

Red 110RT0394 METRICE
Mejorar la eficiencia en el uso de insumos y el ajuste fenológico en cultivos de trigo y cebada

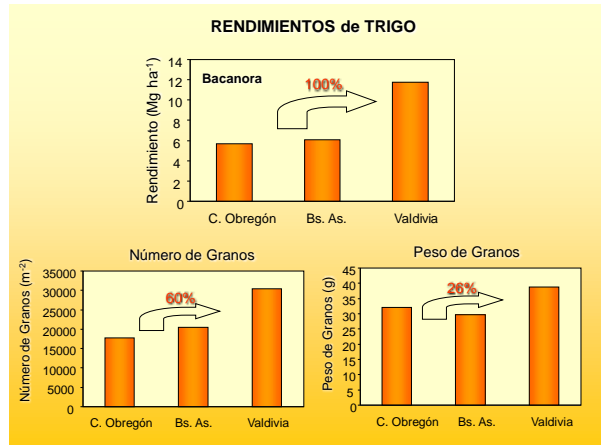
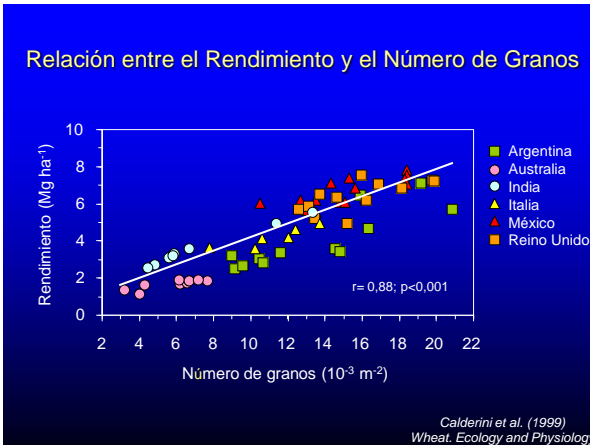
CYTED

Determinación del Rendimiento
Peso del grano: determinantes genéticas y ambientales del peso potencial
Peso final de los granos: Dinámicas de agua y materia seca en respuesta a las condiciones ambientales durante el llenado

Daniel F. Calderini
 Universidad Austral de Chile

Paysandú, diciembre 2012

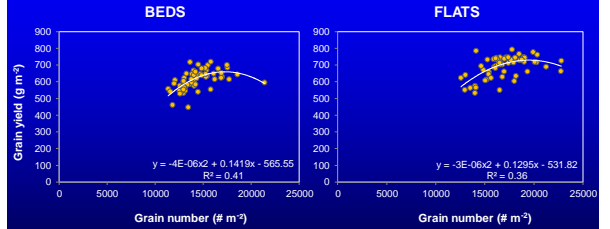
Rendimiento = Granos m⁻² x Peso de Grano

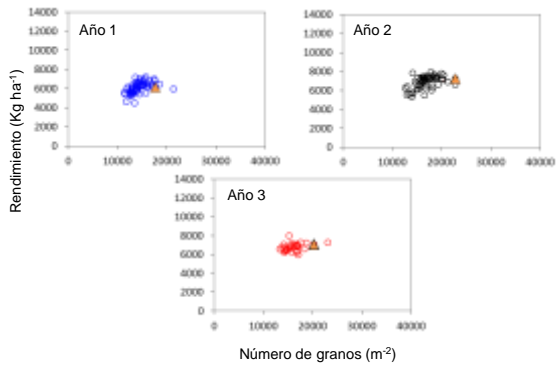
Rendimientos de Cebada

Sitio	Genotipo	Rendimiento (Mg ha ⁻¹)	NG	PG (g)
Bs. As.	Scarlet	7,2	17104	40,6
	"	9,2	24581	37,8
Valdivia	"	12,5	26773	46,6
	"	7,4%	36%	57%

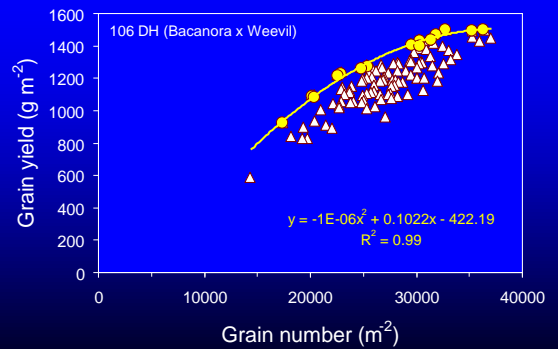
Relationship between yield and grain number



Genotipos CIMCOG

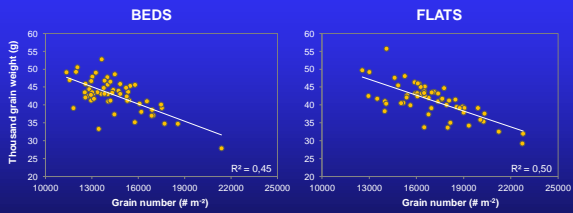


The need of increasing grain weight

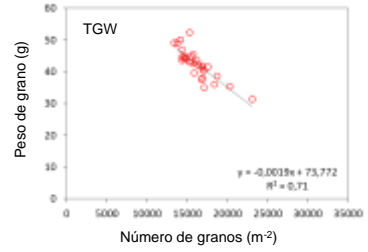


Hasan & Calderini (un published)

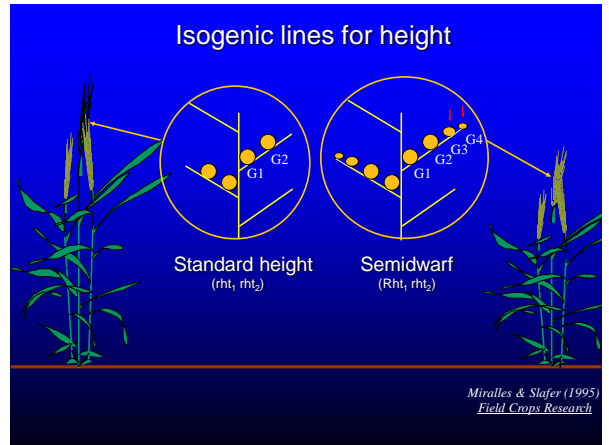
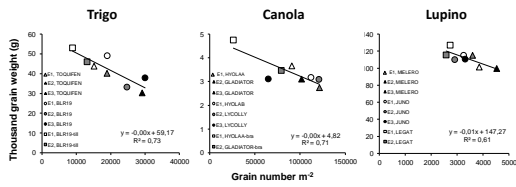
Trade off entre peso y número de granos en genotipos CIMCOG



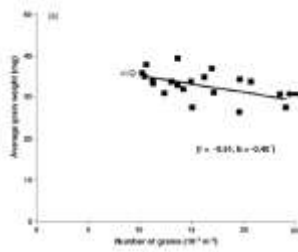
Genotipos CIMCOG



Relación entre peso y número de granos

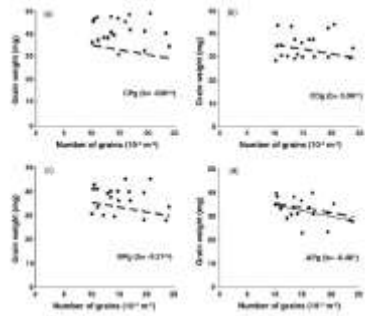


Relación entre el Peso y Número de Granos en Trigo

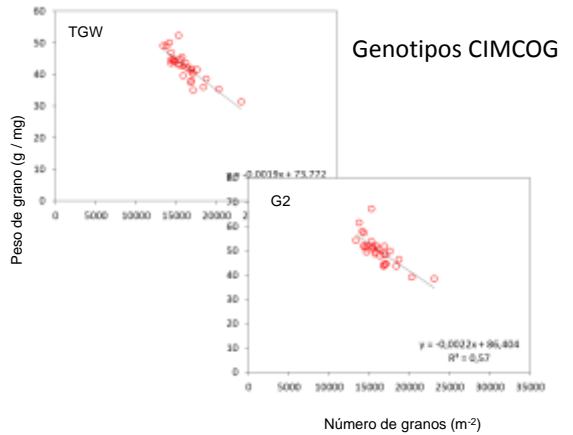
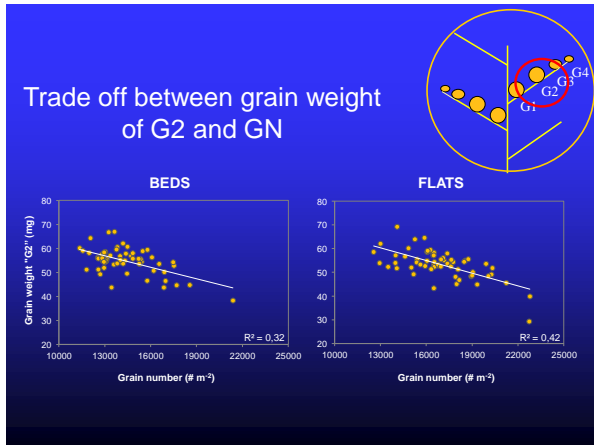


Acreche & Slafer (2006)
Field Crops Res.

Relación entre el Peso y Número de Granos en Trigo en Posiciones de Grano

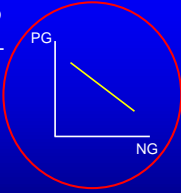


Acreche & Slafer (2006)
Field Crops Res.



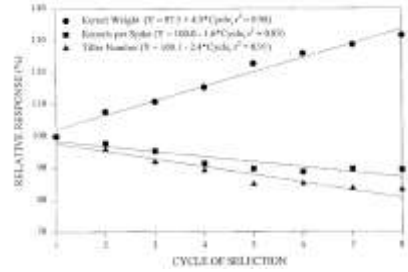
Selección Recurrente para Peso de Grano en Trigo

Ciclo	Peso de Grano (g)	Rendimiento (kg ha ⁻¹)
1	37.2	4065
2	40.0	4142
3	41.2	3888
4	42.9	3845
5	45.6	3797
6	46.8	3855
7	47.9	3920
8	48.9	3968



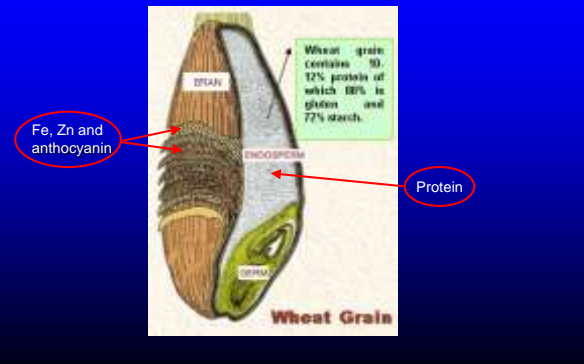
Wiersma et al. (2001)
Crop Science

Efecto de la Selección Recurrente para Peso de Grano Sobre los Componentes del Rendimiento

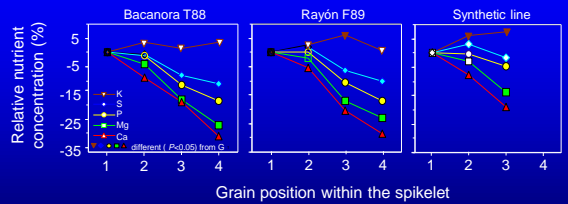


Wiersma et al. (2001)
Crop Science

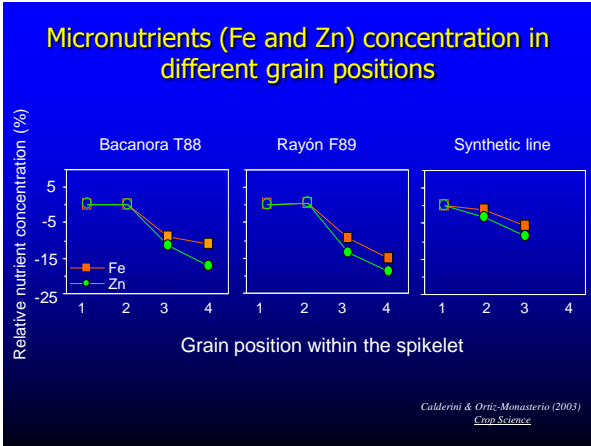
Protein, micronutrients and anthocyanin in wheat grains



Uneven Distribution of Nutrients Within the Spike



Calderini & Ortiz-Monasterio (2003)
Crop Science

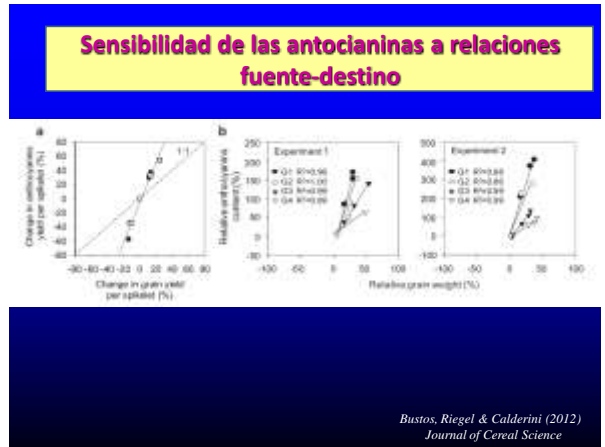
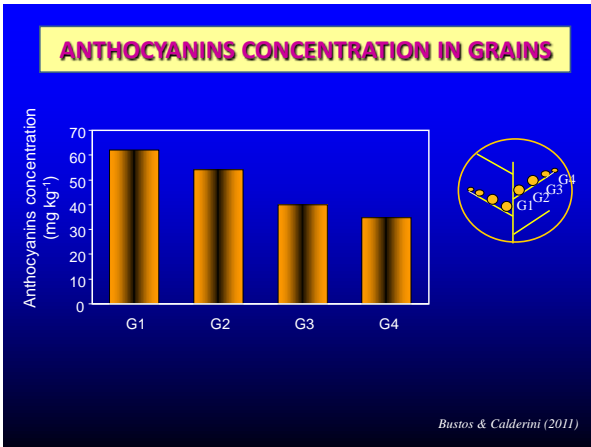


ANTIOXIDANT COMPOUNDS

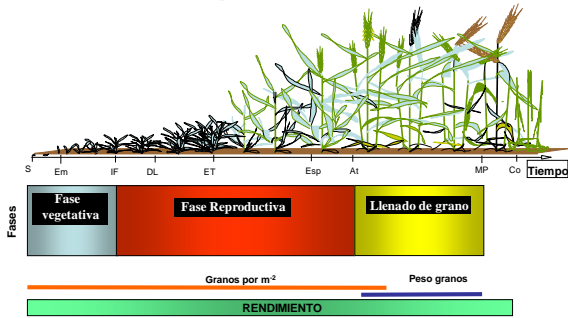
ANTHOCYANINS

White wheat, Red wheat, Purple wheat

Cyanidin 3-glucoside
Peonidin-3-glucoside

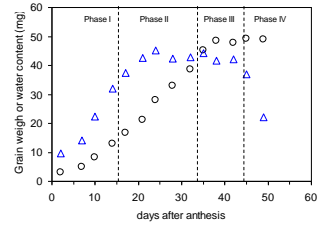


Ciclo del Cultivo de Trigo



Adaptado de Slafer y Rawson (1994)

Fases del Crecimiento de los granos

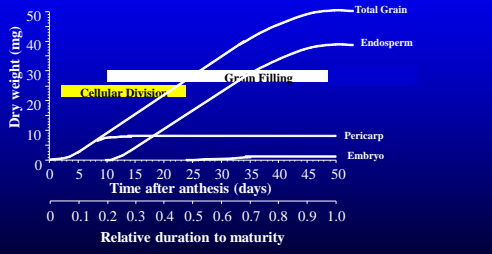


Dorsal view of whole grains at 24 and 48 hours after fertilization. The female stigmas have collapsed and the maternal tissue is swelling rapidly.



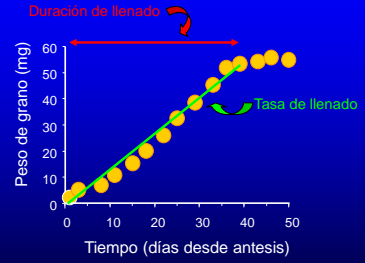
Whole grains at 6, 8 and 10 days after pollination. Between 6 and 8 days after flowering there is very rapid growth of both the outer maternal tissues and the liquid-filled embryo sac inside. At 10 days after flowering the 'Water-ripe' grain is ready to start the grain filling stages.

Pericarpio, Endosperma y Embrión durante el Crecimiento de Grano

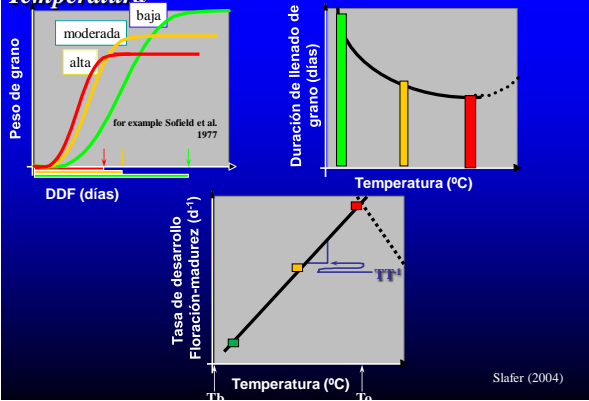


Savin, (1996)
Ph.D. Thesis

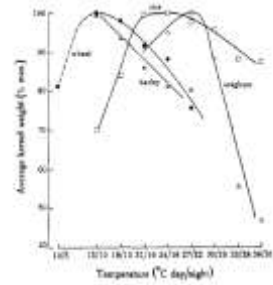
Llenado de Granos



Duración de la etapa floración-madurez fisiológica
Temperatura

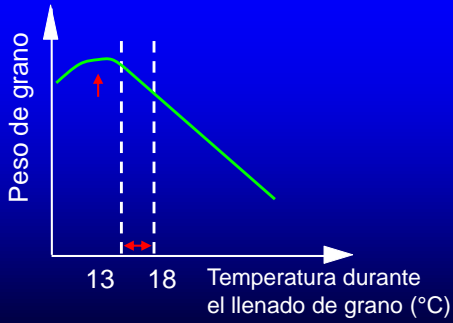


Respuesta del Peso de Grano a la Temperatura



Chowdhury & Wardlaw (1978)
Aust. J. Agric. Res.

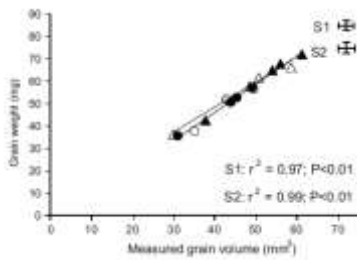
Efecto de la temperatura sobre el peso de grano



Adaptado de Chowdhury & Wardlaw (1978)
Australian Journal of Agricultural Research

Asociaciones entre el peso de grano y otros caracteres

Relación entre Peso y Volumen de Grano



Hasan & Caldenini (2011)
Field Crops Research

Peso Seco, Contenido Hídrico y Volumen de los Granos

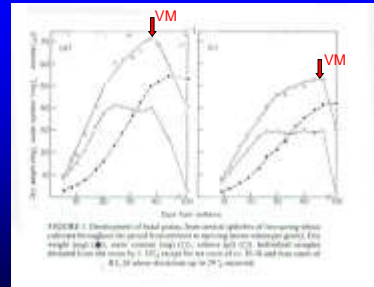
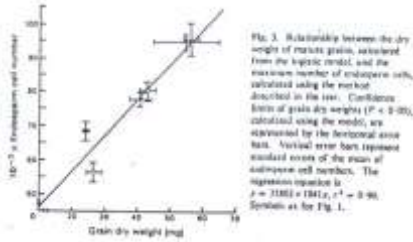


FIGURE 1. Development of final grain, non-starch polysaccharide (NSP) and starch content in grain (mg) and grain volume (mm³) over time (days) for two cultivars (S1, S2) and two harvest dates (H1, H2) under different irrigation treatments (I1, I2).

Millet & Pinthus (1984)
Journal of Cereal Science

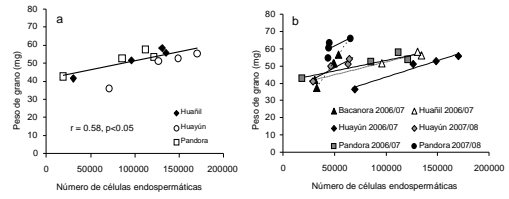
Importancia del Número de Células Endospermáticas

Brocklehurst (1977) mostró que existe relación entre el peso final de los granos de cebada y el número de células del endosperma



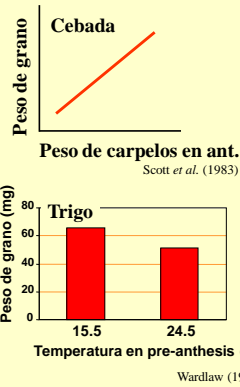
Gleadow et al. (1982) *Aust. J. Plant Physiol.*

Peso de Grano y Células Endospermáticas



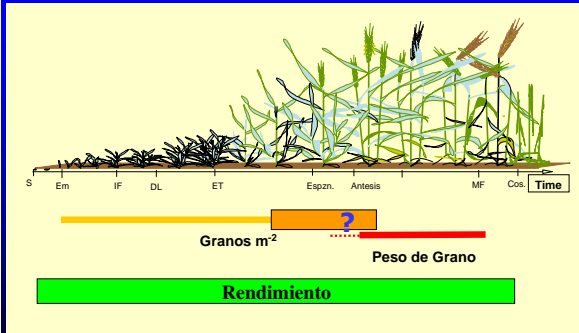
Lizana & Calderini (datos no publicados)

Efecto de la Temperatura en pre-Antesis



Algunos estudios muestran que el período pre-antesis podría tener importancia para el peso de los granos

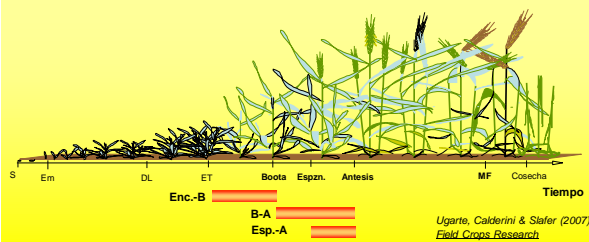
Determinación de los componentes del rendimiento



Evaluación del efecto de las temperaturas previas a la antesis sobre el rendimiento y sus componentes numéricos en cereales de invierno

Tratamientos:

- Genotipo: (1 cv. Trigo, 1 de cebada y 1 de triticale)
- Tratamientos térmicos
 - Testigo
 - Bota-Antesis
 - Espigamiento-Antesis
 - Inicio Encañado-Bota



Estructuras para Incrementar la Temperatura

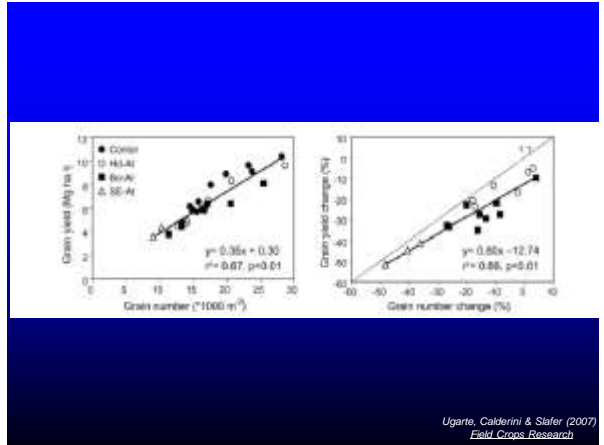


Ugarte, Calderini & Slafer (2007) Field Crops Research

Rendimientos de Trigo, Cebada y Triticale

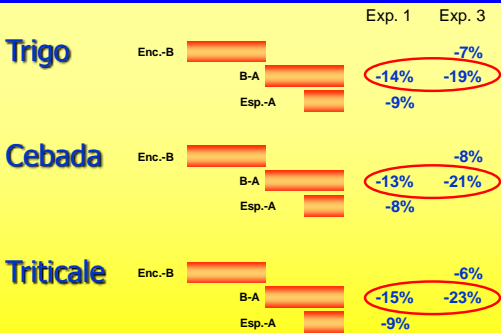
Cultivo	Exp.	Rendimiento (Mg ha ⁻¹)			
		Testigo	B-A	Esp.-A	Enc.-A
Trigo	1	10,4	8,0	9,6	-
	3	9,1	6,3	-	5,0
Cebada	1	6,5	5,9	6,1	-
	3	6,1	4,4	-	3,6
Triticale	1	7,9	5,7	6,6	-
	3	8,9	5,7	-	4,3

Ugarte, Calderini & Slafer (2007)
Field Crops Research



Ugarte, Calderini & Slafer (2007)
Field Crops Research

Reducción del Peso de Granos



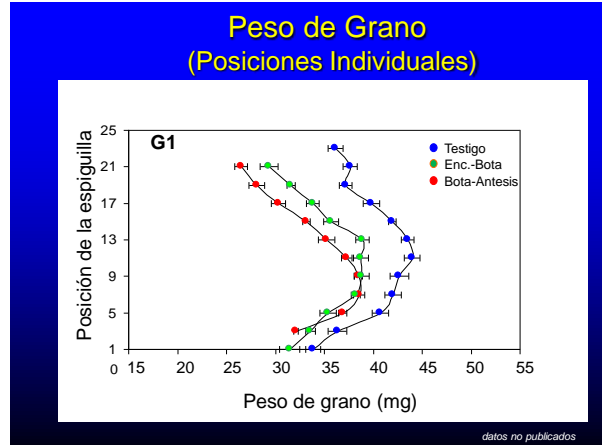
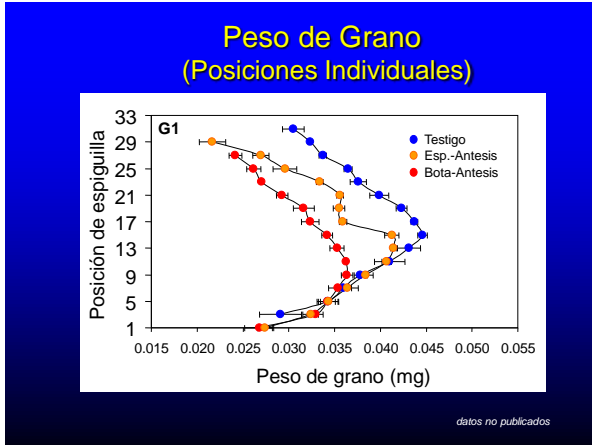
Ugarte, Calderini & Slafer (2007)
Field Crops Research

Table 3
Leaf area index of autumn (LAI₁), leaf area density (LAD) and grain number m⁻² leaf area density ratio (GPR-LAD) of Barred treatment in wheat, barley and triticale during three experimental years.

Crop	Harvest treatment ^a	LAI ₁ (m ² m ⁻²)			LAD (m ³ m ⁻²)			GPR-LAD (m ³ m ⁻²)		
		2000	2001	2002	2000	2001	2002	2000	2001	2002
Wheat	Control	9.9	9.2	9.3	119.6	94.8	92.8	244	177	235
	B-A	8.9	8.6	8.6	118.8	99.8	98.1	230	170	223
	Enc.-A	8.2	8.8	8.6	116.2	91.9	95.1	219	169	217
Barley	Control	6.2	6.0	6.3	118.8	108.7	105.1	136	135	144
	B-A	6.1	6.3	6.2	113.8	117.7	116.1	146	149	149
	Enc.-A	6.0	5.9	6.2	111.1	116.8	115.1	144	147	149
Triticale	Control	6.8	7.8	6.3	123.2	112.3	124.8	141	206	159
	B-A	6.4	6.2	6.1	122.9	108.1	111	141	148	141
	Enc.-A	6.1	5.8	6.1	116.7	109.8	118.2	131	131	141
S.E.M. ^b	0.1	0.1	0.2	2.3	1.9	2.1	30	37	31	

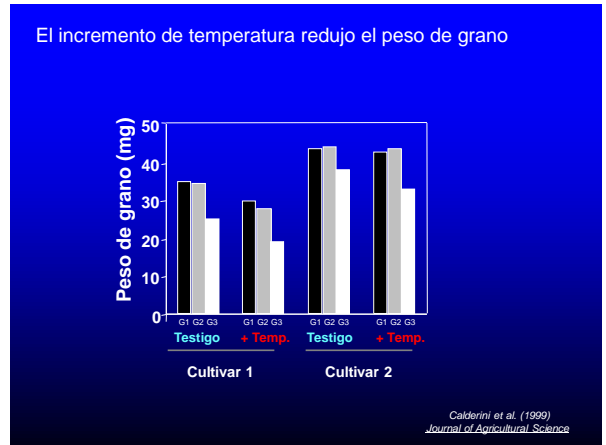
^a SE, B-A, and Enc.-A used for the crop of stem response, leaving, heading and panicle, respectively.
^b S.E.M. stands for the standard error of the mean.

Ugarte, Calderini & Slafer (2007)
Field Crops Research

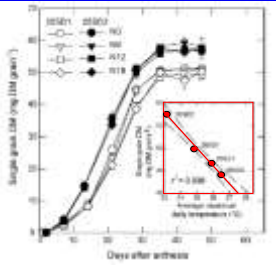


Experimentos donde se incrementaron las temperaturas 6 días previos a antesis

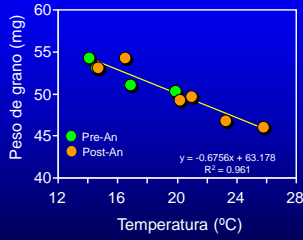
*Caklerini et al. (1999)
Journal of Agricultural Science*



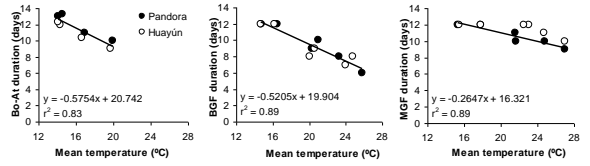
Temperaturas pre- y post-antesis se asocian con el peso final de los granos en trigo



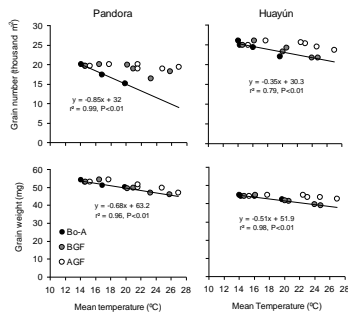
Ferrise et al. (2010)
Field Crops Research



Lizana & Calderini (2013)
Journal of Agricultural Science

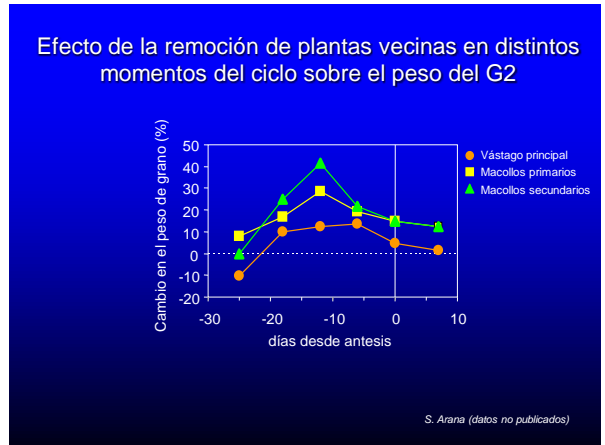
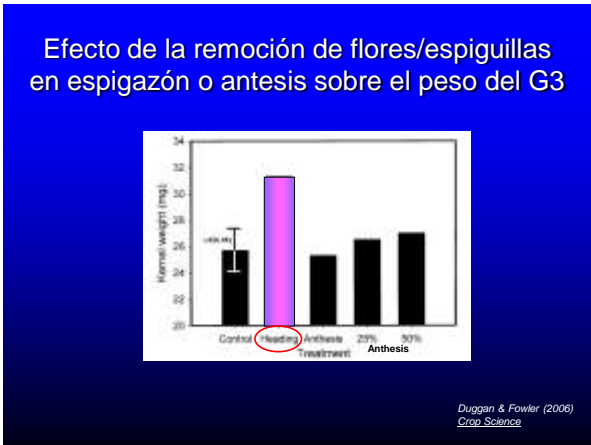
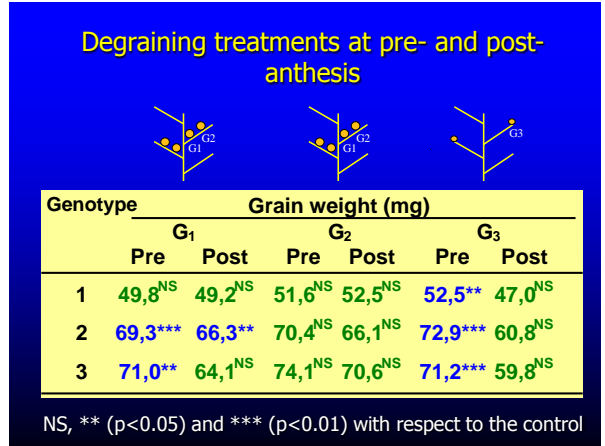
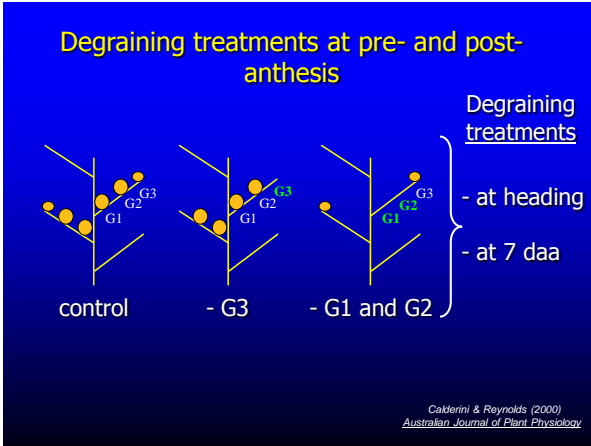


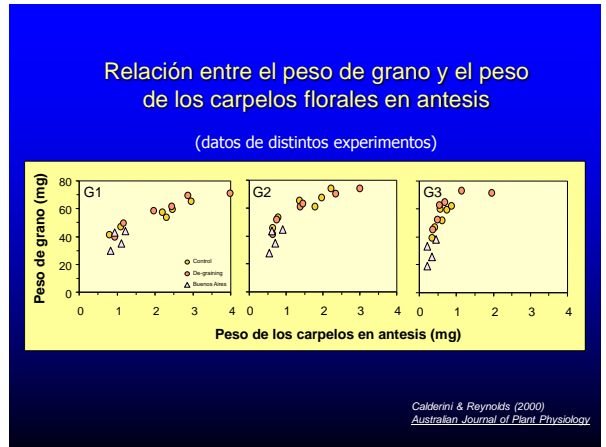
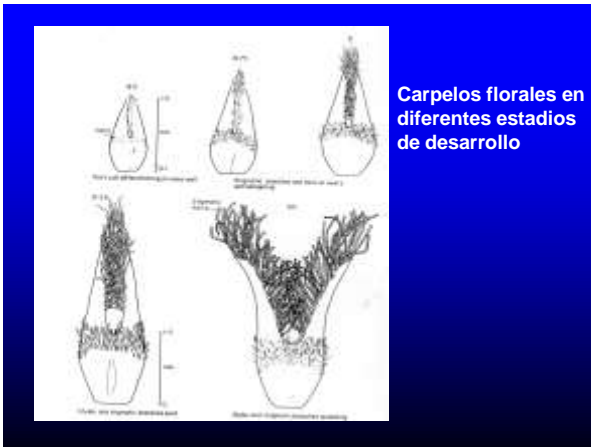
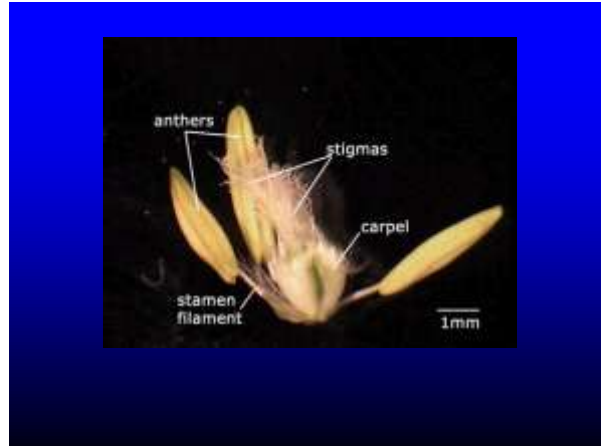
Lizana & Calderini (2013)
Journal of Agricultural Science



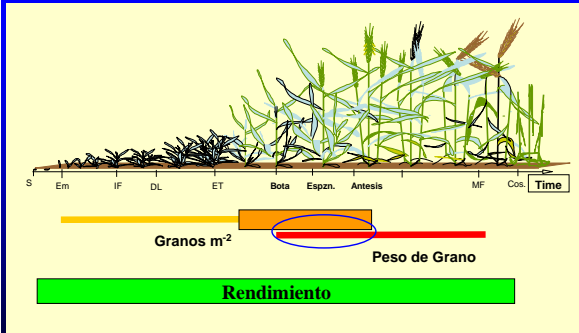
Lizana & Calderini (2013)
Journal of Agricultural Science

Efecto de la Relaciones Fuente-Destino en pre-Antesis

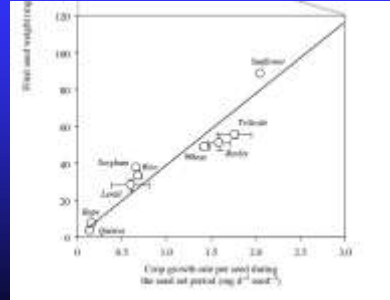




Determinación de los componentes del rendimiento



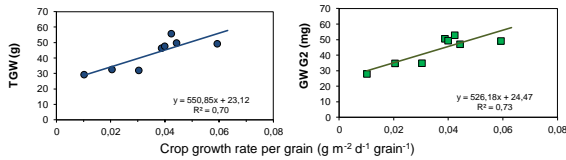
Relationship between grain weight and crop growth rate in different crops



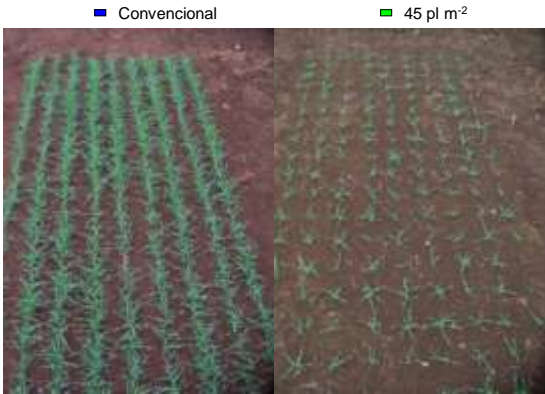
Gambin & Borrás (2010)
Annals of Applied Biology

C. Obregón 2010-11

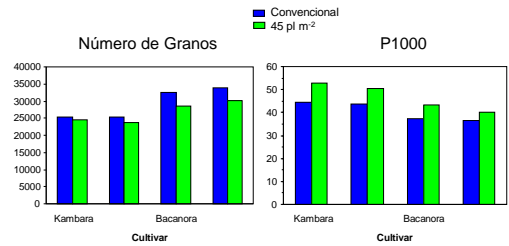
Relationship between grain weight and crop growth rate bracketing anthesis



La densidad y el arreglo espacial del cultivo afectan el peso potencial de los granos



Respuesta del número y el peso de grano a la densidad y arreglo espacial

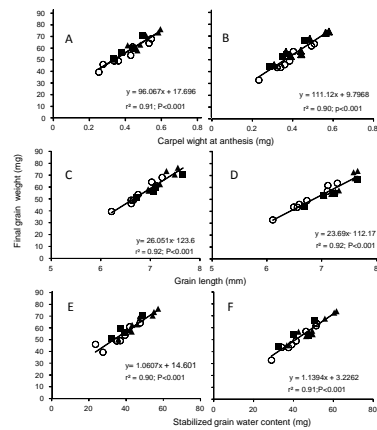


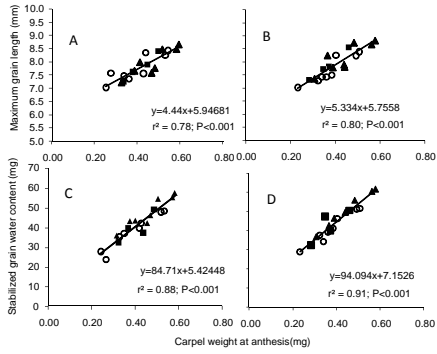
Hasan & Calderini (datos no publicados)

Peso de grano en respuesta a tratamientos fuente-destino

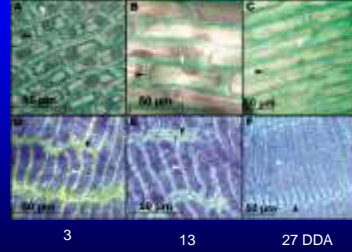
Cultivar	F:D	Peso de grano (mg)			
		G1	G2	G3	G4
Bacanora	Testigo	48.94	53.70	48.79	39.34
	Rem. flores	X	X	56.37	50.89
	Densidad	57.97	62.94	56.77	50.07
	10 DDA	52.59	58.73	52.44	44.16
Kambara	Testigo	64.15	67.94	60.96	45.96
	Rem. flores	X	X	70.37	59.27
	Densidad	73.38	76.21	70.41	62.36
	10 DDA	66.86	69.85	63.74	51.55

Hasan & Calderini (enviado a Field Crops Res.)



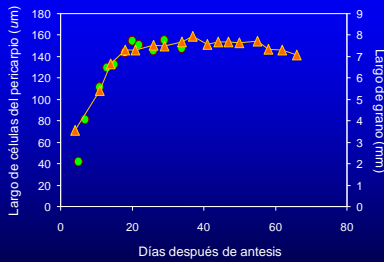


Células del pericarpio y cruzadas a los 3, 13 y 27 días después de antesis



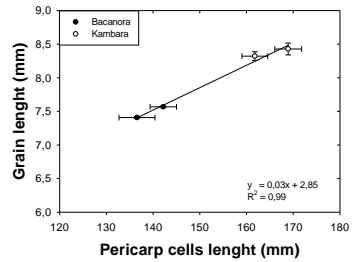
Herrera & Calderini (datos no publicados)

Dinámicas del largo de las células del pericarpio y el largo de grano

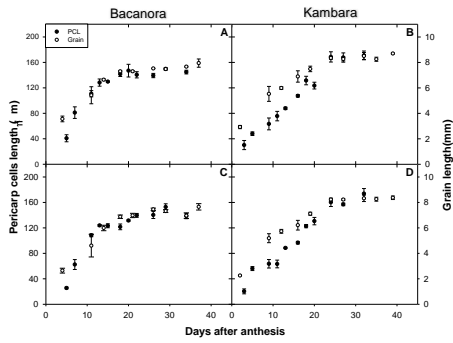


Herrera & Calderini (datos no publicados)

Relación entre el largo de grano largo y el largo de las células del pericarpio

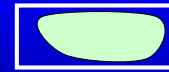


Dinámicas del largo de las células del pericarpio y el largo de grano



Crecimiento Celular

Respuestas del crecimiento celular y la expansión foliar



$$\Psi_a = \Psi_o + \Psi_p$$

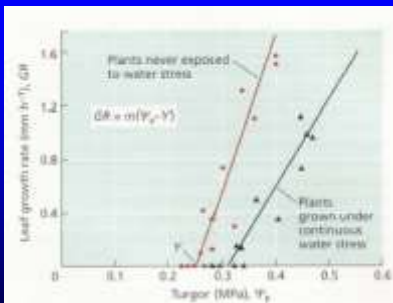
Deseccación celular

Expansión celular:

$$TC (m^3 s^{-1}) = m (\Psi_p - Y)$$

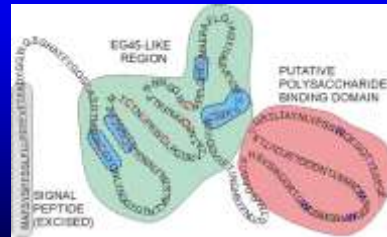
TC: tasa de crecimiento; m: extensibilidad de la pared; Y: umbral de crecimiento (presión mínima necesaria para extender la pared)

Tasa de Expansión Foliar con y sin Estrés Hídrico



Expansinas y crecimiento de grano

Las expansinas son proteínas que controlan el ablandamiento de la pared celular (McQueen-Mason et al., 1992)



<http://homes.bio.psu.edu/expansins>

Expansinas y crecimiento de grano

Debido al rol central que tienen las expansinas en el crecimiento celular evaluamos la relación entre estas proteínas y el crecimiento de los granos de trigo

En un estudio preliminar encontramos:

- ExpA 2
- ExpA 4
- ExpA 6
- ExpA 8
- Exp novel 1 (similar to *Festuca pratensis*)
- Exp novel 2 (similar to *Oriza sativa*)

Peso y Largo de Grano de Trigo

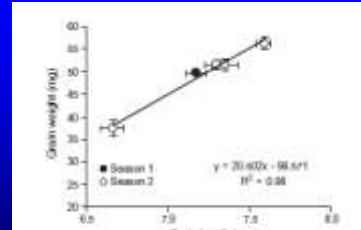
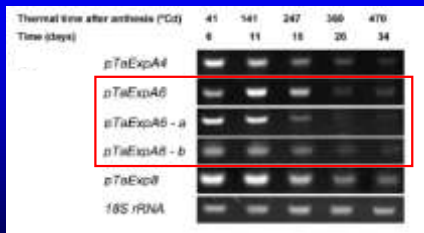


Fig. 2. Relationship between grain weight and stabilized grain length of grain position 2 in season 1 and positions 1-4 in growing season 2.

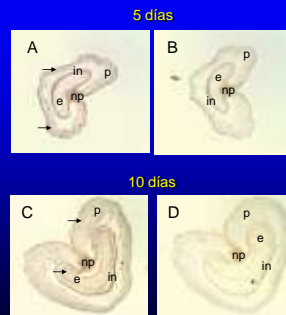
Lizana et al. (2010)
Journal of Experimental Botany

La expresión de expansinas (principalmente ExpA6) mostró una dinámica similar al alargamiento de los granos

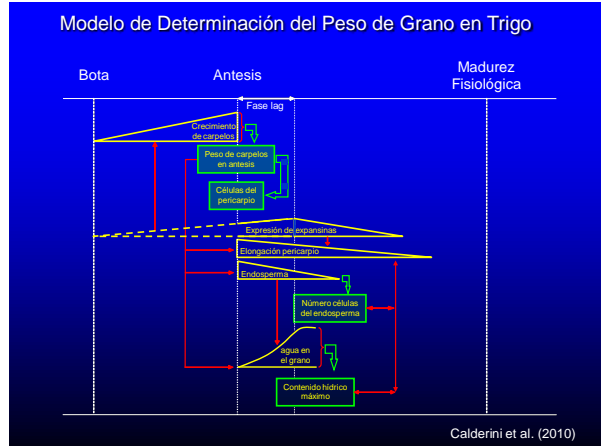
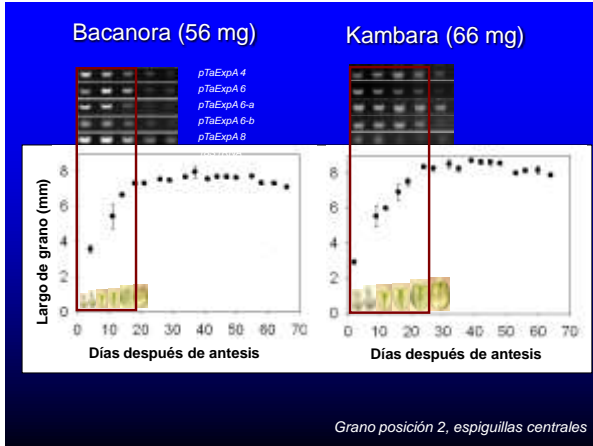


Lizana et al. (2010)
Journal of Experimental Botany

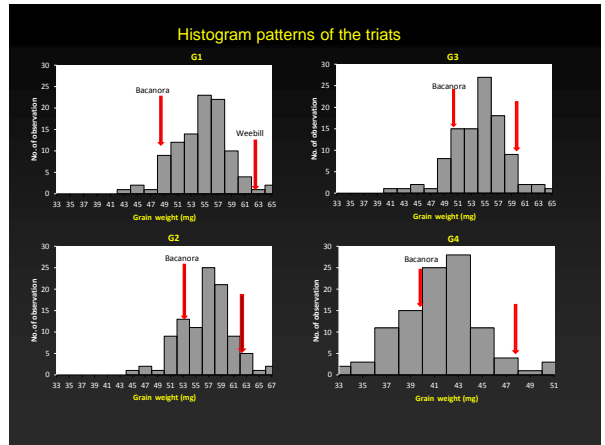
Hibridación de la ExpA 6 en granos después de antesis



Lizana et al. (2010)
Journal of Experimental Botany



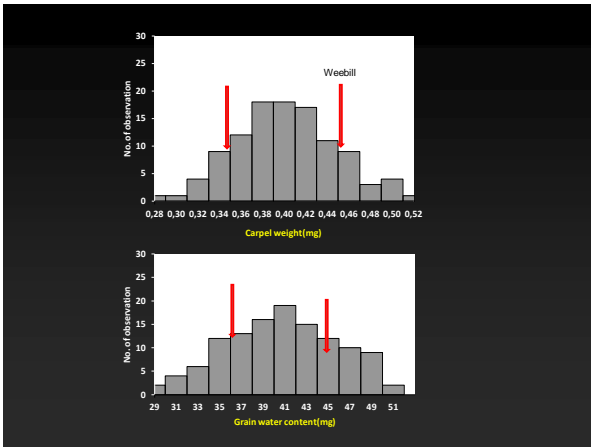
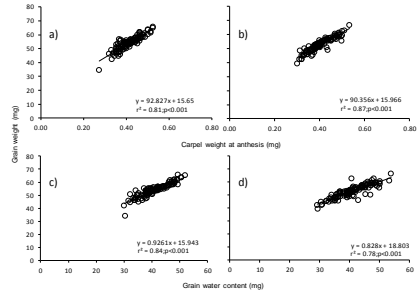
Población doble haploide Bacanora x Weebil (106 líneas)



Trait	Grain position	Mean square			Heritability h ²
		Grain growing condition	Genotype	GXE	
G1W	1	3860.0	480.00	14.00	0.97
G2W	2	4078.0	505.00	15.00	0.97
G3W	3	4858.0	424.00	20.00	0.95
G4W	4	8760.0	341.00	17.00	0.95
CW	2	0.0067	0.01	0.0025	0.81
GWC	2	<i>4.1</i>	149.34	15.93	0.89
G1L	1	8.5	1.70	<i>0.10</i>	0.94
G2L	2	8.8	1.80	<i>0.10</i>	0.94
G3L	3	8.3	1.80	<i>0.10</i>	0.94
G4L	4	14.3	1.20	<i>0.10</i>	0.92
G1wd	1	2.1	0.27	<i>0.03</i>	0.89
G2wd	2	1.9	0.29	<i>0.03</i>	0.90
G3wd	3	2.0	0.25	<i>0.03</i>	0.88
G4wd	4	5.3	0.30	<i>0.05</i>	0.83
G1V	1	2111.0	247.00	16.00	0.94
G2V	2	1931.0	273.00	16.00	0.94
G3V	3	2352.0	211.00	22.00	0.90
G4V	4	4111.0	157.00	16.00	0.90

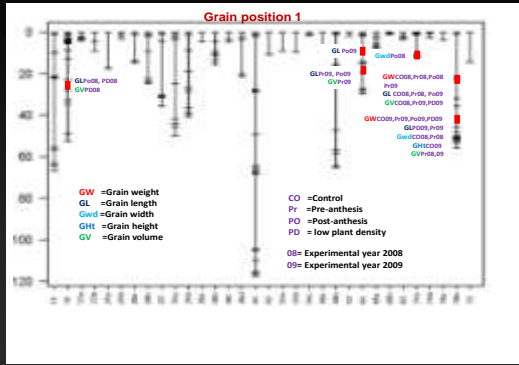
GW = Grain weight, CW =Carpel weight, GWC =Grain water content, GL =Grain length, Gwd =Grain width, GV =Grain volume. 1= grain position 1, 2= grain position 2, 3= grain position 3, 4= grain position 4. All the red marks italic values denotes the non-significant.

Relationships between grain weight and carpel weight and grain water content

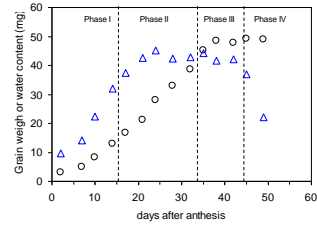


Crop	Traits	Chromosomes with interval(s) carrying QTLs(Chromosomes arranged in homologous groups)						
		1H	2H	3H	4H	5H	6H	7H
Barley	Grain weight	1H	2H	3H	4H	5H	6H	7H
	Grain number	1H	3H	4H	5H	6H		
Wheat	Grain weight	1A,1B,1D	2A,2B,2D	3A,3B,3D	4A,4B,4D	5A,5B	6A,6B,6D	7A,7B,7D
	Grain number	1A,1B	2A,2B,2D	3A,3B,3D	4A,4B	5A,5B,5D	6A	7A,7B
	Grain length and width	1A,1D	2B,2D		4B	5A,5B,5D	6A,6B	
Rice	Grain weight	5	4,7	1	3	9,11,12	2	6,8
	Grain number	5,10	4	1	3	12	2	6,8
Maize	Grain weight	1	2,7	3	5	-	4	-
	Grain number							
Sorghum	Grain weight	E,C	B,F	G	V	1	D,F	A
	Grain number							

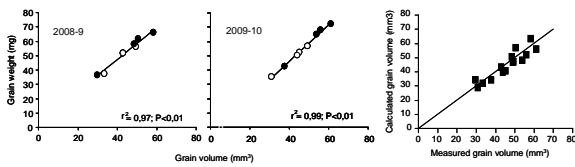
QTLs on grain position 1



Fases del Crecimiento de los granos

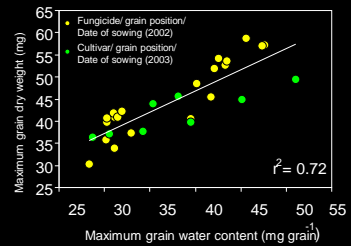


Relación entre el Peso y el Volumen de los Granos



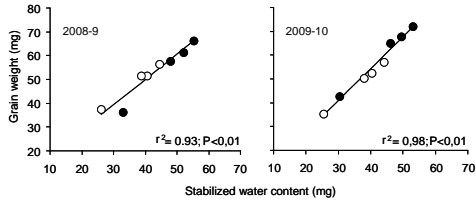
Hasan et al. (2011)
Field Crops Res.

Relación entre el Peso y el Contenido Hídrico de los Granos



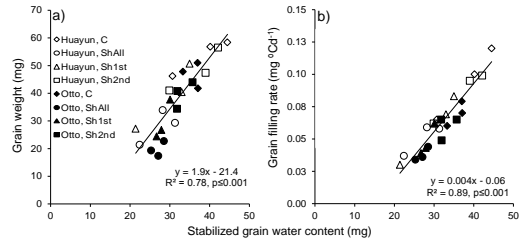
Pepler et al. (2006)
Field Crops Res.

Relación entre el Peso y el Contenido Hídrico Estabilizado de los Granos



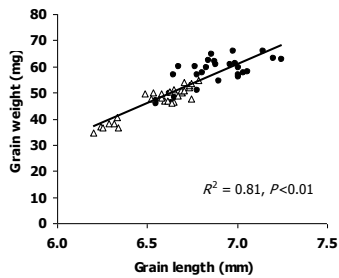
Hasan et al. (2011)
Field Crops Res.

Relación entre el Peso y el Contenido Hídrico Estabilizado de los Granos en Distintas Relaciones Fuente-Destino



Harcha & Calderini
Enviado a Europ. J. Agron.

Relación entre el Peso y el Largo de los Granos en Distintas Condiciones Térmicas



Lizana & Calderini (2012)
International Crop Science Conference

Peso Seco, Contenido Hídrico y Volumen de los Granos

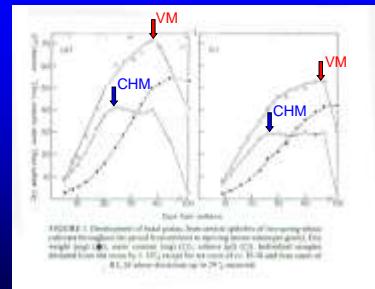
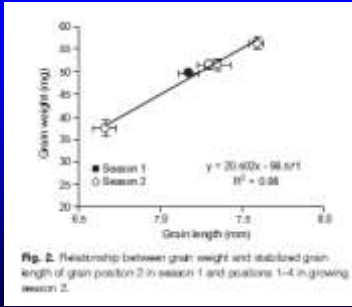


FIGURE 1. Development of final grain, non-starch polysaccharide (NSP) and starch content in grain, and grain weight (mg), water content (mg 100 g⁻¹), volume (μl 10³ g⁻¹) and final weight (mg) of grain (mg) for six genotypes of wheat (cv. 'Santitas' and 'Santitas 2') during grain filling.

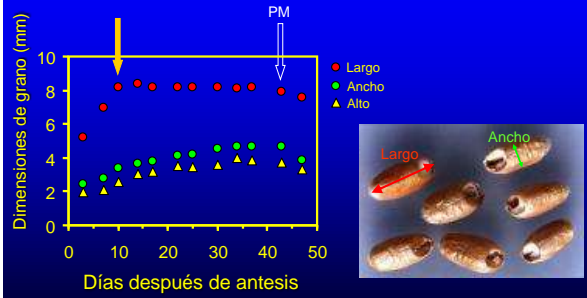
Millet & Pinthus (1984)
Journal of Cereal Science

Peso y Largo de Grano de Trigo



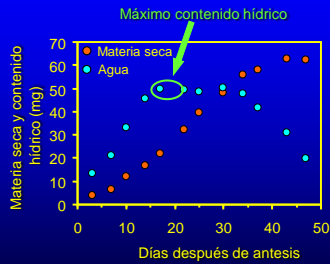
Lizana et al. (2010)
Journal of Experimental Botany

Dinámica de las dimensiones de grano



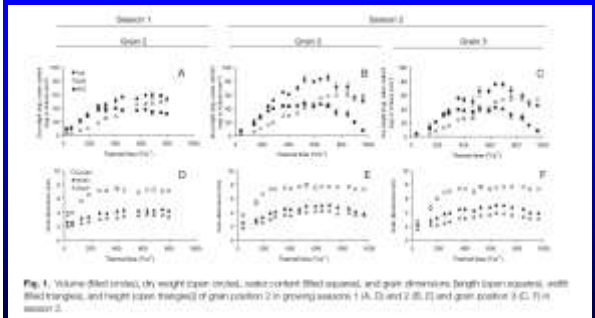
Lizana et al. (2010)
Journal of Experimental Botany

Dinámica de la materia seca y el contenido hídrico de los granos



Lizana et al. (2010)
Journal of Experimental Botany

Dinámicas del Grano



Lizana et al. (2010)
Journal of Experimental Botany

Relación entre las Dinámicas

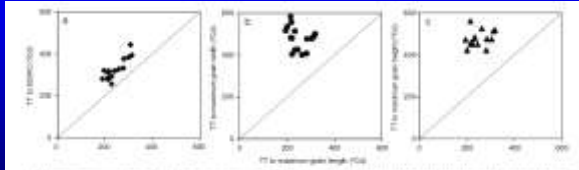


Fig. 4. Relationships among dynamics of 21 stabilized pure lines across 5/2000, 5/2001, and 5/2002 for grain length and timing of maximum grain length (DGL) across and within 5/2000-2002 (n=21 lines).

Hasan et al. (2011)
Field Crops Res.

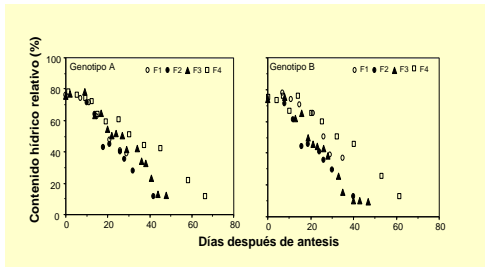
Valores estabilizados y Duraciones del Grano

Table 1: Statistical parameters for 21 stabilized pure lines across 5/2000, 5/2001, and 5/2002. The table lists various traits including grain yield, grain length, and flowering time. A red box highlights specific values for grain yield (DGL) and grain length (DGL) for the 21 lines.

Line	Grain yield (kg/ha)	DGL (mm)	DGL (mm)	DGL (mm)	DGL (mm)	Flowering time (days)	Flowering time (days)	Flowering time (days)	Flowering time (days)	Flowering time (days)
1	752.8	485.5	485.5	485.5	752.8	209.7	148.4	148.4	148.4	209.7
2	776.4	484.8	484.8	484.8	776.4	209.7	148.4	148.4	148.4	209.7
3	813.1	484.8	484.8	484.8	813.1	209.7	148.4	148.4	148.4	209.7
4	833.9	484.8	484.8	484.8	833.9	209.7	148.4	148.4	148.4	209.7
5	833.9	484.8	484.8	484.8	833.9	209.7	148.4	148.4	148.4	209.7
6	833.9	484.8	484.8	484.8	833.9	209.7	148.4	148.4	148.4	209.7
7	833.9	484.8	484.8	484.8	833.9	209.7	148.4	148.4	148.4	209.7
8	833.9	484.8	484.8	484.8	833.9	209.7	148.4	148.4	148.4	209.7
9	833.9	484.8	484.8	484.8	833.9	209.7	148.4	148.4	148.4	209.7
10	833.9	484.8	484.8	484.8	833.9	209.7	148.4	148.4	148.4	209.7
11	833.9	484.8	484.8	484.8	833.9	209.7	148.4	148.4	148.4	209.7
12	833.9	484.8	484.8	484.8	833.9	209.7	148.4	148.4	148.4	209.7
13	833.9	484.8	484.8	484.8	833.9	209.7	148.4	148.4	148.4	209.7
14	833.9	484.8	484.8	484.8	833.9	209.7	148.4	148.4	148.4	209.7
15	833.9	484.8	484.8	484.8	833.9	209.7	148.4	148.4	148.4	209.7
16	833.9	484.8	484.8	484.8	833.9	209.7	148.4	148.4	148.4	209.7
17	833.9	484.8	484.8	484.8	833.9	209.7	148.4	148.4	148.4	209.7
18	833.9	484.8	484.8	484.8	833.9	209.7	148.4	148.4	148.4	209.7
19	833.9	484.8	484.8	484.8	833.9	209.7	148.4	148.4	148.4	209.7
20	833.9	484.8	484.8	484.8	833.9	209.7	148.4	148.4	148.4	209.7
21	833.9	484.8	484.8	484.8	833.9	209.7	148.4	148.4	148.4	209.7

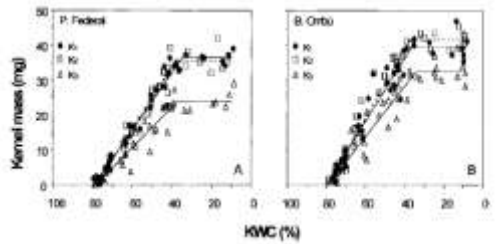
Hasan et al. (2011)
Field Crops Res.

Contenido Hídrico de los Granos



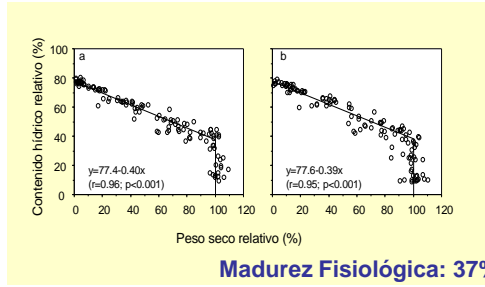
Calderini et al. (2000)
Agronomy Journal

Peso de Grano y Contenido Hídrico



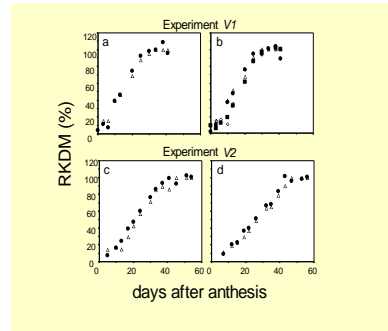
Calderini et al. (2000)
Agronomy Journal

Relación entre el Contenido Hídrico y el Peso de los Granos (%)



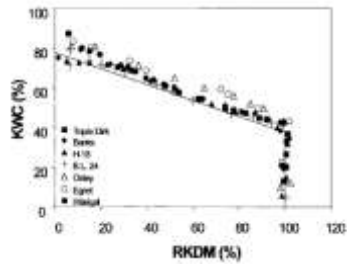
Calderini et al. (2000)
Agronomy Journal

Validación del Modelo de Contenido Hídrico



Calderini et al. (2000)
Agronomy Journal

Validación del Modelo de Contenido Hídrico



Calderini et al. (2000)
Agronomy Journal

La temperatura durante el llenado de granos

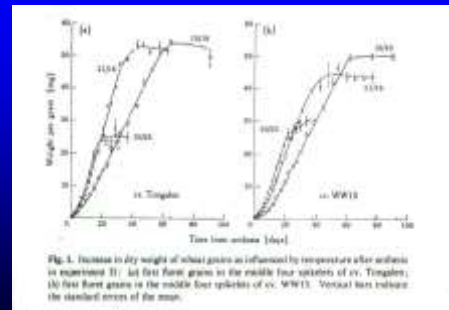


Fig. 3. Increase in dry weight of wheat grains as influenced by temperature after anthesis in experiment 31: (a) first four grains in the middle four varieties of cv. Tongahra; (b) first four grains in the middle four varieties of cv. WW13. Vertical bars indicate the standard errors of the mean.

Sofield et al. (1977)

Peso de Grano

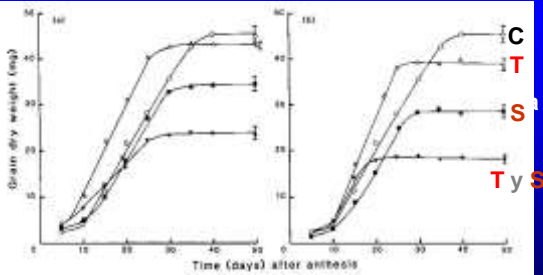


Fig. 2. Grain dry weight of plants subjected to treatments during the early period (a) and late period (b) of cell division. Curves were fitted using a logistic model. ○ Control, △ High temperature, ■ Drought, ▼ Drought x high temperature. Error bars, representing confidence limits ($P=0.05$) of the asymptotic weight, K , were calculated using the model.