New technologies for large scale phenotyping at the Wageningen UR Phenomics Innovation and Demonstration Centre

Gerrit Polder, Wageningen UR, Greenhouse Horticulture
Rick van de Zedde, Wageningen UR, Food and Biobased Research

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COST FA1306, WG1 meting, November 13-14, 2014

Outline

- Introduction
- MRI
- X-Ray tomography
- Germinator
- Marvin
- PhenoTron
- Spicy
- PhenoBot
- TopCrop Viewer
- Open field Plant counter
- CropScan
- Hyperspectral UAV

Wageningen University & Research Centre

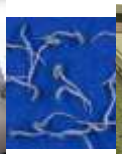
- A university plus R&D organisation for innovation in the agrifood sector.
- Working with industry, governmental authorities and other knowledge institutes

Phenotyping: molecular – canopy level

Proteomics
Metabolomics

MRI

Germinator



X-Ray tomograph

Phenotron

Marvin

Spicy
PhenoBot

TopCrop Viewer
CropScan
UAV

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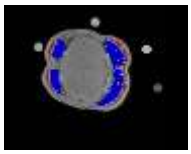
(portable) NMR / MRI and phenotyping

(Henk Van As, Lab. of Biophysics and Wageningen NMR Centre)



- Anatomy
- Internal parameters: transport traits (xylem and phloem; cell-to-cell), water content in different tissues
- Dynamics:
  - growth and (stress) adaptation
  - source-sink manipulations: light, tuber / fruit development, drought, anoxia, flooding
- Information from different organs (roots, stem, fruits, leaves, ..)

Amplitude R_2 T_2

http://www.wageningenur.nl/en/Expertise-Services/Facilities/Wageningen-NMR-Centre/Our-facilities-1/Plants.htm

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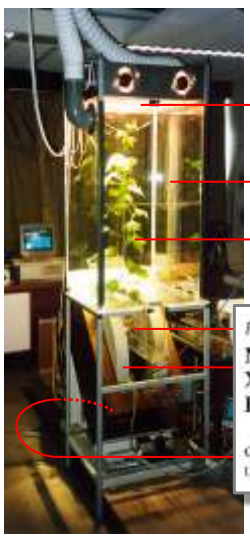
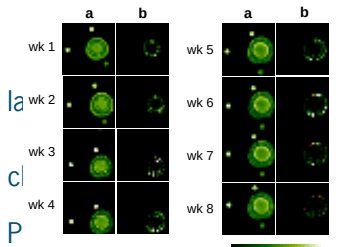
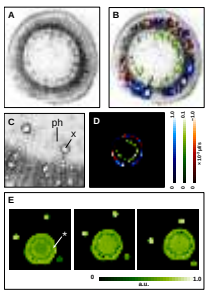
Plant MRI and phenotyping: system I







Plant Physiology®, October 2009, Vol. 151, pp. 830–842

Most Water in the Tomato Truss Is Imported through the Xylem, Not the Phloem: A Nuclear Magnetic Resonance Flow Imaging Study[W][OA]

Carel W. Windt[1*], Edo Gerkema, and Henk Van As
Laboratory of Biophysics, Wageningen University, 6703 HA Wageningen, The Netherlands

cooler

Balance

P.C.

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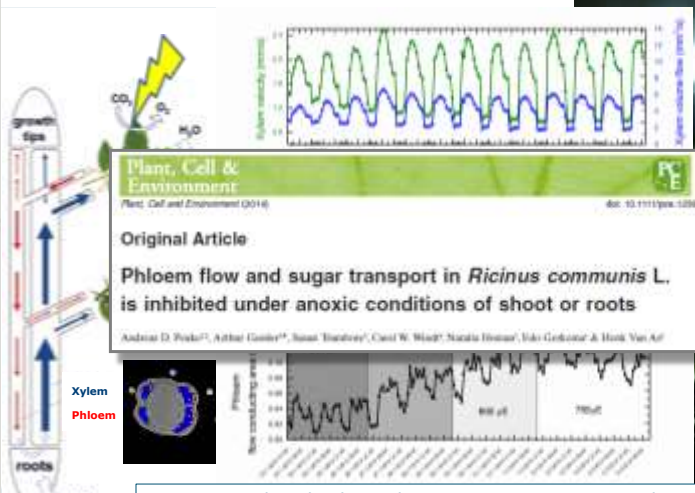
Dedicated Plant MRI system II: effect of light, sink-source manipulations

(tuber formation, fruits, anoxia, ...)



Plant, Cell & Environment

Original Article

Phloem flow and sugar transport in *Ricinus communis* L. is inhibited under anoxic conditions of shoot or roots

Prusova *et al*, Light dependent transport in potato and tomato plants, manuscript in prep.

WUR X-ray tomography facility

- CAT-AgroFood microCT centre operational April 2013
  - XRT Phoenix v[tome]x m GE
  - Two X-ray sources
    - High Resolution (≥ 0.8 µm)
    - Large Sample Size (40cm/50kg)
- Broad range of applications
  - structure-function relations
  - Foods, bio-based materials
  - soil, roots,
  - plants, seeds,
  - insects , ….

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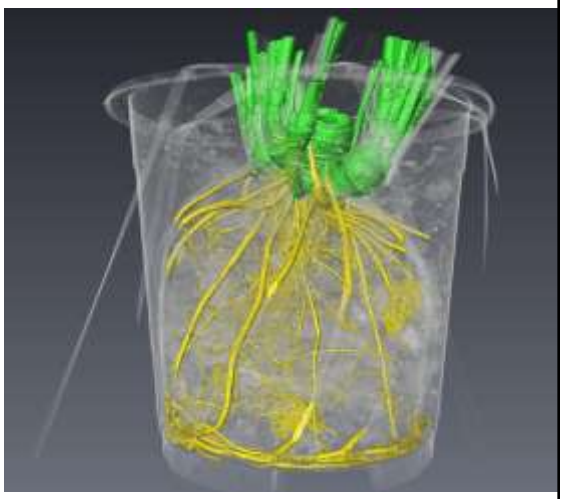
Root morphology

- Non-destructive characterisation of root structure
- Roots can be identified despite denser soil surrounding
- However, contrast of root with water is a challenge



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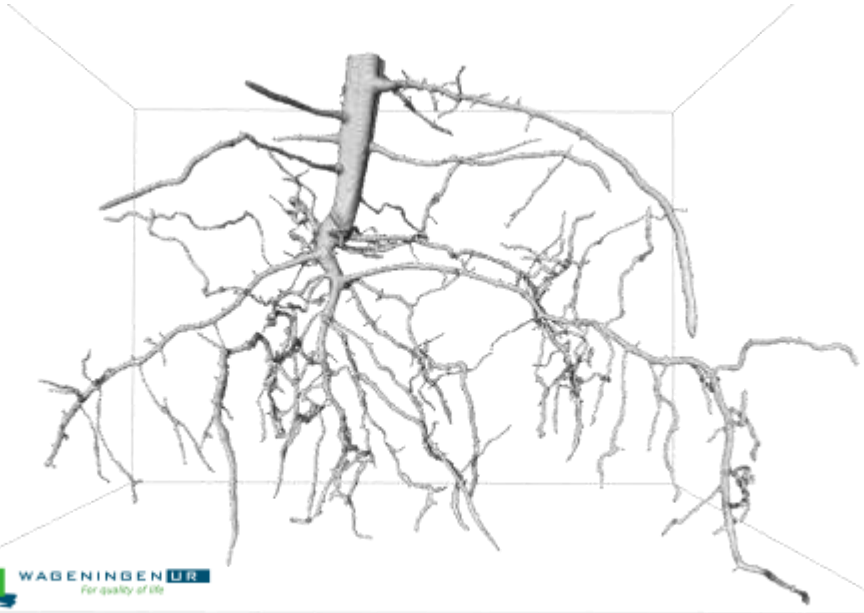
3D root binary voxel space



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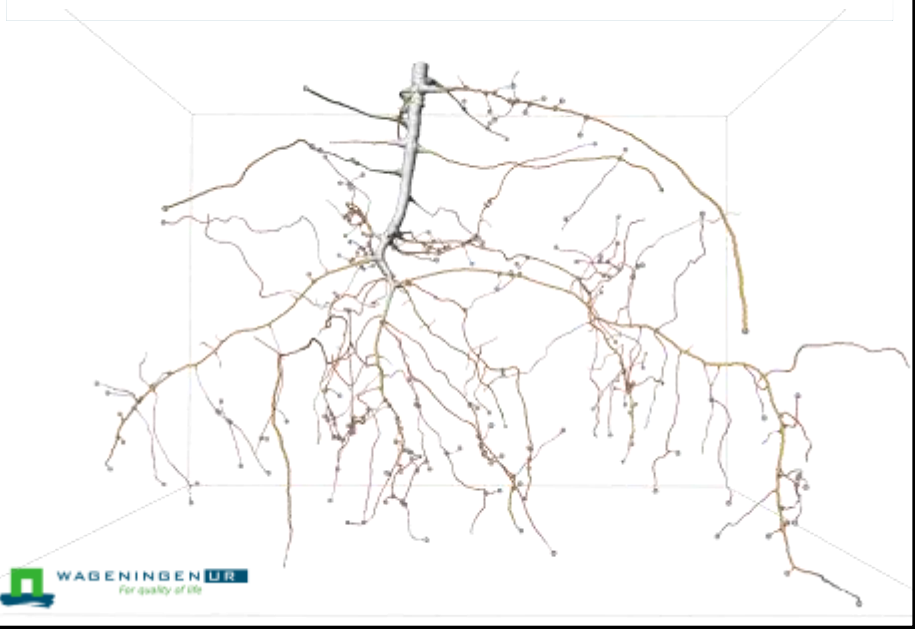
3D spatial graph with thickness



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GERMINATOR: High throughput scoring and analysis of seed germination

- Cost effective system with high accuracy
- Species independent (as long as there is enough color contrast between seed coat and radicle)
- Flexible setup (in number of samples and environments)
- Optimized experimental design (randomization of samples)
- Automatically visualizes and summarize results with graphs and statistics

- http://www.wageningenseedlab.nl/germinator

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SEED LAB
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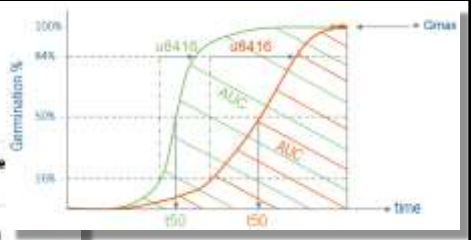
GERMINATOR: results



TECHNICAL ADVANCE

GERMINATOR: a software package for high-throughput scoring and curve fitting of Arabidopsis seed germination

Ronny V. L. Joosen[1*], Jan Kodde[2], Leo A. J. Willems[1], Wilco Ligterink[1], Linus H. W. van der Plas[1] and Henk W.M. Hilhorst[1]

Article first published online: 22 DEC 2009

The Plant Journal
Volume 62, Issue 1, pages 148–159, April 2010

Bioinformatics

Visualizing the Genetic Landscape of Arabidopsis Seed Performance[OPEN ACCESS]

Plant Physiology 2012

Distinct Cell Wall Architectures in Seed Endosperms in Representatives of the Brassicaceae and Solanaceae[OPEN ACCESS]

Plant Physiology 2012

Natural Variation for Seed Longevity and Seed Dormancy Are Negatively Correlated in Arabidopsis[OPEN ACCESS]

Plant Physiology 2012

Plant, Cell & Environment

Complex genetics controls natural variation among seed quality phenotypes in a recombinant inbred population of an interspecific cross between *Solanum lycopersicum* × *Solanum pimpinellifolium*

H. KAZMI[1,2], NOORULLAH KHAN, A. J. WILLEMS[1], ADRIAAN W. EUSDEN[1], WILCO LIGTERINK[1], ENK W. M. HILHORST[1]

Plant, Cell & Environment
Volume 35, Issue 5, pages 928–951, May 2012

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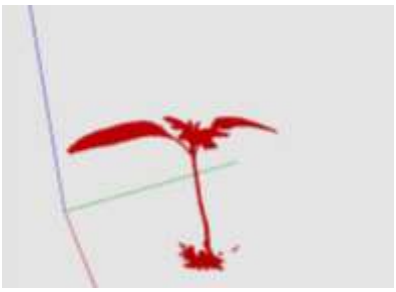
SEED LAB
WAGENINGEN

Phenotyping seedlings - imaging



- MARVIN – 3D based seedling sorting

MARVIN: high speed 3D imaging for seedling classification

N.J.I.P. Koenderink, M. Wigham, F. Golbach, G. Otten, R. Gerlich and H.J. van de Zedde
Wageningen UR – Greenhouse Horticulture, Droevendaalsesteeg 3C, 6708 PD Wageningen, the Netherlands;
nicole.koenderink@wur.nl

Abstract

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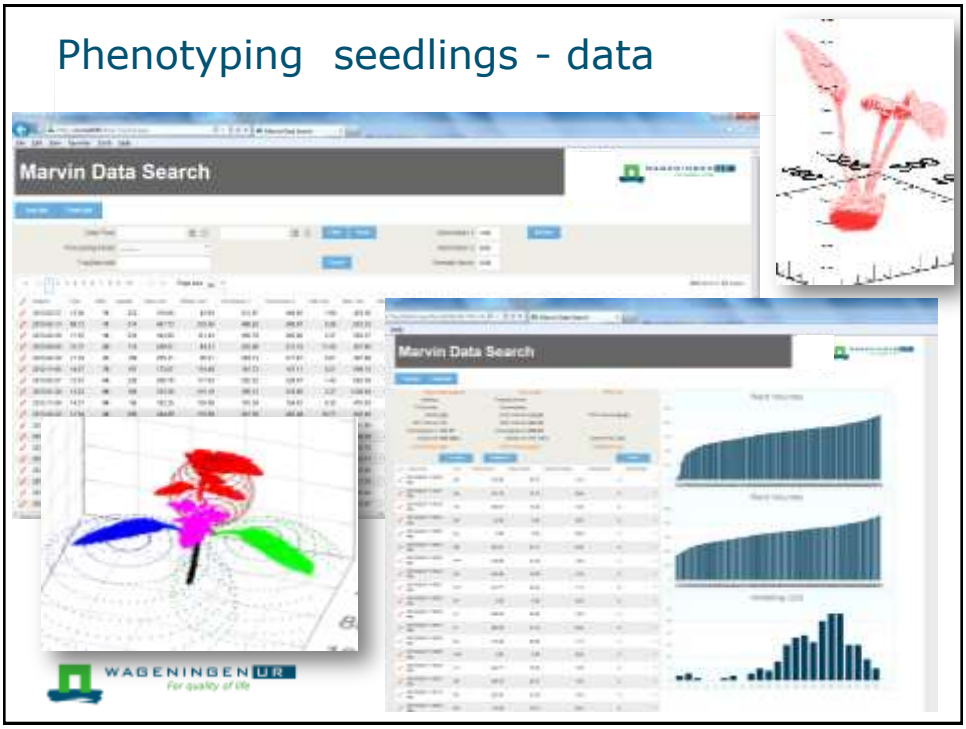
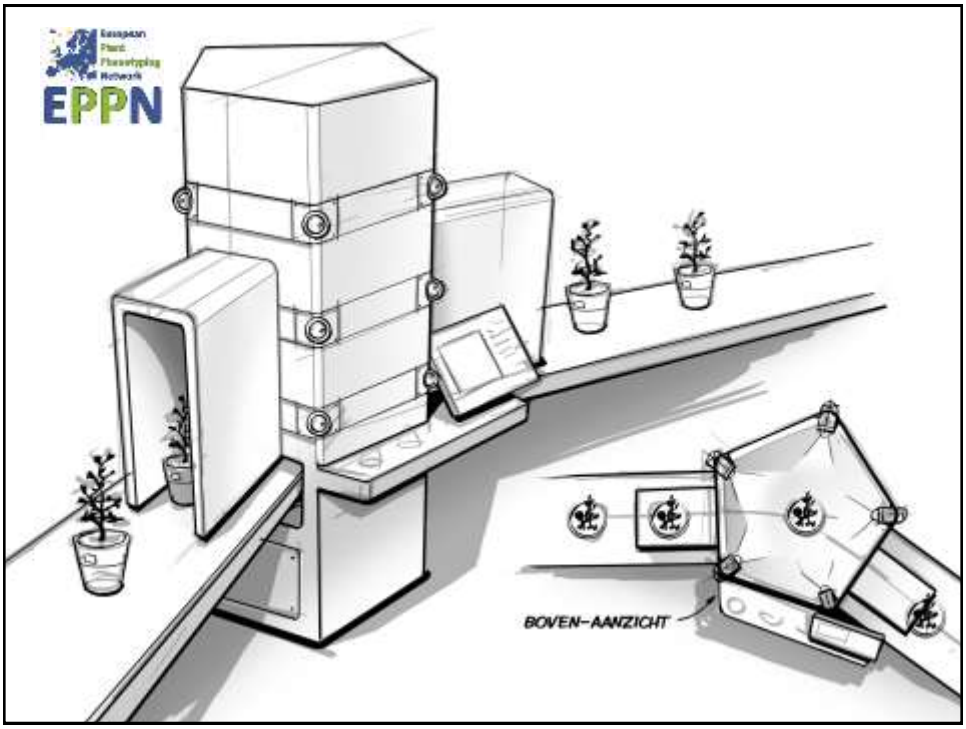
Phenotyping seedlings - data






Height:
4 m
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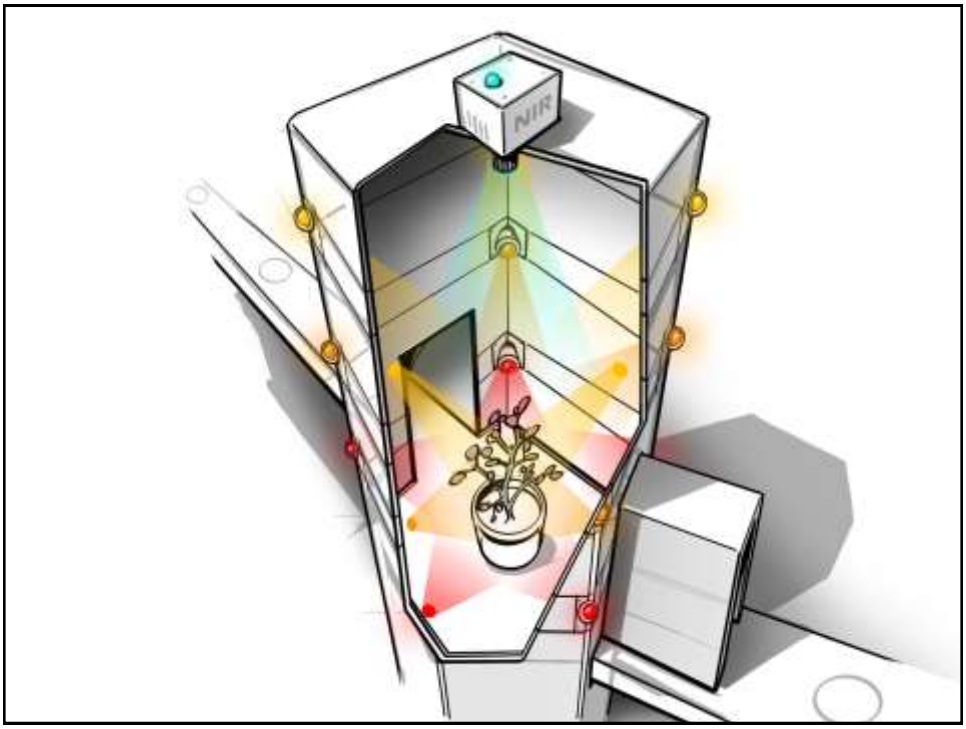
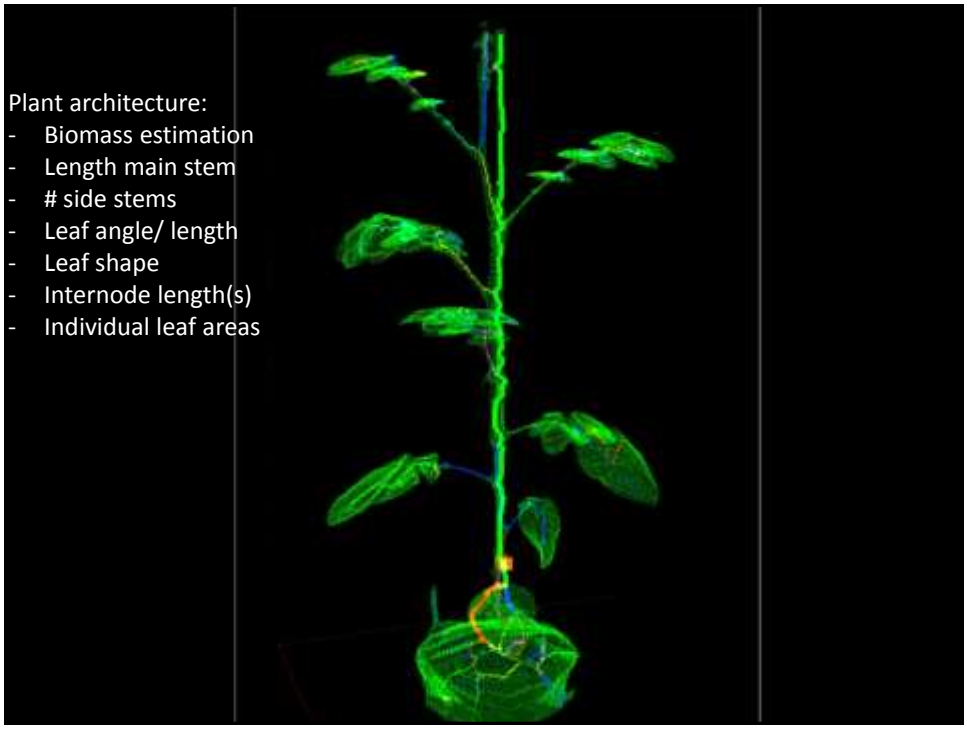
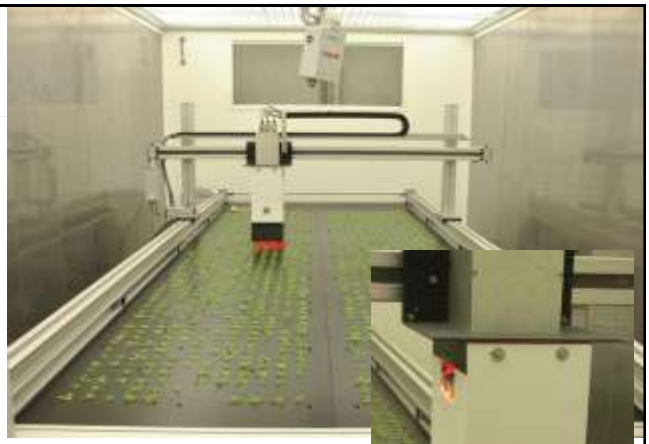

NIR

Plant architecture:
- Biomass estimation
- Length main stem
- # side stems
- Leaf angle/ length
- Leaf shape
- Internode length(s)
- Individual leaf areas



PhenoTron

- chlorophyll fluorescence; Fo, Fo', Fm, Fm', Fs - for Fv/Fm,
- NPQ and ΦPSII (etc) imaging
- NIR imaging: day and night plant imaging



- narrow band imaging for chlorophyll and anthocyanin content
- red, green and blue imaging - colour images
- photochemical reflectance index (ΔA535) = (R531 -R570)/(R531 + R570)

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PhenoTron

- 1440 plants - every plant is fixed and registered
- c. 60 minutes to image every plant ΦPSII at growth irradiance
- typically 25 days per run
- about 100 GB data per run
- one PhD student has imaged about 20.000 plants

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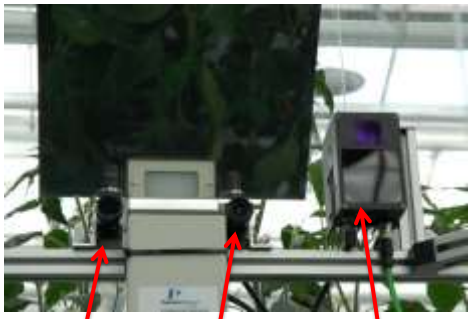
SPICY: Smart tools for Prediction and Improvement of Crop Yield

- Develop tools to predict phenotypic response of a genotype under a range of environmental conditions:
- Molecular tools
- Analysis tools
- Phenotyping tools
- Applied to pepper

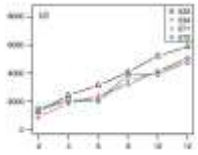
- http://www.spicyweb.eu

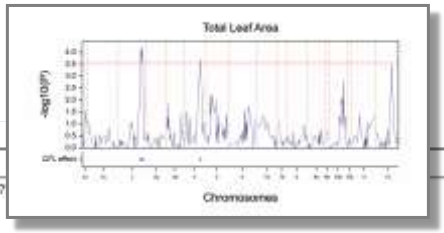
SPICY: Phenotyping tools



4* IR, Colour, Range (ToF) cameras

SPICY: results





CSIRO PUBLISHING
Functional Plant Biology, 2012, 39, 870–87
http://dx.doi.org/10.1071/FP12019

SPICY: towards automated phenotyping of large pepper plants in the greenhouse

Gerie van der Heijden[A,E], Yu Song[B], Graham Horgan[C], Gerrit Polder[A], Anja Dieleman[A], Marco Bink[A], Alain Palloix[D], Fred van Eeuwijk[A] and Chris Glasbey[B]

CSIRO PUBLISHING
Functional Plant Biology
http://dx.doi.org/10.1071/FP14070

Automated estimation of leaf area development in sweet pepper plants from image analysis

Graham W. Horgan[A,E], Yu Song[B], Chris A. Glasbey[B], Gerie W. A. M. van der Heijden[C,D], Gerrit Polder[C], J. Anja Dieleman[C], Marco C. A. M. Bink[C] and Fred A. van Eeuwijk[C]

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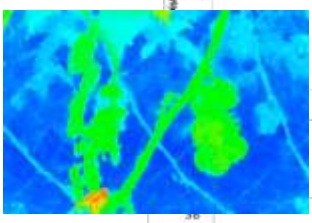
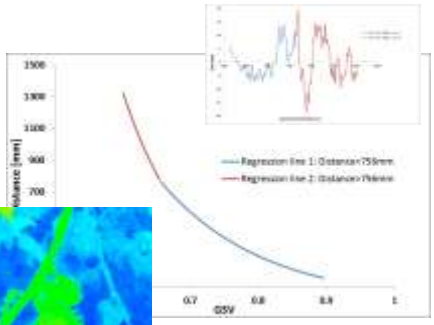
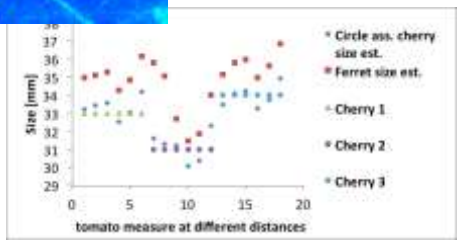
COOPERATION

spicy

PhenoBot – Robotised trolley with 3D lightfield camera







PhenoBot – Greenhouse measurements

An ASABE – CSBE/ASABE Joint Meeting Presentation

Paper Number: 141882255

Phenotyping large tomato plants in the greenhouse using a 3D light-field camera

Gerrit Polder[1,3], Jan Willem Hofstee[2]

[1] Wageningen UR, Greenhouse Horticulture, P.O. Box 644, 6700 AP Wageningen, The Netherlands

[2] Wageningen University, Farm technology Group, P.O. Box 317, 6700 AH Wageningen, The Netherlands

[3] Consortium for Improving Plant Yield (CIPY), P.O. Box 98, 6700 AB Wageningen, The Netherlands

Written for presentation at the

2014 ASABE and CSBE/SCGAB Annual International Meeting

Sponsored by ASABE

Montreal, Quebec Canada

July 13 – 16, 2014

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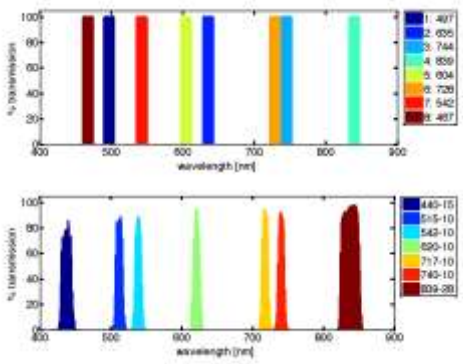
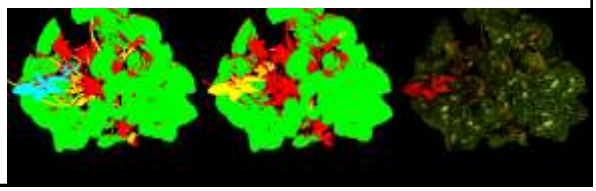
TopCrop Viewer – multispectral disease detection





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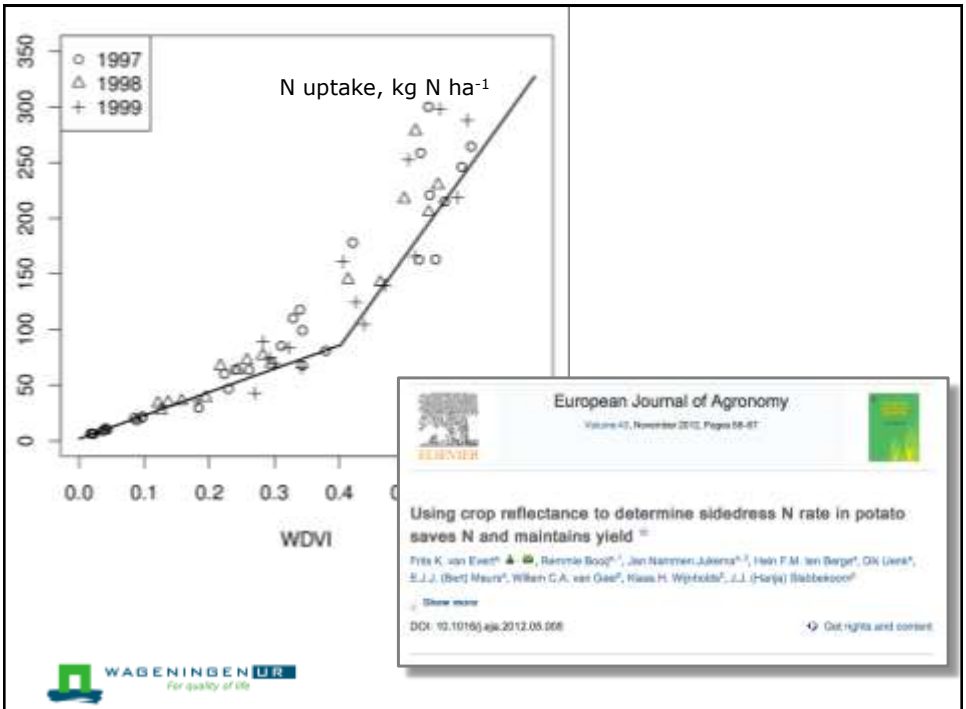
TopCrop Viewer – multispectral disease detection

Automatic plant counter in open field

Pieter Blok, Jochen Hemming

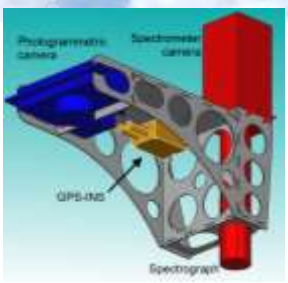
CropScan

- Can N status of potato be measured accurately using crop reflectance?
- Is there a simple translation from crop N status to N sidedress rate?



Hyperspectral Mapping from UAV

- Aerialtronics Altura AT8
  - Programmable autonomous flight
  - 2kg payload
  - 5-10 min flight time
- Pushbroom spectrograph
  - Specim V10
  - 450-950nm
  - FWHM 9nm
  - 20 lines/s
- Consumer RGB camera
- GPS/Inertia navigation System
  - Accuracy: 4m / 0.25°



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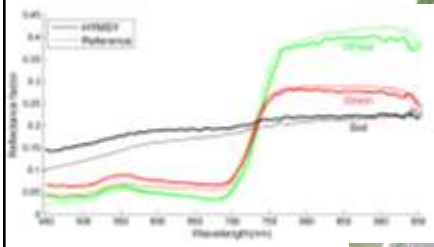
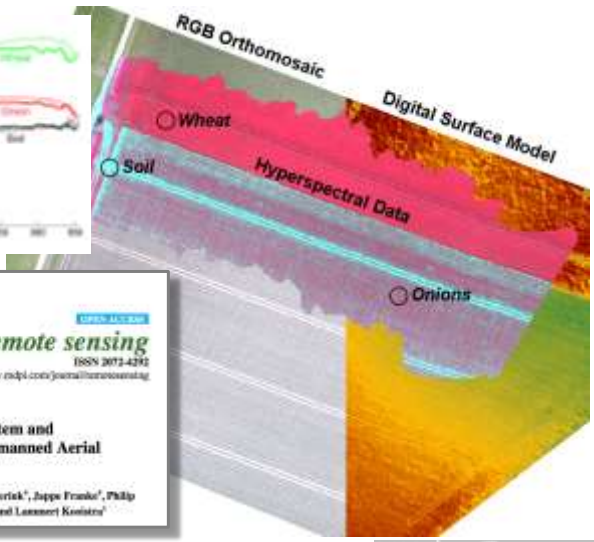
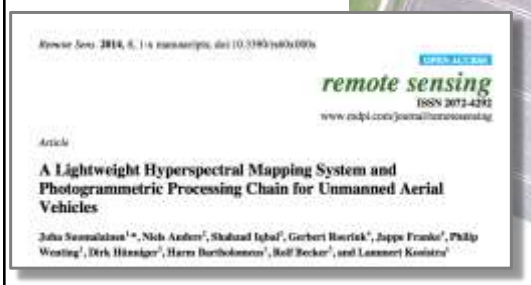
Products Experimental Arable Field







remote sensing
ISSN 2072-4292

Article

A Lightweight Hyperspectral Mapping System and Photogrammetric Processing Chain for Unmanned Aerial Vehicles

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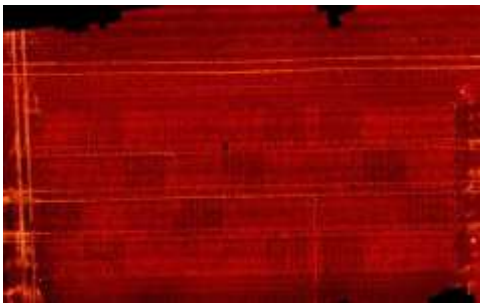
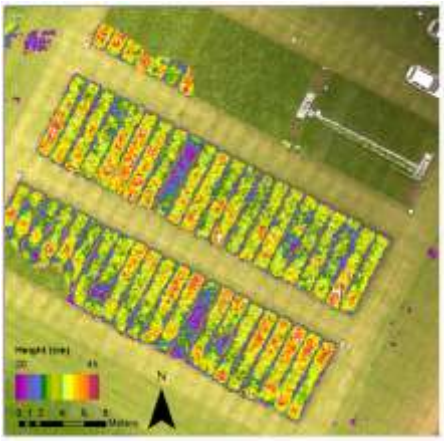
Examples field trails 2014



Winter wheat 160 fields: three varieties, four nutrient levels UAV data products and 10+ traits

More information: www.wageningen-ur.nl/uarsf

Grassland 60 fields: 12 nutrient levels (incl org) UAV data products and 8 traits



Acknowledgements

Henk van As, Wilco Ligterink, Ronny Joosen, Nicoline Koenderink, Mary Wigham, Frank Golbach, Gerwoud Otten, Jeremy Harbinson, Gerie van der Heijden, Yu Song, Graham Horgan, Anja Dieleman, Marco Bink, Fred van Eeuwijk, Chris Glasbey, Dick Lensing, Bram Veldhuisen, Hans Janssen, Marco Snikkers, Pieter Blok, Jochen Hemming, Erik Pekkeriet, Frits van Evert, Juha Suomalainen, Harm Bartolomeus, Lammert Kooistra, Leo Marcelis, and …… many many more!