A controlled gravimetric phenotyping approach reveals variation in transpiration responses to evaporative demand among maize NAM parents

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INTRODUCTION

In maize, restricting whole-plant transpiration [TR] response to increasing vapor pressure deficit [VPD] to a constant level has been associated with drought tolerance and better productivity under water-limited conditions (e.g., Messina et al. 2015). However, until now, such response in maize has only been explored in vivo within a relatively narrow genetic base (Gholipoor et al 2013). The extent of natural variation of this trait within a much diverse genetic background remains to be explored. This is needed to address the important question of how widespread is this restriction in maize and identify potential genetic bottlenecks for this key trait. The goal of this investigation was to examine the natural variation of this trait within a widely used diversity panel consisting of 25 maize Nested Association Mapping parents (McMullen et al. 2009) in addition to genotypes B73 and Mo17.

Because phenotyping for such trait requires an experimental approach where the confounding effects of environmental variables (temperature, PPFD, boundary layer resistance, etc.) are stabilized, we developed for this study an ad hoc gravimetric phenotyping system.

EXPERIMENTAL APPROACH

- ***Development of GPS (Gravimetric Phenotyping of Stress traits) platform***

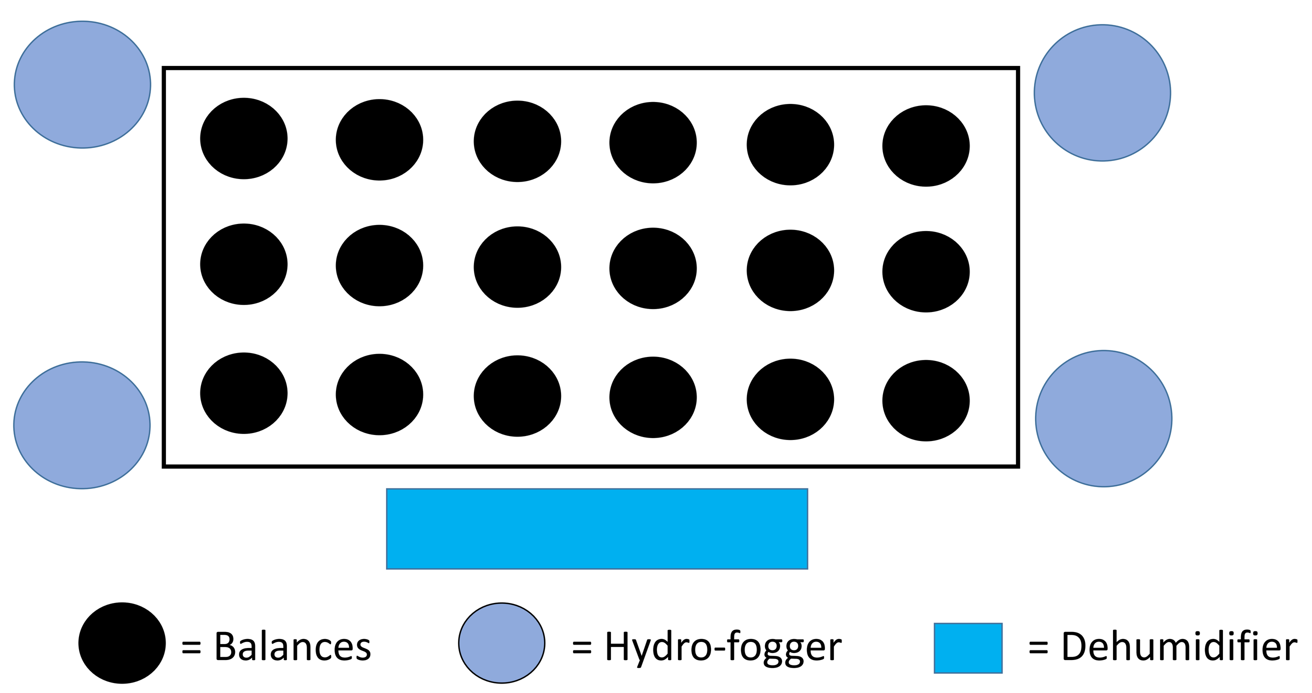

Figure 1. Graphical illustration depicting the main components of the GPS platform, deployed across three identical growth chambers. Hydro-foggers are used to increase the relative humidity (RH) inside the chambers while programmable dehumidifiers are used to sequentially decrease the RH in a controlled fashion. The above shown set-up is contained inside a programmable chamber which allows the control of variables such as light levels, temperature and air mixing. The high resolution balances attached with data loggers track the amount of water lost by pots containing plants while weather loggers record the temperature and RH experienced by plants at canopy level.

- *Phenotyping canopy conductance to increasing vapor-pressure-deficit among maize NAM parents*

-Three independent experiments were carried out on the GPS platform.
- Plants were exposed to six sequentially increasing VPD steps each lasting for an hour (0800 to 1400 hrs) during which the temperature was set at constant 30 °C and PPFD of ~ 600 μmol m^{-2} s^{-1}.

RESULTS

1. The GPS platform allowed to achieve targeted environmental conditions

Table 1. Temperature and VPD conditions imposed inside the growth chambers where the gravimetric phenotyping system was deployed.

Exp.	Environmental conditions[a]						
	Temp. (°C) ± S.E.	VPD1 (kPa) ± S.E.	VPD2 (kPa) ± S.E.	VPD3 (kPa) ± S.E.	VPD4 (kPa) ± S.E.	VPD5 (kPa) ± S.E.	VPD6 (kPa) ± S.E.
1	29.9 ± 0.1	1.7 ± 0.03	2.0 ± 0.02	2.3 ± 0.02	2.5 ± 0.03	2.8 ± 0.04	3.0 ± 0.10
2	30.0 ± 0.2	1.6 ± 0.06	2.0 ± 0.04	2.3 ± 0.04	2.5 ± 0.03	2.8 ± 0.04	3.0 ± 0.10
3	30.2 ± 0.1	1.7 ± 0.05	2.1 ± 0.04	2.4 ± 0.10	2.7 ± 0.10	2.8 ± 0.10	3.1 ± 0.04

[a]VPD1-VPD6 refer to six steps of steady-state VPD conditions imposed to examine transpiration response to increasing VPD.

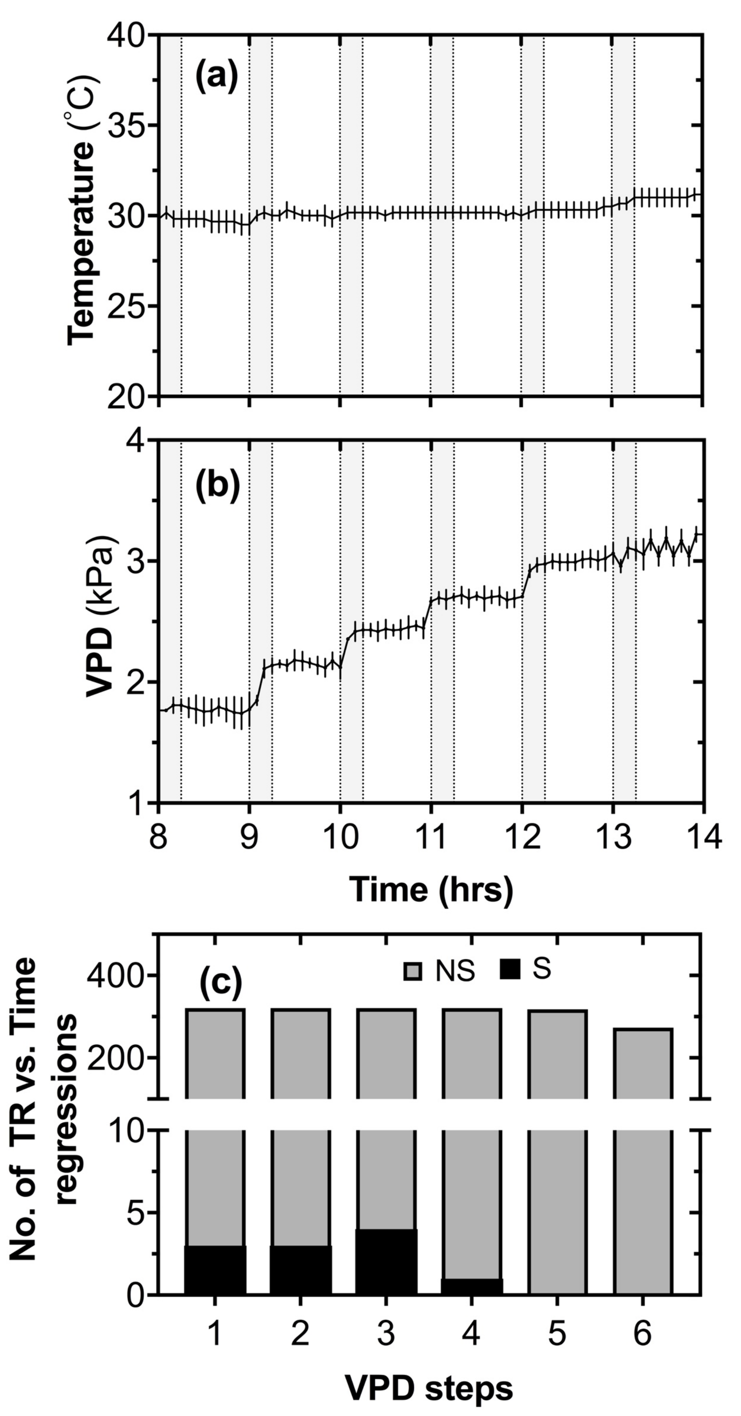

Figure 2. Representative time courses of temperature (panel a), VPD (panel b) and summary of transpiration rate stability analysis carried out during each of the VPD steps imposed (panel c). Data is the average of 3 replications (± SE) for panel (a) and (b) where grey area represents the 15-min acclimation period the data from which were excluded from data analysis. Panel (c) represents the number of TR vs time regressions analyzed for each one of the 6 imposed steady-sate VPD steps (total: .>1800 regressions). Black bars represent number of occurrences when the slopes significantly differed from zero (S) while grey bars are times when they did not.

2. Characterization and diversity in transpiration response to vapor pressure deficit within maize NAM parents

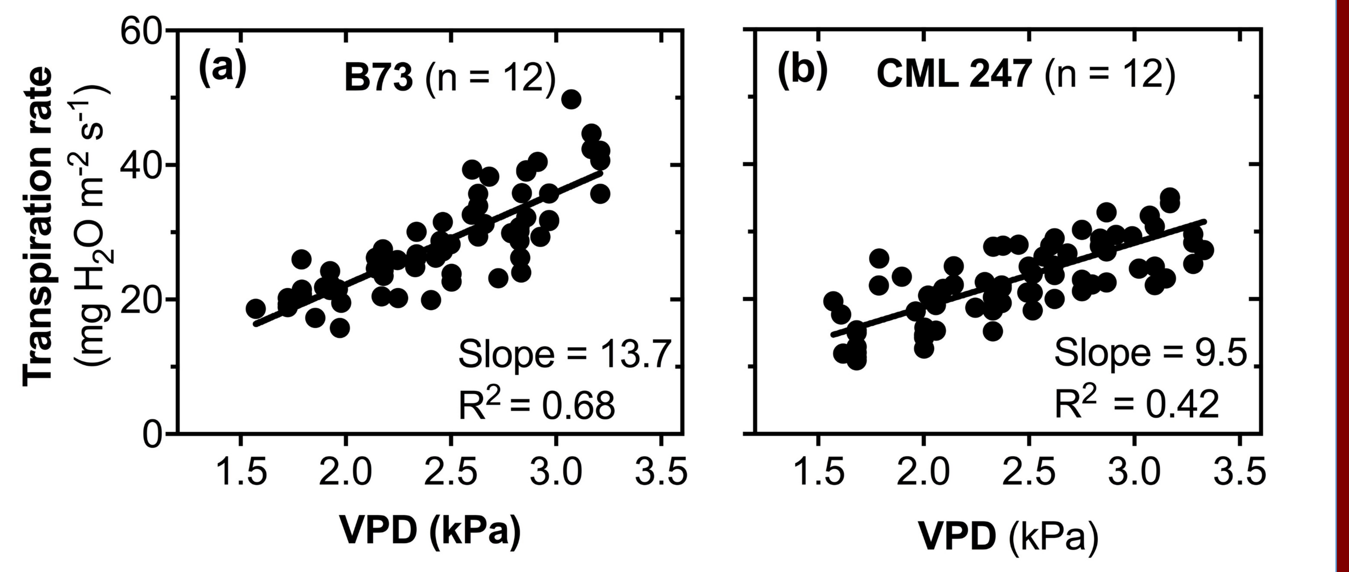

Figure 3. Examples of transpiration rate linear responses to increasing VPD. Panel (a) and (b) represent linear regressions fitted data for genotypes B73 an d CML 247 with n representing number of replicate plants examined. Slopes ranged from 6.8 to 15.2 mg H_2O m^{-2} s^{-1} kPa^{-1} in this panel.

3. Lack of correlation between canopy conductance and developmental traits

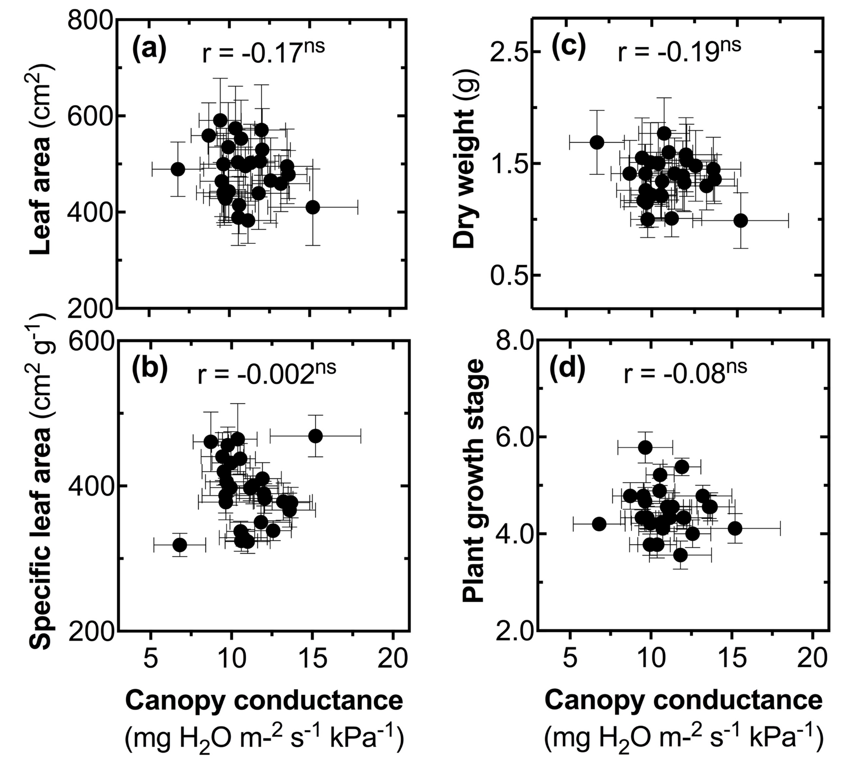

Figure 4. Correlations between canopy conductance and four plant developmental traits (panel (a-d)). Pearson's correlation (r) are provided which are based on data from all 27 genotypes (ns: non-significant correlations at P < 0.05). Error bars reflect standard errors (± S.E.).

MAIN CONCLUSIONS

- Slopes of TR response curves to VPD varied significantly and substantially among the genotypes of the diversity panel, ranging from 6.8 to 15.2 mg H_2O m^{-2} s^{-1} kPa^{-1}, independently from plant size or development.
- However, none of the genotypes exhibited the maximal transpiration response. Because of the diversity of the panel, this indicates that this trait might be rare in maize.
- This in turn highlights the importance of functional characterization of genotypes when assembling diversity panels to explore the genetic basis of complex traits.

REFERENCES

- Gholipoor et. al., 2013. Transpiration response of maize hybrids to atmospheric vapour pressure deficit. J. Agron. Crop Sci. 199: 155-160.
- McMullen et. al., 2009. Genetic properties of the maize nested association mapping population. Science 325: 737-740.
- Messina et. al., 2015. Limited-transpiration trait may increase maize drought tolerance in the US corn belt. Agron. J. 107: 1978-1986.

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