The importance of empirical data in accounting for the long-term and interactive effects of climate change on cocoa

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Climate change research on plant physiology needs to address:

• The interactive nature of climate variables

• The long-term processes in a perennial crop
Interactive effects

Elevated CO₂ & Water deficit

- Negative impact of water deficit on tree biomass production
- When grown under water deficit in a high CO₂ environment the impact of water deficit is reduced
- Genotypic differences in response to environment

*Mature grafted clones, grown under experimental conditions for 2 years

WW = well-watered
WD = water deficit

Lahive et al., Agronomy 2021
https://doi.org/10.3390/agronomy11050818
Interactive effects

**Elevated CO₂, Temperature & Water deficit**

- Positive effect of elevated CO₂ in well-watered and water deficit treatment
- The negative impact of water deficit is ameliorated by elevated CO₂
- Enhanced tolerance to high temperature in plants grown at elevated CO₂ – but only in well-watered conditions

*Seedlings grown under experimental conditions for 90 days*
Modelling interactive effects on NPP

NPP = net primary productivity (green and woody biomass)
**Long-term processes**

**Thermal acclimation in cocoa**

Photosynthetic acclimation: “environmentally induced changes in photosynthetic characteristics that result in an improved performance under the new growth regime” (Berry and Bjorkman, 1980)

**Growing conditions for 1 year**

- Ambient $[\text{CO}_2]$ vs. Elevated $[\text{CO}_2]$
- Control ($31/22^\circ\text{C}$) $T_c$
- High temp ($36/27^\circ\text{C}$) $T_c+5.0^\circ\text{C}$

Perform reciprocal photosynthetic measurements to identify the occurrence of acclimation.

- $31^\circ\text{C} \longrightarrow 36^\circ\text{C}$

**Cooler growing environment**

**Warmer growing environment**
Evidence of thermal acclimation in cocoa

Measured at 31°C

Ambient CO₂

Photosynthesis (μmol m⁻² s⁻¹)

Growth temperature

31°C

36°C
Evidence of thermal acclimation in cocoa

36°C is supra-optimal under current day conditions, evidenced by measured photosynthesis at 31°C.

Ambient CO₂
Evidence of thermal acclimation in cocoa

36°C is supra-optimal under current day conditions

But not under future temperature conditions

Measured at 31°C

Ambient CO₂

Photosynthesis (µmol m⁻² s⁻¹)
Evidence of thermal acclimation in cocoa

36°C is supra-optimal under current day conditions

But not under future temperature conditions

31°C measured at 31°C

36°C measured at 36°C

36°C is elevated CO₂

Ambient CO₂
Evidence of thermal acclimation in cocoa

36°C is supra-optimal under current day conditions. But not under future temperature conditions.

Evidence of thermal acclimation in cocoa
Evidence of thermal acclimation in cocoa

Has the optimum temperature shifted upward in a high CO₂ environment?

36°C is supra-optimal under current day conditions.

But not under future temperature conditions.

Elevated CO₂ Has the optimum temperature shifted upward in a high CO₂ environment? Evidence of thermal acclimation in cocoa

Growth temperature

Photosynthesis (μmol m⁻² s⁻¹)

Measured at 31°C

Measured at 36°C

Ambient CO₂

36°C is supra-optimal under current day conditions

But not under future temperature conditions
Elevated CO₂ has the optimum temperature shifted upward in a high CO₂ environment?

36°C is supra-optimal under current day conditions but not under future temperature conditions.

31°C measured at 31°C and 36°C measured at 36°C.

Enhanced photosynthetic efficiency at under future climate conditions.
Conclusions

• To future proof cocoa production we need to understand how climate change will impact cocoa tree performance

• Experimental data capturing complex climate x plant interactions is required to better predict future outcomes, develop more resilient planting material and develop effective management strategies to secure production for farmers

• The perennial nature of the cocoa tree adds complexity to this picture. Acclimation to prevailing growing conditions can occur over time. Our understanding of these processes and their effects is currently very limited.
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