

## Genotypic variation in tropical maize for growth maintenance under drought.

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### Abstract

Several maize lines selected by CIMMYT can maintain growth of reproductive organs under water limited conditions, a key mechanism for grain production under drought. The objective of this work was to test whether these lines also maintain leaf growth under water deficit. Leaf elongation rate of six tropical maize lines, parents of segregating populations contrasting for silk growth maintenance under drought stress, were analysed via response curves to temperature, evaporative demand and soil water deficit controlled in growth chamber and greenhouse experiments. Large differences were observed in the responses of studied lines, with a tendency that lines with a maintained anthesis-silking interval under water deficit also maintained leaf elongation. Relationships between adaptation traits within this material suggest that evaluation of derived recombinant inbred lines might allow testing co-segregation of key adaptive mechanisms to water-limited environments.

### Media summary

Genotypic variation in tropical maize for vegetative and reproductive growth maintenance under drought stress might allow testing co-segregation of key adaptive mechanisms to water-limited environments.

### Key words

Water deficit, leaf growth, anthesis-silking interval, tolerance, breeding, *Zea mays* L.

### Introduction

Results from CIMMYT have shown that there are sources of tolerant maize germplasm which can maintain growth of reproductive organs under water limited conditions, a key mechanism for grain production under drought (Edmeades et al., 1992). Yield maintenance under drought is inversely related to the anthesis-silking interval (ASI) which is related to the asynchrony between silk emergence and pollen shedding (Ribaut et al., 1996). This result has been extensively used in breeding programs because ASI is easily measurable and has a higher heritability than yield under drought (Bolanos & Edmeades, 1996). As a result, populations with elevated level of tolerance were identified and new tolerant inbred lines were selected. QTL for target traits and physiological pathways were identified in this genetic material in several environments, and a marker assisted selection (MAS) strategy was experimented in Africa (Ribaut and Betran, 1999, Ribaut et al., 2002).

A new method combining genetic analysis and ecophysiological modelling has been developed recently to discover the genetic basis of the responses of leaf growth to air and soil water deficits (Reymond et al., 2003). It allows modelling the genotype \* environment interaction by carrying out a genetic analysis of parameters of response curves, and to predict responses of virtual genotypes (= combination of alleles) in different climatic scenarios (Tardieu, 2003) thereby assisting the breeder in pyramiding favorable alleles for target cropping environments.

The first objective of this study was to broaden the genetic spectrum of this analysis, initially performed on temperate material, in order to identify more sources of tolerance. For that purpose, we characterised leaf growth responses to air and soil water deficits of several tropical maize inbred lines contrasting for ASI maintenance under drought. The second objective was to test for the existence of a genetic correlation between maintenance of vegetative (leaf) and reproductive (silk) growth under drought.

## Experimental Approach

Six maize inbred lines contrasting for drought tolerance and used as parental lines to develop segregating populations at CIMMYT were analysed. This set of lines included tolerant lines characterised by short ASI (P1, H16 and CML444), intermediate ASI (K64R) and susceptible lines presenting long ASI (P2 and SCMalawi). All lines performed well under non-stressed environment.

Plants were grown in a greenhouse until the appearance of leaf 6. Batches of plants were then transferred from the greenhouse to a growth chamber. Leaf elongation rate was measured every 20 minutes with a set of Rotative Displacement Transducers, in plants subjected to a range of temperatures (14 to 28°C during the night) and air vapour pressure deficits (VPD from 0 to 3kPa), over periods of 4 h during 5 consecutive days. In another experiment, leaf elongation rate was measured in plants subjected to a range of soil water statuses. Irrigation was withdrawn a few days before emergence of leaf 6 and soil water content (transformed into predawn  $\Psi_w$  by water release curves) was monitored daily. Within 2 weeks (typically until leaf 8 appeared), plants experienced  $\Psi_w$  ranging from about zero to  $-1.7$  MPa.

Response curves to meristem temperature, vapour pressure deficit and predawn water potential were computed from these data, as presented elsewhere (Reymond et al 2003), using specifically developed software. At least two experiments (e.g. greenhouse and growth chamber) with 3 plants per line and experiment were taken into account to compute response curves.

## Results and prospects

The response of leaf elongation rate (LER) to night temperature was linear, with slopes which significantly differed between lines indicating differences in intrinsic LER (from  $3.87 \text{ mm}^\circ\text{Cd}^{-1}$  for H16 to  $6.03 \text{ mm}^\circ\text{Cd}^{-1}$  for K64R) while x intercepts were close to  $10^\circ\text{C}$  in all lines (data not shown). LER was then expressed per unit thermal time ( $^\circ\text{Cd}$ ) in the rest of the study.

The sensitivity to evaporative demand was estimated via response curve of LER to leaf-to-air vapor pressure deficit. Robust response curves were established with data from different experiments performed at contrasting seasons of the year and in both greenhouse and growth chamber conditions (Fig. 1). Significant differences were found among lines for both the slope of the relationship and the x-intercept (the VPD at which elongation would cease).

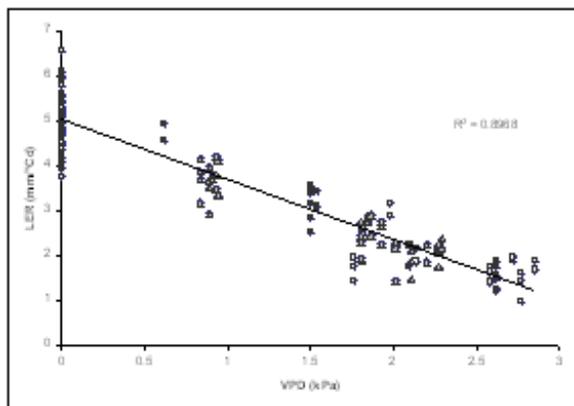


Fig. 1: Leaf growth response to evaporative demand for CML444 across experiments in greenhouse (■, □) and growth chamber (△)

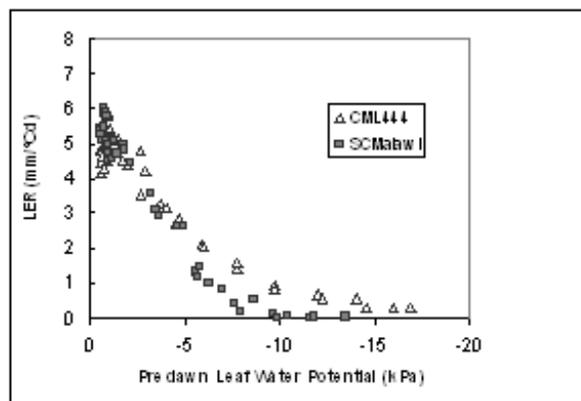


Fig. 2: Leaf growth response to soil water deficit in two lines, SCMalawi (sensitive, ■) and CML444 (tolerant, △)

Leaf elongation rate was significantly reduced by soil water deficit. Significant differences between the tested lines were found (Fig 2) for both the slopes of the LER- $\Psi_w$  relationship and for the x-intercept ( $\Psi_w$  at which elongation would cease). At a given water potential (*i.e.* below  $-0.5$  MPa) line CML444 (tolerant) showed a higher growth rate compared to the susceptible line SCMalawi.

Results indicate that the tropical maize lines studied differed for leaf expansion rate in response to evaporative demand (Fig. 3A) and soil water potential (Fig. 3B). Leaf elongation rate response to VPD ranged from  $-0.724$  (P2) to  $-1.234$  (SCMalawi) while x-intercept ranged from  $3.88$  kPa (CML444) to  $5.6$  kPa (P2, the most tolerant line). Leaf elongation rate response to  $\Psi_w$  ranged from  $-0.307$  (P1) to  $-0.727$  (SCMalawi). X-intercept ranged from  $-0.81$  MPa and  $-1.27$  MPa for the sensitive line (SCMalawi) and tolerant line (CML444), respectively.

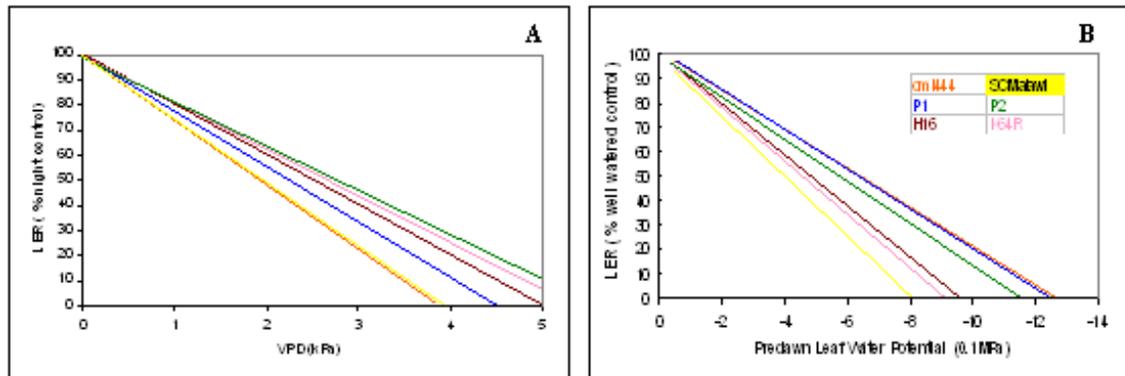


Fig. 3 : Standardized response of leaf elongation rate (LER) to evaporative demand (VPD - A) and soil water deficit (Predawn Leaf Water Potential - B) within maize inbred lines used as parents in genetic analysis

The lines characterised by a short ASI resulting in the maintenance of silk growth under water deficits (CML444 and P1) continued elongation at predawn leaf water potentials lower than lines with low ASI maintenance (SC Malawi and K64R). These results suggest some similarity between the responses of ASI and of leaf growth to soil water deficit. If confirmed on a broader genetic spectrum, they would suggest common processes accounting for both vegetative and reproductive growths responses to water deficits. Evaluation of available recombinant inbred lines derived from these contrasting lines will allow further testing of this hypothesis of co-segregation of key adaptive mechanisms to water-limited environments. By contrast, ranking of inbred lines differed for their responses to air and soil water deficits, suggesting that combination of favorable alleles would be a promising avenue toward increasing tolerance and yield under water-limiting resources.

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