



Nematodes, a Problem for Soybean Crops in the Brazilian Cerrado

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Nematodes can damage and cause significant suppression in soybean productivity (*Glycine max*) directly because of their migration and feeding activities, or indirectly as partners in disease complexes with other organisms. Several cultural practices have been investigated as possible management strategies for nematodes, including manipulation of planting season, soil preparation, and cultivars with higher resistance levels than currently available. This literature review shows that gall nematodes (*Meloidogyne* spp.) significantly reduce soybean productivity [*Glycine max* (L.) Merr.] in the Brazilian cerrado. The most important pathogenic nematodes of soybean, worldwide, are the soybean cyst nematode, *Heterodera glycines*, and some of the gall nematodes, *Meloidogyne* spp. Currently, different management methods are necessary, being chemical, biological, and cultural to obtain maximum efficiency in the control of this pest.

Keywords: *Meloidogyne* spp.; *Heterodera* spp.; control; Cerrado; Brazil.

1. INTRODUCTION

Soybean is among the crops of greatest economic relevance to agriculture Brazil in the 2020/2021 harvest remained the largest soybean producer in the world, surpassing the production of the 2019/2020 crop with an increase of one million tons, thus again achieving a record harvest with a total production of 134 million tons [1].

However, there are some limiting factors, such as the incidence of pests and diseases, among these are diseases caused by nematodes, which are standing out for the severity of the damage caused in crops [2].

In a study carried out in the Cerrado of Tocantins, the soybean x Mombasa and soybean x ruziziensis consortium showed beneficial results for biomass production, soybean grain development, and production [3].

However, despite the numerous benefits for current agriculture, the no-tillage system (SPD) provides ideal conditions for the development and reproduction of phytonematodes, such as *Meloidogyne incognita* and *Meloidogyne javanica* that find ideal temperature and humidity conditions for reproduction during the period of susceptible culture. Thus, eradication becomes very difficult and control requires appropriate management strategies [4].

The nematodes of the *genus* *Meloidogyne* can cause levels of economic damage in various cultures around the world, especially in tropical and subtropical climate regions [5]. The release of esophageal secretions in the vegetable promotes hypertrophy in the roots, reaching a diameter equivalent to twice or triple the normal [6], impairing the transport of nutrients, leaf yellowing, and plant development [7].

Naturally, if the reproduction factor of nematodes in the plant is high, the populations of these parasites tend to increase, reaching such high densities as to hinder control and harm following crops. Second [8] the crop rotation system is efficient when the previous crop controls the population increase of nematodes, preventing potential damage to the next crop.

Being able to assist with the collection of information and thus indicate effective planning for their control, which is by crop rotation, chemical or biological. The main objective of this

study is to assist in the search for information on the management of nematodes adequate to improve soybean production systems.

2. METHODOLOGY

The present work used the method based on the article Experimental Planning Factorial: A brief review [9], published in the journal International Journal of Advanced Engineering Research and Science (IJAERS).

To identify articles that talk about nematodes, soybeans, cerrado, management systems, searches were performed in the Databases PubMed, ScienceDirect, Scielo, Google Scholar, Dialnet, WorldWideScience.org, Tandfonline, Dialnet, Microsoft Academic, DataSus and the Ministry of Agriculture (MAPA).

In the present study, the research strategy on the subject consisted of the use of the keywords in English: 1. *Meloidogyne* ssp. in Brazil; 2. Nematode control systems; 3. Impacts of nematodes on soybean crop; 4. Sensitive socioeconomic factors. The following filters have been added to the search in ScienceDirect: only journals; title, abstract; Keywords.

After consulting all the databases and using the search strategy adopted, repeated articles were identified between the different data sources. The criteria and filters for the inclusion of the articles in this work were: Original research articles that conceptualize the relationship between soybean and nematode methods in different types of research areas, including research completed in the current languages: Portuguese, English, and Spanish.

The studies taken from the study were grouped in the following order: repeated, irrelevant, other publication formats (*edict, short communications, perspectives, letters*), and other languages that were not well understood. In addition, manual searches were performed in bibliographic references of the review articles found with the previously predetermined keywords.

3. RESULTS AND DISCUSSION

Therefore, given the different searches in the databases, 51 articles were found that cover the theme addressed in this study. After the removal of the duplicate articles, the exclusion criteria were applied, as shown in figure 1. Of the total number of articles studied, 19 of them were

removed according to the adopted criteria. Nine duplicate articles were excluded and 3 original research articles were retrieved. Finally, 2 more articles were retrieved through manual search (Fig. 1).

3.1 Nematodes and Soybean Crop

Nematodes are organisms widely distributed in the soil, evidencing great taxonomic diversity and eating habits [10]. Its shape is a worm and often attacks the roots of plants, and this generates great damage to the root system, in its attacks occurs injection of toxins in the root system deforming them and affecting their development leaving them unable to perform their physiological functions, and reducing the absorption of water and nutrients, which are fundamental for the continuity of the life cycle of the crop [11]. Gall nematodes *Meloidogyne incognita* and *Meloidogyne javanica* are the most important species for soybean cultivation in Brazil. *Meloidogyne javanica* has widespread occurrence, while *Meloidogyne incognita* predominates in areas previously cultivated with coffee or cotton [12].

In soybean crops attacked by gall nematodes, stains are usually observed in groups, where the plants become small and yellowish. The leaves of the affected plants sometimes present chlorotic spots or necrosis between the ribs, characterizing the leaf "carijó" (Table 1). There may not be a reduction in plant size, but at the

time of flowering, there is an intense miscarriage of pods and premature ripening of plants [13].

3.2 Nematode Management

Due to the specific characteristics of nematodes, such as their resistance structures and the fact that they are a soil inhabitant, they make efficient control methods impossible for their eradication. However, the use of appropriate measures, as well as the internalization of forms of control, allows the farmer to reduce the population or even control the nematode at population levels that allow coexistence, phytoparasitism, and host, without loss of productivity [18].

3.3 Chemical Control

Chemical control is one of the most used control measures for reducing the nematode population due to the contact effect, preventive action (systemic effect) that gives the plant tolerance to fitonematoid attack, and also the practicality of applying 5 phytosanitary products (seed treatment or planting groove) [19]. At the moment there are ten registered nematicides and three insecticides with a recommendation in the package leaflet for the control of nematodes in the Ministry of Agriculture, Livestock and Supply, whose active ingredients are abamectin, dazomete, fluensulfona, metam-sodium, terbuphos, thiodicarbe, imidacloprid + thiodicarbe, fluopyram, and cadusaphos [20].

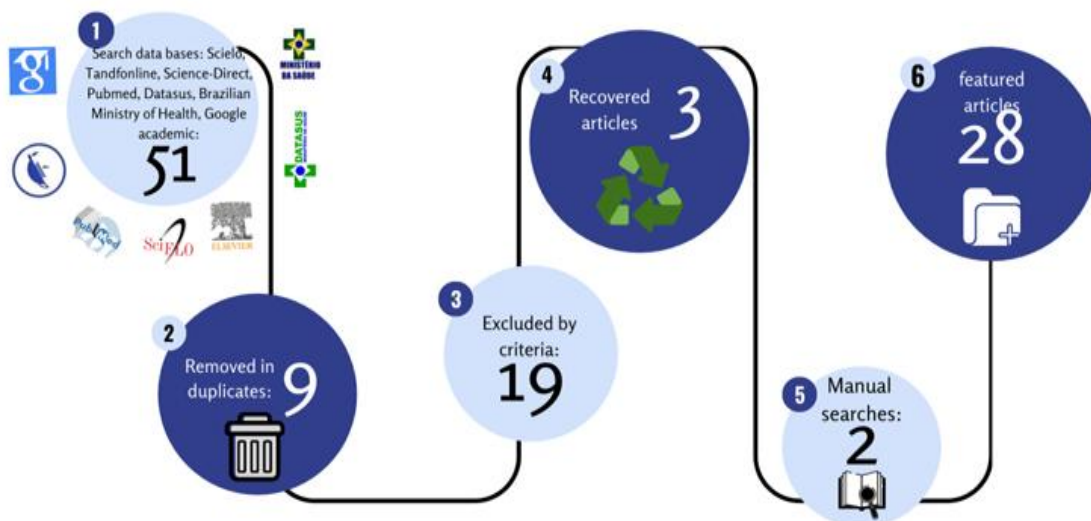


Fig. 1. Flowchart of identification and selection of articles prepared by the authors, 2022

Source: Prepared by the author (2022)

Table 1. Characteristics of the main phytonematodes in soybean culture and symptomatology in plants attacked in roots or shoots

Nematode	Morphology	Symptomatology
Gall nematode (<i>Meloidogyne</i> spp.)	• Females with endoparasite behavior and sedentary at the root, globose, milky color. The shape infectious is the 2nd stage juvenile (J2).	• The roots produce galls due to the expansion of cells of the vascular cylinder. The leaves present yellowing and necrosis between the ribs.
Cyst nematode (<i>Heterodera glycines</i>)	• Endoparasite and sedentary females, however, it may be observed a part of his body out of the Roots. The cyst is the female who after completing her cycle (death), departs from the roots and stays in the soil, containing eggs inside, which remain viable for several years. The infective form is the 2nd stadium (J2).	• Groups of atrophied (nanism) and chlorotic plants, and maybe confused by nutritional deficiencies.
Nematode-reniform (<i>Rotylenchulus reniformis</i>)	• Semi-endoparasite and sedentary females increase in size and acquire the shape of a kidney. The infectious form is the female adult.	• Occurs in groups, where we notice yellowing of leaves, reduction in the size of plants, and production decrease.
Injury nematode (<i>Pratylenchus</i> spp.)	• Endoparasite and migratory individuals. The body is fusiform. The infective form corresponds to all individuals after hatching (2nd, 3rd, and 4th stages and adults).	• Necrosis and rot in the root system, favoring the entry of fungi and bacteria. In the aerial part, severe reduction of gait or death is observed.
Nematode <i>Scutellonema brachyurus</i>	• They are considered root ectoparasites, although there are many reports such as endoparasites in the deepest cortical layers.	• Roots have darkened lesions the roots, similar to those caused by the lesion nematode.
Spiral nematode (<i>Helicotylenchus dihystera</i>)	• They are considered as root ectoparasites, although there are many reports such as semi endoparasites and even endoparasites mig	• Darkened lesions on the roots, similar to those caused by injury nematodes

Source: [6,14–18].

The treatment of seeds with chemicals used to control nematodes was evaluated by [21] for the initial population of 1,000 and 6,000 specimens. The result was a reduction in the number of nematodes per gram of root by about 41% and 65%, respectively. In the work of [22], there was also a significant reduction in the population of nematodes with the use of abamectin and imidacloprid + thiodicarib applied in the treatment of seeds.

Nematicides have a wide spectrum of action, being extremely toxic and persistent, being a great risk to the environment. The concentrated application in the treatment of seeds represents a reduction of this risk, however, there is still the possibility of resistance of phytoememaall to products that restrict the use of this control

method [23, 24]. However, control through pesticides remains a viable resource for the farmer, provided that it is applied correctly and recommended in situations that justify such use. This is because the use of this type of control causes population reduction in a sufficient period of time for the occurrence of good initial development of the crop and, consequently, higher productivity [25].

3.4 Biological Control

The use of living organisms as bioproducts is gaining increasing prominence in world agriculture, and these represent a range of biological-based substances that act in the control of pests and diseases, through different mechanisms of action [26].

The microorganisms that have been standing out in the research on the control of nematodes are *Trichoderma asperellum*, *T. harzianum*, *Bacillus methylotrophicus*, *B. amyloliquefaciens*, *B. subtilis*, *Purpureocillium lilacinus*, *T. harzianum*, *Pochonia chlamydosporia*, *Beauveria bassiana*, and *Metarhizium anisopliae*. In Brazil, to date, there are 14 microbiological nematicides recorded in Ministry of Agriculture (MAPA) [20].

Some characteristics are essential in the choice of these microorganisms as control agents of phytopathogens, among them: not being pathogenic to plants, humans, and other animals; ability to reduce the high density of nematodes; survive on the ground in extreme conditions, even without the presence of the host; parasitizing several species of phytonematodes; high dissemination capacity in the soil; ease of production and economically viable; compatible with fertilizers, pesticides, and other cultural practices; remain infectious over storage time [27].

3.5 Cultural Control

Cultural control is based on a series of practices that aim to keep the nematode population below the economic damage threshold. Within cultural control, crop rotation is cited as one of the main activities, which consists of alternating different plant species (preferably from several botanical families) in the same area and the same growing season [28].

Although this is the practice that guarantees the best results for the management of nematodes, it is not always feasible for the producer who opts for the succession system. Even without conferring the same results, the rotation of the crop of succession to soybean, that is, of the second crop, is a practice that allows the producer to live with nematodes, especially if allied to other management strategies [28].

In the rotation and/or succession system, antagonistic plants, non-host plants or bad hostesses can be adopted, also called unfavorable hostesses, one of the main crops indicated for the control of nematodes is *Crotalaria* and, within the genus, the most used species are *C. spectabilis*, *C. ochroleuca*, *C. juncea* and *C. breviflora*. The species *C. spectabilis* is characterized by antagonism to the main nematodes of the soybean crop, thus being one of the most planted [28].

4. CONCLUSION

The phytoparasitic nematodes most often associated with soybean cultivation are *Pratylenchus Brachyurus*, *Meloidogyne arenaria*, *Meloidogyne javanica*, *Meloidogyne incognita*, and *Heterodera glycines*.

There is no single solution or a single control for this pest, making it necessary to join different methods, being chemical, biological, and cultural, thus being able to obtain maximum efficiency in the control of this pest.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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