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Pathogenic Effects of the Genus *Meloidogyne* Goeldi, 1892 (Nematoda) on the Root Morphology and Tissue of Medicinal Dandelion (*Taraxacum Officinale* Wigg.)

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Abstract This article presents the anatomical structure of the roots of medicinal dandelion (*Taraxacum officinale* Wigg.) affected and unaffected by nematodes of the genus *Meloidogyne* Göeldi, 1887. In the unaffected dandelion roots, biologically active compounds were found to be located in the cortical parenchyma, phloem fibers, and laticiferous vessels. In contrast, in the roots affected by root-knot nematodes, giant cell formations known as root galls were observed in the cortical parenchyma and secondary xylem of the woody tissue. It was determined that in the cortical parenchyma of both primary and lateral roots, 6 to 8 oothecae developed in the giant cells, containing numerous oval-shaped mature eggs. Under the pathogenic influence of the nematode, the damage centers in the roots of the medicinal dandelion enlarged, affecting the protective and mechanical tissues as well as the vascular system. Additionally, changes such as epidermal deformation, tearing, and hypertrophic growths were observed.

Keywords *Meloidogyne* Göeldi, 1887, Medicinal dandelion (*Taraxacum officinale* Wigg.), Root tissue, Galls, Infestation, Giant cells, Cortical parenchyma, Woody tissue, Protective and mechanical tissues

1. Introduction

Nowadays, protecting promising medicinal, edible, and aromatic plants from pests and parasites is of significant importance worldwide. In the flora of Uzbekistan, 4,375 species of wild medicinal plants have been identified, of which nearly 1,200 possess medicinal properties and are used in medical practice [1]. Various pests and parasites from different systematic groups are found on medicinal plants, which negatively affect their medicinal properties. Among these parasites are phytonematodes belonging to the phylum *Nematoda*. Within this group, nematodes of the genus *Meloidogyne* Göeldi, 1887—commonly known as root-knot nematodes—parasitize the roots and cause serious damage to plants [11]. Therefore, studying the effects of *Meloidogyne* spp. nematodes on medicinal plants is of both scientific and practical significance.

Currently, significant attention is being paid to cultivating and propagating promising medicinal, edible, and aromatic plants for industrial production worldwide. In some foreign countries, the medicinal dandelion plant is being cultivated, and its raw material is being exported. Promising medicinal plant species include *Taraxacum officinale* Wigg. and *Taraxacum kok-saghyz* Rodin [13]. These plants are considered valuable sources of medicinal and food-grade raw materials.

Medicinal dandelion (*Taraxacum officinale* Wigg.) possesses healing properties. Its milky latex contains compounds such as taraxacin and taraxacerin, taraxerol, taraxasterol, andosterol, sterin, choline, saponin, ascorbic acid, carotene, apigenin, lutein, nicotinic acid, nicotinamide, 2–3% rubber substances, resins, inulin, fatty acids, essential oils, proteins, tannins, oleanolic acid, linolenic acid, palmitic acid, malic acid, mineral salts, alcohols, flavonoids, asparagine, iron salts, potassium and phosphorus salts [4,14].

Nematodes of the genus *Meloidogyne* Göeldi, 1887 are among the most dangerous pathogens parasitizing both cultivated and wild plants. It is known that nematodes of this genus can infect more than 4,000 species of vegetables, melons, cereals, legumes, industrial crops, berries, and ornamental plants [18]. While the damage caused by *Meloidogyne* spp. to many agricultural crops has been studied, their pathogenic effect

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on medicinal plants—particularly on their root tissues—has not been investigated.

For this reason, the pathogenic effects of *Meloidogyne* spp. on the root morphology and tissues of the medicinal plant dandelion (*Taraxacum officinale* Wigg.) were studied. The histological structure of healthy and infected dandelion roots was analyzed and compared.

2. Materials and Methods

The materials for this study were collected from areas where medicinal dandelion (*Taraxacum officinale*) grows, specifically along the Bogishamol highway and within the Botanical Garden in Yunusabad district, Tashkent city. Samples of medicinal dandelion roots and rhizosphere soil were collected using the method proposed by E.S. Kir'yanova and E.L. Krall (1969) [6] from designated coordinates: 41.344720, 69.310595; 41.344518, 69.312264; 41.344146, 69.314490; 41.344998, 69.310330. Root-knot nematodes were extracted from plant roots and soil using a modified Baermann funnel technique [8].

Sample fixation was carried out according to the method of A.A. Paramonov (1962) [10]. Permanent slides of root-knot nematodes were prepared by making sections through the anal–vulvar region and identifying the species using the Seinhorst technique. As controls, non-infected dandelion plants from the same sampling areas were used.

To study the anatomical structure of *Taraxacum officinale* roots, the samples were fixed in 70% ethanol. Anatomical-histological slides were prepared by hand sectioning, stained with methylene blue, and mounted using a glycerin mixture to create temporary preparations [2]. The anatomical and histological structure of the roots was examined in cross-sections. The organization of major tissues and cells was described based on the methods of K. Esau (1969) [17] and N.S. Kiseleva (1971) [7]. Microphotographs were taken using a Canon A123 digital camera mounted on a computer-adapted microscope, specifically the Motic B1-220A-3 model.

Samples were taken from both healthy and nematode-infected dandelion roots. Changes in tissue and cellular structure and function were studied using histological preparations of the root tissues.

3. Results and Discussion

As a result of the study, it was determined that the roots of medicinal dandelion (*Taraxacum officinale*) naturally growing along the highway were infected with nematodes of the genus *Meloidogyne*. These nematodes cause a disease in plants known as Meloidogynosis. External symptoms of Meloidogynosis in plants include pale or yellowish-white leaves, wilting, reduced leaf size, leaf drop, small fruits, stunted growth, dwarfism, and in severe cases, complete plant wilting. The root system becomes deformed or decayed, and characteristic galls (swellings) form on the roots [8].

During field observations, attention was paid to disease symptoms and external appearance of plants in the infected areas. Aboveground parts of nematode-infected dandelions were noticeably smaller in size and had paler leaves compared to healthy plants. Nematode infection was confirmed through examination of the root systems. Roots were excavated, cleaned from soil, and examined in detail. Morphological damage and the presence of root galls were recorded.

Currently, 97 species of *Meloidogyne* are known worldwide [5]. In Uzbekistan, five species have been identified: *Meloidogyne javanica*, *M. arenaria*, *M. incognita*, *M. acrita*, and *M. hapla* [8,12,15,16]. In this study, three species—*M. incognita*, *M. arenaria*, and *M. hapla*—were found in associative form in infected dandelion roots. The global distribution of root-knot nematodes is as follows: *M. incognita* – 52%, *M. javanica* – 31%, *M. arenaria* – 8%, *M. hapla* – 7%, and other species – 2% [3]. Therefore, the nematode species identified in our research are among the most widespread. Some species of the genus *Meloidogyne* —*M. incognita*, *M. javanica*, *M. arenaria*, and *M. hapla*— are considered major plant parasites [9]. Accordingly, the *M. incognita*, *M. arenaria*, and *M. hapla* species found in this study are also classified as primary plant parasites.

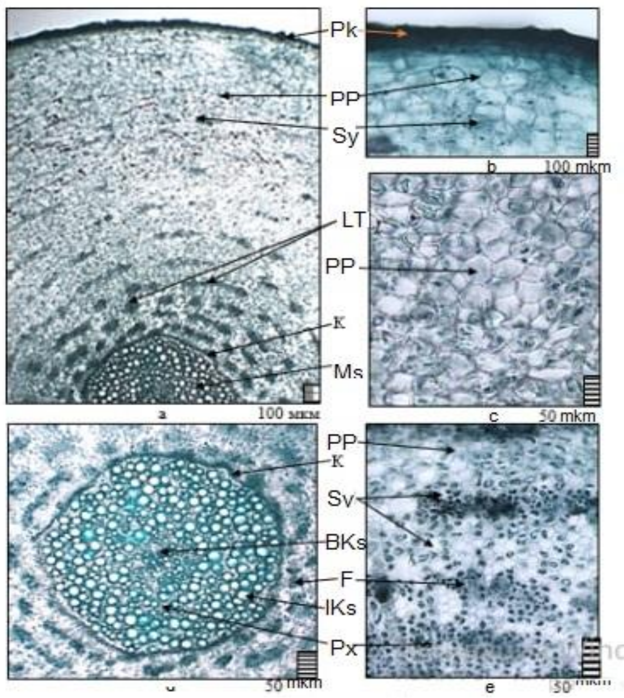
Nematodes of the genus *Meloidogyne* are sedentary endoparasites [10,19]. Their life cycle consists of four juvenile (larval) stages. The first stage (J1) occurs within the egg. The second-stage juvenile (J2), which is capable of infecting plant roots, hatches from the egg. Most invasive juveniles exit the infected root and move into the soil, while others remain in the root system. In the soil, J2 larvae become active and penetrate the plant root cortex. They settle near the vascular tissues with their head and begin feeding, then develop into third-stage (J3) and subsequently fourth-stage (J4) juveniles. As they mature, the larvae thicken and transform into spherical or pear-shaped adult females, reaching up to 1 mm in length [11].

Once the invasive juveniles penetrate the root tissue and establish themselves, they begin secreting enzymatic fluids from their digestive glands. The saliva stimulates increased cell division, dissolving cell walls, and results in the formation of giant cells—5 to 10 times larger than normal plant cells [8]. As a result of parasitic activity, not only morphological but also histological changes occur in the plant. Based on our scientific analysis, it was observed that root-knot nematodes significantly alter the structure and function of root tissues and cells.

In transverse sections, the anatomical structure of the healthy medicinal dandelion (*Taraxacum officinale*) root is round-shaped and classified as a non-stele (non-radial) type, indicating the absence of a radial structural organization. Based on its anatomical features, the root is composed of three main zones: the periderm, the cortical parenchyma, and the central cylinder.

The outermost layer of the root is covered by the periderm, which consists of the phellogen (cork cambium), phellem (cork), and phelloderm. The periderm is relatively thin and composed of dark brown cells that are tightly packed.

The cortical parenchyma is well-developed compared to the central cylinder and occupies approximately three-quarters of the root's diameter. It is composed of both large and small round to oval-shaped parenchymal cells. Within the cortical parenchyma, layers of phloem fibers and laticiferous canals (latex ducts) are arranged concentrically, in which dark brown biologically active substances were observed (Figure 1).

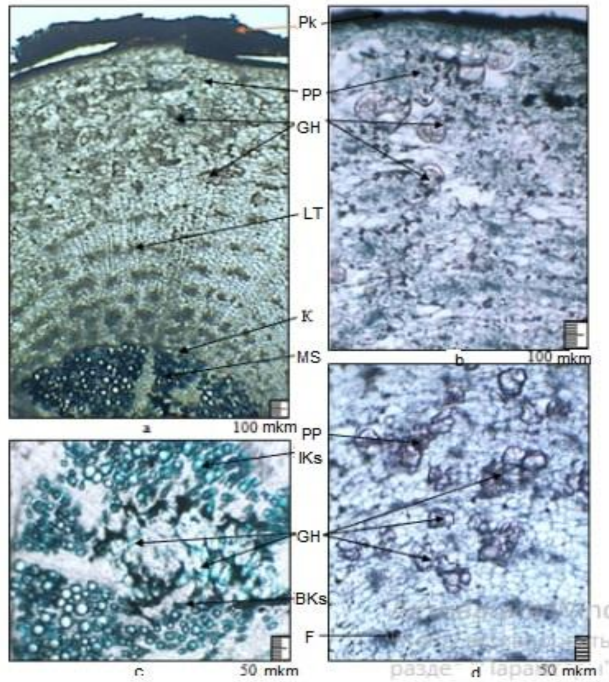


Legend:
PKs – primary xylem vessels,
IKs – secondary xylem vessels,
C – cambium,
LT – phloem fibers,
MC – central cylinder,
Pk – periderm,
PP – cortical parenchyma,
Px – parenchyma,
SY – latex vessels,
F – phloem.

Figure 1. Anatomical structure of the uninfected dandelion (*Taraxacum officinale*) root: **a** – general view of the root structure; **b, c** – cortical parenchyma of the root; **d** – xylem fibers (primary and secondary xylem); **e** – phloem fibers and latex vessels

In the outer region of the central cylinder, the boundary of the cambial cells is well developed. The cambium produces scattered tracheary xylem fibers toward the inner region. The xylem tissue consists of both primary and secondary xylem vessels of various sizes, interspersed with parenchymal cells that store inulin (Figure 1).

In the transverse sections of the main and lateral roots of *Taraxacum officinale* infected with root-knot nematodes, the anatomical structure appears round to oval in shape and remains of the non-stele type. The cortical parenchyma cells, compared to the central cylinder, show significant structural and functional changes due to nematode infestation. As a result of infection, the cortex becomes thickened due to the formation of outgrowths with giant cells in the cortical parenchyma caused by the nematodes (Figures 2, 3).

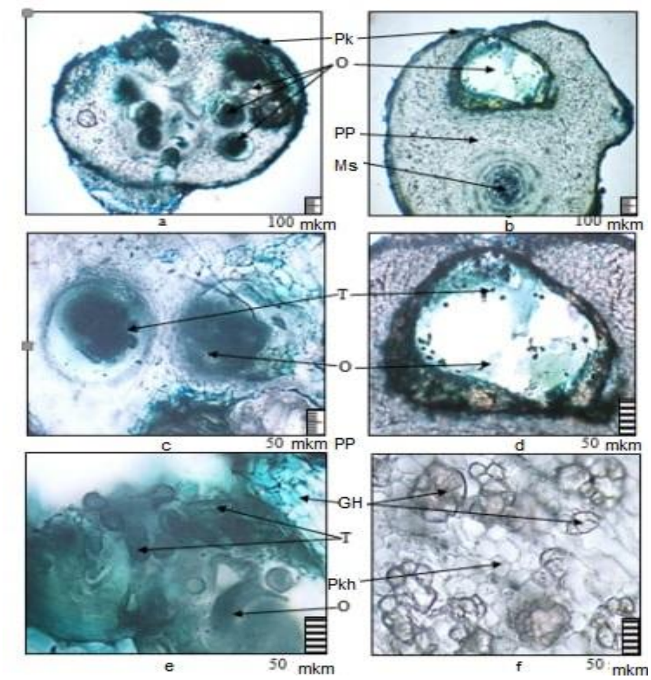


Legend:
PKs – primary xylem vessels,
GH – giant cells,
IKs – secondary xylem vessels,
C – cambium,
LT – phloem fibers,
MC – central cylinder,
Pk – periderm,
PP – cortical parenchyma,
F – phloem.

Figure 2. Anatomical structure of the primary root of dandelion (*Taraxacum officinale*) infected with root-knot nematodes: **a** – general view of the root structure; **b, c** – formation of giant cells in the cortical parenchyma of the root; **d** – giant cells between primary and secondary xylem vessels

Moreover, in the roots of infected *Taraxacum officinale*, the proliferation of cortical parenchyma and libriform tissues leads to damage of cortical cells. Additionally, the formation and multiplication of giant cells in the xylem region of the central cylinder result in tumor-like outgrowths, which can be described as root galls.

The giant cells in both the cortical parenchyma and central cylinder serve as a source of nutrition for the root-knot nematode larvae. The invasive juvenile nematode develops within the cortical parenchyma into an egg-laying female. During oviposition, the female forms an egg sac (ootheca). In infected main and lateral roots, up to 6 to 8 oothecae were observed within the giant cells of the cortical parenchyma, each containing numerous oval-shaped eggs (Figure 3).



Legend:
PKs – primary xylem vessels,
GH – giant cells,
IKs – secondary xylem vessels,
C – cambium,
LT – phloem fibers,
MC – central cylinder,
Pk – periderm,
PP – cortical parenchyma,
F – phloem.

Figure 3. Anatomical structure of the lateral root of dandelion (*Taraxacum officinale*) infected with root-knot nematodes: **a, b** – general view of the root structure; **c, d, e** – formation of giant cells and oothecae in the cortical parenchyma of the root

4. Conclusions

As a result of the study, it was determined that the roots of *Taraxacum officinale* (medicinal dandelion) naturally growing along the roadside were infected by nematodes of the genus *Meloidogyne*, specifically *Meloidogyne incognita*, *M. arenaria*, and *M. hapla*, which were found to occur in association. For the first time, the anatomical structure of both infected and uninfected *Taraxacum officinale* roots was studied, and species-specific structural diagnostic features were identified.

A comparative anatomical analysis revealed that in uninfected roots, biologically active substances were located in the cortical parenchyma, phloem fibers, and laticiferous canals. In contrast, in roots infected by root-knot nematodes, tumor-like structures with giant cells, referred to as "root galls," were observed in the cortical parenchyma and the secondary xylem of the woody tissues.

In both main and lateral roots, 6 to 8 oothecae (egg sacs) were formed within the giant cells of the cortical parenchyma, each containing numerous oval-shaped eggs. These newly identified anatomical features including the presence of outgrowths in the cortical parenchyma and giant cells in the central cylindercan be utilized for the diagnosis, treatment, and prevention of *Taraxacum officinale* root infections caused by root-knot nematodes.

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