Ecofisiología de cereales de invierno

Curso Internacional de la Red METRICE
EEMAC - Paysandú, 5- 7 diciembre 2012

Determinación del Rendimiento I

Componentes
Dinámica en el tiempo
Etapas críticas: rendimiento limitado por fuente

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Yield is a central objective of most breeding and management decisions

It is extremely complex (final outcome of crop growth and development processes, strongly regulated by genetic factors, environmental conditions and genetic x environment interactions throughout a growing season)

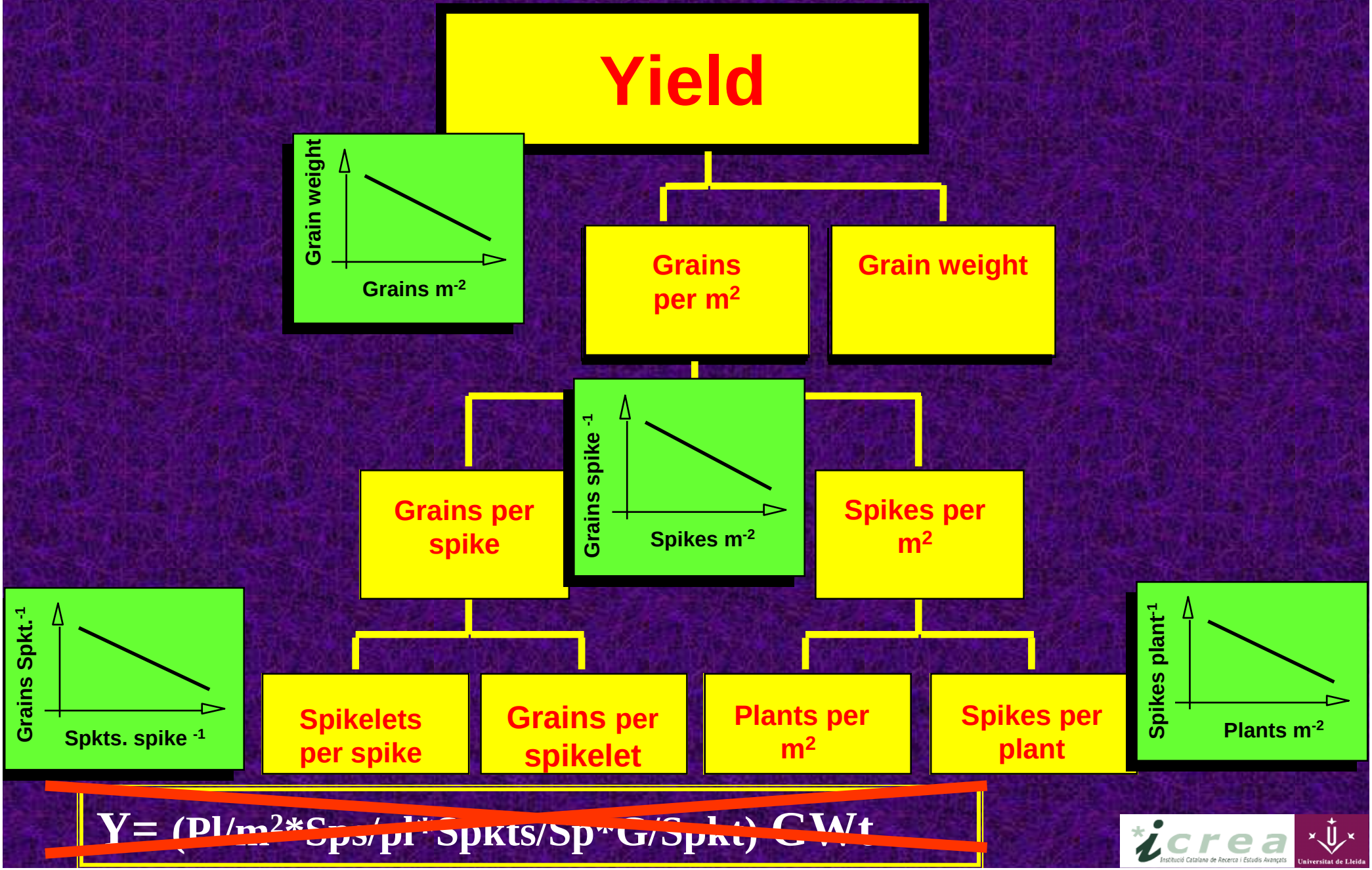
The more we know a complex trait the less uncertain it results the outcome of any intervention to manipulate it

The simplest approach to understand something complex is to identify some of its relatively simpler components

As these components are simpler manipulating them with certitude would be easier

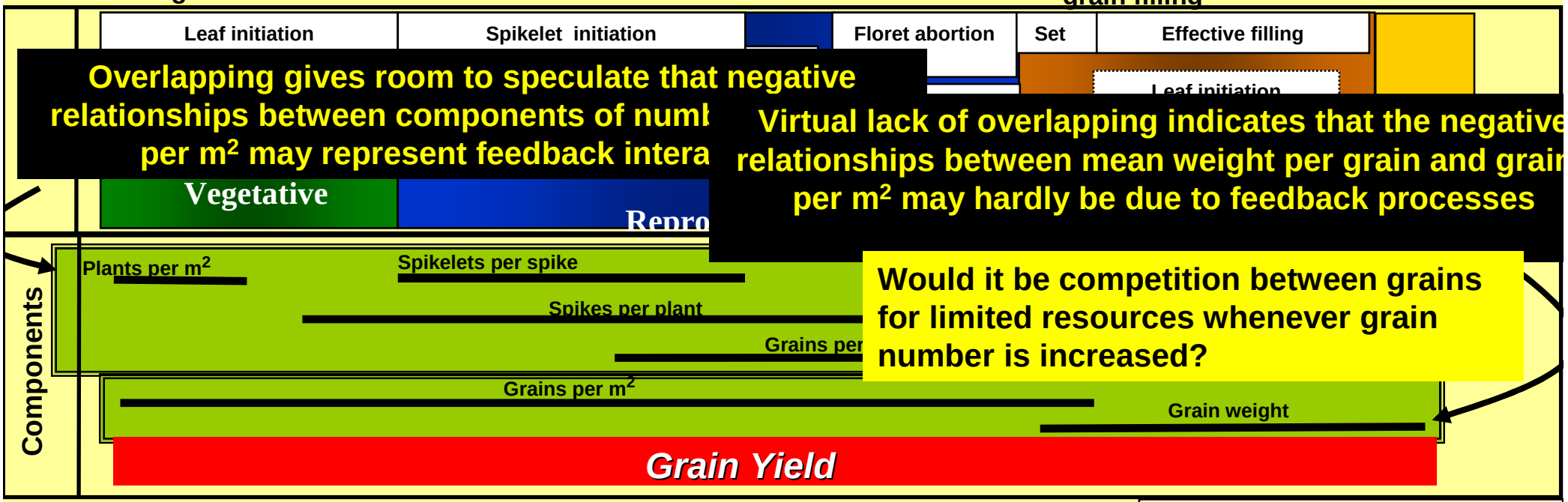
Most popular approach

Slafer & Savin, 2006. In: *Encyclop. Plant & Crop Science*



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

Time scale is arbitrary



Overlapping gives room to speculate that negative relationships between components of numb per m² may represent feedback intera

Virtual lack of overlapping indicates that the negative relationships between mean weight per grain and grain per m² may hardly be due to feedback processes

Would it be competition between grains for limited resources whenever grain number is increased?

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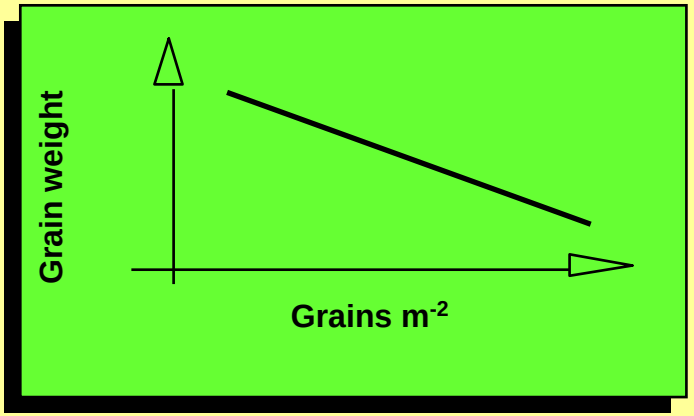
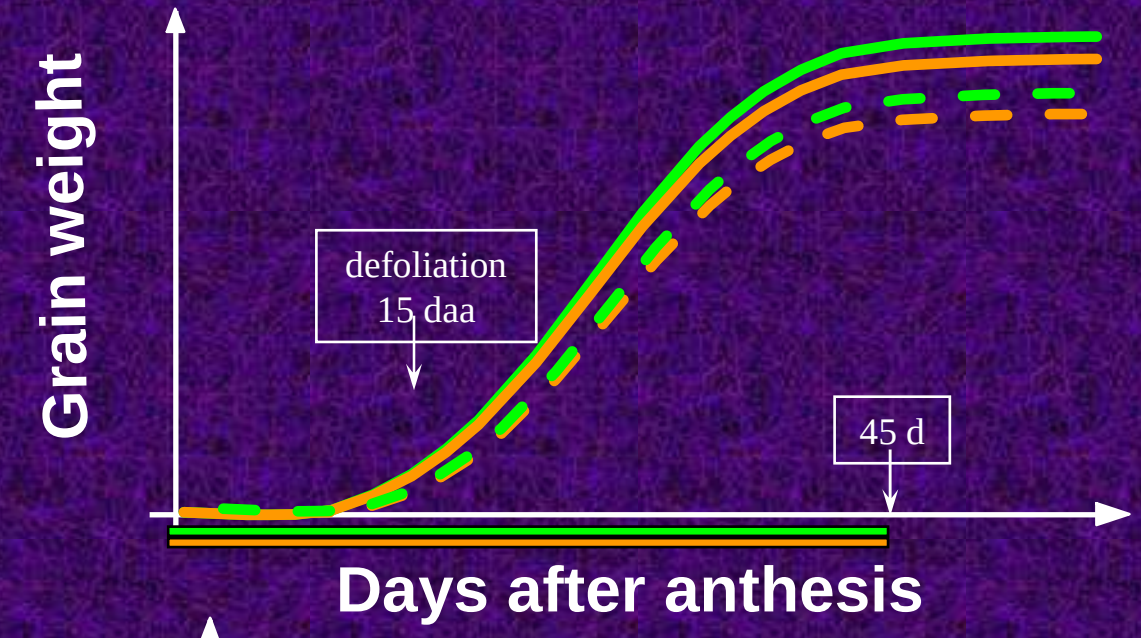
Do grains strongly compete for photosynthetic carbohydrates during their growth?

- It is the most common interpretation, but mostly (only?) based on the relationship itself



- Revising physiological evidences for accepting that the negative relationship between grain weight and grain number is due to competition is critical if we want to have certitude when manipulating components as a startegy to manipulate yield

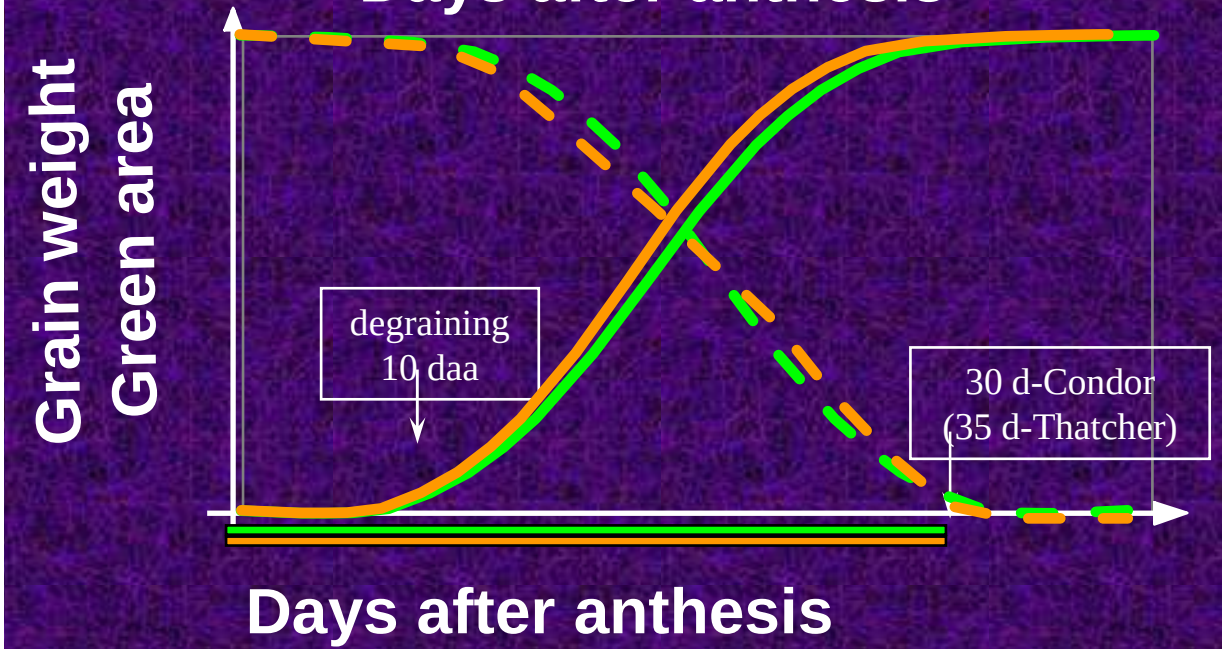
Grain weight responses to *Source-sink manipulations*



Control

Defoliated

From Nicolas & Turner 1993



Control

Degrained

From Slafer & Savin 1994

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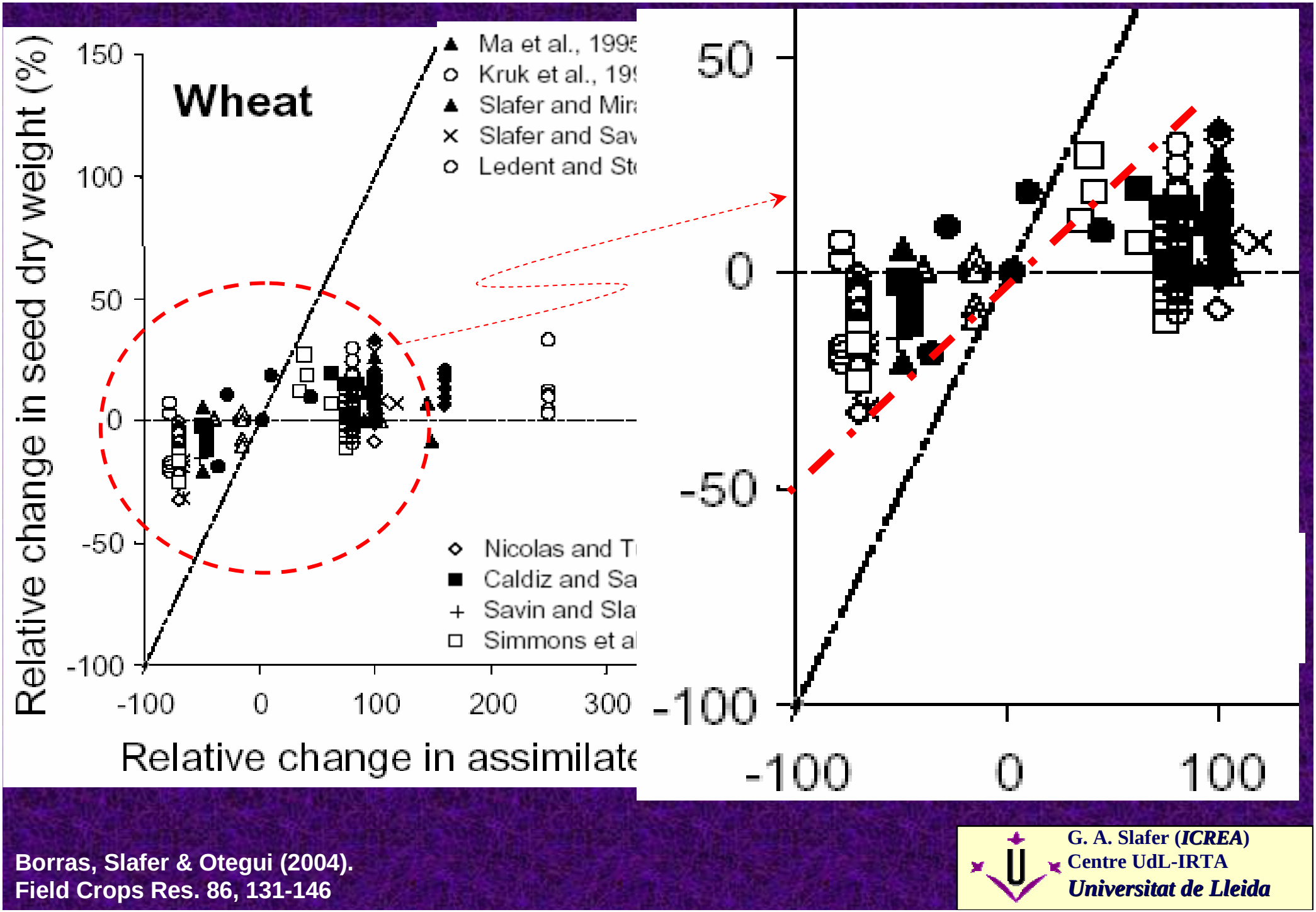

Borras, Slafer & Otegui (2004).
Field Crops Res. 86, 131-146

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Aun en ambientes mediterraneos

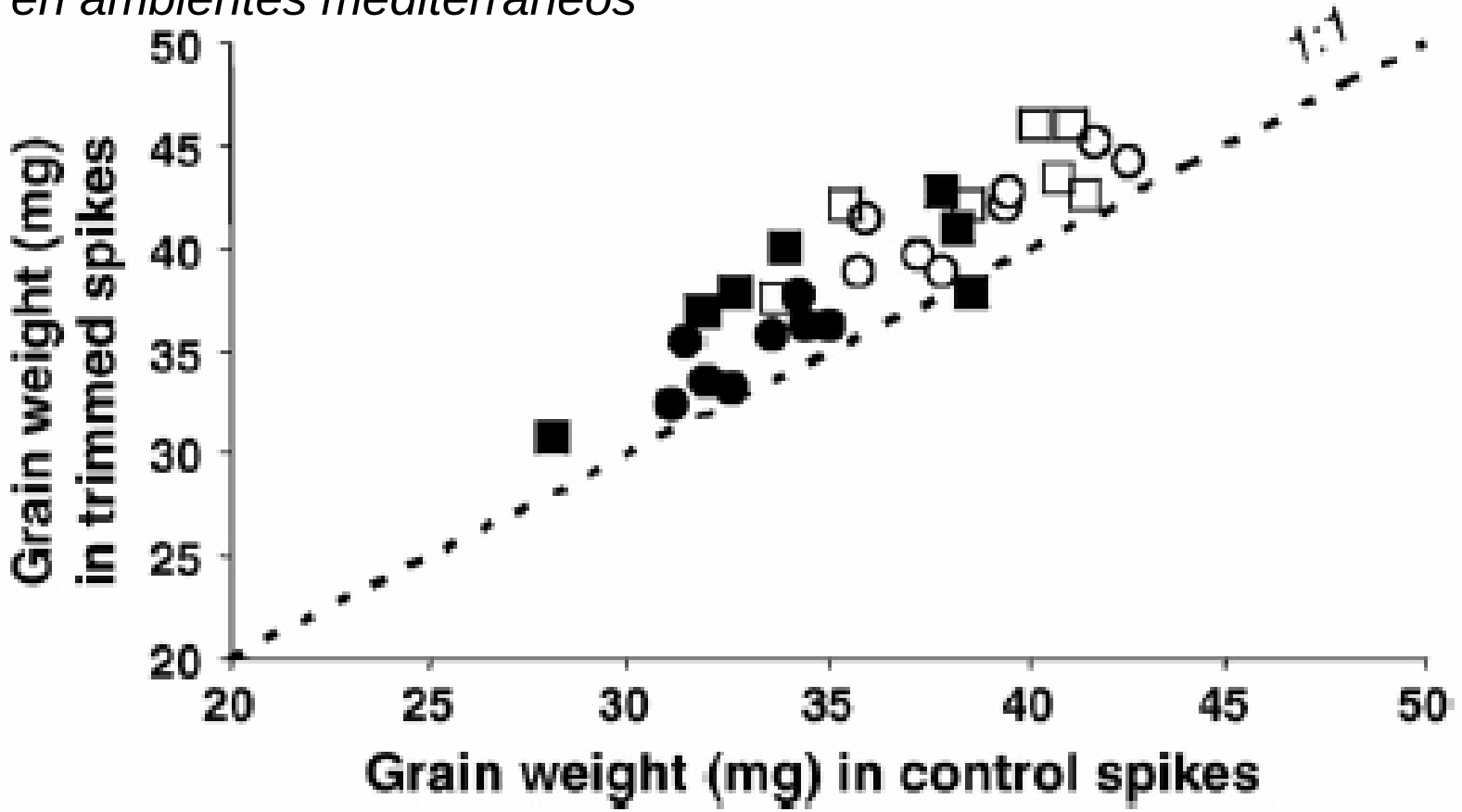

Fig. 4. Averaged grain weight for all grains in the spikes (closed symbols) and for only the proximal grains in central spikelets (open symbols) in trimmed spikes plotted against the same variable in the control spikes for each background treatment in experiments 1 (circles) and 2 (squares). Dashed line represents the 1:1 ratio.

J. Cartelle et al. / Europ. J. Agronomy 25 (2006) 365–371

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Two papers dealt with resolving whether barley yield in the UK is sink- or source-limited

Difference between potential photosynthate supply and grain yield, Mg ha^{-1} at 100% DM for each harvest year 2002–2004

Site	Harvest year		
	2002	2003	2004
Aberdeen	1.84	0.62	1.53
Edinburgh	6.59	8.67	
High Mowthorpe	3.03	0.64	3.21
Rosemaund	2.93	0.75	1.48
Sutton Bonington	3.82	2.99	−0.04
Kings Lynn	2.88	1.28	3.78

Potential supply of CH_2O to growing grains varied greatly between environments (6 sites x 3 years), but in all cases -but 1- exceeded yield actually achieved

Barley was predominantly sink limited

Bingham, Blake, Foulkes & Spink 2007 *(Field Crops Res. 101: 198-211 & 212–220)*

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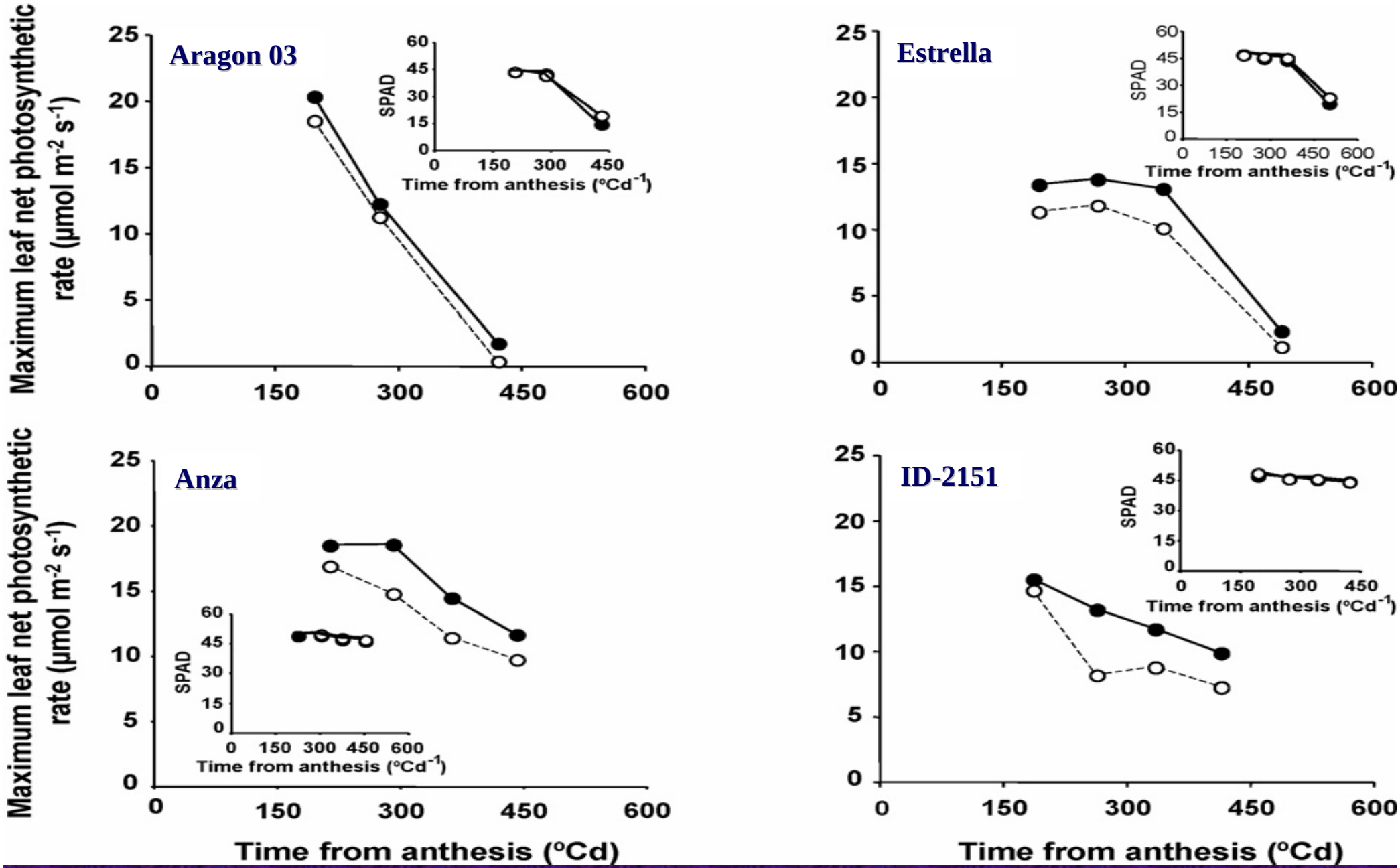
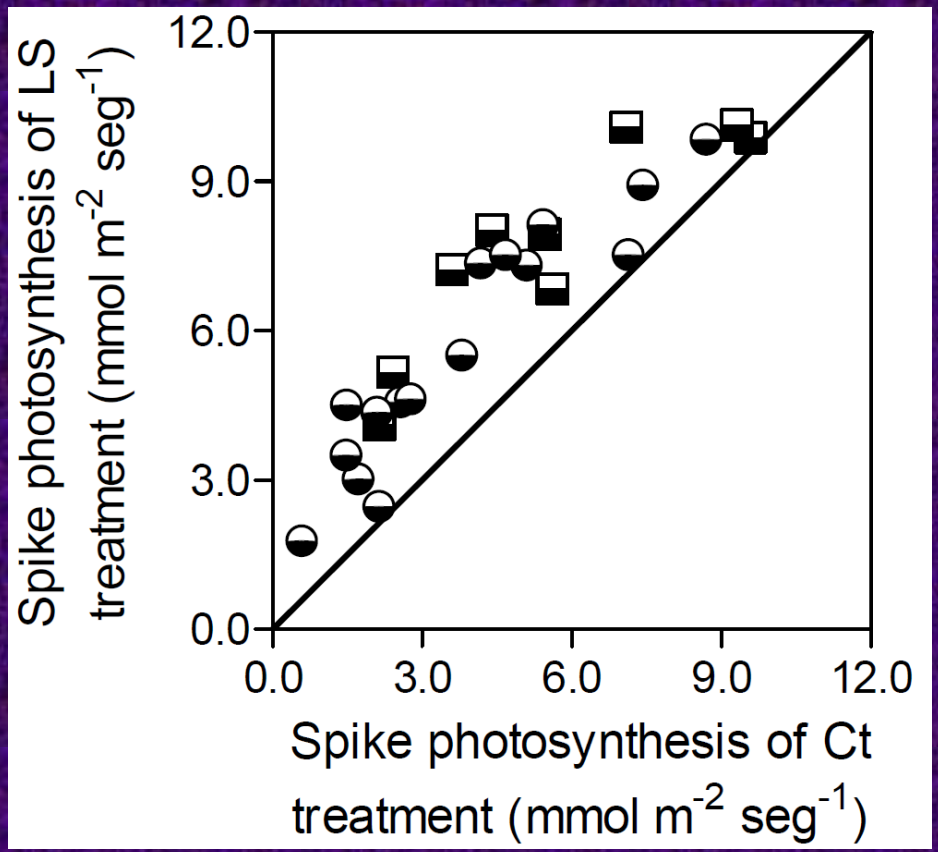
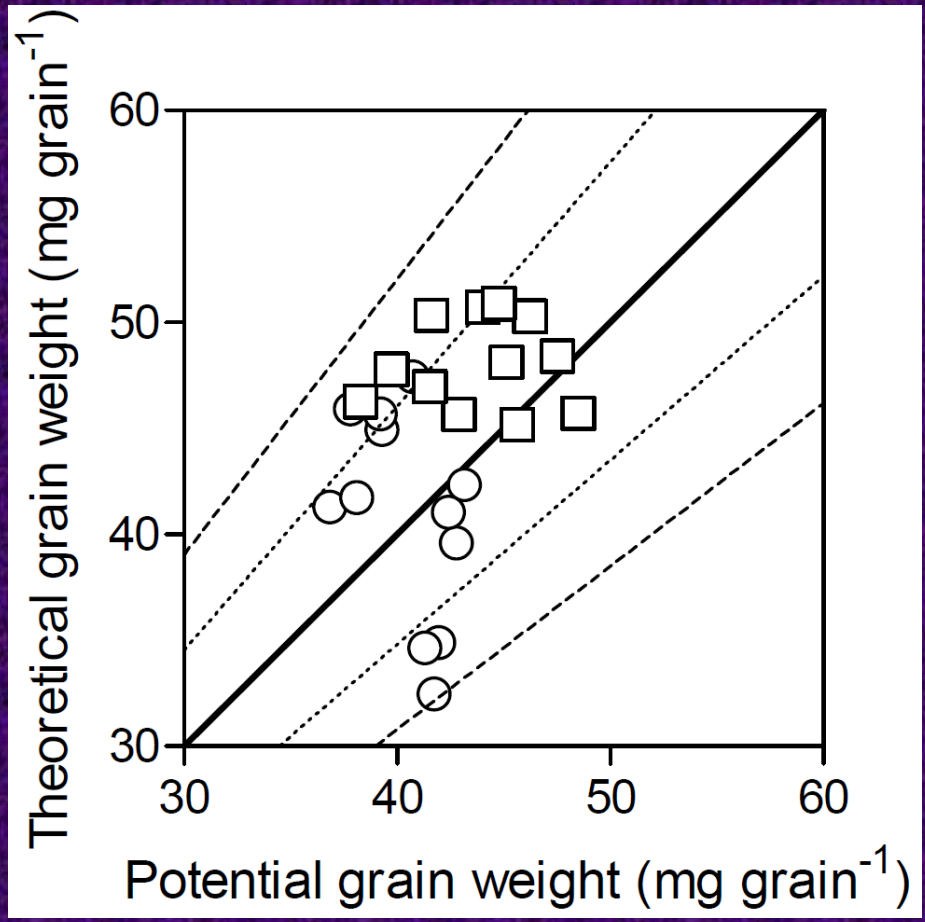


Control (close symbols) - Trimmed (open symbols)

Acreche & Slafer (2009) Field Crops Research 110, 98–105

Serrago, Alzueta, Savin & Slafer, submitted

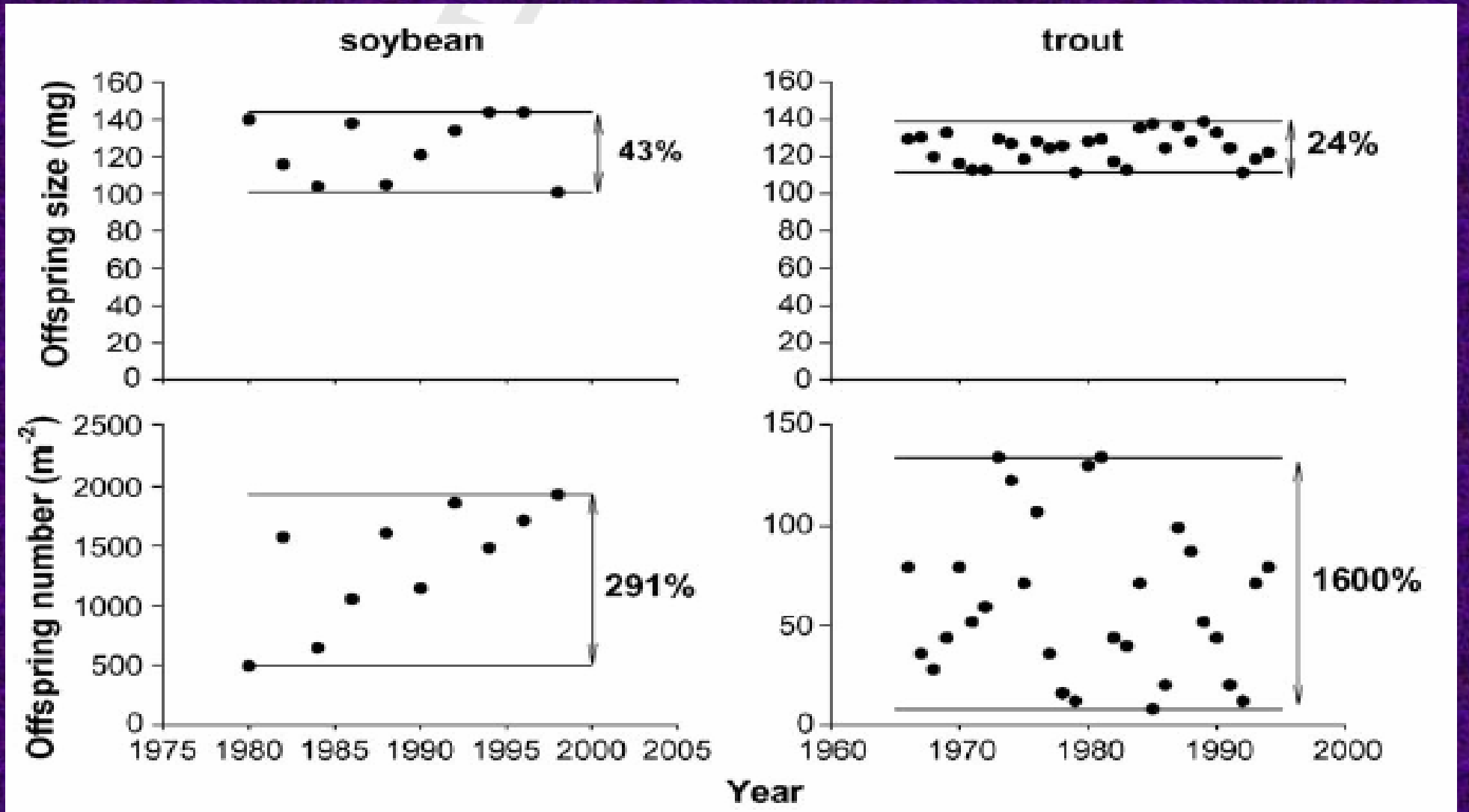




Overall conclusion of this study

- The potential supply of CH_2O to growing grains varied greatly between environments (6 sites x 3 years), but in all cases -but 1- exceeded yield actually achieved
- Can be reasonably extrapolated to cereals in general and in most growing conditions

$\Rightarrow$ cereals are predominantly sink limited



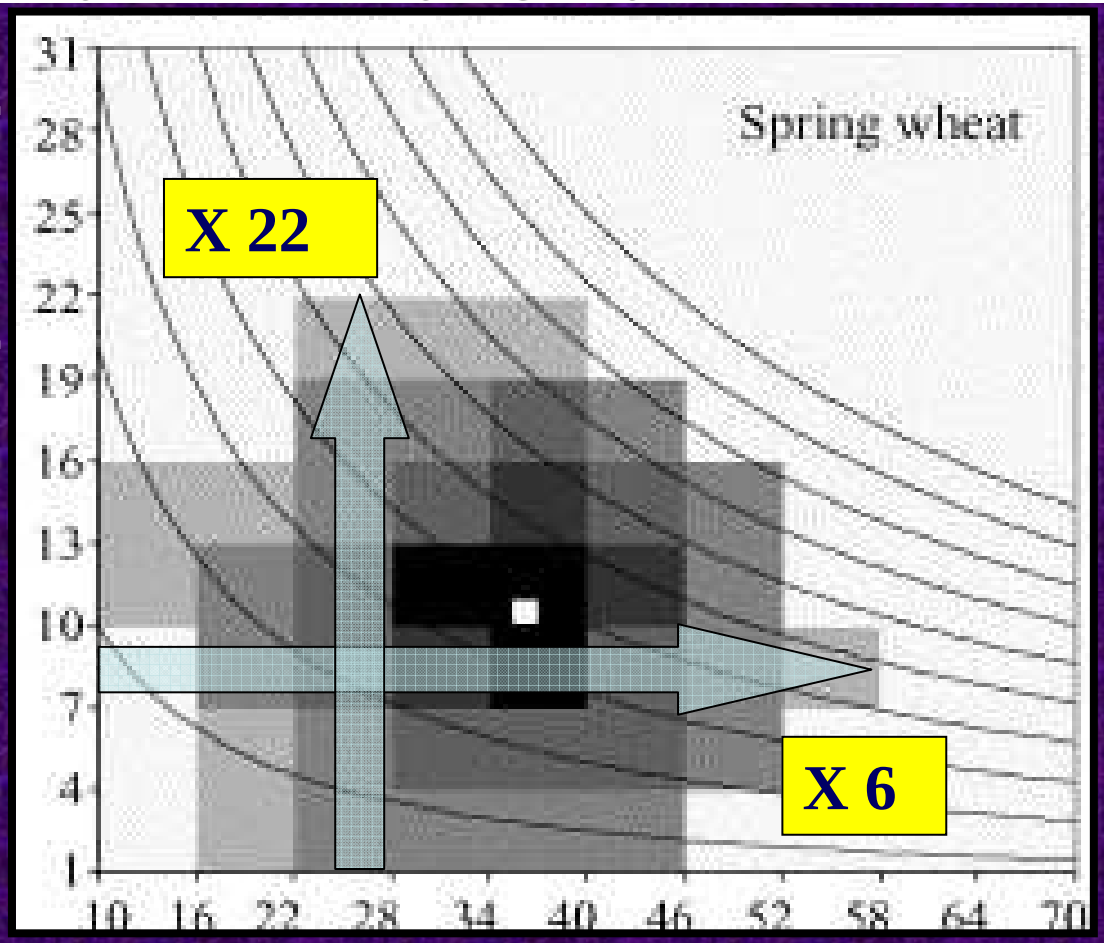
Interannual variation in offspring size and number in soybean (Kelley et al., 2003) and sea-trout (Elliot and Hurley, 1998)

From Sadras (2007). Field Crops Res. 100, 125–138

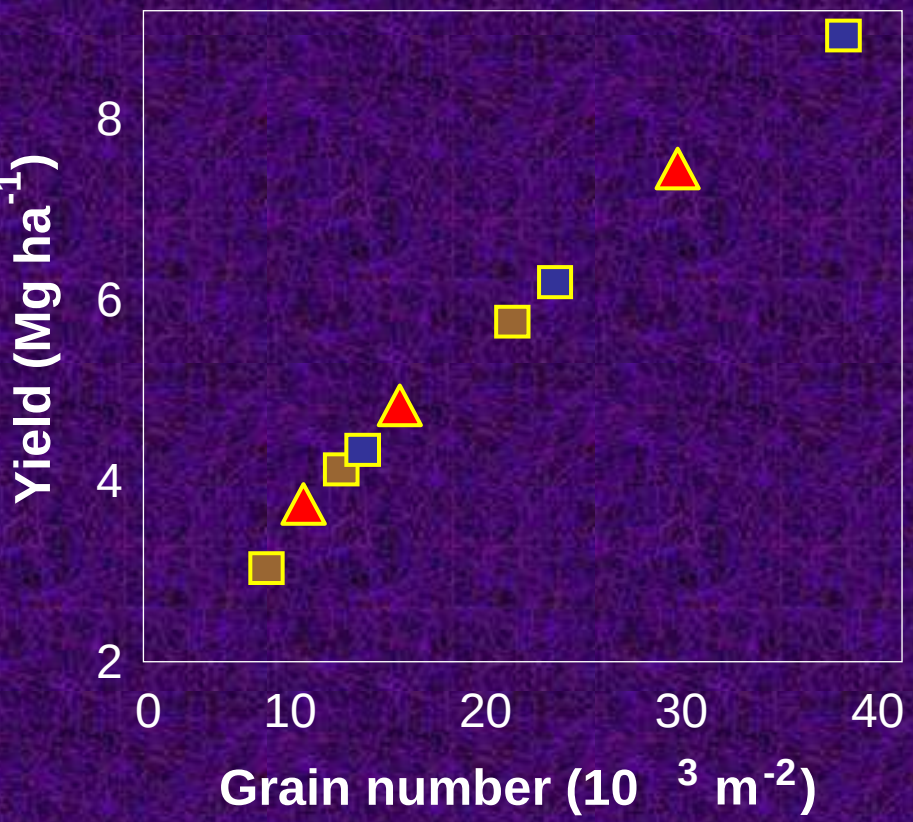
Available online at www.sciencedirect.com
ScienceDirect
Field Crops Research 100 (2007) 179–188
Field Crops Research
www.elsevier.com/locate/fcr

Grain number dominates grain weight in temperate cereal yield determination: Evidence based on 30 years of multi-location trials

Pirjo Peltonen-Sainio [a,*], Arjo Kangas [b], Yrjö Salo [c], Lauri Jauhiainen [d]

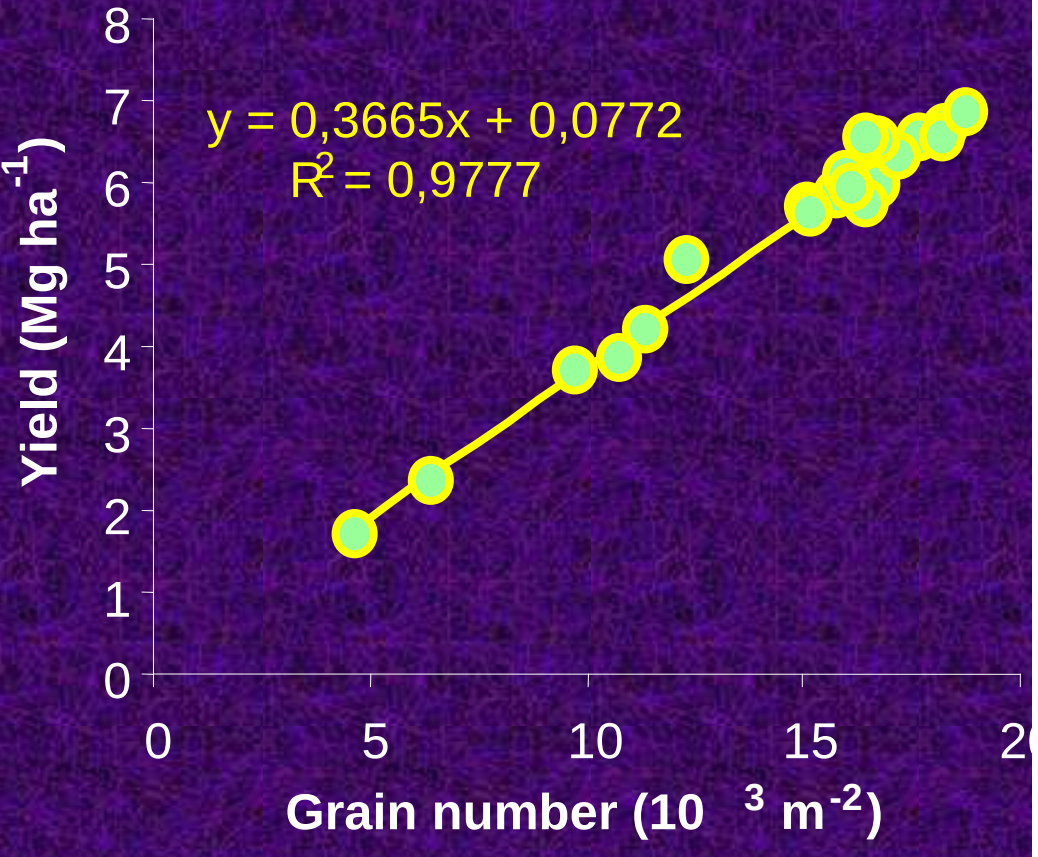


Cvs released at different eras



Slafer & Andrade 1989,1993 Field Crops Res.

Timing and amount of N fertilization



Fischer 1993, Field Crops Res. 33, 57-80

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- **The lack of a competitive relationship between grain number and individual grain weight (**Slafer & Andrade, 1993, Slafer & Miralles, 1993, 1995**)**
- **and the fact that grain weight does frequently not respond to source – sink manipulations during grain filling –even in interaction with streses (***Slafer & Miralles, 1992; Slafer & Savin 1994; Kruk, Calderini & Slafer, 1997; Borras, Slafer & Otegui, 2003***); in agreement with what can be seen in a more general analysis of yield determination in Barley (***Bingham et al., 2007***)**
- **is in line with the almost universally found positive relationship between yield and grain number in wheat** (and other cereals)
  - **which would be less clear if grains were strongly competing for assimilates after anthesis**
  - **which in fact may well have evolutionary bases (***Sadras, 2006***)**

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- **Therefore, to increase yields we must increase either**
  - **–the number of grains per m^2 set by the crop or**
  - **– their potential weight** (*as the negative relationship is not for competition among grains, if grain size potential increase the actual size will also increase*)

… having in mind that grain number is as complex as yield itself and to find out simpler traits determining it we cannot simply decompose it into simpler numerical sub-components as they are negatively related to each other, most likely due to feedback processes

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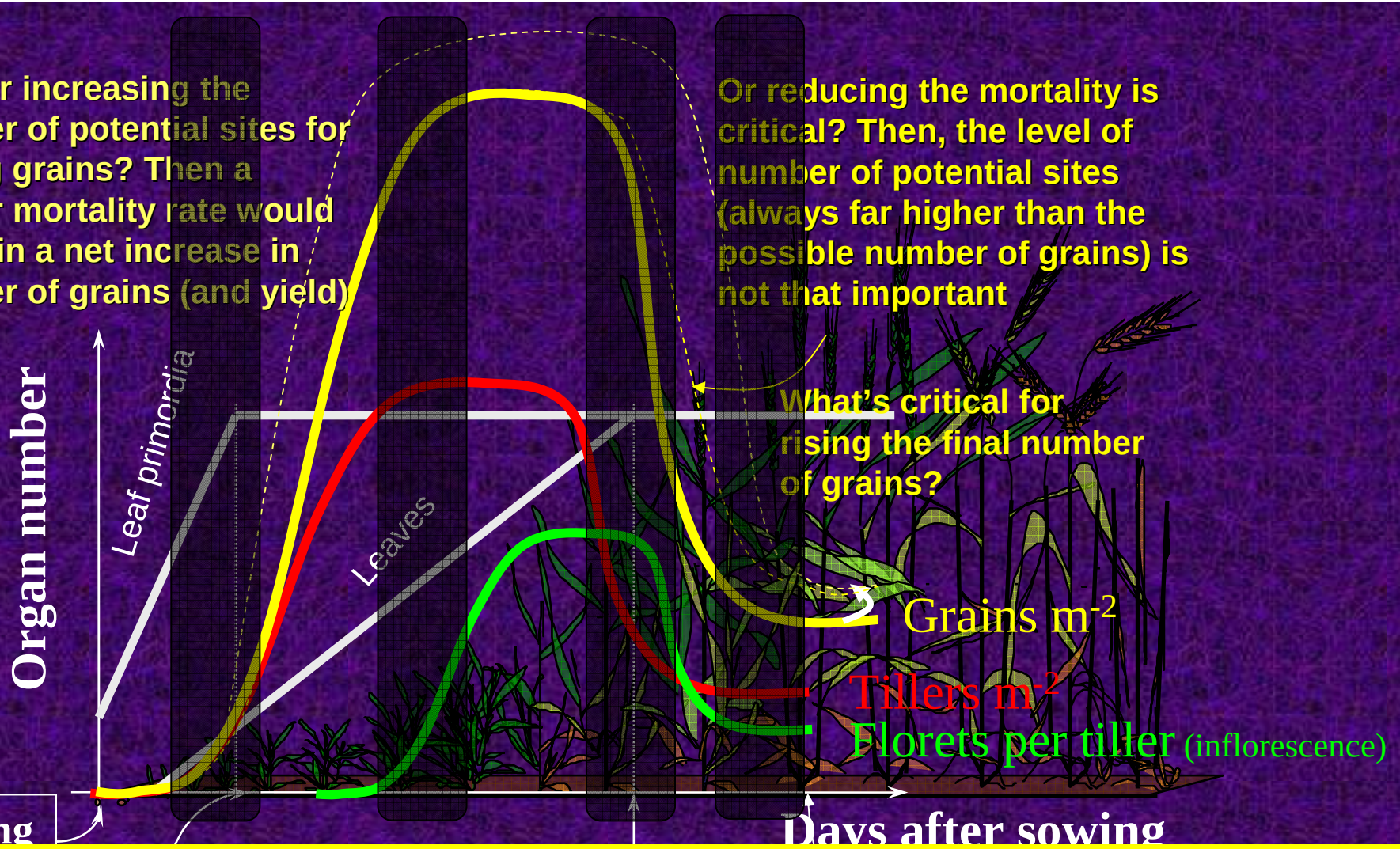
Further increasing the number of potential sites for having grains? Then a similar mortality rate would result in a net increase in number of grains (and yield)

Or reducing the mortality is critical? Then, the level of number of potential sites (always far higher than the possible number of grains) is not that important



Most accepted approaches were those stressing/improving strongly the crop for short periods, to avoid feed-forward effects

***e.g.* short periods of intense shading or CO_2 fertilization**

Leaf initiation | Spikelet initiation | Stem/spike growth

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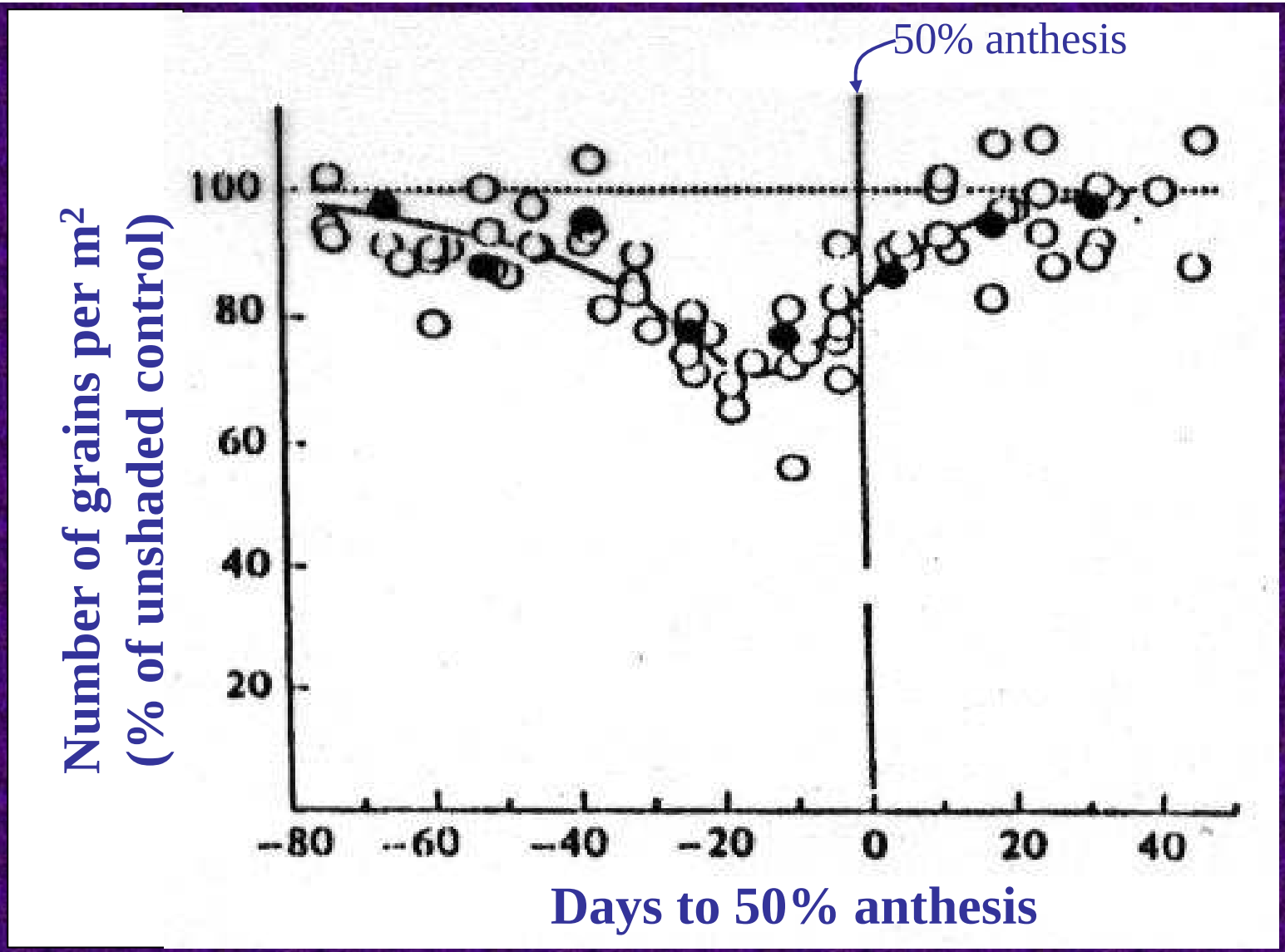

Fischer (1985) J. Agric. Sci.

Savin & Slafer (1991) J. Agric. Sci.

Slafer, Miralles, Calderini & Dreccer (1994) Field Crops Res.

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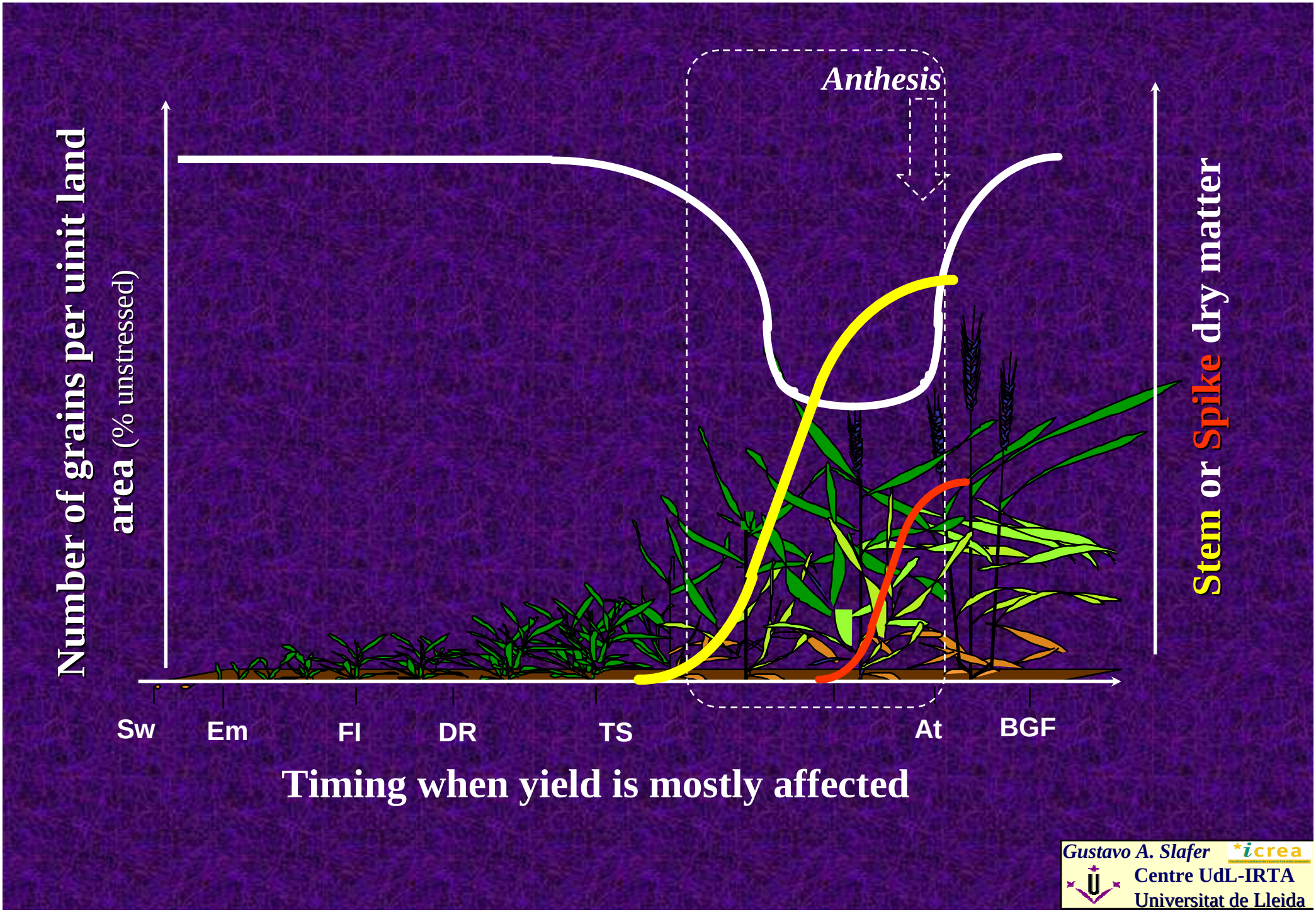

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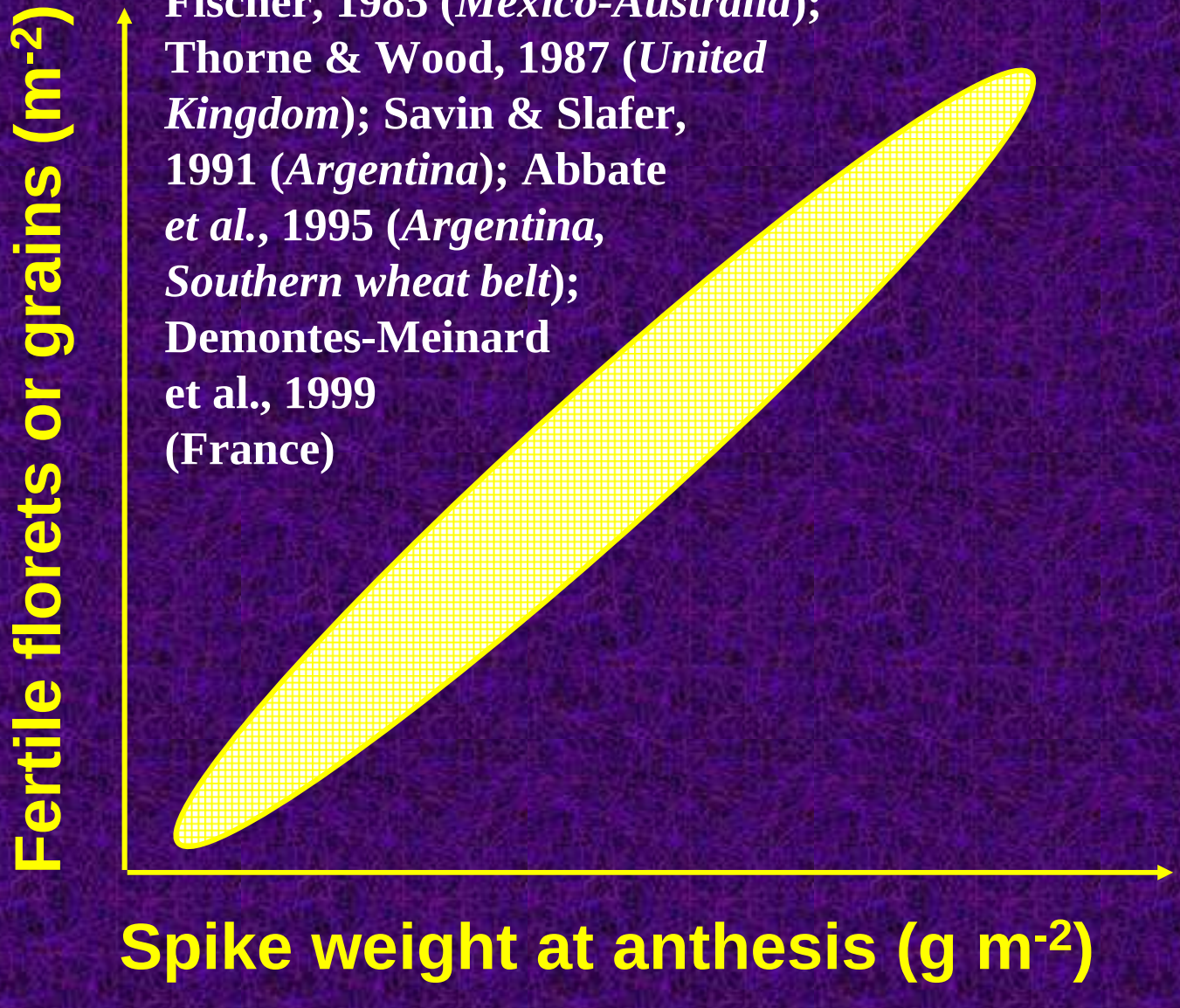
Due to radiation levels

Fischer, 1985 (*Mexico-Australia*); Thorne & Wood, 1987 (*United Kingdom*); Savin & Slafer, 1991 (*Argentina*); Abbate *et al.*, 1995 (*Argentina, Southern wheat belt*); Demontes-Meinard et al., 1999 (France)



Slafer et al 2005, Ann Appl Biol 146,61-70

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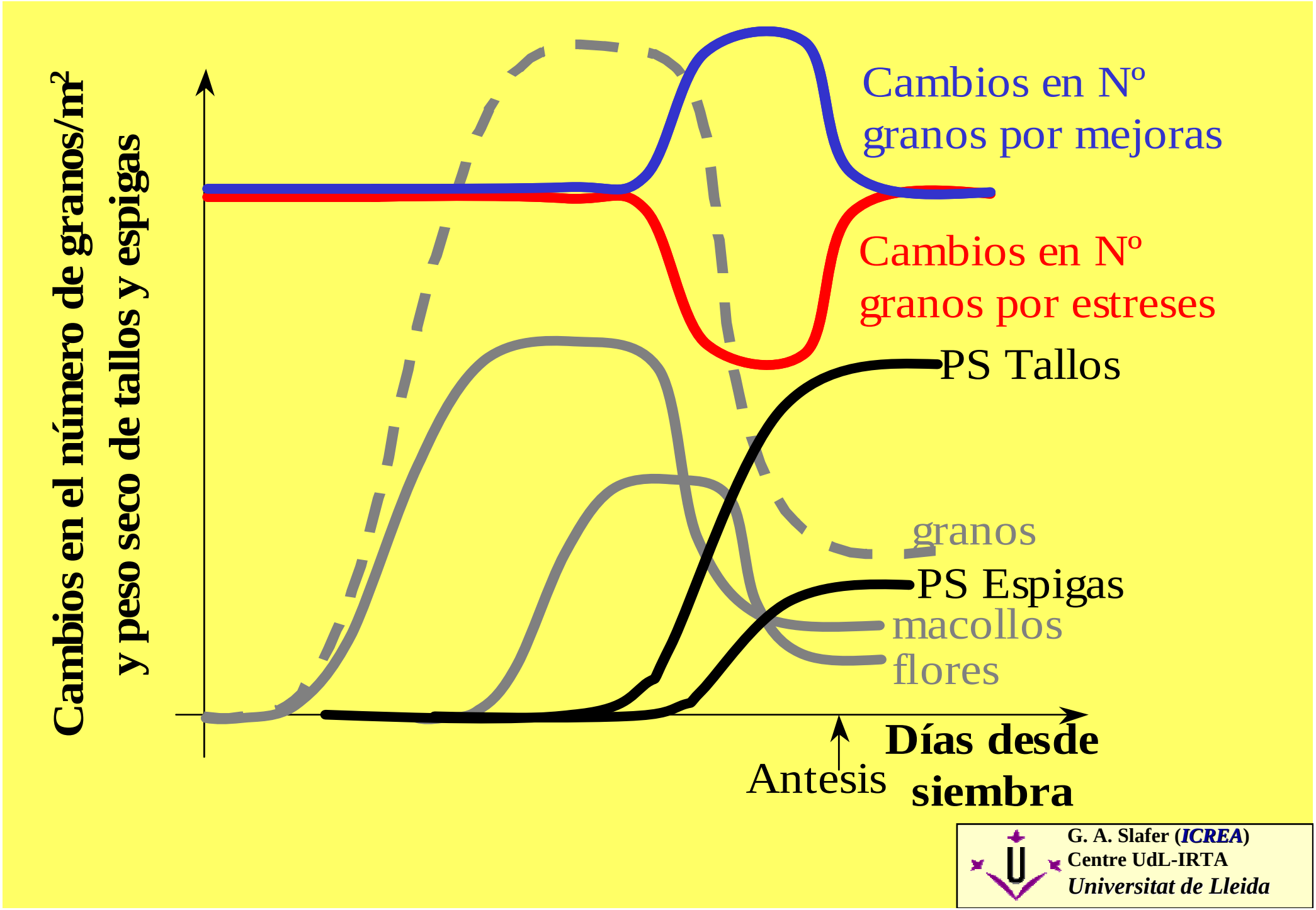

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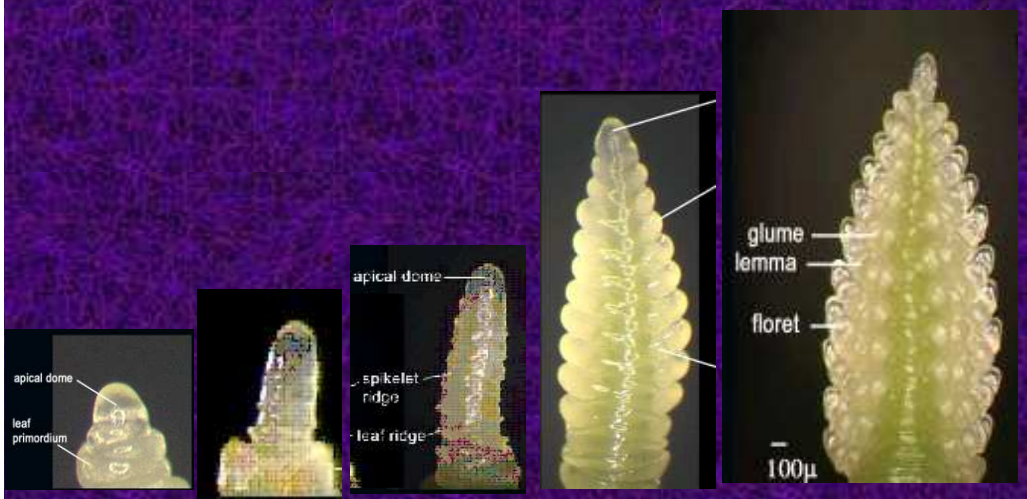
The basis for this strong and consistent relationship may be that while the spike is growing the floret primordia are developing towards fertile florets, most of which will become grains. Then understanding the developmental patterns of the florets may be instrumental

Stem elongation



Floret development within spikelets

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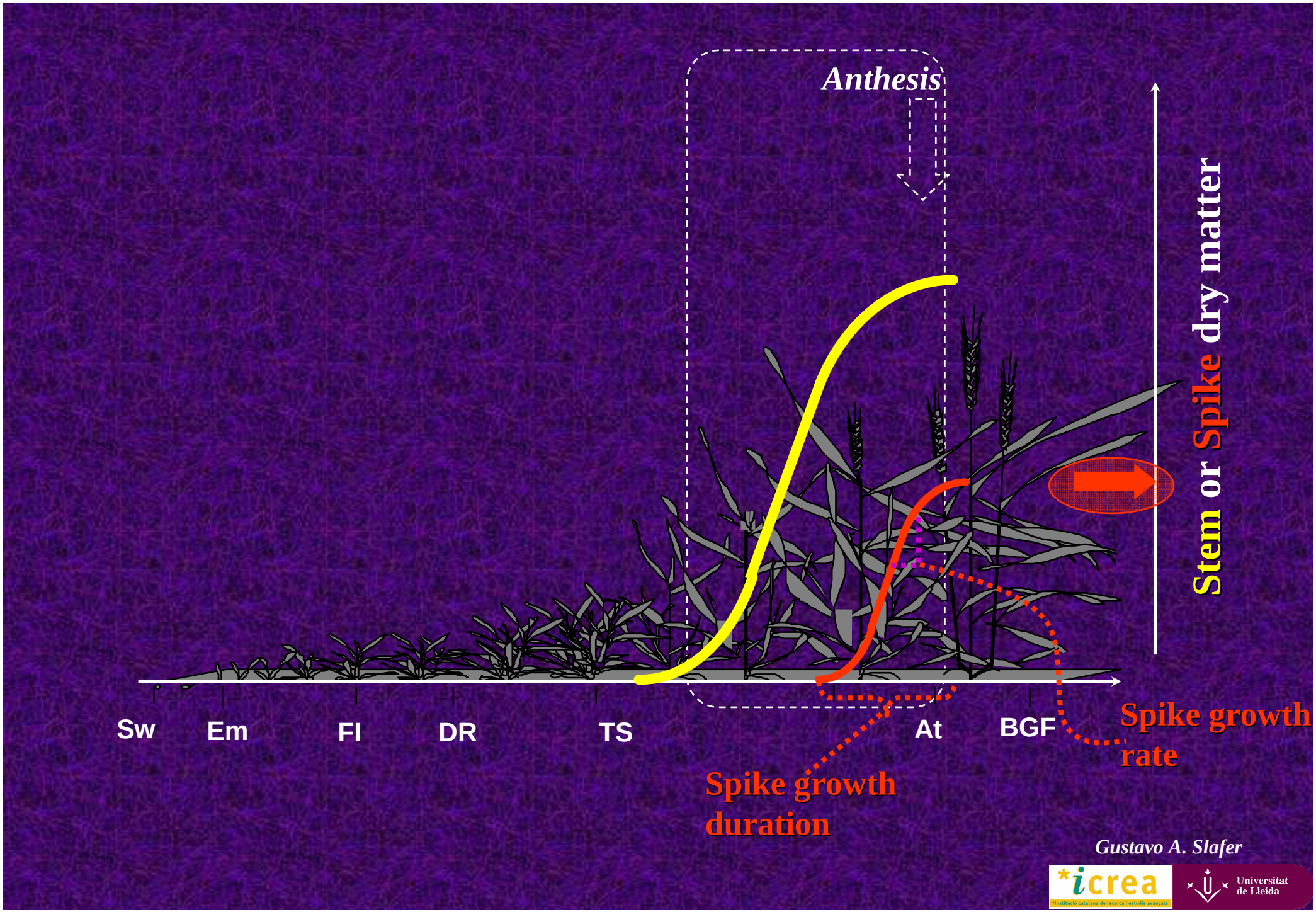
Anthesis
Stem or Spike dry matter
Sw
Em
Fl
DR
TS
At
BGF
Spike growth rate
Spike growth duration
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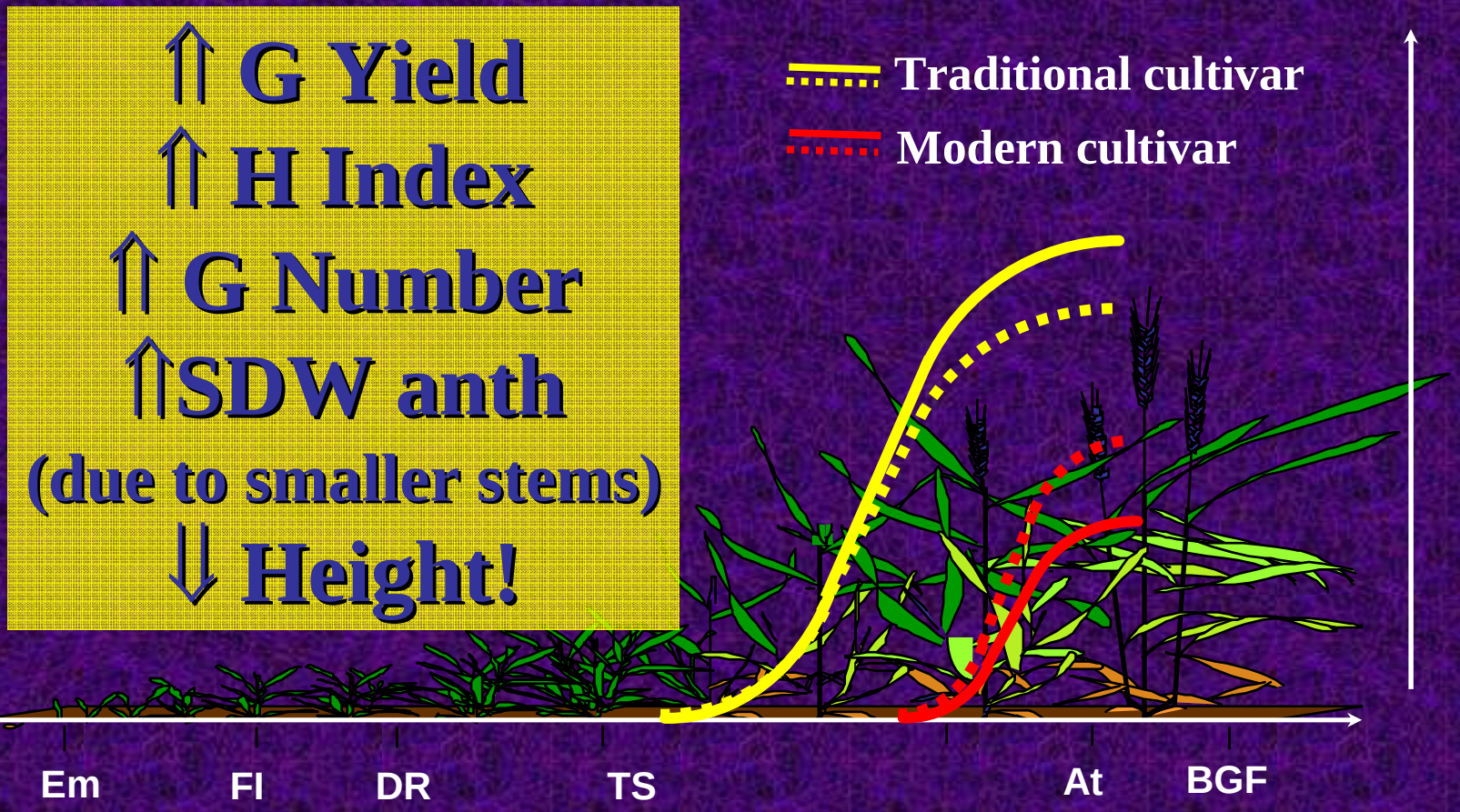
The growth of the spikes in this very short window of time is so relevant that most of the breeding success on improving wheat yields were based on improving this trait (*e.g.* Slafer et al, 1994; Calderini et al., 1999).



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Due to radiation levels
Fischer, 1985; Thorne
Abbate *et al.*, 1995; De
Meinard et al., 1999

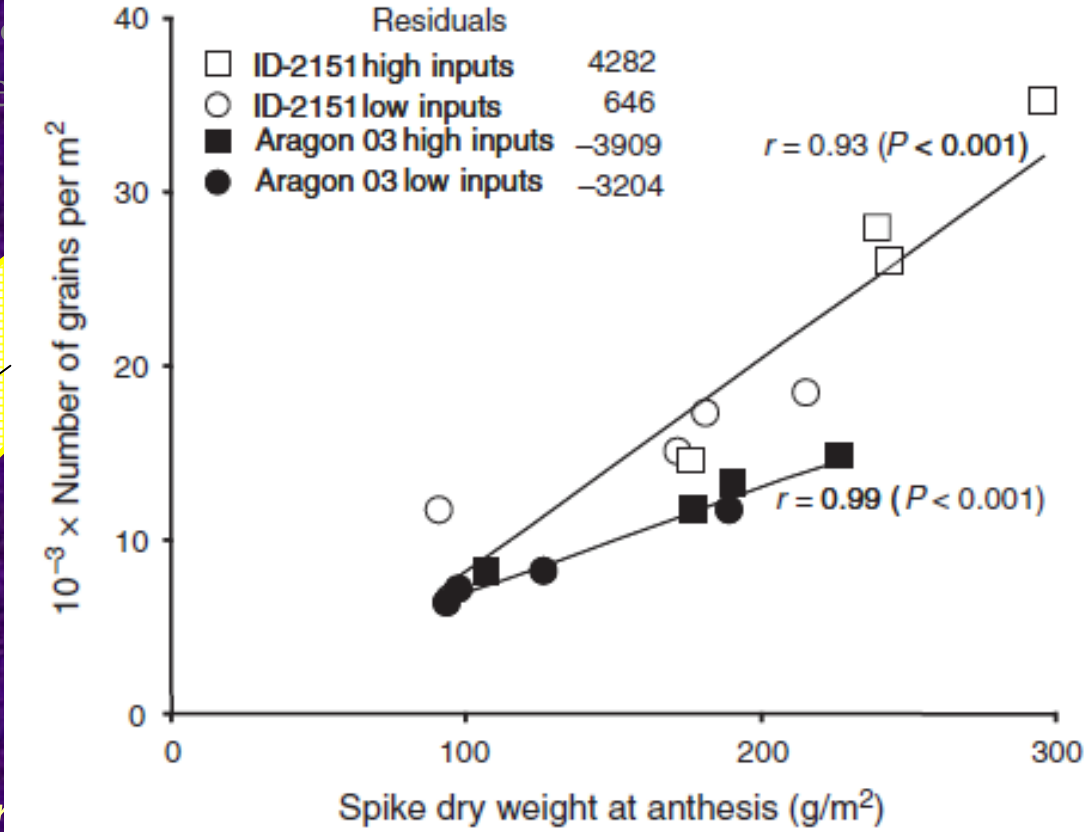
Due to genetics (semidwarf vs tall cvs.)
Brooking & Kirby, 1981; Stockman et al., 1983; Miralles *et al.*, 1998

Due to Lr19 fr
Reynolds *et al.*, 2001

Fertile florets or grains (m^{-2})

Spike weight $_{anthesis}$ ($g\ m^{-2}$)

***Acreche, Briceño, Martin S & Slafer* 2009**
Crop & Pasture Science, 60:271-279



Probably reflecting a better partitioning of resources within the spike between florets and structural parts (*e.g.* Slafer & Andrade, 1993; FCR 31:351-367)

Slafer et al 2005, Ann Appl Biol 146,61-70

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- Lets see empirically how much this general model developed from manipulative experiments of crop physiologists work in reality.
- We need papers that reported on studies on either management or breeding effects on yield that have recorded with some detail (i) dynamics of growth and partitioning during pre-anthesis, and (ii) the fate of florets
- Lets see first examples of management and then from breeding

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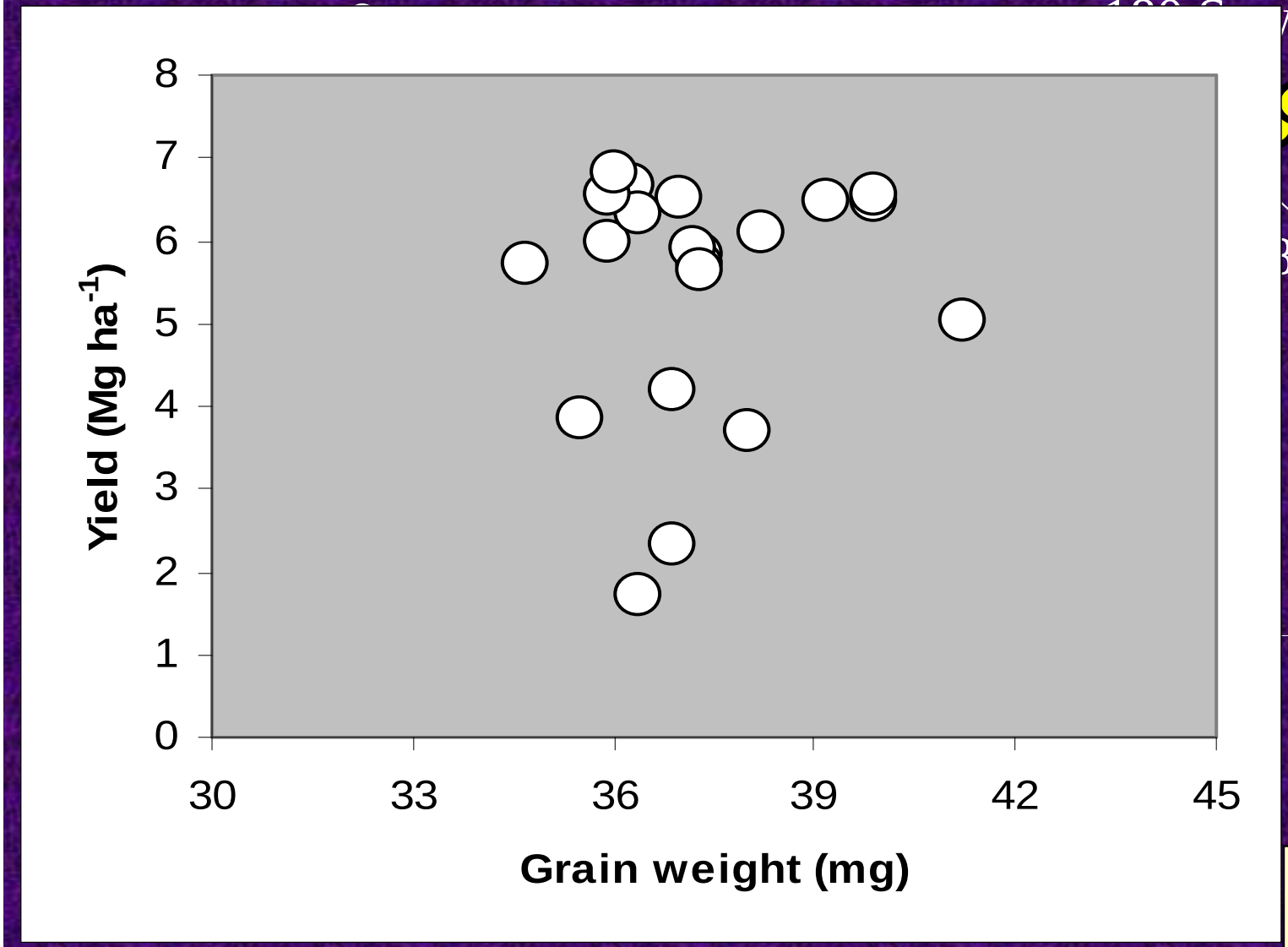
Timing and amount of N fertilization in irrigated wheat

32 N treatments, from 0 to 320 KgN ha^{-1}; from sowing to booting;

Fischer 1993, Field Crops Res. 33, 57-80



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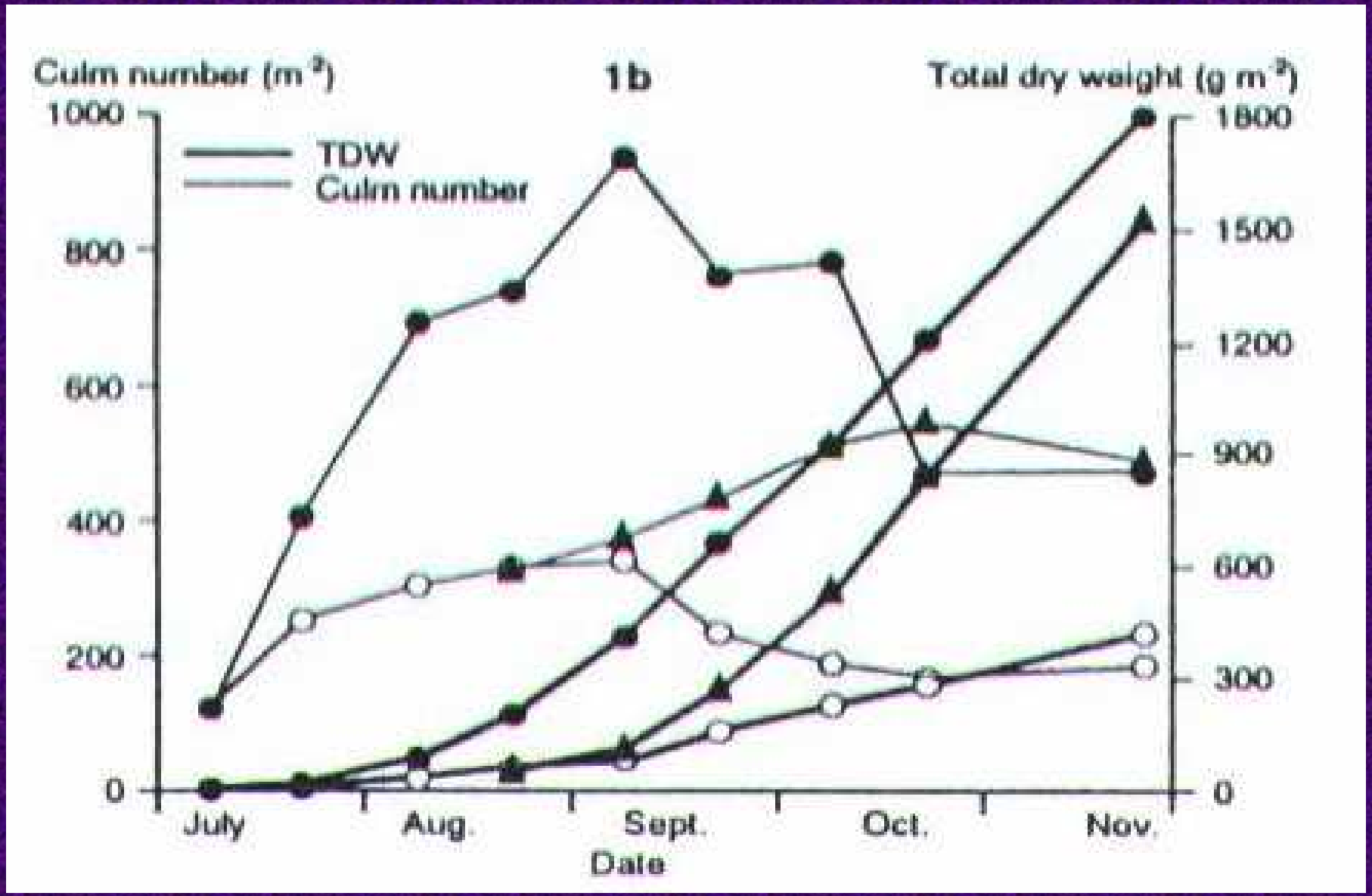
Fischer 1993, Field Crops Res. 33, 57-80



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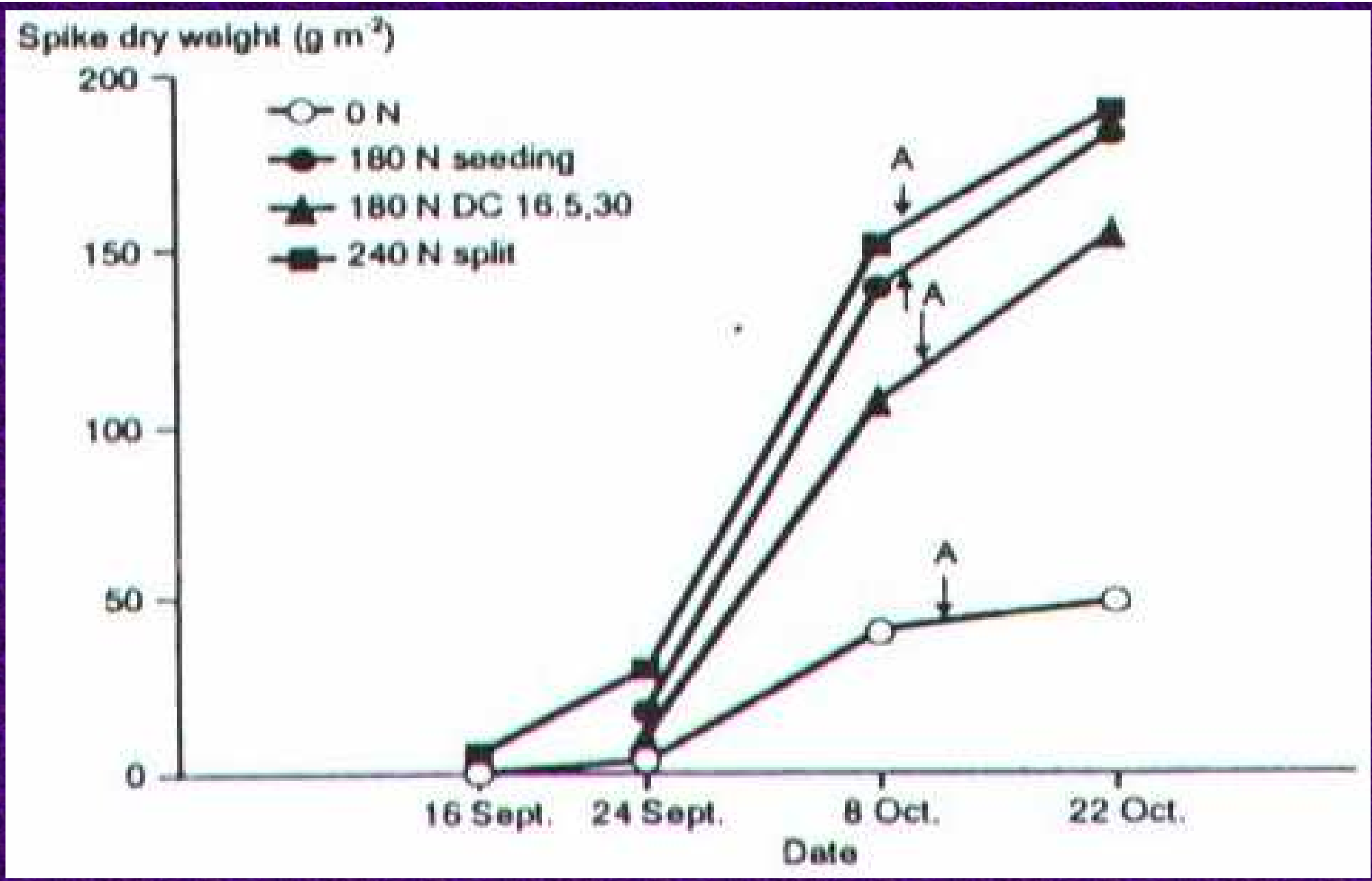

Fischer 1993, Field Crops Res. 33, 57-80

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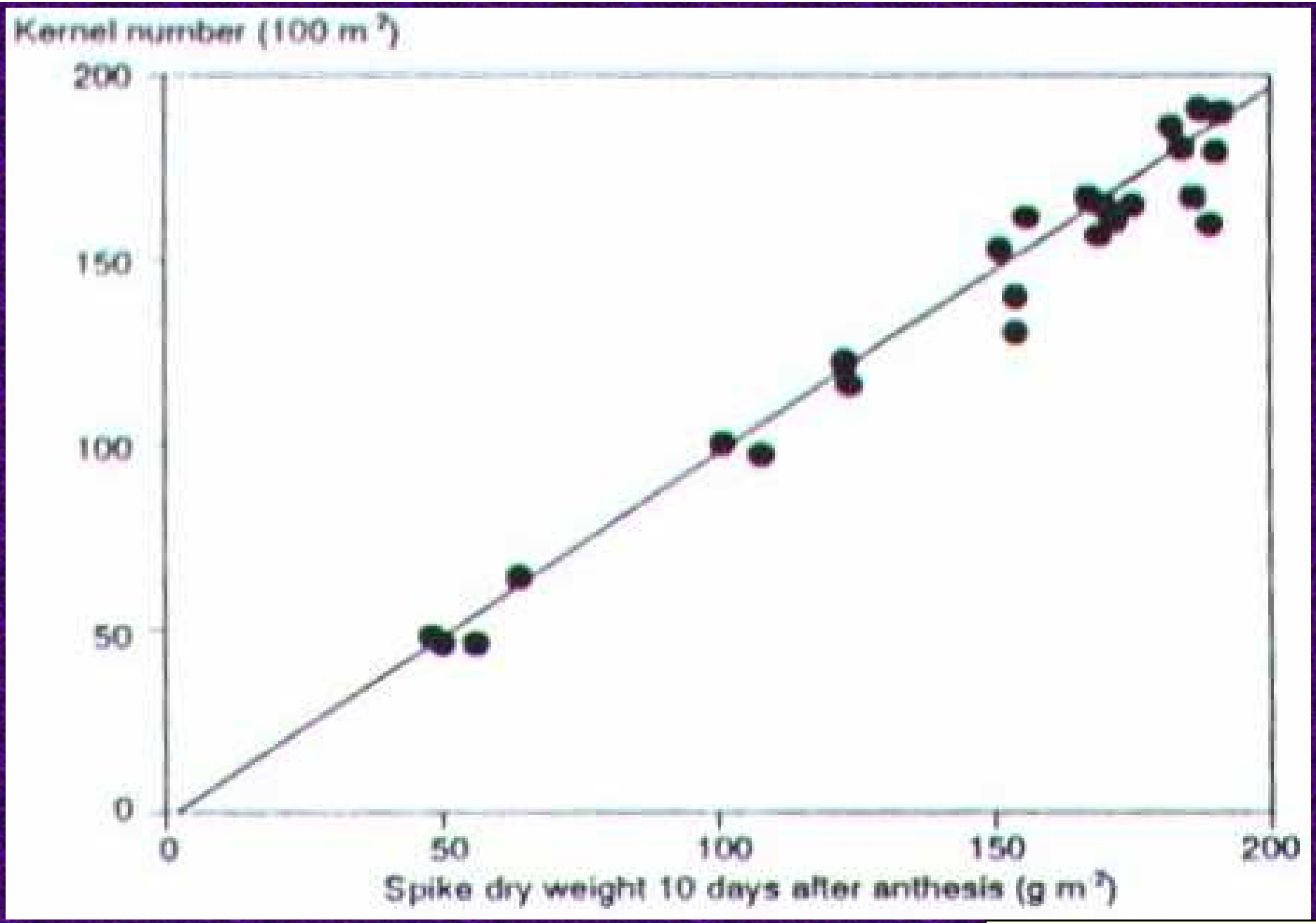

Fischer 1993, Field Crops Res. 33, 57-80

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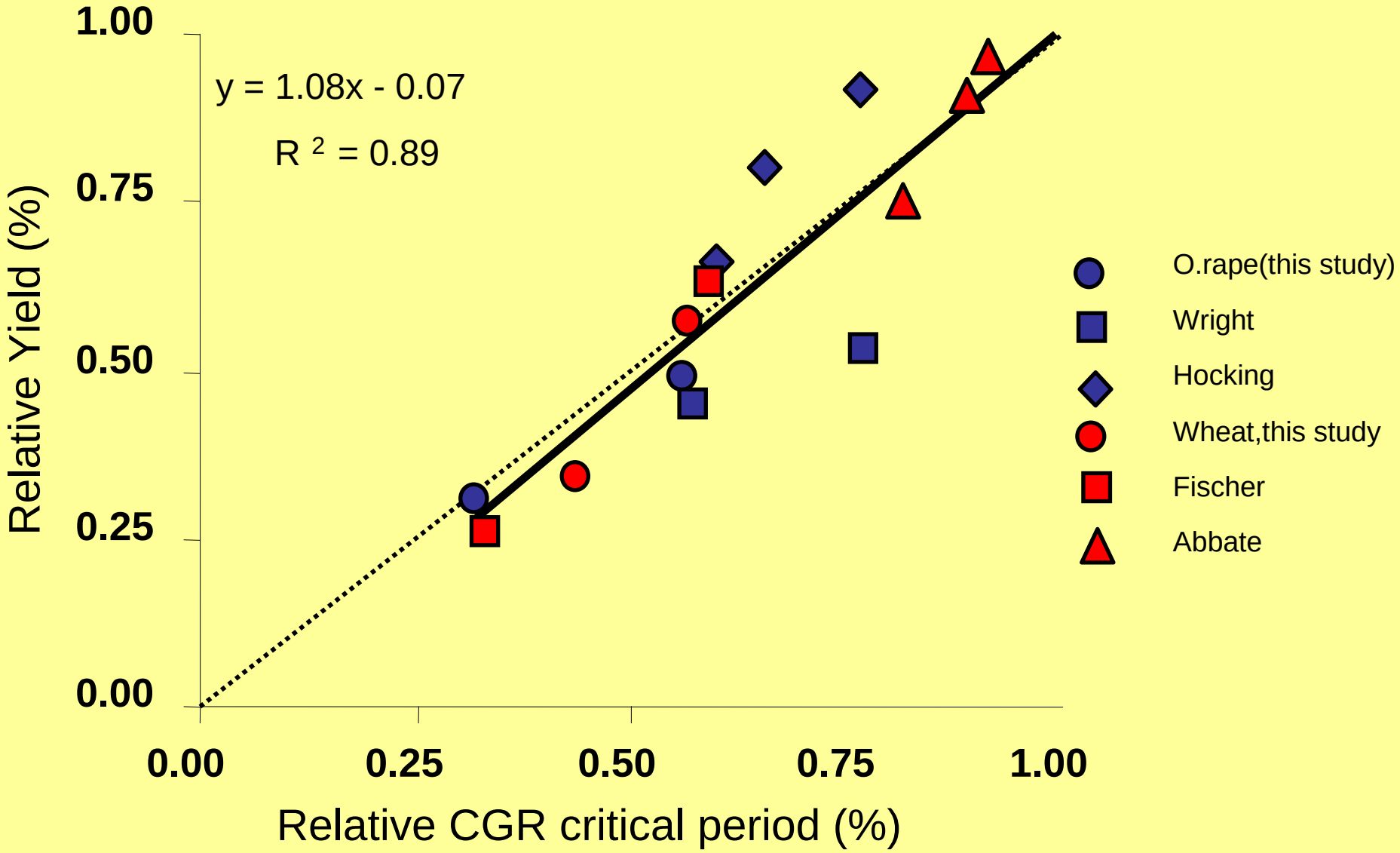

Dreccer, Schapendonk, Slafer & Rabbinge (2000).
Plant and Soil, 220:189-205.

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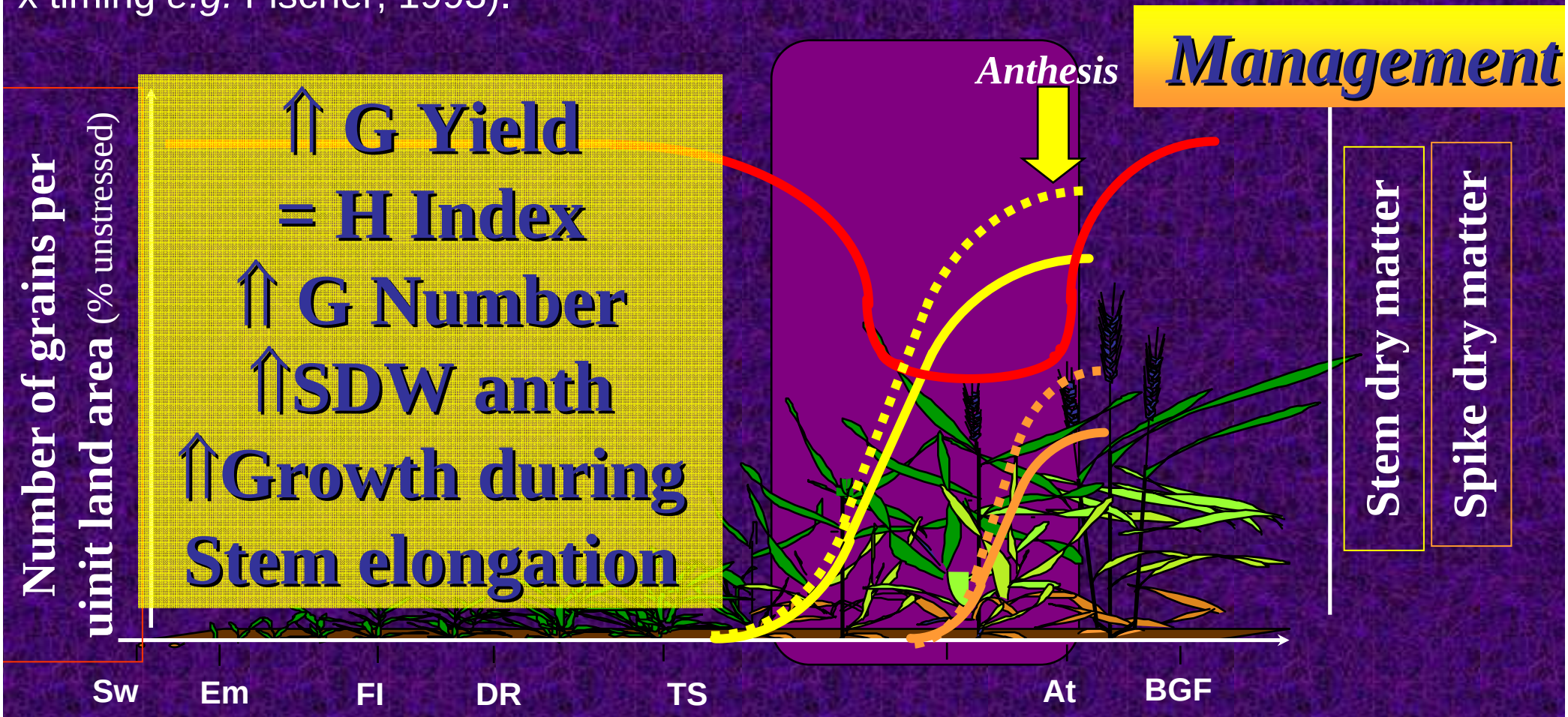
Most management strategies are designed to improve growth during this window of time. For instance, with N fertilisation (doses x timing *e.g.* Fischer, 1993).



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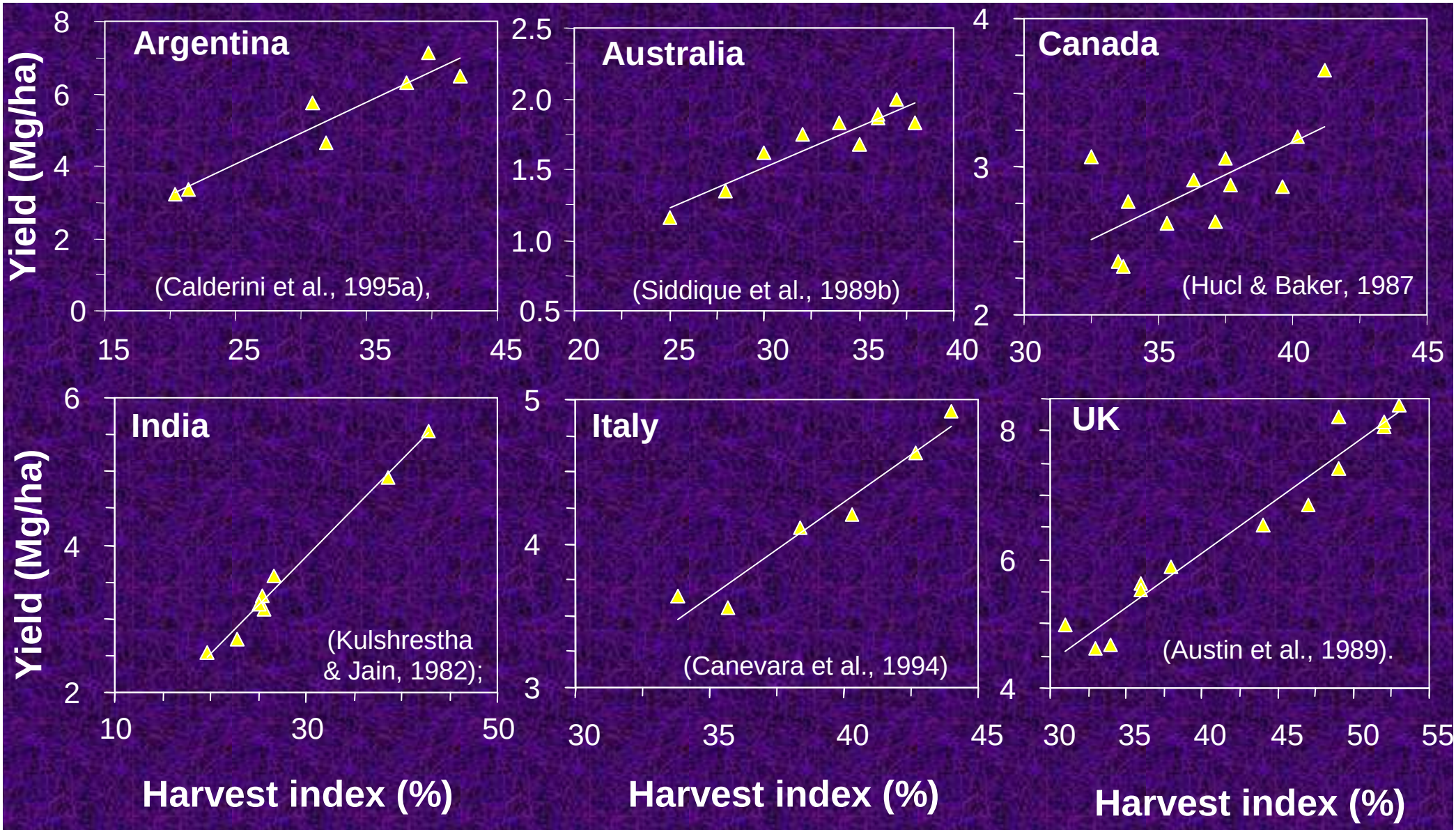

Calderini, Reynolds & Slafer, G.A. 1999. In: *"Wheat: Ecology and Physiology of Yield Determination"* Food Product Press, New York, pp. 351-377

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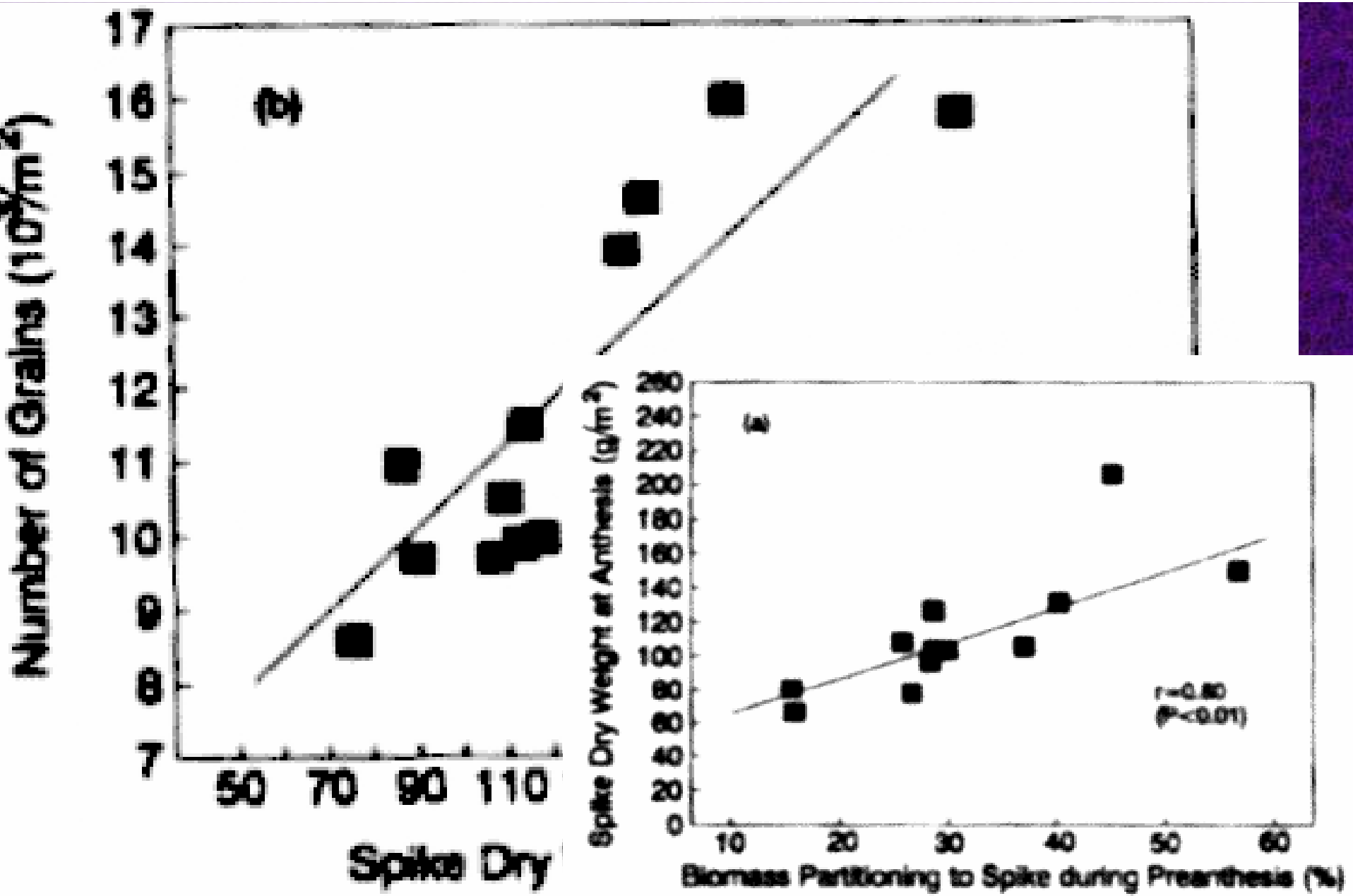

Slafer et al. (1994)

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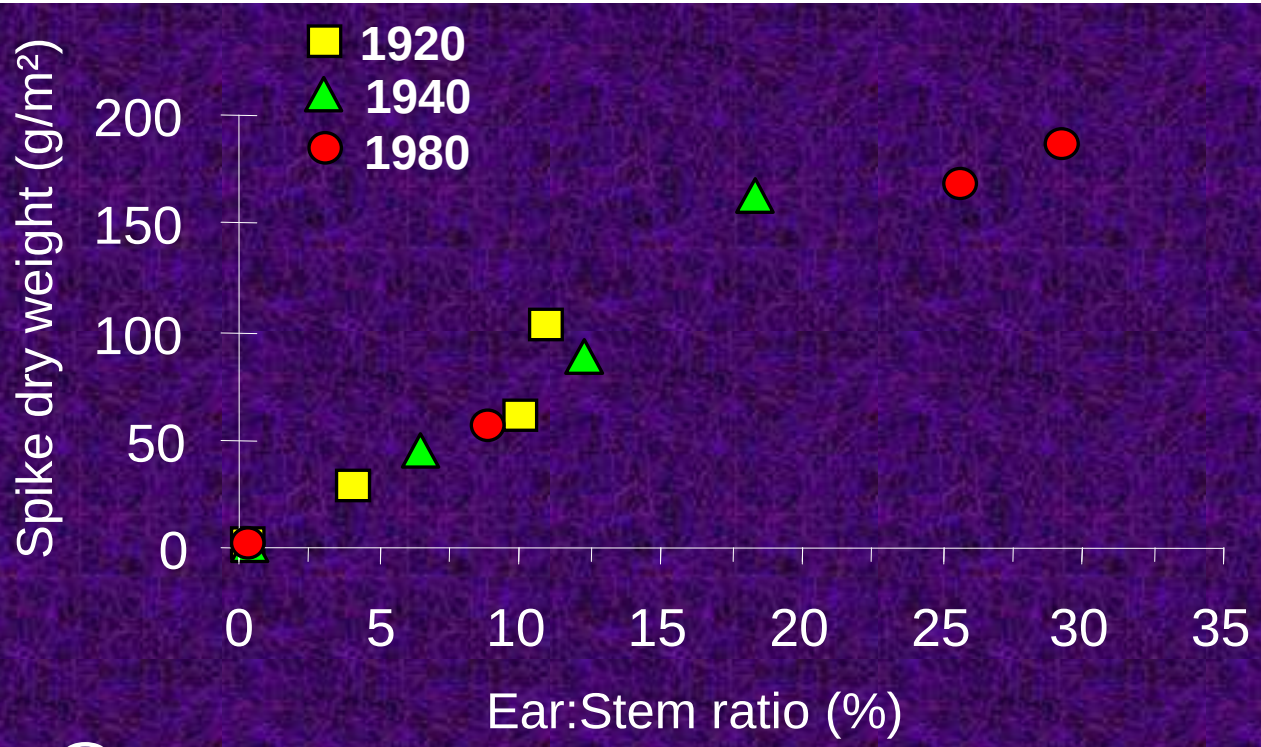

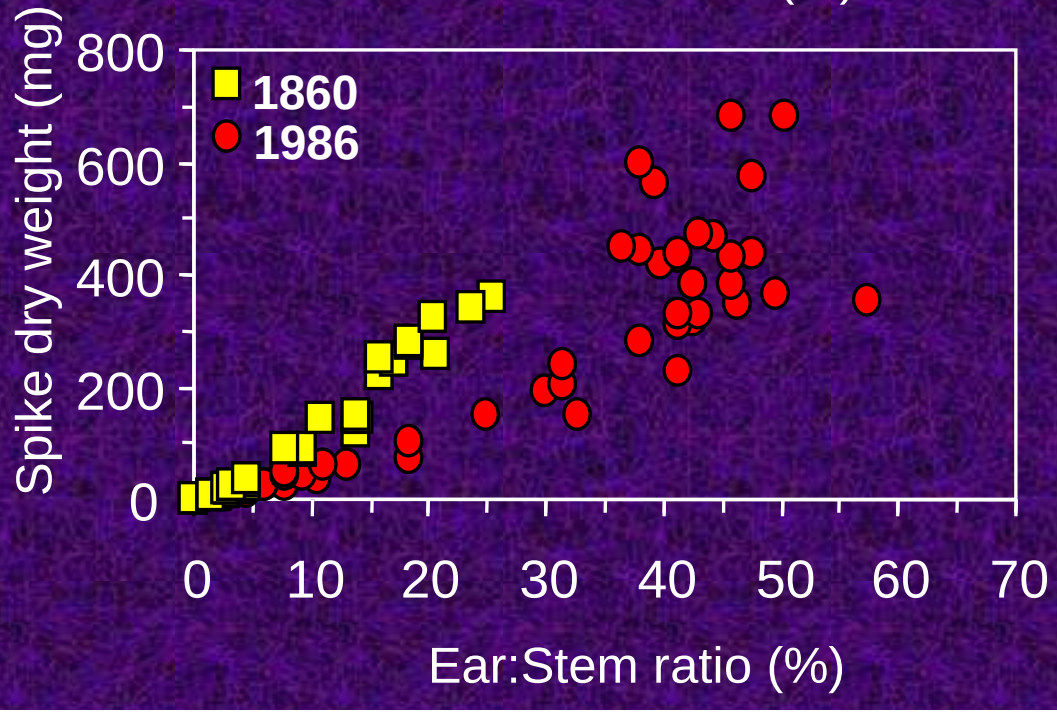

Taken from Slafer et al., 1994; Calderini *et al.* (1999)

With data from Slafer & Andrade, 1993 and Siddique *et al.*, 1989

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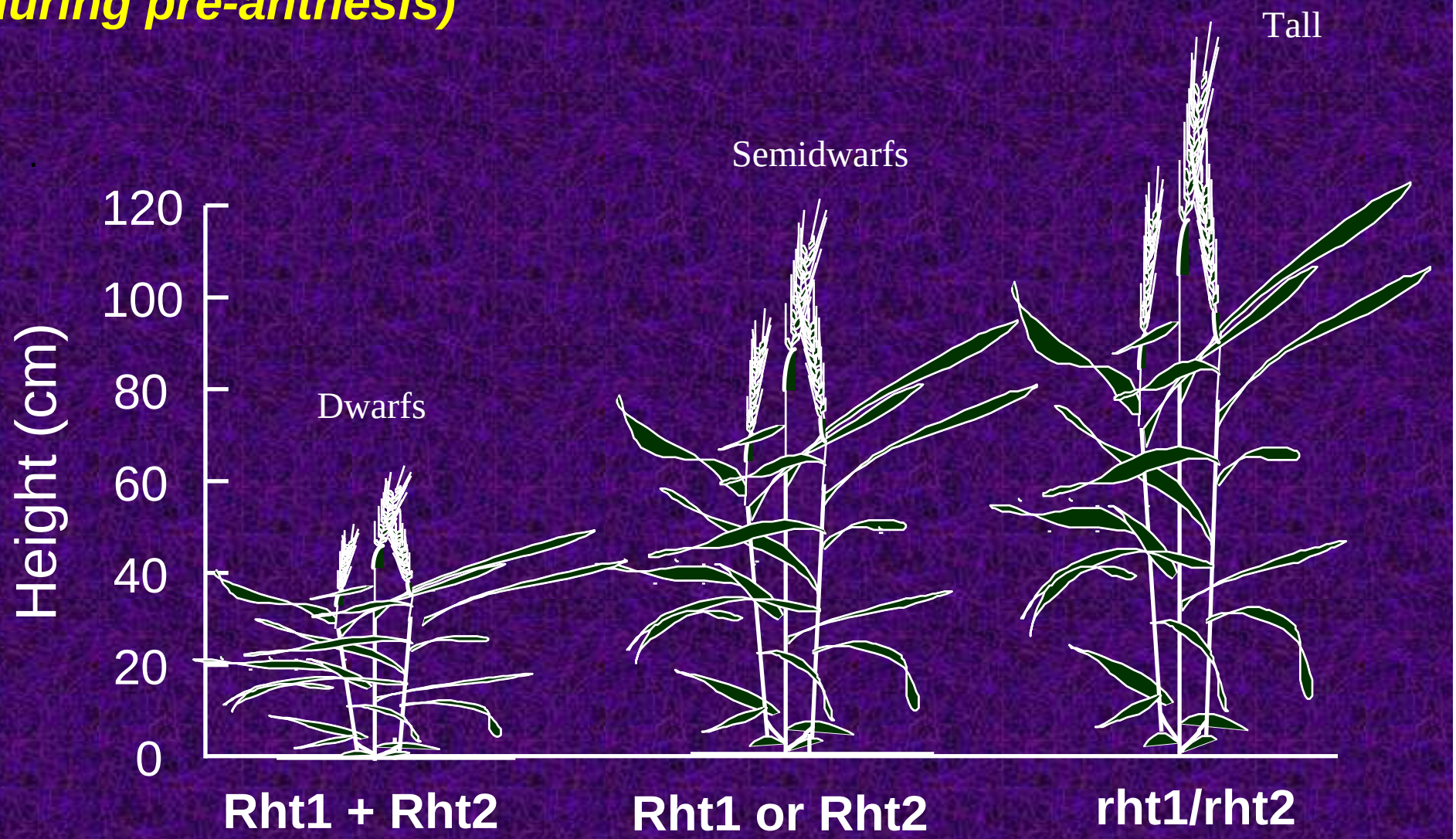
- ***for yield potential (e.g. Rht genes reducing the competitive ability of stems against spikes growing simultaneously during pre-anthesis)***



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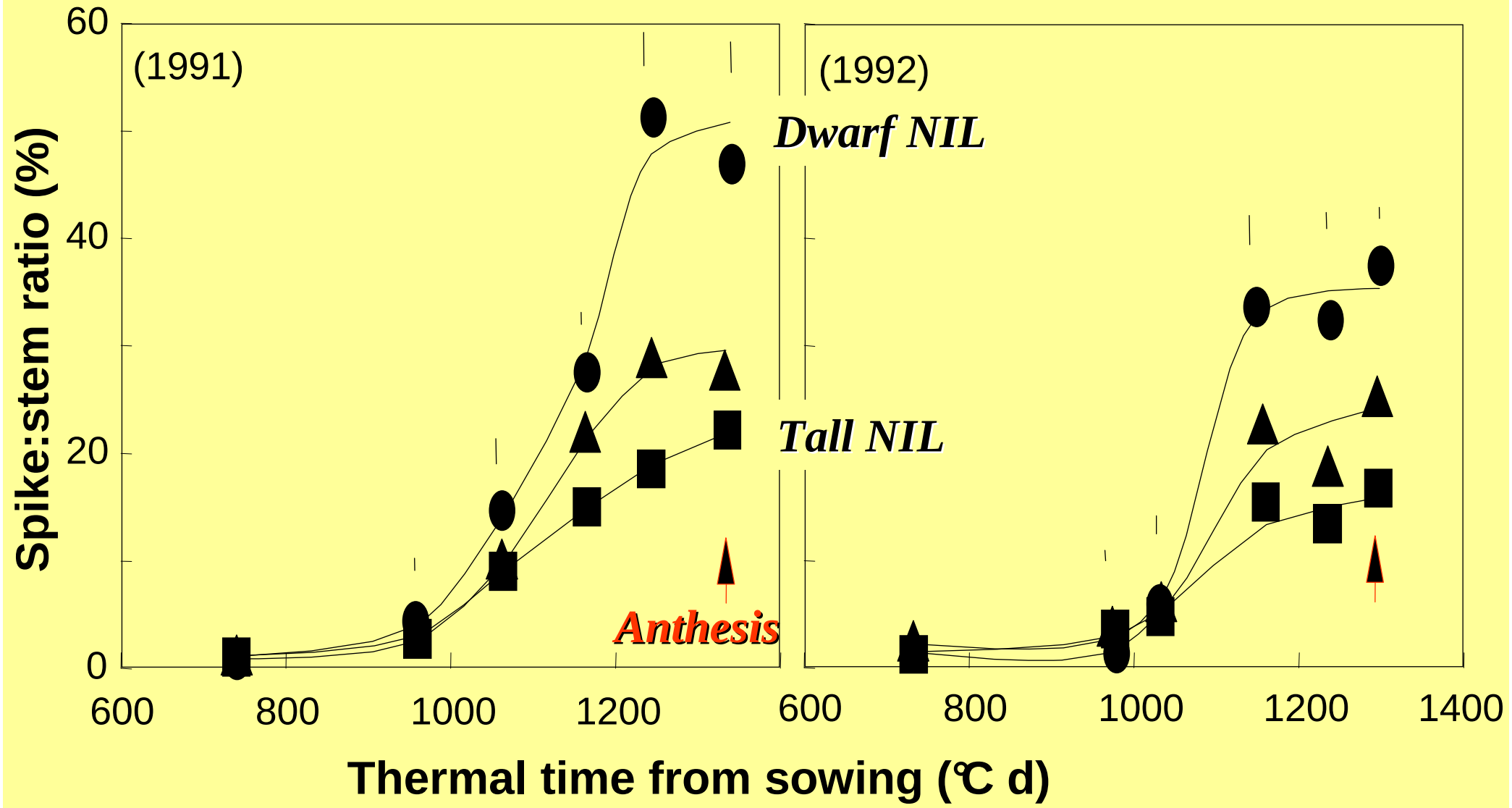

Miralles *et al* . (1998)

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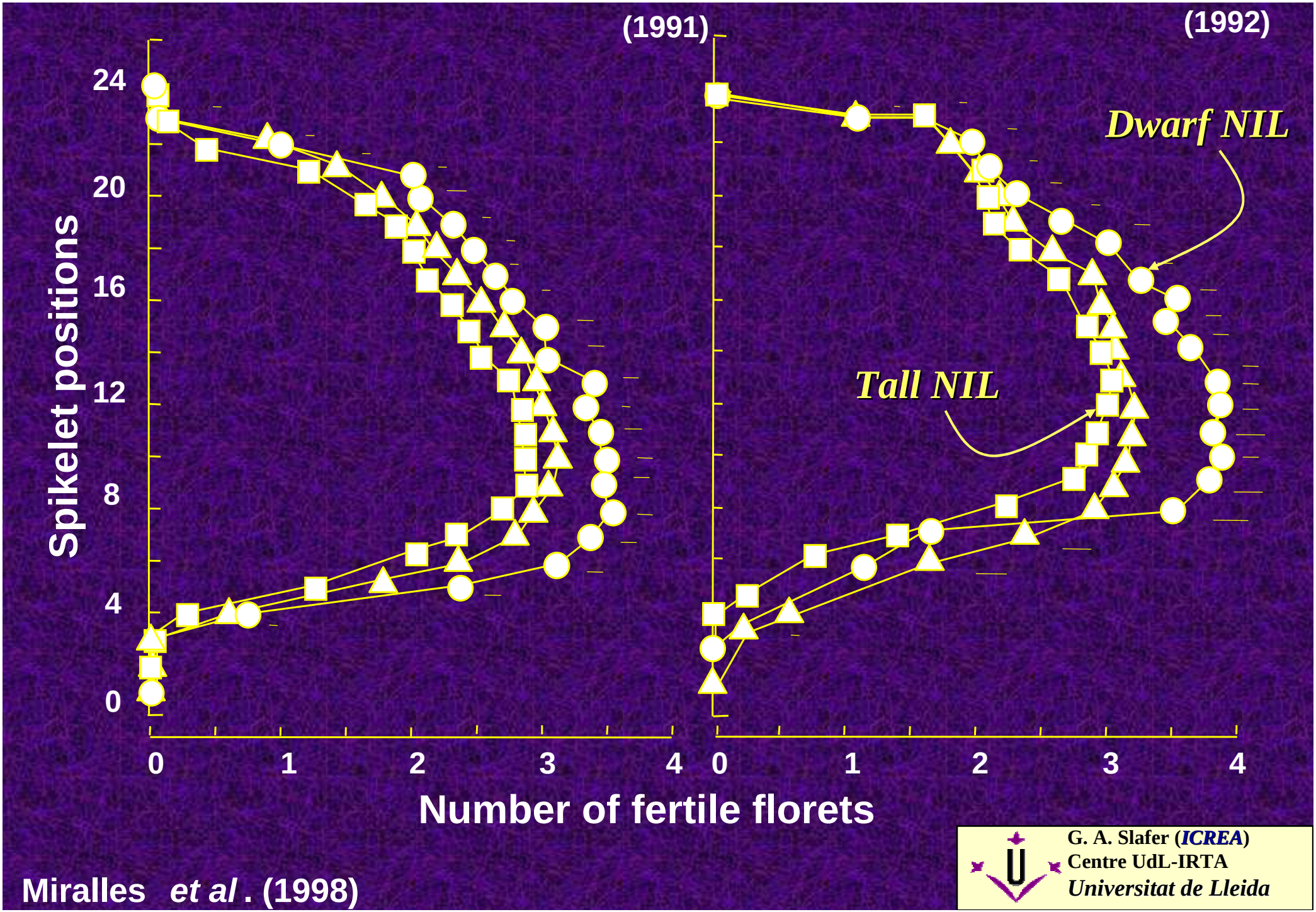
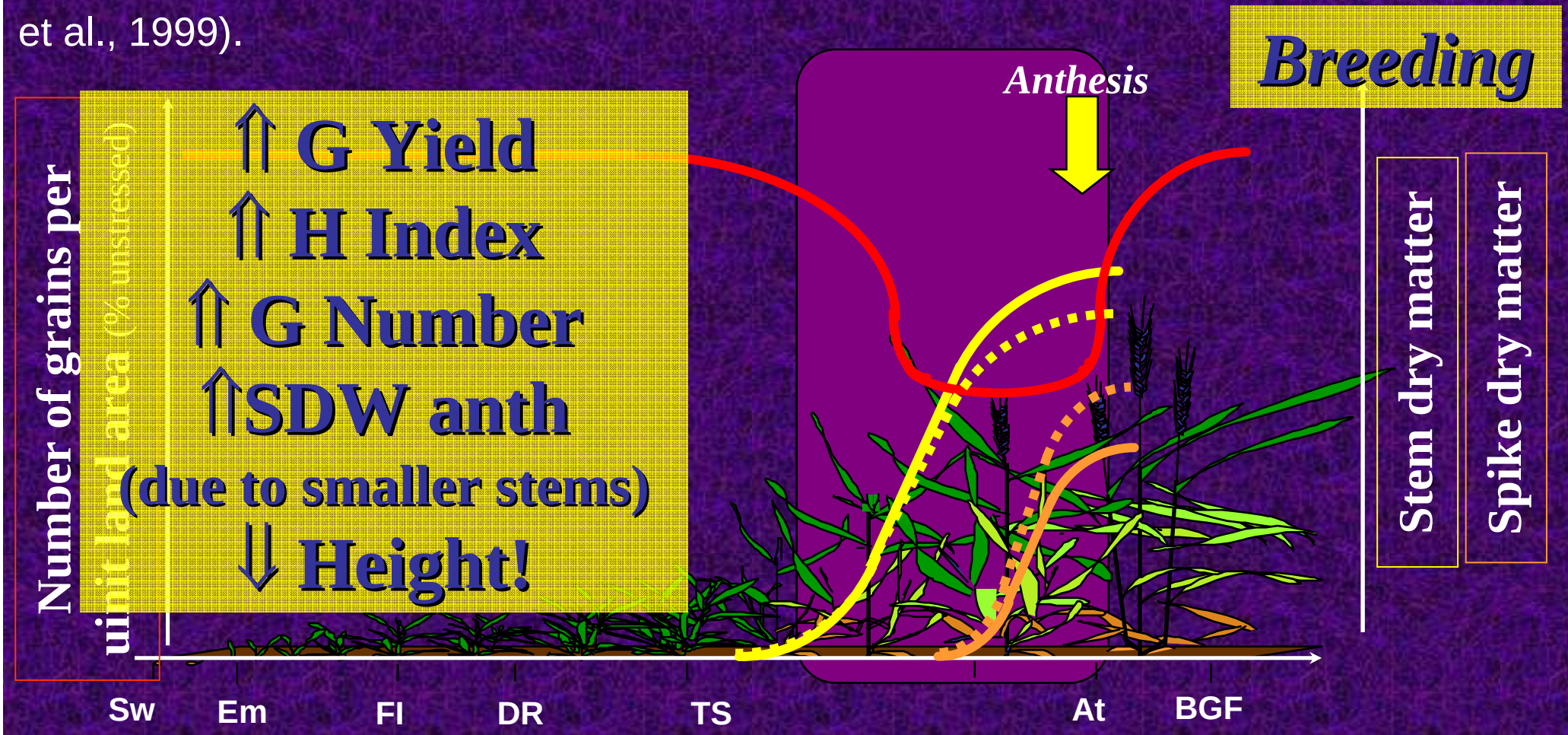

(1991)
(1992)
Dwarf NIL
Tall NIL
Spikelet positions
0
4
8
12
16
20
24
0
1
2
3
4
Number of fertile florets
Miralles et al. (1998)
G. A. Slafer (ICREA)
Centre UdL-IRTA
Universitat de Lleida

The growth of the spikes in this very short window of time is so relevant that most of the breeding success on improving wheat yields were based on improving this trait (*e.g.* Slafer et al, 1994; Calderini et al., 1999).



Timing when yield is mostly affected is affected

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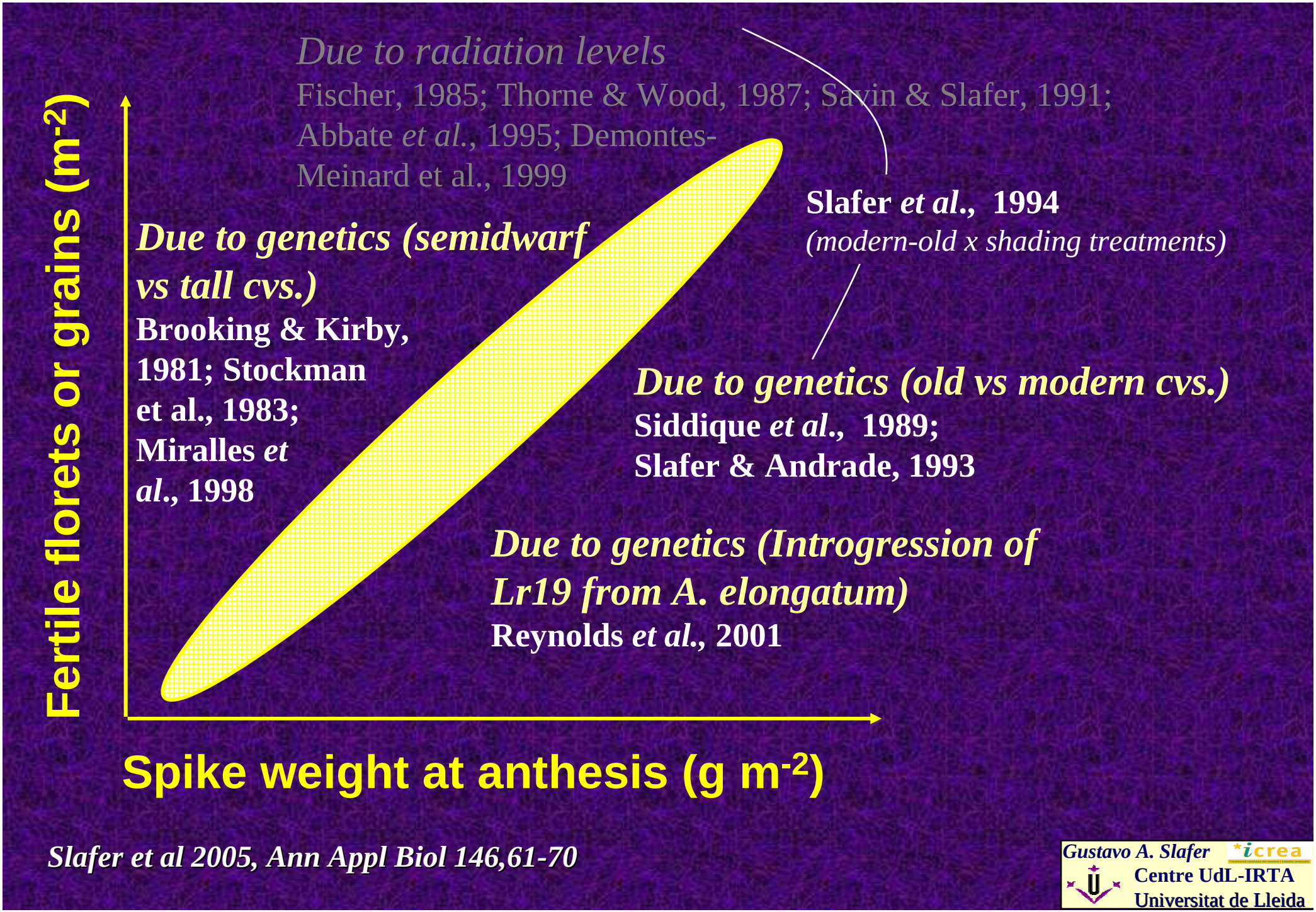

Slafer et al 2005, Ann Appl Biol 146,61-70

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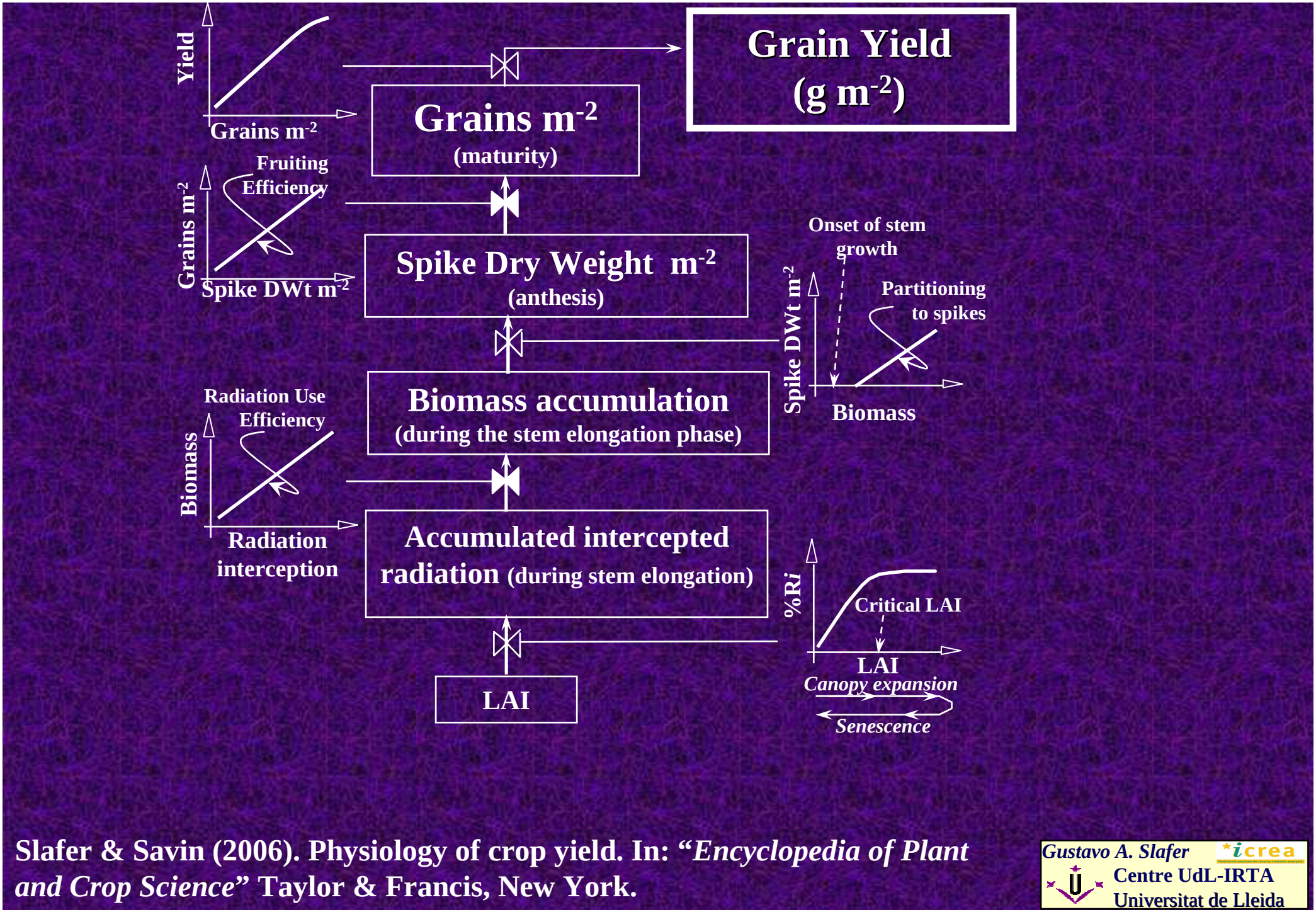

Slafer & Savin (2006). Physiology of crop yield. In: "*Encyclopedia of Plant and Crop Science*" Taylor & Francis, New York.

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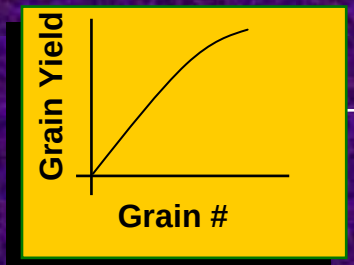
Optimizing development pattern…

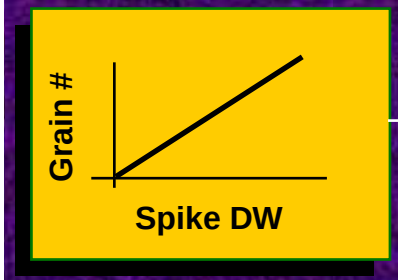
1.- brief description of what we have done

2.- overall proposal of what we want to do

Yield



Grain number m^{-2}



Spike Dry Weight (Anthesis)

Length of the growth period

Crop growth rate

Partitioning to growing spikes

further improvements in partitioning to the spike (reduce peduncle?) **and within the spike**

Past Breeding effects

Improvements in Ri (unlikely in most cases) or in RUE