



The physiology of grain fill and how the environment impacts kernel characteristics

NDSU

EXTENSION SERVICE

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Acknowledgement

- Many slides used from Marina Dobrydina, student working with Frank Manthey, Department of Plant Sciences

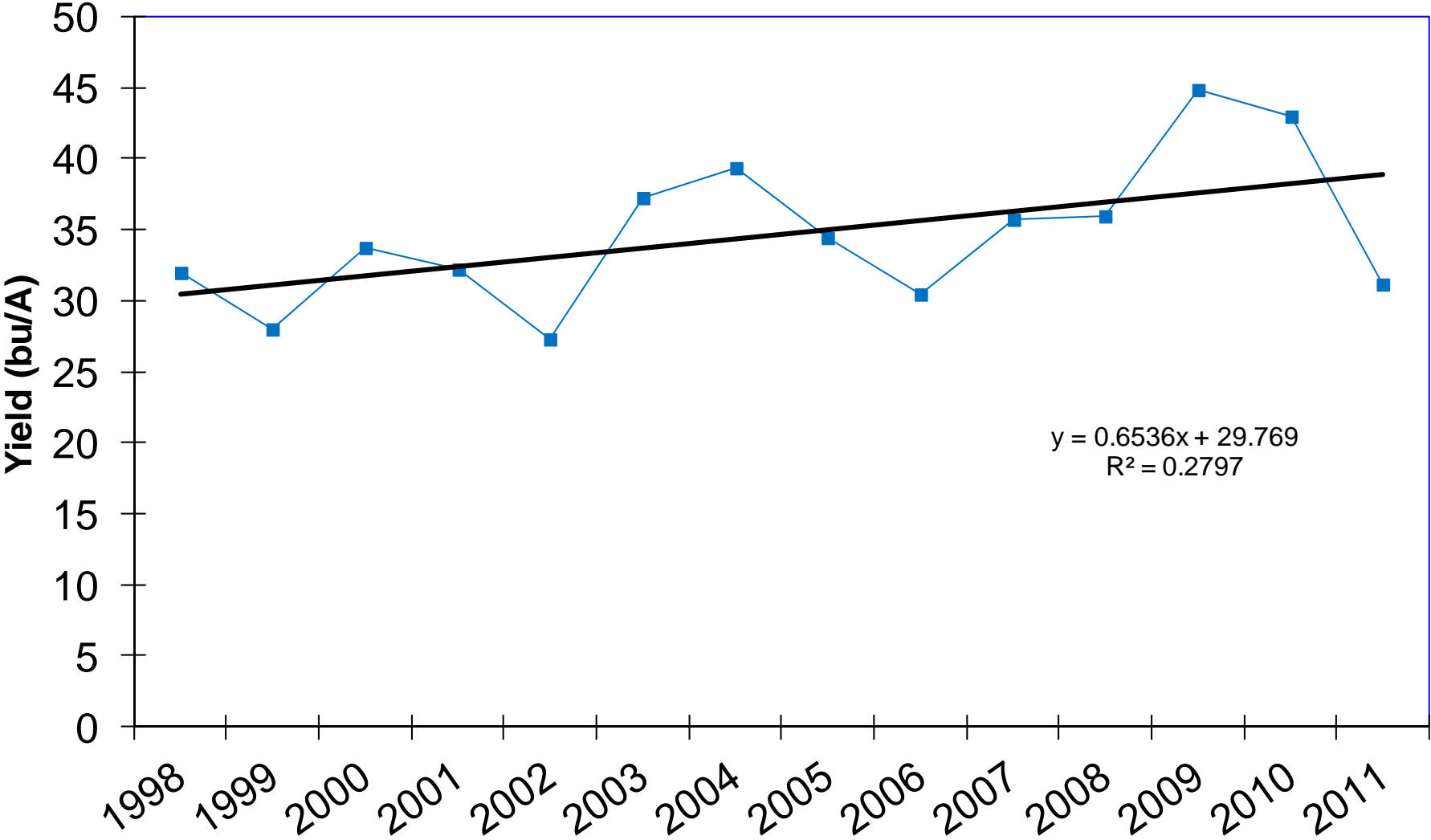
2011 was a tough year for wheat

- Late planting
- Excess water
- Difficulties in managing N
- Hot weather during key developmental stages
- Plenty of disease pressure
- Yields were lower than expected
 - 50 bu straw and 25 bu harvest
 - Protein percent was higher than the bu/a
- Protein was high

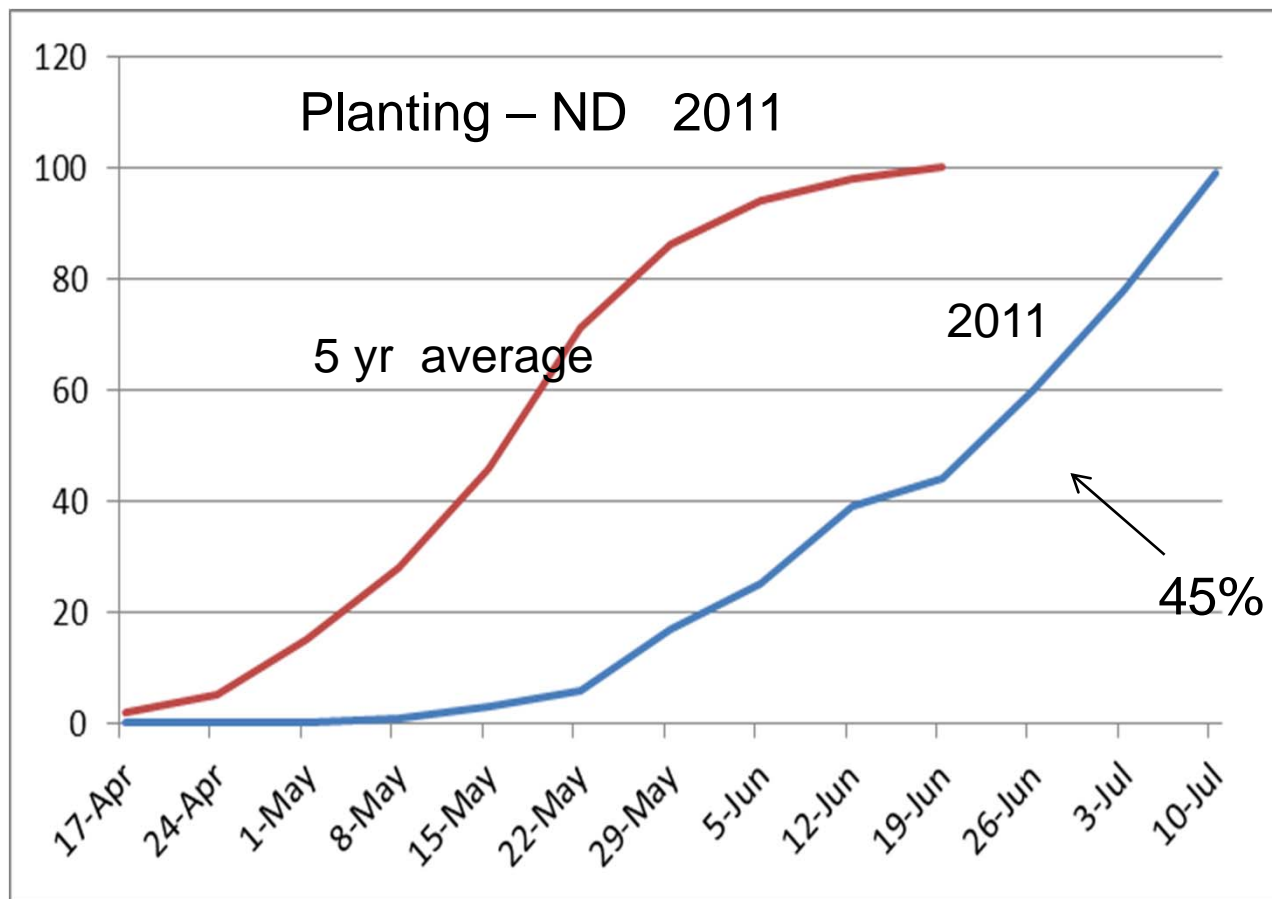


Yield trends in ND 1998-2011

Yield Linear (Yield)



Significant delay in planting



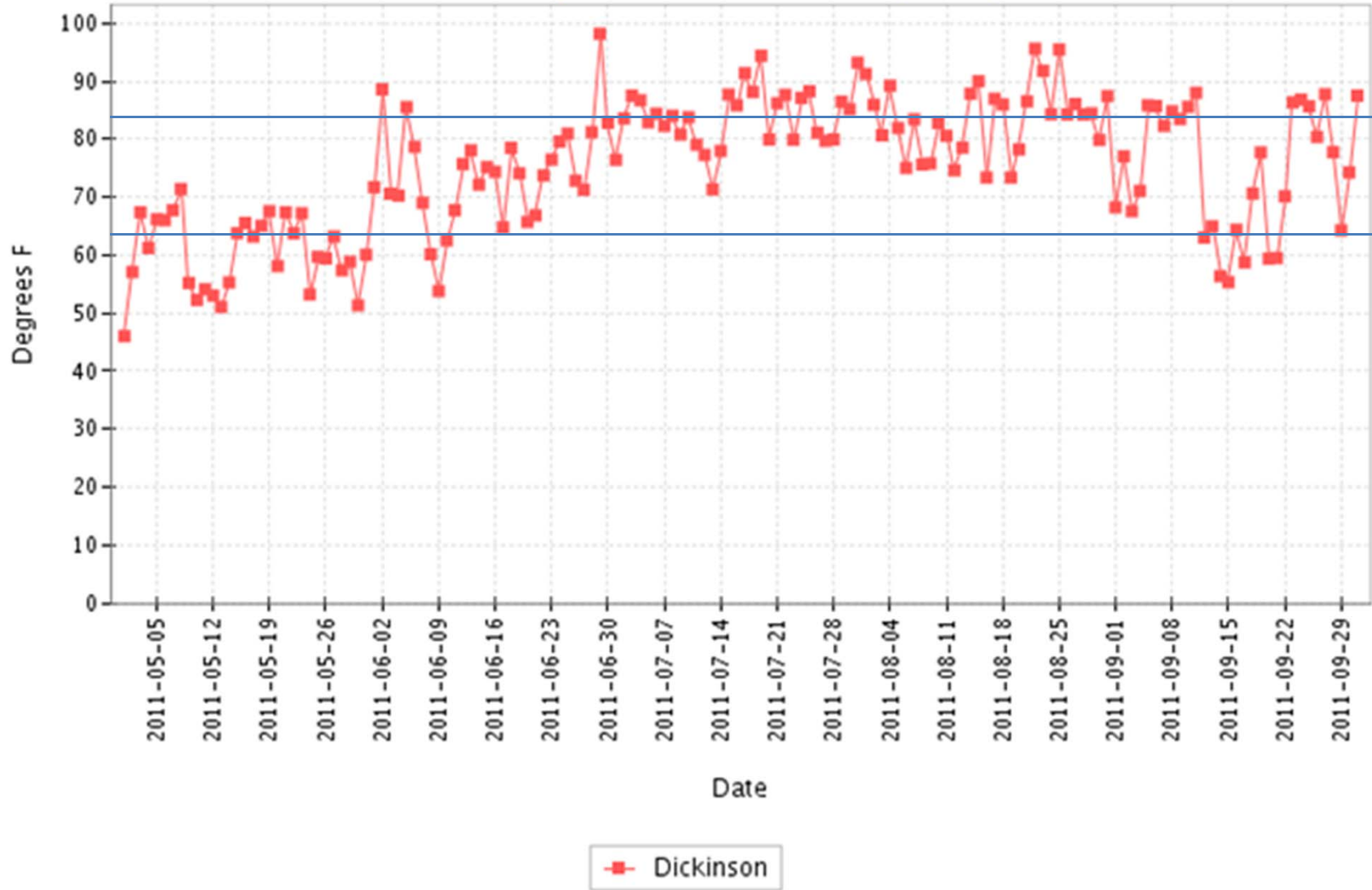
Strong relationship between delayed planting and its impact on yield components

45%

Daily Maximum Air Temperature

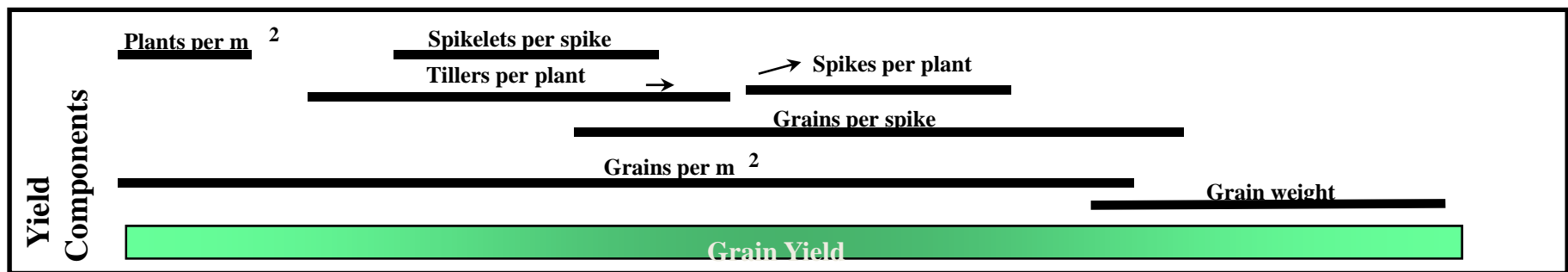
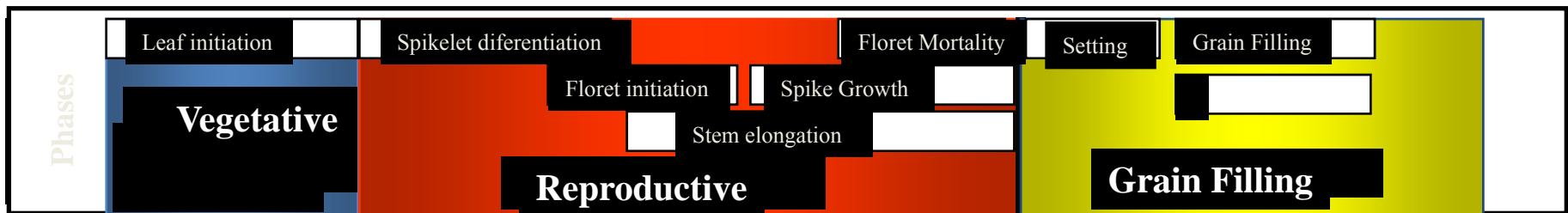
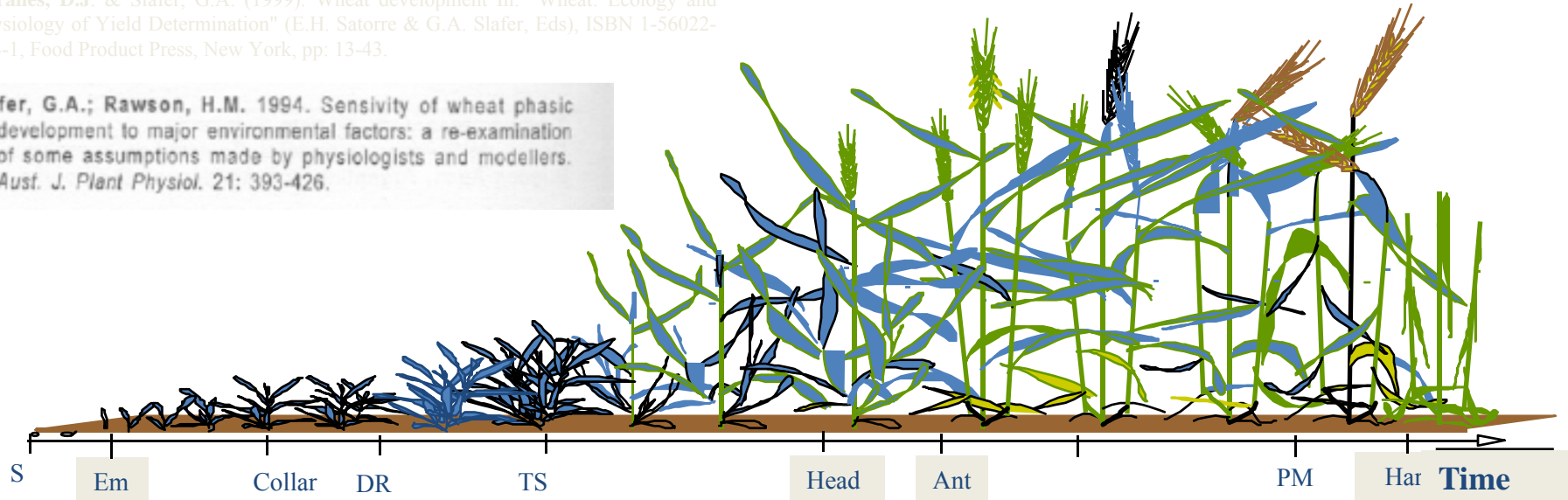
(2011-05-01 - 2011-10-01)

North Dakota Agricultural Weather Network (NDAWN)



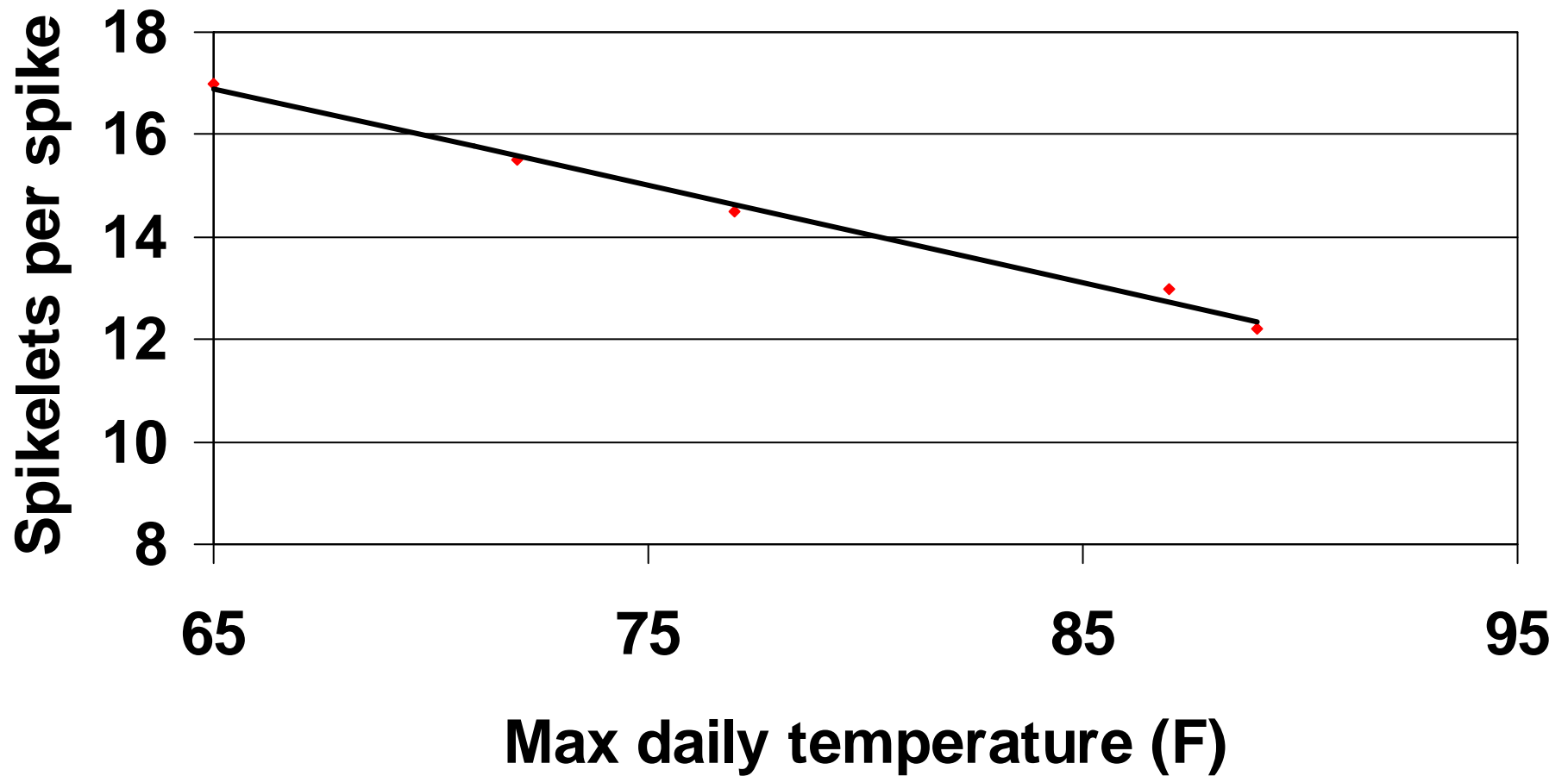
Miralles, D.J. & Slafer, G.A. (1999). Wheat development In: "Wheat: Ecology and Physiology of Yield Determination" (E.H. Satorre & G.A. Slafer, Eds), ISBN 1-56022-874-1, Food Product Press, New York, pp: 13-43.

Slafer, G.A.; Rawson, H.M. 1994. Sensivity of wheat phasic development to major environmental factors: a re-examination of some assumptions made by physiologists and modellers. *Aust. J. Plant Physiol.* 21: 393-426.



Slafer & Rawson (1994)
Miralles & Slafer (1999)

Effect of maximum daily temperature during the 4-5.5 leaf stage on spikelets per spike.



Key points during early REPRODUCTIVE STA

Flowering:

- Pollination/fertilization

Stress: reduces number of kernels/spike (yield)

Embryo/endosperm development:

- Rapid cell division.

Stress: reduces cell number in the endosperm (kernel size).

Key points during the VEGETATIVE STAGE

Stem elongation:

- Spike develops as it moves up the stem.
- N from the soil converted to amino acids/ storage proteins in stem and leaves.

Stress: affects spike development (yield).

affects amount of N stored in the plant.

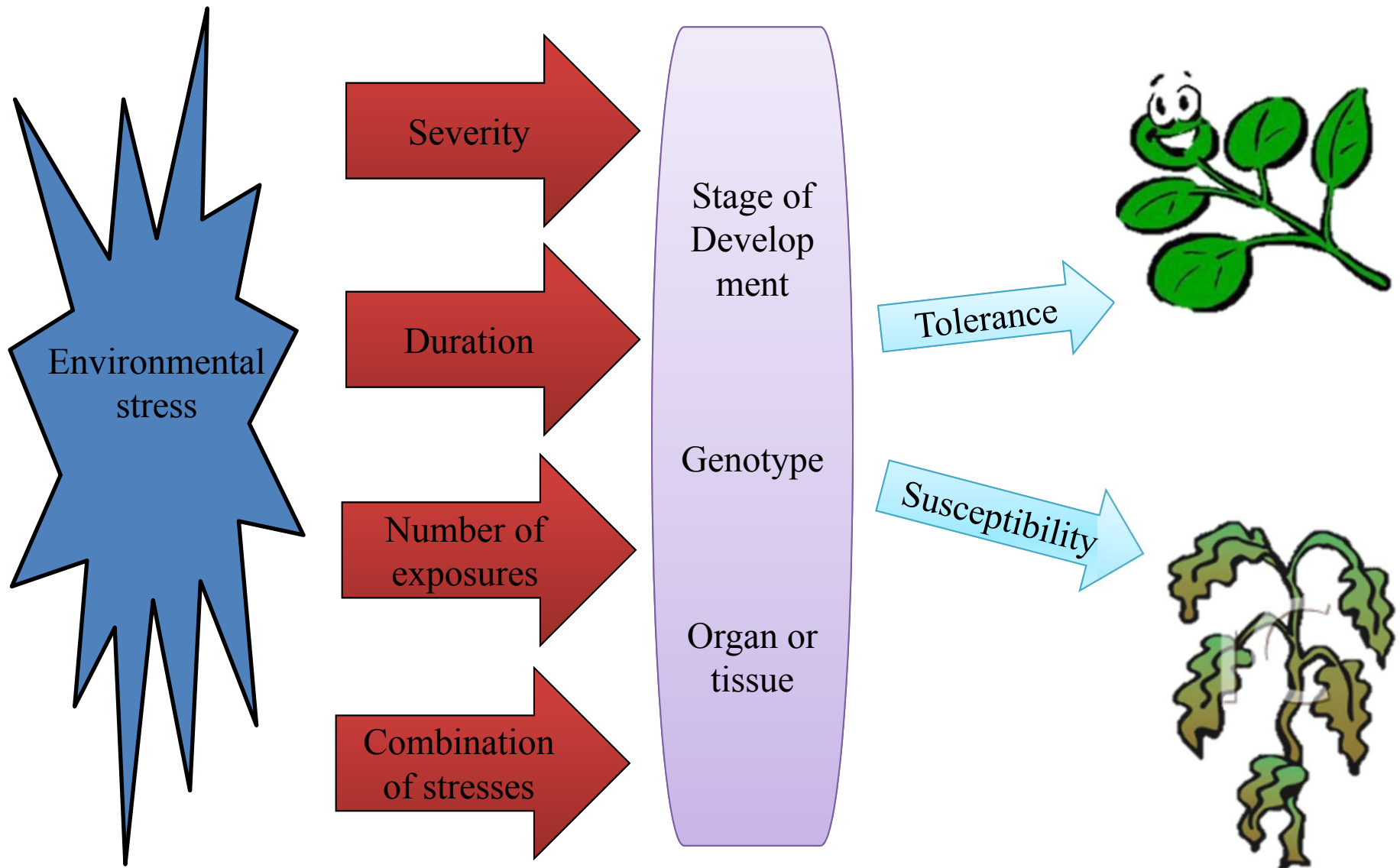
reduces potential protein content of kernel.

80% of N in grain protein is stored in plant during vegetative sta

How did the environment impact kernel development?

- Stresses reduce the rate of photosynthesis
 - Excessive heat
 - Drought
 - Warm night temperatures
 - Nutrient deficiencies
- Lower rates of photosynthesis means less starch to fill the kernel and less yield at harvest
- Other processes are impacted by temperature

Plants' response to environmental stress



Grain development

Boot Stage



T.D. Miller

Prior to anthesis, environment mainly affects formation and therefore number of spikelets.

At anthesis high temperature can cause floral abortion, thereby impacting grain number.

After anthesis, environmental conditions primarily affect kernel size and composition (DuPont and Altenbach, 2003)



Anthesis

T.D. Miller



7 DAA*



11-14 DAA



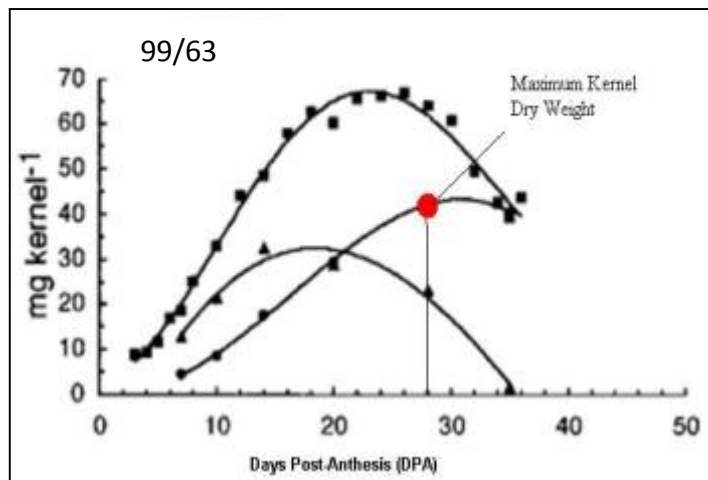
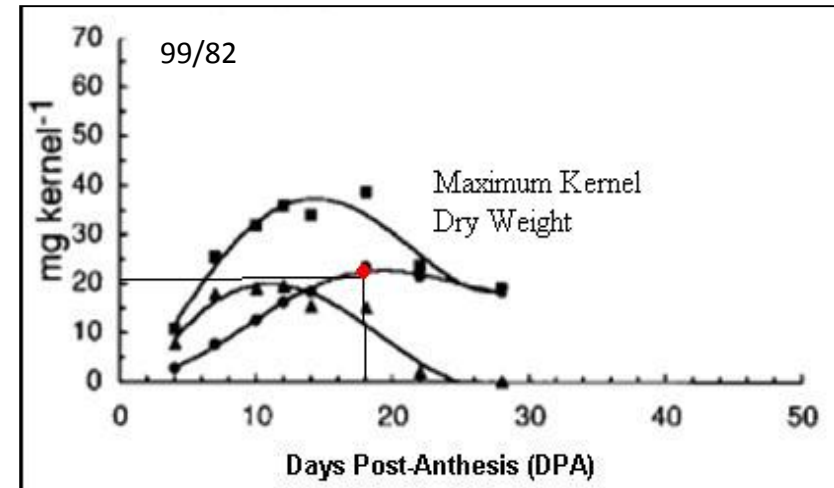
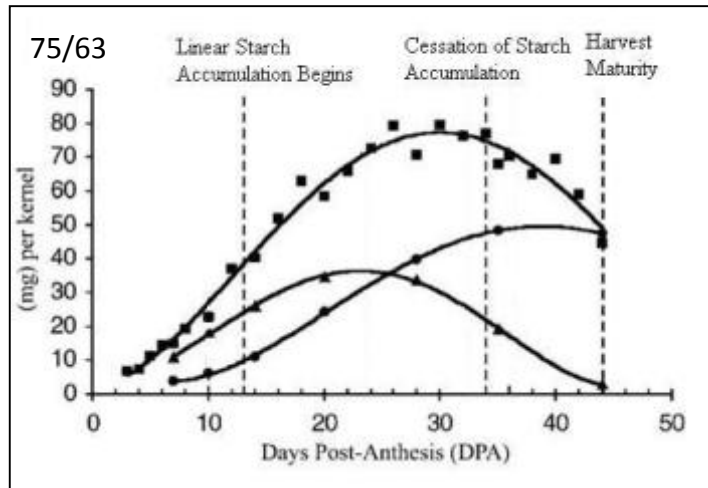
21-25 DAA



30-35 DAA

*DAA – Days After Anthesis

Grain development under high temperatures



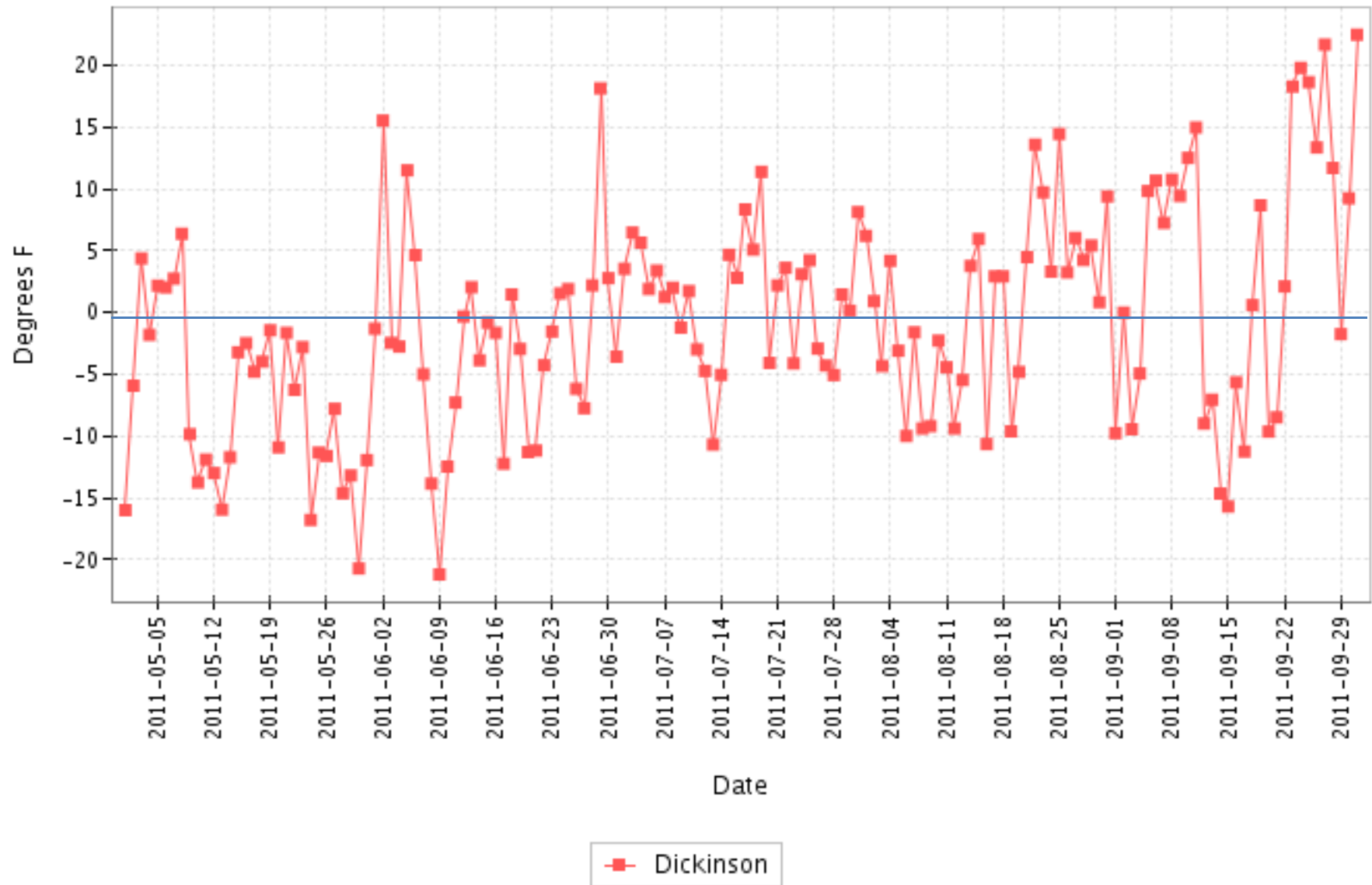
High temperatures shortens the time of grain development, resulting in a lower kernel weight.

Fresh weight (■), dry weight (●), and water content (▲) of developing kernels

Departure from Normal Daily Maximum Air Temperature

(2011-05-01 - 2011-10-01)

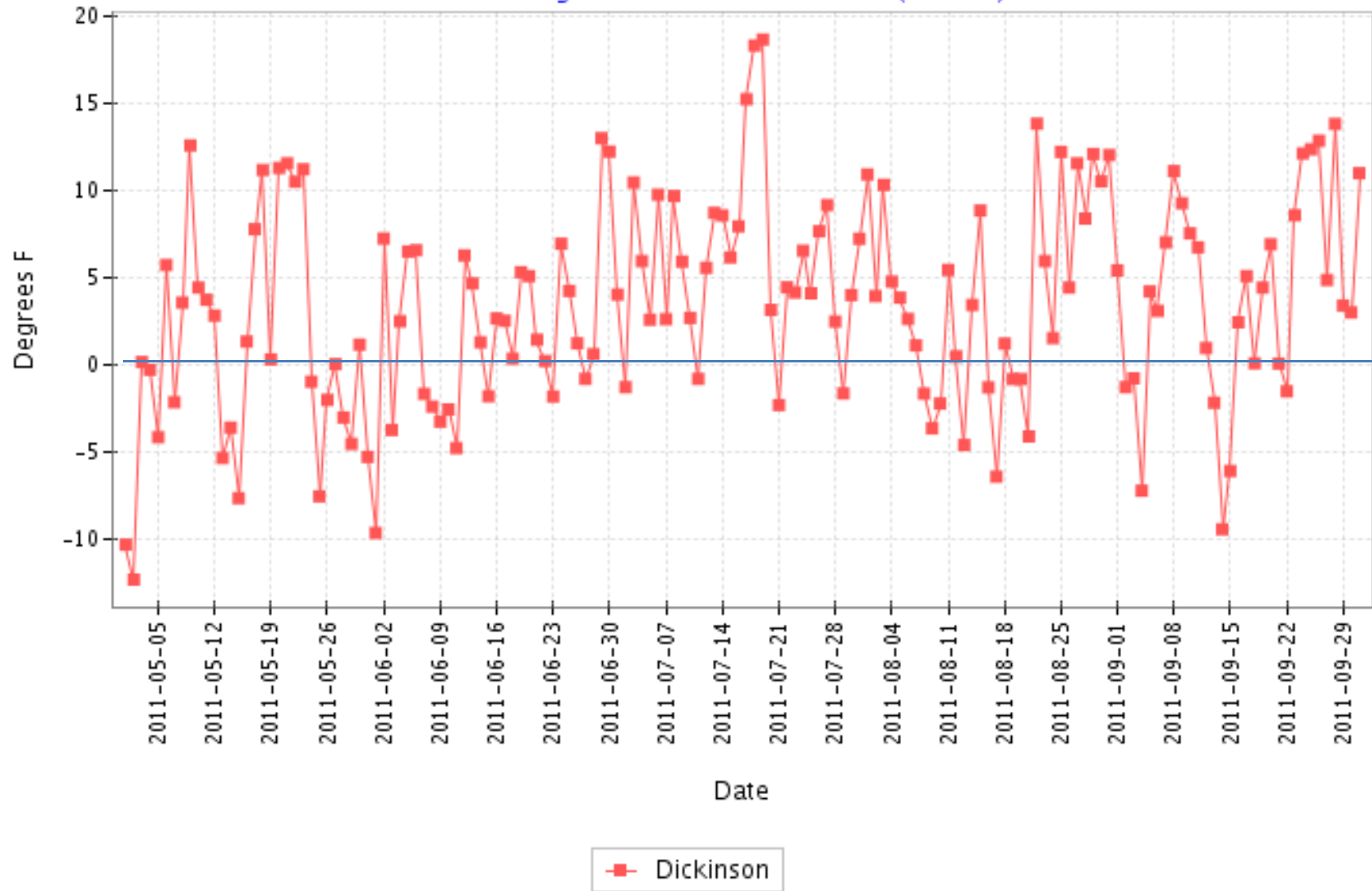
North Dakota Agricultural Weather Network (NDAWN)



Departure from Normal Daily Minimum Air Temperature

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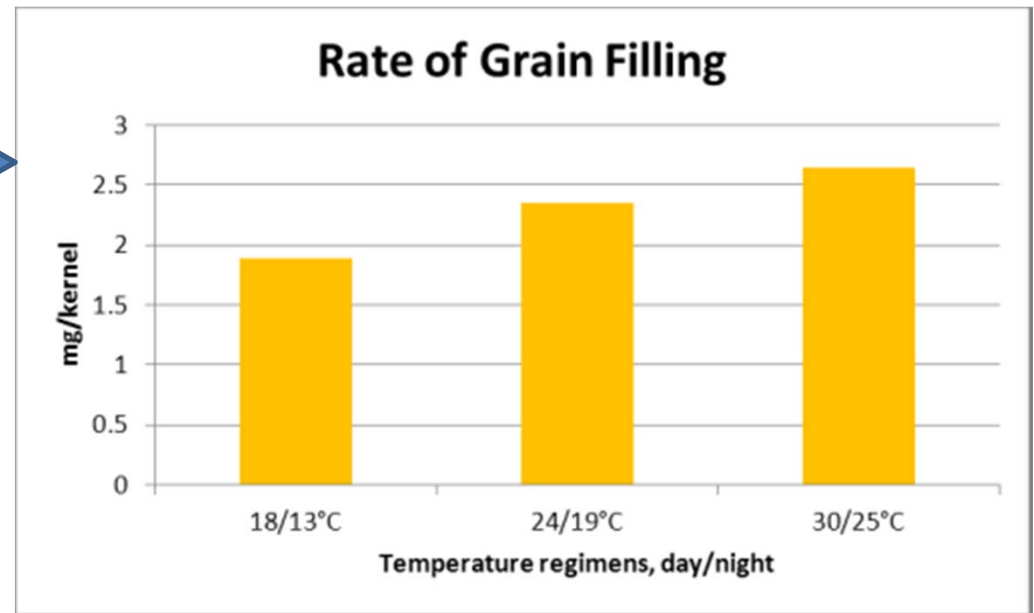


Rate of Grain Filling as Affected by High Temperature

	Rate (mg/day)	Duration (day)	Kernel weight (mg)
18/13°C	1.89	35.6	67.3
24/19°C	2.35	22.6	52.8
30/25°C	2.65	15.9	42.2

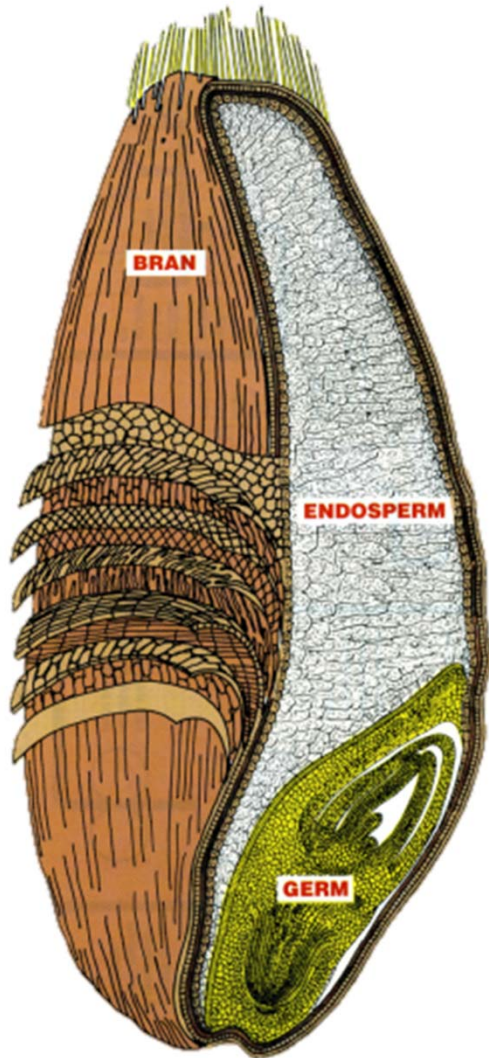
There is an increase in the rate of grain filling at the temperature **up to 30 C (86 F).**

Increase in the rate of grain filling does not compensate for the shortened duration.



Wardlae and Moncur (1995)

Composition of Wheat Kernel

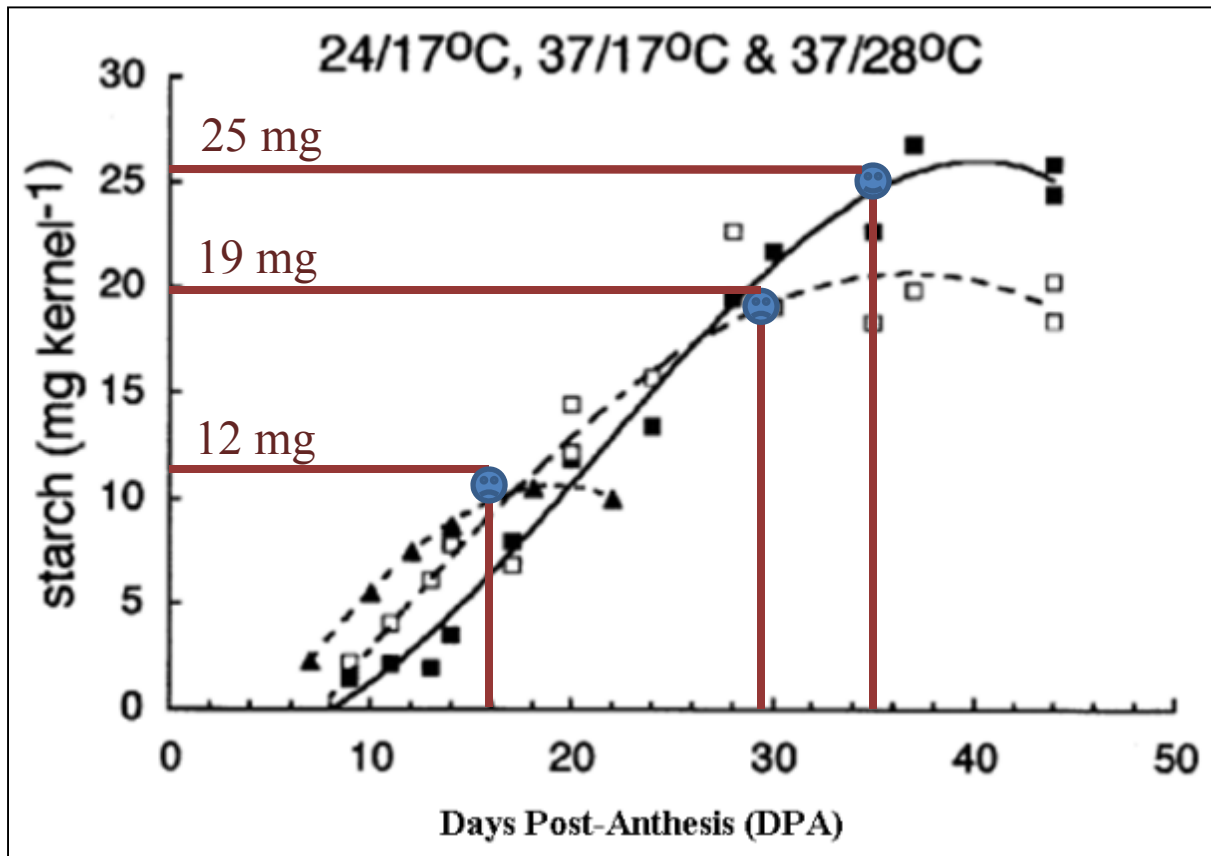


Endosperm –about 83% of the kernel

Endosperm is 65-80% **starch** and around 8-20% **protein**

Grain filling responses to high temperatures are largely attributed to effects on the deposition of starch.

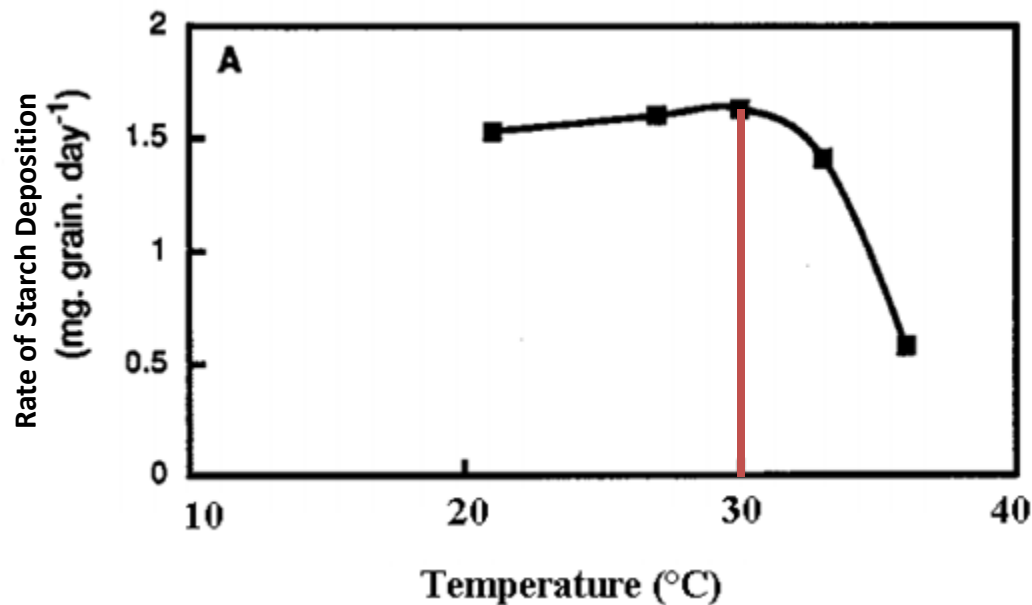
Starch Deposition Under High Temperature



High temperature reduced starch content by shortening the duration of starch accumulation.

The effect was more pronounced when high nighttime temperatures increased.

Effect of High Temperatures on the Rate of Starch Deposition



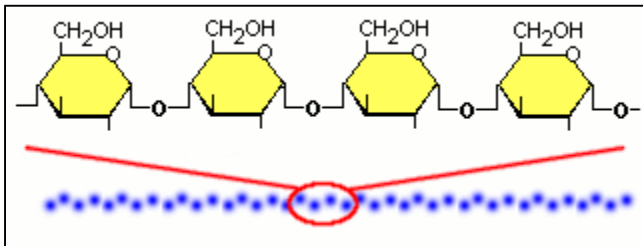
Rate of starch deposition increases with the temperature **up to 86°F** and decreases above this temperature.

High temperature influences activity of enzymes in the pathway of starch synthesis.

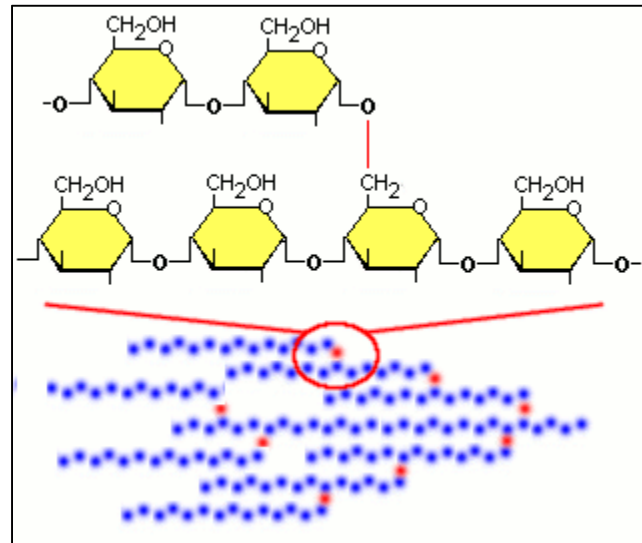
Effect of Temperature on Starch Biosynthesis

Starch contains two classes of molecules:

AMYLOSE (20-35%)



AMYLOPECTIN (65-80%).



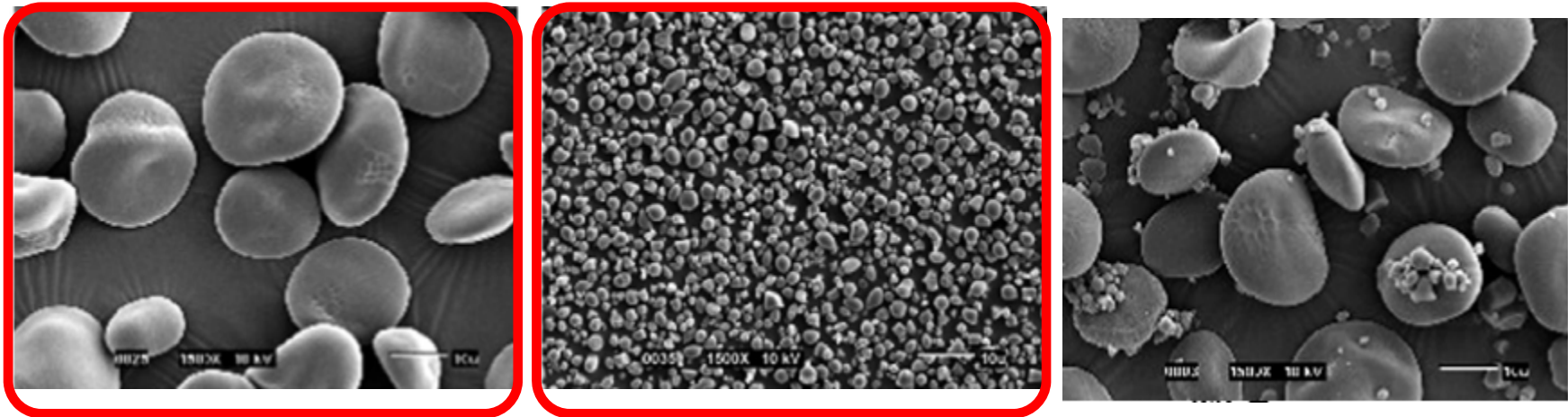
Starch Granule Polymorph Distribution

Amylose and Amylopectin form Starch Granules:

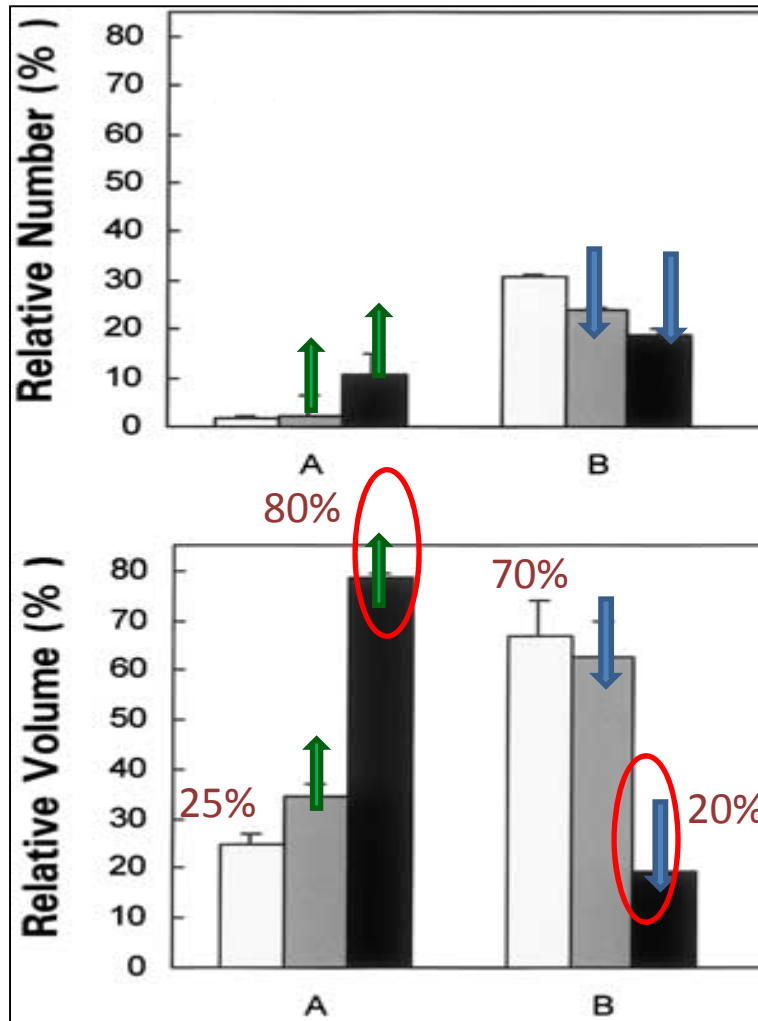
“A” – type granules: Large

“B” – type granules: Small

A-type granules contain 5-10% more amylose than B-type granules (Peng, et al., 2001)



Starch composition as affected by high temperatures



Number of A-granules increases whereas number of B-granules decreases with high temperature.

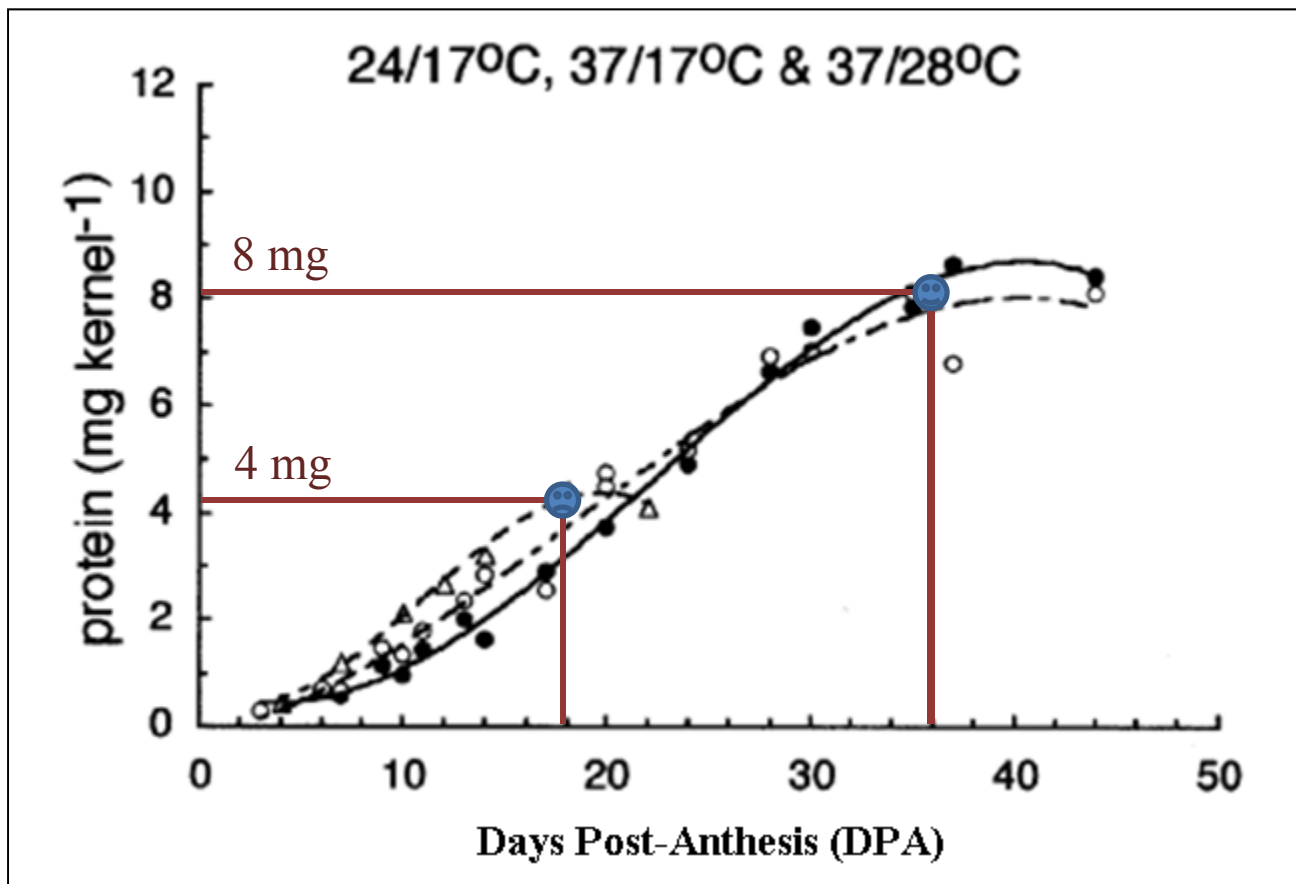
**Therefore
Amylose-to-Amylopectin ratio increases**

Increased ratio reduces dough elasticity (Hung et al 2005).

(□)24/17°C, (■)37/17°C, (■) 37/28°C

Hurkman et al. (2003)

Protein Deposition Under High Temperature



Deposition of protein appeared relatively unaffected by high daytime temperature.

Protein Composition

Low Molecular Weight

Extremely sticky

Little resistance to extension

VISCOUS PROPERTIES



High Molecular Weight

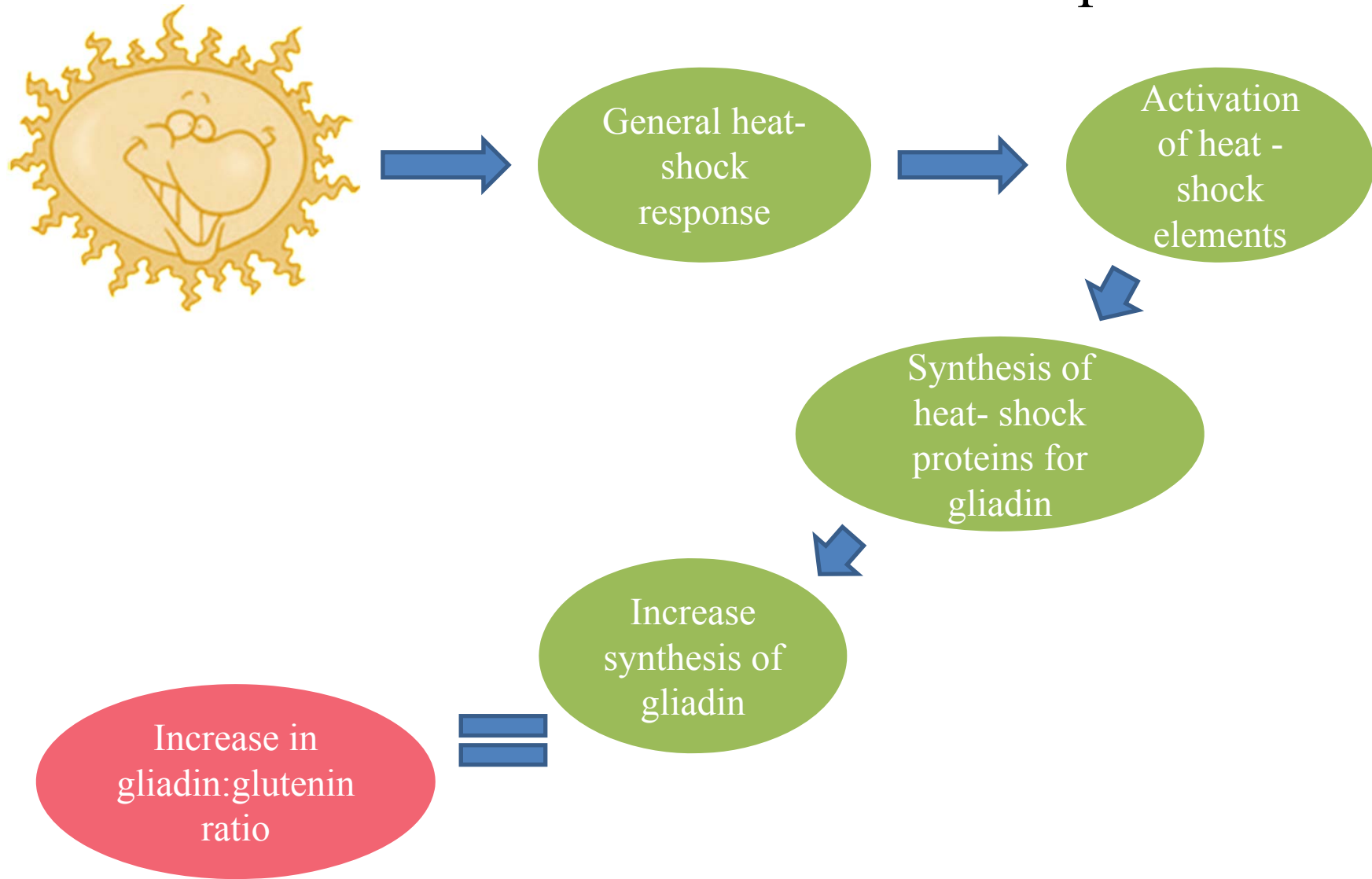
Elastic properties

Resistant to extension

ELASTIC PROPERTIES

Gluten gives elasticity to dough, helping it to rise and to keep its shape, and often giving the final product a chewy texture.

Effect of Heat Stress on Protein Composition



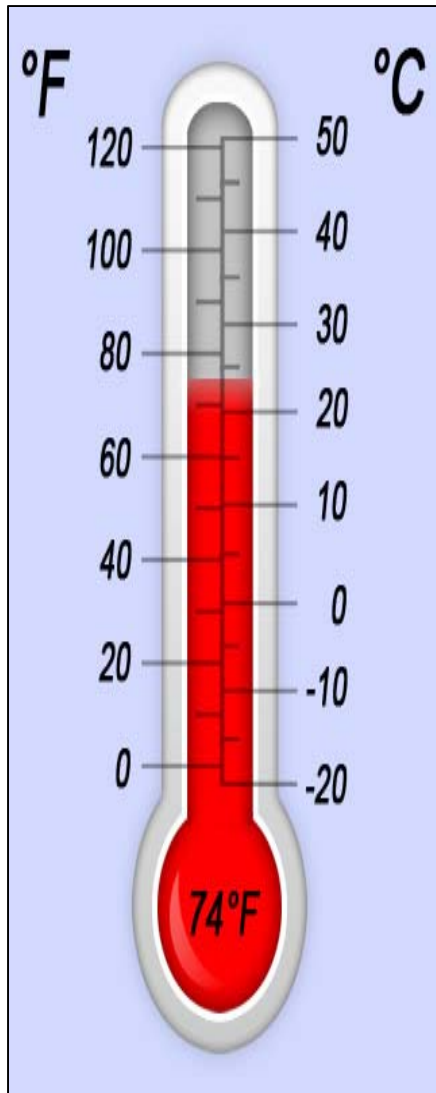
Blumental et al. (1993)

Effect of the Heat Stress on Quality of End-use Products

- Grain size - **Reduced Extraction rate**
- Gliadin:Glutenin Ratio – **Low Bread Loaf Volume and soft pasta/noodles products**
- Amylose:Amylopectin Ratio - **Reduced Dough Elasticity (Hung et al 2005).**



Take Home Message

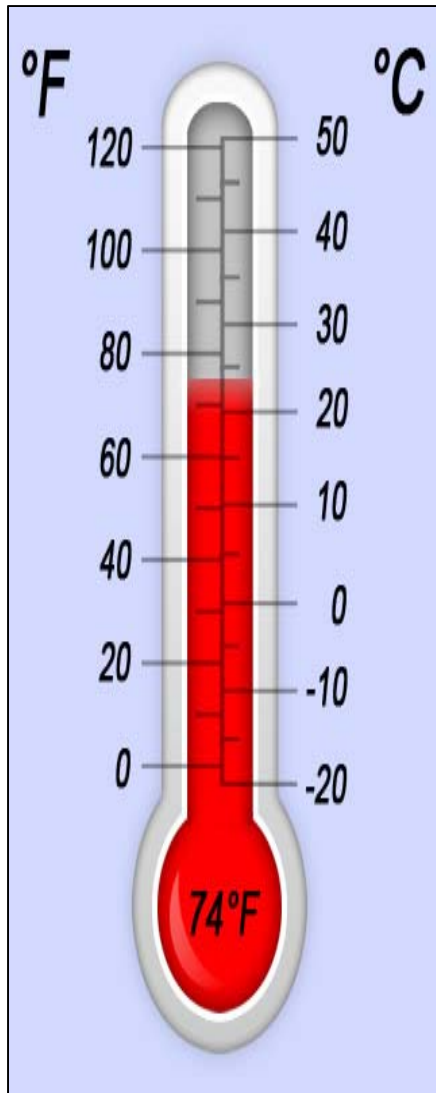


For later planted crop, warmer than optimum temperature reduced tillering and spike size.

For early planted crop, spike numbers were nearly normal, but excessive heat impacted number of kernels per spike and size of the kernel.

Higher than normal night temperatures may have been especially detrimental to yield development.

Take Home Message



The effect of high temperature on grain size and weight is mainly due to a reduction in the duration of grain filling, rather than rate of grain filling.

Warmer than optimum temperatures increased grain protein percentage through a reduction in starch deposition.

High temperature may have affected the functional protein composition by increasing gliadin to glutenin ratio, therefore reducing gluten strength.