Determination of a common genetic basis for tissue growth rate under water-limited conditions across plant organs and genomes.

GCP project 15

CIMMYT

Collaborators

Mark Sawkins	CIMMYT, Mexico
Jean-Marcel Ribaut	CIMMYT, Mexico
Francois Tardieu	INRA (Agropolis) France
Peter Stamp	ETH, Switzerland
Matthew Reynolds	CIMMYT, Mexico
Peter Langridge	ACPFG, Australia
Jill Cairns	IRRI, Philippines
Ravindra Kumar	IGAU, India
John Bennett	IRRI, Philippines
James Gethi	SIRDC, Zimbabwe
Marianne Bänziger	CIMMYT, Zimbabwe
Claude Welcker	INRA (Agropolis) France
Yvan Fracheboud	ETH, Switzerland
Andreas Hund	ETH, Switzerland
Richard Trethowan	CIMMYT, Mexico

CIMMYT MR

Rationale & Overall objective

- One of the first responses to water deficit is an almost immediate (within minutes) reduction in tissue expansion
- Control of tissue development under water deficit may show common mechanisms via the maintenance of tissue expansion
- It is assumed that this is a key and common mechanism which contributes to traits of drought tolerance such as early vigor or crop establishment as well as maintenance of growth of reproductive organs.

Elucidate and integrate common genetic mechanisms (candidate genes) underlying the maintenance of tissue growth in plants subjected to water deficit (across species and organs)

CIMMYT

Expected outcomes

- An updated set of screening methodologies to quantify tissue growth regulation in cereals under controlled and field conditions.
- An understanding of the physiological and biochemical basis for growth maintenance under water-limited conditions.
- Correlations between tissue growth regulation and overall plant performance.
- Models that predict how different allelic combinations impact the growth of several organs under different drought scenarios.
- A set of specific (tissue/species) and common candidate genes and QTL regions involved in tissue growth regulation.
- A set of DNA markers developed from the sequence of candidate gene of interest, to be used in marker-assisted selection experiments.
- Identification and development of new phenotypic and genetic selection criteria for efficient breeding.

CIMMYT MR

Primary activities

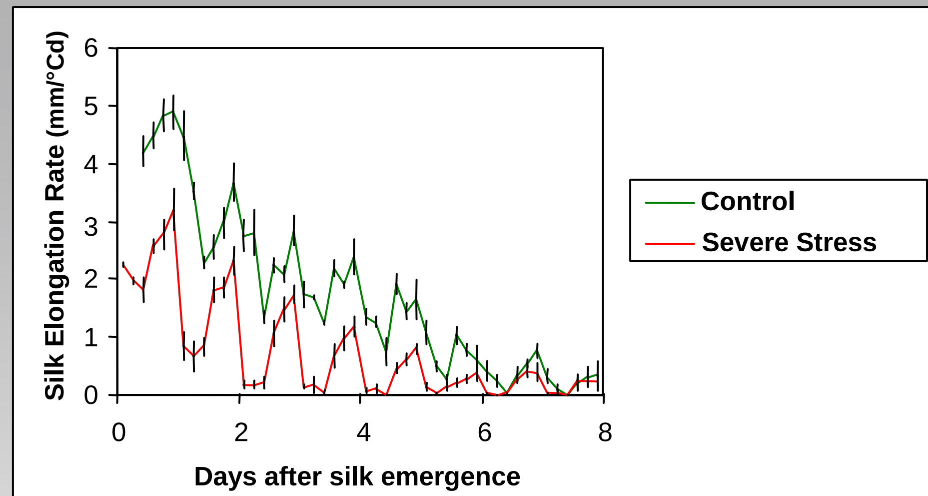
- Modeling – Leaf and reproductive tissue growth
- Phenotyping (rice, wheat & maize)
  - Field and controlled conditions
- Expression profiling

2005 - Activities

- **Modeling**
  - Adapt the silk growth model developed at INRA to tropical maize – **INRA**
  - Model leaf growth in tropical maize - **INRA**
  - Characterization and modeling the variability of rice leaf growth to environmental conditions - **INRA/IRRI**

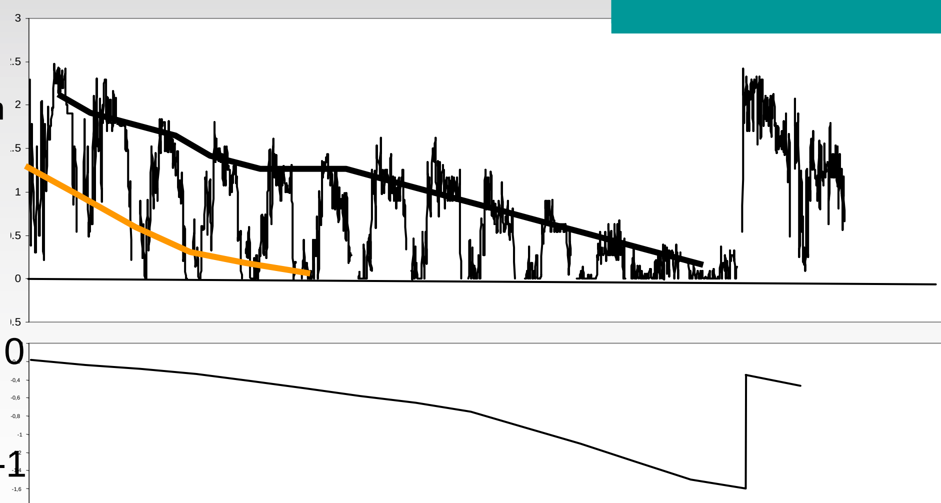
CIMMYT MR

Time courses of response of growth to soil water deficit



Growth decreased slowly during the night,
… rapidly during the day.

Leaf Growth
LERth
(mm Dj-1)



Soil Water Potential (MPa)

Continuous drying period over 12 days (-0.05 to -1.2Mpa)

Re-irrigation

Similar responses of leaf and silk elongation

CIMMYT

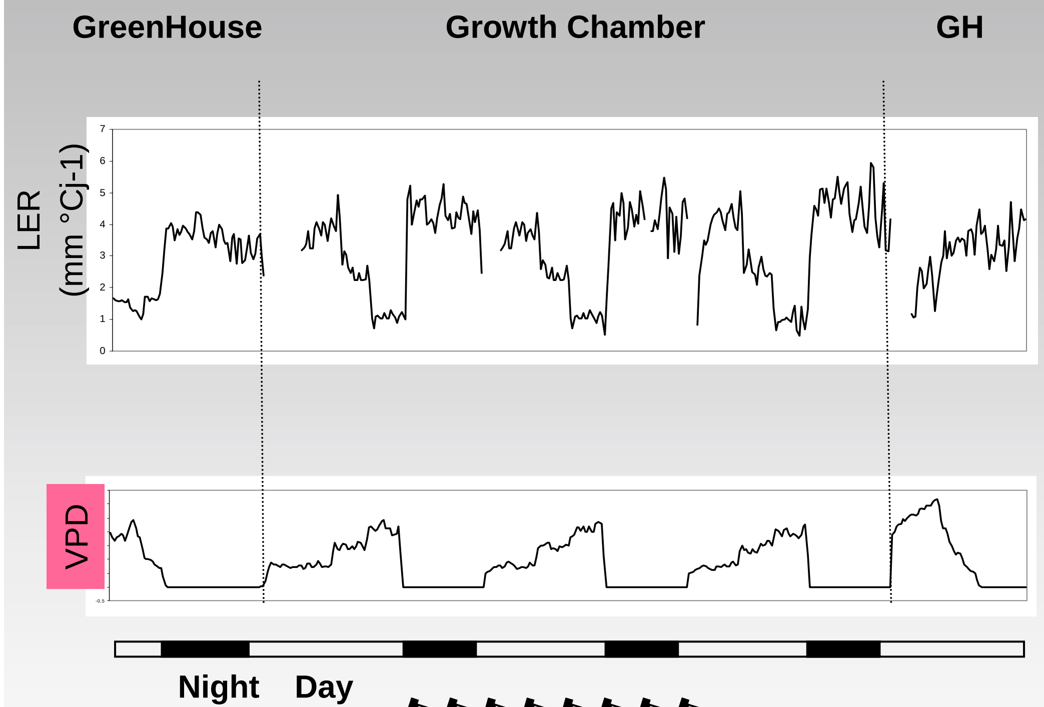
Modeling silk growth

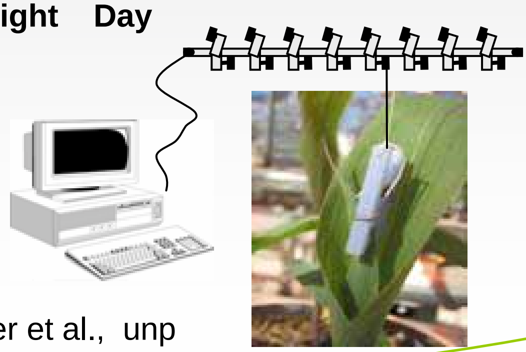
- Tropical maize was grown and subjected to different environmental conditions in a growth chamber
- Silk elongation rate was continuously monitored (non-destructive)
- Growth responded in a linear way to temperature
- Growth changes also paralleled ear leaf water potential
- Results suggest that silk growth rate is partly controlled by plant water status and could be driven by turgor in the growing zone.

CIMMYT MR

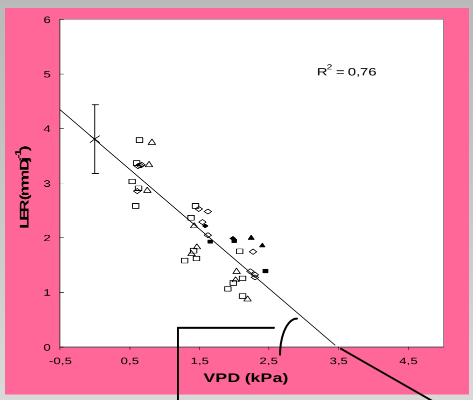
Modeling of leaf response to evaporative demand in P1xP2

Meta-time course

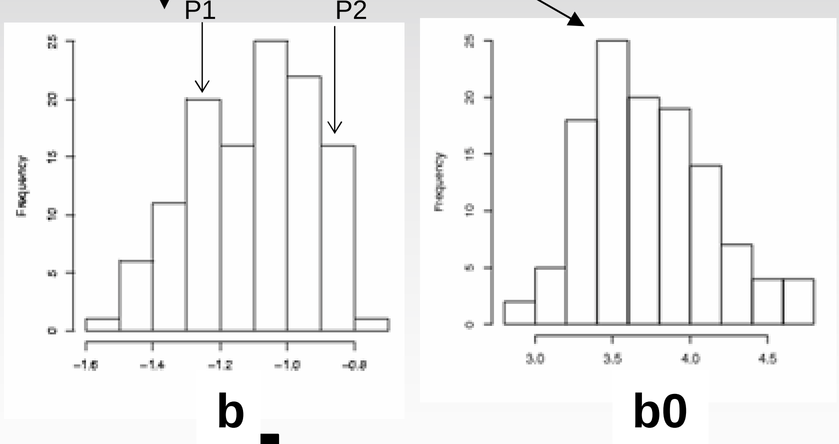




Response curves & Parameters



Linear, reproducible



Genotypic Variability

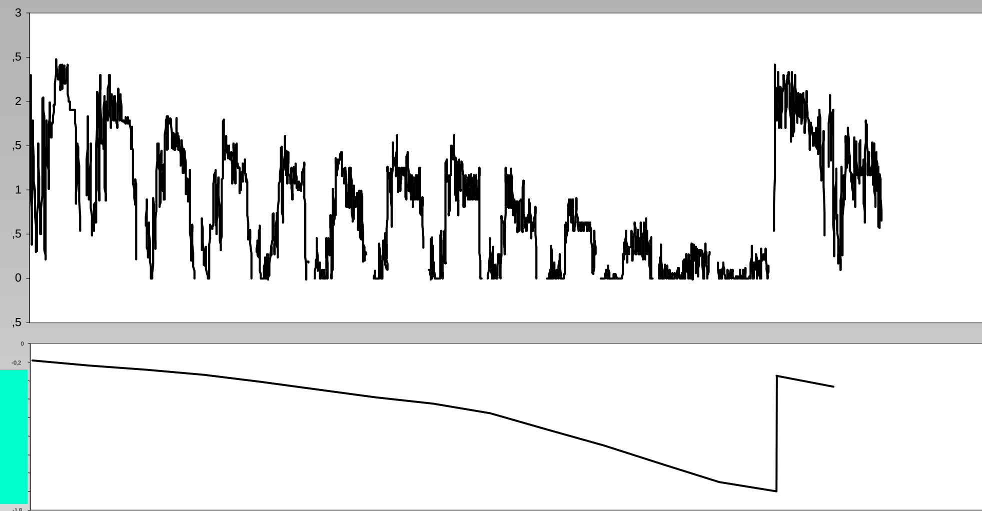
C Welcker et al., unp

INRA CIMMYT

Modeling leaf growth response to soil water deficit in P1xP2

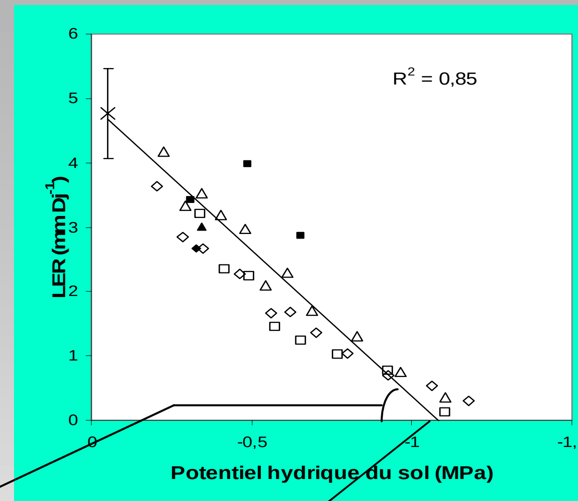
Leaf Growth LERth (mm Dj^{-1})

Soil Water Potential (MPa)



Continuous drying period over 12 days

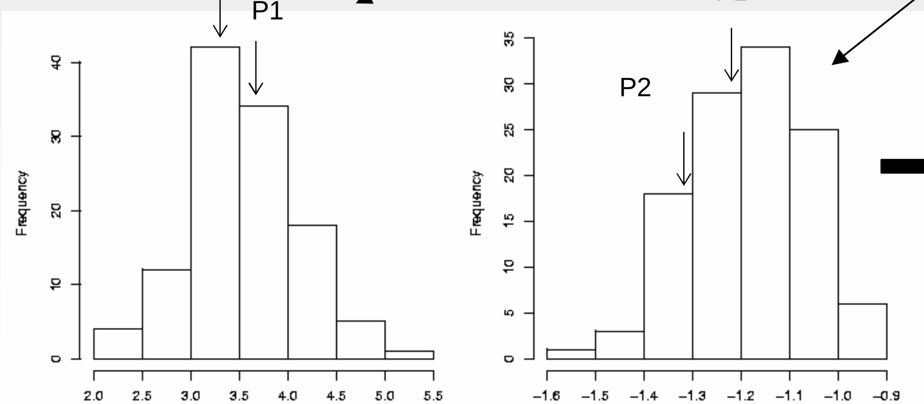
Re-irrigation



Linear response

P2

P1



c

c0

Genotypic Variability

C Welcker et al.unp

Modeling

- Characterization and modeling the variability of rice leaf growth to environmental conditions (**INRA/IRRI**)
  - This activity begins in late 2005 when a new PhD student has joined the team.

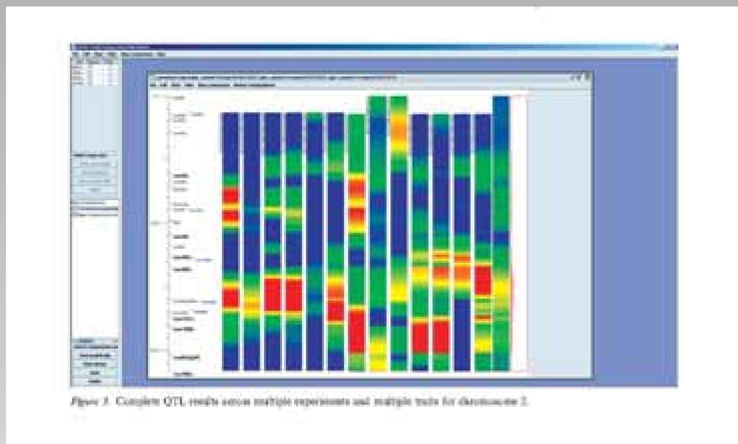
CIMMYT

2005 - Activities

- **Maize (Phenotyping)**
  - QTL detection of maize leaf growth to water deficit (P1xP2 segregating population) - **INRA**
  - Characterization of genetic variability for leaf elongation, leaf development under water stress, yields and related traits in maize in field conditions - **CIMMYT - Mexico**
  - Developing protocols for maize root growth under stress – **ETH**

CIMMYT

Generic QTLs for processes across organs ?

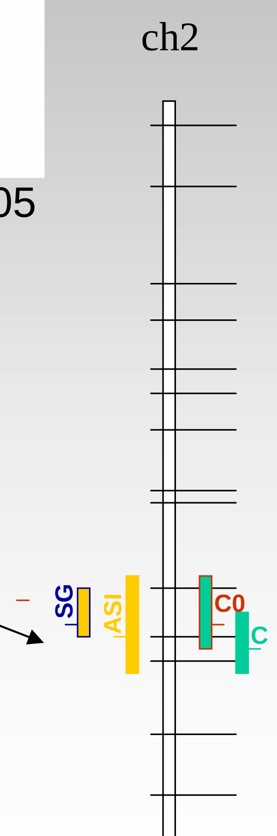


DT QTL on Ch2 - Sawkins et al, 2005

<u>Case study on ch2</u> :

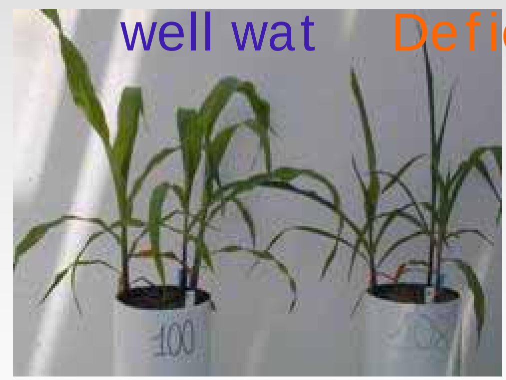
P1xP2 (120 RILS)

one region clearly identified for the control of growth responses of reproductive and vegetative organs



Silk growth maintenance
(ASI; SG... Ribaut et al.)

Leaf growth maintenance
(Welcker et al 2004, *unp.*

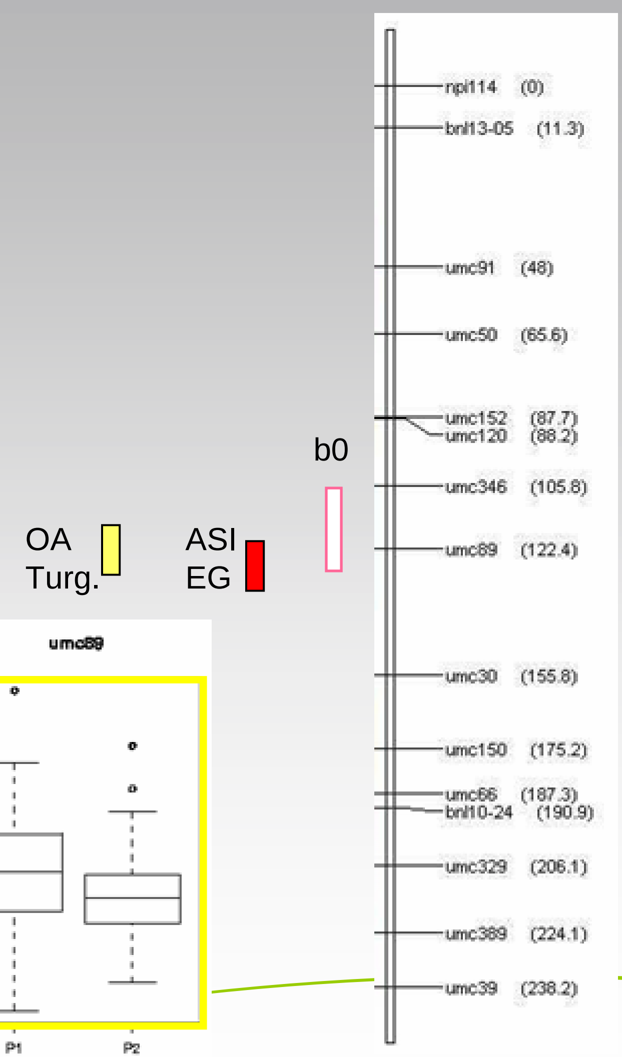


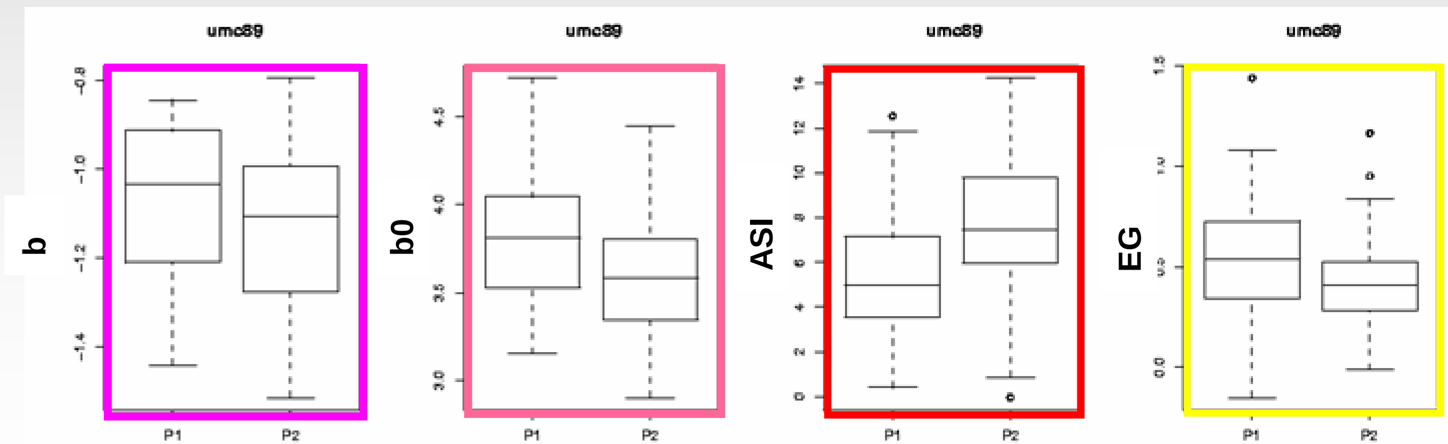
CIMMYT

Common determinism between maintenance of growth of vegetative and reproductive organs in maize ?

Case study on ch8 :

one region original associating maintenance of vegetative and reproductive growth and underlying the major role of hydraulic in the control of growth under water deficit





Ribaut et al, 2002, Welcker et alunp.

Phenotyping - Maize

- A population of RILs (P1xP2 - 220 genotypes)
- 10-12 leaf stage water was withheld
- In February the number of leaves (ligulated and non-ligulated) were recorded once a week until all leaves had emerged
- After 4 weeks, irrigation was re-applied before flowering
- During grain filling, leaf size (length and width), flowering traits, plant morphology, chlorophyll content and senescence were measured for 6 leaves from 5 plants per plot

CIMMYT MR

Root morphology in maize under stress

- P1&P2 CML444 & Malawi

A

B

C

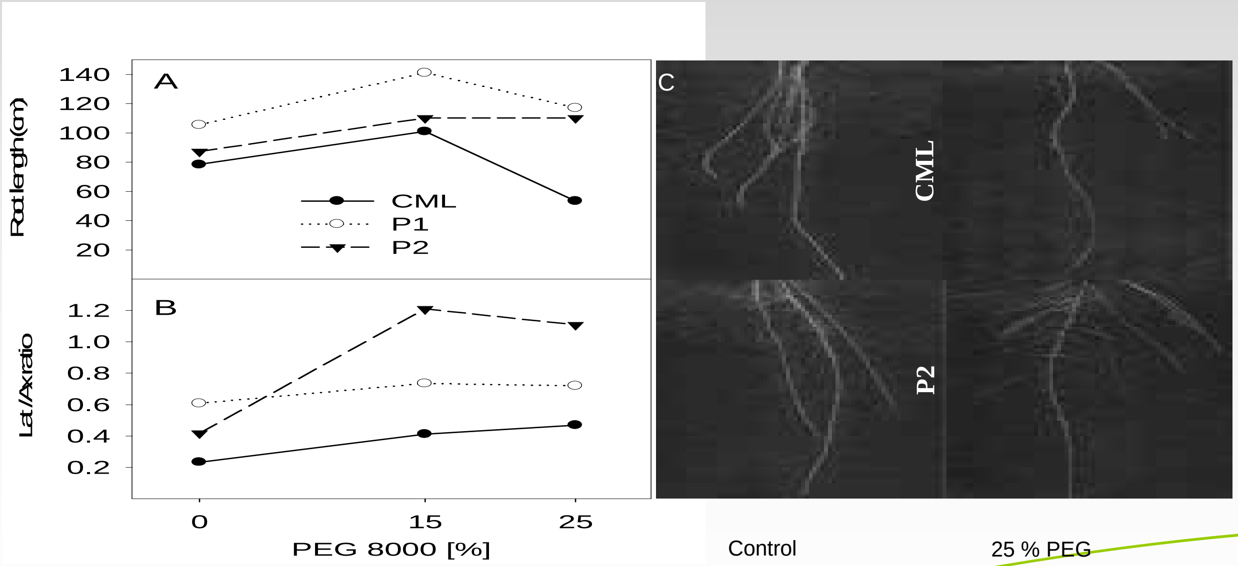
Plants were grown in pouches on filter paper (A and B) and growth columns filled with quartz sand (C)

Pouches - desiccation stress with polyethylene glycol (0, 15 and 25 % PEG)
Sand columns - water supply at sowing (25 and 100 % of maximal water holding capacity) in the sand columns

Root measurements: images processing (WinRhizo®) of scans from pouches and from root samples spread in a flat tray of water, collected destructively from the soil columns.

Pouches - Effect of desiccation stress with polyethylene glycol (PEG 8000) on total root length (A) and the ratio between lateral and axile root length (B)

Treatments applied to seedlings from day 3 onwards by submerging the pouches for 5 min daily into the PEG solutions. Each data point represents 6 plants.



- **Tolerant genotypes** – no deeper root system or higher desiccation tolerance but a lower portion of lateral roots (lower Lateral/Axile) in the upper soil profile
- **The Lat/Ax ratio** is a candidate trait for distinguishing genotypes
- **CML444 and Malawi** differed strongly for the Lat/Ax ratio in the sand columns. Therefore differences in field performance might be due to higher carbon costs of Malawi

2005 - Activities

- **Rice (Phenotyping)**
  - Characterisation of leaf emergence and elongation rate in rice – **IRRI**
- **Wheat (Phenotyping)**
  - Characterization of leaf growth of a set of wheat lines in field under stress and well-watered conditions in the field and controlled conditions (**CIMMYT – Obregon & El Batan**)

CIMMYT

Phenotyping – rice and wheat

- **Rice** –
  - 150 lines - Leaf emergence and elongation rate evaluated using BC lines (Vandana x Moroberekan), under well-watered field conditions, and NILs (IR64 x Azucena), under well-watered and stressed conditions in the greenhouse
- **Wheat** –
  - 100 lines evaluated in the field under stress conditions and trait data collected
  - A subset of these were selected and data for leaf and stem extension rate under stress and irrigated conditions collected
  - Another subset of six pot grown contrasting lines are currently being evaluated for leaf extension rate.

CIMMYT MR

2005 - Activities

- Expression profiling on contrasting lines using leaf growth zone under stress and optimal conditions
  - Maize, rice and wheat (**CIMMYT**, **IRRI**, **ACPFG**)

CIMMYT MR

Material for expression profiling

- P1 & P2 and six contrasting genotypes from the same segregating population evaluated under well watered (2 replicates) and stress (three replicates) conditions
- The whorl was dissected from 30 plants and 5cms of the base of the youngest leaf that had just emerged taken and pooled (SS & WW)
- Leaf emergence recorded weekly (from leaf 10) and numbers of ligulated and non-ligulated leaves
- Chlorophyll content and predawn leaf water potential was measured on parental lines (20 samples SS & WW)

CIMMYT MR