CRUK/University of Reading

Identification of Selection Traits to Maximise Cocoa Productivity and Quality in a Changing Environment Phase I

Improving our understanding of the effects of environmental variables on cocoa growth and development

Climate change is likely to lead to challenging conditions in many cocoa growing areas, with predictions of less evenly distributed rainfall patterns and higher maximum temperatures, often compounded with the environmental effects of local deforestation. Many current cocoa varieties are considered unlikely to perform well in prolonged periods of dry conditions. Although strategic research on temperate crops has indicated that genotypic differences can be exploited to breed new varieties better adapted to a future climate, very little research has been undertaken on tropical perennial crops. This project set out to investigate the effects of water deficit stress, and carbon dioxide (CO_2) levels on cocoa plants using controlled environment greenhouse facilities at the University of Reading. Phase I focussed on vegetative growth and development of Amelonado seedlings and mature plants of a number of varieties obtained from the University's International Cocoa Quarantine Centre (http://www.icgd.reading.ac.uk/icqc/). Phase II focused on flower and pod development and bean quality.

Several climate change models predict that CO_2 levels will reach 700 parts per million (ppm) within the next 100 years so this level was used to evaluate the response of cocoa plants to elevated CO_2 conditions.

Both seedlings and more mature plants responded positively to elevated CO_2 levels in terms of their photosynthetic characteristics and growth, with the strongest growth response observed in seedlings.

Since the plants were grown in a semi-hydroponic system, it was possible to control water availability and investigate the effects of water stress and interactions with CO_2 treatments. Drought stress was found to reduce photosynthesis and growth, though the effects could be ameliorated to some extent by elevated CO_2. It was found that Water Use Efficiency (*ie* the amount of CO_2 fixed as carbohydrate by the plant per unit of water transpired) did increase when plants were growing in elevated CO_2 conditions but this was largely due to the improved photosynthetic rates, rather than by a reduction in the amount of water lost through the leaves due to transpiration. However, there were differences in the responses between the cocoa varieties tested. These findings could have implications for breeding cocoa varieties adapted to future conditions, since it may be possible to select for types that have improved Water Use Efficiency where this is achieved through both an increase in photosynthesis and a decline in stomatal conductance to water (rate of water loss through the leaf stomata).

Elevated CO_2 also improved light use efficiency of cocoa leaves. In these conditions photosynthesis can occur for longer periods during the day and under more shaded conditions

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March 2016

An examination of the impacts of climate change variables on growth and photosynthesis in *Theobroma cacao* L.

Thesis by
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In partial fulfilment of the requirements for the degree of
Doctor of Philosophy
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April 2015

Abstract

Climate change predictions suggest that cacao agriculture will change into the future. This study examines the effects of climate variables (elevated CO_2 and water deficit) on growth and photosynthesis of cacao seedlings (var. Amelonado) and older clonally propagated genotypes (CL 19/10, ICS 1, IMC 47, Pound 7/B, SCA 6 and SPEC 54/1). It also identifies some of the molecular mechanisms regulating stomatal development in cacao. Elevated CO_2 had a positive impact on a number of photosynthetic parameters including light saturated photosynthesis, quantum efficiency and intrinsic water-use efficiency. Genetic variation was also identified in a number of parameters. Biomass production, leaf area and stem diameter were all enhanced in seedlings grown at elevated CO_2. The growth increase in response to elevated CO_2 was stronger in seedlings than older trees. Water deficit enhanced the positive effect of elevated CO_2 on iWUE in older trees, but failed to do so in seedlings due to higher g_s, likely caused by greater stomatal production at elevated CO_2. There was a significant interaction between CO_2 and water stress in relation to quantum efficiency, however, the effect varied for seedlings and older trees. Stomatal production occurred during the period of rapid leaf expansion in cacao. The protein sequences of stomatal development genes *SPCH, MUTE* and *FAMA* in cacao shared a high degree of conservation with the equivalent sequences of *Arabidopsis*. *Cis*-regulatory domains in the promoter regions suggest guard cell-specific and leaf-specific expression of these genes. The expression pattern of *FAMA* suggests this gene functions in regulating the later stages of stomatal development in cacao. Further research is required to determine if increased growth and photosynthesis will impact on pod production in cacao. Elevated CO_2 studies, in combination with other environmental variables, are required to fully understand the impact a changing climate will have on future cacao farming.

The effects of climate change on the reproductive development of Theobroma cacao L.

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In partial fulfilment of the requirements for the degree of
Doctor of Philosophy
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September 2016

Abstract

Cacao (Theobroma cacao L.) is widely farmed throughout the humid tropics where it is an important crop to smallholder farmers. Climate change projections suggest increased temperatures and altered rainfall patterns in these regions. The effects of two key climate change variables; elevated carbon dioxide (CO2) concentrations and water deficit were investigated on the reproductive development of six genotypes of cacao (CL19/10, ICS 1, IMC 47, Pound 7/B, SCA 6, and SPEC 54/1). Genotypes showed variability in their response to treatments; however general observations were also made. At elevated CO2 (700ppm) the mean length of pollen tubes decreased and the degree of fluctuation in flowering intensity increased over time without any overall reduction in flower production. Final pod size and maximum rate of growth increased in response to elevated CO2 in the second year of study. Additionally in the second year there was an increase in husk weight and thickness, and individual bean weight. There was no increase in bean number or shell percentage. Total cocoa butter content and percentage unsaturated fat was lower under elevated CO2 along with reductions in stearic, oleic and linoleic fatty acid content; however these responses varied between genotypes and sampling period. Final woody biomass increased under elevated CO2 whereas leaf biomass was unaffected. Water deficit stress had no observed effect on pollen performance, flowering behaviour, or cocoa butter content and composition. Final pod size and rate of growth was reduced under water stress in the first year of study only. The reduced pod size was reflected in reduced husk and bean weights. Final wood and leaf biomass were both reduced in response to the water stress treatment. Across all parameters measured, no evidence of interaction between elevated CO2 and water deficit stress was observed. Overall, these results demonstrate the potential for yield improvement in cacao through breeding in preparation for future climate scenarios.