
51st Reunión Anual/51st Annual Meeting
Organización de Nematólogos de los Trópicos Americanos/
Organization of Nematologists of Tropical America

San José, Costa Rica

21-25 de Julio de 2019/July 21-25, 2019

ASSESSMENT OF THE RESISTANCE OF THREE WALNUT ROOTSTOCKS TO *Pratylenchus vulnus* AND A MIXTURE OF THREE *Meloidogyne* POPULATIONS [EVALUACIÓN DE LA RESISTENCIA DE TRES PORTAINJERTOS DE NOGALES A *Pratylenchus vulnus* Y A UNA MEZCLA DE TRES POBLACIONES DE *Meloidogyne*]

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Walnut (*Juglans regia*) is one of the fruit trees experiencing greater planting in Chile in the last 10 years, reaching a cultivated area of more than 35,000 ha. Root damage is associated with several plant-parasitic nematodes, mainly *Pratylenchus vulnus* and different *Meloidogyne* species. Nematode presence is associated with medium and light soil textures, previously cultivated with susceptible crops. The aim of this work was to compare the sensitivity of the rootstocks RX1, VX211, and VLACH recently introduced to Chile with ungrafted plants of *J. regia*. Two-month-old plants were obtained from a nursery in a container filled with steamed peat and transplanted to 5-L pots with a substrate consisting of a steamed mixture of sand and soil in the same proportions. Once established, plants were inoculated with 2,000 eggs of *Meloidogyne* obtained from fields cultivated with tomatoes and grape vines. For *P. vulnus*, plants were planted in the pots filled with naturally infested soil, and maintained under

controlled conditions in a greenhouse during spring and summer. Plants were harvested after 110 days to determine number of nematodes in substrate and roots for *P. vulnus* and for eggs of *Meloidogyne* spp. Results showed that the four rootstocks were parasitized by both nematodes, with a reproductive factor (Pf/Pi) >2 for soil populations of *P. vulnus*. With respect to *Meloidogyne* spp., VLACH showed some resistance with a Pf/Pi value lower than 1, different from the other three rootstocks ($P < 0.05$). According to these results, new walnut orchards must be under some nematode management program.

EFFICACY OF THREE ISOLATES OF *Steinernema* SPP. IN THE CONTROL OF *Naupactus xantographus*, AN IMPORTANT PEST OF GRAPEVINE ROOTS IN CHILE [EFICACIA DE TRES AISLADOS DE *Steinernema* SPP. PARA EL CONTROL DE *Naupactus xantographus*, PLAGA DE ALTA IMPORTANCIA EN RAÍCES DE LA VID EN CHILE]

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Among the various pests and diseases that attack grapevines in Chile, *Naupactus xantographus* (Coleoptera: Curculionidae) is one of the most serious. This insect has a long life cycle with a subterranean larval phase of more than 1 yr. During this period, this insect feeds on new roots

severely affecting plant growth, while the adult feeds on the foliage of the plants. Current control is based mainly on synthetic insecticides applied to the soil and foliage with poor results, especially in the soil. Entomopathogenic nematodes (EPN) have previously been shown as a potential alternative to chemical treatments. The aim of this work was to evaluate the efficacy of three Chilean native isolates of two species, the cosmopolitan *Steinernema feltiae* isolates Licanray (LR) and Chillan 4 (CH4) and the native *S. unicornum* isolate Chillan 3 (CH3). Assays were performed in petri dishes, using the last larval instar of the insect, and two concentrations of Infective Juveniles (IJ), 100 and 300 IJ/larva. After inoculation, petri dishes were maintained at 20°C and evaluated after 2 days to determine percent larval mortality. The production of new IJ/cadaver was also evaluated. The assay was performed using a completely randomized design. The most effective isolate was LR, with over 65% mortality, whereas the other two isolates ranged between 35 and 65% mortality 2 days after inoculation. These results suggest that *S. feltiae* LR should be assessed under real field conditions to establish the optimum concentration and opportunity of application.

NEMATODES ASSOCIATED TO RED PALM WEEVIL IN THE SOUTHERN IBERIAN PENINSULA [NEMATODOS ASOCIADOS AL PICUDO ROJO DE LAS PALMERAS EN EL SUR DE LA PENÍNSULA IBÉRICA]

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The red palm weevil, *Rhynchophorus ferrugineus*, is the most damaging pest of palm species in the world. This beetle is native to tropical areas in Southeast Asia and started its expansion 25 years ago. In 1995, the pest was introduced in the Iberian Peninsula through palm trees imported from Egypt and spread fast to other European countries. Leaving aside entomopathogenic species, few other nematodes have been previously recorded in association with this beetle. Adult specimens and larvae cocoons of *R. ferrugineus* collected from an ornamental Canarian palm (*Phoenix canariensis*) affected by the pest near the town of Jaén (southern

Iberian Peninsula) were examined to explore the presence of nematodes. Nematodes were extracted by a modified tray technique. Two species, *Mononchoides macrospiculum* and *Teratorhabditis synpapillata*, recorded for the first time in Spain, were identified using morphological, morphometrical, and molecular (18S and 28S rDNA) data. These findings agree with those recently reported in Italy, where the presence of *R. ferrugineus* has been detected since 2004, and suggest a close association with no adverse effect between both nematode species and the weevils. Thus, the nematodes probably live and feed on the cocoons and the galleries of weevil larvae being carried (phoresy) by adult beetles to other palm trees. Nematodes might originate from southern Asia as at least one of the species, *T. synpapillata*, has been recorded there in soil also.

EVALUACIÓN DE LA TOLERANCIA DE CINCO LÍNEAS DE CAFÉ "SARCHIMOR T5296" A *Meloidogyne exigua* EN ALMÁCIGO EN ALAJUELA, COSTA RICA [EVALUATION OF THE TOLERANCE OF FIVE LINES OF COFFEE "SARCHIMOR T5296" TO *Meloidogyne exigua* IN SEEDBED IN ALAJUELA, COSTA RICA]

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Las pérdidas económicas en la producción de café debido a nematodos fitoparásitos se estiman de un 10 a un 25%. El combate de nematodos es complejo y se necesita integrar diferentes técnicas para reducir las poblaciones a niveles que no afecten los sistemas radicales de las plantas. Determinar líneas con capacidad de resistencia o tolerancia a nematodos es necesario en programas de mejoramiento genético. Se evaluaron variables de crecimiento del cafeto como altura de planta (cm), diámetro del tallo (mm) y número de hojas, a 120 días después de la inoculación. Además, se evaluaron el Índice de Agallamiento Radical (ÍAR), peso fresco del sistema radical, densidades poblacionales y el Factor de Reproducción (FR). Se observaron diferencias significativas tanto entre líneas como entre tratamientos (inoculado y sin inocular). En la variable altura de planta, el testigo Caturra (CT) presentó la menor altura en ambos

tratamientos (inoculado 7.27 cm y sin inocular 10.84 cm). Al comparar solo las líneas San Isidro (SI) (derivadas del Sarchimor T5296), para tratamiento inoculado, la SI35 fue la mejor con altura de planta de (12.5 cm), mientras tanto la que creció menos en presencia de nematodos fue la SI34, (9.31 cm). Para la variable diámetro de tallo, presentaron diferencias significativas las San Isidro (SI), con respecto al testigo. Para la variable ÍAR, el porcentaje de severidad mostró que la línea SI35 fue la menos agallada (5.3%), comportamiento del genotipo “resistente” mientras tanto la SI34, fue la más agallada (59.9%), comportamiento “susceptible”. En la variable peso fresco de sistemas radicales, la línea SI27 presentó el mayor peso radical (6.1 g), mientras tanto el testigo, tuvo el menor peso promedio de raíces (2.6 g). Los conteos poblacionales de nematodos en raíces, presentaron diferencias estadísticamente significativas ($P < 0.05$), la SI35 fue la que presentó en promedio menor cantidad de nematodos con 168, mientras tanto la SI34, presentó un promedio de 1,436 juveniles. Con la variable FR, las líneas SI35, SI31 y SI32, se comportaron como resistentes, mientras tanto las líneas SI27, SI34 y Caturra, resultaron ser susceptibles, según la clasificación de Oostenbrink. La línea más promisoría para futuras investigaciones fue la SI35, ya que mostró las características más sobresalientes en las variables evaluadas.

DEVELOPMENT OF A SCREENING PIPELINE TO IDENTIFY MICROBES TO COMBAT ROOT-KNOT NEMATODES IN SUB-SAHARAN AFRICA [DESARROLLO DE UNA PLATAFORMA DE DETECCIÓN PARA LA IDENTIFICACIÓN DE MICROORGANISMOS PARA EL COMBATE DE NEMATODOS AGALLADORES EN ÁFRICA SUBSAHARIANA]

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West Africa, specifically Nigeria and Benin, is responsible for over 95% of the world's yam production. The plant-parasitic nematode *Meloidogyne* spp. (root-knot nematode) is a major

contributing factor to yield losses in West African root and tuber crops. The tools available to smallholder farmers in Africa to combat nematodes are limited, creating a need for the management of these agronomically devastating pests. At AgBiome, our goal is to harvest the potential of the plant microbiome to develop biological crop-protection solutions. AgBiome has established a discovery pipeline developed around the biology of *Meloidogyne* spp. and their interactions with microbes. Our innovative approach to discovery of a biological nematicide involves the design and implementation of high-throughput *in vitro* and quick-read on-plant assays to identify potential strains that target the vulnerable second-stage juvenile. Candidate microbe strains are then confirmed using greenhouse and field screening trials to measure effects on yield and subsequent generations of *Meloidogyne* spp. By including African yam-associated microbes from plant tissue and field soils in our screens, we can expand the reach of our product discovery to help yam production in West Africa.

EFFECTO DE BLOCKER (PROTEASAS) SOBRE *Meloidogyne incognita* EN *Capsicum annum* L. CULTIVAR PAPIRIKA [EFFECT OF BLOCKER (PROTEASES) ON *Meloidogyne incognita* IN *Capsicum annum* L. CULTIVAR PAPIRIKA]

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En el presente estudio se evaluó el efecto del producto Blocker, que contiene enzimas proteasas como ingrediente activo sobre *Meloidogyne incognita* en *Capsicum annum* cultivar Paprika. El diseño experimental fue al azar con cuatro tratamientos y seis repeticiones. Los tratamientos fueron Blocker (1 kg de extracto + 2 L de activador/200 L), Oxamyl (3 L/200L), testigo *M. incognita* sin nematicida y testigo absoluto (sin inoculación). Las plántulas de *C. annum* de 35 días de edad se sembraron en bolsas que contenían 4 kg de una mezcla de arena, musgo y humus de lombriz

(3:1:1). Cada bolsa se inoculó con 4 000 huevos de *M. incognita*. Sesenta días después de la inoculación, se determinó la densidad poblacional de nematodos en 100 cm³ de suelo, el número de huevos y juveniles en 5 g de raíz y el índice de nodulación. Además, se evaluaron parámetros biométricos de las plantas. Blocker redujo el número de juveniles (J2) en 100 cm³ de suelo en 45,5% ($P=0.01$) y el número de huevos en las raíces en 27% ($P=0.01$). Así mismo, el número de nódulos por gramo de raíz, en plantas tratadas con Blocker fue menor ($P=0.01$) y representó solamente el 10.9% de lo determinado en las plantas sin tratamiento. Además, favoreció la altura de planta en 4.07 cm; la longitud de raíces en 5.19 cm; el peso fresco y seco del follaje en 16.34 y 7.1 g y el peso fresco y seco de raíces en 6.8 y 0.73 g respectivamente, con respecto al tratamiento testigo (*M. incognita* sin nematicida).

IDENTIFICATION AND DISTRIBUTION OF PLANT-PARASITIC NEMATODES ASSOCIATED WITH STRAWBERRY (*Fragaria* spp.) IN COSTA RICA [NEMATODOS FITOPARÁSITOS ASOCIADOS A FRESA (*Fragaria* spp.) EN COSTA RICA]

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Plant-parasitic nematodes are one of the main problems that affect strawberries worldwide. In Costa Rica, there is no information related to the nematodes species associated with this crop, their distribution, damage, diversity. Roots, soil, and foliage samples were collected in the main strawberry production areas of Costa Rica (Cartago, Alajuela, and Heredia). No nematodes were found in foliage samples. Three genera were found on roots, *Meloidogyne*, *Pratylenchus*, and *Helicotylenchus*. In addition to the genera mentioned above, *Aphelenchoides*, Criconematidae, and *Hemicycliophora* were identified in soil. In both soil and root samples, the genera with the highest frequency of occurrence were *Meloidogyne* and *Pratylenchus* at 81% and 54%, respectively. *Meloidogyne* and *Pratylenchus*

had an average population density of 11,897 nematodes/100 g of roots (ranging from 20 to 77,520) and 1,808 (ranging from 540 to 3,490), respectively. PCR-RFLP was performed on four populations of *Meloidogyne* using the primers C2F3/1108 and the amplification product (~520 bp) was digested with the restriction enzyme *DraI*. The restriction pattern corresponded to *M. hapla* and was confirmed using species-specific primers. The *Pratylenchus* populations found on strawberries are currently being characterized with several molecular markers.

DEVELOPMENT OF A NEW BIOLOGICAL CONTROL PRODUCT BASED ON SOIL-BORNE BACTERIAL CONSORTIA AGAINST PLANT-PARASITIC NEMATODES [DESARROLLO DE UN NUEVO PRODUCTO CONTROLADOR BIOLÓGICO A BASE DE UNA BACTERIA DEL SUELO CONTRA NEMATODOS PARÁSITOS DE PLANTAS]

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Root-knot nematodes (RKN), *Meloidogyne* spp., are extremely destructive pathogens with a cosmopolitan distribution and a host range that affects most crops. Safety and environmental concerns related to the toxicity of nematicides along with a lack of natural resistance sources threaten most crops. This emphasizes the need to identify new alternatives to control these devastating plant-parasitic nematodes. Bacterial sources included 120 bacteria from suppressive soil from a banana plantation and from healthy tomato plants in vicinity to RKN-infected plants. Four screening methods were conducted to study bacteria bionematicidal activity against the RKN: a) *in vitro* activity, b) *in terra* activity in small pots containing soil, nematodes and bacteria, c) on

tomato seedlings in short-term experiments, and d) on tomato plants in pots in long-term experiments. To date, *in vitro* screening resulted in the selection of 40 potential bacteria possessing bionematicidal activity against RKN second-stage juveniles (J2). *In terra* experiments indicated that out of 40 studied bacteria, 21 have demonstrated bionematicidal activity against RKN J2 in soil. Out of the 21 potential bacteria, 12 bacteria have been shown to reduce gall appearance and egg production on tomato seedling roots. Antagonistic tests among 12 bacteria were conducted in order to reveal any antagonistic activity between different bacteria. Seven consortia were generated consisting of different bacteria combinations and these were tested for their activity to reduce RKN disease occurrence on tomato plants in pot experiments. Among all tested consortia, three consistently demonstrate activity in reducing galling. Currently, these potential consortia are being further developed to generate a formulation adjusted for field application.

MORPHOLOGICAL IDENTIFICATION, MOLECULAR ANALYSIS, AND REDUCTION OF DAMAGE CAUSED BY *Globodera rostochiensis* IN POTATO [IDENTIFICACIÓN MORFOLÓGICA, ANÁLISIS MOLECULAR Y REDUCCIÓN DEL DAÑO DE *Globodera rostochiensis* EN EL CULTIVO DE PAPA]

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Cyst nematodes are considered one of the most important pests in the cultivation of potatoes (*Solanum tuberosum* L.) in cold and temperate climate areas. A phytoneematological prospecting study will be carried out in potato-producing regions of Mexico. Soil and plant samples with evident signs and symptoms associated with cyst nematodes will be collected. Nematode populations will be identified morphologically and molecularly using CTAB and molecular markers (RAPD and PCR-RFLP) methodology. Amplified and digested bands will be encoded in a binary

matrix, from which a similarity matrix will be made with the NTSyS pc. 2.0 program. The similarity between samples will be evaluated using the Dice coefficient. An *in vitro* study will be developed to evaluate the nematicide effect of different products on *Globodera rostochiensis* juveniles by estimating the proportion of inactive nematodes 24 hr after product exposure. Next, a study will be established in the greenhouse based on the laboratory results, and finally a field validation process will be carried out to ratify the results obtained in greenhouse. The population density of juveniles and females/cyst, as well as the effectiveness of the treatments will be evaluated as indicators to develop pest management practices that can reduce damage caused by *G. rostochiensis* in potato.

CONFIRMACIÓN TAXONÓMICA Y MOLECULAR DE *Meloidogyne exigua* (GÖELDI 1887) EN CAFÉ EN HEREDIA, COSTA RICA [TAXONOMIC AND MOLECULAR CONFIRMATION OF *Meloidogyne exigua* (GÖELDI 1887) IN COFFEE IN HEREDIA, COSTA RICA]

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El nematodo agallador (*Meloidogyne* spp.), es una de las plagas económicamente más importantes que afecta una amplia gama de cultivos en todo el mundo causando daños generalizados. El objetivo de este trabajo fue realizar estudios morfológicos, taxonómicos y moleculares para confirmar la especie de *Meloidogyne* asociada con una plantación de café en Barva, Heredia durante el 2016. Se examinaron sistemas radicales y se observaron pequeñas agallas ubicadas en el extremo apical de la raíz. En promedio se contabilizaron un total de 30 J2/100 cm³ de suelo y 1000 J2/10g. Los estudios morfológicos (diseño perineal de las hembras), taxonómicos y moleculares (secuenciación) mostraron que las hembras y los juveniles pertenecían a la especie *M. exigua*. La amplificación de la región ribosomal del ADN mitocondrial (ADNm) entre *COII* y *16S*, produjo un único fragmento de 580 pb en todas las muestras analizadas. Los productos de PCR

digeridos con la enzima *DraI* generaron fragmentos de 160 pb y 420 pb. El análisis de la secuencia reveló una similitud del 99% con *M. exigua* al compararlas con otras secuencias de Costa Rica y Nicaragua. Se logró la identificación de *M. exigua* asociada a una plantación de café mediante el uso integrado de técnicas taxonómicas y moleculares. Debido a la amplia distribución de la especie en las plantaciones de café, se recomienda prestar especial atención a las áreas donde está presente este nematodo para conocer su distribución y propagación e implementar estrategias de manejo. Finalmente, es necesario estar alerta a la infección de este nematodo para evitar su diseminación en otros sitios.

SUSCEPTIBILIDAD DE LARVAS Y ADULTOS DE *Paranomala undulata peruviana* (GUÉRIN-MÉNEVILLE) A *Heterorhabditis indica* (POINAR) [SUSCEPTIBILITY OF LARVAE AND ADULT OF *Paranomala undulata peruviana* (GUÉRIN-MÉNEVILLE) TO *Heterorhabditis indica* (POINAR)].

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La extensa superficie instalada con caña de azúcar en el proyecto de irrigación e hidroenergético Olmos en el norte del Perú, ha favorecido el establecimiento del escarabajo *Paranomala undulata peruviana* (Guérin-Méneville), cuyas larvas se ubican en el suelo, se alimentan de las raíces y los adultos que son de hábito nocturno migran hacia los campos vecinos de palto y vid cuando están en brotamiento y en este último cultivo cuando está el racimo listo para cosecha, causando grandes pérdidas económicas. En este estudio se evaluó la susceptibilidad de las larvas de *Paranomala undulata peruviana* a *Heterorhabditis indica* aplicando con un nebulizador manual 150 juveniles infectivos (JI) /larva al suelo y 150, 500 y 1000 JI/adulto. Se registró diariamente los síntomas y el porcentaje de mortalidad. Los síntomas en las larvas fueron menor movimiento, muerte y coloración rojiza a las 48 horas después de la inoculación alcanzando un 71.4 % de mortalidad. Los adultos dejan de alimentarse, presentan descoordinación para

caminar y volar, realizan movimientos torpes y mueren 48 a 72 horas después de la inoculación y emiten un olor putrefacto, registrando 54.5, 66 y 76 % de mortalidad. Estos resultados demuestran que *H. indica* puede constituirse en una alternativa biológica importante para el control de larvas y adultos de esta plaga.

NEMATOLOGY IN CENTRAL AMERICA, AN APPROACH TO THE CURRENT STATE OF RESEARCH [NEMATOLOGÍA EN AMÉRICA CENTRAL, UN ACERCAMIENTO AL ESTADO ACTUAL DE LA INVESTIGACIÓN]

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In Central America, historically, the economy has been based on agriculture, tourism, and some small industries. Central America is an area that, due to its geographical position and climatic conditions, presents risks associated with the development of pests and diseases in crops. Among pests and diseases, nematodes stand out because of their impacts on the yield and the cost associated with their control. Therefore, it is important to develop research aimed at establishing indicators that allow an idea of the "State of Nematology in Central America." These databases can become an important tool for systematizing and analyzing different indicators that will be used to compare the activity in different countries, as well as identifying the actors to integrate knowledge networks. A first step to generating an important indicator is to search the final graduation work (thesis) presented over the last 20 years in the main universities in the region, using different tools that provide the Information and Communication Technology (ICT). This is possibly one of the most complicated steps in the investigation, given the lack of systematization and the conditions of each Central American country. It is expected that as a result of this preliminary analysis, we can identify most of the nematologists who work in universities in Central America to increase and strengthen the network of specialists and facilitate the exchange of knowledge for the development and construction of specialized know-how, to generate skills that

allow more effective identification of the problems associated with the control of nematodes.

A METAGENOMIC STUDY OF BANANA NEMATODE ANTAGONISTS IN CANARY ISLANDS [ESTUDIO METAGENÓMICO SOBRE ANTAGONISTAS DE NEMATODOS DEL BANANO EN LAS ISLAS CANARIAS]

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A study was carried out on the ecology of microbial antagonists associated with phytoparasitic nematodes of banana crops in Canary Islands, Spain. Samples included rhizosphere soil from cv Pequeña enana and controls collected from adjacent sites, without banana. Total RNA was extracted from soil and retrotranscribed. To characterize bacterial communities, the variable V3 and V4 regions of the 16S rRNA ribosomal gene were amplified. The ITS region was used for classification of fungal communities. Libraries were sequenced with an Illumina MiSeq™ in paired ends with 300-bp read length, and analyzed with QIIME and STAMP. Nematodes were extracted from soil by the sieving and decanting technique, counted, and identified with light microscopy. Phytoparasitic nematodes were found mostly in the banana rhizosphere. *Pratylenchus goodeyi* was present in 75% of samples from northern farms at densities of 200-1,750 specimens/100 cm³ soil, with lower prevalence (22%) and densities in the southern fields. *Helicotylenchus* spp. included *H. multicinctus* found in northern and southern farms. Metagenomic data showed several fungal OTUs belonging to Sordariomycetes, including Clavicipitaceae such as *Pochonia chlamydosporia* and *Metarhizium anisopliae*. Other taxa were *Trichoderma harzianum*, *T. longibrachiatum*, *T. virens*, *Beauveria* sp., and *Fusarium* spp., together with mycoparasites such as *Acrostalagmus luteoalbus*. Dominant bacterial phyla were Proteobacteria, Actinobacteria, Planctomycetes, Bacteroidetes, Chloroflexi, and Acidobacteria. Principal coordinate analysis of microbial communities showed a direct effect of cropping on

the samples profiles. Beta-diversity also indicated latitude-related factors that clearly separated northern and southern controls from banana rhizosphere samples.

NEMATODE PEST DYNAMICS ON BANANA, PLANTAIN, AND ENSET IN AFRICA AND THEIR MANAGEMENT [DINÁMICA DE NEMATODOS PLAGA EN BANANO, PLÁTANO, Y ENSET EN ÁFRICA Y SU MANEJO]

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Banana, plantain, and enset are important staple food sources in sub-Saharan Africa, which millions of people across the region are dependent upon for food and income. Plant-parasitic nematodes are a major threat to their production reducing yields, extending production cycles, and shortening plantation longevity. Although our knowledge and understanding of plant-parasitic nematodes remains limited for some crops in Africa, the characterisation and distribution of nematodes in banana, plantain, and enset is quite well documented, in comparison for some crops. The community profiles tend to differ between lowland plantain dominated areas in West Africa and Highland cooking banana and enset areas in East and Central Africa. But a gradual shift in the dominance and composition of nematode species appears to be occurring. Traditionally the burrowing nematode, *Radopholus similis*, a thermophilic species has been a major pest. At higher cooler altitudes the less aggressive thermophobic lesion nematode *Pratylenchus goodeyi* tends to replace *R. similis*. However, *P. goodeyi* is being increasingly recovered from lowland, tropical areas and the relative dominance of *R. similis* appears to be gradually being replaced by *Pratylenchus* species across the continent. The implications of this shift and temperature tolerances are discussed in relation to nematode management efforts, such as breeding for resistance, biological control and through transgenic options.

THE NEMATODE THREAT TO FOOD

SECURITY IN SUB-SAHARAN AFRICA [LA AMENAZA DE LOS NEMATODOS A LA SEGURIDAD ALIMENTARIA EN ÁFRICA SUBSAHARIANA]

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The human population in sub-Saharan Africa (SSA) is escalating, as is the rate of rural-urban migration. Agriculture is dominated by smallholders and characterised by low-input systems with sub-optimal productivity. The amount of food produced per person is either stagnant or decreasing. Low yields are due to various reasons, including particularly substantial losses to pests and diseases. This situation is not sustainable. In order to achieve food security, attention towards sustainably intensifying these systems is necessary. However, with such diversity of production systems and agro-ecologies, this proves a challenge. Furthermore, more intensified cropping systems tend to increase the selection pressures for pest and disease emergence. In the tropical and sub-tropical conditions across SSA, pest and disease threats are a major concern, including that of nematode pests. However, while nematode pests are paradoxically among the more important threats, they are among the least known or understood. Commonly overlooked and/or misdiagnosed, nematode damage results in huge losses to crop production, with farmers regularly unaware of nematodes. Nowhere is this neglect more marked than in SSA under resource-limited conditions. To address this issue, it is necessary to increase awareness on the damage that nematodes inflict, towards the implementation of sustainable nematode management options. Farmers will need to be increasingly aware of these threats, and how to deal with them using reliable IPM options, chemical or otherwise, to reduce production losses to nematodes. However, not only are innovative IPM options required but greater capacity in nematology is equally necessary. Creating awareness across the agricultural sector, fostering greater capacity in the discipline and strengthening links between the public and the private sectors (e.g., agro-input industry) will be key to achieving this goal.

WHAT HAVE WE LEARNED AFTER MORE THAN 10 YEARS OF ROOT-KNOT NEMATODE GENOMICS [QUE HEMOS APRENDIDO LUEGO DE 10 AÑOS DE GENOMICA DE NEMATODOS FORMADORES DE AGALLAS]?

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Plant-parasitic nematodes are responsible for the destruction of ca. 11% of the worldwide life-sustaining crop production every year. Plant parasitism has evolved at least four times independently in the phylum Nematoda, and the root-knot nematodes (RKN) are the most devastating of them. Curiously, the RKN that display the wider range of compatible host plants and the broader geographic distribution reproduce without sex and meiosis. This parasitic success without sex has long been considered an evolutionary mystery. In 2008, we coordinated the genome sequencing and analysis of the RKN *Meloidogyne incognita*, using 1st generation sequencing technology (Sanger). This was the first genome for a plant-parasitic animal and the first for a metazoan species reproducing without sex and meiosis. In 2017, we published a more complete genome assembly for *M. incognita* and produced genome sequences for two other devastating asexually reproducing RKN, *M. javanica* and *M. arenaria*, using 2nd generation sequencing technology (illumina + 454). This provided the most comprehensive set of protein-coding genes for a plant-parasitic nematode and enabled comparative genomics analyses. However, because the genome assemblies were still fragmentary and far from chromosome-level resolution, structural genomics analyses and annotation of repetitive elements were still limited. We have recently deployed efforts to re-sequence RKN genomes using 3rd generation ONT long read technology, which already yielded remarkable progress in the contiguity of genome assemblies and opened new perspectives. In this presentation, I will summarize what the 1st, 2nd and 3rd generation genomics analyses have allowed us to learn and understand about the genome structure of parthenogenetic RKN in relation to the evolution of plant parasitism and the surprising parasitic success of RKN despite their lack of sexual reproduction.

THE HIDDEN DIVERSITY IN TRICHODORIDAE: STATE OF THE ART ON THE VIRUS-VECTOR FAMILY [LA DIVERSIDAD OCULTA EN TRICHODORIDAE: ESTADO DEL ARTE EN LA FAMILIA VECTORA DE VIRUS]

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In the 1950s, Trichodoridae were recognized as polyphagous root ectoparasites. Ten years later, their major pest status as vector of Tobravirus became evident and boosted the interest in the family. This interest is reflected in the increase in species descriptions. By the end of the 20th century however, it became clear that the number of virus vector species (11%) is rather limited. This resulted in a decrease of interest for the family and reduction in species descriptions. Up to the end of the last century, species descriptions were based on morphological and morphometric features. Identification of *Trichodorus*, and even more so for *Paratrichodorus* species, is hampered by the general difficulty to fix specimens properly, their largely conserved morphology and restricted number of diagnostic morphological features, overlap of measurements and co-occurrence of at least two species of the same genus in the same soil sample, often with a restricted number of specimens. In the last two decades, molecular analyses mainly based on nuclear ribosomal RNA genes (D2-D3 expansion segments of 28S and partial 18S gene) clearly direct the comparative morphological study while morphology and morphometric help the molecular research to interpret the results when dealing with co-occurrence of several species. This more recent integrated approach leads to the discovery of cryptic species and to interpret formerly described species with wide range in diagnostic characters to represent species complexes. It also provides a better insight into relationships at genus level. This will be illustrated using the Trichodoridae of California as case study.

MANAGING NEMATODES IN HIGH-VALUE CROPS: INCREASING SUSTAINABILITY IN A CHALLENGING

ENVIRONMENT [MANEJO DE NEMATODOS EN CULTIVOS DE ALTO VALOR: AUMENTO DE LA SOSTENIBILIDAD EN UN ENTORNO DIFÍCIL]

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Fruits, vegetables, ornamentals, and other high-value specialty crops are very expensive to grow, with a considerable portion of input costs going towards managing pests and diseases. In Florida, one of the main concerns for fruit and vegetable growers are often plant-parasitic nematodes. Florida's favorable climate and deep sandy soils provide an ideal habitat for nematodes such as root-knot (*Meloidogyne* spp.) and sting nematodes (*Belonolaimus longicaudatus*), both of which can cause considerable damage to a wide range of crops. Since the phase-out of methyl bromide, soilborne pest and disease problems, and nematodes in particular, have increased in many fields. Fumigation is still favored by the majority of Florida growers, because of the broad-spectrum control it provides, and due to the historic lack of non-fumigant nematicide alternatives. However, increasing label restrictions and overall regulatory and societal pressure are putting more strain on the use of soil fumigants. In addition, the recent introduction of new nonfumigant nematicides now provides a more selective and safer alternative to soil fumigants. Whether this will reduce the use of fumigants remains to be seen, as these new nematicides are more selective and lack the broad-spectrum activity of soil fumigants. If growers are to abandon fumigants all together, it will be necessary to integrate the new nematicides with other products and incorporate them into a more integrated nematode and soil management plan. This could include the use of biological nematicides, cover crops, soil amendments, resistant cultivars, and sanitation practices. The emphasis needs to be on understanding the relationship between the production system and nematodes over time and how changes in management practices can reduce crop loss, and benefit farm economics as well as soil health. The development of such integrated nematode

management plans with reduced reliance on soil fumigants will be discussed.

A DNA BARCODING APPROACH TO SOIL NEMATODE COMMUNITY ON MT. SEORAKSAN, SOUTH KOREA [CÓDIGO DE BARRAS DEL ADN PARA EL ESTUDIO DE COMUNIDADES DE NEMATODOS EN EL SUELO EN MT. SEORAKSAN, COREA DEL SUR].

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Nematodes are the most ubiquitous and abundant invertebrates, playing an important role in ecosystems. Since studies on nematode diversity are laborious and inefficient using classical morphological methods, the DNA barcoding approach has been suggested to be an attractive alternative. By sequencing the 18S rRNA gene, we characterized soil nematode communities on Mt. Seoraksan, South Korea, along a ~1,400 m fine-scale-sampling elevational range and a ~1,200 m broad-scale-sampling elevational range. We were interested in discovering how the diversity and community composition of soil nematodes vary along the elevational gradient. Our results indicated that the nematode community on Seoraksan Mountain was dominated by the Prismatolaimidae, followed by an Enoplean family (unclassified), Nygolaimidae, Qudianematidae, Chromadoridae, Mononchidae and 32 other nematode families. Although the diversity of the nematode community at each elevational isochline band was not significantly different, nematode community structure indicated some differentiation according to the different elevational isochline bands. For example, nematodes at low elevations were significantly different from higher isochline bands. Our study also confirmed the effectiveness and reliability of the DNA barcoding approach to investigate nematode communities.

EFFECTOS DEL DESPUNTE SOBRE EL RENDIMIENTO DE GRANO Y POBLACIONES NEMATOLOGICAS EN PALLAR (*Phaseolus lunatus* L.) VARIEDAD GENEROSO DE ICA [Effect of pruning of lima bean (*Phaseolus lunatus* L.) ON YIELD AND

NEMATODE POPULATIONS]

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En el cultivo de pallar de ICA que tiene denominación de origen, en el 2018 se evaluaron el efecto del despunte de los tallos principales sobre el rendimiento de grano y su influencia sobre las poblaciones nematológicas. Los tratamientos experimentados fueron ocho, originados por: tres momentos de despuntes, por dos números de plantas por mata, más dos testigos sin despuntes, con cuatro repeticiones y con un diseño de bloques completos al azar. Las poblaciones nematológicas en suelos se evaluaron a los 10, 60 y 160 dds (días después de la siembra) y en raíces a los 160 dds y se utilizó la técnica del Embudo Baermann Modificado para la separación y cuantificación de nematodos. En suelos se cuantificaron en estas tres evaluaciones nematodos que fueron agrupados en seis grupos con poblaciones en N° /100 cm³ de: 1 - Rh (*Rhabditis* spp.) (Bacteriófagos) de 121 a 197; 2 - Ap (*Aphelenchus* spp.) (Vida libre) de 25 a 158; 3 - Do (*Dorylaimus* spp.) (Omnívoros) de 0 a 41; 4 - Tch (*Tylenchorhynchus* sp.) (Ectoparásito) de 11 a 161; 5 - Pr (*Pratylenchus* sp.) (Endoparásito migratorio) de 0 a 53; y 6 - Ty (*Tylenchus* spp.) (Vida libre) de 0 a 38. En raíces las poblaciones de nematodos en N° /10 g fueron: 1 - Rh de 0 a 11; 2 - Ap de 0 a 2; y 3 - Ty de 0 a 4. Los resultados mostraron diferencias significativas entre los seis grupos de nematodos, entre las tres evaluaciones, y entre los ocho tratamientos, en general las poblaciones nematológicas disminuyeron desde la primera a tercera evaluación, y las mayores poblaciones correspondieron a Rh en los no parásitos, y a Tch en los parásitos de plantas. Los mejores tratamientos para Tch fueron el 1 (Despunte a 65 dds x 2 plantas) y el 4 (Despunte a 95 dds x 3 plantas) y para rendimiento de grano el 2 (Despunte a 65 dds x 3 plantas). Al no haberse detectado nematodos parásitos en raíces y la tendencia de los niveles poblacionales de los nematodos en suelos fue a la disminución se podría considerar al pallar como un cultivo tolerante a los

nematodos parásitos de plantas en Ica, y por lo tanto debería de considerarse dentro de un programa de rotación de cultivos temporales.

RESEÑA HISTÓRICA DE LA DIVERSIDAD NEMATOLÓGICA DESCUBIERTA EN COSTA RICA [HISTORICAL OVERVIEW OF NEMATOLOGICAL DIVERSITY DISCOVERY IN COSTA RICA]

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Costa Rica es reconocida a nivel mundial por su rica biodiversidad. En las últimas dos décadas, se han realizado avances importantes en los inventarios de diferentes grupos de animales y plantas. Los nematodos también han sido objeto de estudio, no obstante, el conocimiento de la diversidad nematológica del país ha avanzado lentamente. La primera especie nueva descrita en Costa Rica fue *Xiphinema costaricense* n. sp. por Lamberti y Tarjan en 1974. Dieciséis años después de este primer descubrimiento, el país apenas registraba 8 especies de nematodos nuevas para la ciencia, siete de las cuáles correspondía a nematodos fitoparásitos. La creación del Instituto Nacional de Biodiversidad (INBio), responsable de desarrollar y ejecutar el inventario nacional de biodiversidad y descubrir usos sostenibles de la riqueza biológica, dio un enorme impulso al conocimiento de la nematofauna costarricense. El inventario actualizado de los nematodos de Costa Rica registra 209 géneros y 219 especies detectadas a la fecha, con 5 géneros y 60 especies nuevas para la ciencia. De las especies nuevas 60% pertenecen al orden Dorylaimida, 15% Tylenchida, 9.0% Rhabditida, 6.7% Araeolamida, 3.4% Mononchida, 3.4% Enoplida y 1.7% Aphelenchida. El conocimiento taxonómico de familias, géneros y especies, son la base para la implementación de estudios ecológicos con nematodos en ambientes tropicales y para la identificación de los principales géneros y especies de nematodos fitoparásitos asociadas a cultivos de importancia agrícola en Costa Rica.

DECIPHERING THE INTIMATE DIALOGUE OF THE ROOT-KNOT

NEMATODE-PLANT INTERACTION [DESCIFRANDO EL DIALOGO ÍNTIMO DE LA INTERACCIÓN PLANTA-NEMATODO NODULADOR].

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Meloidogyne spp., biotrophic sedentary endoparasitic root-knot nematodes (RKN), have many specialized strategies for a successful long-term interaction with their hosts due to the synthesis of effectors protein predominantly secreted by esophageal glands. Previous studies have shown that effectors interfere with and mimic multiple physiological and morphological mechanisms, leading to modifications and reprogramming of host cells functions, thus enslaving the cells to complete their life cycle. Herein, we aimed to reveal novel effectors that might promote parasitism. RNAseq was performed and generated a total of 4,810 differentially expressed genes (DEG) of *M. javanica* second-stage juveniles (J2) exposed to tomato protoplast and 9-HOT oxylipins. Among DEG carrying a predicted secretion signal peptide, several had homology with known effectors in other nematode species, as cell wall degradation and hormone metabolism. In order to localize other unknown potential secreted effectors, a FISH technique was used to detect signals in the RKNs esophageal glands. Those effectors were over-expressed *in planta*. Moreover, since recent findings revealed new functions of lipids as defense signaling molecules, a metabolic profiling of fatty acid derived molecules composition in tomato hairy

roots was conducted resulting in identification of oxylipin products that were specifically altered upon tomato root inoculation with *M. javanica*. LC-MS/MS analysis suggested that different oxylipins were manipulated by the nematode-secreted effectors. This research provides insight into novel nematode effectors underlying the manipulation of the host physiology and defense and a better understanding of oxylipins function in regulating the outcome of the parasitic interaction.

PLANT-PARASITIC NEMATODES ASSOCIATED WITH BLACK PEPPER (*Piper nigrum* L.) IN COSTA RICA [NEMATODOS FITOPARÁSITOS ASOCIADOS A PIMIENTA NEGRA (*Piper nigrum* L.) EN COSTA RICA]

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In Costa Rica, the production of black pepper has acquired great interest due to its high piperine content. Several plant pathogens have been identified associated with black pepper. Unfortunately, information regarding plant-parasitic nematodes associated with this crop in the country is missing. A total of 49 composite samples have been processed until now (26 from soil and 23 from roots). Galls were observed on the roots. The plant-parasitic nematodes identified in roots were *Meloidogyne*, *Aphelenchus*, *Aphelenchoides*, Criconematidae, *Helicotylenchus*, *Hoplolaimus*, *Pratylenchus*, *Rotylenchulus*, *Tylenchus*, and *Tylenchulus*. The same nematodes found on roots plus *Hemicycliophora*, Heteroderinae, *Scutellonema*, Trichodoridae, *Tylenchorhynchus*, and *Xiphinema* were identified in soil surrounding the roots. In roots, the genus with the highest frequency of occurrence was *Meloidogyne* at 78%, followed by *Helicotylenchus* at 43%. Similarly, in soil the same genera had the highest frequency with 88% and 85%, respectively. In roots, *Meloidogyne* had the highest average population density with 11,969 J2/100 g of roots (ranging from 10 to 197,240 nematodes), followed by *Tylenchulus* with

270 nematodes/100 g of roots (ranging from 10 to 790 nematodes). In soil, *Rotylenchulus* presented the highest average population density with 303 nematodes/100 cm³ of soil (ranging from 191 to 415 nematodes), followed by *Helicotylenchus* with 56 nematodes/100 cm³ of soil (ranging from 3 to 196 nematodes). Molecular methods were used to identify the species of *Tylenchulus* and *Meloidogyne* in black pepper. Sequencing results showed 99% similarity with the citrus nematode, *T. semipenetrans*. Six populations of *Meloidogyne* were processed using PCR-RFLP. Restriction patterns corresponded to *M. incognita*. Subsequently, identification was corroborated with species-specific primers. To our knowledge, this is the first report of plant-parasitic nematodes associated with black pepper in Costa Rica.

MORPHOLOGICAL AND PHYSIOLOGICAL STATUS OF SOYBEAN CULTIVARS PARASITIZED BY *Pratylenchus brachyurus* AND INOCULATED WITH *Pseudomonas fluorescens* BRM 32111 [ESTADO MORFOLÓGICO Y FISIOLÓGICO DE CULTIVARES DE SOJA PARASITIZADOS POR *Pratylenchus brachyurus* E INOCULADOS CON *Pseudomonas fluorescens* BRM 32111]

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Pratylenchus brachyurus (lesion nematode) is an important soybean root pathogen in Brazil. Studies have shown that inducing plant defenses and stimulating physiological processes with growth-promoting rhizobacteria can be a viable tactic for managing plant-parasitic nematodes. The objective of this study was to evaluate the physiological response and the development of two soybean cultivars (BRSGO Caiapônia and BRSGO 8560 RR) subjected to *P. brachyurus* parasitism and inoculated with *Pseudomonas fluorescens* BRM 32111 (Pf). The experimental design was a completely randomized 2 x 4 factorial with treatments consisting of the combination of two

soybean cultivars as follows: Control (plants without nematode and bacteria), Pb (plants with nematode), Pf (plants with bacteria) and PbPf (plants with nematode and bacteria). The treatments with Pf were inoculated 24 hr after the nematode inoculation. Plants were evaluated weekly over a period of 63 days after inoculation. Decay of the photosynthetic rate, internal carbon and evapotranspiration in the plants were observed during their development. The soybean genotype BRSGO Caiapônia showed the highest indices of chlorophyll content, height, fresh shoot weight, and fresh root weight (RFW). The bacteria *P. fluorescens* stimulated plant growth, however, in PbPf treatment, plant height and RFW were lower. The reproduction factor and nematode density in roots were higher in plants inoculated with *P. fluorescens* than in those not inoculated with the bacteria.

IDENTIFICACIÓN TAXONÓMICA Y MOLECULAR DE ESPECIES DEL NEMATODO LESIONADOR DE LA RAÍZ *Pratylenchus* (NEMATODA: PRATYLENCHIDAE) ASOCIADO A CUATRO CULTIVOS DE COSTA RICA [TAXONOMIC AND MOLECULAR IDENTIFICATION OF SPECIES OF THE ROOT LESION NEMATODE *Pratylenchus* (NEMATODA: PRATYLENCHIDAE) ASSOCIATED WITH FOUR COSTA RICAN CROPS]

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El nematodo lesionado de la raíz *Pratylenchus*, es considerado el segundo de mayor de importancia económica a nivel nacional. El objetivo de este estudio fue identificar especies de *Pratylenchus* asociadas a un cultivo de arroz en Puntarenas; plátano en Talamanca, piña en Limón y Alajuela y finalmente pasto estrella en Alajuela. Se realizaron estudios taxonómicos (morfológico, morfométrico) y moleculares. Se llevaron a cabo un total de 3500 mediciones morfométricas, que facilitaron la elaboración de un análisis estadístico descriptivo. Además, un total de 2000 microfotografías de hembras y machos que

permitieron discriminar entre las especies de *Pratylenchus*. Los análisis PCR-RFLP del ITS1 indicaron que la especie asociada al cultivo del plátano fue *P. coffeae* con un peso molecular de 700 pb; en arroz y pasto estrella fue *P. zaeae* con 500 pb; en piña *P. brachyurus* con 500 pb. El análisis de RFLP con la enzima *Ded I* reveló para *P. coffeae* fragmentos de 100 y 250 pb; para *P. zaeae* 200 y 250 pb y para *P. brachyurus* 450 pb. Las enzimas de restricción *Pst I* y *Hind III*, no permitieron la discriminación entre las tres especies de nematodos. Además, se amplificaron los segmentos de expansión D2-D3 del 28S ADNr, usando los cebadores D2A y D3B, y se amplificó la región ITS1 utilizando los cebadores 18S y rDNA1. La secuenciación generó resultados similares a la identificación morfológica, morfométrica y de PCR-RFLP para las tres especies analizadas. Además, se establecieron relaciones filogenéticas entre especies de *Pratylenchus* a partir de segmentos de expansión D2-D3 de la región 28S del ARNr y genes de secuenciación de la región ITS del ARNr, utilizando los métodos de Inferencia Bayesiana (IB). De las tres especies de *Pratylenchus* identificadas, *P. zaeae* encontrada en pasto estrella, es el primer reporte para Costa Rica, no así las demás especies de las cuales se tienen reportes. La detección de especies de nematodos en plantaciones agrícolas permite el establecimiento e implementación de una estrategia de manejo para la toma de decisiones que minimice los daños ocasionados y evite la propagación de estos microorganismos.

DETERMINATION *IN VITRO* OF THE BIOLOGICAL EFFECTIVENESS OF DIFFERENT NEMATOPHAGOUS MICROORGANISMS ON *Pratylenchus brachyurus* IN PINEAPPLE CROP [DETERMINACIÓN *IN VITRO* DE LA EFECTIVIDAD BIOLÓGICA DE DIFERENTES MICROORGANISMOS NEMATOFAGOS SOBRE *Pratylenchus brachyurus* EN EL CULTIVO DE LA PIÑA]

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In Costa Rica, pineapple cultivation is affected by phytonematodes, mainly *Pratylenchus brachyurus*. Therefore, the percentage mortality exerted *in vitro* by *Bacillus subtilis*, *Clonostachys rosea*, *Pochonia chlamydosporia*, *Purpureocillium lilacinum*, and two isolates of *Trichoderma* on *P. brachyurus* was evaluated at 72 and 96 hr after inoculation. Controls included the insecticide-nematicide ethoprophos and sterile distilled water (an absolute control). In petri dishes containing water agar medium, each microorganism was inoculated at a concentration between 1.8×10^5 conidia/ml and 6.4×10^6 CFU/ml, and 20 phytonematodes per dish. A completely randomized design was used, consisting of eight treatments and eight repetitions. Data were analyzed using Mixed and General Linear Models (MLMix) and the Bonferroni media comparison tests (0.05%). Treatment statistical differences were determined using the statistical package InfoStat/P ($P < 0.0001$). Results showed that at 96 hours, *C. rosea* treatment was statistically the same as ethoprophos causing mortality of 96.25% and 96.88%, respectively. Overall, the microorganisms tested exerted the greatest mortality on *P. brachyurus* at 96 hr. The percentage mortality exerted by the nematophagous microorganisms could be due to the capacity they have to produce proteolytic and chitinolytic enzymes that may cause immobility, degradation, and eventual death of the nematode.

MORPHOLOGICAL AND MORPHOMETRIC IDENTIFICATION OF THE MAIN PHYTONEMATODES ASSOCIATED WITH PINEAPPLE IN THE NORTHERN REGION OF COSTA RICA [IDENTIFICACIÓN MORFOLÓGICA Y MORFOMÉTRICA DE LOS PRINCIPALES FITONEMATODOS ASOCIADOS AL CULTIVO DE LA PIÑA EN LA ZONA NORTE DE COSTA RICA].

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The objective of this research was to identify the main phytonematodes present in farms dedicated to pineapple production. Six farms located in the North Zone of Costa Rica were selected. Three plots per farm, with plants between 6 and 8 months

of age, were chosen for sampling. Samples included five plants with roots and soil per plot. The extraction of the nematodes was carried out using the centrifugation-flotation technique. The average density and absolute frequency of the phytonematode genera were quantified and, specimens were fixed in anhydrous glycerin by the Seinhorst method for morphometric identification. The genera *Meloidogyne*, *Aphelenchus*, *Pratylenchus*, *Helicotylenchus*, and *Mesocriconema* were morphologically identified. The genus with the highest absolute frequency and average density in root samples was *Pratylenchus*, while for soil samples it was *Helicotylenchus*. The species identified were: *Pratylenchus brachyurus*, *Pratylenchus neglectus*, *Mesocriconema ornatum* and *Mesocriconema onoense*. Species belonging to the genus *Helicotylenchus* could not be identified since morphometrical results overlapped for species. Precise species identification will require molecular studies.

MONITORING AND TACKLING GENETIC SELECTION IN THE POTATO CYST NEMATODE *Globodera pallida* [MONITOREO Y ABORDAJE DE LA SELECCIÓN GENÉTICA EN EL NEMATODO DEL QUISTE DE LA PAPA *Globodera pallida*]

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Management of plant pathogens is probably the most serious challenge in sustainable food production and the maintenance of food security. Due to the strict regulation of or ban on major categories of pesticides, the potato cyst nematode, *Globodera pallida*, has been managed by a combination of crop rotation and the potato resistance locus *Grp1*, a relatively narrow range

resistance gene that was introgressed into commercial potato cultivars in Europe. However, in 2014, populations of *G. pallida* were described from Emsland (Germany) that can no longer be controlled by *Grp1*. Most likely similar highly virulent populations will also emerge in all major potato growing areas in North Western Europe where production practices are very similar. Except for laborious, costly and often moderately accurate pot experiments, there is currently no rapid and reliable method to identify virulent populations. This represents a strong limitation and prevents the accurate and durable management of infestations. The PALADAPT project funded by EFSA represents the first step of a European battle plan against the emergence of virulent populations of *G. pallida* and aims at improving the methods and tools for the fast identification of virulence outbreaks. In this talk, we will present results obtained on life history traits of these nematodes and answer the question whether resistance breaking populations present a fitness cost. We will also present data on recently identified DNA polymorphisms that can be useful to design molecular tools for accurate virulence monitoring.

CONTROL DE *Anomala* spp. EN EL CULTIVO DE ARÁNDANO (*Vaccinium corymbosum*) UTILIZANDO *Heterorhabditis* sp. (NEP) [CONTROL OF *Anomala* sp. ON BLUEBERRIES (*Vaccinium corymbosum*) USING *Heterorhabditis* sp. (EPN)]

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En el Perú, la producción de arándanos ha crecido vertiginosamente, a una tasa promedio de 206% anual entre el 2012 al 2018. Una de las regiones con más auge es La Libertad con un crecimiento de 78.4% y un promedio de 16.8 toneladas/hectárea. Algunos de los factores que ocasionan pérdidas en la producción de este cultivo es la larva del escarábido *Anomala* spp., que se alimenta de las raíces de la planta. En ocasiones, se ha reportado poblaciones entre 70 a 140 larvas por planta; para su control se utiliza gran cantidad de insecticidas y en muchos casos no se logran disminuir los daños, siendo este tipo de control ineficiente. Los nematodos entomopatógenos (NEP), debido a su

amplio rango de acción, y gran capacidad de búsqueda han demostrado ser una alternativa en el manejo de plagas insectiles que pasan gran parte de su ciclo de vida en el suelo. En ese contexto, el objetivo de esta investigación fue evaluar el efecto de la aplicación de *Heterorhabditis* sp. sobre el control de *Anomala* sp. frente a la utilización de agroquímicos. Los tratamientos fueron Chlorpyrifos (2.5%), Fipronil (0.4%) y *Heterorhabditis* a razón de 3 millares/hectárea. La aplicación se realizó por inyección vía válvula de riego con un tanque de aplicación a un volumen de 200 L agua y una lámina de riego de 1.02 mm, todo el proceso de inyección duró 20 minutos. Para una población inicial de 70 larvas de *Anomala* spp. por planta se logró disminuir con los NEP un 64%, mientras que con Chlorpyrifos y Fipronil se disminuyó en un 10%.

EFFECT OF NEMATICIDE ROTATION IN DIFFERENT APPLICATIONS PER YEAR IN THE CONTROL OF NEMATODES ON BANANA (*MUSA* AAA CV. WILLIAMS) ROOTS AND CROP YIELD [EFECTO DE LA ROTACIÓN DE NEMATICIDA EN DIFERENTES APLICACIONES POR AÑO EN EL COMBATE DE NEMATODOS EN LAS RAÍCES DE BANANO (*MUSA* AAA CV. WILLIAMS) Y SU RENDIMIENTO]

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In a randomized complete block design with six treatments and six replicates, nematicide rotations with different applications per year were evaluated. Treatment one and two consisted of two different nematicide rotated per year. Treatments three and four consisted of three different nematicide applications per year. In treatment five, nematicide application was based on the nematode economic threshold, and treatment six was an untreated control. Root samples from three follower suckers in each repetition were collected before treatment application and then every 30 days for 24 months when the experiment ended. Three harvests were

made to determine effects on yield. Averaging the 24 root nematode samplings, the nematicide applications reduced the presence of *R. similis* from 20 to 49% ($P<0.01$), *Helicotylenchus* spp. from 31 to 51% ($P<0.01$), and total nematode populations from 29 to 49% ($P<0.01$). Accordingly, in the treated plants there was an increase of 16 to 21% in functional live root weight ($P<0.001$), from 74.5 to 81.7% in the follower suckers ($P<0.01$), and dead roots decreased by 20 to 46% ($P<0.01$). At harvest, nematicide applications increased bunch weight ($P<0.01$; $P<0.05$), ratio ($P<0.01$ at 12 months), ratooning ($P<0.01$; $P<0.01$) and the number of boxes per hectare per year ($P<0.01$; $P<0.01$) at 12 and 24 months after treatment application, respectively. Plants treated with nematicides increased box number per hectare per year from 671 to 1,158 (12.2 to 21.0 tm) and from 545 to 1,046 (9.9 to 19.0 tm), which resulted in a net profit of \$3,266 to \$5,750 and \$2,587 to \$5,144/ha/year at 12 and 24 months after treatment application, respectively.

ACTIVIDAD NEMATICIDA DE FLUAZAINDOLIZINA (SALIBRO™) EN VID CV. CHARDONNAY DE 24 AÑOS AFECTADAS POR *Meloidogyne ethiopica* EN EL VALLE DE CASABLANCA, CHILE, TEMPORADAS 2016-2017 Y 2017-2018. [NEMATICIDAL ACTIVITY OF FLUAZAINDOLIZINE (SALIBRO™) IN 24-YEAR-OLD GRAPEVINE CV. CHARDONNAY AFFECTED BY *Meloidogyne ethiopica* IN THE CASABLANCA VALLEY, CHILE, SEASONS 2016-2017 AND 2017-2018]

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Meloidogyne ethiopica, debido a su agresividad es el nemátodo más importante en la vitivinicultura chilena y el cv. Chardonnay la variedad que más se afecta por este nematodo. Se evaluó la eficacia

nematicida de fluazaindolizina (Salibro™), a dosis de 2, 3, 4, 5 y 2+2 litros/ha, su efecto sobre raíces, rendimiento, y aspectos vegetativos en plantas de vid cv. Chardonnay. Todas las dosis de Salibro™ mantuvieron las poblaciones de *Meloidogyne ethiopica* deprimidas durante el estudio. El mejor tratamiento de Salibro™ sobre los nematodos fitoparásitos fue con la dosis alta (4 y 5 L/ha) y cuando se aplicó dos veces con 32 días de diferencia. En la segunda temporada Salibro disminuyó las poblaciones de *M. ethiopica* a menos de 100 J2/250 mL de suelo. Los tratamientos de Salibro también mantuvieron bajas las densidades de *Mesocriconema xenoplax*, *Paratylenchus* sp. y *Xiphinema americanum*. La calidad de las raíces mejoró en proporción al incremento de dosis de Salibro. En la segunda temporada los tratamientos de Salibro incrementaron los beneficios en aspectos vegetativos. En la primera temporada (2016-2017) no hubo diferencias en fruta, pero en la segunda temporada (2017-2018), los tratamientos de Salibro, presentaron mejor rendimiento que el testigo no tratado y el testigo químico, lo que se correlacionó con mejora de raíces. El producto Salibro no presentó síntomas de fitotoxicidad. El producto Salibro demostró excelentes cualidades como protector de las raíces y como nematicida sobre los nemátodos fitoparásitos más importantes en la agricultura de Chile.

ACTIVIDAD NEMATICIDA DE FLUAZAINDOLIZINA (SALIBRO™) EN PLANTAS JÓVENES DE VID CV. SAUVIGNON BLANC PARASITADAS POR *Xiphinema americanum* Y *Meloidogyne ethiopica* EN CASABLANCA, CHILE, TEMPORADAS 2016-2017 Y 2017-2018. [NEMATICIDAL ACTIVITY OF FLUAZAINDOLIZINE (SALIBRO™) IN YOUNG CV. SAUVIGNON BLANC PARASITIZED BY *Xiphinema americanum* AND *Meloidogyne ethiopica* IN CASABLANCA, CHILE, SEASONS 2016-2017 AND 2017-2018]

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Se evaluó la actividad nematocida de fluazaindolizina (Salibro™), aplicado a dosis de 2, 3, 4, 5 y 2+2 litros/ha y los efectos sobre las raíces, el rendimiento y aspectos vegetativos de las plantas de vid cv. Sauvignon Blanc por dos temporadas. Luego de finalizadas las dos temporadas de estudio se ratificaron los buenos resultados del Salibro como nematocida. El producto demostró ser capaz de proteger las raíces, en presencia de una alta diversidad de nemátodos fitoparásitos, entre ellos, endoparásitos como *Meloidogyne ethiopica*, *Pratylenchus* y ectoparásitos como *Mesocriconema xenoplax*, *Paratylenchus*, y *Xiphinema americanum*, que representan a los nemátodos más importantes de la vitivinicultura de Chile. Salibro puede ser una excelente herramienta de trabajo que permitirá a los productores agrícolas proteger las raíces de sus cultivos de los ataques de nemátodos fitoparásitos, si se utiliza de la manera adecuada, de dosis y concentración de ingrediente activo en solución, en los estanques de aplicación o en los sistemas de riego tecnificado. Esto se puede lograr capacitando técnicos que guíen a los productores agrícolas y decidan hacer uso del producto, en fechas adecuadas para uso, concentraciones a las que el producto debe ser aplicado desde los sistemas de riego tecnificado y condición de humedad del suelo de acuerdo a su tipo que mejora la eficacia del producto. La mejora en la calidad de las raíces evaluada en cada fecha de muestreo, se tradujo en incremento del material vegetativo expresado como peso de poda, y en la fruta cosechada de la segunda temporada.

SALIBRO™ NEMATOCIDE (REKLEMEL™ ACTIVE): CONTRIBUTION TOWARDS THE MANAGEMENT OF ROOT-KNOT NEMATODES IN TOMATO, CHILI, AND CUCUMBER PRODUCTION IN MEXICO [NEMATOCIDA SALIBRO™ (REKLEMEL™ ACTIVO): CONTRIBUCIÓN HACIA EL MANEJO DE LOS NEMATODOS AGALLADORES EN LA PRODUCCIÓN DE TOMATE, CHILI, Y PEPINO EN MÉXICO]

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According to the Food, Agriculture and Fishing Information Service SIAP in Mexico, this country is the largest exporter of tomato, second largest exporter of chili, and third largest exporter of cucumber in the world. Production of these crops is highly threatened by the damage caused by plant-parasitic nematodes, with the root-knot nematode (RKN) *Meloidogyne* spp. being the most important in terms of economic losses. Market research in 2017 in the main vegetable producing regions in Mexico concluded that more than 75% of vegetable growers are highly dependent on nematicides and need several applications of chemical and biological products to deal with this pest. Corteva Agriscience, the Agriculture Division of DowDuPont, has discovered and developed the novel sulfonamide nematicide ReKlemel™ active (fluazaindolizine, ISO name), offering a new solution for the management of plant-parasitic nematodes. ReKlemel, besides controlling plant-parasitic nematodes, has a favorable toxicological and ecotoxicological profile and is very gentle on many other beneficial organisms or bioagents occurring in or applied to the soil, and therefore can be an important tool for nematode management in Mexican export crops. ReKlemel, formulated as Salibro 500 SC nematicide, has been broadly tested for the control of RKN in tomato, chili, and cucumber crops in both protected and open field conditions, and with a variety of application timings in Mexico. This paper will summarize trends in nematode management in Mexico and highlight trial results with Salibro in key export crops, as a new tool to improve crop establishment and part of a foundation for integrated nematode management programs.

BIODIVERSITY OF FREE-LIVING

NEMATODES IN MEXICO [BIODIVERSIDAD DE NEMATÓDOS DE VIDA LIBRE EN MÉXICO]

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Free-living soil nematode diversity has scarcely been explored in Mexico. Only two studies related to nematode communities in Mexican soils have been published. After thorough research, it was found that there is one work that dates back to the 1980s and contains unpublished data on the presence of 50 genera of soil and plant-parasitic nematodes associated with roots of an extensive variety of crops from the Western region of the State of Michoacán. The second work, recently published, records data and diversity analyses of nematodes associated with both disturbed and undisturbed rainforest in Los Tuxtlas Rainforest, Veracruz that includes 124 genera belonging to 53 families. A third work from Central Mexico includes 41 genera, belonging to 29 species and 22 families. The present work includes new data from two additional regions in Central Mexico. The first region, a former pine-oak forest severely disturbed by goat grazing activities and now a recreation park that sits in the bottom of an extinct ancient volcanic cone in Joya-La Barreta Park in Querétaro, and a second region from the southernmost North American desert that sits in the Biosphere Reserve of Valle de Tehuacán-Cuicatlán in Puebla. Approximately 65 genera and up to 70 genera have been found in these two regions, respectively. Dominant genera seem to vary according to vegetation types or managed agricultural sites during distinct seasons of the year.

REPRODUCTION OF *Meloidogyne graminis* ON SOME COMMON FORAGE GRASSES IN FLORIDA [REPRODUCCIÓN DE *Meloidogyne graminis* EN ALGUNOS FORAJES EN FLORIDA]

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The objective of this study was to determine the host suitability of limpograss (*Hemarthria*

altissima), bahiagrass (*Paspalum notatum*), and bermudagrass (*Cynodon* spp.) to *Meloidogyne graminis*. The experiment was carried out under greenhouse conditions in a completely randomized design with five replications. Nematode-free cuttings of limpograss ('Floralta' and 'Kenhy'), bahiagrass ('Argentine' and 'Pensacola'), and bermudagrass ('Tifton-85', and PI 322) were planted in 15-cm-diam. clay pots containing 1,400 cm³ of sand. Rice (*Oryza sativa*) 'Carolina Gold' and 'Rex' were used as check controls. The plants were inoculated with 3,000 second-stage juveniles (J2) per pot. After 98 days, the plant roots were assessed for egg masses using a 0 to 5 scale and J2 per gram of root. The fresh weight of the root system of each plant was recorded. The egg mass indices were 5 on both rice cultivars, on 'Pensacola,' and on PI 322, 3 on 'Argentine', 2 on 'Kenhy', 1 on 'Floralta', and 0 on 'Tifton-85'. The highest number of J2 per gram of root was collected from 'Carolina Gold' (1,124/g) and 'Pensacola' (2,166/g), and the lowest numbers were recovered from 'Tifton-85' (< 1/g), 'Floralta' (5/g) and 'Kenhy' (86/g). The reproduction factor (RF = Pf/Pi) was 0 or < 1 for 'Tifton-85' (0.0), 'Floralta' (0.04), and 'Kenhy' (0.7). *Meloidogyne graminis* reproduced very well on both rice cultivars, 'Carolina Gold' (RF = 17.4), 'Rex' (RF = 7.7), and on 'Pensacola' (RF = 6.0). PI 322 (RF = 3.5) and 'Argentine' (RF = 2.7) also were good hosts of *M. graminis*.

GENOMICS OF THE SOYBEAN CYST NEMATODE, SHAPING FUTURE SOLUTIONS [GENÓMICA DEL NEMATODO DEL QUISTE DE LA SOYA, FORMANDO SOLUCIONES FUTURAS]

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Soybean is the fourth most cultivated crop on earth and production has had a spectacular growth in some regions. For example, soybean acreage has increased 2.5-fold in the last 10 years in Canada. However, soybean cyst nematode (SCN),

Heterodera glycines, threatens soybean production worldwide and is the most damaging pest of soybean in North America where it causes over \$1.5 billion of losses each year. The main approach to tackle SCN is the use of resistant cultivars. However, a very limited number of lines are adapted to northern conditions and the overuse of a single resistance source has led to the selection of virulent SCN populations. Using the latest genomic tools and modeling approaches, we have identified key elements to consider in developing novel management strategies. SCN populations were found to be very diverse, facilitating their adaptation to various bioclimatic conditions and establishment in new soybean-producing areas. Gene flow was persistent across North America, contributing to large scale dissemination of virulence alleles. The genome sequence of SCN has revealed highly duplicated regions that could be implicated in the diversification of parasitism genes. Exploring gene expression using single-nematode RNA-sequencing suggested that different alleles are expressed in virulent/avirulent individuals and could potentially be used as diagnostic markers for virulence. Combined with the identification of promising resistance sources, this information will allow for the development of an integrated strategy to reduce losses associated with SCN and to extend the lifetime of current resistant cultivars.

EFFECT OF NEW NON-FUMIGANT NEMATICIDES ON DIFFERENT TROPHIC GROUPS OF NEMATODES [EFECTO DE NUEVOS NEMATICIDAS NO FUMIGANTES EN DIFERENTES GRUPOS TRÓFICOS DE NEMATODOS]

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Plant-parasitic nematodes cause more than \$100 billion per year in damage to crops (>14% global crop production). Non-parasitic, free-living nematodes that coexist with plant-parasitic nematodes in soil are critical components of the soil food web and play important roles in nutrient cycling and making inorganic chemicals available to plants. Management of plant-parasitic

nematodes has traditionally relied on the use of broad-spectrum soil fumigants, and organophosphate and carbamate insecticides. Recently, new selective contact nematicides have emerged that offer alternatives to these restricted-use pesticides. The effect on mortality of varying concentrations of three new nematicides and the carbamate nematicide Vydate® L on different trophic groups of nematodes (bacterivore, fungivore, entomopathogenic and plant-parasitic) was tested *in vitro*. Using 48-well tissue culture plates, nematodes were exposed to varying concentrations of the products and evaluated at five different time points (24, 48, 72, 96, and 168 hours). Living and dead nematodes were determined by adding 1 N NaOH to each well and counting the nematodes that were able to react (alive) and the nematodes that were not able to respond (dead) to NaOH. Results indicated that all nematicides affected the plant-parasitic nematode *Meloidogyne javanica* more than the free-living nematodes (*Cephalobus* sp., *Aphelenchus* sp. and *Steinernema* sp.). At low concentrations (1–1.25 ppm, representative of soil-water concentration following field applications) the overall effect of Velum® on all nematode taxa was greater than that of Nimitz® and Salibro™. Nematodes that responded to 1 N NaOH were often sluggish and lethargic. Although these nematodes were technically not dead, their infectivity was likely affected. This effect will be investigated in follow-up studies. In addition, we will continue to evaluate other nematode species/taxa.

ORCHID MYCORRHIZAL FUNGI FOR CONTROLLING *Heterodera glycines* *in vitro* [HONGO MICORRÍZICO ORQUIDOIDE EN EL CONTROL DE *Heterodera glycines* *in vitro*]

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Heterodera glycines is one of the major problems in soybean crop worldwide. Crop rotation and resistant varieties have been the main measures to reduce populations of *H. glycines*, but these measures have not been sufficient. The search for new alternatives for sustainable management, such

as biological control, may be of great value to be included as a control measure. Thus, this study evaluated the potential of the Orchid Mycorrhizal Fungi (OMF) *Waitea circinata* for controlling *H. glycines* *in vitro*. Two experiments were carried out in order to evaluate the effect of different concentrations of mycelial suspensions of *W. circinata* on *H. glycines* second-stage juvenile (J2) mortality and egg hatch. The experiment design was a completely randomized factorial scheme (6 x 3) with 10 replications. Factor A was OMF mycelial suspension concentrations (0, 5, 10, 15, 20, or 25 g/L) and Factor B was timings (24, 48, and 168 hr of incubation). Higher concentrations of the fungus provided more efficient nematode control and better results were found at early evaluations. *H. glycines* J2 mortality was higher at 24 hr after OMF application, reaching 31%, compared to 13% and 10% at 48 and 168 hrs, respectively. *H. glycines* J2 mortality increased over 100% with the use of OMF mycelial suspension. At 24 and 48 hrs of incubation, hatching was very low (5.4% and 7.3%, respectively). At 168 hrs of incubation, hatching was 36.2% and was reduced at concentrations of 15 and 20 g OMF mycelial suspension/L.

FLUCTUACION POBLACIONAL DE NEMATODOS ASOCIADOS CON *Physalis peruviana* L. EN COLOMBIA [POPULATION FLUCTUATION OF NEMATODES ASSOCIATED WITH *Physalis peruviana* L. IN COLOMBIA]

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Los fitonematodos, solos o en interacción con *Fusarium oxysporum* f. sp. *physali* constituyen un limitante al cultivo de la uchuva (*Physalis peruviana* L.) en Colombia, frutal de importancia económica para mercado de exportación y local. En estudios previos se realizó análisis nematológico y pruebas de parasitismo a muestras provenientes de las principales zonas productoras de uchuva. Con el material recolectado se estableció una colección *in vivo* constituida por 50 poblaciones y se realizó el estudio de fluctuación poblacional durante seis ciclos cada uno de 4-5 meses, excepto el último, de 12 meses. En macetas conteniendo suelo de las 50

fincas con su respectiva población de fitonematodos (Pi-1), se sembraron plántulas de uchuva de 1.5 meses de edad procedentes de semilleros esterilizados. Las plantas se fertilizaron al momento del trasplante y 30 días después, además se les suministró riego diario. Pasados 4-5 meses se estimaron las poblaciones de fitonematodos (Pf-1) y el factor de reproducción (Rf-1), y en el mismo suelo se renovaron las plántulas, durante seis ciclos. Ocho taxones se presentaron en la Pi-1, en orden de abundancia: *Helicotylenchus*, *Meloidogyne*, *Pratylenchus*, *Hemicycliophora*, *Trichodoridus*, *Xiphinema*, *Criconematidos*, y *Heterodera*. En el primer ciclo (prueba de parasitismo) se reprodujeron todos los taxones excepto *Heterodera* y *Criconematidos*. En todos los ciclos, *Helicotylenchus* y *Meloidogyne* fueron los géneros predominantes, con abundancia estable; las poblaciones de *Pratylenchus* y *Hemicycliophora* disminuyeron paulatinamente. En el ciclo de 12 meses, la población de *Xiphinema* se incrementó considerablemente en suelo de dos localidades; sin embargo, *Hemicycliophora* no se presentó.

NEMATODES ARE BIOINDICATORS OF SOIL FUNCTION [LOS NEMATODOS SON BIOINDICADORES DE LA FUNCIÓN DEL SUELO]

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The Nematode Maturity Index is a promising indicator for measuring soil disturbance in cropland soils. Ground-breaking research in the 1990s empirically verified the statistical reliability of index variations, sample sizes, appropriate references, and calibration by ecosystem and land use type. Nematode community structure and function respond to land management practices such as nutrient enrichment through fertilization by organic or inorganic nitrogen, cultivation, liming, drainage, plant community composition and age, and toxic substances such as heavy metals, pesticides, and petroleum products. With the renewed interest in soil health and expanding databases of amplicon sequences, it is time to complete the research to identify and verify sentinel taxa that predictably respond to specific disturbance types so molecular-based tool kits can be developed for non-specialists.

**NEMATODES: TAIL OF ECOSYSTEM
FUNCTION [NEMATODOS: COLA DE LA
FUNCIÓN DEL ECOSISTEMA]**

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Nematodes are an example of functional and anatomic economy. A hallmark of the phylum is its exceptional diversity and ubiquity on the globe. A key to nematode success is their ability to survive extreme temperature and moisture regimes. When environmental conditions are favorable, nematode species that feed on decomposer microbes contribute up to 19% in nitrogen mineralization. Composition of nematode communities reflects disturbance to soil by land management practices making nematodes reliable indicators. Formerly, a science focused on control of parasitic and harmful species, soil nematodes can be a tool for testing ecological hypotheses and understanding biological mechanisms in soil.

**PROGRESS AND PRIORITIES FOR
NEMATODES AS INDICATORS
[PROGRESO Y PRIORIDADES PARA LOS
NEMATODOS COMO INDICADORES]**

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Nematode communities were proposed as biological indicators of soil health about 40 years ago. Research in the 1990s empirically verified that 1) indices of successional maturity and food web structure have the greatest statistical reliability and correlate with ecosystem function, 2) long-term perennial crop and untilled soils serve as undisturbed references for agricultural lands, and 3) calibrations need not be coarser than major land resource area and ecosystem type. Advances in sequencing of marker genes for free-living nematodes helps make identification more accessible to a non-specialist. However, calibration and interpretation lag behind, impeding implementation at large regional scales. Meta analysis of existing community data provide candidate taxa to verify for sentinel status and calibration. Interpretation will require empirical validation of index weights (e.g., colonizer persister values) by natural history studies and/or

independent biomarker assessments. This knowledge will create a data-driven decision tool that simplifies indices to contain only taxa that consistently detect particular types and magnitudes of disturbances.

**ASSESSING NEMATODE AND DISEASE
INCIDENCE, SEVERITY, AND CROP
IMPACTS IN FLORIDA STRAWBERRY
USING HIGH RESOLUTION AERIAL
IMAGING [EVALUACIÓN DE LA
INCIDENCIA DE NEMATODOS Y
ENFERMEDADES, SEVERIDAD, E
IMPACTO EN FRESA EN FLORIDA CON EL
USO DE IMÁGENES AÉREAS DE ALTA
RESOLUCIÓN]**

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In Florida, nematodes and soilborne diseases such as *Colletotrichum*, *Phytophthora*, and *Macrophomina*, and the sting nematode, *Belonolaimus longicaudatus*, are very important yield-limiting pests of strawberry. For these studies, digital color imaging and in-field assessments of plant size were used to characterize the distribution and degrees of plant stunting, strawberry yield, and within row measures of green plant canopy cover associated with the sting nematode. Disease incidence, severity, and crop impacts were assessed from a ground survey and analysis of aerial imagery. Aerial imaging surveys of over 20 commercial field locations were seasonally conducted from November 2017 to March 2018 and November 2018 to March 2019 using a DJI™ Phantom 4 Pro UAS drone equipped with a DJI 24mm 20MP camera with an Exmor R CMOS sensor. Image orthomosaics were created using DroneDeploy™ cloud software platform with an image resolution of 10 to 20 mm per pixel. Processed RGB and NDVI maps were oftentimes both visually evaluated and impacted plants enumerated and or analyzed using ESRI™ ArcGIS v10.33. Strawberry canopy cover, relative yields, and enumerations of disease incidence and plant stunting were derived from inspection of drone

images and then compared using regression analysis with ground-truth field surveys. It will be demonstrated that these new aerial imaging techniques and greenness analysis have great potential to facilitate and increase accuracy and precision in quantifying nematode and plant disease incidence, plant growth response, performance of fumigant and nonfumigant pest management practices, and of long term impacts within the strawberry cropping system.

CHARACTERIZATION OF *Heterodera* spp. FROM THE CENTRAL VALLEY OF COSTA RICA [CARACTERIZACIÓN DE *Heterodera* spp. EN COSTA RICA]

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In Costa Rica, information related to morphology, inter- and intra-specific variability, biology, and distribution of cyst nematodes is lacking (excepting for *Globodera pallida*). Two populations of *Heterodera* were found in the Central Valley of Costa Rica, one extracted from *Trifolium repens* (currently under study) and the other from *Rumex* sp. All cysts from soil were a lemon shaped and dark brown in color. The morphological characterization is being described and compared with other cyst nematodes. Two molecular markers were sequenced, the nuclear region *ITS1-5.8S-ITS2* and the mitochondrial gene *cox 1*, and compared with sequences retrieved from GenBank. Divergence levels vary between 0.1% (1 nt) and 1.4% (10 nt), compared with *H. schachtii*, 0.1% (1 nt) and 1.0% (7 nt) compared with *H. trifolii*, and 0.3% (2 nt) and 0.4% (3 nt) compared with *H. daverti*. The Bayesian phylogenetic analysis based on the *ITS* region grouped the *Heterodera* sp. from *Rumex* sp. within the *schachtii* group with a high support value (PP = 100). The partial *cox1* gene provided more resolution than the *ITS* region, with divergence levels of 2.1% (8 nt), 3.3- 3.6% (13-14 nt) and 8.7% (34 nt) compared with *H. daverti*, *H. trifolii*, and *H. schachtii*, respectively. The phylogenetic analysis based on the partial *cox 1* gene resulted in a clade composed with the *Heterodera* sp. sequence from *Rumex* and sequences of *H. daverti* (PP = 93). However, a

subclade was formed only with *H. daverti* sequences (PP = 98), which may indicate the presence of cryptic species.

MORPHOLOGICAL AND MOLECULAR IDENTIFICATION OF TWO FLORIDA POPULATIONS OF FOLIAR NEMATODES (*Aphelenchoides* spp.) ISOLATED FROM STRAWBERRY WITH NOTES ON THEIR BIONOMICS [IDENTIFICACIÓN MORFOLÓGICA Y MOLECULAR DE DOS POBLACIONES DE NEMATODOS FOLIARES (*Aphelenchoides* spp.) EN FLORIDA, AISLADOS DE FRESA CON NOTAS EN SU BIONÓMICA]

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The genus *Aphelenchoides* contains at least 153 species of foliar nematodes. In late 2016, two populations of foliar nematodes were isolated from symptomatic strawberry plants growing in a commercial field in Florida. The populations were tentatively identified as putative *A. besseyi* and *A. fujianensis*. The morphological characters of the Florida population of *A. besseyi* fit those of the original description and re-descriptions. The population of putative *A. fujianensis* did not fit the morphology described for the type population of *A. fujianensis* in China because it was male-less and with females lacking a functional spermatheca, whereas, type *A. fujianensis* is an amphimictic species and with females having a large

spermatheca. The results of phylogenetic analyses using SSU, LSU and COI genes, showed that the Florida and other populations of *A. besseyi* from different hosts and geographical areas clustered in different clades suggesting that *A. besseyi* is a species complex. The putative *A. fujianensis* from Florida did not cluster in the same clade of the type *A. fujianensis* confirming that it is a different species, as inferred by the results of the morphological analysis. This Florida population is considered a new species and its description is in progress. In bionomic studies, the Florida population of *A. besseyi* re-infected strawberry and reproduced well on gerbera daisy. Soybean and alfalfa were poor and non-hosts of the nematode, respectively. This new *Aphelenchoides* sp. from Florida is mainly mycetophagous, although it was found into the trichomes and the mesophyll of soybean leaves in plants inoculated with this nematode.

***Ditylenchus gallaeformans* PHYLOGEOGRAPHY [FILOGEOGRAFÍA DE *Ditylenchus gallaeformans*]**

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How important is coevolution between host and parasite? *Ditylenchus gallaeformans* is a migratory ectoparasite nematode that induces galls in the stem, leaves, and flowers of several Melastomataceae species, including invasive species from the genera *Miconia* and *Clidemia*. *D. gallaeformans* is a possible biological control agent against these invasive plant species. However, culturing this nematode in artificial conditions is challenging and has yet to be established. For this reason, it is important to focus on studies about *D. gallaeformans* biology and distribution to better understand its relation with the host and the environment. A more comprehensive understanding of the phylogeography of *D. gallaeformans* may provide insight about the coevolution between nematode and host, nematode phylogeny, and genetic differences among the populations, which may have influence on host preference, virulence, and pathogenesis. Populations of *D. gallaeformans* used in this study were collected from Brazil, Costa Rica, Dominica,

and Trinidad. DNA was extracted from individual nematodes and the COI region amplified and sequenced. Phylogenetic analysis was conducted using maximum-likelihood (ML) and haplotype networks were constructed for each population according to geographical location and host species. Phylogenetic reconstruction using the COI sequences yielded trees with similar topologies and revealed four major clades determined by location. Haplotype networks for COI were congruent with the phylogenetic reconstructions, showing segregation of the mitochondrial haplotypes according to locality. The results show us that populations of *D. gallaeformans* are genetically different among geographical locations and that the host species does not influence the population's haplotypes.

USING SPARSE SAMPLING AND DENSE ESTIMATION TO STUDY SPATIAL RELATIONSHIPS BETWEEN *Pratylenchus penetrans* AND THE PHYSICAL SOIL ENVIRONMENT [MUESTREO Y ESTIMACIÓN DENSE PARA ESTUDIAR RELACIONES ESPACIALES ENTRE *Pratylenchus penetrans* Y EL AMBIENTE FÍSICO DEL SUELO]

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We modeled spatial patterns of population density of *Pratylenchus penetrans*, 30 soil properties, and their relationship in fields with sandy soils to study the influence of the physical soil environment on high density hotspots of this important nematode species. A global logistic model for nematode density per 100 cm³ soil was developed using data from georeferenced samples collected before crops were planted from seven fields. The binary dependent variable for nematode population density was determined by a threshold value and the independent variables were selected using the least absolute shrinkage and selection operator. Four versions of the model were constructed using thresholds of 25, 75, 100, and 150 *P. penetrans* per 100 cm³ soil for the classification. The discrimination ability was > 0.84 for all models, as evaluated by area under the receiver operating

characteristic curve. The number of independent variables selected ranged from 7-19. Using the kriged values of the independent variables and the designated thresholds, the global logistic model was used to generate probability maps at a 1-m² resolution for each field. Subsequently, each field map was refined by re-estimating the probability at each point using autologistic regression that included neighborhood structure. The probability heat maps and the above-threshold hotspots were analyzed. The 28 maps, one per threshold value per field, showed outcomes consistent with the sparsely collected original nematode data. Our results suggest it is possible to build generalizable global models to inform spatially dependent activities such as sampling or precision management for *P. penetrans*.

BEHAVIOR OF *Nacobbus aberrans* FROM DIFFERENT GEOGRAPHICAL ORIGINS ON TOMATO (*Solanum lycopersicum* L.) CV MIROMA [COMPORTAMIENTO DE POBLACIONES DE *Nacobbus aberrans* DE DIFERENTE ORIGEN GEOGRÁFICO SOBRE PLANTAS DE JITOMATE (*Solanum lycopersicum* L.) CV MIROMA]

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We evaluated the behavior of eight populations of *Nacobbus aberrans* from different geographic origins on tomato cv. Miroma. The tomato plants (29 days old) were inoculated with populations of the nematode from different agricultural regions of Mexico with 0.5 g of galls. The plants were distributed in a completely randomized design with four replicates and kept in a greenhouse for 45 days. Three assessments at intervals of 15 days after inoculation were conducted to determine the penetration and invasion of juveniles in tomato roots. Fifteen days after inoculation (DAI), juveniles from the populations of Romita, Tetela, and Chapingo showed higher rates of penetration and invasion with 50 individuals/g root, whereas at 30 DAI, the number of juveniles in the roots was significantly reduced, and only the population of Silao increased its penetration with 66 juveniles/g root. At 45 DAI, there was an increase in the

number of juveniles and swelling in the roots, mainly with the Romita and Tetela populations, with 102 and 158 juveniles/g of root, respectively. In general, all populations except the control, managed to penetrate and invade the root system of tomato plants, confirming the viability of eggs and biological stages of the nematode, with clear differences in their behavior. The population from Romita, Guanajuato showed greater parasitic capacity on the roots of tomato cv. Miroma.

BRINGING A NEW CROP PROTECTION PRODUCT TO THE MARKET [LLEVAR UN NUEVO PRODUCTO DE PROTECCIÓN DE CULTIVOS AL MERCADO]

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Crop protection is one of the most highly regulated industries in the world. Development of a new product involves many steps: discovery and formulation of the product; trials and field development; toxicology—the study of the effects of the compound; environmental impacts; and final registration. To register a new product, we must show that it is safe for workers, for the environment, for the crops that are being protected, and for the food that is eventually eaten. Sophisticated risk assessments are undertaken and approximately 30% of the cost of a new active ingredient is spent on product safety. It takes a long time and much effort and expertise to move a crop protection product to market. When a product is intended to solve the long-term needs of farmers, we must take advantage of the collective experience, as well as scientific and cultural knowledge, therefore the industry must work with a collaborative approach with universities, institutes of research, and commercial organizations, in order to engage in a new type of dialogue with scientists and researchers. The next generation biocontrols are a new technology example that could bring significant benefits to farmers and the environment.

INCREASING RESOLUTION WITHIN THE *Xiphinema americanum*-GROUP COMPLEX (NEMATODA; LONGIDORIDAE) AS INFERRED FROM MITOCHONDRIAL DNA [INCREMENTO DE LA RESOLUCIÓN

DENTRO DEL COMPLEJO *Xiphinema americanum* (NEMATODA; LONGIDORIDAE) INFERIDO DE ADN MITOCONDRIAL]

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Nematodes within the *Xiphinema americanum*-species complex are economically important because they parasitize a wide range of agricultural crops worldwide and may vector nepoviruses among plants. These nematodes are notoriously difficult to visually identify to species due to phenotypic overlap among characteristic traits. The development of DNA sequence-based identification methods will allow for more accurate species determination within the group. Unfortunately, commonly used loci for nematode identification do not provide adequate sequence divergence for species-level differentiation within the *X. americanum* complex. Previous research endeavors lead us to target a larger portion of mitochondrial (mt) genome than previously reported for phylogenetic studies for primer development. For this study, nematodes belonging to the *X. americanum*-species complex found across the Pacific Northwest of North America were collected from eight geographically disparate locations. Molecular characterization was conducted on individuals from each population, which were first examined morphologically and morphometrically to positively identify each individual was within the *X. americanum*-species complex. Genus-specific primers targeting a 2,800 base pair (bp) region were designed from accessions deposited in GenBank that included the entire mt genome, portions of the cytochrome oxidase 1 (CO1) gene, partial sequences from the 3' end of the ribosomal small subunit (mtSSU), and the cytochrome b (CYTB) gene. PCR amplicons from individual isolates were cloned and sequenced in multiple reactions. With the expanded mtDNA sequence dataset, phylogenetic inference analyses were used to reconstruct evolutionary relationships among these populations and with other species from the *X. americanum* group.

NEMATODE DIVERSITY: MYTH OR TRUTH? [DIVERSIDAD NEMATOLÓGICA: ¿MITO O REALIDAD?]

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With 1,552,319 named species until 2011, animal diversity is the most important component of both continental and marine biodiversity. The contribution of the different animal phyla to animal diversity is, however, totally unbalanced. Only 8 out of 38 animal phyla exceed 10,000 named species each and concentrate mostly in animal taxa. With 24,783 named species, Nematoda is the fifth most diverse animal group, after Arthropoda, Mollusca, Craniata, and Platyhelminthes. Nevertheless, the existing diversity of the nematode group has been a matter of controversy and frequent speculation, with estimations ranging from half a million to one hundred millions species. Thus, if only one of these estimations is a correct approximation, Nematoda would be the second richest animal phylum. The point is, however, that such estimations are based on subjective appreciations rather than the result of rigorous analyses. This contribution provides new insights for a more reliable estimation of nematode diversity by studying available information about species richness of relevant representative taxa, in particular the genera *Bursaphelenchus*, *Meloidogyne*, *Steinernema*, *Xiphinema*, and the entire order Dorylaimida. In all the cases, the number of species described per year reached its maximum at the second half of the past century, but underwent an appreciable decrease at the end of the millennium, a trend that continues nowadays. It means that a more precise extrapolation might be done now to elucidate the existing nematode diversity. Nevertheless, the impact of the so-called 'taxonomic impediment' on the reliability of available data is also a serious handicap to go further in this extrapolation.

THE PHARYNGO-INTESTINAL JUNCTION IN DORYLAIDS, WITH COMMENTS ON ITS TAXONOMICAL INTEREST [LA UNIÓN FARÍNGEO-INTESTINAL EN DORILÁIMIDOS, CON COMENTARIOS SOBRE SU INTERÉS TAXONÓMICO]

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Pharynx and intestine are the largest and the most important sections of the digestive system in the nematode body plan. The pharyngeal base connects the anterior end of intestine with the junction being very often guarded by a valve, the cardia. In dorylaims, the representatives of the order Dorylaimida, the pharyngo-intestinal junction displays relevant variations, which, in general, have not received much attention. The junction consists of a variably shaped and sized cardia but a ring-like structure is usually present. Other (more) specialized elements or differentiations (glands, lobes, etc.) may occur too. The cardia derives from the posteriormost part of the stomodeum. The cardia controls the food flow from pharynx to intestine and is a rounded-conoid, conical, or cylindroid structure usually enveloped by intestinal wall. A fibrous tissue of variable consistency very often embraces the pharyngo-intestinal junction and occasionally may form three radial lobes or only one dorsal lobe. Nygolaims, members of the suborder Nygolaimina, show three large ovoid cells (glands) at this region, certainly an autapomorphic condition of the group. Other very special modifications, for instance intestine joining posterior part of cardia, appear in particular taxa. The tentative interest of these variations for the classification of dorylaims is briefly discussed.

THE NEED OF JOINT VENTURE ALLIANCES IN THE PUBLIC AND PRIVATE SECTOR FOR DEVELOPING COMMERCIAL BIOLOGICAL CONTROL PRODUCTS [LA NECESIDAD DE AVENTURARSE EN UNIÓN DE ALIANZAS EN EL SECTOR PÚBLICO Y PRIVADO PARA DESARROLLAR PRODUCTOS COMERCIALES DE CONTROL BIOLÓGICO]

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It is very well established that most of the research and work needed for developing a biological control product such as sampling, isolation, purification, identification of biological control

agent, as well as the screening of the biological activity against pathogens started in universities, national research centers, and international centers belonging to the public sector. However, few universities and research institutes and scientists have started an enterprise related to development and scaling up of a biological control product. In most common cases, the final phase of mass production and registering the products is conducted by the private sector due to their experience in this matter and possession of the entire platform for scaling up, distribution, application, and commercialization of the products. Therefore, there is a need for universities and research institutes to establish more functional and effective joint venture alliances with the private sector in order to speed the development of biological control products for managing pests and diseases in the agricultural sector. Currently, consumers are demanding healthy foods and on the other side several chemical products, not only nematicides but also fungicides and herbicides, will be banned in the near future. Therefore, it is a great opportunity for the public sector and small enterprises to establish relationships with the private sector for scaling up new biological products. Otherwise, thousands of biological control agents with potential will remain in the laboratories of universities and research institutes and will not reach the final users who are the farmers.

HABILIDAD PARASÍTICA DE ESPECIES FUNGOSAS NEMATÓFAGAS SOBRE HUEVOS Y JUVENILES DEL NEMATODO AGALLADOR (*Meloidogyne* spp.) [PARASITIC ABILITY OF FUNGAL NEMATOPHAGOUS SPECIES ON EGGS AND JUVENILES OF THE ROOT-KNOT NEMATODE (*Meloidogyne* spp.)]

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El nematodo agallador (*Meloidogyne* spp.) es una de las mayores amenazas fitosanitarias en cultivos que constituyen la oferta exportable en el Perú, por las favorables condiciones ecobiológicas, entre ellas, grandes extensiones de monocultivos de especies susceptibles. La demanda por agentes

biológicos que deprimen la población de este nematodo es cada día mayor, pero se hace necesario estimar permanentemente su eficiencia como biocontroladores. El propósito de este trabajo fue evaluar el potencial parasítico de los hongos nematófagos *Pochonia clamydiospora*, *Purpureocillium lilacinum* (cepa SENASA), *Purpureocillium lilacinum* (cepa Lilanova), *Clonostachys roseum*, *Trichoderma harzianum*, *Trichoderma viride* 1, *Trichoderma viride* 2, sobre huevos y juveniles de *Meloidogyne* spp., extraídos del tomate (*Solanum lycopersicum* L.). Para tal efecto se empleó un diseño completamente al azar (DCA) con cinco repeticiones y nueve tratamientos que fueron: 1) *P. clamydiospora*; 2) *P. lilacinum* (cepa SENASA); 3) *P. lilacinum* (cepa Lilanova); 4) *C. roseum*; 5) *T. harzianum*; 6) *T. viride* 1; 7) *T. viride* 2; 8) Oxamylo, y 9) Testigo (sin nematófago). Después de la extracción, los huevos de *Meloidogyne* se mezclaron con una suspensión de 10⁵ conidias/mL de cada uno de estos nematófagos. De la mezcla se tomó una gota que fue depositada en un recuadro dibujado en el centro de una placa de Petri con líneas adicionales para facilitar las observaciones y conteo. Los resultados de siete evaluaciones indican que *T. harzianum* con 81%, *P. clamydiospora* con 80%, *T. viride* 1 con 70%, *P. lilacinum* (cepa Lilanova) con 64% y *T. viride* 2 con 54% inhibieron significativamente la eclosión de huevos de *Meloidogyne* spp. También hubo diferencias significativas respecto al número de juveniles muertos, con 47% en oxamyl, 15% en *P. lilacinum* (cepa Lilanova) y 5% con *P. clamydiospora*. Por los resultados, se considera que la metodología empleada puede contribuir al mejor manejo biológico de *Meloidogyne* spp. en los sistemas agroproductivos de la costa del Perú.

DNA BARCODING AS A TOOL FOR NEMATODE DIAGNOSTICS, SPECIES DISCOVERY, AND MAPPING DISTRIBUTION [CÓDIGO DE BARRAS DEL ADN COMO HERRAMIENTA PARA EL DIAGNÓSTICO DE NEMATODOS, EL DESCUBRIMIENTO DE ESPECIES Y LA DISTRIBUCIÓN DE MAPEOS]

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DNA barcoding using the mitochondrial gene COI is increasingly being applied to questions of nematode species identity and distribution. As a diagnostic marker, the COI gene was instrumental in the discovery of *Heterodera medicaginis*, the alfalfa cyst nematode, in western US agricultural regions. These irrigated production areas had previously been surveyed and collection records indicated the presence of *Heterodera schachtii*, the sugar beet cyst nematode, *Heterodera avenae*, the cereal cyst nematode, and unverified reports of *Heterodera glycines*, the soybean cyst nematode. In this case, it was the initial observation of a unique DNA sequence within the context of a reference database and the construction of a phylogenetic tree that led to species discovery. Similarly, a DNA barcoding survey of the central Great Plains Region of the U.S. has revealed that a minimum of 14 *Pratylenchus* species or haplotype groups exist in the region, but corn, soybean, and wheat production is dominated by just two species *P. neglectus* and *P. scribneri*. In corn-soybean rotations, both species are frequently observed in the same field. However, the increasingly common observation of undescribed taxa, in these and other DNA barcoding surveys, emphasizes the importance of constructing DNA reference libraries that are validated and representative of the geographic range of the taxa. The development of a COI reference library for the suborder Criconematina illustrates the advantages and difficulties associated with library construction.

ANHYDROBIOSIS IN *Nacobbus aberrans* (NEMATODA: PRATYLENCHIDAE) [ANIDROBIOSIS EN *Nacobbus aberrans* (NEMATODA: PRATYLENCHIDAE)]

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Nematodes are a highly diverse group of organisms that have adaptations for survival in extreme conditions in the environments that they inhabit. Nematodes that inhabit plant organs or soils in dry climates often are capable of withstanding prolonged periods of desiccation by entering into a state of anhydrobiosis. Examples include *Anguina tritici* and *Ditylenchus dipsaci*. During our previous research with *Nacobbus aberrans*, we

noted that some tomato plant roots have galls containing mature females 15 days after planting in infested soils. On the other hand, when plants are grown in sterile soil, females are only present in the roots 30 days after inoculation with second-stage juveniles. To determine whether some juvenile stages of *N. aberrans* are capable of surviving in dry roots, we collected a large amount of galled roots in March 2016 and stored them in dry conditions. One year later, at the end of February 2017, we inoculated soil around the roots of tomato cv. Cid with 20 and 40 g of moistened or dry galled roots, with three replicates of each treatment. After 21 days, roots of plants inoculated with dry and moistened roots were evaluated. The gall index of the two treatments was between 3 and 4, respectively (on a 1-5 scale) for both treatments. In 2018, we used the galled roots collected in 2016 to inoculate soil around tomato cv. Rio Grande. The gall index 66 days after inoculation was 1 to 2. After 3 years of storage in dry conditions, our present work shows that *N. aberrans* is still surviving in a state of anhydrobiosis. Future work will evaluate the roles of carbohydrates and lipids in anhydrobiotic nematodes.

NEMATICIDE AND CROPPING SYSTEM PRACTICES EVALUATION ON PLANT-PARASITIC NEMATODES AND SOIL HEALTH [EVALUACIÓN DE NEMATICIDAS Y PRÁCTICAS DE SISTEMAS DE CULTIVO EN LOS NEMATODOS FITOPARASITOS Y BENÉFICOS]

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Plant-parasitic nematodes (PPN) limit yields in crops in Michigan and USA. Soybean cyst nematode (SCN) is considered to be the most damaging pathogen in N. America. Root lesion nematode (RLN) and Northern root knot nematode (NRKN) are common in crops and cause yield losses. The Michigan Applied Nematology Lab has conducted trials to evaluate the effect of cropping systems on these nematodes and soil health to provide applied solutions. We have evaluated compost and manures, nematicides and seed treatments, rotations of SCN-resistant varieties,

surveys of vegetable and field crops, and evaluation of cover crops. A compost blend by Morgan Composting resulted in death of RLN in lab trials, even at concentrations as low as 5%. A SCN trial identified a reduction of SCN juveniles after the incorporation of 5 tons/ha of chicken manure ahead of corn. Several nematicides have been evaluated, and products identified for PPN control. Conversely, we rarely observed a reduction of nematodes (e.g., SCN or beet cyst nematode (BCN)) with seed treatments with the exception of a trial with Abamectin. We have looked at rotation of resistant varieties. Rotating sources of resistance for SCN resulted in a reduction of SCN and yield increases. We have conducted two statewide surveys in vegetables and field crops. We conclude that NRKN are low in soil from vegetable fields rotated with corn. Cover crops increased beneficial nematodes. In the field crops survey, we are correlating tillage and soil type with corn needle nematode. Finally, cover crops are being evaluated for host status to PPN and impact on soil health.

A SEARCH FOR THE BEST YIELD PREDICTOR FOR ROOT LESION NEMATODES. A CASE STUDY OF *Pratylenchus penetrans* ON SOYBEAN [UNA BÚSQUEDA DEL MEJOR PREDICTOR DE RENDIMIENTO PARA LOS NEMATODOS DE LESIÓN DE RAÍCES. UN ESTUDIO DE CASO DE *Pratylenchus penetrans* EN SOYA]

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Pratylenchus penetrans feeds as an ecto- and endoparasite so nematode population densities are routinely determined for both soil and root habitats. The objective of this study was to determine which population density measures best predicted soybean yield in loamy sand soils. Soil samples were collected between soybean rows spaced 75 cm apart at plant emergence (VE). Numbers of *P. penetrans* from 100 cm³ soil, root fragments sieved from 100 cm³ soil, and the sum of the two counts were compared with relative seed weight from two fields for two years in Wisconsin. The number of nematodes from soil and root fragments from the

same 100 cm³ soil volume were only weakly correlated ($r < 0.55$). Soybean yield did not correlate with the nematode population density in soil, whereas, there was a significant negative relationship ($P < 0.05$) for both analyses that included root fragments. This result indicated the danger of using nematode population densities from soil alone as a predictor of yield loss. Based on three goodness of fit measures, the sum of nematode numbers in soil and root fragments were both good predictors. The estimated yield loss by the sum of the two counts was 0.016% per nematode ($P = 0.006$). This value was similar to the estimate determined by a nested component model (0.015%, $P < 0.0001$) based on data from five site-years. The yield loss estimate by the numbers from root fragments alone was 0.025% per nematode ($P = 0.003$). Our study confirms dead roots contain a reservoir of nematodes that should be considered when estimating initial population densities.

EFFECTIVIDAD DE *Pochonia chlamydosporia* VAR. *mexicana* SOBRE *Meloidogyne arenaria* EN CULTIVO DE ZANAHORIA EN CAMPO [EFFECTIVENESS OF *Pochonia chlamydosporia* VAR. *mexicana* AGAINST *Meloidogyne arenaria* IN CARROT UNDER FIELD CONDITIONS]

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Se evaluó la efectividad de la cepa Pcp21 de *P. chlamydosporia* var. *mexicana* sola y en combinación con hojas de brócoli (HB) y Furadan® para el control de *M. arenaria* en zanahoria en un campo hortícola en Puebla, México. De la zona de estudio se colectó suelo, se esterilizó e hicieron determinaciones físico-químicas antes y después del experimento. Se diseñaron doce tratamientos con cuatro repeticiones aplicando el hongo por separado y en combinación con HB (fresco y composteo) y Furadan. Las unidades experimentales (UE) fueron bolsas de polietileno con 2 kg de suelo estéril, siete

semillas de zanahoria, 1x10⁷ clamidosporas (cepa Pcp21), 2300 huevos de *M. arenaria*, 6 g de HB y 2 mg de Furadan según tratamiento. Las UE se llevaron al campo, se enterraron y 12 semanas después se evaluó: peso fresco de la raíz (PFR), peso del follaje fresco (PFF) número de agallas en la raíz (AR), unidades formadoras de colonias (UFC) del hongo por gramo de suelo y raíz y juveniles de segundo estadio (J2). Se realizó una ANOVA unifactorial utilizando la prueba de LSD $P < 0.05$. Las características físico-químicas del suelo no variaron entre los tratamientos al igual que el PFF y PFR ($P < 0.05$). El AR y J2 en suelo disminuyeron en los tratamientos que contenían al hongo. Las UFC/g de suelo y raíz aumentaron en los tratamientos con HB en fresco y composteo. La cepa Pcp21 contribuye a disminuir el AR y J2 en el suelo y su efecto aumenta al combinarlo con HB en composteo.

UNRAVELING THE WHOLE STORY: AN ULTRASTRUCTURAL STUDY OF THE COMMON BEAN AMACHAMIENTO DISEASE CAUSED BY *Aphelenchoides besseyi* [DESCIFRANDO LA HISTORIA COMPLETA: UN ESTUDIO ULTRASTRUCTURAL DE LA ENFERMEDAD DEL AMACHAMIENTO DEL FRIJOL CAUSADA POR *Aphelenchoides besseyi*]

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Foliar nematodes (genus *Aphelenchoides*) are known as facultative endoparasites in a wide range of plant hosts on which they feed and induce several symptoms and diseases. *Aphelenchoides besseyi* has been reported in association with almost a hundred plant species. In common bean (*Phaseolus vulgaris*), this nematode is regarded as the causal agent of “amachamiento”. This disease is characterized by foliar abnormalities combined with a reduction in the number of bean pods causing significant yield losses (up to 80-85%) when mishandled or misdiagnosed. Despite the

identification of *A. besseyi* as the causal agent and its impact on bean crops, the damage to the leaf tissues remains unstudied and unknown. In this research (currently ongoing), we aim to characterize the damage caused by the nematode to the foliar tissues at ultrastructural level by using Transmission (TEM) and Scanning Electron Microscopy (SEM) techniques. Preliminary micrographs show alterations of several organelles (chloroplasts, vacuoles and mitochondria among others) as well as abnormalities in vascular tissues. Additionally, ultrastructural features of *A. besseyi* ex. *P. vulgaris* are given and discussed.

IMPACT OF WINTER *Brassica carinata* AND SUMMER CROP ROTATION ON *Rotylenchulus reniformis* AND FREE-LIVING NEMATODES [IMPACTO DE LA SIEMBRA INVERNAL DE *Brassica carinata* Y LA ROTACIÓN DE CULTIVOS DURANTE EL VERANO, EN EL MANEJO DE *Rotylenchulus reniformis* Y NEMATODOS DE VIDA LIBRE]

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Brassica carinata is an emerging crop in the Southeastern United States. However, the host status of this plant for most nematodes is unknown. In the Southeast, reniform nematode (*Rotylenchulus reniformis*) is one of the most important yield-robbing pathogens of cotton. The objective of this research was to determine the effect of the winter *B. carinata* in a summer rotation system of corn (Cr), cotton (Ct), peanut (P), and soybean (Sy) on reniform (RN) and free-living nematode abundances. Winter field systems were carinata-fallow, oats-carinata, and fallow-fallow. These crops were crossed with a 2-year rotation of Cr, Ct, P, and Sy where each crop phase was present each year. Soil samples were taken during summer 2018 using a Geoprobe®. The abundance of RN populations were measured at soil depths of 0-30 cm and 30-120 cm. RN abundance varied according to each crop. Ct had the greatest RN abundance (1376 nematodes/100 cm³ soil). P, Cr and Sy did not have statistical differences in the abundance of RN. Reniform

nematode, bacterivore and fungivore abundances were greater in the soil profile in the 0-30 cm depth than in the 30-120 cm depth. Winter crops influenced the RN and the bacterivore populations. The greatest populations of RN were seen in the fallow (1,089 nematodes/100 cm³ soil), whereas the greatest bacterivore populations were seen in the oats-carinata (156 nematodes/100 cm³ soil). These initial results suggest *B. carinata* could be considered as a winter cover crop to decrease RN populations. To support this hypothesis, more samples will be taken over a 4-yr period.

NEW REPORTS OF ROOT-KNOT NEMATODES FROM ORNAMENTAL PLANTS [NUEVOS REPORTES DE NEMATODOS AGALLADORES EN ORNAMENTALES]

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A number of ornamental or succulent plants from urban garden pots or planters were found as new hosts of root-knot nematodes. *Ficus microcarpa* grown in pots was parasitized by a population of *Meloidogyne arenaria*. A specimen of the cactus *Stetsonya coryne* was parasitized by a *M. incognita* population, with visible galling induced on roots. The nematode also parasitized plants of *Graptopetalum paraguayense*, present in the same planter. Finally, galls produced by *Meloidogyne* spp. were found on roots of *Sedum dendroideum* and *S. spectabile* in pots. Nematodes were identified by PCR amplification of the 18S ribosomal gene regions, using juveniles and females collected from galls, and/or by the morphology of males, when present. Apart from *G. paraguayense*, the species reported represent new host records for root-knot nematode parasitism. Implications for quarantine issues and nematode pest spreading are briefly discussed.

TRENDS OF BIOLOGICAL PESTICIDES IN THE U.S. MARKET [TENDENCIAS DE LOS PESTICIDAS BIOLÓGICOS EN LOS ESTADOS UNIDOS]

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Availability and usage of biological products in U.S. agriculture continues to increase. Environmental sustainability, food safety, regulatory pressures, and other factors have led to biologicals being one of the fastest growing market segments of agricultural inputs, with some regions in the Americas trending over 15% market growth annually. Product segments including biofertilizers and biostimulants have arisen creating increased grower awareness of the soil microbiome, plant-microbial interactions, and the importance of soil health. Large, multinational pesticide corporations all have biological pesticides and products in their portfolios and are expanding their capabilities to produce and develop biological products. Regulators are adapting with new processes suited to biological products and growers are learning new ways to extract value from production with the use of these biological tools in addition to their existing practices. What once had limited acceptance, the entire U.S. agricultural market has now begun to implement biological inputs as standard practice in commercial production.

PHYLOGENY AND PHYLOGEOGRAPHY OF THE CYST NEMATODES FROM THE GENUS *Globodera* [FILOGENIA Y FILOGEOGRAFÍA DE NEMATODOS FORMADORES DE QUISTES DEL GÉNERO *Globodera*]

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The genus *Globodera* presently contains fourteen valid and three still undescribed species. Three

species, *G. rostochiensis*, *G. pallida*, and *G. ellingtonae* are named as potato cyst nematodes and cause significant economic losses on potatoes around the world. In our study, we provided comprehensive phylogenetic analyses of more than 380 *ITS* rRNA, 220 *COI* and 160 *cytb* gene sequences of 14 species from the genus *Globodera* using Bayesian inference, maximum likelihood, and statistical parsimony. New gene sequences were obtained from 154 populations. The genus *Globodera* displayed two main clades in phylogenetic trees: i) *Globodera* from South and North America parasitizing plants from Solanaceae and ii) *Globodera* from Africa, Europe, Asia and New Zealand parasitizing plants from Asteraceae and other families. Based on the results of phylogeographical analysis and age estimation of clades with a molecular clock approach, it was hypothesized that the *Globodera* species originated and diversified from several centers of speciation located in mountain regions and dispersed from these regions across the world. Possible pathways, including a long-distance dispersal via oceans and secondary centers of diversification are proposed and discussed. Analysis of phylogenetic relationships of populations of *G. pallida* revealed incongruence of the *COI* and *cytb* gene trees, which might be the result of recombination and selective introgression of mtDNA through gene flow between previously isolated populations. This gene flow might limit the use of the mtDNA markers as universal DNA barcoding identifiers for potato cyst nematodes.

SALIBRO™ - A NOVEL SULFONAMIDE NEMATICIDE AND ITS COMPATIBILITY WITH VARIOUS SOIL HEALTH RELATED ORGANISMS [SALIBRO™ – UN NUEVO NEMATICIDA SULFONAMIDA Y SU COMPATIBILIDAD CON VARIOS ORGANISMOS BENÉFICOS DEL SUELO]

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Healthy soils are an important factor in reducing soilborne plant diseases and supporting plant growth. This has been linked to well-developed soil food webs (e.g., different nematode feeding groups), the presence of natural antagonists (e.g., nematophagous fungi), as well as plant growth promoting microbial organisms such as mycorrhizal fungi (AMF) or plant growth promoting bacteria (PGPR). The integrated management of plant-parasitic nematode populations can highly benefit from these natural antagonists and plant symbionts. Consequently, it is important to understand how soil applied nematicides interact with organisms that contribute to the overall soil health network and to include both into an integrated nematode management approach. Salibro™ is a novel sulfonamide nematicide containing the active ingredient fluazaindolizine (Reklemel™ active) that has been developed by Corteva Agriscience and which has shown excellent control of plant-parasitic nematodes in hundreds of field trials around the globe. During Salibro's development, we also thoroughly investigated its effects on various players within the soil health complex and evaluated its compatibility with commonly used antagonists of plant-parasitic nematodes, plant diseases, and insects. Some results of those studies will be shown in this presentation.

OPORTUNIDADES PARA EL MANEJO INTEGRADO DE LA SANIDAD RADICAL DEL BANANO *Musa* AAA CV GRANDE NAINÉ MEDIANTE ESTIMULACIÓN MICROBIANA DEL SUELO Y SU ENTORNO [OPPORTUNITIES FOR THE INTEGRATED MANAGEMENT OF THE ROOT HEALTH OF THE BANANA *Musa* AAA cv Grande Naine BY MICROBIAL STIMULATION OF THE SOIL AND ITS ENVIRONMENT]

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Un sistema radical sano y funcional en la planta de banano es una necesidad primaria.

Tradicionalmente, su manejo se ha focalizado en agentes químicos convencionales para combatir los nematodos parásitos de la raíz. La Corporación Bananera Nacional (CORBANA), en sus objetivos estratégicos, apuesta al fortalecimiento de la salud del suelo y al incremento de su diversidad microbiológica, para estimular el sistema radical y activar la potencial supresividad natural presente en los suelos bajo un apropiado esquema de manejo. Al respecto, se realizó una investigación para evaluar estimulantes biológicos del sistema radical. En condiciones de invernadero en suelo no estéril, con plantas *in vitro* de banano cv Grande Naine en fase IV y con un diseño completamente al azar y 15 repeticiones, se evaluó contra un testigo el efecto de dos rizoestimulante ensilados con microbiota tanto de suelo supresivo como de suelo conducivo, sobre los nematodos y la sanidad radical. Al final fue posible transferir y estimular la microbiota supresora mediante la aplicación de dichos rizoestimulantes biológicos. Con esto se redujo el número de *Radopholus similis* hasta en un 83% ($P < 0.0001$) y se incrementó la biomasa con respecto al tratamiento testigo. En una finca comercial, durante 3 años, se incorporó trimestralmente al suelo, en frente del hijo de sucesión: polvo de piedra, biocarbón, compost y ensilados con microbiota nativa. Se compararon contra un tratamiento testigo absoluto y el Vydate Azul 24SL® (oxamil). Se obtuvo incremento del peso de raíz total y funcional y el porcentaje de raíz funcional en 10, 17, y 3% respectivamente ($P \leq 0.0051$), con respecto al tratamiento testigo. Las variables de biomasa (peso de racimo, número de manos) no difirieron del tratamiento convencional. No se encontraron diferencias ($P > 0.0500$) en el peso de racimo, ni el número de manos entre los rizoestimulantes y el Vydate.

COMUNIDADES DE NEMATODOS EDÁFICOS DE DIFERENTES ECOSISTEMAS EN EL PARQUE NACIONAL DEL AGUA, COSTA RICA [SOIL NEMATODE COMMUNITIES WITHIN DIFFERENT ECOSYSTEMS IN THE DEL AGUA NATIONAL PARK IN COSTA RICA]

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Se presenta un estudio de la nematofauna encontrada en los suelos del área de manejo sostenible de los recursos naturales en el Parque Nacional del Agua en Costa Rica. Se muestrearon cuatro tipos de hábitats (bosque primario, bosque secundario, plantación forestal y pastizal) en cinco localidades situadas en los bordes del parque. Se recolectaron un total de 100 muestras de suelo. Para los análisis de comunidad se utilizaron los índices de madurez, red trófica, diversidad y huella metabólica. Se identificaron un total de 130 géneros pertenecientes a 59 familias y 8 órdenes. Los más abundantes fueron *Helicotylenchus* (15%), *Mesocriconema* (13%) y *Discocriconemella* (7%). Destaca el número de criconemátidos en todos los hábitats y localidades, pero *Mesocriconema* mostró una menor abundancia en el bosque primario, en contraste con *Discocriconemella* que fue dominante en los bosques. Además, la abundancia de dorilámidos herbívoros fue alta en los pastizales y en las plantaciones forestales, si bien tendió a ser menor en estas últimas. Los géneros que presentaron mayores abundancias en ecosistemas alterados con respecto al bosque representan varios grupos tróficos y estrategias de vida: *Alaimus* (Enoplida), *Aphanolaimus* (Plectida), *Metateratocephalus* (Plectida), *Monotrichodoros* (Triplonchida), *Oriverutus* (Dorylaimida), *Pristionchus* (Rhabditida) y *Teratocephalus* (Rhabditida). Los índices que incluyen los nematodos fitoparásitos alcanzaron valores más elevados en pastizales, intermedios en plantaciones de árboles y menores en bosques. La huella de enriquecimiento fue mayor en el bosque secundario, seguido del bosque primario y los ecosistemas perturbados.

EFFICACY OF VERANGO® 50 SC (FLUOPYRAM) IN THE CONTROL OF NEMATODES, PRODUCTION OF BANANA PLANTATIONS (*Musa* AAA) CAVENDISH SUB-GROUP, AND REDUCTION OF CHEMICAL LOAD [EFICACIA DE

VERANGO® 50 SC (FLUOPYRAM) EN EL COMBATE DE NEMATODOS, LA PRODUCCIÓN DE PLANTACIONES DE BANANO (*Musa* AAA) SUBGRUPO CAVENDISH Y LA REDUCCIÓN DE LA CARGA QUÍMICA]

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Banana plantations in Costa Rica are managed as a perennial crop and suffer great yield losses due to root infection by *Radopholus similis*. Nematode control has been accomplished with carbamates and organophosphates and, since 2014, fluopyram. An experiment was performed in a commercial banana plantation. A randomized complete block design with 5 replicates was used. The doses by production unit (PU) used were 0.6 ml fluopyram 50 SC (F), 10 ml oxamyl 24 SL (O), and an untreated control (UTC). During 7 months, fluopyram showed the highest weight ($P=0.0512$) and percentage ($P=0.0009$) of functional root and the lowest ($P\leq 0.0001$) number of *R. similis* and total nematodes. The untreated control had 22,145 *R. similis*/100 g root, and plant weights were reduced by 48 and 68% with O and F, respectively. Plants treated with O and F increased ($P=0.0032$) bunch weight from 1.5 to 1.7 kg, respectively, compared with UTC. In addition, fluopyram increased the weight ($P\leq 0.0337$) and percentage ($P\leq 0.0796$) of functional roots at 0-10, 11-30 and 31-60 cm depths, respect to the UTC. From 2014 to 2018 in commercial banana plantations, 141,322 ha have been treated with fluopyram with 141,322 L of commercial product (CP) and 70,661 L of active ingredient (AI) used. If in this same area an organophosphate (15 GR) had been applied at 20 g of CP (3 g of AI) instead, 34 and 10 times more CP and AI would have been introduced to the environment. The use of fluopyram represented a reduction of 97% in CP and 90% in AI. Thus, fluopyram is a good option to control nematodes, improve production, reduce chemical load, protect the environment, and reduce occupational exposure.

SALIBRO™ (REKLEMEL™ ACTIVE) - A

NOVEL SULFONAMIDE NEMATICIDE FOR THE CONTROL OF *Meloidogyne* spp. IN GRAPES IN PERÚ [SALIBRO™ (REKLEMEL™ ACTIVE) – UN NUEVO NEMATICIDA SULFONAMIDA PARA EL CONTROL DE *Meloidogyne* spp. EN UVAS EN PERÚ]

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The cultivation of table grapes is highly important in Perú. Plant-parasitic nematodes are a threat through the crop cycle decreasing fruit yields and quality. There are several species of plant-parasitic nematodes affecting vines, however, *Meloidogyne* spp. has the highest incidence. Most commonly used products for nematode management belong to the chemical groups of the carbamates and organophosphates. New products are needed that combine efficiency and safety for users and the environment. Salibro™, a 500 SC formulation containing the active ingredient fluazaindolizine (Rekleme™ active), is a novel sulfonamide nematicide that is being developed by Corteva Agriscience, Agricultural Division of DowDupont. The present study summarizes the performance of Salibro™ when applied by drip irrigation in table grapes to control *Meloidogyne* spp. in comparison with cadusaphos and oxamyl. Two trials were established in Ica and another two in Lambayeque and La Libertad. The experimental set up was a completely randomized block design

with 4 replications and 10 plants per plot. Crop-relevant parameters including root damage and nematode root counts, were assessed. Results indicated that Salibro™ demonstrated excellent control of *Meloidogyne* spp. by significantly reducing the number of nematodes in the soil at 30 (4.45 to 8.92-fold reduction) and 90 days after application (9.35 to 18.42-fold reduction) compared to untreated plots and provided performance similar to the tested standard products ($P=0.01$). Therefore, Salibro™ will be a novel and effective tool for nematode management in table grapes in Perú.

SALIBRO™ NEMATICIDE (REKLEMEL™ ACTIVE) - A NOVEL TOOL FOR THE INTEGRATED MANAGEMENT OF PLANT-PARASITIC NEMATODES IN ROW CROPS IN BRAZIL [SALIBRO™, UNA NUEVA HERRAMIENTA PARA EL MANEJO INTEGRADO DE NEMÁTODOS FITOPARASITOS EN CULTIVOS EXTENSIVOS EN BRASIL]

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In Brazil, row crops such as soybean and sugarcane, can sustain significant yield losses due to infestation by root-knot and root lesion nematodes. In soybean, integrated nematode management relies primarily on resistant varieties, nematicide seed treatments, biological control agents, crop rotation, and some limited use of soil-applied nematicides. Whereas in sugarcane, nematode control is mainly dependent on the use of antagonistic plants (e.g. *Crotalaria spectabilis*), application of organic waste products (e.g. vinasse and filter cake) as well as the infurrow application

of nematicides. Salibro™, a novel sulfonamide nematicide containing the active ingredient fluazaindolizine (Reklemel™ active), is currently being developed by Corteva Agriscience™, Agriculture Division of DowDuPont in Brazil for use in these crops. With its remarkable toxicological and environmental profile, Salibro can become a new, sustainable part of integrated nematode control in these crops. Trials conducted across multiple years, in agriculturally important regions of Brazil, and under varying levels of disease pressure, have measured the efficacy of Salibro against *Meloidogyne javanica* and *Pratylenchus brachyurus* in soybean and *Pratylenchus zaei* in sugarcane. Treatments were applied in-furrow at planting at a spray volume of 150 L/ha for sugarcane and 40 L/ha for soybean. Crop-relevant parameters including yield, root damage, and nematode root counts were assessed to determine the efficacy of the treatments as compared to local standards. Overall, Salibro applied in-furrow at-planting reduced the number of nematodes in the roots, demonstrated benefits to root vigor, and contributed to increased yield in soybean and sugarcane. The results of these trials will be discussed in this paper.

FREQUENCIES AND POPULATION DENSITIES OF PLANT-PARASITIC NEMATODES IN BANANA (*Musa* AAA) PLANTATIONS IN HONDURAS DURING THE YEARS 2010 TO 2016 [FRECUENCIAS Y DENSIDADES POBLACIONALES DE NEMATODOS FITOPARASITOS EN PLANTACIONES DE BANANO (*Musa* AAA) EN HONDURAS DURANTE LOS AÑOS 2010 A 2016]

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An analysis of plant-parasitic nematodes occurring in the commercial banana (*Musa* AAA) farms in Honduras from 2010 to 2016 was undertaken. Nematode extraction was conducted using 25 g of fresh roots macerated in a kitchen blender followed by sugar centrifugal flotation recovering the

nematodes with a 0.038-mm pore sieve. The data were subjected to frequency analysis in PC-SAS and the frequency for each genus was calculated as a percentage (number of samples containing a species/numbers of samples collected) * 100. Four plant-parasitic nematode species were detected and based on their frequencies and population densities their relative importance was established as *Helicotylenchus multicinctus* > *Pratylenchus* spp. > *Radopholus similis* > *Meloidogyne* spp. *Helicotylenchus multicinctus* and *Pratylenchus* spp. were the most abundant species, accounting for 17.9 to 72.1% and 11.6 to 55.3%, respectively, of the overall root nematode population throughout each study year. From a total of 425 root samples, 320 (75%) contained *H. multicinctus*, 249 (59%) *Pratylenchus* spp., 248 (48%) *Meloidogyne* spp., 172 (40%) *R. similis*, and when the nematodes present in the samples were pooled (total nematodes) only 3 (0.7%) of the samples were free of nematodes. A larger number of samples had nematode populations above the economic threshold suggested by the laboratory of 1,000-2,000 (for this extraction procedure) nematodes per 100 g of roots. This was observed in all the years, months and the two sampled locations where bananas are grown in Honduras. Statistical differences were detected for the frequencies among the years ($P < 0.0001$), and months ($P < 0.0001$), and between locations ($P < 0.0001$) in most of the nematode genera detected.

EVALUATION OF FLUOPYRAM AS A RESCUE NEMATICIDE FOR MANAGING STING NEMATODE (*Belonolaimus longicaudatus*) ON STRAWBERRY IN FLORIDA [EVALUACIÓN DEL FLUOPYRAM COMO NEMATICIDA RESCATE PARA EL MANEJO DEL NEMATODO *Belonolaimus longicaudatus* EN FLORIDA]

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In Florida, plant-parasitic nematodes are one of the main limiting factors for economically successful production of strawberry. Sting nematode (*Belonolaimus longicaudatus* Rau) is widely distributed within the sandy soils of Central Florida's strawberry production region and causes significant injury to strawberry. A relatively new tactic for nematode management is the use of synthetic non-fumigant nematicides with an in-crop application label, such as fluopyram. In the 2017-2018 growing season, drip application of fluopyram at transplant followed by an application 40 days after transplanting at 0.5 L/ha increased fruit yield and reduced sting nematode populations in soil. In the 2018-2019 growing season, fluopyram was evaluated as an in-crop rescue nematicide for managing sting nematode on commercial strawberry farms. Fluopyram was drip applied at seven commercial strawberry farms into nine fields with a history of sting nematode infestation, or where the nematode had subsequently been detected during the growing season. Soil treatments were arranged in a randomized paired design, with plots consisting of entire planting rows. The soil treatments were: untreated soil or fluopyram (0.5 L/ha) applied through the grower's irrigation system. At two farms, fluopyram reduced population densities of sting nematode 1 month after application. At two different farms, post-application nematode population densities did not differ between the soil treatments; however, plant vigor was increased in the fluopyram treated soil. Results from the end-of-season soil sampling will be discussed. Overall, fluopyram shows potential as a rescue nematicide for managing soilborne disease on strawberry in Florida.

IDENTIFICATION OF MOLECULAR BIOMARKERS ASSOCIATED WITH RENIFORM NEMATODE (*Rotylenchulus reniformis*) RESISTANCE IN SOYBEAN [IDENTIFICACIÓN DE BIOMARCADORES MOLECULARES ASOCIADOS CON LA RESISTENCIA A EL NEMATODO RENIFORME (*Rotylenchulus reniformis*) EN SOYA]

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Reniform nematode (*Rotylenchulus reniformis*) is a yield-limiting pathogen of soybean (*Glycine max*) in the Southeastern region of the United States. Several studies have identified soybean germplasm with resistance to reniform nematode and only a few studies have explored the soybean genome for quantitative trait loci (QTL) linked to reniform nematode resistance. Our objective for this study was to identify high resolution single-nucleotide polymorphism (SNP) biomarkers that correlate with reniform nematode resistance in soybean using genotyping-by-sequencing (GBS). A set of 250 recombinant inbred lines (RIL, F_{2:8}) developed from a cross between reniform nematode resistant soybean cultivar 'Forrest' and susceptible cultivar 'Williams 82' was utilized to correlate reduced nematode reproduction to SNP markers, thereby localizing specific QTL regions in the soybean genome. The phenotype was determined by inoculating three replicates of each line with 2,000 vermiform reniform nematodes and quantifying final populations from the soil and root 60 days after inoculation. Resistant lines were identified using an optimal univariate cluster analysis. DNA was extracted from leaf tissue collected from each line and digested using specific restriction enzymes *MseI* and *PstI* to prepare gene libraries, sequenced on the Illumina HiSeq 2500 platform, and sequences analyzed to generate population genomic summary statistics. Three SNP markers were significantly associated with reniform nematode resistance, one on chromosome 11 (LG B1) and two on 18 (LG G). These genetic markers can be used by soybean breeders in marker assisted selection to enhance efforts in selecting and employing lines with known resistance to reniform nematode.

DIFFERENTIAL RESPONSE OF PLANT-PARASITIC NEMATODES TO THE NEMATICIDE FLUAZADIOZINE [RESPUESTA DIFERENCIADA DE NEMATODOS FITOPARÁSITOS AL NEMATICIDA FLUAZADIOZINE]

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Although widespread and economically important, there are few control measures to combat plant-parasitic nematodes (PPN). To fill this void, there are several newly discovered nematicides. To ensure these compounds' longevity, more information is required regarding the impacts of these compounds on reproduction and mobility of different PPN genera. In this study, a microwell assay system was used to generate 24-hr dose-response curves for four PPN genera exposed to the nematicide, fluazaindolizine. Dose-response curves were generated for second-stage juveniles (J2) of three *Meloidogyne* species (*M. incognita*, *M. chitwoodi*, and *M. hapla*). Additionally, 3 and 6 geographically distinct populations of *M. chitwoodi* and *M. hapla*, respectively, were included. The response of one population each of *Pratylenchus neglectus* (mixed stages), *Globodera ellingtonae* (J2), and *Xiphenema americanum* (mixed stages) was also determined. The 24-hr effective dose (ED) of fluazaindolizine that resulted in the immobility of 25%, 50%, 75%, and 100% of *M. incognita* J2 (ED25, ED50, ED75, and ED100) was then used to expose J2 of *M. incognita*, *M. hapla*, and *M. chitwoodi* for 24-hrs. Exposed J2 were then inoculated on a susceptible tomato 'Rutgers' to quantify reproduction post exposure. *Meloidogyne incognita* was the most sensitive to fluazaindolizine, with an ED50 2X lower than *M. chitwoodi*, and 3X lower than *M. hapla*. *Pratylenchus neglectus* seemed unaffected by fluazaindolizine with a predicted ED50 of >90,000 ppm. A 24-hr exposure to fluazaindolizine ED25, ED50, ED75, and ED100 were effective in preventing reproduction of *M. hapla* and *M. incognita*, but were ineffective against *M. chitwoodi*.

CAN THE FUNGUS *Fusarium solani* MODULATE TROPHIC CASCADES INVOLVING ENTOMOPATHOGENIC NEMATODES AND INSECT HERBIVORES [PUEDE EL HONGO *Fusarium solani* MODULAR CASCADAS TRÓFICAS QUE INVOLUCRAN NEMATODOS ENTOMOPATÓGENOS Y HERBÍVOROS DE INSECTOS]?

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Olfactory signals are critical for soil inhabitants to communicate and respond to the environment. In addition to the well-documented volatile cues from herbivores and herbivore-induced plants, the attraction of entomopathogenic nematodes (EPN) to their insect prey can also emanate from other sources. Using headspace solid-phase microextraction (HS-SPME) combined with gas chromatography mass spectrometry (GC-MS) analysis, two insect-attracting volatile organic compounds (VOC) were detected from the insect-parasitic fungus *Fusarium solani*. Bioassays showed that both compounds attract entomopathogenic nematodes (EPN) on a species-specific basis. In two-choice olfactometers, more *Steinernema diaprepsi* infective juveniles were attracted to both VOC, whereas the closely related and often sympatric *S. khuongi* was not. Attraction to the VOC was greater in saturated soil than in soil at field capacity. Although both compounds are highly attractive to fungivorous insects such as fruit flies, fungus gnats, and rove beetles, the non-fungivorous *Diaprepes abbreviatus* root weevil was strongly repelled by one compound and unresponsive to the other. EPNs may have evolved to exploit these VOC as a means of encountering fungivorous insects. Non-fungivorous arthropods may have evolved to avoid the compounds. These compounds have the potential of serving as baits to facilitate host finding of fungivorous arthropod pests by EPN, especially in poorly drained soils where such pests may be prevalent.

PHYLOGENETIC INFORMATIVENESS INVESTIGATION OF MITOCHONDRIAL PROTEIN-CODING GENES IN PHYLUM NEMATODA [INVESTIGACIÓN FLOGENÉTICA INFORMATIVA DE GENES DE CODIFICACIÓN DE PROTEÍNAS MITOCONDRIALES EN EL PHYLUM NEMATODA]

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The analysis of phylogenetic relationships based on mitochondrial genes is widely utilized to identify species, elucidate population structure, and infer evolutionary histories. To improve our understanding of the utility of mitochondrial protein-coding genes (PCG) when reconstructing phylogenetic relationships in the Nematoda, we explored phylogenetic informativeness (PI) in a total of 12 PCG from 93 species of nematodes whose mitochondrial genomes were available in GenBank plus two recently sequenced mitogenomes from plant-parasitic nematode species (*Hoplolaimus columbus* and *H. galeatus*). We used two methods to explore PI. First, we used concatenated sequences of all PCG to generate a phylogenetic tree of phylum Nematoda as calibration for studying topological distances and similarities among 43 trees of different phylogenetic markers, using the software Environment for Tree Exploration v3. Second, we calculated PI values of all those phylogenetic markers using the server PhyDesign. Results from the two methods were in agreement and suggest that the PI signal embedded in a phylogenetic marker should be considered in order to reconstruct a reliable phylogenetic relationship. Also we found that phylogenetic signal is gene-specific and independent of the gene size. The *nad5* and *nad4* genes are highly informative for nematode phylogeny. Traditional mitochondrial markers, such as the *cox1* or *cytb* gene, contain medium phylogenetic informativeness. We recommend not using *nad3*, *nad4L*, *cox2*, or *nad6* for phylogenetic reconstruction given their low phylogenetic signal.

BIOGEOGRAPHY AND MOLECULAR SPECIES DELIMITATION OF *Pratylenchus capsici* N. SP. A NEW OLD ROOT-LESION NEMATODE IN ISRAEL ON PEPPER (*Capsicum annuum*) [BIOGEOGRAFÍA Y DELIMITACIÓN MOLECULAR DE *Pratylenchus capsici* N. SP. UN NUEVO – VIEJO NEMATODO LESIONADOR EN PIMIENTO (*Capsicum annuum*) EN ISRAEL]

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Root-lesion nematodes of the genus *Pratylenchus* parasitize the roots of various plants and can cause severe damage and yield loss. Here, we report on a new species, *Pratylenchus capsici* n. sp., from Arava rift, Israel, which was characterized by integrative methods, including detailed morphology, molecular phylogeny, population genetics, and biogeography. We found this species widely spread along the Arava rift, causing significant effects on pepper (*Capsicum annuum*) roots and inhibiting plant growth. Both morphological and molecular species delimitation support the recovered species as a new species. We recovered high *COI* (cytochrome oxidase subunit I) haplotype diversity and biogeography analysis suggesting that contemporary gene flow was prevented among different agricultural farms while population dispersal from weeds to pepper was found on a relatively small scale. Our results suggest that weeds are important for the dispersal of *P. capsici* n. sp., either as the original nematode source or at least to maintain the population between growing seasons.

TAXONOMIC STUDIES OF THE PLANT PARASITIC NEMATODE SPECIES OF DORYLAIMIDA IN THE DOMINION ARBORETUM OF CANADA [ESTUDIOS TAXONÓMICOS DE ESPECIES DE NEMATODOS FITOPARÁSITOS DE DORYLAIMIDA EN EL ARBORETO DOMINION EN CANADA]

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The Dominion Arboretum of 40 ha is located at the Central Experimental Farm of Agriculture and

Agri-Food Canada in Ottawa, Ontario, Canada. Originally in 1889, it served as a testing ground of those plants introduced from Europe and then from around the world, for their suitability to the Canadian climate. Now the arboretum is mostly a public display site of about 10,000 of the remaining introduced plants, mostly trees and shrubs. The arboretum's special collections of flowering crabapple trees, lilacs, lilies, and hedge plants are still as much for experimental work and study as for display to the public. In 2017 and 2018, a survey for nematodes was conducted and this presentation focuses on the plant-parasitic nematodes belonging to Dorylaimida. The species discovered and identified using morphology and molecular methods were *Xiphinema americanus*, *X. riversi*, *X. diversicaudatum*, *Longidorus elnogatus*, *Paratrichodorus pachydermus*, and *Paratrichodorus sp.* This is the first report of *P. pachydermus* in Canada.

presented to highlight the rewards and challenges of this type of research. Underpinning all of these efforts is the need to establish and maintain productive collaborations with scientists with diverse backgrounds.

HOW AN APPLIED NEMATOLOGIST USES GENOMIC TOOLS TO ADDRESS PLANT-PARASITIC NEMATODE RESEARCH [COMO UN NEMATOLOGO DE CAMPO UTILIZA HERRAMIENTAS DE LA GENÓMICA PARA ABORDAR LA INVESTIGACIÓN DE NEMATODOS FITOPARÁSITOS].

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The advancements in molecular plant pathology have created an environment in which applied, field-based research programs have the opportunity to utilize genomic tools in their programs. There are potential rewards for incorporating genomics into a research program including enhanced nematode diagnostics, population genetics of infestations, and novel biological discoveries. However, along with these rewards come many considerations including cost, tempered expectations, and the capacity to generate and analyze data. A cautionary tale of such a journey will be presented. Efforts to characterize the nematode microbiomes from a diversity of plant-parasitic nematodes, understand the population genetics of a potato cyst nematode infestation, and sequence and annotate nematodes' genomes will be