Physiological requirements for high grain yields

Dr. Patrick Forrestal

Presentation outline

- My background.
- Yield: the trends and what makes it up.
- Solar radiation, temperature and green leaf area.
- Building a high yielding crop: the key phases.
- Why were yields generally high in 2011?
- Lessons from 2011/ Conclusion.
- Questions, comments, share your observations.

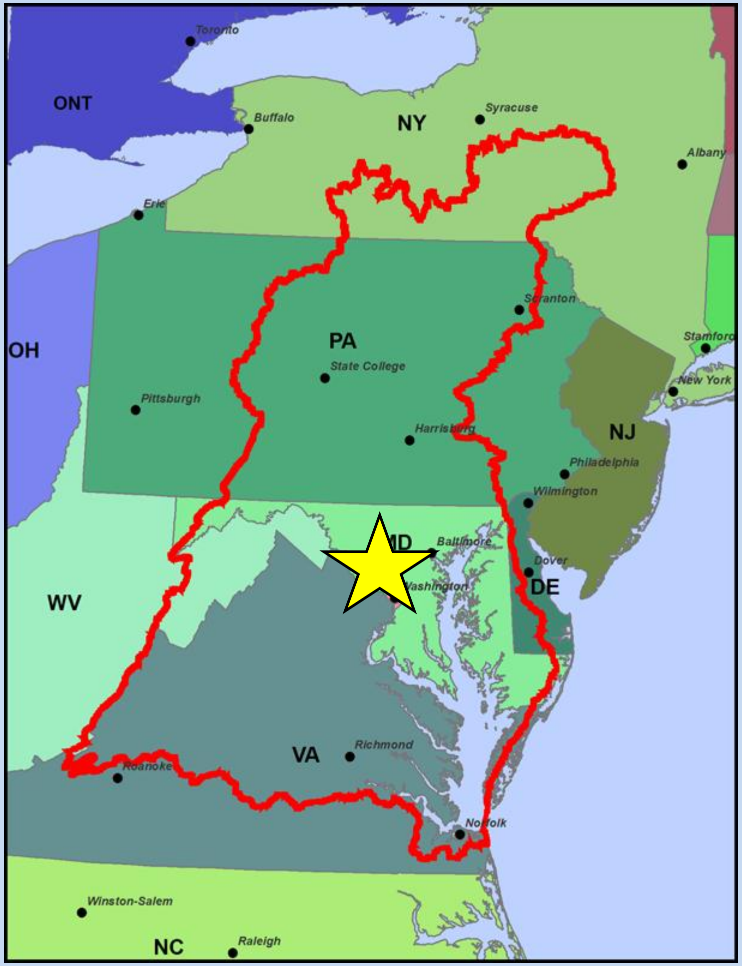
My background


Source: P.J. Forrestal

- Grew up on mixed farm in the “sunny southeast”.
- UCD:
  - B.Agr.Sc. Animal and Crop Production 2003
  - M.Agr.Sc. Crop Science 2005
- University of Maryland, U.S.A.
  - Crop Research Technician
  - Ph.D Plant Science 2011

Developed autumn N recommendations for wheat based on quick soil nitrate test


Source: P.J. Forrestal



Chesapeake Bay watershed

Winter cover cropping

Maize management and N stabilizers

Source: P.J. Forrestal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Source: P.J. Forrestal

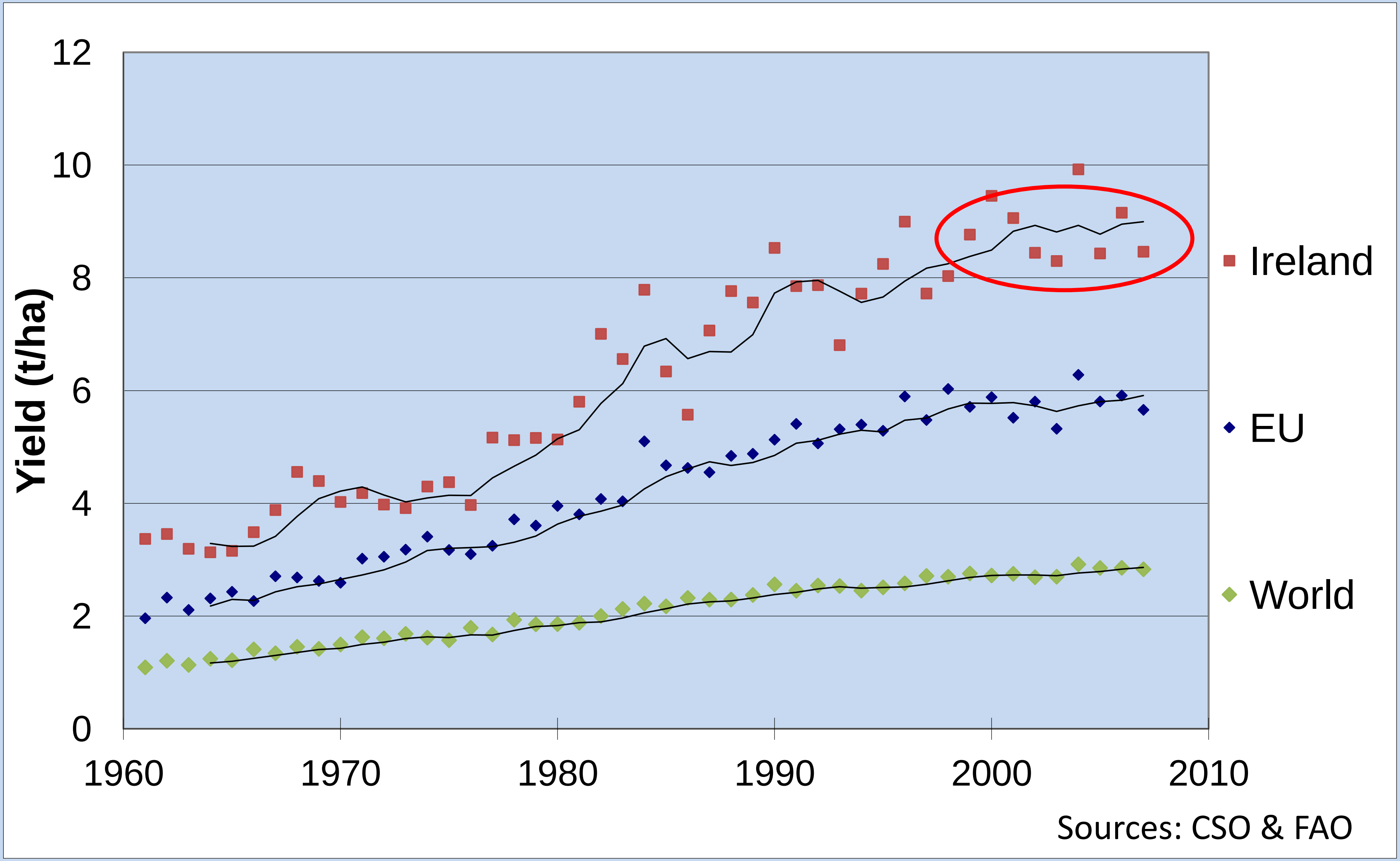
World wheat yield record holder?

Michael Solari (left) Otama, <u>New Zealand</u>: 15.6t/ha (6.3t/acre)

Winter Wheat Yield Trends

1980s: increase of 2.1 % per annum

1990s: increase < 1.0 % per annum



Yield potential and Ireland

Yield achievable if:

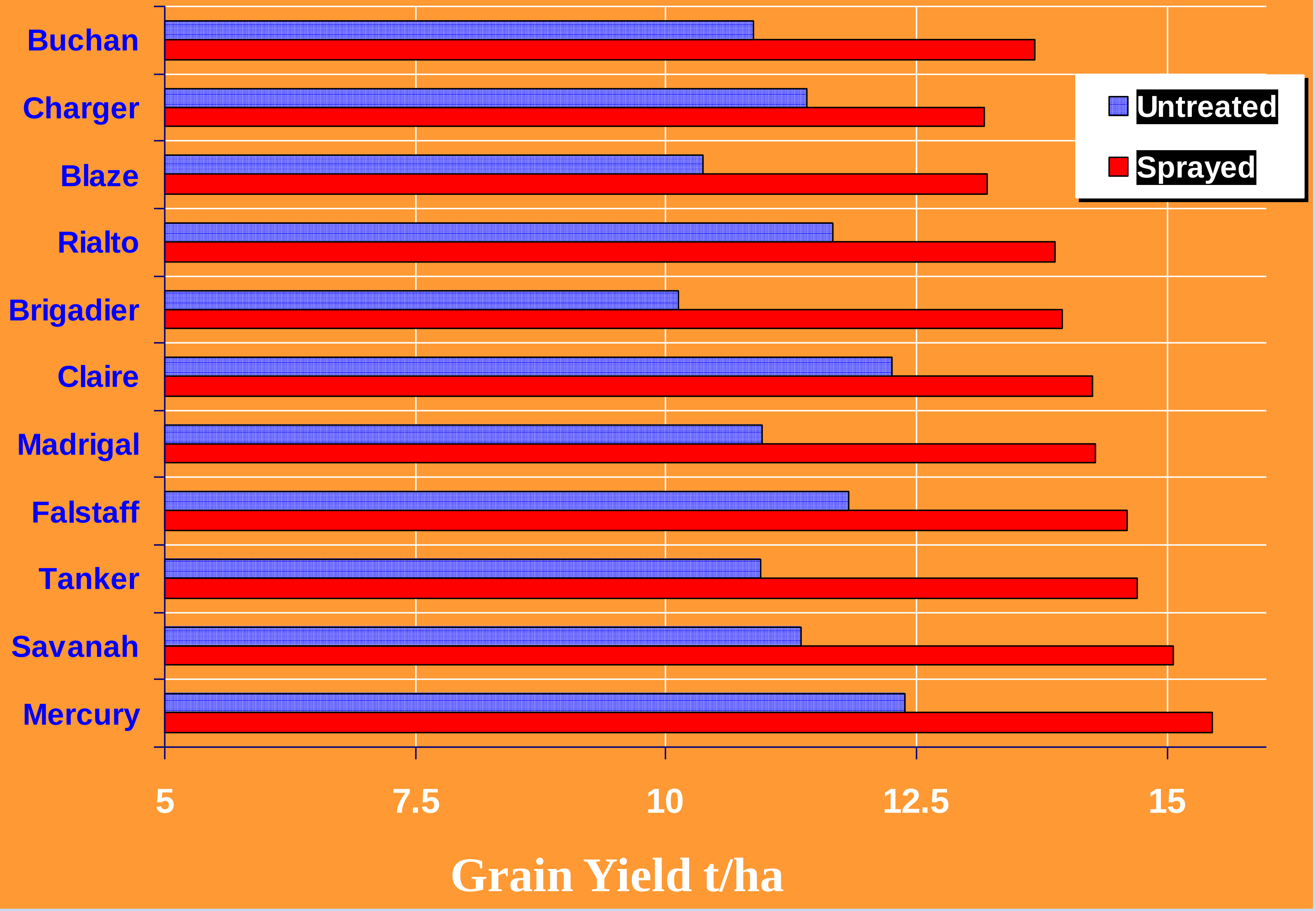
- water, nutrients are adequate
- Diseases and weeds are controlled.

- It is yield limited by solar radiation, temperature.

- We receive enough solar radiation to produce **19.8 t/ha winter wheat (dry)** (Burke *et al*., 2011)

Winter Wheat Variety Trials Mean Yield (T/Ha) Oak Park

Source: Prof J.I. Burke UCD

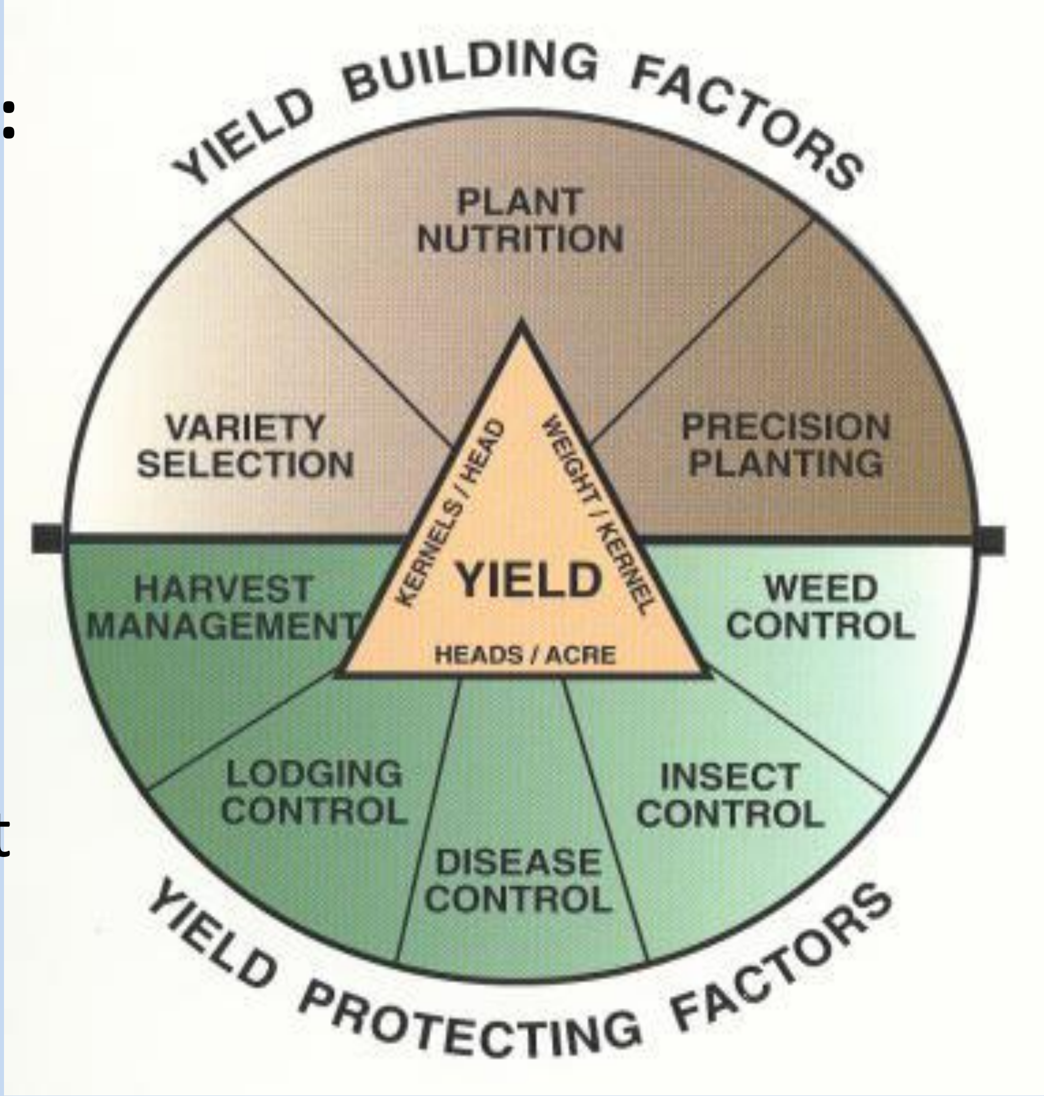


What makes up yield ?

The 3 yield components:

1. Heads/m^2
2. Kernels/head
3. Kernel weight

Environmental and management factors influence each component at particular times.



Example: 2 different 10t/ha crops

Yield Component	Crop 1	Crop 2
Heads/m^2	600	500
Kernels/ear	36	40
Kernel weight (mg)	46.3	50

Chris Dennison (New Zealand) Former wheat yield world record holder. Broke 15 t/ha (dry) in 2003

We're trying to **harvest the sun** to produce carbohydrates and protein. Think about how to manage the crop to harvest sunshine most efficiently.

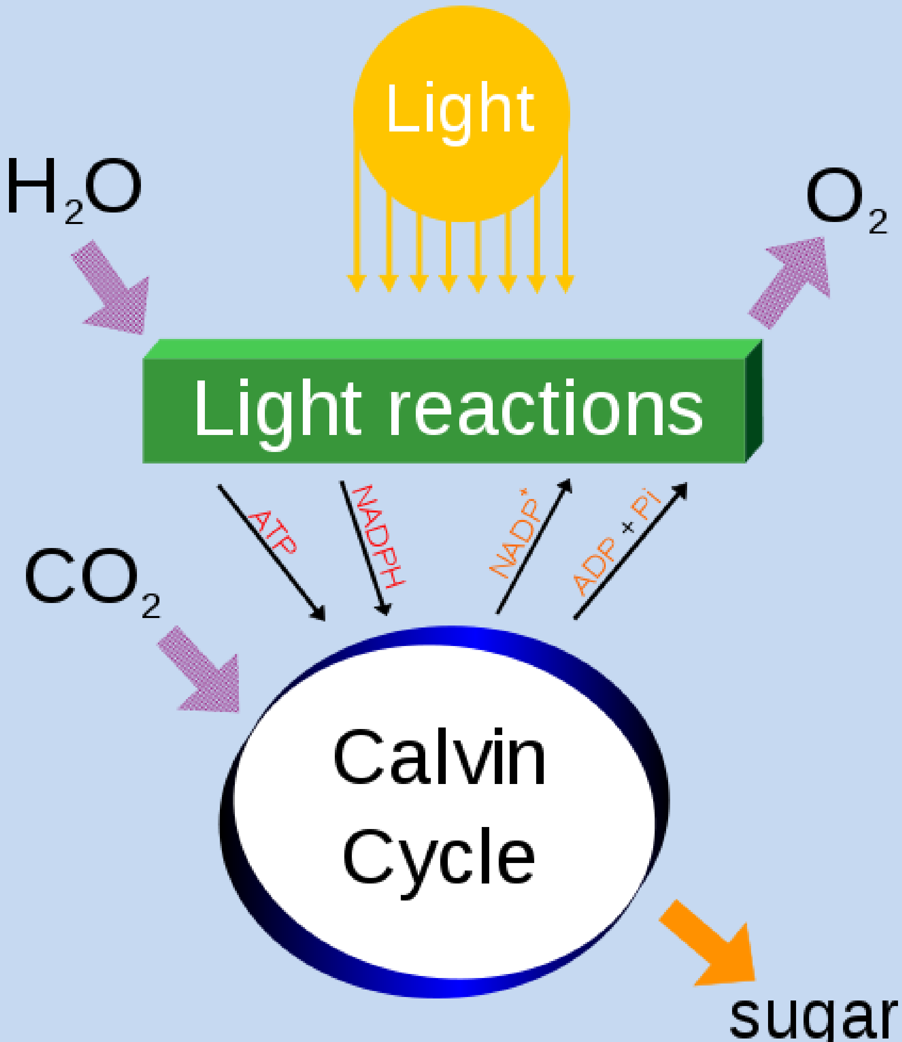
"Harvest the sun" and plant physiology

PHOTOSYNTHESIS

Chlorophyll pigments absorb **solar radiation.**

Used to drive biochemical processes producing

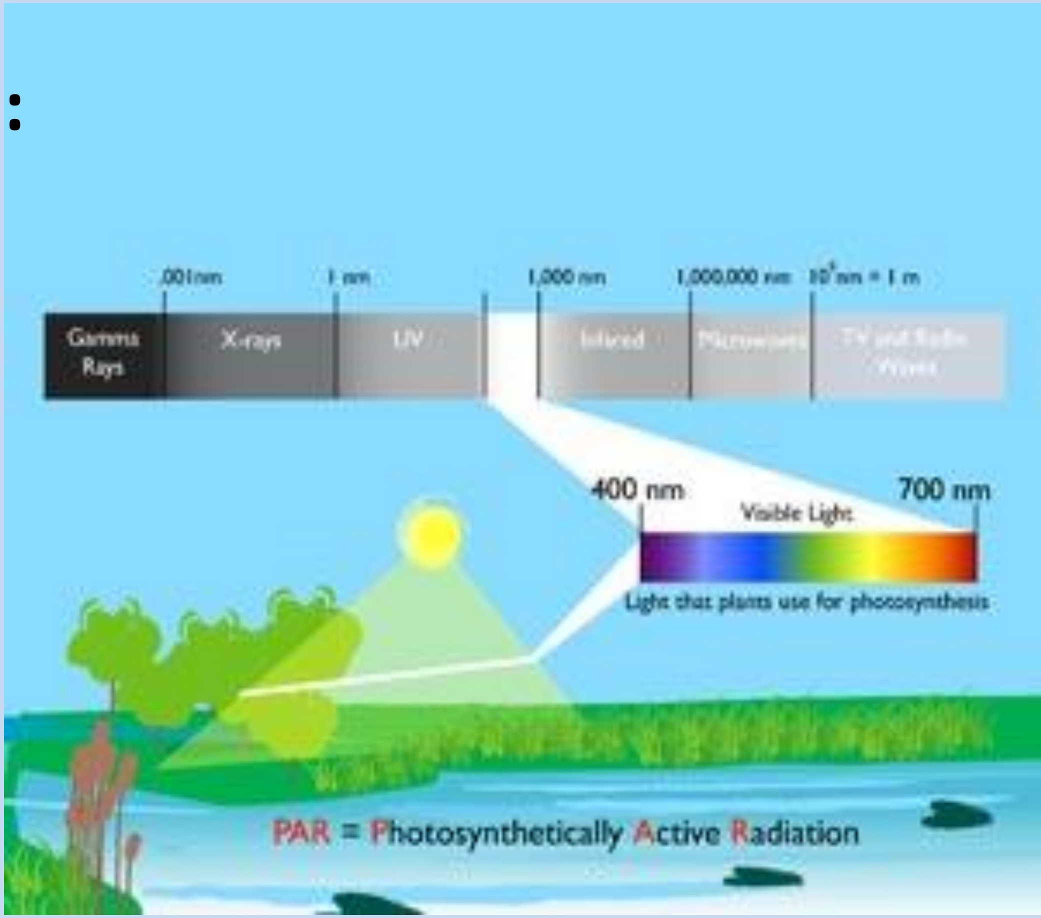
Carbohydrate (the assimilate which fills grain)



Solar Radiation?

Plants use a specific fraction of solar radiation:

Photosynthetically active light (PAR)



Why is the wheat canopy green?

Chlorophyll pigments absorb red and blue light most strongly.

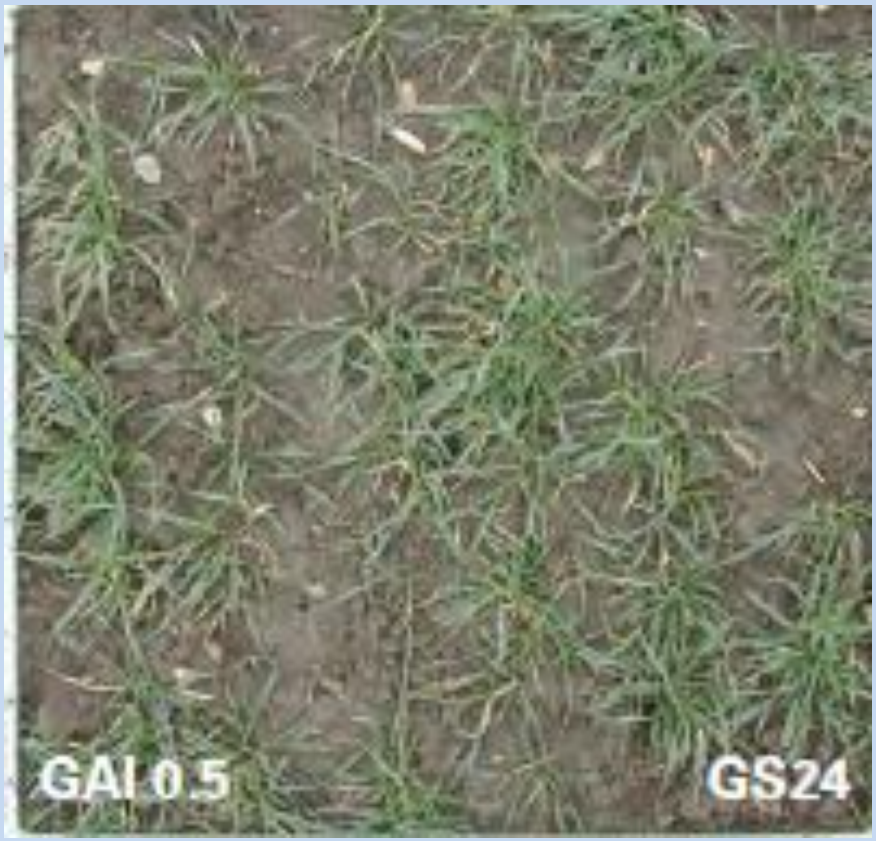
Green light is reflected.

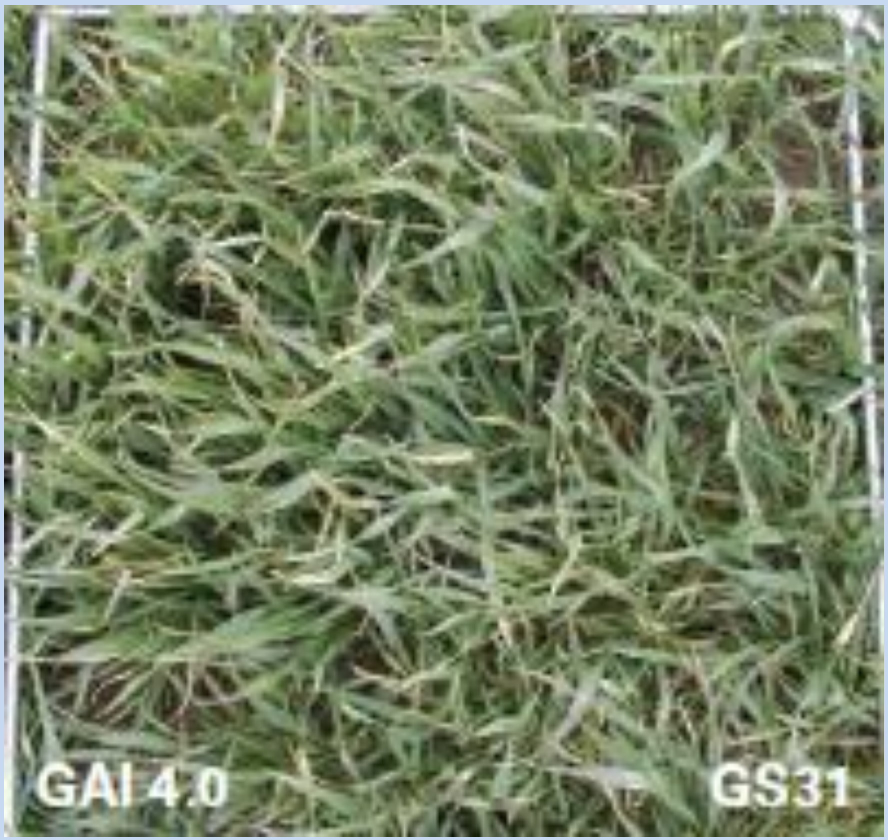
Solar radiation drives photosynthesis rate

Manage your crop utilize what is available

Capturing PAR for photosynthesis

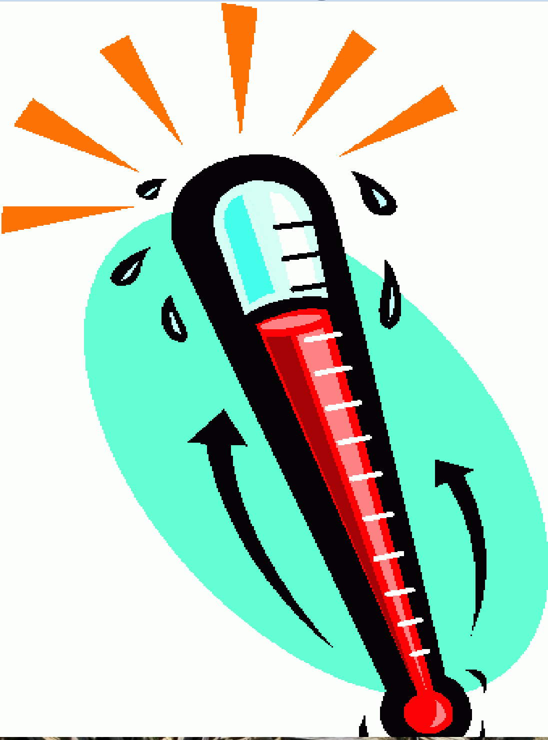
Green leaf area is key





Source: HCGA

Temperature drives development rate



Growing degree units (GDU)

Calculated as:

$$\frac{\text{(Daily Max Temp + Daily Min Temp)}}{2} - (0^0\text{C})$$

E.g. $\frac{10^0\text{C} + 4^0\text{C}}{2} - (0^0\text{C}) = 7 \text{ GDUs}$

Each tiller takes 62 GGUs = 9 days at above temp.

Lower average temperatures

=> longer the growth phases.

=> Including grain fill.

An unusual application of GDUs


Source: P.J. Forrestal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Building high yields through key development phases

- **Foundation period:**
  - sets shoot numbers (heads/m^2)

- **Construction period:**
  - sets final crop structure (heads/m^2 and kernels/head)

- **Production period:**
  - (kernel weight)

- **Roughly:**
  - winter, spring and summer for winter crops

1. The Foundation period

The upper number of heads/m^2 is set

- Viable seeds planted and emergence.
- tillers/plant.

What favors tiller production?

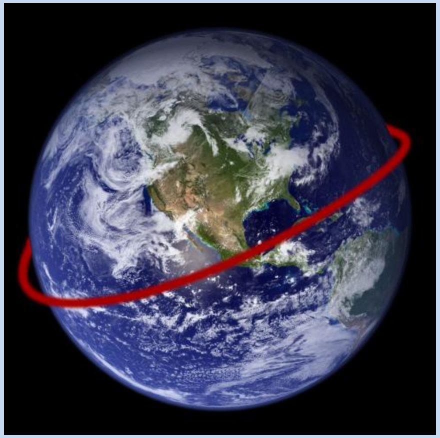
- Moist, warm weather.
- Early sowing.
- Good soil fertility, particularly N.

When?

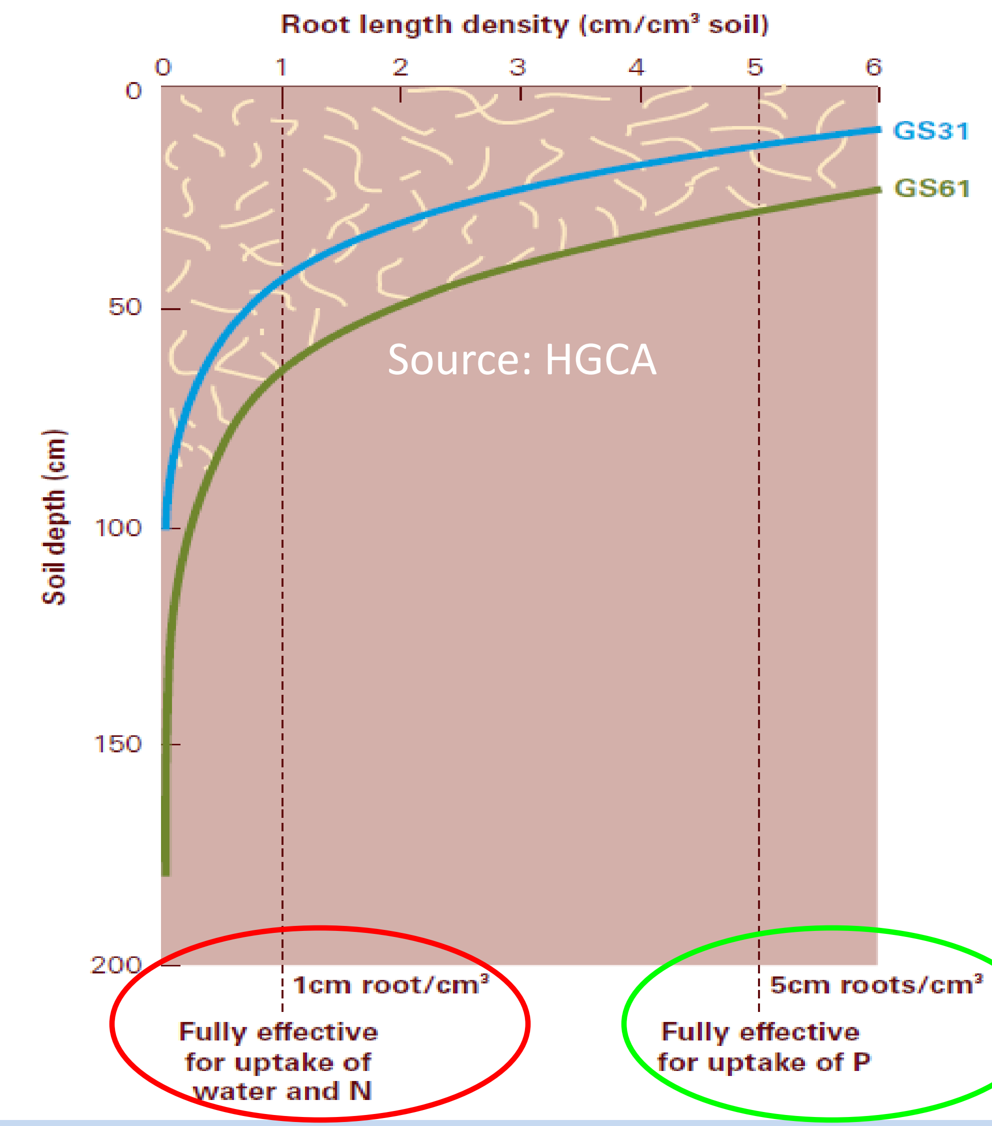
- Prior to the stem elongation.

Roots the foundation for nutrient and water uptake

- Some nutrients are more difficult to recover.
- P is less mobile.
- 150,000 km roots/ha by GS 31



> 3 time around earth



Response to light during the foundation period

- **(Evers *et al*. 2006) examined wheat grown at:**
  - 25 and 100% light.
  - 3 population densities.
- **Tillering stopped when:**

a) PAR interception exceeded **40-45%** of total available.

a) Ratio of red to far-red light drops below **0·35–0·40.**

- Early warning signal for future competition.
- Plant detects shading by its neighbours.

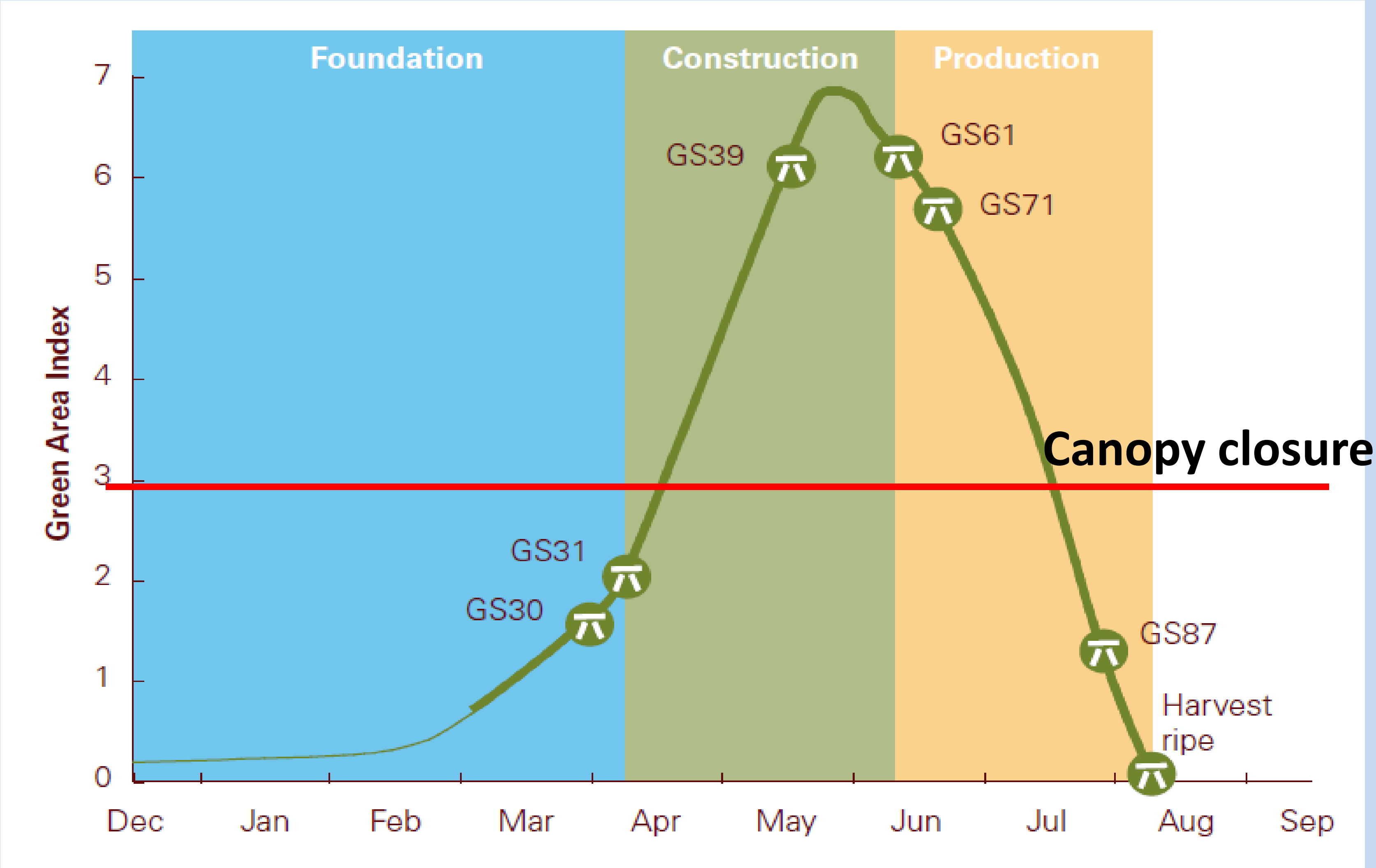

Source: P.J. Forrestal

Source: J.I. Burke

2. Construction period defining the "sink" and building reserves

- > half total growth.
- > an extra 160,000 km/ha
  of root growth.
- Rapid canopy expansion.
- More green leaf area for photosynthesis.
- Formation of the grain producing organs.

Green leaf area over time



Source:HGCA

Lessons from other farmers

- **Francis Childs (1939 -2008)**

3 time world record maize grain yield.

- **2002: 27.7 t/ha (11.2 t/ac)**

"The Foundation for producing BIG yield is **building a healthy soil environment**. It all starts with the root zone get ***healthy roots*** and ***healthy plants***, and *the* ***yield*** *will be high"*

Building Stem reserves

- Stem reserves and yield potential.
  - Bidinger *et al*. (**<u>1977</u>**) stem reserves: **<u>10%</u>** above ground D.M.
  - Shearman *et al*. (**<u>2005</u>**) stem reserves: **<u>20-27%</u>** of above ground D.M.
- **Influence of reserves on yield:**
  - Yield Component effect: no. kernels set/ear.
  - Assimilate remobilizes to help fill grain.
- Good crop husbandry and early establishment aids building reserves.

Kernels/ear

Influenced by:

Assimilate availability

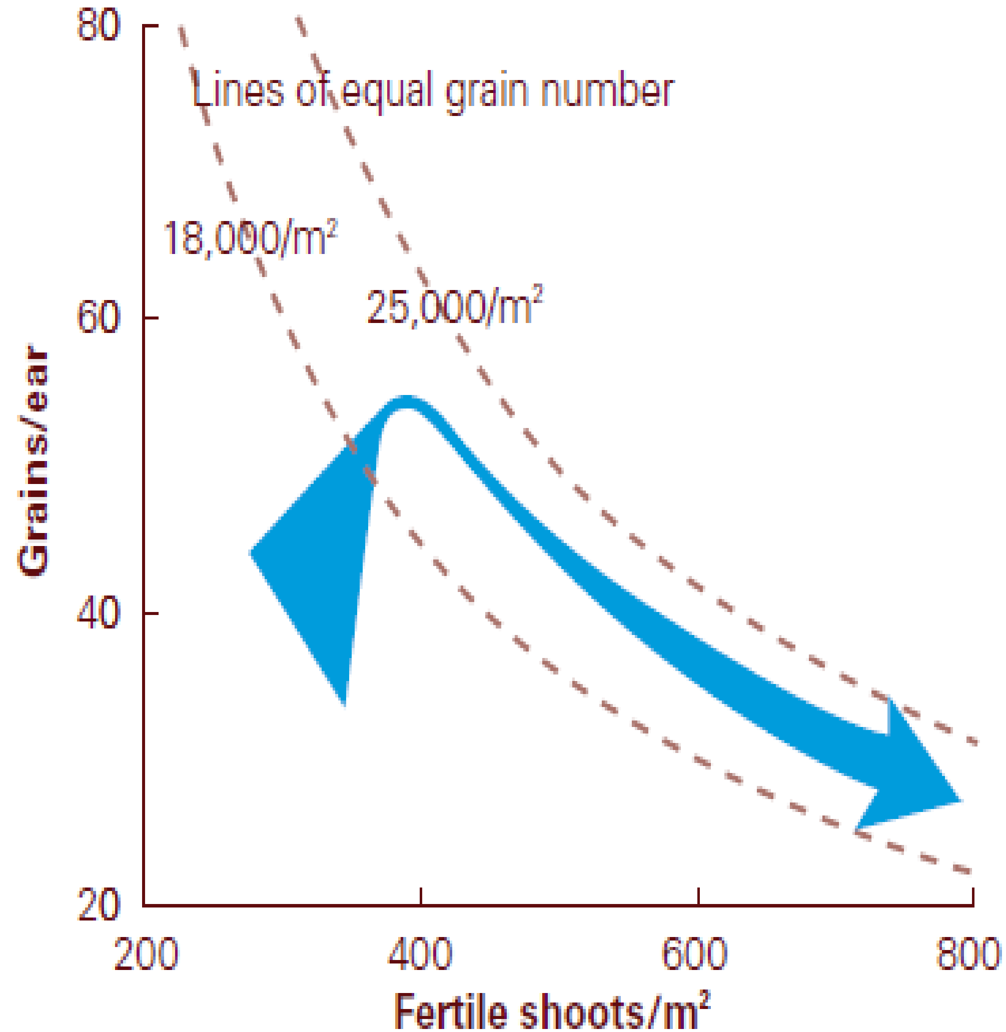
Shading

Variety differences

Weather conditions:

Cool and bright before flowering ++

Heavy rain, heat or drought at flowering --



Source: HGCA seed rate trials

3. Production "filling the sink" Kernel weight

Source of grain filling assimilate?

1. Ear and leaf photosynthesis after flowering (75% Jamieson et al. 1998).
2. Stem reserves.

High yields require <u>long sustained grain fill</u>.

U.K. winter wheat benchmark:

- 49 days from GS 61-87(Sylvester-Bradley *et al*. 1997)

Management factors affecting length of grain fill

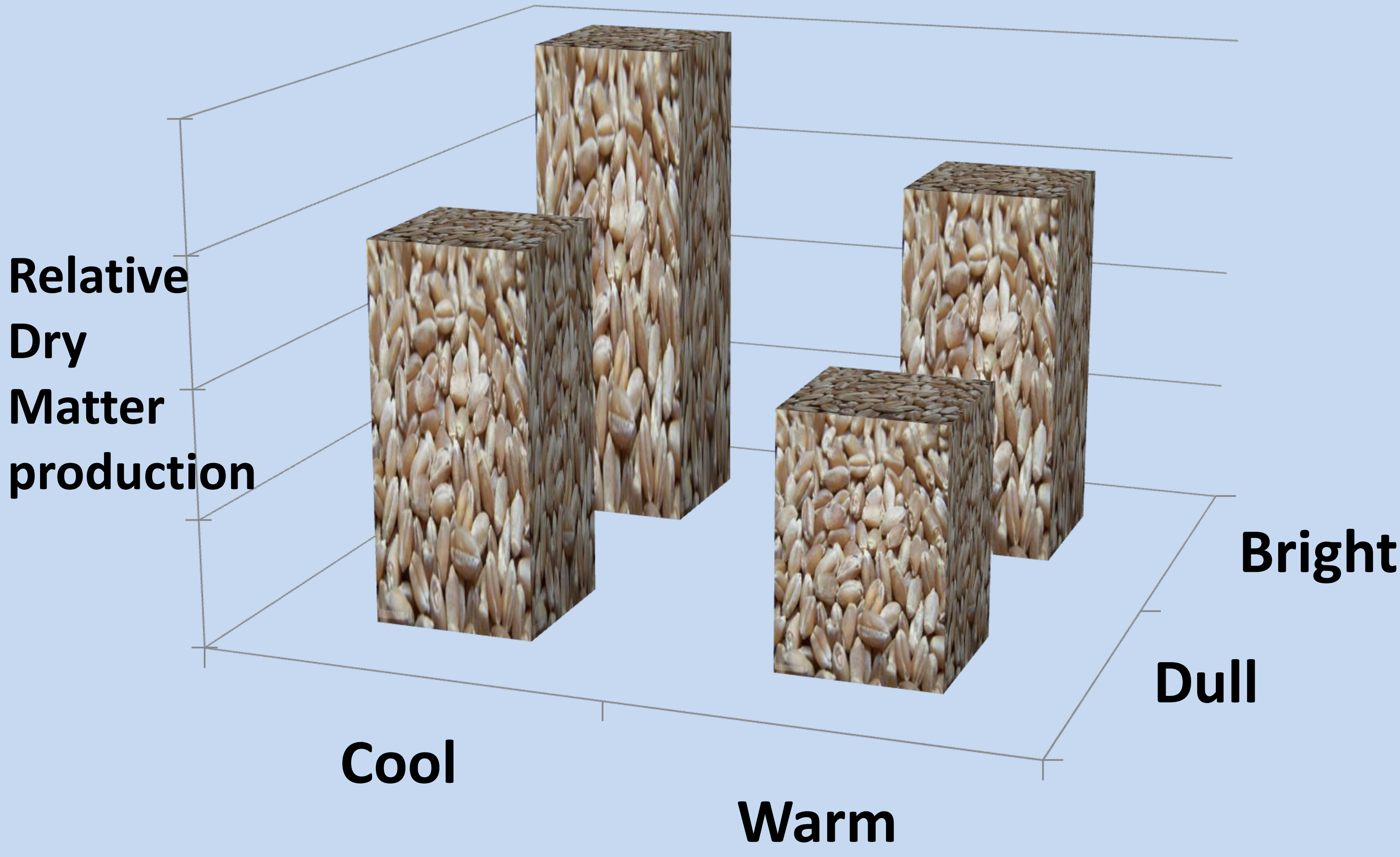
- N fertiliser (Hocking and Stapper 2001).
- Fungicides (Gooding et al. 2000).
- Pesticides and irrigation (Panozzo and Eagles 1999).
- Sowing date and cultivar selection (Hocking and Stapper 2001).

2011: typically excellent grain yields
Why?

What have we learned?

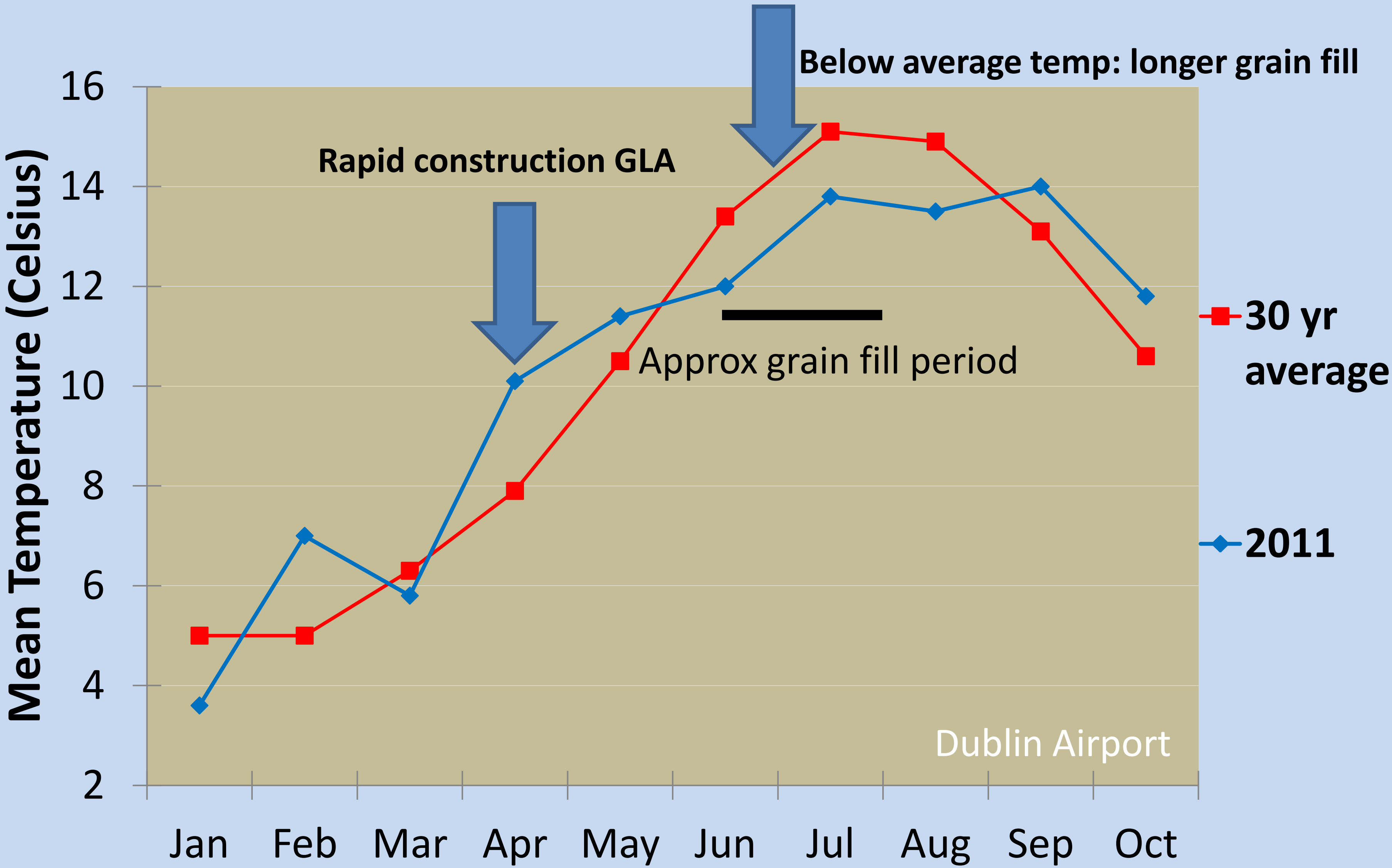
- Harvest the sun with maximum efficiency.
- This is the aim of all our crop husbandry.
- Need:
  - Prompt **canopy closure** to capture the sun.
  - Optimize the yield components for large "**sink**".
  - Good stem reserves
  - Long **grain fill period**.

Temperature, sunlight and dry matter production



Temperature trend in 2011

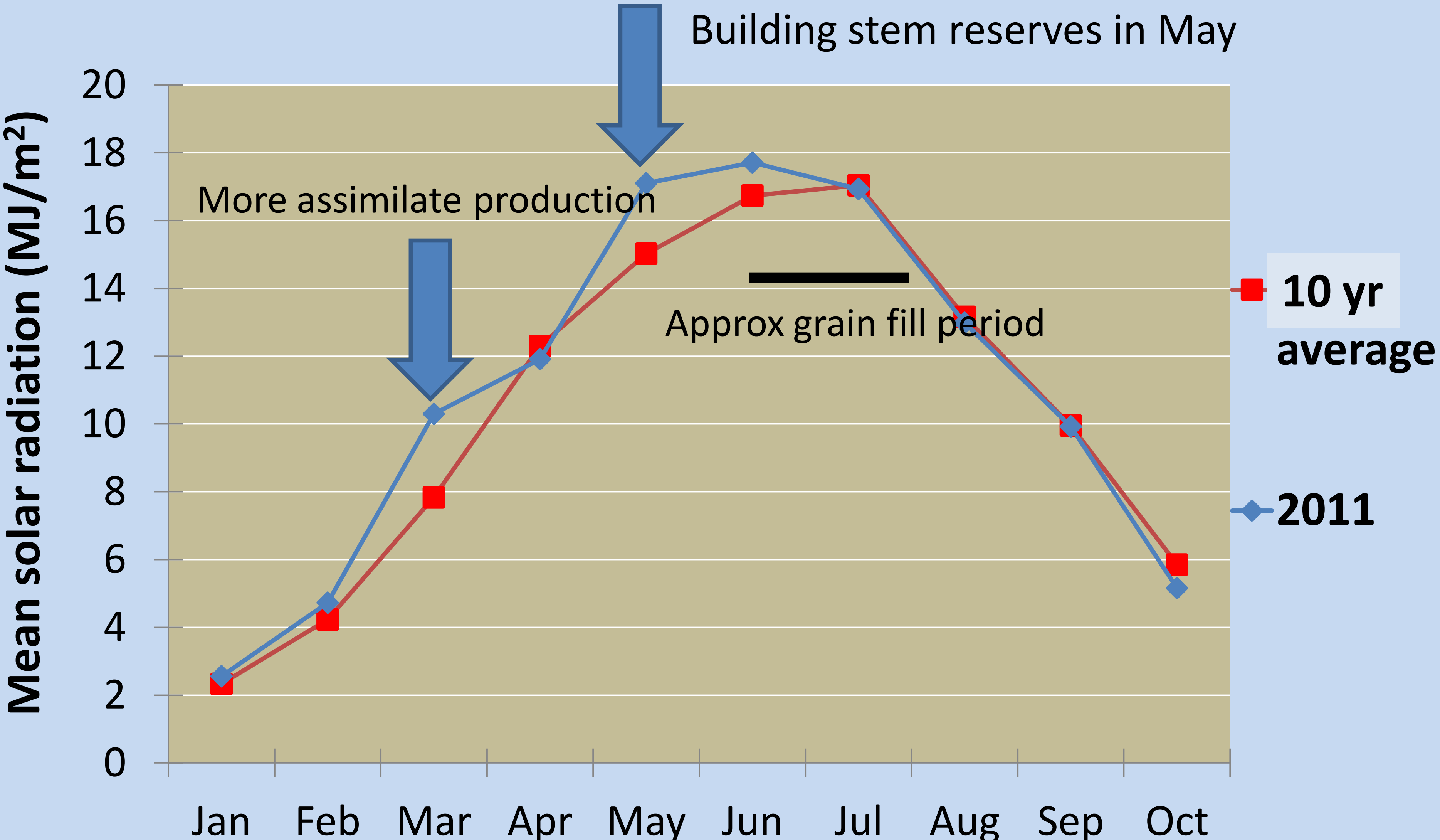
Facilitated rapid canopy expansion & long grain fill



Data courtesy: Met Eireann

Solar radiation trend in 2011?

Above average or average throughout the growing season



Data courtesy: Met Eireann

Lessons from 2011

- Weather favored good yields. **BUT remember**
- “A rising tide lifts all (most) boats.”
- **YOU** are the key to sustained high yields.
  - Timeliness of operations.
  - Husbandry decisions.
- Manage your crop to **“harvest the sun”**:
  - Start early: Optimise each yield component.
  - Prompt canopy coverage in spring.
  - Build stem reserves.
  - Facilitate canopy retention to maximize photosynthesis during grain fill.

Questions

Comments

Share your observations

Source: P.J. Forrestal