Integrating xylem and phloem fluxes into a whole-plant model for simulating grape berry growth and quality

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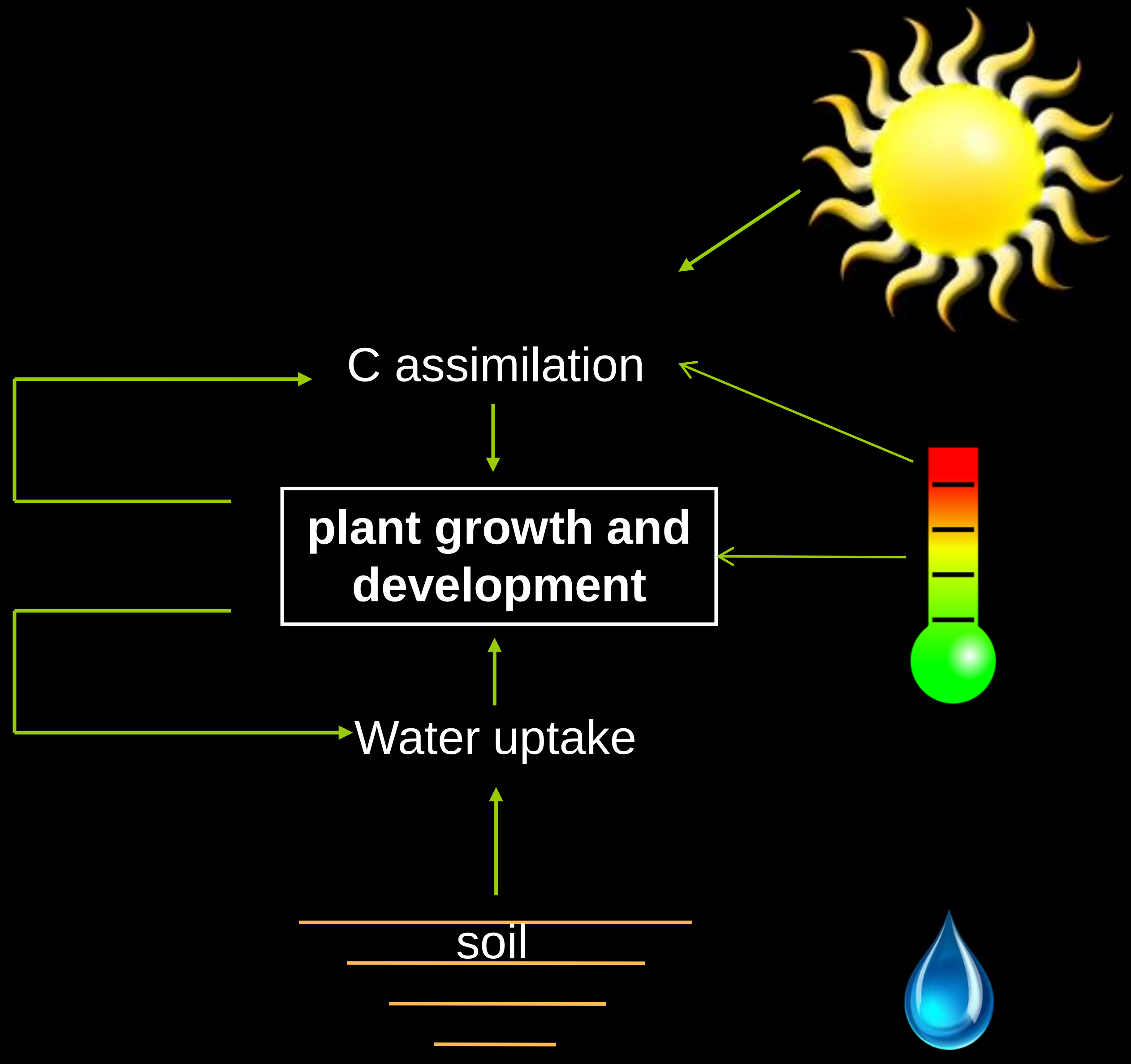
Climate change and viticulture

Photo credit: punchdrink.com

What do we want to know?

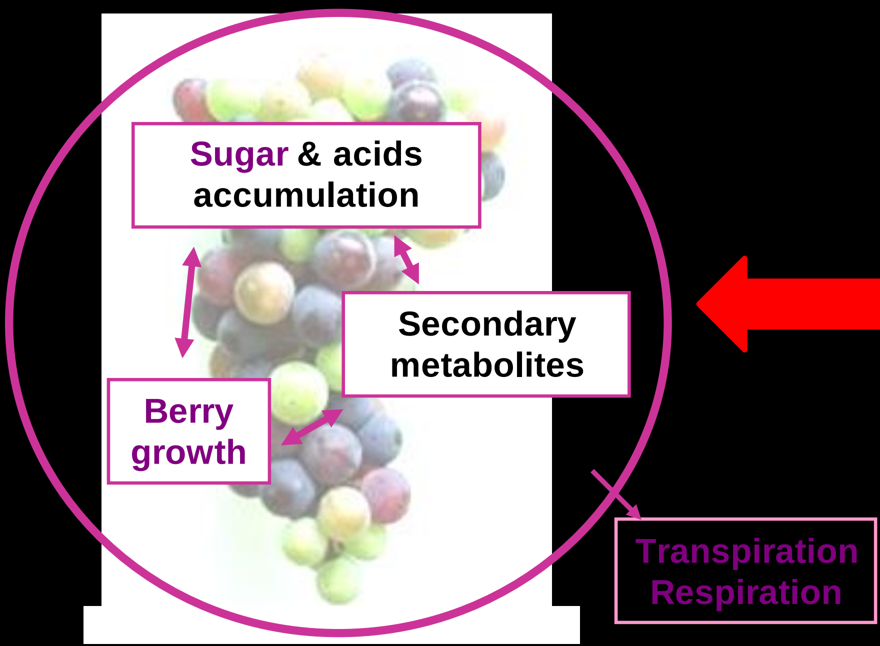
- How will climate change affect:
  1) the chemical composition of the berry?
  2) the suitability of current viticultural area?
  3) the tastes of wine for a given region?
- How will management mitigate the effects of climate change?

Plant model for integrating knowledge

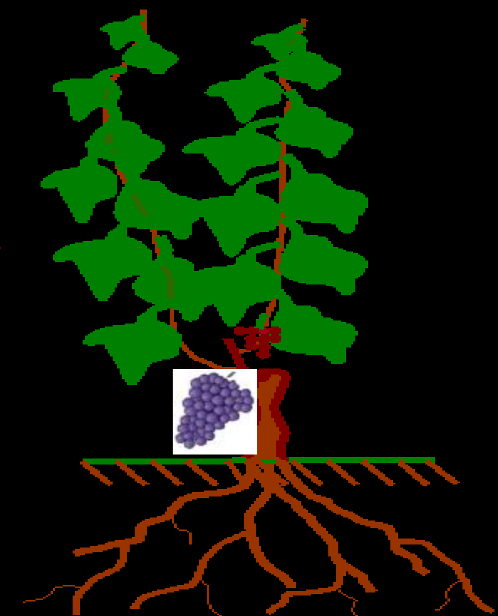


Previous work on grapevine modeling

Berry level



Plant level



Berry growth model (Dai et al., 2008)

Sugar accumulation model (Dai et al, 2009)

Anthocyanin model (Dai et al, 2015)

Flavonol model (under develop)

Organic acid, pH model (under develop)

Cluster Microclimate -Berrytone(Cola 2009)

Phenology (Duchene 2012, Parker 2013)

Transpiration-TOPVINE (Lebon 2003)

Statistical yield model (Trought 2009)

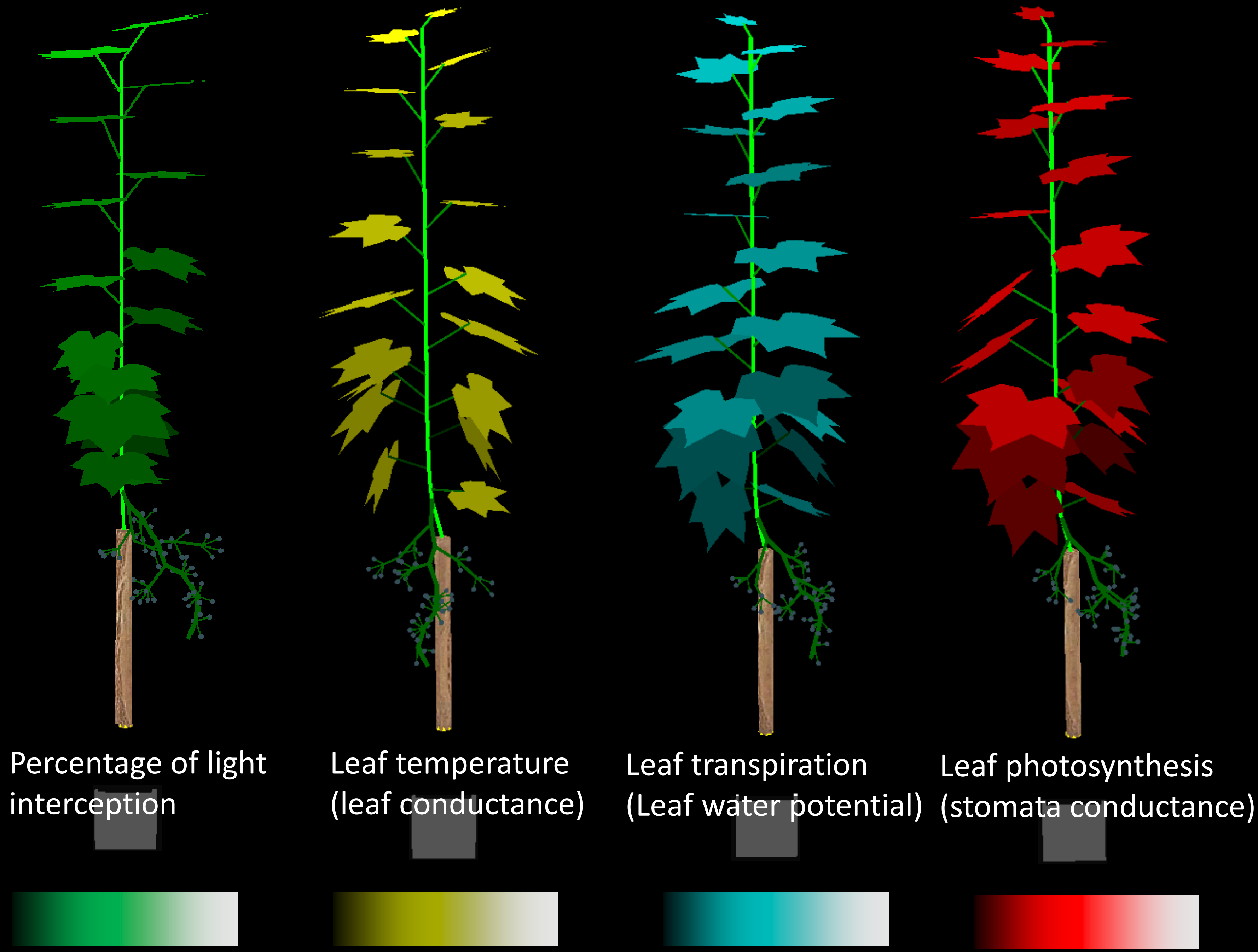
C-based yield model (Bindi 1996, Vivin 2002)

Stics-vigne (Garcia de Cortazar 2006)

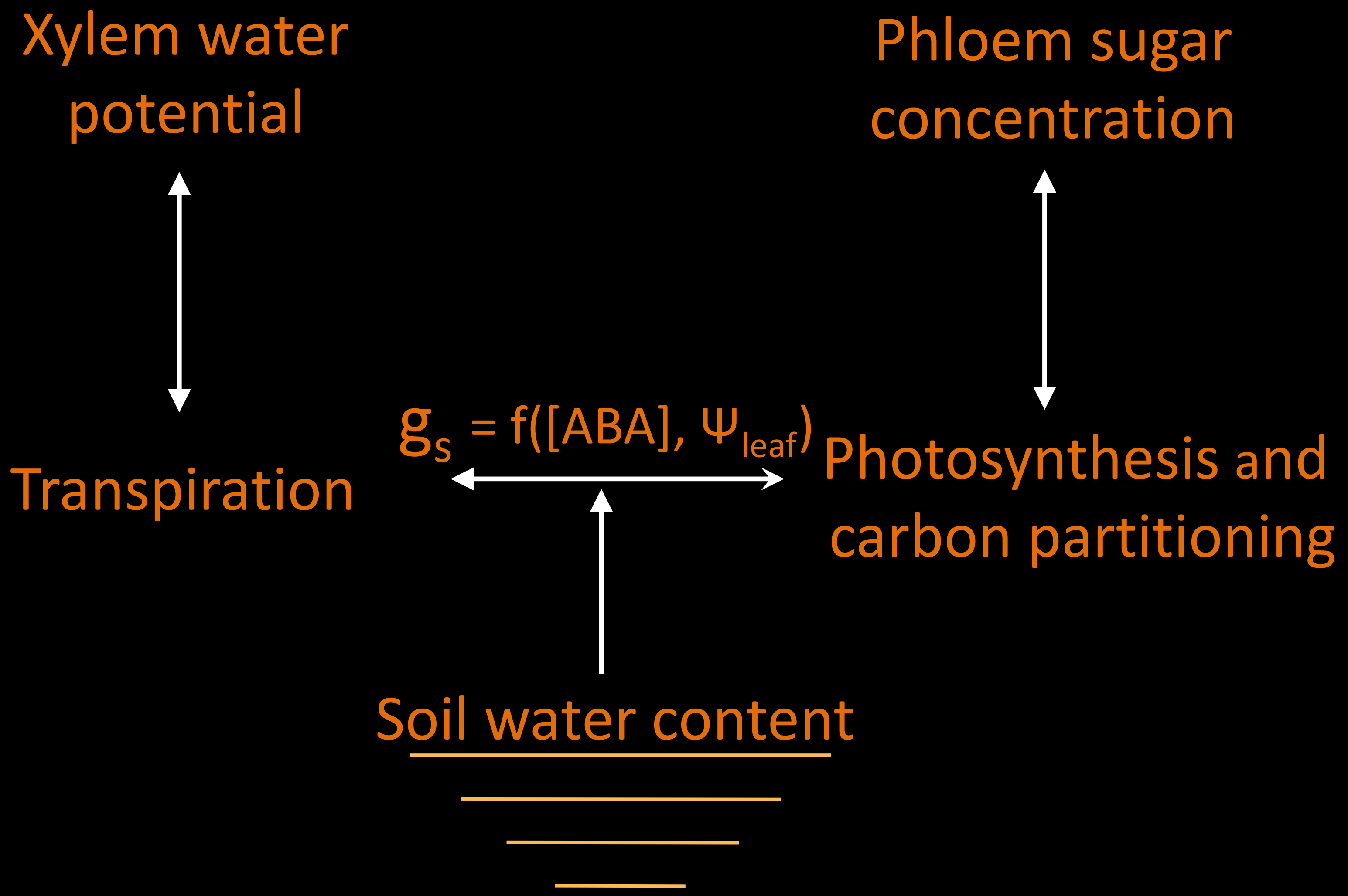
Green-lab grapevine (Louarn 2008)

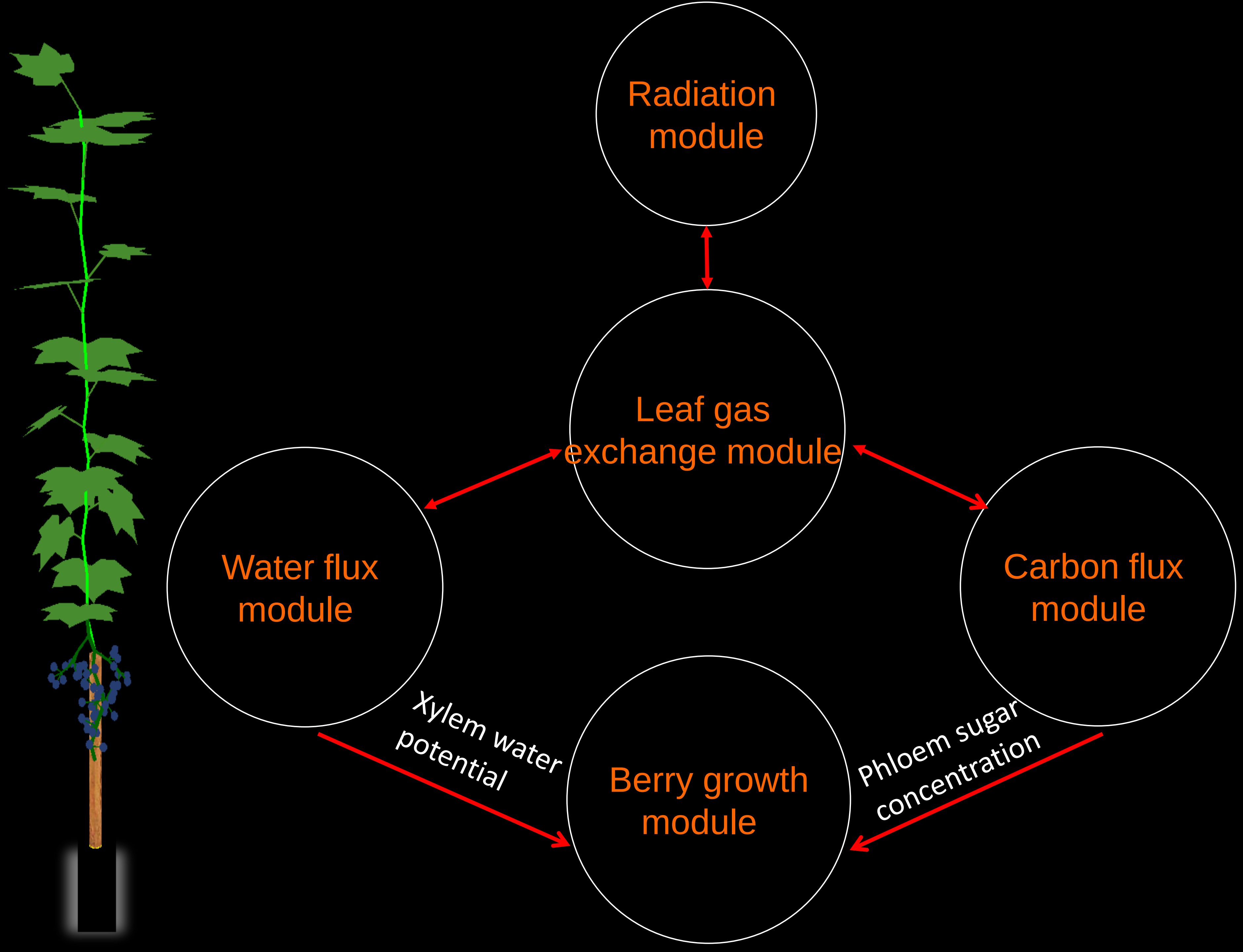
Fruiting cutting

Mullins 1966 Nature
Dai et al., 2013

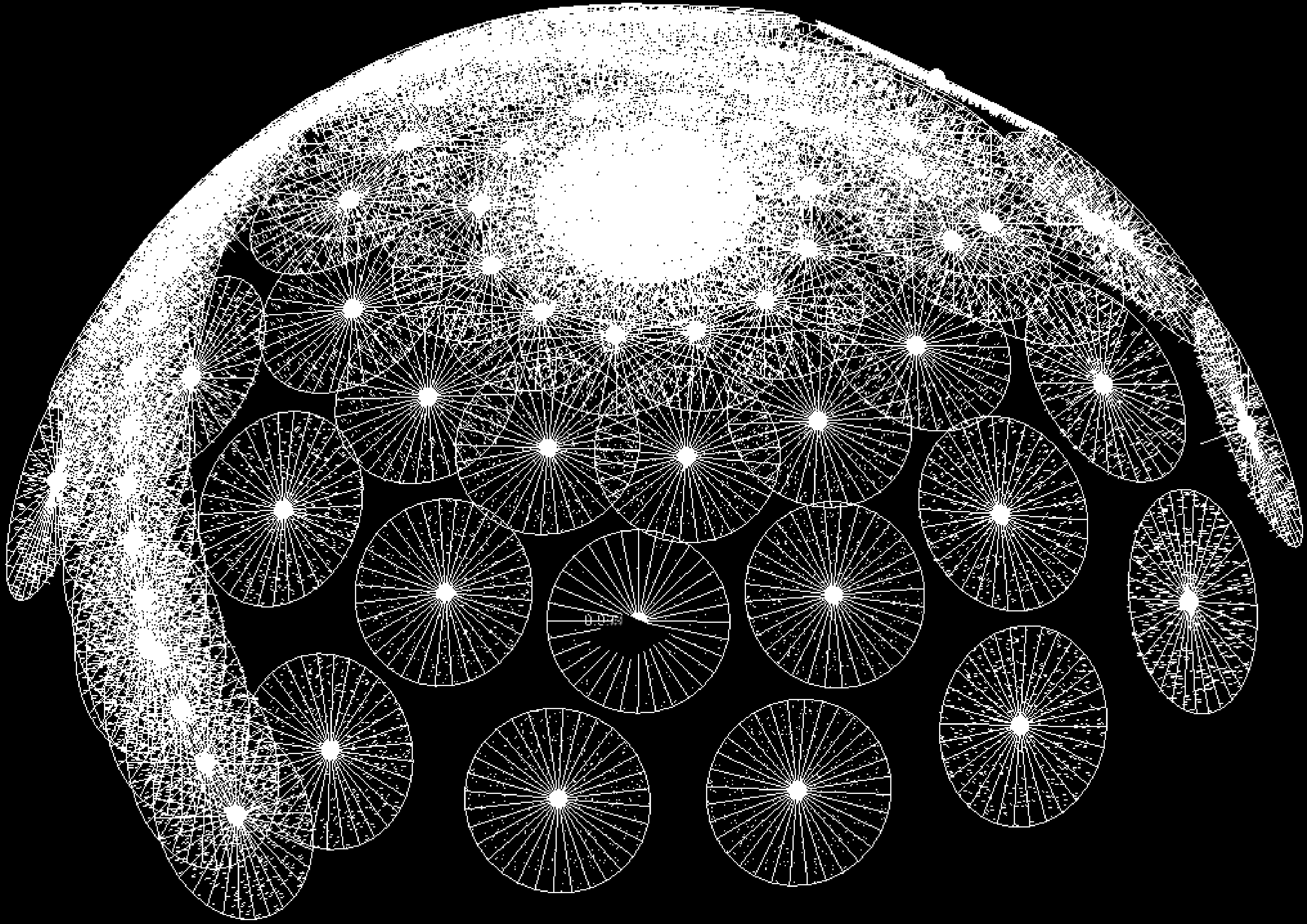

Percentage of light interception
Leaf temperature (leaf conductance)
Leaf transpiration (Leaf water potential)
Leaf photosynthesis (stomata conductance)

Model abstraction

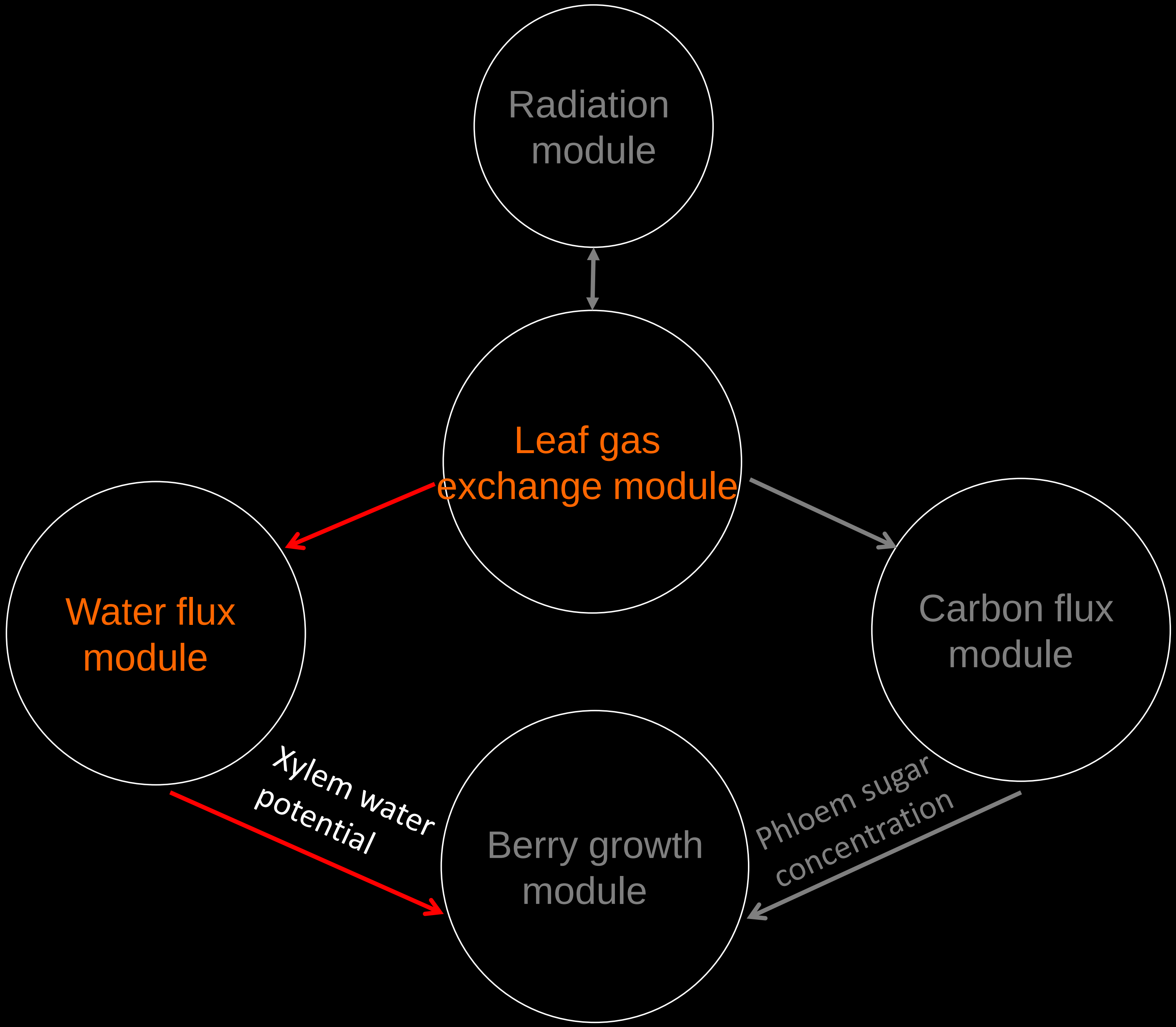



Radiation module
Leaf gas exchange module
Water flux module
Carbon flux module
Berry growth module
Xylem water potential
Phloem sugar concentration

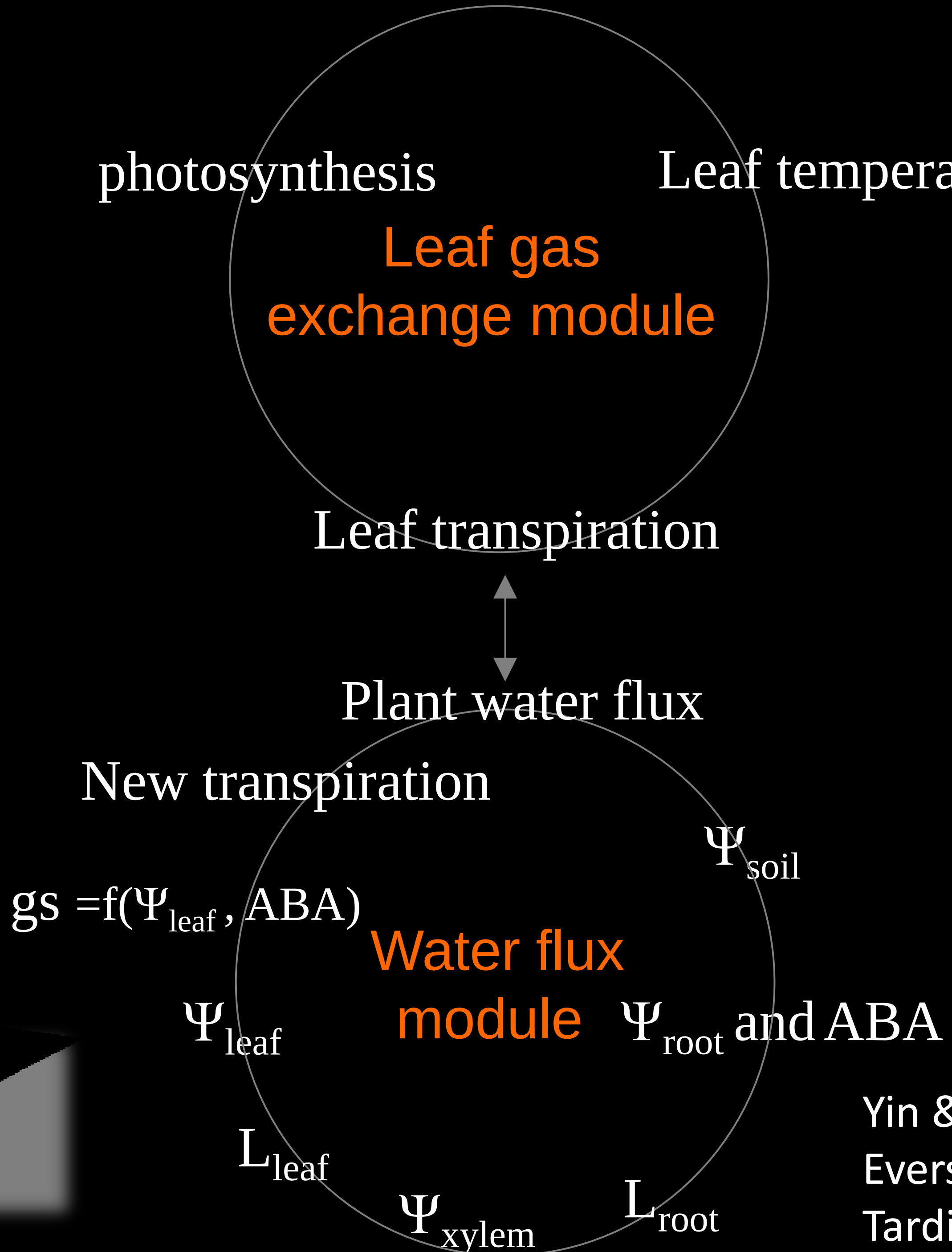
Radiation module



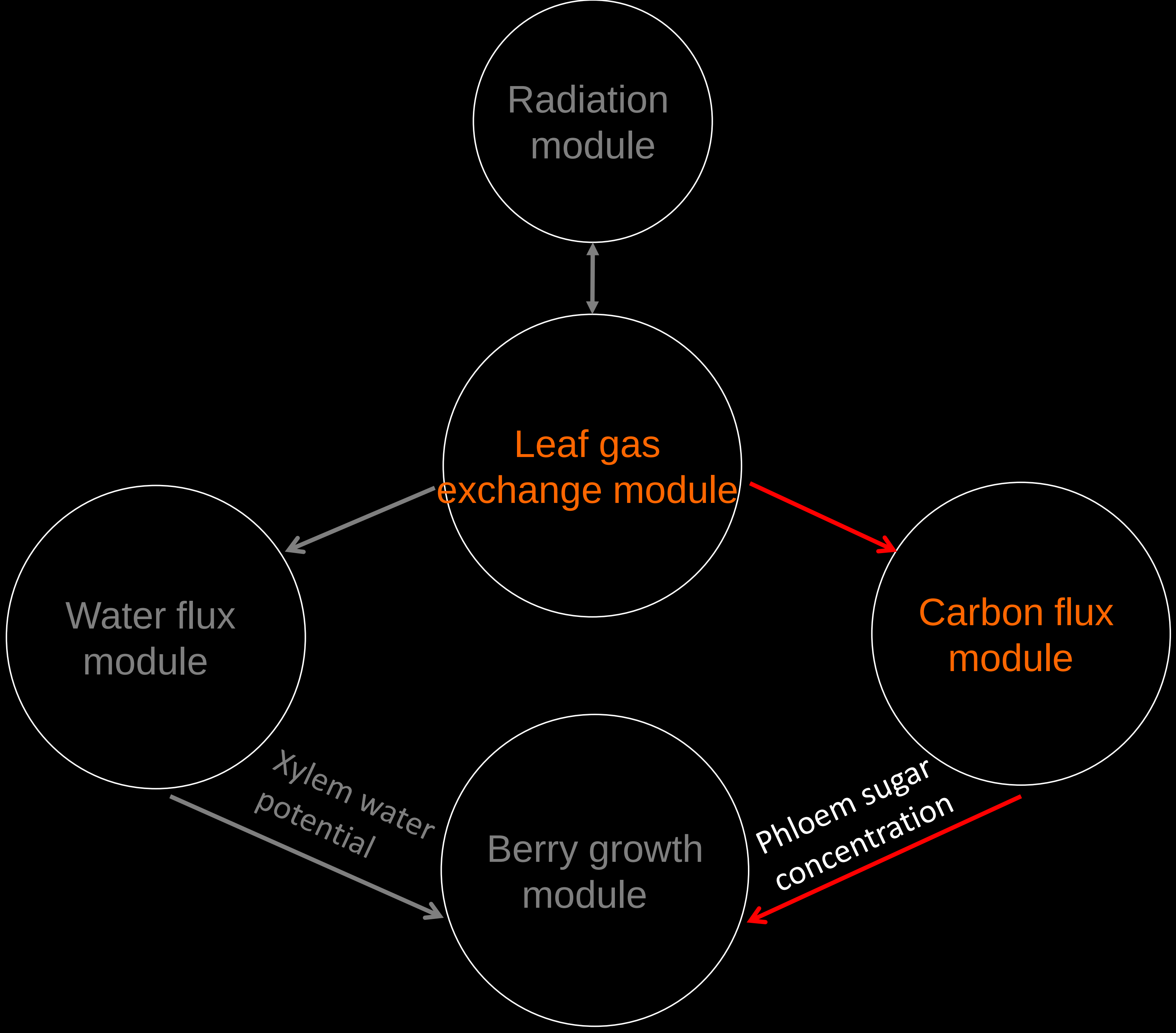
(Evers et al., 2010; Buck-Sorlin et al., 2011; Zhu et al., 2015)



Radiation module
Leaf gas exchange module
Water flux module
Carbon flux module
Berry growth module
Xylem water potential
Phloem sugar concentration



Yin & Struik, 2009;
Evers et al., 2010;
Tardieu et al., 2015;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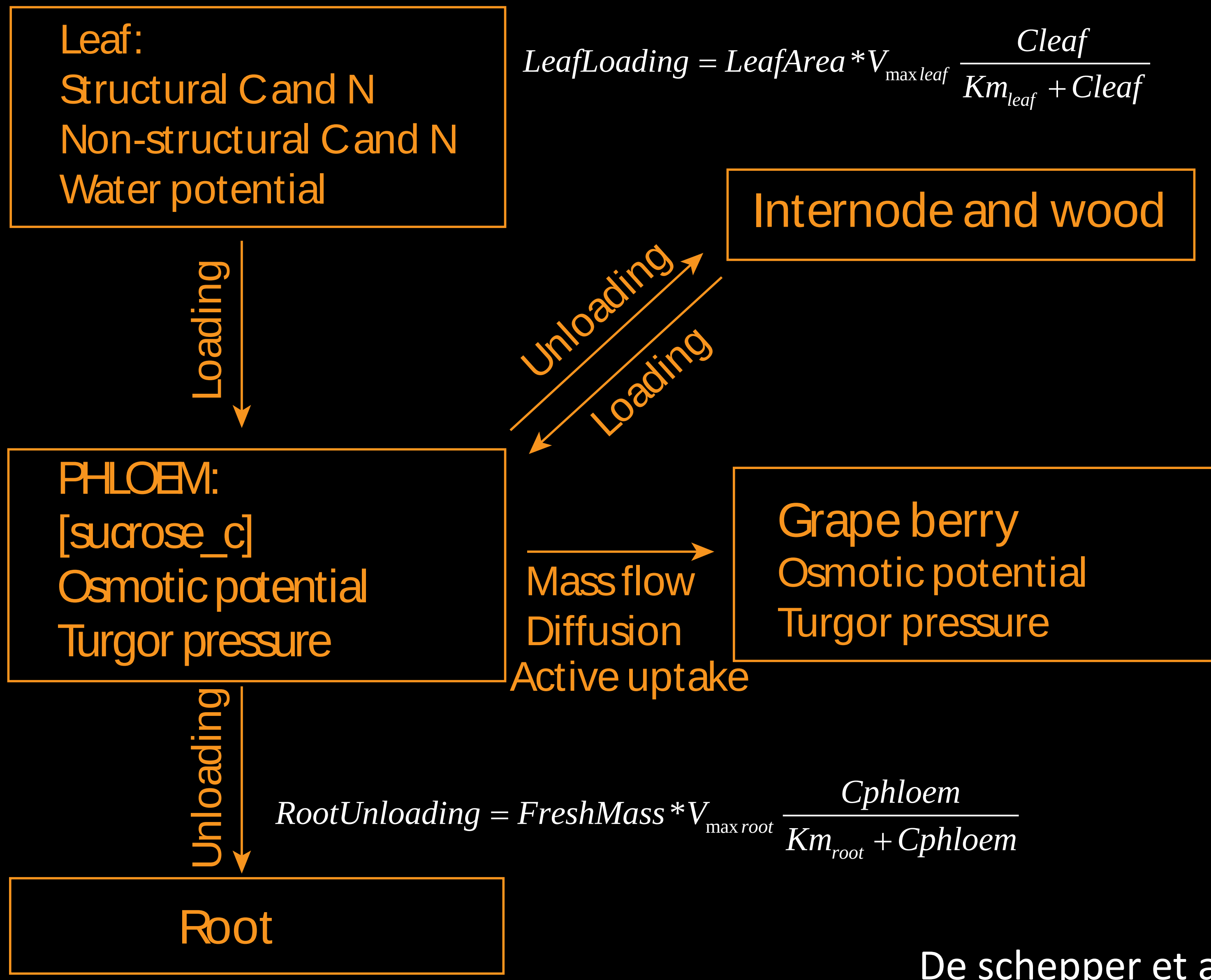
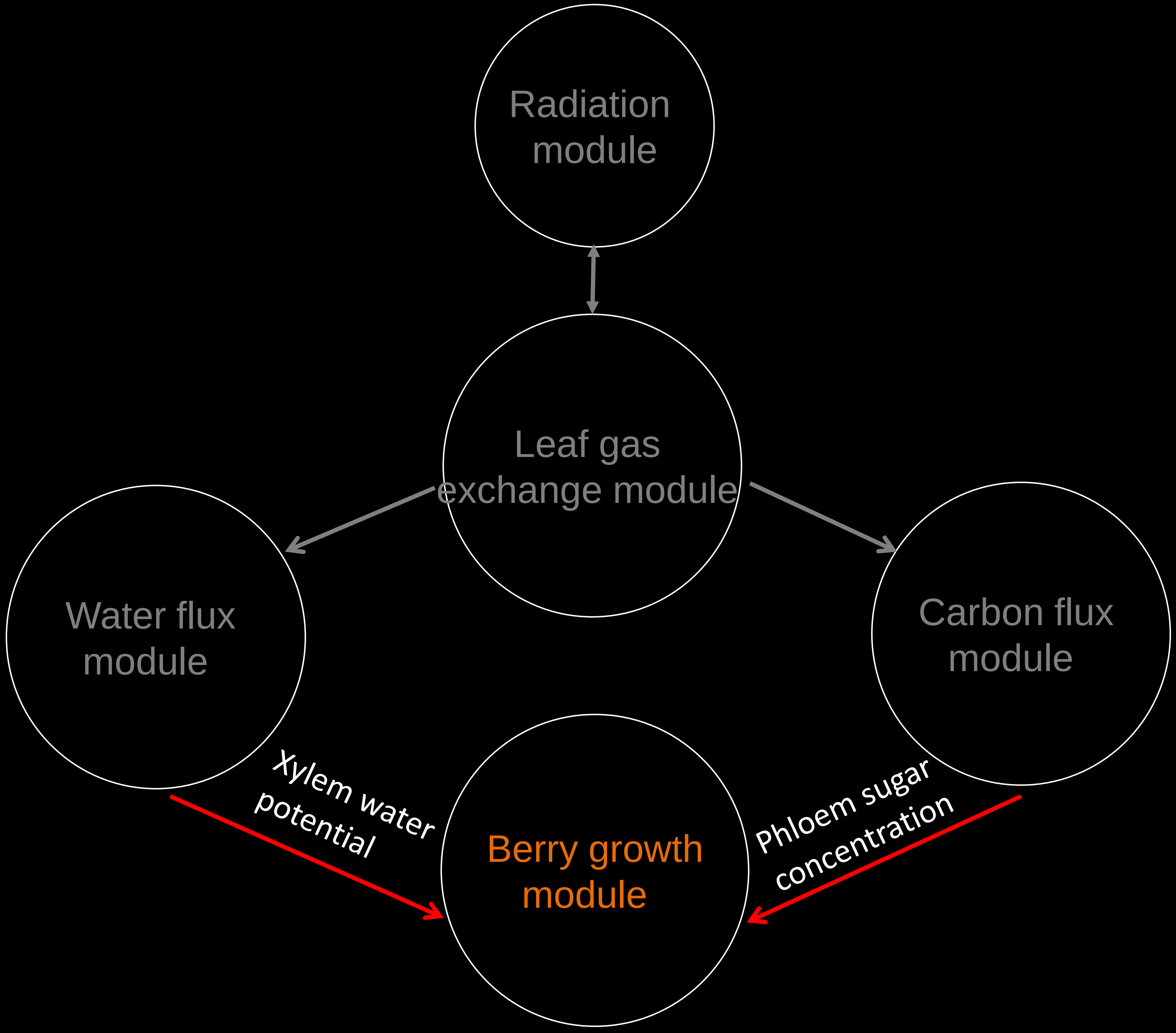
Phloem sugar concentration



$$LeafLoading = LeafArea * V_{\max leaf} \frac{Cleaf}{Km_{leaf} + Cleaf}$$

$$RootUnloading = FreshMass * V_{\max root} \frac{Cphloem}{Km_{root} + Cphloem}$$

De schepper et al., 2010
Baldazzi et al., 2013;


Radiation module
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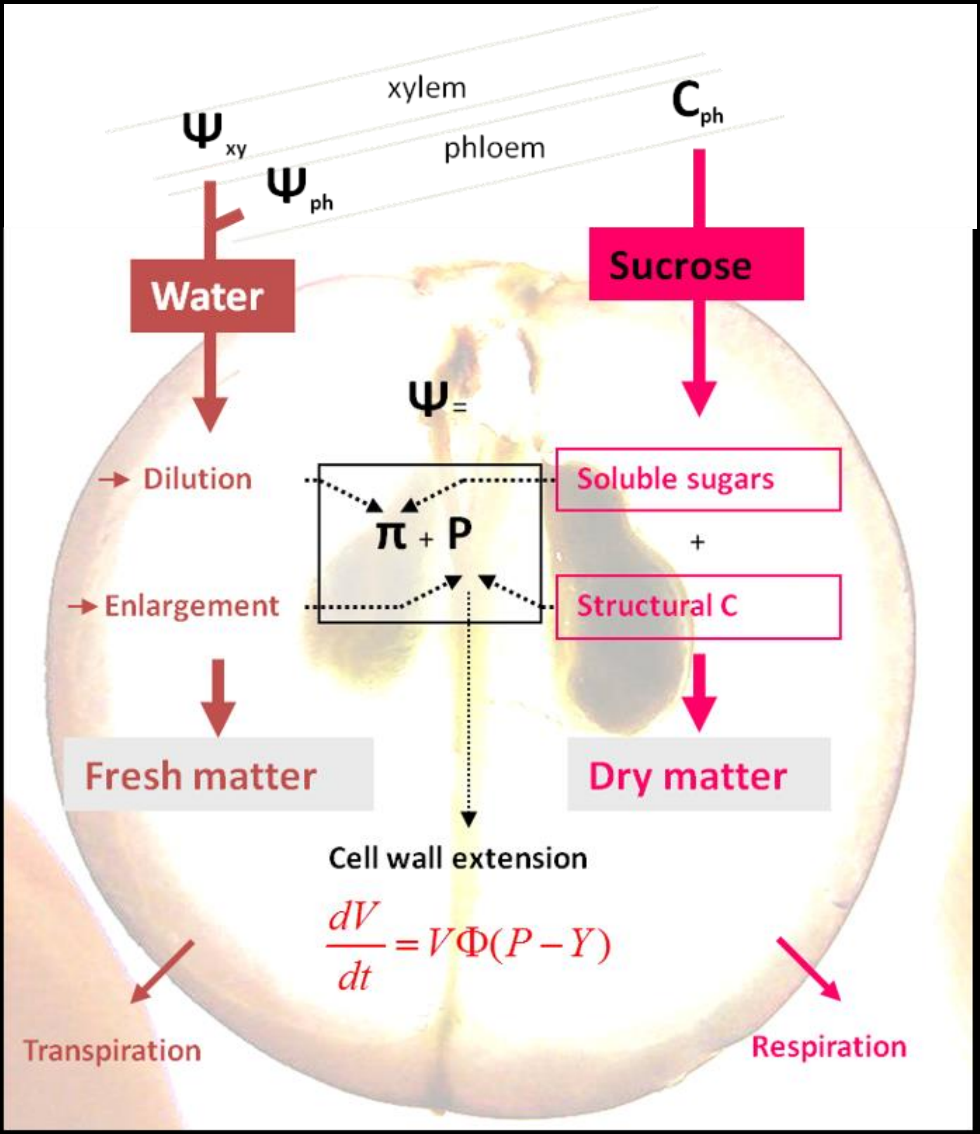
Berry growth module



- **Main physiological processes:**

  Water influx
  Mass flow = f (Lp, s , a_f, DY)

  Water loss
  Transpiration = f (r, A_f, T , RH)

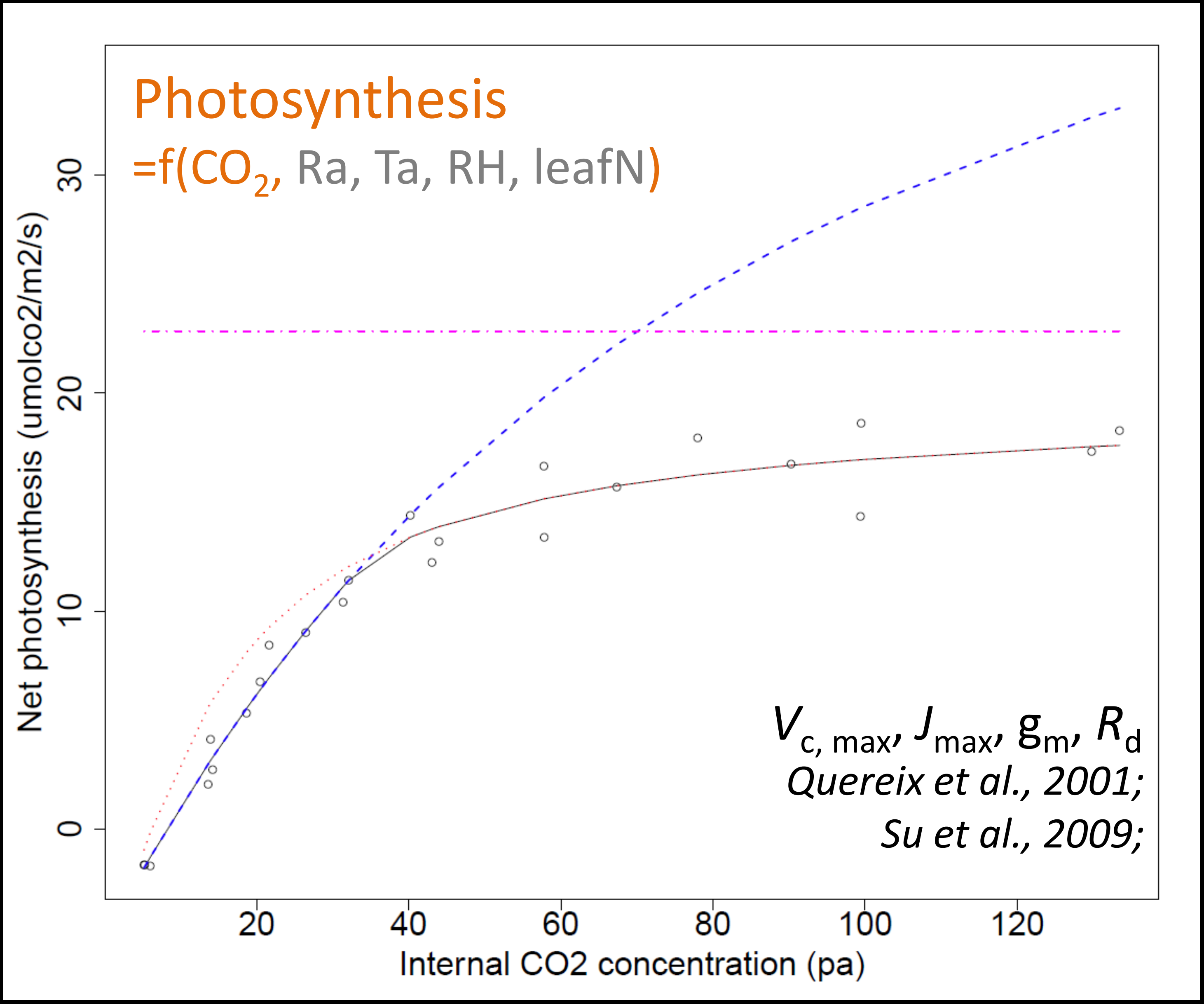
  Carbon influx
  Active transport = f(V_m, L_m, t*, t, C_{ph})
  Mass flow = f (Lp, s, a_f, DY)
  Passive diffusion = (P_s, A_f, DCsug)

  Carbon loss
  Respiration = **f (q_m, q_g, Q_{10}, T)**

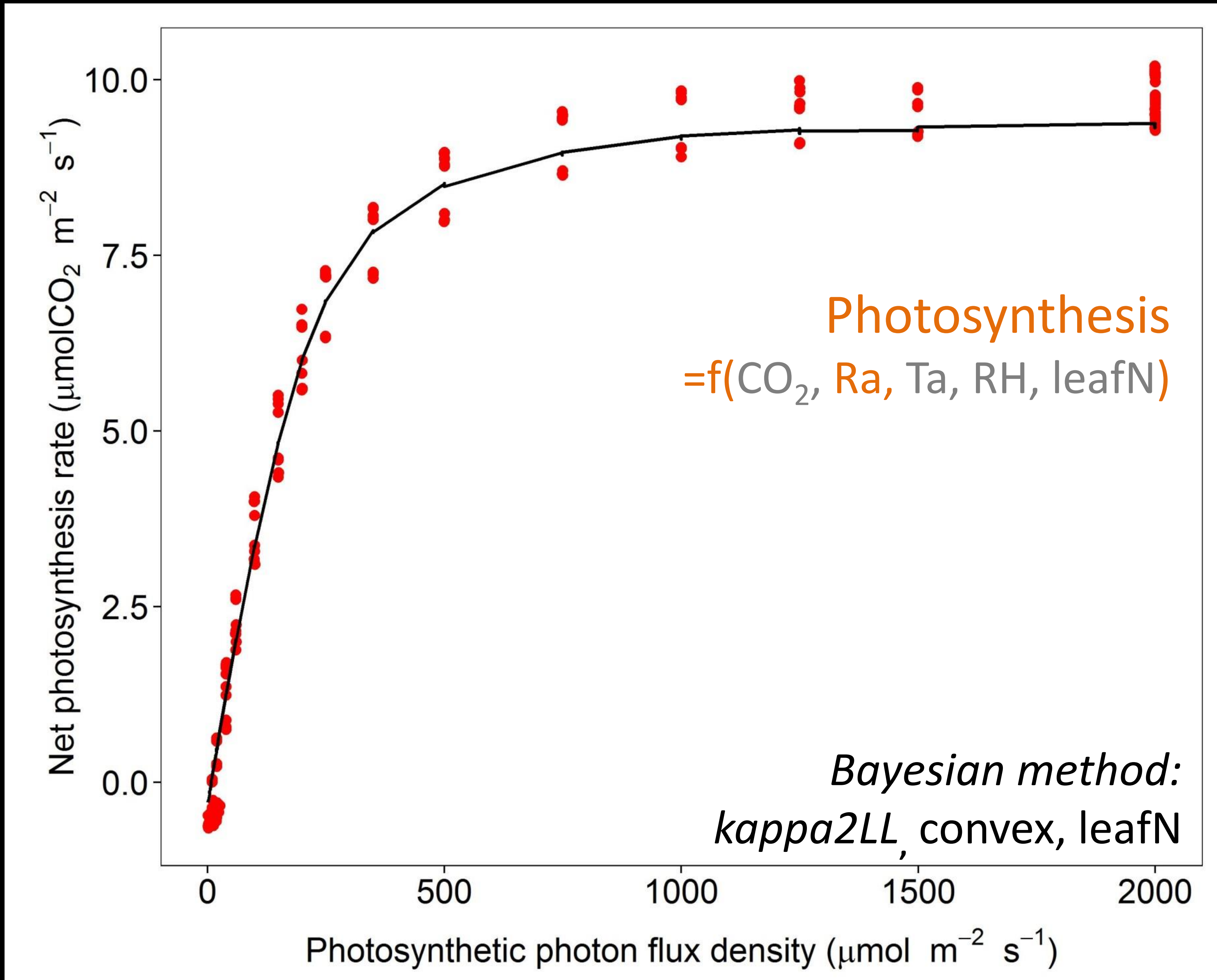
Dai et al, 2008

Model calibration

CO_2 response curve



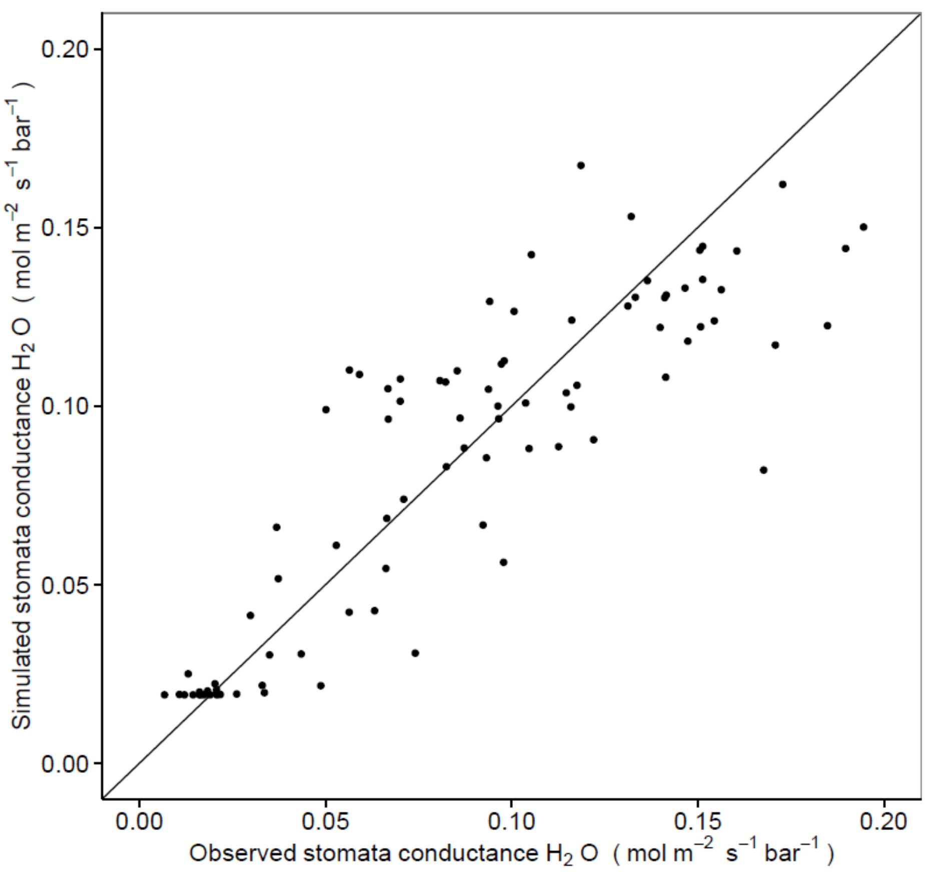
Light response curve

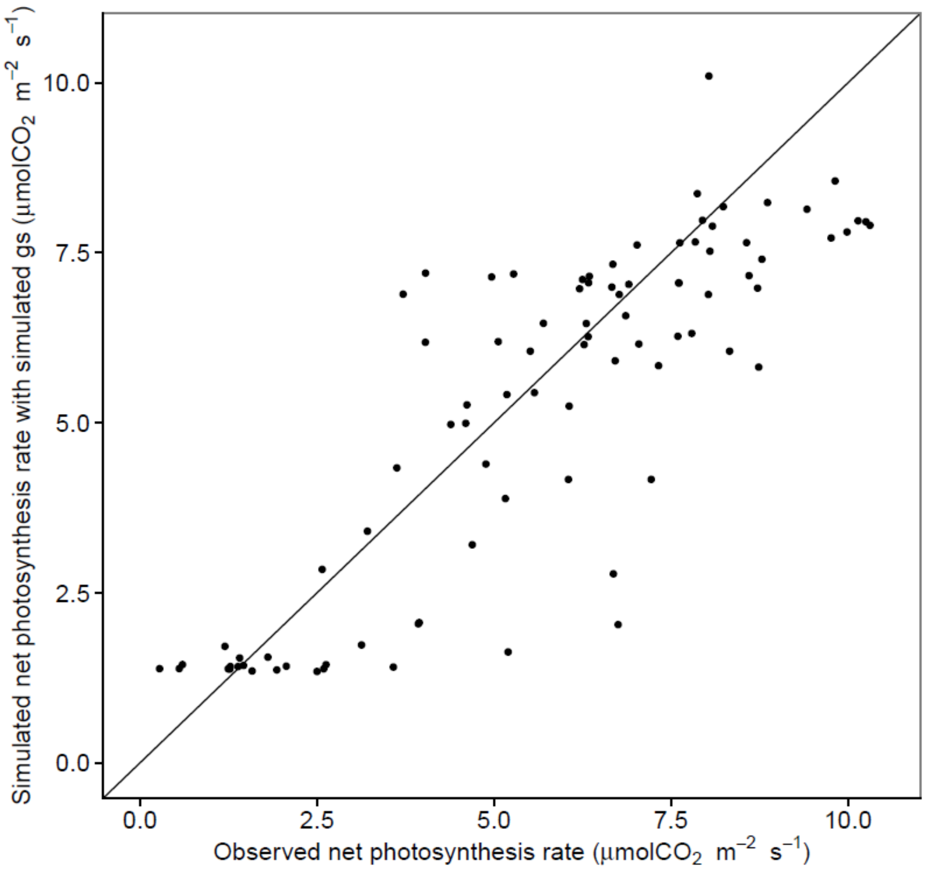


Photosynthesis under water stress

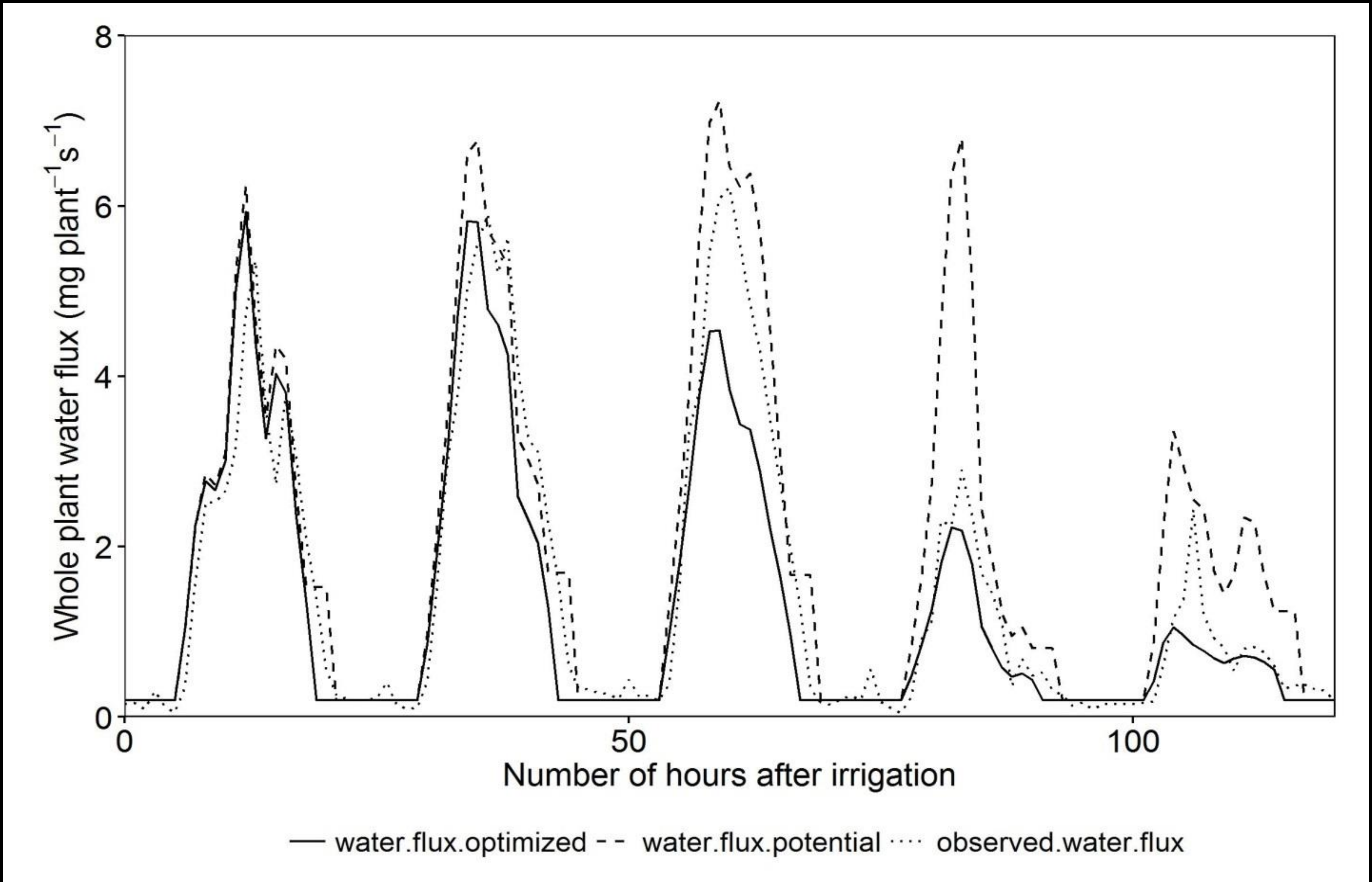
$g_s = f(ABA, \Psi_{leaf})$

$E \xleftrightarrow{g_s} Anet$

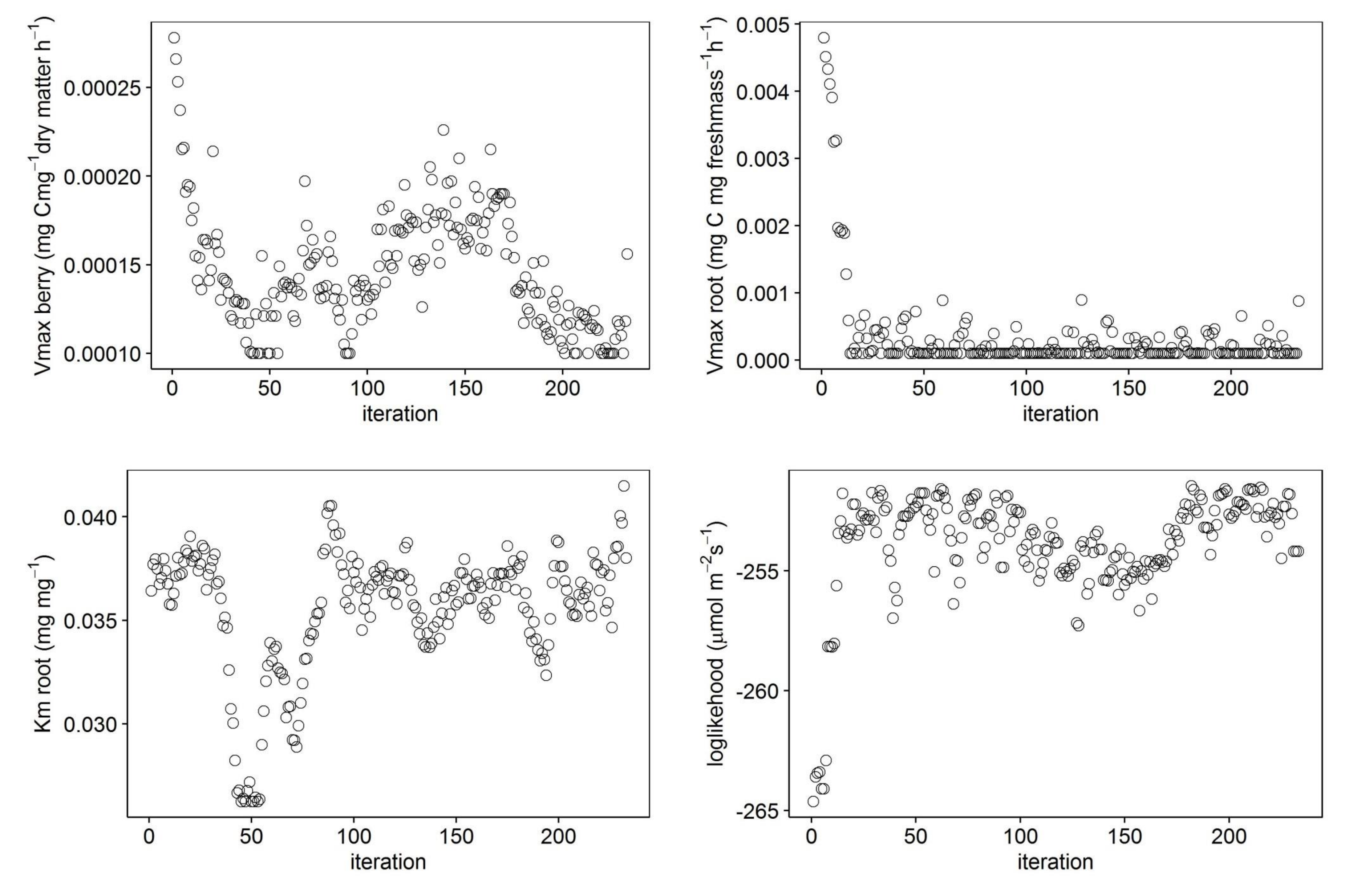




Whole plant water flux

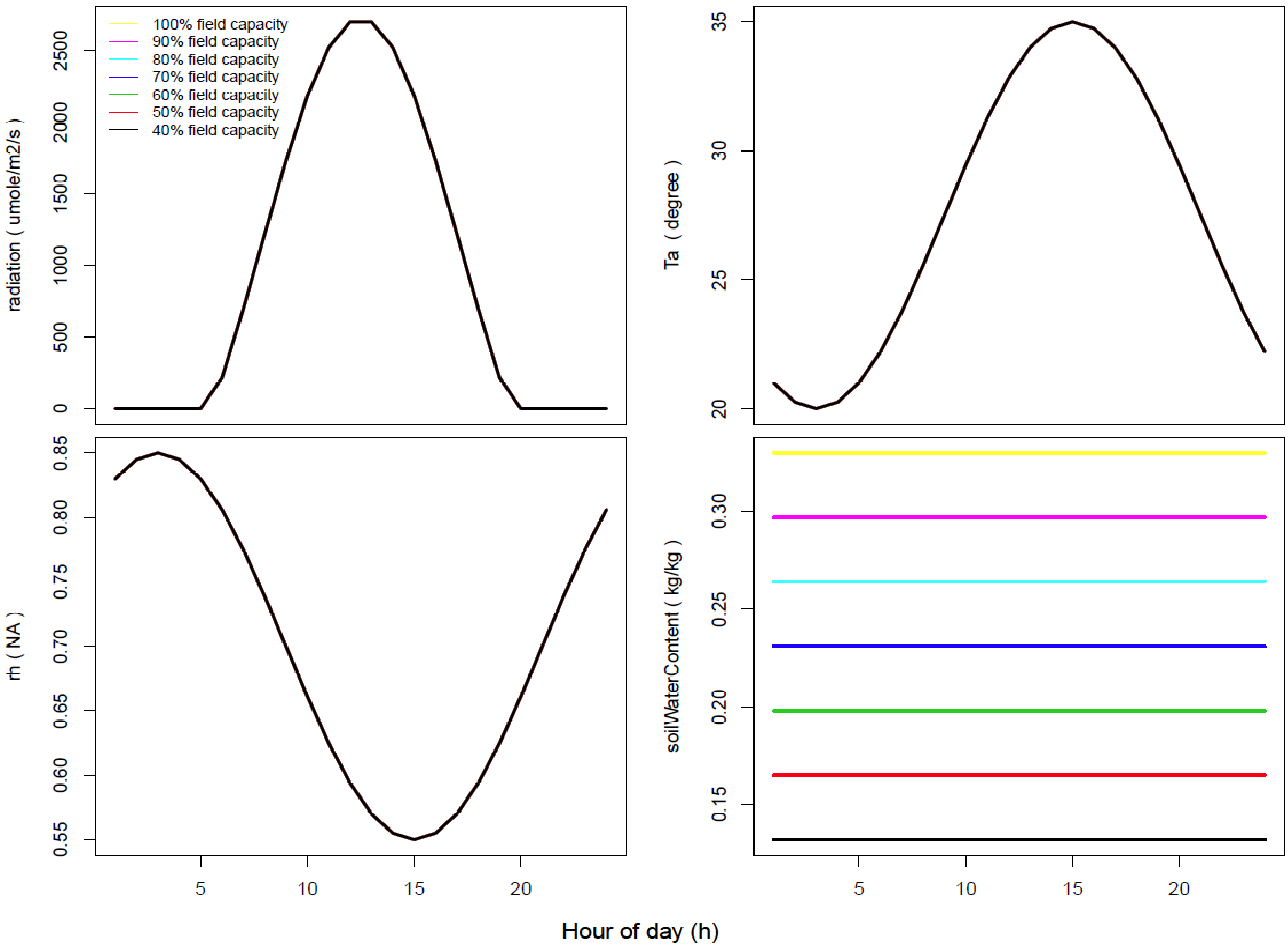


Carbon partitioning parameters



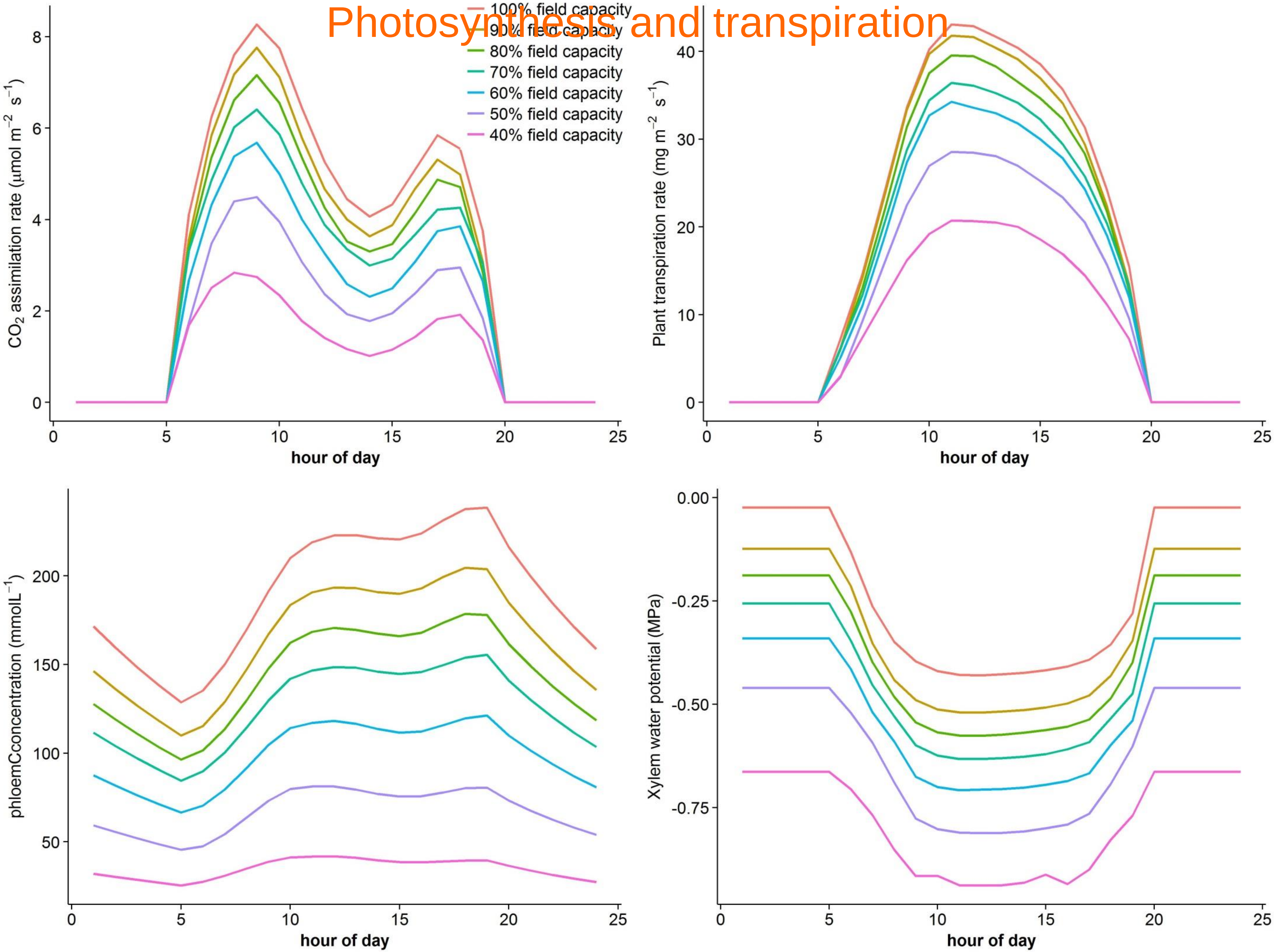
Effect of water stress on berry development and composition

Model input

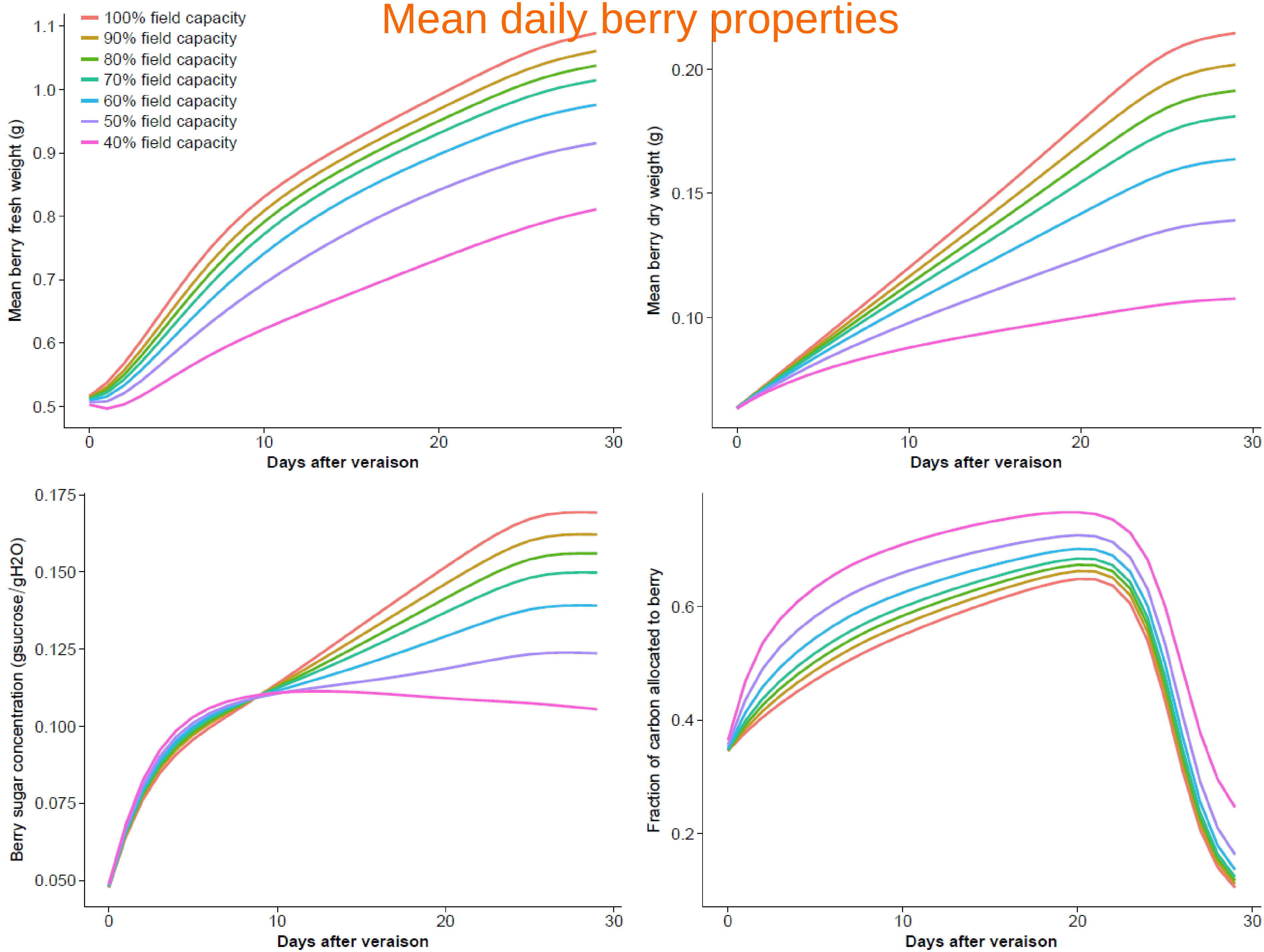


100% field capacity
90% field capacity
80% field capacity
70% field capacity
60% field capacity
50% field capacity
40% field capacity
radiation (umole/m2/s)
0
500
1000
1500
2000
2500
Ta (degree)
20
25
30
35
rh (NA)
0.55
0.60
0.65
0.70
0.75
0.80
0.85
soilWaterContent (kg/kg)
0.15
0.20
0.25
0.30
5
10
15
20
Hour of day (h)

Photosynthesis and transpiration



Mean daily berry properties



A novel grapevine model that can account for the effects of multiple environmental factors on berry growth and composition

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inno
vine
INNOVATION IN VINEYARD

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Thank you very much for your attention!