Variability in fluorescence and photosynthesis of sorghum genotypes to cold and drought stress

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INTRODUCTION

Sorghum bicolor (L) Moench is a promising bioenergy crop because of its high level of biomass production and tolerance to environmental stress, especially drought. Furthermore, the ample genetic diversity in this crop can be exploited for selecting for increased drought and cold tolerance.
Portable fluorescence and photosynthesis meters can be used to evaluate a large number of genotypes, exploit the sorghum genetic diversity and discover genes associated with stress tolerance. The development of protocols to accurately evaluate photosynthesis and fluorescence for a large number of genotypes in sorghum is essential to select and breed for these characteristics.

OBJECTIVES

1) Determine the phenotypic diversity in fluorescence and photosynthesis of sorghum genotypes subjected to drought and cold stress and their subsequent recovery.
2) Develop an accurate protocol for high-throughput phenotyping of sorghum plants to be used in linkage disequilibrium (LD) studies.

MATERIALS AND METHODS

For cold stress experiments, 12 contrasting genotypes were subjected to control (28°C day/24 °C night) and low temperatures (10ºC day/10°C night) with different stress duration periods (5 and 7 days). Control temperatures (28°C day/24 °C night) were reestablished after cold stress for the recovery evaluation.
For drought experiments, 9 genotypes were subjected to 2 final water levels (0.05 and 0.15 m^3/m^3 volumetric water content) during 13 days, after which they were re-watered. Temperatures were 28/24 °C (day/night). Initial measurements at full irrigation were used as controls.
In all cases, photosynthesis and fluorescence measurements were taken with a Li-cor 6400XT device. Photosynthetically active radiation was set to 1600 µmol photons m^{-2} s^{-1}.

RESULTS

Under cold treatments, photosynthesis was significantly decreased compared to controls (58 and 75% for 5 and 7 days of cold conditions, respectively). In both cases, plants recovered 86% of their original photosynthetic rate on average (Fig. 1 A). Plants grown under control temperatures showed no trend in photosynthesis due to phenology (Fig. 1 B).
In the 7 day cold experiment, genotypes showed significant differences in photosynthesis and the main fluorescence parameters after 7 days of cold treatment (Fig. 2).
The recovery of photosynthesis in plants after release of cold stress was negatively associated with the level of decrease in photosynthesis at maximum cold stress ($p<0.05$). Besides, photosynthesis performance under cold conditions was significantly associated with PhiPS2 (Fig. 3 B).

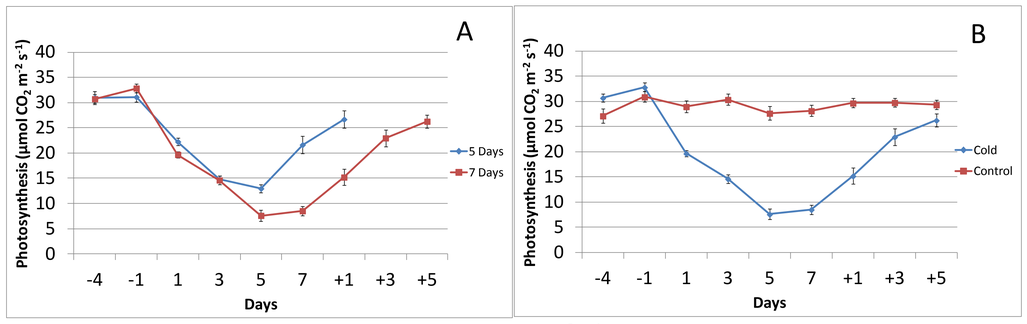

Figure 1. A) Average response in photosynthesis (µmol CO_2 m^{-2} s^{-1}) of 12 genotypes subjected to 5 and 7 days of cold conditions (10ºC day/10°C night) and subsequent recovery. B) Average response in photosynthesis (µmol CO_2 m^{-2} s^{-1}) of 12 genotypes under control (28ºC day/24°C night) and 7 days of cold conditions (10ºC day/10°C night) and subsequent recovery.

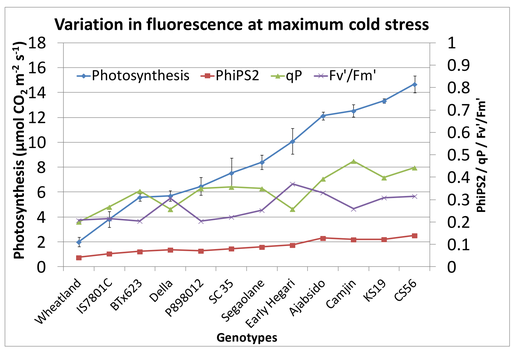

Figure 2. Variation in fluorescence and photosynthesis at maximum cold stress conditions of 12 genotypes subjected to 7 days of cold conditions (10ºC day/10°C night) .

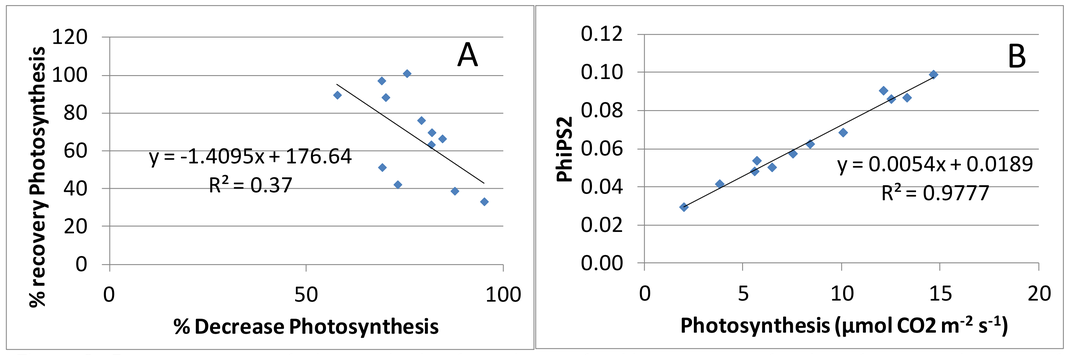

Figure 3. Percent recovery of photosynthesis after release of cold stress as a function of percent decrease of photosynthesis at maximum cold stress (A); Quantum yield of photosystem II as a function of photosynthesis (µmol CO_2 m^{-2} s^{-1}) in plants subjected to 7 days of cold conditions (10ºC day/10°C night) (B) .

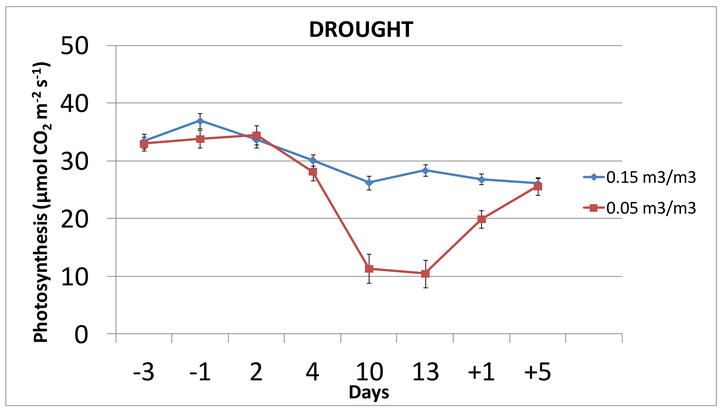

Figure 4. Average response in photosynthesis (µmol CO_2 m^{-2} s^{-1}) of 9 genotypes subjected to two final water levels (0.05 m^3/m^3 and 0.15 m^3/m^3 volumetric water content) and subsequent recovery.

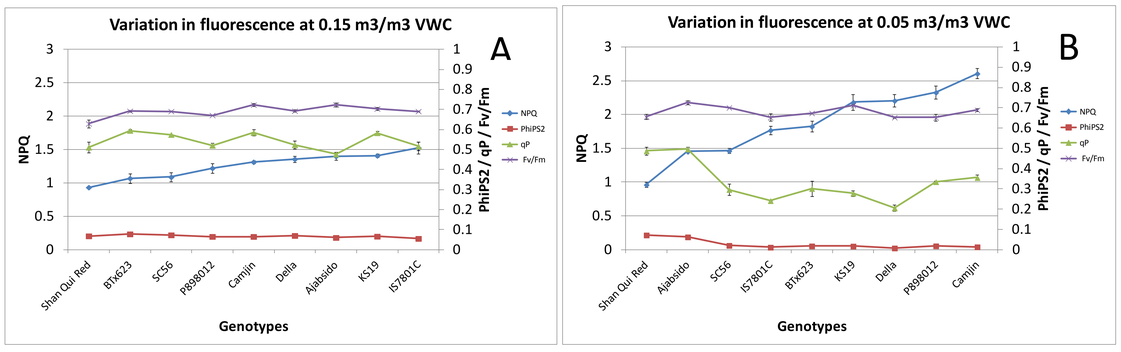

Figure 5. Variation in fluorescence of 9 sorghum genotypes at maximum drought stress conditions subjected to 0.15 m^3/m^3 VWC (A) and and 0.05 m^3/m^3 VWC (B) final water levels .

In the drought experiment, photosynthesis was reduced by 68 and 25% under severe (0.05 m^3/m^3) and moderate (0.15 m^3/m^3) drought conditions respectively (Fig. 4). Five days after watering, in both treatments plants reached similar recovery levels compared to initial conditions (75 %).
After 13 days of drought, there was a large genotypic variation in photosynthesis and the main fluorescence parameters (Fig. 5), although the range of response was higher in the severe drought treatment (Fig. 5 B).

CONCLUSIONS

Under both cold and drought stress conditions, photosynthesis was strongly reduced in all treatments. Under maximum stress conditions, genotypes expressed a wide range of variation in fluorescence parameters (NPQ, PhiPS2, Fv'/Fm', Fv/Fm, qP) and photosynthesis. Recovery of plants after stress was generally high (75 to 86 %). The knowledge generated in this study could be applied to develop accurate protocols for high throughput phenotyping of sorghum plants.

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