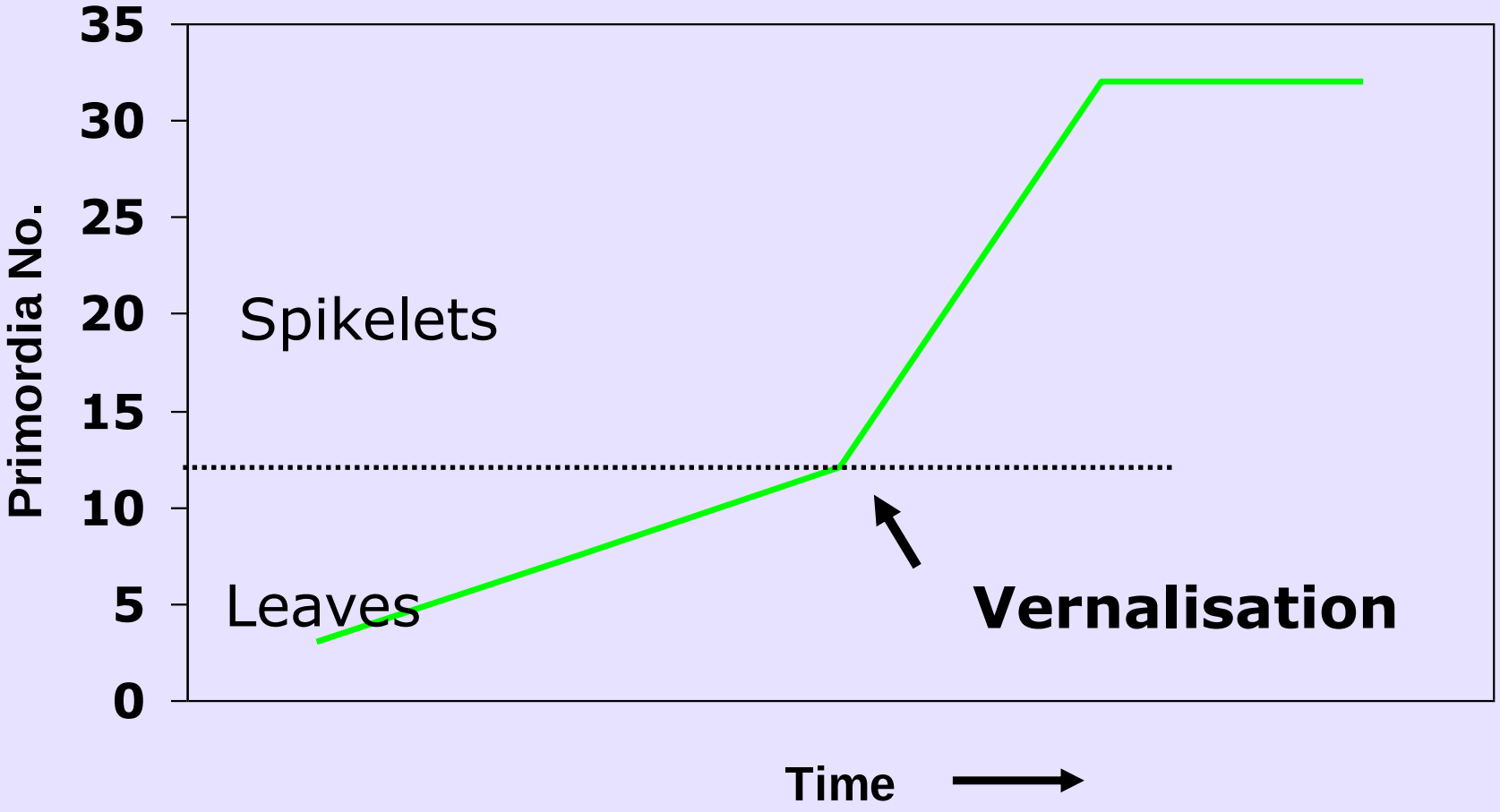
Introduction

- Development ~ progress through growth stages (visual assessment and dissection of apex)
- Growth ~ increase in crop size or weight
- Leaf canopy size and structure
- Light interception and biomass accumulation
- Climate change - benefits and threats to yield?

Development

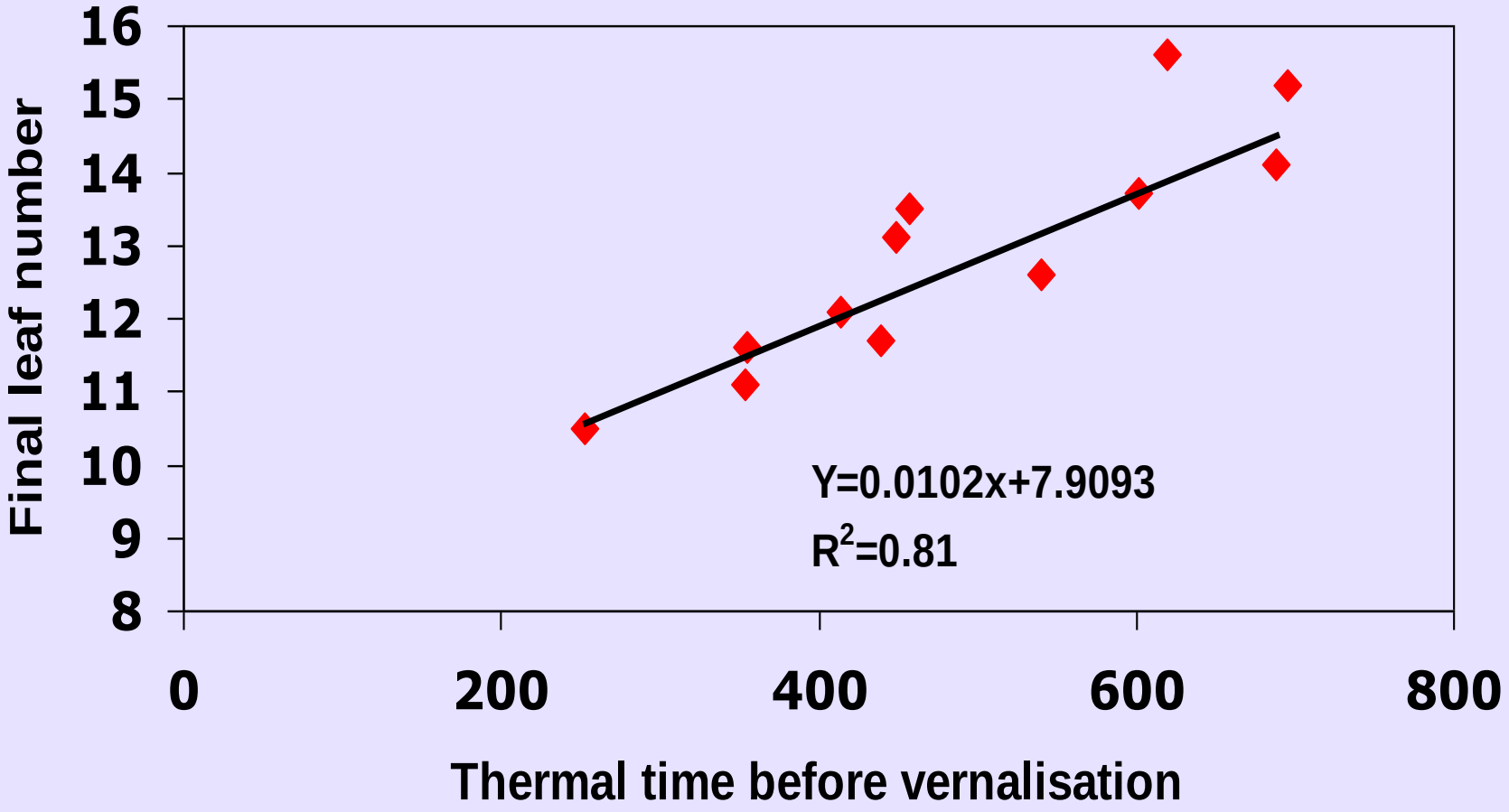
- Leaf appearance
- Temperature and sowing date
- Leaf canopy size and structure
- Apical development
  - Thermal time = sum of mean daily temperatures expressed as day degrees
  - Vernalisation = induction of flowering by low temperature

Wheat (cereal) apical development



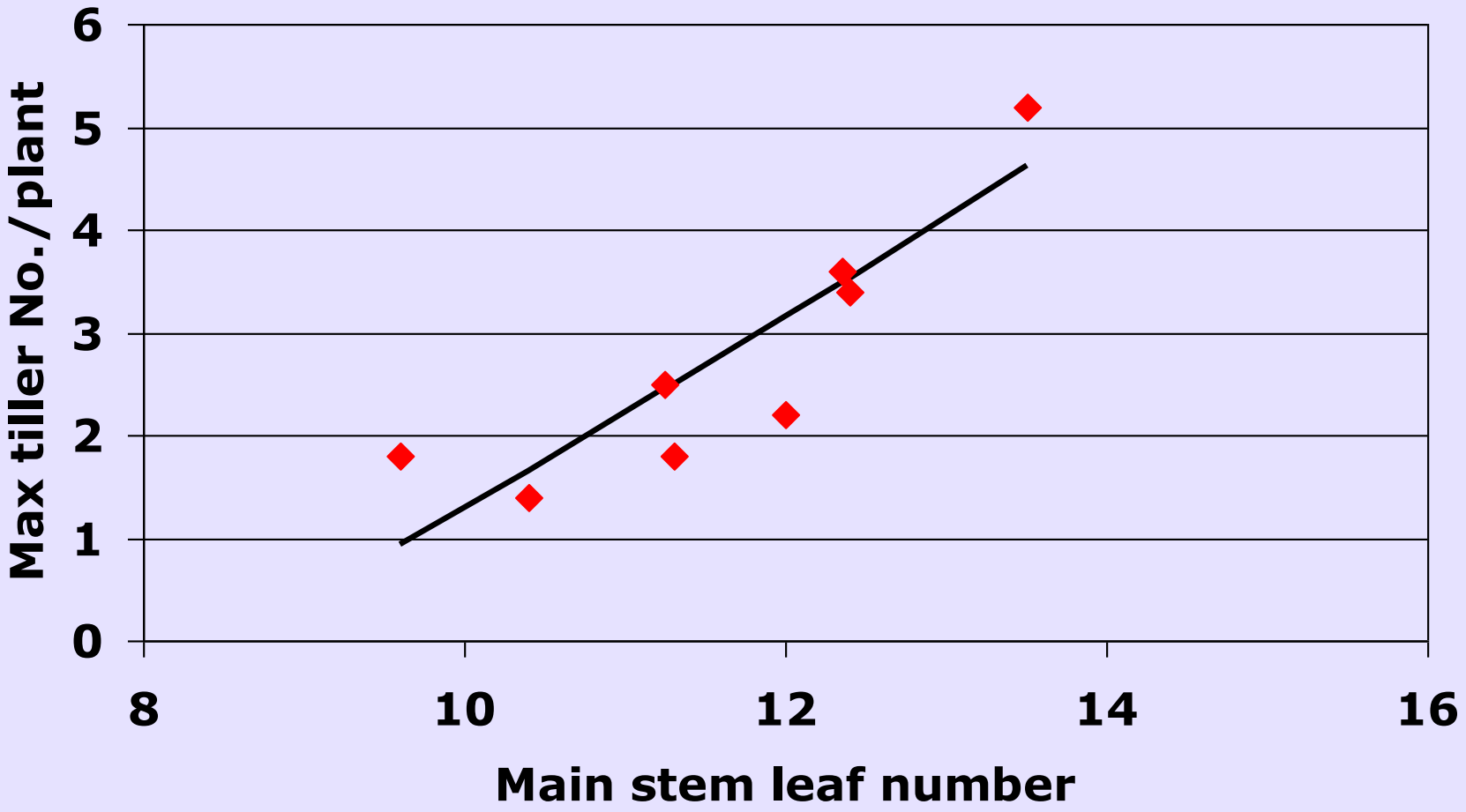
Spink *et al*. 2000, HGCA Report 234

Thermal time before vernalisation effects final leaf number



Spink *et al*. 2000, HGCA Report 234

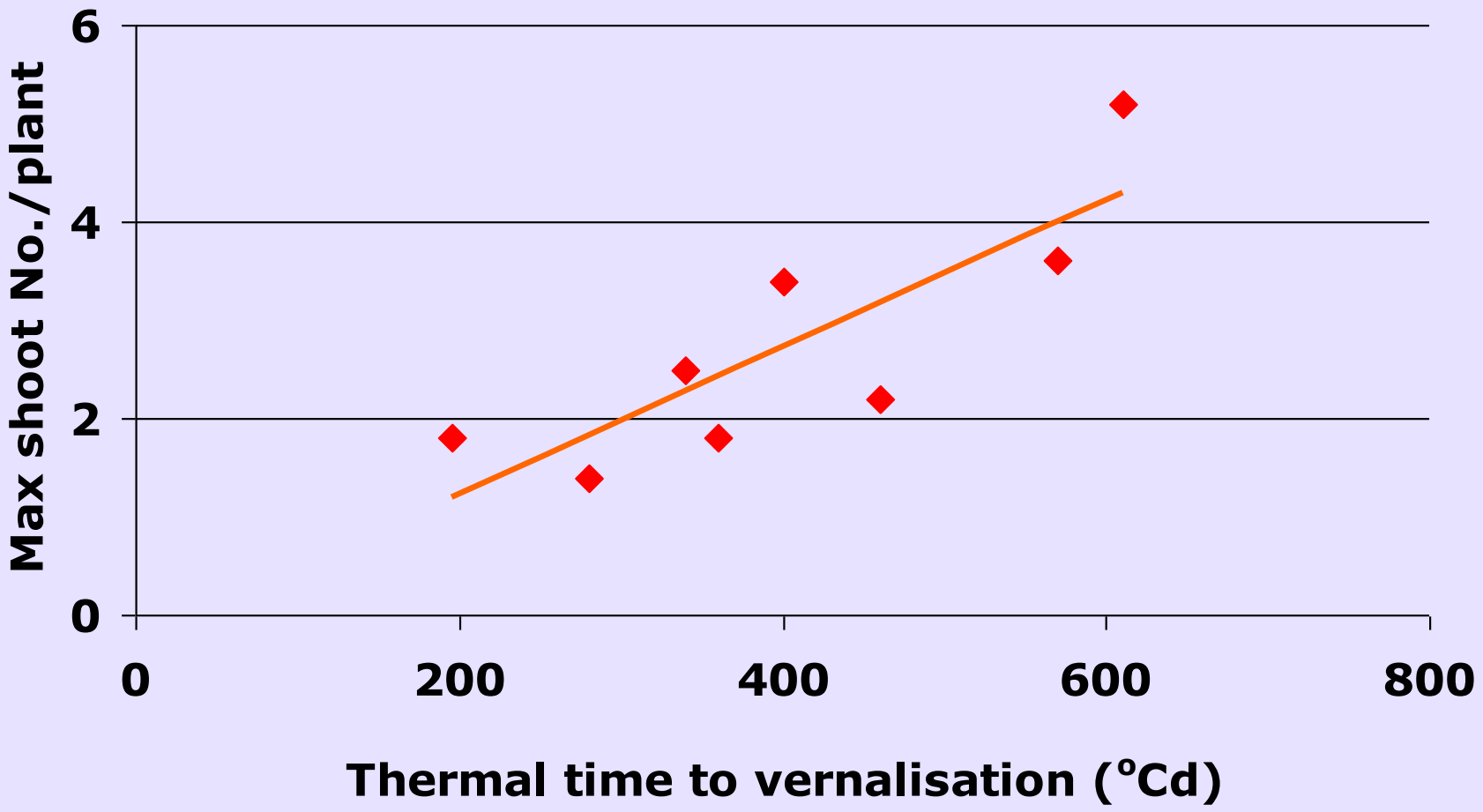
Fewer leaves = fewer shoots



200 plants per m^2, $R^2 = 0.81$

Spink *et al*. 2000, HGCA Report 234

Later sowing results in fewer shoots



Late November sowing

Mid September sowing

Spink *et al*. 2000, HGCA Report 234

Leaf canopies

- Green Area Index (GAI)
- Leaf canopies and light capture
- Radiation capture and dry matter accumulation

Biomass production

$$P_n = S_t \cdot \varepsilon_i \cdot \varepsilon_c / \beta$$

$$g\ m^{-2} = MJ\ m^{-2} \cdot 0.9 \cdot 0.05 / (17.5\ KJ / g)$$

P_n = net production; S_t = incident solar radiation; ε_i = efficiency of light interception; ε_c = efficiency of light conversion; β = energy content of plant BM

Long et al. 2006

Efficiency of light capture, ε_i

ε_i is determined by the speed of leaf canopy development and closure, canopy size, canopy duration and structure

ε_i is approximately 0.9 at ear emergence in a typical cereal leaf canopy

ε_i is determined by canopy size and structure

A canopy of 5 units of GAI intercepts 85-95% of PAR

Nobel et al. 1993; Long et al. 2006; Scott et al. 1994

Light capture within the leaf canopy

Light decreases exponentially down the leaf canopy.

Light attenuation is a function of leaf area distribution and leaf growth habit and is described by the foliar absorption coefficient (*k*)

$$Q_L = Q_0 e^{-kL}$$

Q_0 = incident photon flux density; Q_L = light at leaf level L; L = leaf area at level L; *k* = foliar absorption coefficient

Nobel et al. 1991

Light attenuation in leaf canopies

The foliar absorption coefficient (*k*) ranges from 0.2 to 1.2, depending on leaf habit: for cereals the range is 0.3 to 0.8.

Canopies with upright (erectophile) have low *k*

Canopies with lax (planophile) have high *k*

$$k = \ln [Q_0 / Q_L] / L$$

Example: A total leaf area (or GAI) of 5 and Q_L of 0.05 indicates *k* = 0.46 i.e. an erectophile leaf habit

Nobel et al. 1993

Efficiency of light conversion, ε_c

Efficiency with which intercepted radiation is converted into biomass

ε_c is determined by photosynthetic activity of all leaves in the canopy, minus respiratory losses

ε_c is potentially 0.05, though is typically 0.025*

*This is equivalent to a conversion of PAR of 0.05

Long et al. 2006

Efficiencies at each stage from light interception to biomass accumulation

		Energy loss at each stage
PAR as % of total solar radiation	= 0.50	= 50%
Reflected, transmitted & absorbed light	= 0.86	=7%
Photochemical efficiency & carbohydrate synthesis	= 0.27	= 31%
Respiration	= 0.42	= 7%
Resulting ε_i	**= 0.05**	**(potential ε_i)**

Hall et al. 1993; Long et al. 2006

Radiation Use Efficiency (RUE, g m^{-2})

If ε_i = 0.05 (potential),

RUE_{St} = 2.86 g MJ^{-1}

RUE_{PAR} = 5.72 g MJ^{-1}

However, maximum values for ε_i are typically 0.02 to 0.03.

RUE_{PAR} for cereals ranges from 2.2 to 2.6 g MJ^{-1}

Long et al. 2006

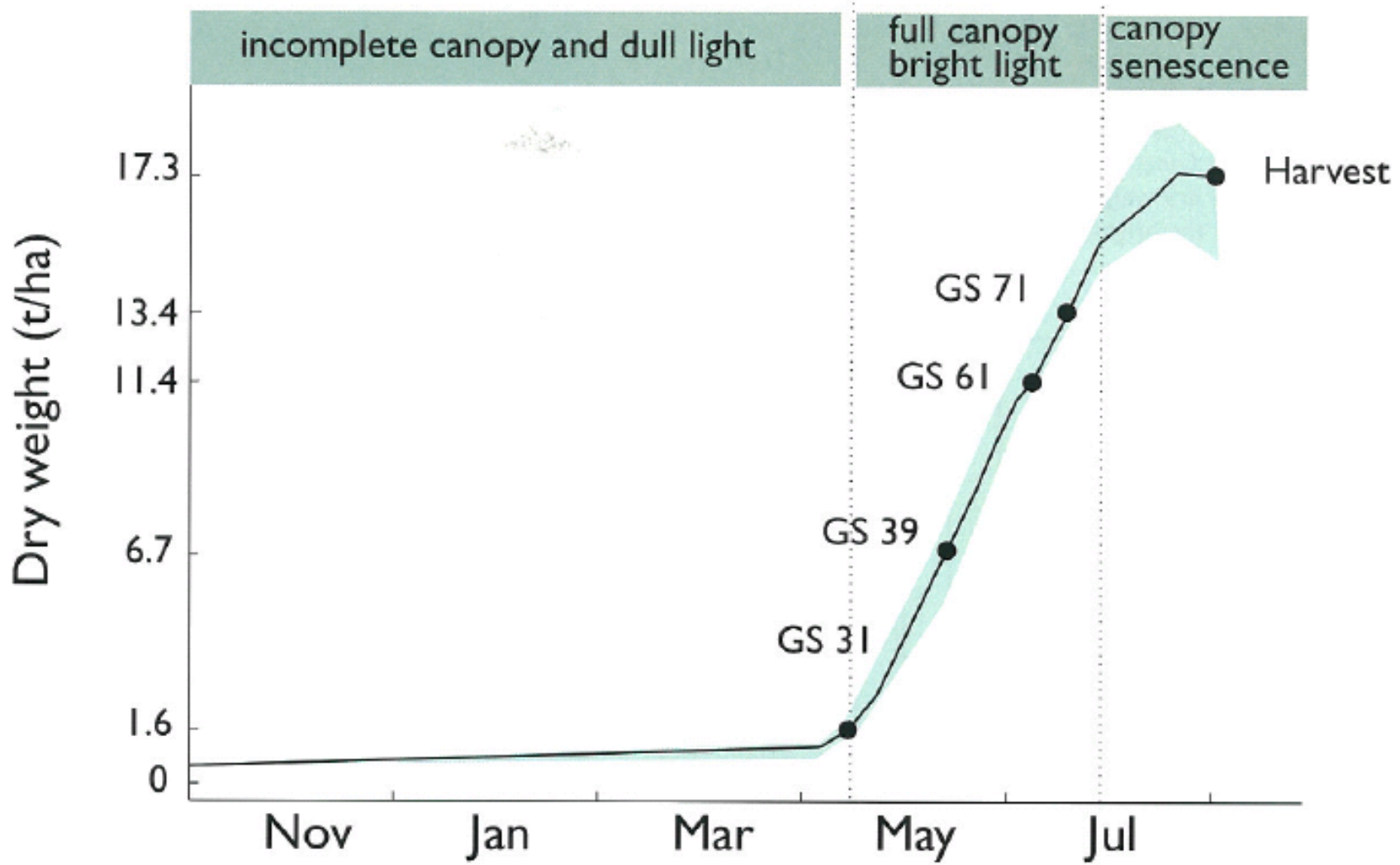
Biomass accumulation

Between flag leaf stage to grain filling a crop could intercept 900 MJ m^{-2} (solar radiation)
i.e. 15 MJ m^{-2} d^{-1}

If RUE_{PAR} = 2.4 g MJ^{-1},

then biomass accumulation = 10.8 t ha^{-1}

Biomass accumulation in wheat



HGCA Wheat Growth Guide, 1998

Grain yield (Y_g)

$$Y_g = P_n \bullet HI$$

HI = harvest index or efficiency with which biomass is converted in the harvested product (e.g. grain), as dry weight

HI ranges from 0.45 to 0.6 in cereals

Long et al. 2006

Ear structure in wheat

5 florets per spikelet: 2-3 will form grains

WB = 2 or 6-rows

SB = 2 rows

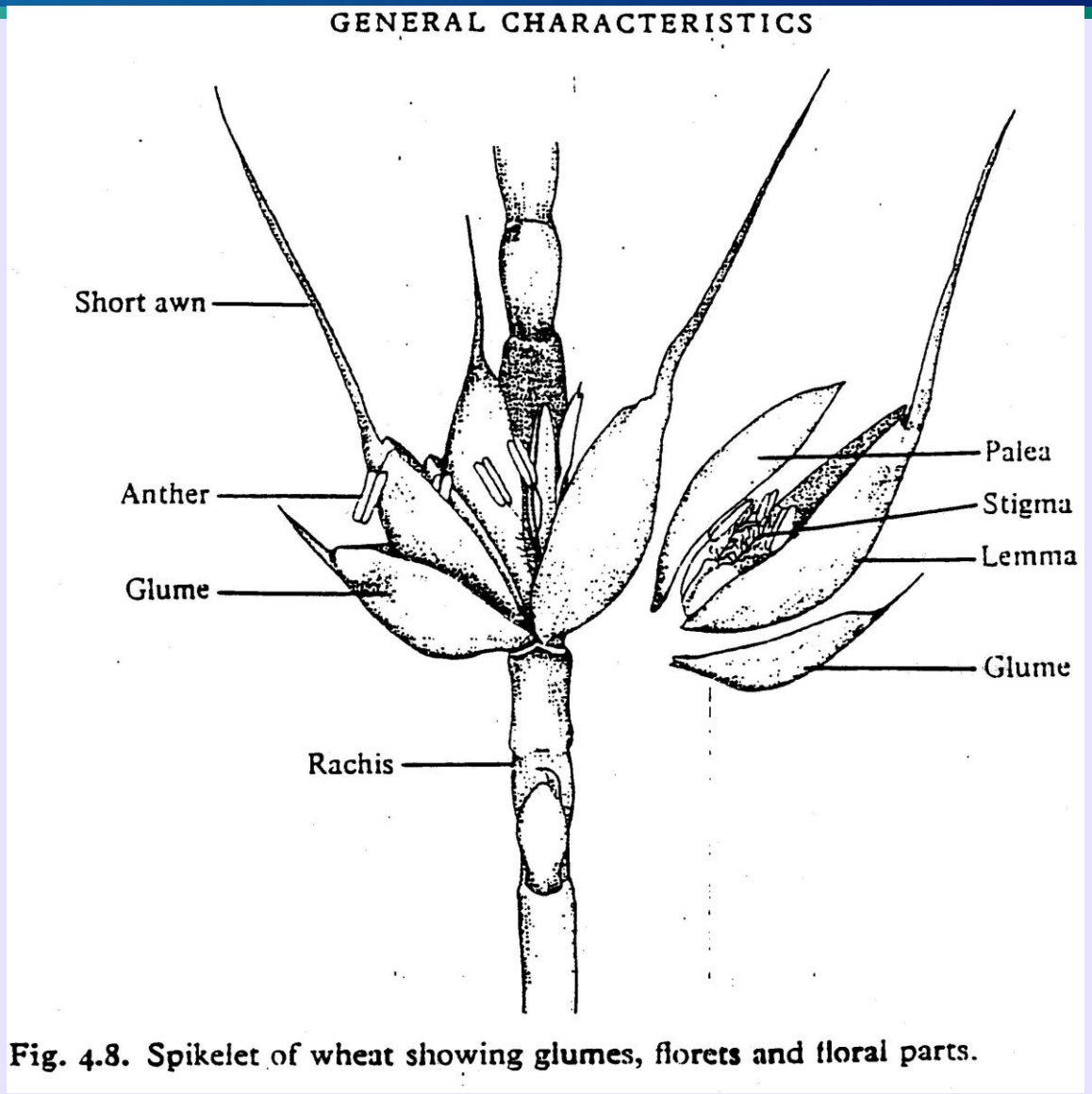


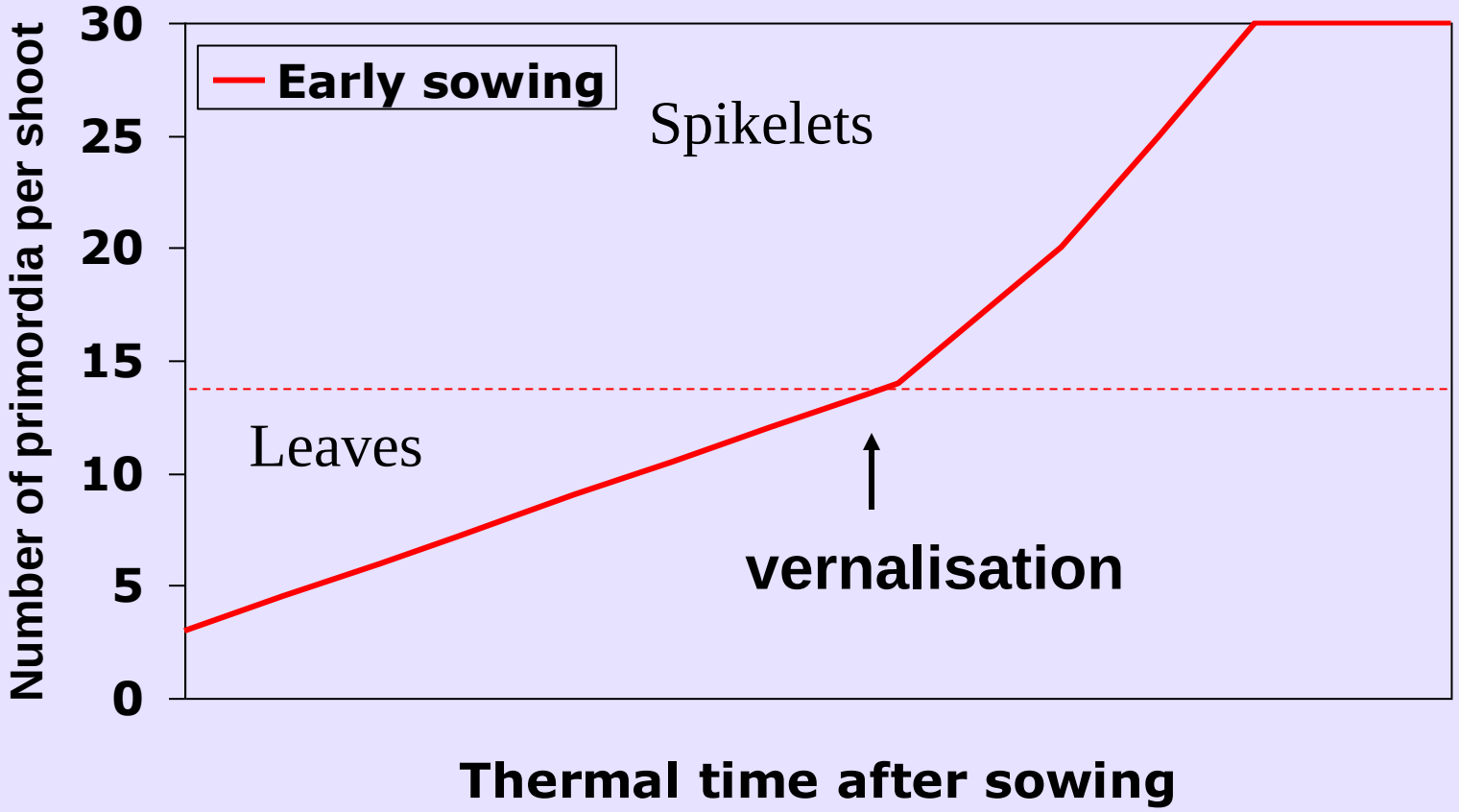
Fig. 4.8. Spikelet of wheat showing glumes, florets and floral parts.

Crop development and climate (change)

- More rapid *versus* slower development
- Earlier *versus* later sowing
- Potential benefits or threats to yield
- Work Packages 1.4 and 1.7 (modelling)

Wheat apical development

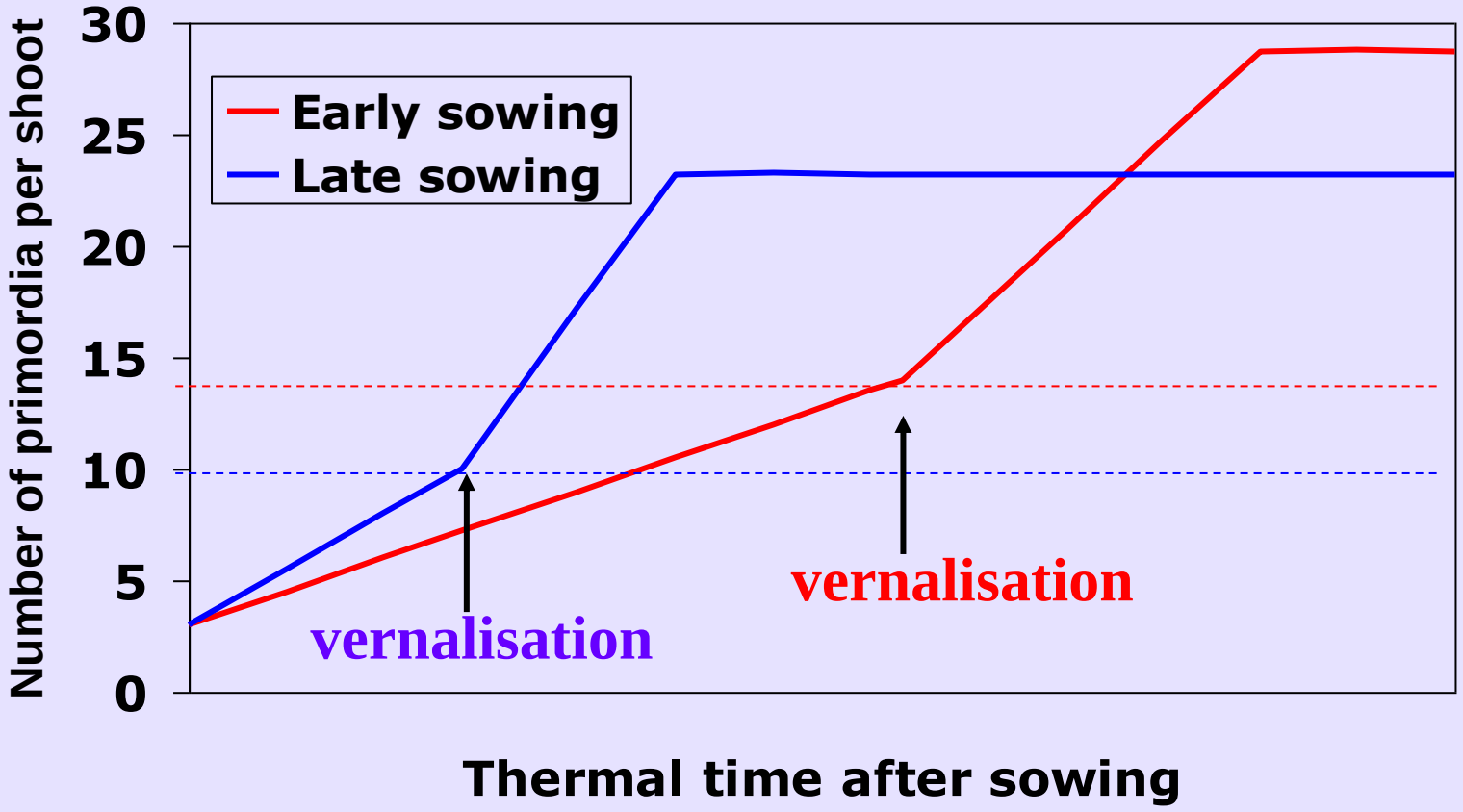
Will early sown crops develop too rapidly in a warmer climate? Change in vernalisation?



HGCA 'Sow to Succeed', 2005

Wheat apical development

We may need to grow slower developing varieties or sow later in autumn



HGCA 'Sow to Succeed', 2005

Frost damage

Cold shocks even in a warmer climate?

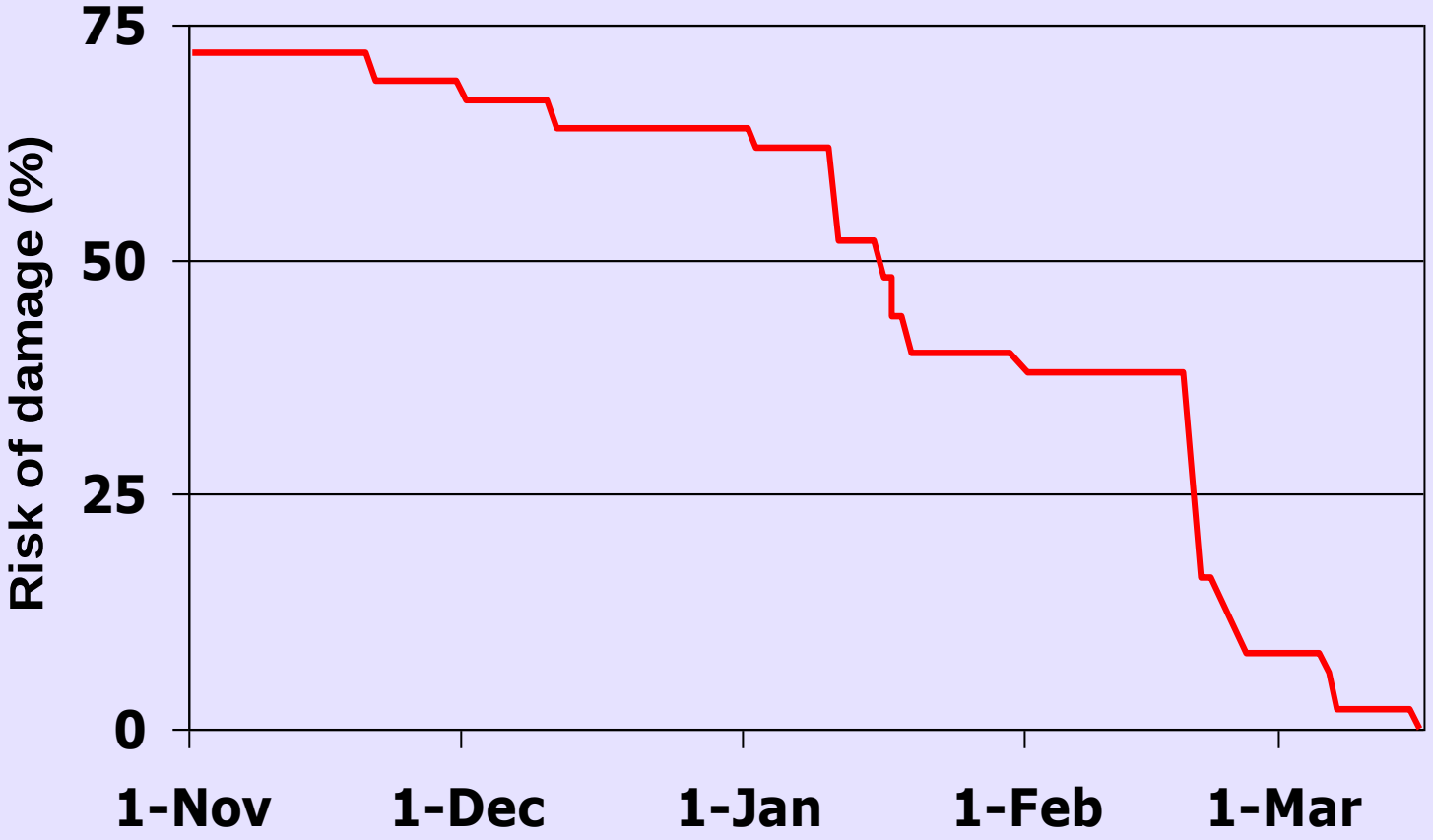
Apex

Ear

HGCA ‘Sow to Succeed’, 2005

Risk of frost damage to the apex

Warmer autumn's could speed development and make crop more vulnerable to frosts

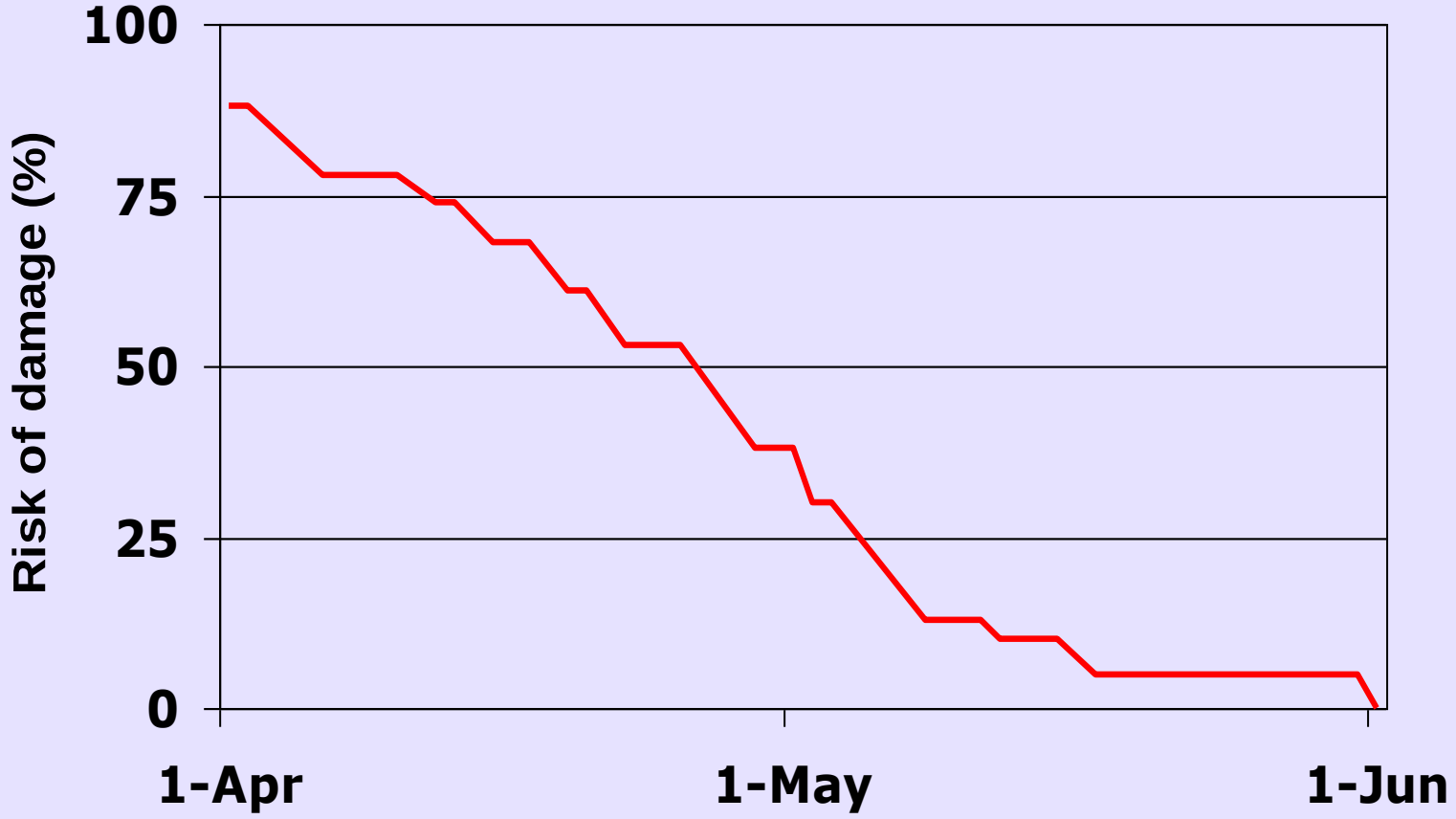


2 consecutive days air min
< -5°C (1959-97)

HGCA 'Sow to Succeed', 2005

Risk of frost damage to the ear

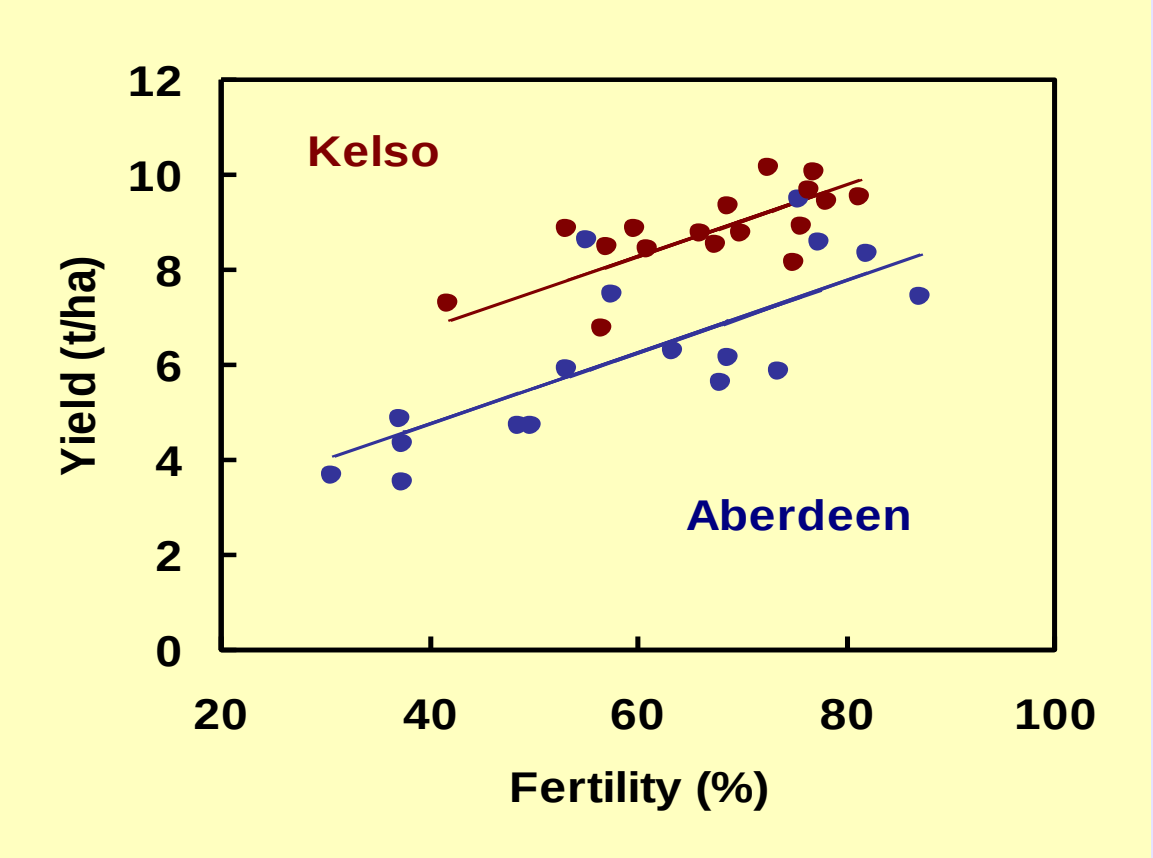
Would more rapid development make crops more vulnerable to spring frosts?



Ground min < -5°C (1959-97)

HGCA 'Sow to Succeed', 2005

Effect of fertility on yield across varieties in RL/NL2 trials 1997

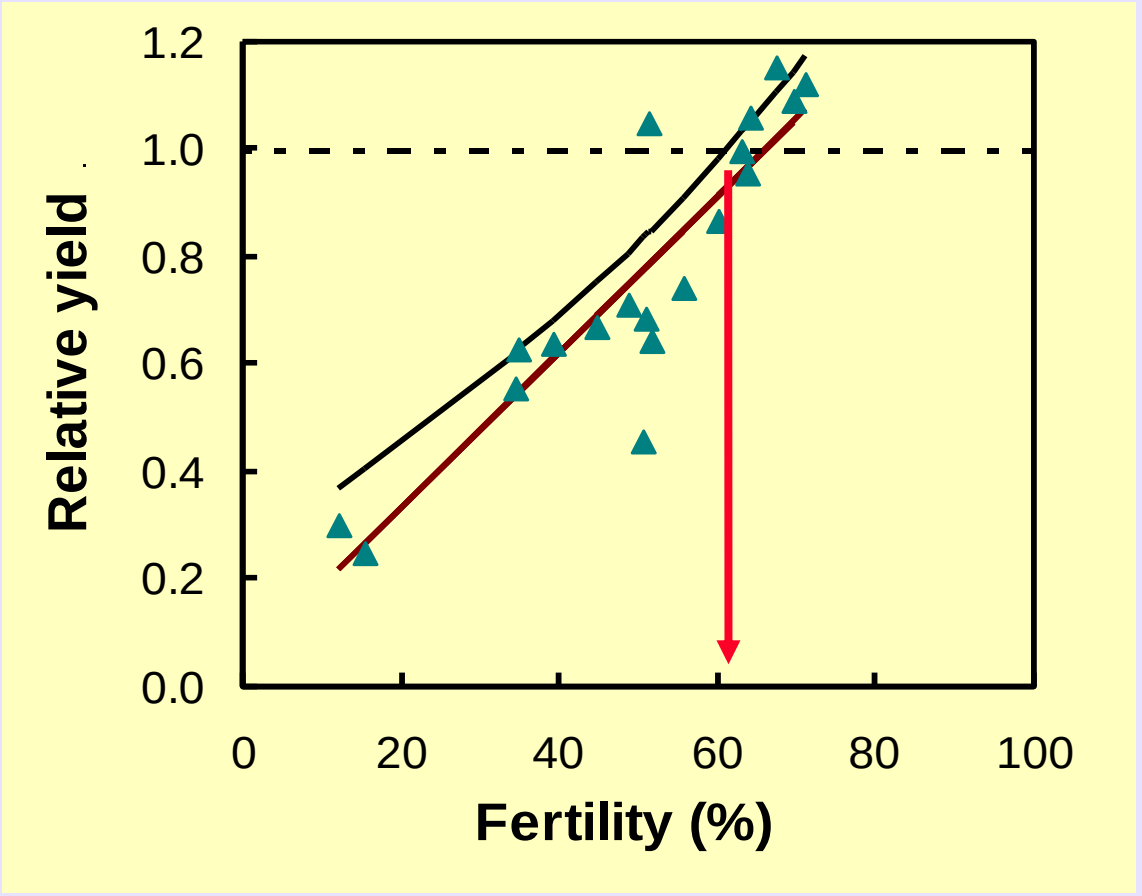


Can we identify critical thresholds of reduced fertility in the UK crop?

Hoad et al. 1999 HGCA Report 193

Effect of fertility on yield across varieties in NL1 (Aberdeen 1997)

Measuring the point at which yield falls significantly below what was expected



Hoad et al. 1999 HGCA Report 193

Radiation and temperature during grain filling

- Grain filling lasts ~700^{o}C days
- The amount of radiation per unit of thermal time declines between May and September
- Duration of grain filling is less in later sown crops
- The amount of radiation intercepted during grain filling is less in later sown crops

Radiation intercepted during grain filling

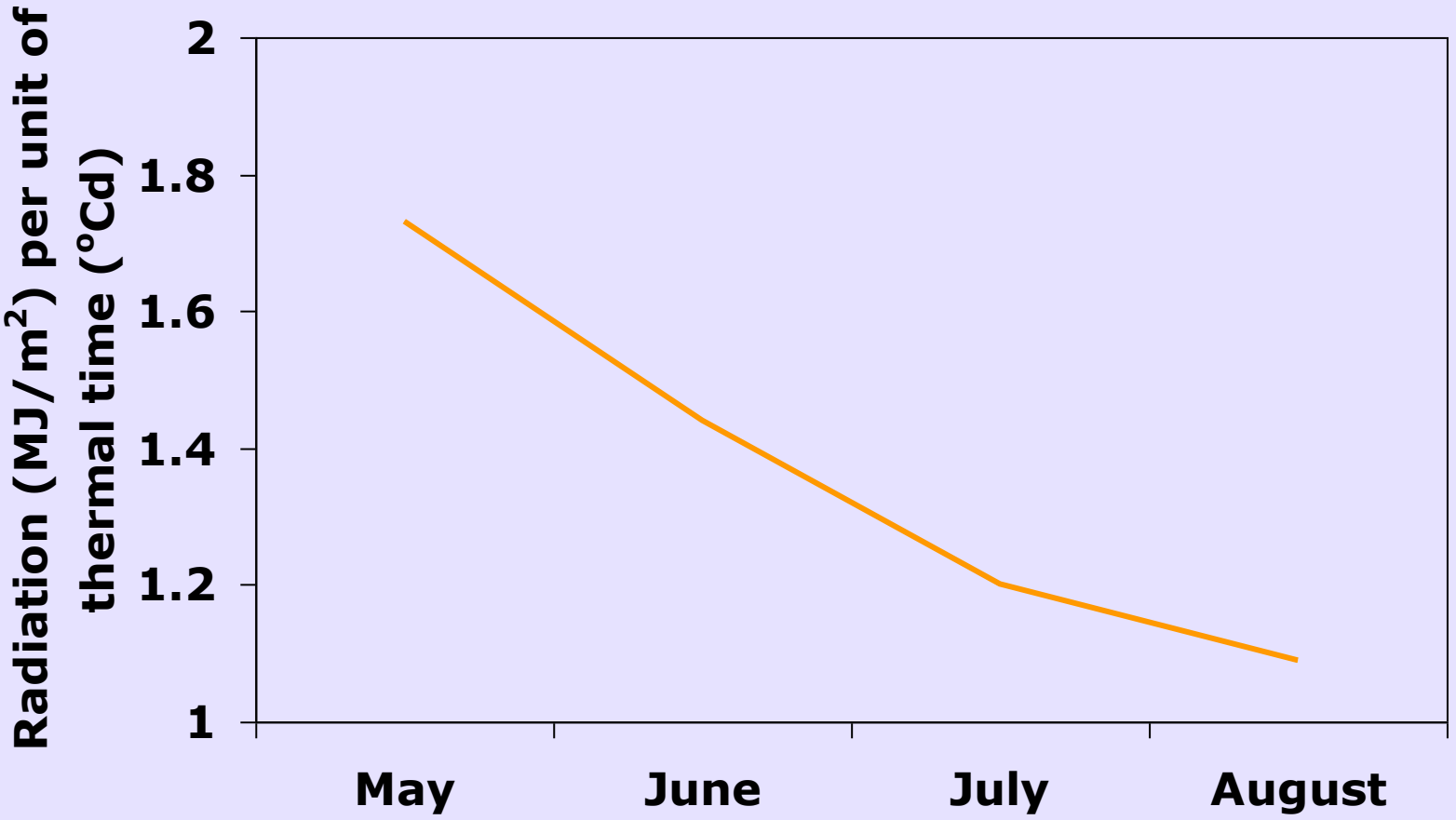
Grain filling lasts ~700°C days

Grain filling Start date	Duration (days)	Radiation intercepted
1 May	57	1109 Mj
1 June	48	942 Mj
1 July	44	818 Mj

HGCA ‘Sow to Succeed’, 2005

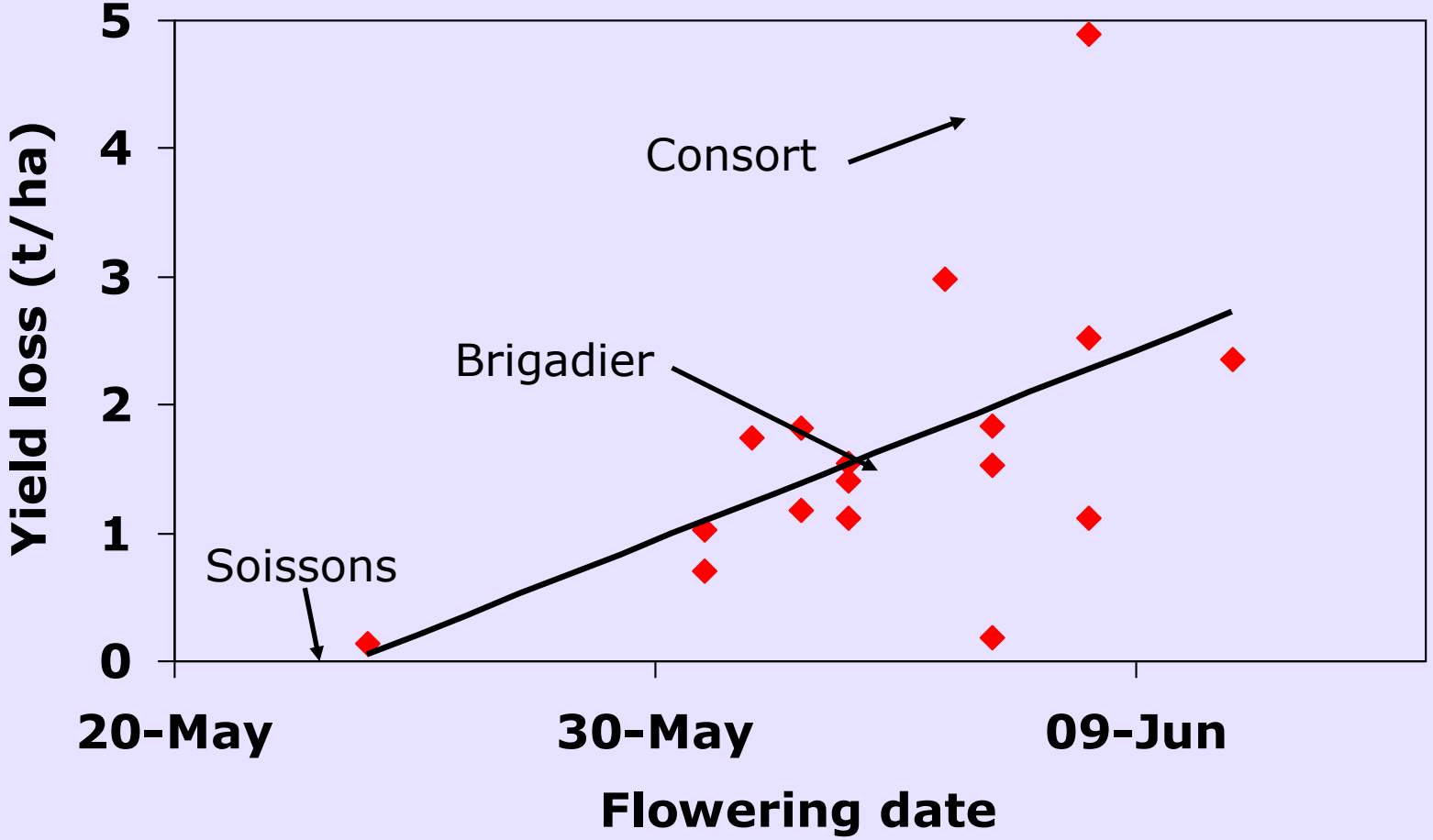
Radiation per unit of thermal time

Later flowering = less radiation intercepted



HGCA 'Sow to Succeed', 2005

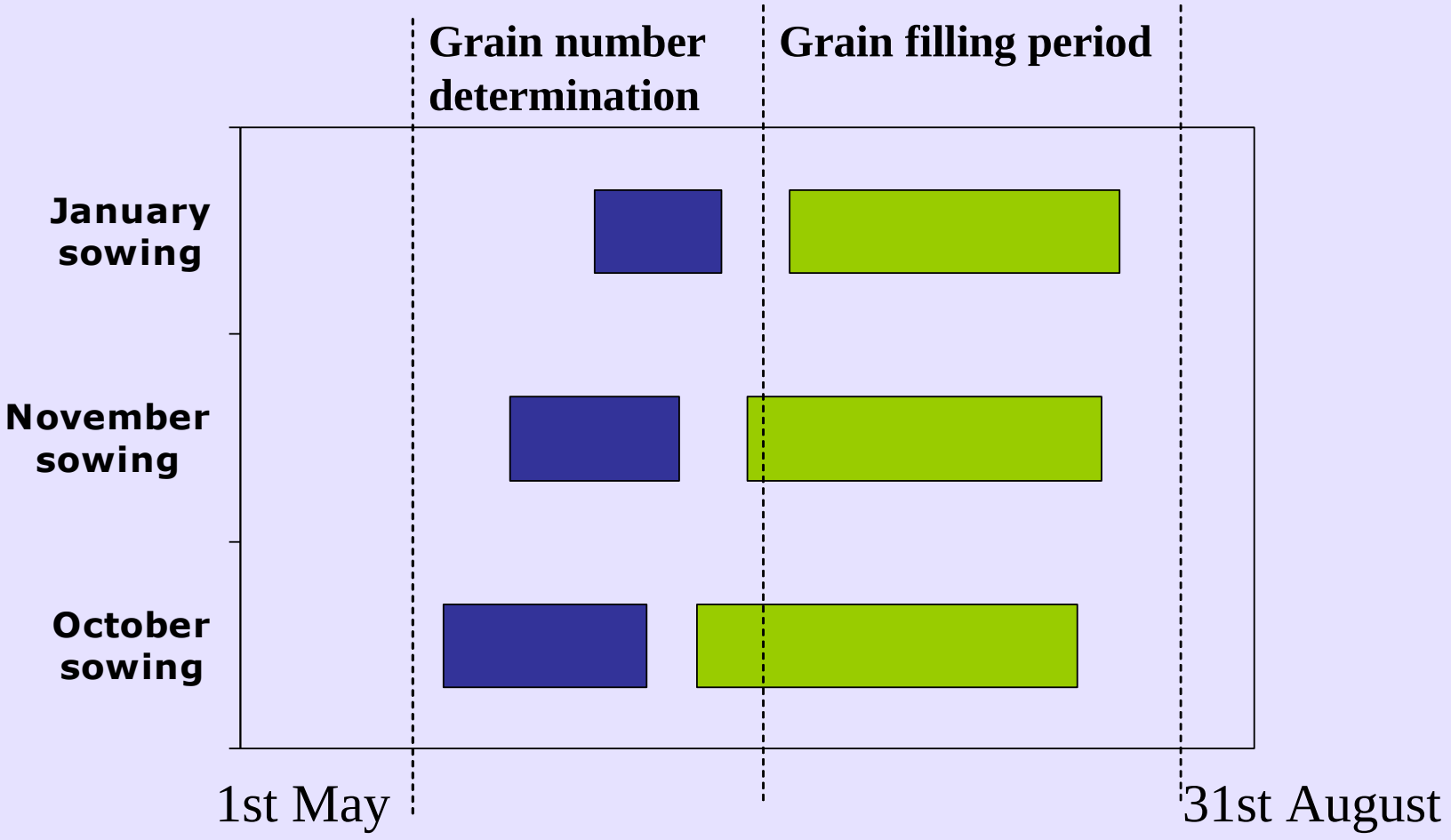
Earlier flowering could mean less ‘yield loss’



HGCA Report 193

Benefits / risks of higher spring temperatures for growth in current variety types

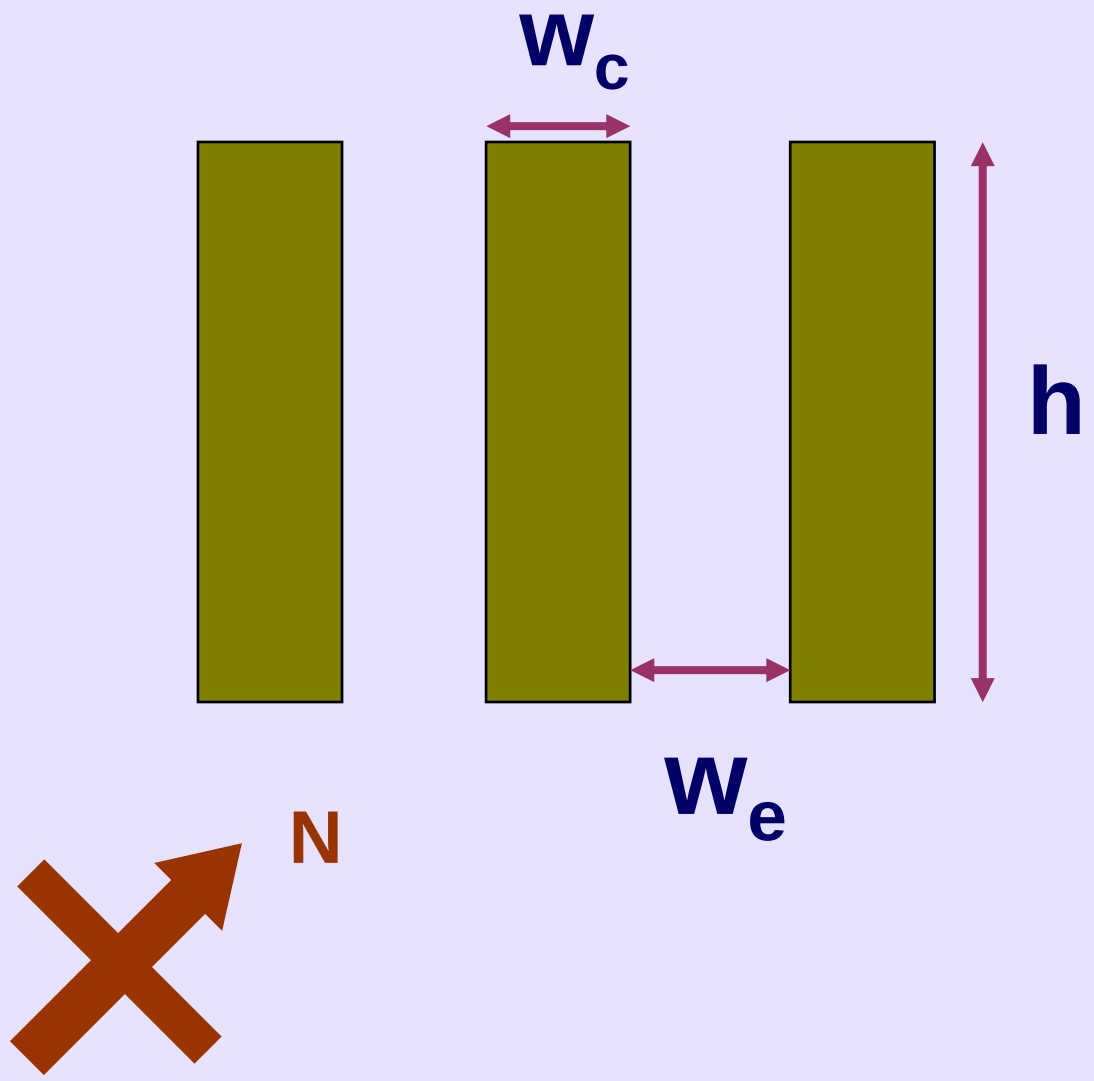
Grain number and grain filling in current varieties



HGCA 'Sow to Succeed', 2005

On-going work in Work Packages 1.7 and 1.4

Modelling the cereal leaf canopy



h = Crop height

w_e = gap width

w_c = width of canopy

WECOF, 2002-2004

Light interception model

- Based on Beer's Law, describing direct and diffuse light absorbed by canopy.

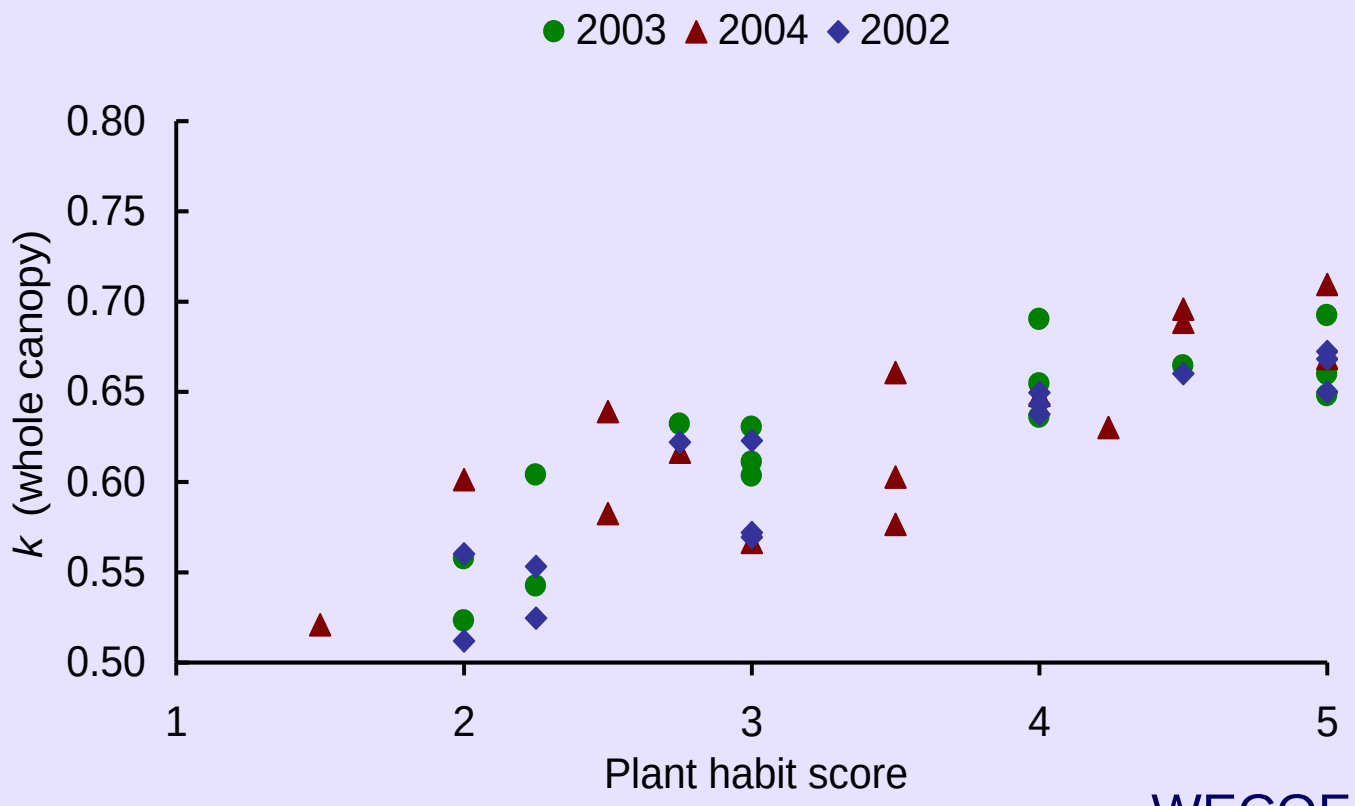
- Sub-models:
  - position of sun
  - diffuse and direct PAR
  - light interception by canopy
  - reflection coefficient of canopy

WECOF, 2002-2004

Can we give physiological meaning to our description of plant growth habits?

Use of a foliar absorption coefficient (*k*)

(b) Plant habit at GS65

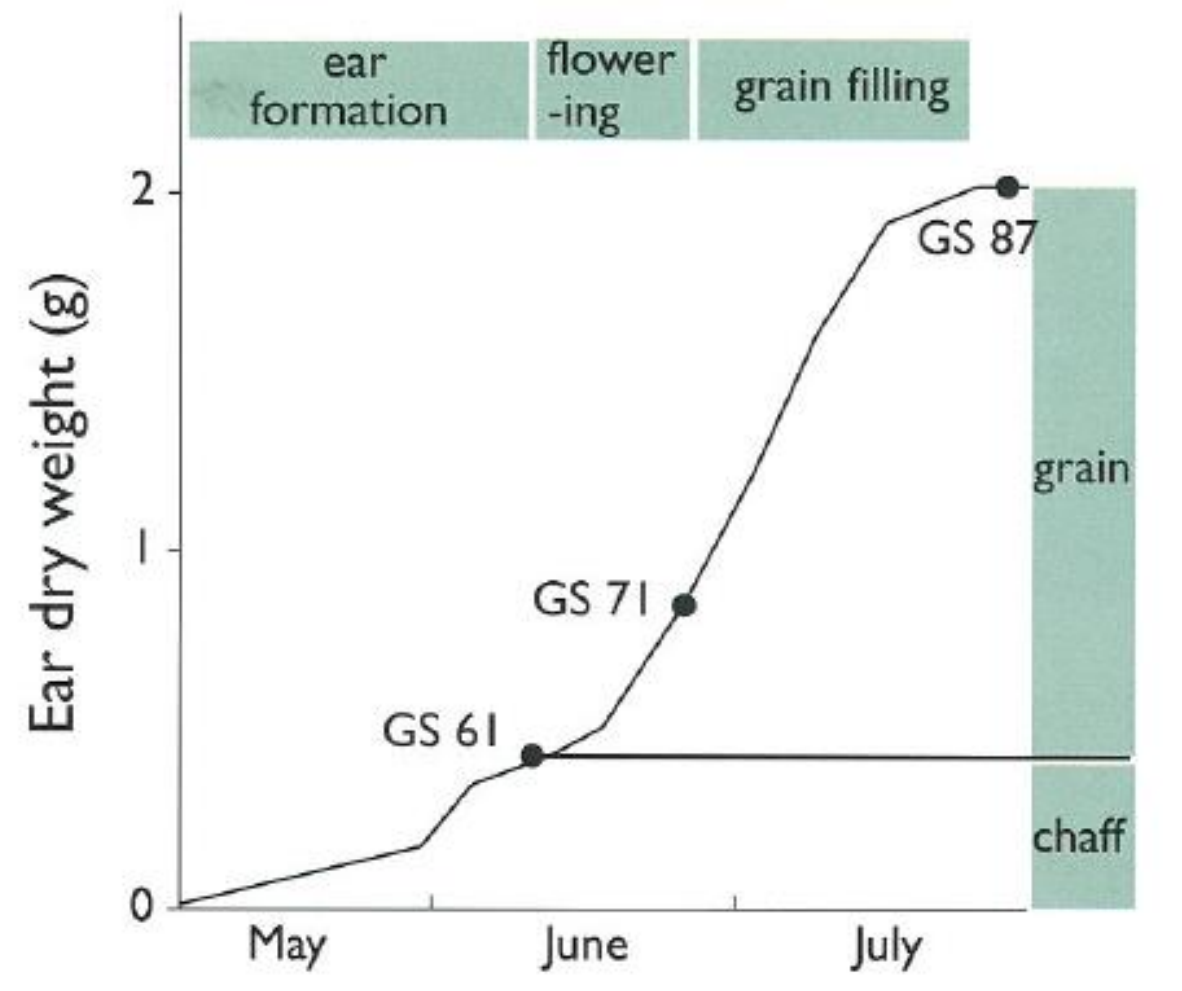


WECOF, 2002-2004

Source-sink relations

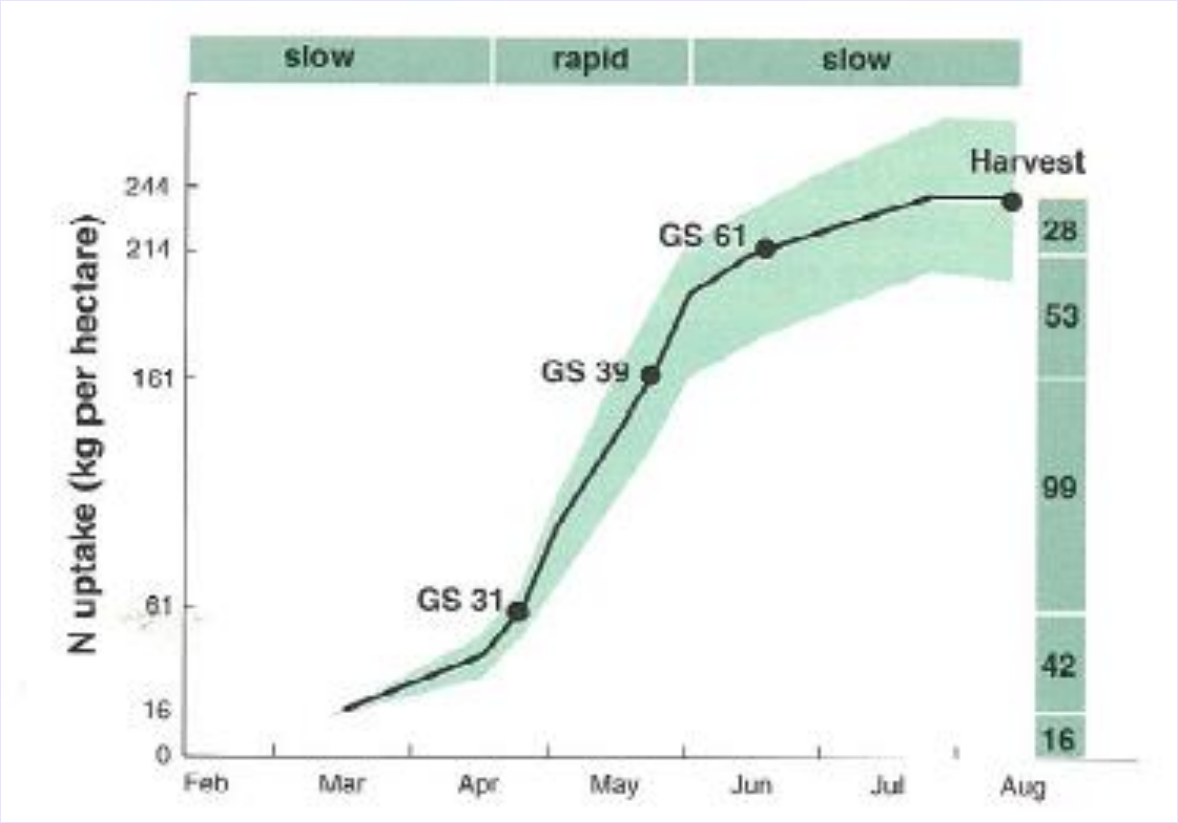
- Are cereal crops source or sink limited?

Ear development (in wheat)



HGCA Wheat Growth Guide, 1998

Nitrogen offtake (in wheat)



HGCA Wheat Growth Guide, 1998

Supporting the
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