Modelling fungal diseases in intercrops

Author(s) [A. Deheinzelin; M. Launay; T. Vidal; M-O. Bancal, P. Lecharpentier]

INRAE

INTERCROP VALUES

L'INSTITUT agro Rennes Angers

INRAE

esa EUROPEAN SOCIETY FOR AGRONOMY

18th Congress of the European Society for Agronomy in Rennes, France

How can we model aerial fungal diseases in intercropping systems?

Intercrops

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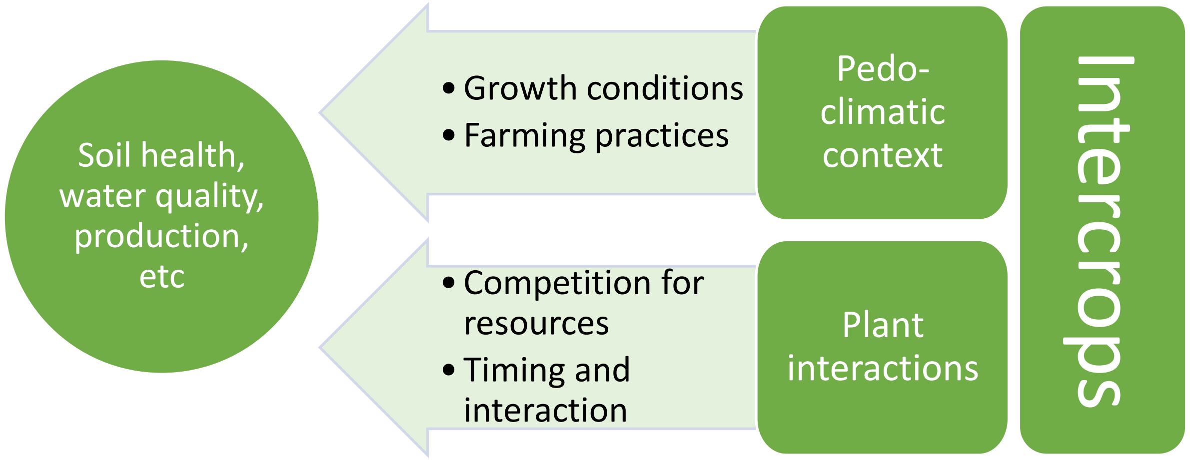

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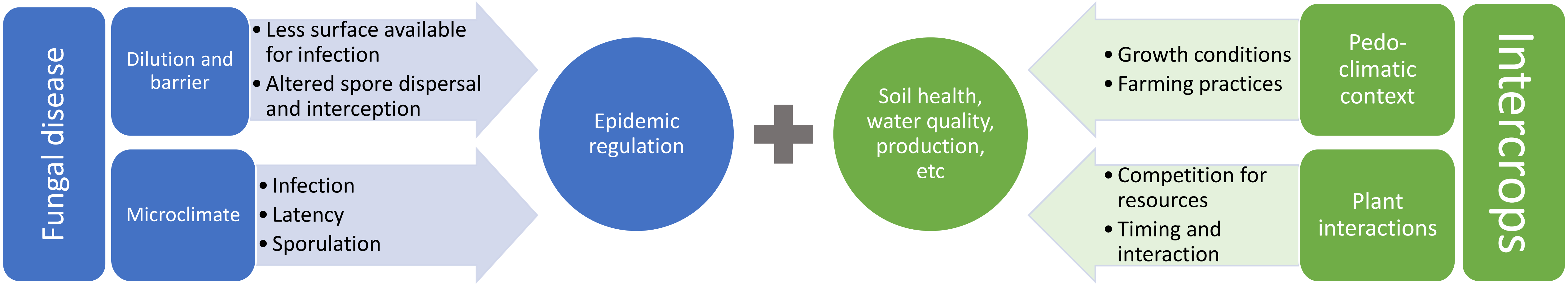

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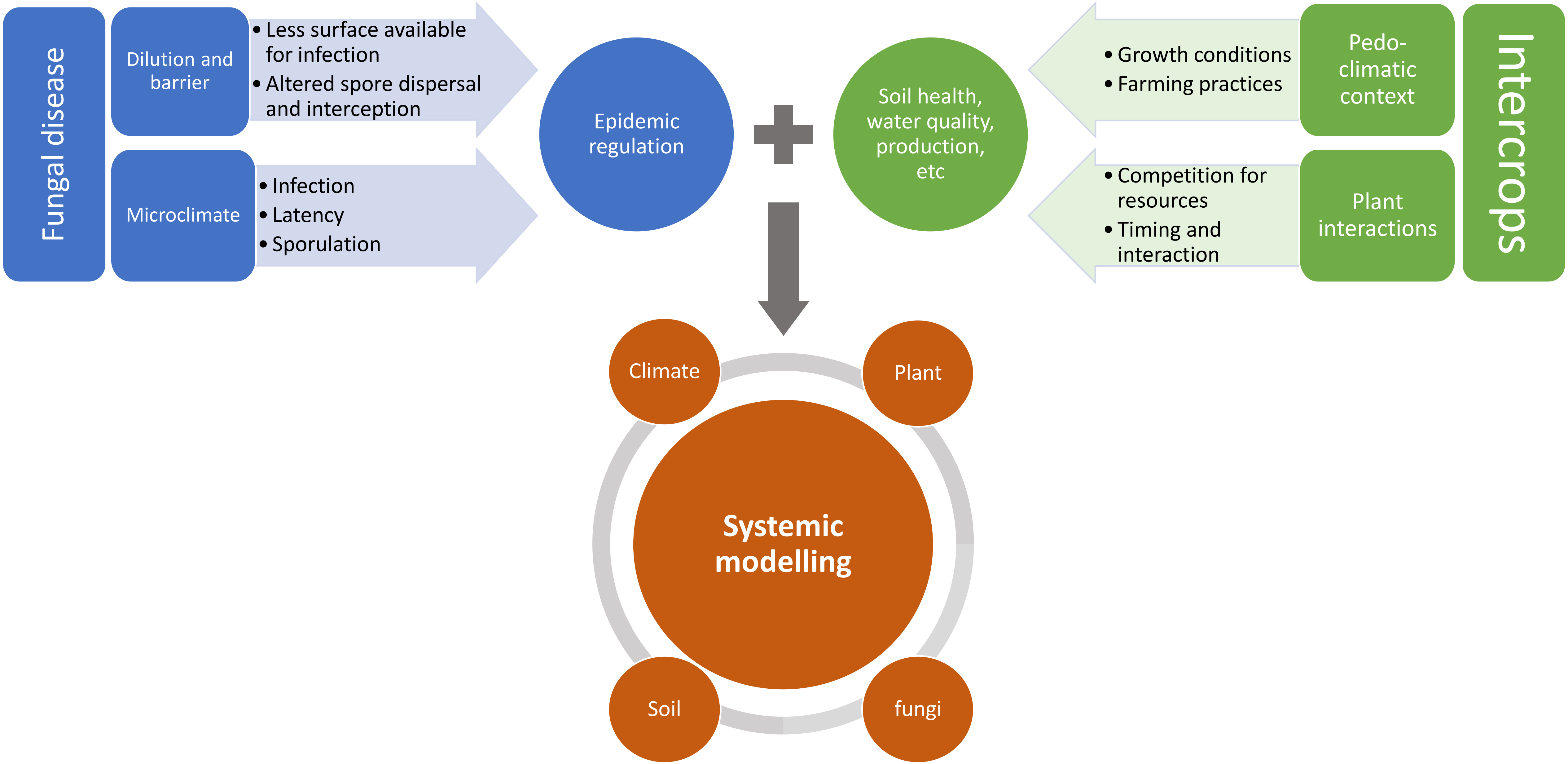

Modelling framework

Global Inputs
Plant parameters
General parameters
Local Inputs
Initialisation
Weather
Crop management
Soil characteristics

Main characteristics

- **Crop model STICS**
- Generic (external parameter files)
- Recalibrated on intercrops (Vezy et al., 2023)
- Microclimate calculations
- Agronomic specifications (fertiliser, sowing, tillage, etc)

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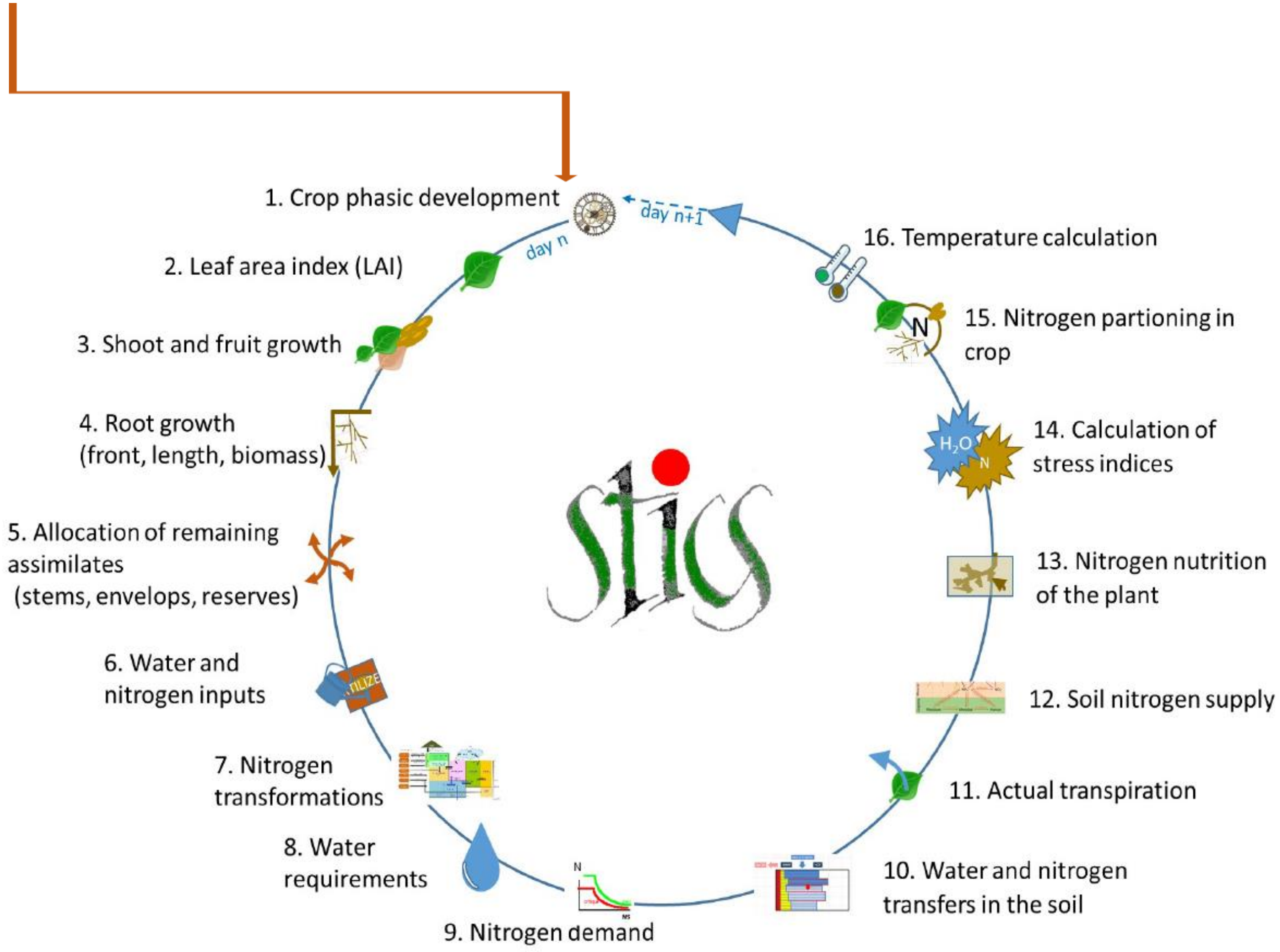

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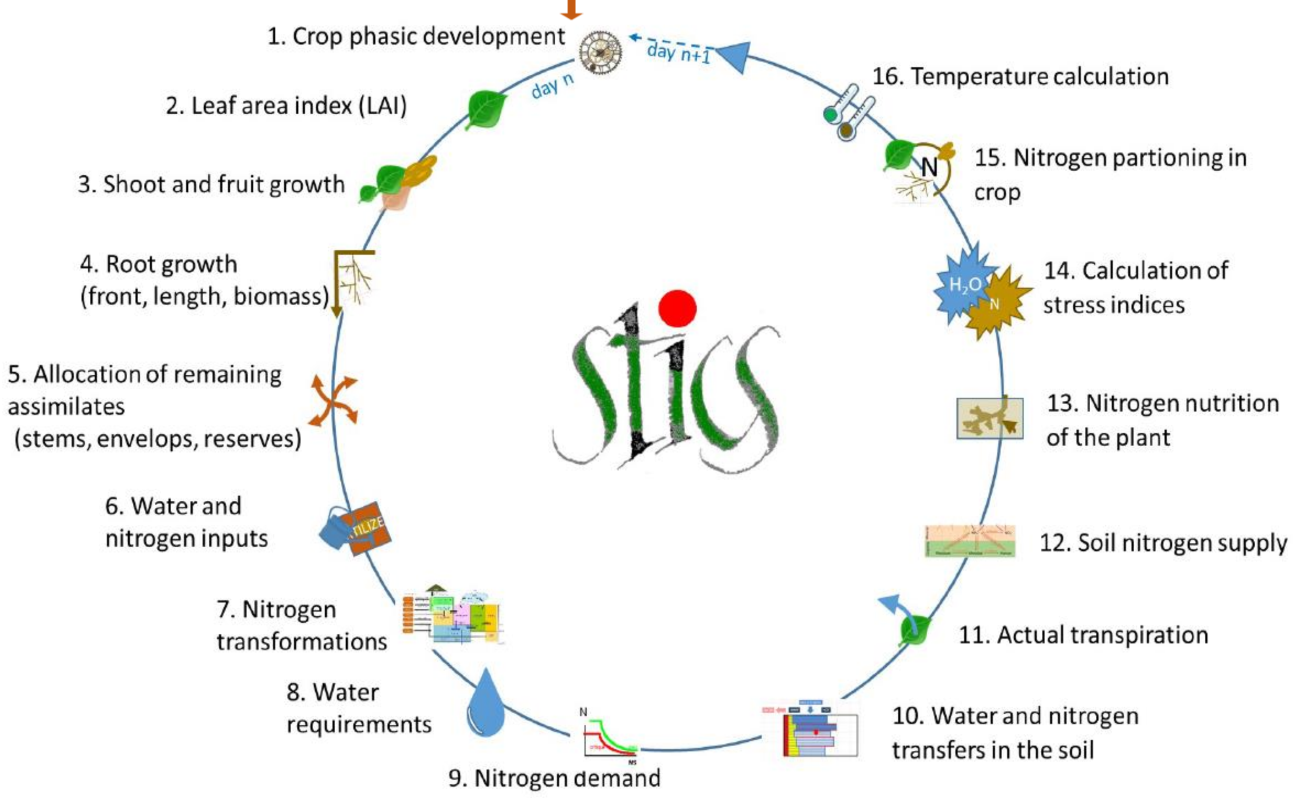

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  - calibrated for a variety of polycyclic airborne fungal diseases (Caubel et al., 2012 and 2017) on single cropping systems

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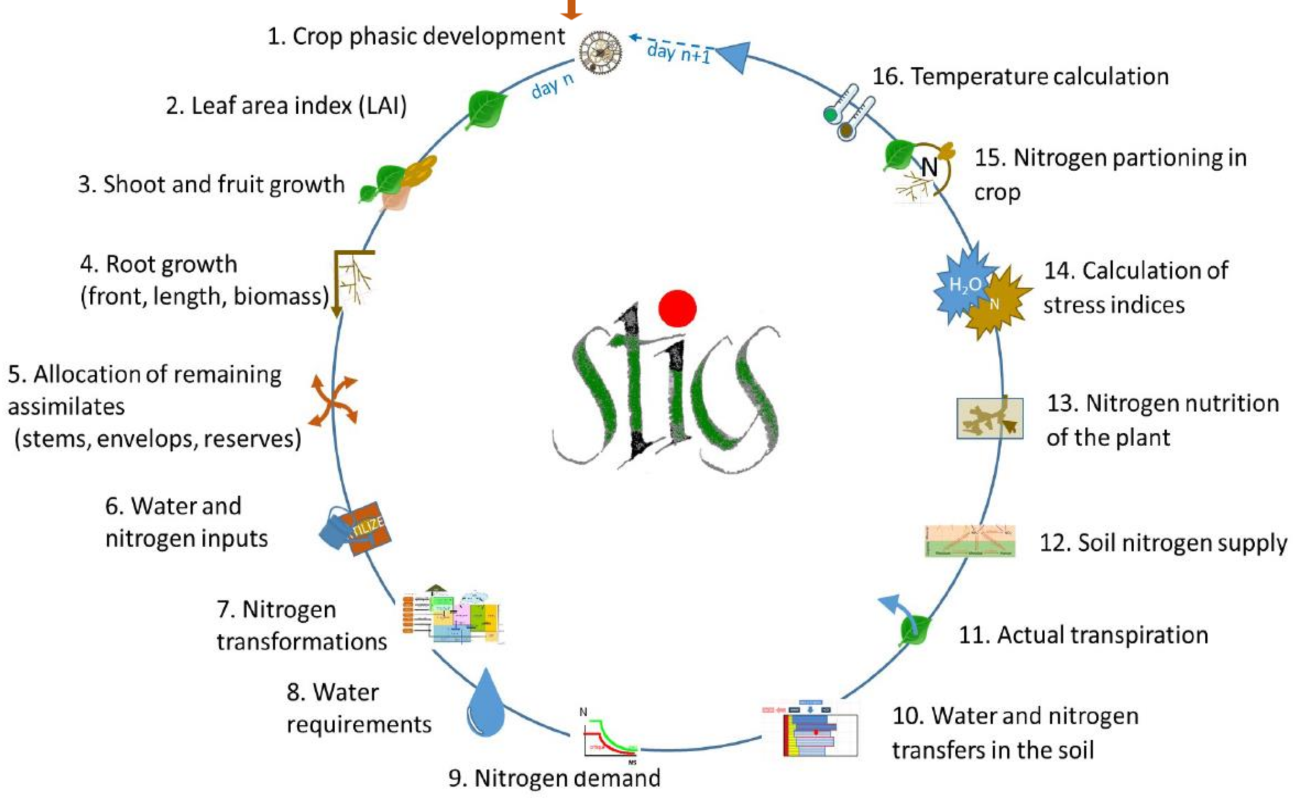
Disease parameters
Spore dispersal
Infection
Spore lifespan
Spore production

Daily loop for spore dynamics (cohorts)

Daily or cumulative outputs
Spores intercepted, produced, dead, etc
Severity, AUDPC



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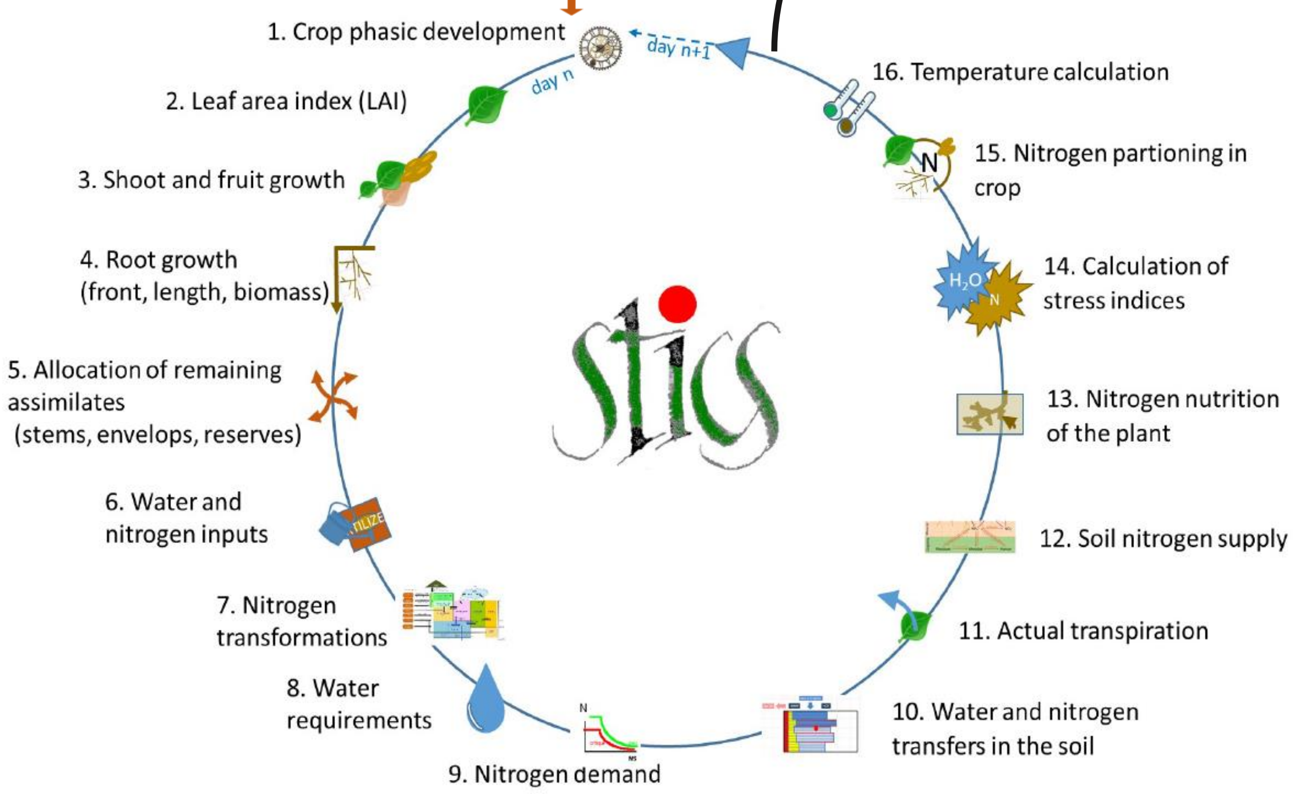
Inputs
Microclimate
Weather
Phenology
Surfaces



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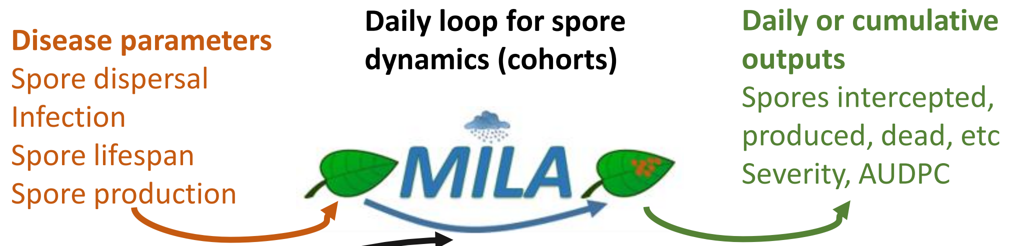

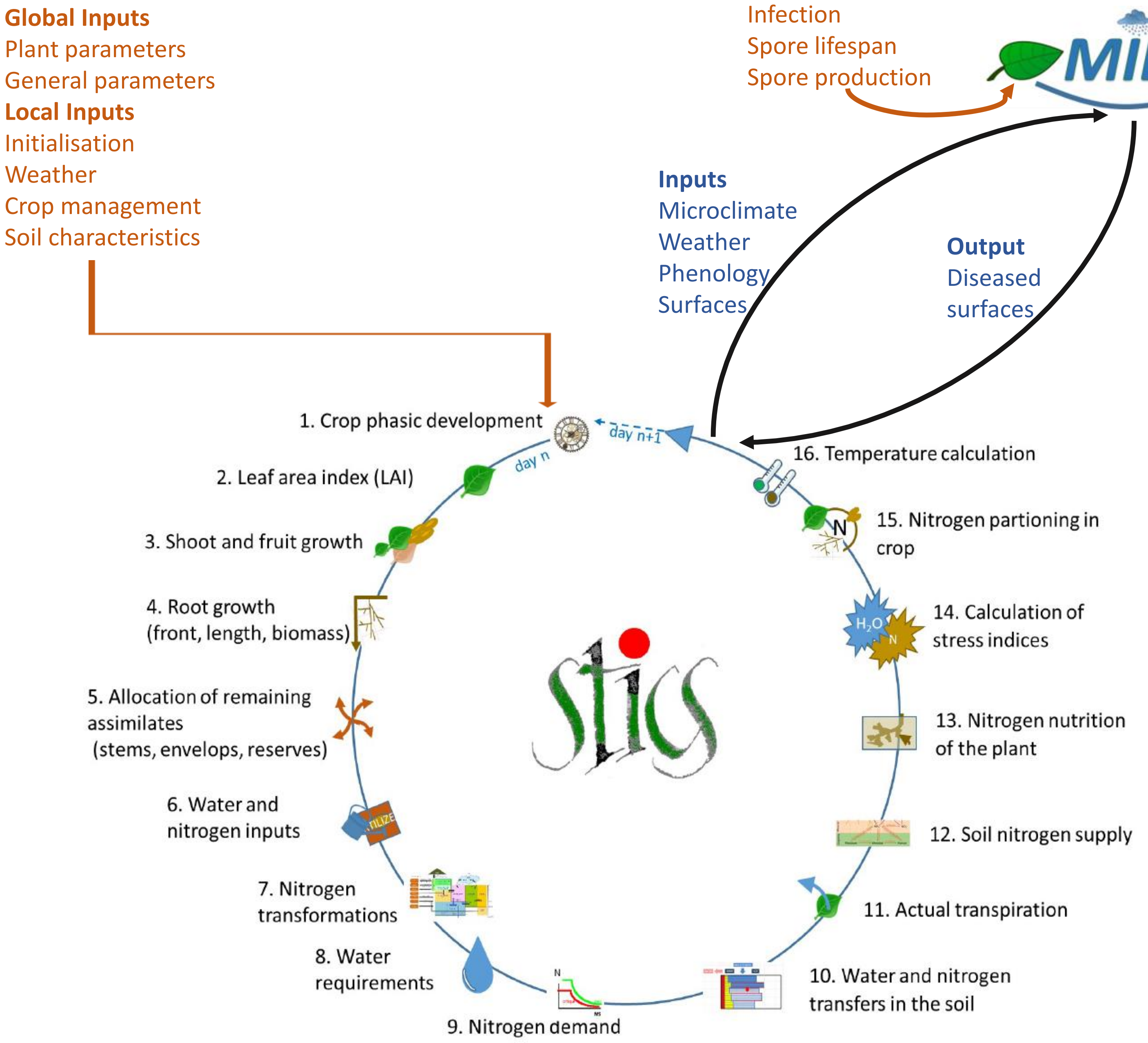

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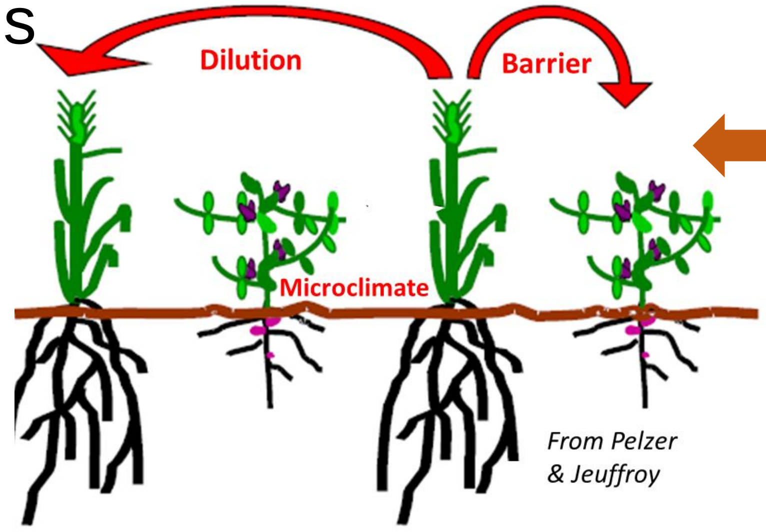
- **Coupled models**
  - Mechanistic, process-oriented
  - Dynamic (daily time step)
  - Integrated: many environmental variables available as outputs to study the agrosystem as a whole

Method – Model behaviour analysis

Adapt MILA-STICS to intercrops

Method – Model behaviour analysis



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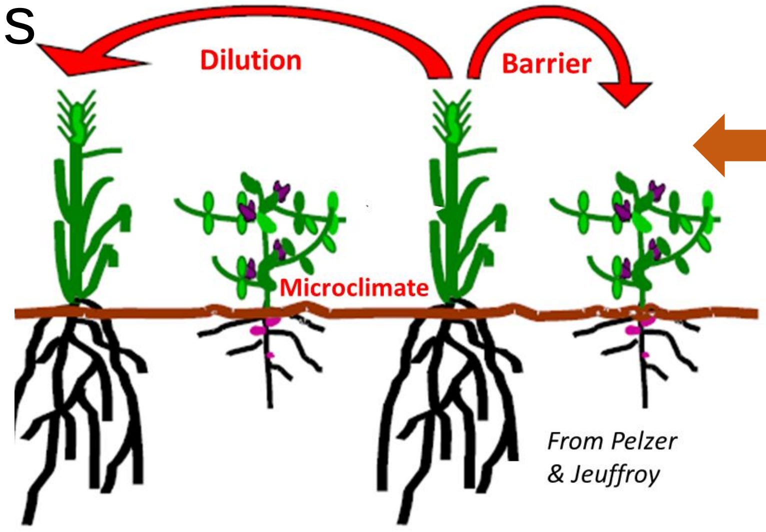
Method – Model behaviour analysis

Microclimate in STICS



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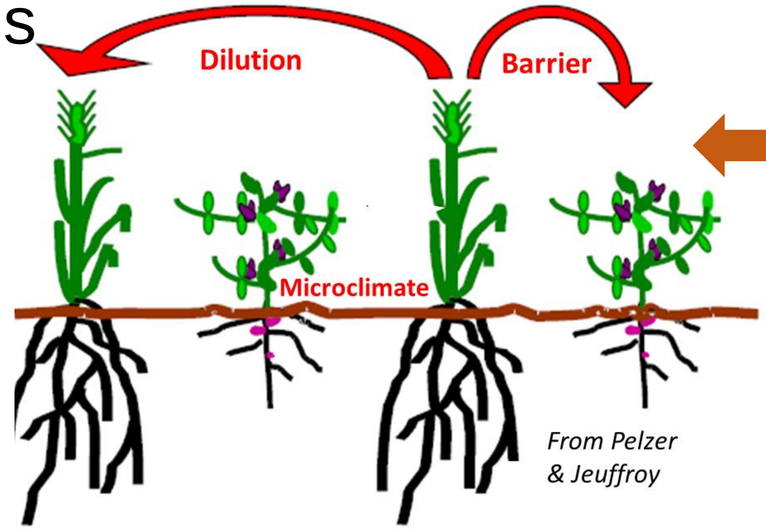

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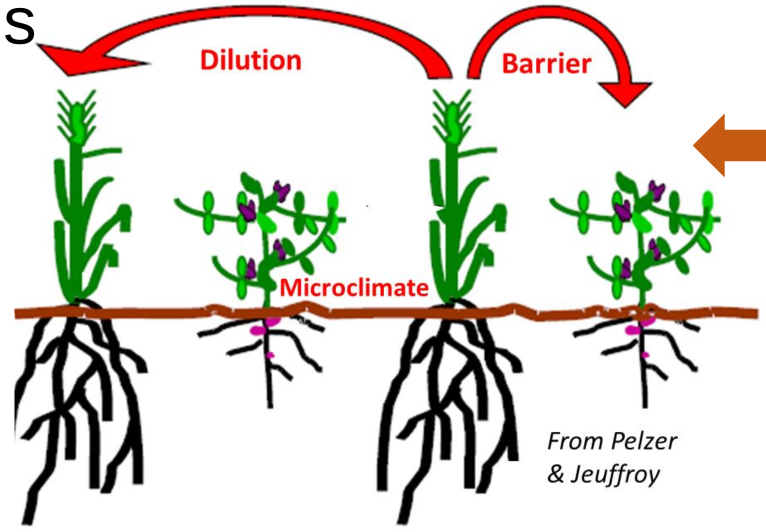
2 - ERIN



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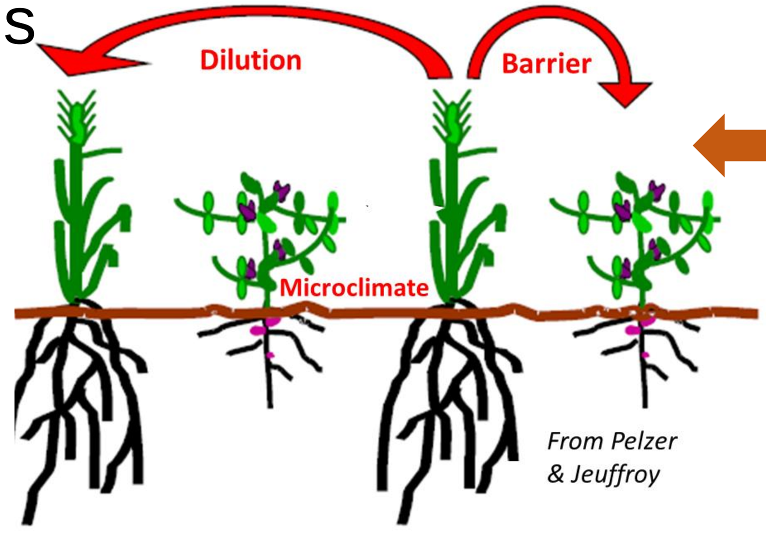
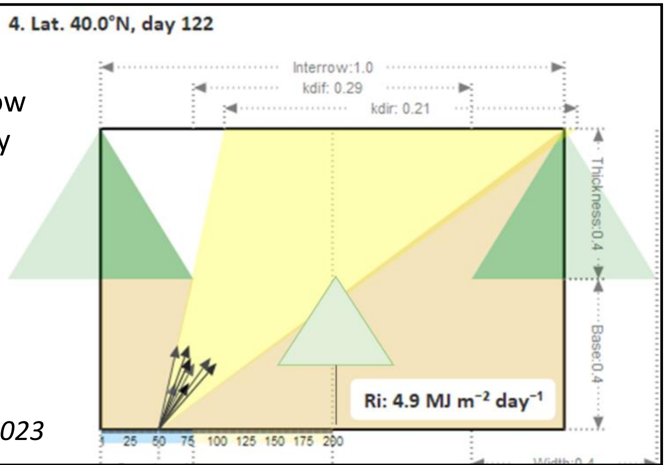


From Pelzer & Jeuffroy

Adapt MILA-STICS to intercrops

RADI

f(LAI, height, row spacing, canopy geometry)



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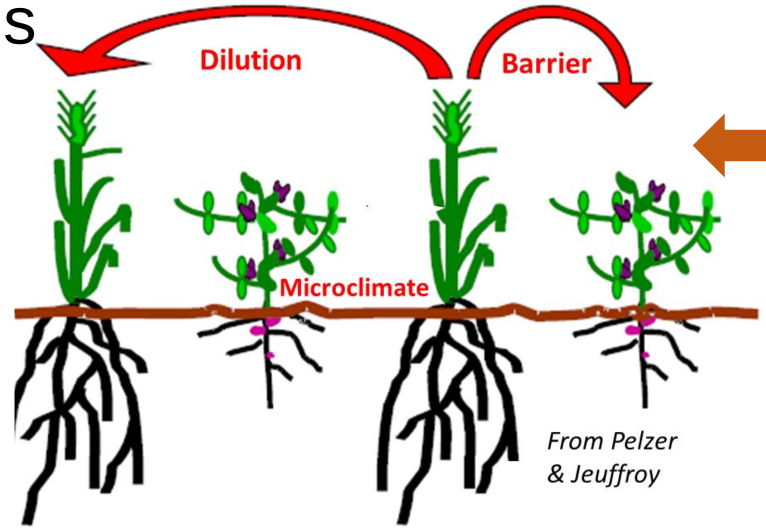

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- Extreme cases with a dominance factor (height)

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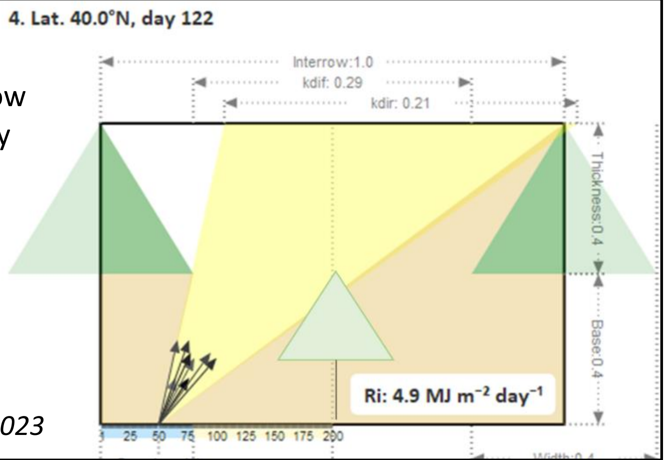

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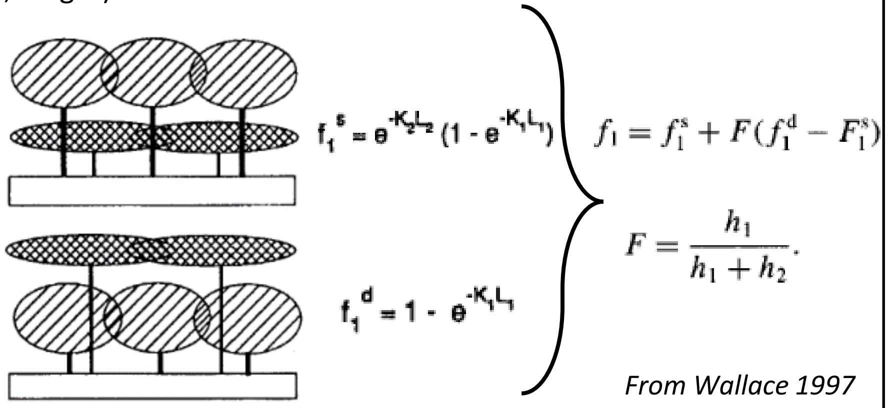
ERIN f(LAI, height)



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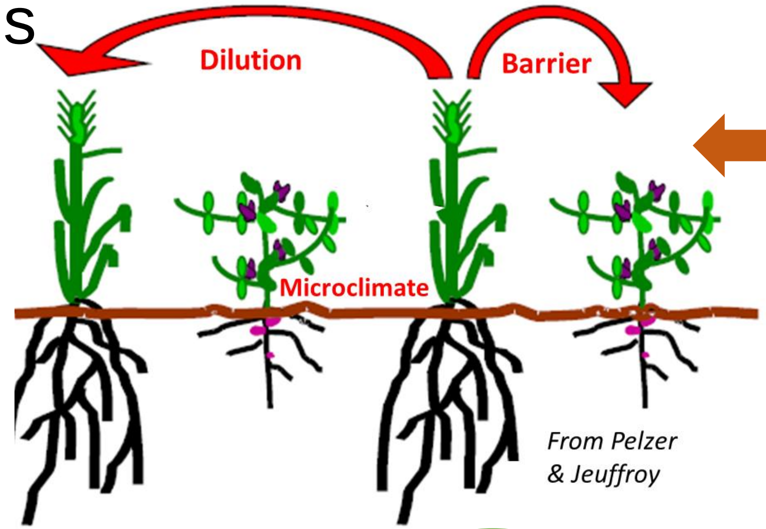

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MILA / Wheat brown rust

STICS IC

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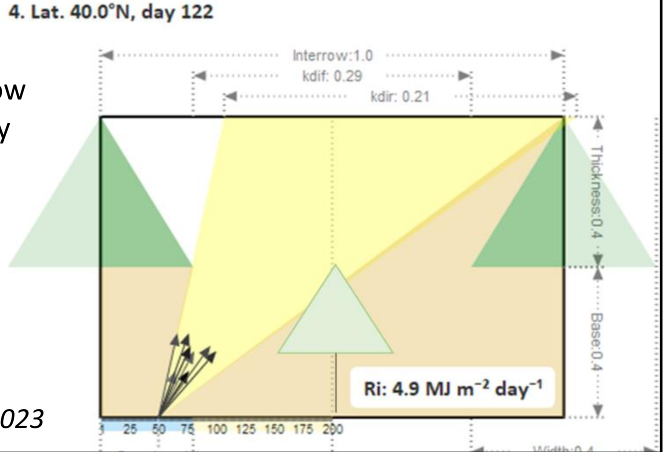

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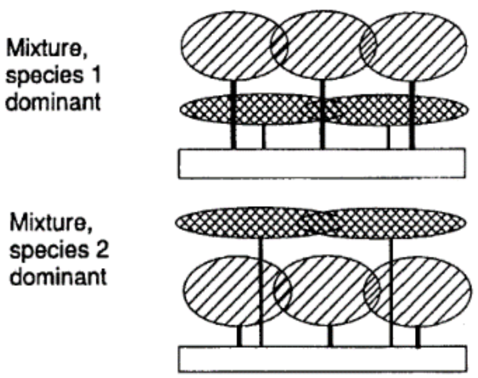
ERIN

f(LAI, height)



$$f_1^s = e^{-K_2L_2}(1 - e^{-K_1L_1})$$

$$f_1^d = 1 - e^{-K_1L_1}$$

$$f_1 = f_1^s + F(f_1^d - F_1^s)$$

$$F = \frac{h_1}{h_1 + h_2}.$$

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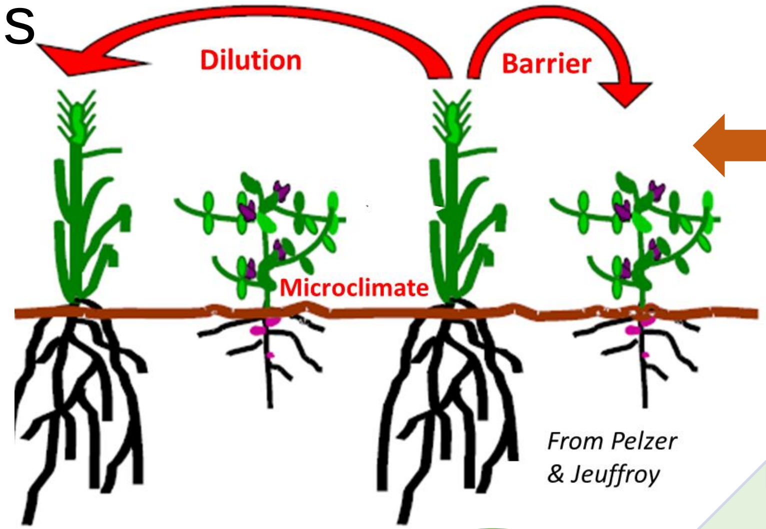

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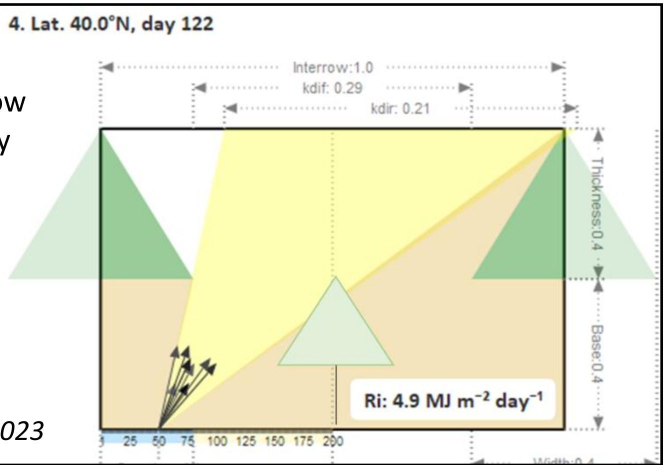
MILA / Wheat brown rust + STICS IC

- Wheat as single crop
- Varying row spacing and density

Dilution effect alone

RADI

f(LAI, height, row spacing, canopy geometry)



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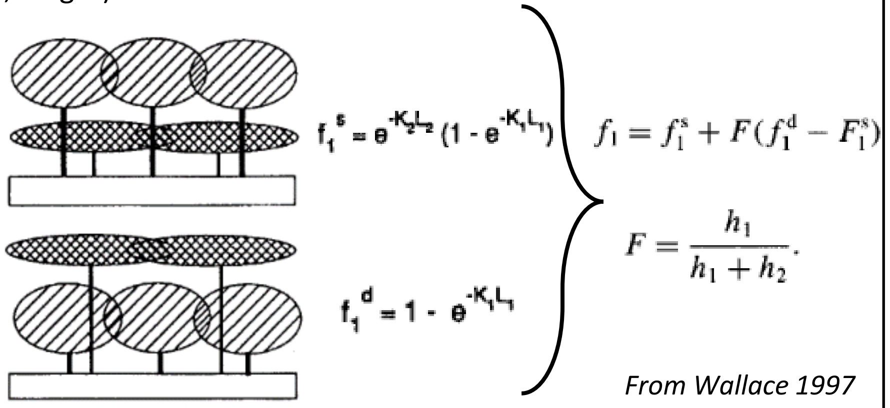

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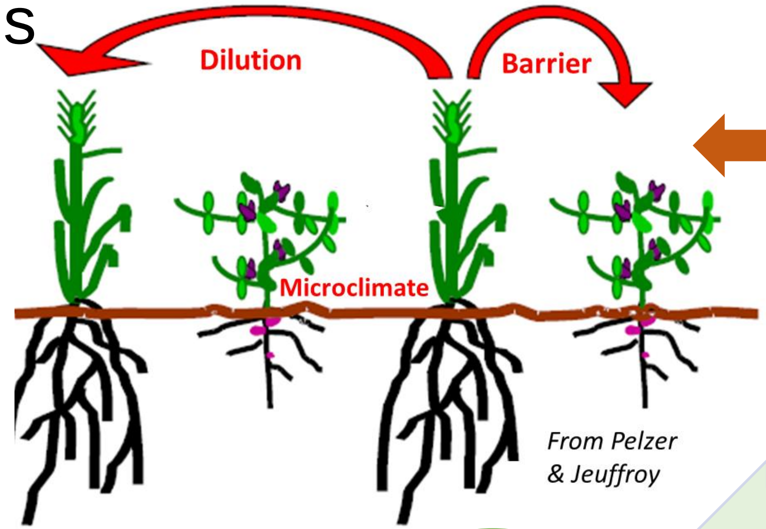

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MILA / Wheat brown rust

+

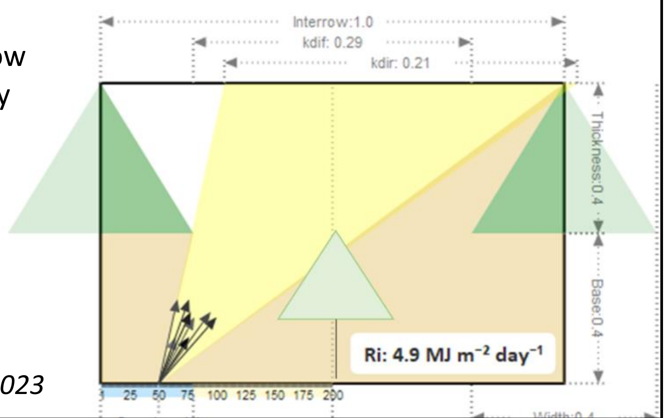
STICS IC

Dilution effect alone
- Wheat as single crop
- Varying row spacing and density

Dilution AND barrier effects
- Wheat – Pea system
- Varying proportion and total density

RADI

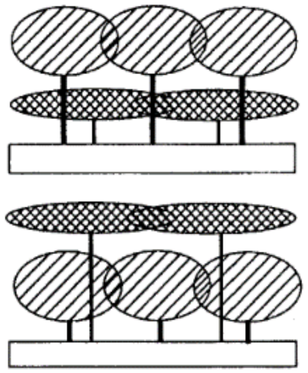
f(LAI, height, row spacing, canopy geometry)



From Vezy et al 2023

ERIN f(LAI, height)

Mixture, species 1 dominant



$f_1^s = e^{-K_2L_2}(1 - e^{-K_1L_1})$

Mixture, species 2 dominant

$f_1^d = 1 - e^{-K_1L_1}$

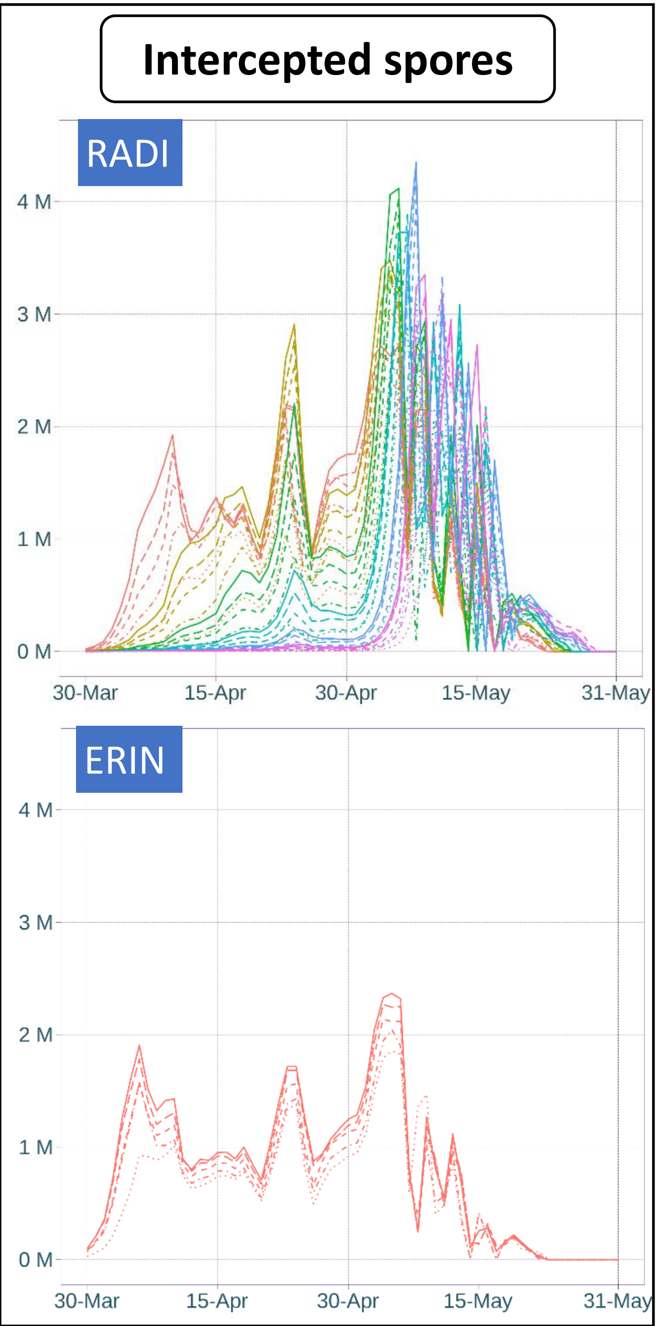
$$f_1 = f_1^s + F(f_1^d - F_1^s)$$

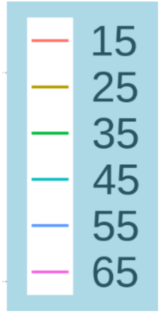
$$F = \frac{h_1}{h_1 + h_2}.$$

From Wallace 1997

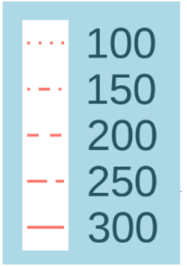
Situation:
- Auzeville, South-Western France
- Season 2005 – 2006
- Winter sowing
- Plant parameters calibrated for the new intercrop version of STICS (Vezy, 2023)

Dilution effect – Wheat single crop





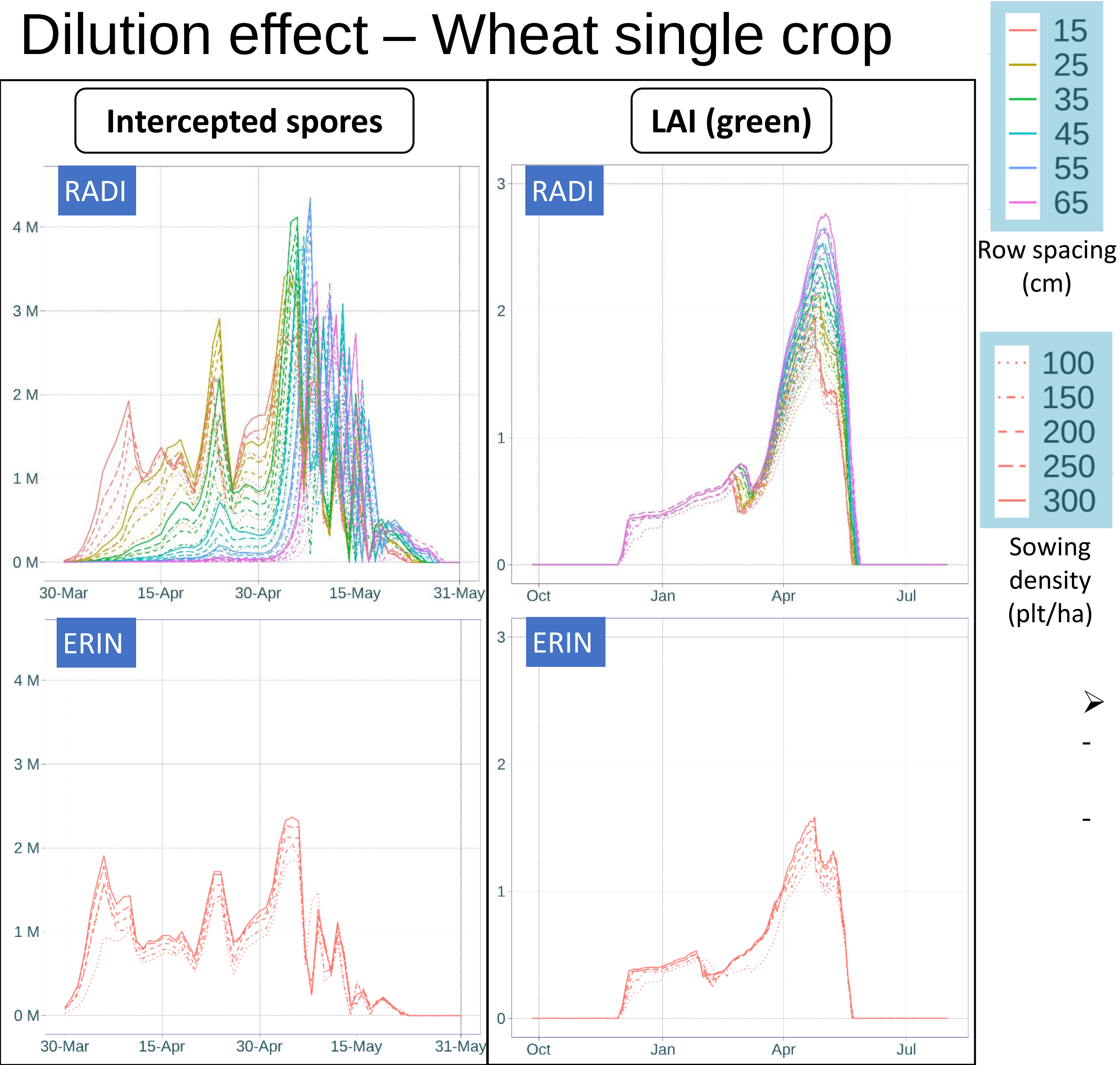
Row spacing (cm)



Sowing density (plt/ha)

- **Key findings**
- No effect of row spacing on ERIN, expected with Beer-Lambert

Dilution effect – Wheat single crop



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- Notable effect of the solutions on LAI

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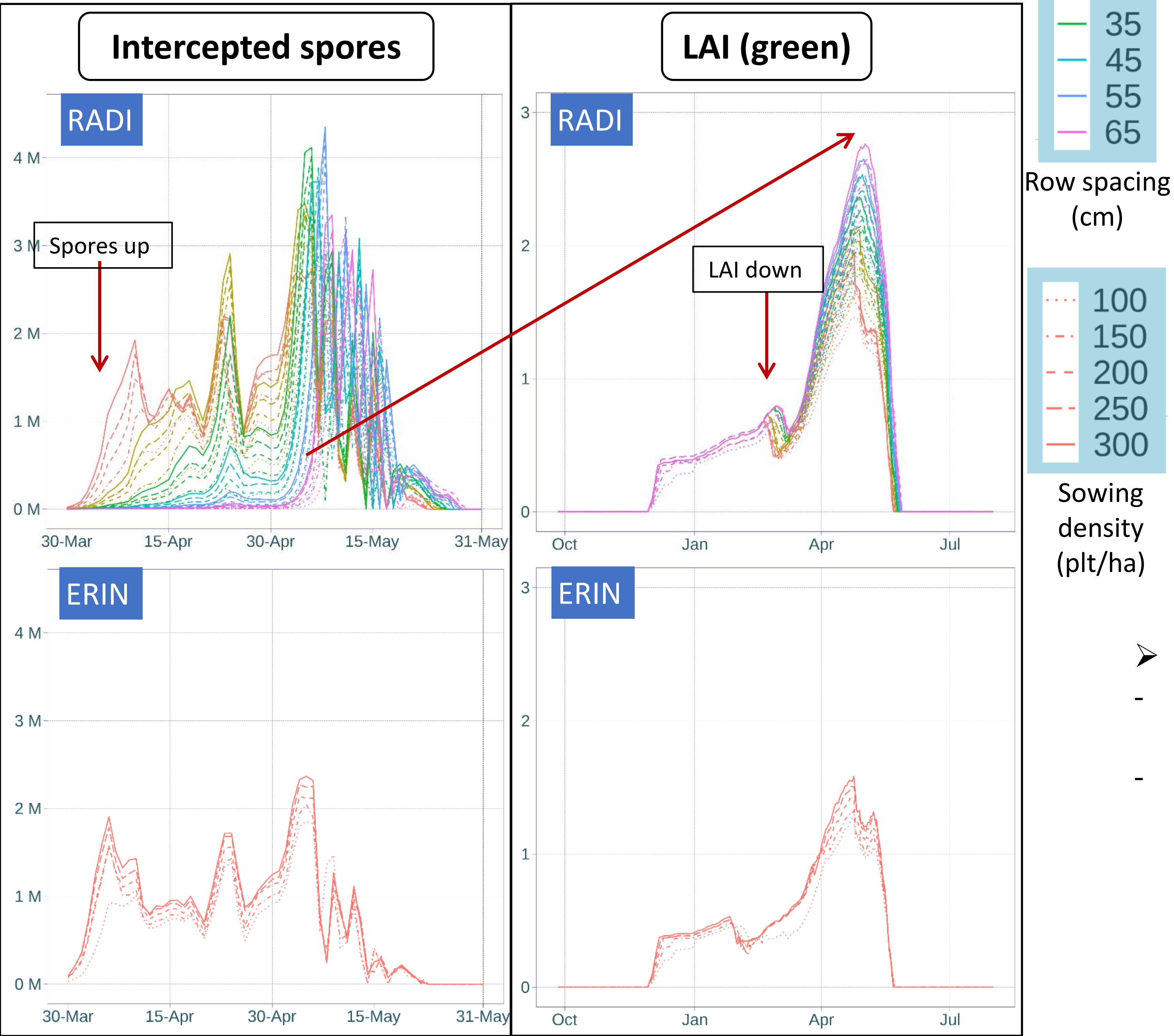

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- No effect of row spacing on ERIN, expected with Beer-Lambert
- Notable effect of the solutions on LAI due to delay in the start of spore interception via the row spacing

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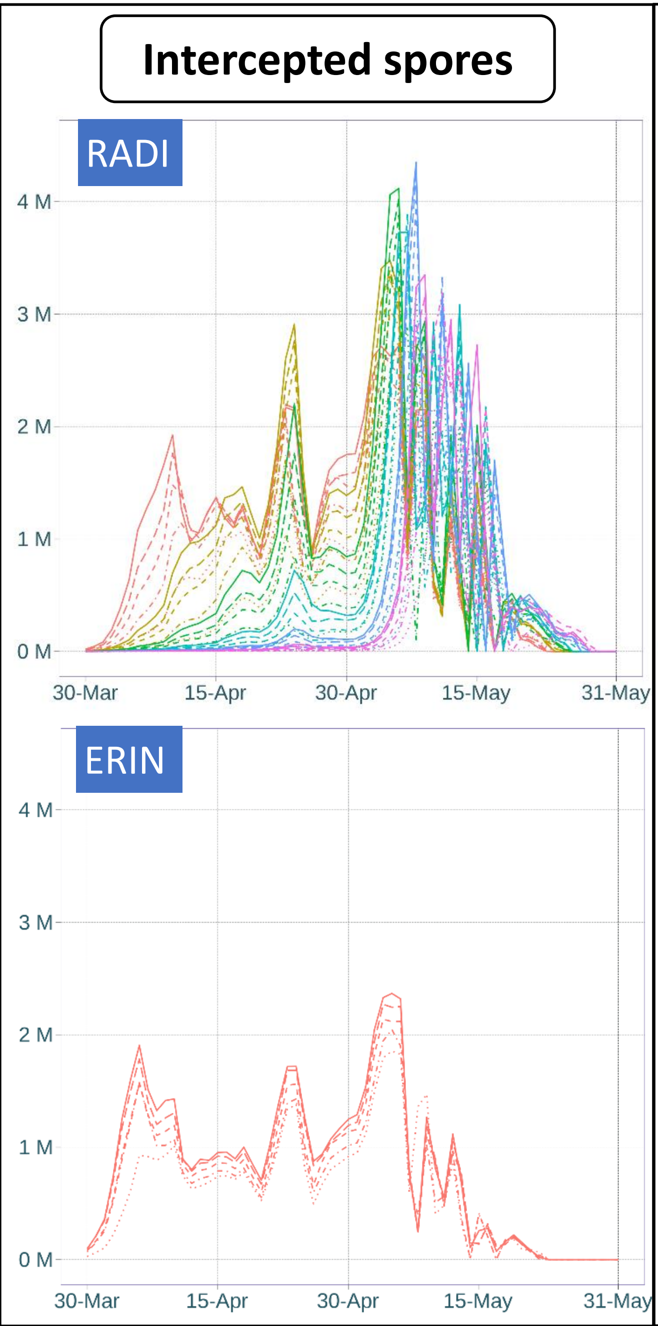
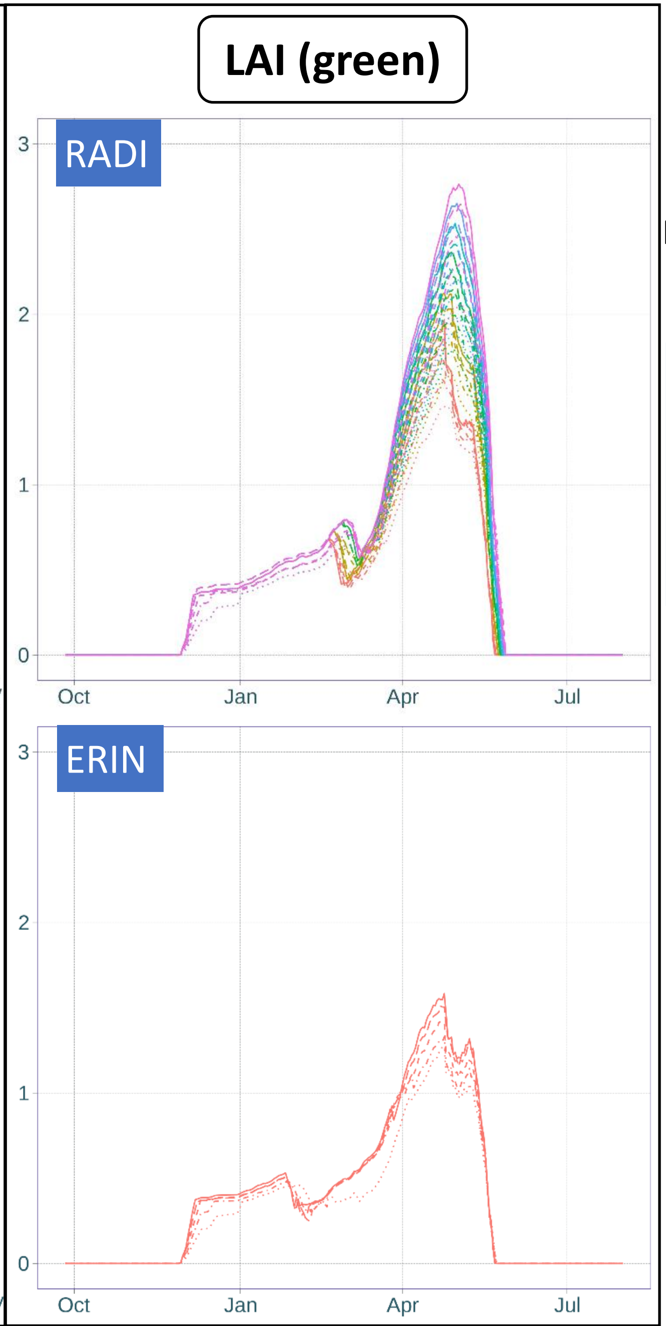
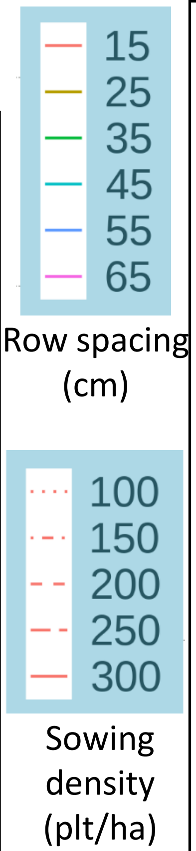
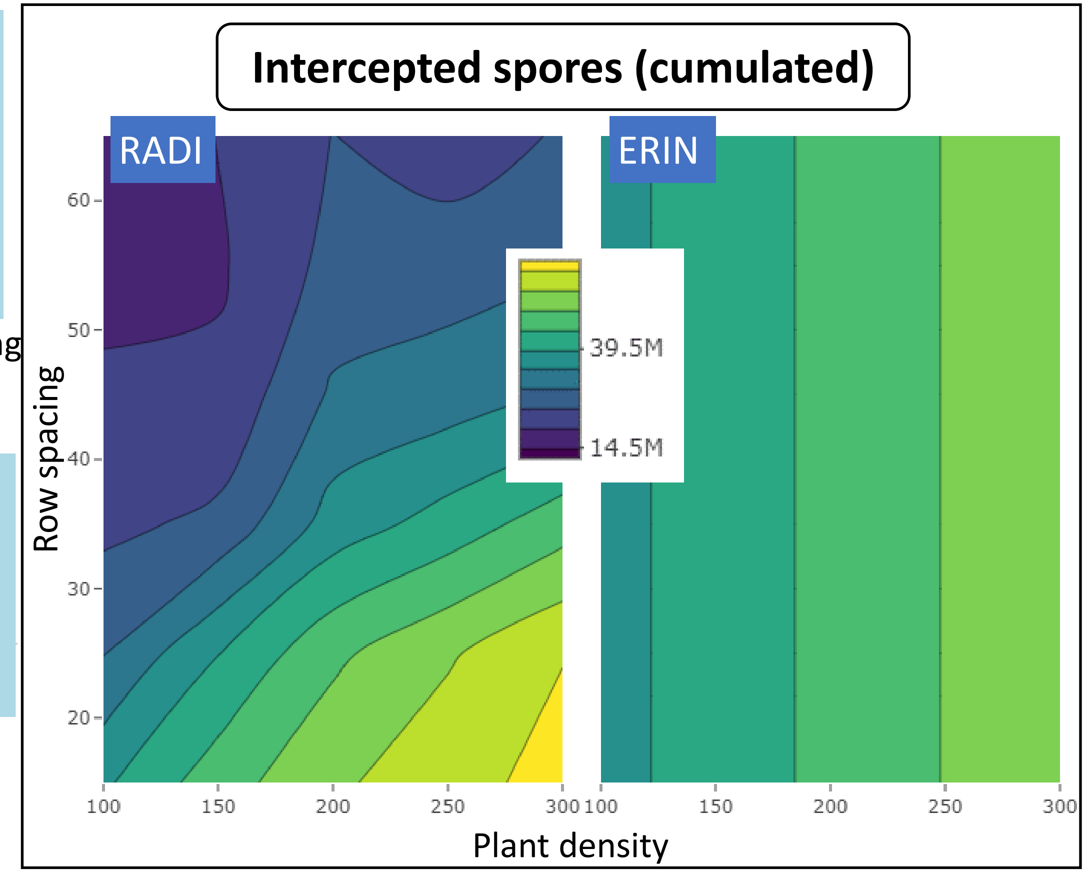


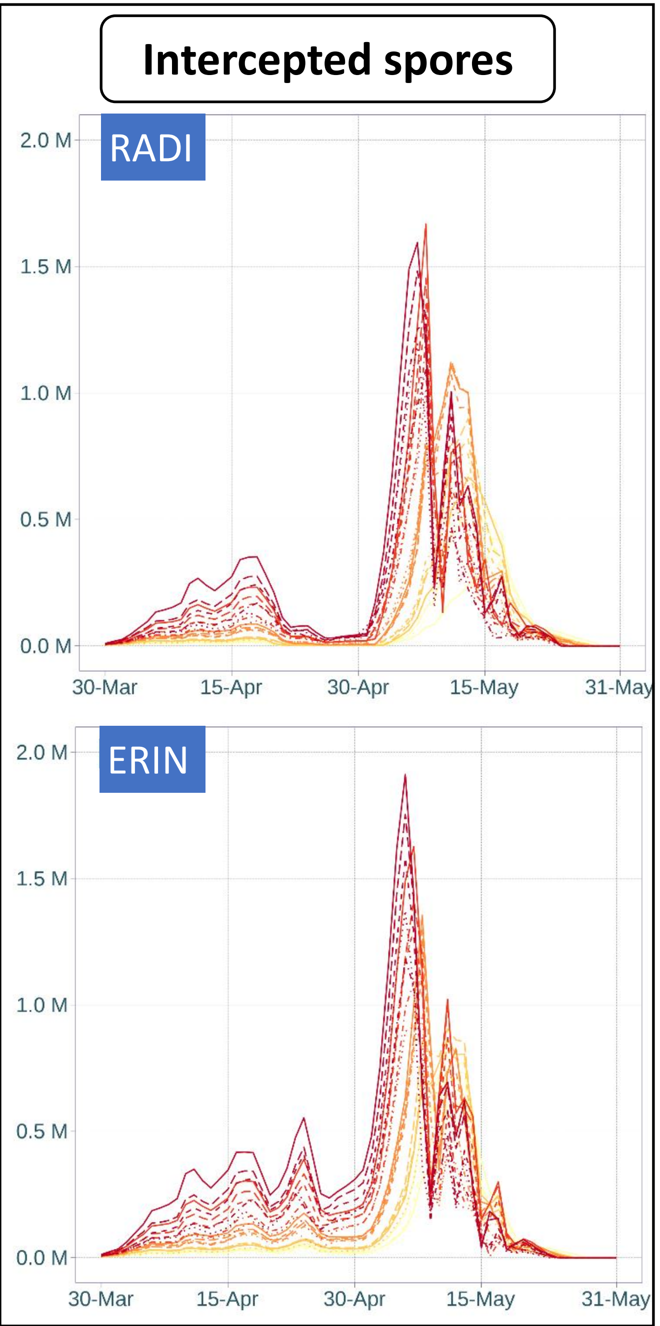


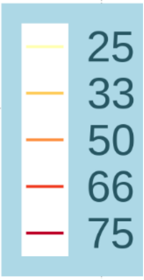




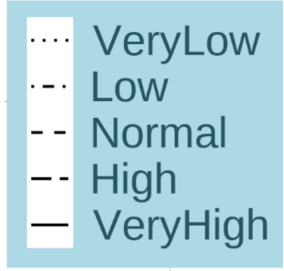
- **Key findings**
  - No effect of row spacing on ERIN, expected with Beer-Lambert
  - Notable effect of the solutions on LAI due to delay in the start of spore interception via the row spacing
  - Agronomic levers to reduce diseases levels: density and/or row spacing

Dilution and barrier effects – wheat/pea intercrop





Wheat proportion

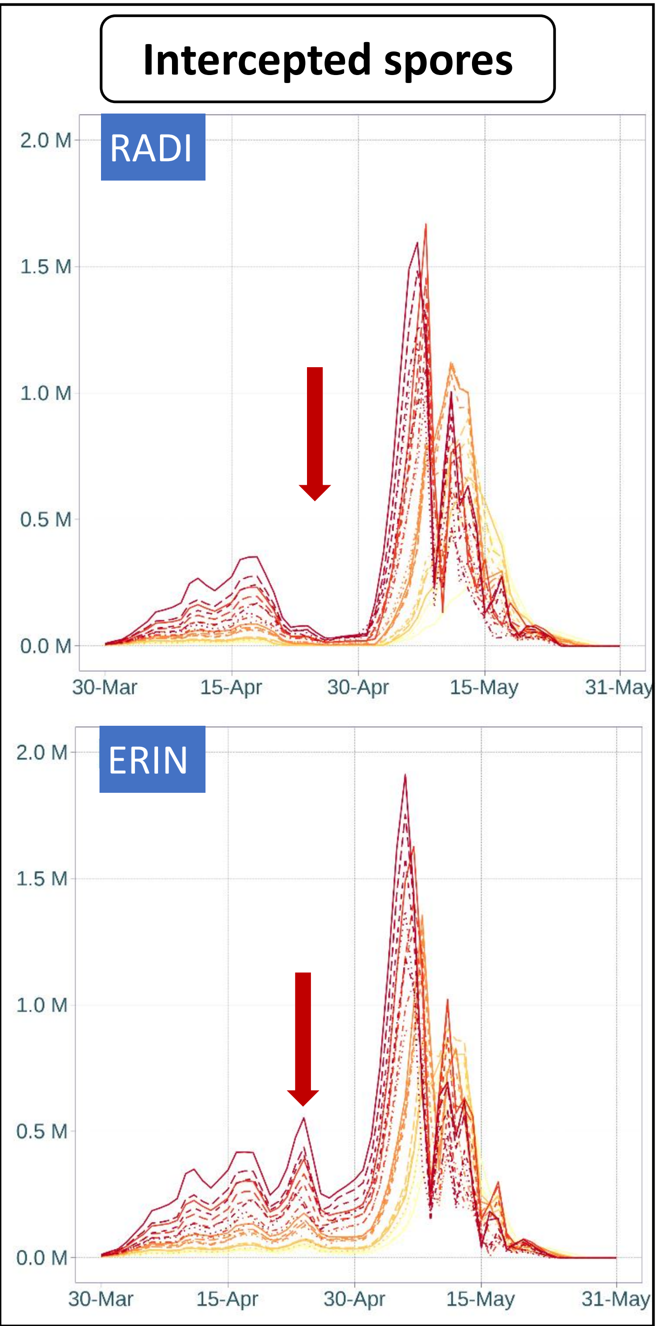


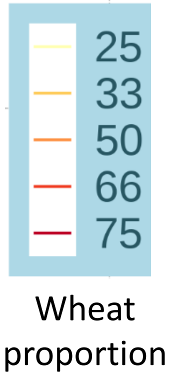
Total sowing density

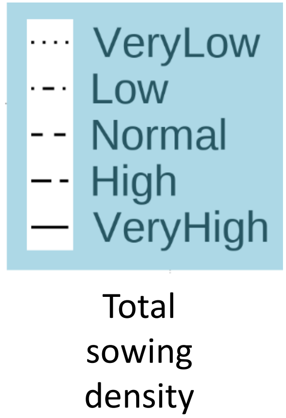
➢ **Key findings**

- No notable difference between the 2 formalisms

Dilution and barrier effects – wheat/pea intercrop



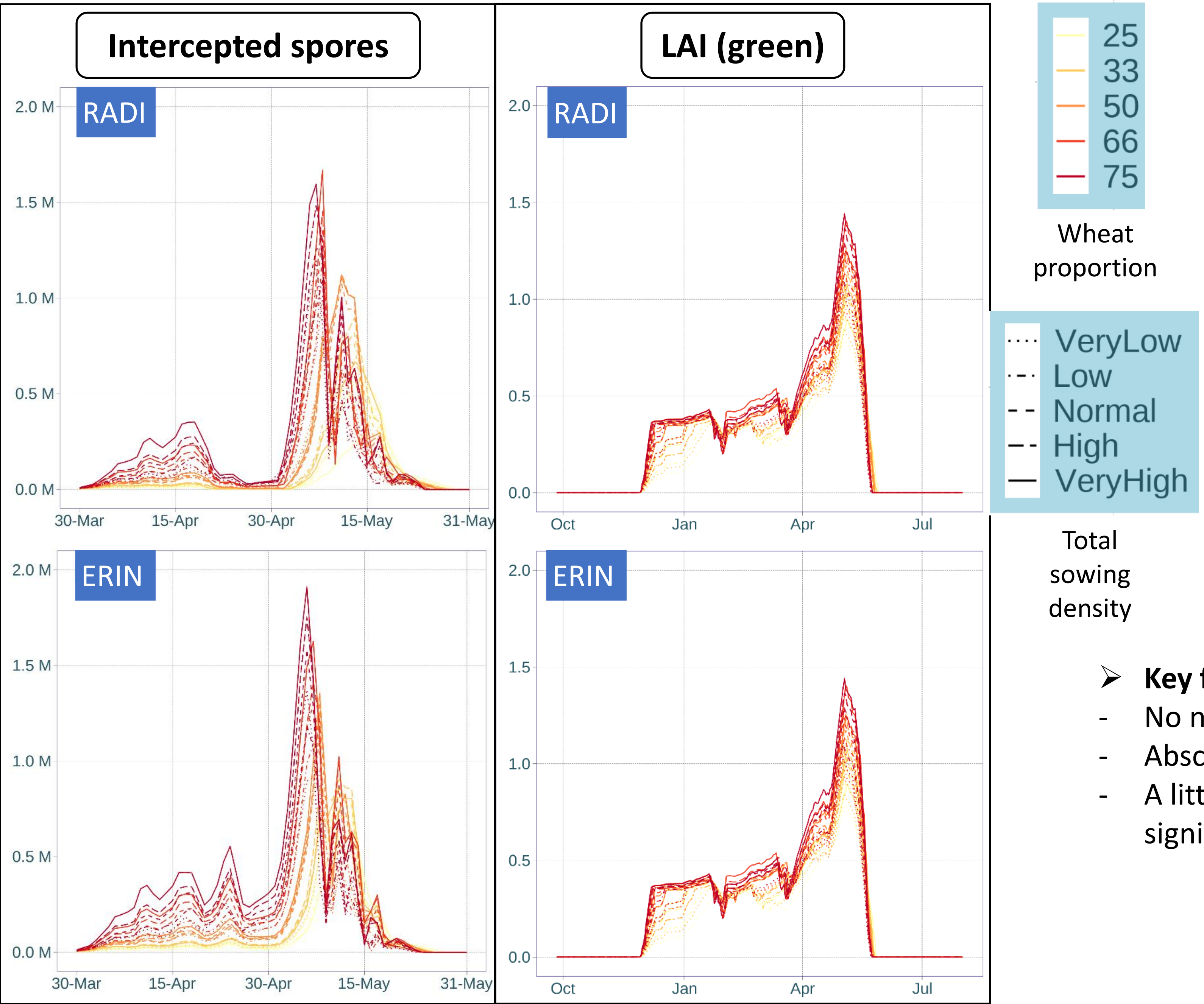




- **Key findings**
- No notable difference between the 2 formalisms
- Abscence of a peak with RADI

Dilution and barrier effects – wheat/pea intercrop

Intercepted spores (cumulated)



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- A little more intercepted spores with ERIN but no significant impact on LAI

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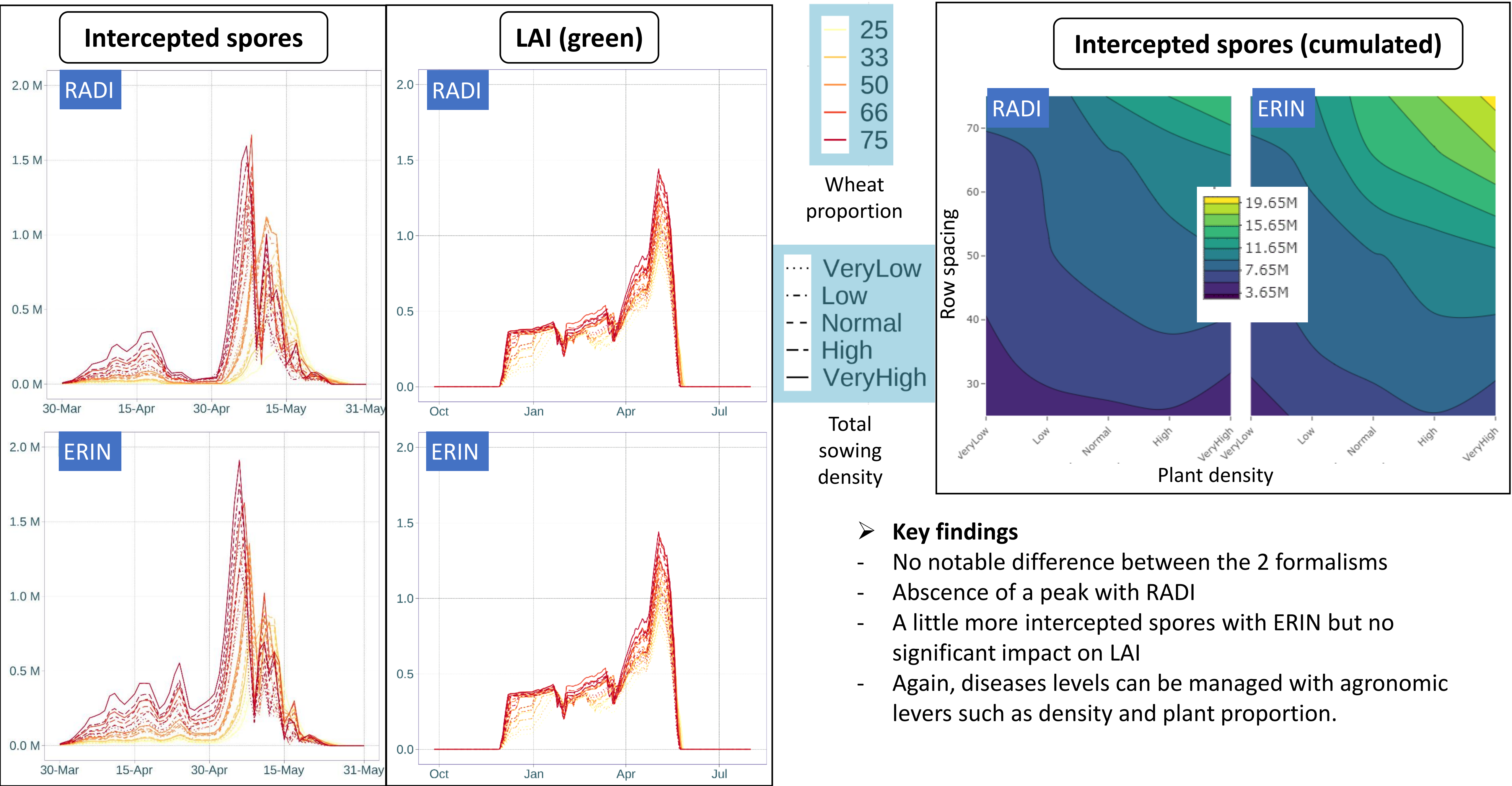
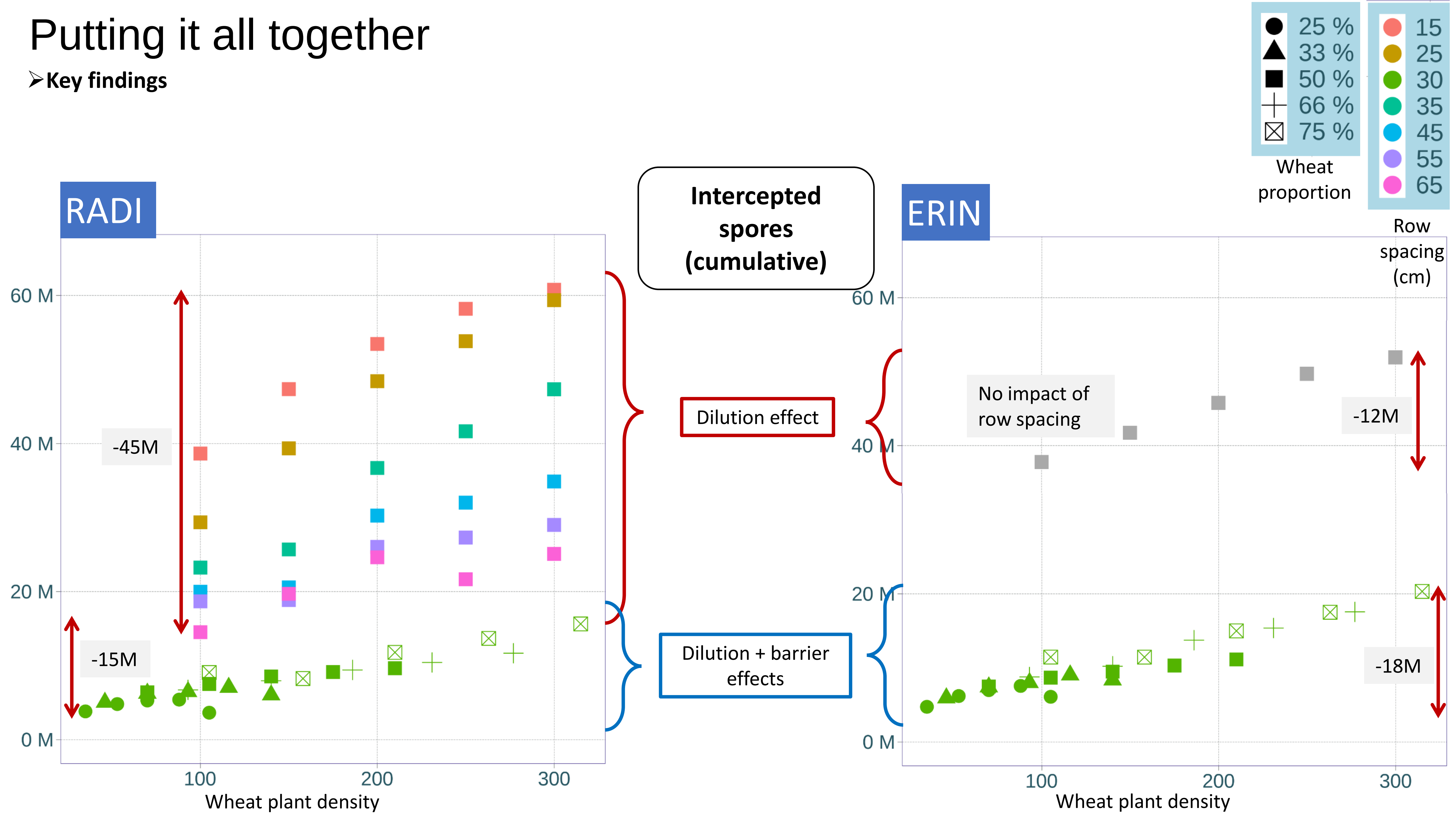


➢ **Key findings**

- No notable difference between the 2 formalisms
- Absence of a peak with RADI
- A little more intercepted spores with ERIN but no significant impact on LAI
- Again, diseases levels can be managed with agronomic levers such as density and plant proportion.

Putting it all together

➢ **Key findings**



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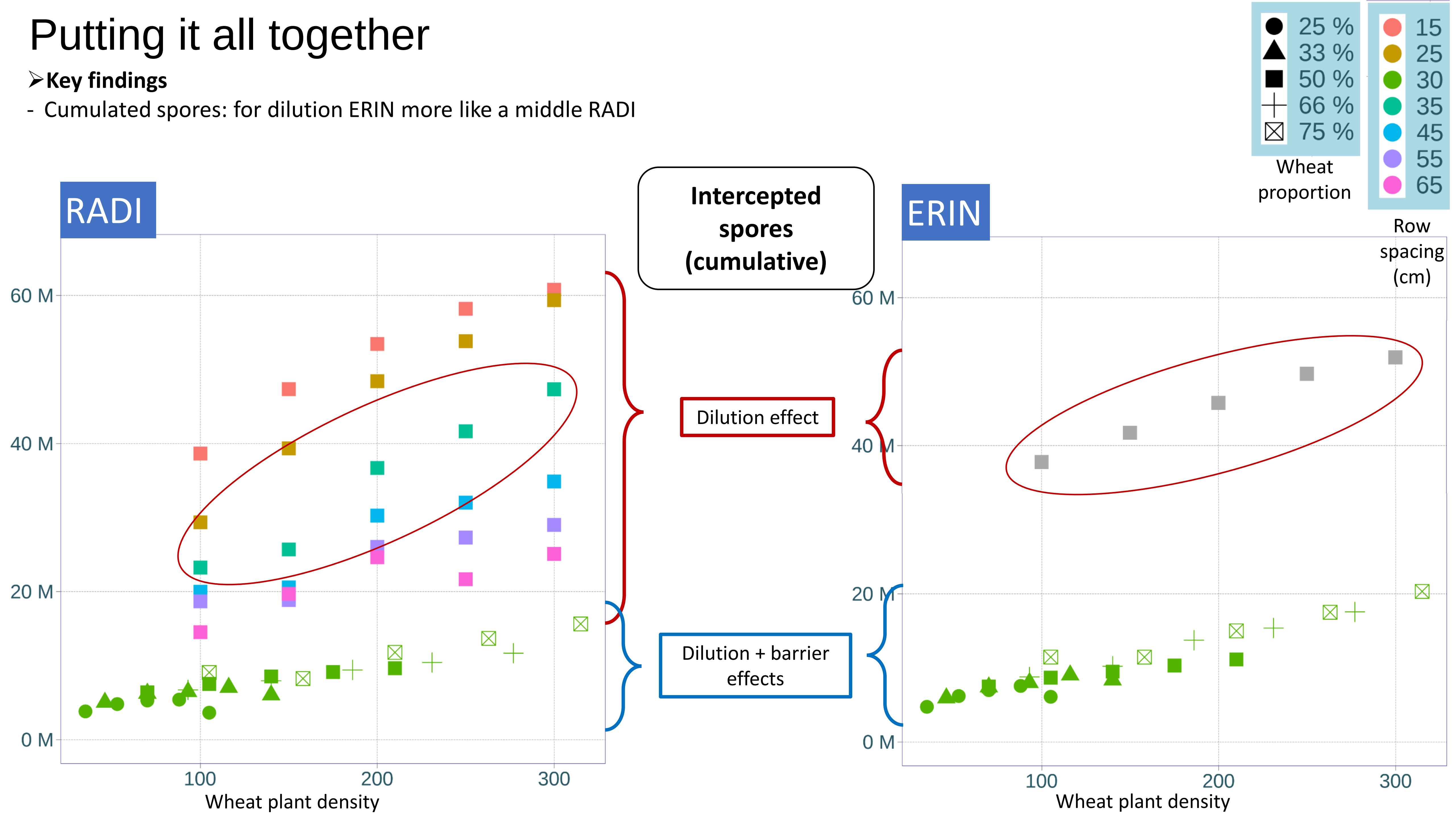
- Cumulated spores: for dilution ERIN more like a middle RADI



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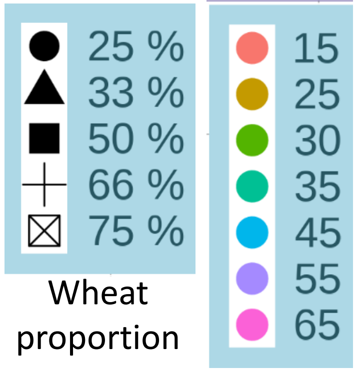
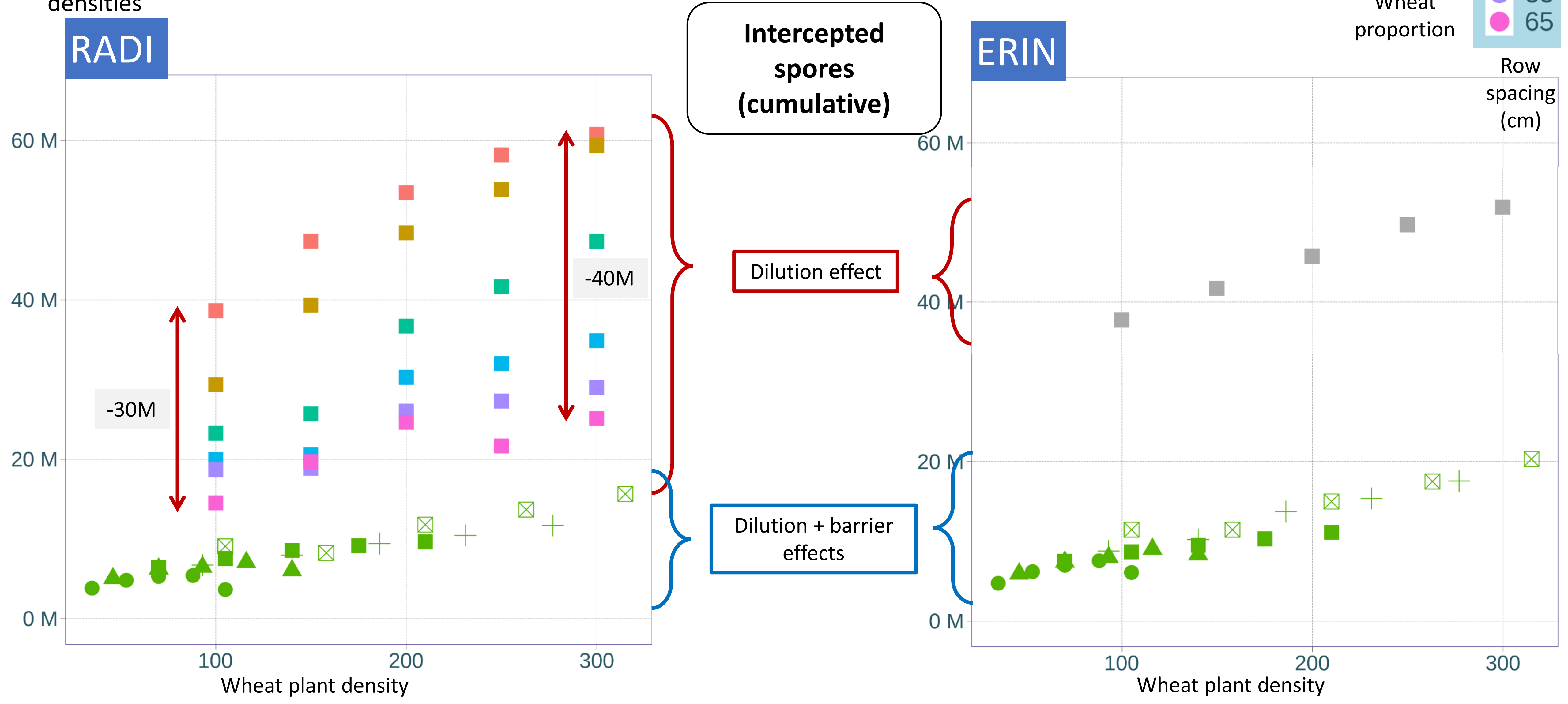
- Increasing row spacing reduces spores, even more at high densities





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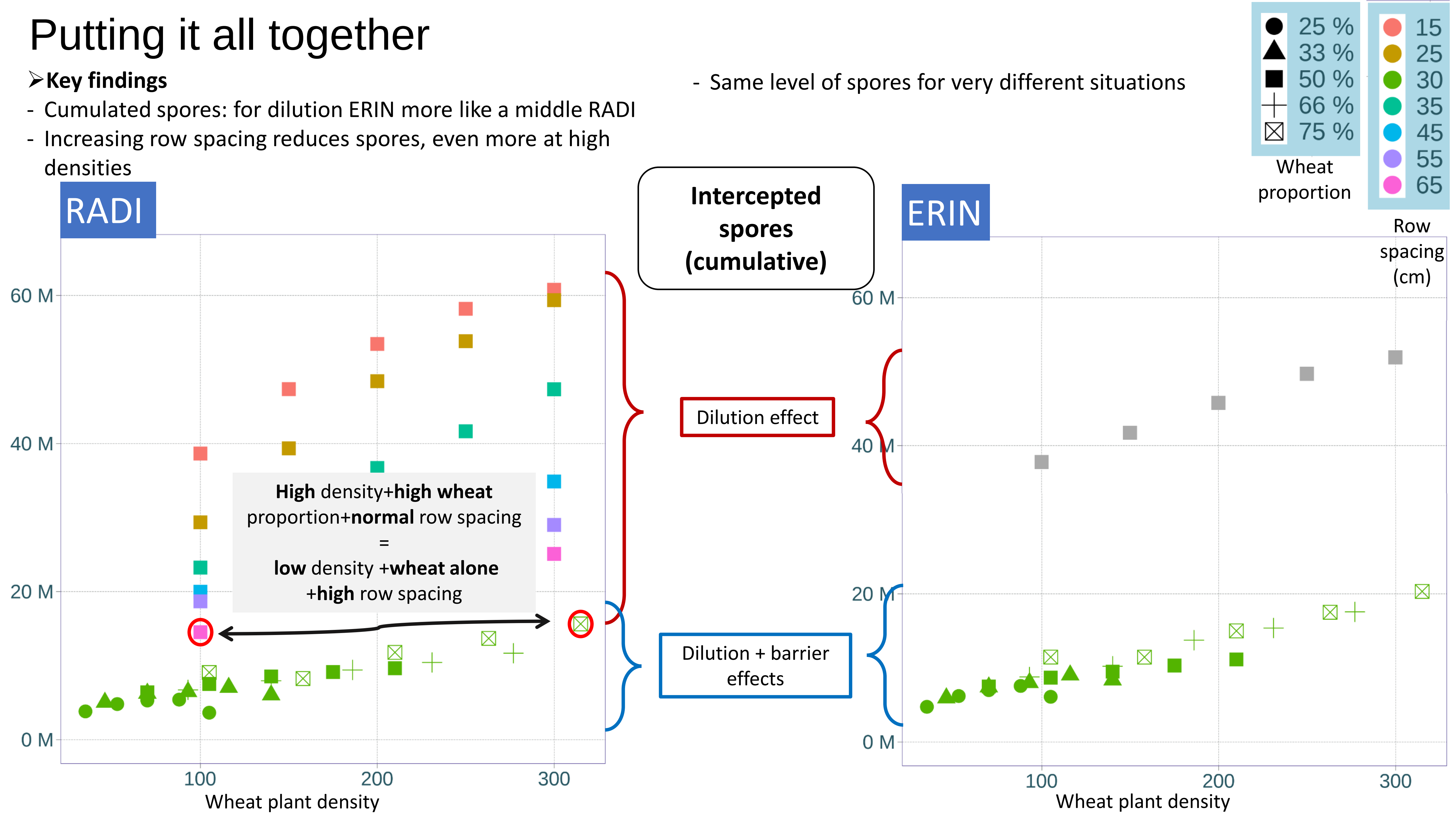
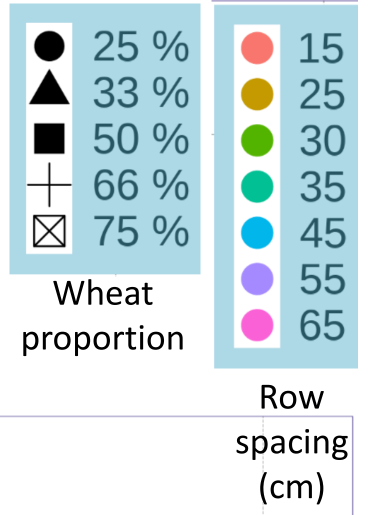
- Cumulated spores: for dilution ERIN more like a middle RADI
- Increasing row spacing reduces spores, even more at high densities
- Same level of spores for very different situations

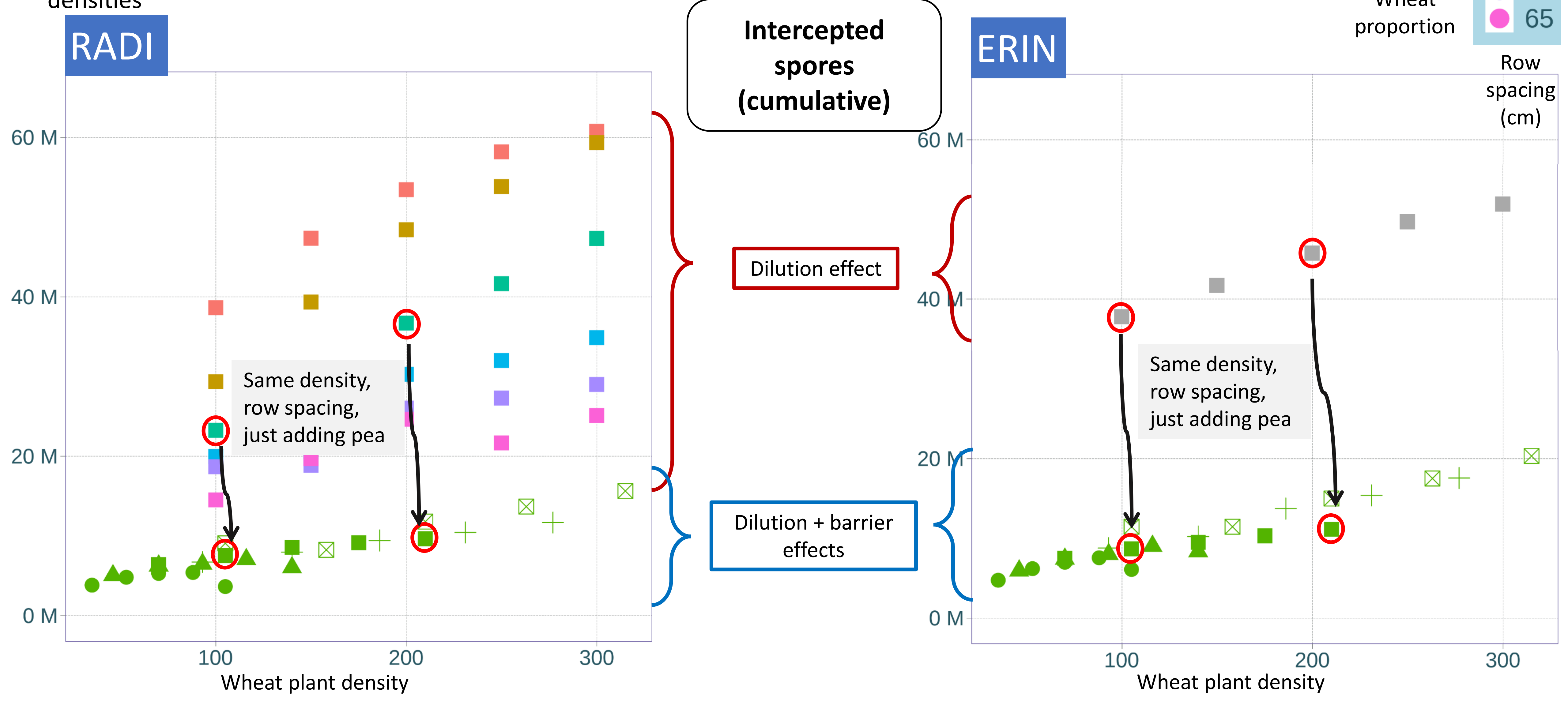


Putting it all together

➢ **Key findings**

- Cumulated spores: for dilution ERIN more like a middle RADI
- Increasing row spacing reduces spores, even more at high densities
- Same level of spores for very different situations
- Adding pea = adding barrier to dilution. -15M at low density, -30 at high density





Conclusion and perspectives

Comprehensive framework

- Test hypotheses on disease dynamics
- Optimise spatial temporal arrangement

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Comprehensive framework	RADI better?
• Test hypotheses on disease dynamics • Optimise spatial temporal arrangement	• Canopy and field geometry • More sensitive to agronomic levers

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More outputs (feedback loop, interaction with other disease processes)

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- MILA-STICS IC: upcoming (datasets available autumn/winter)