne javanica*, with *Meloidogyne arenaria* also being present in some areas. Yield losses of up to 60% have been recorded in field experiments where the former two species are abundant. Classical and practical examples about the devastating effect of

this genus in grain-based cropping systems are represented by the inclusion of rotation crops (i.e. dry bean, maize, soybean, sunflower, various vegetable crops) in the Free State and North-West provinces that are all highly susceptible to this nematode genus, resulting in severe damage (lower yields and quality of produce). Except for research on *Meloidogyne* spp., other plant-parasitic nematodes (e.g. *Pratylenchus* spp.) are also included in various projects. The ultimate goal is to exploit and develop strategies to manage the economically important nematode pests in fields of producers. Updated nematode surveys have been, and are periodically done in grain production areas to determine the abundance and diversity of nematode pests in crop fields. This way knowledge about nematode problems is generated, enabling the team to address and deal with it. For example, extensive nematode surveys have been done by MSc and PhD students (Maretha Pretorius and Suria Bekker, respectively) for local maize crops since 2011 under both conventional and conservation agriculture practices. In fact, the first survey in maize fields under conservation agriculture has been done as a result of this initiative during which novel and valuable information has been generated. It was for example discovered by Dr Suria Bekker that *Rotylenchulus* spp., omnipresent in local maize production areas, dominated and outcompeted *Meloidogyne* spp. in roots of grain crops grown under conservation agriculture practices. This is an important finding since the hectares under conservation agriculture is expanding in South Africa and producers should be informed timely, and be guided to take note of and address the nematode situation in such fields. Except for nematode surveys in local maize fields, the same have been, and is still done for soybean as part of PhD (Akhona

Mbatyoti) and MSc (Chantelle Girgan) studies. These initiatives focused on conventional and genetically-modified, glyphosate-tolerant soybean (dominating the local market) crops with novel information being generated. The listing of seven plant-parasitic nematode species as first reports in terms of their association with soybean in South Africa for example represents novel information. Moreover, the MSc study was the first that correlated the presence of beneficial nematodes and soil microbial communities in local soybean fields. Other nematode surveys conducted as part of my research focus include that of the emerging threat root-knot nematode species, *Meloidogyne enterolobii*, in and outside local guava orchards. The first surveys were conducted from 2014 to 2016 (MSc studies of Melissa Visagie and Maretha Pretorius), and another in 2018 (PhD study of Milad Rashidifard). The MSc studies of Melissa Visagie and Maretha Pretorius generated first reports of *M. enterolobii* in roots of potato and maize, respectively, on the Highveld of the Mpumalanga Province. Concurrently, the study by Milad Rashidifard resulted in first reports of this root-knot nematode species in the North-West and Northern Cape provinces as well as it parasitizing six new crop hosts, namely bean, eggplant, groundnut, lettuce, pumpkin and spinach. Further studies by myself and colleague Prof Willie van Aardt (animal physiologist) on this root-knot nematode species include i) determining its reproduction potential in roots of a dry bean and soybean cultivar that are susceptible to its counterpart *M. incognita* and ii) measuring the oxygen consumption of these two root-knot nematode species as part of a comparative study. Although results for both studies were not significant between the two species, the reproduction rates *of M. enterolobii* were 1.6 and 1.4 times higher on the dry bean

and soybean cultivars than that of *M. incognita*. This may offer an explanation why this species is more injurious than *M. incognita* and other thermophilic species. Two other studies that focus on *M. enterolobii* are also currently in progress and focus on i) its morpholgical and molecular identification and, investigations regarding its genome to explain the virulence exhibited by the species (PhD study of Milad Rashidifard), and ii) the life cycle duration and reproduction potential of this species compared to that of its thermophilic counterparts *M. incognita* and *M. javanica* (MSc study of Raymond Collet).

Additional research projects focus on various aspects such as the effect of soil types (MSc study of Mr Joel Kangolongo) on the predominantly occurring *M. incognita*, while the host status of crop plants such as soybean are also determined for the latter species as well as for *M. javanica* (MSc and PhD studies of Chanté Venter and Akhona Mbatyoti, respectively). The latter included traditional, greenhouse screenings as well as techniques including the use of enzymes to verify resistance and understand resistance mechanisms exhibited by cultivars with the resistance trait. Research projects are also done that focus on the exploitation and investigation of environmentally-friendly strategies, with the main aim being to stimulate beneficial nematodes through manipulation of nematode communities. This way nematode assemblage structures are altered so that nematode pests are in the minority and less pathogenic nematode pests dominate. The use of Brassicaceae cover crops in an 8-ha field study at Christiana (North-West Province), for example, resulted in enhancing the quality of the soil by using nematodes as bioindicators. However, population densities of the target nematode pest *M. incognita* were high at

tuber initiation of the follow-up potato crop and the study had to be terminated and a synthetic nematicide applied to prevent quality and concurrent financial losses. The use of animal manures, solarization and *Tagetes* mulches and intercropping also proved to reduce root-knot nematode population densities substantially in fields of developing farmers in the Limpopo and North-West provinces. In addition, *in vitro* studies were done showing the adverse effect of Vetiver (*Chrysopogon zizanioindes*) root exudates on the motility of *Meloidogyne* spp. second-stage juveniles. This study followed a former investigation during which the poor host status of Vetiver grass (cultivar Sunshine) was recorded for *M. incognita* and *M. javanica*, respectively, and proved the beneficial effects of this grass in combatting root-knot nematode pests.

Although my research does not focus on taxonomy, the expertise of an Iranian Post-Doctoral Fellow Dr Ebrahim Shokoohi contributed to identify another nematode pest of groundnut *Robustodorus arachidis* n.comb. of which individuals were found in severely damaged pods from the Vaalharts area in 2016. This research is currently continued as part of an MSc study by Tinyiko Chauke that focuses on the abundance of pod nematodes of groundnut crops in selected production areas. Research on nematode pests associated with weeds and African Leafy Vegetables are also part of my research, with Nancy Ntidi completing both her MSc and PhD studies on this topic. And, apart from research directly linked to Agriculture, the abundance and diversity of nematodes in both terrestrial and aquatic ecosystems in caves have also been conducted as part of an MSc study (Gerhard du Preez). The effect of irrigation water on soil health in the Marico and Crocodile catchment

areas, using the TRIAD approach and nematodes as bioindicators was recently completed as part of a PhD study by the latter student. From outside the borders of South Africa, PhD student Tesleem Bello is studying the nematode assemblages associated with watermelon in Nigeria as well as the use of genetic host plant resistance to minimize damage caused by root-knot nematode pests.

I conclude this Inaugural Lecture by accentuating the major highlights of my career which were: i) publication of the book "Nematology in South Africa: A view from the 21st century" as initiator and chief editor, ii) development of seven local soybean lines with resistance to *M. incognita*, iii) using *Eragrostic curvula* as a poor host and cover crop in a potato producer's field near Mooiriver (Kwa-Zulu Natal) to alleviate a *Meloidogyne chitwoodi* problem and iv) the use of soil amendments (animal manures and compost) and solarization to minimize root-knot nematode problems and damage in fields of developing producers in the Bushbuckridge (Limpopo Province) and Ventersdorp (North-West Province) areas.

Ladies and gentleman, the 'peeking at nematodes' will continue since through future research me and my team's main aim is to keep on assisting producers to reduce nematode problems and produce crops sustainably under changing climatic conditions. Although I have experienced it already in my career thus far, I believe that ''Somewhere, something incredible is waiting to be known' as stated by Carl Sagan.