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Importance of Agricultural Nematology Outreach

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Abstract: The surface of continental Argentina is 2,791,810 square kilometers, with phytogeographic regions characterized by soils, climates and different vegetation cover. Of that area, 34 million hectares are used for agriculture. In this context, soil nematodes that cause damage to crops can find many suitable places to colonize and multiply. So far, the true importance of these organisms is not taken into account. We believe that this situation is due to the limited information held by producers and technicians who advise, regarding soil nematodes in general and phyto-parasites in particular. Because of this, the task of extension is very limited and does not contribute to raise awareness of the serious damage that some species cause to agriculture. Therefore, some people who work mainly in basic research, we decided to engage with agronomists, producers and members of ministries of agriculture, to convey results of our daily work. As a result, research projects on nematodes that affect the cultivation of pepper for paprika began. Positive results that open good prospects for managing the populations of these organisms pest in the country were obtained.

Key words: plant parasitic nematodes, research and outreach n the cultivation of pepper

1. Introduction

Television programs regarding agricultural activity in Argentina often address several issues, with the main ones focusing on different pests and their incidence on yield of the most important crops in the country

In 2015, a long report was shown about the leptidopteran *Helicoverpa armigera* and the serious damage it causes to horticultural, floral and fruit crops in Brazil. A Brazilian technician was interviewed, who described in detail the main biological and agronomic aspects associated with that pest. He indicated the difficulty in differentiating that species from others, especially from the corn earworm *Helicoverpa zea*, since their morphological and morphometric characteristics are very similar, making its rapid identification in the field practically impossible. A method suggested for their identification was the use of traps baited with the pheromone of *H. armigera*; however, *H. zea* can be equally attracted by those traps.

Therefore, it is considered essential to use laboratory techniques to analyze genitalia and molecular aspects, which requires the intervention of specialized taxonomists. The technician also mentioned the need to immediately notify the producer's advisor as soon as the presence of corn earworms in the crop is detected, so that live specimens could be captured and taken to the laboratory for identification.

In light of these comments, it can be inferred that the struggle against this pest (as well as many others) requires considering three different aspects: taxonomy, outreach and biology. Correct interpretation of these three aspects may allow us to elaborate strategies for the management of populations of these lepidopterans.

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So, what happens with Agricultural Nematology in Argentina? “Almost nothing” is not an exaggerated response. Comments on TV about any soil nematode and its significance to agriculture are very rare. It is very strange that in a heavily agricultural country like ours, these organisms do not receive the attention they deserve. Some soil nematodes, cause significant yield reductions, are responsible for huge economic losses worldwide [1]. Then, how can we explain such low concern (almost indifference) by producers, agricultural engineers, and governmental agencies? Several questions arise from this brief overview. As we mention them below, we will attempt to answer these questions based on real data.

2. Why Do Soil Nematodes in Argentina Not Receive the Attention They Deserve?

We consider that this situation is — mainly — due to the lack of knowledge of their characteristics and particular aspects. In addition, several issues would conspire against the existence of a clear awareness about the topic.

First, soil nematodes cannot be observed with the naked eye due to their small size; most of them are microscopic and are a maximum of 1 mm in length (except for some species of the family Mermithidae, which females can be more than 15 cms long [2].

Extraction of nematodes from the soil requires special procedures and their detection demands the use of adequate optical equipment (light and stereoscopic microscopes).

Moreover, the observer should be duly trained in the handling and use of this equipment.

Second, the problems caused by species that attack roots do not generally produce visible symptoms in the aerial part of the crop. This aspect is highly important because it is difficult to recognize that plants not showing visible symptoms have their roots parasitized.

In most cases, only a reduced development (short internodes), presence of chlorotic leaves and a tendency to wilting can be observed. Only when the plant yield is assessed, will values below the expected ones be confirmed. This phenomenon is in contrast with what usually occurs with other pests. Although some organisms can also not be observed with the naked eye (bacteria, fungi and viruses), fairly well defined symptoms are visible (either in leaves, stem or fruits) [3-5]. And when there is an attack by insects, the agent responsible for the problem is generally easily observed (as well as the signs of its presence in the affected plants) [6].

Accordingly, it is similarly important to know that the symptoms mentioned above can be also caused by other diverse factors not related to harmful plant-parasitic nematodes. Furthermore, it is necessary to consider that only in very few occasions can the presence of these organisms in the soil represent a limiting factor, not only for crop production but also for crop development. These situations are usually observed in greenhouse crops after several years of monoculture. Considering these aspects is therefore essential for evaluating the possibility of assuming the presence of harmful plant-parasitic nematodes in the evaluated crop.

3. How Long Ago Were Soil Nematodes Detected in the Country?

The first report on soil nematodes in Argentina dates back to the end of the 19th century, when the presence of *Heterodera radicicola* de Greef in grapevines exhibiting symptoms caused by *Phylloxera* was reported [7]. Later, the results of an excellent work were published in a journal of broad dissemination in the country. In a long article, several aspects of agronomic and biological interests are mentioned, particularly the host-parasite relationship (*Heterodera marioni* = *Meloidogyne incognita* - tomato) and possible methods to control the harmful organism [8]. It is clear that despite the publication of the relevant article, which was published in Spanish and in Argentina, the topic was not addressed according to the

importance of soil nematodes in general and the diverse trophic categories that define them.

4. Why Are the Main Characteristics of Soil Nematodes Unknown in the Country?

Two situations help answer this question. First, these animal organisms are not included in almost any educational programs of primary or secondary schools. Second, and although it seems unbelievable, none of the Schools of Agronomy in Argentina has an obligatory course about Agricultural Nematology. Occasionally, only a brief module about the topic and, sporadically, post-graduate courses are offered in some university schools.

Secondly, representatives of agrochemical product companies have long contributed to the generation of a great confusion among their potential clients. Protected by the generalized lack of knowledge about these organisms, companies established the idea that the presence of nematodes in the soil puts the crop at risk. And that to enable the plant to grow healthy and yield the expected production, the solution was the application of products named nematicides. Since the different trophic categories that can be recognized among soil nematodes were ignored, all of them were considered harmful. Bacteriophagous. mycophagous, predatory, entomopathogenic, entomoparasitic, omnivorous and phytophagous nematodes were all categorized as being harmful to agriculture.

However, this is far from reality. Some of these categories comprise species that are very useful for crops: bacteriophagous nematodes participate in the recycling of organic matter; predatory nematodes feed on various other nematodes; entomopathogenic and entomoparasitic nematodes act as biological control agents of insect pests. On the other hand, most mycophagous and omnivorous nematodes are harmless. Considering that nematodes — as a whole — can reduce crop yields is a mistake. At present, this concept is not well assimilated in the mentality of producers or technical advisors.

5. When There Are Plant-Parasitic Nematodes Present in the Soil, Can They Be Considered Responsible for all the Problems Observed in Crops?

While this is the idea promoted by the marketers of “nematicides”, it is if fact not that way. Of the 4100 species of plant-parasitic nematodes known so far [9, 10], only some 50 species — in some situations — can cause significant yield reductions. This means that only approximately 1% of the described species can be harmful to crops.

This fact should be definitively taken into account, since it shows that, overall, not all species are alike (despite their sharing the same trophic category), nor are they equally significant to agriculture. A considerable number of these species are harmless because either they are present in very low population densities or the cultivated plants are not a suitable host. Therefore, it is very important to remember the concept of diversity and variability not only in the frame of soil nematodes in general but also among the members of the trophic category of plant-parasitic nematodes in particular.

In Argentina, two sendentary-endoparasitic plant parasitic nematodes species stand out: *Meloidogyne incognita* and *Nacobbus aberrans*. We ask ourselves if they share any characteristics with *Helicoverpa armigera*. The following table speaks by itself:

The considered organisms represent three different entities. It is clear that, taxonomically, the lepidopteran is very far from nematodes and among the latter, their relationships with hosts and, particularly, their general biology are equally different. We need only to mention that the geographical distribution of the genus *Meloidogyne* is cosmopolitan, whereas that of the genus *Nacobbus* is restricted to the Neotropical region. This fact is very significant and clearly shows that the possibilities of adaptation of *Nacobbus* species to the environment are not the same as those of the former. On the other hand, the respective species of both genera induce different reactions in the parasitized root tissues

of the attacked hosts. Plants attacked by *Meloidogyne* react by generating giant or transfer cells, whereas those affected by *Nacobbus* generate a syncytium.

It is evident that the three organisms are biologically different. However, from the crop perspective, they clearly share numerous characteristics of considerable seriousness. Why then does the importance of plant-parasitic nematodes to agriculture in the country remain neglected?

6. Why Has the Number of Nematologists in Argentina Been and Still Is Very Low?

Agricultural Nematology is an independent discipline and not part of Phytopathology or Entomology. Training of a nematologist requires robust knowledge in several fields: taxonomy, genetics, ecology, reproductive biology, molecular biology, biochemistry, host-parasite relationships, statistics and experimental design, among the most important ones. It should be noted that most of these topics are not part of the programs of the Agricultural Engineering course of studies in Argentina; they are considered in the course of studies of Biology and/or Natural Sciences, with a focus on Zoology.

Furthermore, most agricultural engineers are devoted to professional practice and not to research. Indeed, most of the works conducted on the topic in Argentina have been developed by biologists or zoologists, and are published in scientific journals. Since it is not promoted by government agencies as an important discipline for agriculture in Argentina, Agricultural Nematology does not gather too many advocates.

7. Is There A Lack of Local Information about These Organisms and the Problems They Cause?

Although it is true that the number of specialists in the field in Argentina has always been very low, overall they have generated a considerable number of works (about one thousand) that have been published in scientific journals and at national and international conferences. Despite this, both the producer and the technical advisor ignore the problems that these organisms may generate and their significance in terms of soil health.

The producer does not receive the necessary information by government agencies, which should aim at transferring sufficient knowledge about the topic. On the other hand, agricultural engineers get their degrees without having had any course devoted to this discipline. Meanwhile, crop yields decrease — sometimes drastically — and the producer does not receive a reasonable explanation and will be, therefore, inexorably induced to apply nematicides.

8. What is Known about Plant-Parasitic Nematodes in Argentina?

Basic knowledge about the main soil nematode species and their association with the most important crops in the country are scarce and very fragmented, being non-existent for most of the species.

In almost all cases, not only is the nematode species identity ignored but also the particular characteristics of the different populations, which are specific to the different agricultural areas. As an exception, we can mention the works conducted with populations of *N. aberrans*, related to potato and pepper crops in several areas of northwestern Argentina [11-19].

Those works contributed with the concept of pathotypes or races, which were subsequently addressed within the frame of relatively recent research works [18]. Likewise, the behavior of a given plant implanted in different areas is not completely known. The large cultivated area in Argentina, distributed in very different zones in terms of climate, edaphic characteristics and plant cover [20], makes basic research activity still completely useful. Only when this information is available will it be possible to elaborate management strategies for populations and, thus, preserve these crops.

9. What is the Role of the Laboratories that Perform Soil and Plant Nematological Analyses?

Some sporadic courses on Agricultural Nematology (see question below) contributed to the awareness of agronomists and producers about the existence of soil nematode species harmful to agriculture. Since then, several laboratories offer the service of detection of dangerous species for cultivation in soil samples (obviously paid services) for agronomists appeared. As there was no system regulating the professionals that could provide that information, numerous people lacking specific and demonstrable background started to address taxonomic aspects of Agricultural Nematology. As mentioned above, a specialist in the field cannot be improvised. The interested person must approach his/her training under the supervision of people of renowned background in the field and have the necessary time to ensure good training.

The present situation is worrying. Both the people responsible for the laboratory and their assistants have not been duly evaluated in their capacity by a specialist. This can lead to different taxonomic levels often being confused, from Orders to species, through all the intermediate levels. Many of these people consider themselves capable of recognizing different species because they have recorded the characteristics of those species that can affect one or several crops. And the error lies in this criterion. Knowing the morphological-morphometric parameters defining a species is not enough; not confusing the species with several other identical ones is essential. The clearest example may be that of the species *Heterodera trifolii* and *Heterodera glycines*; both the filiform and globose stages are practically identical (only a duly trained person can differentiate them). In the field, *H. trifolii* parasitizes roots of *Trifolium repens* but not soybean roots, whereas *H. glycines* is the main pest of soybean crops worldwide. This fact explains the seriousness involved in confusing the species.

10. What is the Role of Outreach Activity?

There are national and provincial agencies related to outreach tasks. Furthermore, all the Agronomy Schools in the country have an Outreach Department. However, Agricultural Nematology is not included among the topics considered important. Some exceptions include: a) Balcarce Station, INTA (National Institute of Agricultural Technology) — School of La Plata, (Buenos Aires), where Dr. Eliseo Chaves developed courses for undergraduate students for some time; and b) the participation of two of the authors of this article (M.D and P.L), who, for some years now, have been giving courses in the School of Agricultural Sciencies of the National University of Córdoba, and in various universities and agencies in the country, when time allows. To date, more than one century after the publication of a detailed and excellent article by Huergo (1902), outreach agencies do not seem to have duly capitalized the research that was made about the topic [8].

Given this situation, the few nematologists that work in the country devote part of our time to establish relationships with agricultural engineers and other professionals that are in direct contact with crops and producers. This interaction allows us to show them our research and prompt them to adopt measures that include much more than simply applying toxic products to the soil.

The agronomists acquainted with producers from his/her area of influence and their problems represent the ideal intermediary to participate in meetings (mainly in cooperatives) to deal not only with the problem but also with management possibilities via adoption of certain criteria. The main criteria include: knowledge of the main plant-parasitic soil nematode species before crop establishment, use of nematode-free seedlings, establishment of non-susceptible (or tolerant) crops to the attack of the nematodes present in the soil that will be cultivated, crop rotation, use of trap plants, methods to promote

the increase of natural antagonists of nematode pests in the cultivated soils.

During these meetings, it is very important to develop a theoretical part followed by the corresponding practical one. Thus, the participants can easily relate the theoretical concepts to the subsequent practice, incorporating preventive notions that are, definitely, part of the key to ensuring management of populations of these pests. And, whenever feasible, it is very useful to use a plot of a producer to develop experiments related to yield assessment. For this reason, the participation of the agricultural engineer or technical advisor is essential.

At the same time, it is essential to attempt to generate a change of mentality in those people involved in agriculture. A change that goes from thinking of the need to eliminate an enemy to thinking of accepting the idea of having to live with the enemy. This can be accomplished by trying to keep the pest population density below the threshold of crop damage.

To illustrate the above mentioned comments, here we refer to what happened shortly after detecting *H. glycines* on soybean roots in crops located in the central area of Argentina [21]. On that occasion, a local technological promotion agency asked the staff what should be done to avoid dispersal of the pest. The suggested solutions were merely well-known data and recommended revising the cultivated plots in search of "white females" of the parasite on host roots. Evidently, this method was not the right one. The most efficient way of ensuring the detection of *H. glycines* consists of processing soil samples to extract cysts (dead females of the nematode with the sclerotic cuticle and, in general, full of eggs inside). Those cysts are then analyzed (to confirm the presence of eggs) and counted. At the same time, soil samples are analyzed in search of second-stage (infective) juveniles and males (if present). Only then will it be possible to have an approximate idea of the population status.

The authors of this article (M.D. and P.L) organized the first postgraduate course given in the country about the mentioned pest (*). To this end, we invited a Brazilian specialist who had developed a management program in the locality of Londrina to maintain the parasite population density below the critical level. Several participants from different Argentine provinces (and neighboring countries) attended the course; however, the recommendations that emerged from that meeting were not taken into account appropriately. For example, the usual practice of seeding soybean on the road shoulders was continued. Simultaneously, important financial resources were allocated by the aforementioned promotion agency to advance in the knowledge of the nematode. Thus, a technique for extracting cysts from the soil was developed [22], which is different from the usually applied technique [23]. As a consequence, it was not possible to make valid comparisons between results obtained by different groups working in the country.

Accordingly, and given the efforts required in isolating the various representatives of *H. glycines* that may be present in the soil, the development of a new technique permitted to obtain cysts, infective larvae and males from a single sample. However, although it was published in a journal related to Nematology [22], this technique does not seem to be used by those working in the field.

In short, it is necessary to inform the producer about the procedures related to what is known as Integrated Pest Management. The sum of small and varied interventions will make it possible that crops and pest coexist, without necessarily causing a reduction in the expected yields. Accordingly, it is important to highlight the interaction between the Nematology Laboratory, the Ministry of Agriculture of the Province of Catamarca and the Department of Agricultural Zoology (National University of Catamarca). As part of this collaboration, meetings took place in the premises of the Cooperativa Diaguita (in the locality of Santa María del Valle de Catamarca) with the participation of producers of paprika pepper, professors of the mentioned university and one of the

authors of this article (MD). The results are very encouraging, since the participants received, over one or two days, theoretical and practical information about what these animals are and the problems they cause.

To conclude, we believe that the amount of information in Argentina on soil nematodes that compromise crop yields is sufficient to perform outreach activities. Currently, this important activity is undertaken mainly by researchers and technical advisors. The sum of knowledge from both areas will help the problems derived from such pests and the best way to manage their populations known.

(*) Management modalities nematode Heterodera glycines in relation to soybean cultivation. Doucet, M. E., P. Lax, Flavio Veloso and Hector J. Baigorri. Center for Applied Zoology (National University of Córdoba). 27-30 April 1998.

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