Potentiel de la méthode REP-ASCA pour la sélection variétale

Cas d’étude de l’utilisation de la spectroscopie VIS-NIR sur des essais stress hydrique

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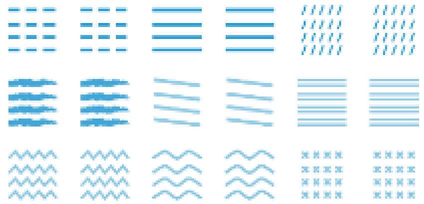
Introduction

When studying influence of factors on data:

Experimenter's tools *[Fisher, 1937]*

- **Experimental design**



Experiment in an **optimal way**
- Blocking
- Randomisation

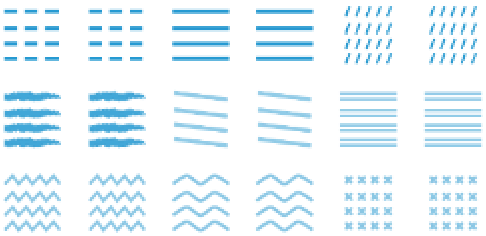
- **Analysis of Variance**

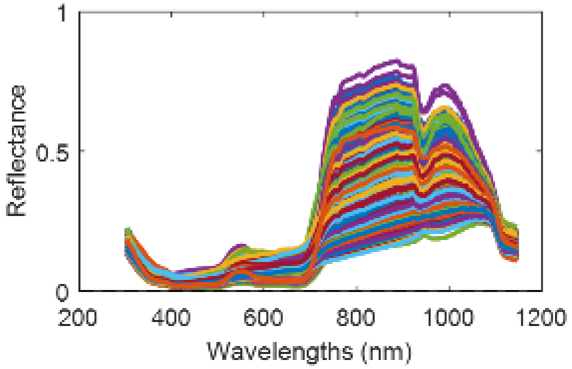
[Ståhle and Svante, 1989]

$$\mathbf{X} = \mu + \underbrace{\mathbf{X}_{\mathrm{A}} + \mathbf{X}_{\mathrm{B}}}_{\textit{Main terms}} + \underbrace{\mathbf{X}_{\mathrm{AxB}}}_{\textit{Interaction term}} + \underbrace{\mathbf{R}}_{\textit{Residuals}}$$

Introduction

Analysis of variance for multivariate data





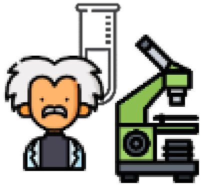
REP-ASCA: *Remove Error of Repeatability – Analysis of variance Simultaneous Component Analysis*

[Ryckewaert et al., 2020]

Based on ASCA *[Smilde et al., 2005]*

Introduction

Repeatability error

 $\neq$  **?**

The **repeatability error** is the difference between measurements ***under same conditions***

depends on what we call '*conditions*'

$$\mathbf{X} = \mathbf{X}_\mu + \mathbf{X}_A + \mathbf{X}_B + \mathbf{X}_{A\times B} + \mathbf{R}$$

Error

Included in all factors
Cannot be declared as a factor

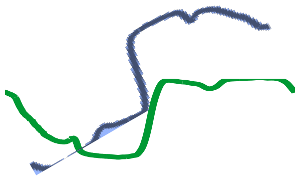
REP-ASCA

$\mathbf{X}_S$ **Dissociated dataset**
To describe repeatability error

REP-ASCA
Theory

1 **Finding components related to repeatability error P**

$\mathbf{X}_s$ **Dissociated dataset**

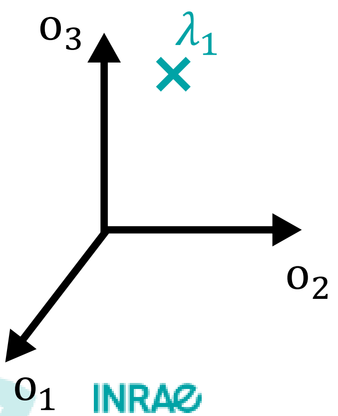


$\mathbf{P}$

2 **Removing repeatability error**

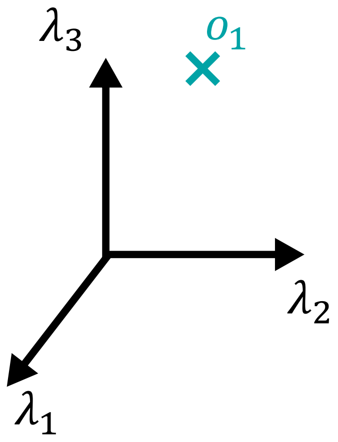
Column-space $\mathbb{R}^n$

$\mathbb{R}^p$ **Row-space**



~~ASCA ($\mathbf{X}$)~~ $\mathbf{X}$

Remove space spanned by $\mathbf{P}$



Orthogonal projection

$$\tilde{\mathbf{X}} = P^{\perp}_{\mathbf{W}}\mathbf{X}$$
$$= \mathbf{X}(\mathbf{I} - \mathbf{P}^t\mathbf{P})$$

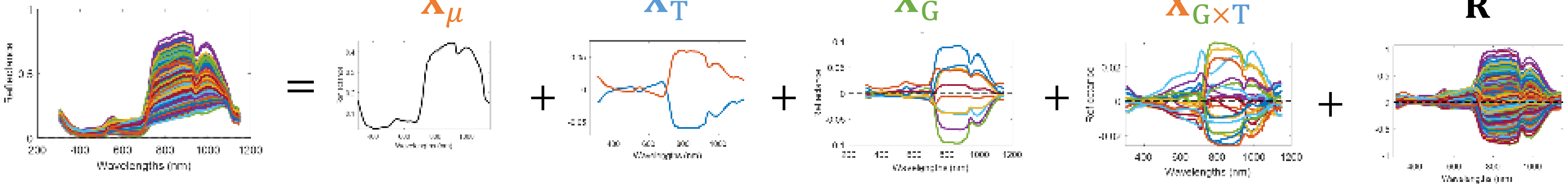
ASCA ($\tilde{\mathbf{X}}$)

REP-ASCA

Main steps

1- Variance decomposition

$$\mathbf{X} = \mathbf{X}_{\mu} + \mathbf{X}_{\mathrm{T}} + \mathbf{X}_{\mathrm{G}} + \mathbf{X}_{\mathrm{G}\times\mathrm{T}} + \mathbf{R}$$

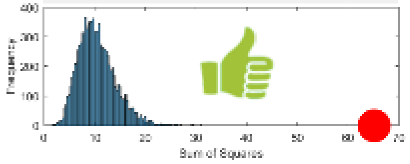


2- Significativity of factors

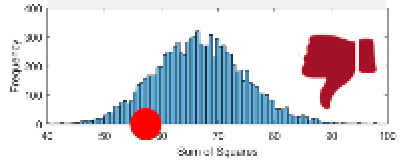
Permutation test

Initial variance compared to variances obtained by n permutations

Statistically significance

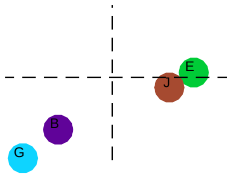


NOT significance



3- Component analysis

$$\mathbf{X}_{\mathbf{Genotype}} = \mathbf{T}\mathbf{P}^{\mathbf{t}}$$



P : Loadings

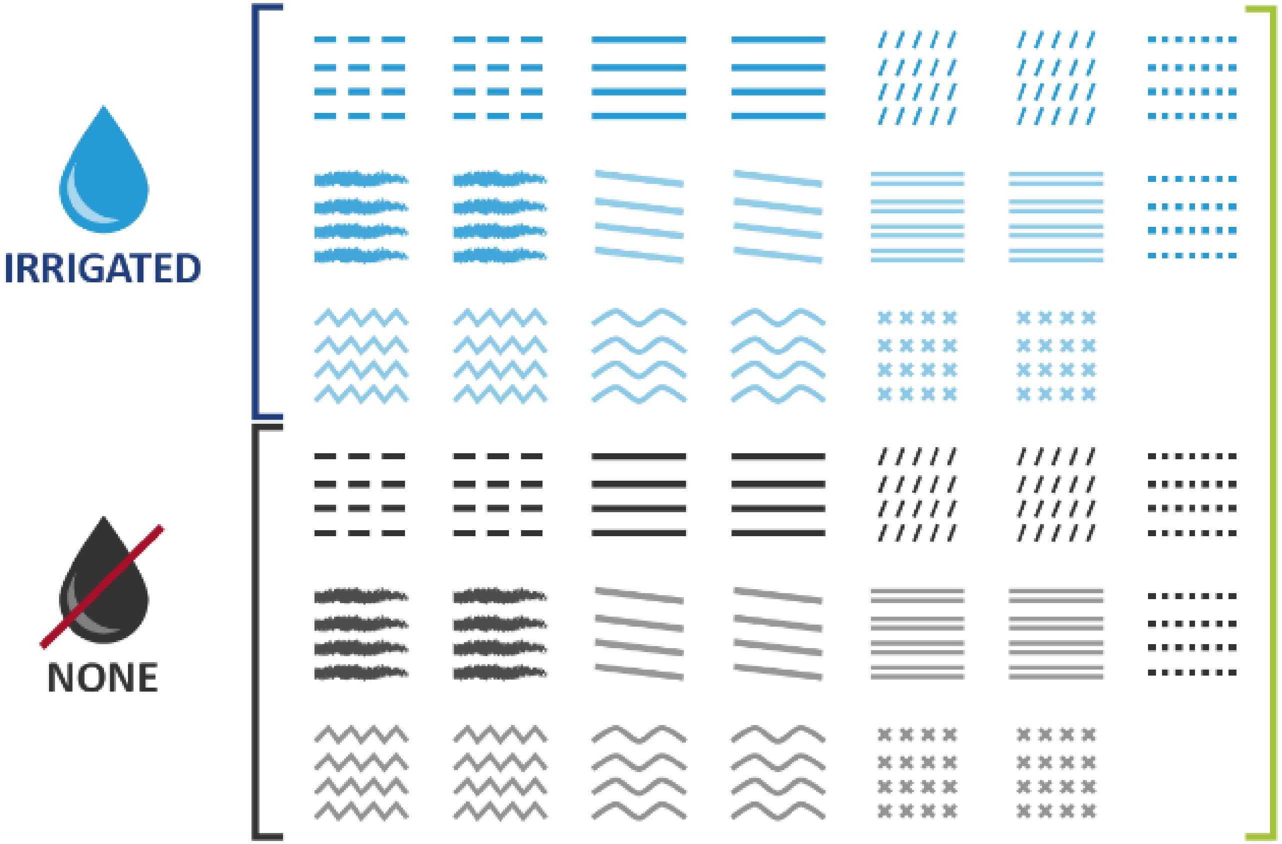
- Spectral regions involved
- Interpretation

T : Scores

- Classification

Materials and methods

Phenotyping Maize in the field with VIS-NIR Spectroscopy



840 m²

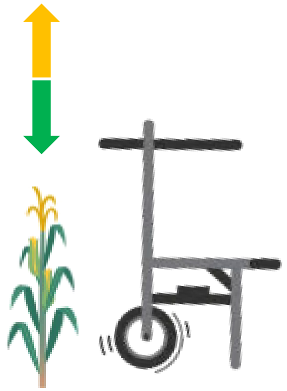
40 micro-plots sowed in 4 rows

- 2 treatments
- 2 replications
- 10 genotypes

Materials and methods

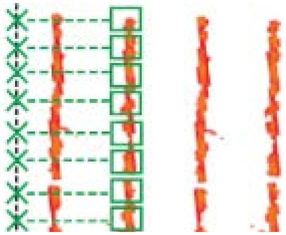
Phenotyping Maize in the field with VIS-NIR Spectroscopy

Figure : Connected wheelbarrow



How to get reflectance spectra?

- A connected wheelbarrow
- Spectrometer: Zeiss MMS1
  VIS/NIR from 300 nm to 1150 nm

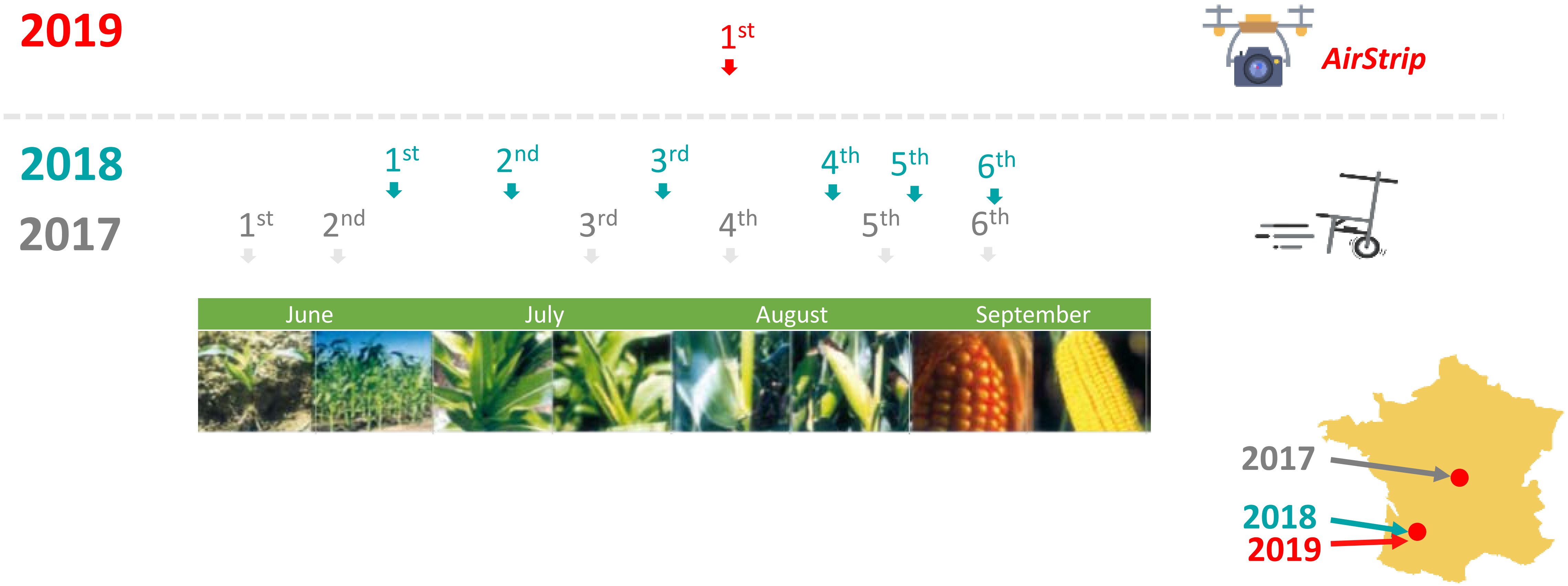


Protocol:

- 8 reflectance spectra by micro-plot
  320 spectra
- And 160 spectra of repeated measures

Materials and methods

Different acquisition dates



Materials and methods

But which year/date to choose?

2017: 130Qt / 115Qt

IRRIGATED NONE

Low water deficit which has no impact on yield

2018 103Qt / 71Qt

IRRIGATED NONE

High water deficit for the non-irrigated part

Significant difference between the two treatments

Ranking of genotypes

2019 114Qt / 95Qt

IRRIGATED NONE

Moderate water deficit

Materials and methods

But which year/date to choose?

2018

At the harvest

Genotypes ranking (Yield)

A B C D E F G H I J

Tolerant
Sensible

3rd Date

Where water deficit is maximal!

REP-ASCA

+ <u>Investigation</u> dataset:

2018	1st	2nd	~~3rd~~	4th	5th	6th
2019	1st					
2017	1st	2nd	3rd	4th	5th	6th

Materials and methods

REP-ASCA: Factors used

$$\mathbf{X} = \mathbf{X}_{\mu} + \underbrace{\mathbf{X}_{\text{Treatment}} + \mathbf{X}_{\text{Genotype}}}_{\textit{Main terms}} + \underbrace{\mathbf{X}_{\text{Interaction}}}_{\textit{Interaction}} + \underbrace{\mathbf{R}}_{\textit{Residuals}}$$

Is the factor
- Genotype
- Treatment
- Interaction

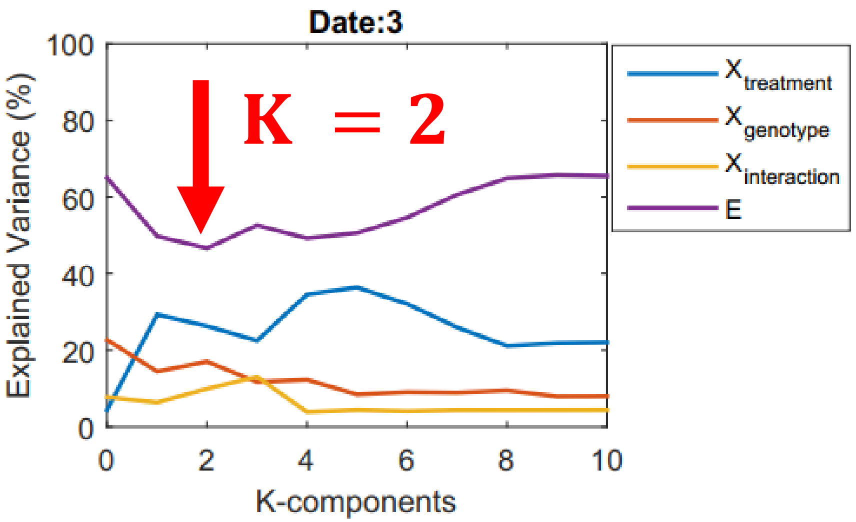
has an effect on the variance?

Results

REP-ASCA: components to remove

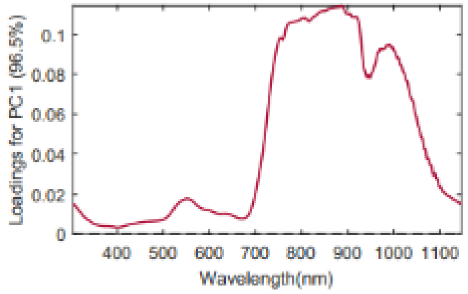
K-choice

Number of components to remove



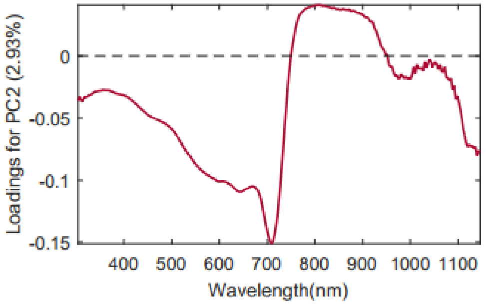
- Hidden Treatment factor !
- Reduction of residuals

Repeatability error



Systematic effect

additive and multiplicative



More complexe Error

Difference pigments/NIR

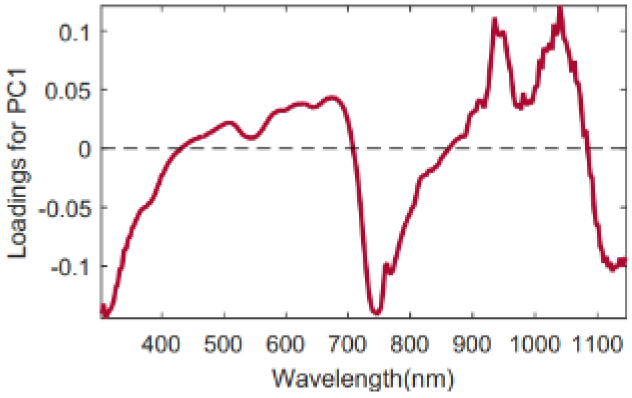
Slope ….

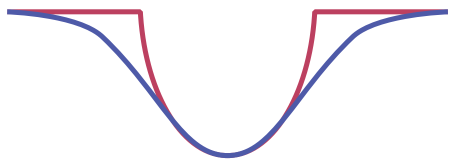
Results

REP-ASCA:

Treatment factor $\mathbf{X}_T$

Loadings of PC1

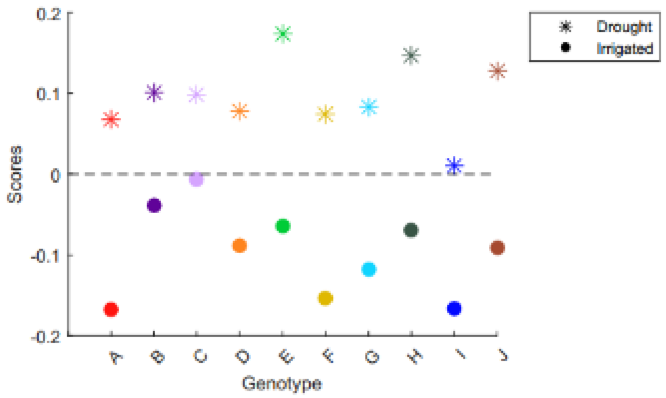




- Two surrounding peaks around 980 nm: Water
- Slope UV: absorption affects the yield,
  [Teramura, 1983]
- RED-EDGE : inflection point

Scores

average scores per genotype/treatment



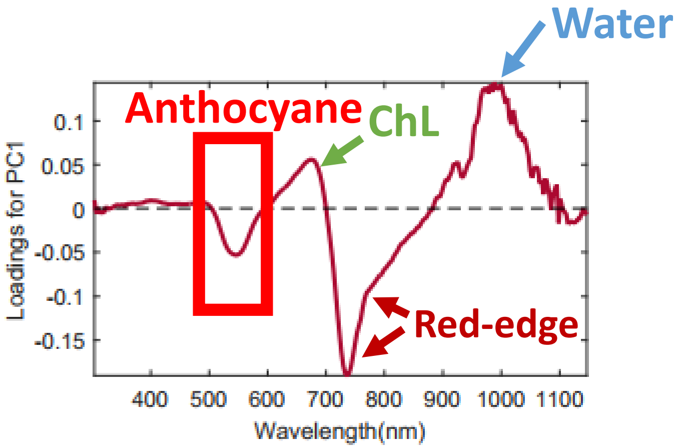
- Irrigated/non-irrigated dissociation
- Distinction of genotypes

Results

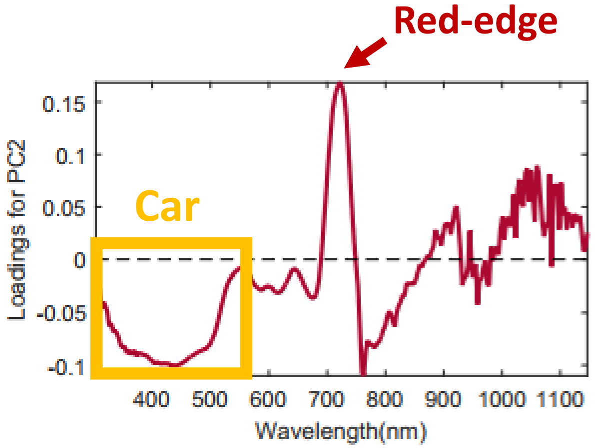
REP-ASCA:

Genotype term $\mathbf{X}_G$

Loadings of PC1 and PC2



(a)



(b)

- State of the plant
- Photosynthetic activity

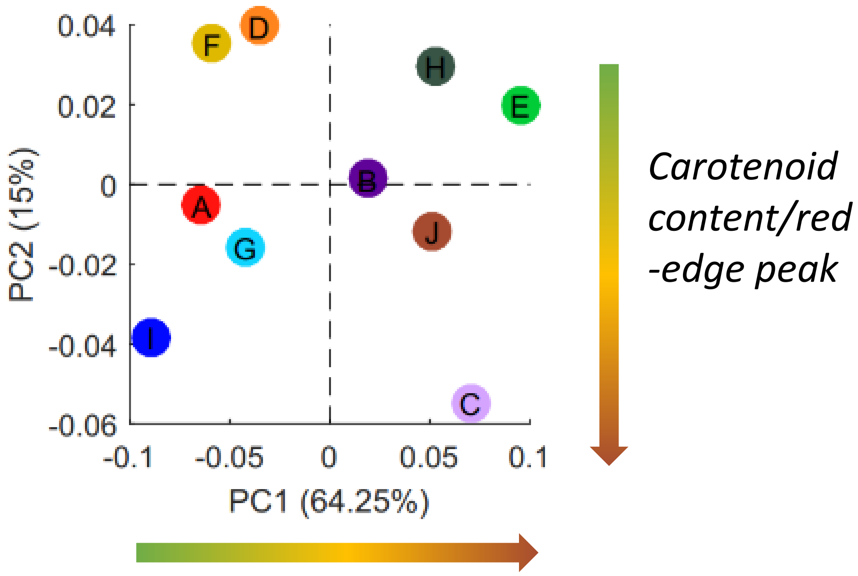
Photosynthesis

- Too much light
- Facing stress

Resistance

Scores

average scores per genotype

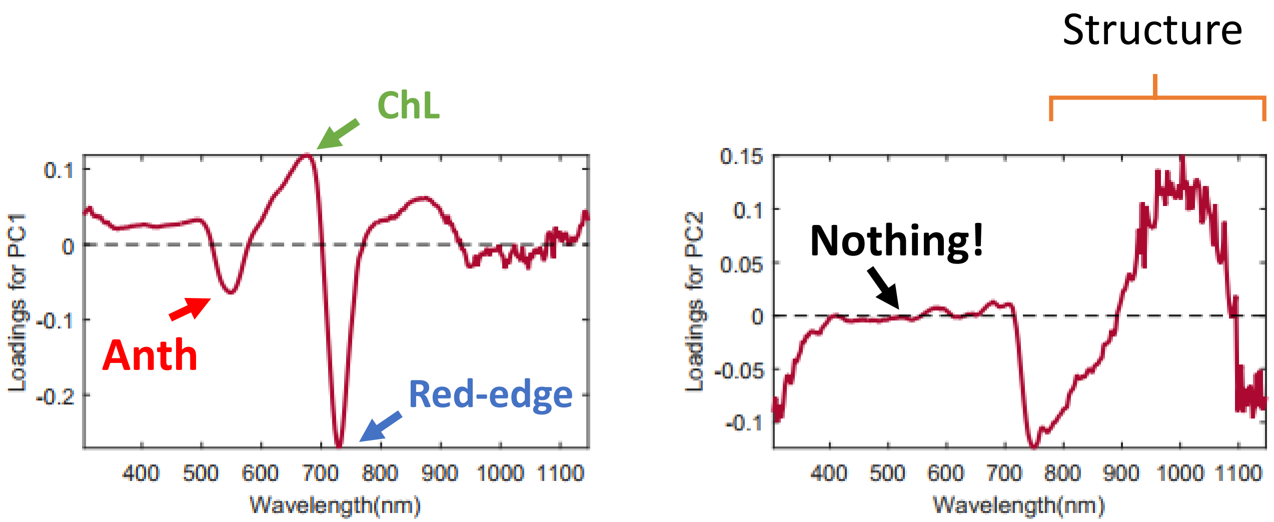


Results

REP-ASCA:

Interaction term $\mathbf{X}_{GxT}$

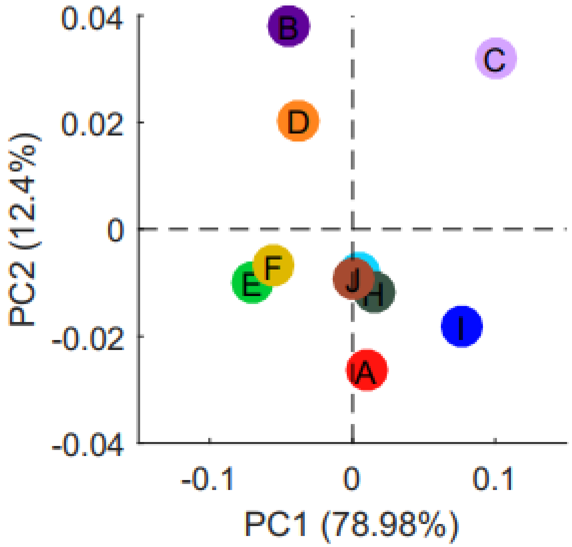
Loadings of PC1 and PC2



(a) (b)

Scores

average scores per genotype



- Dissociation: pigment (PC1) and structure (PC2)
- A classification on genotypes responses

Results

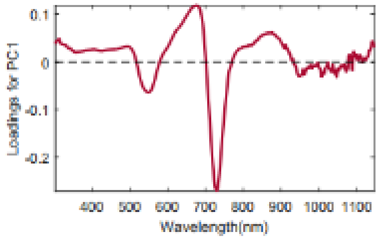
And now?

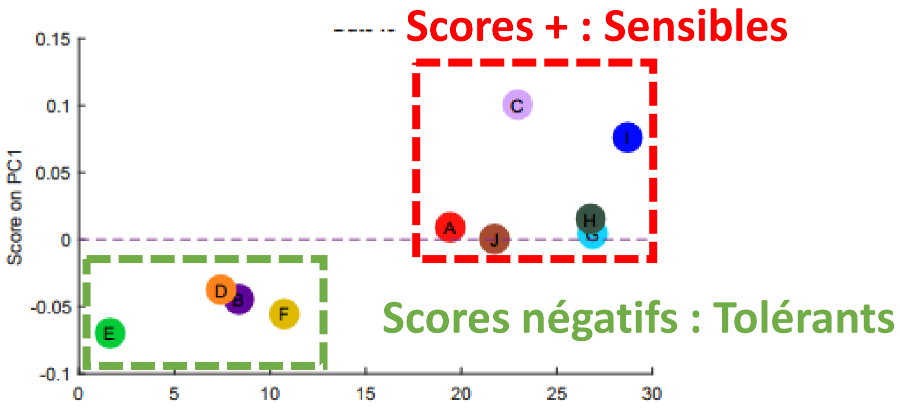
To relate these information (scores) to percentage of yield losses?

2018

Interaction term $\mathbf{X}_{GxT}$

First component (PC1)

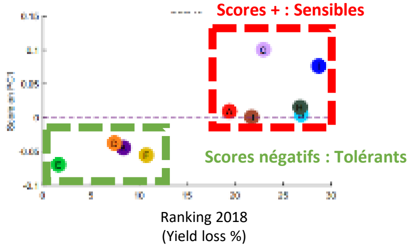


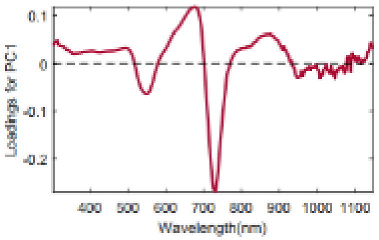


Can we apply this spectral signature to others dates/others environment?

Results

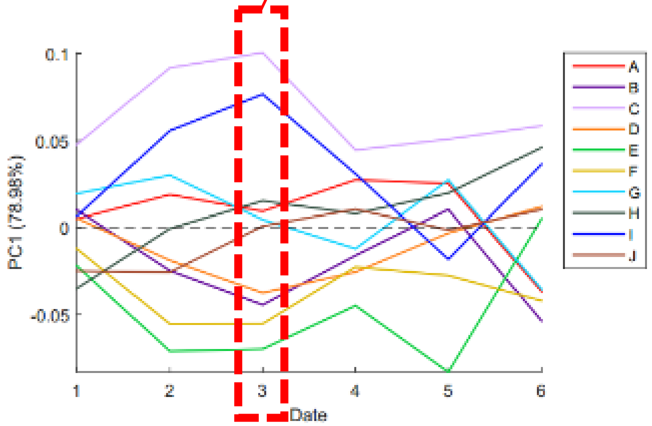
Investigation dataset:





2018

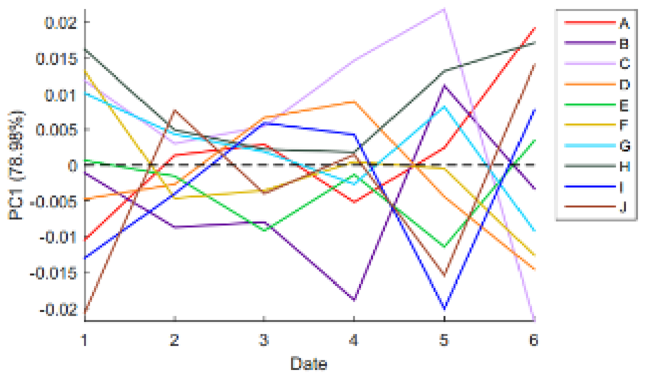
Projection



Date	Corrélation
1	0.18
2	0.75
3	0.81
4	0.77
5	0.62
6	0.39

2017

Projection



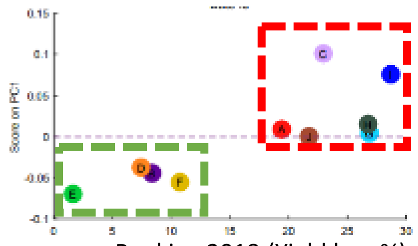
Date	Correlation (to 2018)
1	0.01
2	0.58
3	0.60
4	0.28
5	0.14
6	0.27

Results

And now?

To relate these information (scores) to percentage of yield losses?

2018



Tensiometry

231.5 cbar

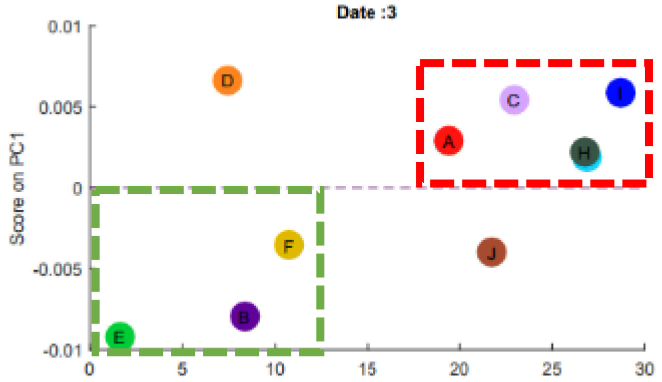
78.5 cbar

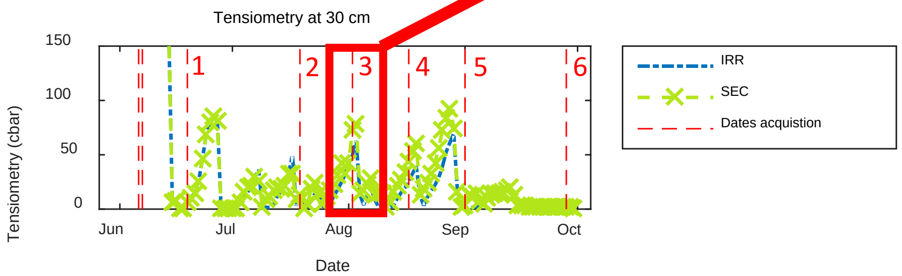
73.42 cbar

50.08 cbar

2017

low hydric stress



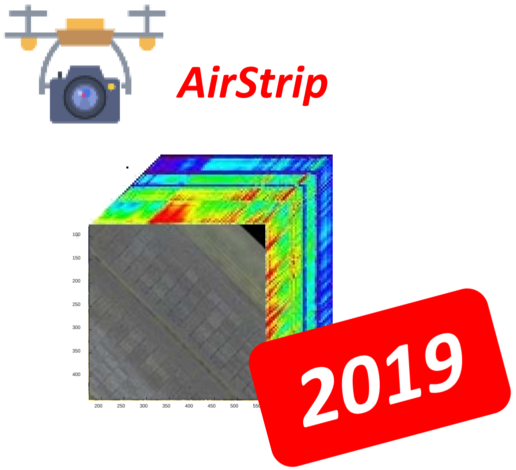


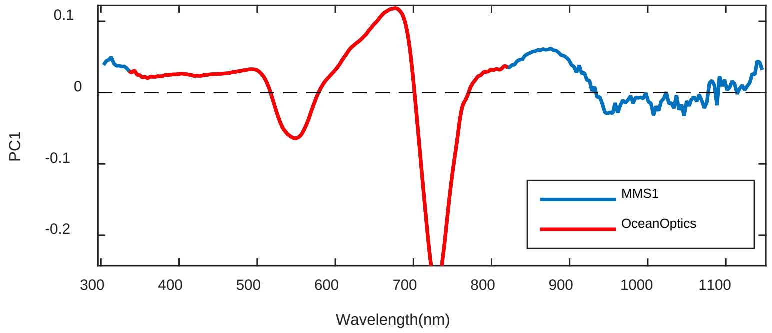
Robust spectral signature related to yield loss?

For low stress in 2017, scores obtained in 2017 are related to 2018 ranking

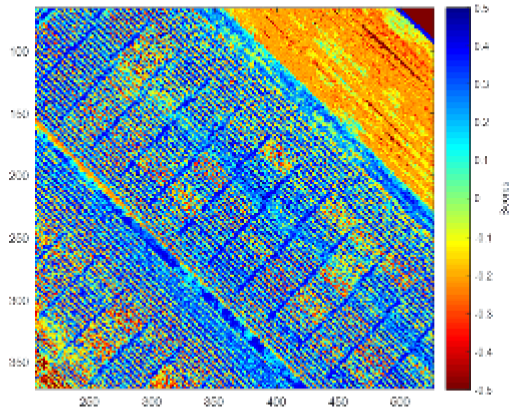
Results

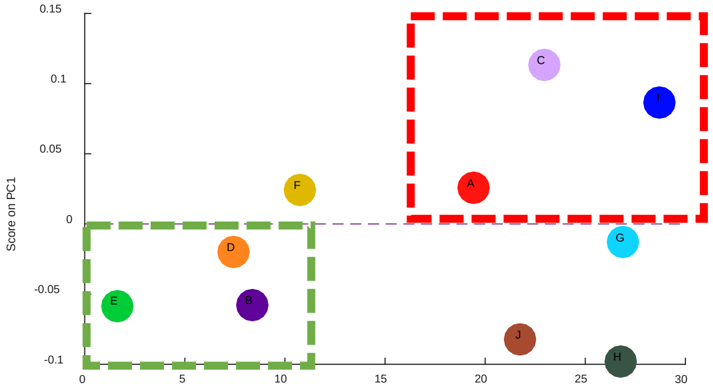
Application with another tool





Projection





Tensiometry

239.0 cbar

173.5 cbar

Conclusion

REP-ASCA:

a method to **reduce repeatability error** for an analysis of variance

with an additional dataset containing repeated measures

→ Adapted protocol

Spectral signature successfully applied to another environment

An not necessary on high level of water stress intensity

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Original papers

Potential of high-spectral resolution for field phenotyping in plant breeding: Application to maize under water stress

Maxime Ryckewaert [a,b,*], Nathalie Gorretta [a], Fabienne Henriot [c], Alexia Gobrecht [a], Daphné Héran [a], Daniel Moura [a], Ryad Bendoula [a], Jean-Michel Roger [a,b]

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[c] Limagrain Europe, Chappes, France

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Thank You

Is there any questions?