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PARASITIC NEMATODES IN FLOWERING AND ORNAMENTAL PLANTS: EFFECT OF PARASITES ON THE PLANTS AND RESPONSE OF THE PLANTS TO THE PRESENCE OF NEMATODES

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Parasitic Nematodes in Flowering and Ornamental Plants: Effect of Parasites on the Plants and Response of the Plants to the Presence of Nematodes. Sigariova, D. D., Karpliyk, V. G. — We studied the composition of the parasitic nematodes in the flowering and ornamental plants cultivated at the greenhouse facilities in the city of Kyiv. We found 9 species from the genera *Meloidogyne* Goeldi, 1887, *Ditylenchus* Filipjev, 1936, *Pratylenchus* Filipjev, 1934, *Rotylenchus* Filipjev, 1936, *Tylenchorhynchus* Cobb, 1913, *Helicotylenchus* Steiner, 1945, *Paratylenchus* Micoletzky, 1922, and *Heterodera* Schmidt, 1871. We also discovered the nature of the external manifestations of the nematodes' effect on the plants and the plants' response to the infection. Special attention was paid to the loss of the ornamental properties. In order to rank the loss of the ornamental properties of the plants under nematode infection, the scale (ranking system) was suggested. It includes 5 grades applicable to the exterior appearance of the plants, where "5" stands for "excellent"; "4" stands for "good" "3" stands for "satisfactory"; "2" stands for "unsatisfactory"; and "1" stands for "bad". The joint parasitic activity of two nematode species (*D. dipsacii* and *R. robustus* in asparagus, and *D. dipsacii* and *M. incognita* in begonia) caused the highest level of infection progress observed (4 points), and this resulted in worsening of the exterior appearance of plants and in decrease of their ornamentality/ornamental properties down to "bad" (1 point). The parasitic activity of *P. penetrans* in coleus coincided with a high degree of the infection progress (3 to 3.5 points) while the ornamental properties of the plants corresponded to the gradations identified as "unsatisfactory" (2 points) and "bad" (1 point).

K e y w o r d s: phytoparasitic nematodes, phytohelminthiasis of flowering and ornamental plants.

Паразитические нематоды цветочно-декоративных растений: влияние паразитов на растения и реакция растений на присутствие нематод. Сигарева Д. Д., Карплюк В. Г. — Изучен состав нематод в цветочно-декоративных растений, выращиваемых в тепличных хозяйствах Киева. Обнаружено 9 видов из родов *Meloidogyne* Goeldi, 1887, *Ditylenchus* Filipjev, 1936, *Pratylenchus* Filipjev, 1934, *Rotylenchus* Filipjev, 1936, *Tylenchorhynchus* Cobb, 1913, *Helicotylenchus* Steiner, 1945, *Paratylenchus* Micoletzky, 1922 и *Heterodera* Schmidt, 1871. Выявлена также природа внешних проявлений действия нематод на растения и ответ растений на инфекцию. Особое внимание было уделено потере декоративных свойств растений. Для того чтобы ранжировать потери декоративных свойств растений при нематодозах, был предложен масштаб изменений (система ранжирования). Она включает в себя 5 степеней, применимых к внешнему виду растений, где «5» соответствует «отлично»; «4» — «хорошо»; «3» —«удовлетворительно»; «2» —«неудовлетворительно» и «1» означает «плохо». Совместное паразитарное действие двух видов нематод (*D. dipsacii* и *R. robustus* на аспарагусе, *D. dipsacii,* и *M. incognita* на бегонии) дало наивысший уровень развития заболевания (4 балла), что привело к ухудшению внешнего вида растений и снижению их декоративности/декоративных свойств, вплоть до «плохого» (1 балл). Паразитная активность *P. penetrans* на колеусе совпадала с высоким баллом развития инфекции (от 3 до 3,5 баллов), а уровень декоративности растений совпадал с градациями — «неудовлетворительный» (2 балла) и «плохой» (1 балл).

К л ю ч е в ы е с л о в а: фитопаразитические нематоды, фитогельминтозы цветочно-декоративных растений.

Introduction

The role of nematodes in the life of ornamental plants is complex, manifold, and not fully studied yet. Even randomly selected data show that a number of parasitic nematodes belonging to the species *Ditylenchus* Filipjev, 1936, *Meloidogyne* Goeldi, 1887, *Aphelenchoides* Fischer, 1894, *Pratylenchus* Filipjev, 1934, *Rotylenchus* Filipjev, 1936, *Paratylenchus* Micoletzky, 1922, *Heterodera* Schmidt, 1871, *Tylenchorhynchus* Cobb, 1913, *Tylenchus* Bastian, 1865 and some other are capable of causing significant damage to flowering and ornamental plants, especially during the period of growing of the planting material at seedbeds, greenhouses, and growth rooms.

The nematode damage to plants usually occurs as mechanic deformation of cells and tissues, physiological transformation of parameters, inoculation of fungal and bacterial microbial flora, transmission of viral infections, and disturbances of the symbiotic linkage to the mycotic fungi, and others (Hubin, 2013).

Some of nematode species remain in soil for the most of time (ectoparasites) and others can be found in different parts of plants (endoparasites). The first group is represented by the *Ditylenchus* and *Pratylenchus* genera since they live and multiply inside of the tissues of the root system (the *Pratylenchus*) and inside of stems and leaves (the *Ditylenchus*). The *Meloidogyne* and *Heterodera* genera are mezoparasites since they live partly immersed in the roots of plants. As to the representatives of *Rhotylenchus, Tylenchorhynchus, Helicotylenchus,* and *Paratylenchus* genera, they are viewed as ectoparasites since they live and multiply in soil and, the same time, consume the contents of the cells in the root system.

As the endoparasitic nematodes travel inside of the tissues of the host plant, they do mechanical damage to the plant and cause destruction, formation of necrotic spots, and death of individual cells (Kiryanova, Krall, 1969). Besides, the digestive enzymes produced by the nematodes lyze the tissues and also cause disturbances to the metabolic activity and to the homeostasis of plants in general. It all can finally result in the retardation of the damaged tissues of a plant in terms of growth and development, and in the deformation of roots, stems, and leaves, and in the dieback of separate parts of a plant, or can lead to the death of a strongly damaged plant. Often the formation of buttons is retarded, the blooming is disturbed, and some of the flowers may be deformed and their quantity may be decreased. This has an essential impact on the quality of the products and is especially not desired when the breeding of flowering plants is in scope.

The *ectoparasitic* nematodes do less harm to plant tissues as they cause the formation of necrotic spots only at the places where they stick to a plant for feeding, and they also produce wounds, erosions, and deformation of roots throughout the entire root system. A great number of nematodes in the root zone of a plant (the rhizosphere) cause the destruction to the root system accompanied by the overall disturbances in the metabolic activity to a greater extent as compared to the impact of the *endoparasitic* nematodes. There are inoculations and penetration of pathogenic microflora, viruses, and fungi thru the wounds. This all influences the exterior appearance, ornamental properties, and blooming capabilities of the plants, which is a much undesired thing, in fact.

The plants normally respond to the invasion of nematodes with inhibition and retardation of growth and dieback of separate parts of a plant. However, in contrast to agricultural plants where nematodoses cause the loss of crops in terms of weight and in some other terms as determined by the correlative linkage to the quantity of parasitic nematodes, such an approach is not acceptable when it comes to the nematodoses in flowering and ornamental plants since the ornamental properties cannot be interpreted in terms of weight and thus require some other criteria to determine how the ornamental properties are lost.

The symptoms of the nematode damage to plants can take the forms of dwarfism, redtops of leaves and acerose, deformation and thinning of stems, and surface wilting, while the most serious symptoms are the reduction and malformation (distortion) of the root systems. Such symptoms are not specific and can be caused by low fertility of the ground, droughts or excessive moisture, or can be caused by insects, fungi or bacteria (Hubin, 2013; Kiryanova, Krall, 1969; Matveeva, 1989).

However, there are also some specific symptoms an unaided eye can detect in the roots of flowering plants. Among them mentioning is deserved by gall formation (hyperplasia), which develops in the event of damage to the root systems caused by gall eelworms (the *Meloidogyne* genus). The spot necrosis should also be mentioned here, since it is the most widespread reaction of plants to the nematode penetration, and it can be caused by ectoparasites (*Rotylenchus*, *Tylenchorhynchus, Helycotylenchus, Paratylenchus,* and others) as well as by endoparasites (*Pratylenchus* and *Ditylenchus*). The ectoparasites consume the external sections of the root systems of plants while the endoparasites bolt into the tissues of the absorbing roots. Necrotic spots are formed in the places of ectoparasites and endoparasites penetration (Hubin, 2013; Decker, 1972).

The purpose of our research was to study the particularities of the relationship between nematodes and flowering plants, the external manifestations of nematode infection of the plants, and the role of nematodes in decreasing the ornamental properties of flowering plants cultivated at greenhouses.

Material and method

Our study encompassed the infection of various species of nematodes in the flowering and ornamental plants cultivated at the greenhouse facilities in the city of Kyiv. The greatest attention was dedicated to the manifestations of suppression and fallout of individual plants and to the changes in the physiological

condition of the ornamentality of the plants. The collection of plant and soil samples was carried out in accordance with the methodology generally accepted in nematology (Goodey, 1959; Kiryanova, Krall, 1969). In the laboratory, plant samples were washed up in order to remove the soil particles. The female specimens of cyst nematodes and galls along with the wounds and necroses caused by other nematode species were observed. On leaves and stems, the attention was focused on the spots and corrugations caused by *Ditylenchus* (stem nematodes) and *Aphelenchus* (foliar nematodes). The height and the development degree of the plants were measured and recorded. Nematodes were extracted through the watering pot approach out of the soil samples of 20 cm^3 and out of the root samples of 3–5 g. The identification of the species composition and the calculation of the nematode quantity were conducted from the temporary hydroglyceric slides with the aid of the MBI-15 microscope (Goodey, 1959; Sigareva, 1986). The quantity of the parasitic nematodes was juxtaposed with the symptoms of the damage, and the nematode disease progression degree was determined through the 5-grade scale we developed (Matveeva, 1989). The exterior appearance and the ornamental properties of the plants were assessed.

Results and discussion

Four plant species: coleus (*Plectranthus scutellarioides* (L.) = *Coleus blumeii* Benth), begonia (*Begonia hiemalis*), asparagus (*Asparagus densiflorus* Kunth), and dahlia (*Dahlia variabilis* (Willd.)) were examined. The parasitic nematodes detected belonged to *Meloidogyne*, *Ditylenchus*, *Pratylenchus*, *Rotylenchus*, *Tylenchorhynchus*, *Helicotylenchus*, *Paratylenchus*, and *Heterodera* genera (table 1).

In the material collected, the most widespread were *Ditylenchus dipsaci* (Kuhn, 1857) Filipjev, 1936; *D. destructor* (Thorne, 1945), *Meloidogyne incognita* (Kofoid et White, 1919) Chitwood, 1949, *Pratylenchus penetrans* (Cobb, 1917) Filipjev et Sch. Stekhoven, 1941, and *Rotylenchus robustus* (deMan, 1876) Filipjev, 1936.

To the best of our knowledge, the available literary sources contain no information as to the grades of the ornamental properties. In our research, we produced a five-level gradation to describe the loss of the ornamental properties of flowering plants and juxtaposed it with the five-grade scale of the nematode disease progression. The large populations of parasitic nematodes caused invasion foci in the form of nematodoses in flowering plants

Table 1. Nematode species that inhabit ornamental plants grown in the utilities on the content of green space area of Kyiv

No.	Nematode species	Host plant	District
1	*Meloidogyne incognita*	*Plectranthus scutellarioides*, *Begonia hiemalis*, *Dahlia variabilis*	Desnianski, Obolonski, Podilski, Golosiyivski
2	*Ditylenchus dipsaci*	*Plectranthus scutellarioides*, *Asparagus densiflorus*, *Begonia hiemalis*	Desnianski, Obolonski, Podilski, Golosiyivski
3	*Ditylenchus destructor*	*Dahlia variabilis*	Podilski
4	*Rotylenchus robustus*	*Plectranthus scutellarioides*, *Asparagus densiflorus*, *Begonia hiemalis*, *Dahlia variabilis*	Desnianski, Podilski
5	*Pratylenchus penetrans*	*Plectranthus scutellarioides*, *Begonia hiemalis*, *Dahlia variabilis*	Desnianski, Obolonski, Podilski, Golosiyivski
6	*Tylenchorhynchus claytoni*	*Plectranthus scutellarioides*, *Begonia hiemalis*, *Dahlia variabilis*, *Salvia divinorum*	Desnianski, Obolonski, Podilski, Golosiyivski
7	*Helicotylenchus dihystera*	*Plectranthus scutellarioides*, *Begonia hiemalis*, *Dahlia variabilis*, *Salvia divinorum*, *Ageratum houstonianum*, *Alternanthera bettzickiana*, *Impatiens balsamina*	Desnianski, Obolonski, Podilski, Golosiyivski
8	*Paratylenchus nanus*	*Plectranthus scutellarioides*, *Dahlia variabilis*, *Echeveria elegans*, *Geranium sanguineum*, *Anthurium scherzerianum*, *Iresine herbstii*	Desnianski, Obolonski, Podilski, Golosiyivski
9	*Heterodera fici*	*Ficus benjamina*	Sviatoshinski ("Terra Flor" Co.)

Table 2. The scale to determine the loss of the ornamental properties of flowering plants caused by nematodoses

Disease Progression Points	Exterior appearance of a plant					Points of ornamental properties	Degree of ornamental properties
	Meloidogynosis (caused by *M. incognita*)	Ditylenchosis (caused by *D. dipsaci*)	Pratylenchosis (caused by *P. penetrans*)	Rotylenchosis (caused by *R. robustus*)	Ditylenchosis (caused by *D. destructor*)		
0	Healthy plants	Healthy plants	Healthy plants	Healthy plants	Healthy plants	**5**	Excellent
1	Small galls (1 x 1 mm), both separate and all over the roots.	Occurrence of corrugation on leaves and partial deformation of stems.	Occurrence of small yellow and brown elliptic stains in roots and insignificant retardation of growth.	Occurrence of brown stains on the ends of the roots. Insignificant retardation of growth	Occurrence of separate impressed stains on bulbs.	**4**	Good
2	Small galls of 10 to 30 in quantity and larger galls (2 x 2 mm) of less than 10 in quantity. When the first syngalls occur, their diameter does not exceed that of the roots by more than 2 to 4 times.	Retardation of growth. No offspring is produced from lateral gemmed. Twisted leaves and stems.	Necrotic stains conjoin to produce ulcerations. Ends of leaves become yellow. Retardation of growth occurs.	The stains transform into small areas of necrosis. Chlorotic signs occur.	The number of the impressed stains increases; ulcerations occur in bulbs; and retardation of growth occurs in bulbs.	**3**	Satisfactory
3	If at lease one large syngall occurs with the diameter 10 times greater than that of the root.	Inhibition of growth; excessive tilling capacity; corrugation and tuberosity of leaves; chlorotic signs.	The damaged tissues of the root become necrotized. Chlorotic signs and fading occur in leaves.	The damaged tissues of the root become necrotized. Yellowish areas and fading occur in leaves.	The stains become larger and take the form of slough-like ulcerations. Bulbs become deformed. Insignificant retardation of growth occurs.	**2**	Unsatisfactory
4	Small and medium-size galls of more than 20 in quantity. There are large galls with diameter 10 times greater than that of the root. Such galls are yellowish and are at the phase of decomposition.	Significant retardation of growth and deformation of the sections of a plant above the ground. There are bulges, distortions, and corrugations in leaves and stems and there are dropouts of separate loci.	The ulcerations conjoin to occupy the entire young root and fissures occur. The root system acquires unkempt appearance. The growth is retarded, and chlorotic signs and fading occur.	The ulcerations conjoin to occupy the entire young root, which becomes dark-brown. The growth is retarded, and chlorotic signs and fading occur.	Large number of slough-like ulcerations, bulbs are seriously deformed. The growth is retarded and chlorotic signs occur.	**1**	Bad

with specific external manifestations. In order to rate the nematode-caused losses of the ornamental properties in ornamental plants, we developed a scale based on the changes in the exterior appearance of plants depending on different phases of progression of the respective nematodoses. The proposed scale has five grades to describe the condition of a plant: 5 for "excellent"; 4 for "good"; 3 for "satisfactory"; 2 for "unsatisfactory"; and 1 for "bad" (table 2).

The four researched plant species had strongly different degrees of parasitic nematode infection for different greenhouse locations and they also corresponded to different stages of progression of nematodes.

We matched the quantity of various nematode species registered at particular greenhouse facilities to the condition of the plants determined by their exterior appearances, analyzed the results obtained, and determined the respective invasion progression degrees and their impacts on the ornamental properties of the plants.

D. dipsaci and *M. incognita* were the most malignant for begonia and asparagus, reaching the largest quantities in the samples collected at the greenhouses of the greenbelt maintenance company in Desnianski District of the city of Kyiv. They were detected in begonia, with the average numbers being 1082 and 1020 specimens per 100 cm^3 of soil and 380 and 20 specimens per 1 g of the roots. Asparagus showed a big number of *D. dipsaci* (2153 specimens per 100 cm^3 of soil and 42 specimens per 1 g of the roots). These plants demonstrated the maximum progression of ditylenchosis (4 points) and the decrease in the ornamental properties down to the "bad" level (1 point).

A significant number of *M. incognita* was detected at the greenhouses run by the GBMC's in Obolonski and Podilski Districts (with 550 and 400 specimens per 100 cm^3 of soil and 704 and 100 specimens per 1 g of the roots, respectively). This resulted in an intensive progression of the disease (3.5 to 3 points) and in the decrease in the ornamental properties down to the "a" (1 point) and "unsatisfactory" (2 points) levels.

The *D. destructor* we found in dahlia in Podilski District was smaller in quantity. This matched to some better exterior appearance of the plants and to a lower degree of disease progression, which is 1 point, and also to a higher level of the ornamental properties being "4" ("good").

The specific signs of the parasitic activity of *R. robustus* were detected in the roots of asparagus at the greenhouses of Desnianski District. Here, the numbers of *R. robustus* were 359 specimens per 100 cm^3 of soil and 29 specimens per 1 g of the roots. The rotylenchosis infection of the asparagus coincided with the simultaneous progression of another type of nematodoses in these plants caused by *D. destructor*, localized in the sections of a plant above the ground. This aggravated the disease progression, with its degree being "4" while the level of the ornamental properties went down to "bad" (1 point).

The most significant signs of pratylenchosis were found in coleus grown at the greenhouses in Desnianski District (the mother plantation) and in Golosiyivski District. The numbers of *P. penetrans* were 510 and 410 specimens per 100 cm^3 of soil and 21 and 113 specimens per 1 g of the roots, respectively. The infection progress degree fluctuated between 3.5 and 3.0 points while the level of the ornamental properties dropped down to 1.5 ("bad") and 2.0 ("unsatisfactory").

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