Root-Knot Nematodes *Meloidogyne* spp.
as Emerging Pests

Meloidogyne spp.

- Root-knot nematodes - one of the most polyphagous and damaging genera of PPNs
- RKNs are biotrophic endoparasites, able to infest virtually any species of higher plant
- Cosmopolitan distribution
- Typical symptom is the formation of galls at nematode feeding sites
Meloidogyne spp.

*Meloidogyne* about 100 species, regulated:

- In Europe Q list (EPPO):
  - *M. chitwoodi* (A2)
  - *M. fallax* (A2)
  - *M. enterolobii* (A2)
  - *M. ethiopica* (Alert - early warning, 2011)
  - *M. mali* (Alert - early warning, 2016)

- “Tropical group “ RKN species in Europe: greenhouses all over Europe, open field mainly in Mediterranean climate (vegetables, grapevine, fruit plants). Tropical group RKNs few species in Europe:
  - *M. incognita* WIDESPREAD (resistance breaking populations)
  - *M. javanica* WIDESPREAD
  - *M. arenaria* WIDESPREAD
  - *M. hispanica* (greenhouse and open field, Prunus – Spain, Portugal)
  - *M. enterolobii* (greenhouse Switzerland), resistance breaking populations
  - *M. ethiopica* (greenhouse SLO, Turkey; open field Greece, Turkey, Italy)
The global spread of crop pests and pathogens

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Fig. S2. CPP category saturation over time. Saturation (fraction of countries inhabited, that produce the host crops of the CPP) for 410 CPPs, for which temporal data were available. Blue lines denote individual CPPs (numbers given by n), black lines show median per year.
The global spread and pathogens

Daniel P. Bebber, Timothy Holman

Fig. S2. CPP category saturation over time. Saturation (fraction of crops) produce the host crops of the CPP) for 410 CPPs, for which temporal lines denote individual CPPs (numbers given by n), black lines show models runs.
Emerging pests
Emerging pests

1. Global market
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1. Global market
2. Lack of natural resistance
Emerging pests

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3. Global worming
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4. Environmentally friendly plant protection (in Europe)
Emerging pests

1. Global market
2. Lack of natural resistance
3. Global warming
4. Environmentally friendly plant protection (in Europe)
5. Wide host range & extreme reproduction potential
Emerging pests

1. Global market
2. Lack of natural resistance
3. Global worming
4. Environmentally friendly plant protection (in Europe)
5. Wide host range & extreme reproduction potential
6. Fast adaptations (e.g. Mi – gene resistance breaking)
   most reproduce by obligatory mitotic parthenogenesis,
   possess aneuploid genomes, hybrid taxa
Damage

Three major factors:

• the host plant
• the level of initial population
• growth conditions (the temperature)
M. incognita on potato tubers; Open field (2014), 80% of harvest damaged
**M. ethiopica**

- *M. ethiopica*, first time in Europe in Slovenia, later reported from Turkey, Greece, Italy
- Severe infestation symptoms: wilting, stunting, early flower & fruit drop
- wide host range (~90 sp.), woody, herbaceous, mono & dicotyledones
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![Image description](image-url)
S. America, Africa

Africa
• described from Tanzania
• Present: Ethiopia, Kenya, Mozambique, South Africa, Zimbabwe
• no reports on damage

S. America
• In Chile occurs over a range of ca 1000 km on grapevine (*Vitis vinifera*), kiwi (*Actinida deliciosa* C.) and potatoes in 80% of samples (Carneiro et al., 2007) collected in this area – major RKN pest
• Brazil – wide distribution
• Peru – detected
“Get to know your enemy”

• Open field survival
• Reproduction cycle, modelling
• Germplasm screenings
• Bio control
• Early detection
• Buried vessels, tomato
• Survived at both locations 4 winter seasons
• EPPO Alert pest
Data Analyses
M. ethiopica reproduction cycle

- At 4 main mean daily temperatures: 13.9, 18.3, 22.7 & 26.3°C
- Tomato, cucumber & bean
- 13.9°C, 120 DPI no reproduction
- Max: 67, 48, 36 DPI

<table>
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<th>Mean daily temperature (°C)</th>
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Michaelis-Menten models – Reproduction Cycle

\[ M. \text{arenaria} \quad y = 10.33x / (-14.48 + x) \]
\[ M. \text{hapla} \quad y = 16.31x / (-13.19 + x) \]
\[ M. \text{hispanica} \quad y = 15.92x / (-13.98 + x) \]
\[ M. \text{incognita} \quad y = 12.13x / (-13.69 + x) \]
\[ M. \text{javanica} \quad y = 11.78x / (-15.19 + x) \]
\[ M. \text{ethiopica} \quad y = 18.96x / (-13.25 + x) \]
\[ M. \text{ethiopica} \text{ first} \quad y = 8.96x / (-15.05 + x) \]
Michaelis-Menten models – Reproduction Cycle

- Days Post Inoculation

- Temperatures (°C)

- $M. arenaria \ y = 10.33x / (-14.48 + x)$
- $M. hapla \ y = 16.31x / (-13.19 + x)$
- $M. hispanica \ y = 15.92x / (-13.98 + x)$
- $M. incognita \ y = 12.13x / (-13.69 + x)$
- $M. javanica \ y = 11.78x / (-15.19 + x)$
- $M. ethiopica \ y = 18.96x / (-13.25 + x)$
- $M. ethiopica$ first $y = 8.96x / (-15.05 + x)$

- Pi/Pf - egg to egg
- host status, resistance testing, effect of compounds, population dynamics, prediction of No. generation/growing season (greenhouses & open field) etc.
Michaelis-Menten models – Reproduction Cycle

- Pi/Pf - egg to egg
- host status, resistance testing, effect of compounds, population dynamics, prediction of No. generation/growing season (greenhouses & open field) etc.
**In-vivo Model Testing – *M. ethiopica***

- Outside field conditions; Daily soil T (10 cm)
- Accurate prediction
- Predictions for agr. production (greenhouses, open field)
- Combining (Seinhorst, 1965) damage prediction
Resistance of Lettuce Accessions – KIS GENE BANK

- Inokulum 3000 egg/plant;
- $R_f = \frac{P_i}{P_f}$, GI

$R =$ resistant ($GI < 2$, $R_f < 1$)
$HR =$ Hipersensitive reaction ($GI > 2$, $R_f < 1$)
$S =$ Susceptible ($GI > 2$, $R_f > 1$)
The use of antagonistic fungi for control of RKN

- Studying the interaction between RKN and fungi from the genus *Trichoderma* and *Clonostachys*
- The fungi were isolated from the infested roots with the RKN

Parasitism of *Trichoderma longibrachiatum* on eggs of *Meloidogyne incognita*.
The use of antagonistic fungi for control of RKN

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- Parasitism of *Trichoderma longibrachiatum* on eggs of *Meloidogyne incognita*.
Remote sensing detection of RKN infestation

variable
- RKN + drought
- RKN + watered
- control_watered
- control_drought

Agricultural Institute of Slovenia
RKN + drought stress analyses

Database of hyperspectral fingerprints

RKN

DROUGHT

Physiological plant response to different and combined stresses

Differential molecular plant response to RKN and drought at water stress conditions
RKN + drought stress analyses

Integrated analyses for holistic understanding combined stress and its management

Database of hyperspectral fingerprints

RKN

DROUGHT

Physiological plant response to different and combined stresses

Differential molecular plant response to RKN and drought at water stress conditions

Agricultural Institute of Slovenia
RKNs emerging pests

Successful RKN management strategy – a combination/diversification of all efficient approaches:
• prevention of spreading, appropriate detection, natural resistance, new biotech solutions, biological control, crop rotation, biofumigants etc.
• DSS for the future
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