Several enemies at the same time: interaction between two cocoa pod diseases and a cocoa pod borer and their impact in Peruvian agroforestry systems

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Simultaneous infection of multiple diseases

- Classically one pathogen and one host
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• Classically one pathogen and one host
• Multiple interacting pathogens in a given host
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  • resource-mediated
  • host-mediated
  • interference
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![Graph showing competitive exclusion in Paramecia](image)
Simultaneous infection of multiple diseases

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Cocoa pests and diseases in South America

-Multiple pest simultaneously
-Only 22% of cocoa pods are healthy when harvesting
  -58% infected
  -20% affected by other agents
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Moniliasis
Frosty pod rot disease
*Moniliphtora roreri*

Mazorca negra
Black pod disease
*Phytophthora palmivora*
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Mazorquero
American Cocoa pod borer
*Carmenta forasemnis*
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American Cocoa pod borer
*Carmenta foraseminis*

Otros (roedores, aves)

Mazorquero + Mazorca negra

Infection

- separate
- together
Upper Huallaga river
8 plots with differences in shade and managing practices
40 trees per plot
Measurements each 15 days
Fruits removal if infected
Data: total # healthy and infected pods per date per tree

18 months of monitoring in the Peruvian Amazon
Multipest spatio-temporal dynamics

1. Is there a prevalent disease?
2. Do disease infections follow a geographical pattern?
3. Are there differences in infection through time? If so, are these differences related to resource availability? To climate oscillations?
4. Are coinfection events promoted by season and/or by spatial differences?
1. Is there a prevalent disease?

- Monilia affects the highest number of fruits in general
• Monilia affects the highest number of fruits in 5/8 localities
• Incidence of diseases differs between localities
2. Can we detect a geographical pattern on disease infection?
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Cluster plot

Based on total fruits healthy and affected by the different diseases per tree
2. Can we detect a geographical pattern on disease infection?

• Very little geographic structure at large scale
• Perhaps structure at intra-plot scale?
2. Can we detect a geographical pattern on disease infection?

- Very little geographic structure at large scale
- Perhaps structure at intra-plot scale?
3. Is there a temporal pattern on the infection by different diseases?
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- Number of healthy and sick fruits per tree per date of monitoring.
- General temperature and precipitation in the study area during the monitoring period
Total infected fruits through time

- **Monilia**
- **Mazorca negra**
- **Mazorca negra + Mazorquero**
- **Mazorquero**
- **Otro**
• All diseases are correlated to total amount of fruits produced ➔ availability of resource.
• Correlation between them too, probably through resource availability.
• All diseases are correlated to total amount of fruits produced ➔ availability of ressource.
• Correlation between them too, probably through ressource availability
• Weak correlation between infection and general weather ➔ Microclimate effect?
Percentage of infected fruits through time

- **Total fruit production**
- **Monilia**
- **Mazorca negra**
  - 9%
  - 0.5%
- **Mazorca negra + Mazorquero**
  - 4.5%
  - 2%
- **Mazorquero**
  - 2.5%
  - 1%
- **Otro**
  - 0.5%
  - 5%
Percentage of infected fruits through time

- Temporal differences also on percentage of infection
4. Are there temporal or spatial conditions that can favour disease coinfection at the tree level?

- 1000 times simulation of real infection values per tree per disease per date
4. Are there temporal or spatial conditions that can favour disease coinfection at the tree level?

- 1000 times simulation of real infection values per tree per disease per date
- Observed data is under the median of simulated data in several cases
Multipest spatio-temporal dynamics

1. Is there a prevalent disease? Yes!
2. Do diseases infections follow a geographical pattern? No
3. Are there differences in infection through time? If so, are these differences related to resource availability? To climate oscillations? Yes!
4. Are coinfection events promoted by season and/or by spatial differences? No, but fewer coinfection!
Muchas gracias

¡Los agricultores!
Marcos Ramos, Jhoner Alvarado, Clémentine Alline, Gerben Martijn Ten Hoopen, Leïla Bagny-Beilhe

¡Ustedes por su atención!
Supplementary slides
How to propose ecologically friendly solutions?

1. Multipest temporal and spatial dynamics
2. Shade effect on infection
3. Management practices useful against pest and diseases
Monilia vs fruit availability through time after covid

No correlation between monilia and temperature nor precipitation
Mazorcanegra vs fruit availability through time after covid

Mazorcanegra affected by temperature but not by precipitation

no
Mazorquero vs fruit availability through time after covid

No correlation between mazorquero and temperature nor precipitation
Positive correlation between availability of fruits as a whole and by phenological state
No effect of temperature but negative effect with precipitation
Positive correlation between availability of fruits as a whole and by phenological state
No effect of temperature but marginal effect of precipitation in co-infection
Temporal interaction of diseases throughout time?

Positive correlation between all diseases pairs throughout time = resource is far from being limitant and produce competition.

Graphically I cannot see facilitation or synergistic effect but check how to test them statistically.
Per date
Per locality
Otro

120

Otro

4.5%

%
Ciclo de vida del Mazorquero

El tiempo de vida del Mazorquero, en condiciones de campo, es de 71 días.

1. **ADULTO**
   - Vive por 7 días y puede poner hasta 90 huevos.

2. **NUEVO**
   - Las esporas llegan al fruto y demoran entre 8 a 12 horas en infectarlo.

3. **LARVA**
   - Se alimenta de la mazorca durante 36 días.

4. **PUPA**
   - Vive durante 21 días, durante los cuales se prepara para salir como insecto.
Ciclo de vida de la “mazorca negra”

El tiempo de vida de la “mazorca negra”, en condiciones de campo, es de 11 días y sus esporas pueden desarrollarse en frutos en solo 48 horas.

1. **DISPERSIÓN**
   De la mazorca contaminada se liberan esporas que pueden transportarse por acción de:
   - Lluvia
   - Viento
   - Insectos

2. **GERMINACIÓN**
   Las esporas llegan al fruto y a los 2 días empiezan a infectarlo.

3. **PRIMEROS SÍNTOMAS**
   Los primeros puntos oscuros se convierten en una mancha uniforme color café.

4. **EXPANSIÓN**
   Dos días más tarde empieza la formación de micoles cremaos. La mancha café cubre buena parte del fruto.

5. **ESPORULACIÓN**
   Después de 3 días, el micoles cubre todo el fruto, las esporas están listas para esparsarse.
Ciclo de vida de la Monilia

El tiempo de vida de la Monilia, en condiciones de campo, tiene una duración de 68 a 85 días.

1. **Dispersión**
   De la mazorca contaminada se liberan esporas que pueden transportarse por acción de:
   - Lluvia
   - Viento

2. **Germinación**
   Las esporas llegan al fruto y demoran entre 8 a 12 horas en infectarlo.

3. **Primeros Síntomas**
   A los 50 - 40 días se muestran gibas y puntos aceitosos.

4. **Mancha Marrón**
   Aproximadamente 60 días después de la germinación, aparece una mancha marrón uniforme.

5. **Mielesoporulación**
   A los 70 días aparecen las manchas blancas.

Mazorca con apariencia saludable
Mazorca enferma
Ciclo de vida de la Escoba de Bruja (Manihot esculenta)

1. **Dispersión**: De la mazorca contaminada se liberan esporas que pueden transportarse por acción de la lluvia o el viento.

2. **Germinación**: Las esporas llegan al fruto y demoran entre 8 a 12 horas en infectarla.

3. **Primeros Síntomas**: Alrededor de 35 días después, se presentan deformaciones en la planta.

4. **Deformación**: A los tres meses, aparecen brotes con una estructura parecida a una escoba o un nido de ave.

5. **Esporulación**: A los casi seis meses, aparecen los paraguas o setas.

El tiempo de vida de la "Escoba de bruja", en condiciones de campo, tiene una duración de 170 días.

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