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Traits for avoiding lodging in sunflowers

Ben Hague & Pete Berry

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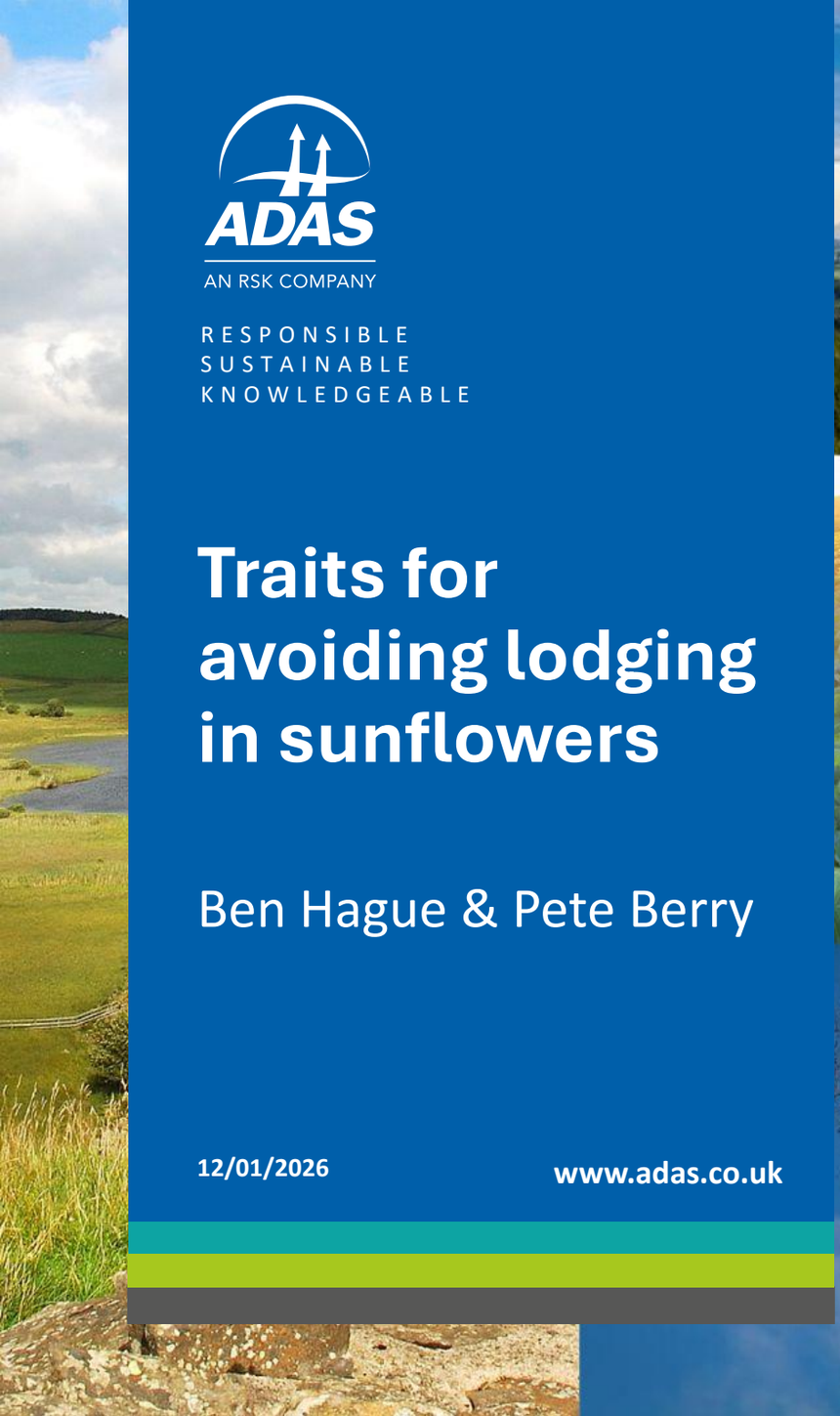







Sunflower lodging

- Sunflower productivity is limited by the risk of lodging
- About 10% of sunflower crop lodges annually, for an estimated loss of US$40million (Bragachini et al., 2001)
- Sunflowers have a high risk of lodging because they are often tall and their leaves & heads (capitulum) present a large surface area for wind loading

Two types of lodging: Stem lodging & Root lodging

Modelling the lodging process

In 2010, UK wind engineers and crop scientists worked with Agronomists in Argentina to develop and test a mechanistic model of the lodging process in Sunflowers

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Modelling root and stem lodging in sunflower

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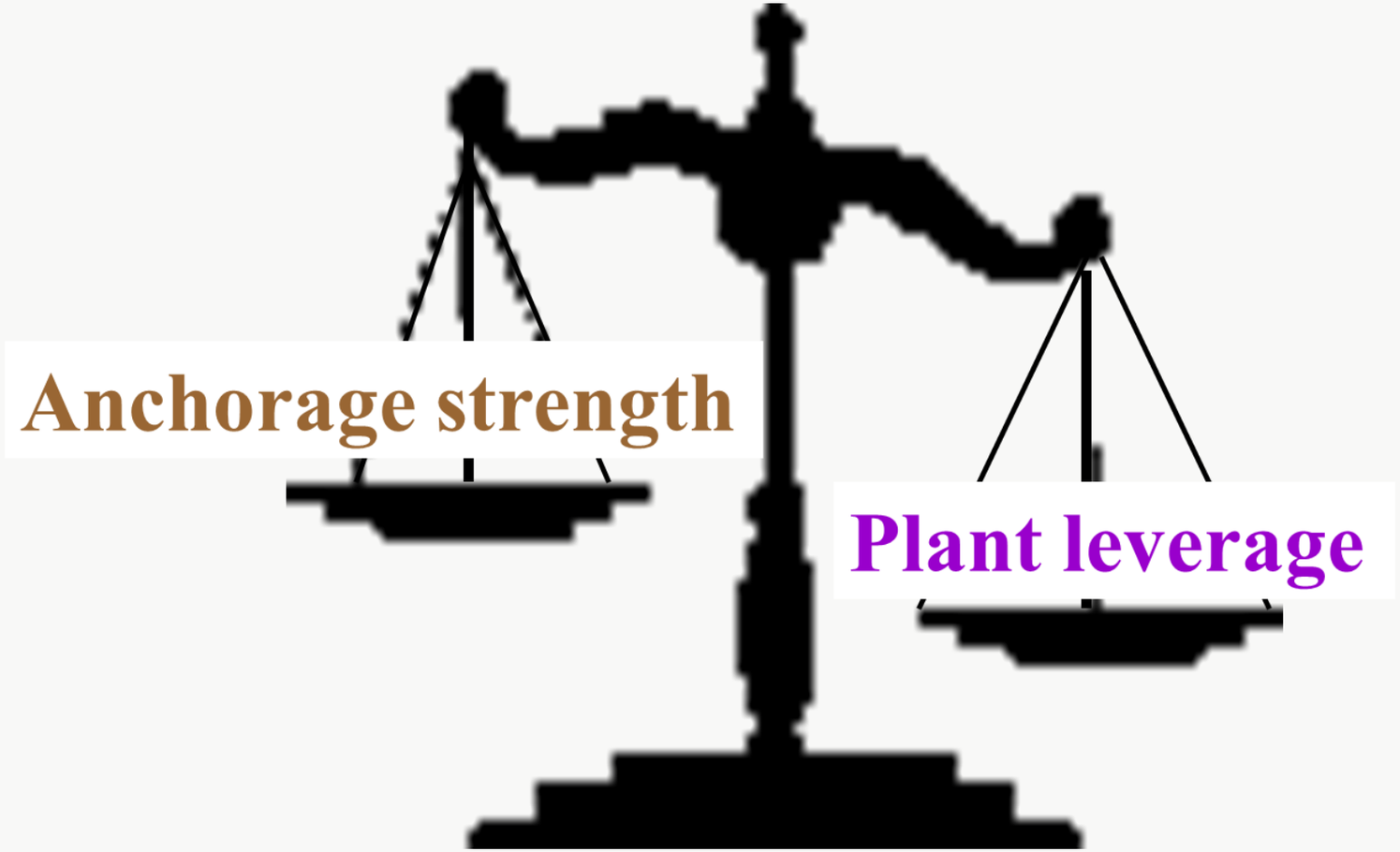
ABSTRACT

Stem and root lodging constitute significant adversities to sunflower (*Helianthus annuus* L.) cropping in Argentina. We have adapted previously developed models of the lodging process in cereals to the particularities of sunflower by using functions, developed using data obtained by mechanical lodging, for the [root failure moment/plant anchorage] and [stem failure moment/thickness of stem wall] relationships, and estimates of plant area loaded by wind gusts. The model uses this information to estimate wind failure speed (i.e., the wind speed at which lodging [stem or root, as appropriate] is expected to occur). The model was tested against information (plant and soil characteristics, measured wind gust velocity immediately preceding rainfall) obtained in 26 naturally lodged plots (6 stem-lodged, 20 root-lodged) which occurred across a network of trials (2 seasons, 4 sites, 3 hybrids, 4 crop population densities, all experiments fitted with automatic meteorological stations). Lodging events took place over a range of crop developmental stages between visible capitulum and harvest maturity. Lodging index (proportion of plants lodged) against the difference between observed and model-estimated wind failure speeds showed that the model had good predictive skill across the range of conditions explored in these experiments and was able to distinguish between hybrids of differential susceptibility to lodging within the same experiment. Sensitivity analyses showed that the principal determinants of lodging susceptibility were root plate diameter, stem wall thickness, and the area of the plant loaded by wind gusts. Within the observed ranges (almost twofold) of stem height and stem natural frequency, these two variables had little influence on lodging susceptibility. We conclude that the model, despite the simplifications incorporated into its structure, provides an effective and useful tool for the integration of the complex factors that determine lodging susceptibility in this species.

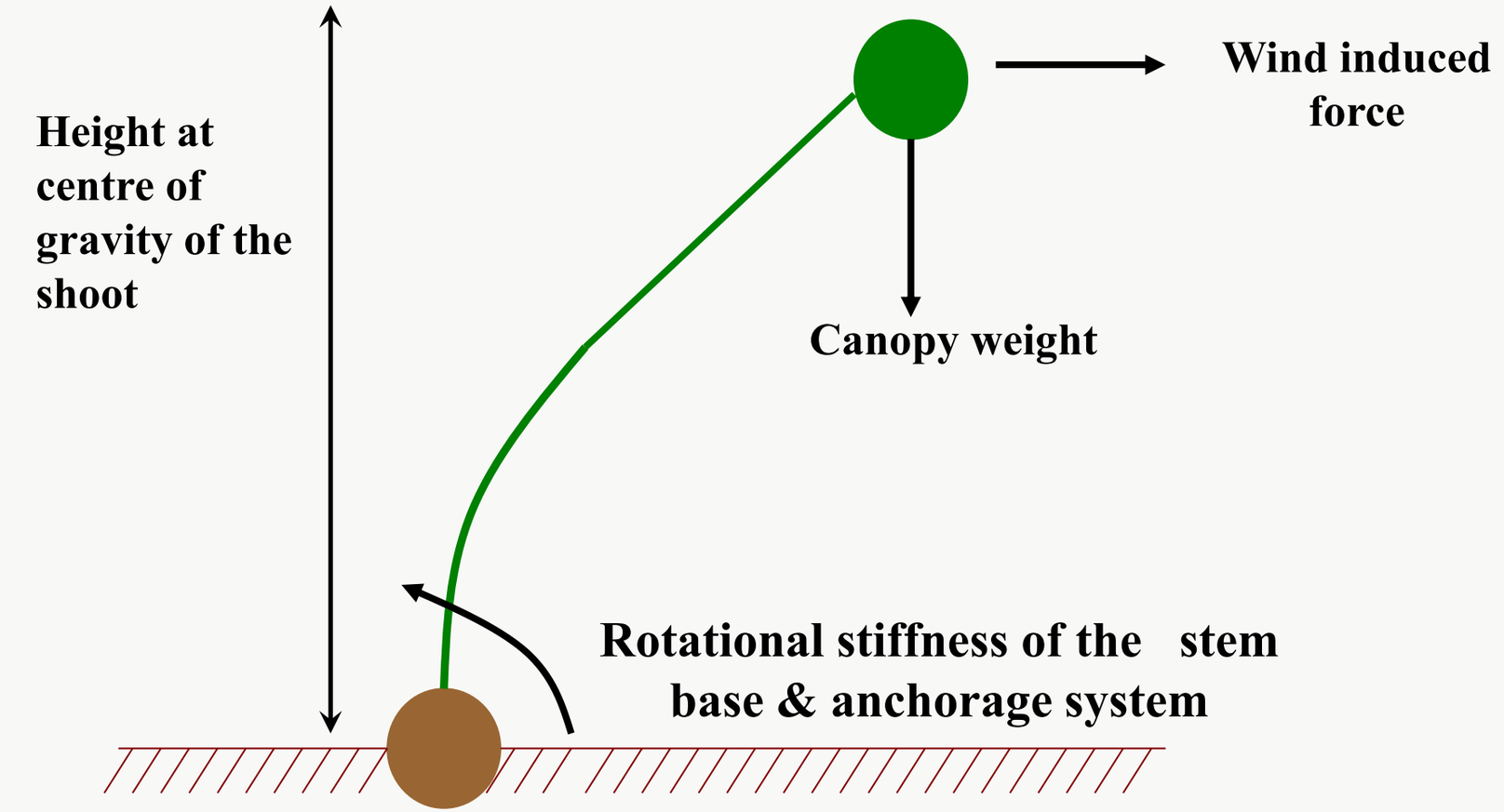
Root lodging occurs if



Stem lodging occurs if

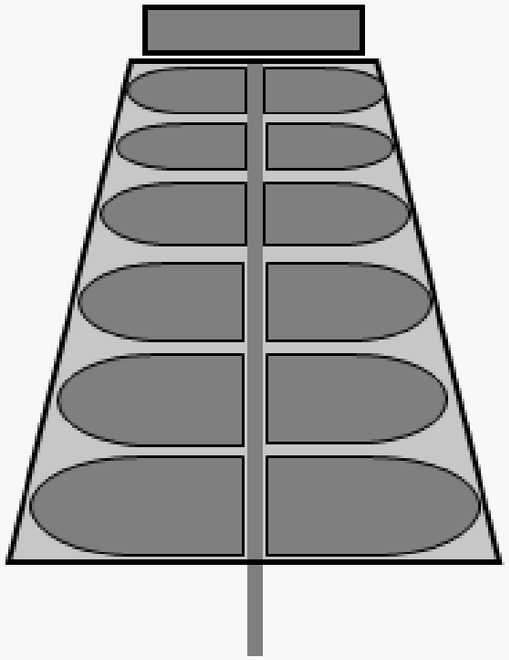
How to model the lodging process

Shoot movement is modelled as a damped harmonic oscillator.

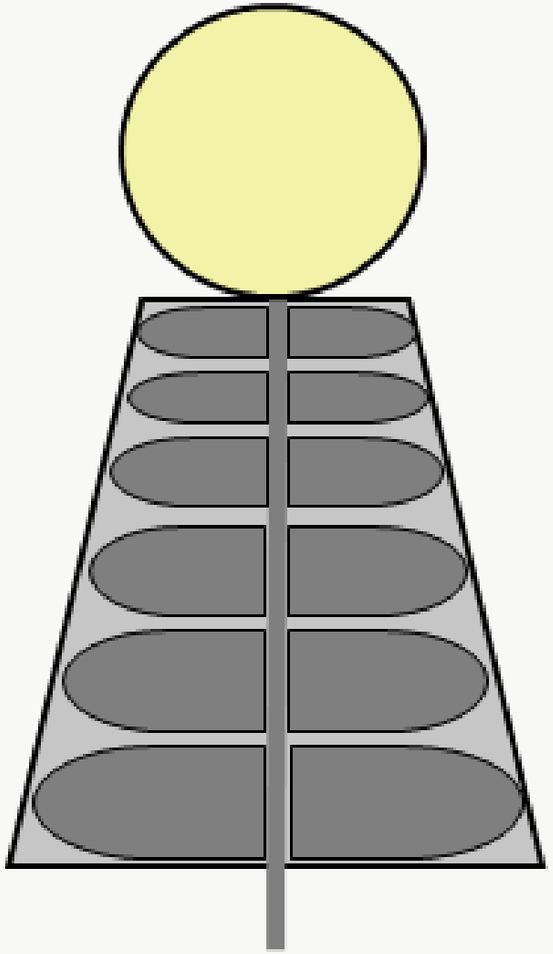


Surface area presented to wind loading

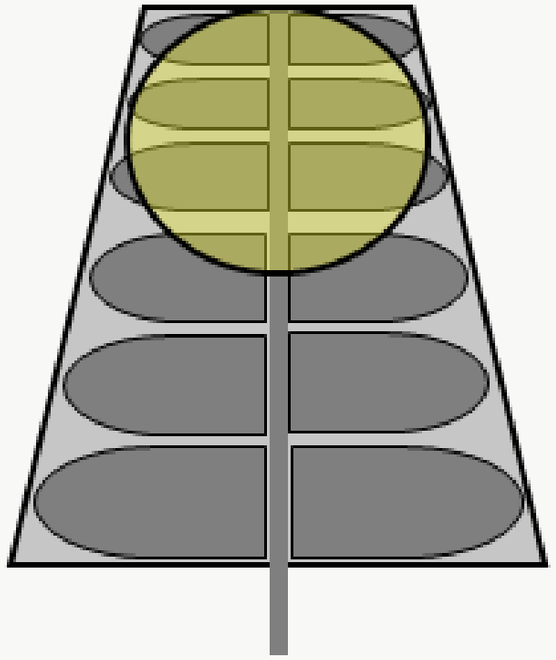
Pre-heading



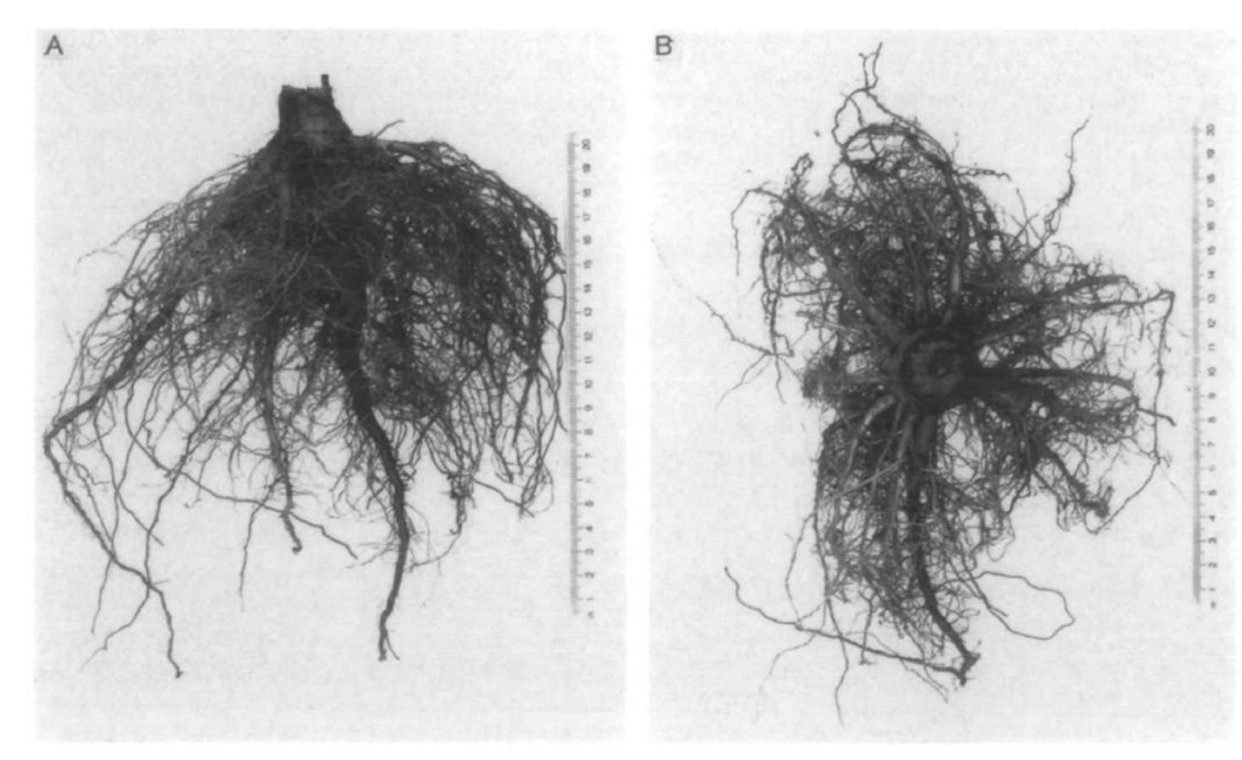
Post-heading
(up to mid grain fill)

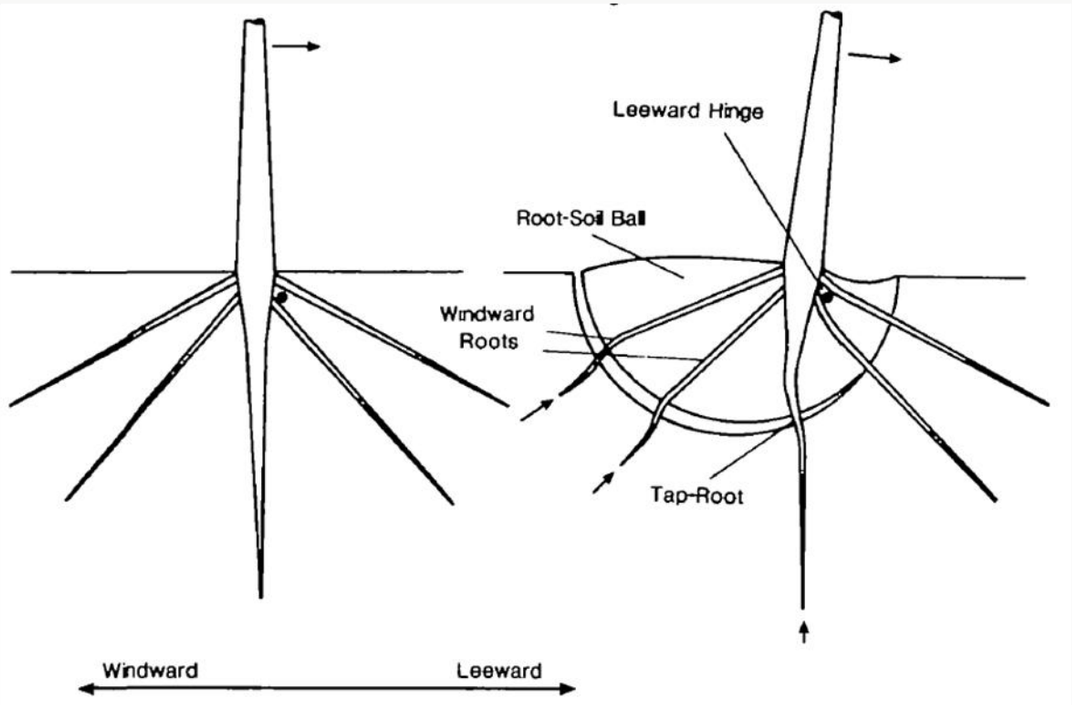


Post-heading
(maturity)



Anchorage strength



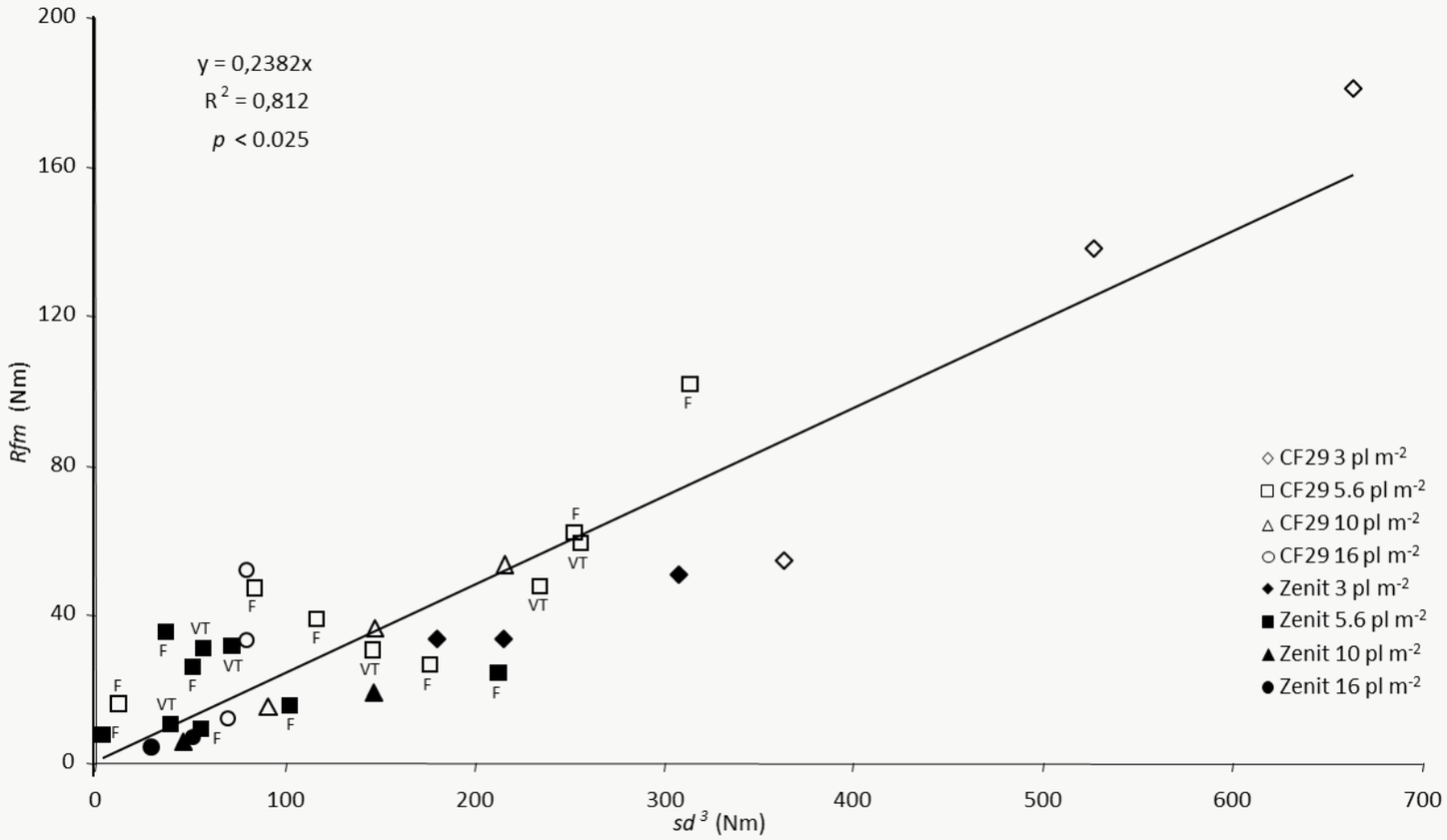


From Ennos et al. (1993). J. Exp. Bot. 44, 133-146

Anchorage failure results from rotation about a hinge leeward of the stem base and the root-soil ball is pulled out of the soil

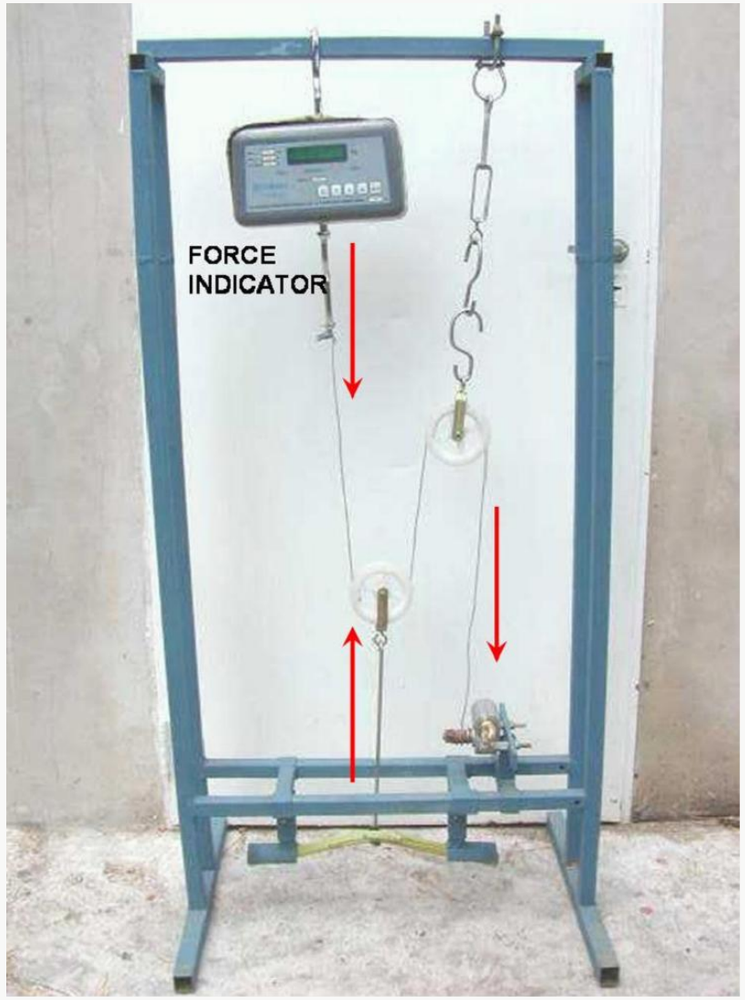
Anchorage is determined by the diameter of the root plate

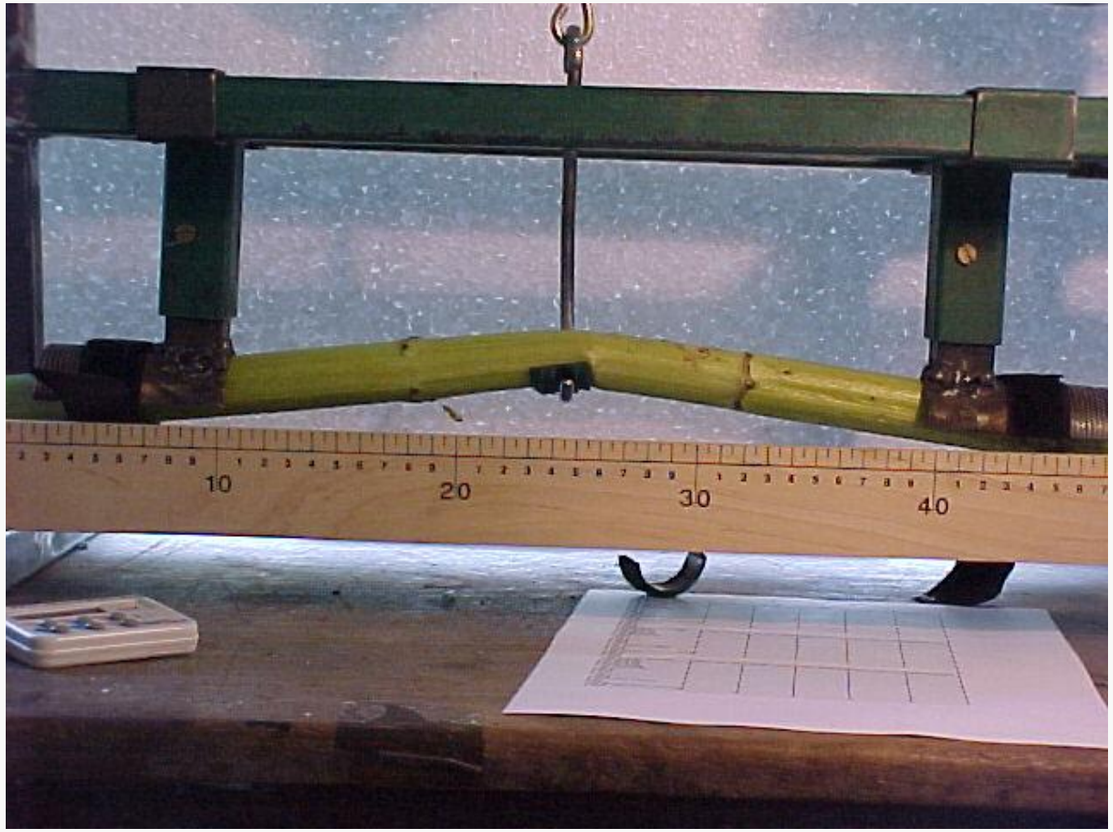
Anchorage strength (Nm)

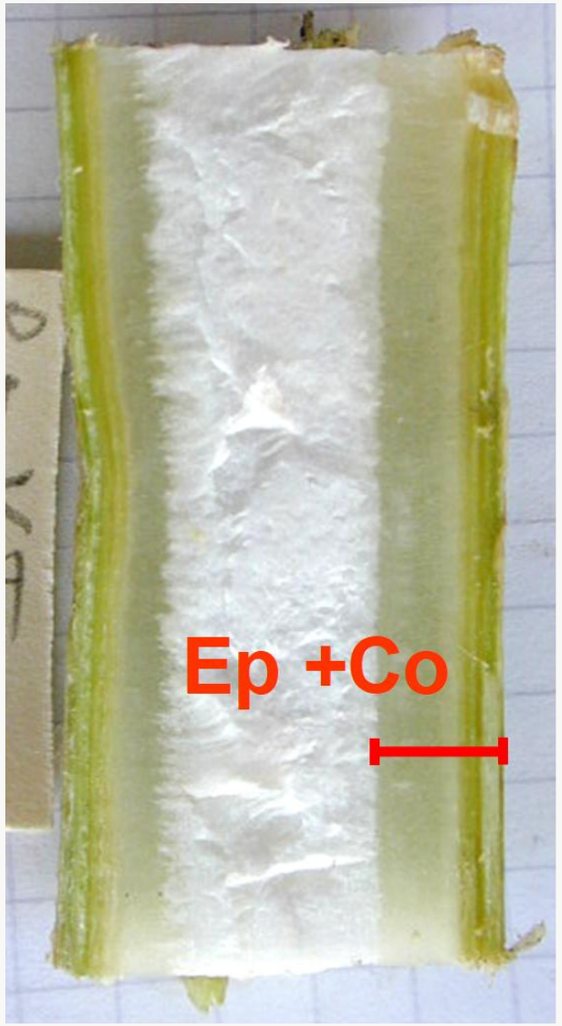


Root plate diameter cubed x soil shear strength (Nm)

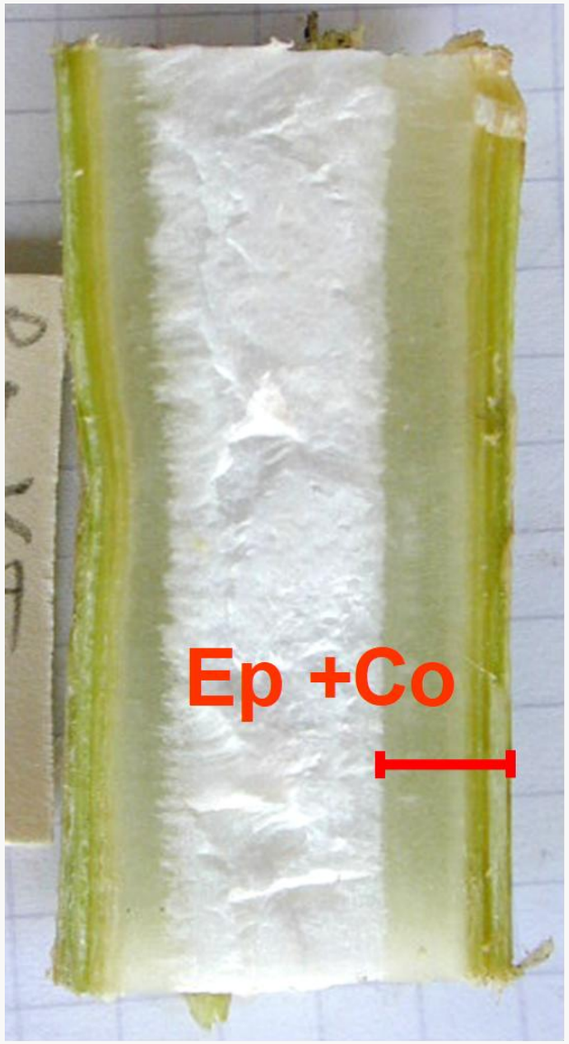
Stem strength

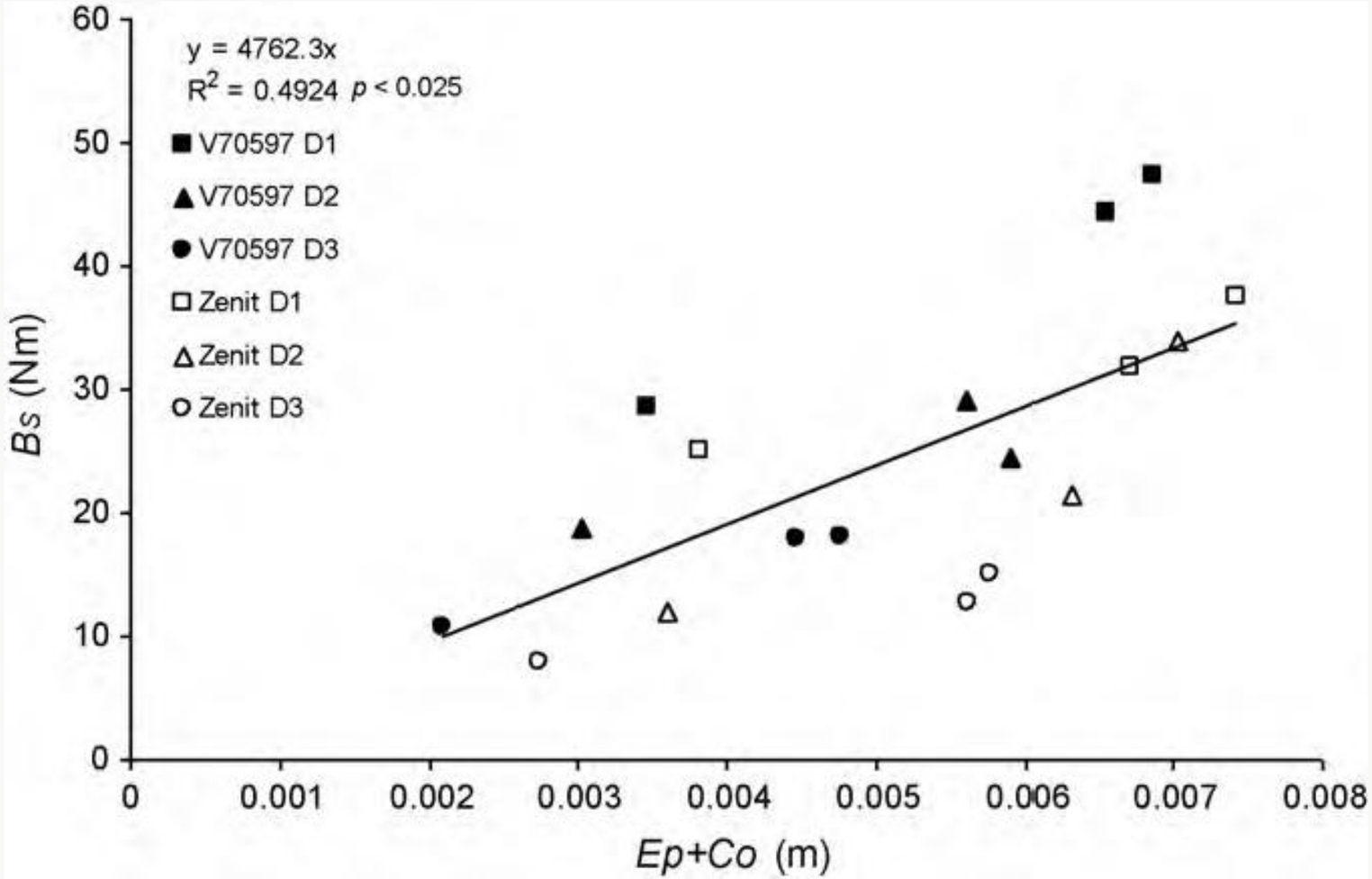




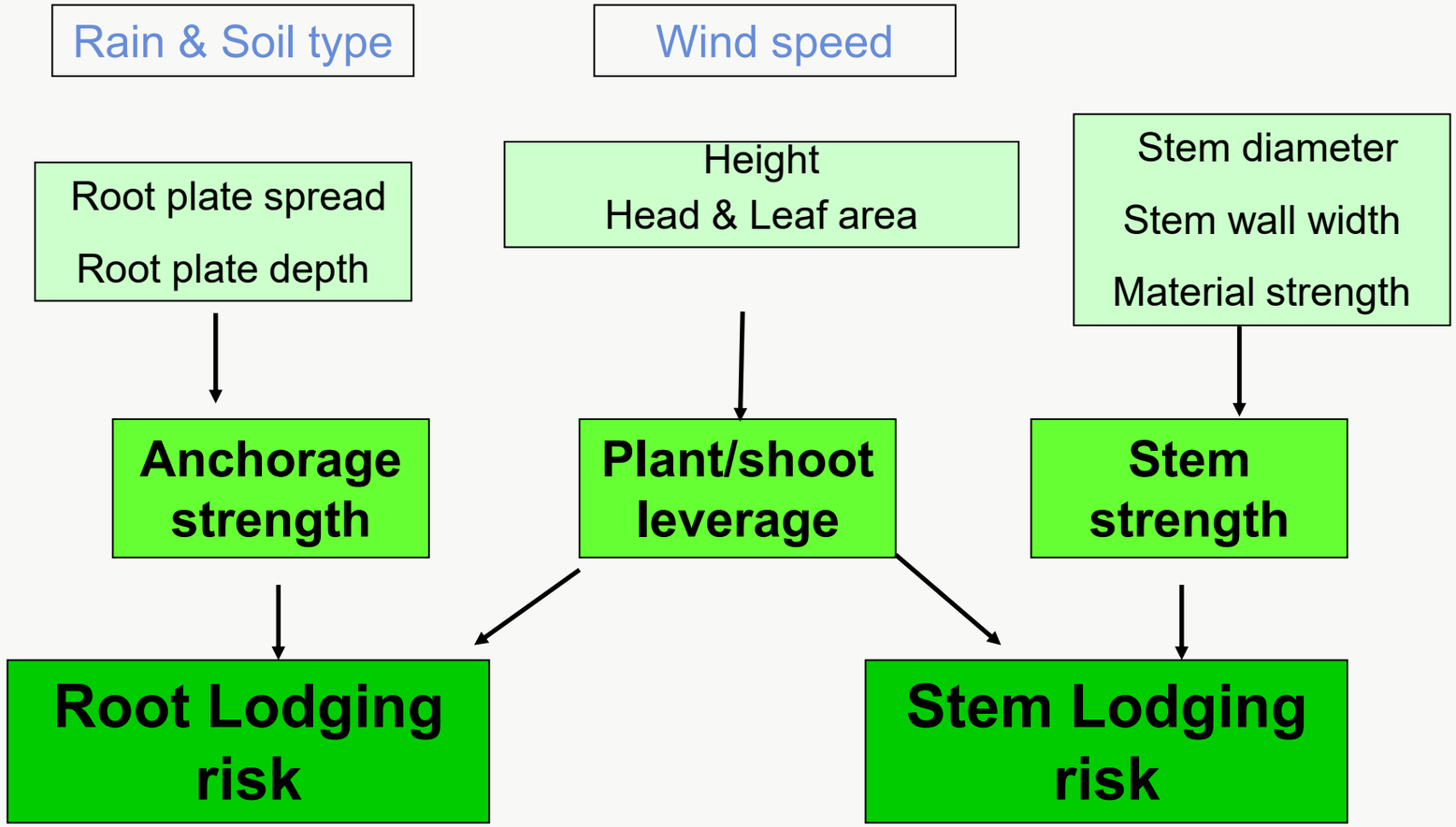


Stem strength determined by stem wall thickness





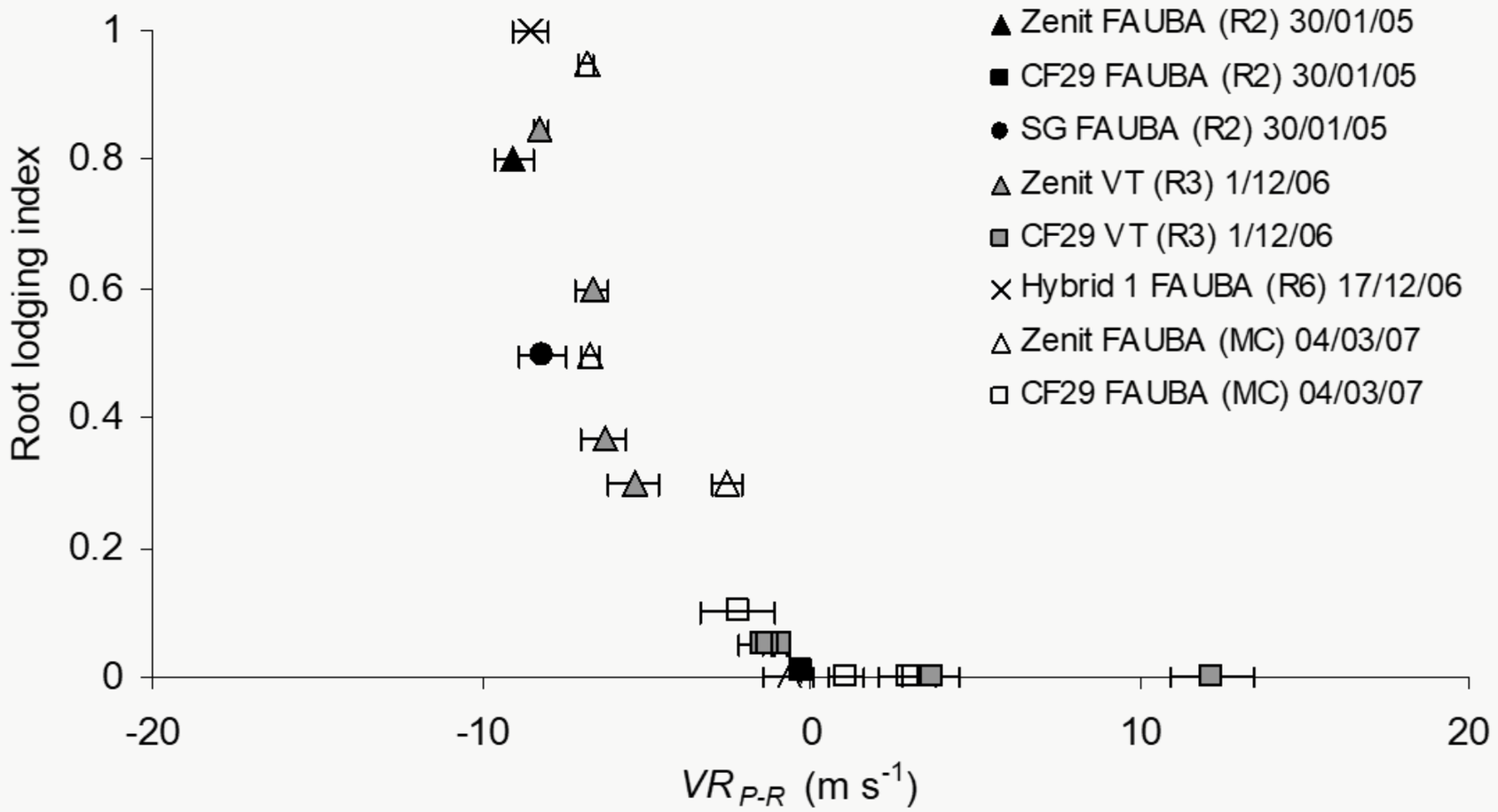
Summary of the lodging model



Lodging risk in terms of failure wind speed

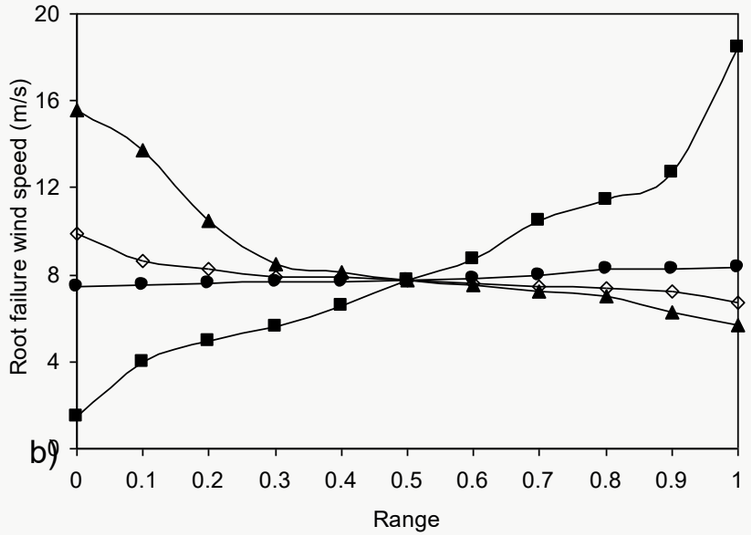
Testing the lodging model

Observed lodging



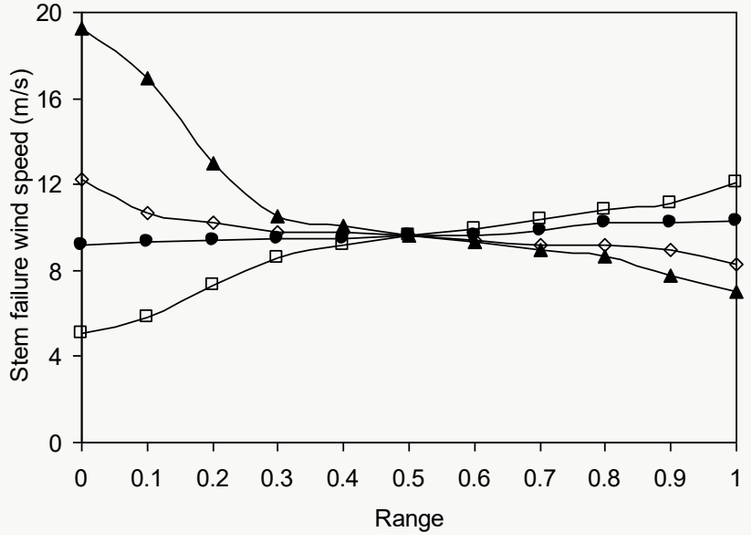
Predicted root failure windspeed minus observed wind speed

Model sensitivity analysis



b)

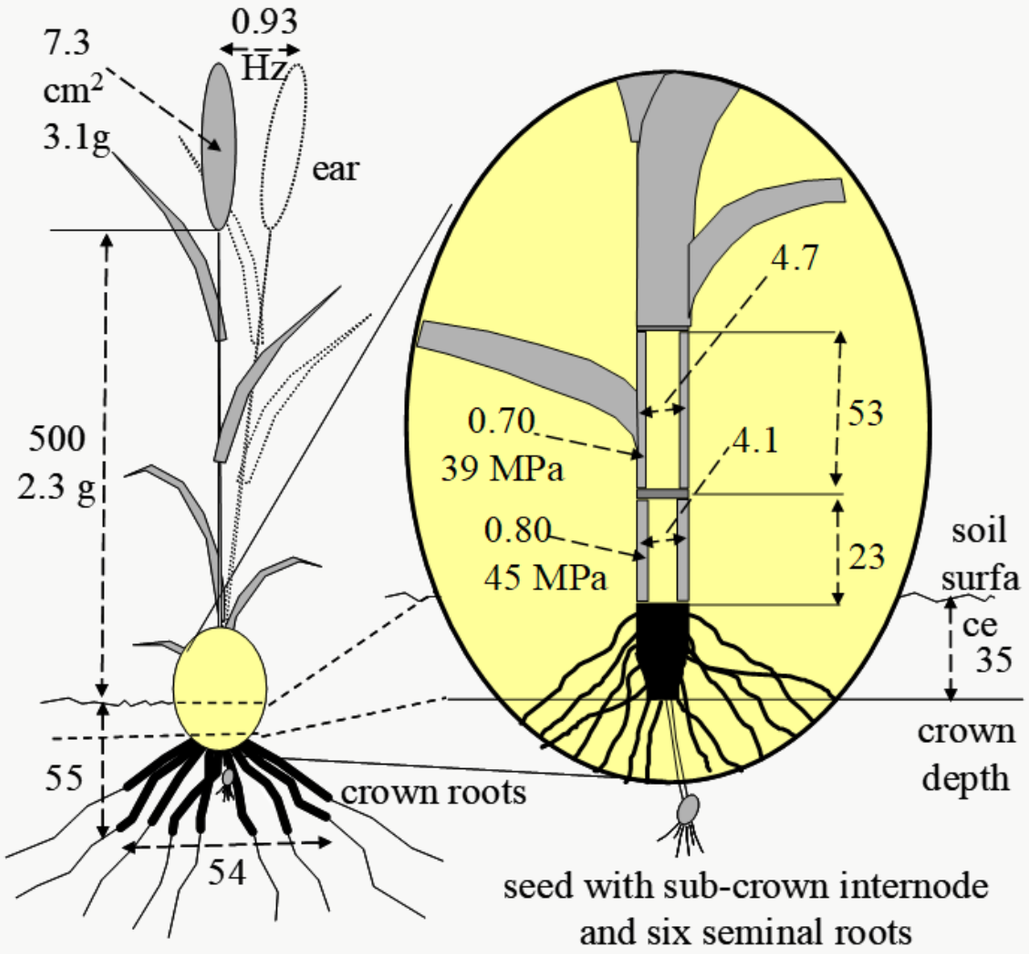
h (1.11-2.17m) — Height
Root plate diameter — Root plate diameter
A (0.13-0.96m2 — Surface area
n (1.05-2.63Hz) — Natural frequency



h (1.11-2.17m) — Height
ep+co (1.5-8.6mm) — Stem wall thickness
A (0.13-0.96m2) — Surface area
n (1.05-2.63Hz) — Natural frequency

Designing a lodging-proof ideotype

Wheat as an example



Conclusions

- Lodging limits sunflower productivity
- Sunflower lodging is caused by both stem failure and anchorage failure

- Traits that affect lodging risk the most include:
  - Head and leaf area
  - Stem wall thickness
  - Root plate diameter

- Further work must:
  - Identify germplasm with strong stems and strong anchorage
  - Design a lodging-proof ideotype

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