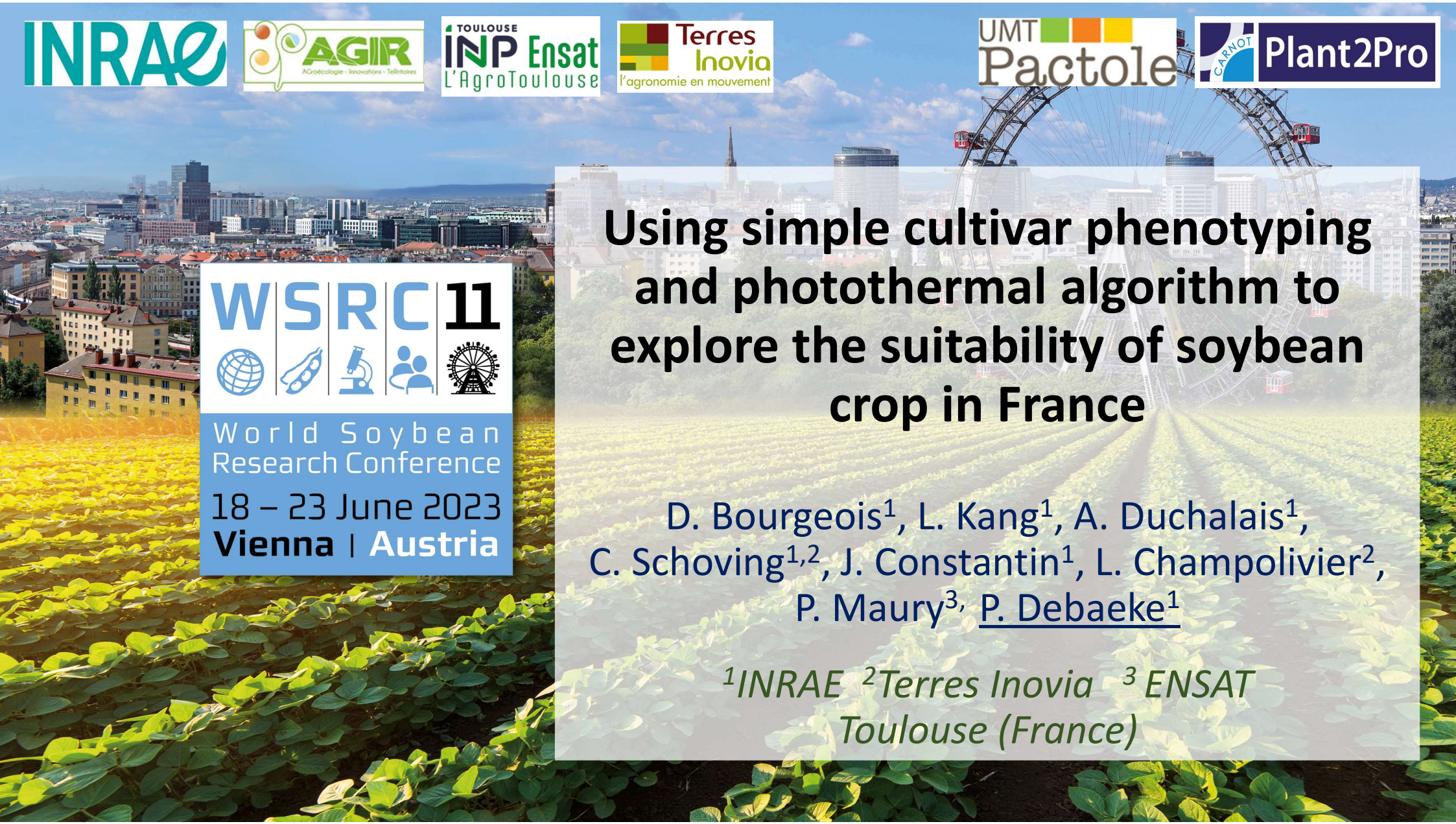

Using simple cultivar phenotyping and photothermal algorithm to explore the suitability of soybean crop in France

D. Bourgeois[1], L. Kang[1], A. Duchalais[1], C. Schoving[1,2], J. Constantin[1], L. Champolivier[2], P. Maury[3], P. Debaeke[1]

[1]INRAE [2]Terres Inovia [3] ENSAT Toulouse (France)

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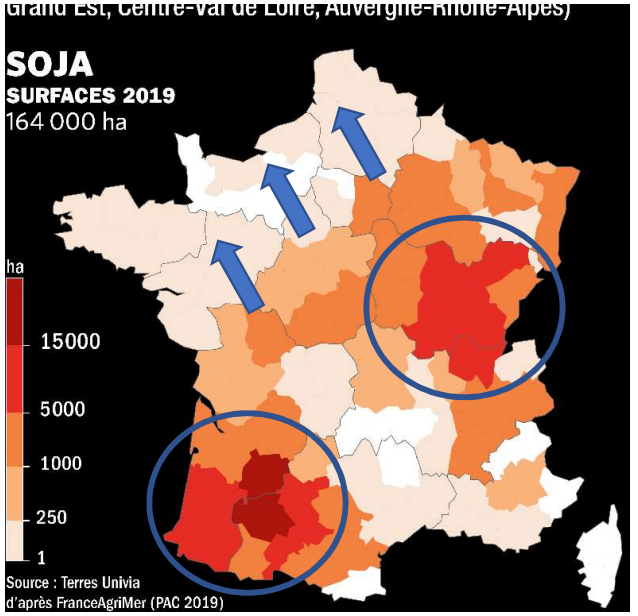
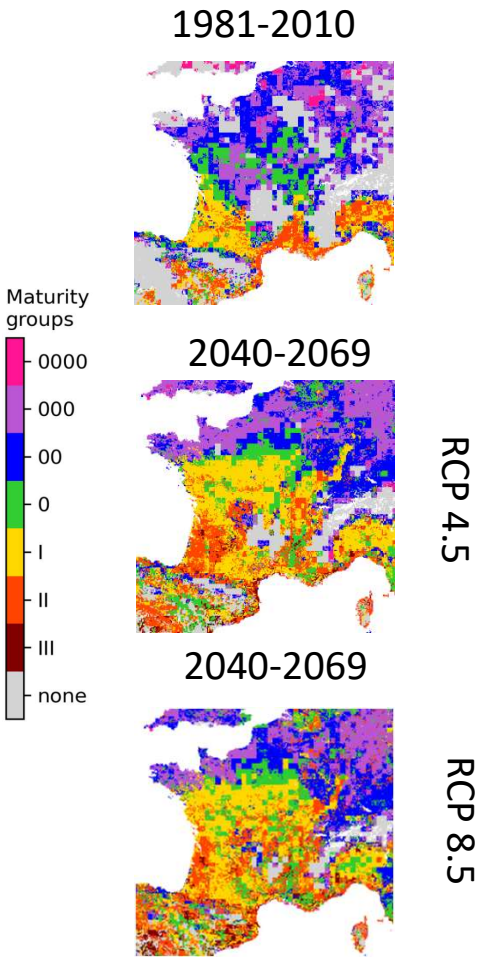
Development of soybean in France

- Including more legumes into cereal-based rotations (N economy + other ecosystem services)
- Soybean : a summer crop with no N fertilization and low pesticides (29 % under OF)
- Search for protein self-sufficiency by domestic production

Moving northward from traditional regions (SW, NE)





➡ from 37 000 ha (2012) to 187 000 ha (2020)

Nendel *et al* (2023), GCB

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A tool for evaluating crop suitability

- A need for a simple phenological model for predicting the main growth stages and evaluate the feasability of soybean varieties :
  - In regions where soybean is presently poorly developed (but could expand with climate change)
  - As a sequential double crop in regions with available water during summer
  - To optimize sowing date and choice of maturity group
- This tool should be calibrated easily with data from controlled conditions (from a given site) or from a network of field experiments well distributed in a country (*e.g.* France)

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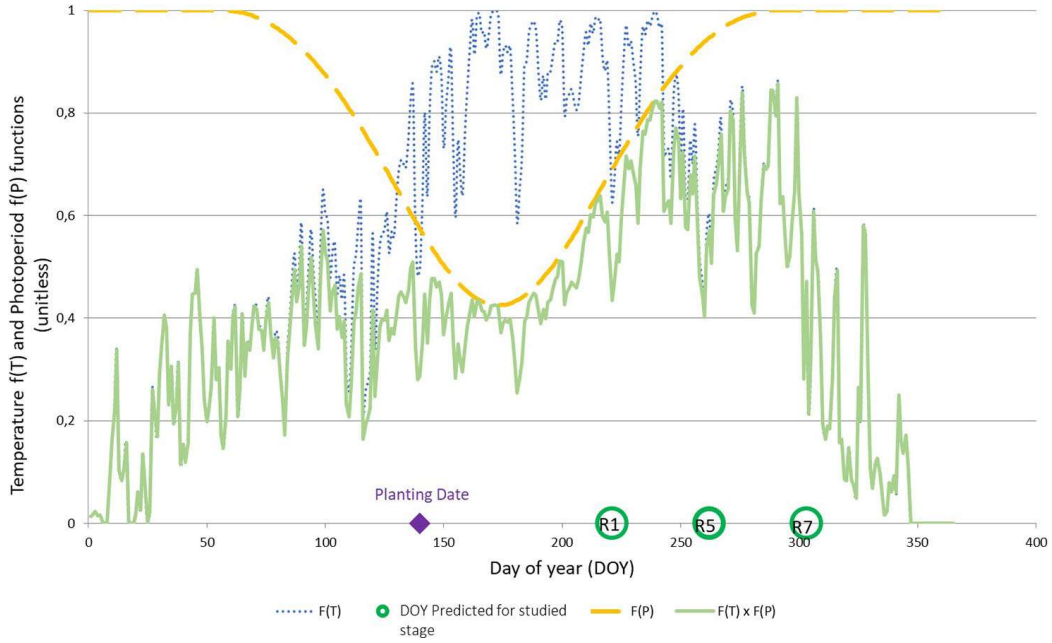
A simple photo-thermal algorithm (SPA)

On a daily basis

$$R_{dev} = R_{dev.max} \times f(T) \times f(P)$$

Rdev = rate of development
f(T) = temperature factor, 0-1
f(P) = photoperiod factor, 0-1

Under optimal conditions $R_{dev} = R_{dev.max}$
Under T or P limiting conditions $R_{dev} < R_{dev.max}$



Schoving *et al.* (2020), *Front Plant Sci* **10**: 1755

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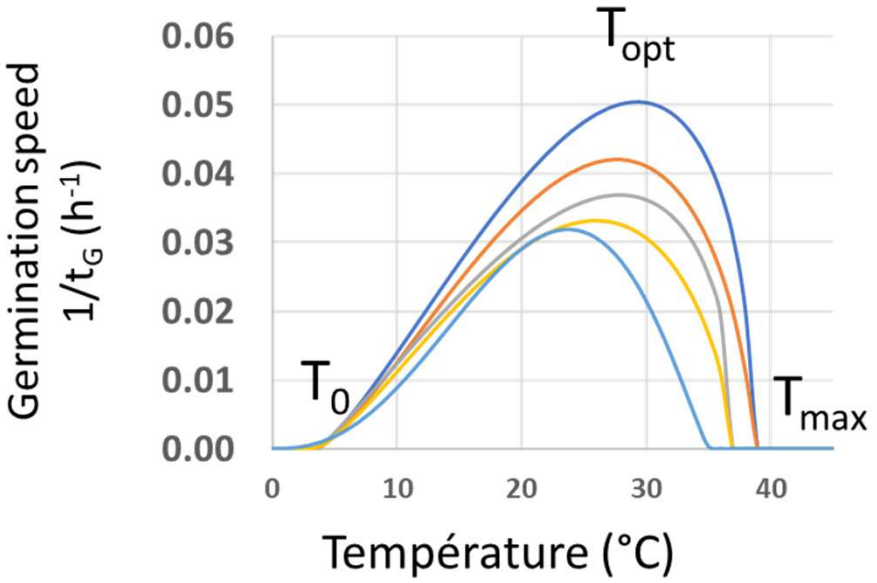
7 parameters for calibrating SPA

Name	Unit	Abbreviation	Origin of data
Minimum temperature of development	(ºC)	T0	**EXP1**
Optimal temperature of development	(ºC)	Topt	**EXP1**
Maximum temperature of development	(ºC)	Tmax	**EXP1**
Optimal daylength for maximum development	(h)	Popt	Setyono *et al* (2007)
Critical daylength for zero development	(h)	Pcrt	Setyono *et al* (2007)
Physiological development days in optimal conditions of temperature and photoperiod	d	$PDDopt_{c,p}$	**EXP2** + Optimization
Sensitivity coefficient to the photoperiod	unitless	S	**EXP2** + Optimization

Schoving *et al* (2020)

EXP 1. Response to temperature

Cardinal temperatures are similar for all the plant development processes (Parent et al., 2010)
→ determination of the rate and speed of seed germination in climatic chambers (incubators) is a simple method for testing the response of numerous varieties to temperature

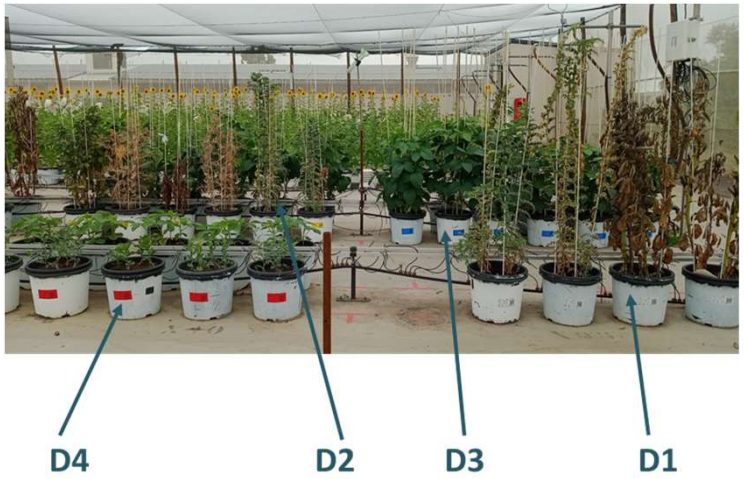


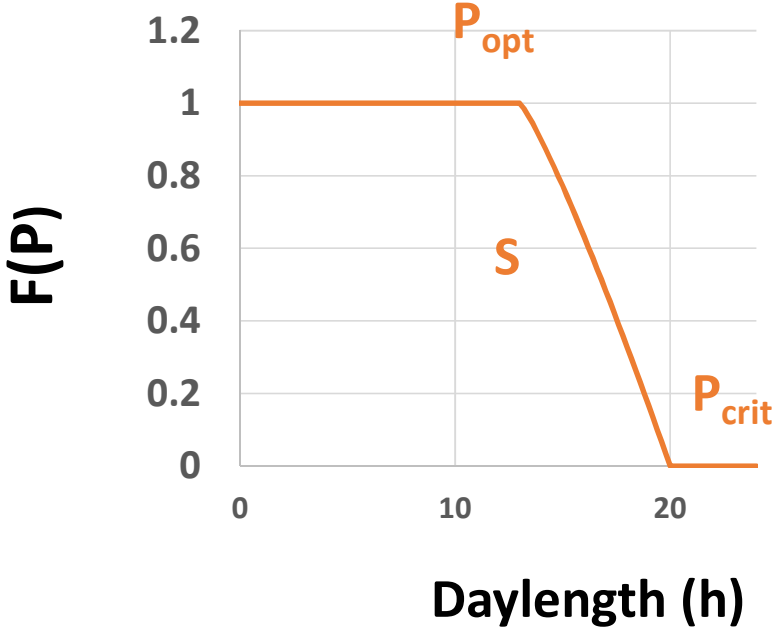
Yin *et al* (1995)

4 x 25 seeds per genotype
11 temperatures from 3° to 43 °C

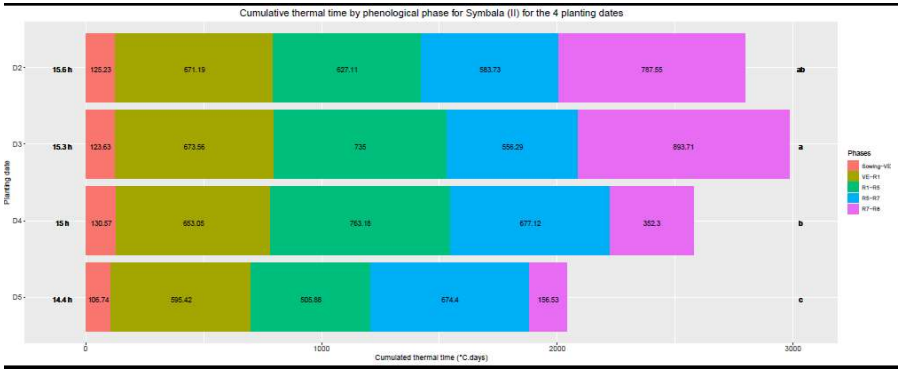
$$R_{dev} = R_{dev.max} \times \boldsymbol{f(T)} \times f(P)$$

EXP 2. Response to photoperiod

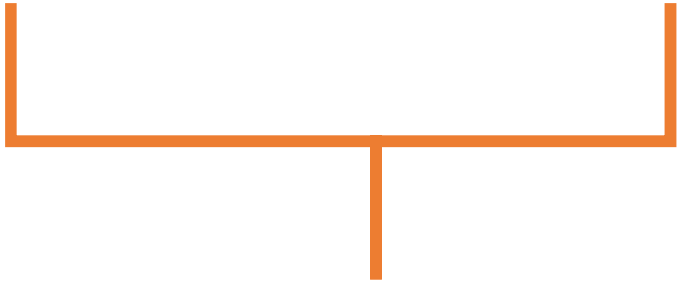




Phasic thermal time



cv.Symbala (II)



$$R_{dev} = R_{dev.max} \times f(T) \times f(P)$$

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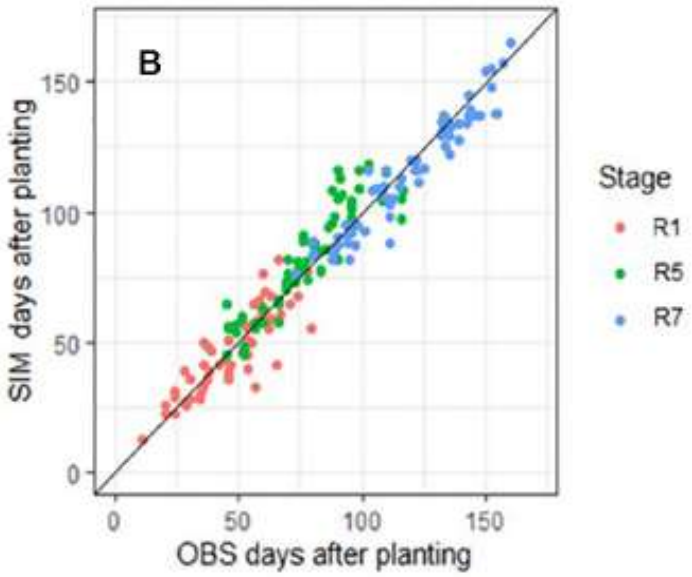
Model evaluation on a multi-environment trial



2013-2018 (4 years) – SW France

RMSE = 5.6 to 9.4 days
Bias = -3.5 to 4 days
RRMSE = 5 to 17 %

Schoving *et al.* (2020)

MGS 000 to II

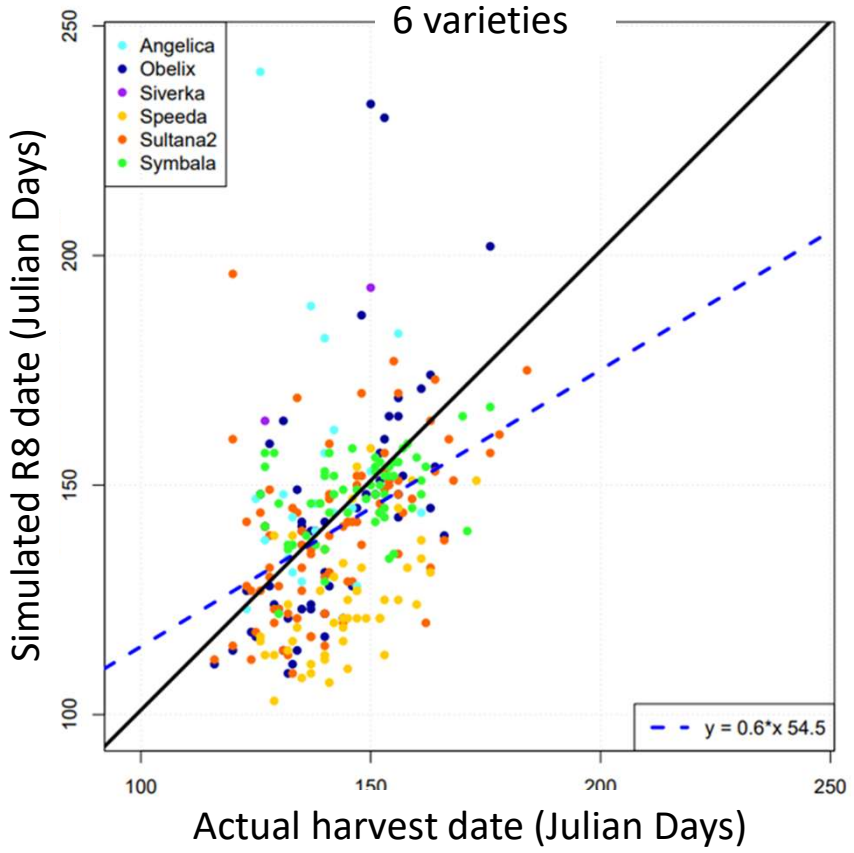
France

2010-2021 (12 years)
268 « variety x trial »

RMSE = 19.7 days
Bias = -2.4 days
RRMSE = 13.7 %

Post-registration trials

Terres Inovia
l'agronomie en mouvement



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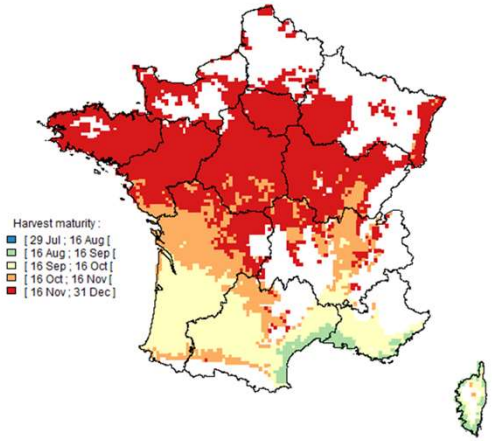
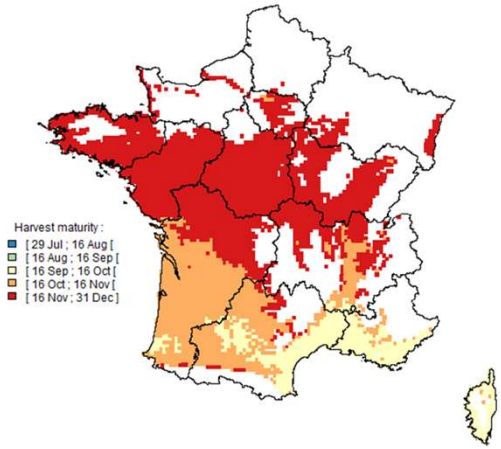
Application to the determination of harvest dates

Harvest of soybean 8 years out 10 during or before the time window **2001-2021**

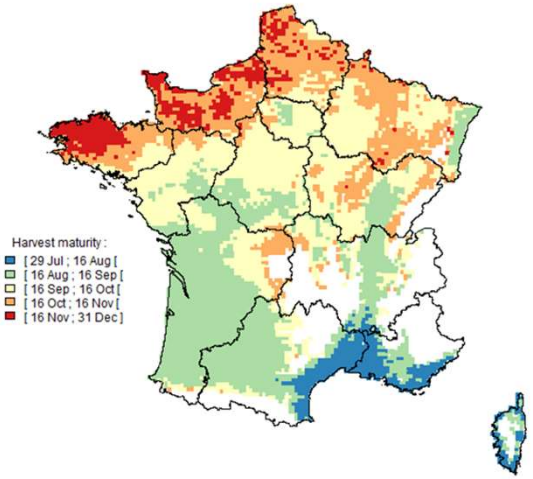
cv Symbala (MG II)
Sowing date **25/03**



cv Symbala (MG II)
Sowing date **05/05**

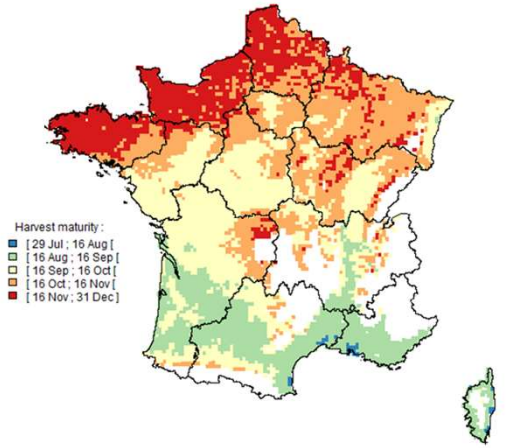


cv Sultana (MG 000)
Sowing date **25/03**



< 16/08	avoid
< 16/09	suitable
< 16/10	suitable
< 16/11	risky
< 31/12	avoid

cv Sultana (MG 000)
Sowing date **05/05**



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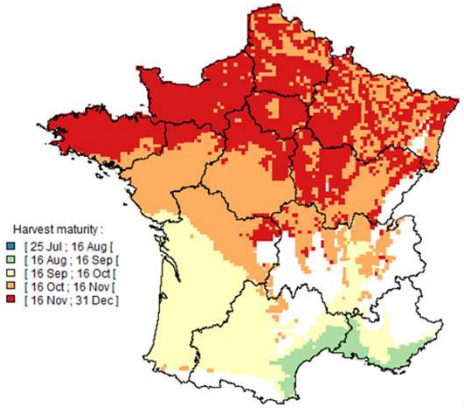
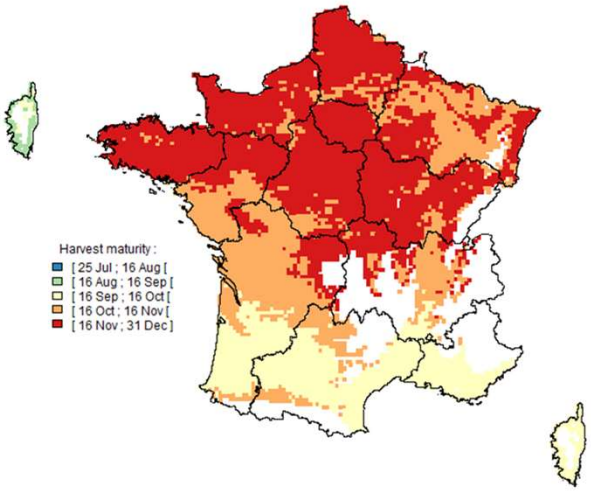
Application to the determination of harvest dates

Harvest of soybean 8 years out 10 during or before the time window 2030-2050 (RCP 8.5)

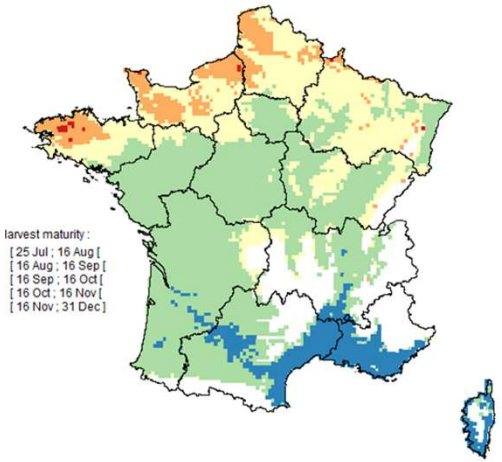
cv Symbala (MG II)
Sowing date **25/03**



cv Symbala (MG II)
Sowing date **05/05**

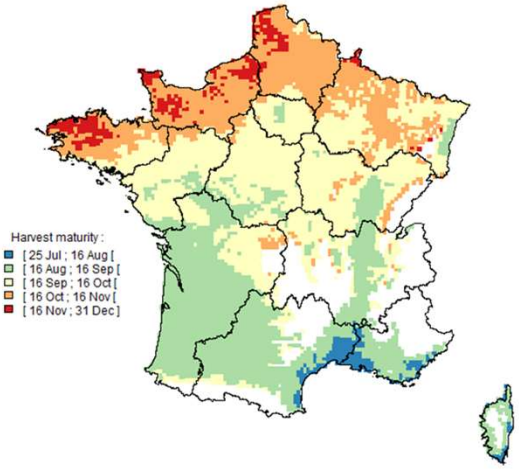


cv Sultana (MG 000)
Sowing date **25/03**



< 16/08	avoid
< 16/09	suitable
< 16/10	suitable
< 16/11	risky
< 31/12	avoid

cv Sultana (MG 000)
Sowing date **05/05**



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Perspectives for improving SPA model and use

- Implementation of the effect of water stress on phenology
- Refining decision rules for sowing (soil moisture) and harvest (grain moisture)
- Coupling with decision tools for choosing areas suitable for soybean (adding other criteria for soybean growing feasability)
- Comparing two methods for calibrating SPA : platform (one site with different planting date and frequent phenology scoring) vs network (several field experiments across the country)
- Application to the feasibility of double cropping in France

*See Maury et al (**board 204**) for more details on the phenotyping approach*

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Thank you for your attention

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CASDAR 3C 2a 3 cultures en 2 ans

UMT Pactole

CARNOT Plant2Pro

ECODIV project

anr agence nationale de la recherche

FRANCE 2030

SOYSTAINABLE project

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