



Scientific Research

Efficacy of summer fallow on the RKN *Meloidogyne* spp. population density in sustainable celery

Mohammed A. Shedhan¹, Hussein A. Khalaf² & Basil H. Kandouh¹

1-Department of Plant Protection, College of Agriculture, University of Kufa, Iraq

2-Department of Plant Production Technologies, Al-Furat Al-Awsat Technical University, Najaf, Iraq

ARTICLE INFO

ABSTRACT

Article History:

Received: 2025/12/13

Review: 2026/01/26

Accepted: 2026/02/01

Keywords:

Leafy greens,
post-fallow agriculture,
continuous cropping,
Galling index,
root-knot nematode

DOI: [10.48311/fsct.2026.118302.82987](https://doi.org/10.48311/fsct.2026.118302.82987)

*Corresponding Author E-Mail:
mohamedm.alssawy@uokufa.edu.iq

This study evaluated the adoption of summer fallow in celery cultivation and its impact on *Meloidogyne* spp. knot nematode densities across 24 fields in four districts of Najaf Governorate, Iraq, during October-November 2024. Data on irrigation, fertilizer, pesticides, and previous crops were collected. Results showed continuous cropping consistently led to the highest nematode infection rates, galling indices, and counts of eggs/J2 per plant and per 100g of soil. The highest field infection rate (93%) was in Mishkhab under continuous cultivation. In contrast, post-fallow fields generally showed reduced nematode levels. For example, in Suhaila, continuous cropping resulted in 316 eggs/J2 per 100g of soil, while post-fallow in Mishkhab had only 83. Despite this reduction, fallow adoption did not eliminate nematodes, as significant populations persisted, with post-fallow infection rates still reaching up to 80% in Suhaila. The findings demonstrate that while summer fallow significantly reduces nematode densities compared to continuous monocropping, it alone is insufficient for complete control. The practice's effectiveness varied by location, highlighting the influence of local edaphic and agronomic factors.

1-Introduction

Intensive monoculture practices, driven by the global demand for high-value vegetable crops, have inadvertently exacerbated soil-borne pest pressures, threatening the sustainability and profitability of production systems [1]. Among these pests, root-knot nematodes (*Meloidogyne* spp.) stand out as a pervasive and economically devastating pathogen complex, capable of inflicting significant yield losses in a wide range of horticultural crops [2]. Celery (*Apium graveolens*), a crop characterized by its extensive and shallow root system, is particularly susceptible to nematode parasitism. Infection leads to the formation of characteristic galls, impairing water and nutrient uptake, causing stunting, wilting, and ultimately reducing both marketable quality and yield. In the context of sustainable agriculture, where the reliance on synthetic nematicides is increasingly restricted due to environmental and regulatory concerns, developing effective, ecologically sound management strategies is a paramount research priority [3].

Current integrated pest management (IPM) frameworks for *Meloidogyne* spp. emphasize crop rotation, the use of resistant cultivars, and biological control [4]. However, the efficacy of these tactics can be constrained by biological and practical limitations. The host range of many *Meloidogyne* species is notoriously broad, limiting rotation options, while commercially acceptable resistant celery cultivars are not yet widely available [5]. Furthermore, the plasticity and adaptability of nematode populations can undermine biological control agents. Within this challenging landscape, cultural practices that manipulate the agroecosystem to disrupt pest life cycles have regained scientific interest for their simplicity, low cost, and alignment with agroecological principles [6].

One such foundational cultural practice is fallowing—the deliberate resting of land from susceptible host crops [7]. The underlying supposition is that by creating a host-free period, the soil population of obligate parasitic nematodes will decline through natural mortality and starvation. Summer fallow, in

particular, may be enhanced by the interaction of host absence with abiotic stressors such as elevated soil temperatures and reduced moisture, which can be detrimental to nematode survival [8]. Nevertheless, the quantitative impact of a summer fallow period on *Meloidogyne* spp. population dynamics in subsequent celery crops impact inadequately remains and appears. Critical knowledge gaps persist regarding the minimum effective duration of fallow required to achieve a biologically meaningful reduction in nematode pressure, the rate of population decline under specific edaphic and climatic conditions, and the potential for compensatory population rebound once a susceptible host is reintroduced. Moreover, the broader agroecological trade-offs of fallowing, including impacts on soil health, weed seed banks, and short-term economic returns, necessitate a holistic evaluation to assess its true viability within sustainable production systems [9].

The study aimed to conduct a field survey to evaluate the adoption of summer fallowing in celery cultivation and to assess its effect on the population densities of root-knot nematodes (*Meloidogyne* spp.) in different farms across Al-Najaf Al-Ashraf.

2- Materials and Methods

2.1. Field Survey and Sample Collection A comprehensive field survey was conducted across four major agricultural regions in southern Iraq during October and November 2024. Celery (*Apium graveolens* L.) plants exhibiting symptoms suggestive of root-knot nematode infection were systematically sampled. A total of 22 fields were surveyed: 8 fields in the Maysan District, 4 in Al-Mashkhab, 6 in the Houli Farms District, and 4 in the Suhaila region. From each field, ten plant samples, along with their root systems and surrounding soil, were collected. Detailed agronomic data were recorded for each sampling site, including irrigation water source, fertilization regime, pesticide application history, and the preceding summer crop.

2.2. Assessment of Nematode Infestation

Plant roots were visually examined for the presence of root galls to determine the field infestation rate. To quantify the severity of infection, second-stage juveniles (J2) were extracted from the galled roots. The roots were gently washed, cut into 2–3 cm segments, and subjected to a modified sodium hypochlorite extraction technique. Root pieces were shaken for 4 minutes in a 0.6% NaOCl solution (prepared as a 9:1 dilution with distilled water). The resultant suspension was poured through a nested sieve set (106 μm over 25 μm). The material retained on the 25 μm sieve was washed into 50 ml centrifuge tubes.

2.3. Nematode Extraction and Quantification

The samples were centrifuged at 1800 rpm for 5 minutes. After discarding the supernatant, the pellet was re-suspended in a 45% sucrose solution and centrifuged at 1800 rpm for 2 minutes. The nematode-rich supernatant was then poured through a 25 μm sieve to remove the sucrose, thoroughly rinsed with water, and the final residue was transferred to a counting plate. The number of eggs and second-stage juveniles (J2) of *Meloidogyne* spp. per sample was counted under a stereo microscope.

2.4. Data Integration and Analysis

The effectiveness of existing control methods and agronomic practices was evaluated by correlating nematode population density (eggs and J2 per plant) with field records of crop history, applied management practices, and observed plant health parameters.



Figure (1) B-A illustrates the deterioration of celery plants as a result of infection by the root-knot nematode *Meloidogyne* spp. C represents the second stage juvenile (J2), which is the infective stage of the *Meloidogyne* spp. Nematode.

3- Results and Discussion

The field survey across 24 fields in four districts of Najaf Governorate revealed a high prevalence of root-knot nematodes (*Meloidogyne* spp.) in celery cultivation, with infection dynamics significantly influenced by local agricultural practices. The results, summarized in Table 1, demonstrate clear patterns in infestation severity and population density based on the cropping system.

3.1. Geographic Variation in Infestation Incidence and Severity

The overall incidence of infection was highest under continuous cropping systems. The Mishkhab region exhibited the most severe infestation, with 93% of plants infected (Table 1). This elevated incidence is likely attributable to persistently high soil moisture and waterlogged conditions, which favor nematode survival and mobility. These edaphic conditions are a consequence of the

region's prevailing rice-based cropping systems, known for their intensive irrigation requirements [11]. Similarly, the Suhaila district recorded a 90% infection rate under continuous cropping. In contrast, the Maysan district showed the lowest incidence (50-72%) under the same system. A significant reduction in infestation rates was observed in fields utilizing a post-fallow agricultural system. For instance, the infection rate in Suhaila dropped from 90% (continuous) to 80% (fallow), while in Maysan, it decreased to 50-52%. This aligns with established principles where fallow periods disrupt the nematode life cycle and reduce inoculum density in the soil [7, 11].

3.2. Impact of Cropping System on Galling Index and Nematode Density

The galling index, a direct measure of root damage, further underscored the effect of cultivation practices. Continuous cropping consistently resulted in higher galling indices compared to the post-fallow system. Under continuous cropping, the most severe root galling (index 11-16) was recorded in Maysan, whereas the lowest (2-9) was in Hawli. Within the fallow system, Maysan again showed the least damage (index 2-7), while Mishkhab exhibited the highest (2-9) among fallow fields. Quantification of nematode eggs and second-stage juveniles (J2) per plant revealed substantial population differences. Under continuous cropping, the highest egg/J2 count (2,720 per plant) was found in Suhaila, and the lowest (1,840) in Mishkhab. The fallow system effectively suppressed populations, with the highest count reduced to 1,233 (Maysan) and

the lowest to 266 (Mishkhab). A similar trend was observed for the population density per 100 g of soil, where continuous cropping in Maysan yielded the highest count (243 eggs/J2), and fallow practices in Mishkhab resulted in the lowest (83 eggs/J2). This progressive suppression of population density with increased fallow duration is well-documented [13].

3.3. Synthesis and Implications for Management

The data collectively demonstrate that the continuous monocropping of celery facilitates the buildup of *Meloidogyne* spp. populations, leading to high disease incidence and severe root pathology. The integration of a fallow period into the crop sequence emerges as a critically effective cultural practice, significantly reducing all measured indices of nematode pressure—infection rate, galling severity, and soil/root population density. The geographic variation, particularly the severe infestations in rice-growing areas like Mishkhab, highlights the role of regional water management practices in exacerbating nematode issues. These findings advocate for an integrated pest management (IPM) strategy for celery production in the region. This strategy should prioritize crop rotation incorporating fallow periods, careful selection of preceding crops to avoid those that create favorable conditions for nematodes (e.g., flooded rice), and the potential integration of resistant varieties or soil amendments in high-risk areas.

Table 1. The effectiveness of the summer fallow in the percentage of the severity of the infection of the celery plant *Benematoda al-Takud Meloidogyne* spp. In different farms of Al-Najaf Al-Ashraf governorate

District	Number of fields	Type of agriculture	Type of irrigation water	Total number of samples	Number of infected samples	Infection rate	Galling Index	Number of eggs and J2/per plant	Number of eggs and J2 in 100 g of soil
Suhaila	4	fallow	river water	40	32	80%	8-3	954	120
	2	continuous	river water	20	18	90%	8-13	2720	316
Maysan	4	fallow	river water	40	21	50-52%	2-7	1233	136
	4	continuous	river water	40	29	50-72%	11-16	2440	243

Hawli	6	continuos	well water	60	33	55%	2-9	2240	176
Mashkhab	1	fallow	river water	10	7	70%	2-9	266	83
	3	continuos	river water	30	28	93%	8-14	1840	136

4- Conclusions

This study provides a comprehensive assessment of root-knot nematode (*Meloidogyne* spp.) infestation in celery crops across four major districts in Najaf. The field survey and subsequent laboratory analysis revealed that continuous celery cultivation, particularly in regions with high groundwater levels and waterlogged conditions like Al-Mishkhab, leads to severe nematode pressure, as evidenced by high infestation rates (up to 93%), elevated galling indices, and substantial egg/J2 counts. Conversely, the integration of a summer fallow period into the agricultural cycle proved to be a highly effective cultural control strategy. Post-fallow fields

consistently exhibited significantly reduced infection rates, galling severity, and nematode population densities in both plant roots and soil. The findings underscore the critical role of crop rotation and land management practices in disrupting the nematode life cycle and reducing inoculum potential. Specifically, the data demonstrate that fallowing suppresses nematode accumulation, thereby mitigating infection severity and preserving plant health. This research highlights the vulnerability of continuous celery monoculture to parasitic nematodes and establishes soil fallow as a key, sustainable component for integrated pest management in celery production systems within the region.

Acknowledgments

We would like to extend our sincere thanks to the University of Kufa for their support of this research.

Contributions of authors

M.A.S, study design, carried out experimental work, acquisition of data, proposal writing drafting and revising the manuscript, and submitted the final manuscript.

H.A.K, study design, planned methodology, read, revised, and approved the manuscript.

B.H.K, study conception, analysis of data, and drafting of the manuscript.

ORCID

M.A.S.: <https://orcid.org/0009-0005-5097-8095>

H.A.K : <https://orcid.org/0000-0003-2405-7047>

B.H.K.: <https://orcid.org/0009-0007-3110-1604>

Conflicts of interest

The authors declare that there are no conflicts of interest.

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