The temperature response of dry matter and sugar accumulation in grapevine berries

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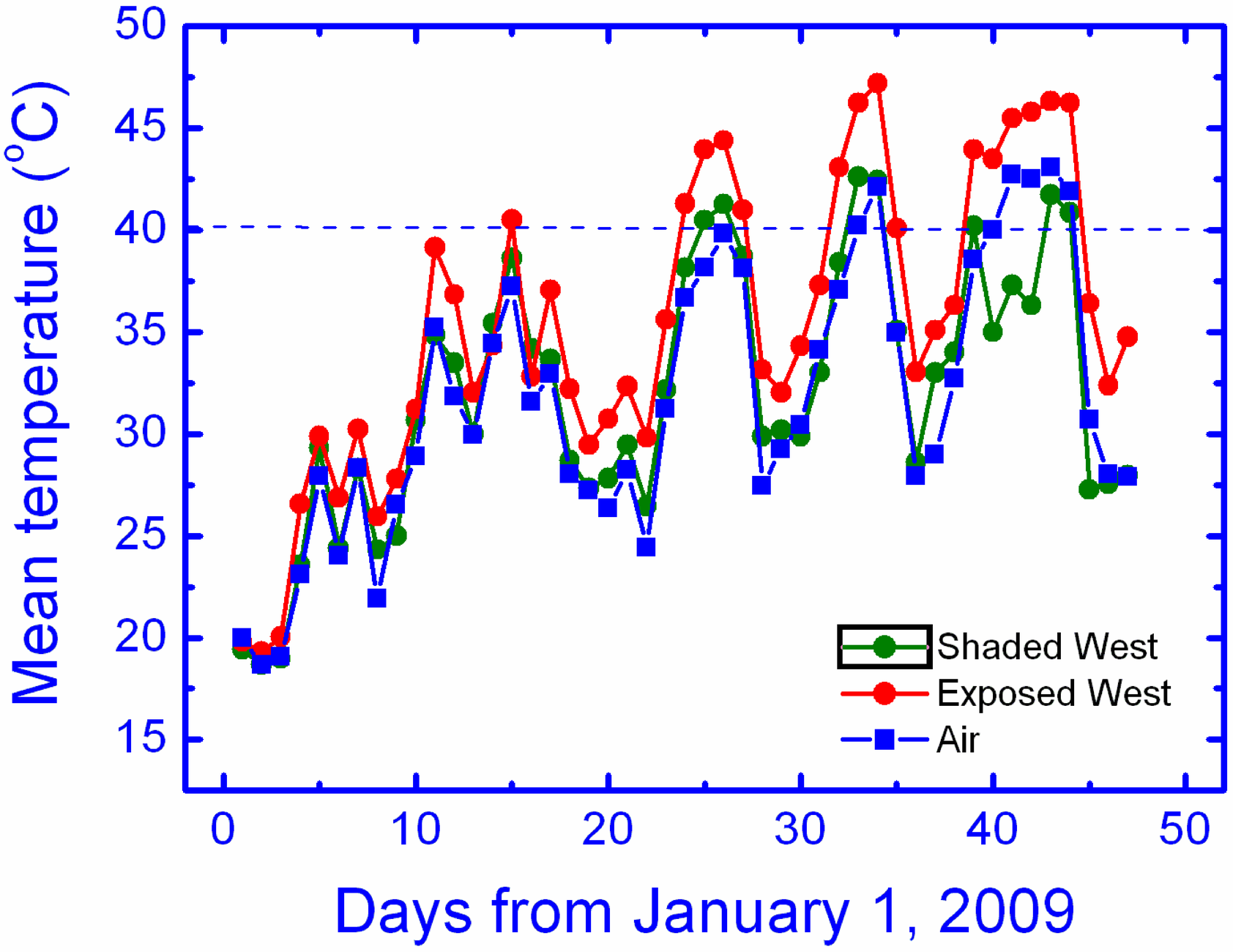
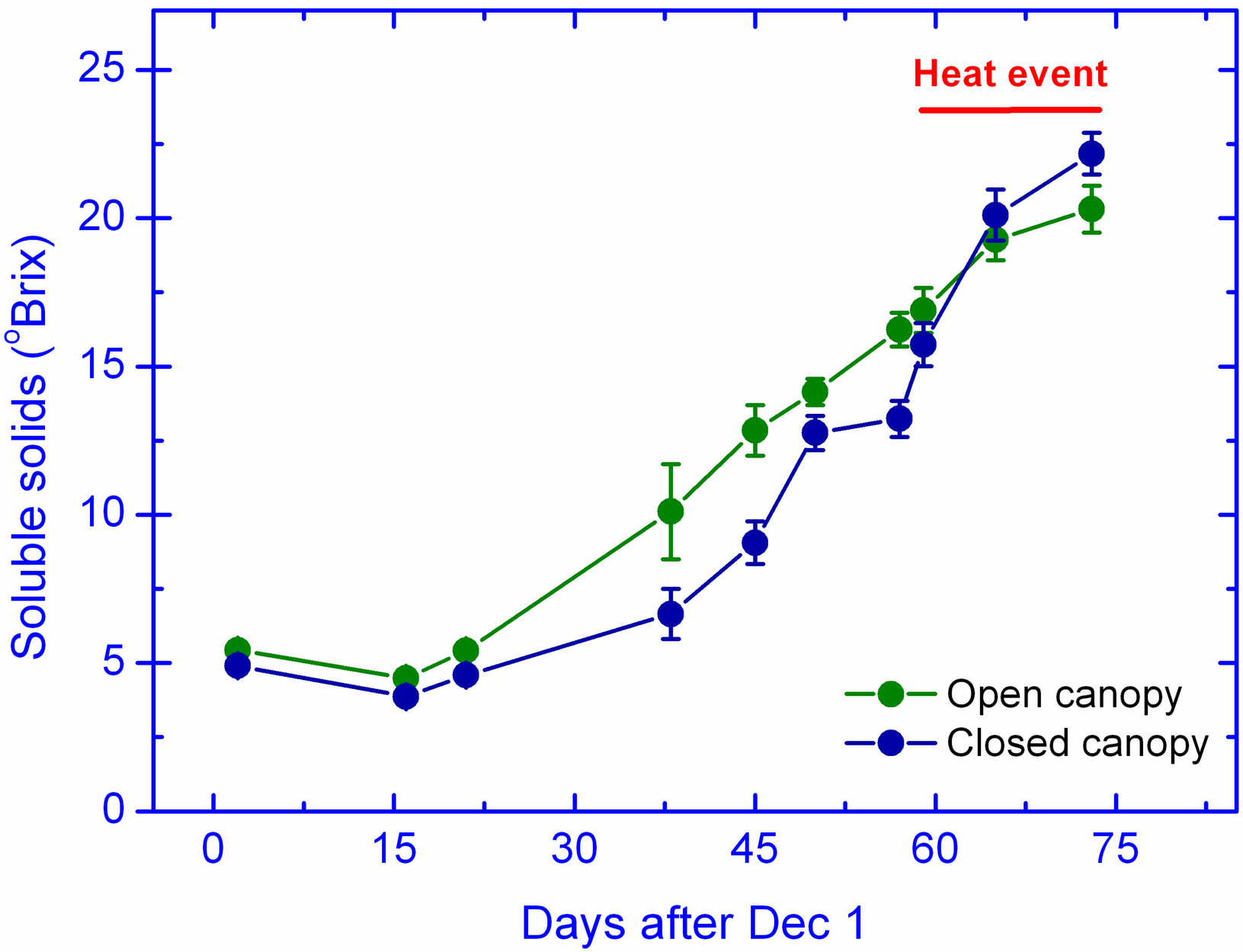
Introduction

- During a 14-day heat event, Semillon vines under protective shade suddenly increased their rate of ripening.
  - Protected vines: 0.85 ± 0.11 ^{o}Brix day^{-1}
  - Exposed vines: 0.38 ± 0.01 ^{o}Brix day^{-1}
  - Exposed canopy temperatures exceeded 45^{o}C.
  - Protected vines stayed below 40^{o}C.

The heat event



Berry ripening



Western canopy – sun exposed

An explanation of increased ripening

- Prior to heat event, protected canopy temperatures generally < 30°C.
- During heat event, temperatures averaged 38°C.
- What caused increased rate of ripening?
- Berry ripening at high temperatures?
- CE's required to resolve this question.

Hypothesis

"Semillon berries have a high temperature ripening response".

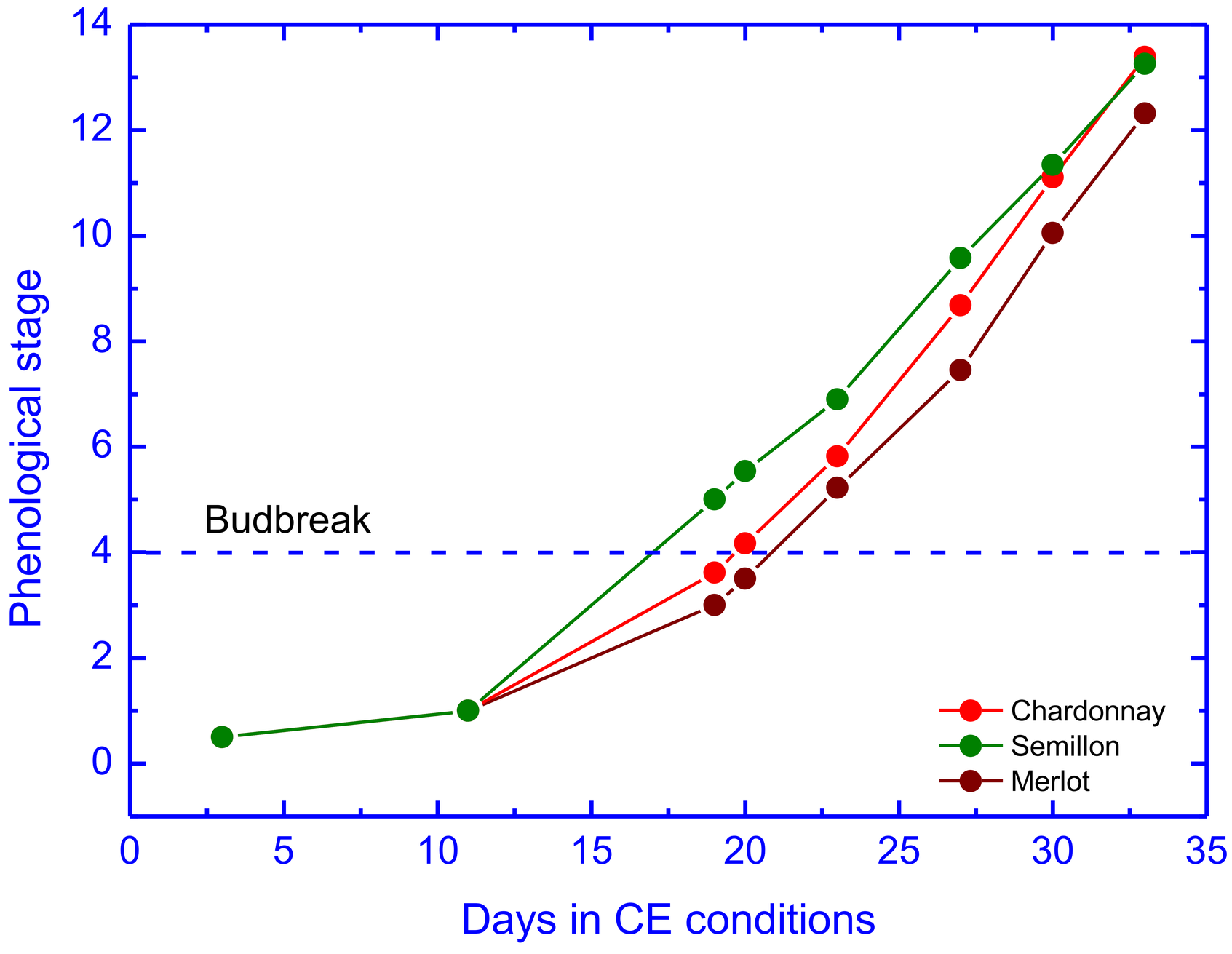
- To test:
  - Vines of cv. Semillon, Chardonnay and Merlot were grown in controlled environments from dormancy to harvest at 28/18^{o}C to compare growth and development and ripening.

Methods

- Phenology, shoot and leaf growth measured.
- Just after veraison (start of ripening), vines shifted to five temperature treatments of 20, 25, 30, 35 and 40^{o}C for 18 – 6 days.
- Berry diameter, total soluble solids and dry weights then measured and sugar content calculated over treatment duration.

Semillon vines in the CE chamber

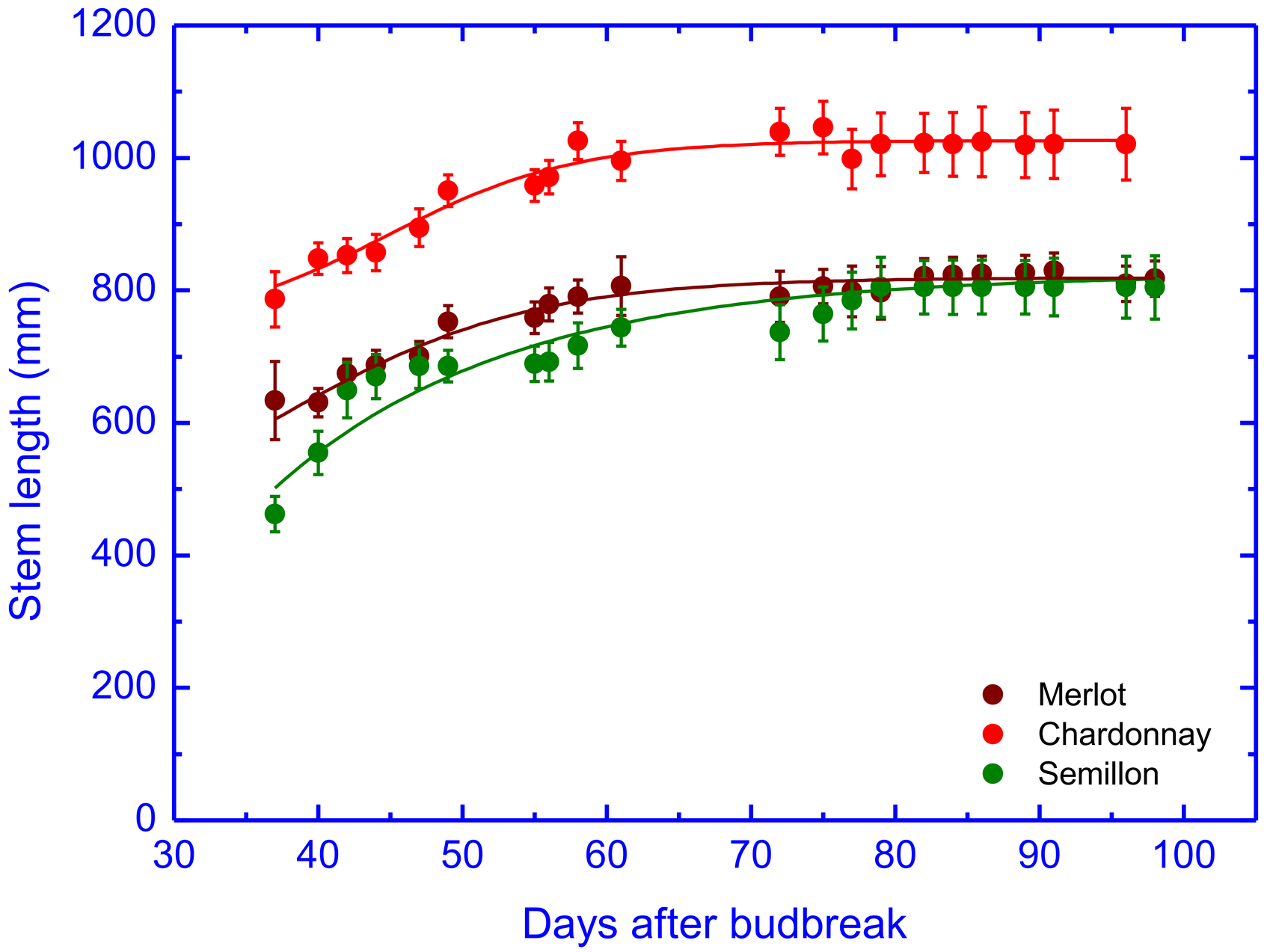
Results: Phenology



Semillon buds broke about 6 days before Chardonnay and 7 days before Merlot.

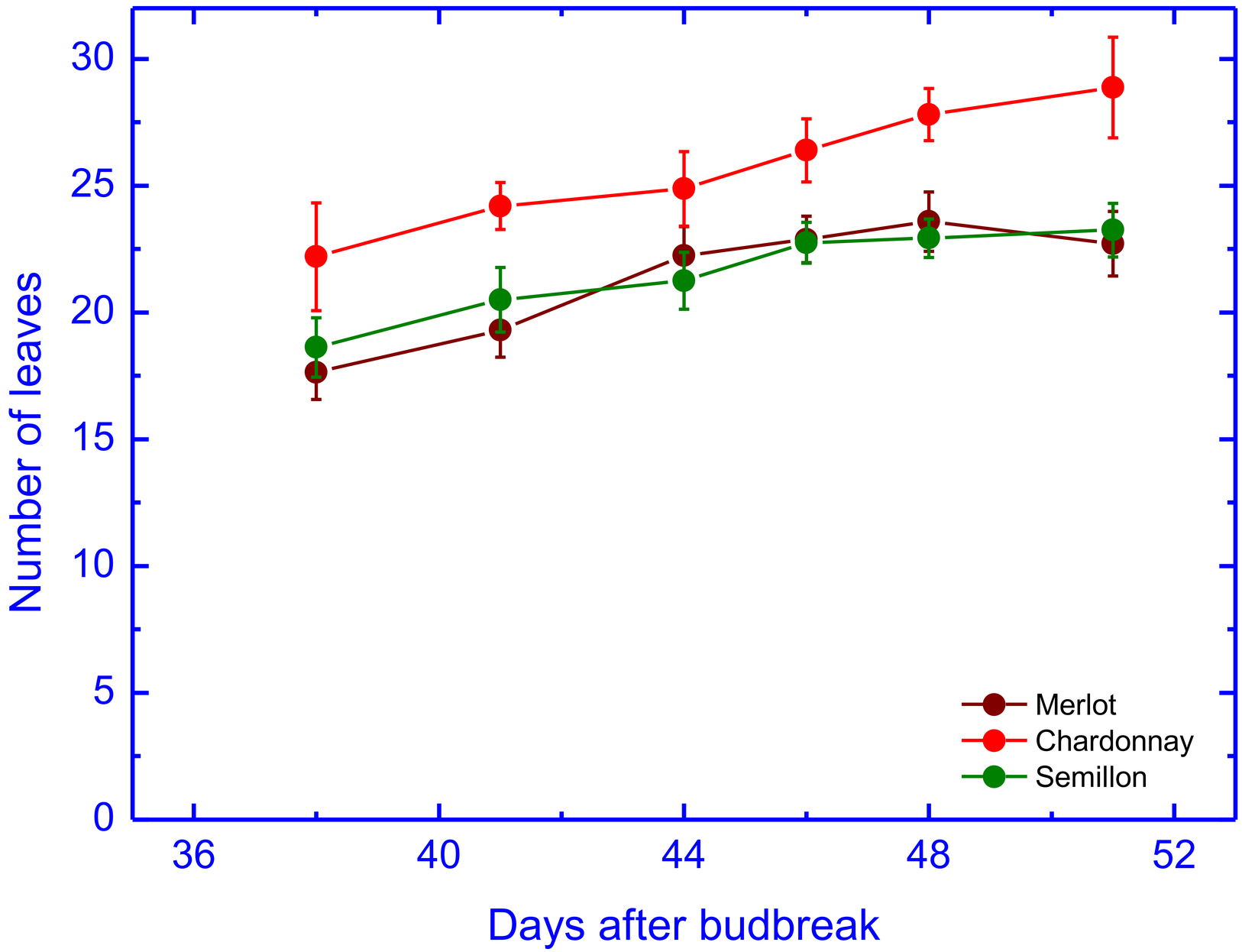
Chardonnay flowered 24 days after budbreak (DAB), Semillon flowered 27 DAB and Merlot flowered 29 DAB.

Shoot growth



Chardonnay vines grew the longest to over 1 m while the Semillon and Merlot vines were 80% of this size.

Numbers of leaves



Chardonnay vines produced 28 leaves while both other cultivars produced 23 leaves.

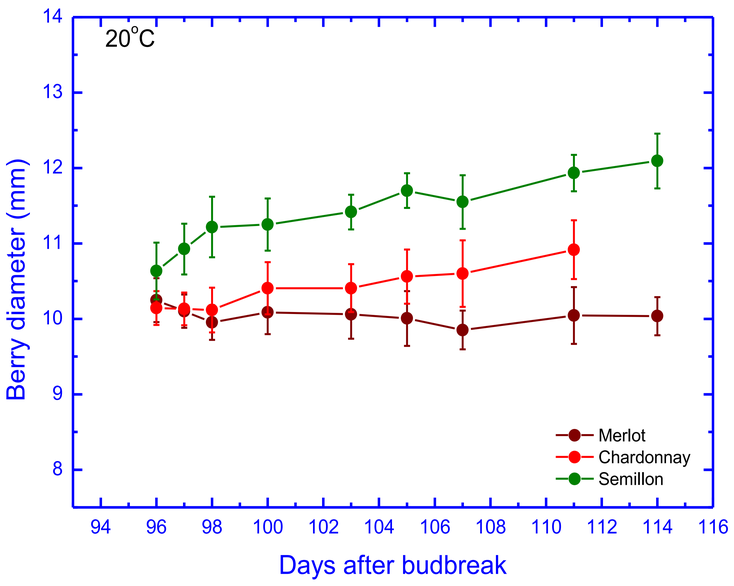
Summary of cultivars differences in vegetative growth

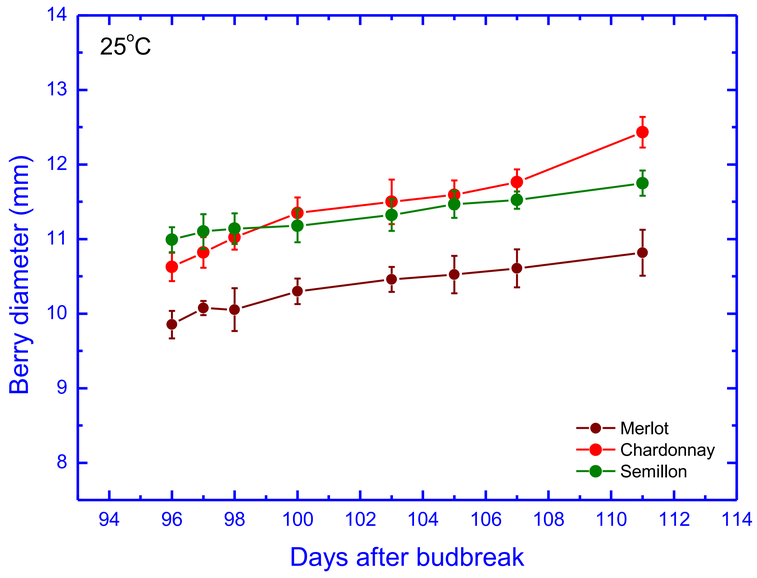
- Semillon was first cultivar to break bud and Merlot the last.
- Chardonnay was the first cultivar to flower and Merlot the last.
- Clearly cultivar differences in phenology.
- Chardonnay had the most vegetative growth.
- Differences in vegetative growth between Merlot and Semillon were small.

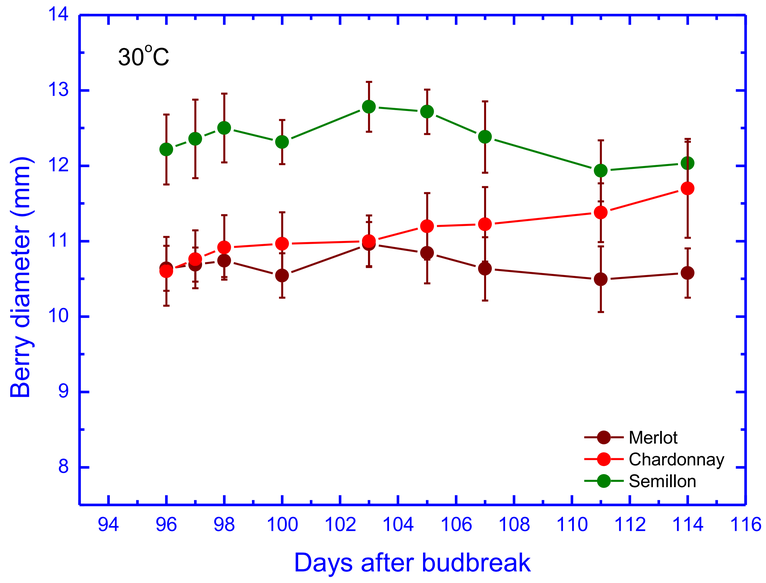
Reproductive growth at the different temperatures

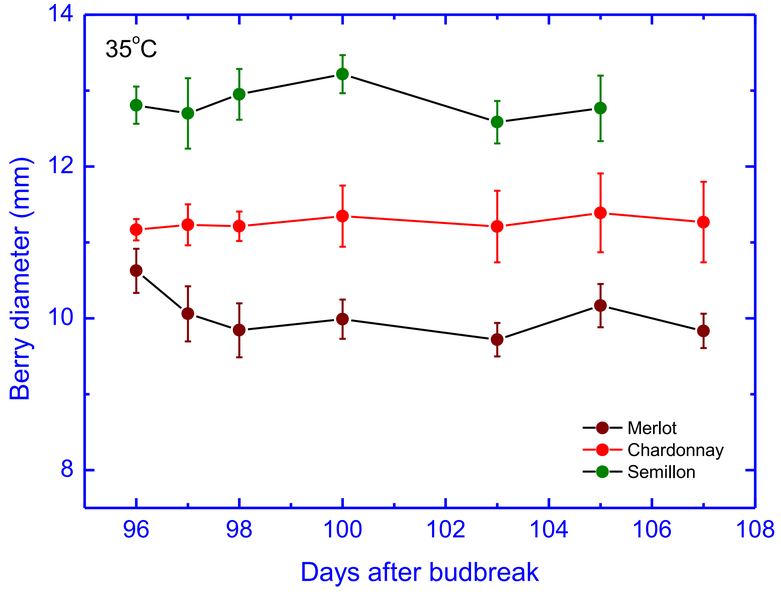
- Berry expansion
- Berry dry weight accumulation
- Sugar accumulation
- Rates of response to temperature

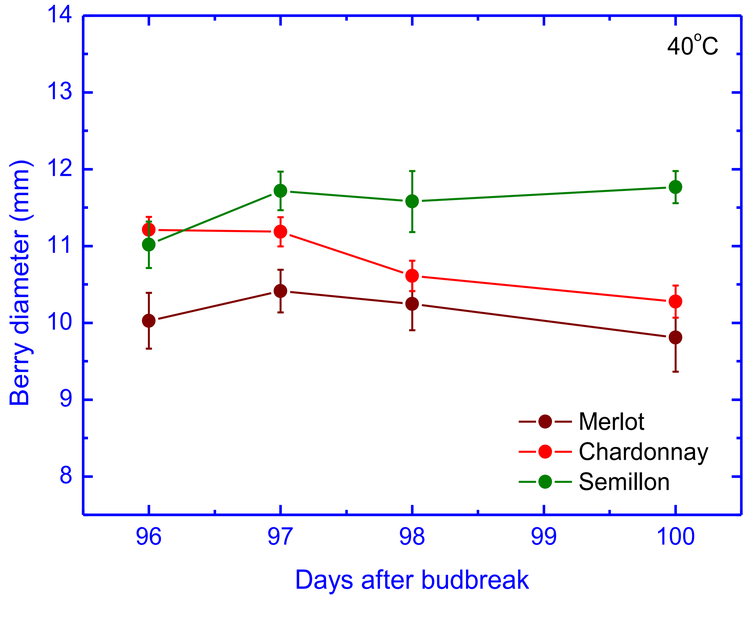
Berry expansion







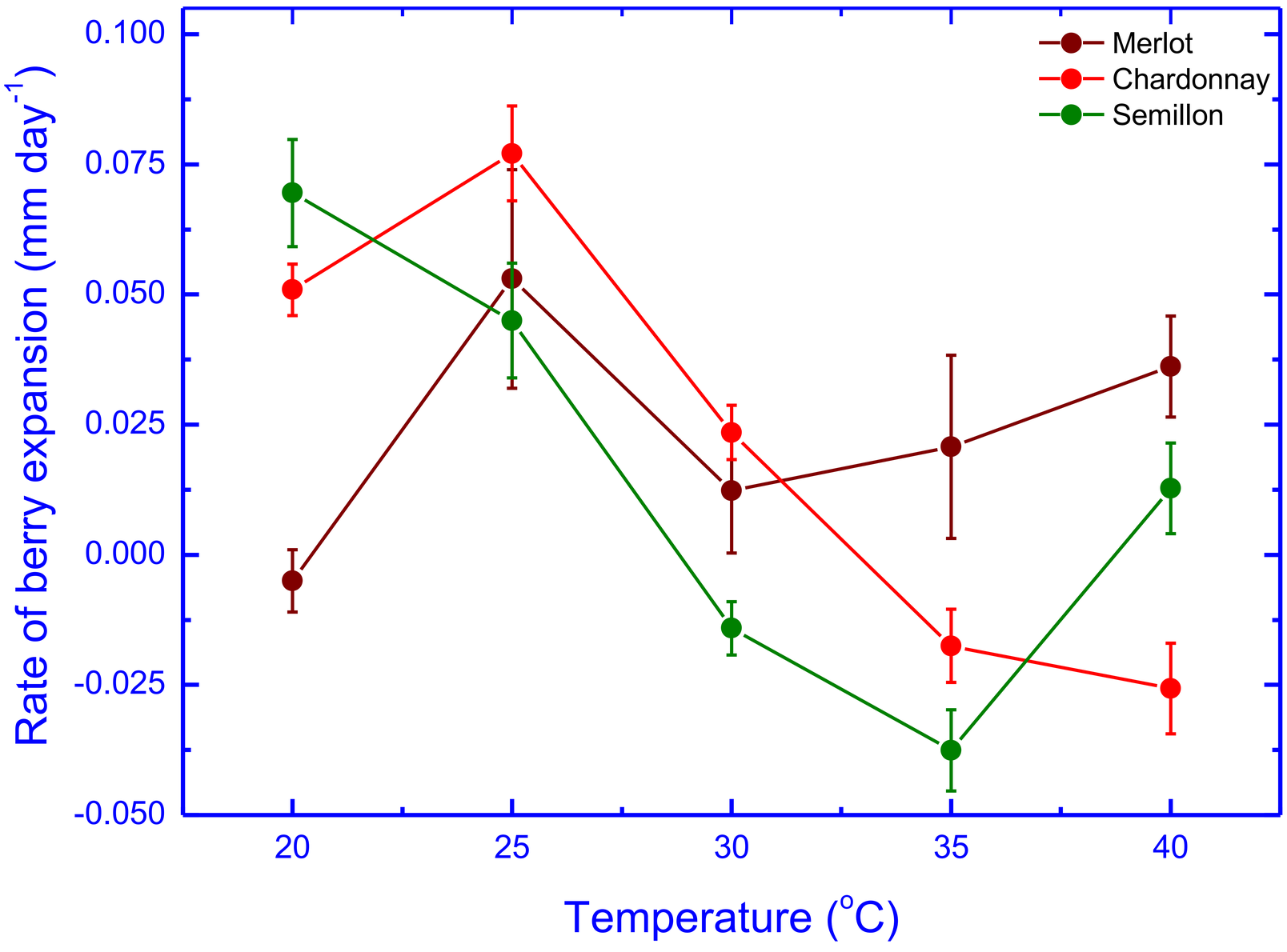




Significant differences in berry size, with Semillon consistently biggest and Merlot consistent smallest.

Only Semillon berries expanded at 20°C but all expanded at 25°C. Little expansion or some shrinkage at temperatures above 30°C.

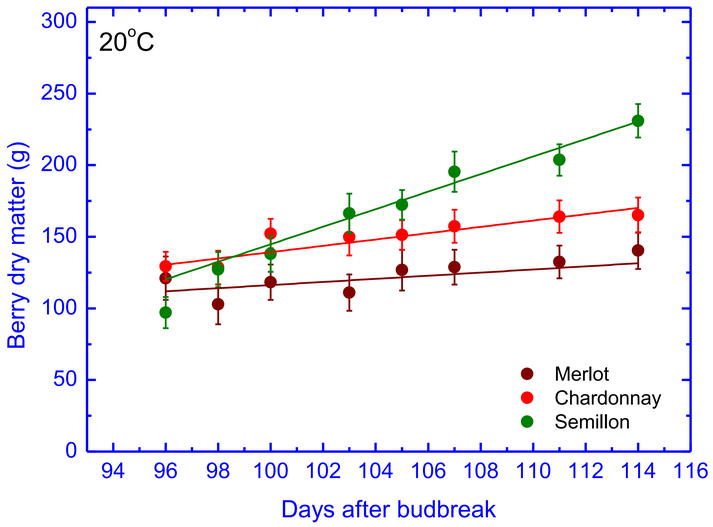
Rates of berry expansion at different temperatures

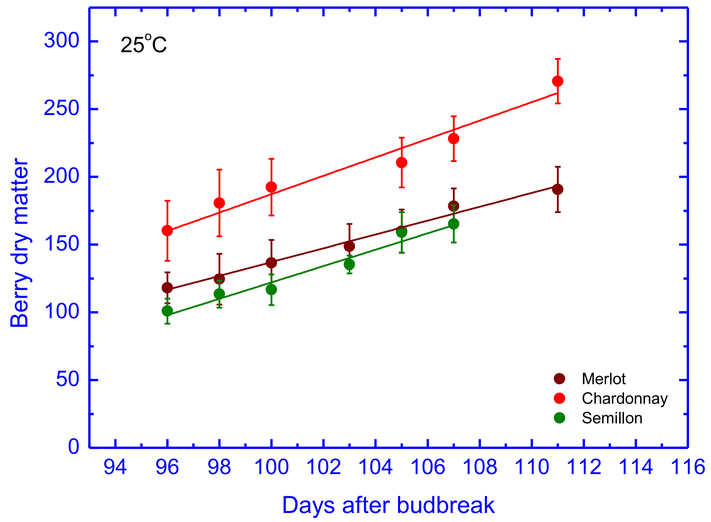


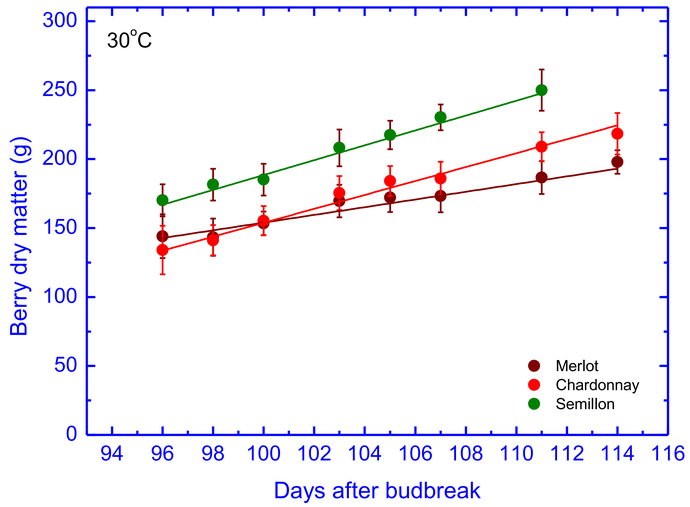
Merlot and Chardonnay expansion was fastest at 25°C but for Semillon, it was fastest at 20°C.

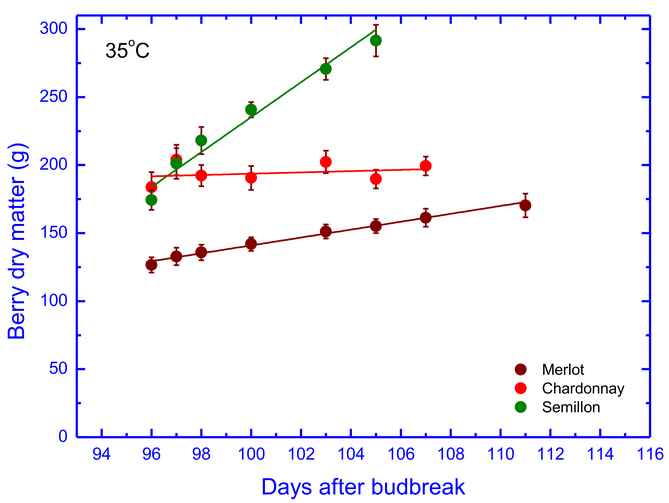
All temperatures above 30°C were detrimental to berry expansion, with slow or negative expansion (shrinkage)

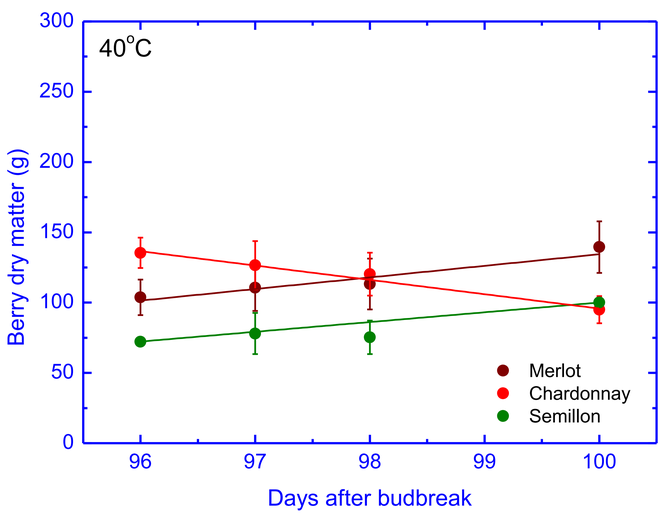
Dry weight gain (or loss)







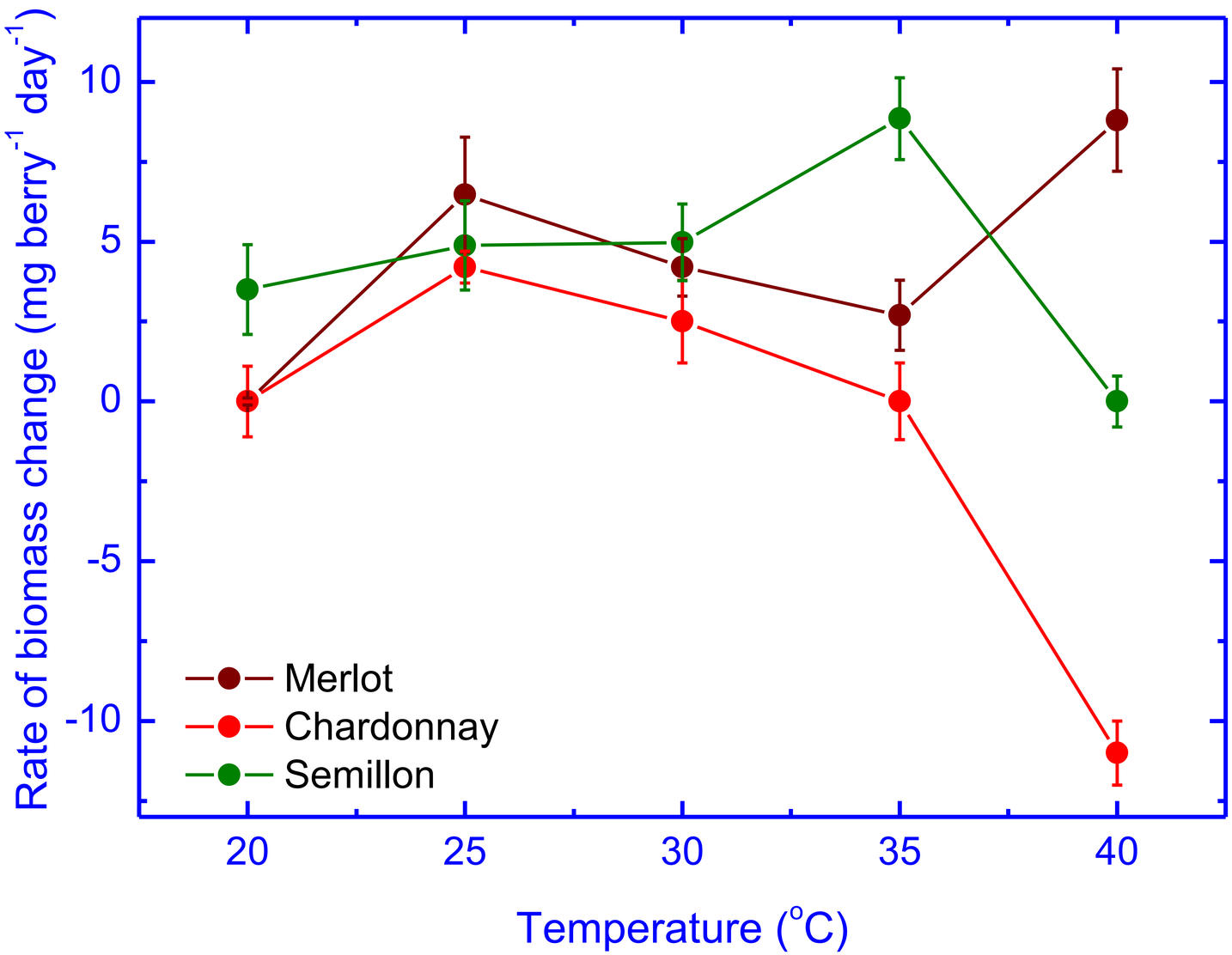




Apart from Merlot at 20°C, and Chardonnay at 35 and 40°C , all cultivars accumulated dry matter at a linear rate.

Chardonnay lost dry matter at the high temperatures.

Rates of berry dry matter accumulation at the different temperatures

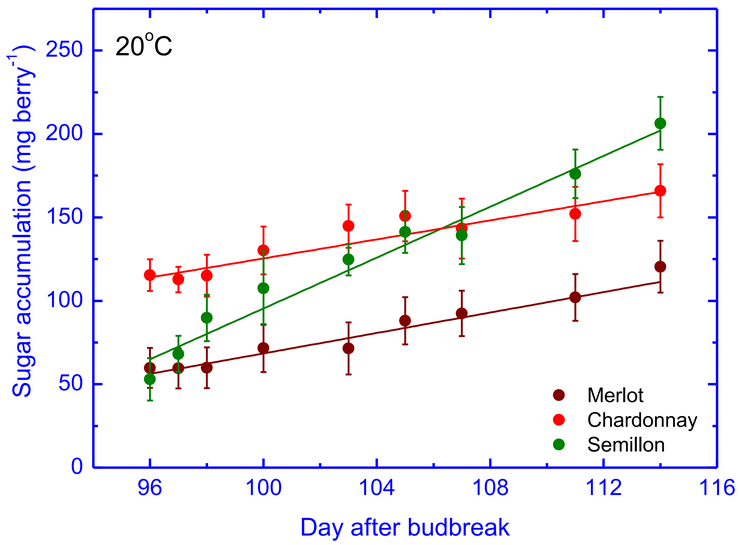


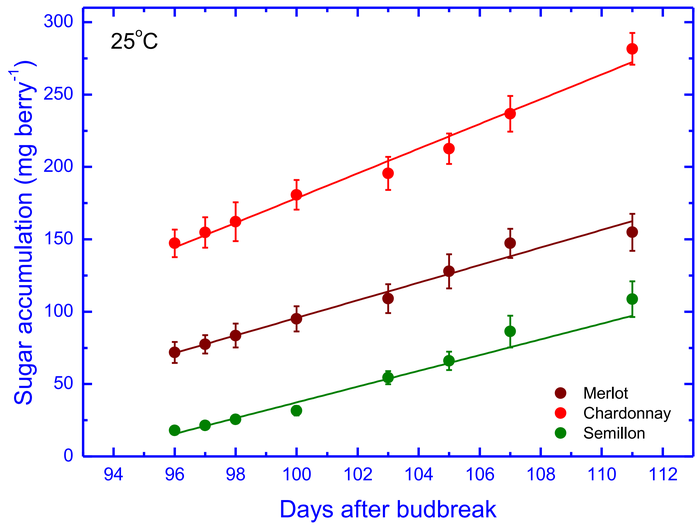
Chardonnay berries accumulated dry matter optimally at 25°C and all temperatures above were detrimental, especially 40°C.

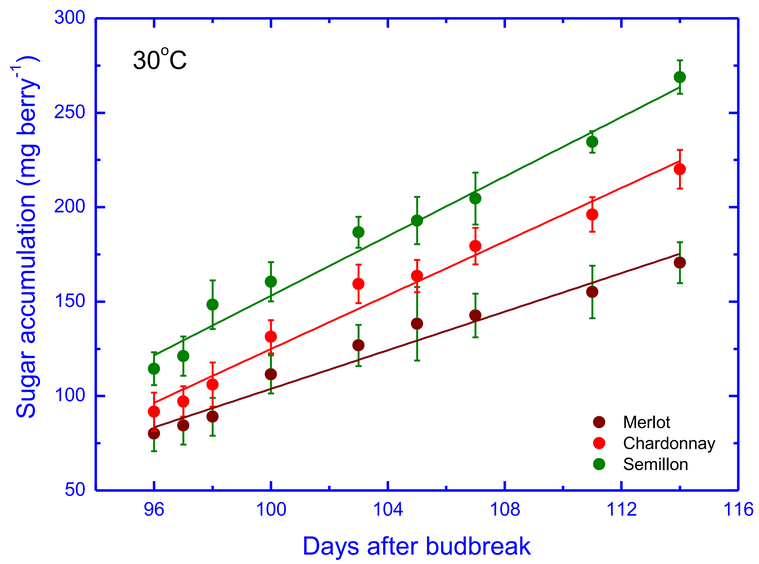
Semillon berries accumulated maximally at 35°C but at a faster rate than the Chardonnay berries.

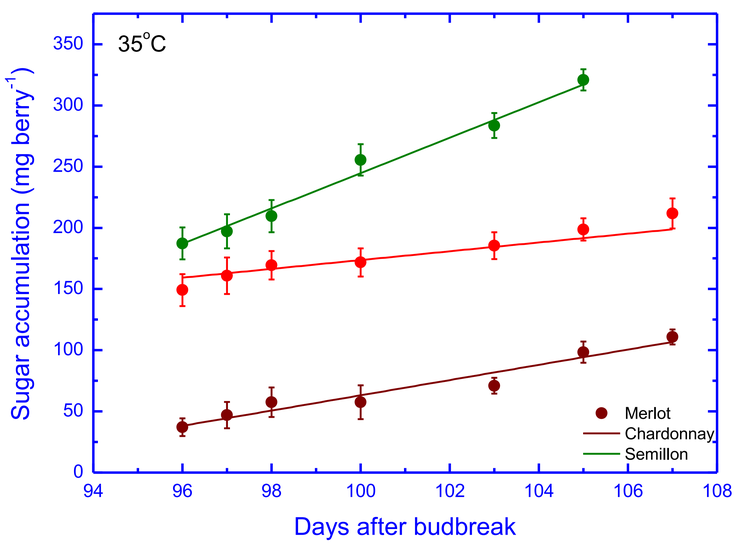
Merlot berries appeared to be maximal at both 25 and 40°C, and at the highest temperature, was as fast as the Semillon berries at accumulating dry matter at 9 mg day^{-1}.

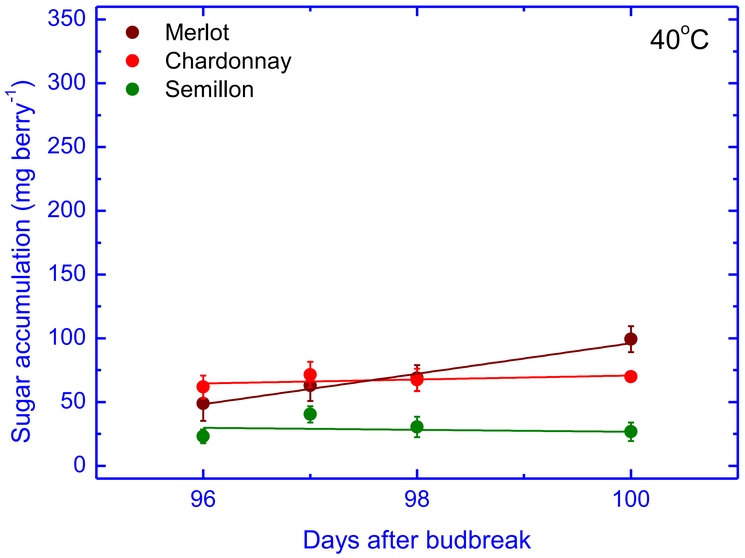
Sugar accumulation at the different temperatures











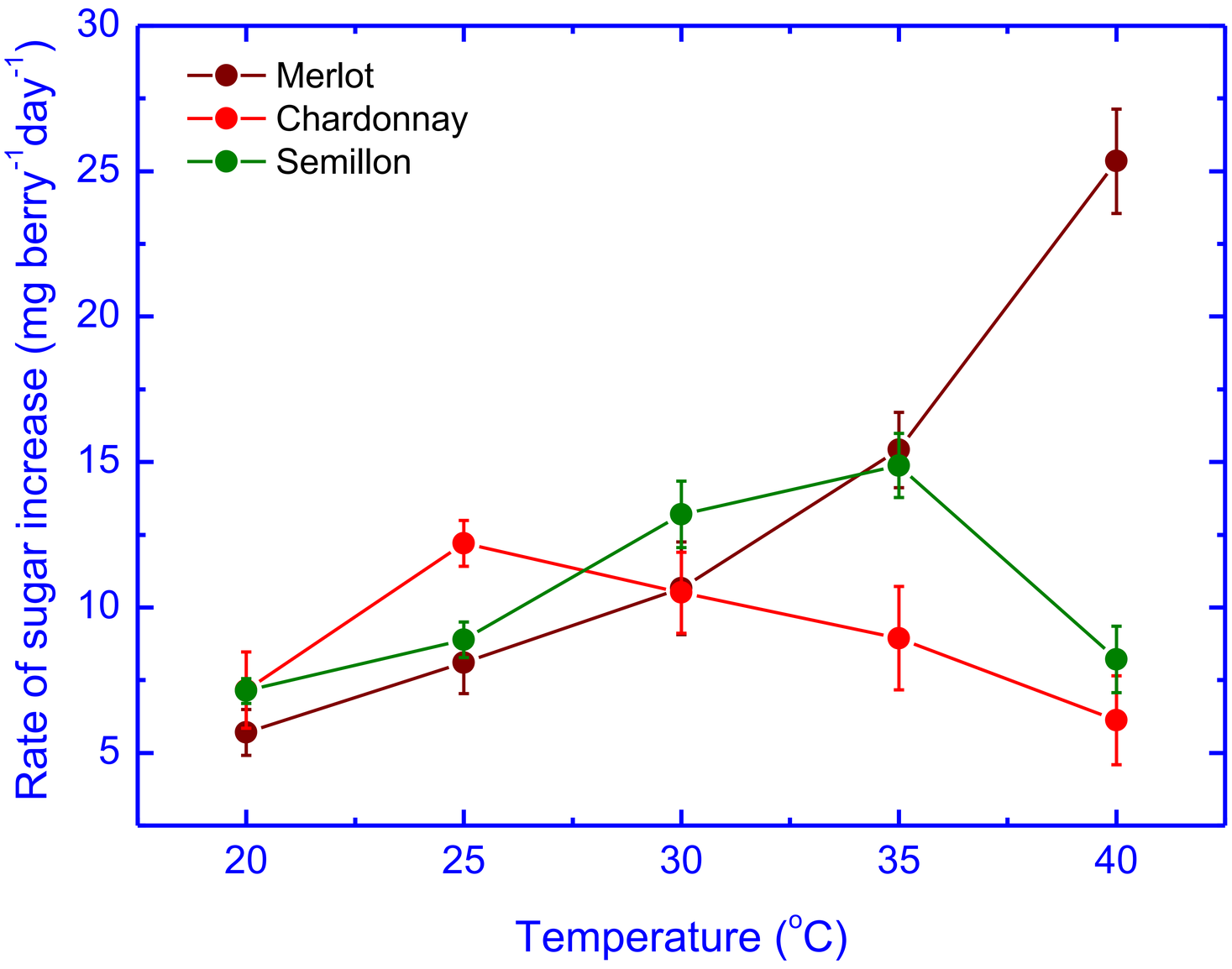
Sugar accumulated at a linear rate over the treatment time in all cases.

Chardonnay berries accumulated most sugar at 25°C.

Semillon berries accumulated most sugar at 35°C.

Merlot berries had the lowest sugar content.

Rates of sugar accumulation as a function of temperature



Chardonnay optimal sugar accumulation at 25°C.

Semillon had optimal sugar accumulation at 35°C – hypothesis proven!

Merlot had maximal sugar accumulation at 40°C!

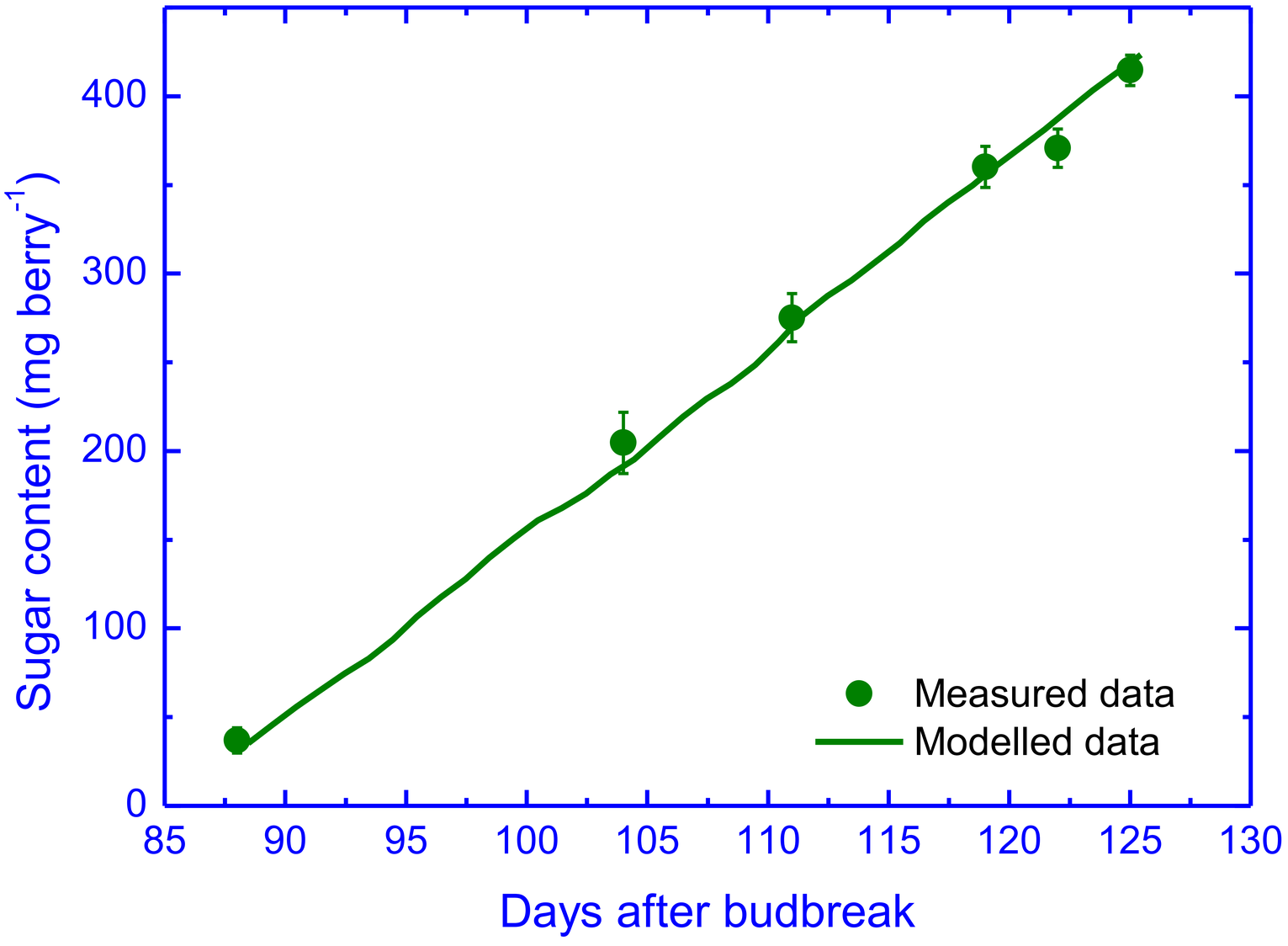
Summary of cultivars differences in reproductive growth

- Berry expansion in all cultivars optimal at 20 – 25^{o}C.
- No marked differences in rates of berry expansion between cultivars.
- Dry matter and sugar accumulation optimal at 25, 35 and 40^{o}C in Chardonnay, Semillon and Merlot vines, differences significant.
- High temperatures detrimental to dry matter and sugar accumulation in Chardonnay vines.
- Hypothesis that Semillon berries have a high temperature ripening response proven.

Modelling sugar accumulation in vineyard-grown vines

- Fit an empirical polynomial function to the temperature-dependent sugar accumulation response of Semillon.
- Apply this function to the canopy temperatures measured over the growing season to predict sugar accumulation.
- Compare predictions with measured sugar accumulation.

Modelled progression of sugar accumulation in Semillon berries



Modelled progression fitted the measured data extremely well.

Demonstrates that validity of the temperature function for sugar accumulation.

Provides additional proof for the hypothesis that Semillon has a high-temperature ripening response.

Conclusions

- Temperature has a marked effect on berry growth of the three grapevine cultivars.
- Quantifying the temperature-function is only possible using controlled environments.
- Successfully extending the temperature-function to field conditions to predict sugar accumulation.
- Demonstrated that potted vines and controlled environments can be used to mimic field behaviour.
- This is the real power of using controlled environments and the approach needs to be endorsed and promoted widely.

Acknowledgements

- Dr Mark Weedon carried out much of the work.

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