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Leaf area and leaf orientation measurement by using stereo-vision

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Introduction

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Introduction

- Ecotron
  - Limited cultivated area
    - ⇒ Limited possibilities for sampling
    - ⇒ Needs for a non-destructive measurement technique, dedicated for scientist who are not expert in the measurement system (Image analysis)
  - Aerial parts
    - Leaf area index : LAI
    - Average leaf angle : ALA
    - N, …
  - Root system

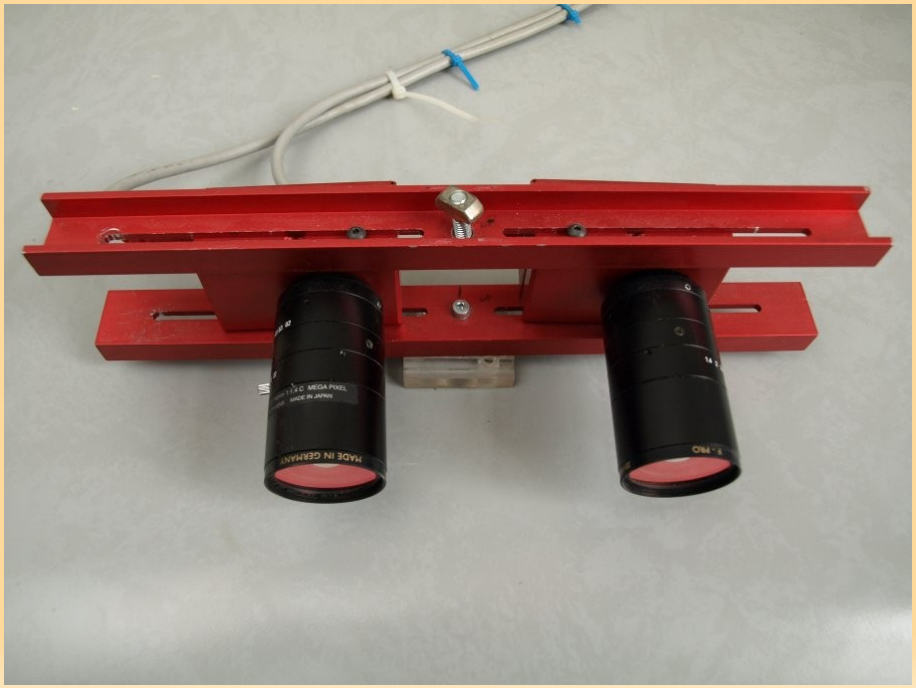
Introduction

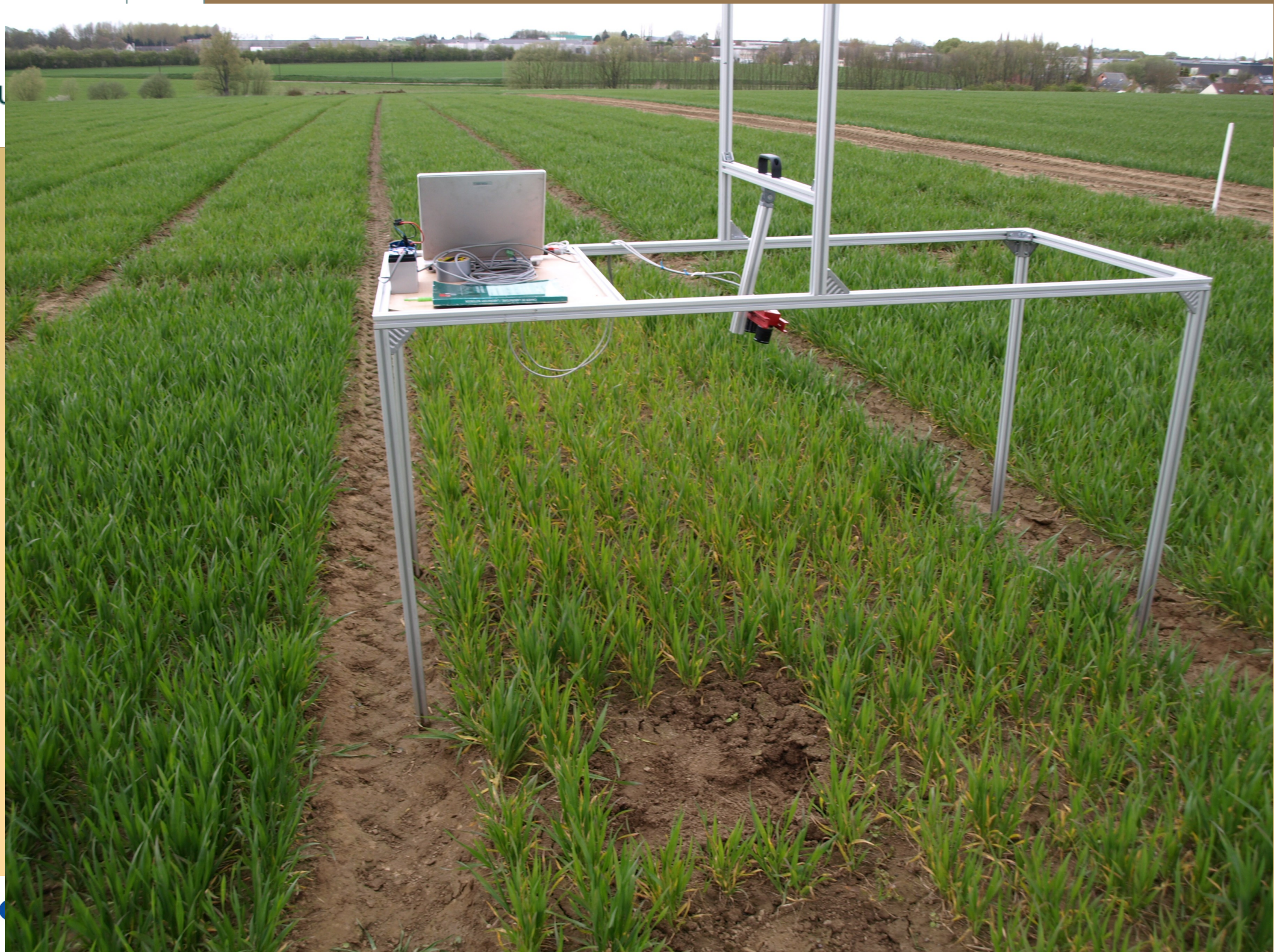
- Ecotron
- Field measurements
  - Leaf Area Index (LAI) is an important measurement for agronomist and modellers
  - Its measure is destructive, tedious and expensive


28x20 cm
Date : 4/6/13
Bloc : 408 - 1
Repet. :
Page : 1

Material

- Stereo images acquisition :
  - Two cameras 1024*768 or 1280 * 960 pix
  - Base distance : 115 mm
  - Distance camera-crop :+/- 1.3 m
  - Focal length : 16 mm
  - Vergence : 3.5°
  - Disparity of 1 pixel ≈ Δz 2 mm





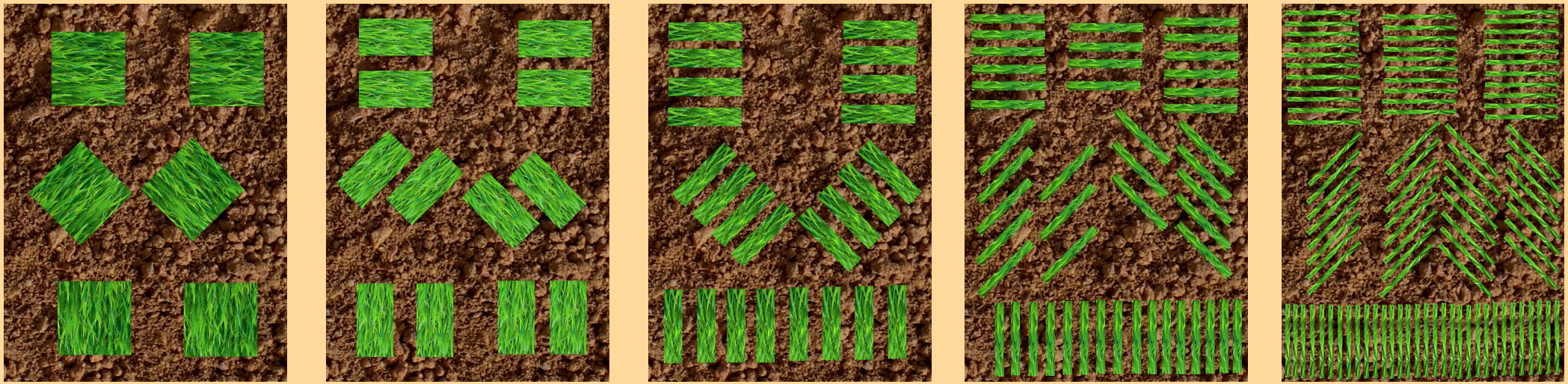
Method

- Measurements were made on 8 plots dedicated to N application assessment in order to have different LAI references
  - 2 N applications
  - 4 plot repetitions
  - 3 dates (8thApril, 6th May, 4th June)
  - 5 stereo image couples per plots
  - 1 destructive reference measures on 50 cm for each plot

    $\Rightarrow$ Quantification of the accuracy and the precision

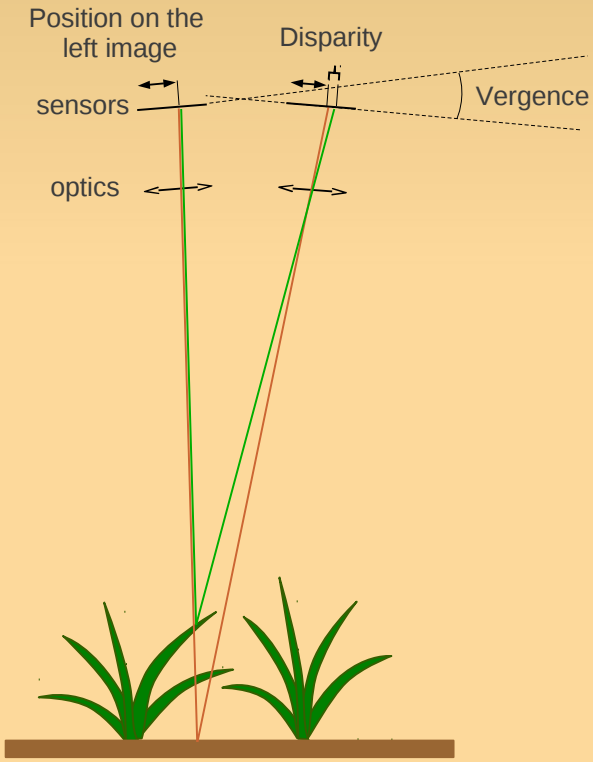
Method

- Error quantification
  - Accuracy and precision were assessed by using 5 pattern of known “leaf” area (0.0155m²) :



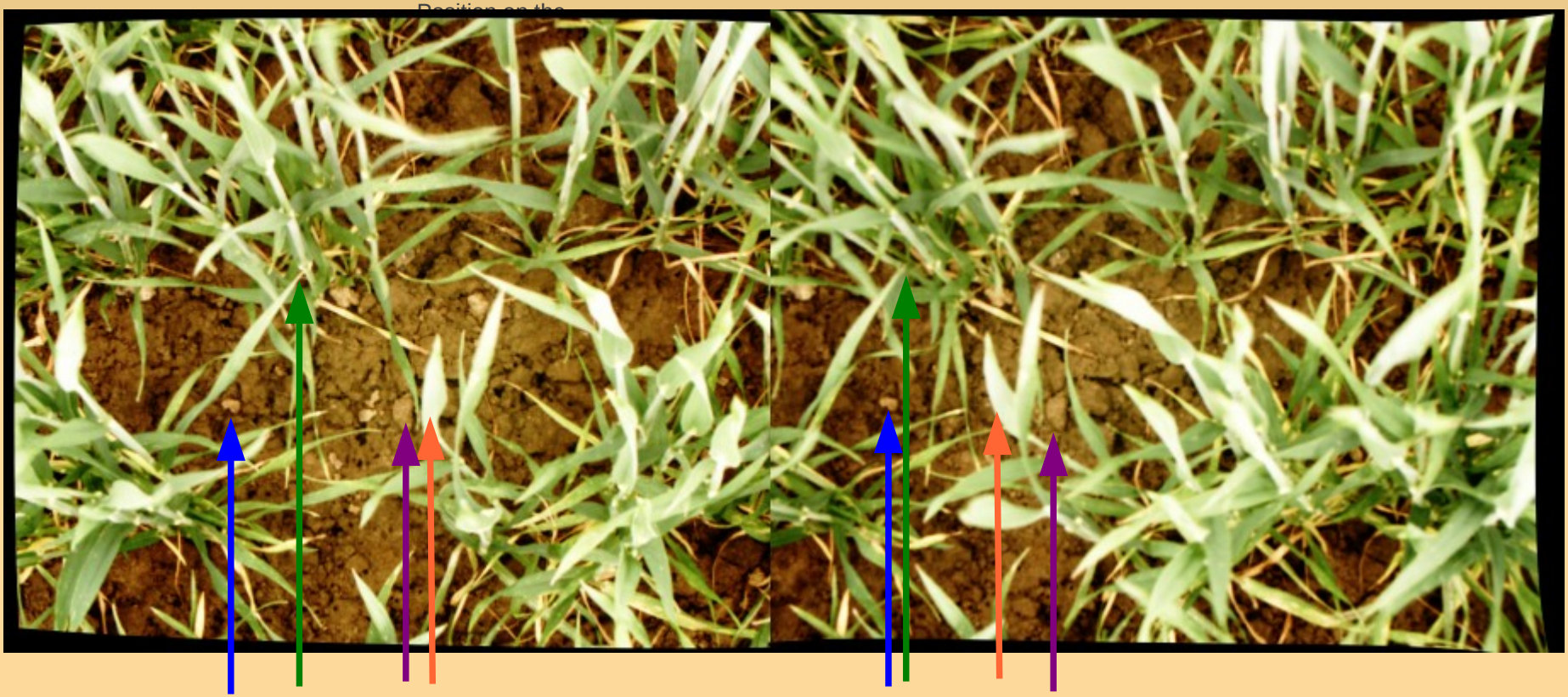
Method

- Principle



Method

- Principle



Method

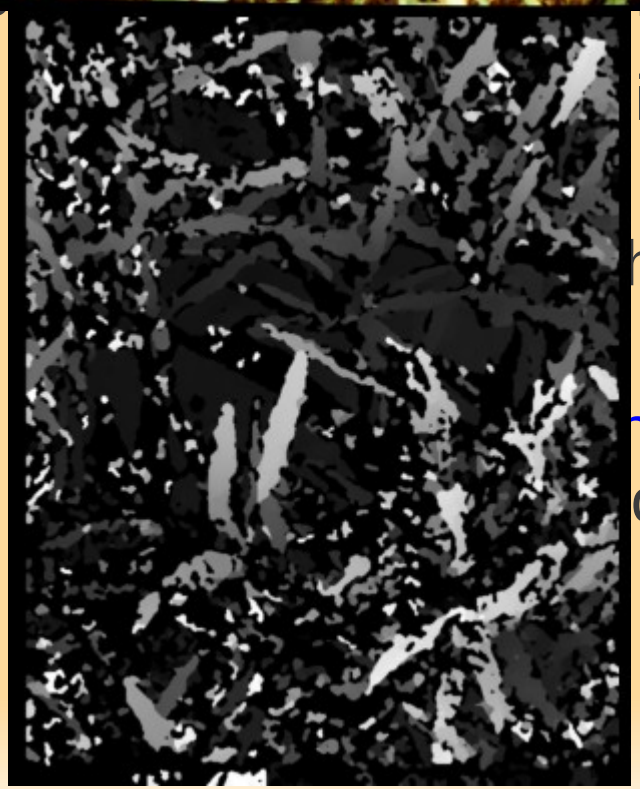
- Algorithm
  - Histogram equalisation *
  - Image rectification *
    - To have the same points on the same lines on both images

* : OpenCV Libraries

Method

- Algorithm
  - Histogram equalisation *
  - Image rectification *
  - Measurement of the disparities in pixels *
    - “modified H. Hirschmuller algorithm”
    - For each pixel of the left image, research in the right image the best match of a block centred on the pixel
    - Block size, MinDisparity, DisparityRange are parameters to be given to the software

* : OpenCV Libraries



irschmuller algorithm”

of the left image, research in the
he best match of a block centred

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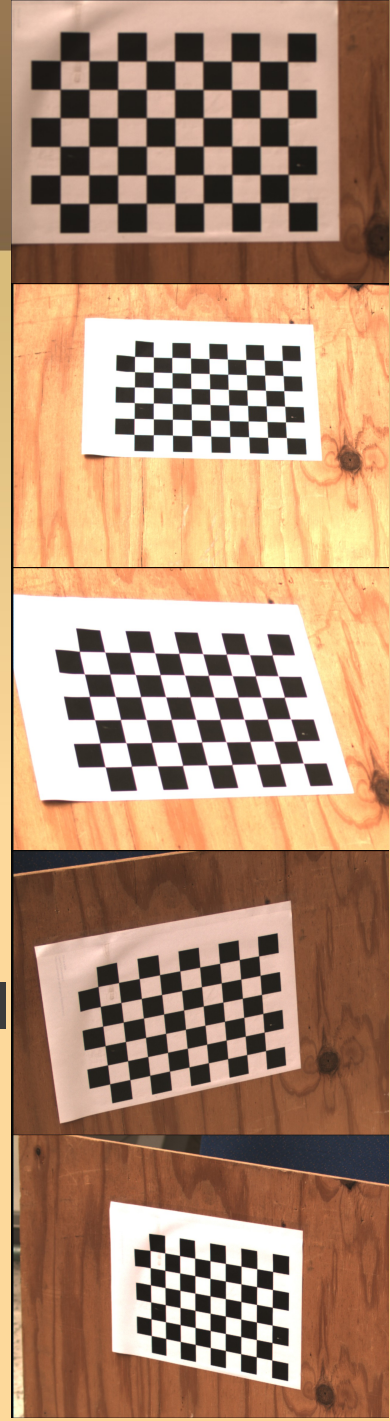
Method

- Algorithm
  - Histogram equalisation *
  - Image rectification *
  - Measurement of the disparities in pixels *
  - Post treatments *
    - Eliminate doubtful data and hidden pixels
    - Compute xyz in ”human” coordinates *

      xyd [pixels] → xyz [m]

* : OpenCV Libraries

Method



- Algorithm
  - Histogram equalisation *
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xyd [pixels] → xyz [m]

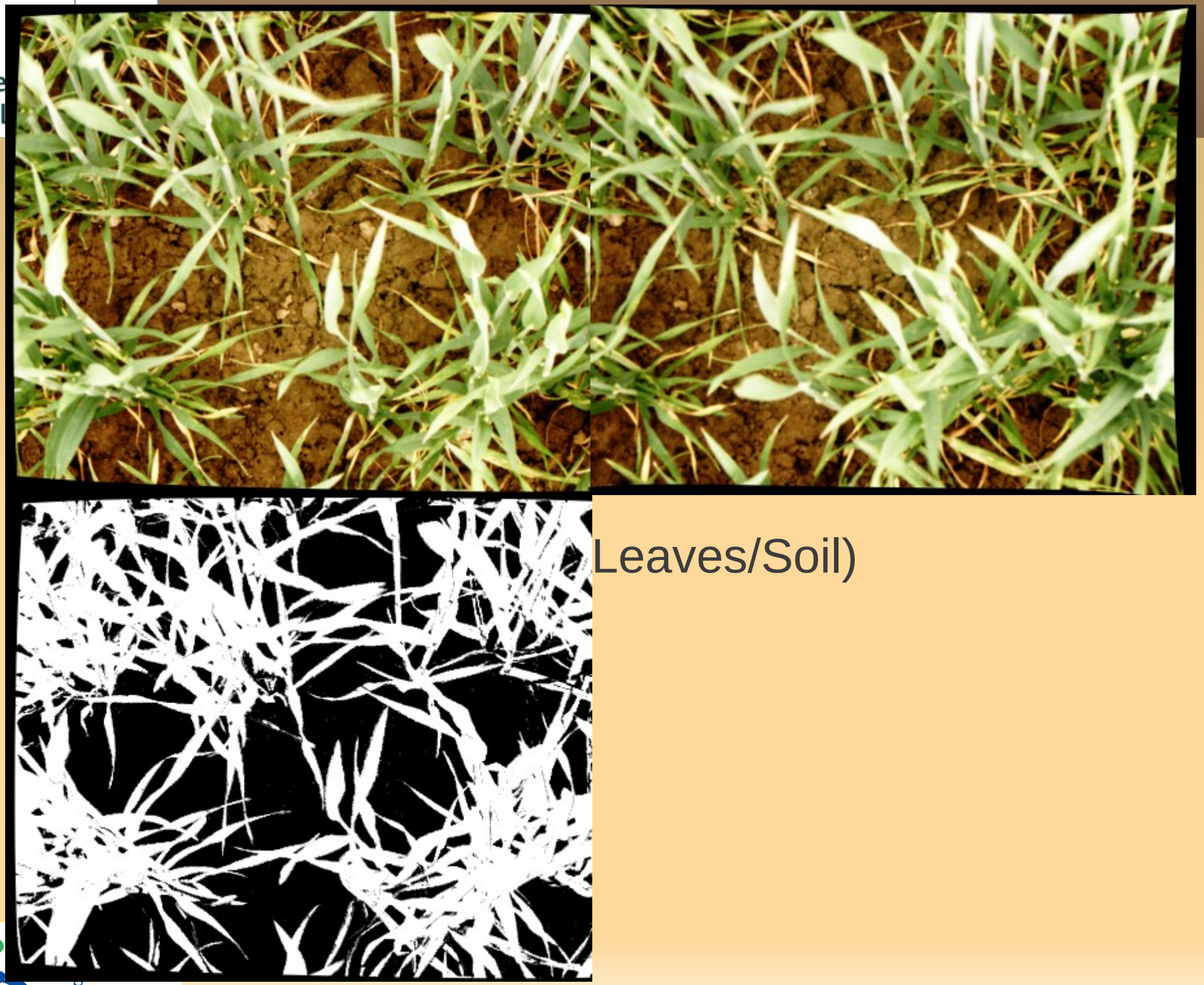
Calibration setup by using calibration * (indoor, check-board)

* : OpenCV Libraries

Method

- Algorithm
  - Histogram equalisation *
  - Image rectification *
  - Measurement of the disparities in pixels *
  - Post treatments *
  - Image segmentation (Leaves/Soil)
    - Linear discriminant analysis * on RGB

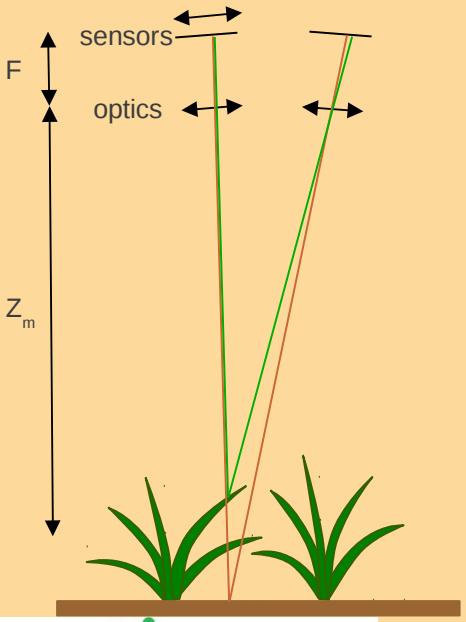
* : OpenCV Libraries



Leaves/Soil)

Method

- Algorithm
  - ...
  - Image segmentation (Leaves/Soil)
  - Computation of the areas
    - Leaves $\sum_{triangles} |\overrightarrow{AB} \times \overrightarrow{AC}|/2$
    - Total : based on the mean leave z plane
    - LAI = Leave Area / Total Area
    - ALA : mean of α



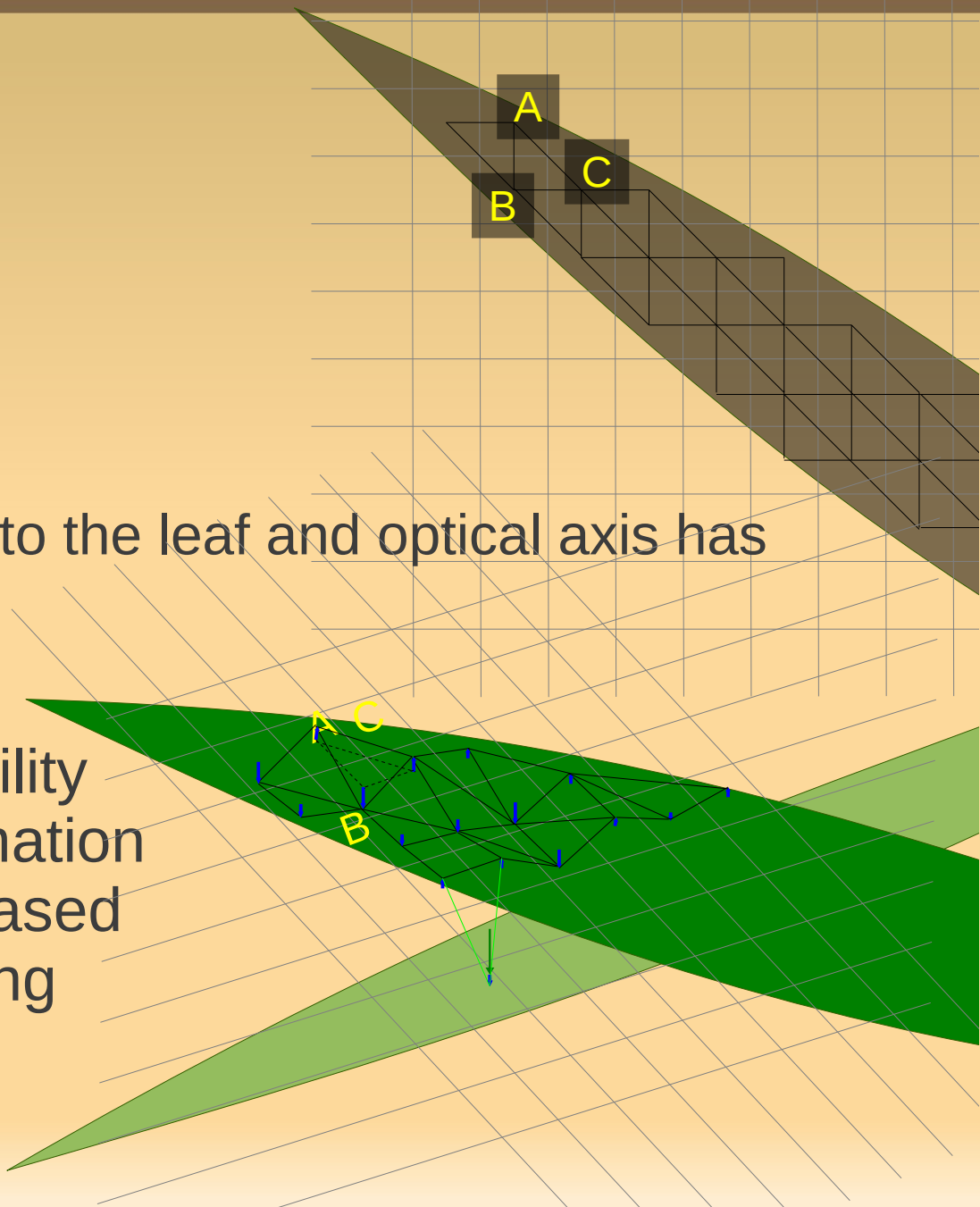
$$CP = \overrightarrow{AB} \times \overrightarrow{AC}$$

$$\alpha = acos\left(\frac{CP_z}{|CP|}\right)$$

Method

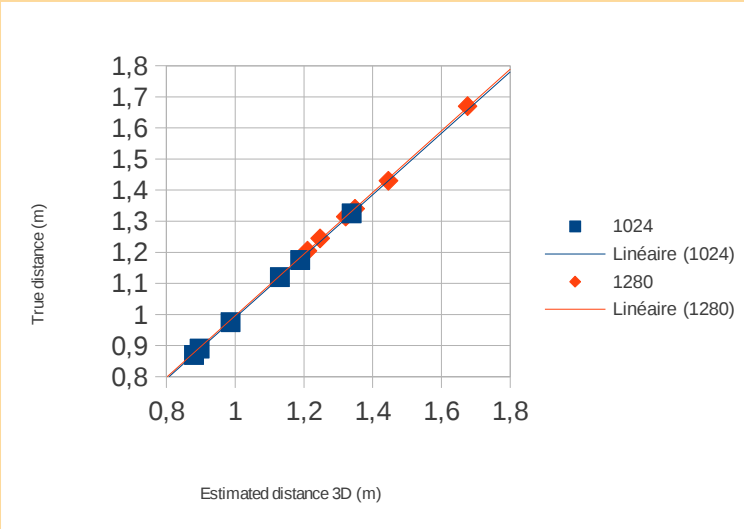
- Possible sources of error
  - Measurement noise in z
  - Leaves criss-crossing
  - Angle with the optical axis
  - $\Rightarrow$ Angle between normal to the leaf and optical axis has been limited : $\cos(\alpha) > 0.2$

- Because of the high variability of the LAI in the field, estimation of the reference LAI was based on stereo vision LAI by using regression



Results

- Analysis of the errors
  - Only the noise is considered here
  - Correlation between estimated and true distance (based on the patterns) : r = 0.9997, slope= 1.0003

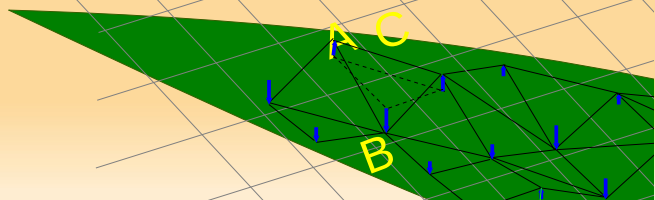


Results

- Analysis of the errors
  - Only the noise is considered here
  - Correlation between estimated and true distance (based on the patterns) : r = 0.9997, slope= 1.0003
  - Accuracy and precision (patterns – ref. area = 0.0155)

Resolution	1024*768		1280*960	
	relative (%)	m²	relative (%)	m²
Accuracy	34	0.0053	49	0.0075
Precision	10.9	0.0017	15.8	0.0024

Error analysis showed that standard deviation on z should be respectively around $3\ 10^{-4}$ m and $5\ 10^{-4}$ m to achieve the given precision
Necessity of a regression to estimate Ref LAI



Results

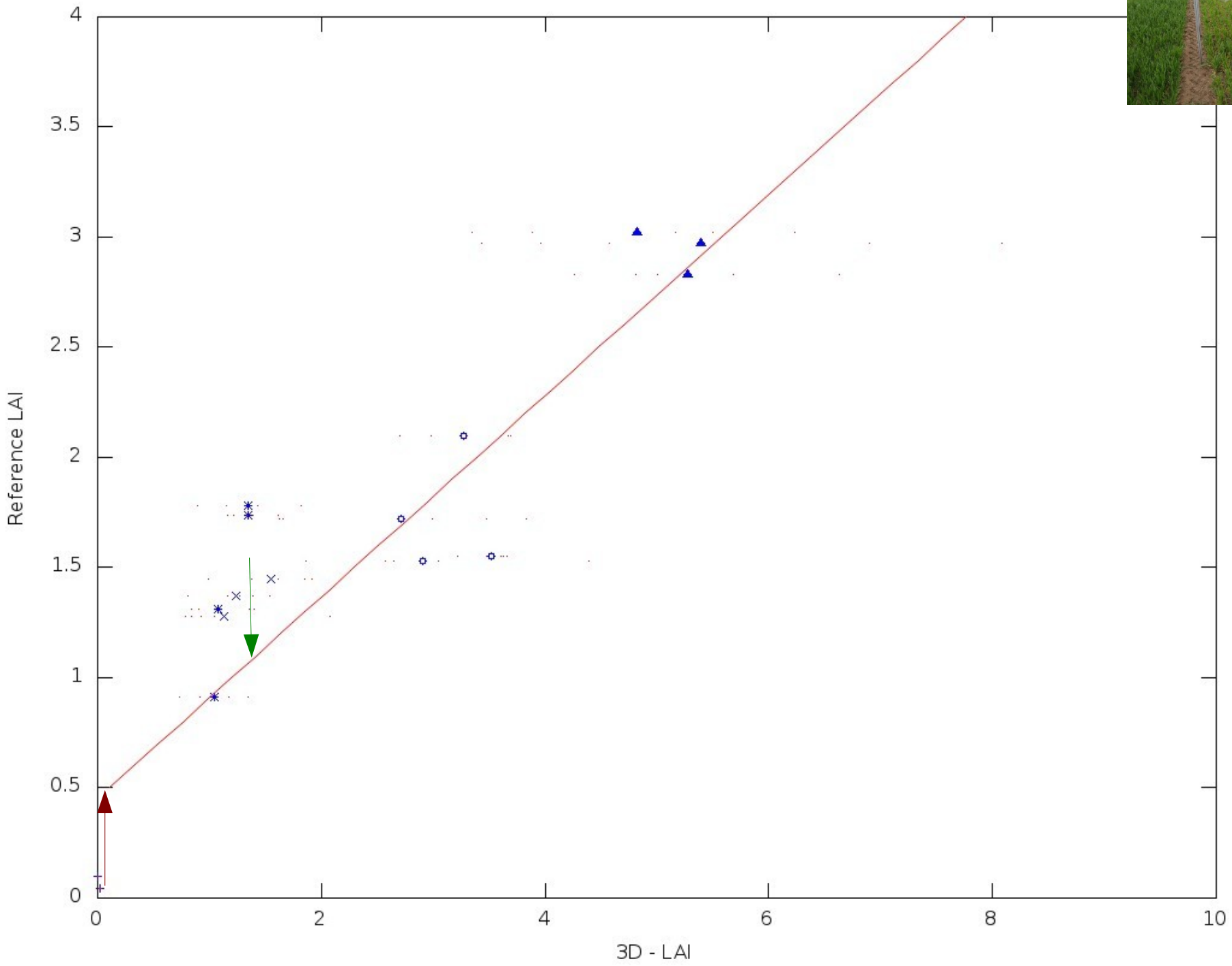
- Repetitions on the same spot
  - 5 repetitions
  - standard deviation on LAI = 0.09 ($m_{LAI} \approx 1$)
  - standard deviation on ALA = 0.02 rad ($m_{ALA} \approx 1.3$)





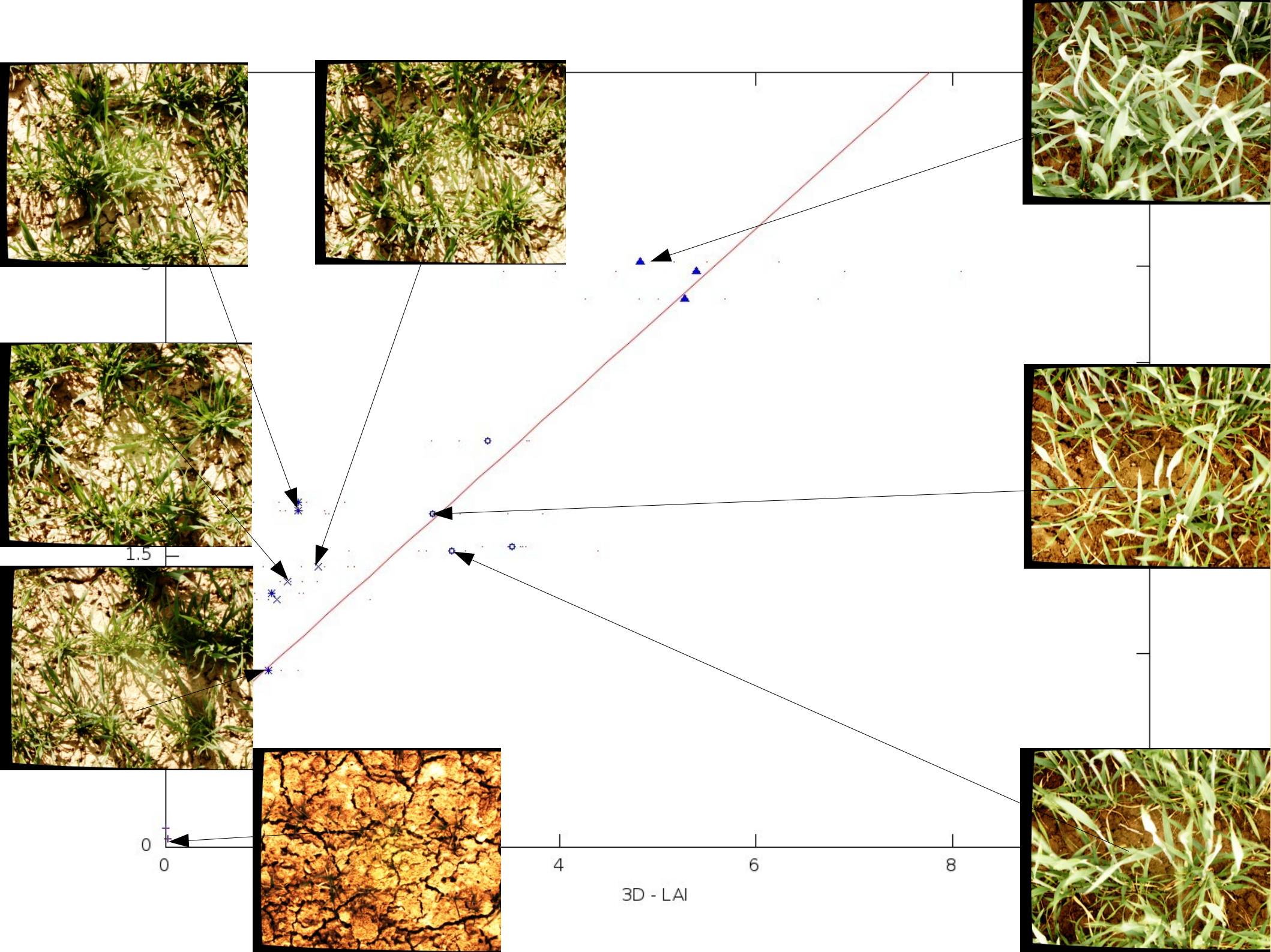
Results

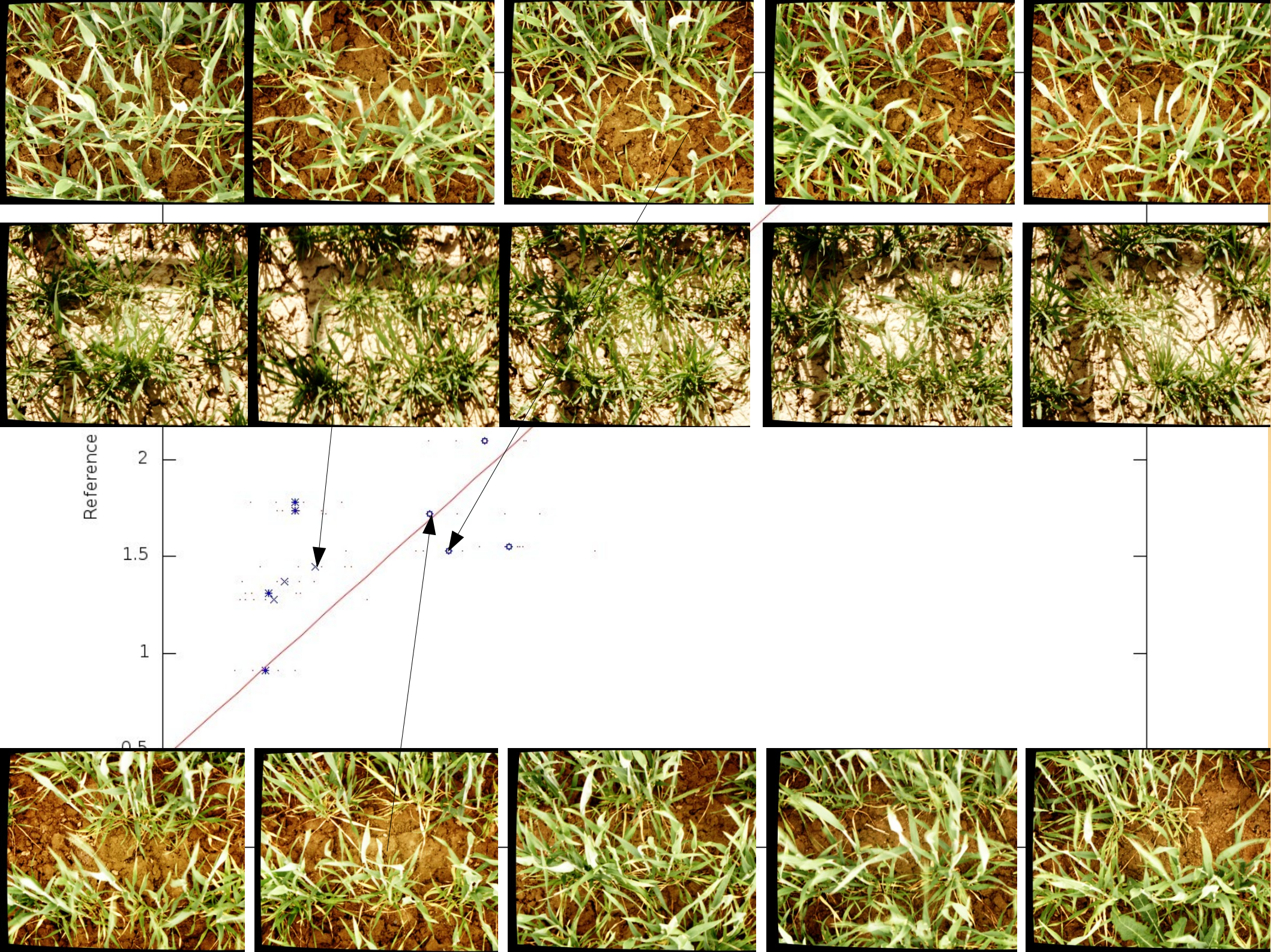
- Estimation of the LAI (Ref LAI = f (3D-LAI))


Reference LAI
3D - LAI
0
0.5
1
1.5
2
2.5
3
3.5
4
0
2
4
6
8
10

Results

- Estimation of the LAI (Ref LAI = f (3D-LAI))
  - Linear regression is correct (no saturation observed)
  - standard deviation for the reference (4 plots) : 0.23
  - standard deviation for the estimation based on 1 stereo vision measurement : 0.22
  - correlation coefficient (3D, Ref) : 0.88
  - standard deviation for the estimation based on 5 stereo vision measurement : 0.14
  - correlation coefficient (5 * 3D, Ref) : 0.91


1.5
0
0
4
6
8
3D - LAI


Reference
2
1.5
1
0.5

Softwares

- Sofware developped using OpenCv and GTKmm libraries
- Two software are warped in an “easy to use GUI” aimed to be a tool for scientist having no direct interest in Image analysis
  - LAI/ALA measurement
  - Image segmentation
- Two software are still “PhD student versions”
  - Acquisition
  - Calibration

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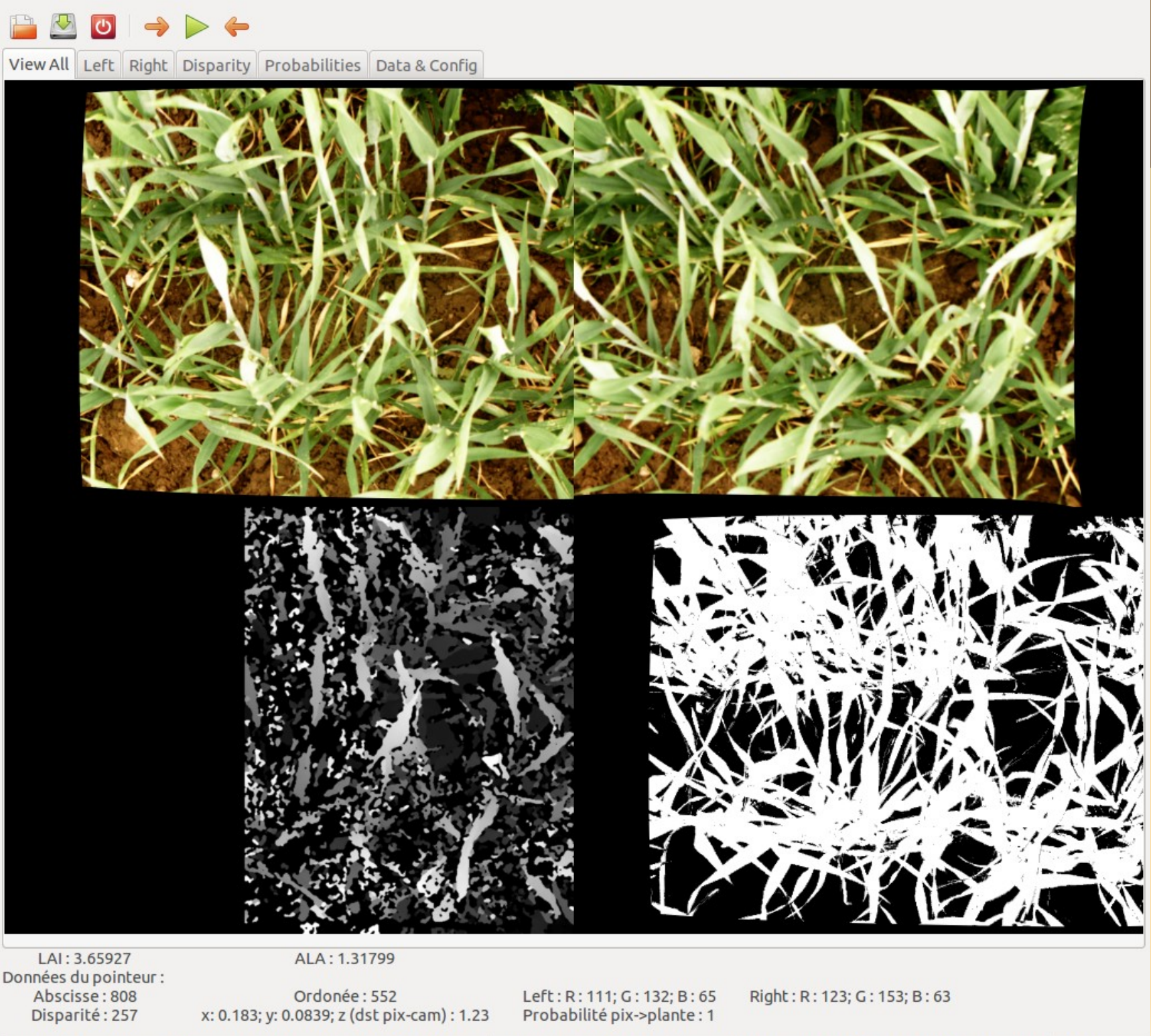
- Two s
  GUI”
  direct
  - LAI
  - Ima
- Two s
  - Acc
  - Cal



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- Two s
  GUI”
  direct
  - LAI
  - Ima
- Two s
  - Acc
  - Cal

View All | Left | Right | Disparity | Probabilities | Data & Config

Data

LAI : 3.48004 ALA : 1.31271 Coverage Ratio : 0.460247 Nombre de ligne de culture observées : 38
Distance caméra-plantes : 1.07781 Aire observée : 0.11205 Aire des feuilles : 0.140418 Proportion de pixels correctement mesurés : 0.360101

Configuration

Egalisation de l'histogramme

☑ Egalisation avant segmentation ☑ Egalisation avant calcul des disparité

Paramètres stéréoscopiques

Minimum disparity : 240 Number of disparities : 192 Disparité maximale : 432 Matched block size : 5

Fichiers

Noms d'images : /home/vincent/Projects/StereoLAI/ListLiroux1024_04062013.txt
Paramètres extrinsèques : /home/vincent/Projects/Calib/extrinsics1024_MaiJuin13_355.yml
Paramètres intrinsèques : /home/vincent/Projects/Calib/intrinsics1024_MaiJuin13_355.yml
Paramètres de segmentation : /home/vincent/Projects/ClrDiscrim/ModeleNBLiroux040613.yml
Image de gauche : /home/vincent/Ecotron/Stereo/Images/Liroux040613_1024/Triti0_1.tiff
Image de droite : /home/vincent/Ecotron/Stereo/Images/Liroux040613_1024/Triti1_1.tiff
Fichier de données (sortie) : /home/vincent/Projects/StereoLAI/LAILiroux1024_040613.txt

LAI : 3.48004 ALA : 1.31271
Données du pointeur :
Absice : Ordonée : Left : R : ; G : ; B : ; Right : R : ; G : ; B : ;
Disparité : z (dst pix-cam) : Probabilité pix->plante :

/home/vincent/Projects/StereoLAI/ListLiroux1024_04062013.txt | /home/vincent/Ecotron/Stereo/Images/Liroux040613_1024/Triti0_1.tiff | 2/40

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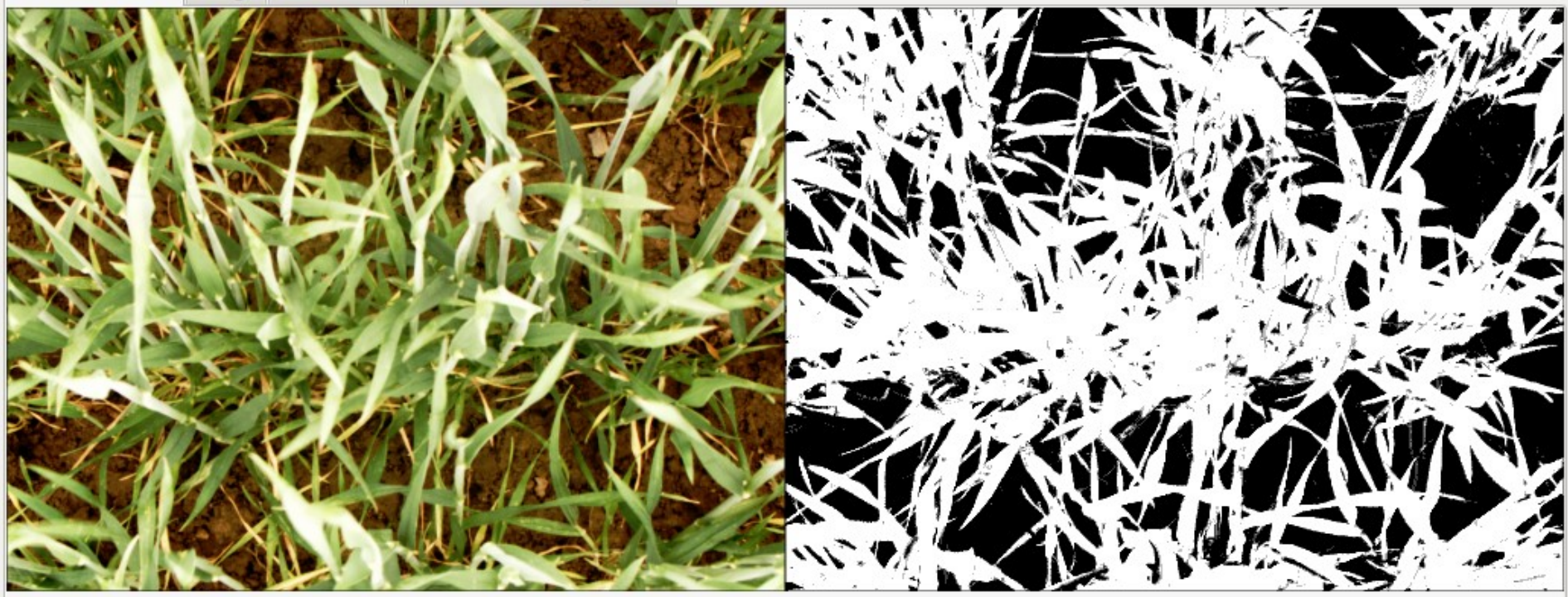
Vue d'ensemble
Image
Classement
Données & Configuration
Ground
Leaves
140 samples
89 samples
Abscisse : 614
Ordonée : 450
R : 202
G : 219
B : 151
Class : 255
/home/vincent/Projects/ClrDiscrim/ListLiroux1024_04062013.yml
/home/vincent/Ecotron/Stereo/Images/Liroux040613_1024/Triti0_0.tiff
1/68

Conclusion

- The proposed method based on stereo vision system is
  - able to achieve a precision similar to the reference method
  - much quicker than the reference method
  - affordable
- It will be tested more extensively

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Thank you for your attention

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