THE PEST AND DISEASE CONTROL FUNCTION OF AGROBIODIVERSITY AT THE FIELD SCALE

A. Ratnadass, J. Avelino, P. Fernandes
R. Habib & P. Letourmy

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Background: Challenges facing tropical agriculture

- food insecurity and low-income in low-input traditional agrosystems
- pesticide-induced adverse impacts on human health and the environment in intensive systems
- export restrictions due to strict regulations imposed by importing countries
Plant species diversification as the main pillar of ecological intensification

- Human & environmental health
  - Beneficial organisms
    - Pest & disease impact
      - Soil fertility
      - Soil biological activity
        - Quantity of farm production
        - Quality of farm production
  - Positive impact
  - Negative impact
  - Mixed impact

- Agroecology / Ecological intensification
  - Plant species diversification (PSD)

- Agrochemistry
  - Chemical pesticide & fertilizer application
Agroecological pathways of pest & disease regulation via vegetational diversification in agroecosystems

- Vegetational diversification
- Pest repellency
- Natural enemy conservation
- Pest attractiveness
- Resource dilution
- Cycle rupture (temporal/spatial)
- Reduced impact of pests & diseases
- μclimate change
- Barrier effects
- Allelopathy
- Physiological resistance
- Soil suppressiveness
- Enhancement of diversity & activity of soil biota
Tropical example: the «push-pull» system in Eastern & Southern Africa

Napier grass

Maize

Desmodium

Veliver grass

PUSH-PULL SYSTEM

Main Crop

Trap Crop

Attract natural enemies

Moths are pushed away

Attract moths

after J. v/d Berg
Examples of application of these principles at Cirad at the soil and field levels

- Influence of soil organic matter quantity and quality on the status of Scarab beetles associated with upland rice in Madagascar
- Study of the various host plants of sorghum panicle-feeding bugs in Mali and Niger
- Evaluation of trap crops for management of Tomato fruit worm on Okra in Niger
Influence of soil organic matter quantity and quality on the status of Scarab beetles associated with upland rice in Madagascar

• In Madagascar, growing demand for rice and resulting increased pressure on inundated lands has favoured the cultivation of upland rice on hill slopes, particularly in the high & medium altitude regions of the island.

• If conventional tillage is used, this type of agriculture cannot meet the objectives of both sustainability and of high yields, due to high erosion, and to attacks by white grubs & black beetles, particularly in the medium-elevation region of Lake Alaotra.

• Direct seeding, mulch-based cropping (DMC) systems have opened new prospects for upland rice, reducing erosion, and after a few years, attacks by white grubs & black beetles in the Central Highlands of Vakinankaratra.
**Example of reduction of black beetle impact on upland rice production in Central Highlands of Vakinankaratra (Madagascar)**

Rice yield (cv FOFIFA 161) in 2002-03 (t/ha) (/annual rice//soybean rotations, conducted since 1998 under DMC on crop residues and under conventional tillage)

<table>
<thead>
<tr>
<th>Location</th>
<th>DMC with Imidacloprid seed-dressing</th>
<th>DMC without seed-dressing</th>
<th>Conventional tillage with Imidacloprid seed-dressing</th>
<th>Conventional tillage without seed-dressing</th>
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</thead>
<tbody>
<tr>
<td>Andranomanelatra</td>
<td>3,2</td>
<td>2,6</td>
<td>2,8</td>
<td>1,7</td>
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<tr>
<td>Ibity</td>
<td>3,7</td>
<td>2,4</td>
<td>2,3</td>
<td>1,7</td>
</tr>
<tr>
<td>Scarab beetle species</td>
<td>Damage to rice roots (%)</td>
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<td>---------------------------------------</td>
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<td></td>
<td></td>
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<tr>
<td>Apicencya waterlotii</td>
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<td></td>
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<tr>
<td>Heteronychus arator rugifrons</td>
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<tr>
<td>Heteronychus bituberculatus</td>
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<tr>
<td>Heteronychus plebejus</td>
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<td></td>
<td></td>
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<tr>
<td>Heteronychus paradoxus</td>
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<td></td>
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<tr>
<td>Hexodon unicolor unicolor</td>
<td></td>
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<td></td>
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<tr>
<td>Bricoptis variolosa</td>
<td></td>
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</tr>
</tbody>
</table>

Objective: Minimizing Scarab beetle role as pests and optimizing their function as ecosystem engineers in multiple species-based Direct-seeding, Mulch-based Cropping (DMC) systems.
% cases when rice attacked

- poor soil + rice straw
- poor soil + cow dung
- poor soil

Apicencya waterloti
Heteronychus arator rugifrons
Apicencya waterloti

% cases when rice attacked

- Poor soil + rice straw
- Poor soil + cow dung
- Poor soil

Apicencya waterloti
Heteronychus arator rugifrons
%cases when rice attacked

- Apicencya waterloti
- Heteronychus arator rugifrons
- Heteronychus bituberculatus

Factors:
- poor soil + rice straw
- poor soil + cow dung
- poor soil

Values:
- 0%
- 10%
- 20%
- 30%
- 40%
- 50%
- 60%
- 70%
- 80%
- 90%
- 100%

Legend:
- a
% cases when rice attacked

- Apicencya waterloti
- Heteronychus arator rugifrons
- Heteronychus bituberculatus
- Heteroconus paradoxus

- Poor soil + rice straw
- Poor soil + cow dung
- Poor soil

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
sol pauvre+paille
sol pauvre
+fumier
Heteronychus plebejus
Heteroconus paradoxus
Heteronychus bituberculatus
Heteronychus arator rugifrons
Apicencya waterloti
%cases when rice attacked
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
poor soil+rice straw
poor soil+cow dung
poor soil
Heteronychus plebejus
Heteroconus paradoxus
Heteronychus bituberculatus
Heteronychus arator rugifrons
Apicencya waterloti
sol pauvre

poor soil + rice straw

poor soil + cow dung

poor soil

%cases when rice attacked

Apicencya waterloti
Heteronychus arator rugifrons
Heteronychus bituberculatus
Heteroconus paradoxus
Heteronychus plebejus
Hexodon unicolor
& Bricoptis variolosa

0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

% cases where rice was attacked
Sorghum panicle-feeding bugs in West and Central Africa

Eurystylus oldi
Management of plant bugs on castor bean to reduce sorghum infestation

• Studies conducted at the village level in 1998-99 in resp. 5 and 16 villages of the Kolokani region, Mali
• Split-plot designs with 3 factors: sorghum cv (8); date of sowing (2); and « castor treatment » (2-3):
  – 1998 : sorghum fields located in the vicinity vs remote from castor plants
  – 1999 : all sorghum fields located in the vicinity of castor, with management of castor spikes (insecticide spraying or spike manual removal) vs no treatment)
Alternate hosts and life-cycle of Eurystylus oldii in Sudano-Sahelian West Africa.
In Niger, in terms of trap cropping & conservation biological control potential for *Helicoverpa armigera* on okra:
- Pigeon Pea > Sorghum > Cotton
Pros and cons of three plant species tested in Niger as perimeter trap plants around okra fields for Tomato Fruit Worm (*Helicoverpa armigera*) control

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Plant species</th>
<th>Pigeon Pea</th>
<th>Sorghum</th>
<th>Cotton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attractiveness level</td>
<td>+</td>
<td>+/-</td>
<td>+/-</td>
<td></td>
</tr>
<tr>
<td>Attractiveness period duration</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Ease of visual inspection and manual control</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Conservation biological control effectiveness</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Potential for “assisted” control</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Effects against other pests</td>
<td>+/-</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
Importance taking into account upper scales

- Emerging adults of « plastic » white grubs species will damage neighbouring upland rice fields that are not managed in an agroecological manner.
- In the case of trap-cropping (e.g. vs TFW on okra), or cycle-breaking strategies (e.g. panicle-feeding bugs on sorghum), if the alternate host used has no dead-end properties, care should be taken not to turn a « sink » for pests into a « source » of infestation at upper spatial and temporal scales.
- At an even larger scale, dead-end trap plants that are both highly attractive for egg-laying by adult female pests and unfit for the development of their progeny, may also end up selecting pest populations that will overcome this suicidal egg-laying behaviour.
Optimisation des Mécanismes Écologiques de Gestion des bio-Agresseurs pour une Amélioration durable de la productivité des Agrosystèmes” Ω3
Hypotheses regarding PSD effects on pests & diseases generated by observation

Parameterization of existing models

Adding to the knowledge base

Validation of models through observation and experiments

Ideotypes of PSD-based cropping systems resilient to pests & diseases

Construction of mechanistic models

Indicators

Scenarios & decision-making rules

Experimental checking of suspected PSD effects

Ω³’s methodological flow-chart

Validation of models through observation and experiments

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Thanks to our partners:

- ICRISAT (Niger & Mali)
- ICRISAT, INRAN, University of Niamey (Niger)
- FOFIFA, University of Antananarivo & TAFA (Madagascar)
- Farmers
Session 3: The functional role of agrobiodiversity: from farms to landscapes

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2. Cirad - Controlling Pests and Diseases in Tree Crops research unit – IICA/PROMECAFE – San José – Costa Rica
4. Cirad – Persyst Scientific Department Director – Montpellier – France
5. Cirad – Annual Cropping systems research unit – Montpellier – France

Abstract - Among agrobiodiversity enhancement options, the planned introduction and management of plant species diversity (PSD) in agroecosystems is a promising way of breaking with “agrochemistry” and moving to “agroecology”. Besides agronomic and economic benefits, PSD may reduce pest and disease impact via several causal pathways. We report on instances pest and disease regulation processes in tropical cropping systems, emphasizing the soil and field levels. We thus studied the influence of soil organic matter quantity and quality on the status of Scarab beetles associated with upland rice in Madagascar, in view of minimizing their role as pests and optimizing their function as ecosystem engineers in multiple species-based Direct-seeding, Mulch-based Cropping (DMC) systems. We also studied in West Africa the various host plants of sorghum panicle-feeding bugs, in order to manage these pests (and grain molds they transmit) via a combination of trap cropping and cycle rupture, and the potential of several trap crops for managing the tomato fruitworm (and in a subsidiary way the cotton white fly and the TYLC-transmitted disease) on okra. Although processes studied primarily operate at the field level, results obtained stress the need to take into account larger scales, both spatial and temporal. This approach is developed in the Cirad Omega3 project which builds on tropical case studies, representing a broad range of PSD scales and deployment modalities (soil, field, landscape, and DMC, horticultural and agroforestry systems), according to a typology of pests and pathogens based on life-history traits the most amenable to manipulation by PSD (specificity and dispersal ability). Further to results aiming at immediate impact, more generic results are expected, after formalizing the ecological processes studied, namely decision-making rules which will help set up models to predict the impact of PSD on pests and pathogens with similar life-history traits.