Irrigation equipment

	Mobile gun (hose réel)	Center – Pivot / Spray line	Spray line on hose reel	Sprinkler solid set system	On surface drip system	Sub surface drip system
Plot shape	*All*	*Well adapted to large plot*	*Parcelle plutôt rectangulaire*	*All*	*All*	*All*
Slope	*All*	*Not more than 15%*	*Not more than 15%*	*All*	*Dépend du débit des goutteurs*	*All*
Movement possibility	+++	+	++	+	+	*No*
Possibility to irrigate at early stage	*Yes*	*Yes*	*Yest*	*Yes*	*No*	*No*
Work time before and after crop	++	+	++	+++	+++	+
Work time during crop development	+++	+	+++	++	+	+
Energy consumption	+++	++	++	++	+	+
Spatial uniformity	+	+++	++	++	+++	+++
Application efficiency	+	+++	++	+	+++	+++
Pluviométrie instantanée	++	++	+++	++	++	++
Cost	++	+	++/+++	++	+++	+++

+ few and +++ lot

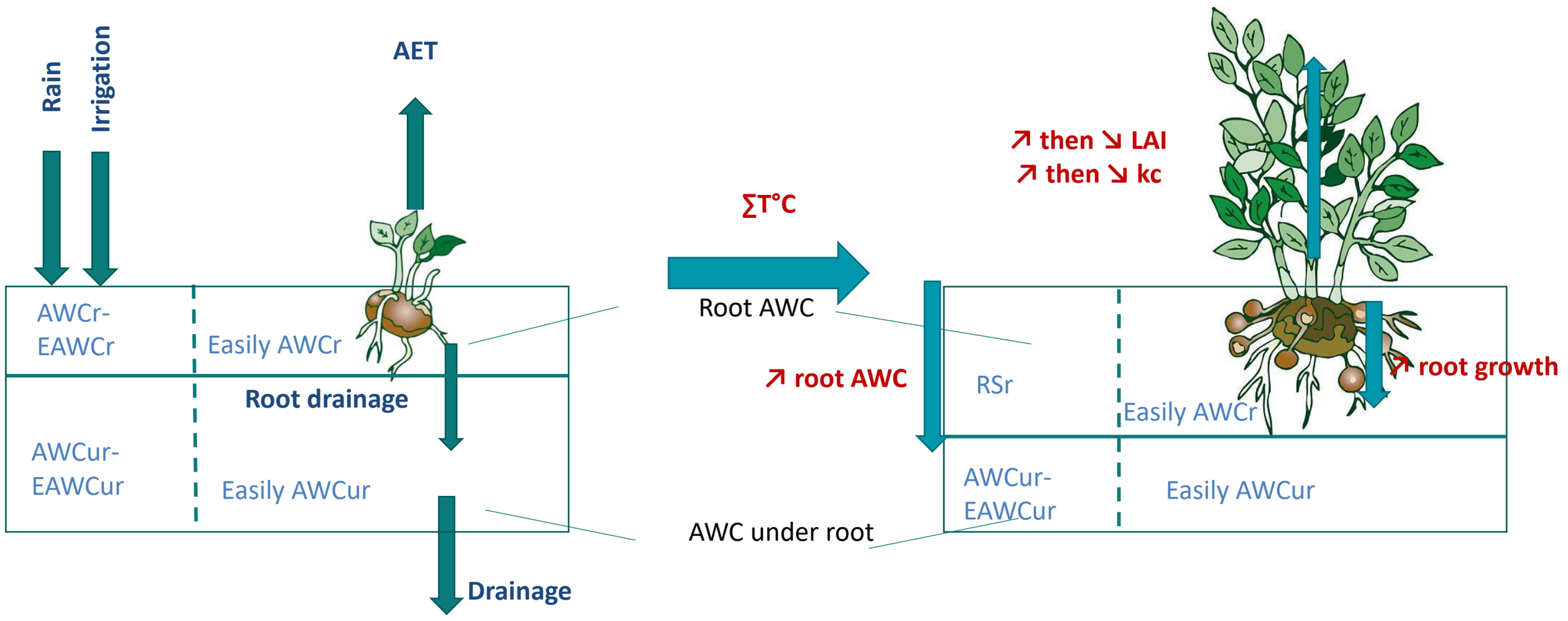
Irrigation management

$$= \frac{Irrigation\ water\ use\ efficiency}{yield\ with\ irrigation\ - yield\ without\ irrigation}{irrigation\ water\ amount}$$

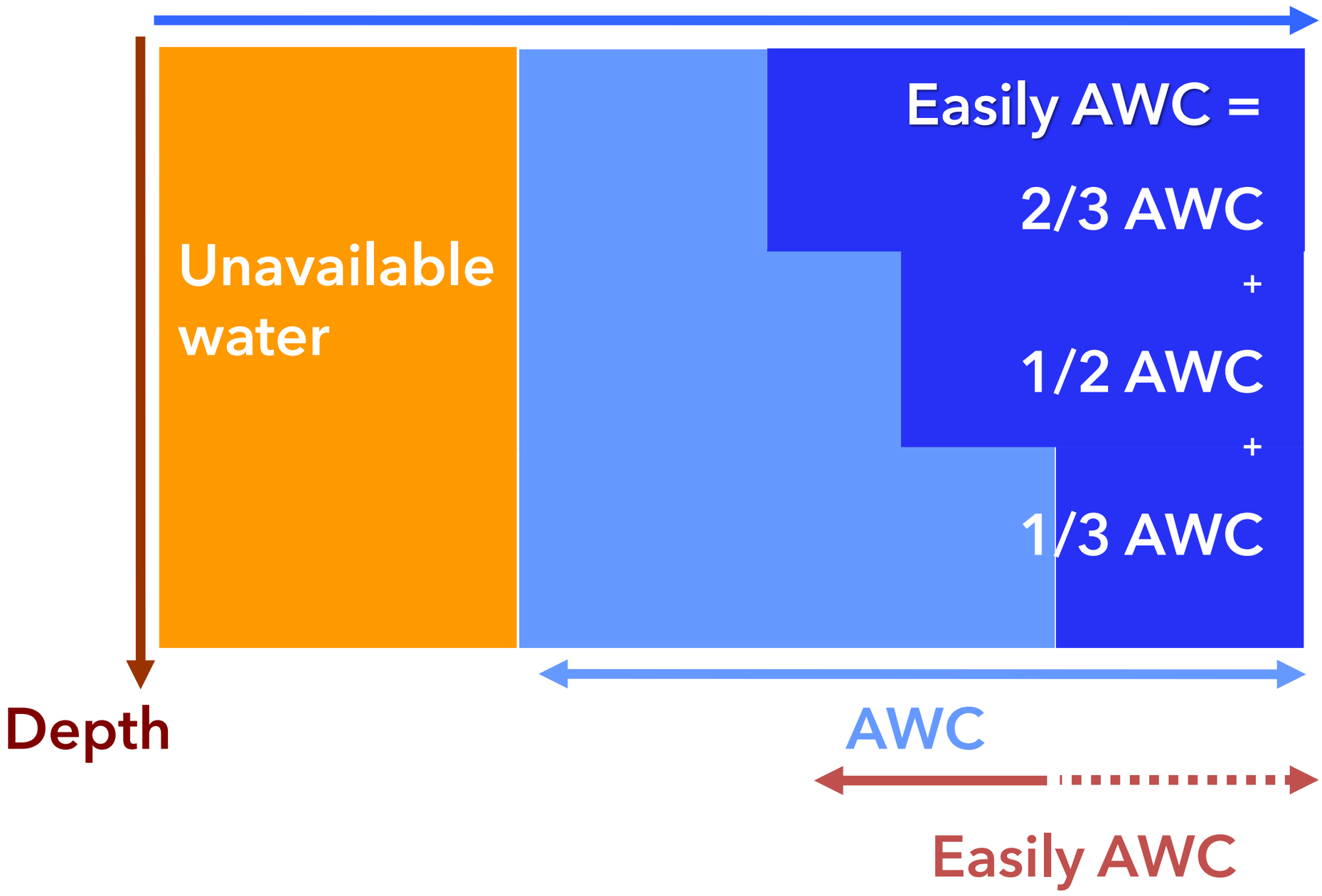
Potato efficiency

6 to 8 q/ha/10 mm

Crop	Water savings	Yield	Quality	Plot arbitration
Potato	++	+++	+++	ø

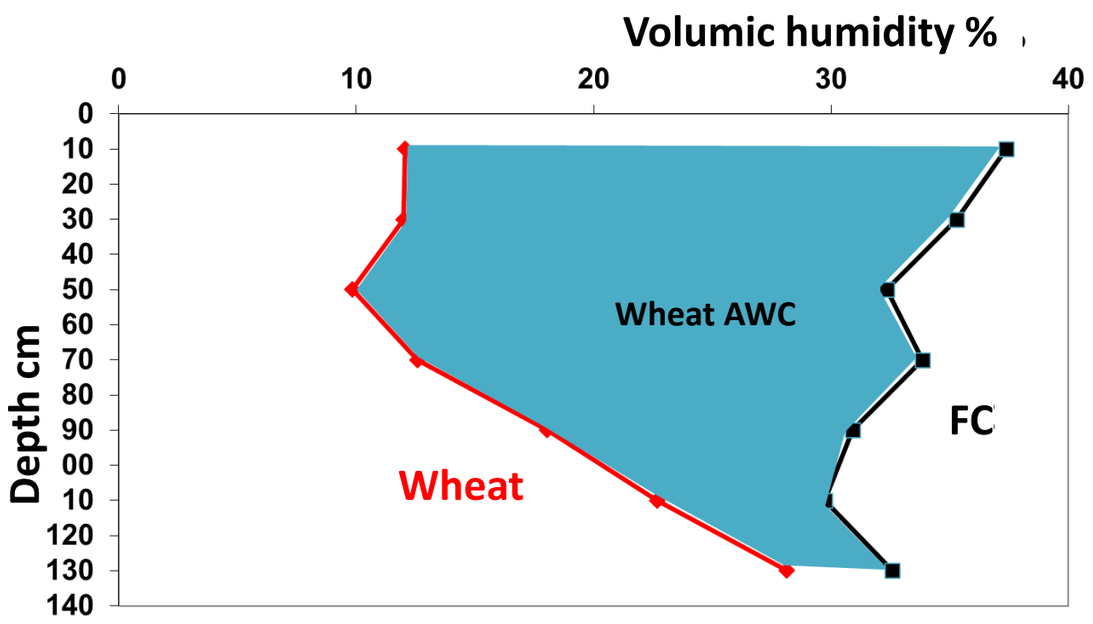


Avalaible Water Capacity

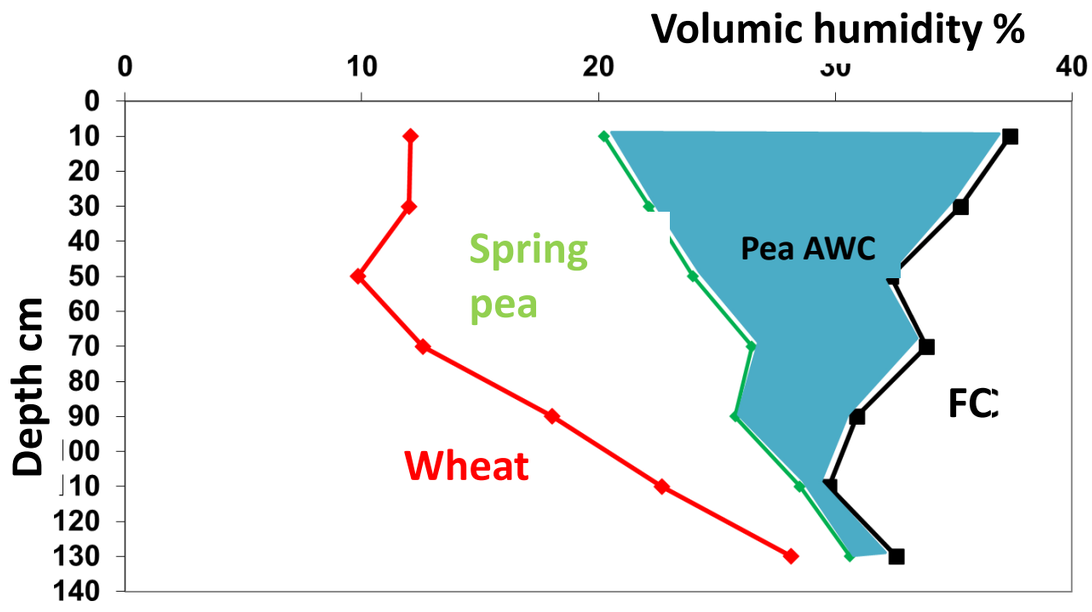


AWC is different according to crops

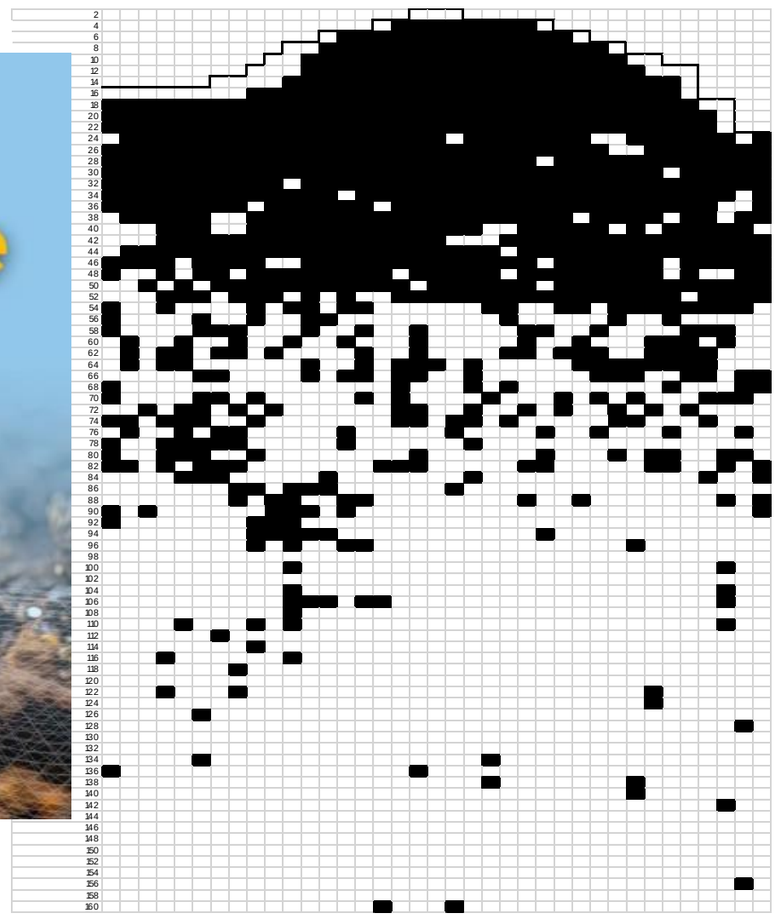
Depth + root density effect



Crop + root structure effect



Data : ARVALIS (Le Magneraud)



Potato root profile

Root volume estimation

Néoluvisol de limon loessique - Beaudoin et al., 1995

Impact of cover crops on soil fertility

What cover crops change

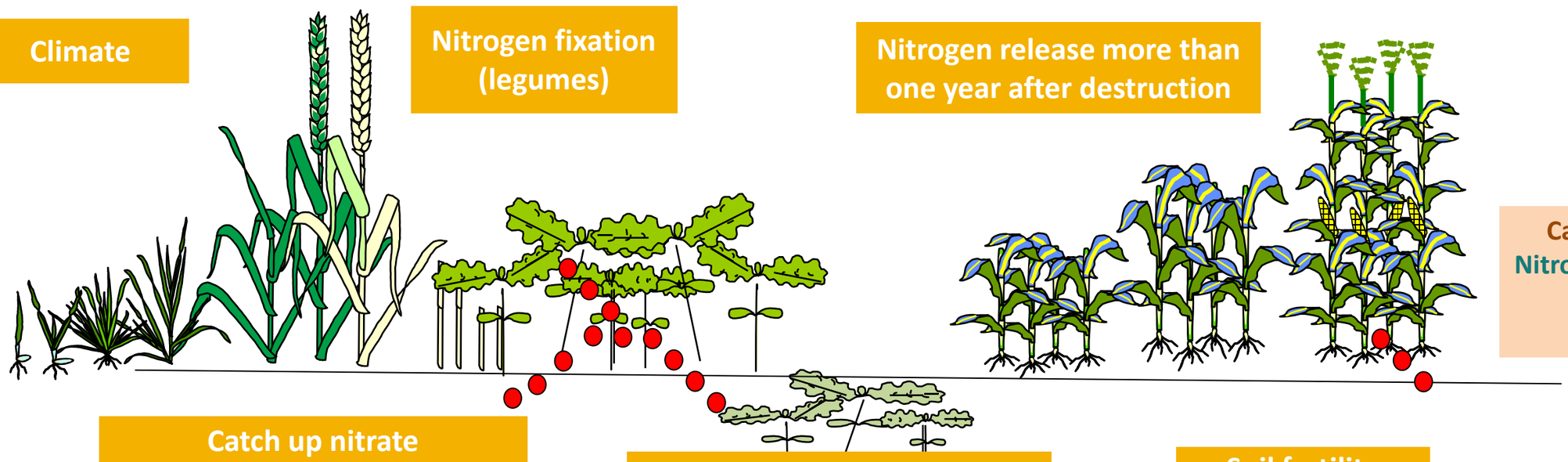
Climate

Nitrogen fixation (legumes)

Nitrogen release more than one year after destruction

$\frac{C}{N}$

Carbon content constant (44%)
Nitrogen content varies according to species
C/N ratio depends of %N



Catch up nitrate

Pests regulation

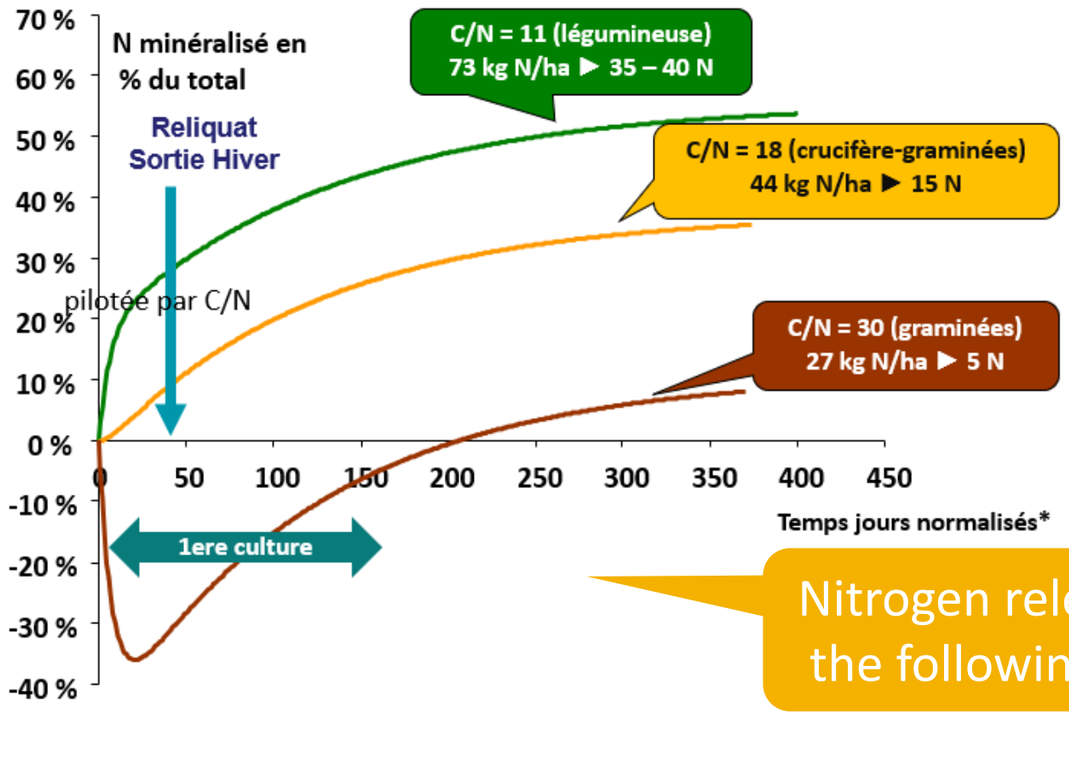
Nitrogen release weeks and months after destruction

Soil fertility

Carbon storage on the long term

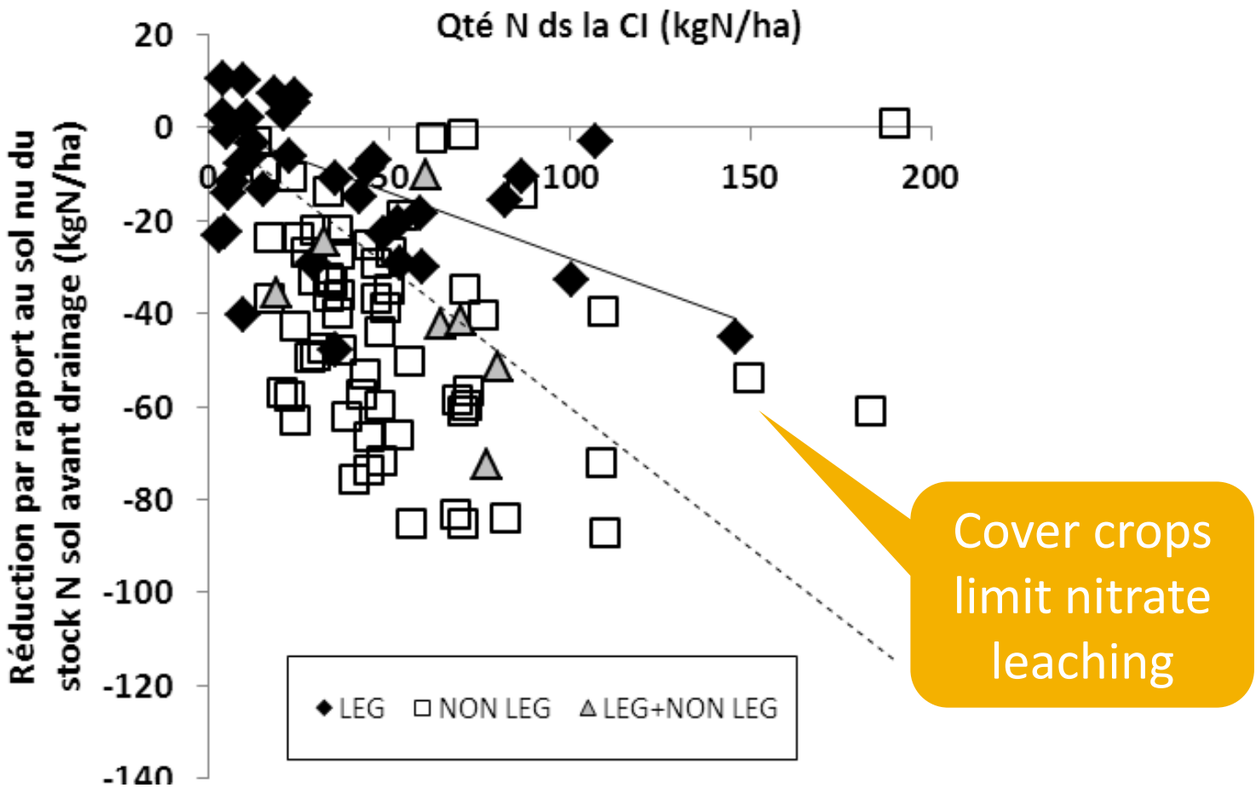
Nitrogen release

Nitrogen mineralisation kinetic depends on C/N ratio



Nitrogen release to the following crop

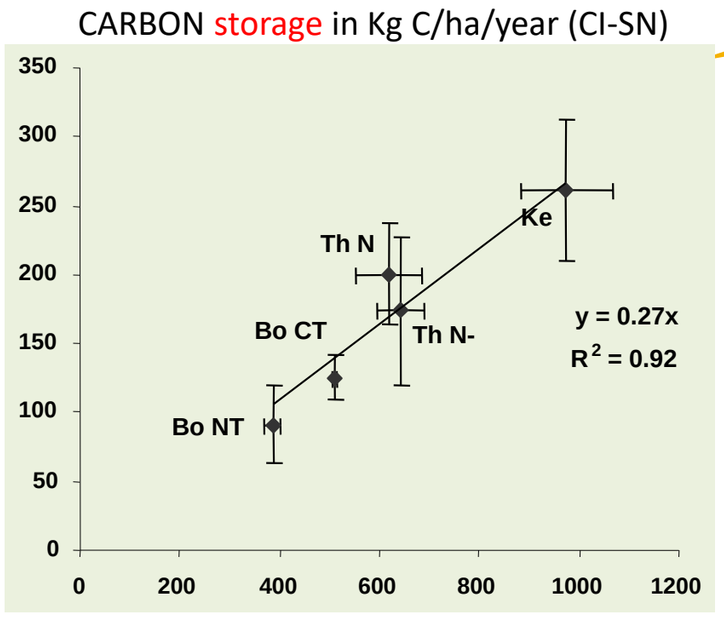
Nitrate catch up

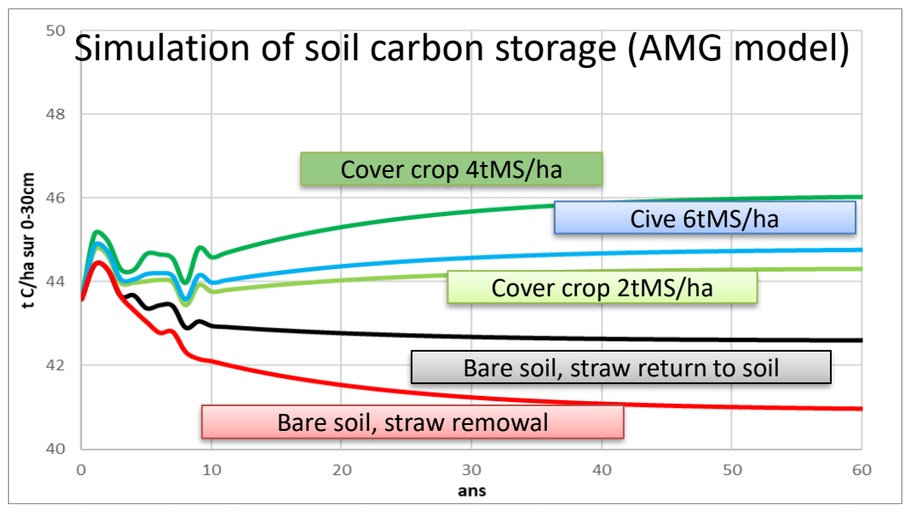


Cover crops limit nitrate leaching

Soil carbon storage

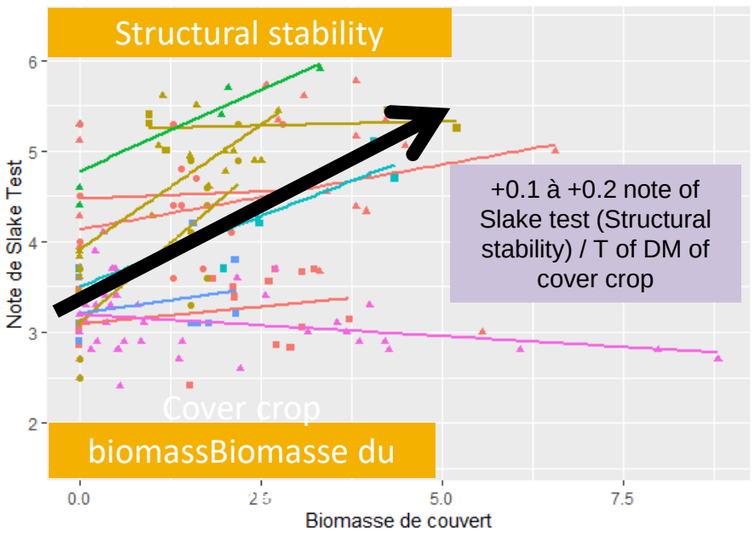
1 tonne of dry matter of cover crop = 440 kg of Carbon
27% of Carbon brought by Cover Crops are transformed in Organic Matter (whatever is the C/N ratio)





Silty soil with 1.8% of OM ; Ploughing at 25 cm 1 year/2
Crop rotation Sugar beet/ Potatoes/ Wheat/Beans/Wheat

Soil physical and biological fertility



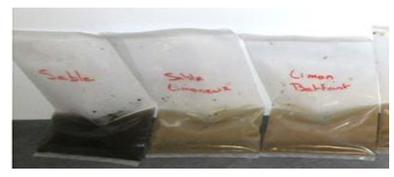
- Surface protection of capping soils
- Improvement of structural stability
- Reduction of soil erosion
- Loosening of compacted soils scarse
- Posditive impact on biological abondance and activity

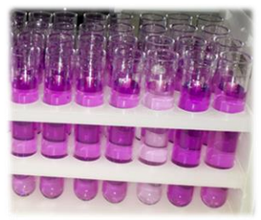
ARVALIS

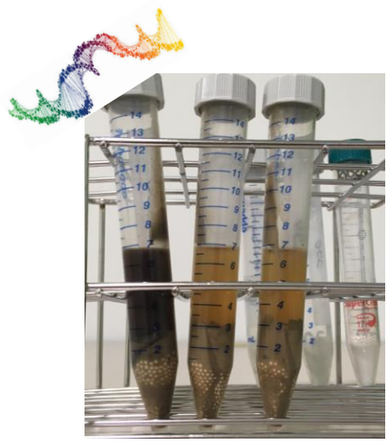
Soil diagnosis: interpretation of the new indicators

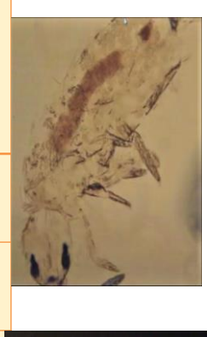
New methods of analysis and quantification

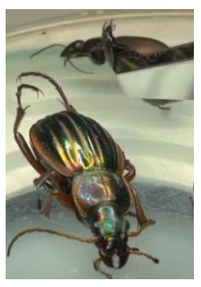
	Type of indicator	Method	Level of maturity
Organic status	Quality of organic matter	·**Particle size fractions of organic matter**	Standard method, laboratory frameworks
		·**Microbial carbon by fumigation-extraction**	Standard method, laboratory frameworks
		·**Permanganate Oxidable Carbon**	Current benchmarking
		·**Biologically mineralizable nitrogen**	Current benchmarking
		·**Potentially mineralizable nitrogen**	Current benchmarking
		C and N mineralization by aerobic incubation	Standard method, laboratory frameworks
Abundance	Microbial abundance	• **Total microbial DNA**	Several existing methods, including INRAE Dijon, with RMQS repository
		• **Relative abundance of fungi (18S rDNA) and bacteria (16S rDNA) (F/B ratio)**	Several existing methods, including INRAE Dijon, with RMQS repository
	Abundance and diversity of earthworms, carabids and springtails	**Identification by morphological analysis**	Standard method (sampling) Researcher frameworks
		Molecular diversity of soil fauna	Not yet done
	Abundance and diversity of nematodes	**Identification by morphological analysis**	Standard method ELISOL repository
Activity	Microbial activity	**Enzymatic activities (N, C, P, S)**	Standard method Several laboratories including INRAE UMR Ecosys with INRAE/RMQS repository
Diversity	Diversity of bacteria and fungi	**Taxonomic diversity by high-throughput DNA sequencing**	INRAE Dijon method with RMQS reference system

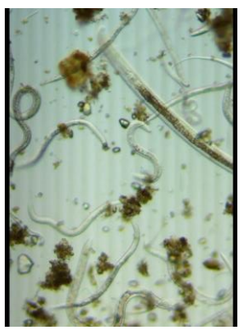












How to move from indicators to diagnosis and advice?

Example of the Agro-Eco Sol interpretation process

1- Definition of a typology of cropping systems and pedoclimate

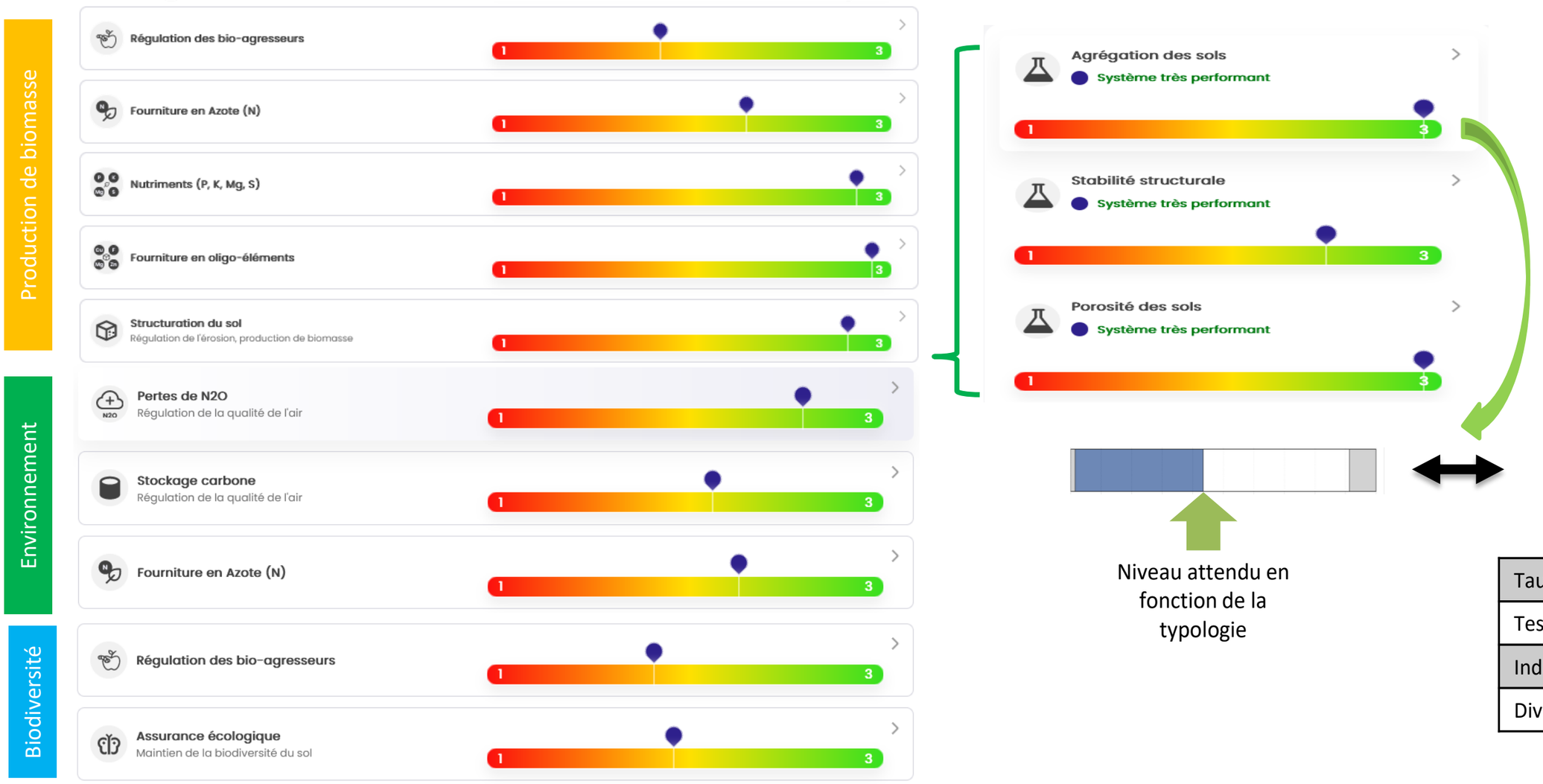
Wheater

Soil type

Cultivation strategy

Fertilization

2- Diagnosis of function satisfaction and processes based on indicators



Taux de MO	2,5
Test bêche	2,5
Indice de battance	3,0
Diversité microbienne	3,0

3- Advice with setting up levers

Le projet est accompagné par l'ADEME dans le cadre du programme « Industrie et Agriculture éco-efficientes » du programme des Investissements d'Avenir

Evaluate the fertility of your soil…and more!

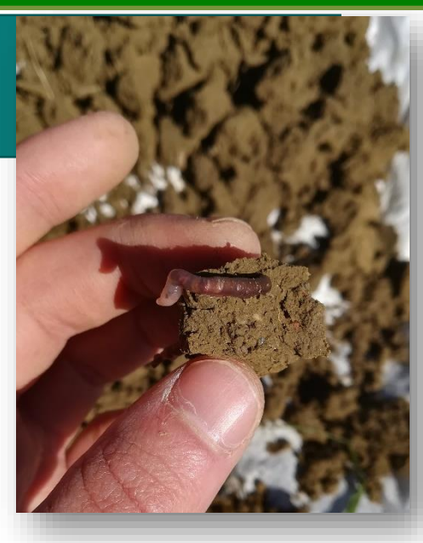
Fertility

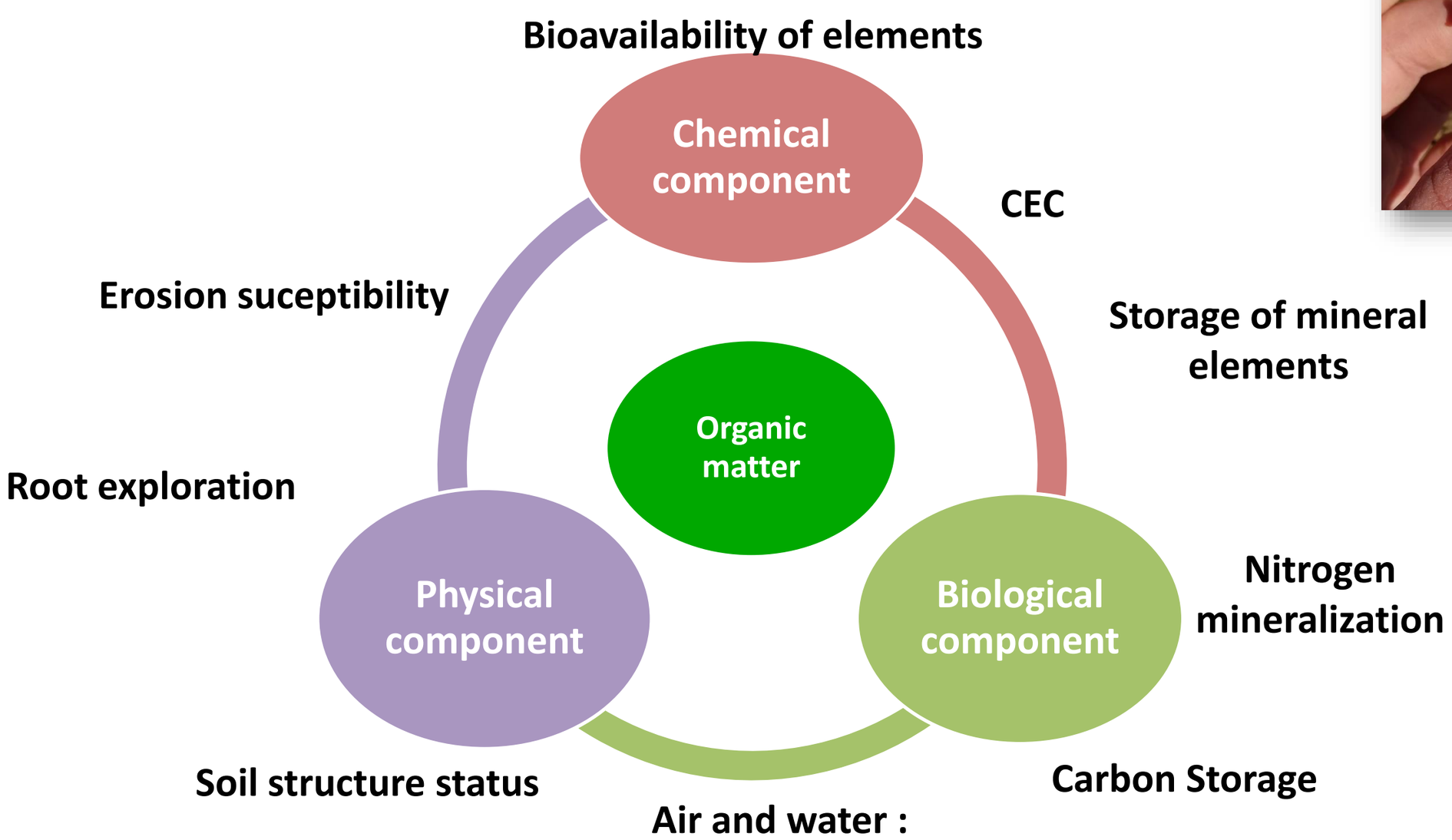
Ability of a soil to produce sustainably under a climate and for a cropping system

Quality

Ability of soil to perform its functions to enable production, maintain water and air quality, and support human health

Why is it important?

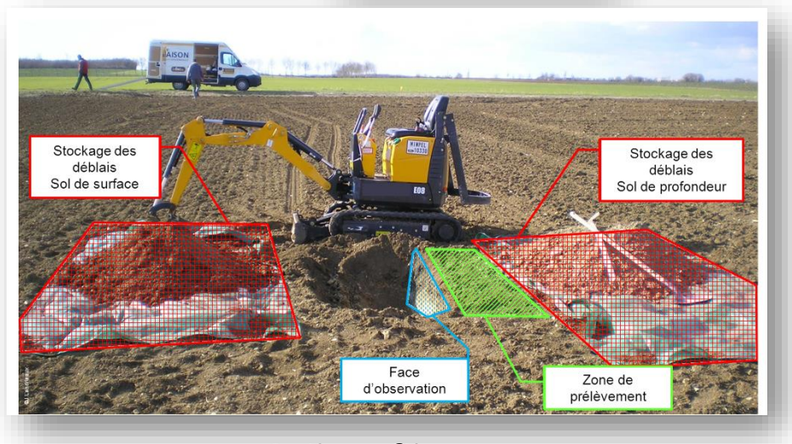




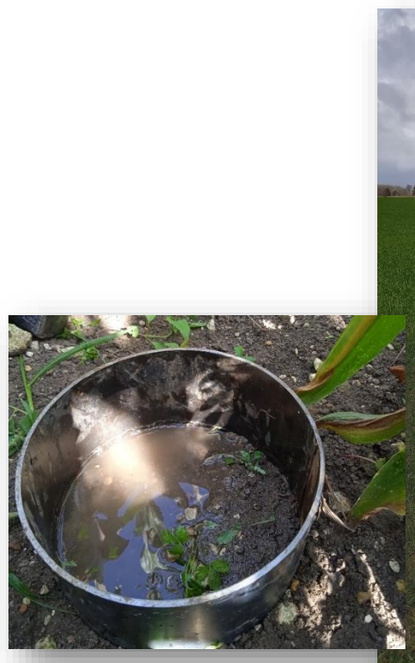
How to evaluate it:

	Criteria	Tests and indicators	Advantages	Limits
Chemical fertility	**Availability and content of mineral elements**	Soil analysis: pH, CEC, PK, OM levels...	Standardized and accurate measurement	Necessary for a diagnosis but not sufficient
Biological fertility	**Abundance, diversity and microbial activity**	Soil analysis : OC, oxydable C, ABM, B-GLU…	Standardized measurment	Benchmarking in progress to link to soil functions
Physical fertility	**Soil structure status**	Cultural profile	Direct observation of all prospected horizons	Difficulty of execution and destructive measure
		3D Profile	Easy to do	Surface soil horizon
		Spade test (ISARA)	Easy to do	Surface soil horizon
		Penetrometer: Resistance to penetration (kPa)	Fast Extrapolation of unrepeatable observations	Very sensitive to soil moisture Indirect measurement
	Infiltrometry	Beerkan test: Infiltration speed	Simple and minimally destructive	Depending on the texture of the soil Long in some soils (>1h)
	Sensitivity to beating	Slake test : Structural stability	Simple, fast and minimally destructive	Depending on the texture of the soil

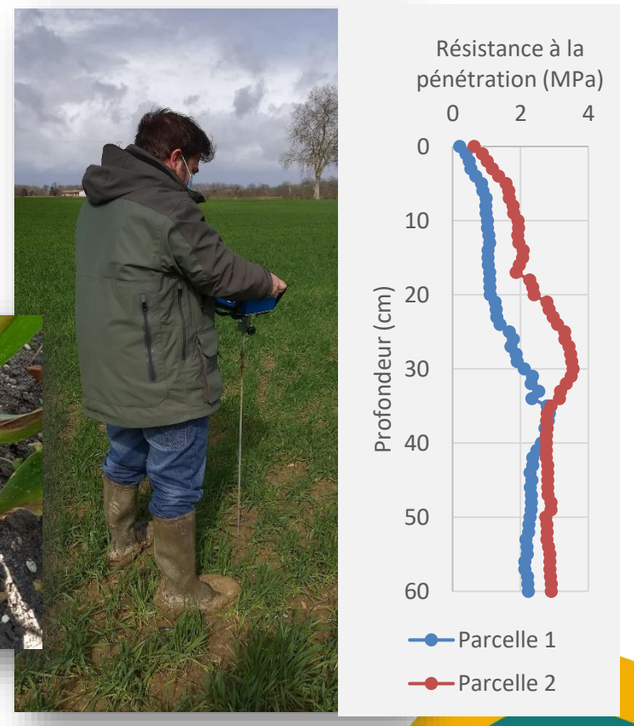
Auger sampling



Soil profile



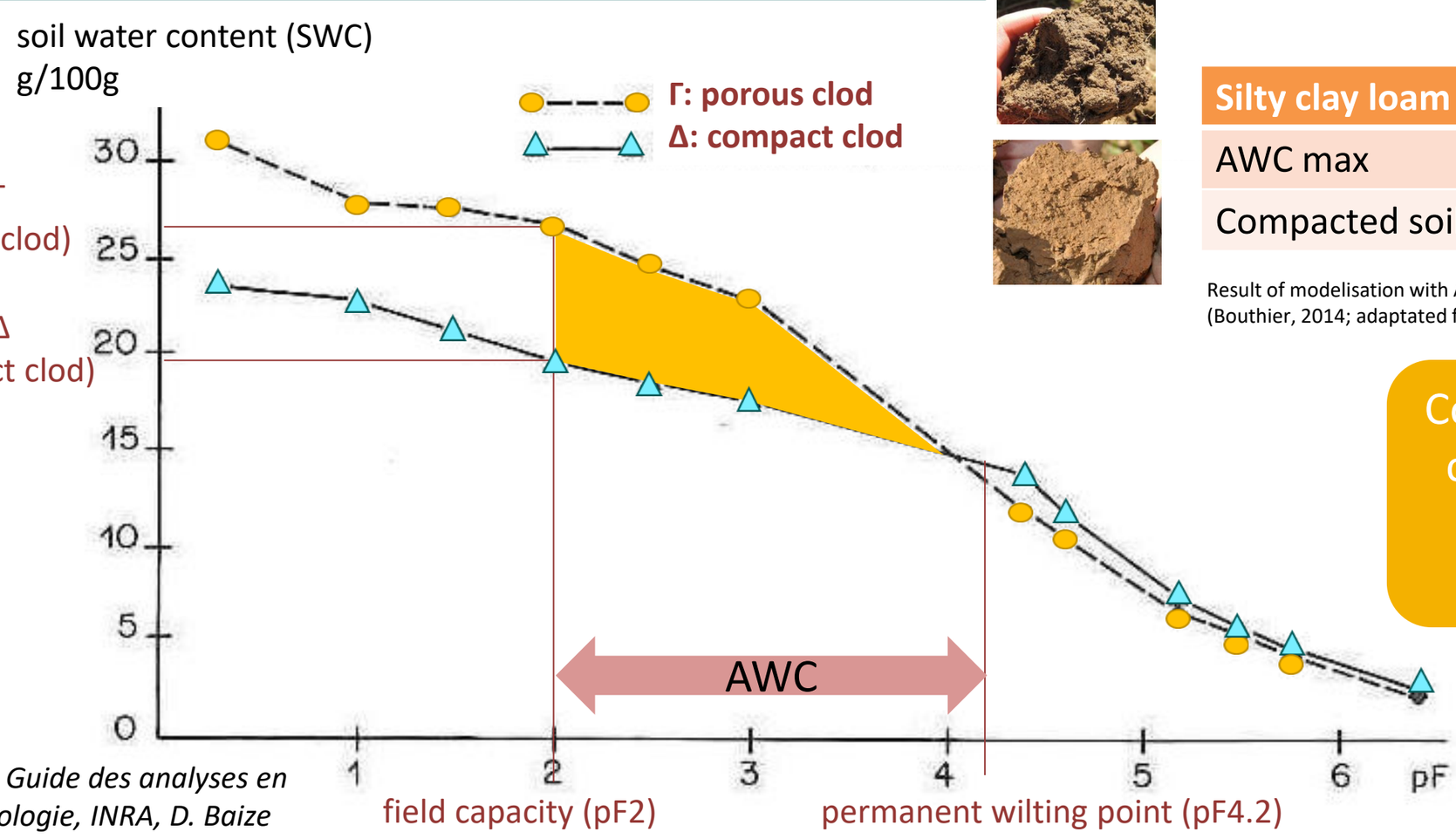
Beerkan test



Penetrometer

Consequences of soil compaction

On Available Water Capacity (AWC)



From Guide des analyses en pédologie, INRA, D. Baize

Silty clay loam soil type (on 100 cm)	
AWC max	123 mm
Compacted soil AWC	111 mm

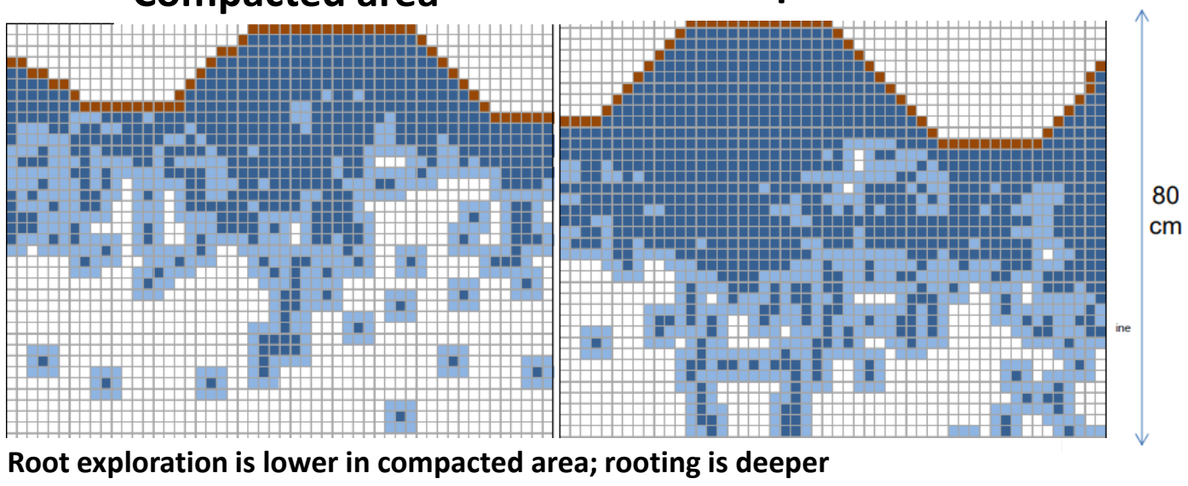
Result of modelisation with Arvalis's pedotransfert function (Bouthier, 2014; adaptated from Bruand, 2004)

Compacted soils and clods have a lower water storage capacity

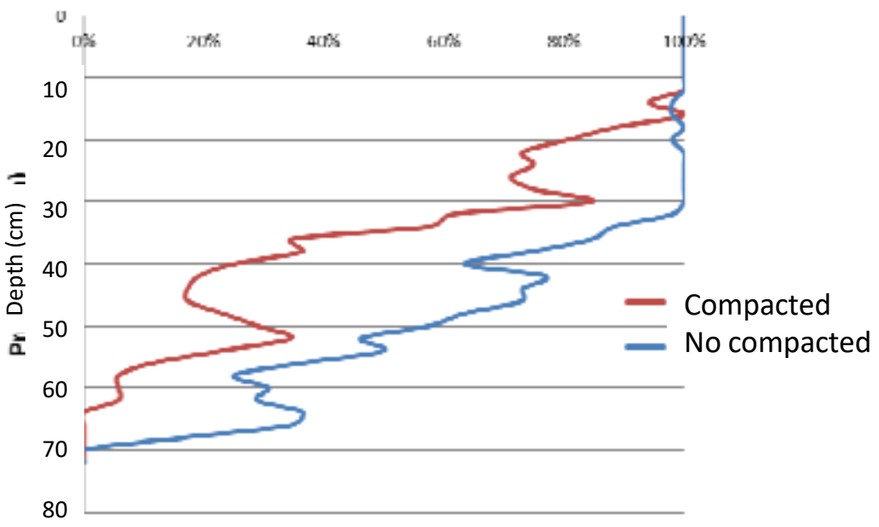
On rooting

Roots profile

Large wheel, Higth pressure



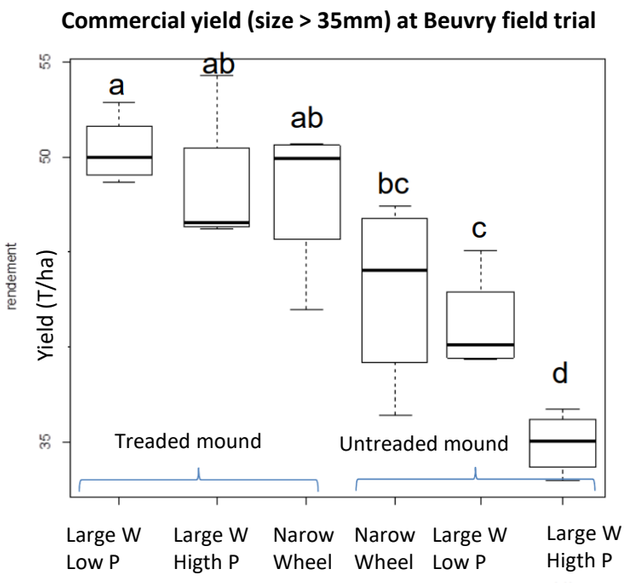
Root exploration is lower in compacted area; rooting is deeper without compaction



Soil compaction hinders rooting (reduce explored volume and decrease root number under treaded mound) with consequences on aerial development

On productivity and quality

Yield reduction of 30% under wheel tracks and 5 to 15% in global



Proportion of cracked potatoes increases with soil compaction

And also:

Excessive fuel consumption, lower efficiency of fertilizer, GES emission, slower infiltration that increase risk of runoff and flood, etc.

Find the “perfect" cover crop

1. Following crop and crop rotation

Sources :
ARVALIS, ITB, Terres Inovia, UNILET

	Nematode-resistant white and brown mustard	Nematode-resistant fodder radish	Other radish	Oilseed rape	Other brassicas	Phacelia	Linen	Sunflower	Niger	Buckwheat	Rye, Triticale, Canary grass	Common oat, Bristle oat	Foxtail millet, sorghum	Italian Rye Grass	Faba bean, Lupin	Peas	Fenugreek, BC, CC, R-Aphano Comm	Other vetches, Lentil, Grass pea	Birdsfoot trefoil, sainfoin, R-Aphano WC and RC	Lucerne, other WC and RC
Winter wheat after a wheat																				
Other cereals																				
Maize																				
Sugar beets (Heterodera schachtii)																				
Sugar beets (Ditylenchus dipsaci)																				
Potatoes																				
Linen																				
Peas, Beans, Lentil in crop rotation																				
Canned peas, Beans																				
Protein peas, Lentil																				
Faba bean, Lupin																				
Oilseed rape (with clubroot) in crop rotation																				
oilseed rape (without clubroot) in crop rotation																				

	Beneficial impact of cover crop
	Fairly beneficial impact of cover crop
	No impact of cover crop
	Slight risk due to cover crop
	Risk due to cover crop
	Cover crop not advised

BC: Berseem clover
CC: Crimson clover
WC: White clover
RC: Red clover
R-Aphano: varieties resistant to Aphanomyces

2. Sowing and destruction periods

Summer cover crop

Overwintering cover crop

Long-term association

Companion plants

Living mulch

3. Sowing and destruction techniques

4. Objectives of cover crops

Fast soil coverage

Harvesting as fodder

Maintaining biodiversity

Crop protection

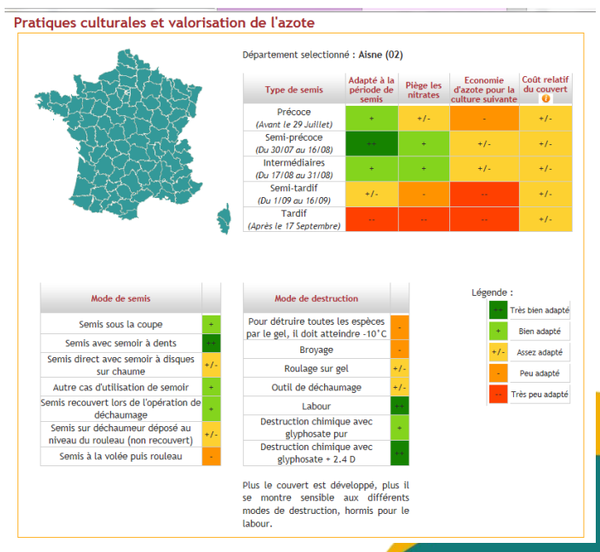
Increase chemical fertility

Soil protection

To discover on (only in french):
www.choix-des-couverts.arvalis-infos.fr

Choix des couverts

In a few clicks, choose from more than 200 pure species or mixtures!



Which phenotyping method can be used to assess root architecture traits in the field ?

Katia BEAUCHÊNE et Florent CHLEBOWSKI

Contact : k.beauchene@arvalis.fr

Root2Res
Root phenotyping and genetic improvement for rotational crops resilient to environmental change

Funded by the European Union
UK Research and Innovation
Project funded by Schweizerische Eidgenossenschaft / Confédération suisse / Confederazione Svizzera / Confederaziun svizra — Swiss Confederation; Federal Department of Economic Affairs, Education and Research EAER, State Secretariat for Education, Research and Innovation SERI

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www.root2res.eu

Introduction

In the context of climate change, the root system is an essential component of tolerance against abiotic stresses and key to delivering to farmers varieties that are more resilient. This is the aim of the European **Root2Res** project, running from 2022 to 2027.

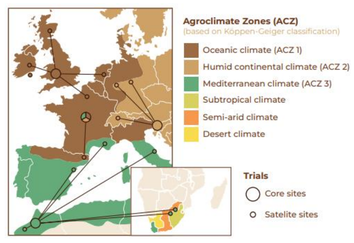
Architectural root traits are relatively easily measured in controlled conditions, but root characteristics assessed in field conditions are needed to understand crop resilience to climate change.

One of the first steps of Root2Res project was to **evaluate** and **improve methods** available to describe morphological root traits in field environment in three agro-climatic zones (UK-France, Slovenia and Morocco).

The aim of this work is to characterize methods and improve them to be able to provide a set of tools that can be used to identify root ideotypes that are most suitable for specific environments but also that could be used to characterize a large diversity of genotypes.

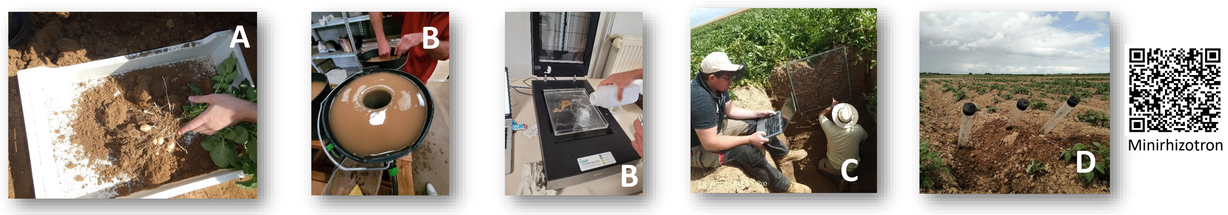
Materials and Methods

We performed field experiments with at least the same 4 core varieties per crop on core sites:



2023 : 4 Potato trials in Scotland, France (x2) and Slovenia
2024 : 4 Potato trials in Ireland, Scotland, France, Slovenia and Morocco

Root traits characterization included 4 methods in field environment: shovelomic sampling (A), root/soil core extraction (B), soil pit view (C) and minirhizotron measurement using a transparent tube and image analysis (D).



We also measure yield, yield components and above-ground traits using sensors (green cover fraction, vegetation indices) and carry-out destructive measurements (biomass).

Results

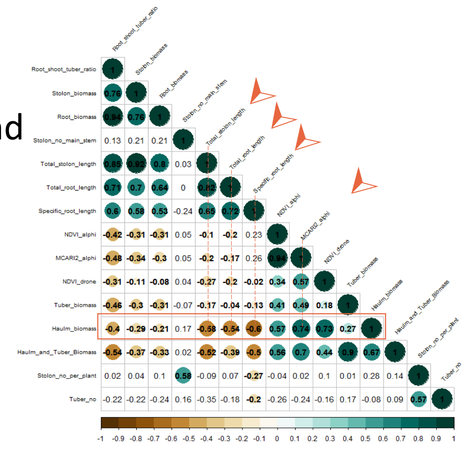
Each method is described with its standard operating procedure, organized in workshops to train people and will be shared with videos, tutorials and practice abstracts. The main results highlight the advantages and disadvantages of each method evaluated. Shovelomic and soil coring characterization could be applied on most sites.

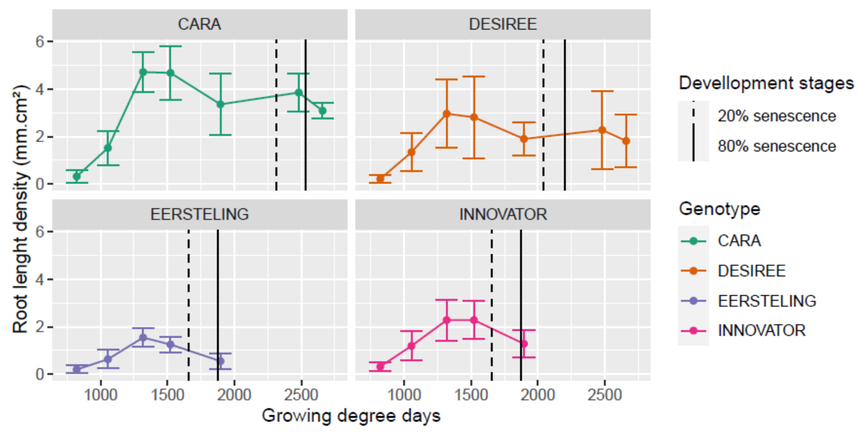
Methods	Potato Shovelomic	PotatoExcavation	Soil coring	Minirhizotron	Soil Pit
					
Sample	5 plants	5 plants	850 cm3 per core	600 cm2	10 000 cm2
Depth	0-25 cm	0-25 cm	0-80 cm	30-100 cm	0-100 cm
Time per sample	7 h	39 h	4 h / core	20 min / date	4 h
Cost (invest)	40€ shovel (7 000 € Winrhizo)	40€ shovel (7 000 € Winrhizo)	36 500 € soil corer 7 000 € Winrhizo	22 000 € rotative scanner	Excavator rental
Main Traits	Root and stolons : biomass, length, surface area and diameter Root branching index	Biomass, length, surface area, diameter and root branching index for stolons, stolon roots, node roots de stolons and mother tuber roots	Root biomass, length, surface area and diameter	Dynamic root length density (cm.cm²) and dynamic avreage of root diameter	Root density (presence/absence of roots per cm²)
Disadvantages	First horizon sampling	Extremely time consuming	Time consuming	Not available on the first horizon (0-30 cm)	Very destructive, once
Advantages	Easy to apply 3D architecture, main biomass	Comprehensive measurement of all roots in the ridge	Deep rooting, root biomass all over 80 cm depth	Non destructive ! Dynamic measurements on deep rooting	Wide and deep field of view

Example of results from ARVALIS potato field trials in 2023 (Audeville –Center France and Villers-Saint-Christophe – North France)

Correlation between aboveground data and shovelomic traits.

- Selection of main traits to be measured in genetic panel characterization in 2024.





Root length density measured during growth stages using image analysis with the minirhizotron method.

Conclusion and next steps

Access to root traits in field is still labour intensive. To choose the best approach, we must define which are the key traits we want to assess. Within the Root2Res project, the dataset of the methodological trials will be analysed to improve each method and try to find good proxies for root system development and connect field and control environment root phenotyping methods. This will help to measure root morphological traits to improve root growth modelling under stressed conditions, to characterize more resilient ideotypes/varieties or select and breed new varieties.

References :

A- Shovelomic: *York, L. M. et al. (2018). Wheat shovelomics I: A field phenotyping approach for characterising the structure and function of root systems in tillering species. BioRxiv; doi 10.1101/280875.*

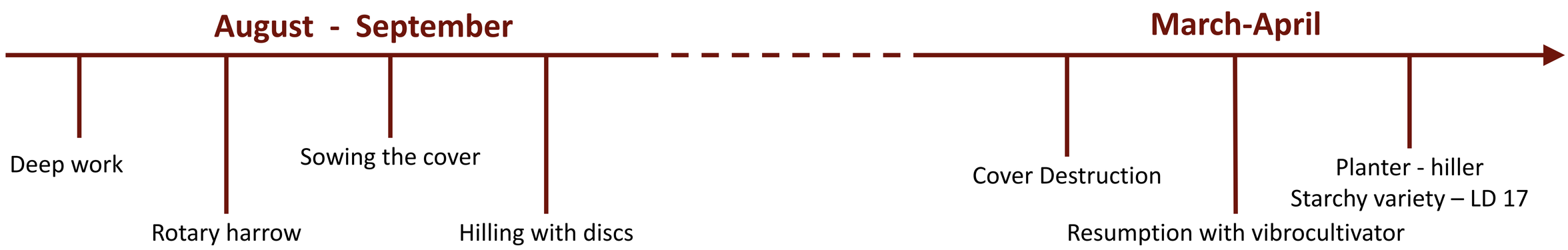
B- Soil core: *White, C. A., et al. (2015). Root length densities of UK wheat and oilseed rape crops with implications for water capture and yield. Journal of Experimental Botany; doi 10.1093/jxb/erv077.*

C- Soil pit: *Zarzyńska, K., Boguszewska-Mańkowska, D. and Nosalewicz, A. (2017) 'Differences in size and architecture of the potato cultivars root system and their tolerance to drought stress', Plant, Soil and Environment, 63(4), pp. 159–164. Available at: https://doi.org/10.17221/4/2017-PSE*

D- Minirhizotron: *Postic, F., Beauchêne, K., Gouache, D., Doussan, C., 2019. Scanner-Based Minirhizotrons Help to Highlight Relations between Deep Roots and Yield in Various Wheat Cultivars under Combined Water and Nitrogen Deficit Conditions. Agronomy 9, 297. https://doi.org/10.3390/agronomy9060297*

Pre-hilling on Syppre : A winning technique

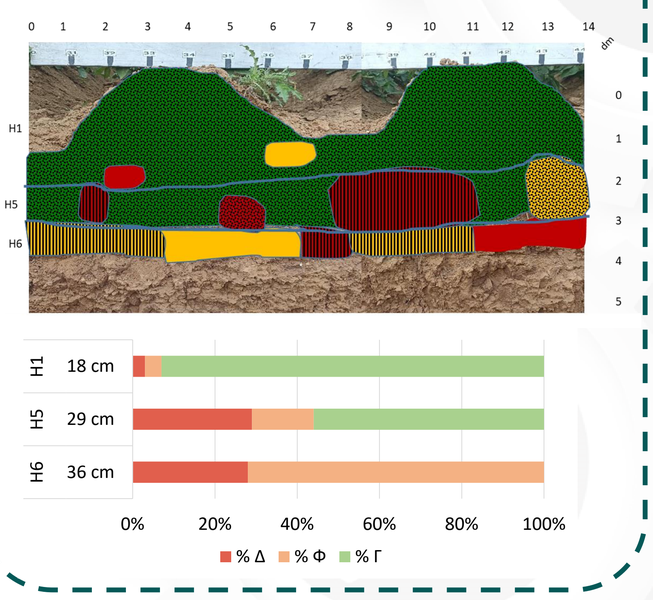
The goal : to work the soil using cover during the winter



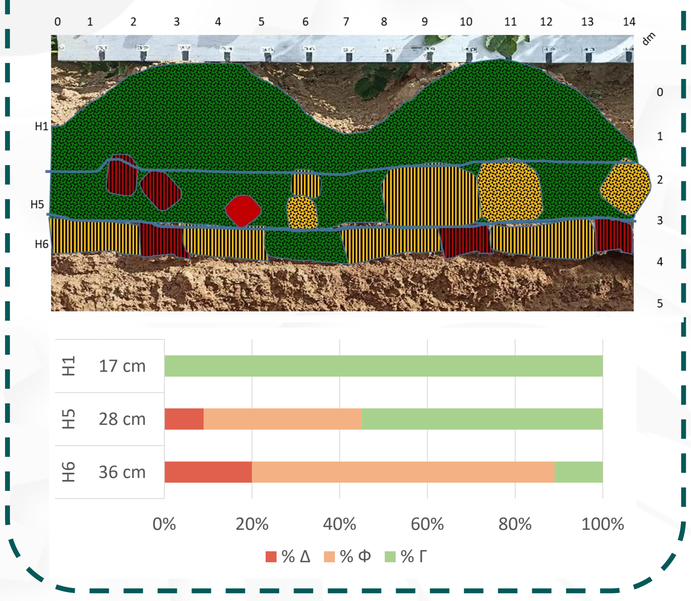



An improved soil structure in the innovative system

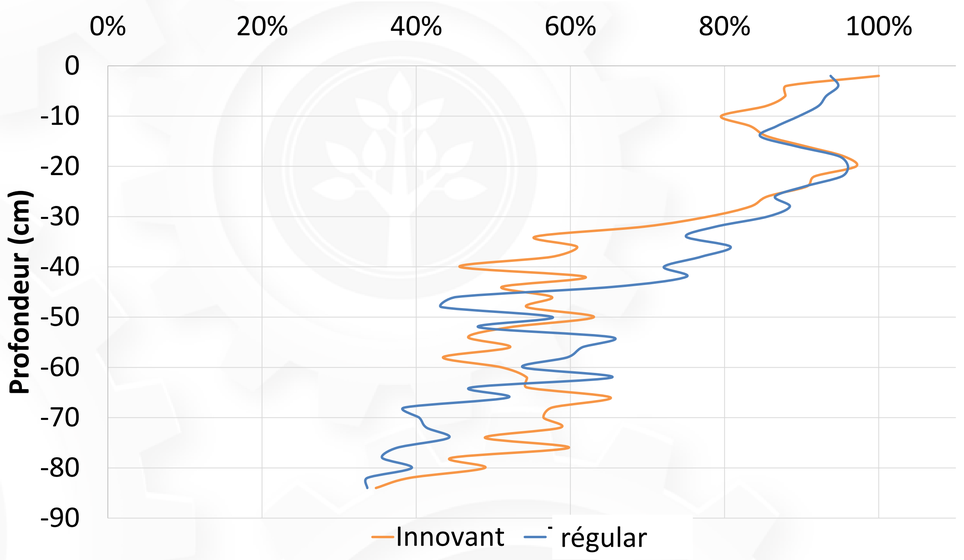
Control system 2022 :
Regular plowing / céréales previous



Innovative système 2022 :
Pre-hilling / rapeseed previous



Root Density potato **2022**

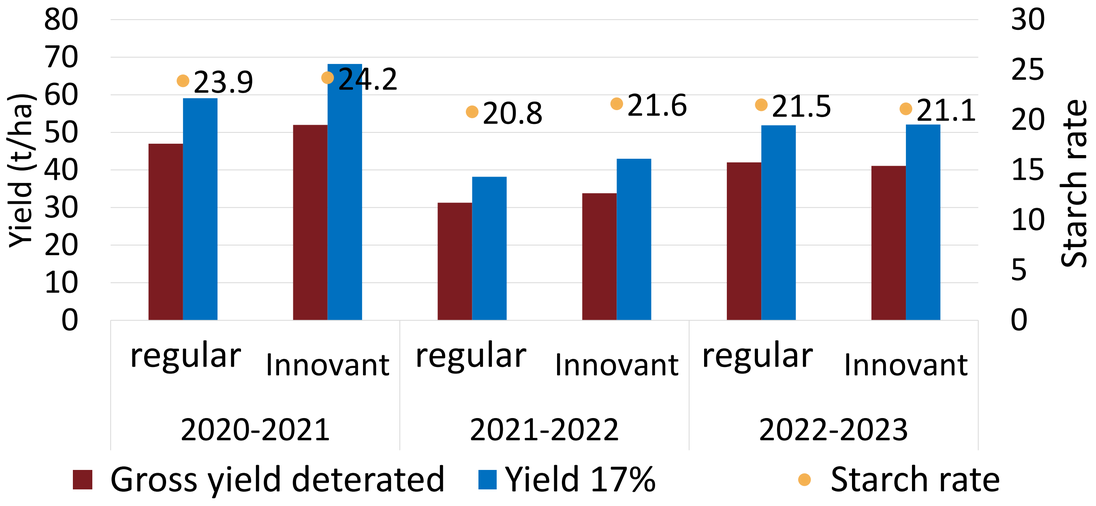


Δ (compact) Φ (crack compact) Γ (friable, porous) B0 (no bioturbation) B1 (with worm gallery) B2 (with gallery and droppings)

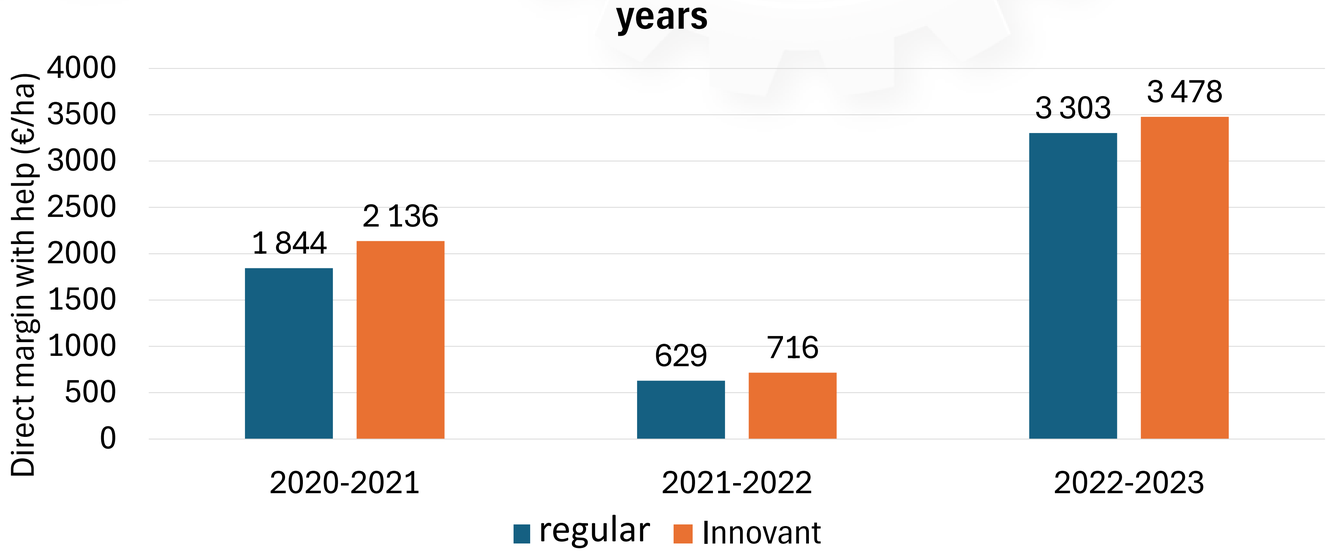
- Improved structure & porous (optimized water)
- Similar results with no-till on soil fertility :
  - Simplified installation & destruction
  - What about « drying » with simplified cultural technique (TCS) ?

Profitability guaranteed, favored by the cultivation system

Potato yield



Direct margin with help of potato depending on systems and years



The success factors of starch on Syppre

- Extended rotation : 6 → 9 years
- Positive impact of tillage and ante-precedent
- Rapeseed previous
- Fréquent intake of organic waste product and favorable simplified soil work on starch
- Work on intercultures (implantation/destruction) and choice of species

Reduction of nitrogen fertilizers

Room for progress identified to reduce IFTS

- Separate phytosanitary programs (herbicid / fungicid)

Avec la participation de :

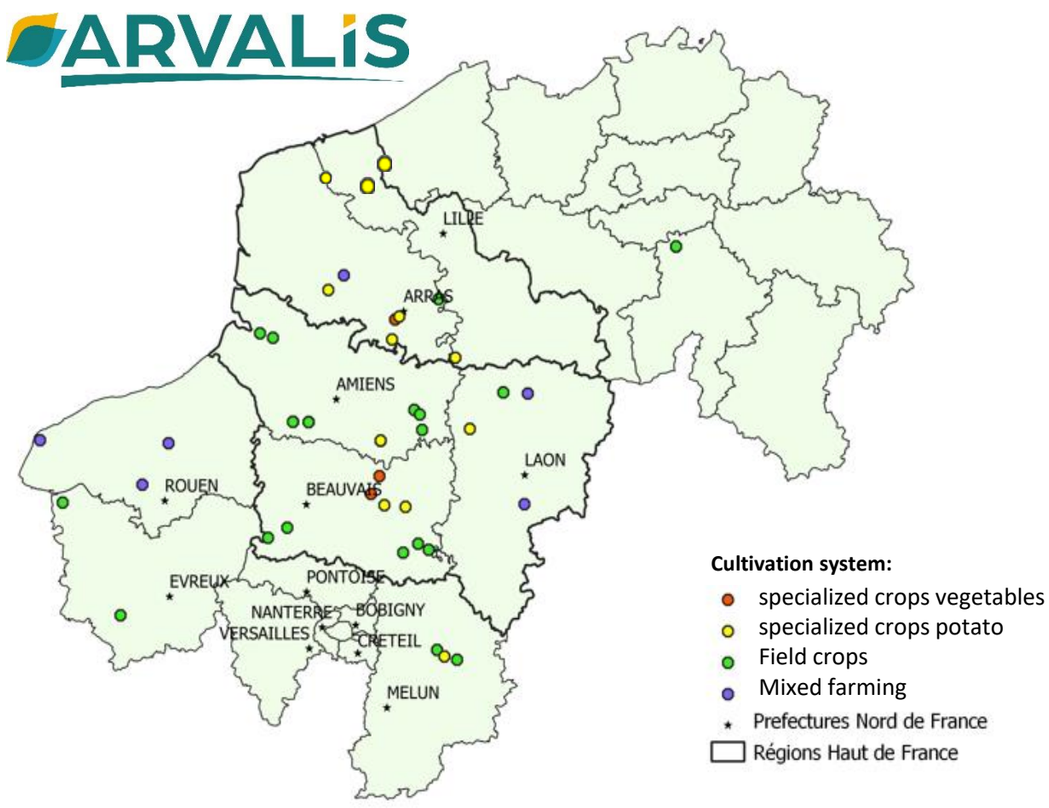
Build the futur systems together

Avec la contribution financière du compte d'affectation spéciale développement agricole et rural CASDAR
MINISTÈRE DE L'AGRICULTURE ET DE LA SOUVERAINETÉ ALIMENTAIRE
Liberté Égalité Fraternité

Soil Fertility Observatory

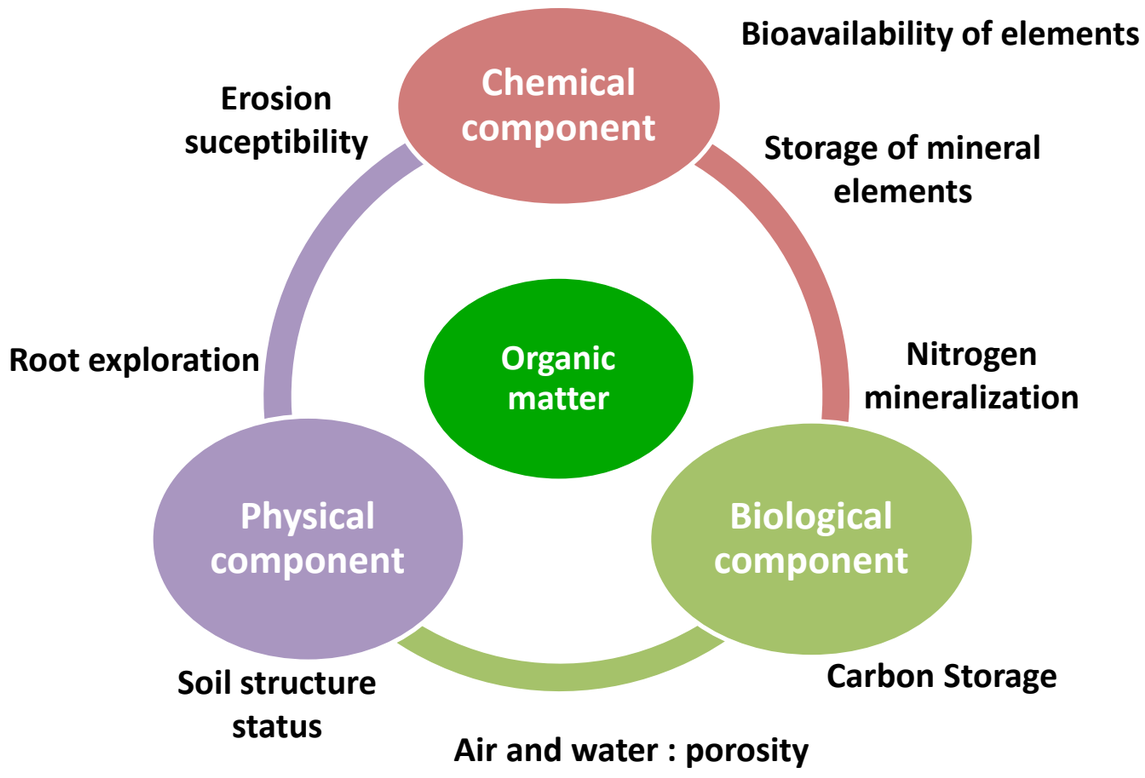
An innovative partnership approach

- **Animation of a network of partners in the north**: economic, development, research organizations …
- **20 partners – 57 plots**
- **Several representative cropping systems** : field crops, specialized crops (potatos, flax, vegetables, …)
- **Different practices and types of soil** : conventional, soil conservation agriculture, organic farming, loam, loam-clay, sandy …
- **Development of a network of farmer plots :** research and development support, characterize the main properties of the soils



Partners :

The 3 components of soil fertility : chemical, physical and biological



Fertility

Ability of a soil to produce sustainably under a climate and for a cropping system

Quality

Ability of soil to perform its functions to enable production, maintain water and air quality, and support human health

Soil fertility assessment and monitoring : different tests and indicators

Measurements every year on each plot, and monitoring planned for 7 years !

Soil type : particle size analysis
System analysis : history of practices over 5 years

Chemical fertility : soil analysis : pH, CEC, PK, Organic Matter levels …

Biological fertility : biological analysis (microbial biomass, oxydable carbon, …

Guide to interpreting soil analysis
© ARVALIS - Institut du végétal - Octobre 2020

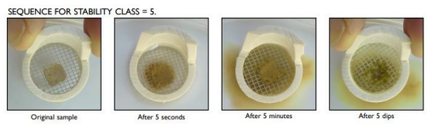
Cultural profile

Penetrometer

Physical Fertility :

- **Structural stability** : Slake test
- **Soil structure status :**
  - **On the surface :** spade test (ISARA)
  - **In depth :** Penetrometer : resistance to penetration
- **Infiltrometry speed :** Beerkan test

Slake test



Slake test

Spade test (ISARA)

Les 3 types d'état interne des mottes

Porous Clods Γ **Compact clods Δ**

Beerkan test

Soil Fertility Observatory

Example of plot diagnosis

Fiche parcellaire

Location: Davenescourt (80)
Type of soil : loam
2% organic matter
Crop 2023 = wheat
Rotation : Wheat / Rapeseed/Wheat/Beets/Wheat/Flax

- Specific practices : **Reduction of tillage since 2016**, no plowing
- Presence of agronomic cover for long intercrops
- **Additions of pig manure every 1 to 3 years**
- Two heavy agricultural machinery passage (slurry supply in 2020 and corn harvest in 2022) since the last decompaction in 2017.

Measurement of physical fertility

Stability structural : Slake test

	- stable						+ stable
0 - 2 cm	0	1	2	3	4	5	6

Obs Ferti North Values : Méd : 2.8 [1.2 – 5.7]

2.8

	- stable						+ stable
2 - 10 cm	0	1	2	3	4	5	6

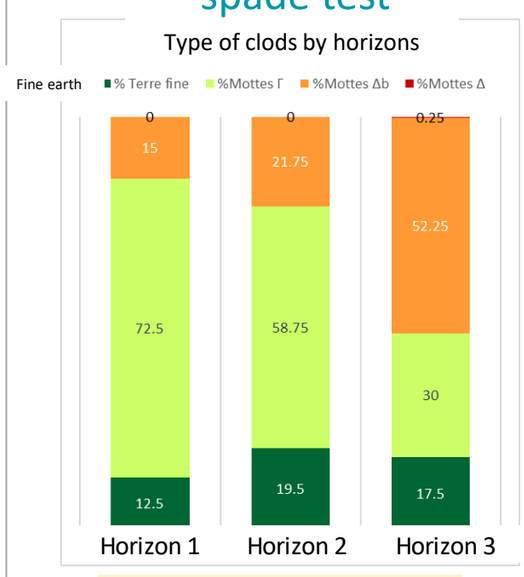
Obs Ferti North Values : Méd : 3.4 [1.2 – 5.5]

2.3

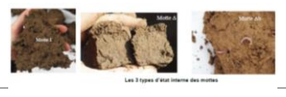
Certain stability : The soil si moderately stable to resist destructuring by rain. Moderate risk of threshing and erosion

Crop profile on 23/03/23

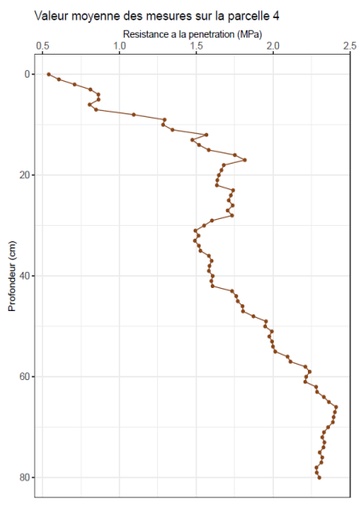
Surface structural condition : spade test



	Horizon 1	Horizon 2	Horizon 3
Middle Class	1.5	2.0	3.5
Average depth (cm)	7	20	28



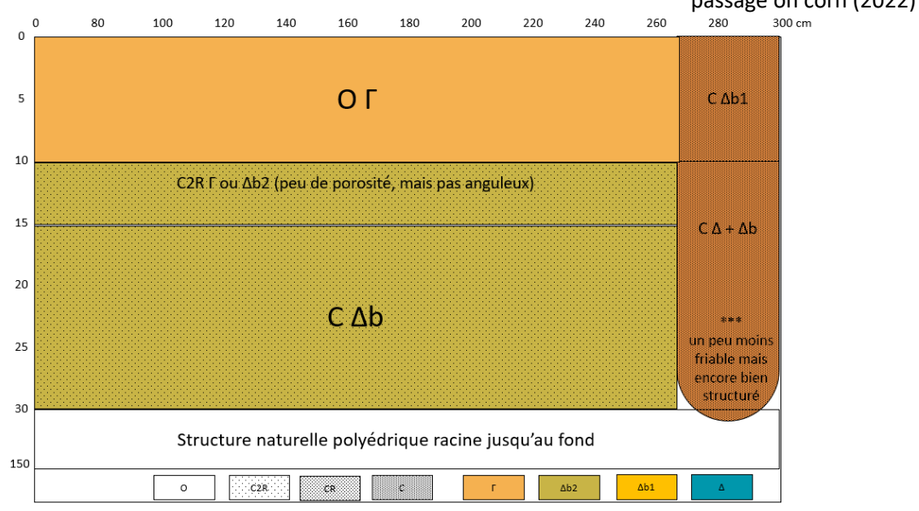
Soil structure status : Resistance to penetration



Spad test / penetrometer test : no compaction in surface but more compact layer beyond 20 cm. It's related to an increase penetration resistance.

Soil profile

More compacted zone : manure spreader passage on corn (2022)

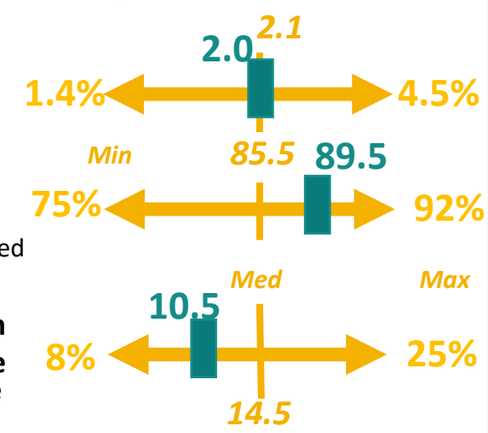


Soil profile : open structure, gamma clods over the first 10 cm, then more compact with less porosity without prenting angular packed clods. Presence of roots and earthworm galleries.

Measurement of biological fertility

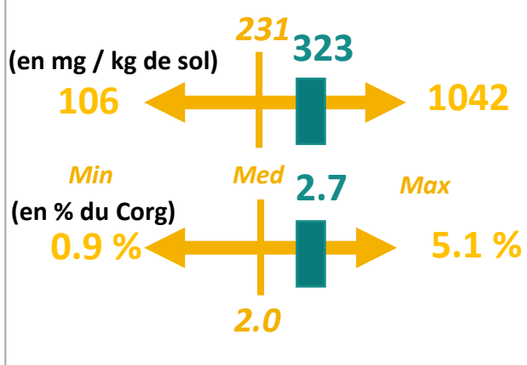
Interpretation in relation to their evolution over time

Organic Matter Quality : Particle size of organic matter



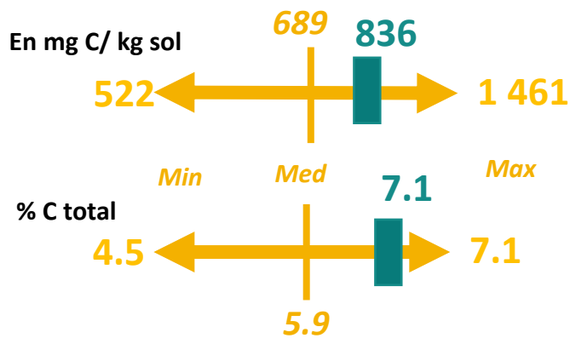
The humified fraction is the most stable part of the organic matter, It allows to identify the long-term storage of carbon. This stable fraction influences water retention and CEC.
The labile fraction corresponds to decomposing plant debris. It is a source of energy for living organisms.

Abundance indicators Microbial biomass

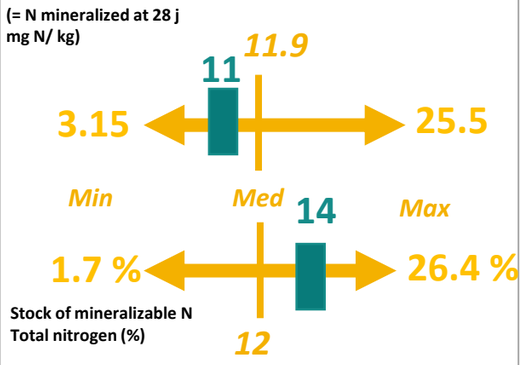


Microbial biomass : represents the quantity of carbon in soil bacteria, soil fungus and protozoa.
A high value may results in potentially high OM mineralization and structural stability. **Available carbon (C KMnO4), usable for micro_organisms=** Source of energy for soil organisms.
«Indicator of engine size, relative to car size ».

Abundance indicators Oxidizable carbon (KMnO4)



Activity indicators Nitrogen mineralization potentiel



A high value potentially indicates a high nitrogen supply and good structural stability.

Regional scale: Main results from the first year of monitoring (2023)

To be continued

Biological Fertility:

- The variation range observed in the North observatory is similar to the variation range of the Microbioterre dataset (France-wide scale).
- Microbial biomass and biologically mineralizable nitrogen values in the North region are slightly lower than those in the France reference dataset.

Physical Fertility:

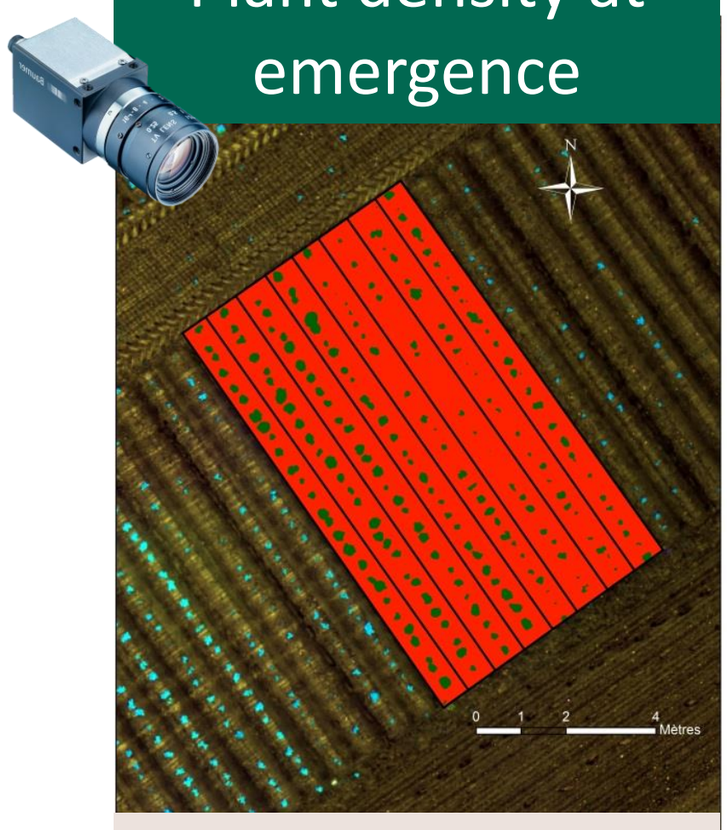
- The surface structural stability of the soils in Hauts-de-France is fragile, with a strong predominance of silty soils
- Compaction issues are quite common and tend to occur more frequently at greater depths (between 30 and 40 cm)

Digital tools and potato trial

Phenotyping

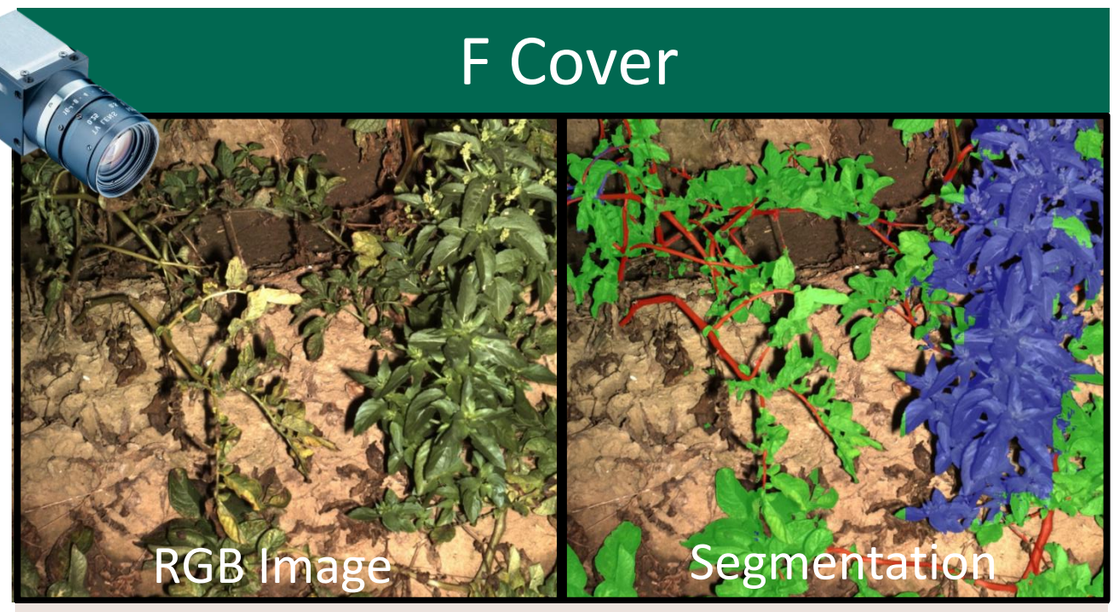
Some dedicated devices (vehicle + sensors) to characterize every steps of potatoes.

Plant density at emergence



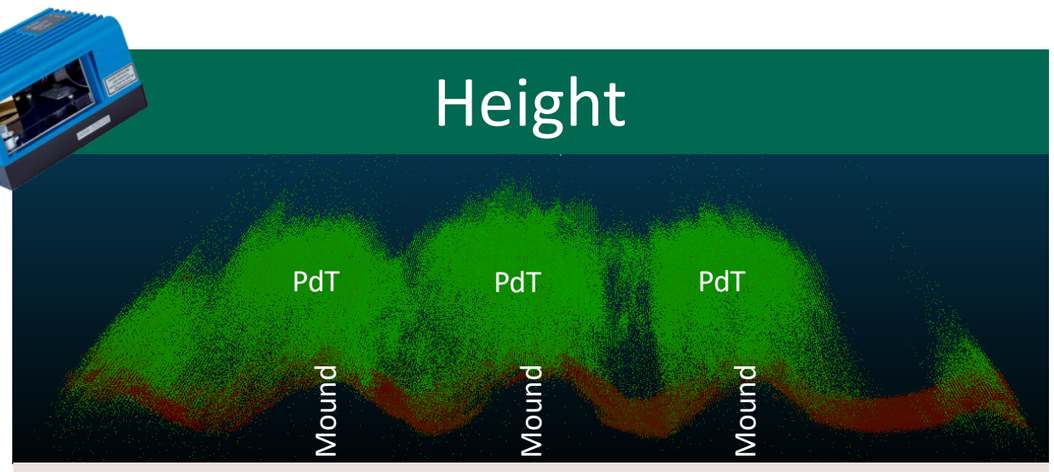
Area calculation
+ plant detection model
= Density

F Cover



A Deep Learning model calculates the pourcent of soil / leaves / stem / weeds

Height



Using the 3D points cloud, calculation of the height of vegetation

Biomass and Nitrogen

Variable	CIGREEN	MTCI	NDVI
Haulm biomass *(t/ha)*	50%	75%	42%
Dry matter *(%)*	56%	39%	44%
Haulm Nitrogen absorbed *(kgN/ha)*	83%	58%	67%
Plant Nitrogen absorbed *(kgN/ha)*	70%	80%	50%
Total Yield *(t/ha)*	39%	33%	22%

Each Vegetation Index (NDVI,….) is specific and is more or less correlated with the agronomic variables

Interreg
2 Seas Mers Zeeën
INNO-VEG
European Regional Development Fund

Conclusion

The digital phenotyping devices datas, used and tested since 2019 in Villers-Saint-Christophe, are now integrated in the Arvalis databases to complete the cultivars characterizations, the modalities comparisons, the ecophysiological studies.

ARVALIS

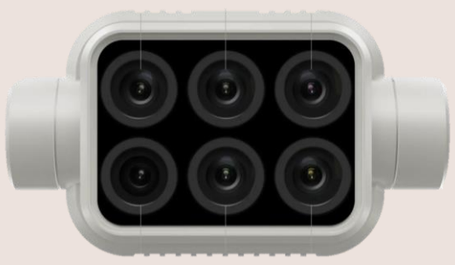
Digital tools for plant characterization

Description of the main phenotyping tools used by Arvalis on crops

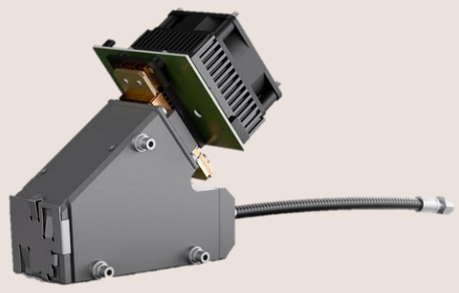
Vehicles

Sensors

RGB Camera



Multispectral Camera



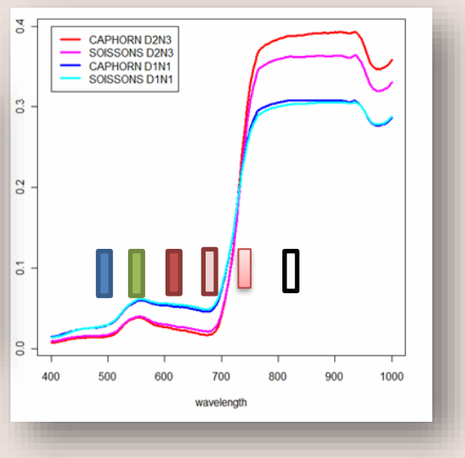
Spectro-radiometer

LIDAR

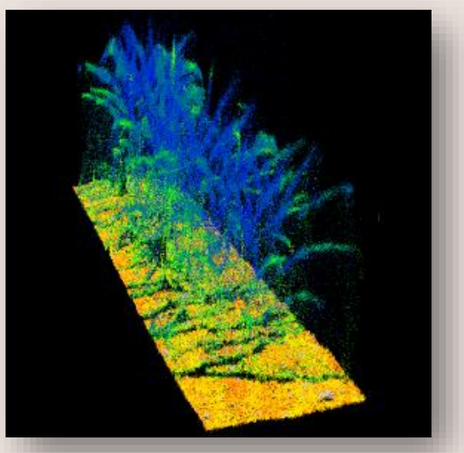
Raw datas

RGB Images

Composite Images



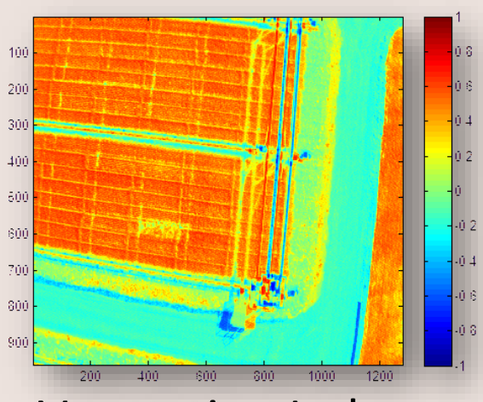
Spectrum



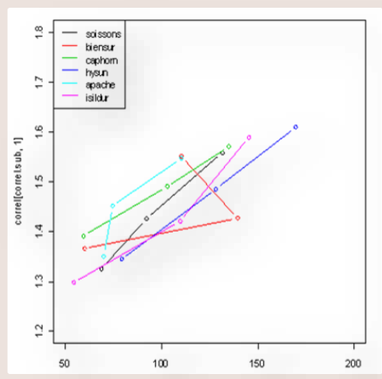
Length

Processed datas

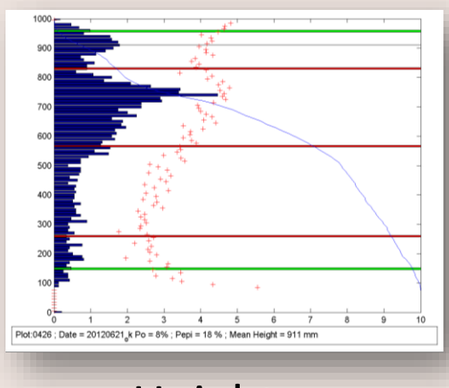
F Cover, Green Fraction



Vegetation Index Map



Vegetation Index, Chl, N content

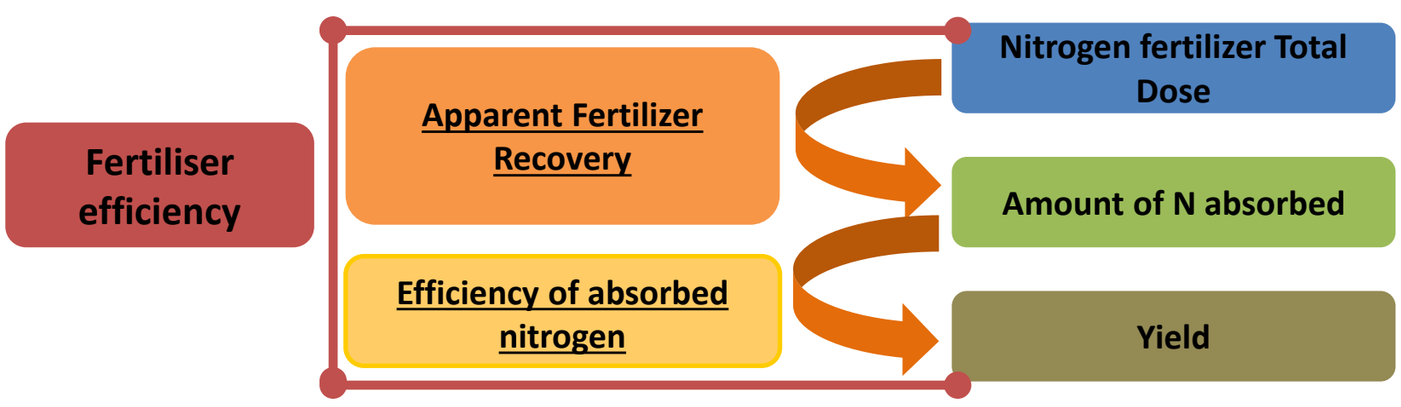


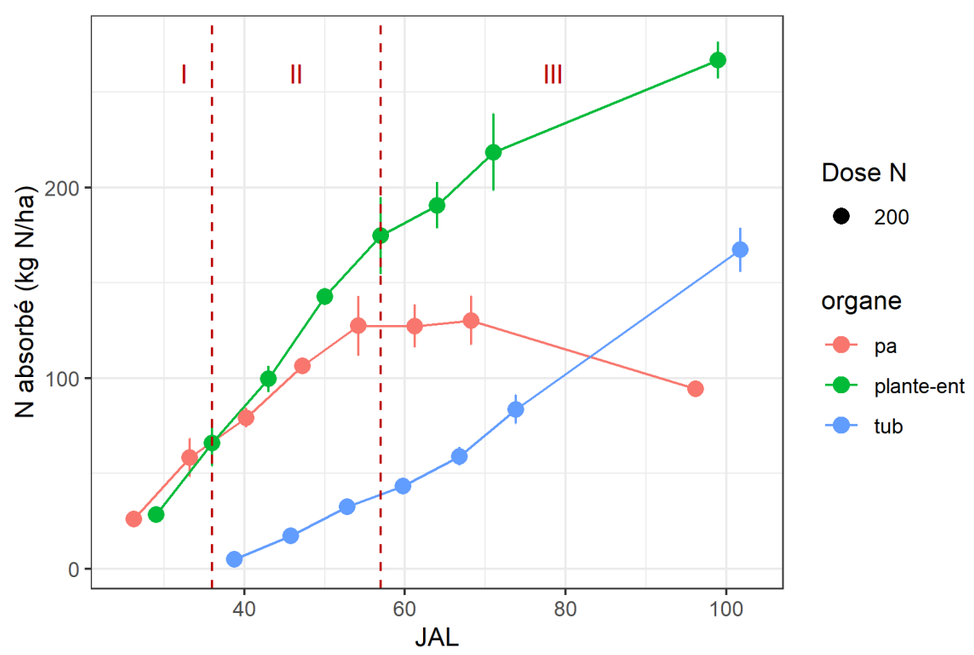
Height, Foliar Angle

Managing Nitrogen Fertilization

Why increase nitrogen efficiency?

Increase the Efficiency of Nitrogen Use from Fertilizers: Maximize the amount of nitrogen utilized in yield relative to the amount of nitrogen applied with fertilizer





The five-R key practices

1. **Right Nitrogen Forms** (Ammonium nitrate, etc.)
2. **Right dose** Correctly using soil mineral nitrogen stock at the plantation and the method to forecast total dose.
3. **Application Methods** (buried, localized)
4. **Splitting and Management -** Apply nitrogen as close as possible to the plant's peak demand and absorption capacity
5. **Enhancing Nitrogen Use** Through irrigation or positioning based on rainfall.

Principle of Management

Planting
Initial Nitrogen Application
(dose X – MER)

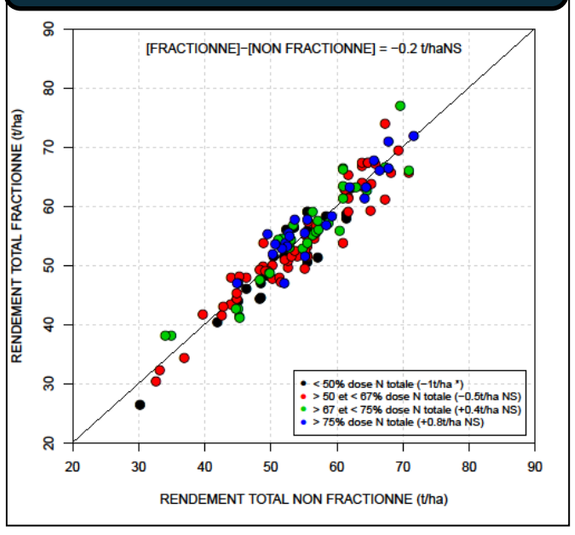
30 to 45 Days After Emergence
Diagnostic
One or several samples/measurements/images, depending on the method

Up to 45 days after emergence
Application
If indicator < activation threshold

1. **Use an indicator to diagnose nitrogen nutrition status.**
2. **Interpret the indicator value using a reference scale.**
3. **Adjust fertilization during crop growth.**

1&2. RATIO and RATE : How much N should be applied at the plantation?

Total Yield
Without and with split applications



The first application should be at least 50% of the total nitrogen fertilizer amount.

3. TIMING : At which stages of the crop cycle are the N supply the most efficient?

Total Yield	DAE 2nd split (GDD from emergence)		Yield > 50 mm
+1t/ha^{NS}	**< 471 °C**		+2.3t/ha***
-0.1t/ha^{NS}	**> 471 °C et < 624 °C**		-0.8t/ha^{NS}
-0.5t/ha^{NS}	**> 624 °C et < 813 °C**		-1.2t/ha***
-1t/ha*	**> 813 °C**		-1.9t/ha***

The best efficiency is observed for applications between 30 days and until 60 days after plant emergence

DIAGNOSTIC: Is the potato crop lacking nitrogen?
PROGNOSTIC: How much nitrogen does the potato crop need?

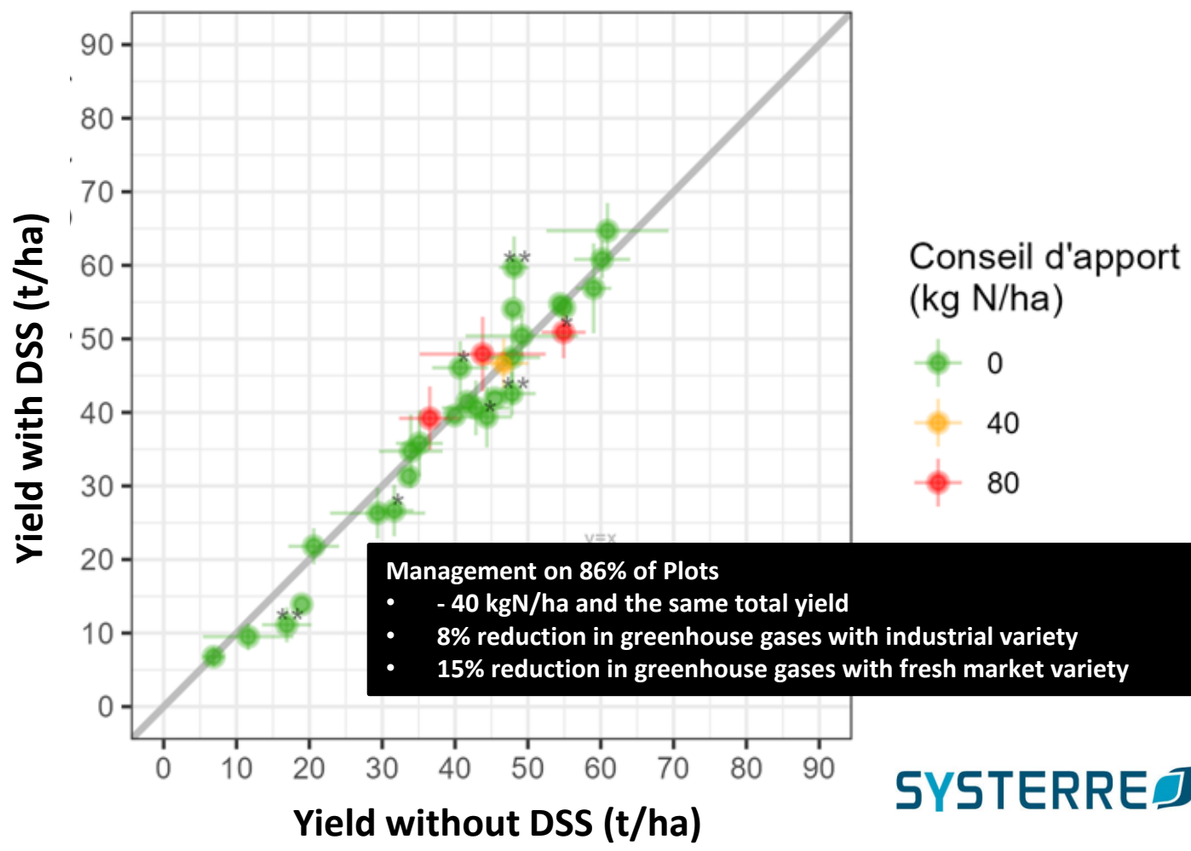
Plot Characteristics
Crop data
Farm management data
Localization data

Biophysical data from satellite images

Average Nitrogen Quantity to Apply: 0, 40 ou 80 kgN/ha

Intra-Plot Dose Distribution: 0, 40 ou 80 kgN/ha

Yield comparison
With and without DSS
(30 potato on-farm experiments)



Partners : ACOLYANCE, ARVALIS, AVIKO, Cérésia, CAR Normandie, CA 51, CA 59-62, CA 76, CETA Haut de Somme, Coudeville-Marcant, EXPANDIS, GITEP, McCAIN, ROQUETTE, Pom-Alliance, SETAB, TERREOS, Ternoveo, UNEAL

Evaluation of Biostimulant Solutions to Improve Potato Resilience to Abiotic Stress

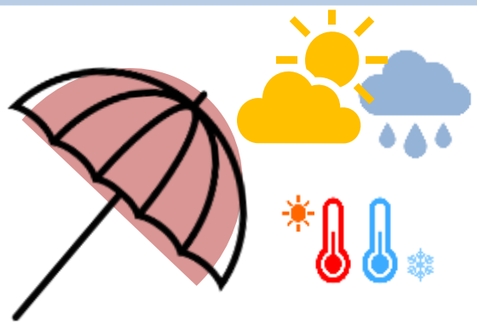
Definition of a Biostimulant: Function of stimulating nutritional processes.

Improving quality characteristics

independently of the nutrients they contain

Improving the availability of nutrients confined in the soil and rhizosphere

Improvement in Tolerance to Abiotic Stress



Improving Nutrient Use Efficiency

Protection against biotic stress

Biostimulant ≠ Biocontrol

- A biostimulant is defined by its function, not by its composition!
- Its action is not linked to the nutrients it may provide.

Objectives of the STIMPOM Project

- Evaluate the effectiveness of the most common biostimulant products.
- Select a subgroup of products for strip trials.
- Identify and possibly characterize correlations between products, locations, varieties, trials, and effects of "rain-fed" or "irrigated" conditions.

Product Claims:

Improvement in Tolerance to Abiotic Stress:

- Armonika (Rovensa Next)
- BIIMORE (RoensaNext)
- EXEL GROW (ADAMA France)
- HELIOPOLIS (Action Pin)
- Spiruline
- SUPER FIFTY (FMC agro)
- SYNCHRO NATURAL (Action Pin)

Improving Nutrient Use Efficiency:

Nutrient Assimilation Efficiency:

- Blue N (Utrisha N)
- VERALEAF (VERAGROW)

Plant Growth and/or Development Stimulator:

- TUBER MAX (UPL)
- GO UP (NUFARM S.A.S.)

Experimental Setup :

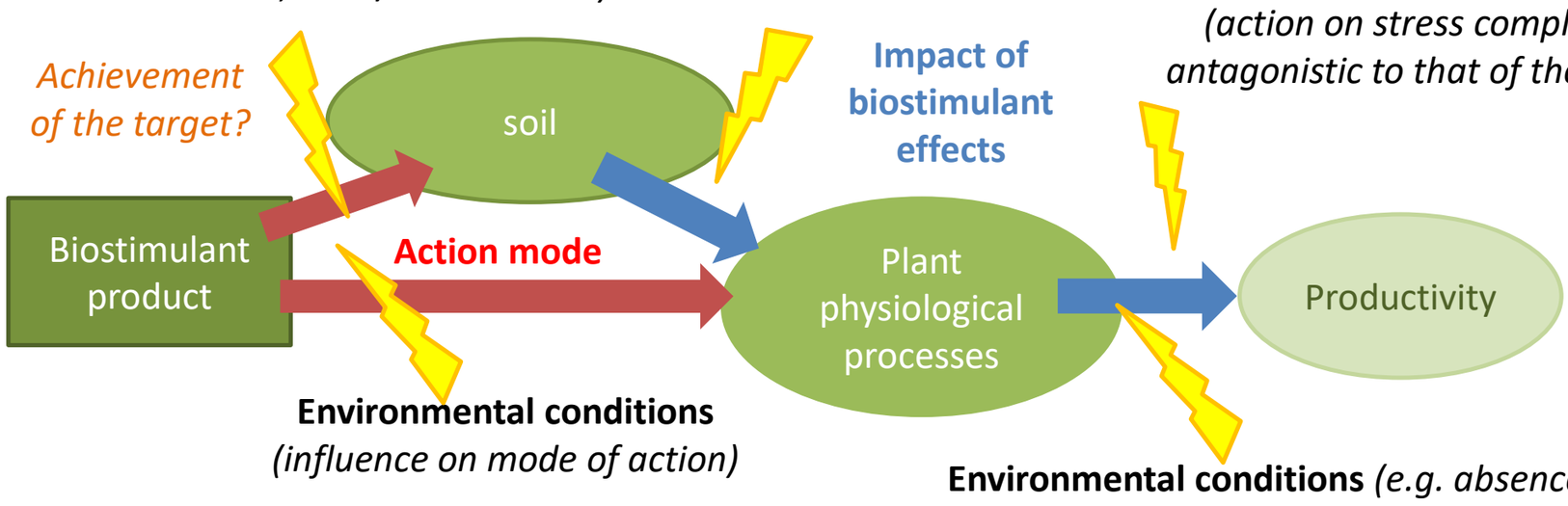
- Positive control (untreated with biostimulants, under nitrogen stress).
- Block trials with 4 repetitions.
- Agronomic measurements: monitoring stage development, biomass, and nitrogen content at defoliation, using drones for vegetation indices.

Why Non-Systematic Benefits?

Biostimulants can be effective but not necessarily useful.
Even if generally effective, they might not be useful in all scenarios.

Conditions of use
(stage, dose, formulation, application conditions, ideal/realistic FMP)

Farm Management Practices
(action on stress complementary or antagonistic to that of the biostimulant)



Environmental conditions
(influence on mode of action)

Expression of the mode of action (e.g., mycorrhizae inhibited if soil P levels are high).

Environmental conditions *(e.g. absence of stress, limiting factors other than those on which the biostimulant acts)*

Difference between the concept of efficacy evaluated during approval and the benefits expected by the farmer.

Difference between the notion of efficacy and the usefulness of the product in relation to stress experienced by the plant.

Is the improvement of soil properties or plant functions necessary?

ARVALIS

optimising nutrient balance on several spatial scales

NutriBudget

Objective: to optimise the nutrient balance in agriculture. To develop a prototype integrated nutrient management platform (OAD), at different spatial scales, for farmers, advisors, European decision-makers and regional authorities.

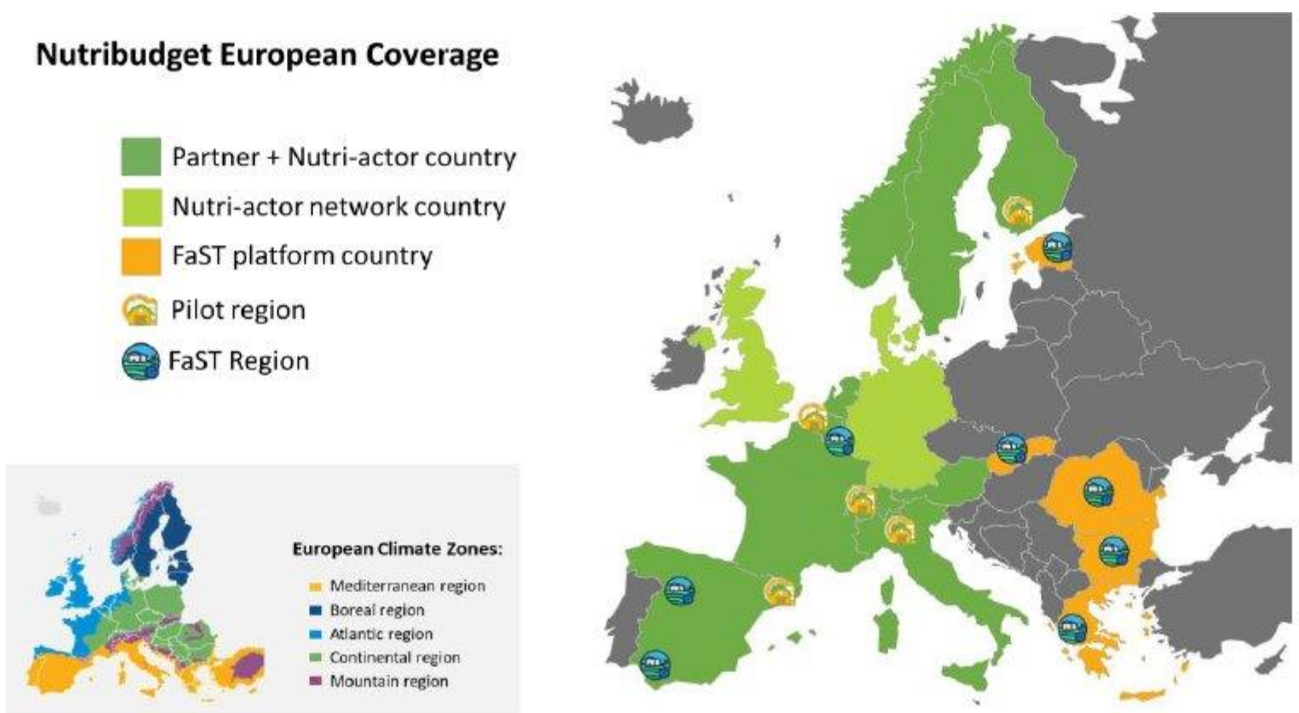
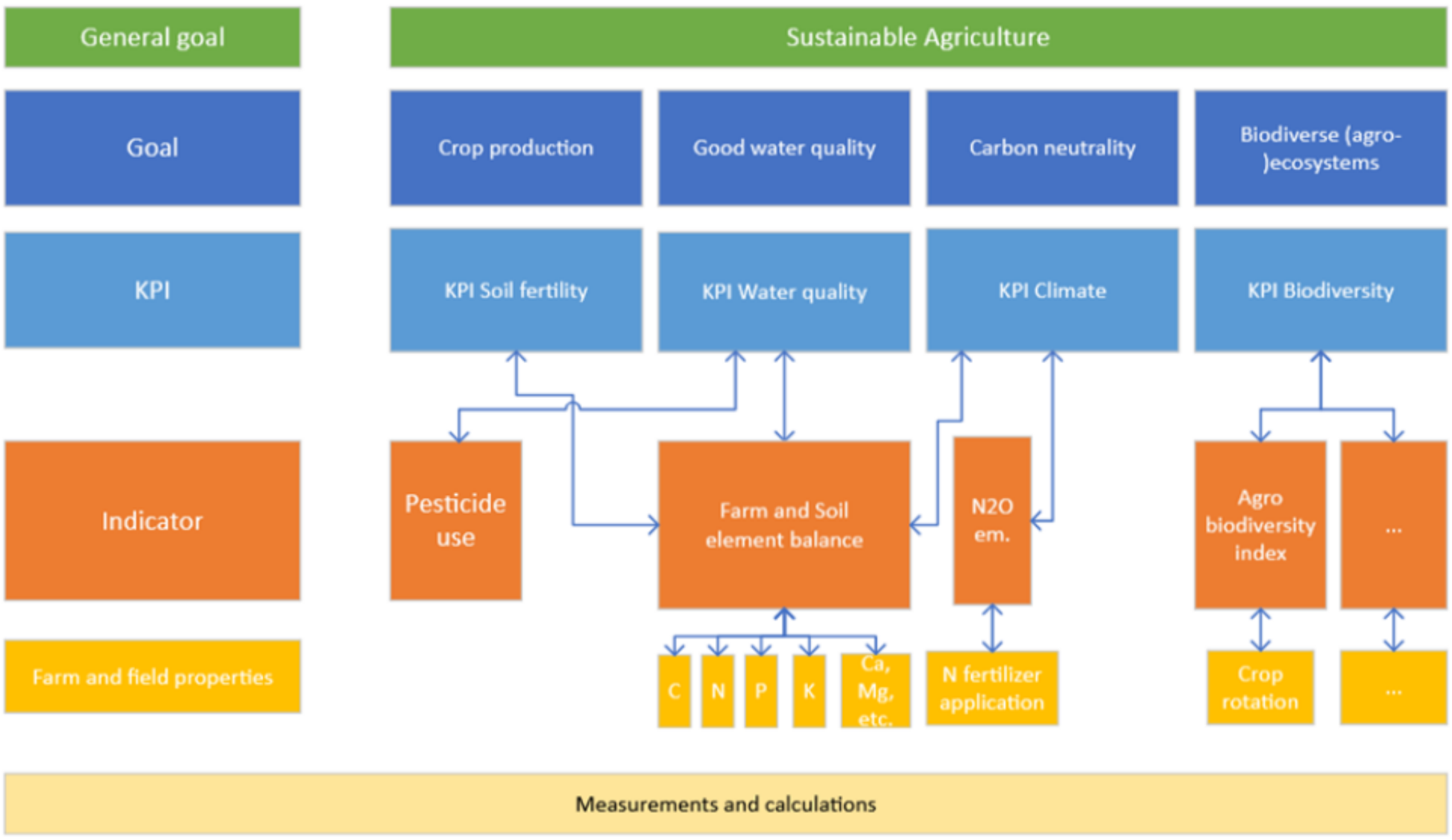


Figure IV – Consortium, pilot and FaST distribution across Europe

Framework for developing indicators to assess agricultural practices and public policies



- Inventory of measures and their performance in influencing nutrient flows (Nitrates Directives, COMIFER, other regulations).
- Identification and development of performance indicators for fertilisation practices
- Integration of certain priority nutrient balance indicators into SYSTERRE®.
- Methodological approach for assessing practices and quantifying nutrient balances at regional level

Activities planned for 2024-2025 :

- WP1: meta-analysis of agricultural practices already introduced into public policy and those not yet integrated to improve nutrient management performance.
- WP2: integrate the CHN model into the chain of models for a multi-scale approach
- WP3: test system performance indicators in terms of nutrient management in SYSTERRE.

ARVALIS

Optimizing crop nutrition

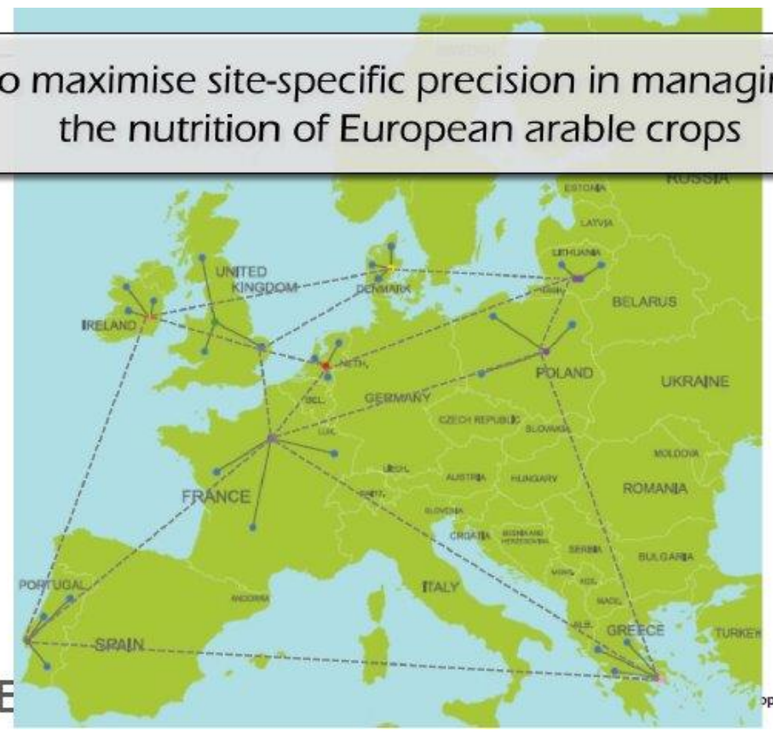
Objective: maximise the consideration given to specific territorial characteristics in the management of plant nutrition in arable crops

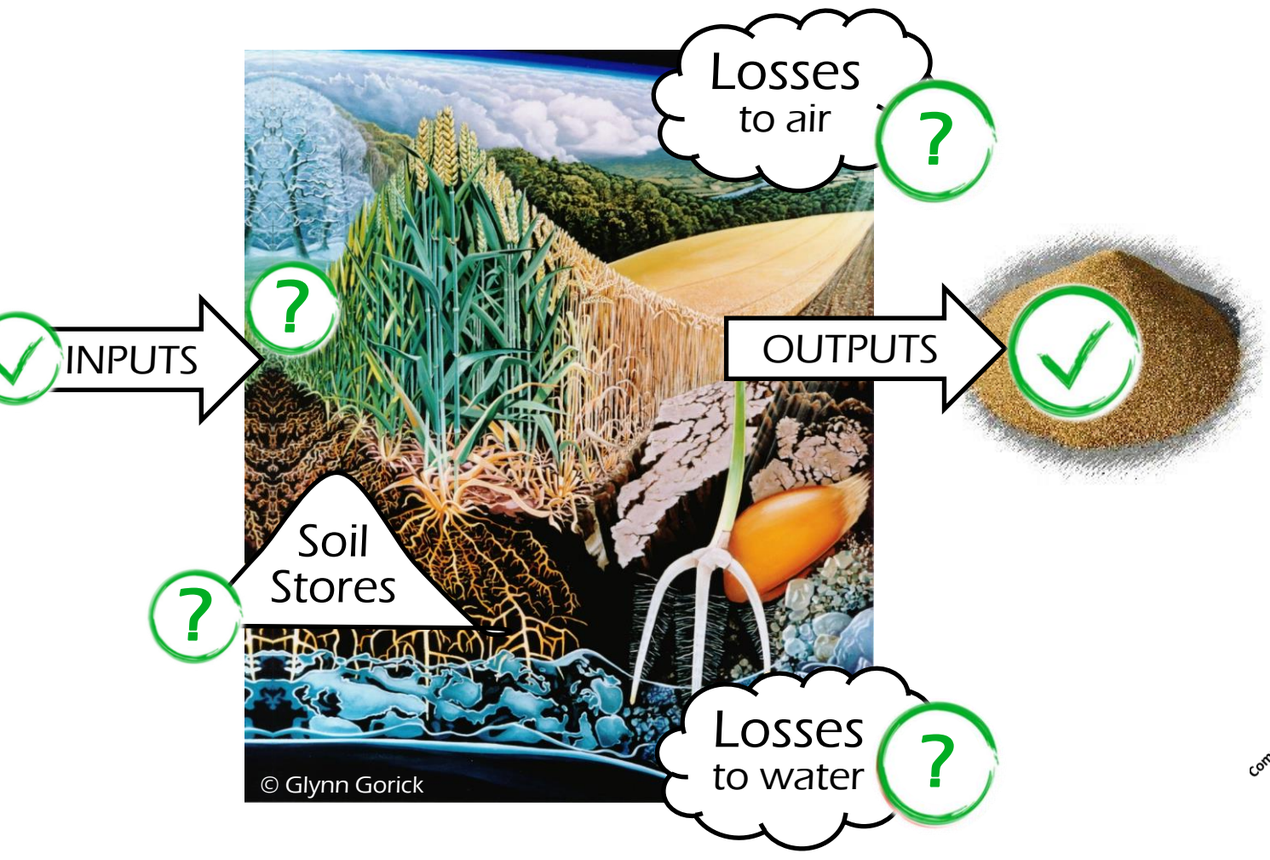
Multi-player thematic network (knowledge exchange) to improve nutritional accuracy via DSS: nutrient monitoring at farm level

NUTRI-CHECK NET
OPTIMISING CROP NUTRITION

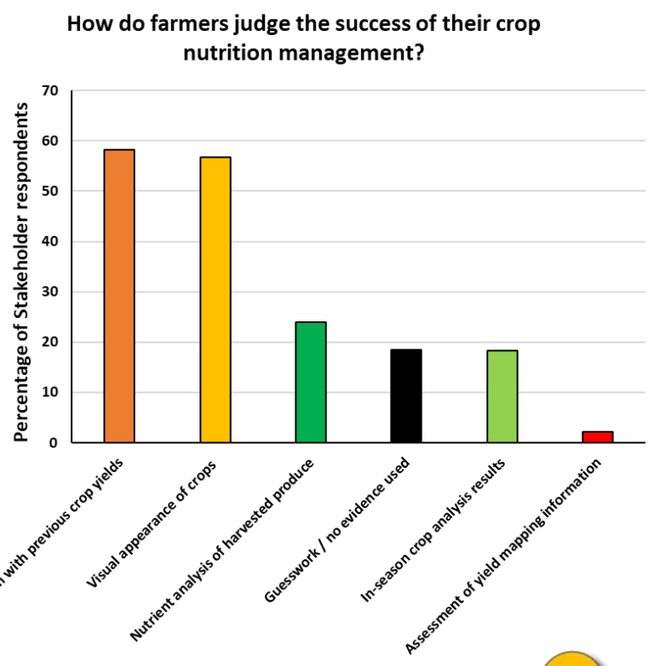
to maximise site-specific precision in managing the nutrition of European arable crops

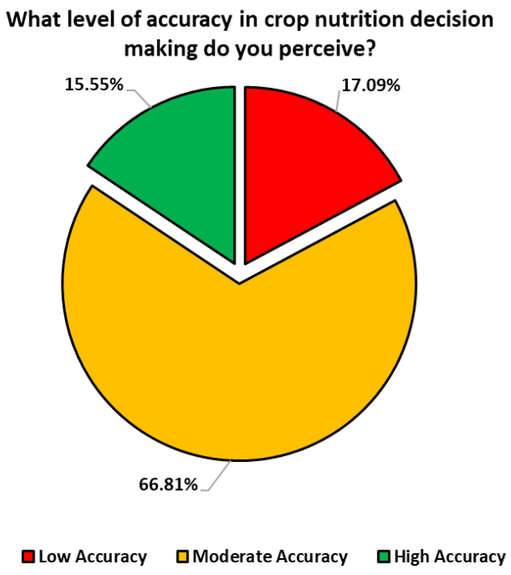
Sarah.Kendall@adas.co.uk



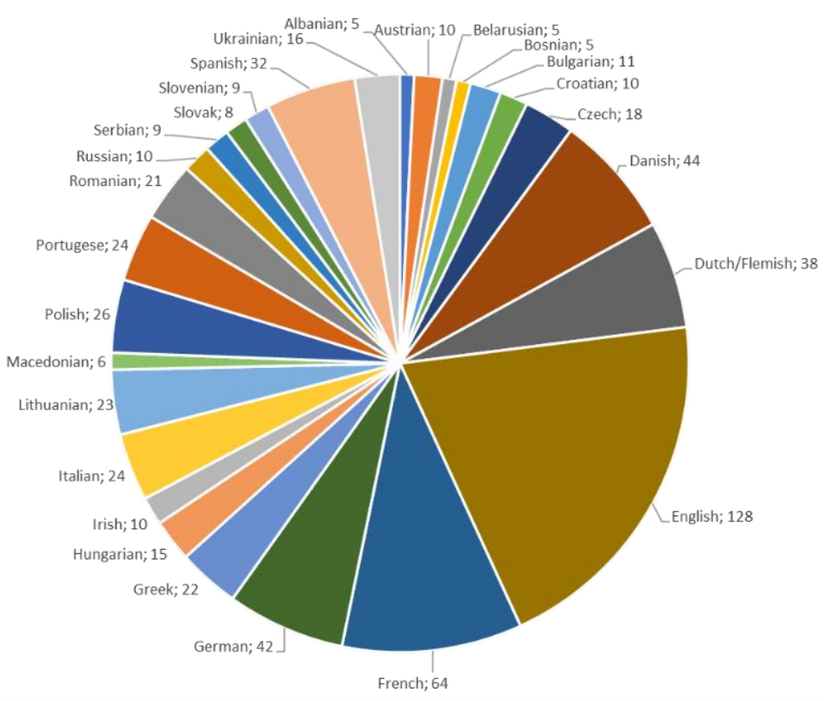


How do farms currently measure success?





159 DSS in over 25 languages - listed and analysed



Activities planned for 2024-2025 :

- evaluation of tools and methods in networks of farmers
- provide a summary of recommendations on fertilization reasoning and fertilization management tools at European level
- to propose a common approach to fertilization management in three stages (planning, readjustment, evaluation)

Steamed potatoes

Comité National Interprofessionnel de la Pomme de Terre

Usage Characteristics

Varieties are classified, primarily based on their degree of disintegration during **cooking (Fig 1**), the firmness of their flesh, and their flouriness into groups A, B, C, and D.

Group A

Fine flesh, not or barely floury, watery to moderately watery, and not disintegrating during cooking.

Group B

Fairly fine flesh, slightly floury, and disintegrating little during cooking.

Group C

Floury, dry, coarse flesh, and showing a rather pronounced disintegration.

Group D

Very floury, dry flesh, almost entirely disintegrating during cooking.

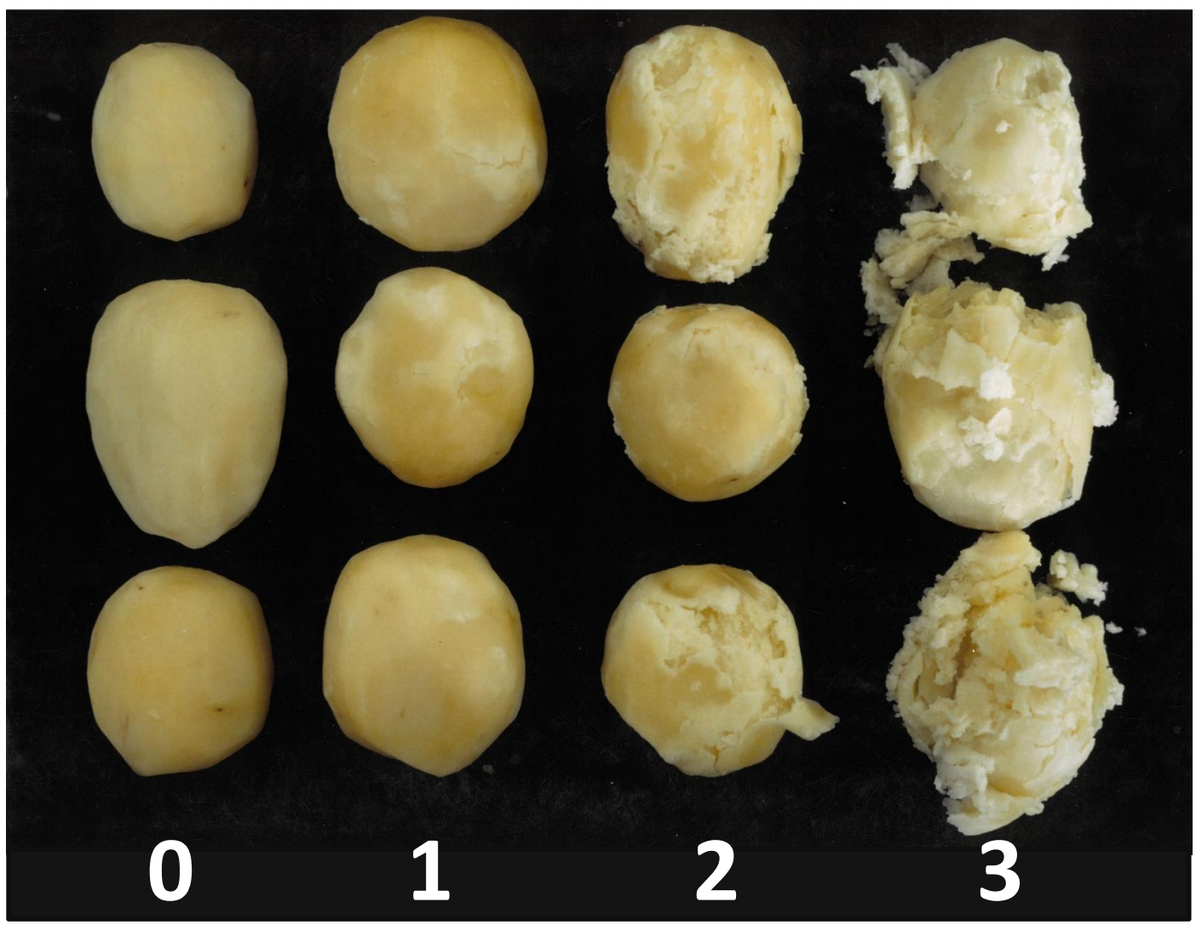


Fig.1 : Disintegration scale

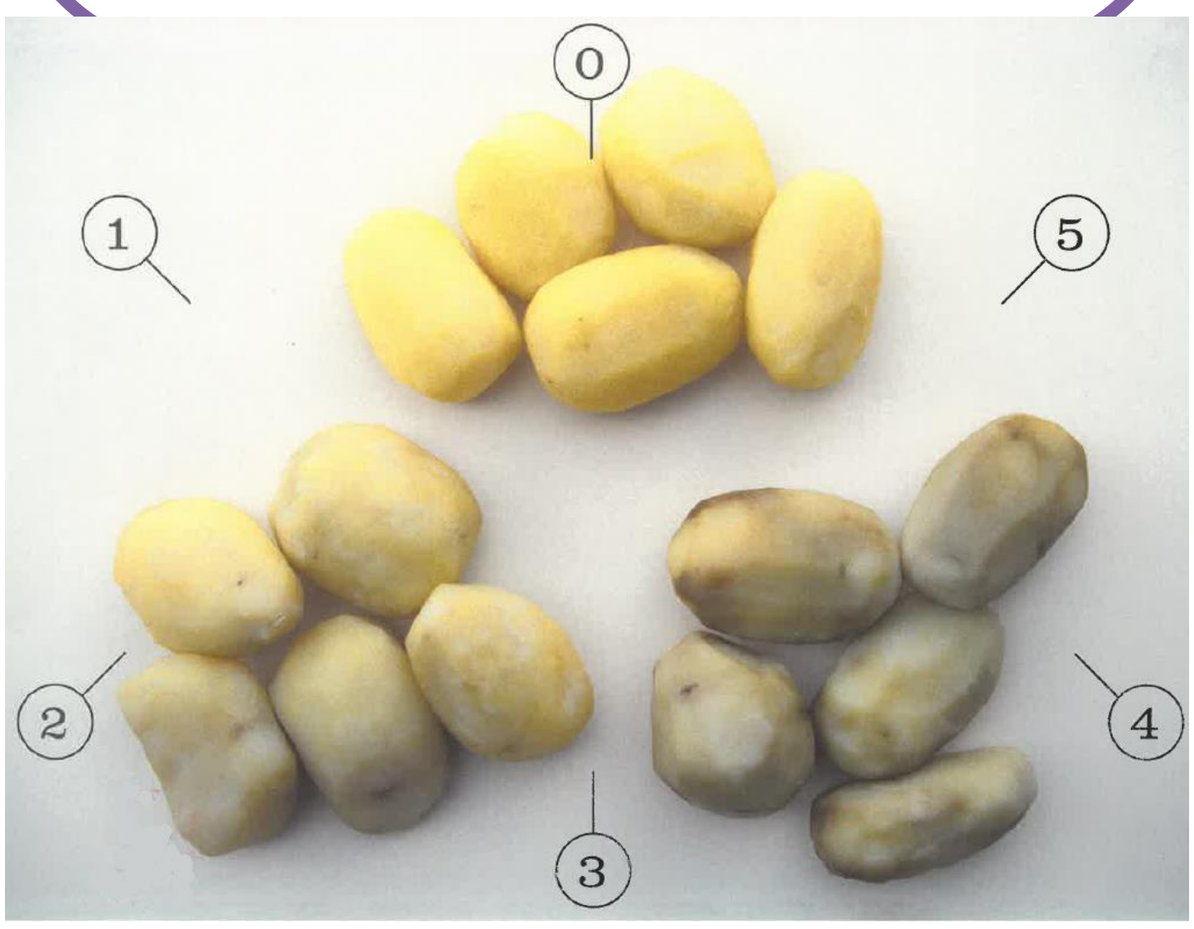


Fig.2 Blackening after cooking scale

Blackening after cooking

Also known as "graying" of the flesh, it occurs mainly when tubers are cooked in water or steamed, peeled, or cut and left exposed to the air. Sensitivity to this factor is partly varietal but also depends on the pedoclimatic context, with a negative effect from unbalanced potassium (K) fertilization, soil rich in organic matter, and cold, rainy seasons.

Texture Homogeneity

Texture is one of the most complex characteristics of the potato. It is strongly influenced by environmental conditions and cultivation techniques but largely depends on the varietal factor. The more or less pronounced tendency of the tuber's tissues to disintegrate during cooking, the fineness, or the flouriness of the flesh are essential elements of quality and marketability.

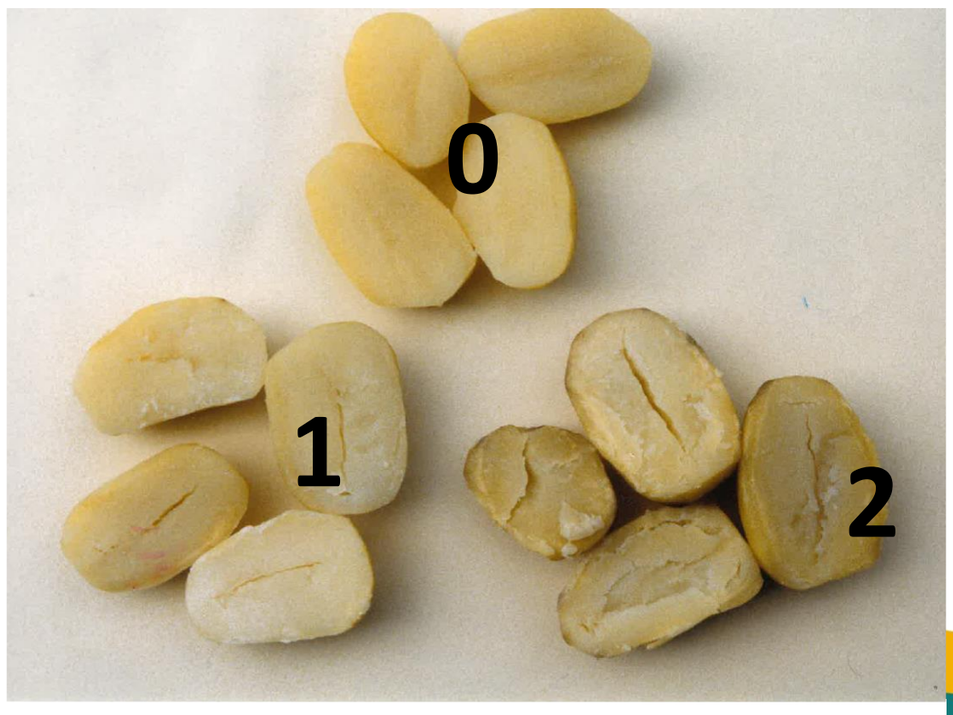


Fig.3 : Texture homogeneity scale

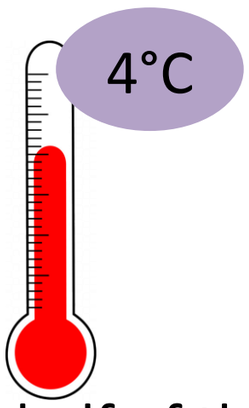
ARVALIS

The Quality of French fries and Crisps

Storage
(1 month and more)

Crisps | **French Fries**

+



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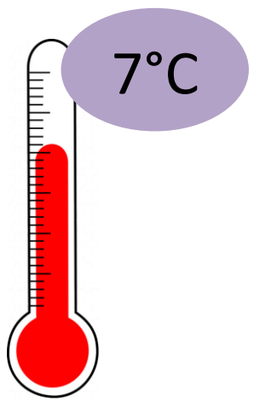
(Ex : upper shelf of the fridge…)

+



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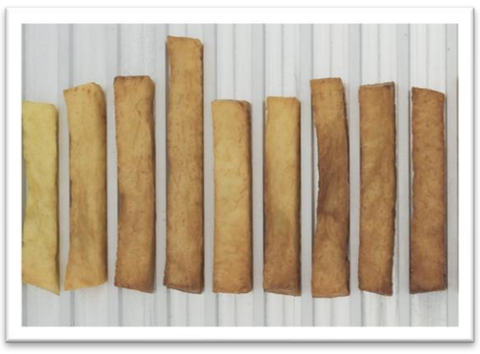

(Ex : down shelf of the fridge…)

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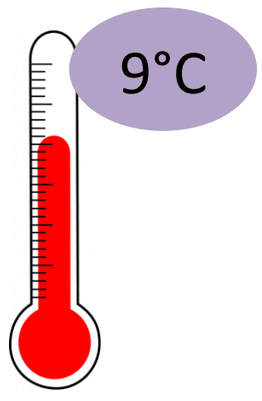

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(Ex : cave…)

In potatoes, the sugar content in the juice is on average responsible for nearly 85% of the color of the fried product. Therefore, managing the chosen variety and storage temperature is crucial for controlling this quality parameter. Storage duration, temperature, and reconditioning are all factors that can influence this sugar content and, consequently, the color (Fig. 1).

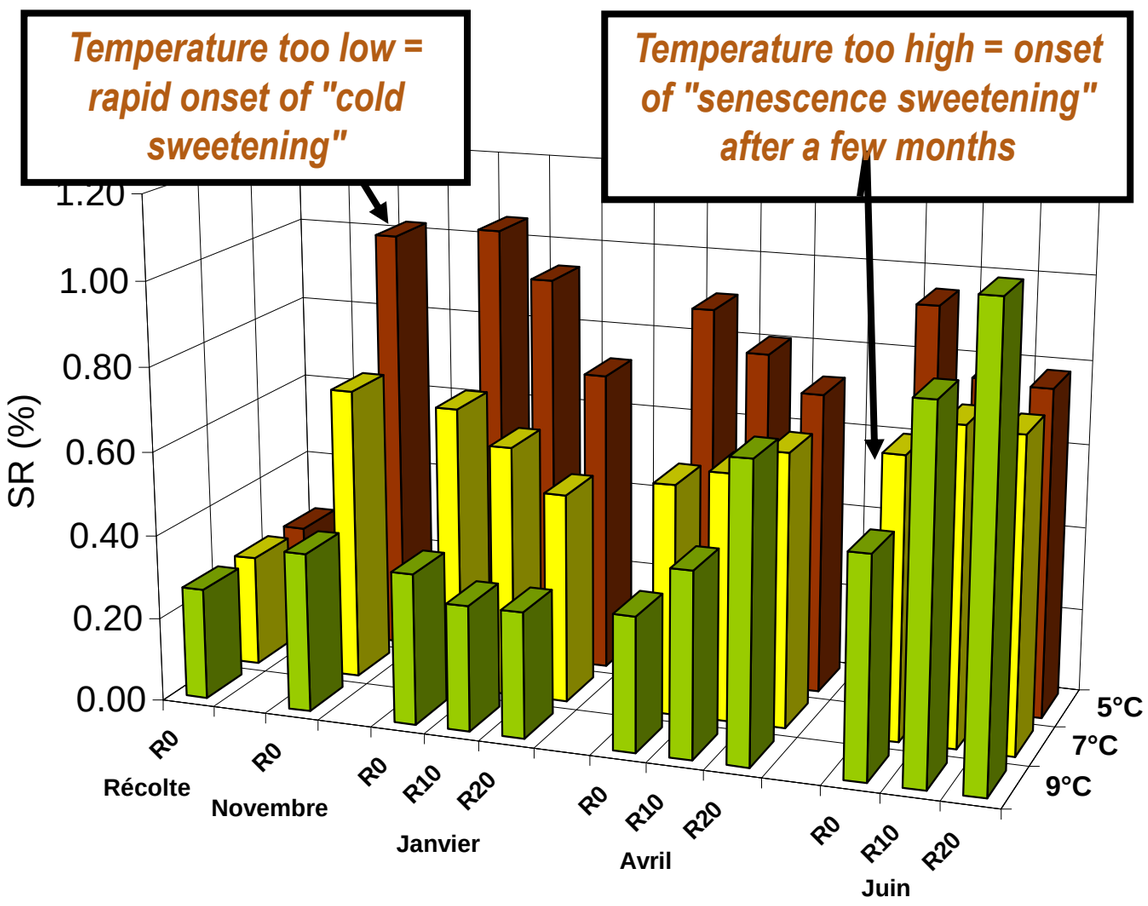


Fig. 1 : Evolution of reducing sugars in potatoes stored at different temperatures. Effect of reconditioning for 10 days **(R10)** and 20 days **(R20)** at 15°C.

Variety and **storage** temperature are two essential factors influencing the color of fried products.

ARVALIS

The Nutritional Qualities of the Potato

Comité National Interprofessionnel de la Pomme de Terre

Potato rhymes with light, oh!

Thanks to a high proportion of water (78% on average) and a very low quantity of lipids, **the caloric density of the potato is moderate, with only 85 kcal per 100g when cooked in water.** This makes it a light accompaniment to integrate into dishes with sauces, soups, or salads to restore the balance of carbohydrates.

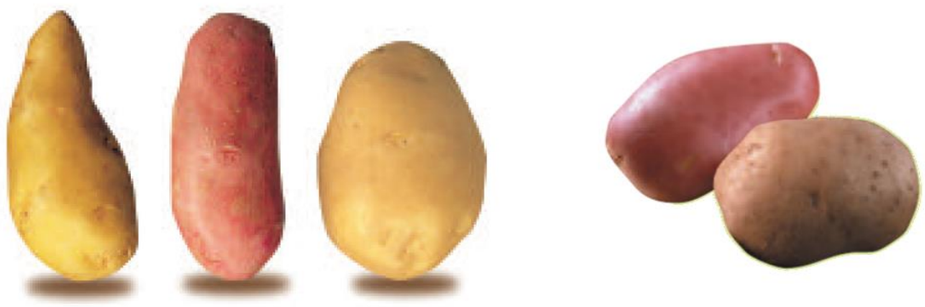
Vitamin C, for well-absorbed iron.

The potato provides 0.80 mg of iron per 100 g on average, which is similar to cereals. However, the high proportion of Vitamin C contained in a serving of unpeeled potatoes allows **for covering approximately 20% of an adult's daily iron needs (12 mg/day).**

Potassium galore!

With 564 mg of potassium in an unpeeled potato, a 300 g serving covers more than half (56%) of a man's daily needs, estimated at 3 g per day, and 38% if peeled. It provides more potassium than a banana.

	Pomme de terre cuite à l'eau	
Pour 100 g	Non pelée	pelée
Valeur calorique (kcal)	85	
(kJ)	20	
Eau (%)	78	
Glucides (g)	19	
Fibres (g)	2,50	1,50
Lipides (g)	0,1	
Protéines (g)	2	
Vitamines (mg)		
B1	0,09	0,08
B2	0,03	0,03
B3	1,50	1,20
B6	0,20	0,18
B9	0,01	0,01
C	13	9
Minéraux (mg)		
Potassium	564	376
Magnésium	27	18,60
Fer	0,80	0,40
Manganèse	0,25	0,14
Cuivre	0,19	0,09
Chrome	0,02	-
Zinc	0,41	0,28



Fiber too!

A 300 g serving of potatoes covers 15% of the recommended daily fiber intake, and 25% with the skin.

The starchiest food richest in vitamins and minerals!

The potato has a good nutritional density in minerals: potassium, iron, magnesium, zinc, copper, and chromium. It also contains a wide range of B vitamins: B1, B2, B3, B6, and B9, and is **notably the only starchy food that is a source of vitamin C!**

ARVALIS

Early Blight : Better understand its emergence to better control it!

Prophylaxis

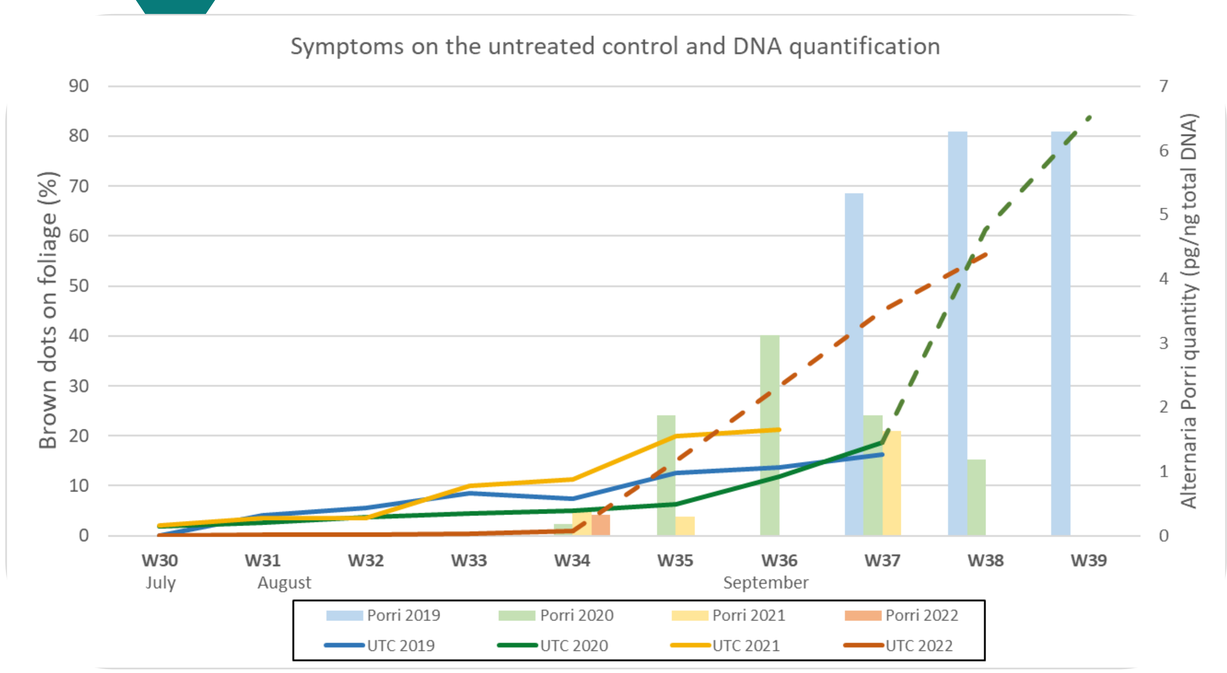
→ Good management by agronomy

Destroy sources of primary inoculum
Cull piles, volunteers…

Balanced fertilization and irrigation
Watch out for excess!

Avoid any stress of the plant causing early senescence

Weakness disease



Symptoms decorrelated of the presence of the pathogen. It appears very late in the season and in connection with senescence.

Misleading symptoms

There is a lot of confusion: deficiencies, lesions, burns, senescence…

We are talking about “supposed” symptoms of early blight

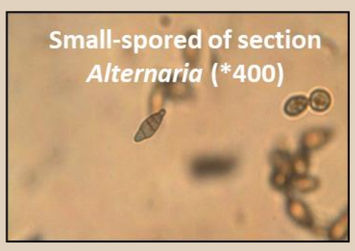
In 2/3 of the cases, an assumed symptom of early blight is not confirmed by the analysis

This leads to unnecessary treatments, because too early, sometimes as early as June/July

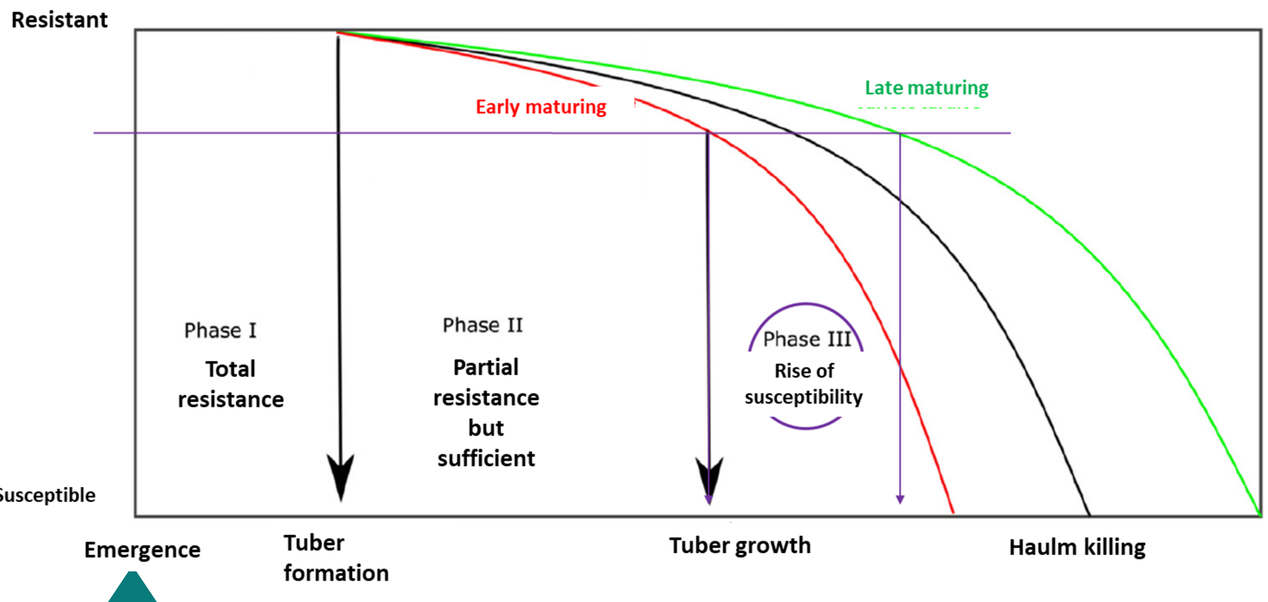
To ensure the presence of Alternaria

Damp room and observation of spores with a magnifying glass

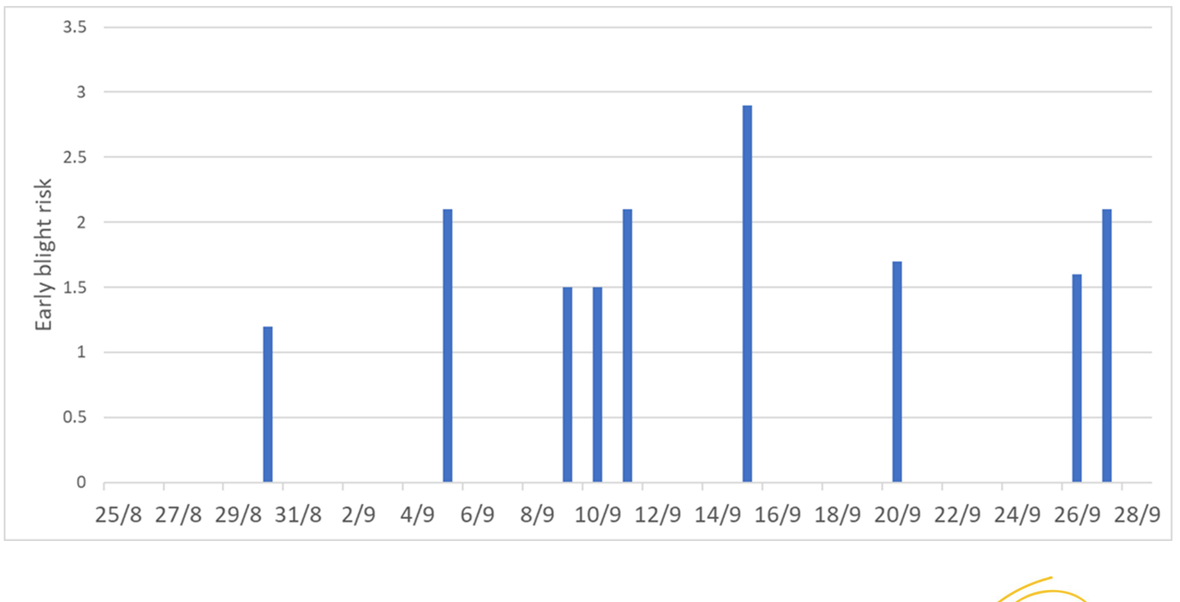
Laboratory analysis to know the species



Step 1: When does the plant become too sensitive (Phase III)?
Physiological model



Step 2: In phase III, when to start the T1 and renew it if necessary?
Epidemiological model



A risk model in Mileos®

To check before treat Early Blight:

Using the model :

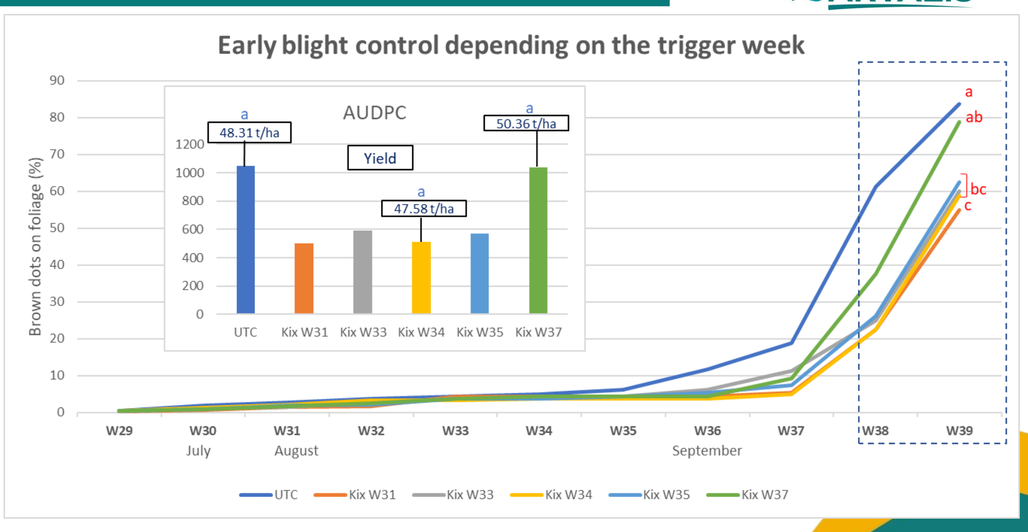
Susceptibility treshold reached ? → Physiological model

Conditions conductive to disease ? → Epidemiological model

In the field :

Maturity stage of tubers
What size is targeted? → Size reached or almost : no risk / Size far from the target : potential risk

When haulm killing is planned ? → Avoid late treatment, to close to the haulm killing



Interreg France-Wallonie-Vlaanderen
UNION EUROPÉENNE EUROPESE UNIE
SYTRANSPOM
ARVALIS
Avec la contribution financière du compte d'affectation spéciale développement agricole et rural CASDAR
MINISTÈRE DE L'AGRICULTURE ET DE LA SOUVERAINETÉ ALIMENTAIRE
Liberté Égalité Fraternité
Etude réalisée avec le concours financier du Compte d'Affectation Spécial pour le Développement Agricole et Rural (CASDAR) géré par le Ministère en charge de l'agriculture.

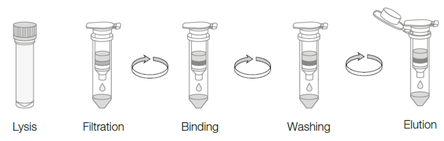
SYNAPTIC project : Results to promote the adoption of integrated management

Primary inoculum monitoring and aerial dispersion of spores

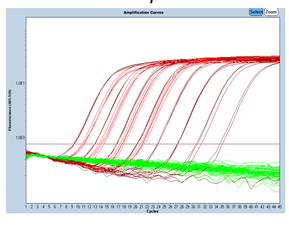
Spore Traps

Spore Traps (1 tube per day)

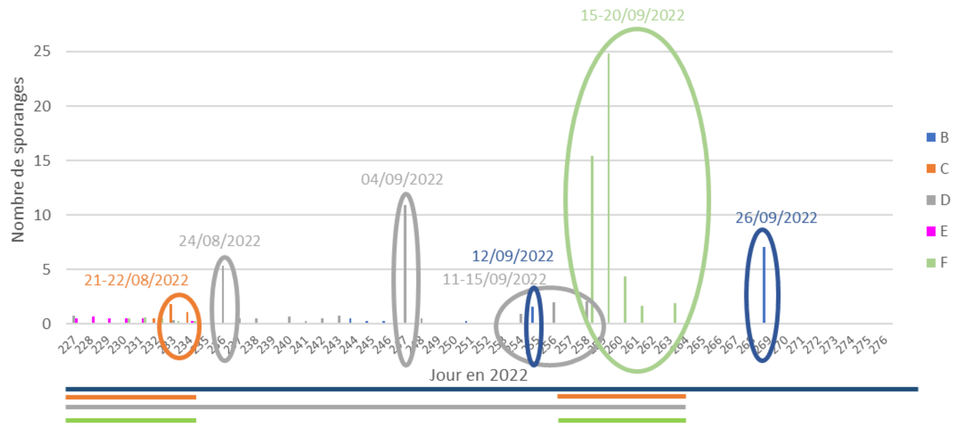
Samples sent to INRAEDNA extraction from sporangia



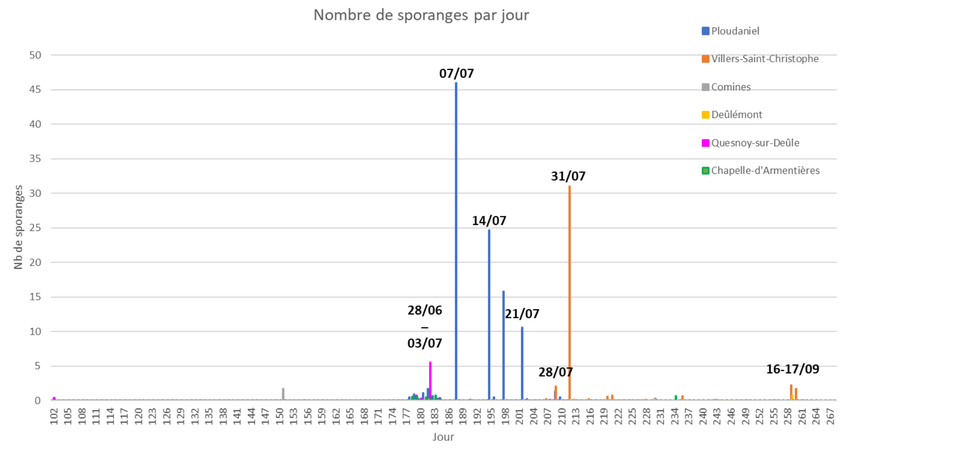
Quantification of sporangia number by qPCR technique



2022



2023



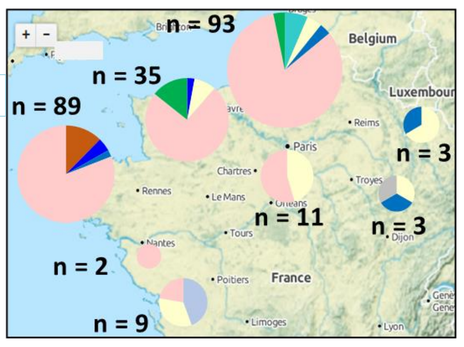
- 2022 is considered a low blight pressure year compared to 2021. Drought was unfavorable to the disease until mid-August. There is good consistency between spore flights and field epidemics.
- 2023 is considered a year of moderate blight pressure. Drought was unfavorable to the disease until the end of July at Villers SC. There is good consistency between spore flights and field epidemics.
- These early results also show a good match between sporangia flights and risk periods identified by Mileos®.

FTA cards

FTA cards allow farmers and gardeners to send symptomatic leaf DNA samples to the lab. Widely distributed, these cards are a powerful means of tracing the genotypes of P. infestans.

	2021	2022	2023
Number of FTA cards NPDC	30	6	93
Number of FTA cards Lille	14	3	13

2023

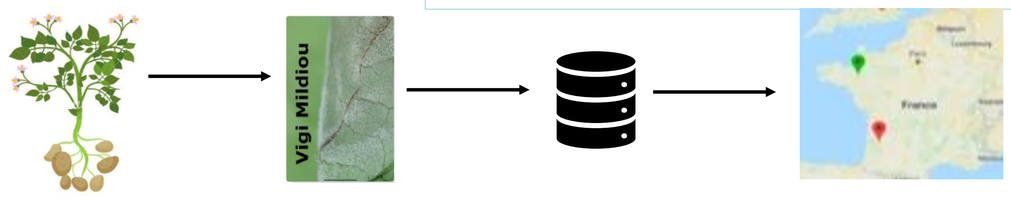


Key Points from 2023:

- EU_36_A2 predominantly throughout France.
- First detection of **EU_43_A1** in the North (6).
- **EU_45_A1** moving west. No detection of **EU_6_A1**.
- Low proportion of lineages: **EU_39_A1**, **EU_13_A2**, and **EU_37_A2**

VigiMildiou

VigiMildiou is a citizen science app designed for anyone to report a symptomatic plant (potato or tomato) by providing a photo and location. The data is stored and reviewed by experts, then an infection map is generated.



Survey results

Gardeners

- Wastes usually destroyed but tubers remain in the ground
- Volunteers are not systematically destroyed
- **74%** of cultivated varieties are susceptible
- **High diversity:** Nearly 20 varieties
- Short rotations 1/5 irrigate on leaves
- Critères: 1 – Goût 2- Usage culinaire 3- Précocité 4- Résistance
- 50% do not remove leaves contaminated by late blight

Expectations:
- Willing to adopt safer habits.
- Request technical information.
- Willing to grow without using copper.

Farmers

- 50% of cull piles are not managed
- Volunteers controlled by mechanical weeding
- **71%** of cultivated varieties are susceptible
- **Low diversity:** only 3 varieties represent 67,5% of the area
- Good practices of rotation and irrigation
- They all use Mileos®
- Criteria: 1 - Market, 2 - Yield, 3 - Storage, 4 - Resistance

Expectations:
- Request resistant varieties.
- Willing to improve their practices.
- Request technical and financial support to change their practices.

Industries

- Mileos® is useful, but opinions on biocontrol are mixed
- Interest in late blight risk management and fungicide input reduction, but these are not decisive criteria for variety selection
- Consumer opinion is hardly considered, and there is no communication about varietal choices
- A change in the specifications with varietal change and TFI reduction is possible
- Good knowledge of blight and integrated protection

Surveys supplemented by 2 collective intelligence sessions:
Definition and prioritization of actions to be taken to reduce the TFI,
Imagining a change timeline for the next 10 years through the generalization of best practices, the promotion of research results, and better coordination among industry stakeholders
Creation of detailed action sheets.

"Practice Evolution" during the Project:
Farmers: Few changes in practices over 3 years, willing to commit to TFI reduction but need support and recognition of efforts and risks by the market.
Gardeners: Few changes in practices over 3 years, not very aware of risky practices, need technical information to better assess risks, evolution of the varietal range

IPM programs trails and fields

2021

Disease pressure was high during the season, making it difficult to significantly reduce TFI. TFI savings were only possible at the beginning of the season because Mileos® continuously triggered treatments. The average TFI is 12% lower than the reference TFI (24,25).

Susceptibility	# of treatments	TFI
Intermediate	17	21,22
Susceptible	16	21,36
Average	**16,4**	**21,3**

Cultivar
- Susceptible (CTPS ≤ 4) Ex: Bintje
- Moderate resistance (CTPS ≥ 5) Ex: Magnum

DSS
Treatments triggered with Mileos®

Biological control
Potassium phosphonate with adjusted dose of traditional fungicide

Fungicide
Adjusted dose regarding cultivar, disease pressure

2022

Blight pressure was historically low during the season. Producers trusted Mileos® and used biocontrol. Significant TFI reduction is possible under the climatic and sanitary conditions of 2022. The average TFI is 70% lower than the TFI for systematic treatment.

Susceptibility	# of treatments	TFI
Intermediate	6	6,05
Susceptible	5	5,06
Average	**5,4**	**5,5**

Precocity	# of treatments	TFI
Mid-early	2	3
Mid-late	6,5	6,1
Late	6	6,05
Average	**5,4**	**5,5**

2023

The blight pressure was moderate in both intensity and early onset. Producers trusted Mileos® and used biocontrol. The average TFI is 35% lower than the TFI for systematic treatment. The proposed support was greatly appreciated.

Sensitivity	# of treatments	TFI
Intermediate	11,5	14,3
Susceptible	10	14,2
Average	**10,6**	**14,3**

Precocity	# of treatments	TFI
Mid-early	9	12,5
Mid-late	10	11,1
Late	11,3	15,9
Average	**10,6**	**14,3**

Conclusions:

There is an annual effect due to climatic conditions.

The duration of the cycle has an impact depending on earliness

Conclusions

The first three years of the SYNAPTIC project have yielded encouraging results. Spore traps, FTA cards, and the VigiMildiou app allow for good characterization of atmospheric inoculum, strain dynamics, and inoculum source locations. Continuing these techniques will help improve the consideration of primary inoculum in Mileos® for its treatment triggers. Overall, producers are satisfied with Mileos® and have tested biocontrol to reduce conventional fungicide inputs, but they find it too costly. Surveys show that farmers are willing to adopt safer practices, such as using resistant varieties, but the industry must add value to the effort and risk and open specifications to this type of more virtuous practice

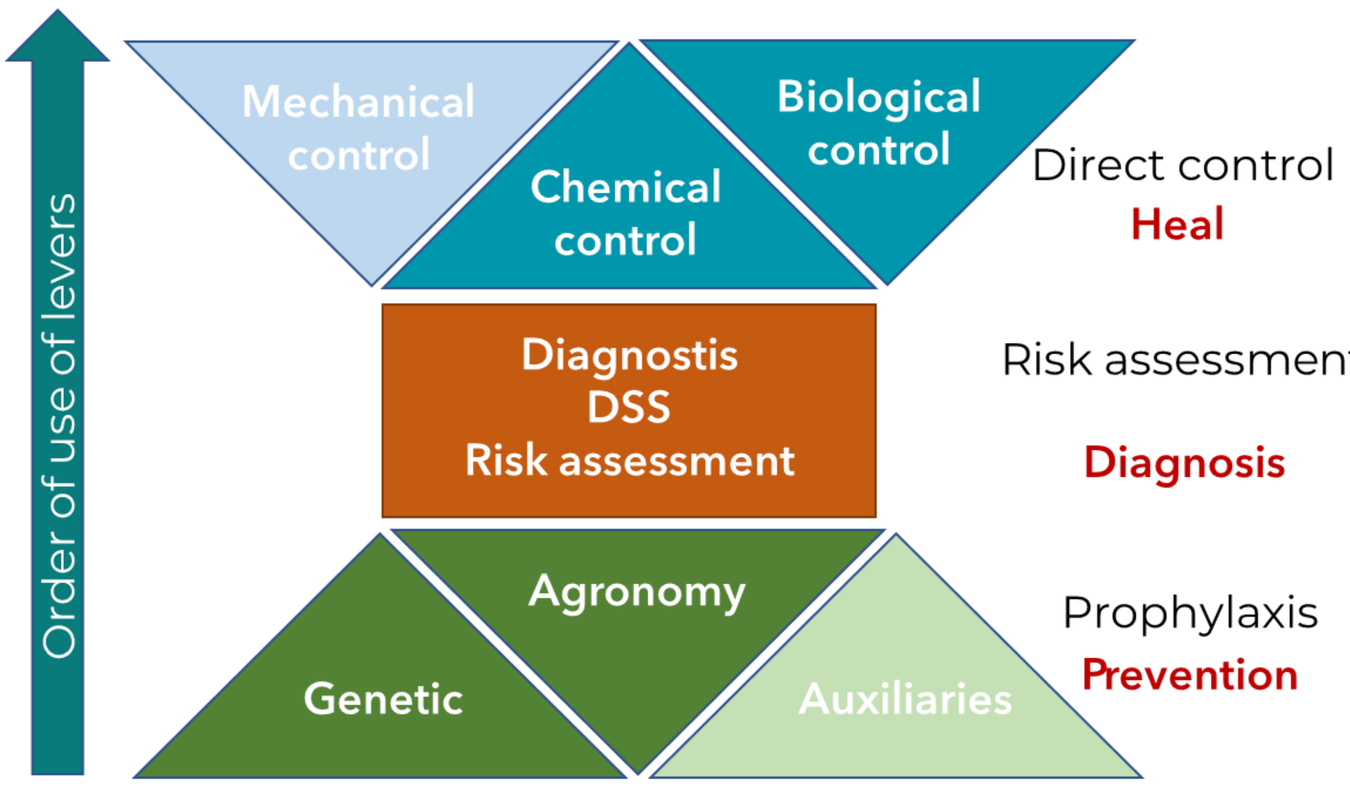
This action is carried out by the Ministries of Ecological Transition, Agriculture and Food, Solidarity and Health, Higher Education, Research and Innovation, with the financial support of the French Office for Biodiversity with levies for diffuse pollution from the Ecophyto II+ plan.

The winning combo against Potato Late Blight

Context

Significantly reduce potato fungicide TFI (Treatment Frequency Index) with integrated crop protection

Integrated Pest Management (IPM)



Levers used

Assess the Treatment Frequency Index (TFI) reduction potential and efficacy of IPM programs

Cultivar

- Susceptible (CTPS ≤ 4) Ex: Bintje
- Moderate resistance (CTPS ≥ 5) Ex: Magnum

DSS

Treatments triggered with Mileos®

Biological control

Potassium phosphonate with adjusted dose of traditional fungicide

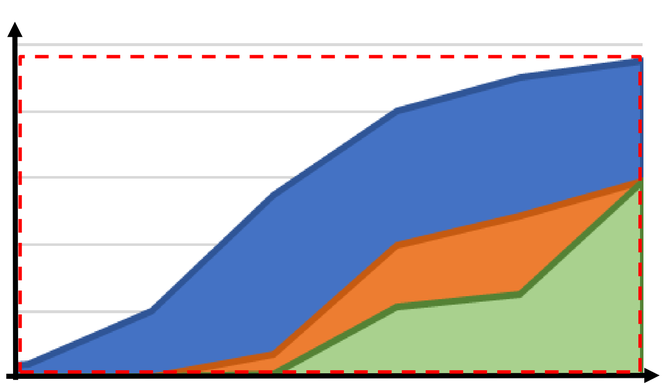
Fungicide

Adjusted dose regarding cultivar, disease pressure

rAUDPC (0-1)

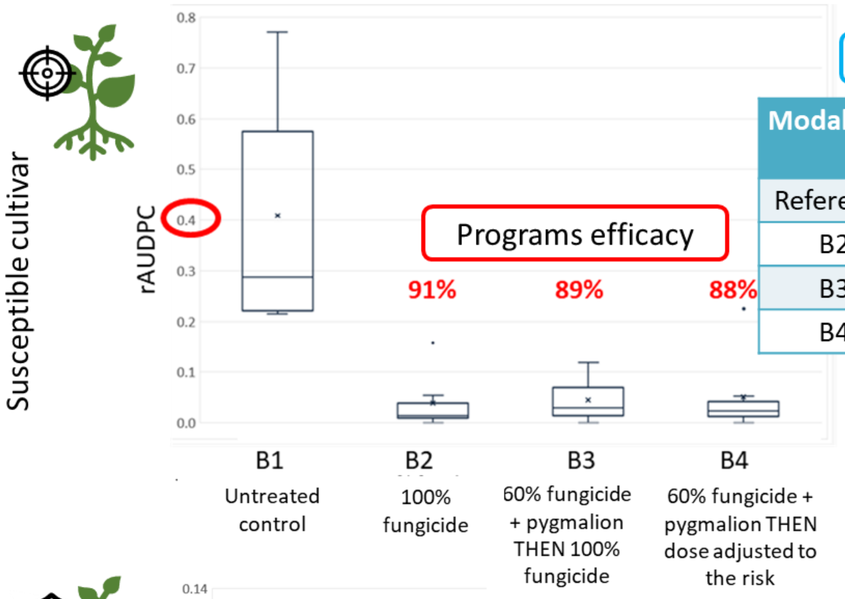
The value of rAUDPC reflects disease pressure during the season

AUDPCmax > AUDPC > AUDPC > AUDPC



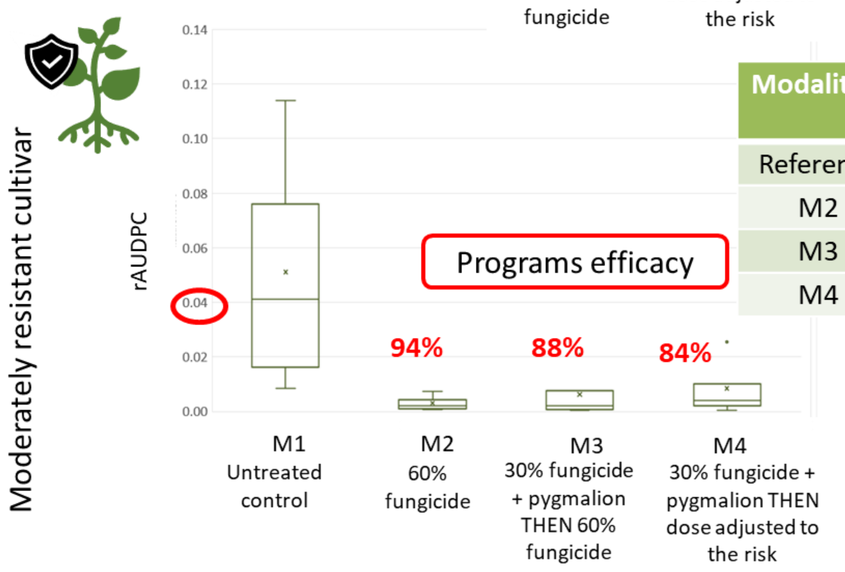
Results

2018-2020 : low pressure



Programs TFI

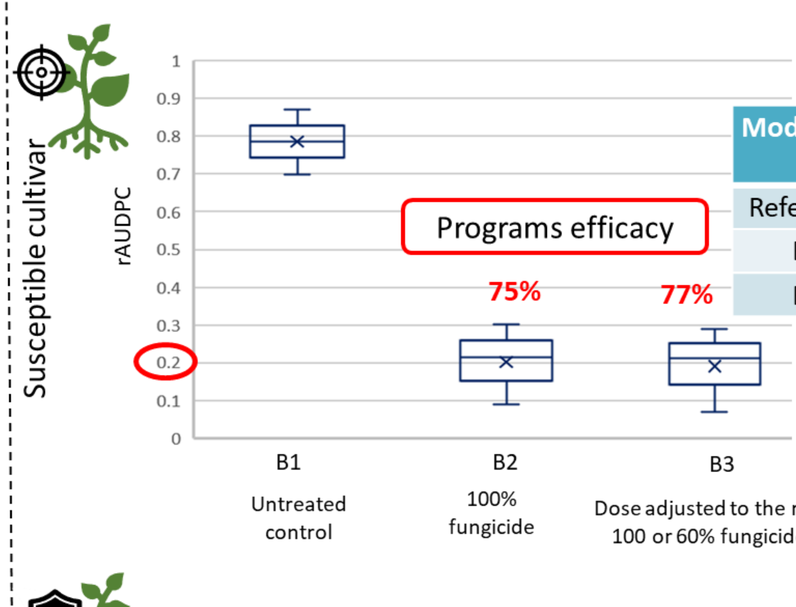
Modalities	Global TFI	TFI reduction
Reference	11.3	
B2	7.1	- 37%
B3	6.2	- 45%
B4	4.8	**- 58%**



Programs TFI

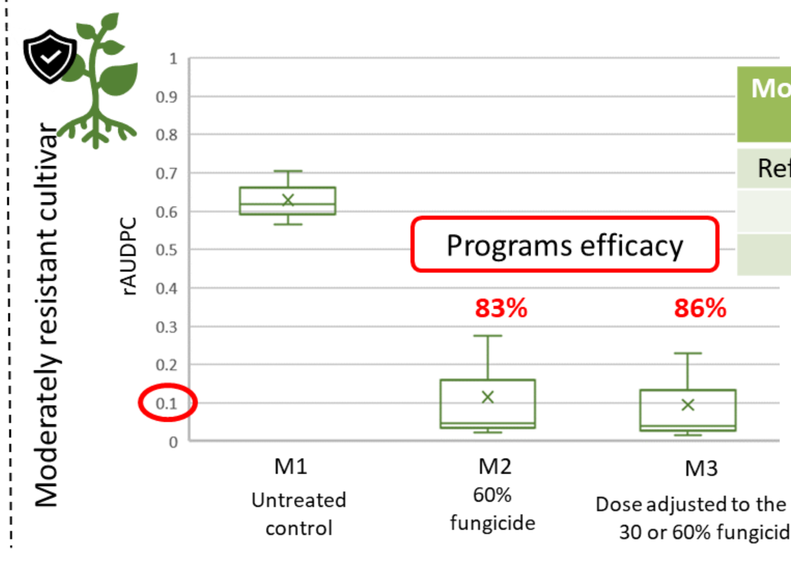
Modalities	Global TFI	TFI reduction
Reference	11.8	
M2	4.2	- 64%
M3	2.6	**- 78%**
M4	2.4	**- 80%**

2021 : high pressure



Programs TFI

Modalities	Global TFI	TFI reduction
Reference	12	
B2	9	- 25%
B3	8.6	- 28%



Programs TFI

Modalities	Global TFI	TFI reduction
Reference	12.6	
M2	6.8	-46%
M3	5	**-60%**

Conclusions

Low/moderate pressure: TFI reduction: **-50% on Bintje** et **-80% on Magnum**.

High pressure: TFI reduction, **-30% on Bintje** et **-60% on Magnum** to preserve good efficacy.

The varietal lever is **the corner stone of the IPM**: less infestation, reduction in the number of treatments, enhance biocontrol and dose adjustment

Perspectives

In light of current and future withdrawals of active ingredients, societal and environmental expectations, how can late blight be managed, in 10-20 years, in a low TFI environment, in a difficult year?

- Substitution of the very susceptible varieties today by intermediate varieties or gradually to very little sensitive
- Better management of primary inoculum (dumps, volunteers, gardens, etc.)
- Generalization of the use and respect of the recommendations of DSS Mileos®
- Adaptation of fungicide doses to varietal resistance and late blight risk

ARVALIS

Etude réalisée avec le concours financier du Compte d'Affectation Spécial pour le Développement Agricole et Rural (CASDAR) géré par le Ministère en charge de l'agriculture.

Avec la contribution financière du compte d'affectation spéciale développement agricole et rural CASDAR

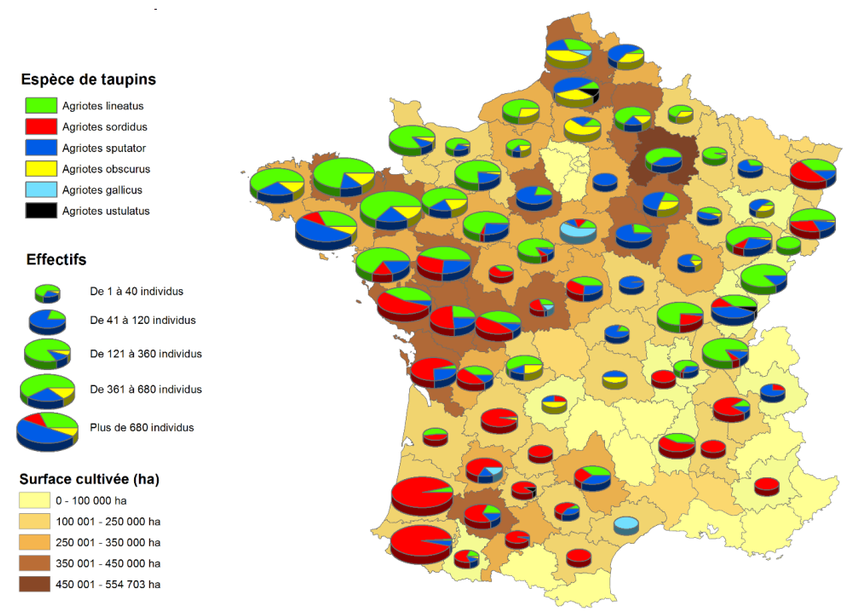
MINISTÈRE DE L'AGRICULTURE ET DE LA SOUVERAINETÉ ALIMENTAIRE
Liberté Égalité Fraternité

Wireworms : description and IPM research

• The pest

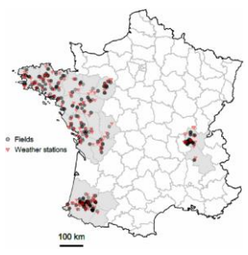
- Wireworms Agriotes harmfull to crops (4 species))
  - 3 species with long life cycle : *A. lineatus, A. sputator, A. obscurus* (4-5 years larval stage into the soil)
  - 1 larval cycle species : *A. sordidus* (1-3 years larval stage into the soil)

- National distribution of species (Study Bayer / INRA Montpellier / Arvalis – 2005-2014 ≈ 1 200 fields et 12 000 wireworms identified)
  - 43 % *A. lineatus*, 30 % *A. sordidus*, 20 % *A . sputator*

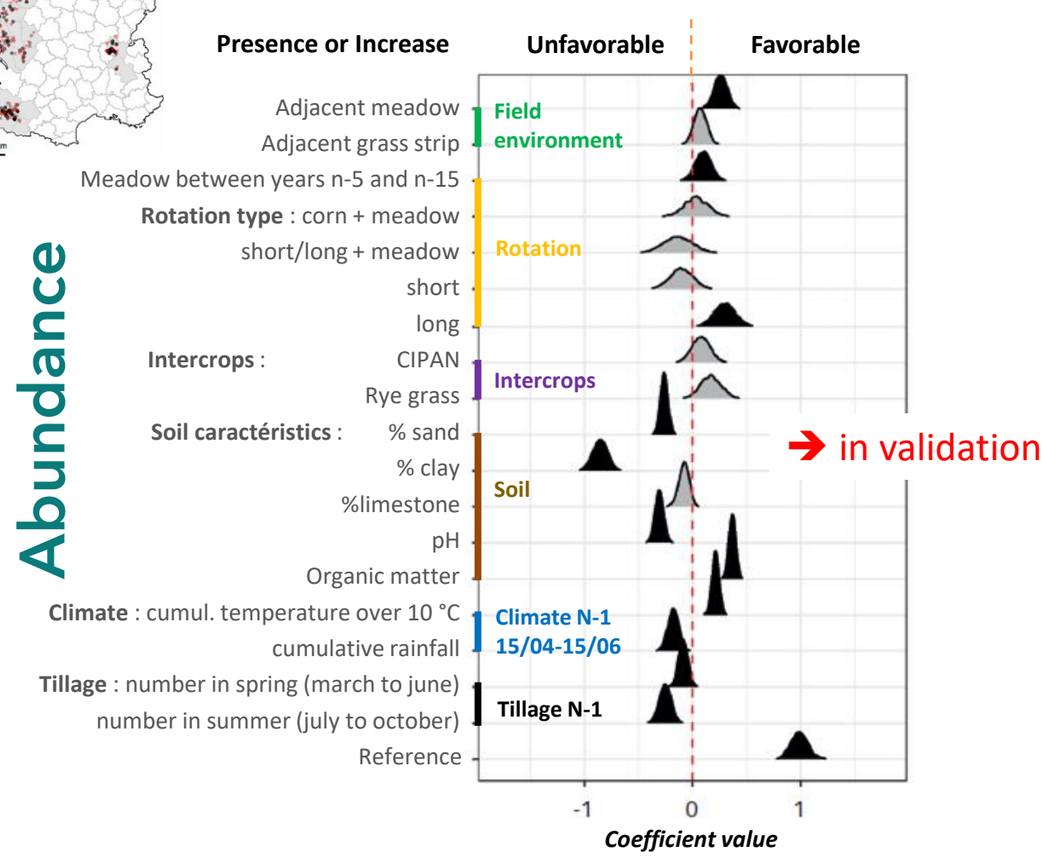


• Characterize and rank risk factors for infestation and damage on field

- **Project TAUPIN LAND (Corn - financement SEMAE)**
- **Project TAUPIC 2021-2024 (Potatoes - financement CASDAR RT)**
  (chef de file FNPPPT & MIDI AGRO & organisations régionales de producteurs Bretagne Plants, Comité Centre et Sud, Comité Nord, partenaires INRAE-UMR IGEPP, FREDON Hauts de France, ARVALIS)



Bayesian model to predict the abundance of wireworms in corn fields (agronomy, climate, soil, environment)

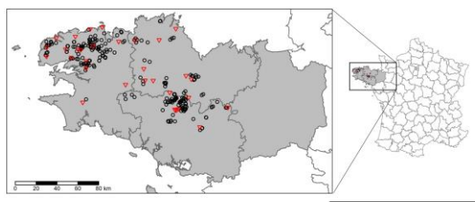


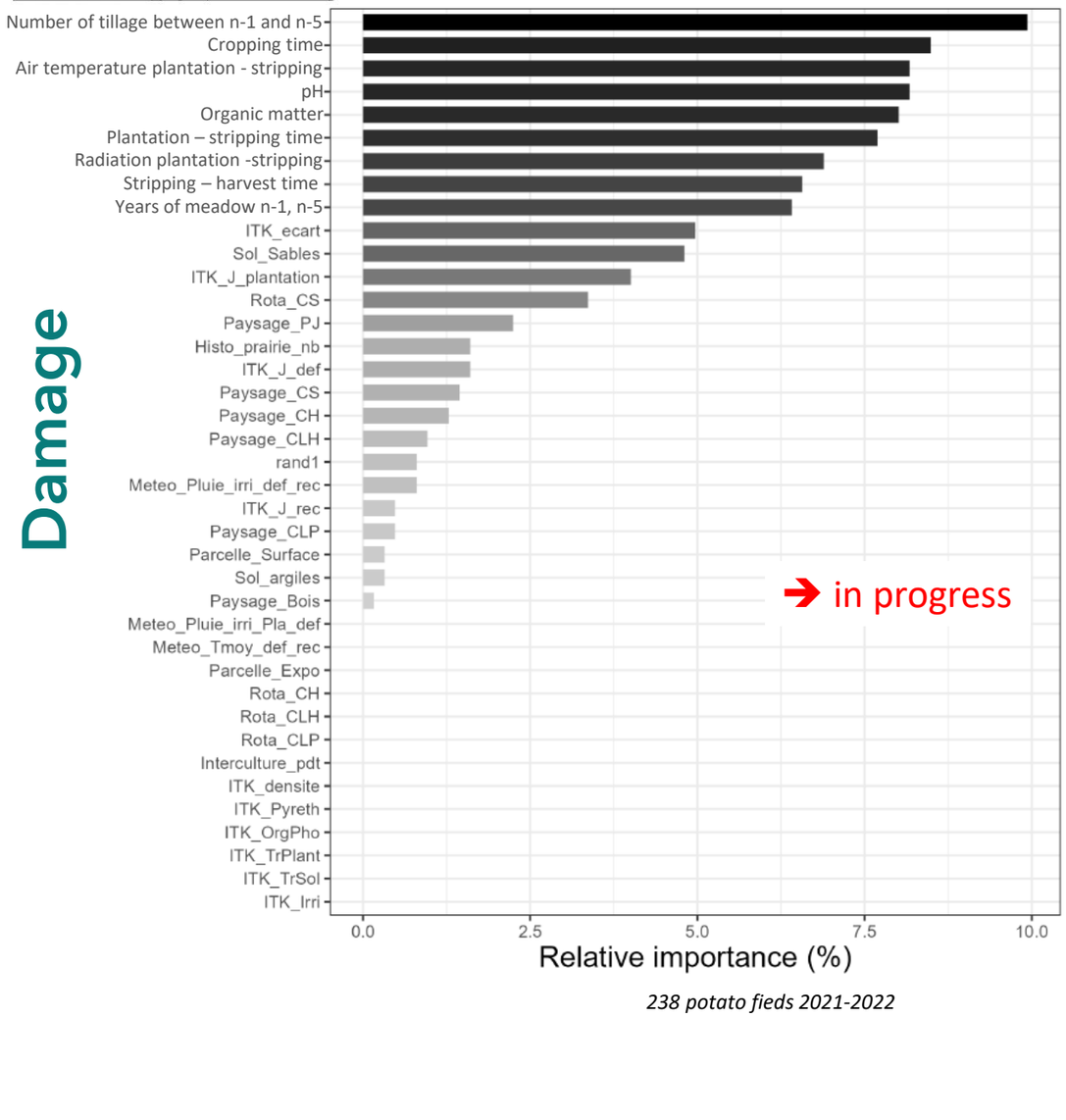
➔ in validation

Roche et al., 2023

419 corn fields 2012-2014 (3 soil samples, 8 liters)

Cubiste model to explain damage on tubers (agronomy, climate, soil, environment)



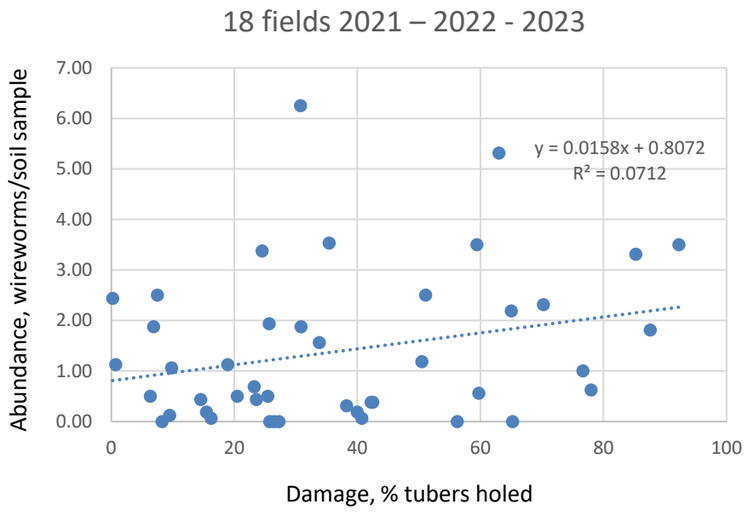


➔ in progress

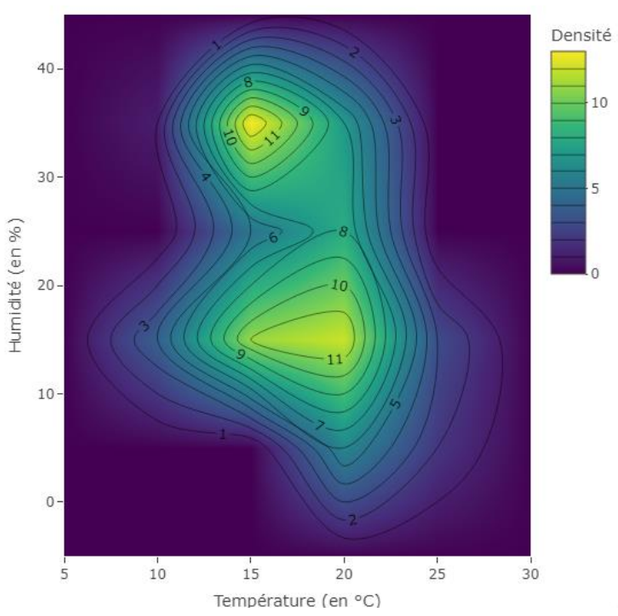
238 potato fieds 2021-2022

• Understanding attack conditions during cultivation

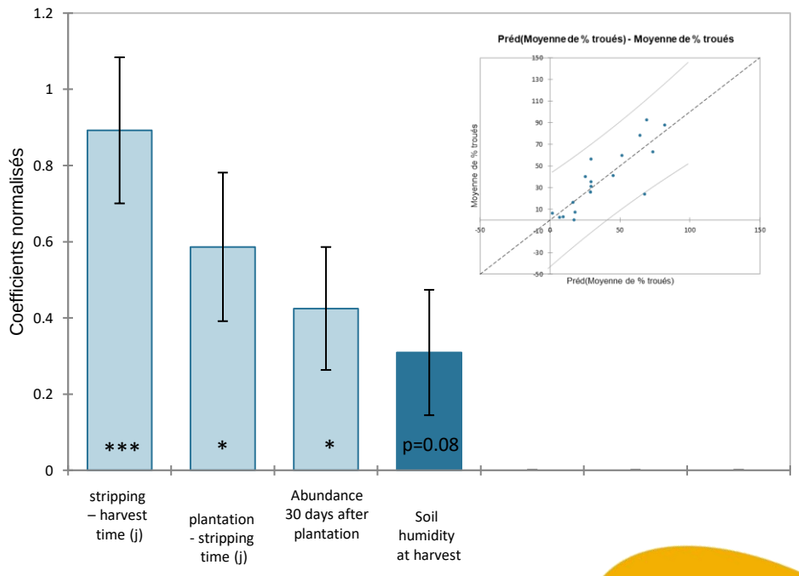
The relationship between abundance and damage is not clear!



Climate and wireworms abundance



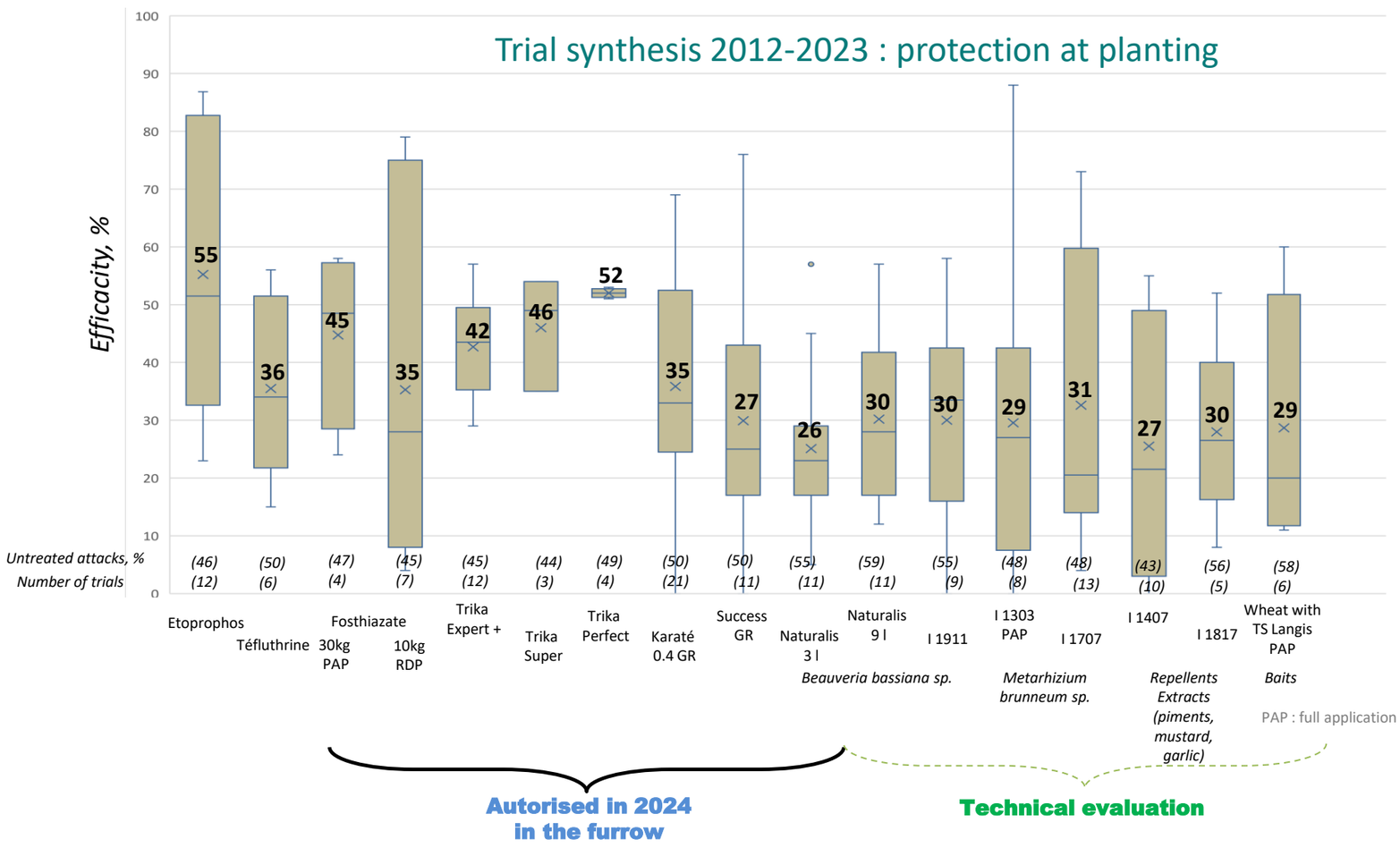
Damage explanation on tubers



Wireworms : limited tuber protection

- **Protecting tubers**

Protection at planting limited in terms of specialities …and efficiency



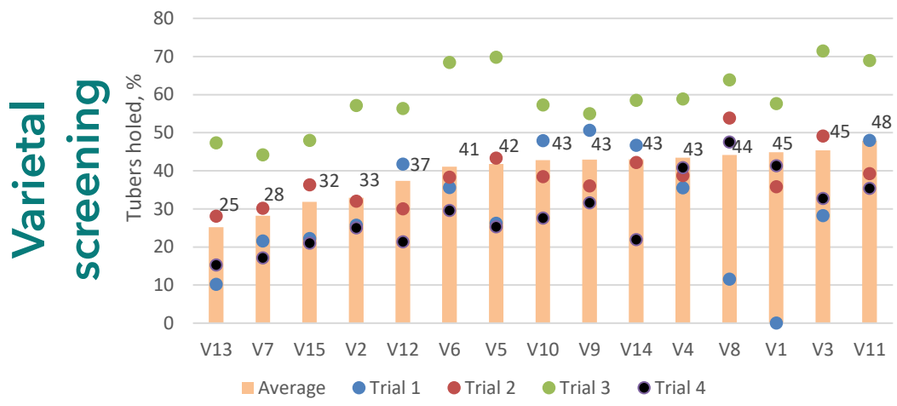
For weaker attacks, efficacy is improved

Delayed protection (repellents, attractants) difficult to implement, as we need to incorporate them to hope for an effect... no real improvements for the moment (work in progress).

- **Avoiding attacks**

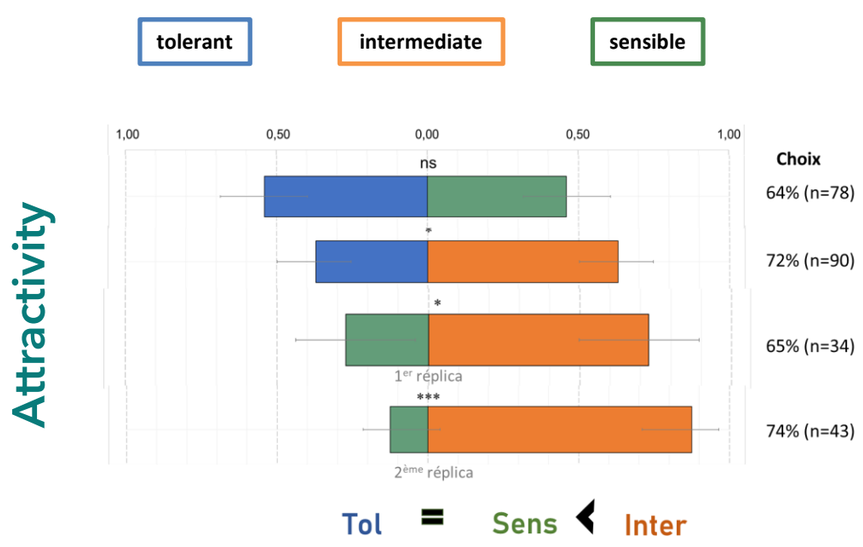
Understanding the mechanisms of attractiveness and susceptibility of different potato varieties to wireworm attacks

In field conditions

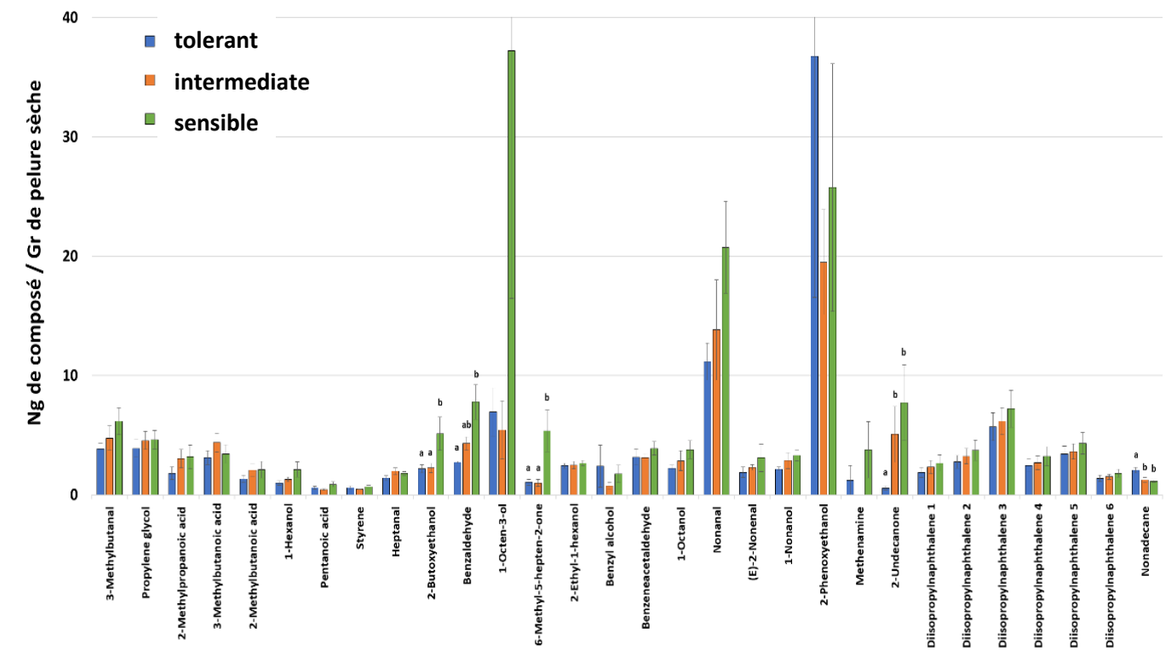


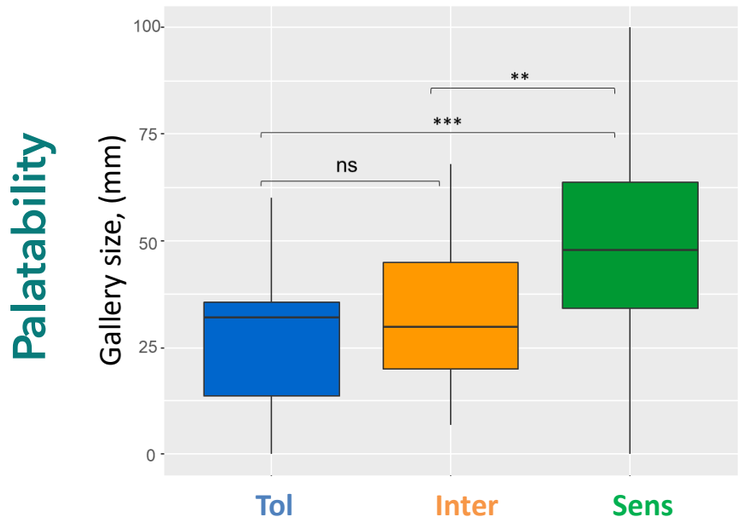
In laboratory conditions

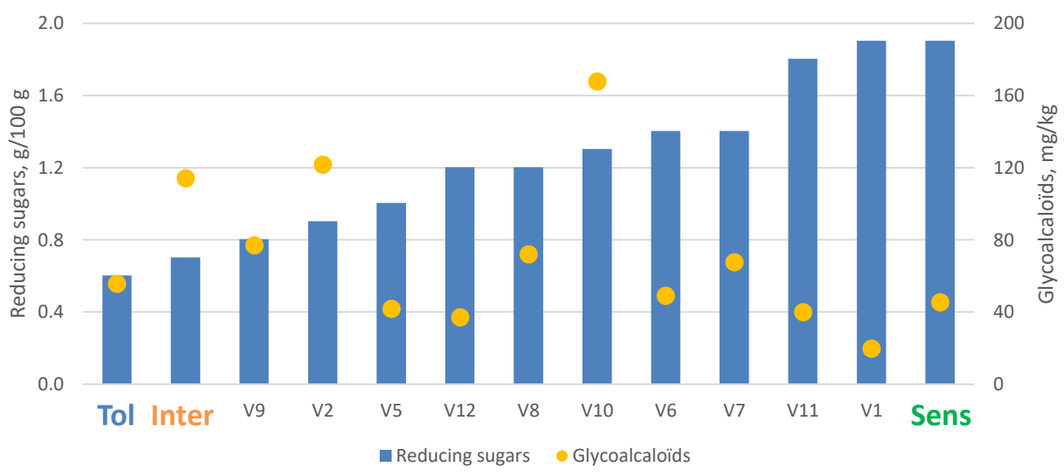
➢ Wireworms behavior



➢ Tubers caracteristics





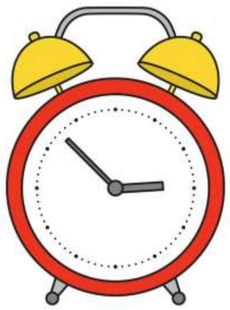


Others compounds : secondary metabolits, … ??

8 dynamic weeding and haulm destruction demos as alternatives to chemicals!

Weeding	• AVR • GRIMME
Haulm killing	• AGRONOMIC • EURODIRECT (Baselier) • GRIMME • NUCROP • ROPA • VEGNIEK

Demonstration schedule



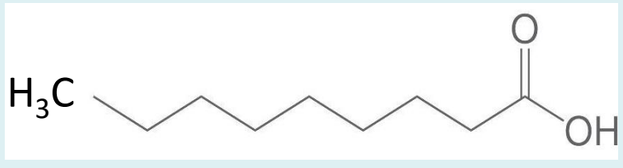
- Wednesday September 11
  - Morning : 11.00 a.m
  - Afternoon: 3.00 p.m
- Thursday September 12
  - Morning : 11.00 a.m
  - Afternoon: 3.00 p.m

ARVALIS

Haulm killing with a new fatty acid: caprylic acid

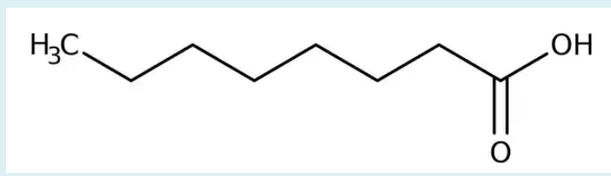
Haulm killing, 3 molecules available in France

- **Carfentrazone-ethyl** (Spotlight Plus 1 l/ha)
- **Pyraflufen-ethyl** including Gozaï, Sourcier/Gerrier and Dolbi products, homologated at 0.8 l/ha. Mixed with an oil for the Pack Dolbi and ammonium sulfat in the Pack Gozaï Max.
- **Pelargonic acid** (Beloukha 16 l/ha, **biocontrol**)



Caprylic acid

Since 2021, ARVALIS test a solution including caprylic acid for potato haulm killing in a product soon to be homologated.

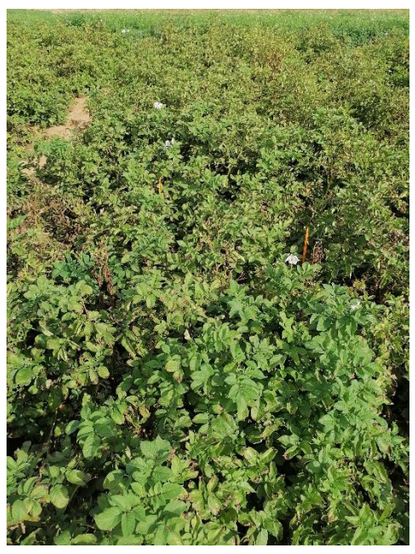
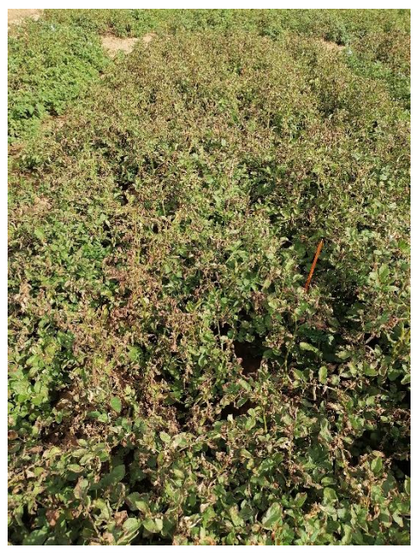


→ Mode of action :

- Contact herbicide ; **Fast (1-2 h)**
- Non-selective
- **Destroy plant cuticle** (the protective layer on the epidermis) = plants are drying out

Two applications of caprylic acid compete with the market solutions in a difficult haulm killing situation

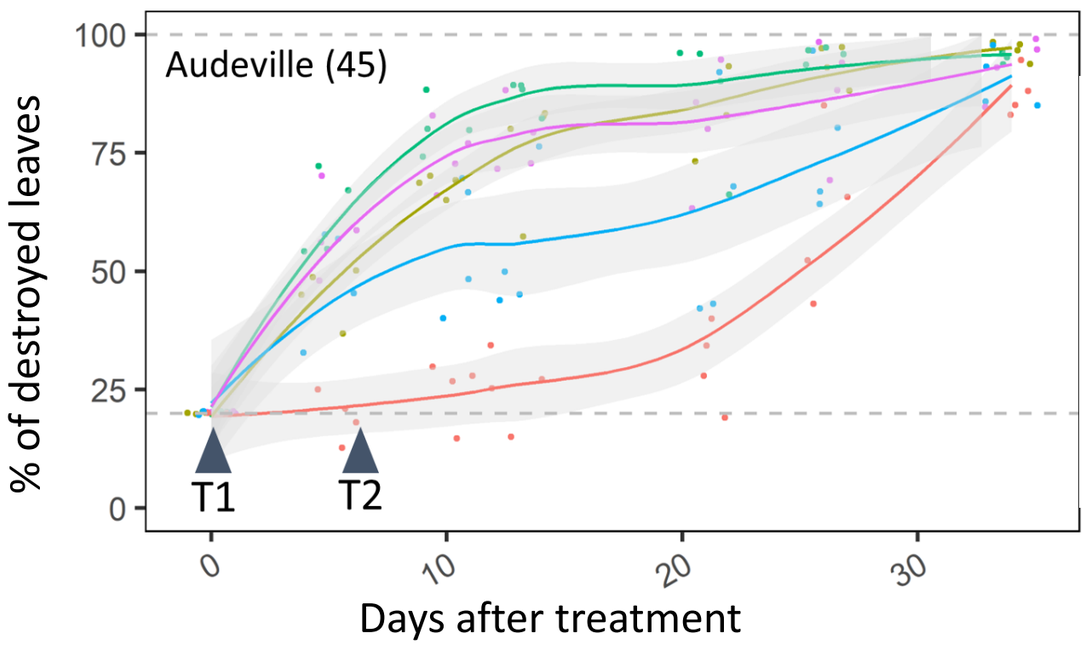
2023's trial : Mozart variety, ~25% senescence at first treatment: difficult haulm killing situation
4 mounds micro-plots in 4 blocs; at Audeville (45)

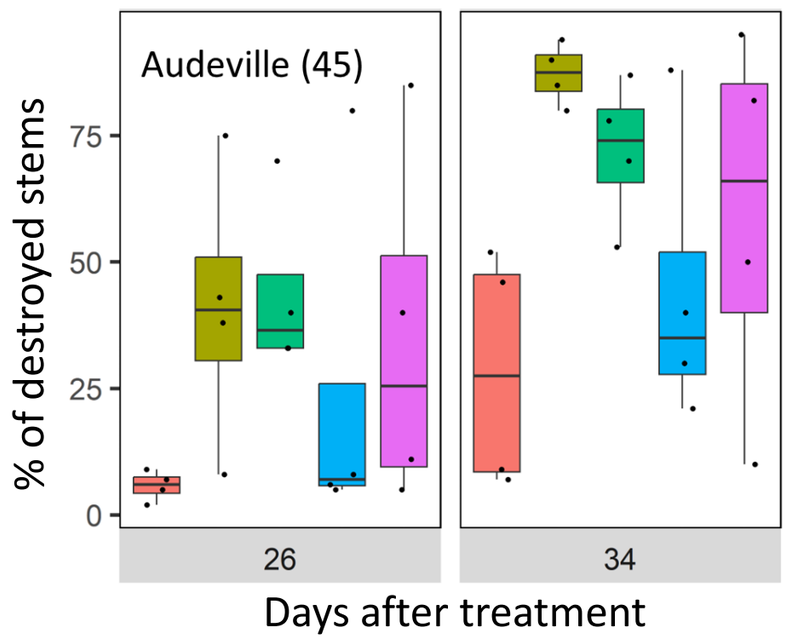
	Control	Spotlight Plus (1 l/ha) T1 + T2	**Caprylic acid (20 l/ha) T1 + T2**	Beloukha (16 l/ha) T1
16/08/23 (T1 + 5d)				
06/09/23 (T1 + 26d)				

→ Caprylic acid valided it « **choc effect** », faster than pelargonic acid (Beloukha).

→ An increase of 30% of leaf destruction at T1 + 16d in comparison with pelargonic acid.

→ For stem killing, caprylic acid is in between both market specialities, tendency previoulsly observed in 2021 and 2022.





No impact on yield

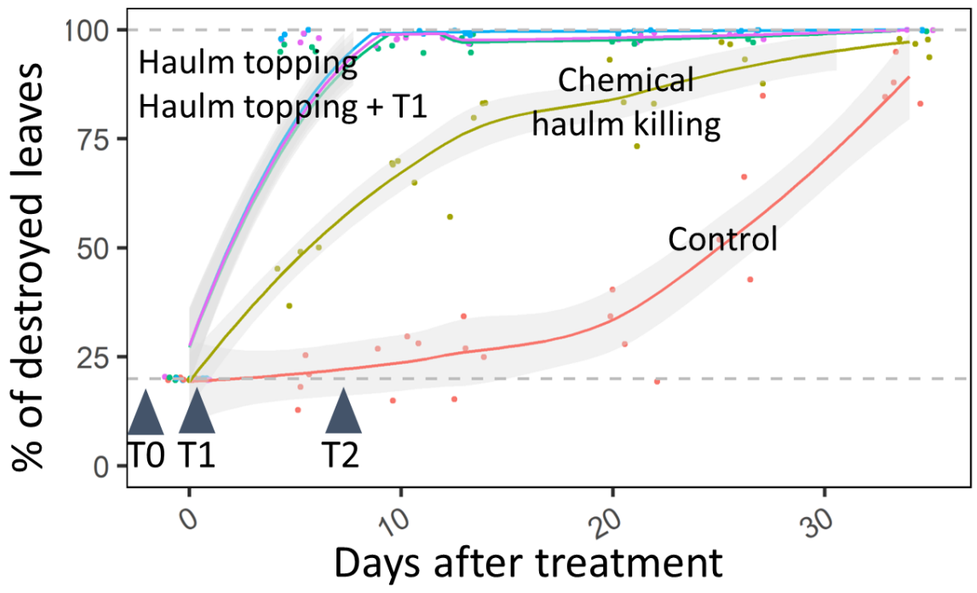
Control
T1 +T2 : Spotlight Plus (1 l/ha)
T1 +T2 : Caprylic acid (20 l/ha)
T1 : Beloukha (16 l/ha)
T1 : Caprylic acid (20 l/ha)
T2 : Spotlight Plus (1 l/ha)

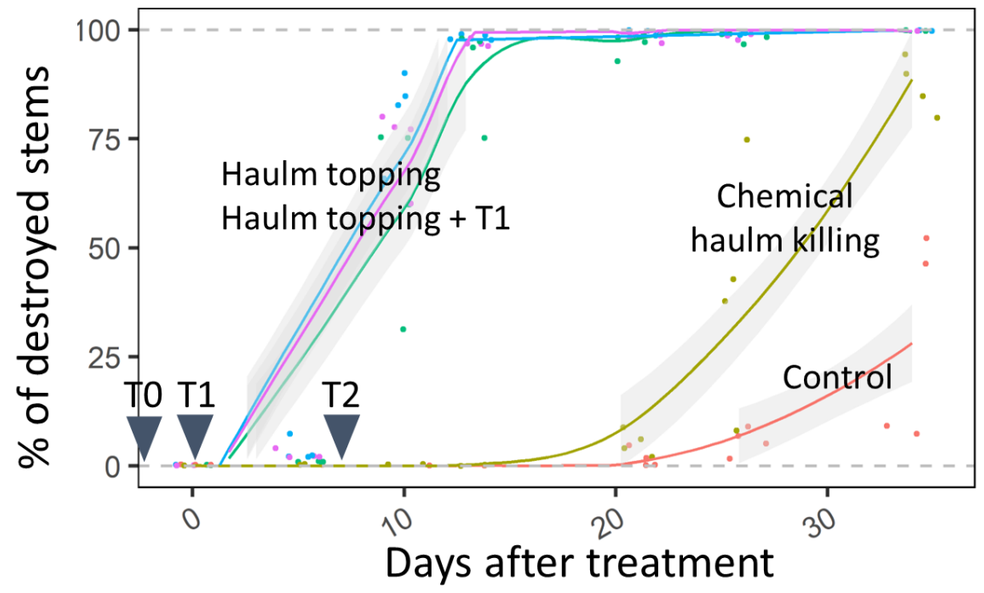
ARVALIS

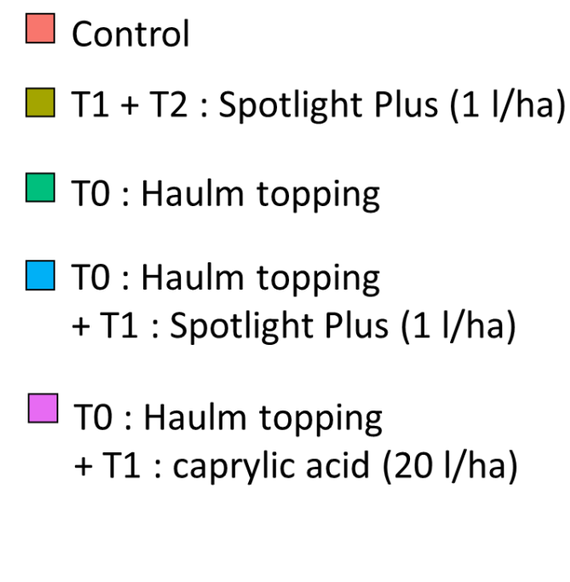
Haulm killing using mechanical methods: efficient and profitable solutions in dry weather conditions

Haulm topping induces fast and efficient leave and stem destruction

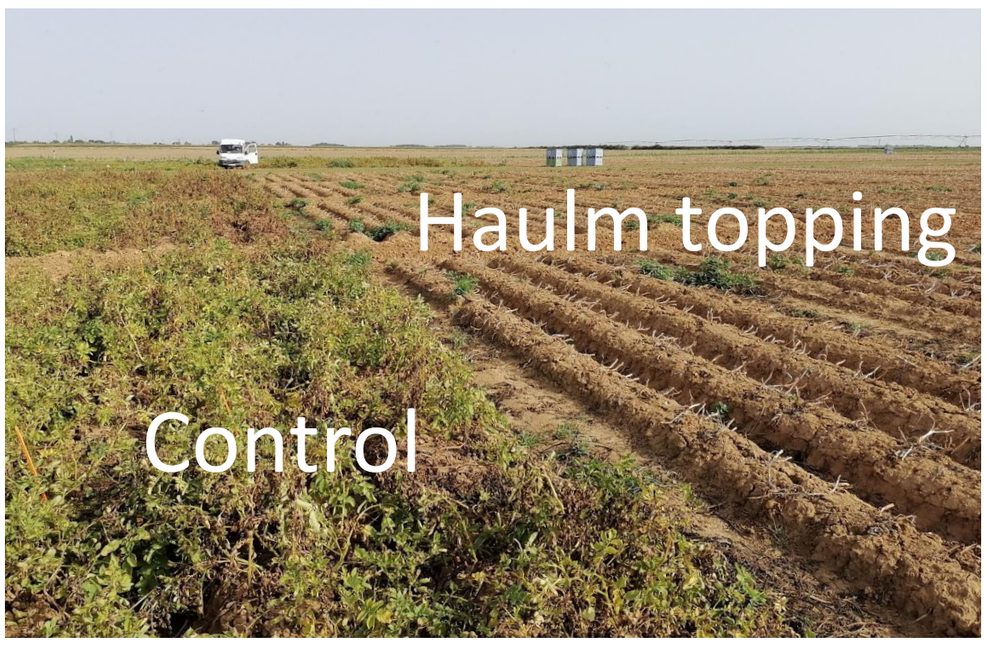
2023's trial: Mozart variety, first treatment at ~25% senescence : difficult haulm killing
4 mounds micro-plots in 4 blocs; at Audeville (45; France)







T1+26d
06/09/23

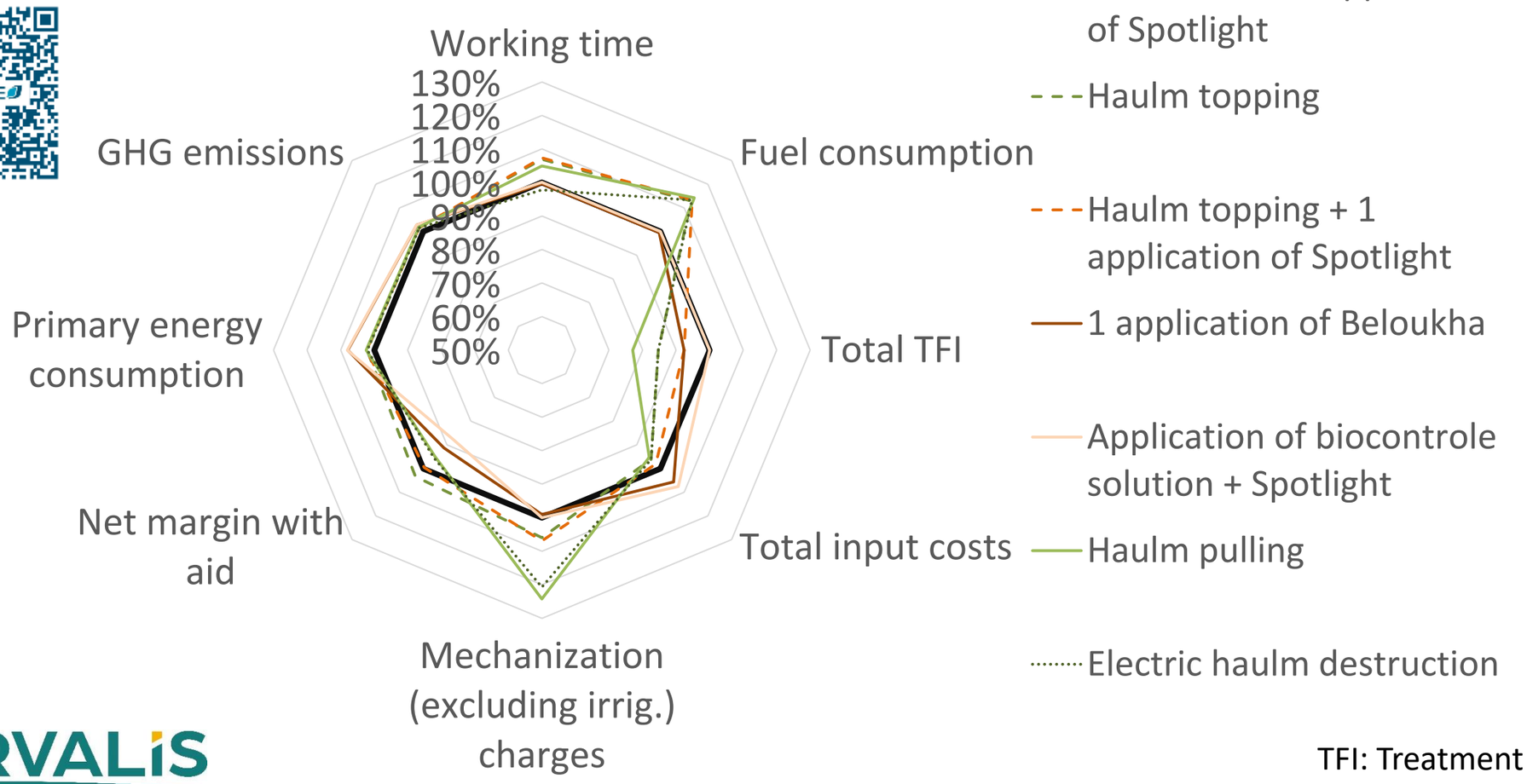


→ In 2022 et 2023, the weather was favorable to haulm topping. Mecanical haulm-killing allowed faster and more efficient haulm and stem destructions than chimical treatments.

Multi-criteria evaluation indicates a small increase in net margin with haulm topping in addition to the reduction of TFI

Multi-performance assessment of haulm-killing techniques: simulation realised with the tool SYSTERRE, on the typical technical itinerary of a farm producing for the industry in the North of France (*Hauts de France*). 2023's supply and selling prices.

Comparison of haulm-killing techniques (% of the reference practice)



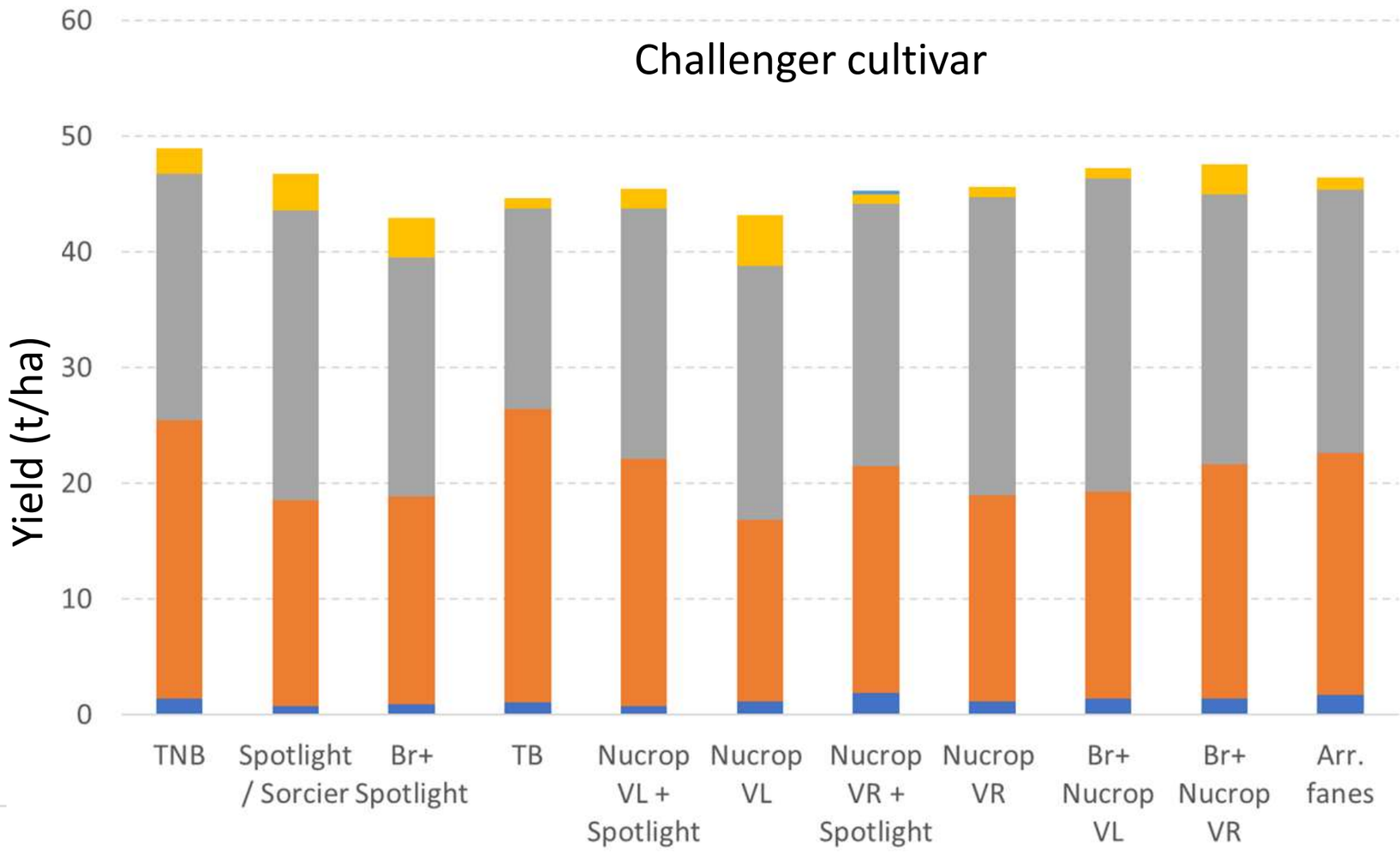
→ A remarquable decrease of TFI (1 to 3 points) was observed with all techniques coupled with a tendency of increase working hours, fuel consumption, operational and mecanical charges. However, the net margin is stable or with a small decrease exept when using haulm topping only.

TFI: Treatment frequency indice

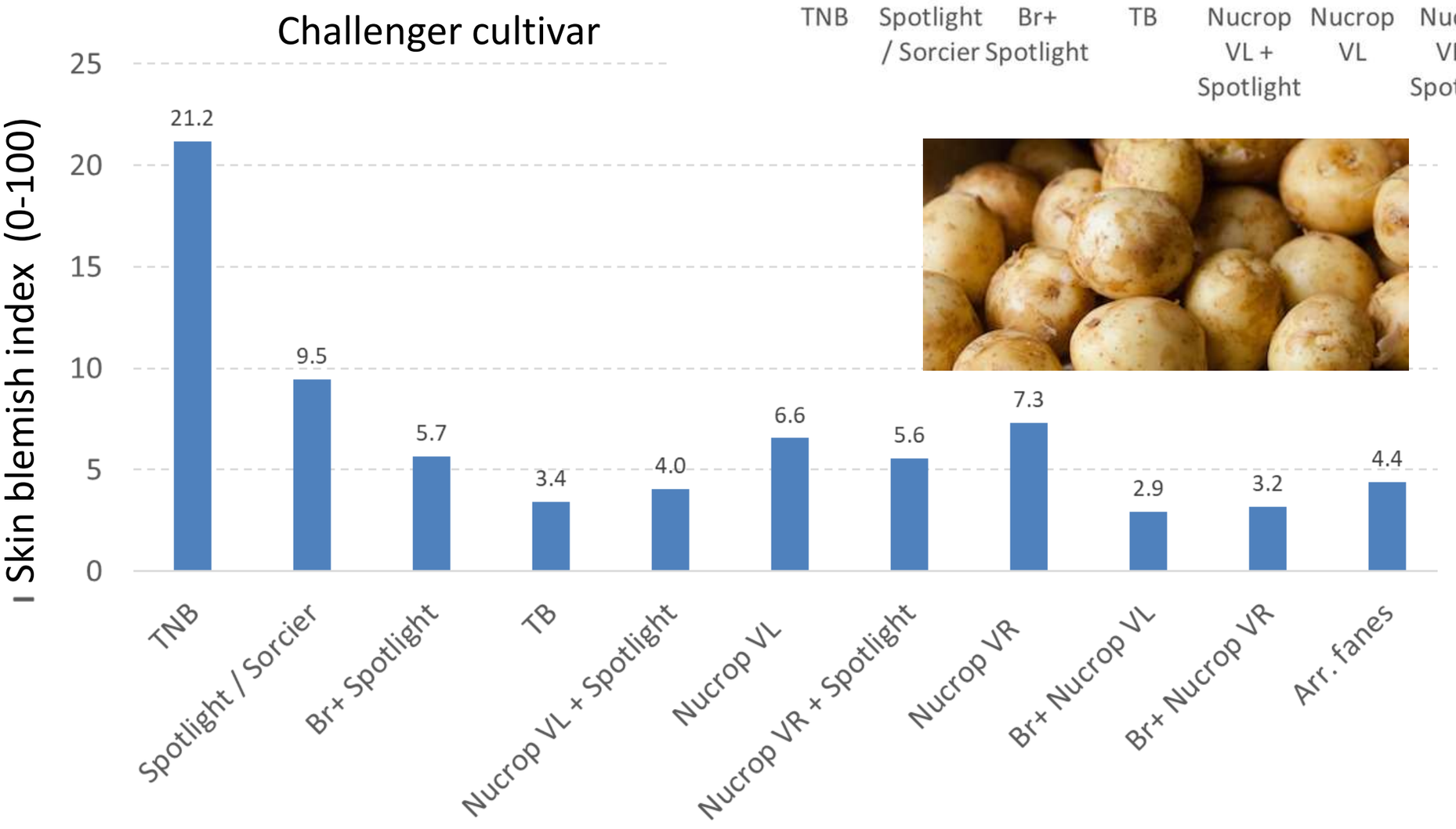
Performance references for alternative mechanical haulm destruction techniques

- **Haulm destruction**

- **Tuber growth stop speed**



- **Skin finish**



23 days after setting up the trial

TNB : Untopped ref. - TB : Topped ref.
VL : Slow speed (5 km/h) - VR : Fast speed (8 km/h)

Various techniques as an alternative to chemical desiccants

- **Haulm topping**

Principle : Flails of different lengths rotating on a rotor more or less finely chop the tops present on the mounds (tops and sides) and group them or not in the inter-mounds.

Strong points: Instant destruction of 75 to 90% of vegetation – Often sufficient action on near-mature vegetation – Facilitates the rapid subsequent action of a weed killer on immature vegetation

Weak points: Need to complete its action in immature vegetation with a complementary technique (chemical, electrical, removing tops) + work generally on 4 to 8 rows maximum

- **Haulm pulling**

Principle : After preliminary crushing of the tops, the residual stems are extracte by a rotating top pulling device which pinches and tears them vertically or in a mo manner (balloons, strips, discs, etc.) while metal strips maintain tubers in the mou plumbed at the end of the passage to restore their good resistance to bad weather and limit the risk of greening of the tubers.

Strong points: Instantaneous destruction of almost 100% - Separating the tubers from the tops allows for faster completion of their maturation and limits their recontamination by certain diseases carried by the tops (rhizoctonia, silver scab, arthrosis, etc.)

Weak points: Need to intervene in sufficiently dried soil conditions – For certain models, it is possible to complete the removal of tops with a root cutter device.

- **Electric haulm destruction**

Principle : Positive and negative electrodes trailing on the vegetation diffuse a hi intensity electrical current which electrocutes the plants and leads to their progressive destruction. An electrolyte previously sprayed on the vegetation can amplify the action of the diffused current.

Strong points: Fairly large width of intervention per passage (9 to 12 m) allowing a significant work output – Intervention possible even in wet soil conditions – Significant impact on immature vegetation without physical destruction of the tops – Reinforced action on crushed tops.

Weak points: Need to have dry foliage for good electrocution effectiveness – Risk of inflammation of the tops if intervention on already mature and dried out foliage – Progressive destruction of the vegetation – Difficulty of reaching all the stems in the case of vegetation very compact.

Don't miss the dynamic demonstrations planned every day at PotatoEurope 2024 to appreciate the modes of action of the equipment on display!

ARVALIS

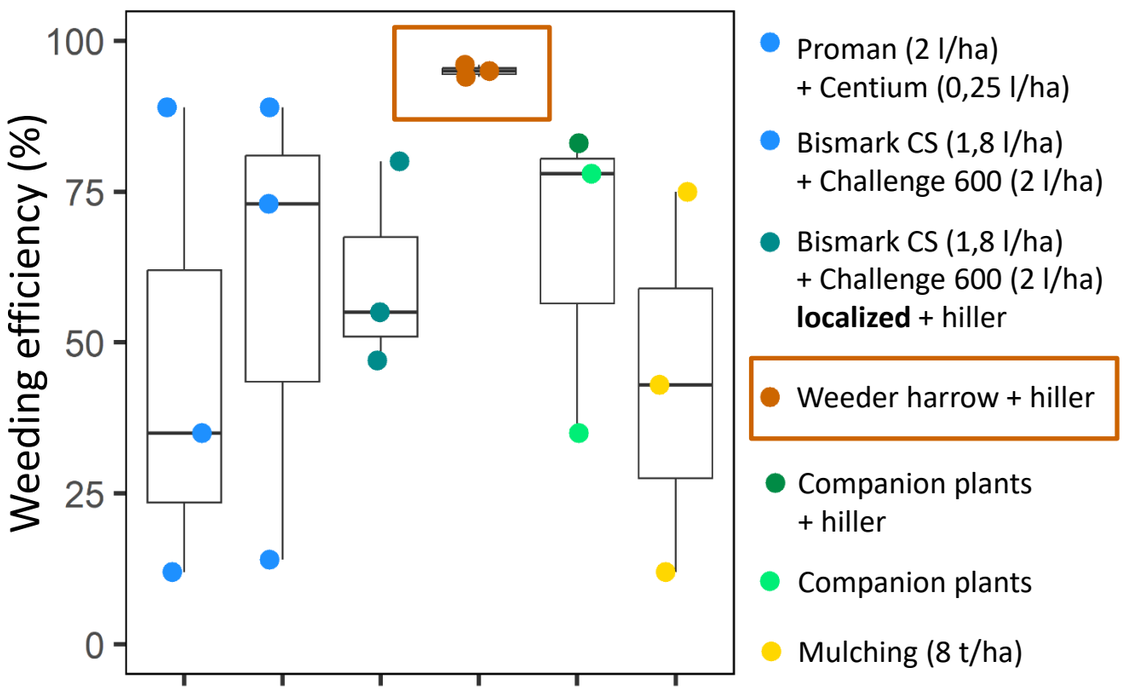
Weeding : which solutions to which weather conditions and at what price?

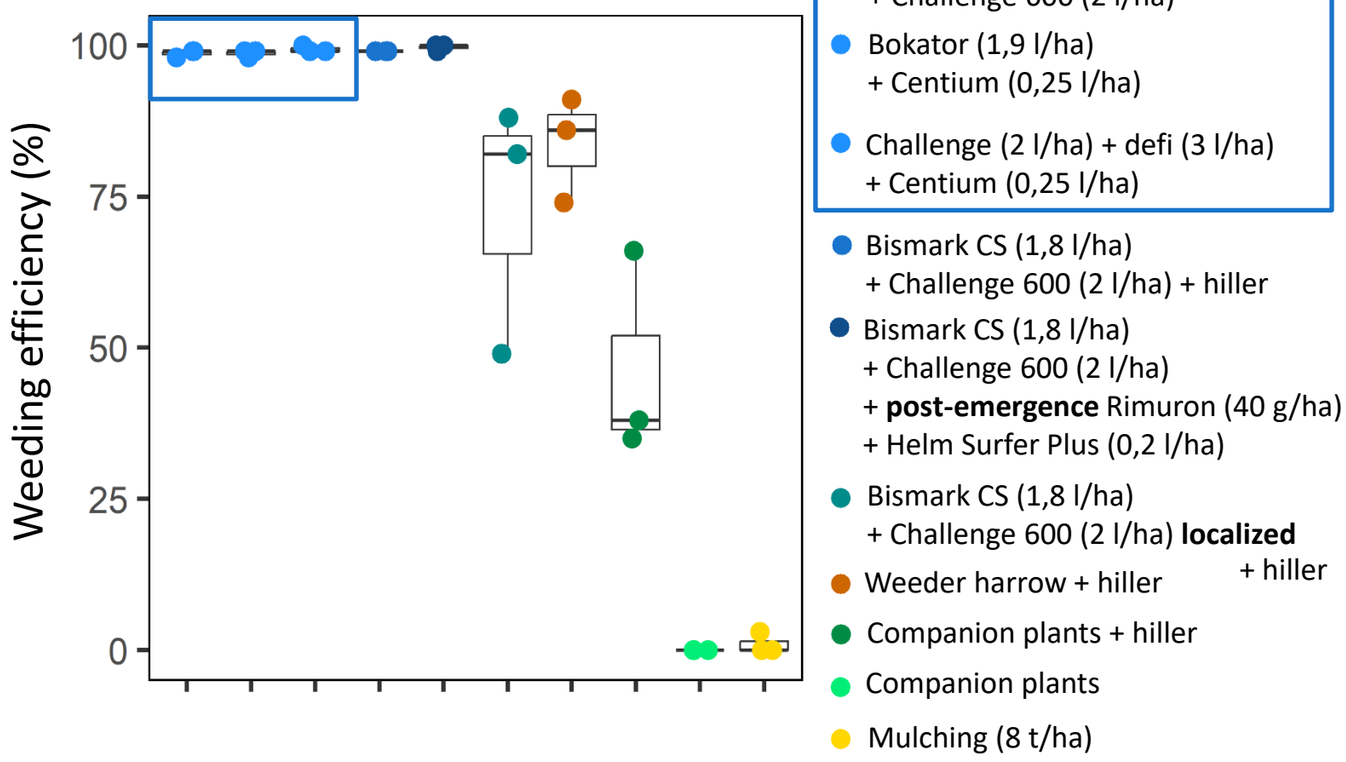
Comparison of the 2023's and 2024's ARVALIS trials

Allians variety – 4 mounds micro-plots in 3 blocs; at Boigneville (91)

2023 **Dry weather conditions:** condition that favour mecanical weeding

2024 **Multiple spring rains** : soil humidity at treatment and after that favour chemical treatments





→ Pre-emergent herbicides in trouble, the **mechanical weeding winner with 95% efficiency** !

→ Pre-emergent herbicides efficient at **99% without metribuzin**! Mecanical weeding in difficulty by the rains.

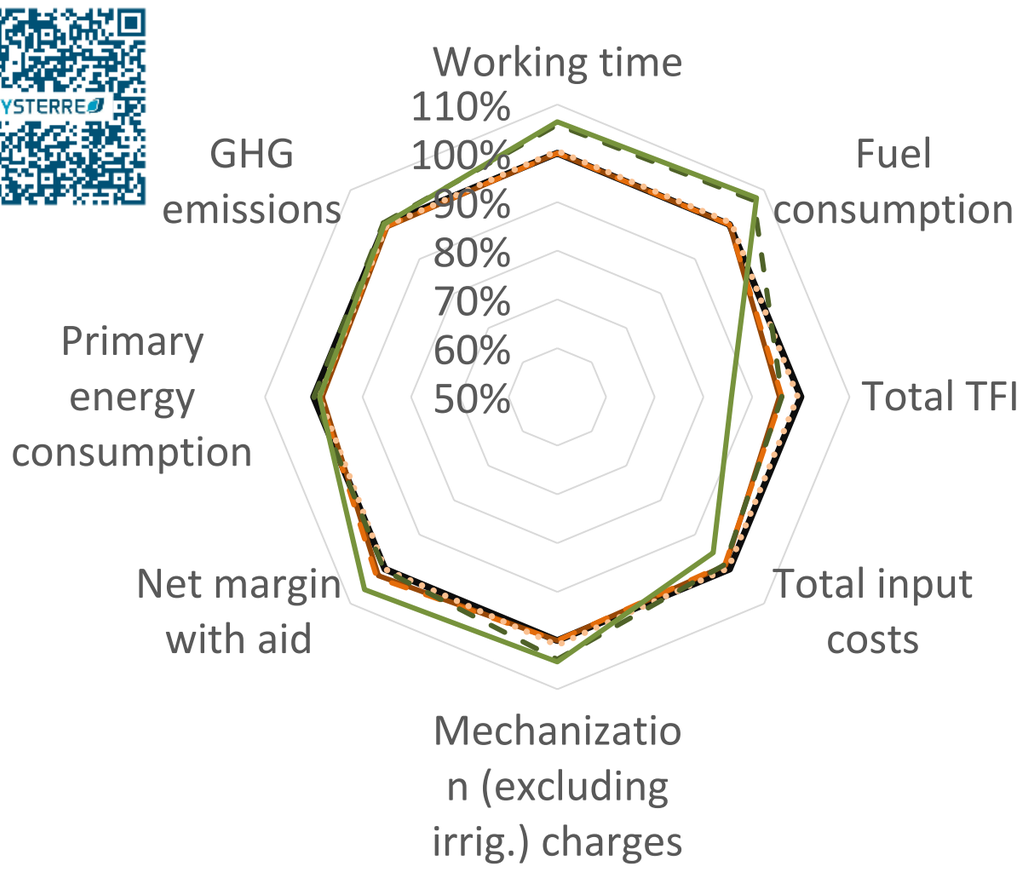
→ An interesting compromise is to combine a **treatment localized on the row** and mecanical weeding on the inter row using a hiller.

Multi-criteria assessment: mechanical and chemical solutions with similar results, mecanical weeding (pre + post-emergence) showed the highest net margin.

Multi-performance assessment of weeding techniques: simulation realised with the tool SYSTERRE, on the typical technical itinerary of a farm producing for the industry in the North of France (*Hauts de France*). 2023's supply and selling prices.

Comparison of potato weeding techniques (% of the reference practice)

SYSTERRE



→ Mechanical solutions increase working hours and fuel consomption. However, operational and mecanical charges are not changed: the net margin is stable across different weeding techniques or a bit higher using a weeder harrow + hiller. Nevertheless, with mecanical solutions the goal of TFI reduction is reached!

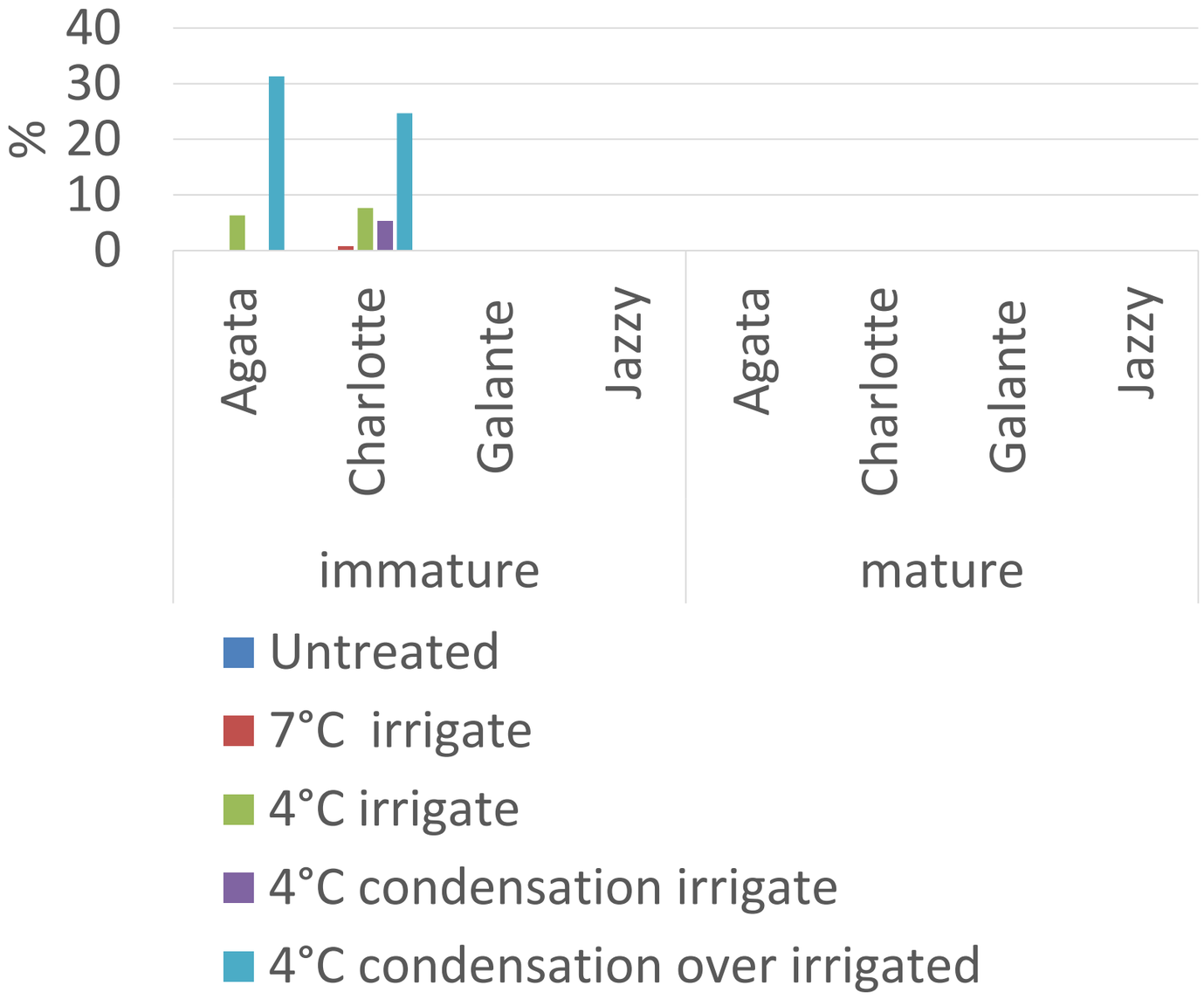
ARVALIS

1,4-DMN

Treatment advice

- Favors mature tubers
- Apply after good healing and complete drying of tubers
- Apply before sprouting begins, or at the first stage of sprouting initiation
- Be careful to limit over-irrigation, especially close to harvest, as this can lead to lenticels opening
- Take extra care with thin-skin varieties (salad potato type)
- Possibility of postponing the first application thanks to maleic hydrazide treating during vegetation

Percentage of tubers affected by selectivity defects due to various risk parameters in the field or in storage



Tubers affected by symptoms of lack of selectivity after treatment at the start of the season with 15ml/t of Dormir according to different modalities (campaign 2022/2023)

- Varietal effect
- Negative impact of immaturity
- Greater risk for tubers showing condensation before treatment and having received intensive irrigation

Points to consider

- Mature, dry and well cured tubers needed
- Thin-skin varieties (salad type) ➔ Application rate limited to 8-10ml/t
- 30-day withholding period (WHP)

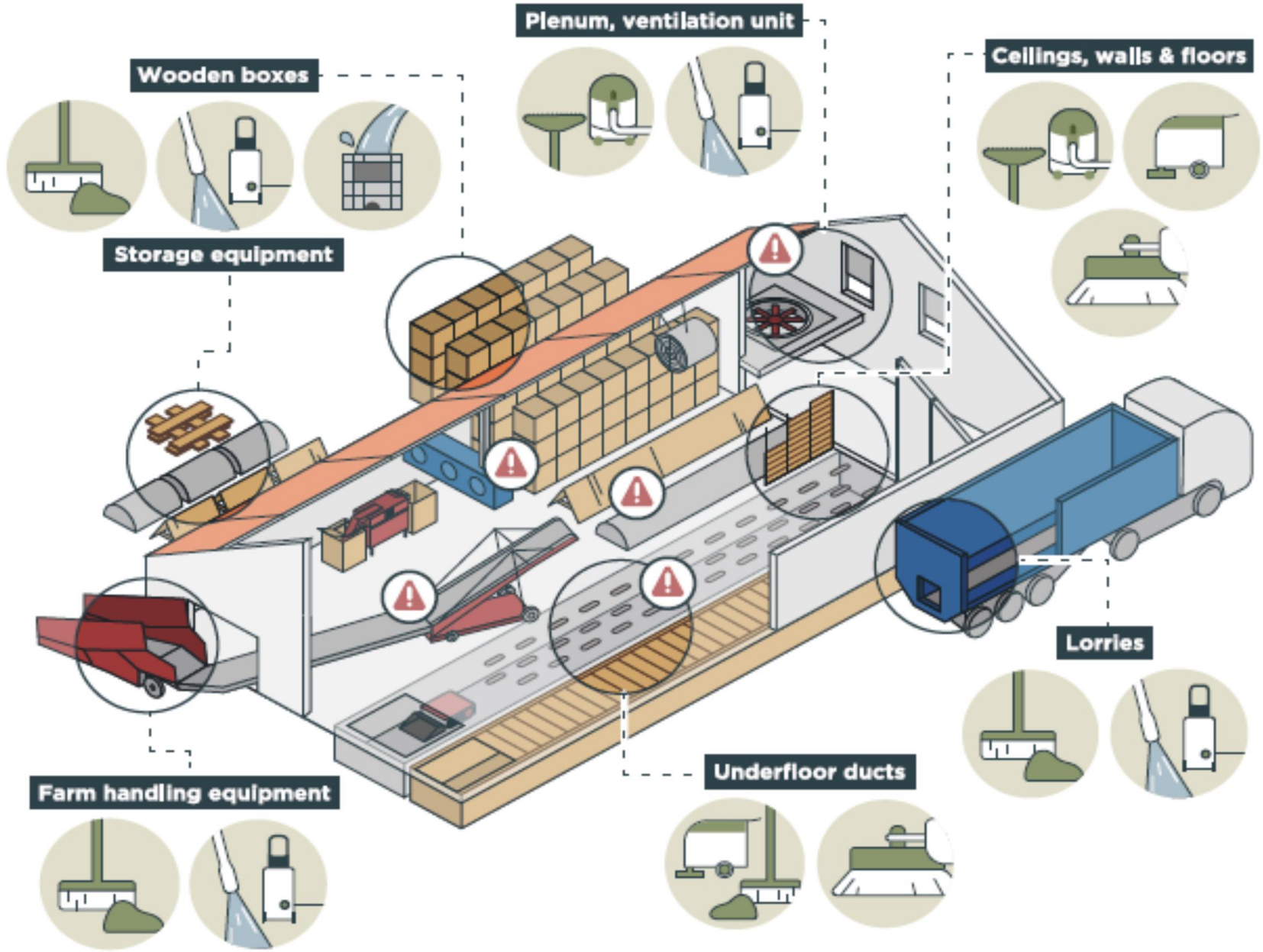
Cleaning guidelines for reducing CIPC residues from stores and equipment

Key principles

- Stores must be cleaned as soon as 2019 crop has been unloaded
- Always use personal protection and pay attention to safety
- Keep written records and/or pictures of what has been cleaned, how and when
- Clean from top to bottom (i.e. from roof to floor)
- Hotspots: pay greater attention to areas of higher contamination

Cleaning methods

- Use dry cleaning methods first (broom + vacuum)
- Use mechanical (industrial) brush
- Complete with water cleaning only if dry cleaning not sufficient - take care on waste water management
- Collect waste water in the tank or pit
- Clean boxes and storage equipment first dry and possibly wet. Keep them outside as much as possible
- Refresh air of the store continuously by leaving hatches and doors open during the empty period

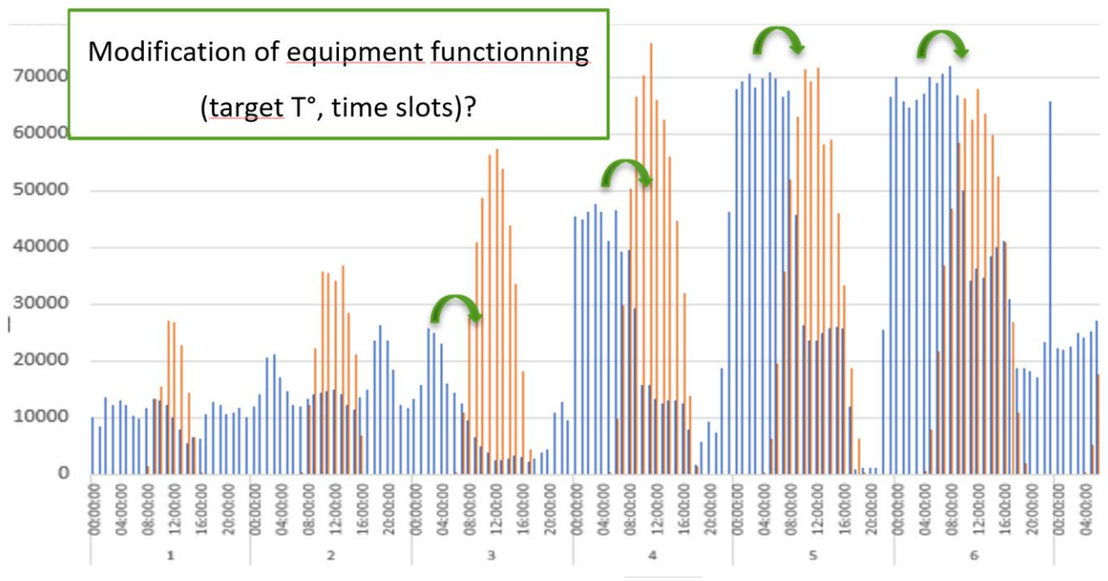


This is a best practice based on the current knowledge, Spring 2020

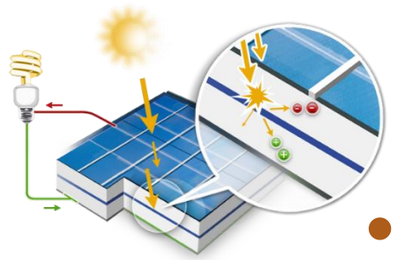
Avec la collaboration de

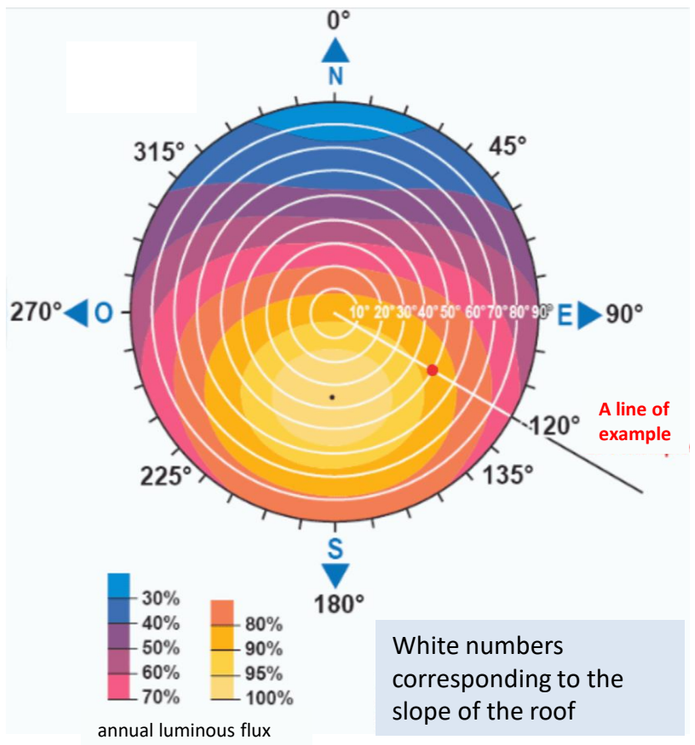
Control your energy costs

- **Identify current and/or future substitutable needs**
  - Analyze the farm's electricity consumption profile
  - Change processes
  - Shift needs

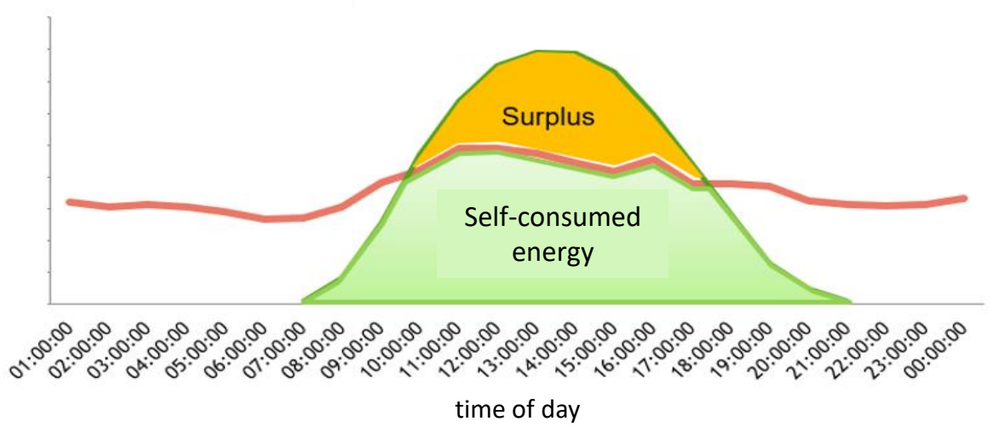


- **Produce using photovoltaic solar panels**
  - Resell the entire electricity production
    - Enhancement of existing roofs
    - Additional income source
    - Assistance in financing a new building or renovation of an existing one (asbestos)
    - Buyback rate over 20 years





  - Self-consume and resell the surplus
    - Substitute a share of grid electrical energy / self-produced electricity
    - Reduce the electricity supply bill
    - Controlling electricity price increases
    - Additional source of income



CHAMBRES D'AGRICULTURE HAUTS-DE-FRANCE

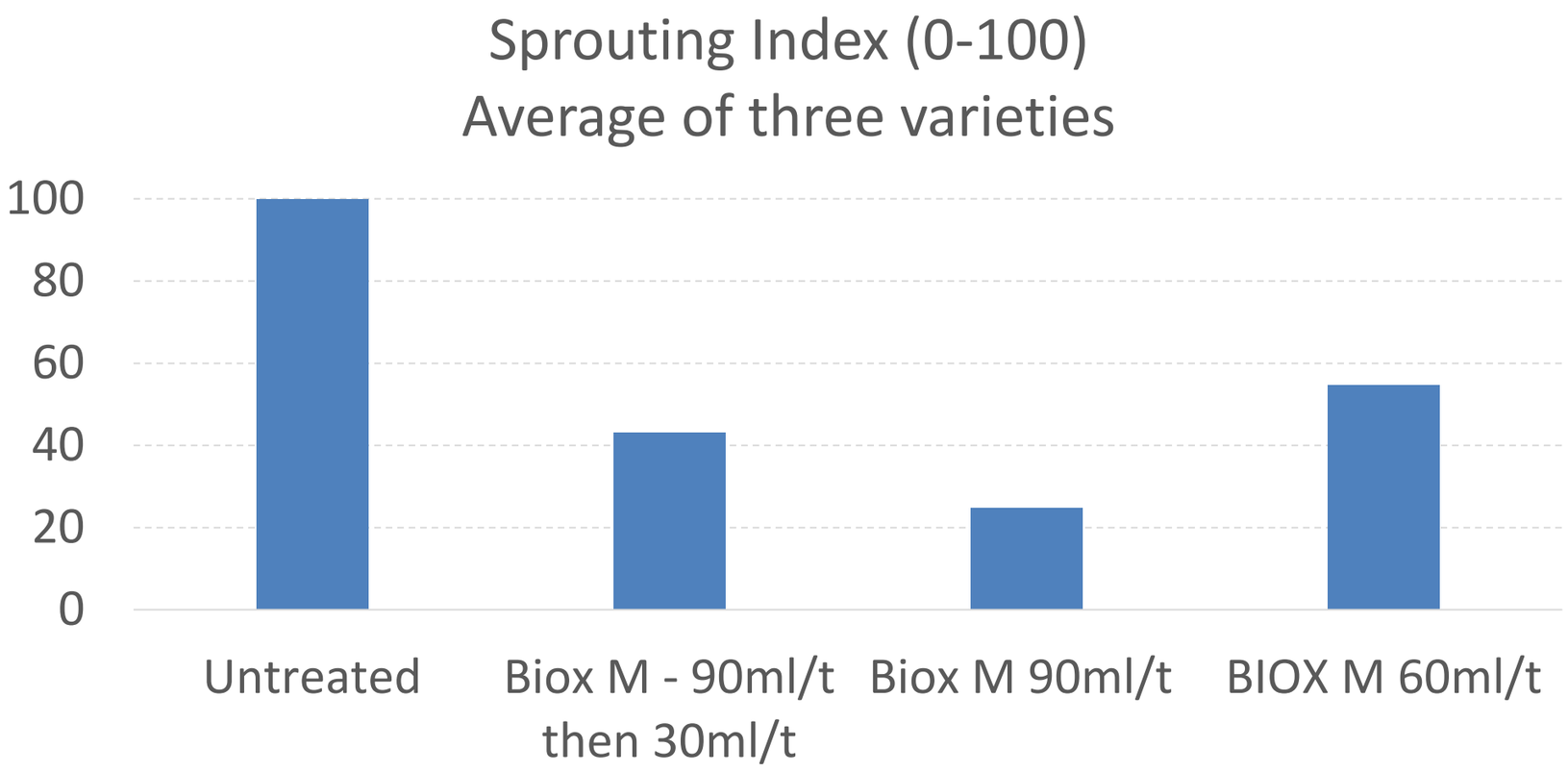
ARVALIS

Essential oils

Treatment advices

- Apply at the white bud stage or on small initiated sprouts, particularly for orange oil which needs to be applied at full rate (100 ml/t)

- For mint oil: adapt the dose to the size of the sprouts present, giving preference to sufficient doses (60 à 90 ml/t), especially during periods of high sprouts pressure, to ensure proper destruction



Sprouting index after 8 months storage at 7°C with different doses of mint oil compared with an untreated control - Average of three varieties: Agata, Charlotte, Monalisa (2022/2023)

Benefits of use

Their curative action is highly effective in necrotizing young sprouts.
It is advisable to combine their use with preventive products which can :
- Slow sprouts growth to facilitate their necrosis
- Limit the risks of internal sprouting in long-term storage

In the case of maleic hydrazide :
- More flexibility for the first application in storage ➔ limits the risk of lack of selectivity
- Reduced number of applications and cost

Points to consider

- Do not let sprouts to develop, as this may result in necrotic sprout traces and more difficulty in good sprouting control
- Use Orange oil in combination with a preventive molecule
- Caution for cold fogging, as there is an increased risk of burns on tubers.

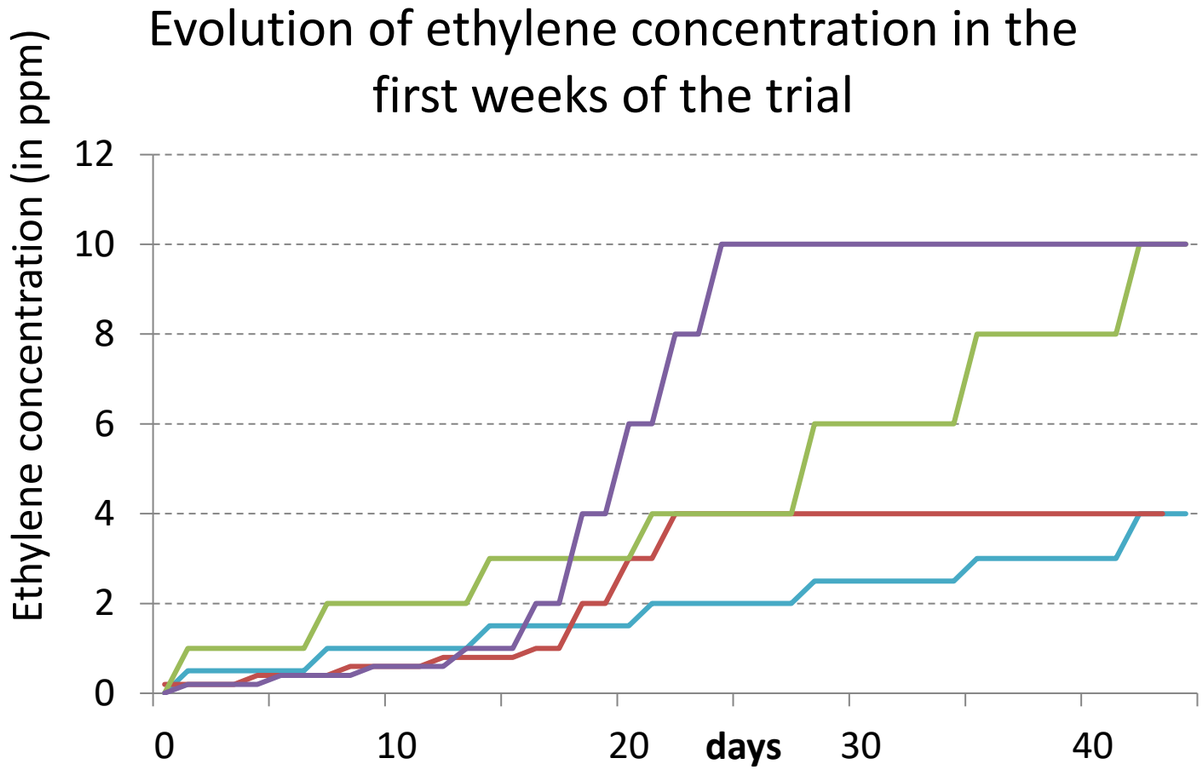
Ethylene

Coloration after frying: Very gradually increase the ethylene concentration

Questions are being raised about the use of ethylene for processing, because of its attractive cost. Depending on the variety, ethylene can have a great or minor impact on the coloration of fried products. Markies, Fontane and Magnum show little risk of coloration degradation with ethylene. However, it is important to :

- Warn the processing company
- Monitor coloration after frying along storage period

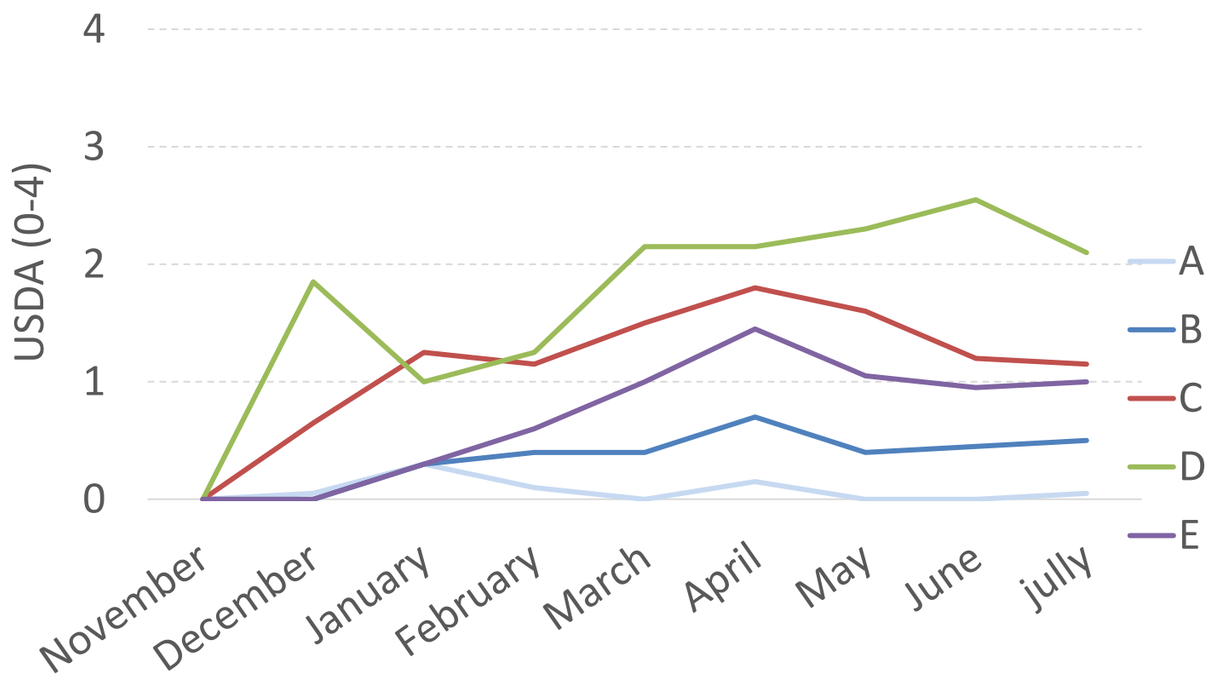
Evolution of ethylene concentration in the first weeks of the trial



Ethylène 4 ppm continue - Ethyl. 4 ppm progressive
Ethylène 10 ppm continue - Ethyl. 10 ppm progressive

8 months of storage
7°C

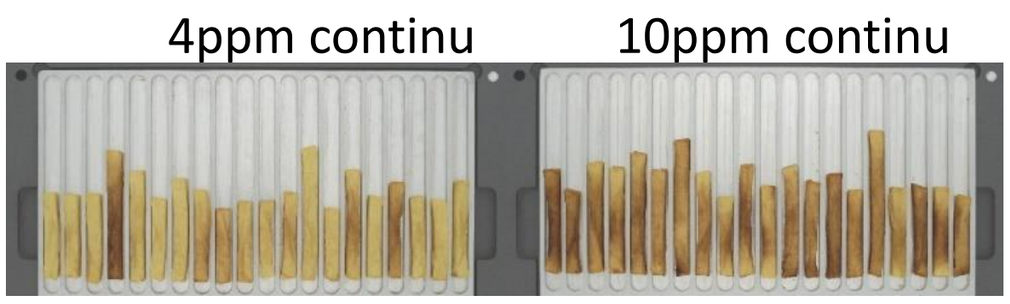
Coloration after frying – French fries
MARKIES



A: mint oil - B : Ethylène 4 ppm continue - C : Ethyl. 4 ppm progressive
D : Ethylène 10 ppm continue - E : Ethyl. 10 ppm progressive

Frying color and sprouting index after 8 months at 7°C for tubers treated with different ethylene levels during the first weeks of storage compared with mint oil (2021/2022)

- The first few weeks of application are important for coloration, even for long-term storage.
- Effect of ethylene rate on coloration
- Variable behaviour depending on variety: Need of rigorous monitoring of color evolution of fried products.



Points to consider

- Sufficiently airtight building
- Very gentle increase of ethylene concentration
- Beware of processing variety choice and monitor frying along storage period
- Monitor CO_2 evolution : maintain concentration < 3000ppm

OptiGERM® : Your new DSS to help you on potato sprouting management!

NEW

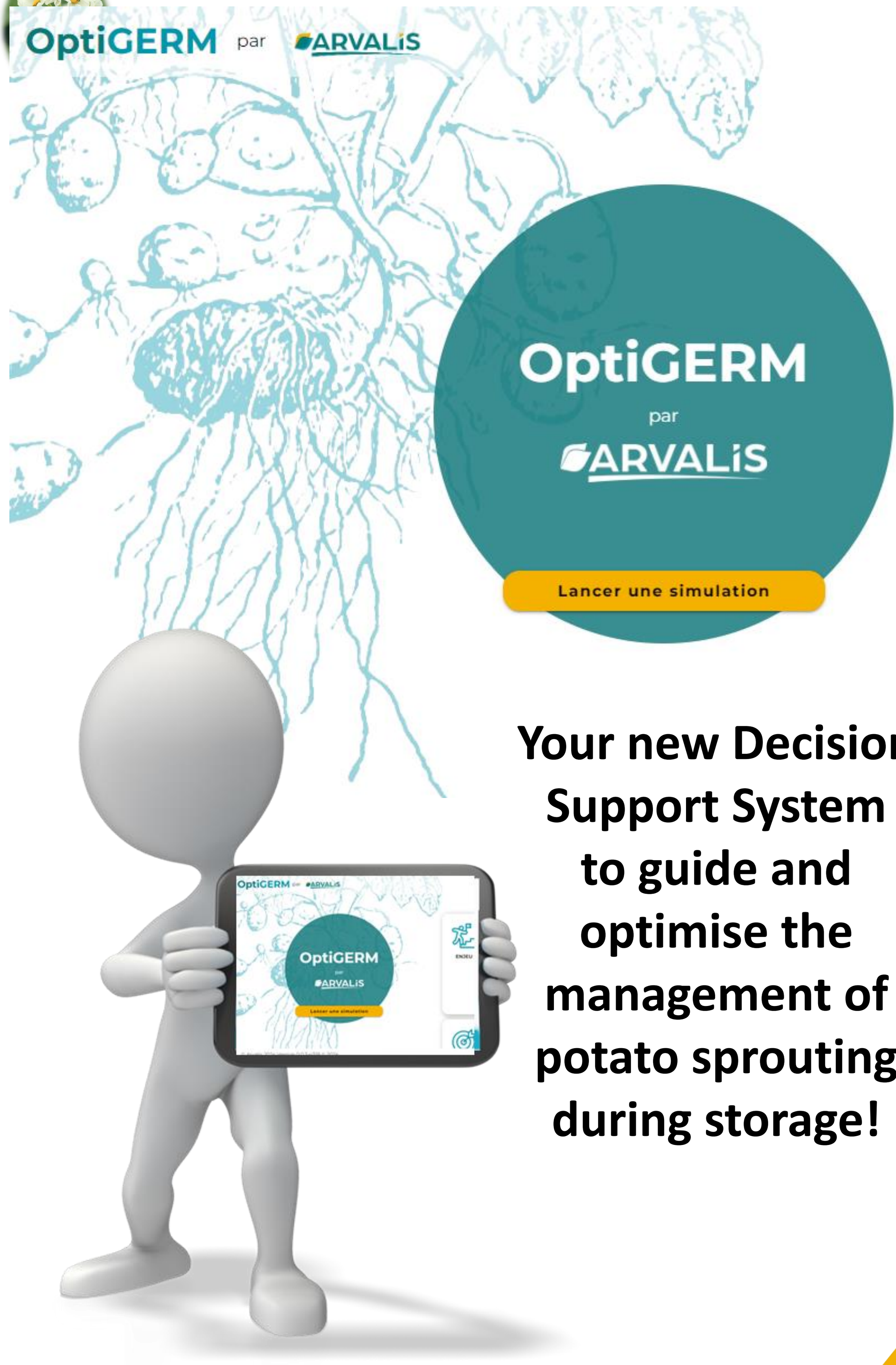
FREE

- **Objectives**
  - To assess the risk of sprouting before store removal
  - To diagnose the strong and weak points of sprout control
  - To suggest factors to improve storage
  - To propose anti-sprouting programs adapted to the type of production and storage conditions

- **Taking into account multiple factors**
  - Variety (dormancy)
  - Production practices (irrigation, treatment during cultivation)
  - Climatic context in the field and during storage
  - Storage practices (target temperature, ambient air and/or cooling unit)
  - Outlet specifications
- **For strategic and tactical use**
  - To assess the risk of sprouting from planting to harvest
  - To consider the “year effect” and anticipate storage risks of early sprouting
  - To adapt to a new date of retailing
- **Archiving simulations possible**
  - For a greater and quicker use in the event of multi-varietal storage
  - To take practical cases from previous years

Log in and create your account to use the OptiGERM tool!

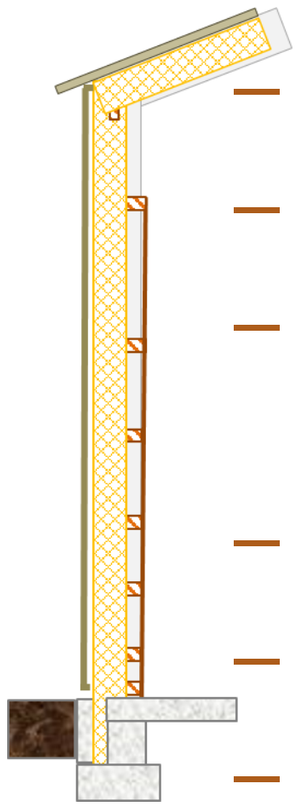
ARVALIS



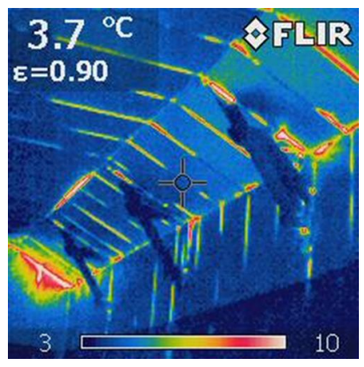
Your new Decision Support System to guide and optimise the management of potato sprouting during storage!

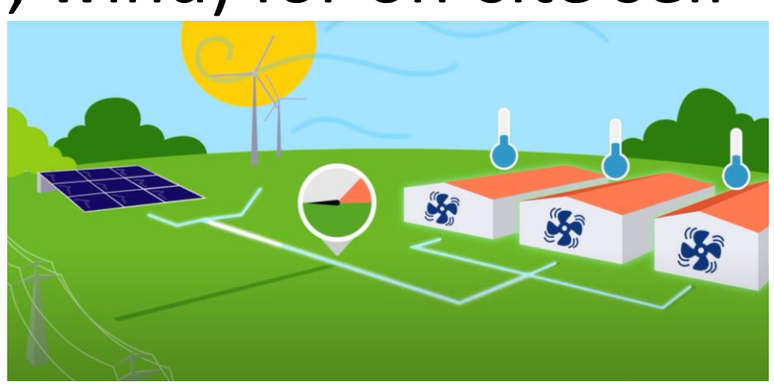
Proposed actions for more energetic sobriety during storage

- **Strategic investments**

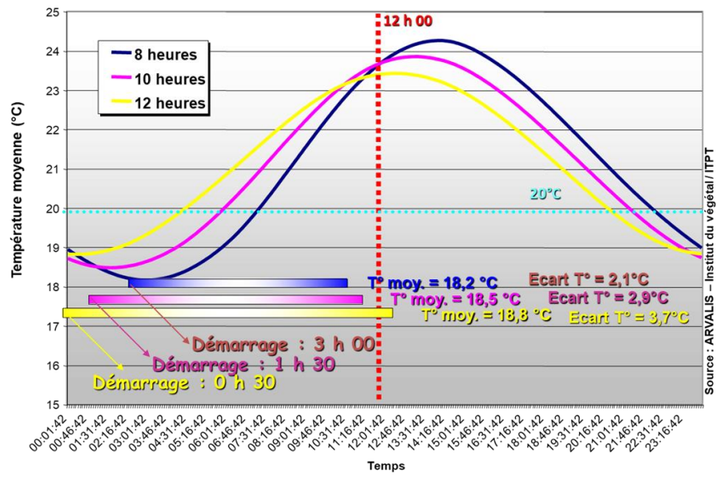


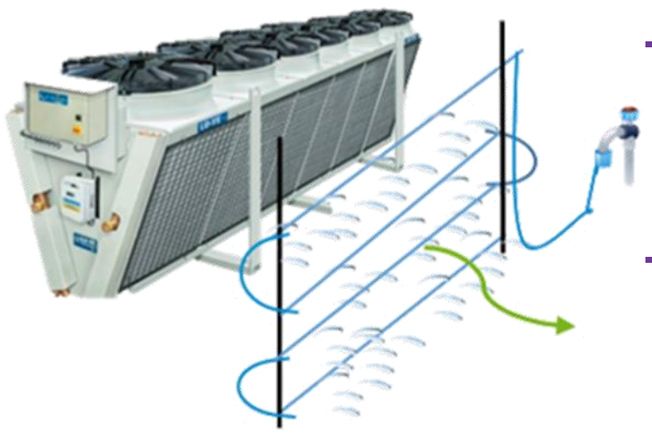
  - High-performance insulation without thermal bridges
  - Variable speed fans with inverters
  - Chiller with high COP taking into account the GWP of the refrigerant
  - Favor cooling units with floating HP and LP
  - Adopt specific CO_2 extractors
  - Ensure local electricity production (solar, wind) for on-site self-consumption
  - Switch to LED for building lighting and limit greening
  - Valuing the calories recovered in the building (heat recovery)





- **Tactical approaches and settings**
  - Harvest in the cooler hours of the day during summer harvests
  - Adapt the setpoint temperature and the choice of the differential according to the possibilities





  - Improve the COP of the chiller at the hottest hours
  - Keep clean the surfaces of the cold unit heat exchangers
  - Run installations as much as possible during off-peak hours

Considering the non-exhaustive list of levers above may reduce the energy cost of storage by more than 20%