Proximal sensors of vegetation for sustainable agriculture

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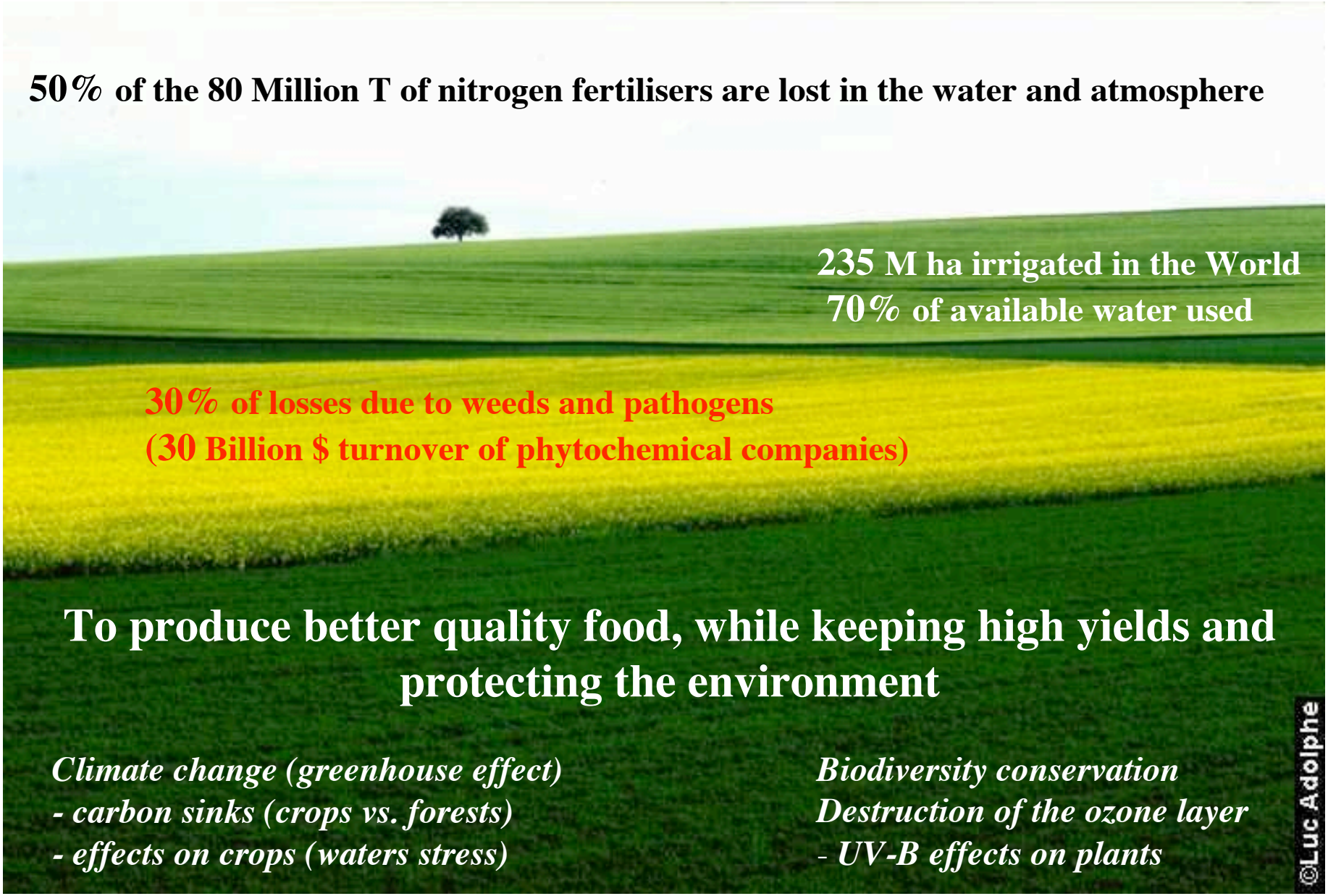
"to see the invisible"

Need for objective information for agriculture & environment



Advantages of optical sensor solutions

Field and production monitoring

Optical sensing

- non-destructive
- non-contact (remote)
- rapid (light)
- high frequency
- large surfaces
- large sampling
- mapping possible

compared to

chemical analysis

- more sensitive
- more precise
- established protocols

- limited sampling
- labour intensive
- delayed results

Remote and proximal sensing of vegetation

ACTIVE

artificial light source

Reflectance or **Fluorescence**

Type of functioning

PASSIVE

the Sun as light source

Reflectance or Fluorescence

Working distance

contact — small — medium — large

leaf clips — Multiplex — LIDAR — aircraft — MERIS satellite

CASI

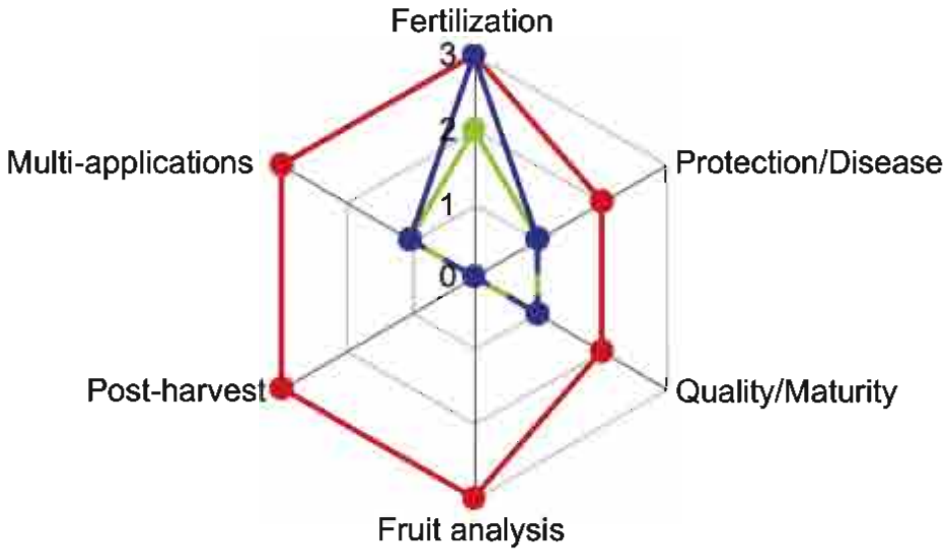
(Fibre optics)

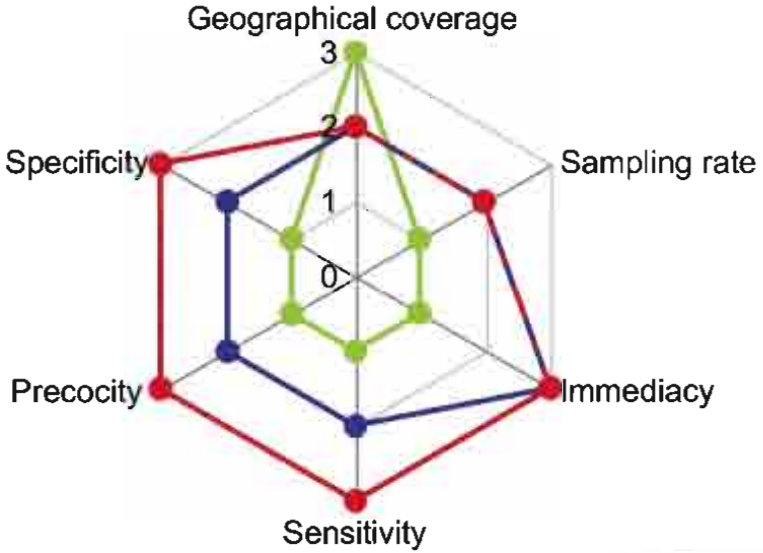
Spectral Domain

UV — visible — NIR — SWIR — thermal — radio

Phen Car Anth Chl LMA Prot H_2O

Comparisons: remote vs. proximal, reflectance vs. fluorescence



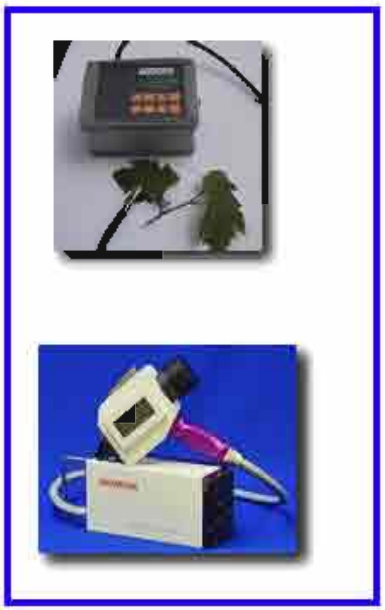


Reflectance (Satellite/Plane)

Reflectance (Ground passive/active sensors)

Fluorescence (Multiplex sensor)

Proximal sensors overview



Greenseeker

SPAD 502

Dualex

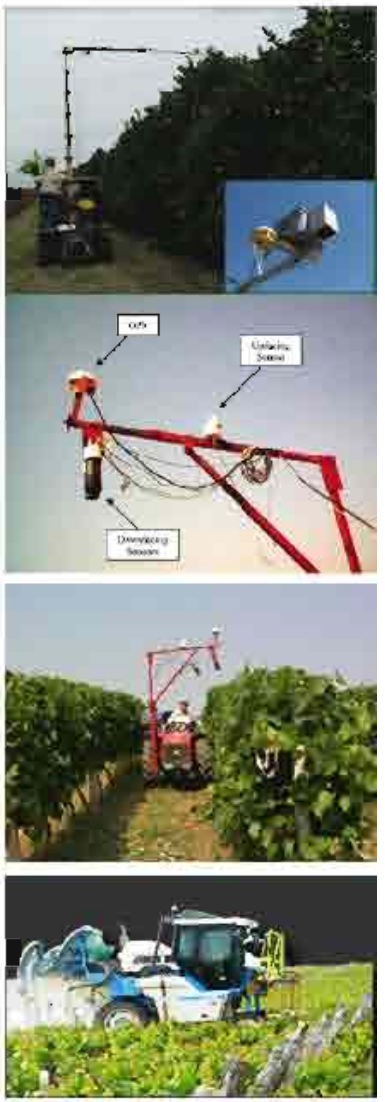
Crop Circle **N-sensor**

Multiplex

Spectron

UV-A-PAM

Luminar



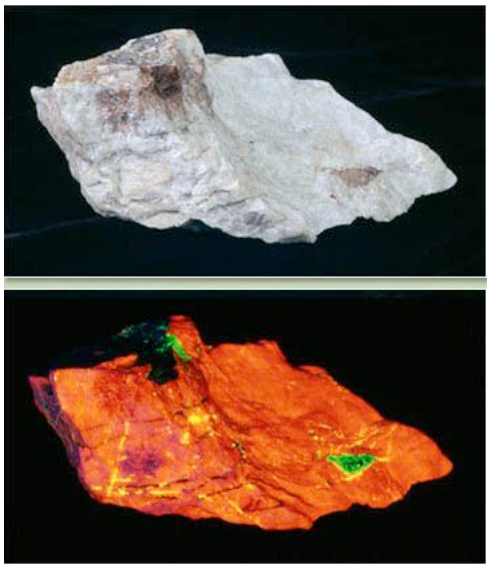
Vehicle (tractor) mounted fluorescence-based sensors

Multiplex
(FORCE-A)

Laser-N-Detector (Planto)

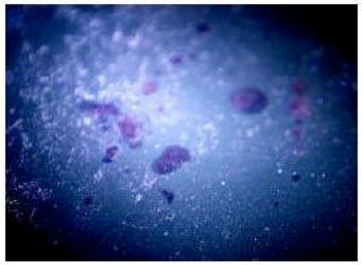
MiniVeg (Fritzmeier)

Fluorescence under UV light - The invisible information



VIS

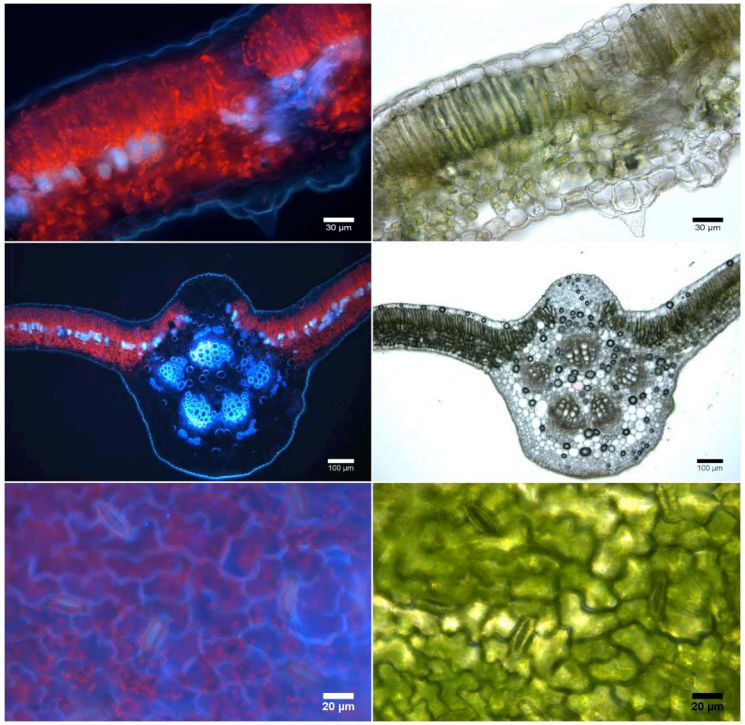
UV



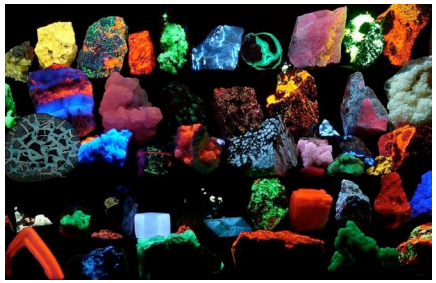
Mineralogy

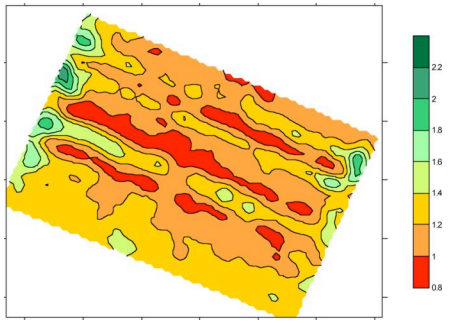
Forensics

UV VIS

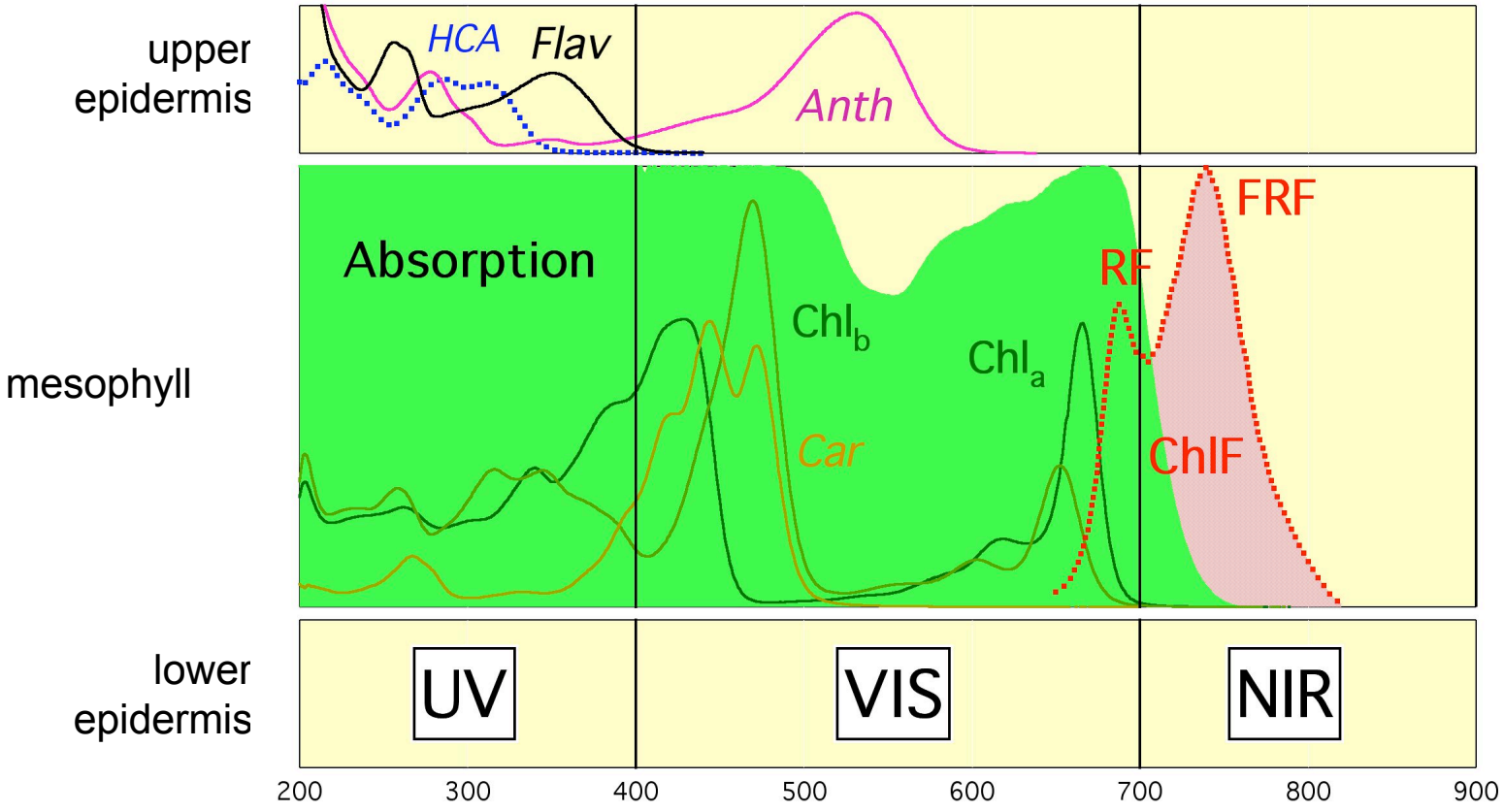


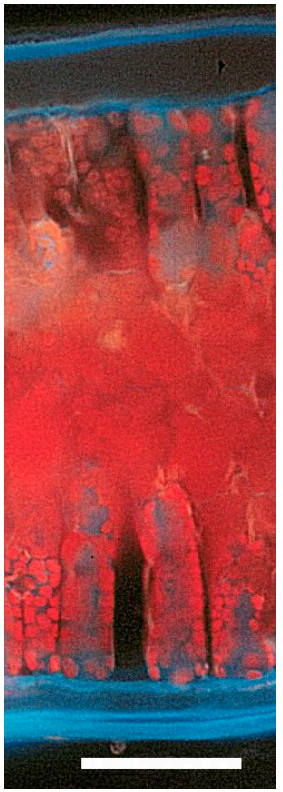
Plants & Agriculture





Chlorophyll fluorescence *in vivo*





Cerovic et al. (1999) Agronomie, ***19:*** *543*

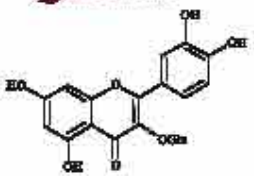
Dualex leaf-clip - Pigments as indicators of nitrogen nutrition

Chlorophyll a & b

Chlorophylls ≈ Nitrogen

Flavonols ≈ Light (LMA)

Quercitrin



DUALEX: from 1G to 4 Generation

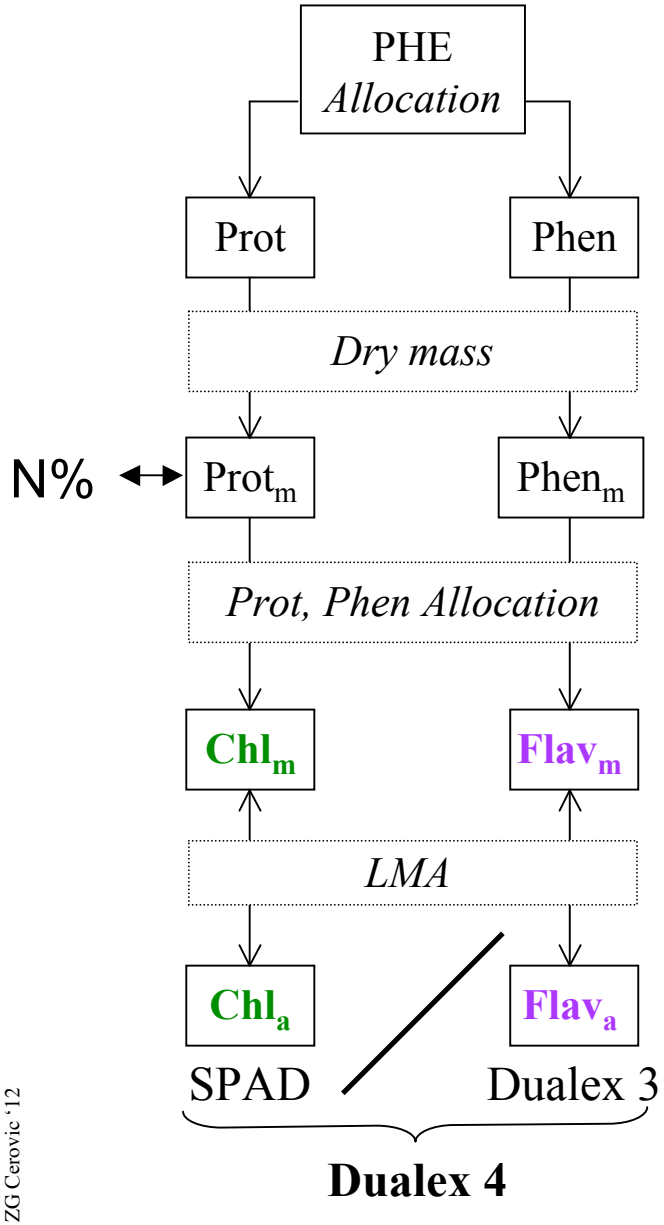
1G Lab 1999 & Field 2000

2 G 2003

3G, 2005/06

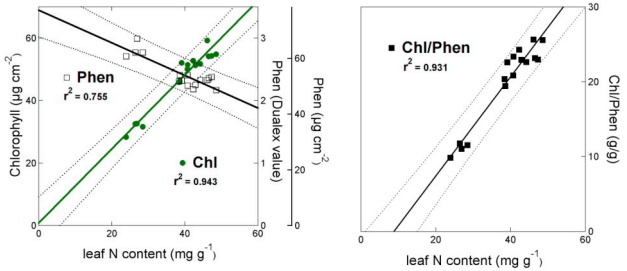
4G, 2009

The Chl/Phen ratio: Nitrogen Balance Index (NBI)

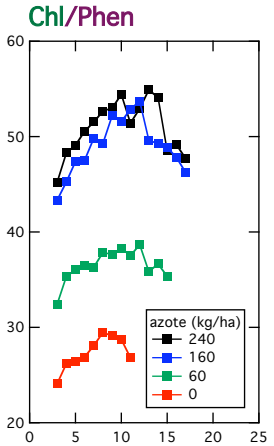


Three Beneficial effects

1. The **opposite dependence** on nitrogen increases the dynamic range



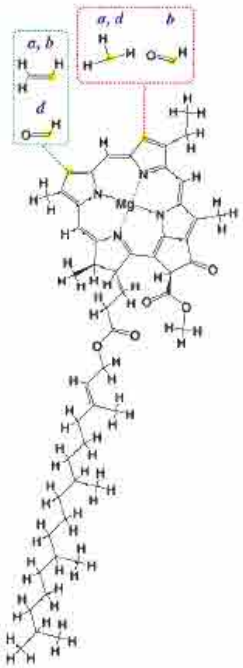
2. The **parallel dependence** on leaf age decreases leaf position influence

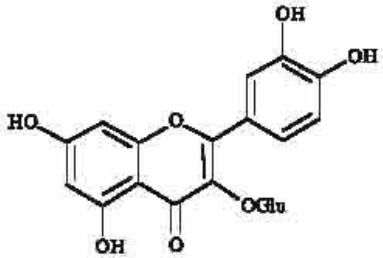


3. The ratio of **two surface-based measurements** avoids the influence of LMA

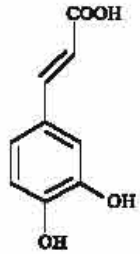
Multiplex proximal sensor - a multiparametric sensor

Chlorophyll a & b

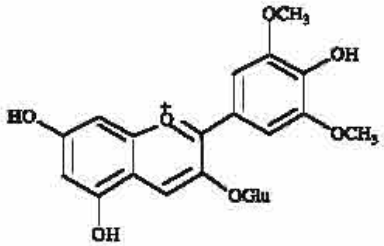




Quercitrin



Caffeic acid



Oenin

MULTIPLEX: towards 4G

1.5 - 2005

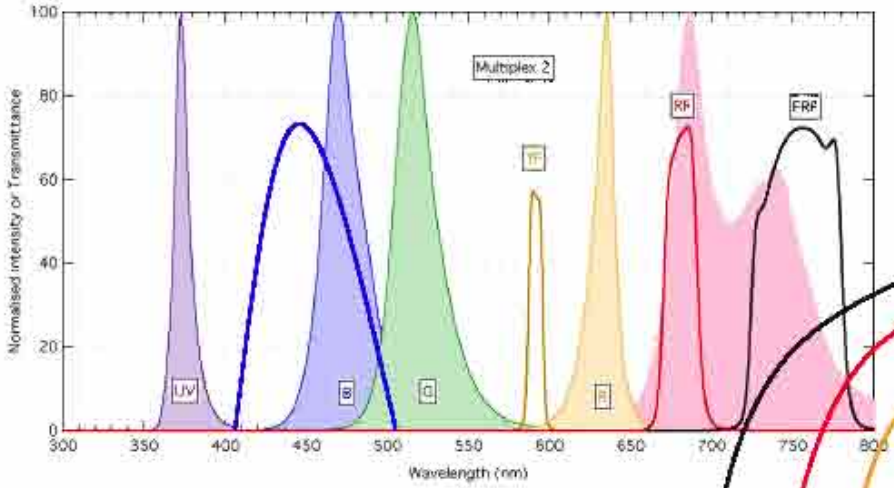
2G - 2007

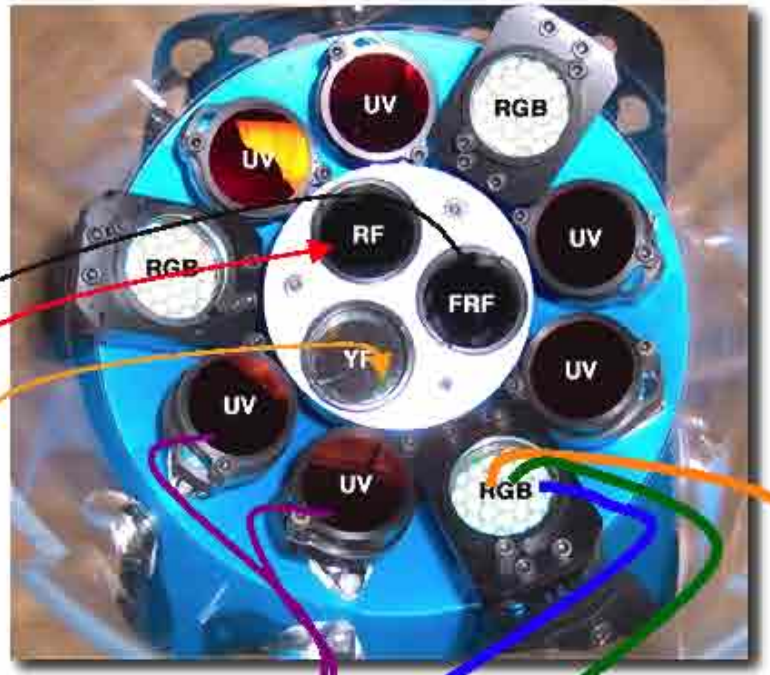
3G – 2008 / 2009

4G

The Multiplex sensor

Stress Chl Flav HCA

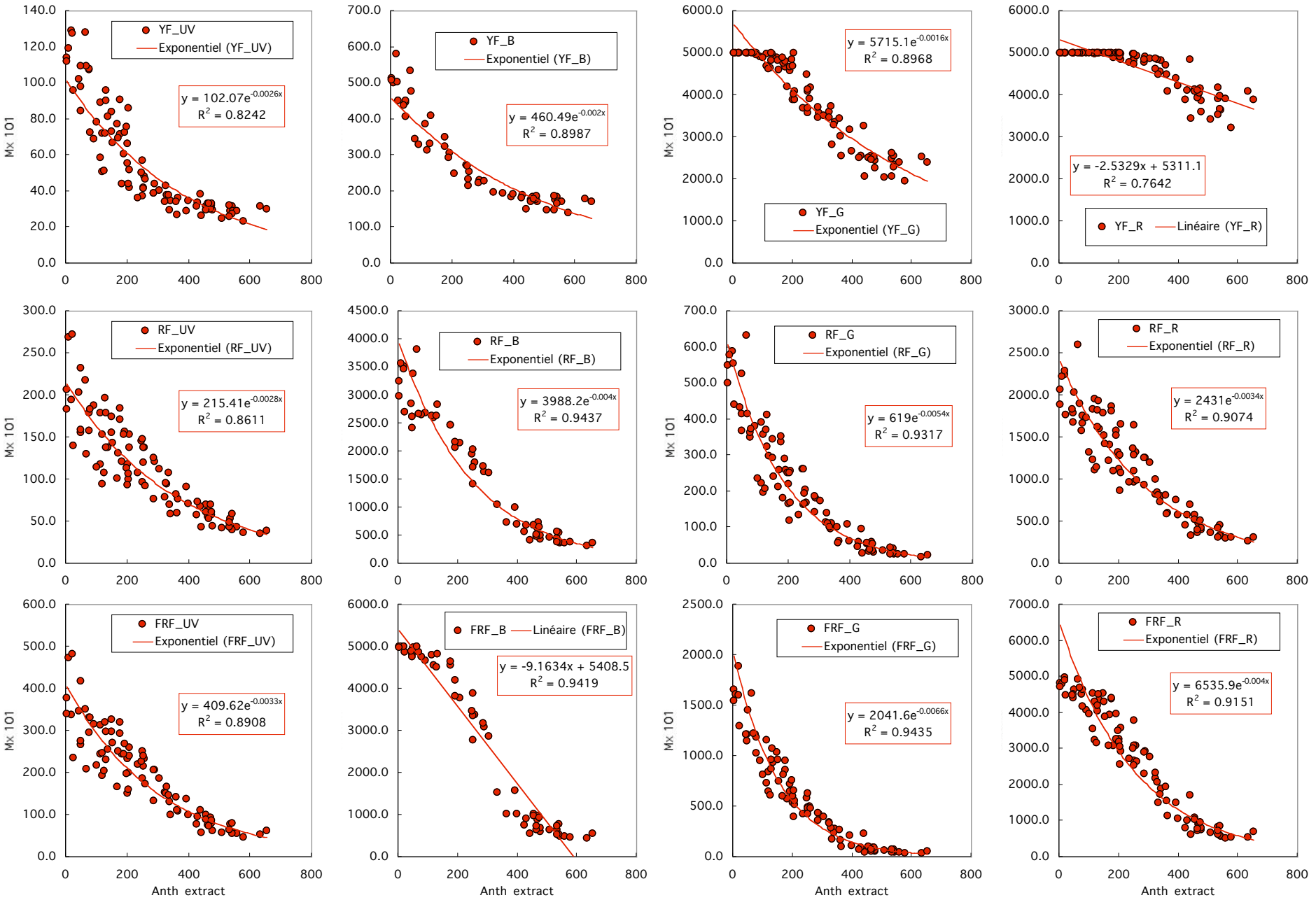




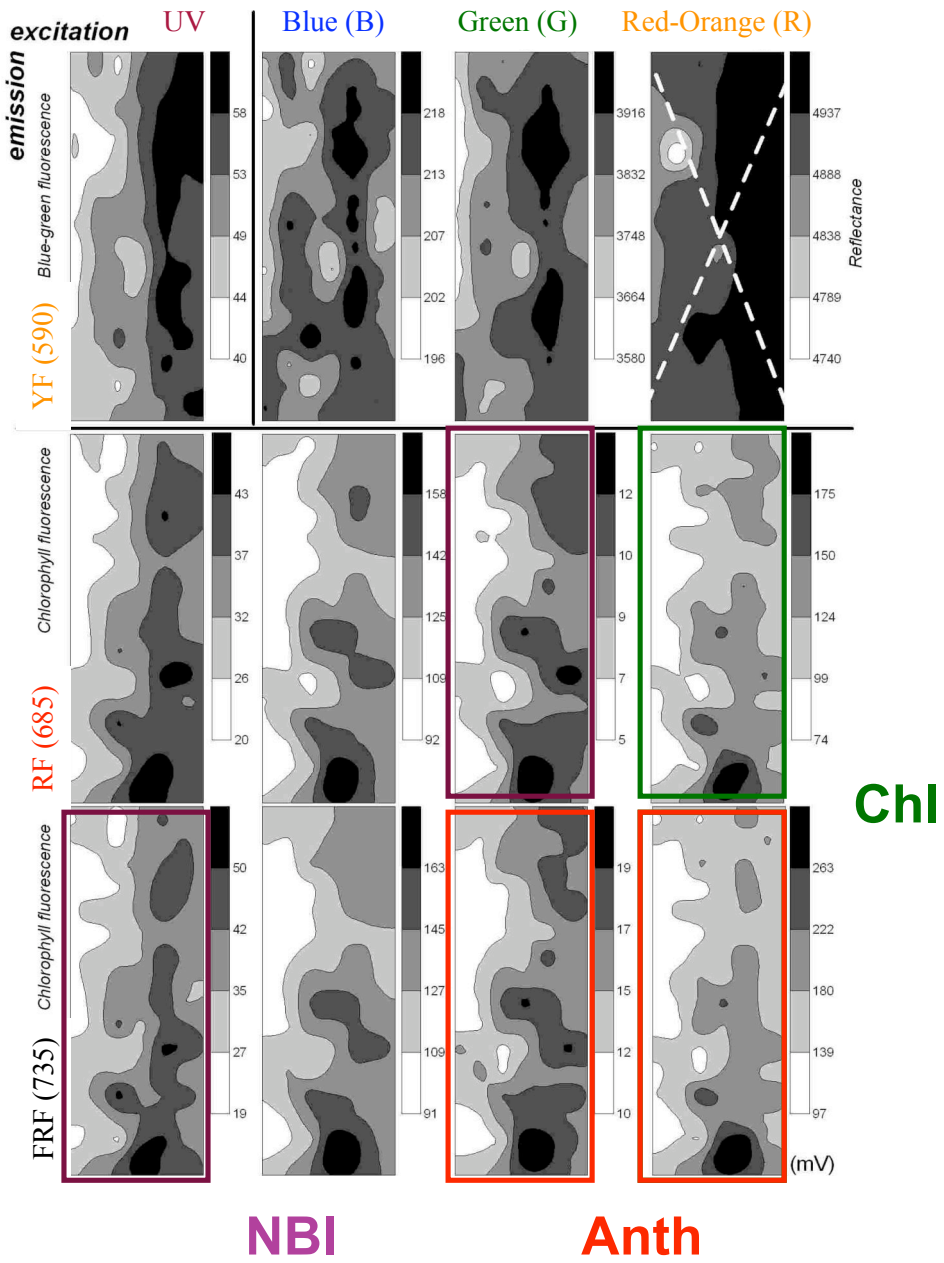
Emission (nm)	Excitation			
	UV	Blue (B)	Green (G)	Red-Orange (R)
YF (590)	YF_UV	YF_B = *R*	YF_G = *R*	YF_R = *R*
RF (685)	RF_UV	RF_B	RF_G	RF_R
FRF (735)	FRF_UV	FRF_B	FRF_G	FRF_R

20 µs flashes
4 excitations
3 emission channels
Repeated 500 times
6000 measurements
0.5 s per sample
In situ
Under daylight

The Multiplex signal matrix - time (grapes maturation)



The Multiplex signal matrix - space (grapes maturity)



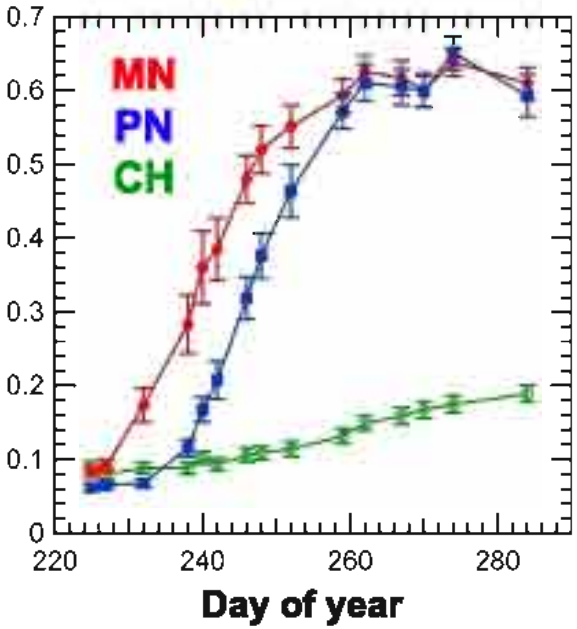
Grapes at harvest

Viticulture in Champagne

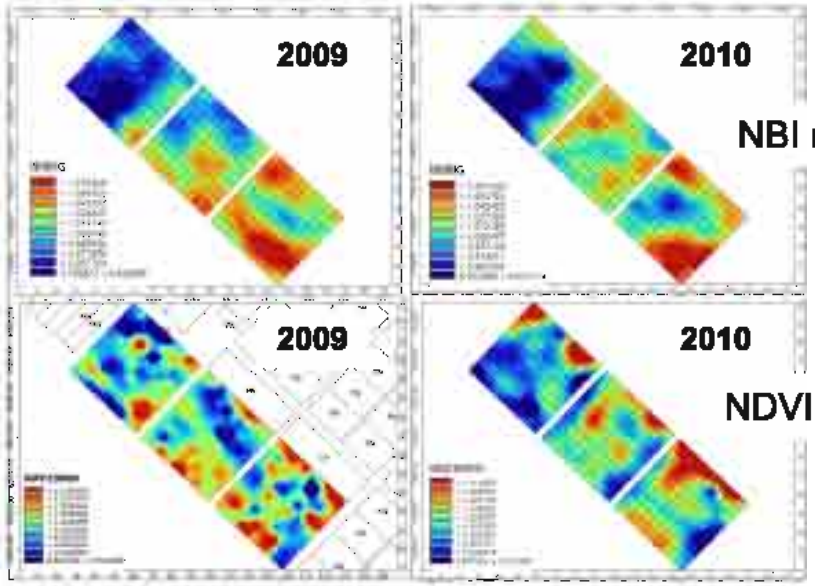
Grape maturation kinetics

40 marked clusters

ANTH_RG (Mx units)



Ben Ghozlen et al. (2010)
Sensors, 10: 010040

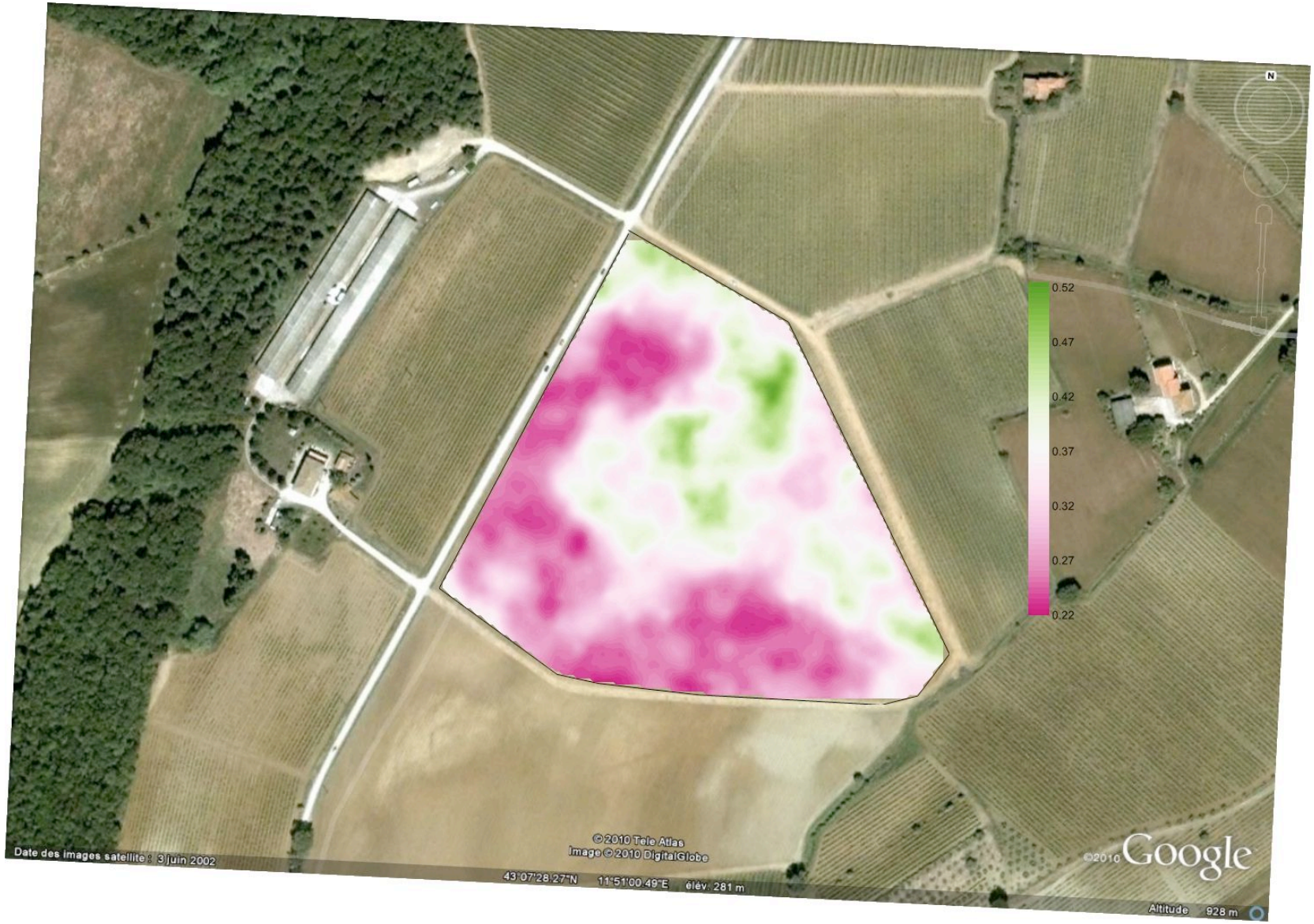


NBI $r^2 = 0.75$

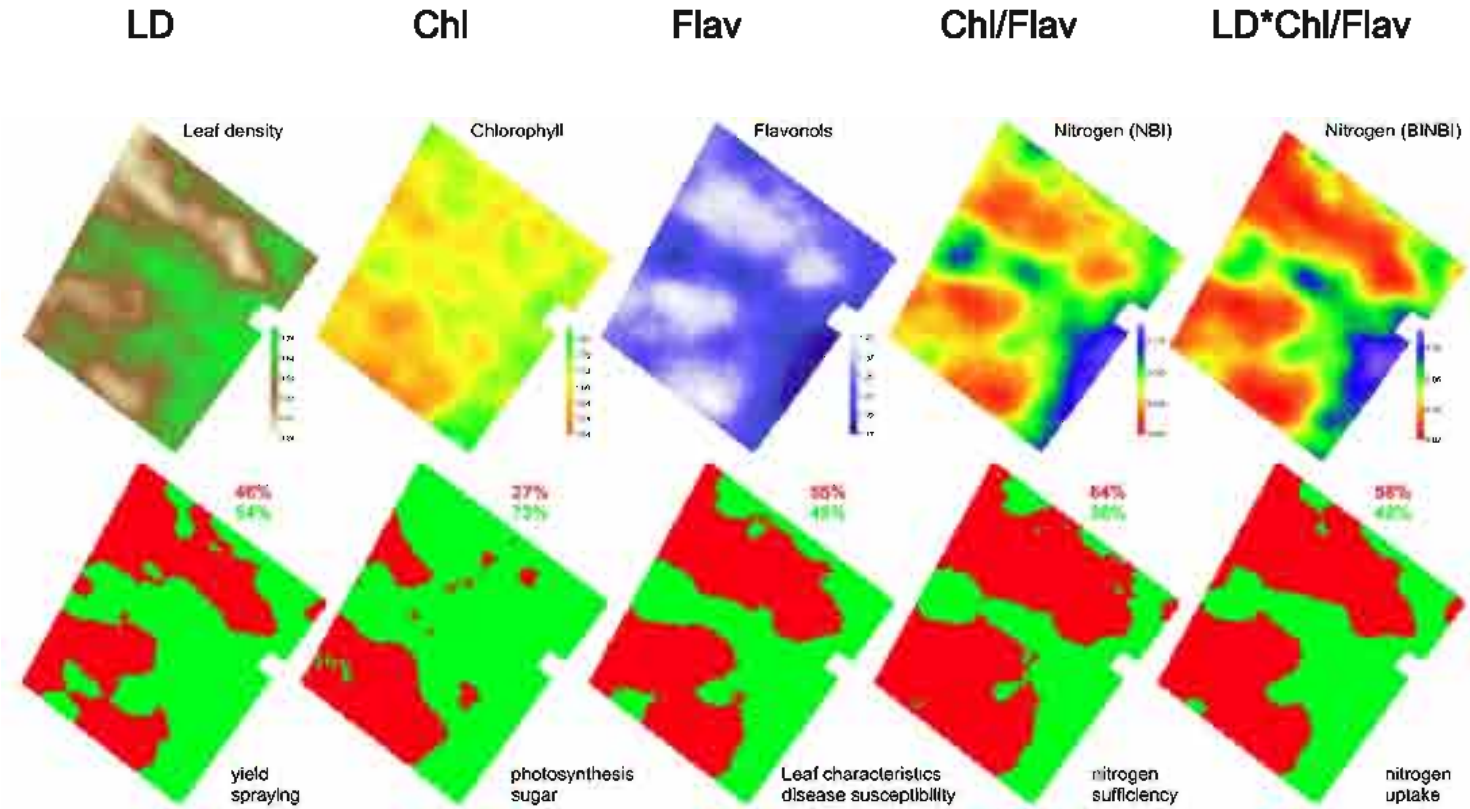
NDVI $r^2 = 0.11$

Debuisson et al. (2010)
10th ICPA, Denver

Grape-quality selective harvesting (Tuscany)



Mapping and zoning of leaves in viticulture (Bordeaux)



Mabrouk et al. (1998)
Stamatiadis et al. (2010)

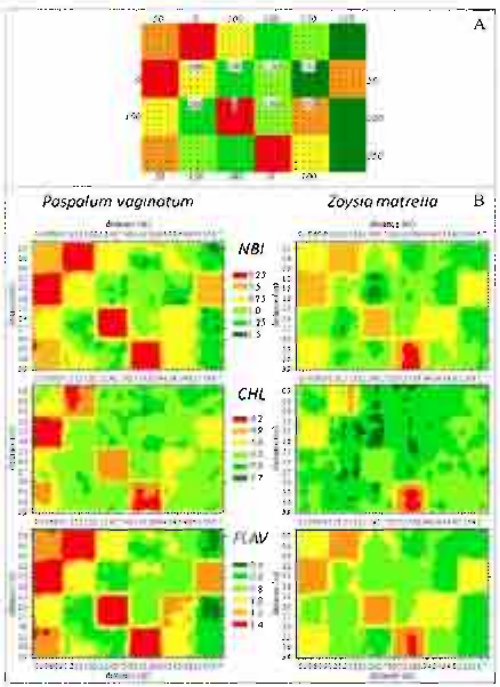
Martin et al. (2007)
Meggio et al. (2010)

Bavaresco & Eibach (1987)
Agati et al. (2008)

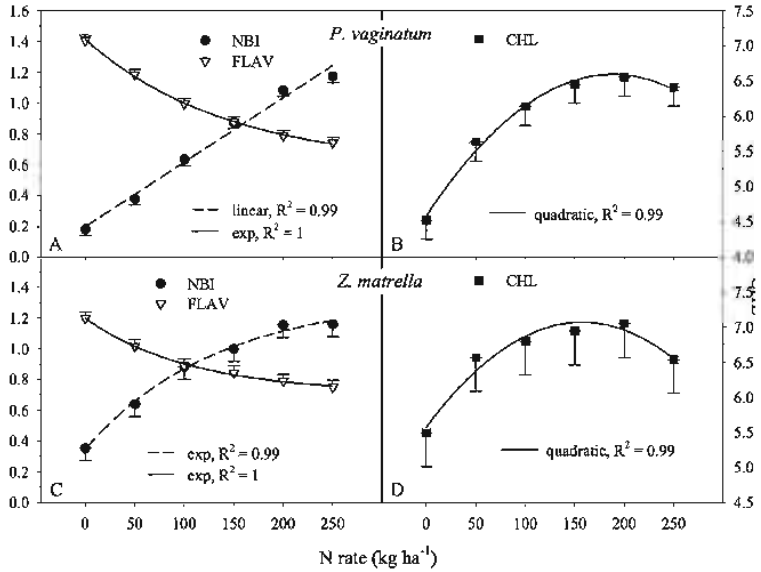
Cerovic et al. (2007) patent
Cerovic et al. (2009)

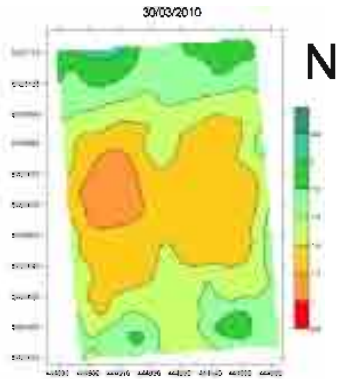
Debuisson et al. (2012)

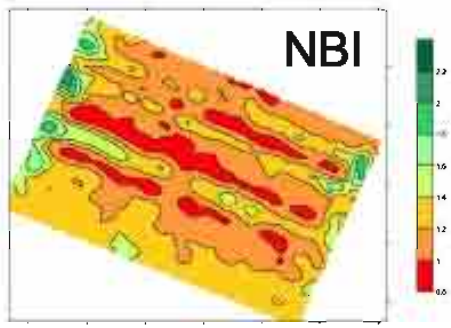
Turf grass



Agati et al. (2012) submitted to RSE

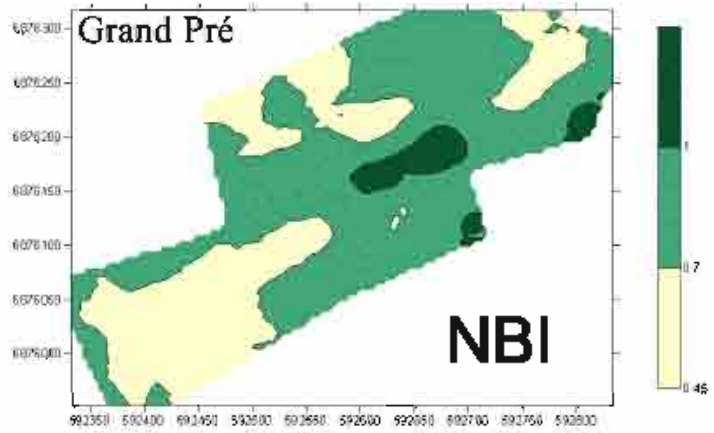


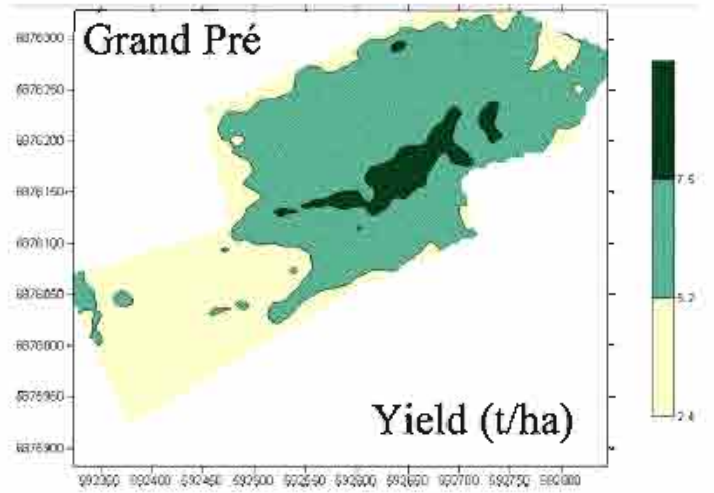




Lejealle et al. (2010)
10th ICPA, Denver

Wheat (row corps)





and also

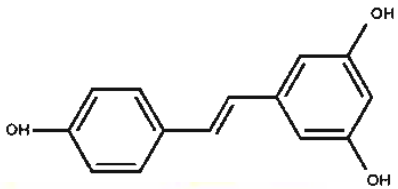
- maize
- rapeseed
- potato…

Martinson et al. (2010)
10th ICPA, Denver

Diseases diagnostics: downy mildew in grapevine

Mx-330

UV-exited "blue" fluorescence



Resveratrol

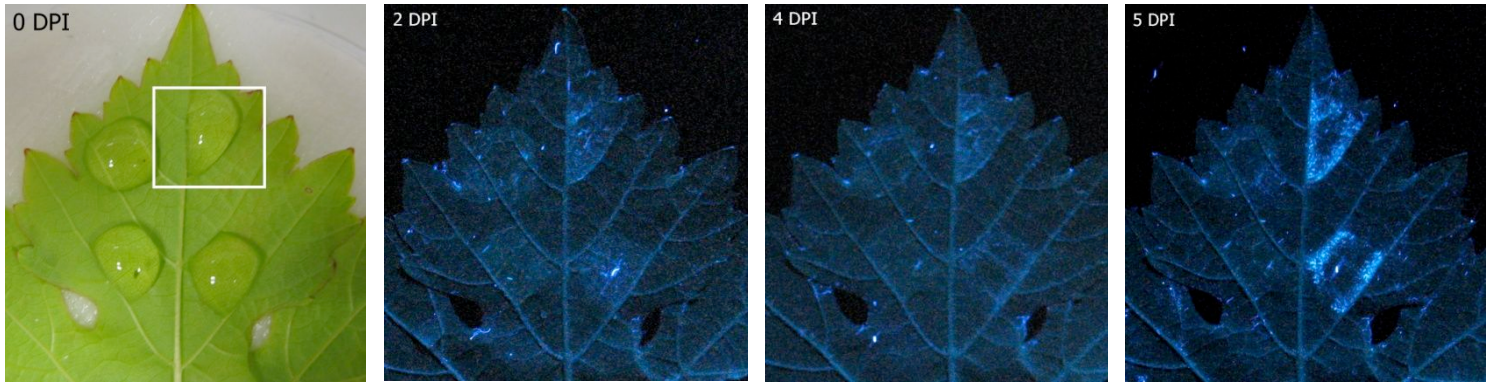
HCA

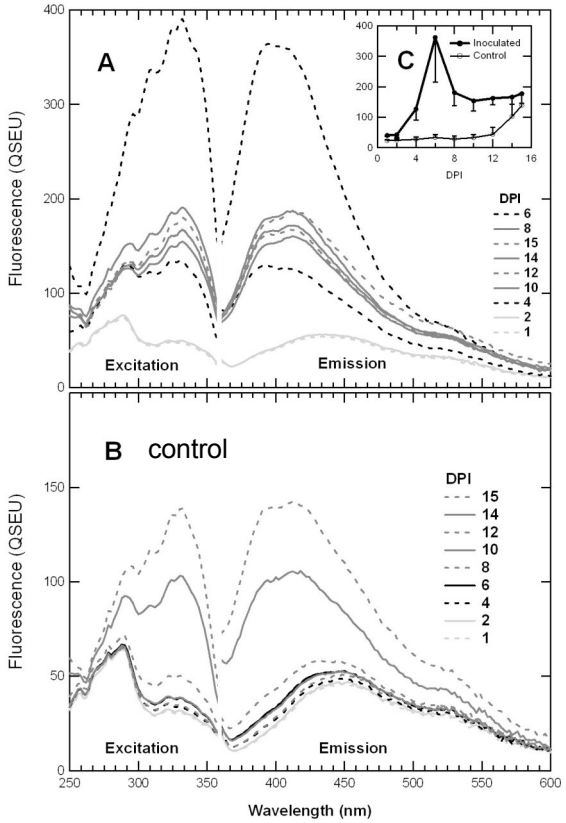
stilbenes

Fungi

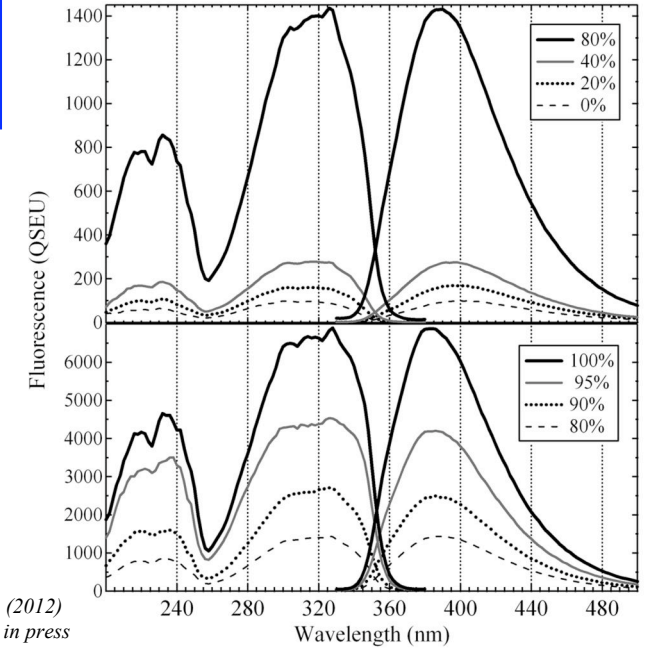
Resveratrol (stilbene) fluorescence as an indicator

Bellow et al. (2012) unpublished





Violet-blue fluorescence *in vivo*



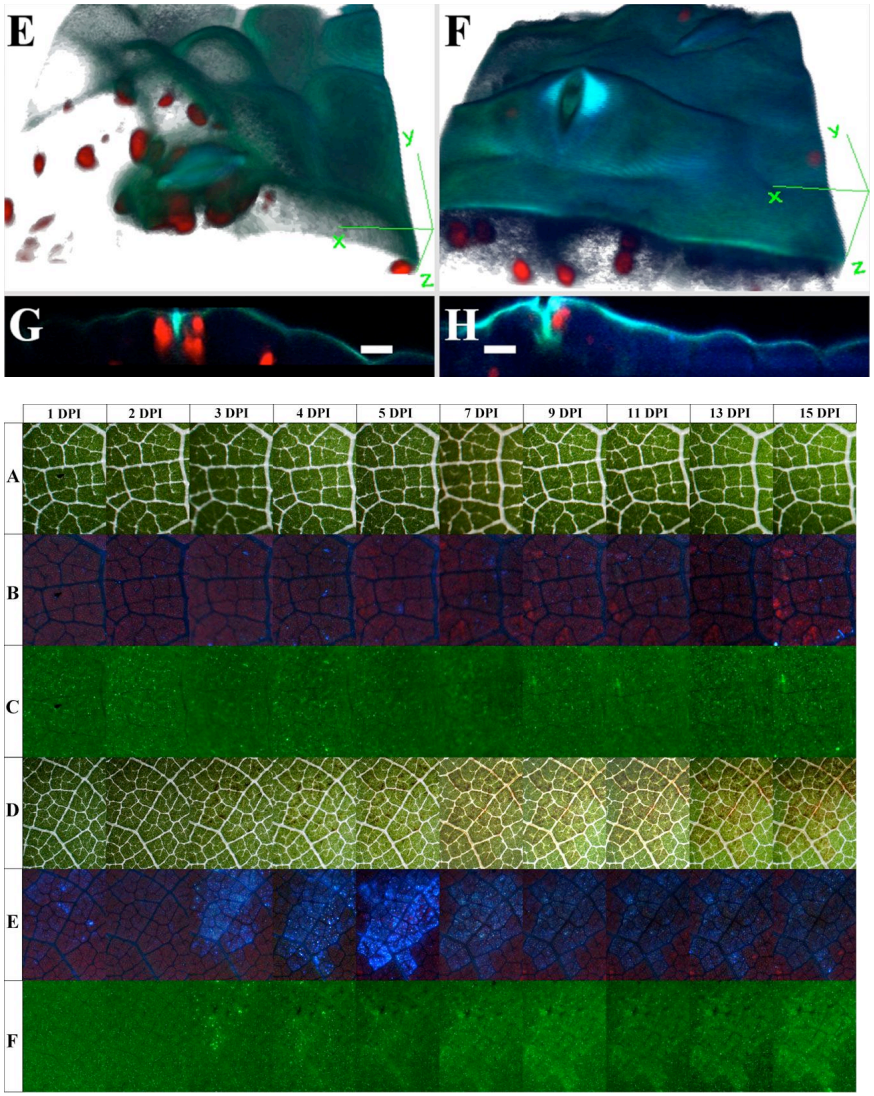
Bellow et al. (2012)
J. Exp. Bot., in press

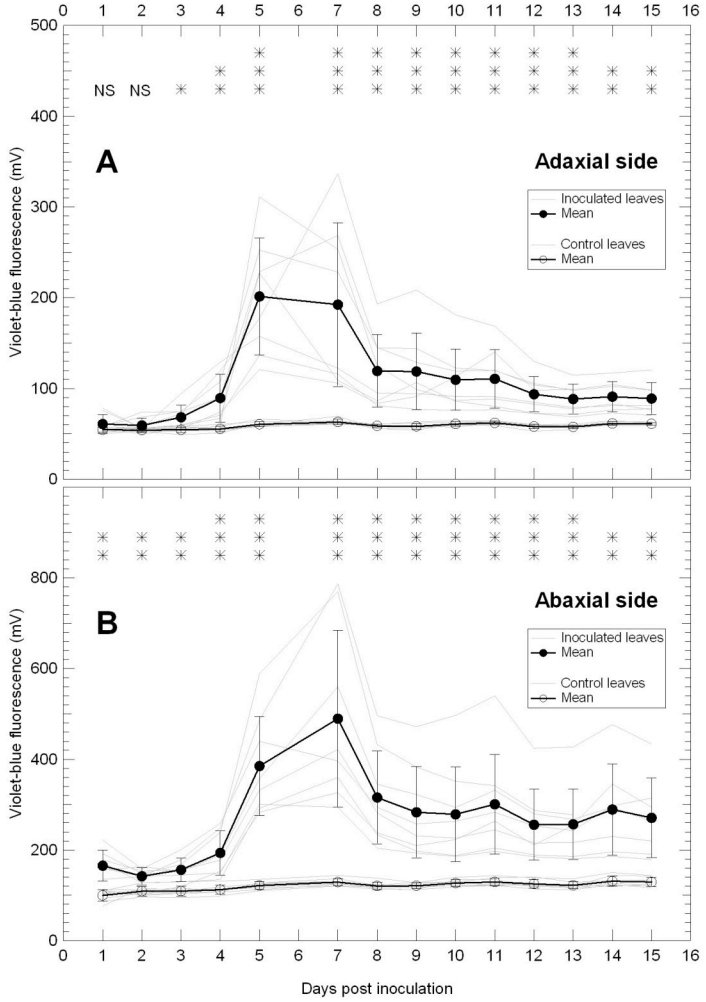
Bellow et al. (2012)
submitted to RSE

Resveratrol in glycerol/water

Diseases diagnostics: Downy mildew in grapevine

Bellow et al. (2012) J. Exp Bot., in press





Bellow et al. (2012) submitted to RSE

Take-home message

The concept of precision agriculture (PA)
has evolved.

Site-specific crop management (SSCM)
has now new better tools.

Sustainable agriculture (SA)
based on information technology and optical sensors
is at reach.

PA can contribute to the synergies between the four SA goals:

1) Satisfy human food, feed and fiber needs, and contribute to biofuel needs.

2) Enhance environmental quality and the resource base.

3) Sustain the economic viability of agriculture.

4) Enhance the quality of life for farmers, farm workers, and society as a whole.

National Research Council U.S.A. (2011)
Towards Sustainable Agricultural Systems in the 21st Century

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