CIP thanks all donors and organizations that globally support its work through their contributions to the CGIAR Trust Fund: www.cigar.org/funders

CIP INTERNATIONAL POTATO CENTER

CGIAR

Short-Term Memory Induction, a Method for Improving Drought Stress Tolerance in Sweetpotato Crop Wild Relatives

Fernando Guerrero-Zurita[1] • David A. Ramírez[1] • Javier Rinza[1] • Johan Ninanya[1] • Raúl Blas[2] • Bettina Heider[1]

[1] International Potato Center (CIP), Lima, Peru.
[2] Universidad Nacional Agraria La Molina (UNALM). Crop Husbandry Department, Lima, Peru.

Introduction

Sweetpotato crop wild relatives (SP-CWR) (*Ipomoea* series *Batatas* (Choisy) D. F. Austin) are a poorly studied group of species potentially useful in crop improvement programs breeding for drought stress tolerance. In sweetpotato, several physiological traits have been used for screening drought tolerant genotypes such as chlorophyll concentration, canopy cover, leaf temperature and ^{13}C discrimination. Previous studies in other plants such as *Arabidopsis thaliana*, potato, cassava, wheat, and grasses have shown that an exposure to stress in early development stages "prepares" the plant for a subsequent exposure to the same stress. The aim of this study was i) to determine potential short-term memory induction in SP-CWR and its manifestation in ecophysiological traits like senescence, foliar area, leaf-minus-air temperature and leaf ^{13}C discrimination and ii) to identify the memory-induced physiological mechanisms related to the development of drought tolerance in SP-CWR.

Material and Methods

A pot experiment was conducted in two screenhouses from July 13th to December 18th, 2018 at the experimental station of the International Potato Center (CIP) located in the tropical Andean region of Central Peru (San Ramón, Junín, 850 m a.s.l.). Fifty-nine SP-CWR accessions were selected from CIP's genebank. The plant material included four accessions of cultivated hexaploid *I. batatas* (L.) Lam, two accessions of wild tetraploid (4x) *I. batatas* (L.) Lam. and 53 accessions encompassing ten species of the series. The SP-CWR assessed in this study were: *I. australis* (O'Donell) J.R.I. Wood & P. Muñoz (5), *I. cordatotriloba* Dennstedt (1), *I. cynanchifolia* Meisn. (3), *I. grandifolia* (Dammer) O'Donell (5), *I. leucantha* Jacquin (2), *I. ramosissima* (Poir.) Choisy (8), *I. splendor-sylvae* House (3), *I. tiliacea* (Willd.) Choisy (2), *I. trifida* (H.B.K.) G. Don (16), and *I. triloba* L. (8).

Eight individual plants per accession were distributed at random in both screenhouses. Four individual plants per accession were randomly assigned to two experimental treatments: priming and non-priming (**Figure 1**). The priming process consisted of three water restriction periods of increasing length (8, 11, and 14 days) followed each by a recovery period of 14 days with full irrigation.

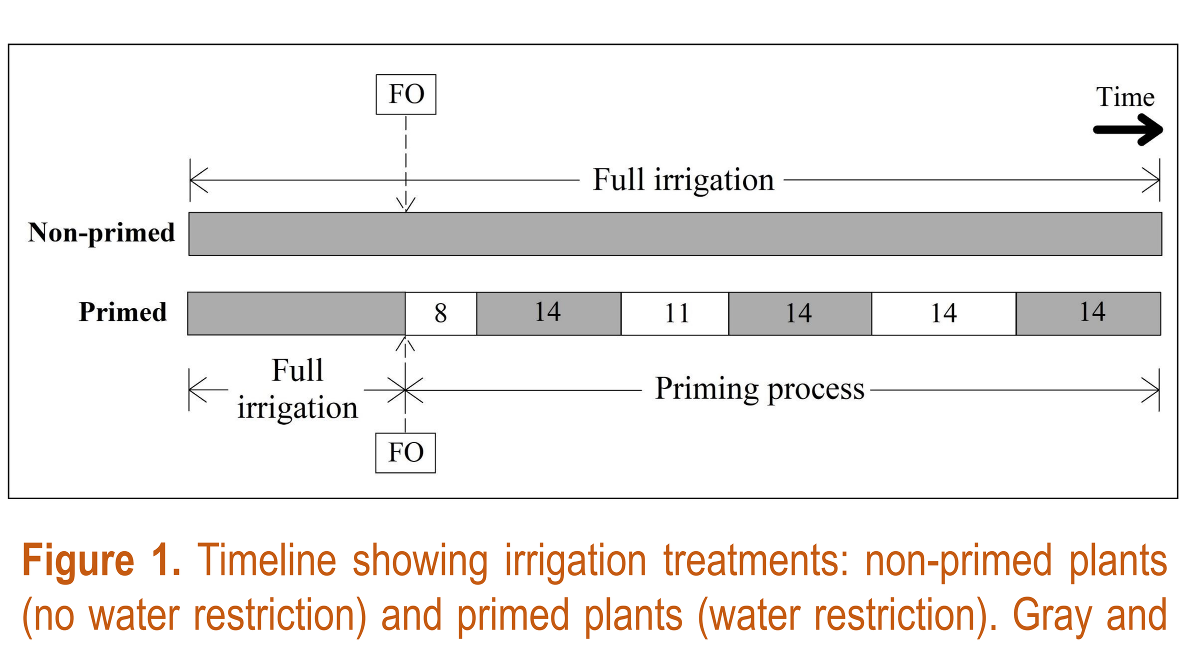

Figure 1. Timeline showing irrigation treatments: non-primed plants (no water restriction) and primed plants (water restriction). Gray and white blocks mean full irrigation and no irrigation, respectively. Duration of every period during the priming process is indicated in days within the blocks. The priming process started after flowering onset (FO).

Short-term memory (STM) occurrence was calculated based on ecophysiological indicators such as senescence (STM_S), foliar area (STM_{FA}), leaf-minus-air temperature (STM_{dT}), and leaf ^{13}C discrimination (STM_Δ). Based on total biomass production, resilience capacity (RCI) and production capacity (PCI) were calculated per accession to evaluate drought tolerance (Thiry et al. 2016).

Results

Increase in foliar area, efficient leaf thermoregulation, improvement of leaf photosynthetic performance, and delayed senescence were identified in 23.7, 28.8, 50.8, and 81.4% of the total number of accessions, respectively (**Figure 2**).

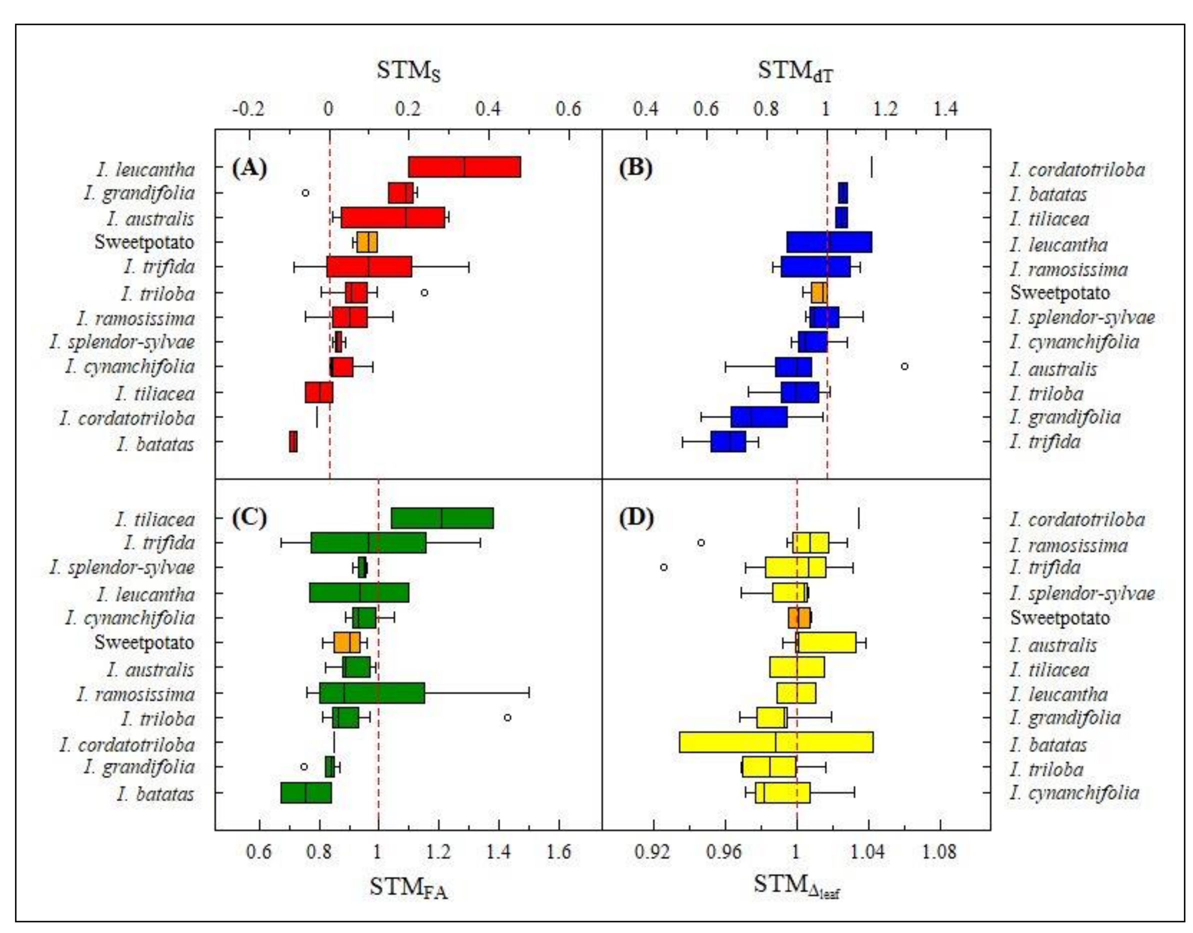

Figure 2. Boxplot of STM values per CWR species and sweetpotato cultivars (orange boxplots) for senescence (STM_S) (A), foliar area (STM_{FA}) (B), leaf-minus-air temperature (STM_{dT}) (C) and leaf 13C discrimination (STM_Δ) (D). Red dashed line indicates the STM occurrence.

PCA analysis showed that under a severe drought scenario, a resilient response included more long-lived green leaf area (24 accession forming cluster I) while a productive response was related to optimized leaf thermoregulation and gas exchange (four accessions from cluster II) (**Figure 3**). The enhancement of drought tolerance was supported from a physiological point of view since clusters I and II contained the highest number of accessions with STM_Δ occurrence (**Figure 4**).

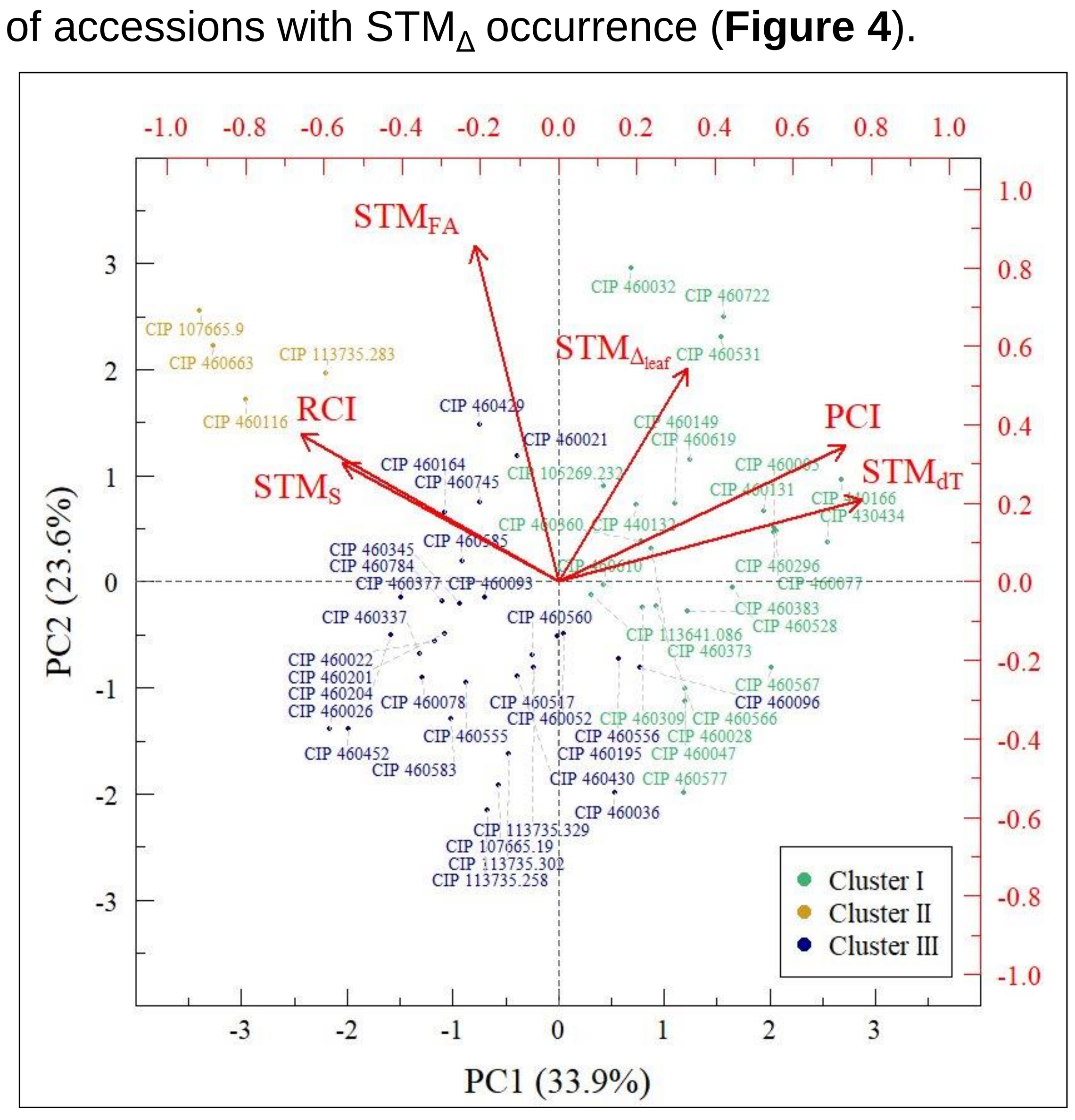

Figure 3. Clustering analysis and 2D ordination of sweetpotato cultivars and its CWR species based on Principal Component Analysis.

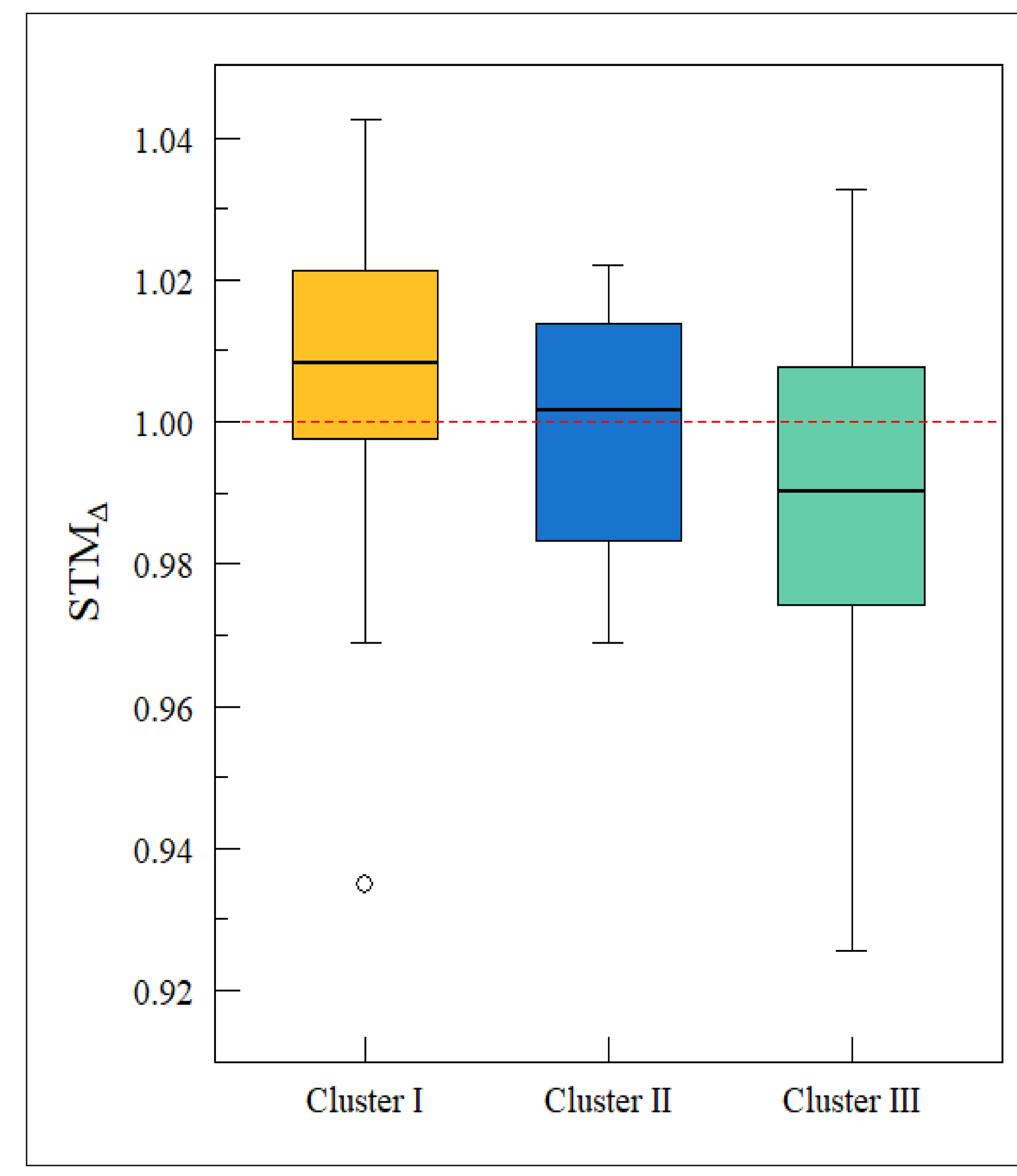

Figure 4. Boxplot of short-term memory (STM) effect on leaf ^{13}C discrimination (STM_Δ) for each cluster. Red dashed line indicates the STM occurrence ($STM_\Delta > 1$). In each cluster's boxplot: inside black line represents the median value. Boxplot contains the variation between 25 and 75%.

Conclusion

Potential short-term memory induction constitutes a promising method to enhance physiological responses in SP-CWR. We showed that SP-CWR developed drought tolerance through two basic mechanisms: i) resilience, by developing more leaves with an increased time to fix carbon and ii) productivity, by optimizing leaf thermoregulation and gas exchange. The use of resilience capacity and productivity capacity, simultaneously, allowed us to easily identify genotypes from Group C (Fernandez et al., 1992), a group of plants expressing a relatively higher performance under stress conditions, which is highly appreciated by breeders. Our results set a precedent in stress memory in SP-CWR and demonstrates that this group constitutes a potential and untapped source of valuable physiological traits for sweetpotato improvement programs.

References

Dempewolf, H. et al. (2014). Adapting Agriculture to Climate Change: A Global Initiative to Collect, Conserve, and Use Crop Wild Relatives. *Agroecol. Sust. Food* 38, 369–377. doi: 10.1080/21683565.2013.870629

Fernandez, G. C. J. (1992). "Effective selection criteria for assessing plant stress tolerance," in *Proceeding of the International Symposium on Adaptation of Vegetables and other Food Crops in Temperature and Water Stress*, Ed. C. G. Kuo (Tainan, Taiwan: AVRDC), 257–270.

Thiry, A. A. et al. (2016). How can we improve crop genotypes to increase stress resilience and productivity in a future climate? A new crop screening method based on productivity and resistance to abiotic stress. *J. Exp. Bot.* 67, 5593–5603. doi:10.1093/jxb/erw330

Acknowledgments

This research was undertaken as part of, and funded by, the CGIAR Research Program on Roots, Tubers and Bananas (RTB) and supported by CGIAR Trust Fund contributors (https://www.cgiar.org/funders/). The study was part of the initiative "Adapting Agriculture to Climate Change: Collecting, Protecting and Preparing Crop Wild Relatives" which is supported by the Government of Norway. The initiative is managed by the Global Crop Diversity Trust with the Millennium Seed Bank of the Royal Botanic Gardens, Kew, UK, and implemented in partnership with national and international genebanks and plant breeding institutes around the world. For further information, see Dempewolf et al. (2014), and http://www.cwrdiversity.org/. The sweetpotato CWR project was led by North Carolina State University (NCSU).

RESEARCH PROGRAM ON Roots, Tubers and Bananas · CROP TRUST · NC STATE UNIVERSITY