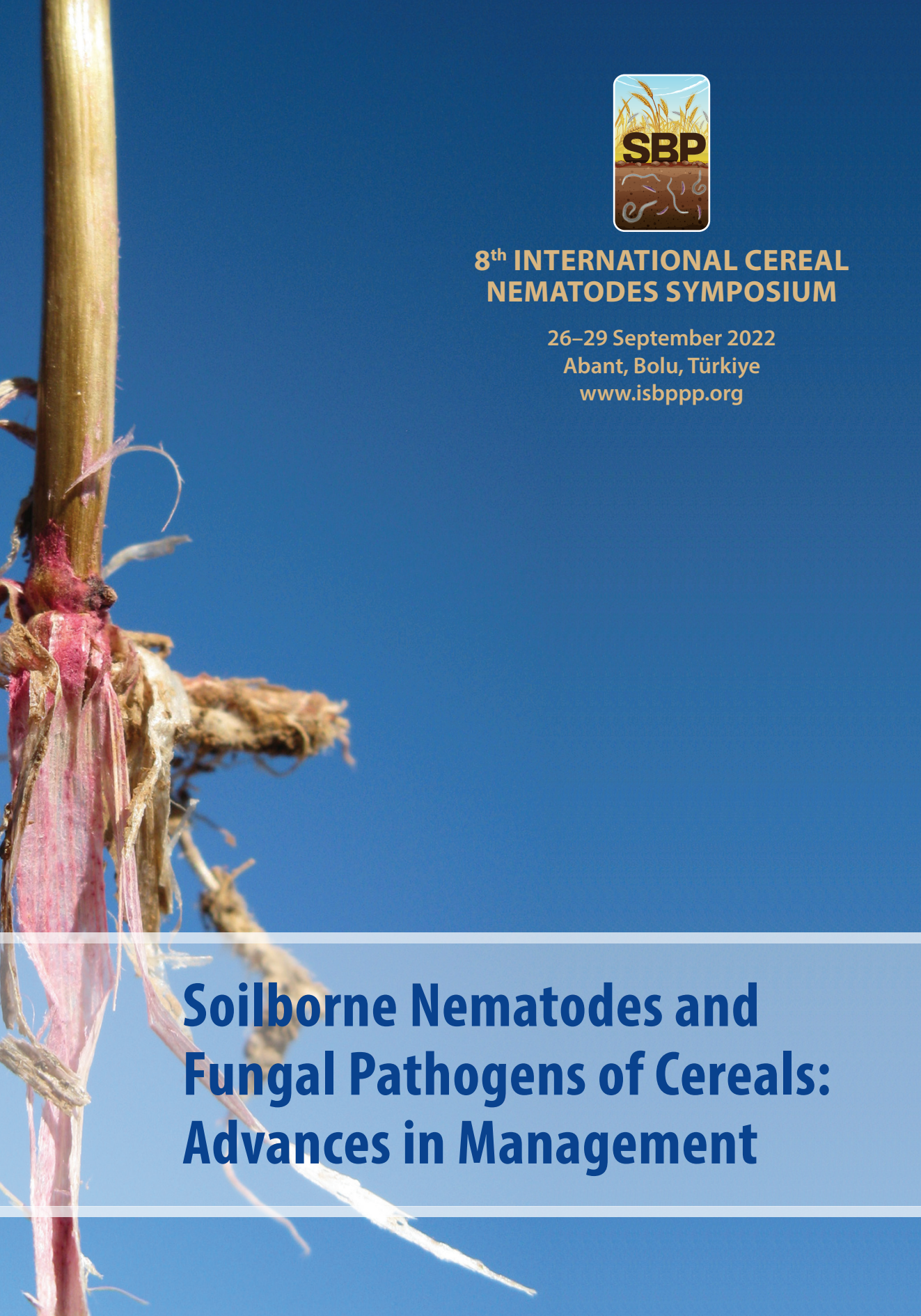


8th INTERNATIONAL CEREAL NEMATODES SYMPOSIUM

26–29 September 2022
Abant, Bolu, Türkiye
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Soilborne Nematodes and Fungal Pathogens of Cereals: Advances in Management

Soilborne Nematodes and Fungal Pathogens of Cereals: Advances in Management

Proceedings of

the 8th International Cereal Nematode Symposium

26-29 September 2022,

Abant, Türkiye

Abdelfattah A. Dababat, Zahra Tanha Maafi,
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Background: The International Cereal Nematodes Symposium (ICNS) is an extension to the International Cereal Nematode Initiative (ICNI) that was established in 2006. It aims to create a critical mass of scientific capacity and skills to deliver sustainable solutions by working at both the practical and theoretical level. It was initially founded as the International Cereal Cyst Nematode Initiative (ICCNI) and later expanded to include all-important genera of cereal nematodes (CN).

Cereal nematodes including both the Cereal Cyst Nematodes (Heterodera spp.; CCNs) and the Root Lesion Nematodes (Pratylenchus spp.; RLNs) are acknowledged as a global economic problem on wheat production systems in developing as well as in developed countries.

During the last 20 years research has been undertaken by a large network of groups including: 1) the ICWIP (ICARDA CIMMYT Wheat Improvement Program) which relates to wheat improvement research in Central Asia, West Asia and North Africa, 2) CIMMYT and the Turkish Ministry of Agriculture and Forestry in collaboration with ICARDA, and 3) our National Program partners from developing countries and several research institutions in Australia and Europe. The objectives of these groups have been to:

1. **Understand the importance and distribution of CCNs and RLNs,** which are widespread in wheat production systems throughout West Asia, North Africa, parts of Central Asia, Northern India and China.
2. **Investigate potential control options with a major emphasis on host** resistance, through validation and integration of resistant sources (traditional and molecular) into wheat germplasm for global wheat production systems (particularly focused on rainfed or supplementary irrigation systems). Rotation has been partially explored.
3. **Provide training for scientists from developing countries.** The 1st ICCNI was held in Antalya, Türkiye and proceedings can be downloaded from the following website: http://www.spipm.cgiar.org/reports. The 2nd workshop was held in Vienna, Austria and the 3rd workshop was held in Adana, Türkiye. The 4th workshop was held in Beijing, China. The 5th workshop in Ankara Türkiye and the proceeding can be downloaded from the following website: http://www.fao.org/3/a-i4934e.pdf. The 6th Symposium was held in Agadir, Morocco and the 7th Symposium was held in New Delhi, India. Those workshops were very successful in identifying the global status of the problem of cereal nematodes and forming networks and partnerships to continue working on these problems.

Because of the significant interactions between nematodes and soil borne fungal pathogens of cereals in farmers' fields, this nematode Symposium held in Türkiye included a very specialized session on fungal soil borne diseases. At the end of the meeting, the organizing committee met and explored ideas of changing the symposium name into the International Symposium of Cereal Soil Borne Pathogens (1st ISCSBP) to take place every 3 years. This Symposium will bring together researchers tasked with developing solutions to manage intractable soil borne pathogens of cereals for which there are currently limited on farm management solutions.

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Cover illustration: Characteristic symptoms of Fusarium crown rot in wheat showing browning of the lower stem and pink fungal growth. Grant Hollaway Agriculture Victoria, Australia.

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These proceedings are dedicated to

The Global Wheat Program at CIMMYT

Foreword

Small grain cereals account for approximately 20% of calories consumed globally, and about half of all crop area globally. Crops such as wheat, rice, barley, oats, rye and triticale therefore are critical to global food supply.

Organizations such as CIMMYT and ICARDA are dedicated to helping farmers in developing countries to produce more with the same amount of land, without increases to costs of production. We are striving to meet this goal through the genetic gains achieved by our breeding programs, however ending global hunger is another matter. Cereals are important sources of energy, fiber and a wide range of minerals and vitamins and as such are not only a source of calories, but critical for nutrition also. To end global hunger however, according to the Ceres 2030 report[1], an estimated USD$14 billion from funding agencies (double current funding levels) in annual investment would be required in addition to USD $19 billion from Governments in the global south and USD$50 billion from the private sector. The context of events in Ukraine, Syria, Afghanistan and very recently in Pakistan, puts even more pressure on the global food system, coping with rising food prices because of the impacts on supply and supply chains caused by conflicts and natural disasters.

Farmers also need cereal varieties that perform well in the context of a changing climate. This includes response to wide variations in temperature and rainfall as well as resistance to the pests and diseases present in their environments. Meeting the needs of farmers and consumers globally depends on our abilities to continue developing new technologies and applying them, not only in breeding, but in on-farm improvements also. CIMMYT and the Global Wheat Program have been building on the work of Nobel Peace Prize Laureate Dr Norman Borlaug since his work catalyzed the green revolution in South Asia in the 1970s. Today CIMMYT-derived varieties can be found on 60 million hectares worldwide, released by our partners around the world and providing high yielding, nutritious, climate and disease resilient varieties to farmers in Africa, Asia, and Latin America.

Soil borne diseases and in particular, plant-parasitic nematodes, are known to be a major constraint to production of small grain cereals. A recent estimate suggested that global yield losses equivalent to about 10% of global production[2] confirming the importance of a continuing research and breeding focus on mitigating damage.

This workshop will be successful if it continues to build on the progress made in the understanding and control of cereal nematodes. Since the launch of this series of workshops, under CIMMYT leadership since 2009, the community of scientists in attendance continue to dedicate themselves to understanding and mitigating the effects of plant-parasitic nematodes. The improvement of cereal productivity incorporating this knowledge continues to be important for reducing the impact they have on producers and consumers of small grain cereals.

Dr Alison Bentley
Global Wheat Program Director
CIMMYT

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[1] Ceres 2030 Report, Cornell, IFPRI and IISD World without hunger, Berlin October, 2020 https://ecommons.cornell.edu/handle/1813/72799.
[2] Dixon J, Braun HJ, Kosina P, Crouch J (Eds.). 'Wheat Facts and Futures 2009.' (CIMMYT, Mexico) https://www.researchgate.net/publication/46472222_Wheat_Facts_and_Futures_2009/link/0f317536d19f288437000000/download.

Foreword

This 8th International Cereal Nematodes Symposium continues a tradition in providing a forum for researchers to unite and share opportunities to develop improved strategies for the management of plant pathogenic nematodes. In recognition that cereal farmers, in addition to managing nematodes, are also managing soil borne fungal pathogens this Symposium includes a special session on Soilborne Plant Pathogenic Fungi. Both soil borne fungal and nematode parasites co-exist in the same ecological niche within the cereal field's ecosystem and both attack the root systems, reducing the uptake of nutrients and water, especially under conditions of drought stress. They are both widespread, insidious subterranean constraints for which there are limited genetic and/or chemical control options available making their on-farm control difficult. Furthermore, nematodes and fungi interact. They can have synergistic or antagonistic interactions. Nematodes by direct alteration of plant cells and consequent biochemical changes predispose the host plant to invasion by soil borne pathogens. Root rotting fungi can destroy the healthy host needed by obligate parasites such as cereal nematodes. For a holistic approach, we need to consider the entire biotic community in the soil, and how they affect both fungi and nematodes.

Soil borne pathogens (SBPs) are a major biotic constraint to cereal production worldwide. SBPs include microscopic root-rotting fungi and cereal nematodes, which attack roots and crowns of wheat plants, become problematic in rainfed systems where post-anthesis drought stress is common. The most important pathogens are cereal cyst nematodes, root lesion nematodes, the dryland crown and foot rot complex caused mainly by *Fusarium culmorum* and *F. pseudograminearum*. The lesion nematode *Pratylenchus thornei* has been reported to cause yield losses in wheat up to 38-85% in Australia and 12-37% in Mexico. In southern Australia, grain losses caused by P. *neglectus* ranged from 16-23% and 56-74% in some concomitantly infested areas. The cereal cyst nematodes are *Heterodera species* and the most economically important studied species are *Heterodera avenae*, *H. filipjevi* and *H. latipons*. *H. avenae*, the most damaging species on temperate cereals, is a problem worldwide and is the most studied species while *H. filipjevi* is an economically important nematode on cereals due to its widespread distributions around the world. Yield losses due to *H. avenae* ranged from 15-20% in Pakistan, 40-92% in Saudi Arabia, and 23-50% in Australia. In Türkiye, *H. filipjevi* caused up to 50% crop losses in Central Anatolia Plateau conditions and *H. avenae* up to 24% in the Eastern Mediterranean wheat growing regions.

Fusarium spp. is a globally recognized, economically important group of fungi which includes more than one hundred species causing crown rot, foot rot, root rot and head blight in wheat. Yield losses from crown rot have been recorded up to 35% in the Pacific Northwest of America and 25-58% in Australia, mounting to US$13 million and US$80 million, respectively, due to reduced grain yield and quality.

There are examples internationally where plant pathologists, plant breeders and agronomists have worked collaboratively with a shared objective and successfully developed control of yield limiting soil borne pathogens. An example of this is the development and widespread deployment of CCN resistant cereals in Australia that has led to long term control of this devastating pathogen. Through

this symposium scientists will have the opportunity to develop collaborations to further facilitate the development of on-farm strategies for control of these intractable soil borne pathogens.

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On behalf of organizers and editors

Dr Abdelfattah A Dababat
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CIMMYT (International Maize and Wheat Improvement Centre) and ICARDA (International Centre for Agricultural Research in Dryland Agriculture) are non-profit International Research Centres with the mandate to improve agriculture in developing countries as part of the Consultative Group of International Agriculture Research (CGIAR). CIMMYT's mandate is to improve the productivity of wheat and maize systems through sustainable management and improvement. The Türkiye office works in West Asia, Central Asia, and North Africa. ICARDA programs are currently coordinated from Lebanon, with technical facilities being coordinated from Jordan. ICARDA works regionally in dryland areas on cereal, legume and animal production systems, once again improving productivity of these through sound management practices. ICWIP (ICARDA-CIMMYT Wheat Improvement Program) is the collective effort of both centres to address food security for cereals in West Asia, Central Asia, and North Africa. CIMMYT and ICARDA are gratefully acknowledged for scientific leadership in research on cereal nematodes, technical input, international capacity building and financial support towards this workshop. For further information see www.cimmyt.org and www.icarda.org.

The Food and Agriculture Organization (FAO) of the United Nations is an intergovernmental organization of 194 member nations plus two associate members and the European Union. FAO has headquarters in Rome, Italy and has staff in over 130 countries. The main goals of the FAO are to eradicate hunger, food insecurity and malnutrition, to eliminate poverty and improve economic and social progress for all, and to foster sustainable management and utilization of natural resources (land, water, air, climate and genetic) for the benefit of present and future generations. FAO has endorsed the Rome Declaration on Nutrition and the Framework of Action, which enshrines the right of everyone to have access to safe, sufficient and nutritious food, and commits governments to prevent malnutrition in all its forms. FAO's support in capacity building throughout the world and particularly for printing this book is recognized. For further information see www.fao.org.

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The Republic of Türkiye 's Ministry of Food, Agriculture and Livestock (MFAL) is responsible for food safety, veterinary and phytosanitary policy development, and enforcement activities for food and feed safety, animal health, animal welfare and plant health in Türkiye. MFAL is responsible for coordinating agricultural research and development projects in cooperation with the General Directorate of Agricultural Research and Policy (GDAR). The GDAR is the center of the national agricultural research system in Türkiye, with 49 research stations located to best serve the needs of citizens throughout the Republic. GDAR coordinates research

on plant breeding and production, plant protection, animal breeding and husbandry, animal health, fishery and aquaculture, food and feed, postharvest technologies, biodiversity/genetic resources, organic agriculture, bio-safety, and soil and water resource management. Thanks is given to MFAL for hosting and financially supporting this workshop. For further information see www.tagem.gov.tr.

Bolu Abant İzzet Baysal University, one of the noteworthy universities in our country, located in an area surrounded by natural beauties between two metropolis İstanbul and Ankara, was founded on 3 July 1992. The university, which has been developing rapidly since its foundation, has campuses in the city center and three districts of Bolu (Gerede, Mengen, Mudurnu). The main campus of the university, namely İzzet Baysal Campus, is located in Gölköy, which is 8 km from the city center and surrounded by a unique natural beauty. The university comprises 16 faculties, 1 institute, 1 schools, 8 vocational schools and 20 research centers. 1.557 faculty members and 1.181 administrative staff in the university are proud to provide a quality and modern educational setting for about 32.064 students.

Disclaimer

This volume contains papers voluntarily contributed by participants of the 8th International Cereal Nematodes Symposium, 25-29 September 2022, Abant, Türkiye.

Information and views expressed in these papers are entirely those of the authors, whose papers have not been formally peer-reviewed to independently confirm the veracity of the content.

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Session I
An update on the status of the global distribution of cereal nematodes

Current status of root lesion nematodes (*Pratylenchus* spp.) in Türkiye

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Summary

Root lesion nematodes (RLNs) are one of the most common cereal nematodes causing significant damage to cereals in the globe where cereals grow. They infect more than several hundred of species and may found in temperate, Mediterranean climate, warm, and tropical climate zones. RLNs placed in the *Pratylenchus* genera which have several species such as *Pratylenchus neglectus, P. penetrans, P. zeae, P. coffeae, P. thornei* and *P. vulnus* are some of the most common species in the world. Several species of RLNs are widely distributed in in cereal growing fields in Türkiye. *P. penetrans P. zeae, P. neglectus, P. sefaensis, P. pratensis, P. thornei, P. pratensisobrinus, P. agilis, P. crenatus, P. loosi, P. vulnus, P. delattrei* and *P. mediterraneus* are species of RLNs found by several researchers in Türkiye. These nematodes cause damage to plants at an economic level. As a result of RLNs feeding on the roots of hosts, their water and nutrient intake is limited, and numerous soil-borne pathogens can easily infect through the wounds by the assistance of nematode induced wounds. The status of RLNs in Türkiye, its damage to plants, and some gaps related to RLNs are not fully understood. Therefore, in this review, RLN status, damage and interactions with host plants are presented.

Introduction

Root lesion nematodes are ranked third among the most damaging nematode species after cyst and Root knot nematodes (Jones et al. 2013; Janssen et al. 2017). Root lesion nematodes may infect about 400 plant species and are widely found in tropical, temperate and cool climate zones (Castillo and Vovlas 2007; Bernard et al. 2017). *Pratylenchus neglectus* and *P. thornei* are the predominant species (Maafi et al. 2015).

P. thornei, P. zeae, P. penetrans, P. coffeae P. neglectus and *P. vulnus* are the most common species. Many of the RNLs are polyphagous and mostly reproduce parthenogenetically. RLNs can move between cells in the root and cause damage to the roots as a result of their feeding. When the RLN nematodes feed on the roots, water and nutrient intake is restricted, and many soil-borne pathogens may enter from wounds. A total of 13 species including *P. penetrans, P. thornei, P. delattrei, P. sefaensis, P. vulnus, P. pratensisobrinus, P. zeae, P. agilis, P. pratensis P. loosi, P. crenatus, P. mediterraneus* and *P. neglectus* are found in Türkiye (Kepenekci et al. 2012).

Status and damage of root lesion nematodes

Numerous species (68 species) of *Pratylenchus* genus (Castillo and Vovlas 2007) are found in the world. Several species of this genus are found in cereals fields such as *P. crenatus, P. thornei, P. neglectus* and *P. penetrans* that are distributed in globally (Rivoal and Cook 1993).

Root lesion nematodes may infect many plant species (Castillo and Vovlas 2007; Bernard et al. 2017) may cause damage to trees varies depending on biotic stress factors (Dickerson et al. 2000). *P. coffeae* causes a growth retardation of up to 80% in citrus fruits (O'Bannon and Tomerlin 1973) and *P. penetrans* causes growth retardation at 30 individuals/100 cm^3 soil density in pear, 80 individuals/100 cm^3 soil density in cherry and 320 individuals/100 cm^3 soil density in plum (Nyczepir and Halbrendt 1993). In addition, root lesion nematode species causes up to 75% damage on peach trees at soil densities in 457 individuals/100 cm^3 (Nyczepir and Halbrendt 1993).

Wheat is an important food crop for many countries and plays important roles in food grain production in the world. Wheat has an important place in human nutrition. Wheat is cultivated on an area of 219006893 hectares in the world and 260925831 tons of product is obtained and the average yield is 34744 kg/ha (FAO 2020). In Türkiye, wheat is planted on 6914632 hectares, the average yield is 29647 kg/ha, with a total production of 20500000 tons (FAO 2020).

Worldwide crop losses caused by nematodes are estimated at more than a hundred billion dollars per year (Abad et al. 2008). In addition to other plant parasitic nematode genera, the root lesion nematodes, the *Pratylenchus* genera, may cause significant yield losses (Rivoal and Cook 1993).

P. thornei is a major species in both wheat and barley fields (Ahmedi et al. 2015). Root lesion nematodes are found in 35% in wheat fields and 42% of barley fields (Ahmedi et al. 2015). Population densities of root lesion nematodes ranged from 1 to 365 nematodes/g root in wheat fields and 0 to 1334 nematodes/250 cm^3 in barley (Ahmedi et al. 2015).

The root lesion nematodes are identified using molecular (Waeynberg et al. 2000), morphological and morphometric characters (Loof 1991). The distributed rate of plant parasitic nematodes genera: *Pratylenchus* (73.3%), *Tylenchorhynchus* (37.3%), *Helicotylenchus* (38.8%), *Paratylenchus* (26.6%), *Pratylenchoides* (66.6%), *Merlinius* (78.6%), and *Heterodera* (82.6%) are commonly found in Bolu province of Türkiye (Imren et al. 2015).

More than 8 species of *Pratylenchus* are parasitic on small grain cereals (Nicol 2002; Nicol et al. 2003; McDonald and Nicol 2005; Castillo and Vovlas 2007) and P. *thornei, P. crenatus, P. penetrans* and *P. neglectus* are found as an economically important root lesion nematodes in temperate cereal-producing regions in the world (McDonald and Nicol 2005). *Pratylenchus* species is one of the most economically damaging nematodes for cereals in the world (Nicol et al. 2011; Duncan and Moens 2006). Root lesion nematodes cause crop losses up to A$ 73 million in Australia (Meagher et al. 2015; Murray and Brennan 2009).

P. *thornei, P. fallax, P. neglectus, P. penetrans* and *P. crenatus* are found in barley and wheat growing regions including the Central Anatolia Region, Eastern Mediterranean Region and South East Anatolian Region of Türkiye (Kılıc et al. 2012; Imren and Elekcioğlu 2008; Ocal 2012; Sahin et al. 2009).

P.neglectus and *P. thornei* exist in 82% of the wheat fields (Tanha Maafi et al. 2009). *P. penetrans* is the most plentiful and prevalent species in Morocco in wheat growing fields (Mokrini et al. 2012). The population density and frequency of *Pratylenchus* species in cereals fields were found in different localities where host plants grow (Riley et al. 2002). Among the root lesion nematodes *P. neglectus* is the most significant and widely distributed in the western and southern regions of Australia (Vanstone et al. 2008, Meagher et al. 2015, Riley and Kelly 2002).

The yield losses caused by root lesion nematodes ranged from 19-70% in Türkiye (Toktay et al. 2015). *P. thornei* and *P. neglectus* are common species in Erzurum, Igdir, Kars, Elazig, Erzincan, Sivas and Malatya provinces in wheat fields of Türkiye (Toktay et al. 2015). *P. neglectus* and *P. thornei* are found in 43% of samples in the Central Anatolian Region of Türkiye (Şahin et al. 2009).

Crop rotation is a favored in management practice, limiting damage by RLNs species through rotation, however *Pratylenchus* species infect many host plant species (Talavera and Vanstone 2001; Vanstone and Russ 2001). *P. neglectus* and *P. thornei* are most important wheat nematodes in Türkiye, and national wheat varieties and wild landraces are moderately resistant to those species (Kasapoglu et al. 2015). Development of tolerant and locally adapted varieties is essential for preventing damage by RLNs population densities and are influenced by cropping systems (Gitti et al. 2015, Riley et al. 2002). Nematicide application on wheat decreases the RLNs population up to 92% and increases the yield of grain by 22.3% (Gitti et al. 2015).

Some resistances are available against *P. thornei* in cereal in Australia (Sheedy and Thompson 2009). Possibly six genes involve in resistance against to *P. thornei* (Thompson and Seymour 2011; Meagher et al. 2015). The resistance presents to *P. neglectus* in 6DS and 2BS chromosomes and 6DL, 6DS, 2BS chromosomes to *P. thornei* (Zwart et al. 2010; Meagher et al. 2015). In addition, RNA interference gene silencing reveals that the reproduction nematodes decrease at 80% when target genes are silenced (Tan et al. 2013; Meagher et al. 2015).

Conclusion

The genetic resistance to root lesion nematodes in cereals genotypes and varieties are important. Türkiye has a diverse climate conditions and contains landraces that probable contain resistance genes of cereals against to root lesion nematodes more than was once thought. Comprehensive studies lead to determine management strategies by seeking resistance sources in Turkish cereal landraces and commercial cultivars by using both phenotypic screening and molecular markers. The economic importance of the some common species of root lesion nematodes has not been fully understood. Therefore, determining and researching intensively on crop losses, distribution, biology of common and economically important species of root lesion nematodes are decisively important.

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