Bases fisiológicas y genéticas de la generación del rendimiento y la calidad en trigo pan y cebada cervecera. Implicancias para el manejo agronomico y el mejoramiento genetico

Factores ambientales que determinan la fenología y la adaptación a distintos ambientes y su cuantificación.

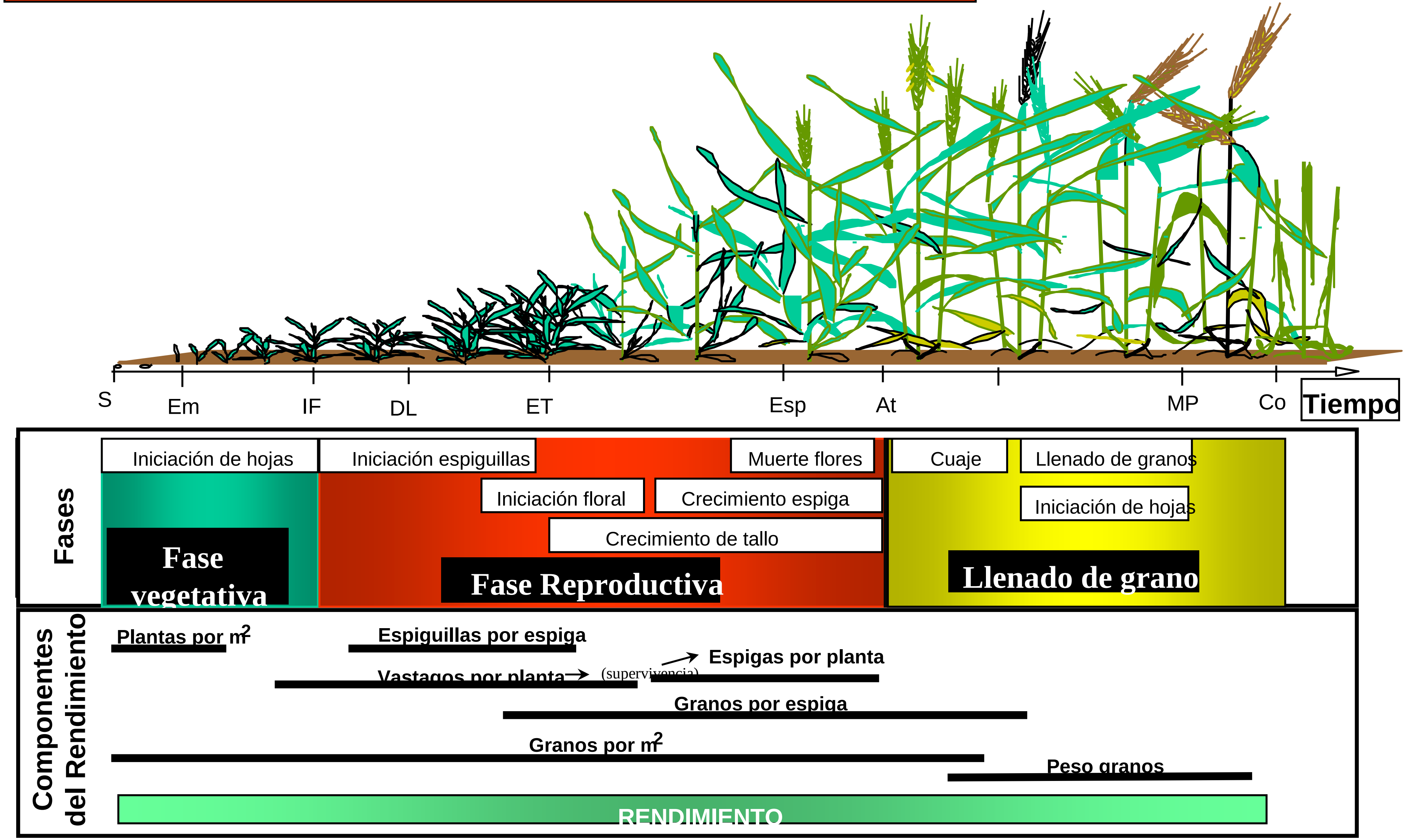
Daniel J. Miralles, Fernanda González, Gabriela Abeledo, Ignacio Alzueta

Curso CYTED-INTA Pergamino

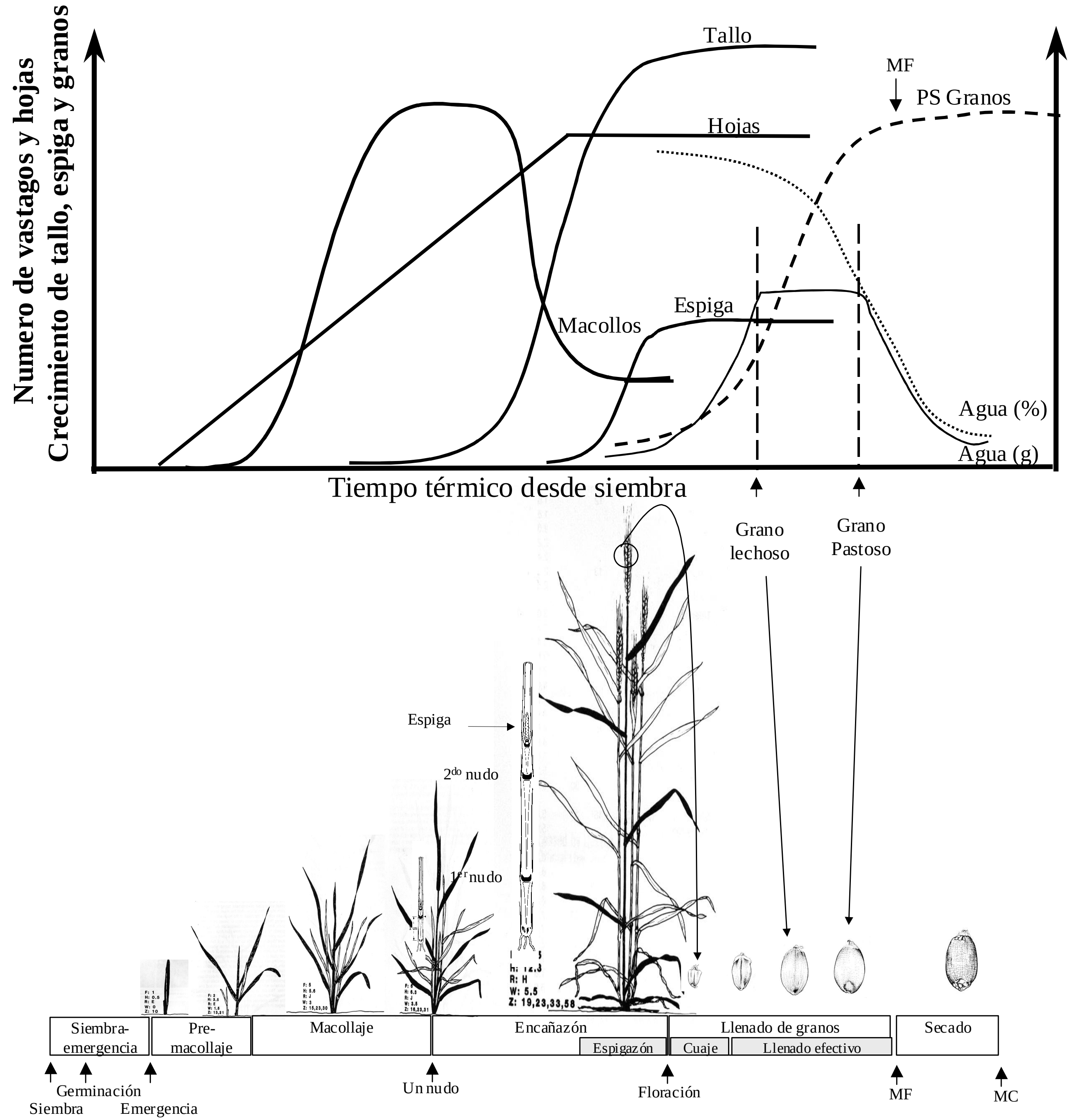
Septiembre 2010

Generacion del rendimiento

Daniel J. Miralles
Facultad de Agronomía
Univ. de Buenos Aires

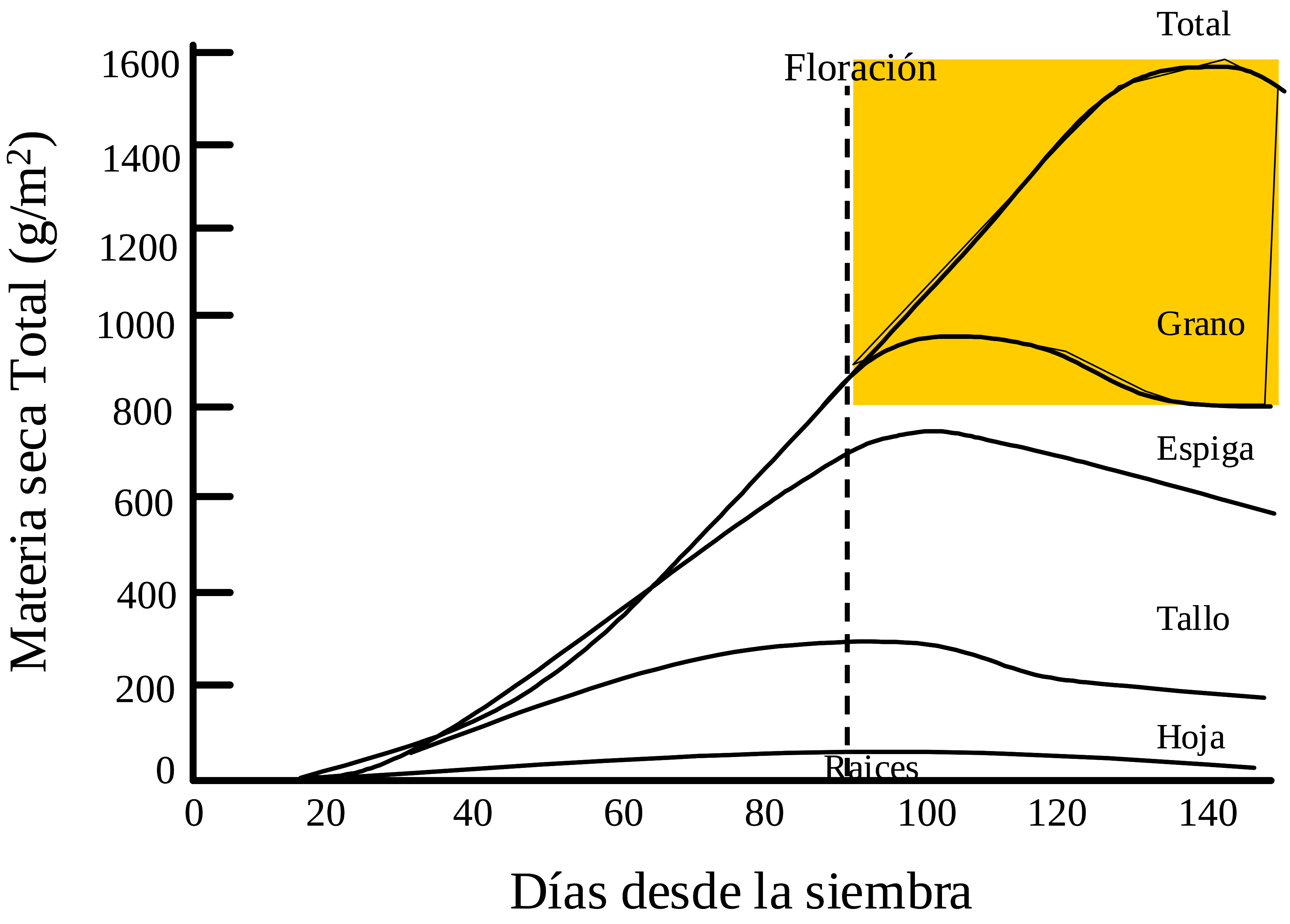


Adaptado de Slafer and Rawson (1994)

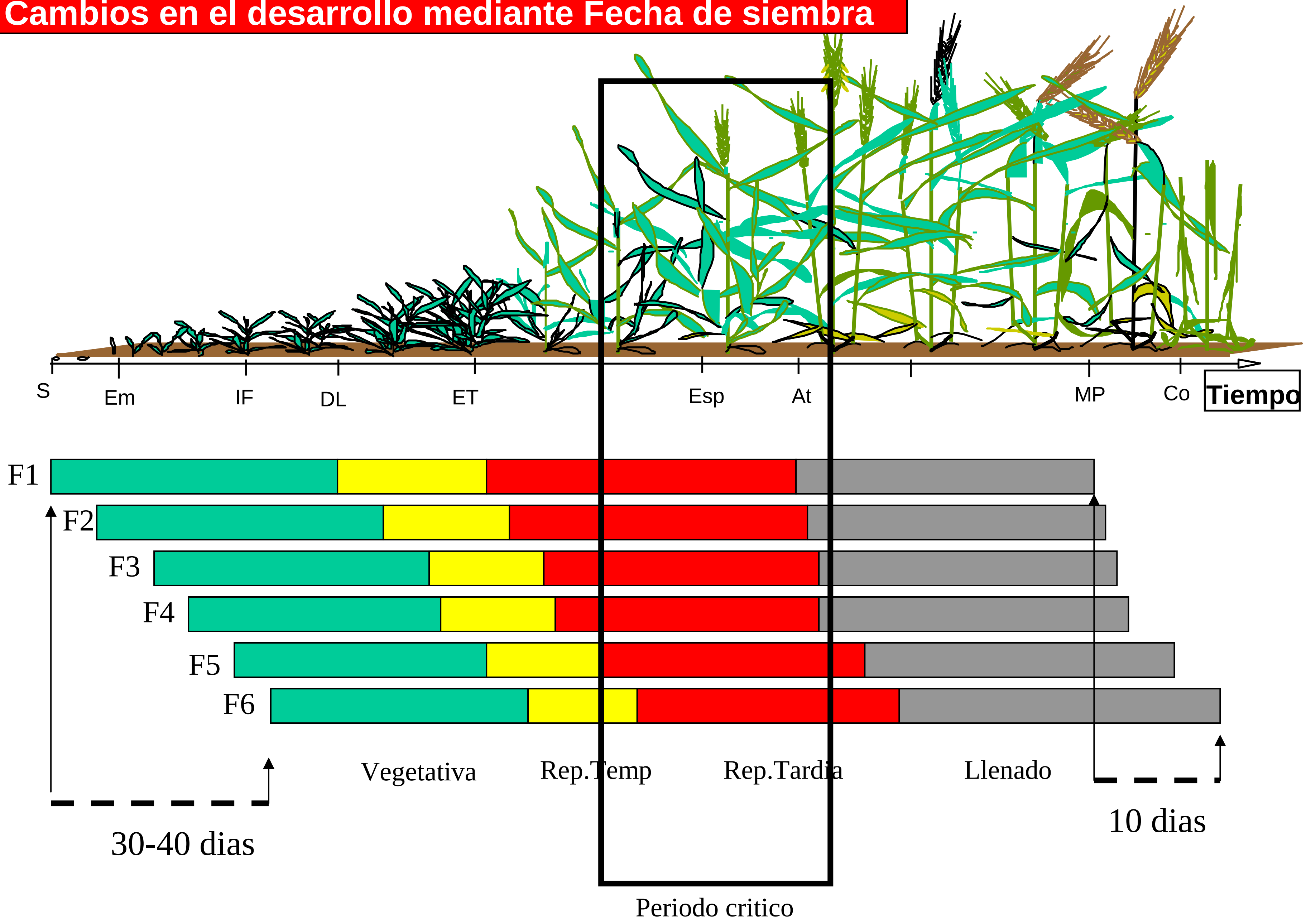


Numero de vastagos y hojas
Crecimiento de tallo, espiga y granos
Tallo
MF
PS Granos
Hojas
Espiga
Macollos
Agua (%)
Agua (g)
Tiempo térmico desde siembra
Grano lechoso
Grano Pastoso
Espiga
2do nudo
1er nudo
Siembra-emergencia
Pre-macollaje
Macollaje
Encañazón
Espigazón
Llenado de granos
Cuaje
Llenado efectivo
Secado
Siembra
Germinación
Emergencia
Un nudo
Floración
MF
MC

Distribución de biomasa a lo largo del ciclo



Cambios en el desarrollo mediante Fecha de siembra



TRIGO

primavera

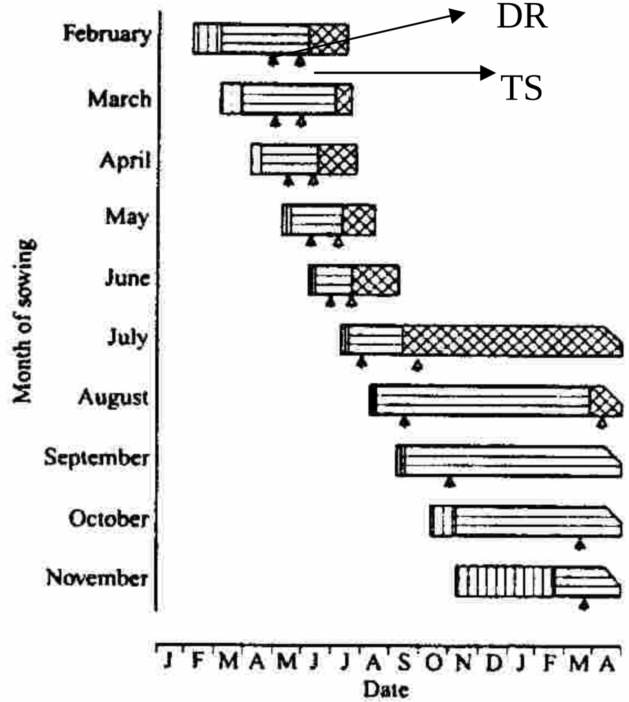


Fig. 7. Apical development of triticale (cv. Lasko) in monthly sowings. The bars represent the periods from sowing to seedling emergence (▥), from emergence to the onset of stem extension (▤) and from stem extension to anthesis (⊠). Solid arrows indicate the onset of the double ridge stage and open arrows the attainment of the terminal spikelet stage.

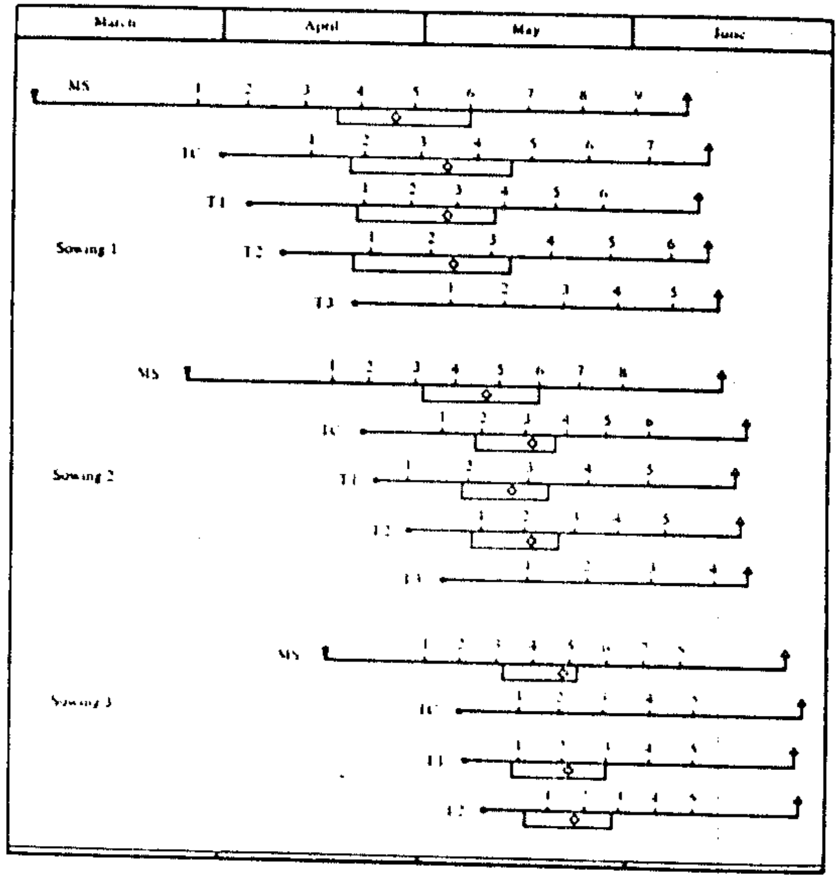
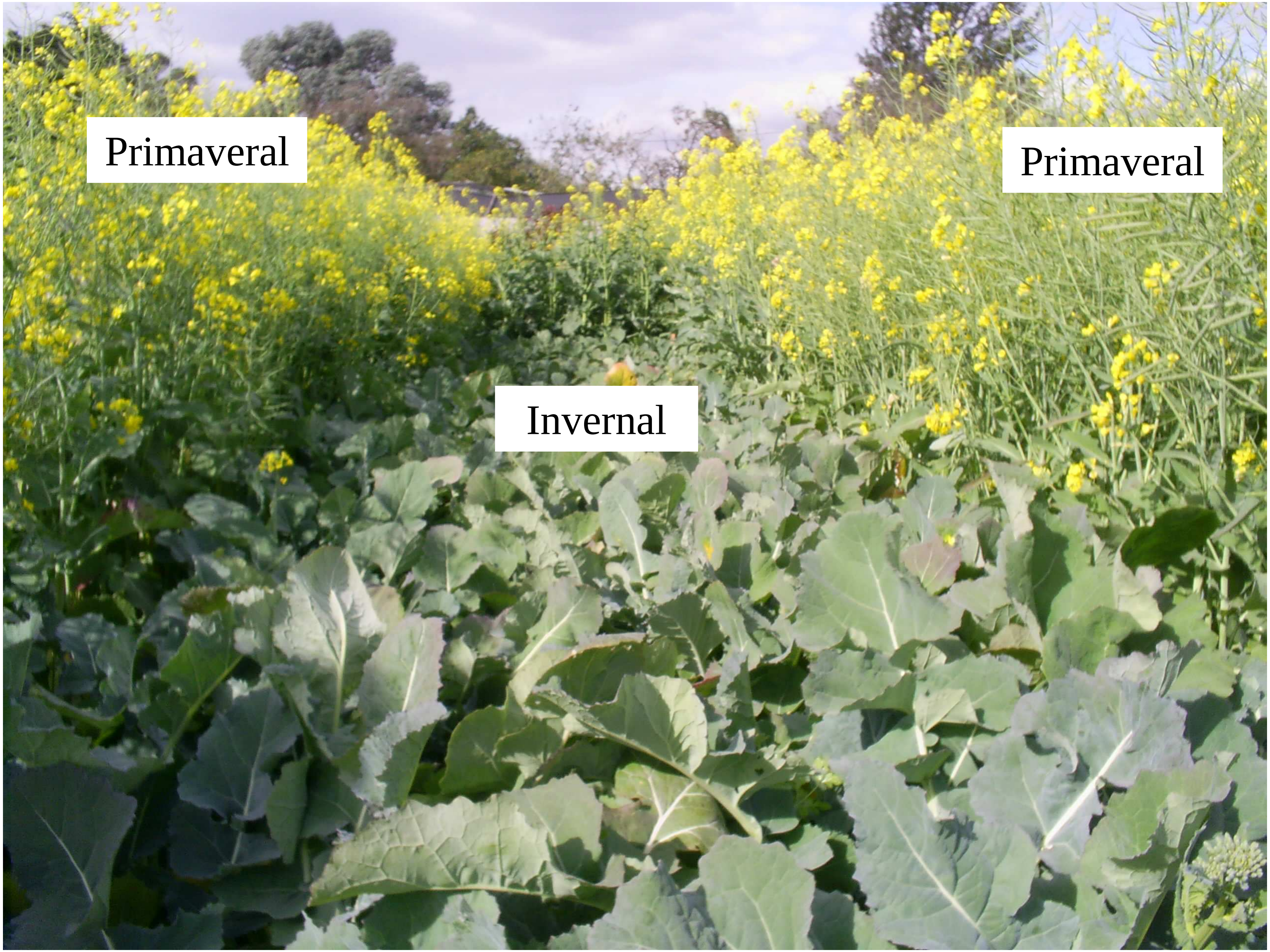


Fig. 9. Time courses of development of three sowings of Kolibri spring wheat grown in the field at Cambridge, U.K., in 1973. The numbers indicate the time of appearance of leaves of main shoots (MS), coleoptile tillers (TC) and primary tillers in the axils of mainshoot leaves 1 and 2 (T1, T2). The timing of events is indicated by ▼ sowing; ◇ double ridge; ● tiller bud initiation and △ anthesis (from Stern and Kirby 1979).

Hay and Kirby, 1991


Primaveral
Primaveral
Invernal

Ciclo-estación de crecimiento

Arroz

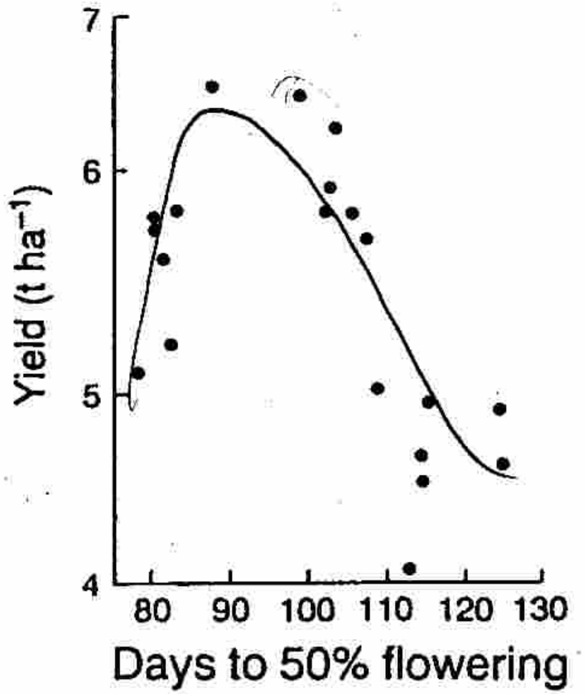


Figure 4.2. Influence of the time to flowering on the yield of rice cultivars of various duration at Hyderabad. Adapted from Venkateswarlu *et al.* (1969).

La fenología (la influencia del ambiente sobre la ontogenia) es el factor particular más importante en determinar la adaptación genotípica (Lawn e Imrie, 1994)

Optimizar la productividad implica ajustar la ontogenia (secuencia de estadíos de desarrollo) de forma que el cultivo explore durante su ciclo de crecimiento las mejores condiciones ambientales (ej.: temperaturas favorables o buena disponibilidad de agua) y, cuando las condiciones desfavorables son inevitables, minimizar la coincidencia de estas con los estadíos mas vulnerables del cultivo (Lawn e Imrie, 1994)

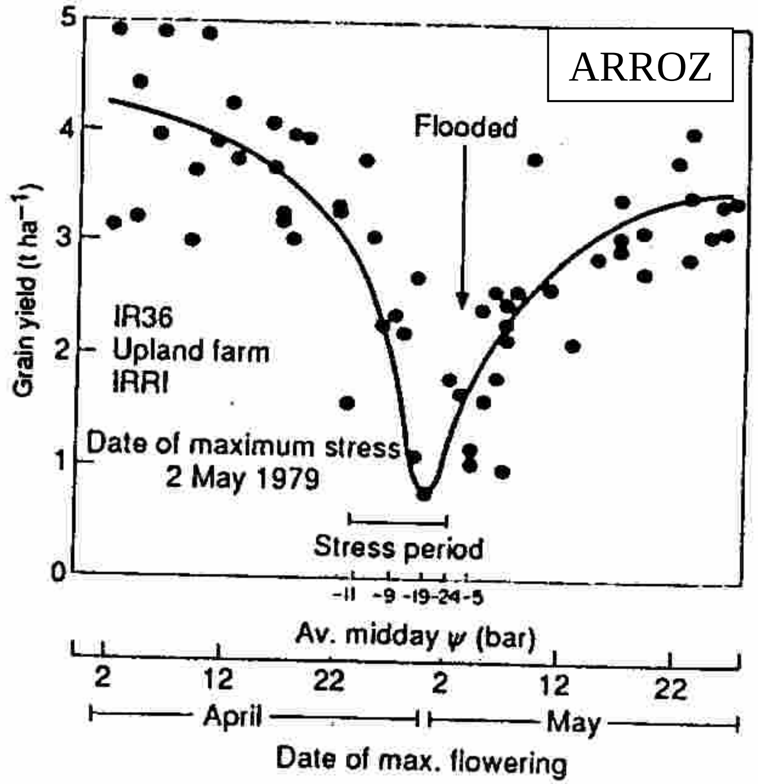
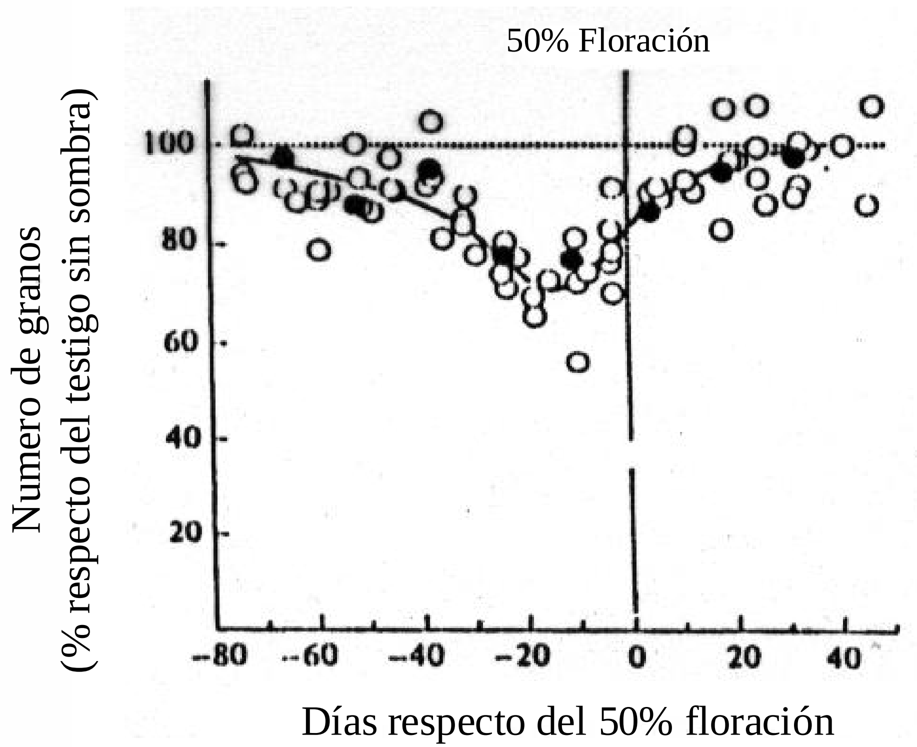


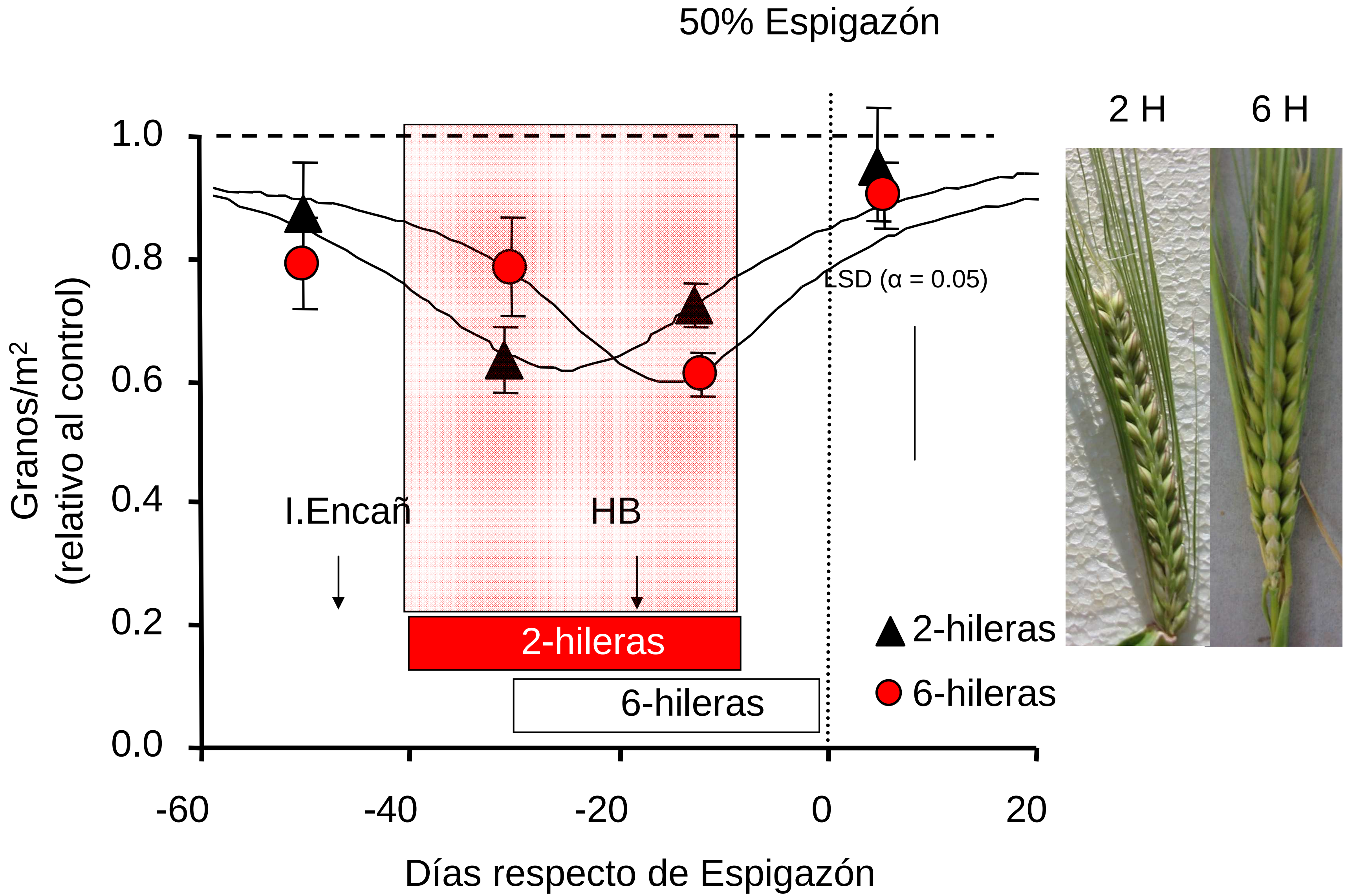
Figure 4.11. Effect on the yield of IR36 rice of the timing of a period of water stress in relation to the time of flowering as shifted by planting date (O'Toole, 1982). Crops which flowered on 2 April were near to maturity during the stress period, whereas those flowering on 22 May were near to panicle initiation during the stress period.



TRIGO

Fischer 1984

Periodo Critico Cebada



Arisnabarreta& Miralles (2007)

Ontogenia de un cultivo anual

Modo de determinación	Estadio Fenológico	Fase
Observación	Germinación	
		Establecimiento
Observación	Emergencia	
		Fase Juvenil
Experimento	Fin Fase Juvenil	
		Fase inducible
Disección	Comienzo diferenciación foral	
		Fase diferenciación floral
Disección	Fin diferenciación floral	
		Fase determinación de sitios potenciales de Rto
Observación	Antesis	
		Fase Cuaje de granos
Experimento	Comienzo llenado de granos	
		Fase llenado granos
Exp/Observ.	Fin llenado granos	
		Fase secado o Maduración
Exp/Observ.	Madurez cosecha	

Control ambiental del desarrollo

TEMPERATURA

FOTOPERIODO

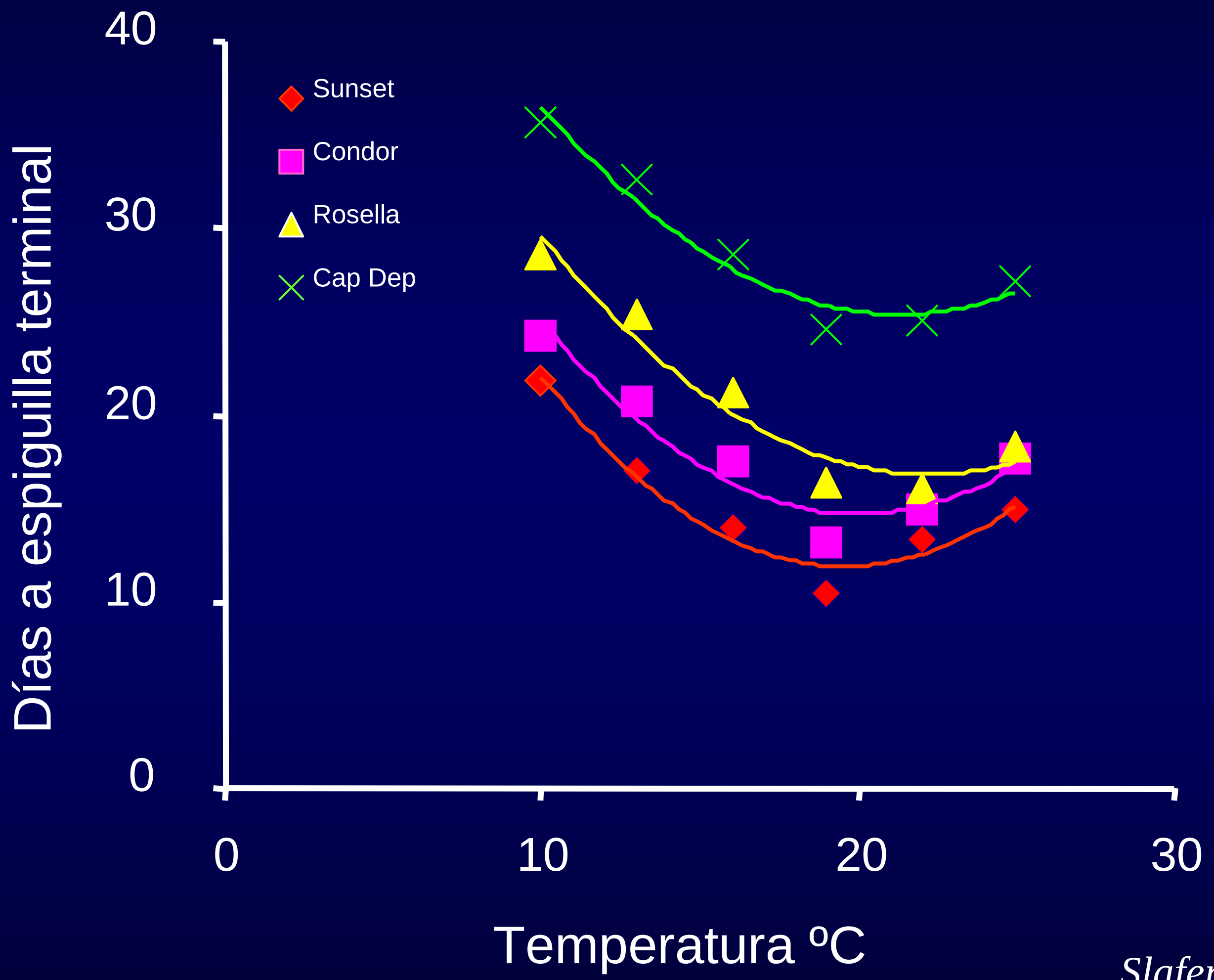
VERNALIZACION

El control del desarrollo depende fuertemente de los efectos de la **temperatura** el cual es universal actuando a lo largo del ciclo del cultivo.

El **fotoperíodo** y la **vernalizacion** puede afectar el desarrollo en algunas etapas del desarrollo especies y/o cultivares.

Otros Factores: Agua, nutrientes, etc ??????

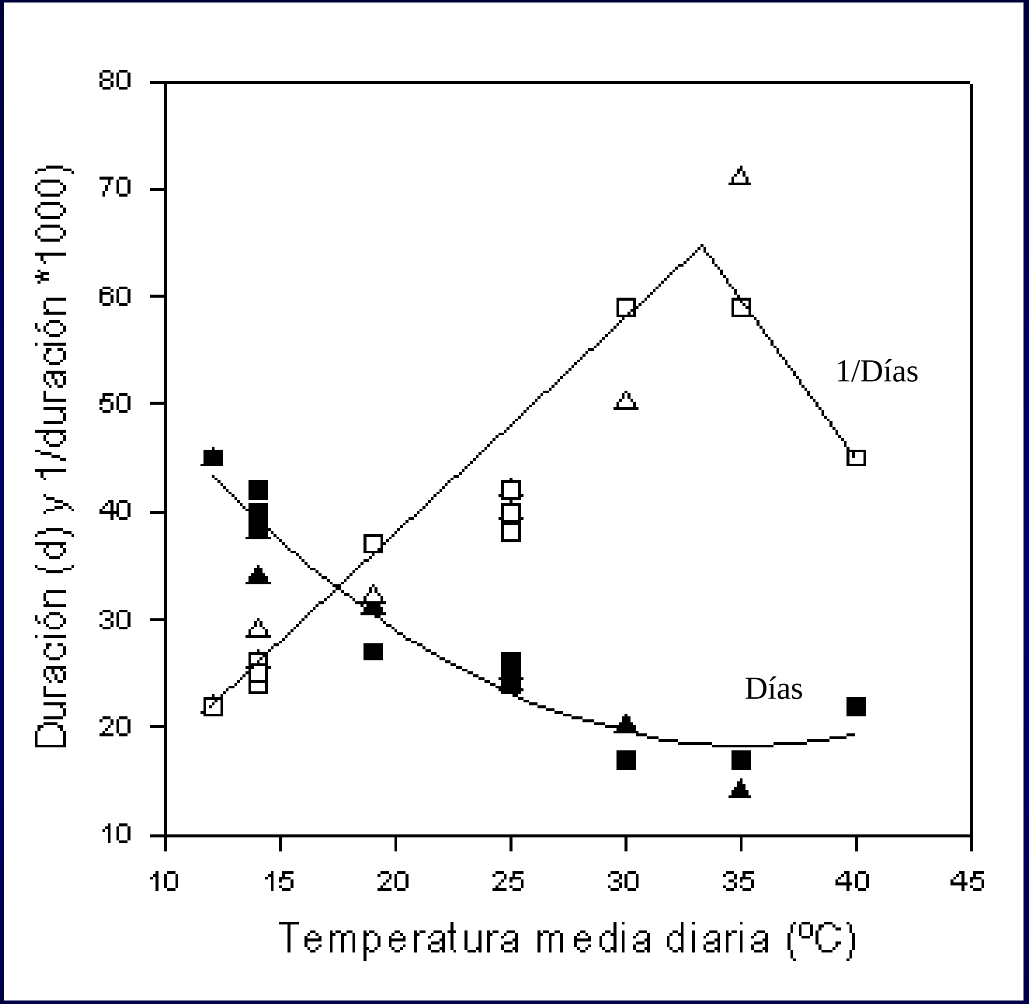
Temperatura



50 dias Vernalizacion
18 h Fotoperiodo

Slafer and Rawson, 1994.
Field Crops Res. 39

Modelo de tiempo térmico **_Temperatura_**



Efecto de la temperatura sobre la duración del crecimiento del embrión en girasol (Chimenti et al. , 2001)

Modelo de tiempo térmico

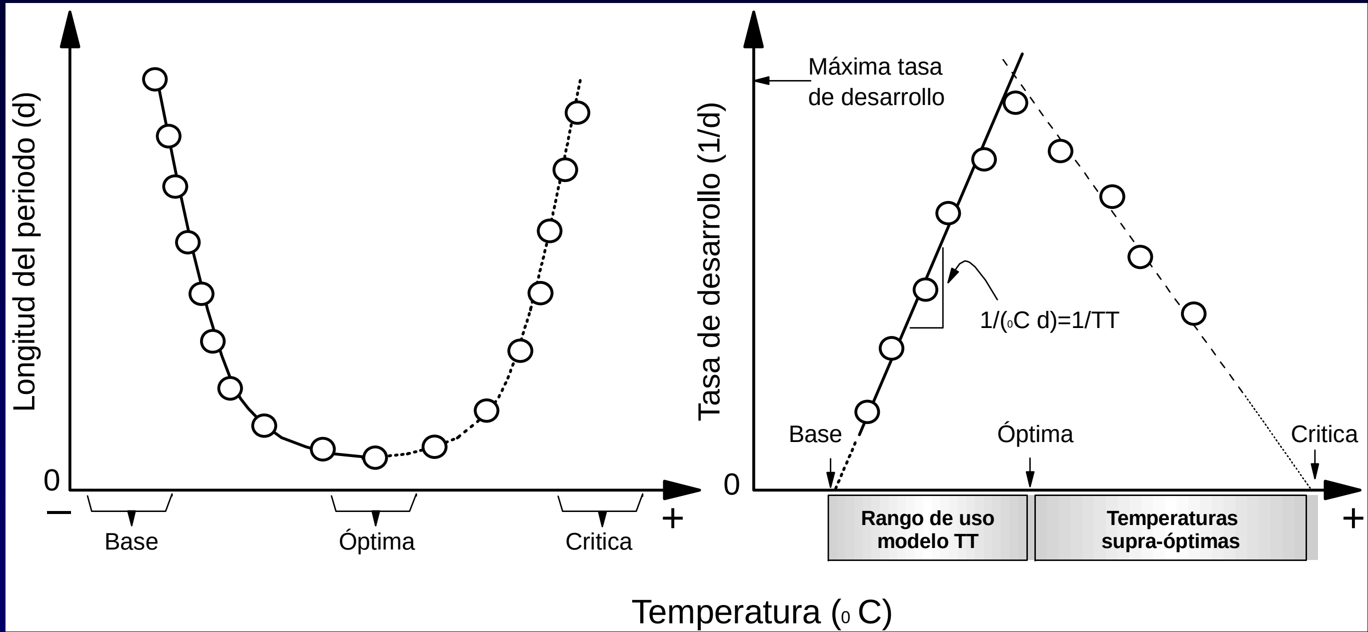


Table 5.5 *Thermal units (TU) calculated above base temperature (T_b) for the establishment of various agricultural species*

Species	TU	T_b	R^2 (%)
Wheat	78	2.6	46
Barley	79	2.6	39
Oat	91	2.2	32
Maize	61	9.8	91
Sorghum	48	10.6	96
Pearl millet	40	11.8	97
Field pea	110	1.4	10
Soybean	71	9.9	87
Peanut	76	13.3	99
Navy bean	52	10.6	86
Rapeseed	79	2.6	45
Safflower	70	7.4	68
Sunflower	67	7.9	73
Linseed	89	1.9	37
Buckwheat	37	11.1	90
Amaranthus	32	11.7	86

Source: Adapted from Angus *et al.* (1981).

Cálculo del tiempo térmico

Para valores de temperatura entre Tbase y Toptima

$$\text{Tiempo térmico (TT)} : \sum_{dia=i}^{dia=n} (T_{diaria} - T_{base})$$

Donde Tdiaria es temperatura media diaria.

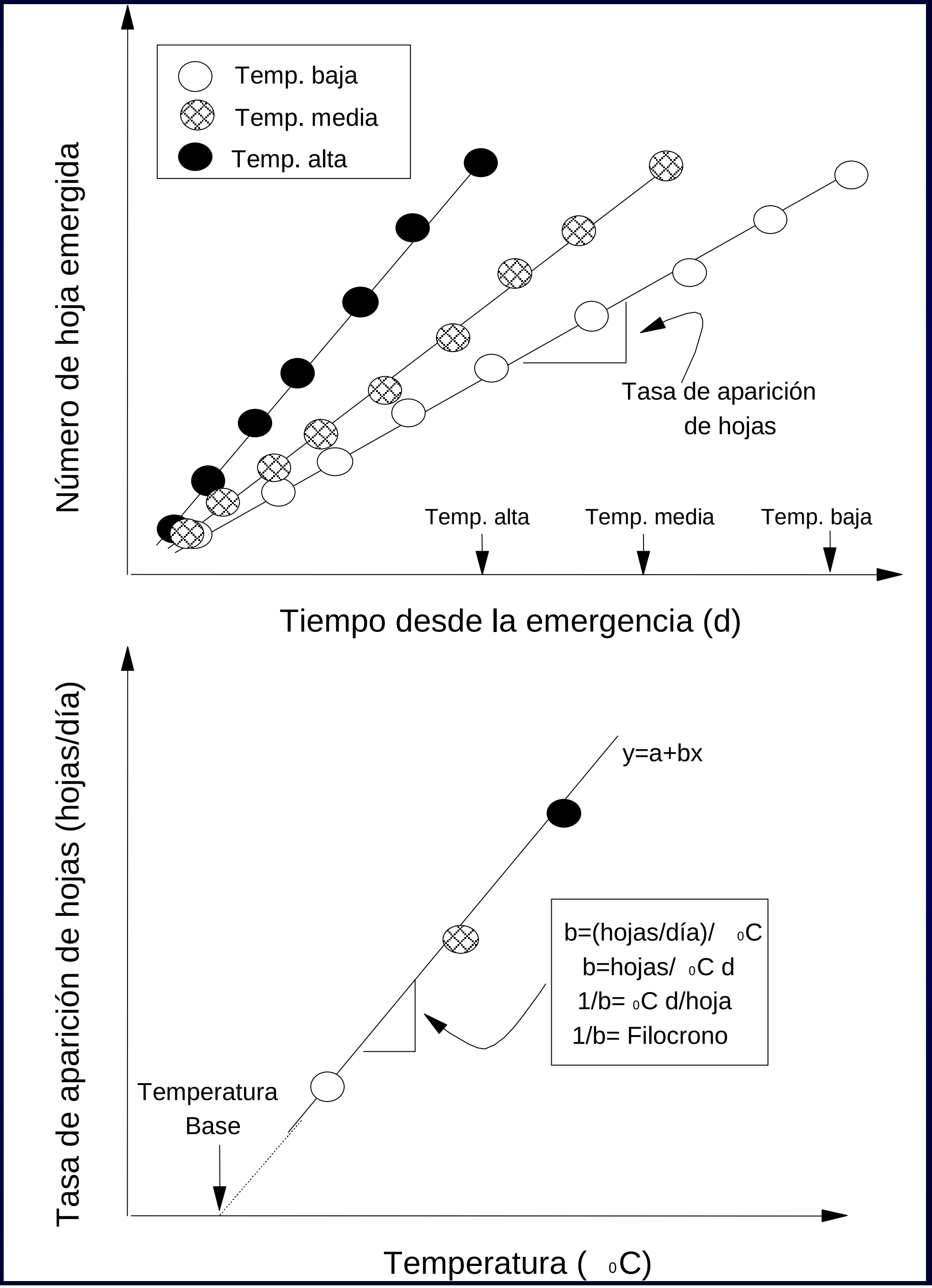
Se requieren tratamientos más complejos para situaciones en que T °> Topt ó T° < Tb durante todo o parte del día.

<u>CONSECUENCIA:</u> El uso del TT permite comparar el desarrollo de cultivos que crecen bajo regímenes térmicos diferentes, superando las debilidades inherentes en el uso de tiempo calendario, que no contempla los efectos fisiológicos de la temperatura.

Daniel J. Miralles
Facultad de Agronomía
Univ. de Buenos Aires

Modelo de tiempo térmico

Temperatura



Temperatura

TABLE 1. *Maximum and minimum temperatures and photoperiod (including civil twilight) for the phenological phases studied (Sw, sowing; Em, emergence; TS, terminal spikelet; An, anthesis; and Mt, physiological maturity) averaged over cultivars, in Buenos Aires during 1989 growing season*

Sowing date	Mean temperature (°C)				Photoperiod (h:min)		
	Sw–Em	Em–TS	TS–An	An–Mt	Em–TS	TS–An	An–Mt
11 July	13·3	22·4	16·3	19·7	12:29	14:12	15:36
31 July	14·7	14·8	16·7	20·2	13:13	14:28	15:50
29 August	12·8	15·2	18·2	22·0	13:56	15:18	16:19
28 September	16·5	18·0	21·5	24·7	15:02	16:21	16:44
23 October	19·0	21·9	25·3	26·6	15:55	16:58	16:49

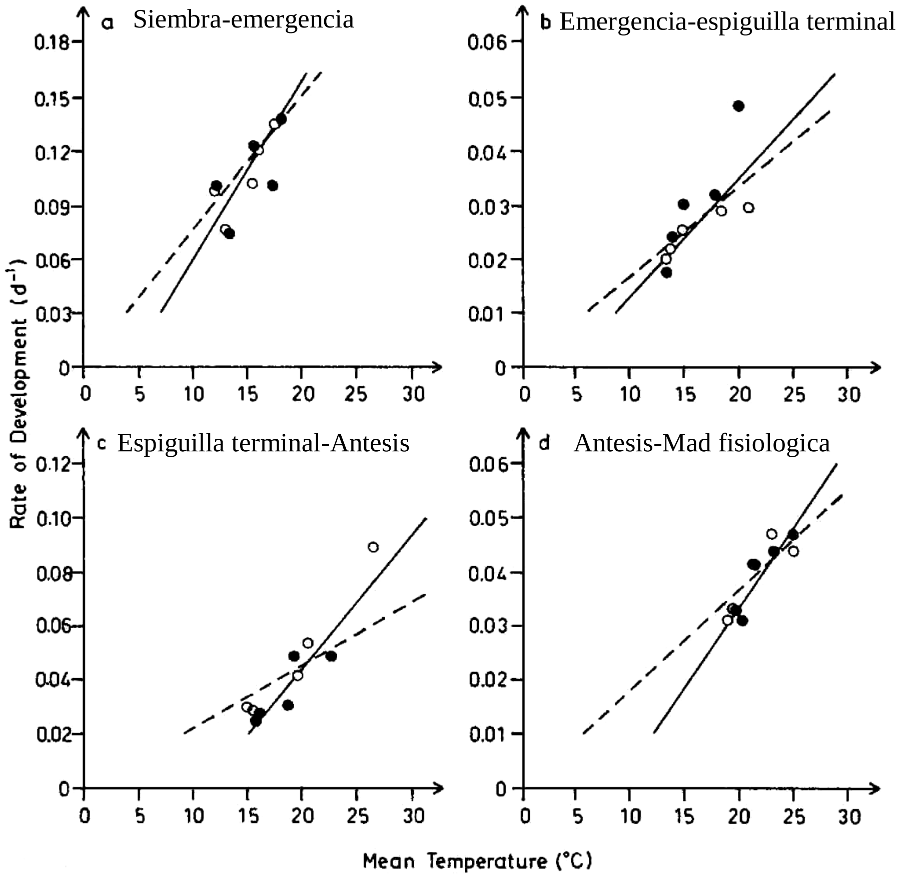


FIG. 1. Relationship between rate of development (a) from sowing to emergence, (b) from emergence to terminal spikelet, (c) from terminal spikelet to anthesis, (d) from anthesis to physiological maturity, and mean temperature in those phases for two mediterranean wheat cultivars (Marcos Juarez INTA, open symbols and Las Rosas INTA, closed symbols) grown in Buenos Aires. The solid and broken lines represent the regression lines fitted with a free intercept and forced through the origin (intercept = 0 °C), respectively.

Slafer & Savin
J. Exp. Bot 1991

Temperatura

Slafer and Savin—Developmental Base Temperature in Wheat

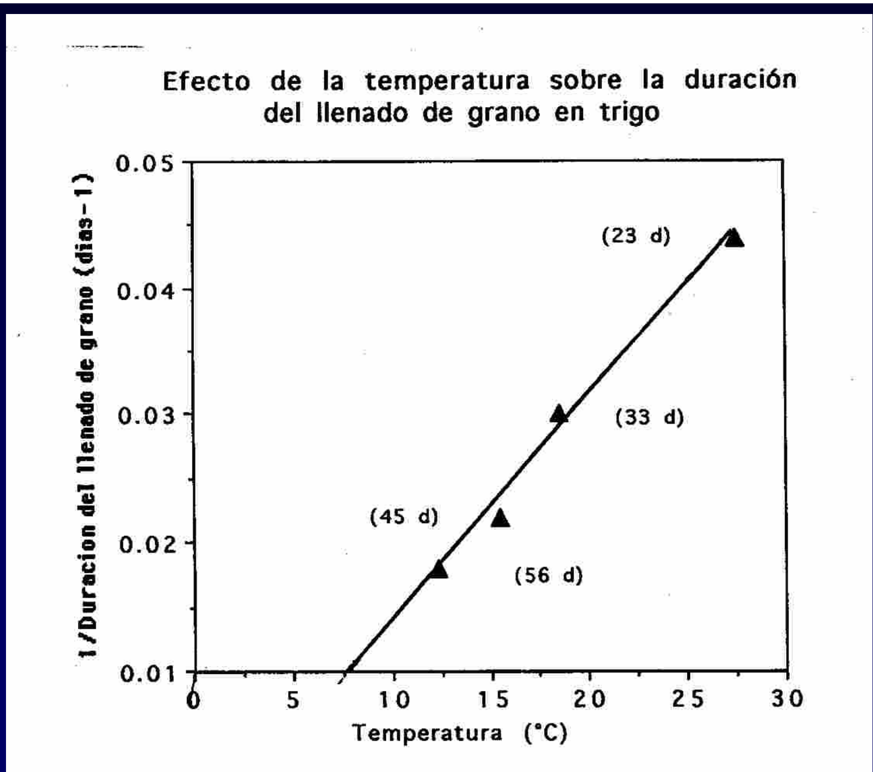
TABLE 3. *Comparative values of developmental base temperatures in different phenological phases (Sw, sowing; Em, emergence; DR, double ridge; TS, terminal spikelet; An, anthesis; and Mt, physiological maturity) of wheat crops obtained by different authors using winter, spring and mediterranean wheats*

<table>
<tr><th rowspan="2">Group</th><th colspan="5">Base temperature (°C)</th><th rowspan="2">Reference</th></tr>
<tr><th>Sw–Em</th><th>Em–DR</th><th>DR–TS</th><th>TS–An</th><th>An–Mt</th></tr>
<tr><td>Winter 1</td><td>0·1</td><td>—</td><td>2·0</td><td>3·5</td><td>5·7</td><td>Porter et al. (1987)</td></tr>
<tr><td>Spring 2</td><td>2·6</td><td>3·3</td><td colspan="2">5·1</td><td>8·9</td><td>Angus et al. (1981a, b)</td></tr>
<tr><td>Spring 5</td><td>2·8</td><td colspan="2">2·0</td><td>6·4</td><td>10·1</td><td>Del Pozzo et al. (1987)</td></tr>
<tr><td>Mediterranean 2</td><td>4·0</td><td colspan="2">4·1</td><td>10·6</td><td>8·2</td><td>This paper</td></tr>
</table>

The number following the wheat groups are the number of genotypes used in each experiment. When the authors considered more than one of the phases included in this table as only one longer phase (Em–TS or DR–An) the corresponding base temperatures were placed in the middle of those phases.

J Exp Bot, 1991, 42

Temperatura



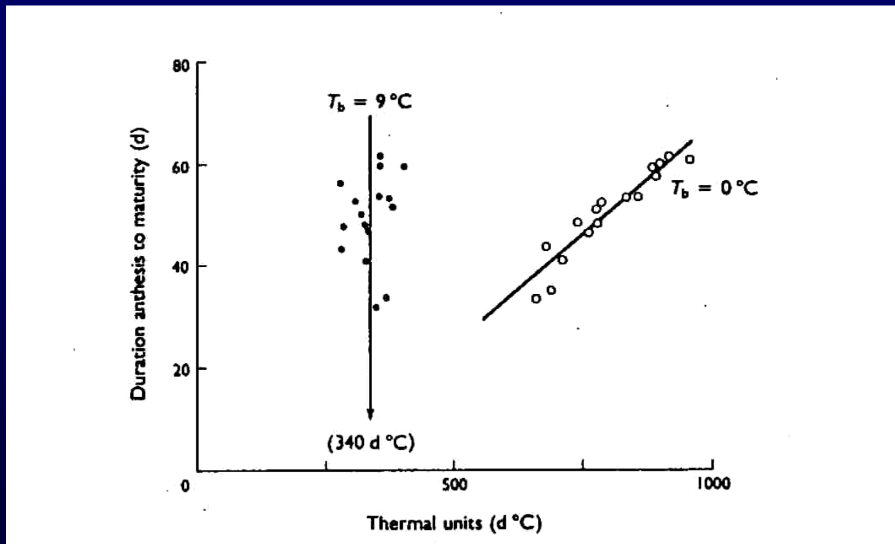


Fig. 5.8. Thermal analysis of the duration of the phenophase anthesis to maturity in four cultivars of wheat. For each cultivar, thermal units calculated to a base temperature (T_b) of 9 °C explain the duration of all times of sowing. Calculations to $T_b = 0$ °C do not (after Weir *et al.* 1984).

Temperatura

676 G. A. Slafer and H. M. Rawson *Plant, cell & Environ. 18*

Table 1. Parameters of the positive linear regression between rate of development and temperature for different phenological phases and their calculated cardinal (base and optimum) temperatures for four wheat cultivars grown after 50 d of vernalization under natural radiation and 18 h photoperiod. Thermal times were calculated as the reciprocal of the slopes

Cultivar	Intercept (d^{-1})	Slope (°Cd^{-1})	Correlation coefficient	n*	P*	Temperature (°C) base	Temperature (°C) optimum†	Thermal time (°Cd)
Beginning of experiment to terminal spikelet initiation								
Sunset	–0·0102 (0·0094)‡	0·00539 (0·00063)	0·986	4	0·013	2·22 (1·49)	19·5	185·5
Condor	0·0008 (0·0095)	0·00378 (0·00064)	0·973	4	0·027	0·58 (2·41)	19·5	264·5
Rosella	0·0086 (0·0055)	0·00257 (0·00034)	0·951	5	0·005	–2·40 (2·46)	21·0	389·1
C. Desprez	0·0128 (0·0027)	0·00143 (0·00018)	0·985	4	0·015	–8·23 (2·87)	20·0	699·3
Terminal spikelet initiation to heading								
Sunset	–0·0021 (0·0035)	0·00263 (0·00021)	0·990	5	0·001	1·08 (1·26)	23·5	380·2
Condor	–0·0018 (0·0026)	0·00280 (0·00014)	0·995	6	0·001	0·81 (0·87)	>25·0	357·3
Rosella	–0·0045 (0·0042)	0·00299 (0·00026)	0·989	5	0·001	1·83 (1·26)	23·5	334·4
C. Desprez	–0·0003 (0·0041)	0·00195 (0·00022)	0·975	6	0·001	1·03 (1·97)	>25·0	512·8
Heading to anthesis								
Sunset	–0·1020 (0·0176)	0·01357 (0·00106)	0·991	5	0·001	7·67 (0·73)	22·0	73·7
Condor	–0·1077 (0·0307)	0·01347 (0·00168)	0·970	6	0·001	8·56 (1·27)	>25·0	74·3
Rosella	–0·1266 (0·0263)	0·01466 (0·00144)	0·963	6	0·001	8·96 (0·97)	>25·0	76·7
C. Desprez	–0·0845 (0·0488)	0·01440 (0·00267)	0·938	6	0·006	7·28 (2·09)	>25·0	69·4

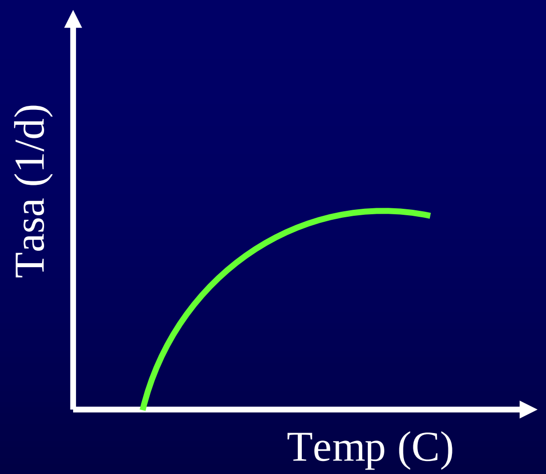
*n and P denote number of data considered in the calculation of the positive relationship between rate of development and temperature and the probability level of the F-ratio value for the linear regression, respectively.
†Optimum temperatures were estimated by eye (from Fig. 3).
‡Values in parentheses are the standard errors of the estimated parameters.

Temperatura

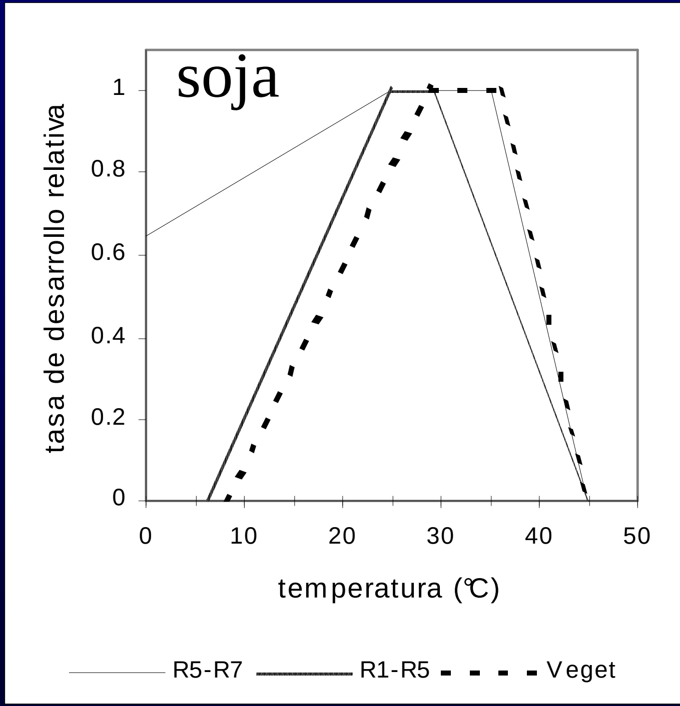
Uso del Modelo de TT

- Estimación de Tb y Top, (distintas etapas y cultivares)
- Calculo de Tmed
- Respuesta lineal de la Tasa de desarrollo

Modelos alternativos



Angus et al. 1981 FCR
Rawson 1993 FCR
Rawson y Zajac 1993 AJPP



Boote et al. 1994

Temperatura

Atkinson & Porter 1996.
Trends in Plant Science 1 (4)

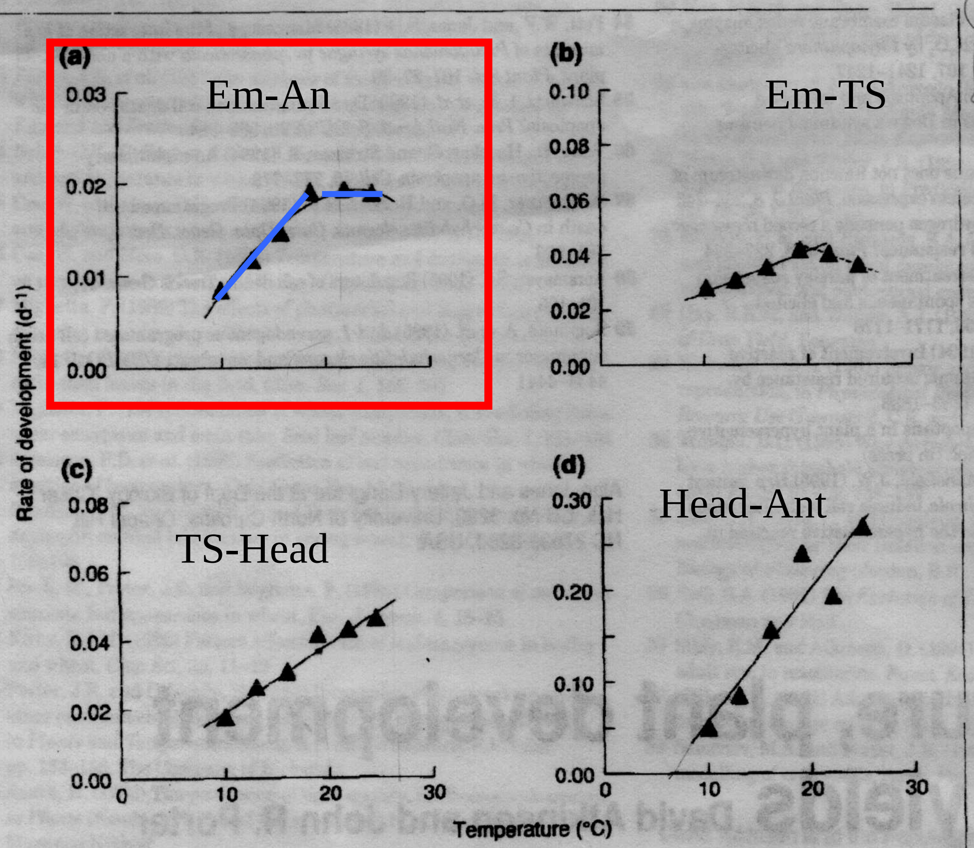
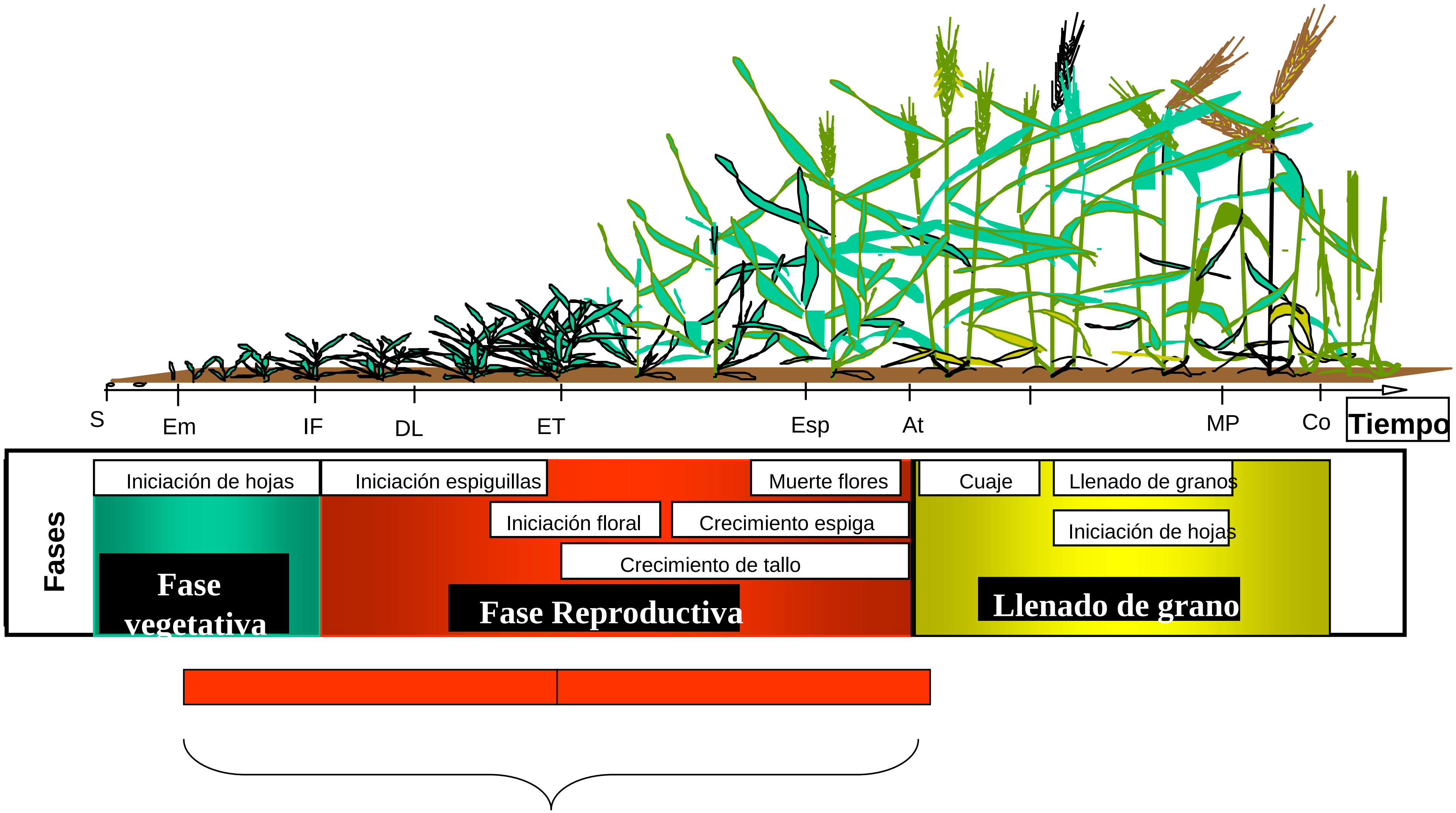


Fig. 1. The rate of development to anthesis (flowering) is expressed as the reciprocal of the time taken to anthesis, in days^{-1}. Although relationships between this rate and temperature in the suboptimal range are often assumed to be linear, a nonlinear relationship has recently been observed in two wheat (*Triticum aestivum*) cultivars (data for the cultivar Cappelle Desprez are shown). The nonlinear relationship is shown in (a). The line was fitted by a quadratic regression model; the coefficient of determination (R^2) is 0.969; $p<0.001$ (Ref. 22). The relationships were, however, linear in the suboptimal range for each of three subphases prior to anthesis: (b) from the beginning of the experiment to terminal spikelet initiation; (c) from terminal spikelet initiation to heading; and (d) from heading to anthesis. In (b)–(d), solid lines were fitted by linear regression models. The dashed line, in (b), was fitted by eye. A progressive increase in optimum temperature during development appeared to explain the overall nonlinearity[22].

Fotoperiodo

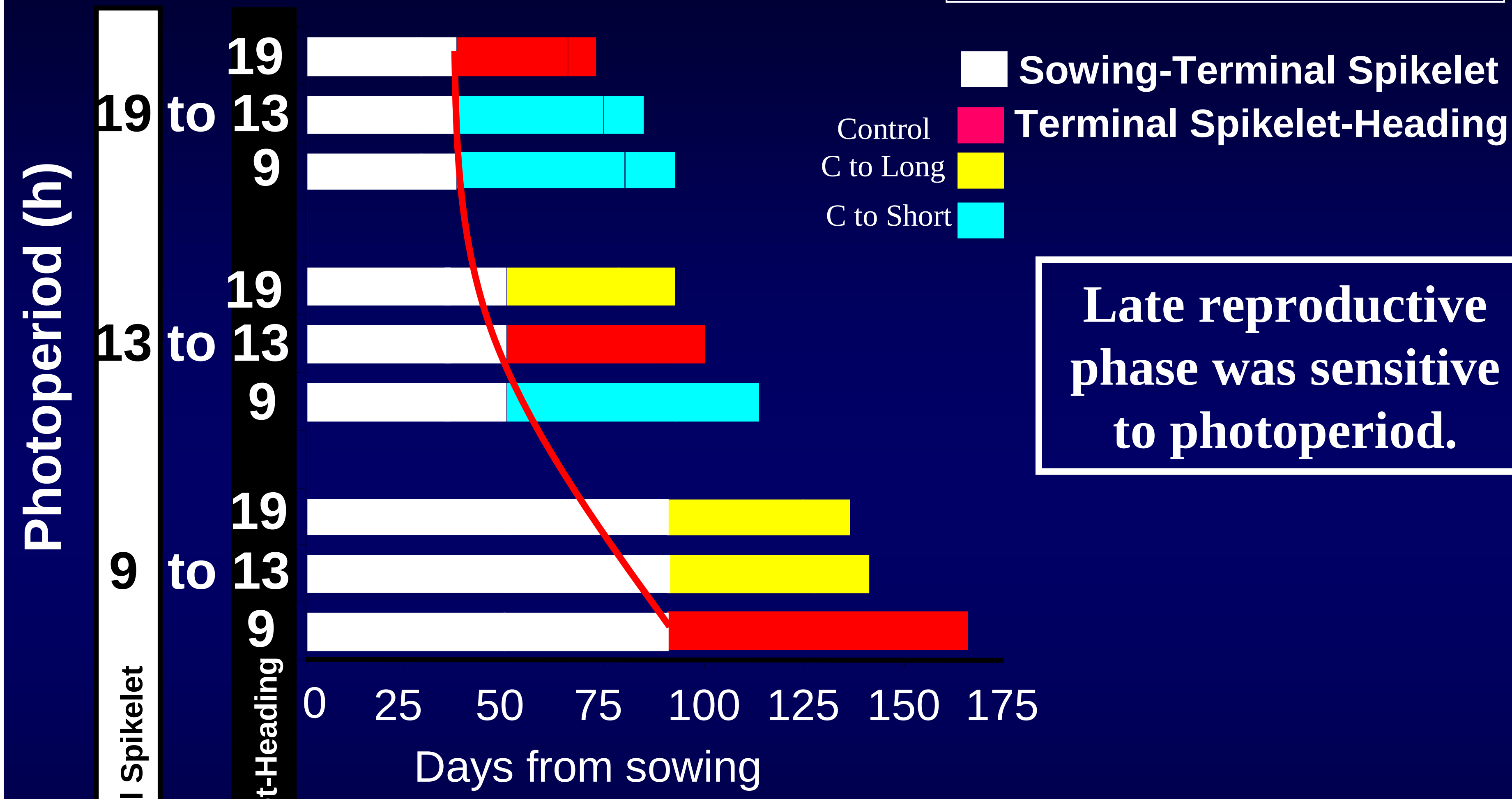


Sensibilidad al fotoperiodo

Adaptado de Slafer and Rawson (1994)

WHEAT

Photoperiod Sensitivity



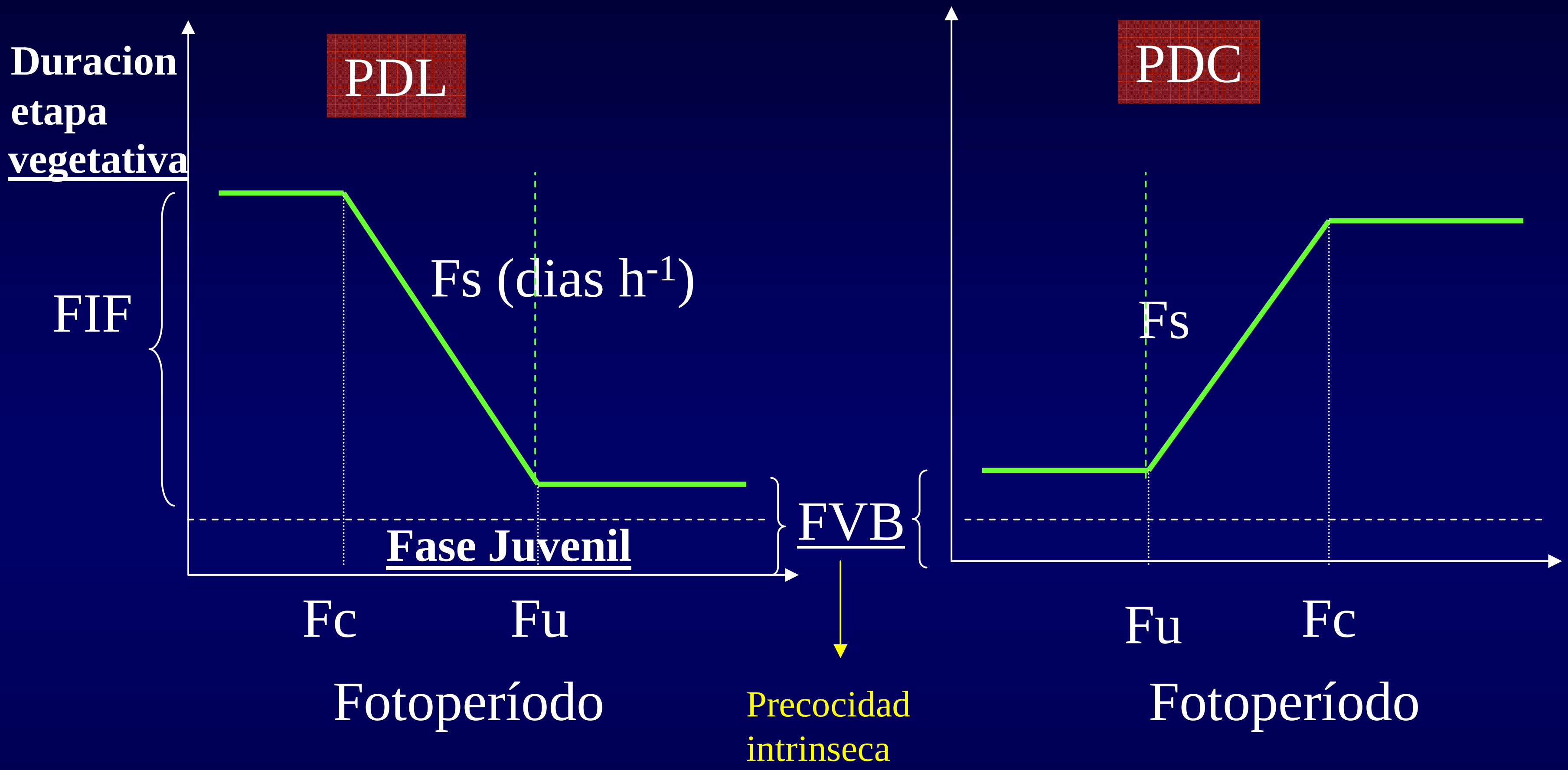
Miralles & Richards, 2000
(Ann. Bot. 85)

Late reproductive phase was sensitive to photoperiod.

The direct response to photoperiod was evaluated under field condition.

(Whitechurch & Slafer 2000, *Euphytica 118*
González, Slafer & Miralles 2002, *Field Crops Res.*

Fotoperíodo



Fu = fotoperíodo umbral; Fc = fotoperíodo crítico
FS= sensibilidad al fotoperíodo; FVB = fase vegetativa básica
FIF = fase inducida por el fotoperíodo

Precocidad intrínseca

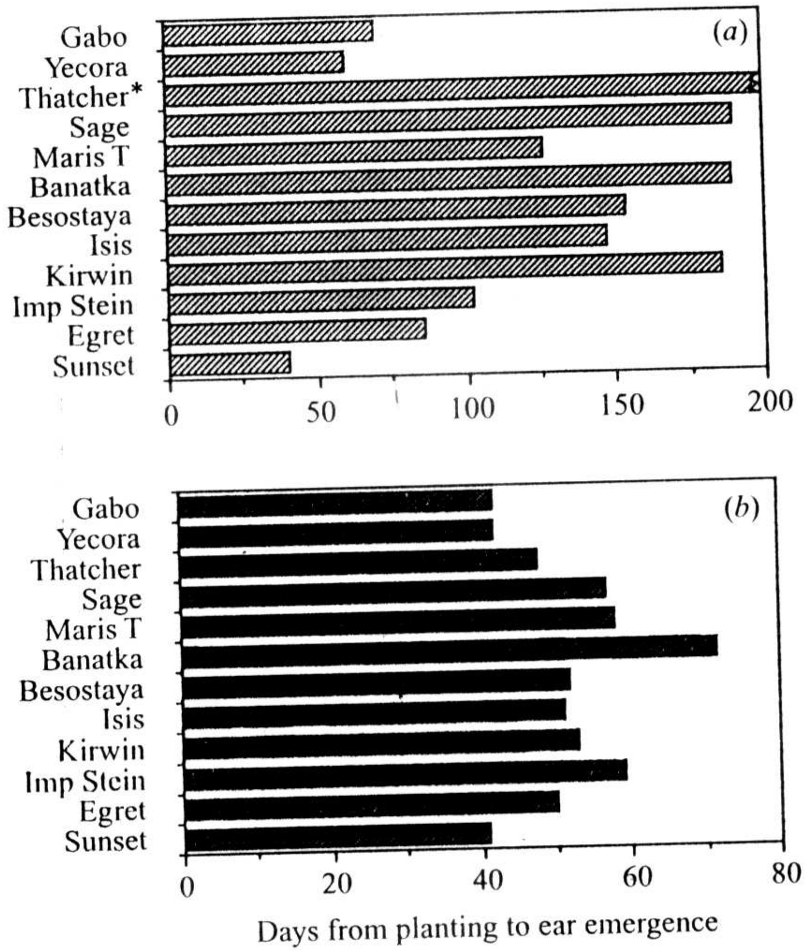


Figure 2. Time from planting to ear emergence of different cultivars grown under (*a*) short photoperiod (< 11 h) after no vernalization; and (*b*) under long photoperiod (16 h) and after 56 days of vernalization. Cultivars were selected from Fig. 3 in Davidson *et al.* (1985). Maris T is the cultivar Maris Templar and the asterisk means that Thatcher under short photoperiod did not reach ear emergence within the 250 days of the experiment.

Slafer 1996
J. Agric. Sci. Cambridge

Fase juvenil

Sigue como si estuviera en Fotop. Largo

Sigue como si estuviera en Fotop. Cortos

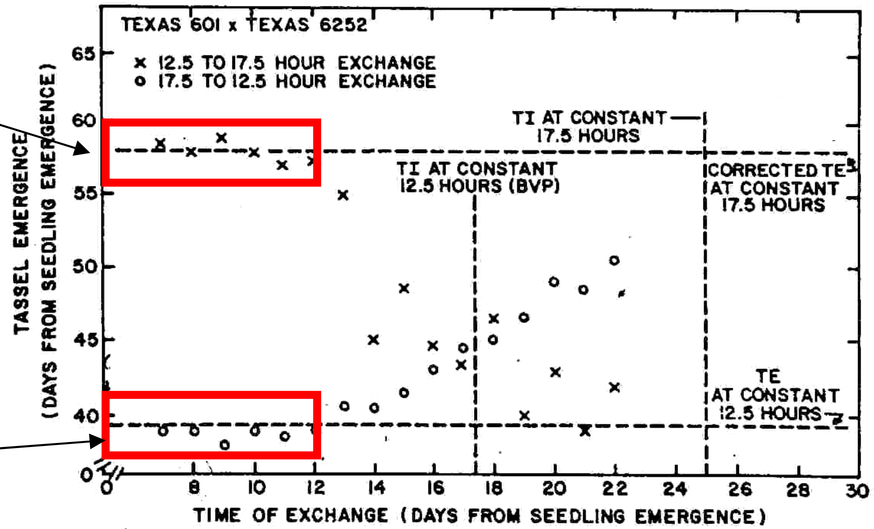


Fig. 1. Timing of tassel emergence (TE) for maize plants of cultivar Tx601 × Tx6252 when photoperiod was changed at different times. The times of tassel initiation (TI) in constant photoperiods are shown for comparison with times of photoperiod change.

Especie	Duración (d)	Referencia
Sorgo	5-9 10-23	Alagarswamy et al, 1998 Alagarswamy y Ritchie, 1991
Arroz	14-42	Collinson et al, 1992
Soja	3-11 (25°C) Cero	Upadhyay et al., 1994 Wilkerson et al. 1989 Wang et al. 1998
Cebada	11-33 (25° C) 8-10 (15 °C) vernalizado 32 (15 °C) no vern	Collinson et al. 1993 Roberts et al. 1988
Maiz	12 (25 °C)	Kiniry et al., 1983
Girasol	12-18 (25 °C)	Villalobos et al. 1996
Trigo	¿0?	Slafer y Rawson, 1995

Fotoperíodo

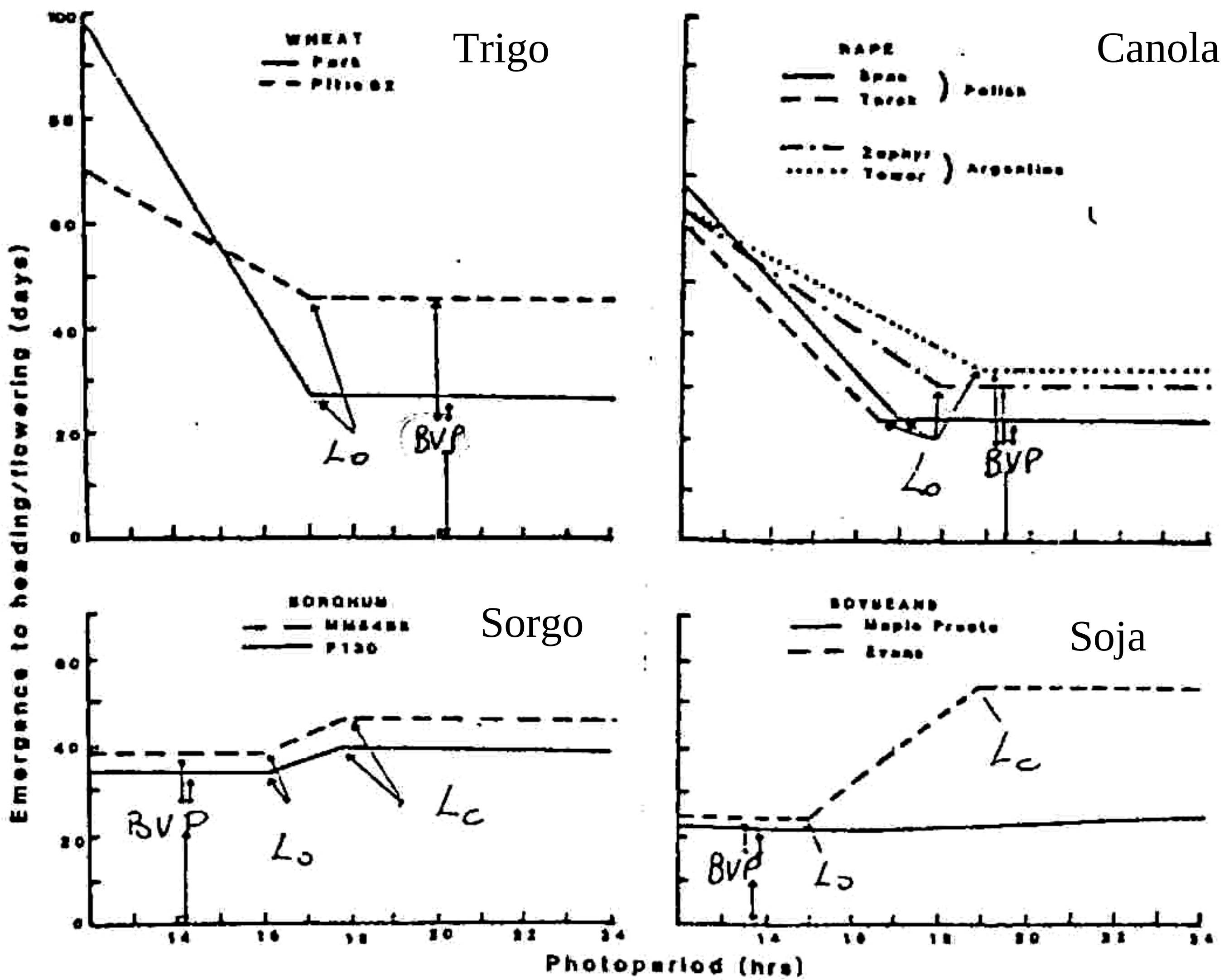
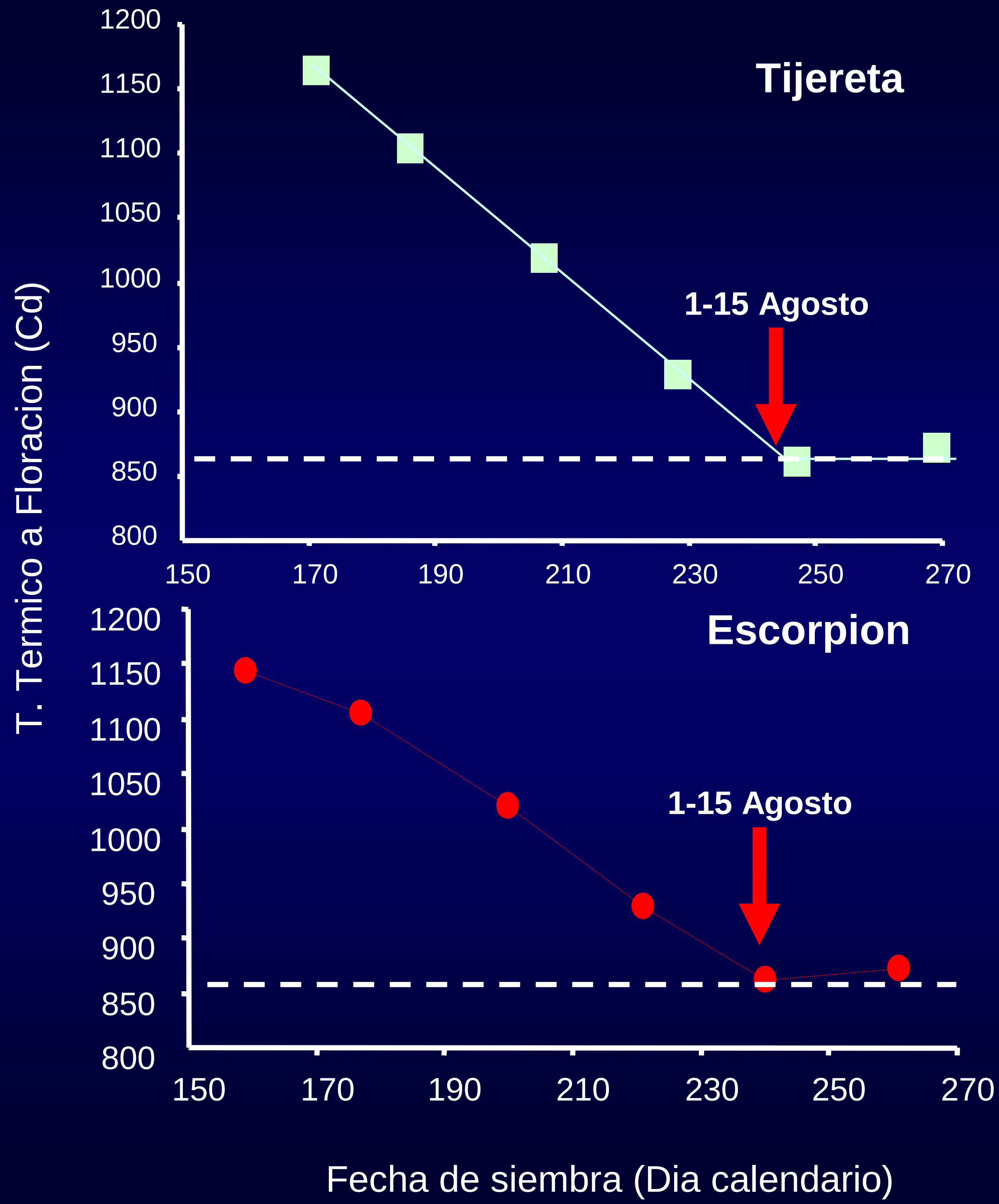


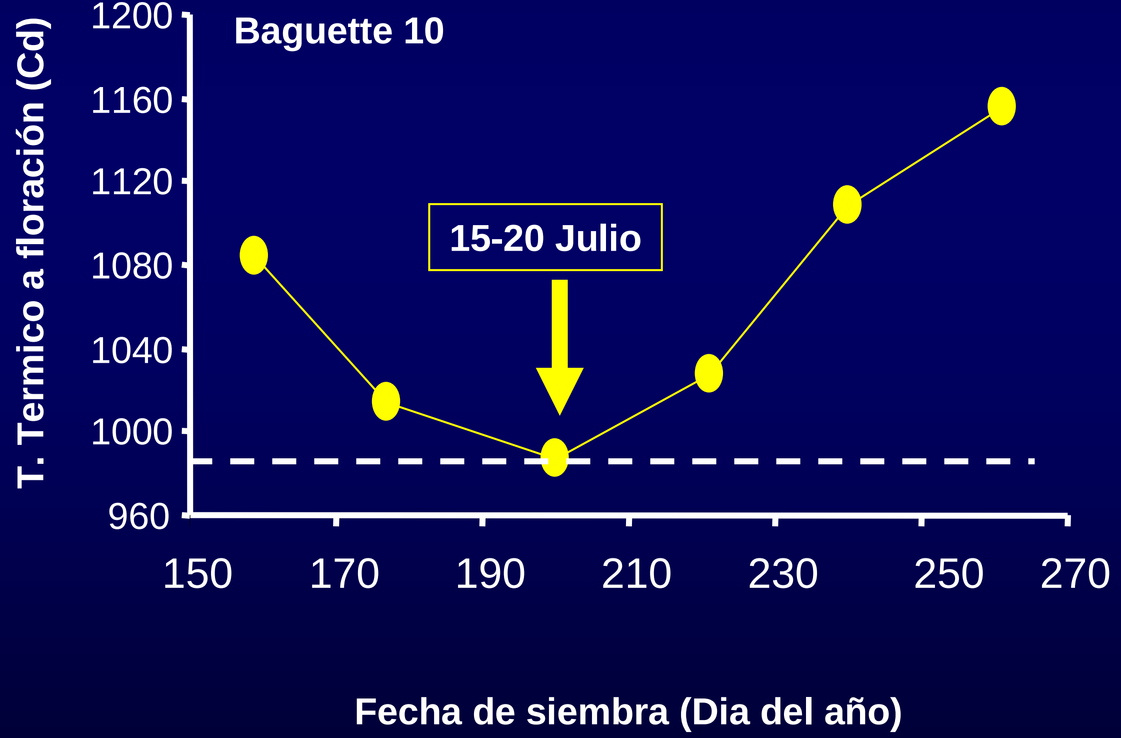
Fig. 12 Responses to photoperiod of heading or flowering measured in controlled environment chambers.
(V = minimum vegetative period, O = optimum photoperiod, C = critical photoperiod.) (From Major, 1980)

Cultivares con sensibilidad al fotoperiodo y SIN requerimientos de Vernalización



Spinedi et al (2005)

Cultivares con requerimientos de Vernalización



Spinedi et al (2005)

Fotoperíodo

Miralles & Richards 2000 Ann Bot 85

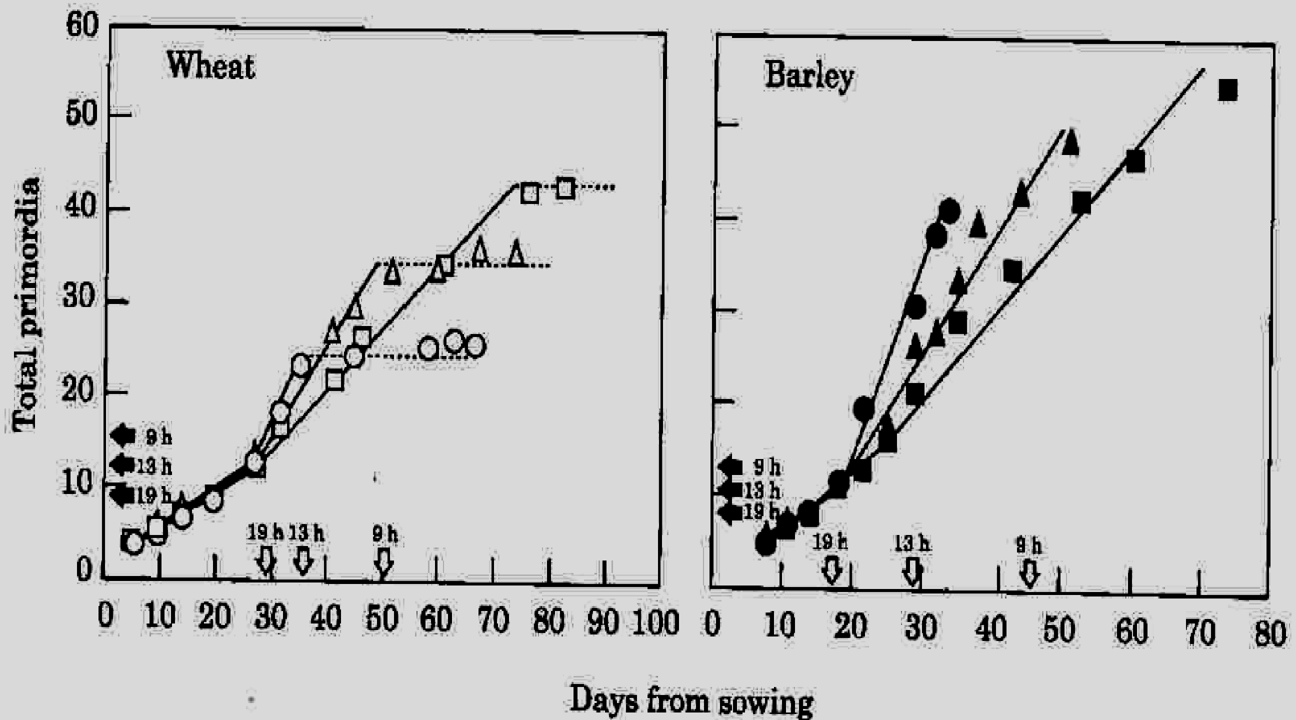


FIG. 7. Time courses of total number of primordia per main stem apex under different photoperiods for wheat and barley. Constant photoperiods were 9h (□, ■), 13 h (△, ▲) and 19 h (○, ●). Solid lines were fitted by a bi-linear model, using an optimization technique. Open arrows indicate the time of double ridge and closed arrows show the highest number of leaf primordia initiated under each photoperiod.

Fotoperíodo

Miralles & Richards 2000, Ann. Bot. 85

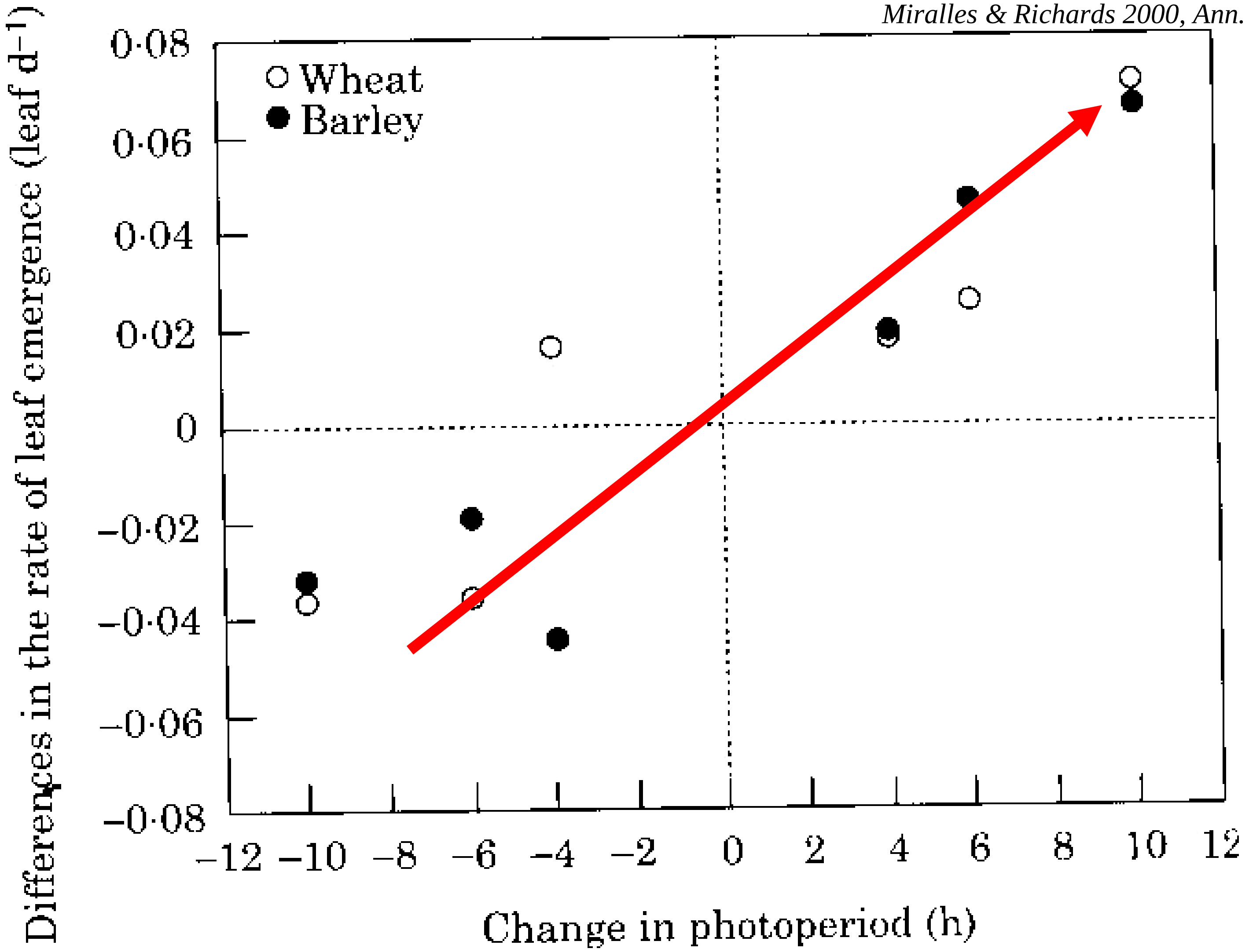


FIG. 4. Differences in the rate of leaf emergence (leaves d^{-1}) in wheat and barley associated with changes in photoperiod at TS/TM. The differences were calculated as in Fig. 2.

Trigo

Fotoperíodo

Baker et al. 1980
Plant, Cell and Environ. 3

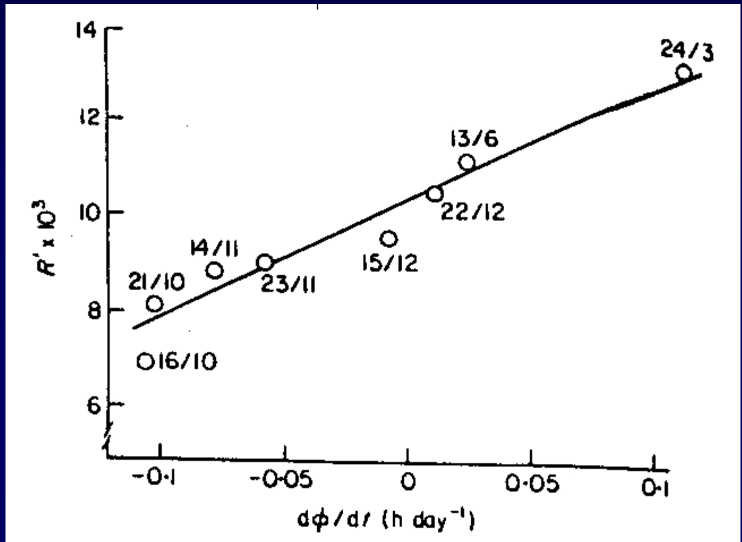


Figure 3. Mean rate of leaf appearance in thermal time (R') plotted against rate of daylength change at crop emergence ($d\phi/dt$). The date of emergence is beside each point. The equation of the fitted line ($P < 0.001$) is: $y = a + b(d\phi/dt)$. When R' has units of $(°C\ day)^{-1}$ and $d\phi/dt$ is in h day^{-1} $a = (10.4 \pm 0.2) \times 10^{-3}$ $(°C\ day)^{-1}$ and $b = (0.62 \pm 0.05)\ (°C\ day)^{-1}$.

Slafer et al. 1994
Ann. Bot 74

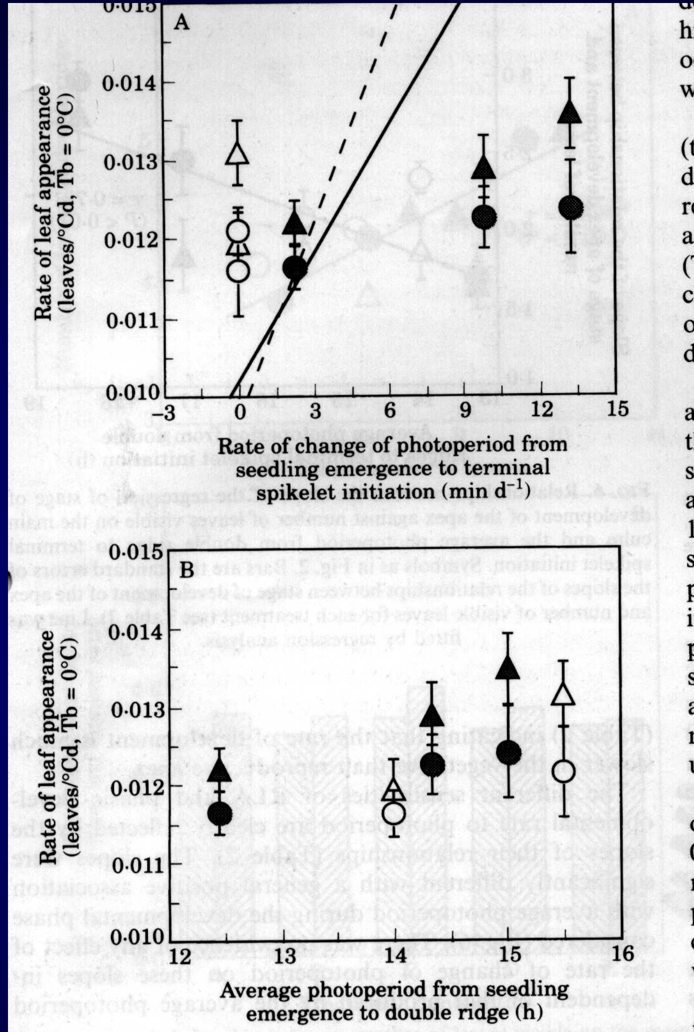


FIG. 4. Relationship between rate of leaf appearance on the main culm and the rate of change of photoperiod from seedling emergence to terminal spikelet initiation (A) and average photoperiod from seedling emergence to double ridge (B). Symbols as in Fig. 2. Bars are the standard error of the slopes of the relationships between number of leaves and thermal time after sowing for each treatment (see Table 1). Lines in (A) were fitted by regression analysis of these variables in two different time-of-sowing experiments (see text for details).

Tasa de cambio fotoperiodica

Modelos de respuestas a temperatura y fotoperíodo

Slafer & Rawson 1995
FCR 44

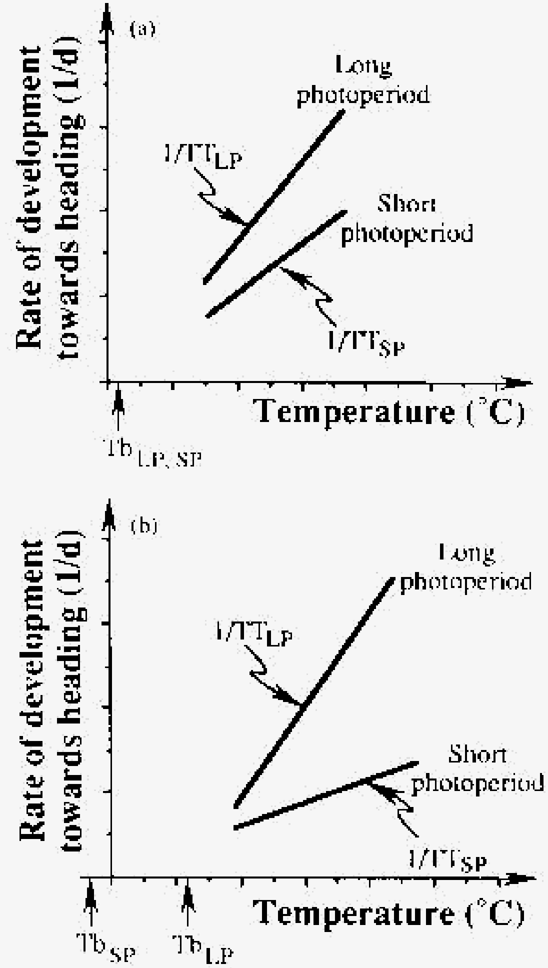


Fig. 5. Schematic models of the effects of photoperiod on the response of rate of development to temperature (between a base and an optimum temperature). The effects of photoperiod were exclusively on thermal time (a), or on base temperature and thermal time simultaneously (b). TT, LP, SP and Tb stand for thermal time, long photoperiod, short photoperiod and base temperature, respectively.

Vernalizacion

Baja Temperatura → per se, al disminuir la temperatura disminuye la tasa de desarrollo del cultivo

↓

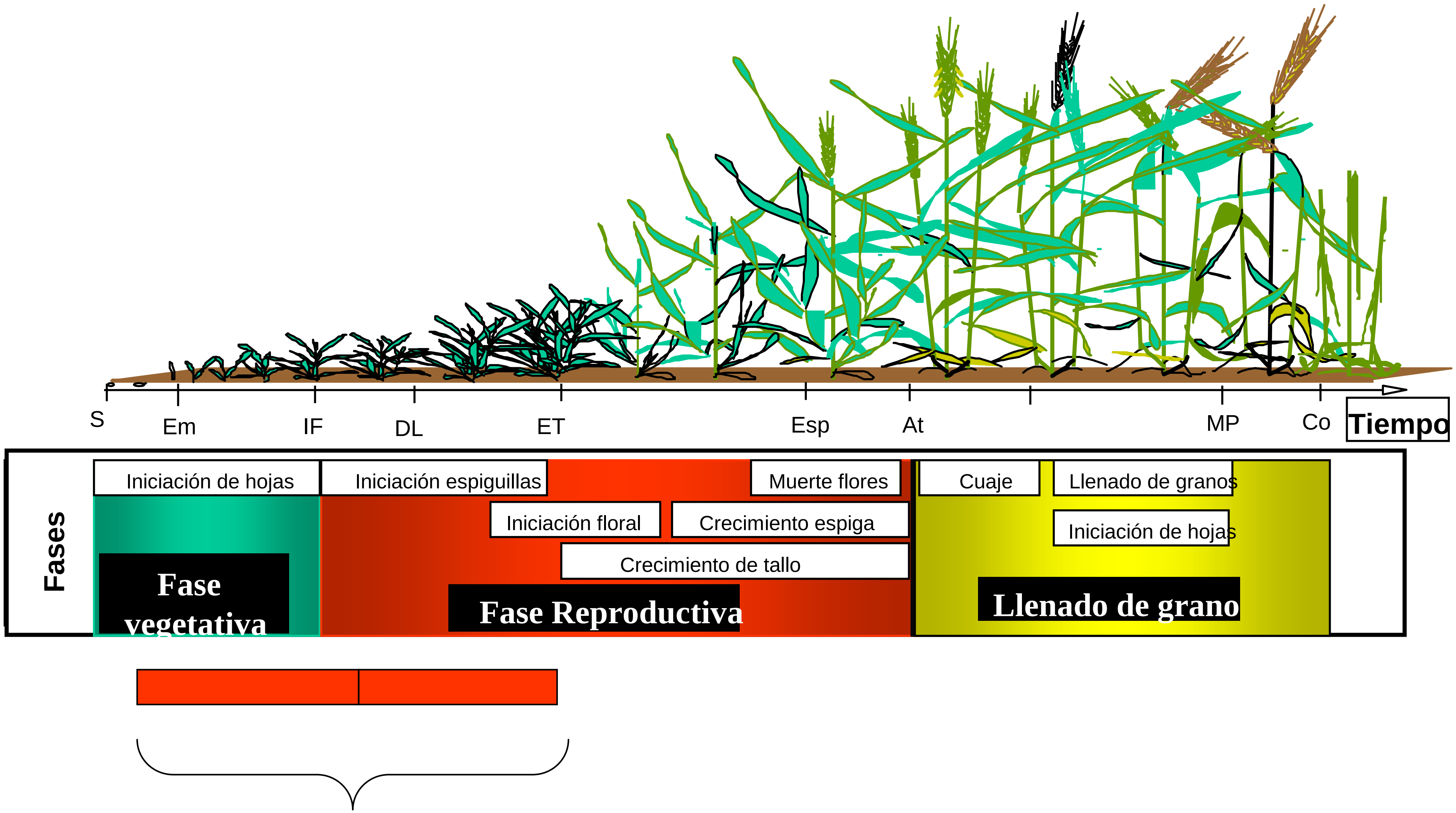
Vernalización

Aceleración del desarrollo hacia floración dado por la exposición a un período de bajas temperaturas

Requerimiento del cultivo de estar expuesto a un período determinado de bajas temperaturas para acelerar o poder progresar en su desarrollo posterior

El aumento de la tasa de desarrollo luego de la exposición por un período de tiempo a baja temperatura a partir de la imbibición de la semillas (Purvis, 1961)

Vernalización



Vernalización

Adaptado de Slafer and Rawson (1994)

Vernalizacion

INVERNALES: suelen responder más a menores temperaturas que los primaverales requieren períodos más largos para saturar su respuesta

MEDITERRÁNEOS o INTERMEDIOS

PRIMAVERALES

COLZA
TRIGO

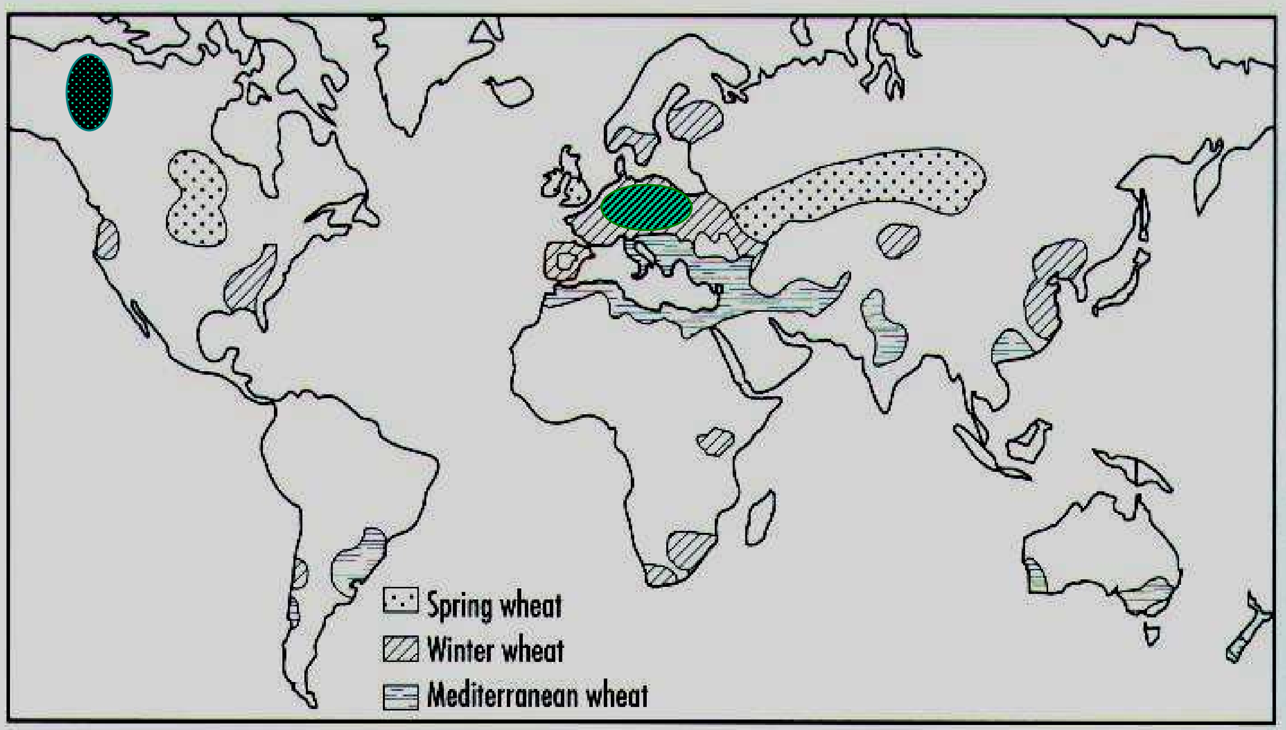
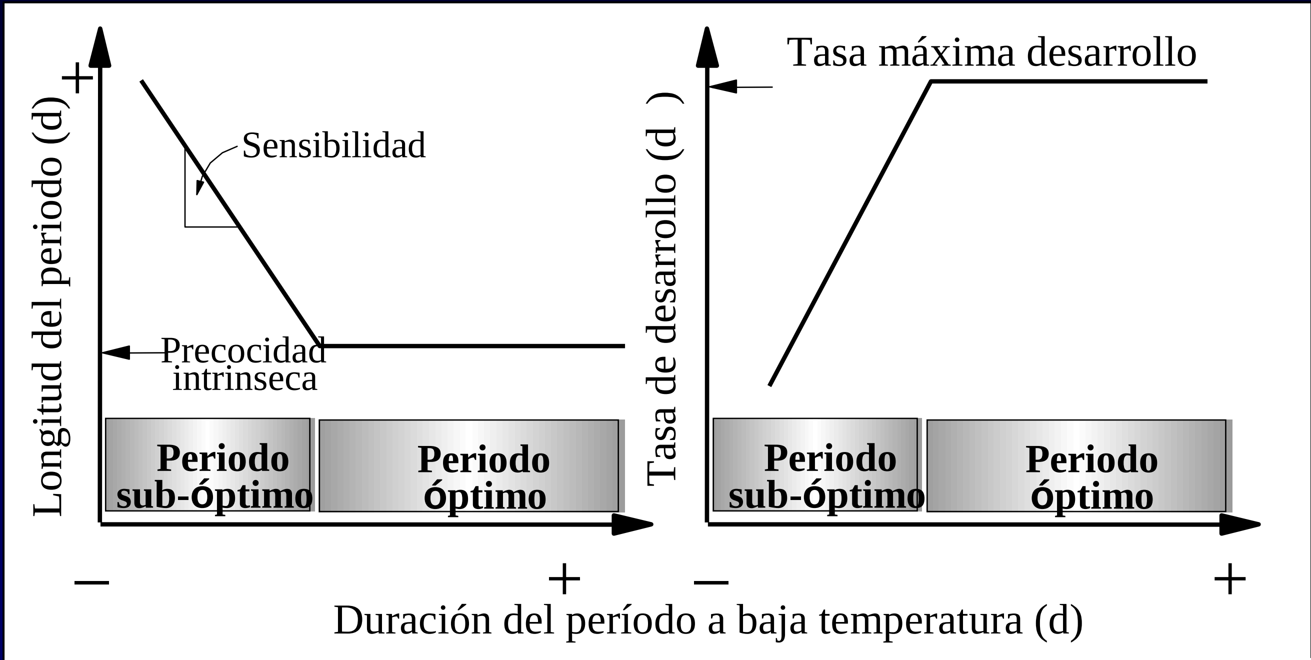
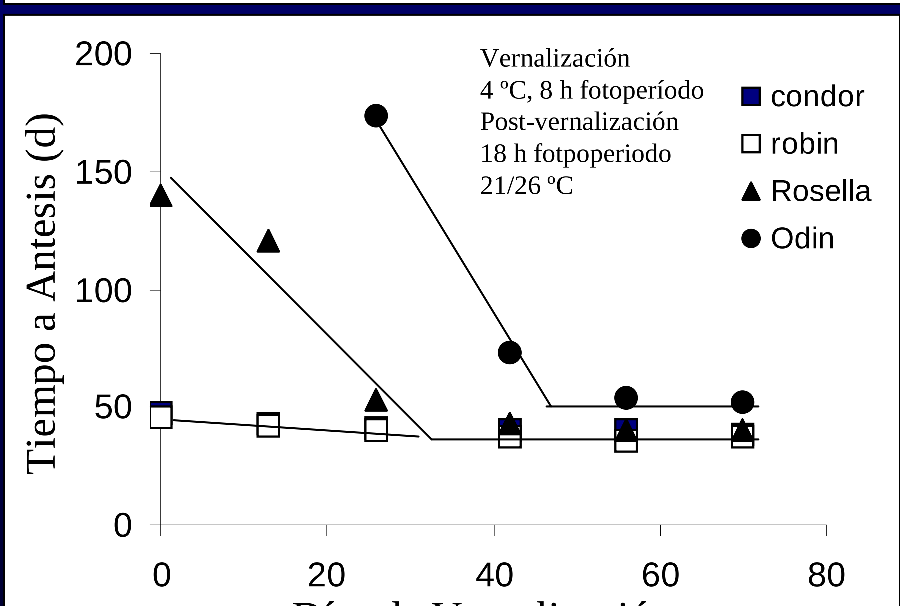


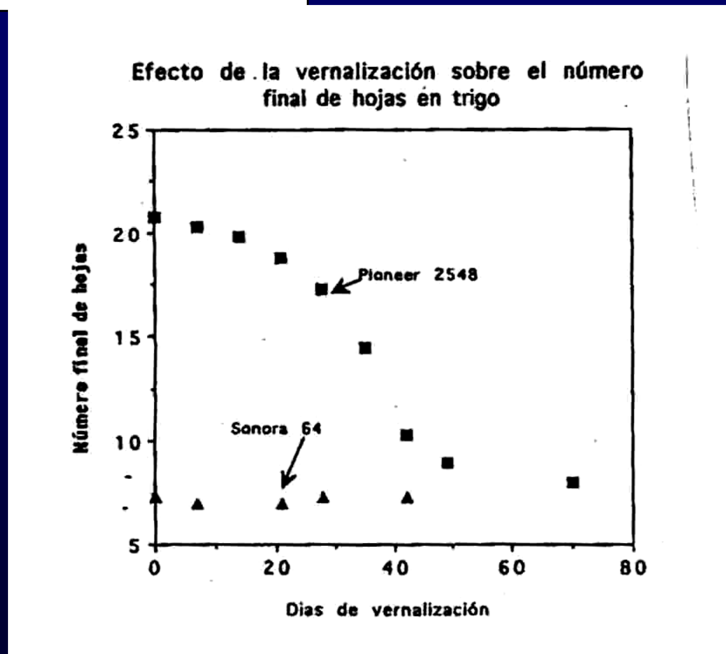
Figure 1. Distribution of different wheat types in countries with more than 5% of their arable land under wheat.
Source: Adapted from Bunting et al. (1982).

Vernalizacion

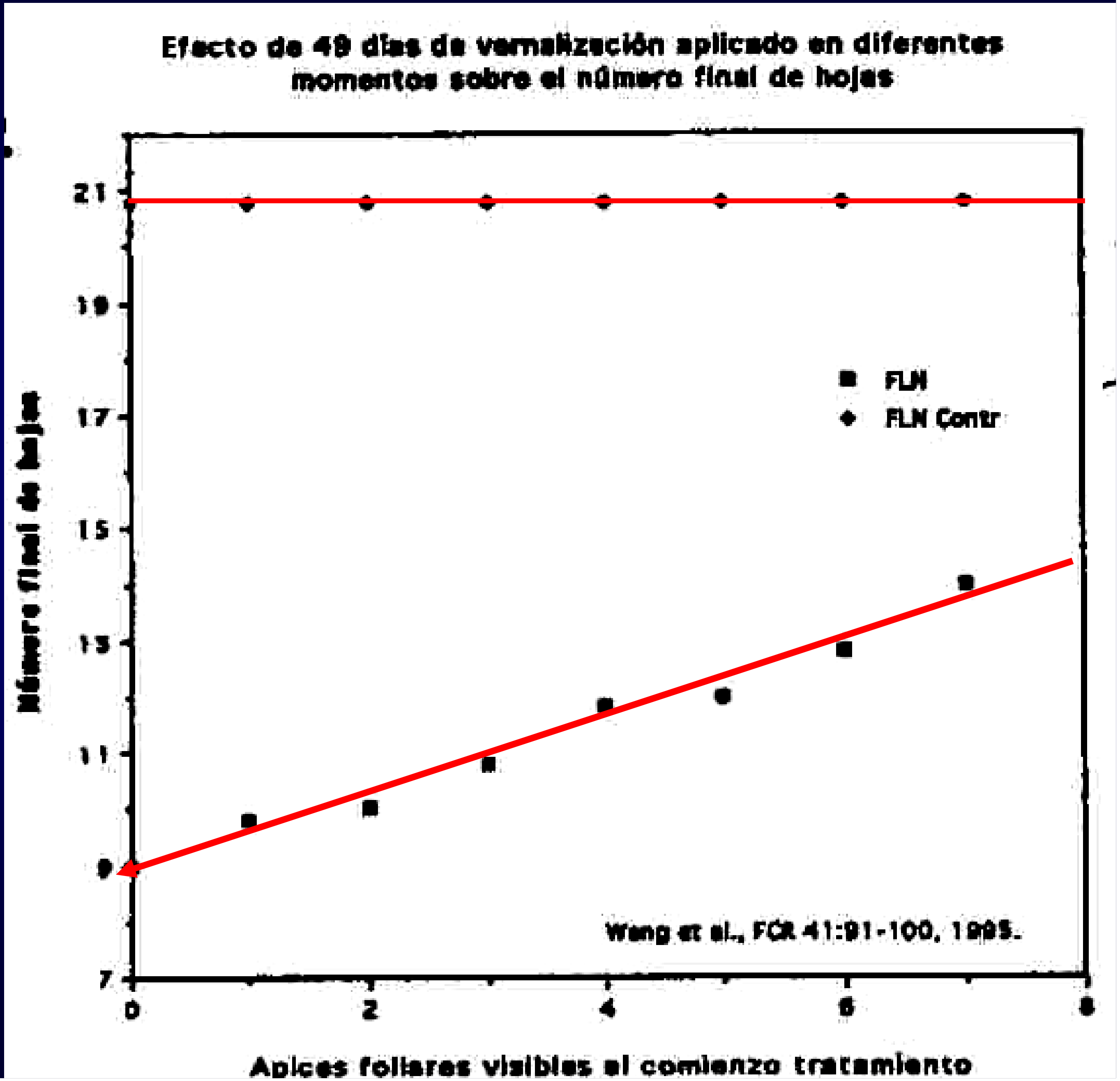




Slafer, 1995

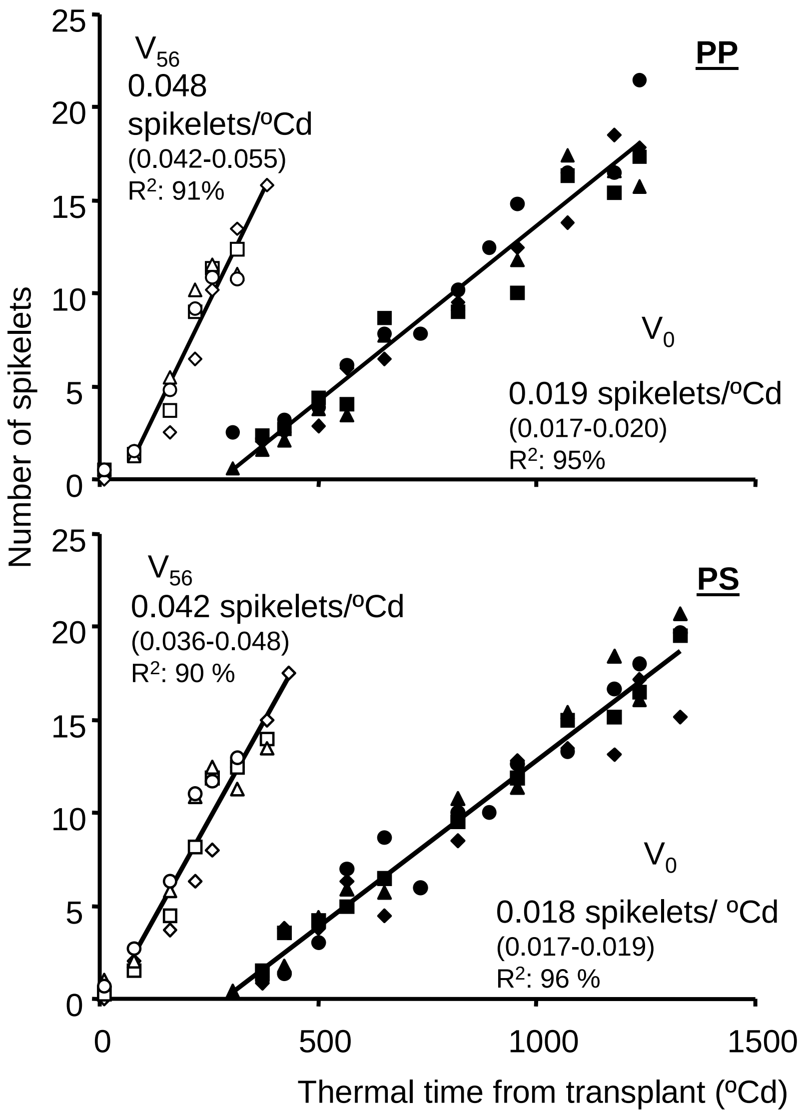


Vernalizacion



Hodgson, 1978

Vernalizacion



González et al. 2002 FCR 74

Table 1

Percentage of fertile emerged spikes [(number of plants with fertile emerged spikes/total number of plants) × 100] at the end of the experiment (i.e. 2,560 °C d from transplant)

Treatments		Cultivars		
Vernalization	Photoperiod	ProINTA Puntal	ProINTA Super	Klein Pegaso
V_{56}	NP +0	100	100	100
	NP +2	100	100	100
	NP +4	100	100	100
	NP +6	100	100	100
V_0	NP +0	25	24	100
	NP +2	24	31	100
	NP +4	33	40	100
	NP +6	33	53	100

Figure 4: Dynamics of spikelet initiation in ProINTA Puntal (PP) and ProINTA Super (PS) in vernalized (open symbols) and unvernalized plants (closed symbols). Different symbols inside each vernalization treatment represent the photoperiod treatments: (◇ , ◆) NP+0, (□ , ■) NP+2, (△ , ▲) NP+4, (○ , ●) NP+6. The spikelet initiation rates with their 95% confidence intervals are provided inset.

Vernalizacion

COLZA

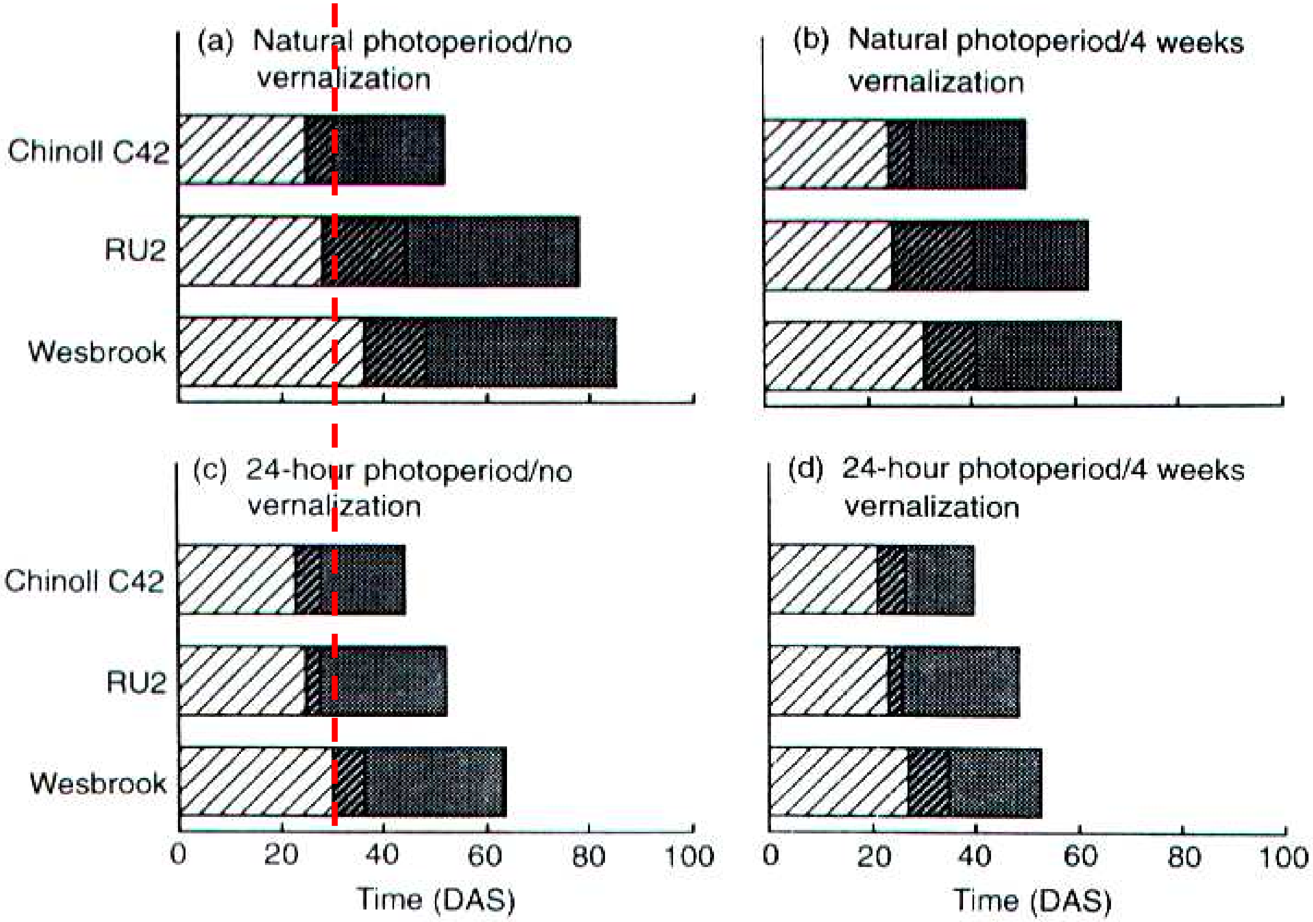


Fig. 2.3. Effects of photoperiod and vernalization on pre-anthesis development in selected *B. rapa* (Chinoli) and *B. napus* populations. Three phases in sequence: vegetative (▨), post-initiation (▨) and stem elongation (▩). DAS = days after sowing. Source: Thurling and Kaveeta (1992a).

Vernalizacion

Efectividad de la temperatura

Fuente	Temperatura (*C)
Ahrens & Loomis (1963)	0 - 8
Poehlman (1987)	1 - 3
Purvis (1961) *	1 - 7
Napp-Zinn (1984) *	1 - 7
Trione & Metzger (1970)	1 - 9
Heyne (1986)	3 - 8
Weir et al. (1984)	3 - 10
Hedel et al. (1986)	< 10 - 12

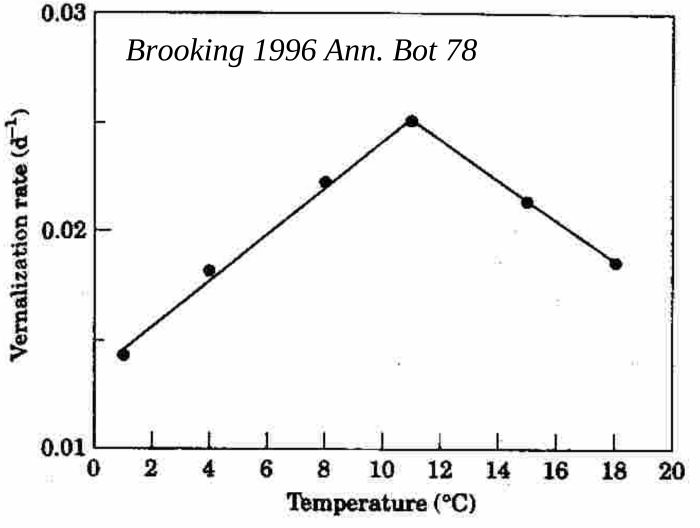


FIG. 4. Rate of attainment of saturation of vernalization as a function of temperature for Norin No. 27 wheat. Data were derived from a reanalysis of Experiment 1 of Chujo (1966) using definitions and criteria described in the text.

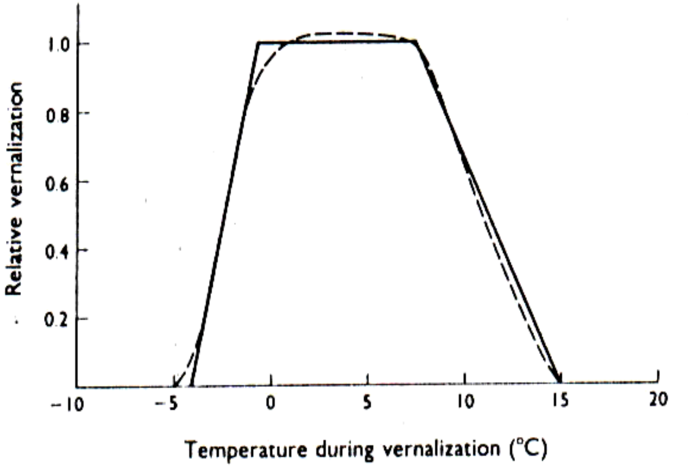


Fig. 5.5. Vernalization response of flowering in winter cereals (based on data for 'Petkus' rye from Salisbury (1963); see also Weir *et al.* 1984).

Vernalizacion

Table 1. Summary of earlier proposals for the relationship between temperature and vernalising effectiveness in wheat, with the variable used to measure vernalisation, the effectiveness function proposed and cultivars tested, whether plant development that was concurrent with vernalising treatments was excluded from effects ascribed to vernalisation, and the cardinal temperatures for vernalisation

Previous study	Variable measured	Effectiveness function	Cultivar	Treatments excluded	Cardinal temperatures for vernalisation (°C)		
					Minimum	Optimum	Maximum
Brooking 1996	Leaf number	Bilinear	Norin 27	No	–2	11	24
Chujo 1966	Leaf number	n.a.	Wheat	n.a.	<1	n.a.	15–18
Chujo 1975	Leaf number	n.a.	Norin 27	n.a.	<5	4–12	>15
Craigon *et al.* 1995	Leaf number	Bilinear	Norin 27	Yes	–4.8	5.2	26.6
				No	–5.05	5.5	18.8
Gardner and Barnett 1990	Cold units	Uniform	Wheat, rye	n.a.	0	0–10	10
Kirby 1992	Effectiveness of vernalisation	Multilinear	Wheat	n.a.	–0.5	0.5–8	12
Maas and Arkin 1980	Effectiveness of vernalisation	Multilinear	Wheat	n.a.	–4	0–3	16
Porter and Gawith 1999	Effectiveness of vernalisation	Multilinear	Winter wheats	Various	–1.3	3.8–6.0	15.7
Reinink *et al.* 1986	Effectiveness of vernalisation	Multilinear	Wheat	n.a.	–1	0–3	9
Robertson *et al.* 1996	Leaf number	Linear	Agent	No	–1 to 5	~5	14–17
Trione and Metzger 1970	Crown to apex distance	Bilinear	n.a.	Yes	<4	~7	<12
Yan and Hunt 1999*b*	Leaf number	Beta	Norin 27	Yes	0	5.7	21.3

n.a., Not applicable or not available.

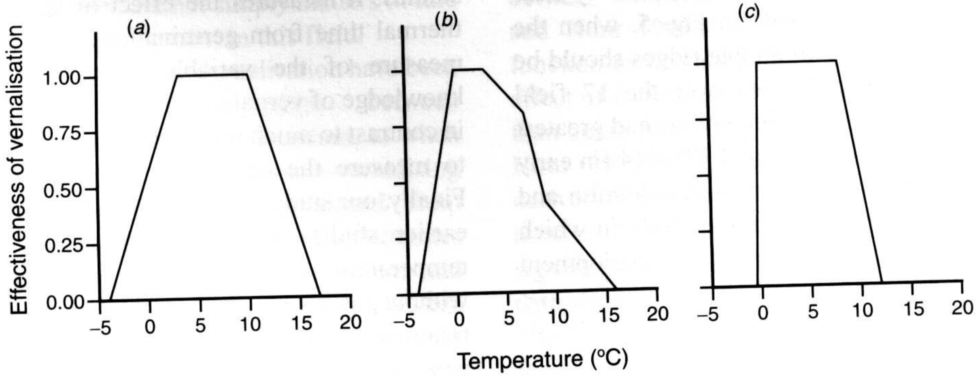


Fig. 3. Relationships between temperature and vernalising effectiveness for the 3 linear interpolation functions that were evaluated in this study. These were described in (*a*) Lumsden (1980), (*b*) Maas and Arkin (1980), and (*c*) Cao and Moss (1997), and are all scaled to have a maximum vernalising effectiveness of 1.

Penrose et al. 2003 Aust. J. Agric. Res 54

Devernalización

La vernalización es un proceso reversible: los efectos se pueden revertir si el período de bajas temperaturas es interrumpido.

Gregory y Purvis (1948) → > 30ºC
Purvis y Gregory (1952) → Ray -grass

Dubert et al. (1992) → > 20 ºC

Slafer (1995) → > 18ºC

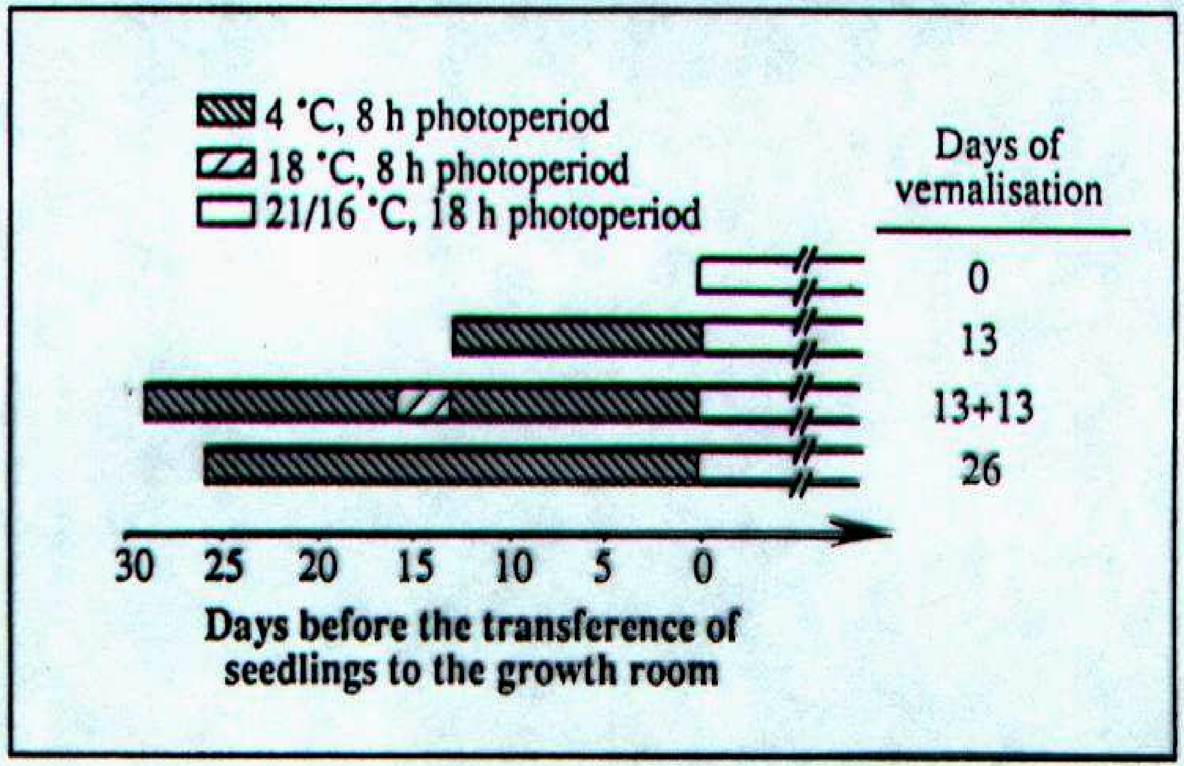


Fig. 31. Diagram for the treatments of the devernalisation study.

Slafer, 1995

Devernalización

Slafer, 1995

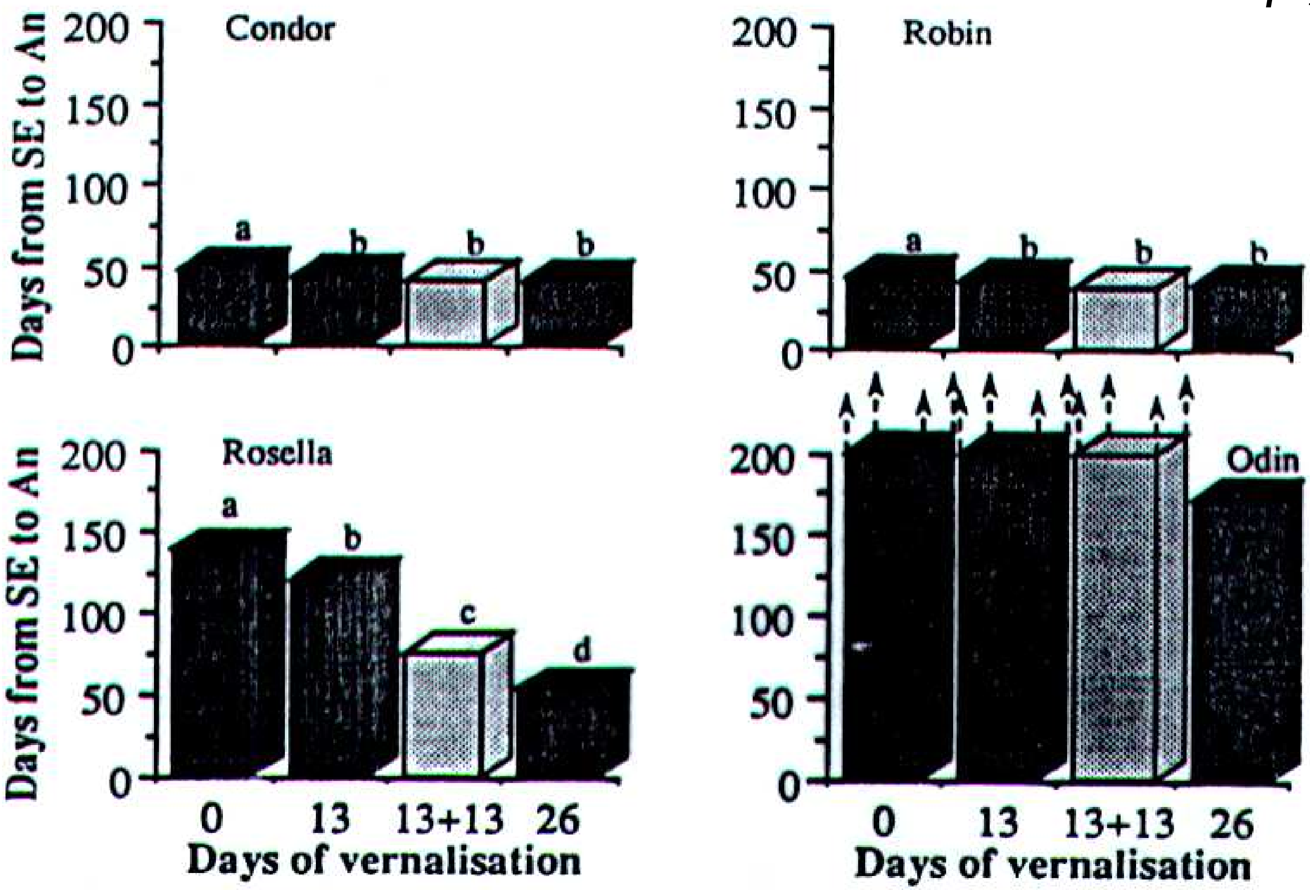


Fig. 32. Duration from seedling emergence (SE) to anthesis (An) in four wheat cultivars [Condor, Robin, Rosella and Odin] grown at 18 h photoperiod and 21/16 °C after being subjected to 0, 13 and 26 continuous days of vernalisation (at 4 °C and 8 h photoperiod) or to two periods of vernalisation of 13 days interrupted by three days at 18 °C (13+13). Values of bars with different letters above (within each cultivar) are significantly different ($P<0.05$). Bars of cultivar Odin with arrows above indicate that the treatments did not reach anthesis by the end of the experiment.

Qué factores debemos tener en cuenta al analizar la respuesta a la vernalización?

- Variabilidad genotípica

-Longitud del período de vernalización

-Temperatura vernalizante

Efectividad de vernalización

- Sensibilidad a la vernalización en c/u de las etapas del ciclo ontogénico

-Devernalización

-Interacción fotoperíodo

F x V

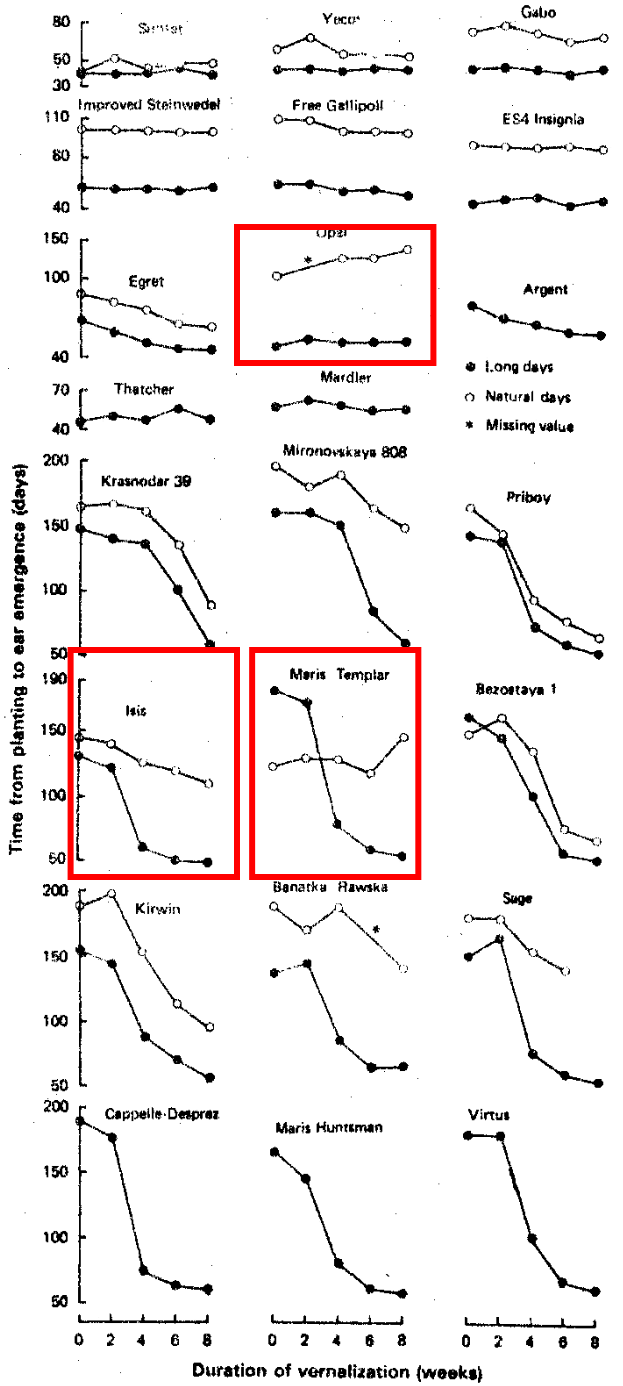


Fig. 3. Influence of duration of vernalization on the period from planting to ear emergence on varieties grown under natural (○) and long (●) photoperiods.

Davidson et al. 1985
Aust. J. Agric. Res 36

Masle et al., 1989
Crop Sci. 29

12 cultivares trigo
Vernalizado y no vernalizado
2 localidades = latitud

4 años
17 fechas de siembra
desde Otoño hasta primavera

F x V

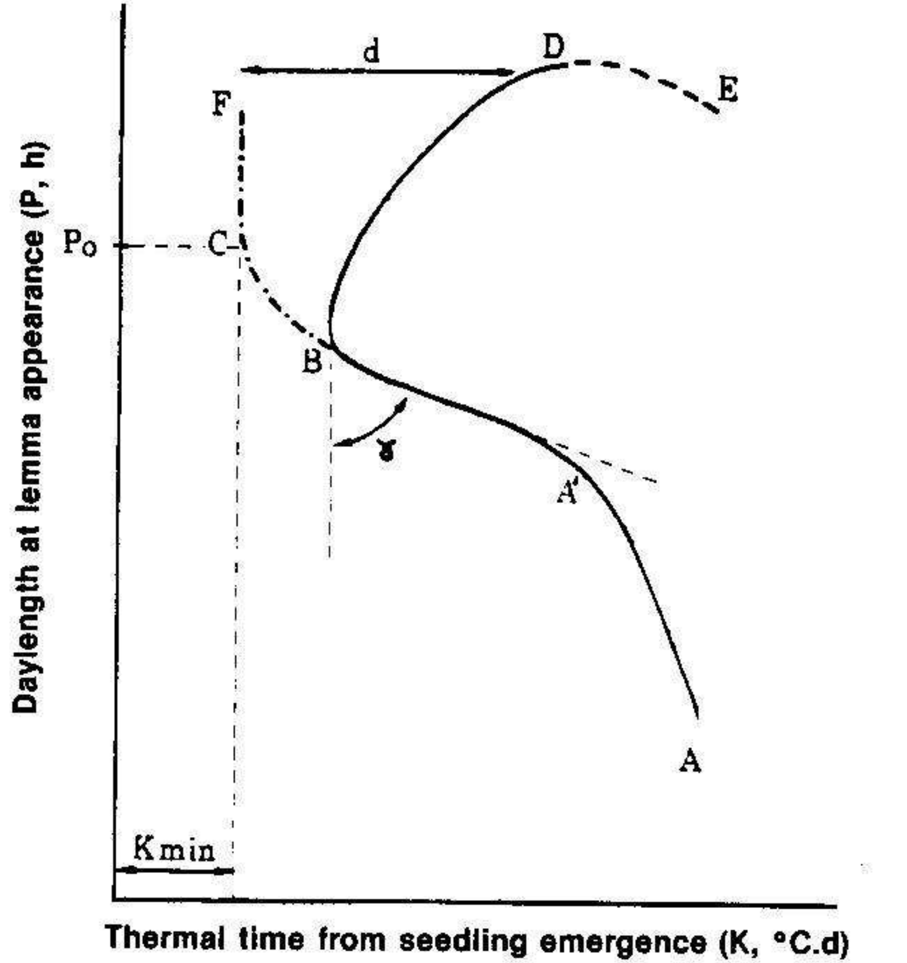
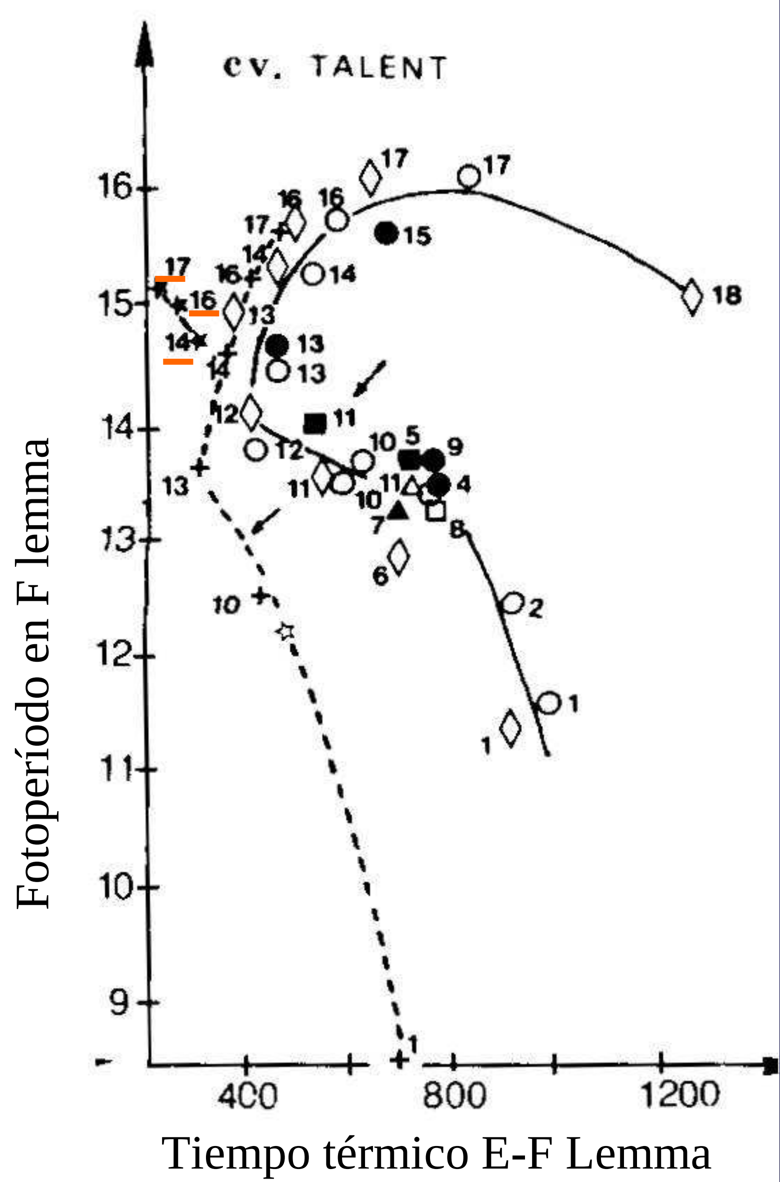
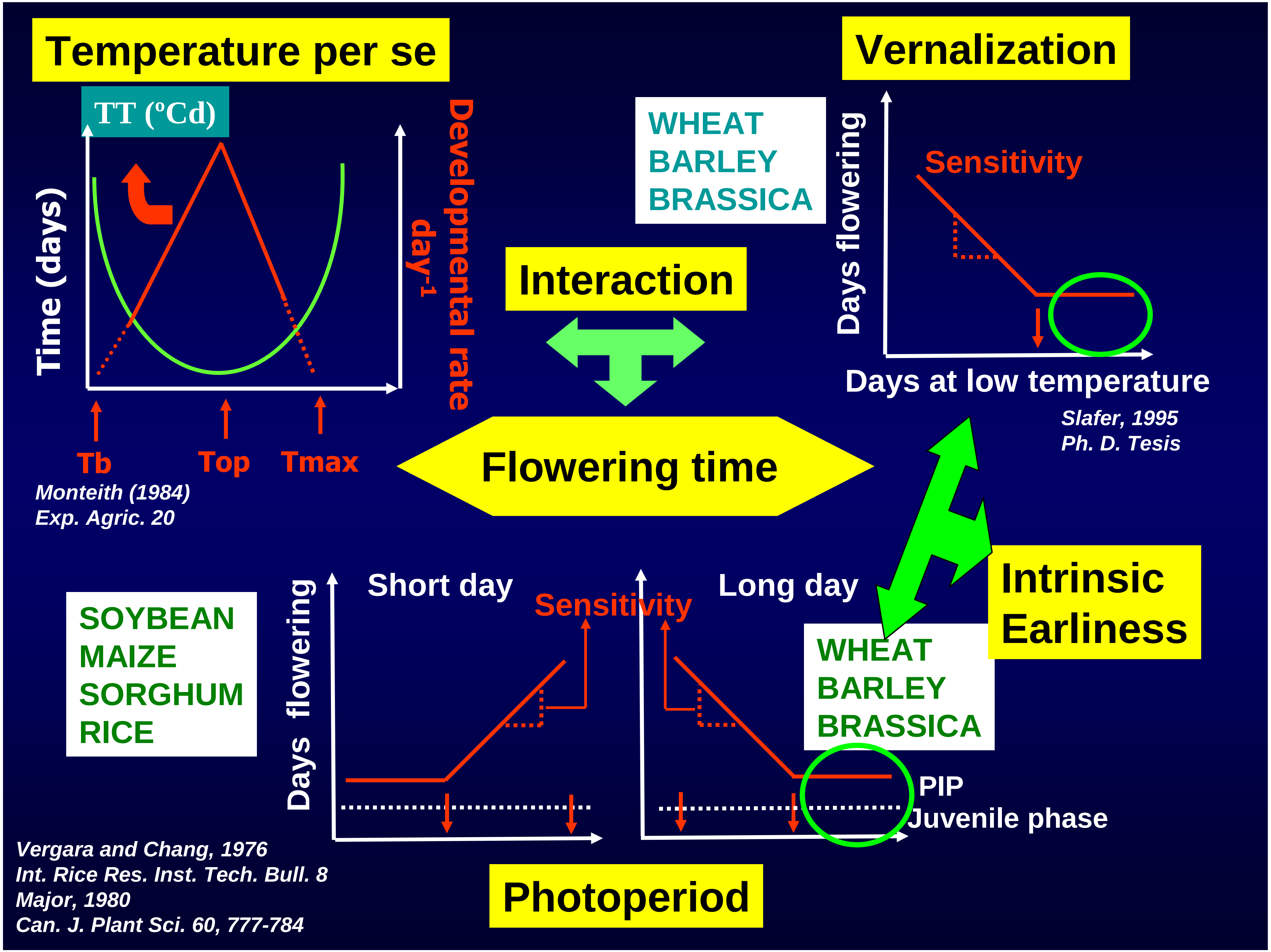


Fig. 7. Schematic diagram of the general curve for the family of curves shown in Fig. 4. Vernalization requirement (d), intrinsic earliness (K_{min}), and relative sensitivity (γ) to photoperiod and temperature as defined in the text are indicated. Curve BF was obtained with vernalized seeds; curve AE was obtained with unvernalized seeds.





Temperature per se
TT (ºCd)
Time (days)
Developmental rate
day-1
Tb
Top
Tmax
Monteith (1984)
Exp. Agric. 20
Vernalization
WHEAT
BARLEY
BRASSICA
Days flowering
Sensitivity
Days at low temperature
Slafer, 1995
Ph. D. Tesis
Interaction
Flowering time
Intrinsic
Earliness
SOYBEAN
MAIZE
SORGHUM
RICE
Days flowering
Short day
Sensitivity
Long day
WHEAT
BARLEY
BRASSICA
PIP
Juvenile phase
Vergara and Chang, 1976
Int. Rice Res. Inst. Tech. Bull. 8
Major, 1980
Can. J. Plant Sci. 60, 777-784
Photoperiod

WHEAT

Intrinsic earliness Eps

Genome

Chromosome nº	A	B	D
1			
2	*2AS*	***2BS***	*2DLS*
3			
4			
5			
6			
7			

Vrn **Vernalization**

Genome

Chromosome nº	A	B	D
1			
2			
3			
4			
5	***A1 /A2***	***B1***	***D1***
6			
7		*B4*	

Flowering time

Photoperiod Ppd

Genome

Chromosome nº	A	B	D
1			
2	*A1*	***B1***	***D1***
3			
4			
5			
6			
7			

Snape et al.,2001
(Euphytica 119)

Fernanda G. González
Facultad de Agronomía
Univ. de Buenos Aires

Future Challenges
Gene isolation

Intrinsic earliness Eps

Genome: Wheat (A, B, D) / Barley (H)

Chromosome nº	A	B	D	H
1				
2	2AS	**2BS**	2DLS	2HS/HL
3	3AL	3BL	3DL	3HL
4	2AL	4BL	4DL	4HL
5	5A	5B	5D	5H
6	6AL .1/.2	6BL .1/.2	6DL .1/.2	6HL.1/.2
7	7AS /AL	7BS /BL	7DS /DL	7HS/HL

Vrn Vernalization

Genome: Wheat (A, B, D) / Barley (H)

Chromosome nº	A	B	D	H
1	A3	B2	D2	Sh3 (-H3)
2				
3				
4		B2	D2	Sh (-H2)
5	**A1 /A2**	**B1**	**D1**	Sh2 (-H1)
6				
7		B4		

Flowering time

Photoperiod Ppd

Genome: Wheat (A, B, D) / Barley (H)

Chromosome nº	A	B	D	H
1	A2	B2	D2	H2
2	A1	**B1**	**D1**	**H1**
3				
4				
5				
6	A3	B3	D3	ea_7
7				

Snape et al.,2001
(Euphytica 119)

Fernanda G. González
Facultad de Agronomía
Univ. de Buenos Aires

Photoperiod

Flowering Time insensitivity order

B1>A1>D1	**Law et al., 1978** **(SL)** *(Heredity, 41)* **CS**
B1>D1>A1	**Scarth & Law, 1984** **(SL)** *(Z. Pflanzenzüchtg, 92)* **CS**
D1>B1>A1	**Scarth & Law, 1984** **(SL)** **2D Ciano 67, 2B Timstein** *(Z. Pflanzenzüchtg, 92)*
D1>B1	**Worland, 1996** **(MCRL)** *(Euphytica, 89)*
A1>D1>B1	**Stelmakh, 1998** **(NIL)** *(Euphytica, 100)*
B1=D1	**Whitechurch & Slafer, 2002** **(SL)** **2 CS 1Ci** *(Field Crops Res., 73)*
D1>A1>B1	**Butterworth et al., 2002** **(NIL)** *(Jhon Innes Centre)*
D1>B1	**González et al., 2003** **(NIL)** *(unpublished)*

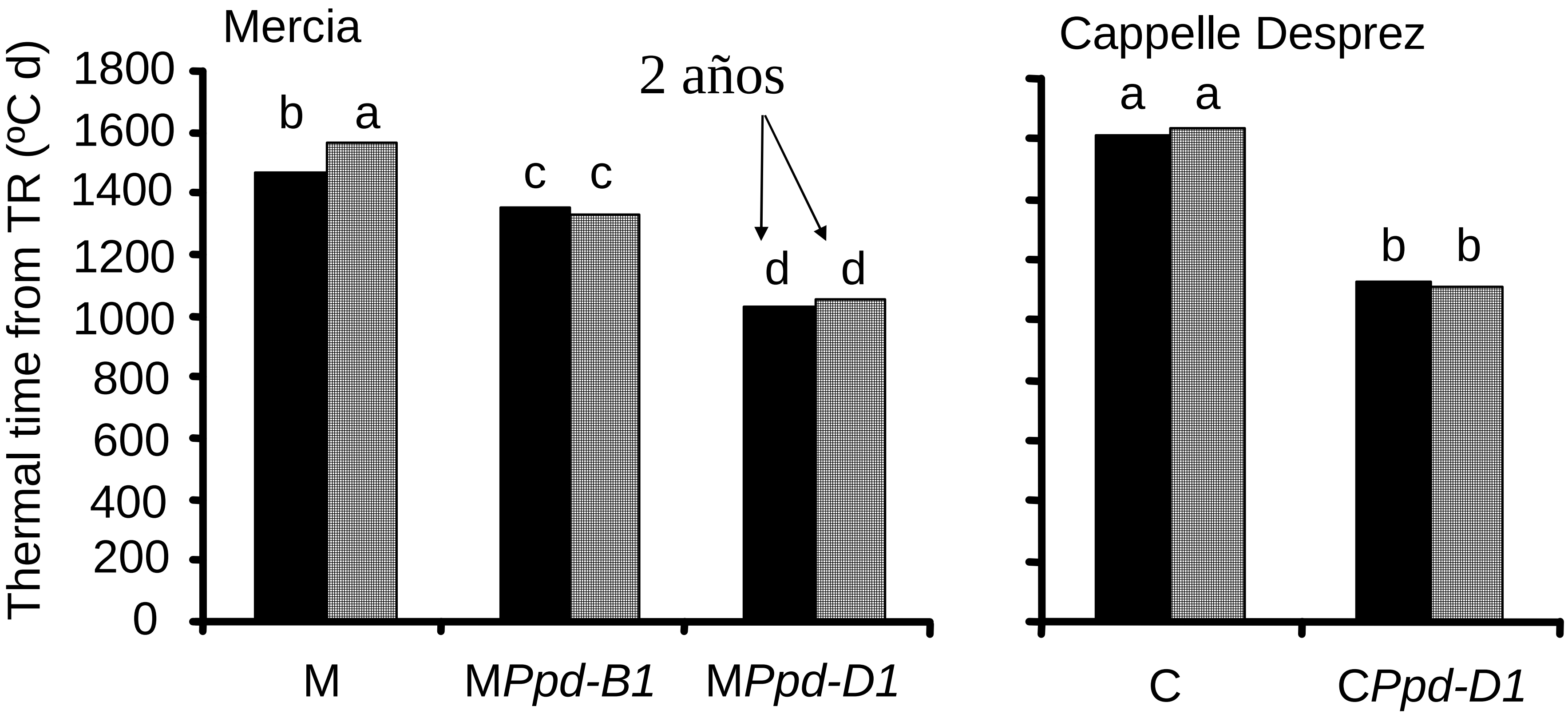
Phase by phase effects?

	VP	ERP	LRP	
D1	No	Yes	Yes	Scarth et al., 1985 *(Ann. Bot., 55)*
	Yes	Yes	Yes	Whitechurch & Slafer, 2002
	Yes	Yes	Yes	González et al., unpublished
B1	No	Yes	Yes	
	Yes	Yes	Yes	
	No	Yes	Yes	
A1	?	?	?	

Fernanda G. González
Facultad de Agronomía
Univ. de Buenos Aires

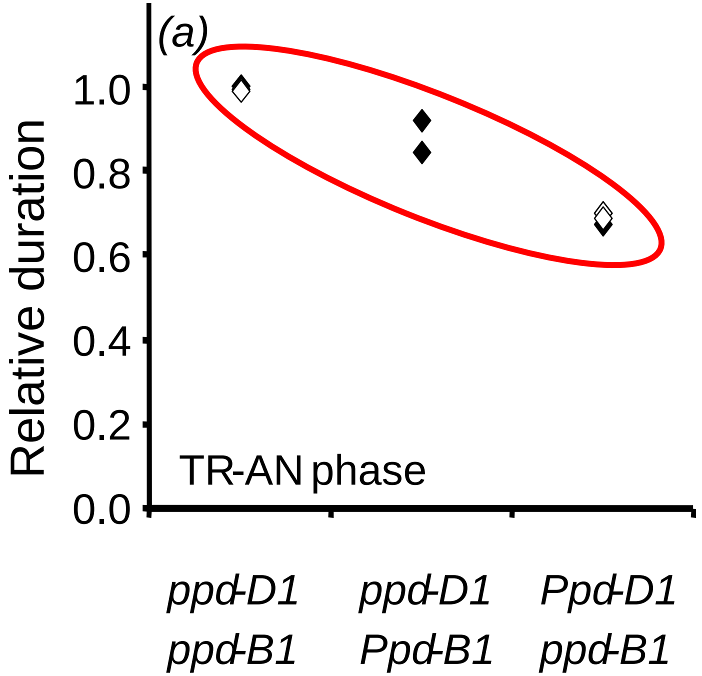
Genes de fotoperiodo y su impacto sobre la duración de las etapas

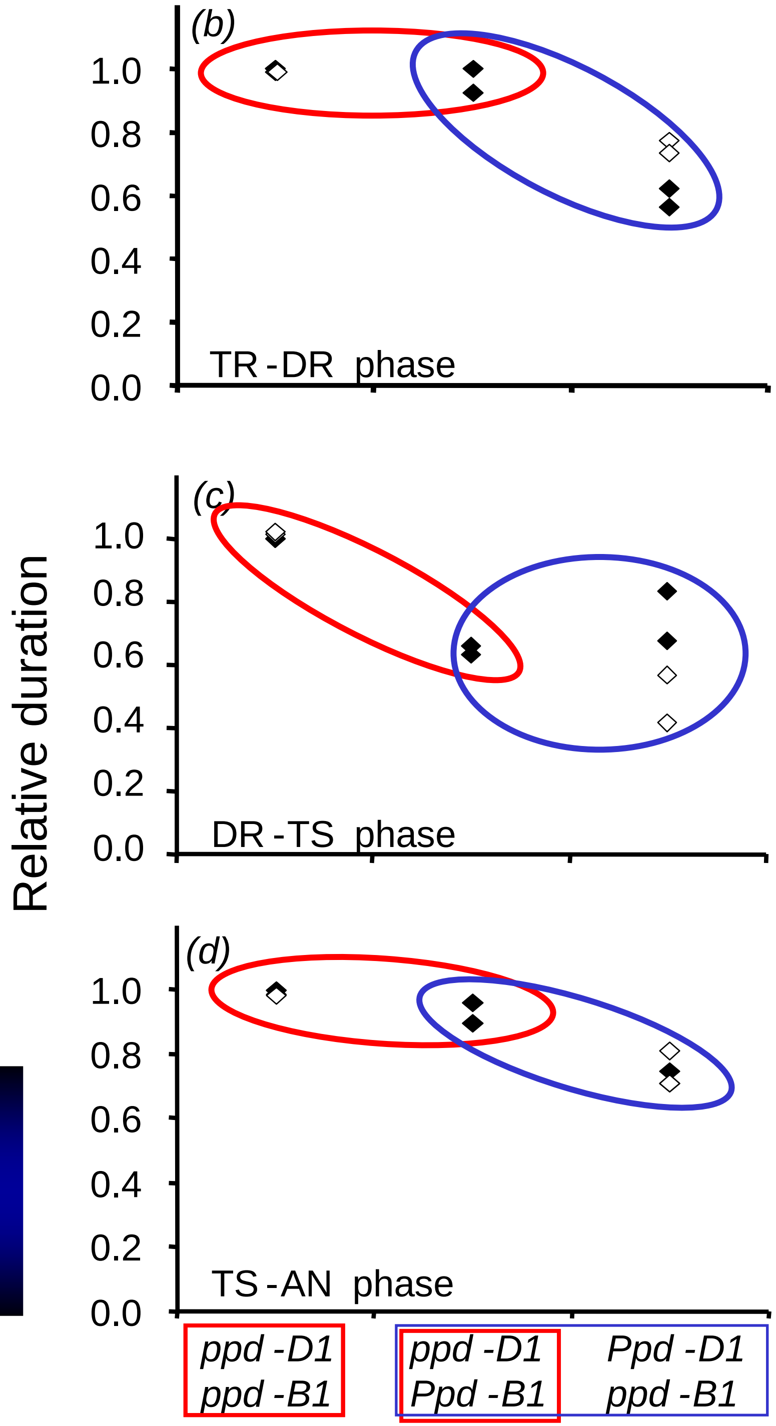
Background	Genome		
Mercia	D	B	A
M	*ppd-D1*	*ppd-B1*	*ppd-A1*
M*Ppd-B1*	*ppd-D1*	*Ppd-B1*	*ppd-A1*
M*Ppd-D1*	*Ppd-D1*	*ppd-B1*	*ppd-A1*
Cappelle Desprez			
C	*ppd-D1*	*ppd-B1*	*ppd-A*
C*Ppd-D1*	*Ppd-D1*	*ppd-B1*	*ppd-A1*



Gonzalez, Slafer & Miralles (2004)

Genes de fotoperiodo y su impacto sobre la duración de las etapas





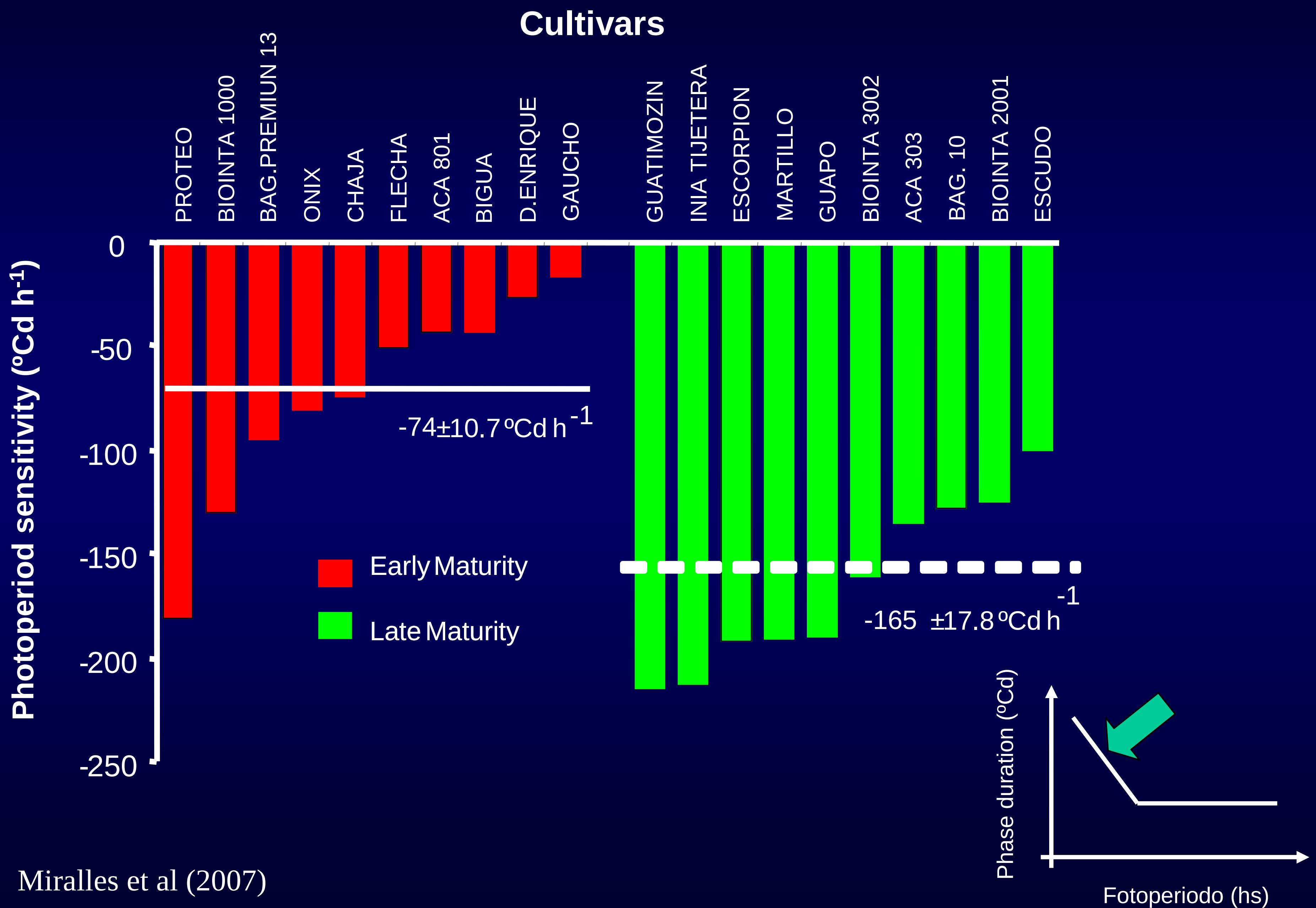
Los genes PpB1 y PpD1 tienen distintos impacto en las etapas ontogénicas.

Gonzalez, Slafer & Miralles (2004)

Respuesta al fotoperiodo y la vernalizacion de los cultivares Argentinos de Trigo y Cebada

RESULTS

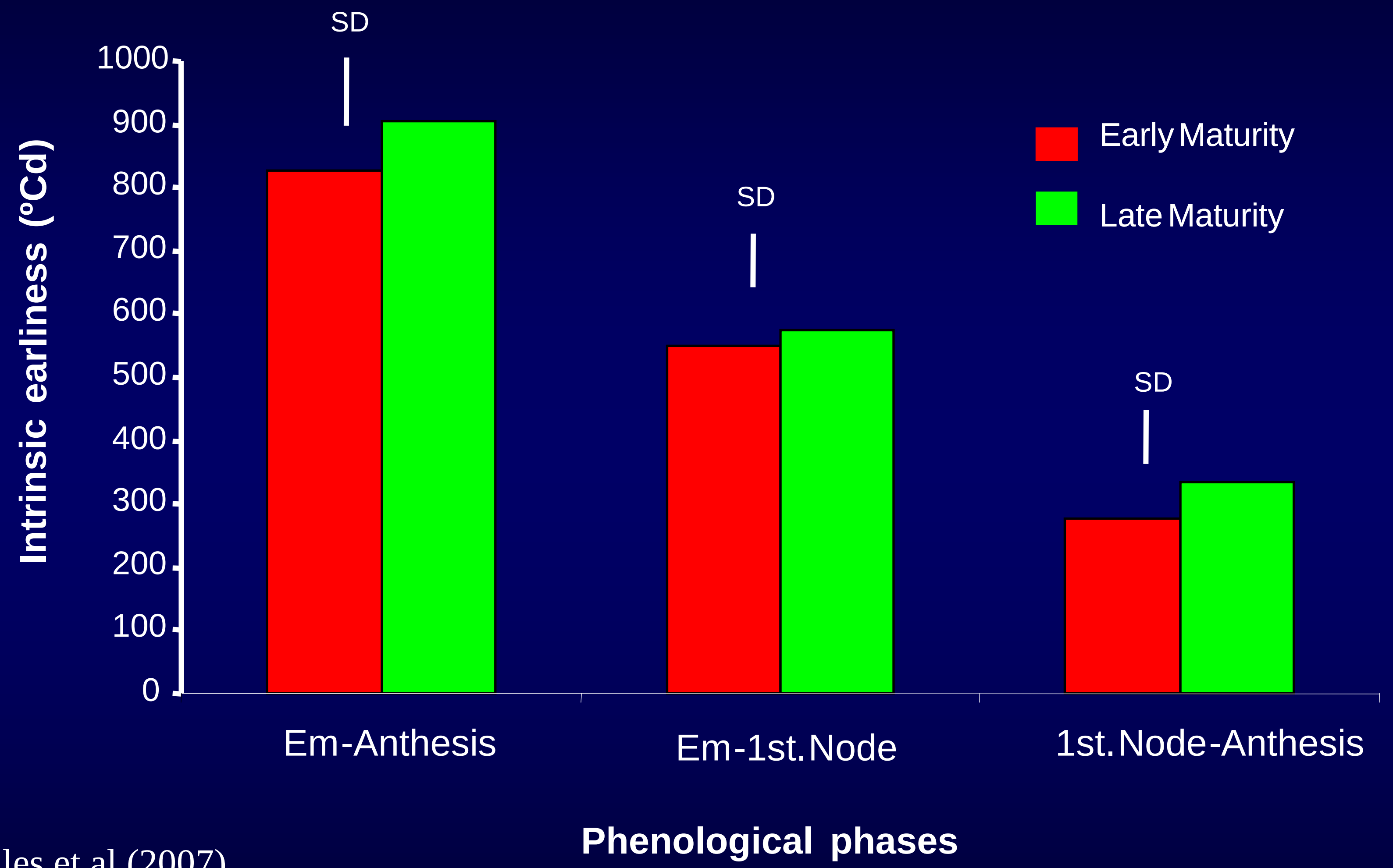
Emergence-Anthesis Phase



Miralles et al (2007)

RESULTS

Intrinsic Earliness

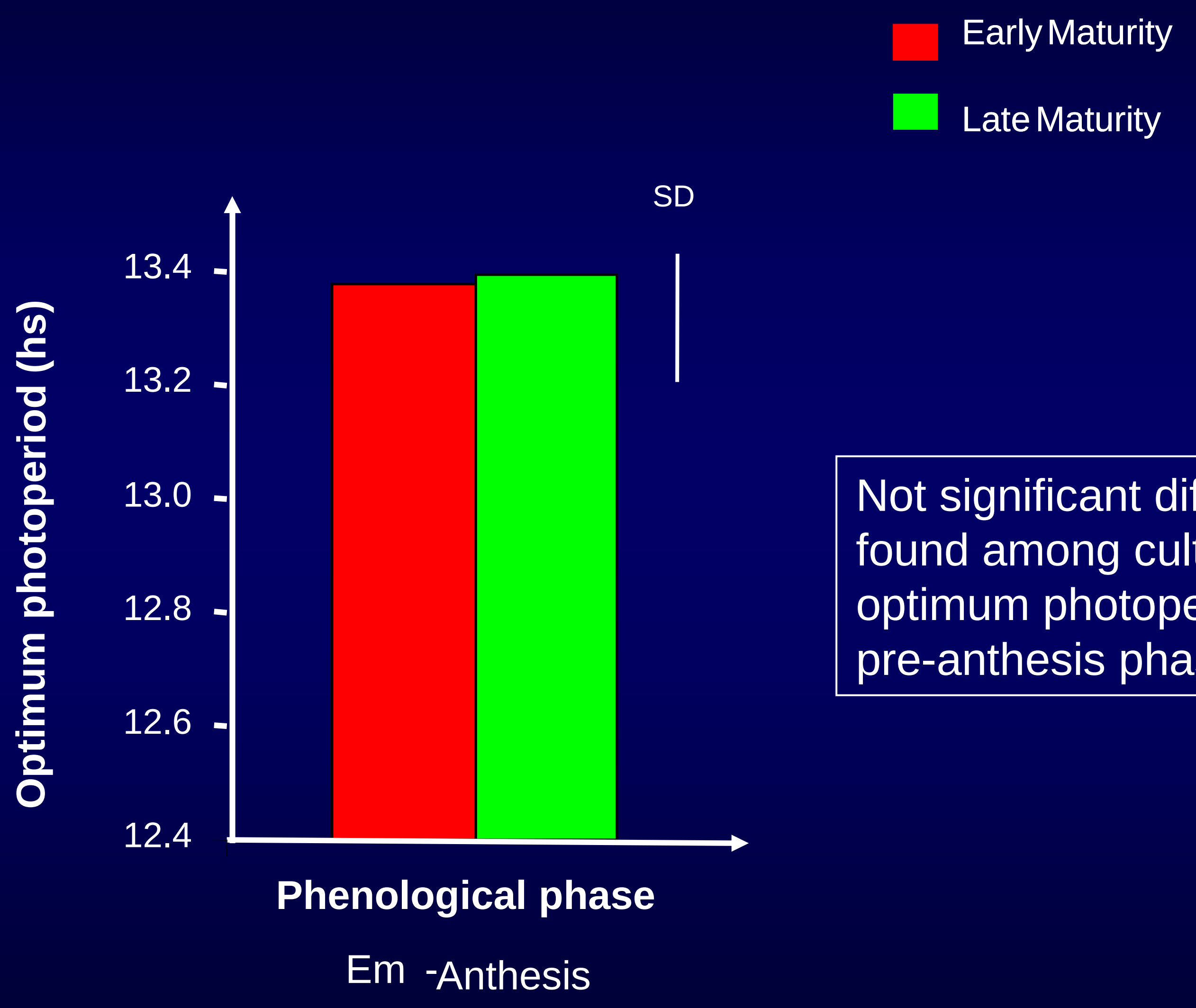


Miralles et al (2007)

Intrinsic earliness of the emergence-anthesis phase ranged between 760 and 1040 ºC d and between 800 and 1160 ºC d, for early and late maturity group, respectively.

RESULTS

Optimum photoperiod

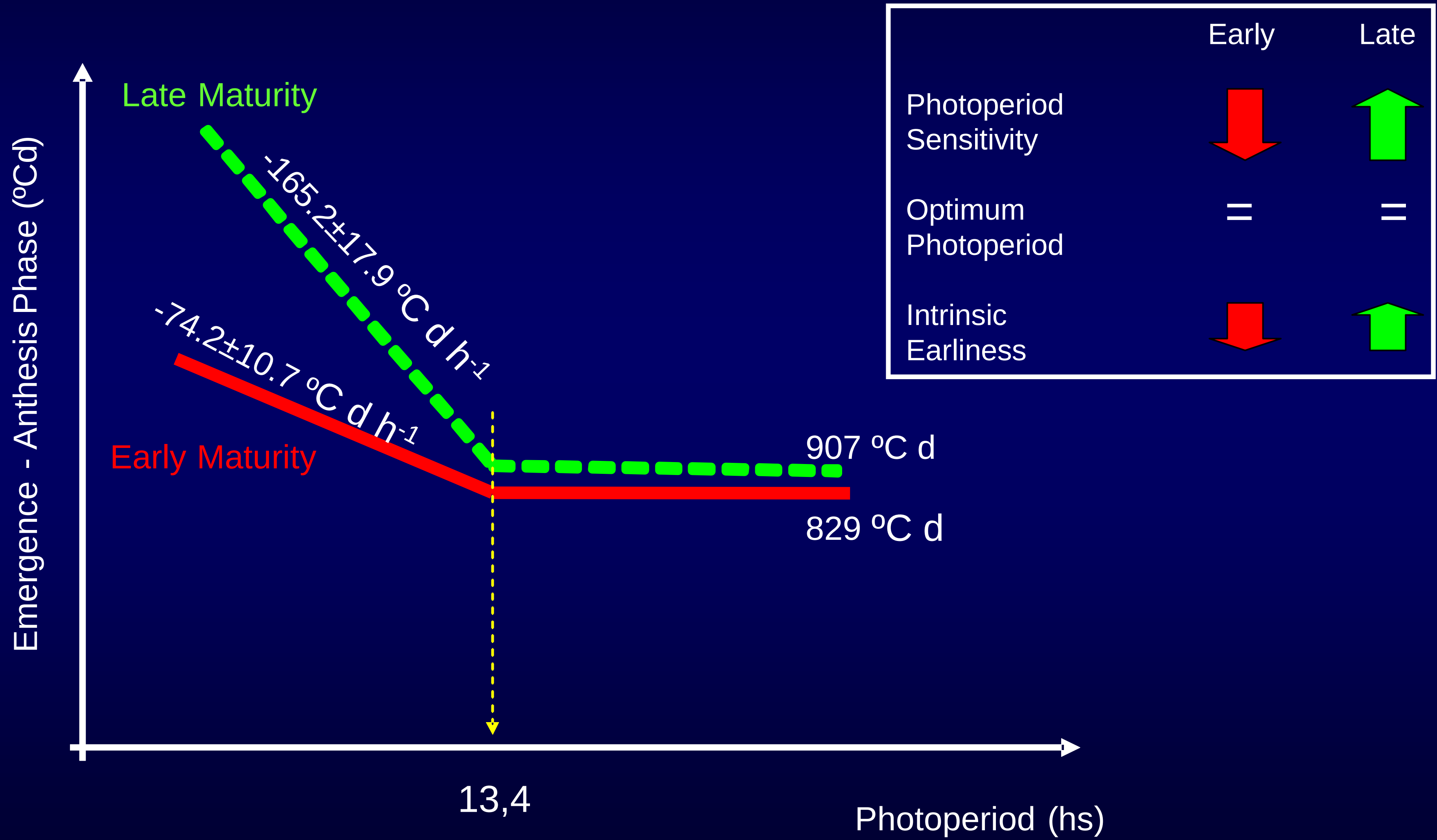


Not significant differences were found among cultivars for the optimum photoperiod during the pre-anthesis phases.

Miralles et al (2007)

Results

General Model

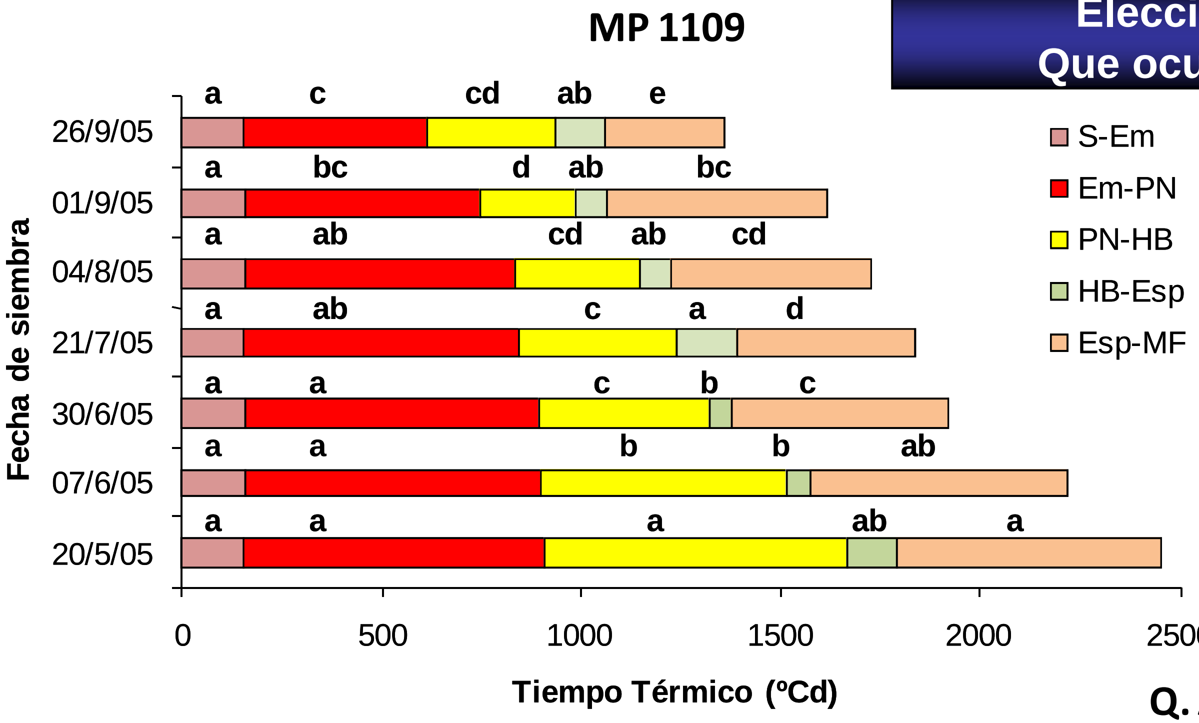


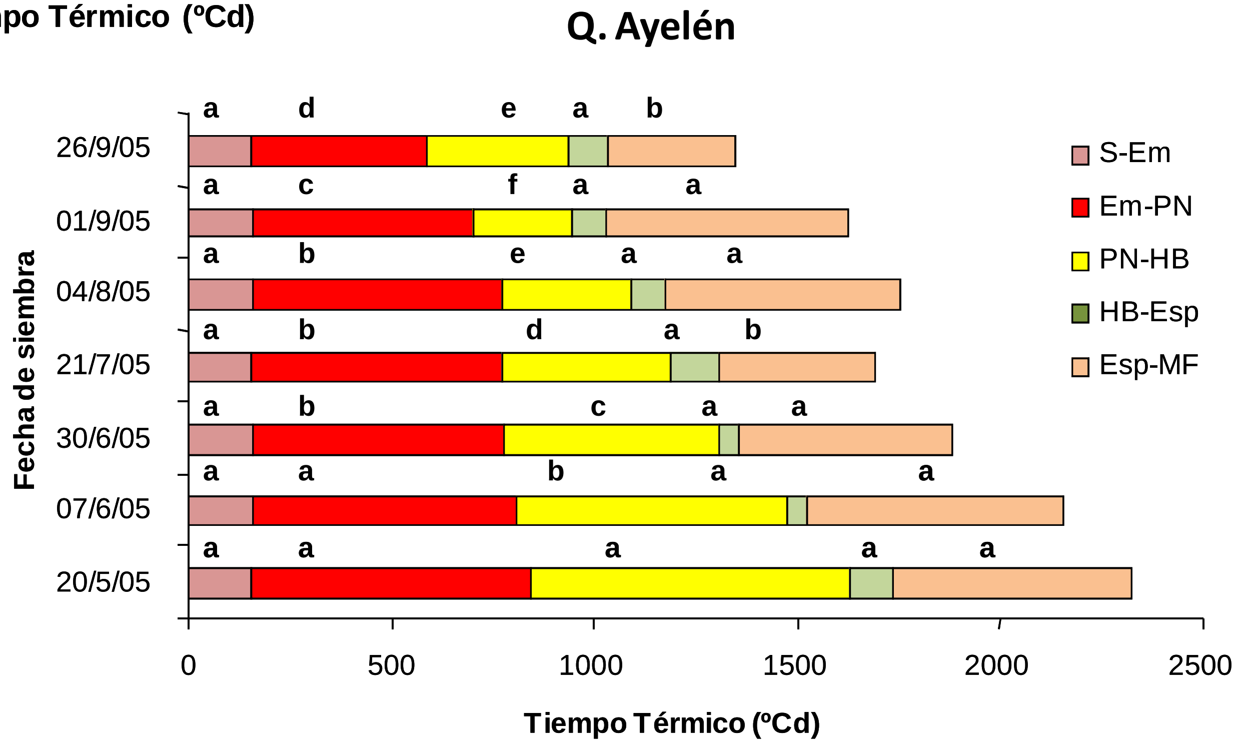
Miralles et al (2007)

Base Temp= 5 ºC

Elección de Fecha de siembra
Que ocurre en las fechas tardías?

CEBADA



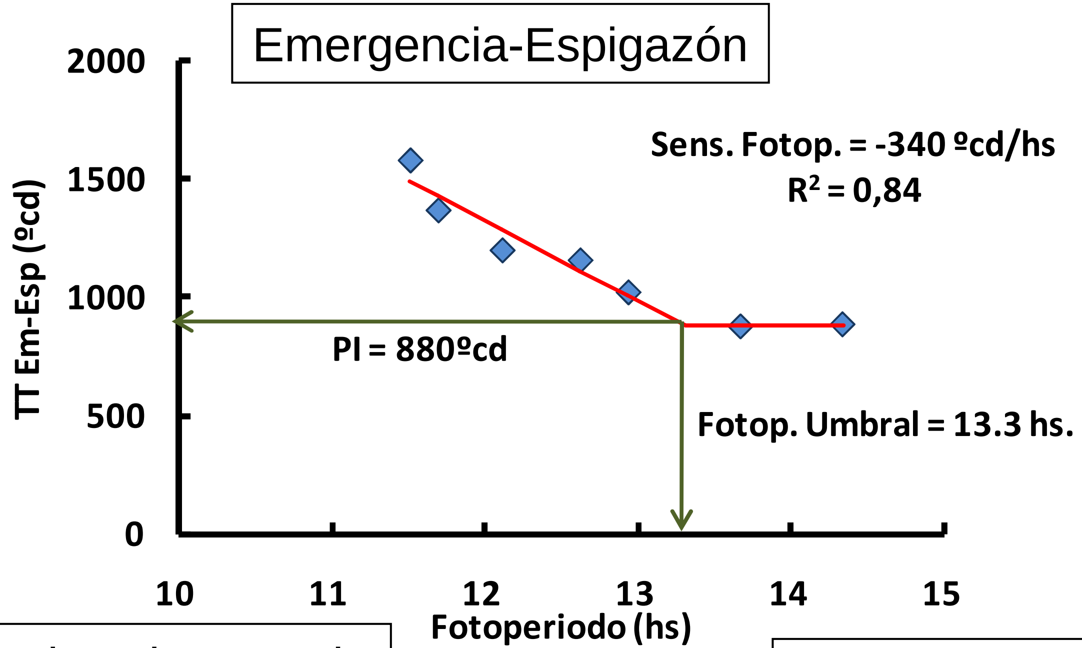


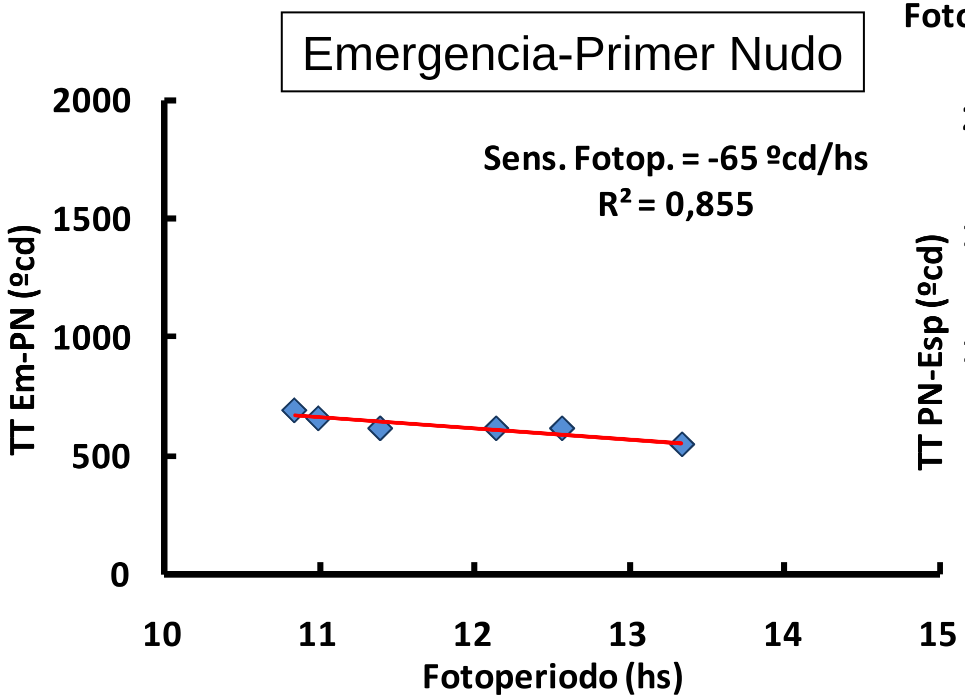
Las cebadas cerveceras Argentinas actuales no tienen requerimientos de vernalización

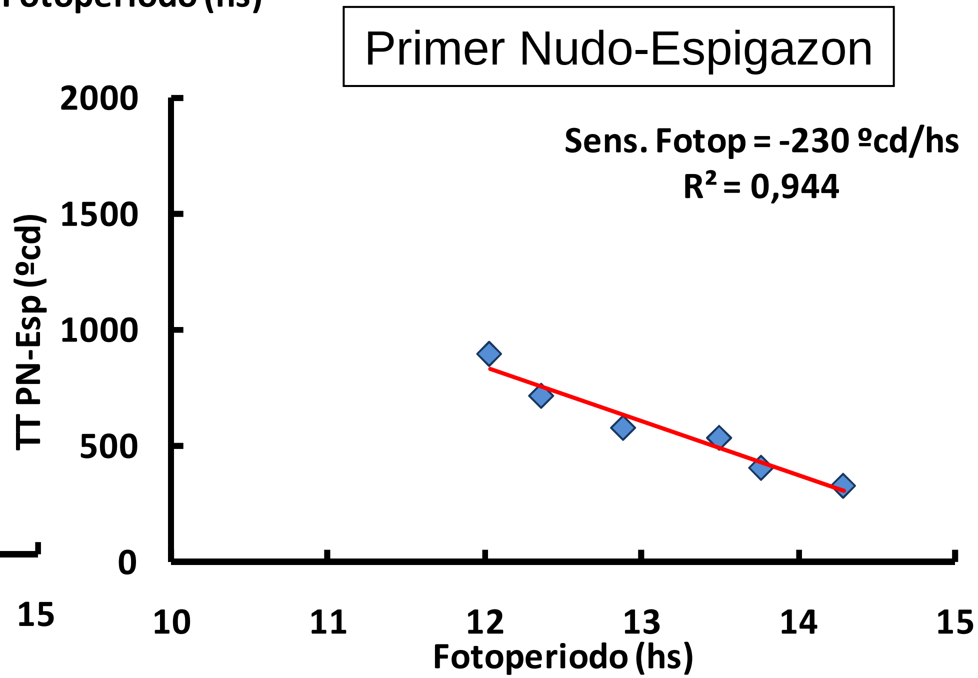
Alzueta et al (2007)

Modelos de sensibilidad fotoperiodica

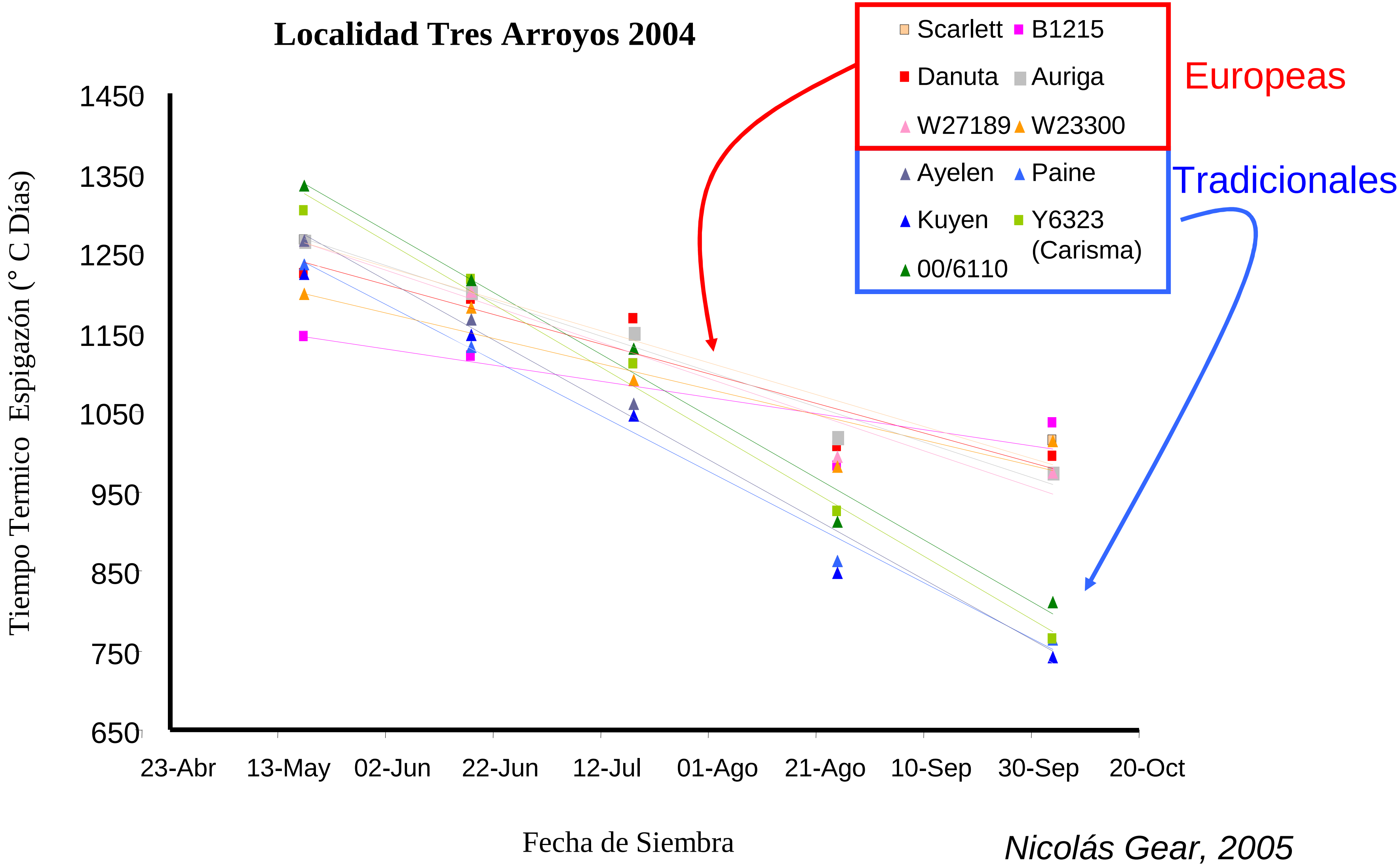
Q. Ayelen







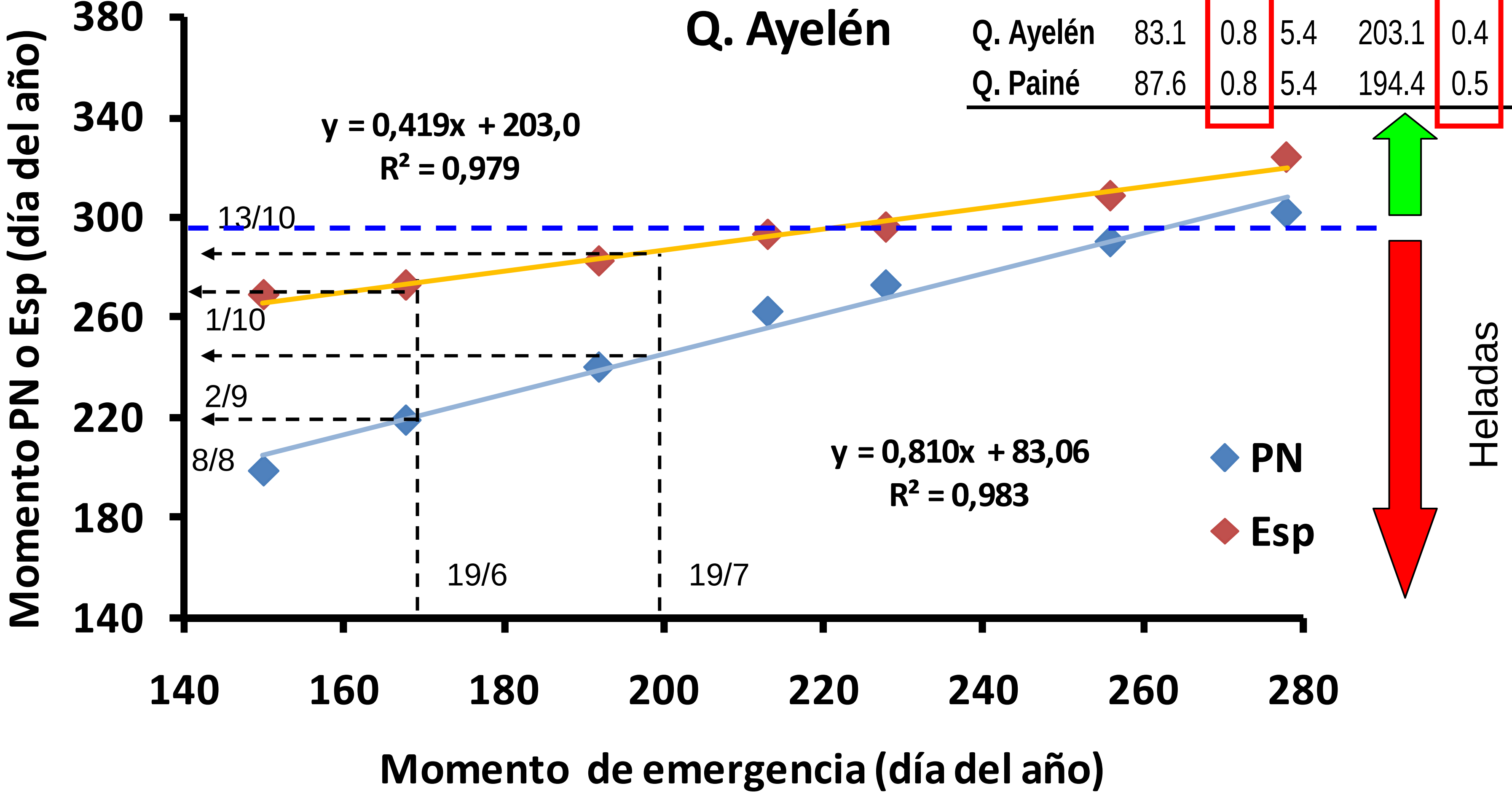
Modelos de Termofotoperiodicos aplicados al manejo del cultivo: Diferencias entre cultivares Europeos y Tradicionales



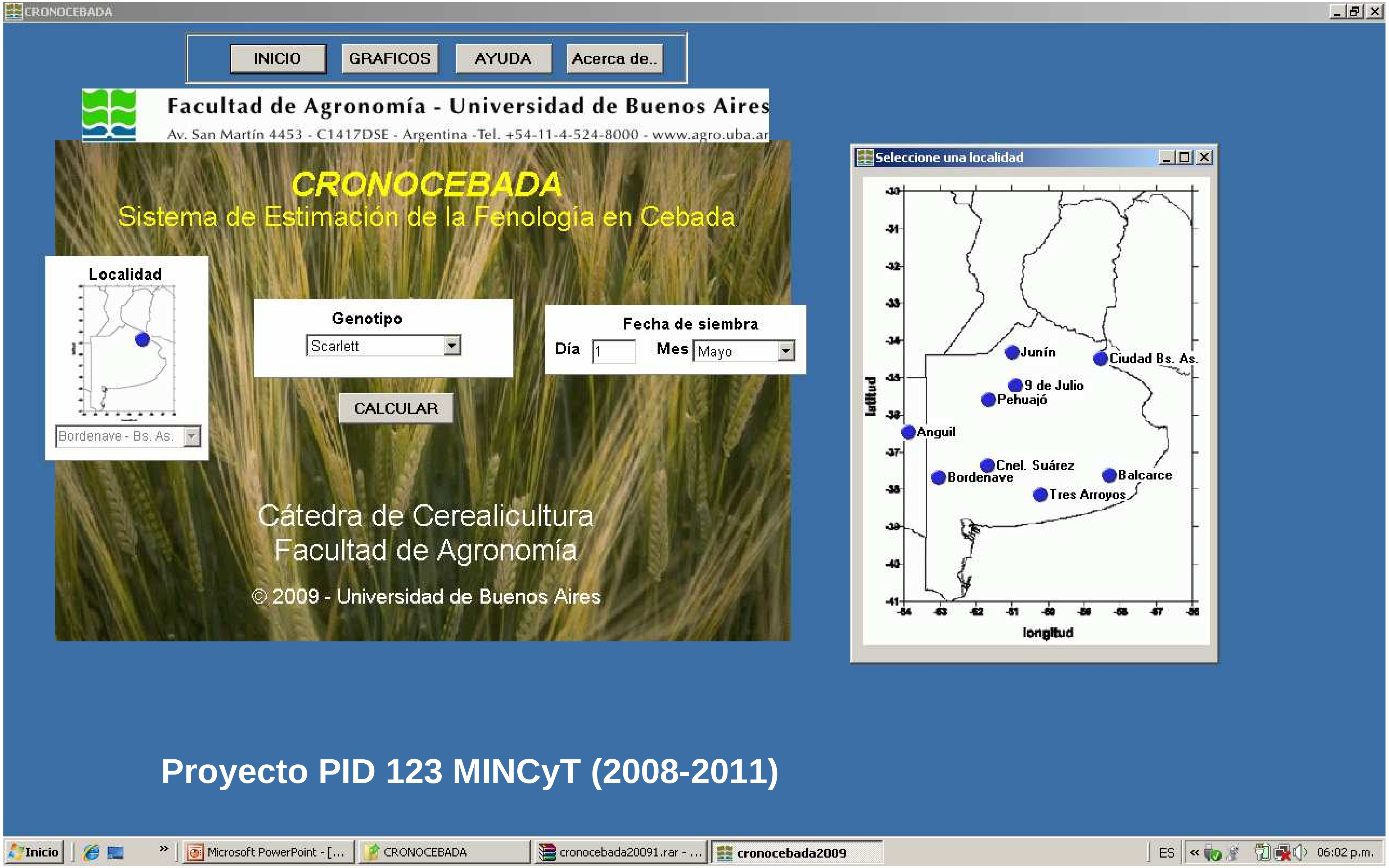
Nicolás Gear, 2005

Modelos sencillos de predicción fenologica

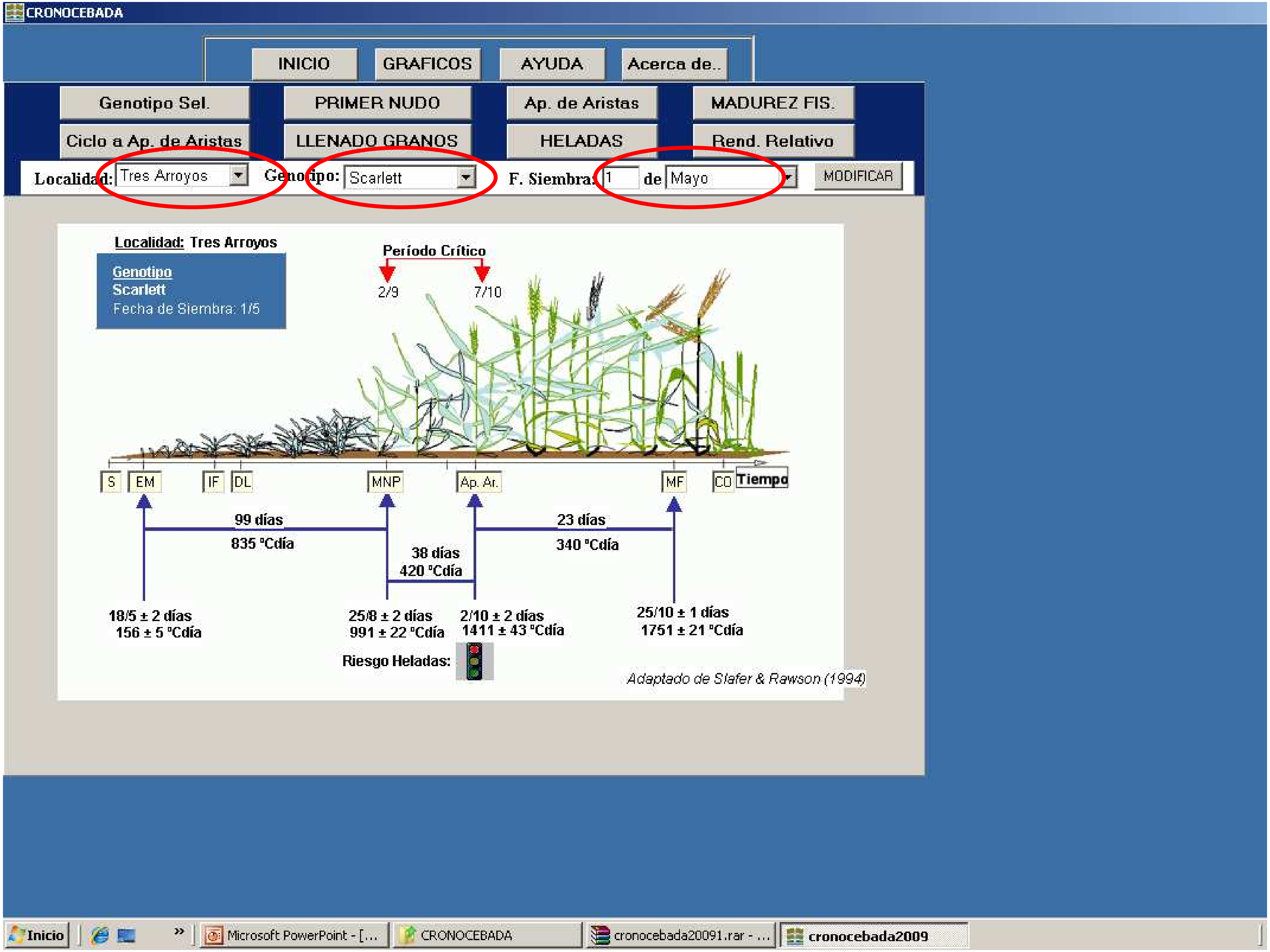
Cultivar	Em-PN a	Em-PN b	Em-PN ee	Em-Esp a	Em-Esp b	Em-Esp ee
B1215	89.2	0.8	5.5	181.8	0.5	3.1
BRS 195	114.8	0.7	7.1	181.4	0.6	3.8
Danuta	84.0	0.8	5.1	189.1	0.5	2.4
Dayman	97.1	0.8	5.7	187.5	0.5	2.4
MP 1109	99.9	0.8	6.4	207.8	0.4	3.1
Q. Ayelén	83.1	0.8	5.4	203.1	0.4	3.0
Q. Painé	87.6	0.8	5.4	194.4	0.5	2.8

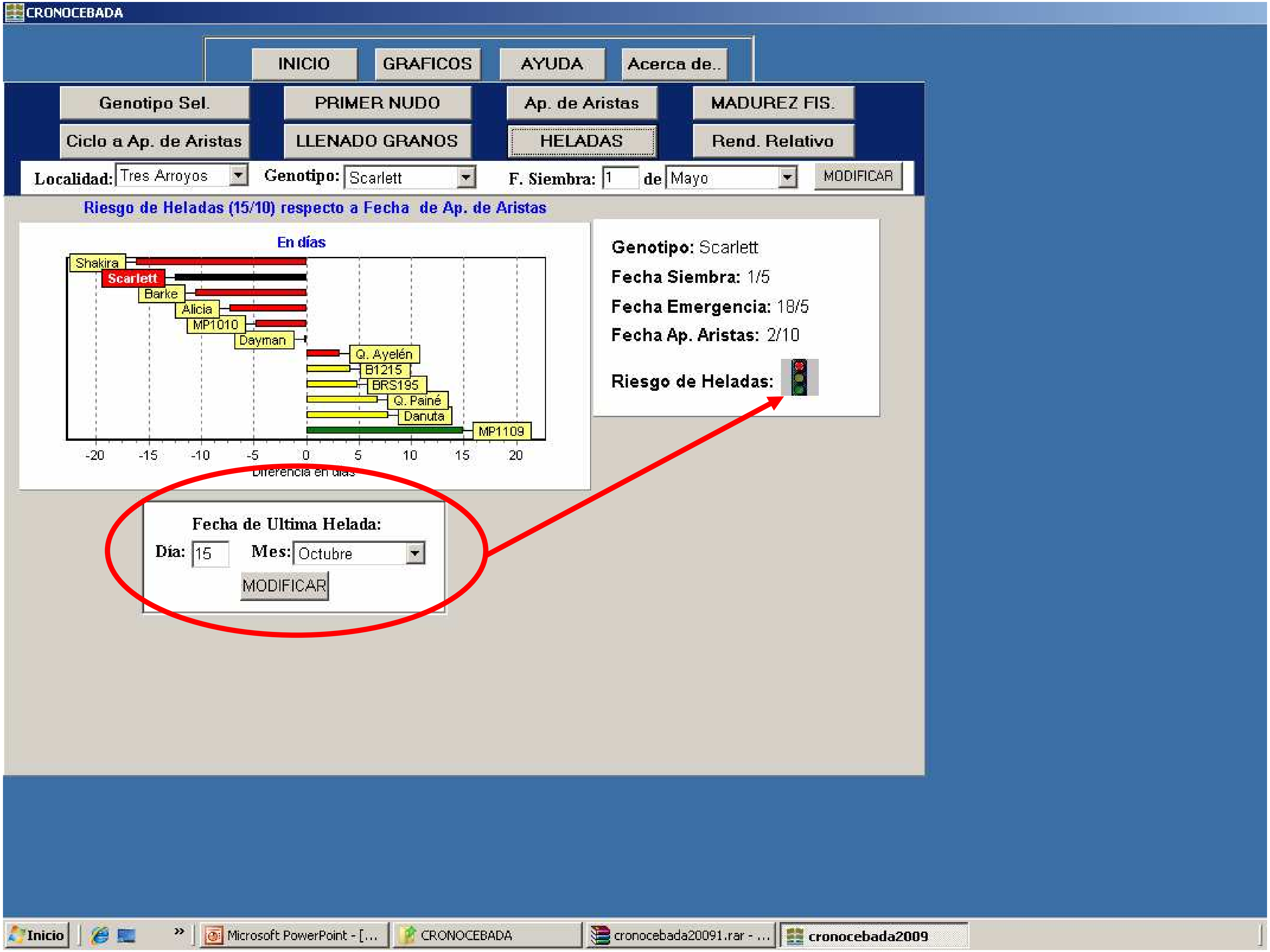


Modelo de Predicción Fenologica: CRONOCEBADA©
Convenio MINCyT-Cámara Cervecera Argentina-Fac. Agronomía UBA

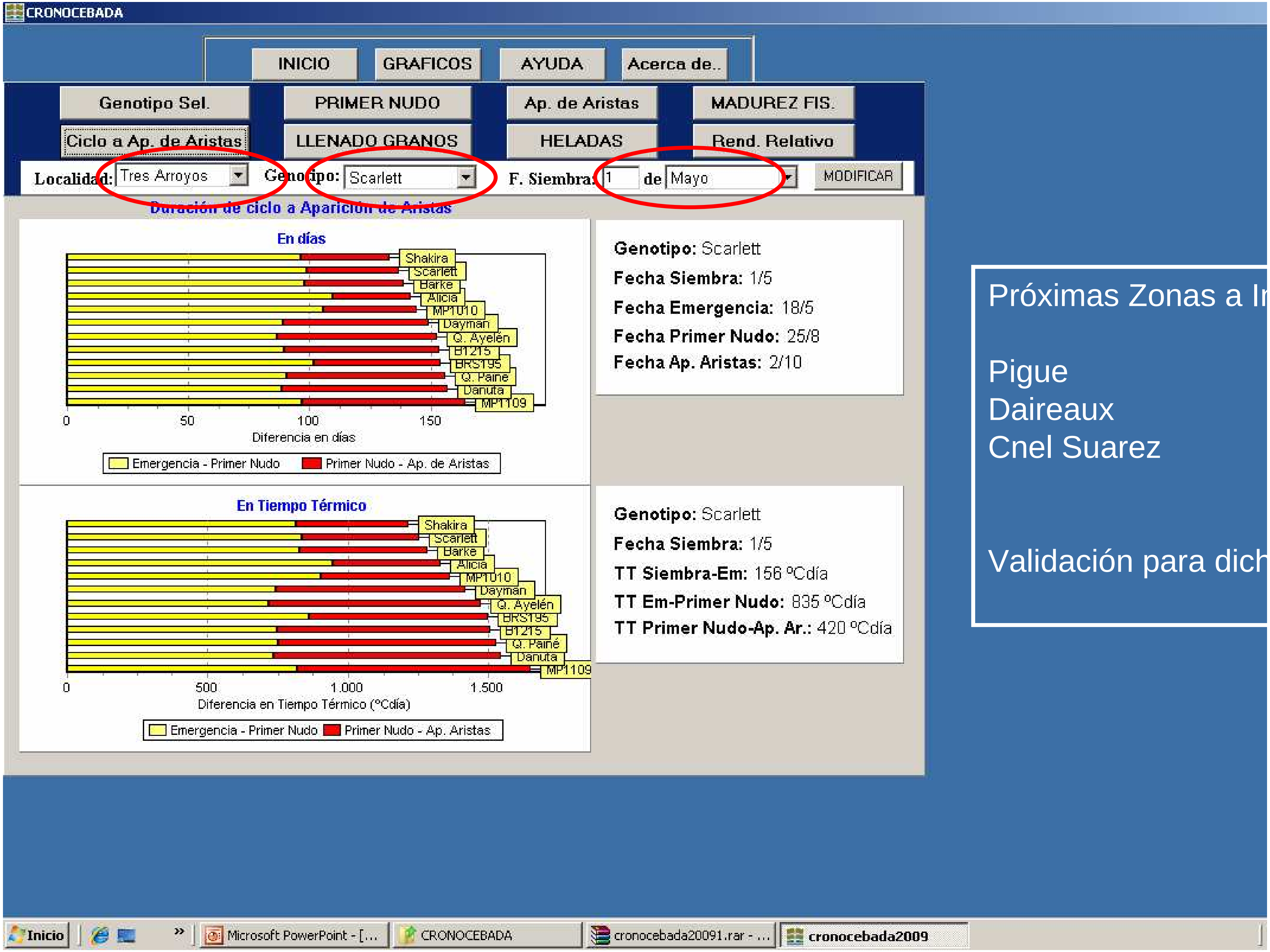


Proyecto PID 123 MINCyT (2008-2011)


CRONOCEBADA
INICIO
GRAFICOS
AYUDA
Acerca de..
Genotipo Sel.
PRIMER NUDO
Ap. de Aristas
MADUREZ FIS.
Ciclo a Ap. de Aristas
LLENADO GRANOS
HELADAS
Rend. Relativo
Localidad: Tres Arroyos
Genotipo: Scarlett
F. Siembra: 1 de Mayo
MODIFICAR
Localidad: Tres Arroyos
Genotipo
Scarlett
Fecha de Siembra: 1/5
Período Crítico
2/9
7/10
S
EM
IF
DL
MNP
Ap. Ar.
MF
CO
Tiempo
99 días
835 °Cdía
38 días
420 °Cdía
23 días
340 °Cdía
18/5 ± 2 días
156 ± 5 °Cdía
25/8 ± 2 días
991 ± 22 °Cdía
2/10 ± 2 días
1411 ± 43 °Cdía
25/10 ± 1 días
1751 ± 21 °Cdía
Riesgo Heladas:
Adaptado de Slafer & Rawson (1994)
Inicio
Microsoft PowerPoint - [...
CRONOCEBADA
cronocebada20091.rar - ...
cronocebada2009



CRONOCEBADA
INICIO
GRAFICOS
AYUDA
Acerca de..
Genotipo Sel.
PRIMER NUDO
Ap. de Aristas
MADUREZ FIS.
Ciclo a Ap. de Aristas
LLENADO GRANOS
HELADAS
Rend. Relativo
Localidad: Tres Arroyos
Genotipo: Scarlett
F. Siembra: 1 de Mayo
MODIFICAR
Riesgo de Heladas (15/10) respecto a Fecha de Ap. de Aristas
En días
Shakira
Scarlett
Barke
Alicia
MP1010
Dayman
Q. Ayelén
B1215
BRS195
Q. Painé
Danuta
MP1109
-20
-15
-10
-5
0
5
10
15
20
Diferencia en días
Genotipo: Scarlett
Fecha Siembra: 1/5
Fecha Emergencia: 18/5
Fecha Ap. Aristas: 2/10
Riesgo de Heladas:
Fecha de Ultima Helada:
Día: 15
Mes: Octubre
MODIFICAR
Inicio
Microsoft PowerPoint - [...
CRONOCEBADA
cronocebada20091.rar - ...
cronocebada2009



Próximas Zonas a I

Pigue
Daireaux
Cnel Suarez

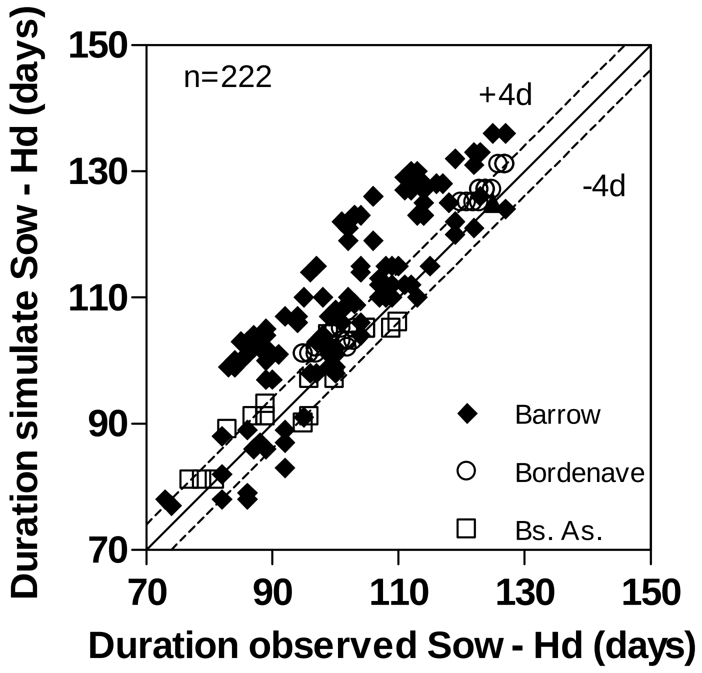
Validación para dich

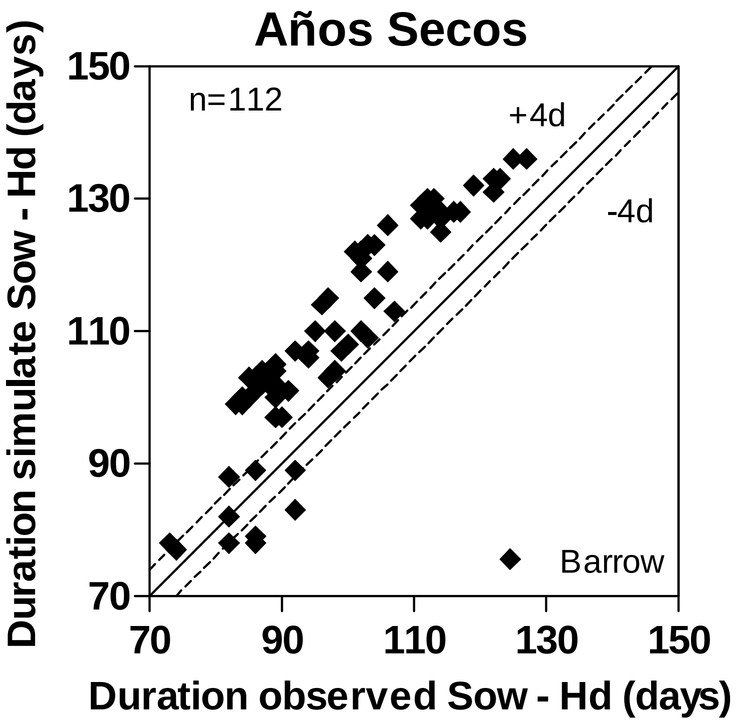
Validación del modelo

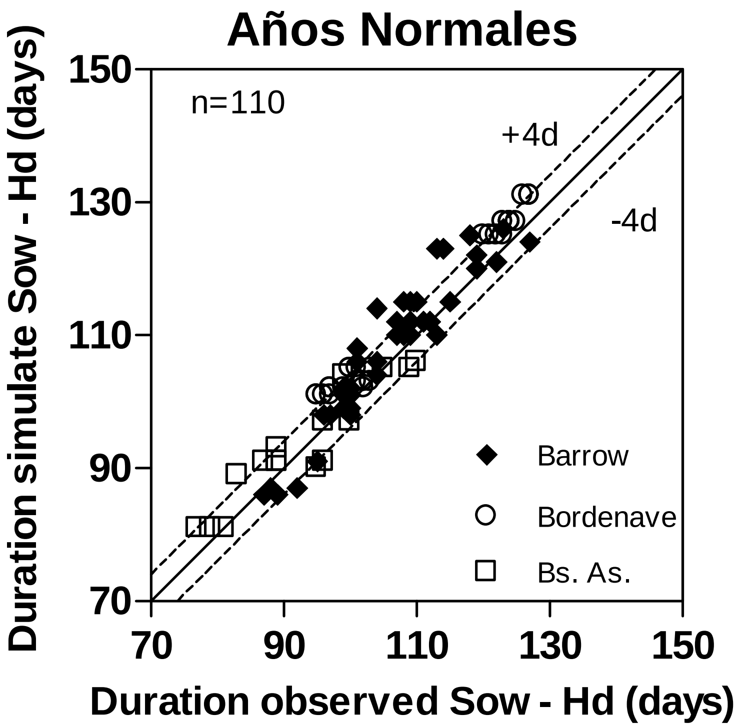
Tres Arroyos-Barrow
Bordenave
Buenos Aires

Años:
'98-'99-'00-'01-'02-'04-'05-'06-'07-'08

<u>Datos aportados por</u>: Antonio Aguinaga, RET CEBADA 2007 y FAUBA



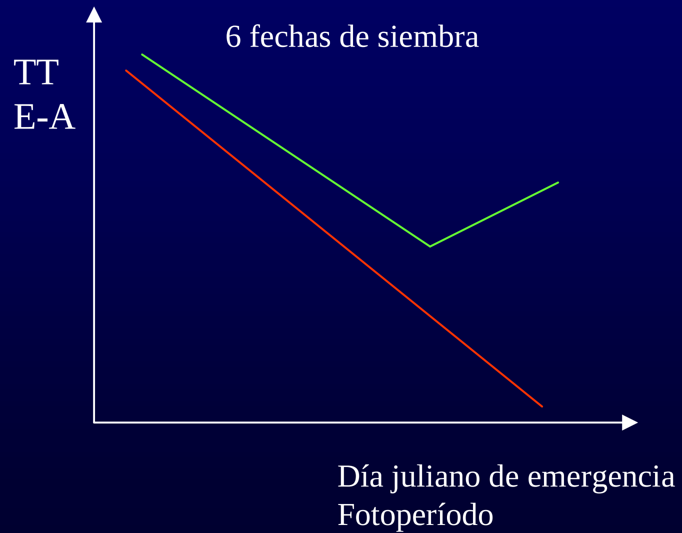




Descripción de las respuestas combinadas a la temperatura, el fotoperíodo y la vernalizacion

1. Si se conoce las respuestas de la duración de la fase (ej. Emergencia-espigazón en trigo) en términos de a) TT mínimo de la fase o precocidad intrínseca, b) fotoperíodo umbral, c) sensibilidad al fotoperíodo y d) sensibilidad a la vernalización se puede estimar la duración en TT de la fase para el fotoperíodo, grado de vernalización y cultivar en cuestión.

2. Asumir respuestas lineales a temperatura y fotoperíodo y establecer mediante experimentos efectuados en una gran variedad de regímenes térmicos y fotoperiódicos el requerimiento en TT para la duración de la fase en cuestión. Funciona mejor para fotoperíodos menores (PDL) o mayores (PDC) a los umbrales y es menos confiable para fotoperíodos en los cuales las respuestas están saturadas. Ej. CRONOTRIGO



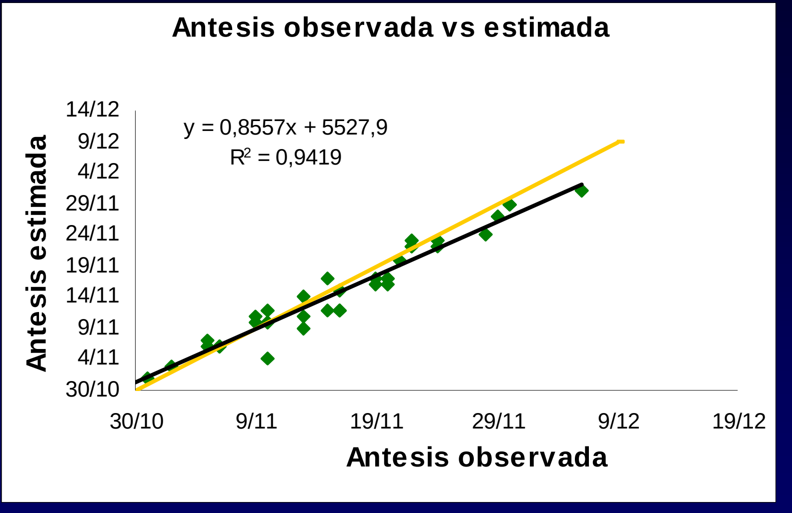
-Asume un valor de Tb para la etapa en cuestión

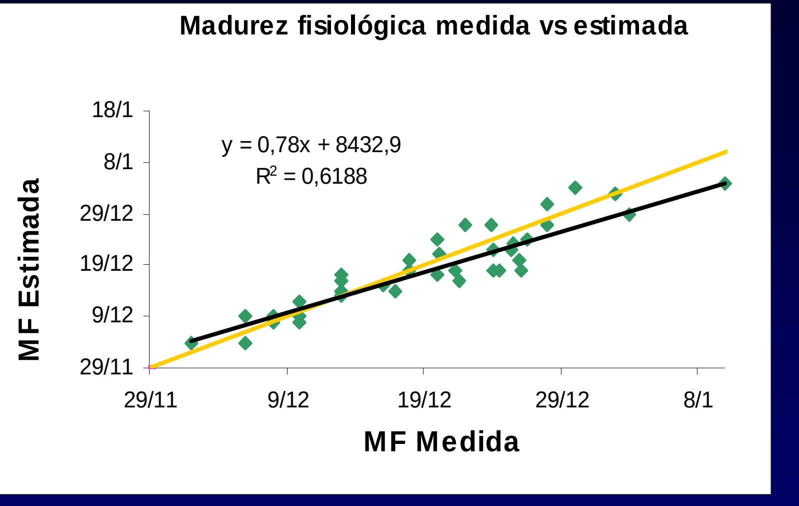
-Datos térmicos históricos

↓

Permite predecir fecha de espigazón al variar la fs

Gelso, González & Miralles datos no publicados





3. Usar funciones curvilíneas para ponderar los efectos del fotoperíodo y la vernalización sobre el TT. Ej. Ceres-Wheat, Ritchie 1991 Modeling Plant and Soil Systems-Agronomy Monograph 31 ASA-CSSA-SSSA, 677 S. Seogoe Rd. Madison WI53711, USA

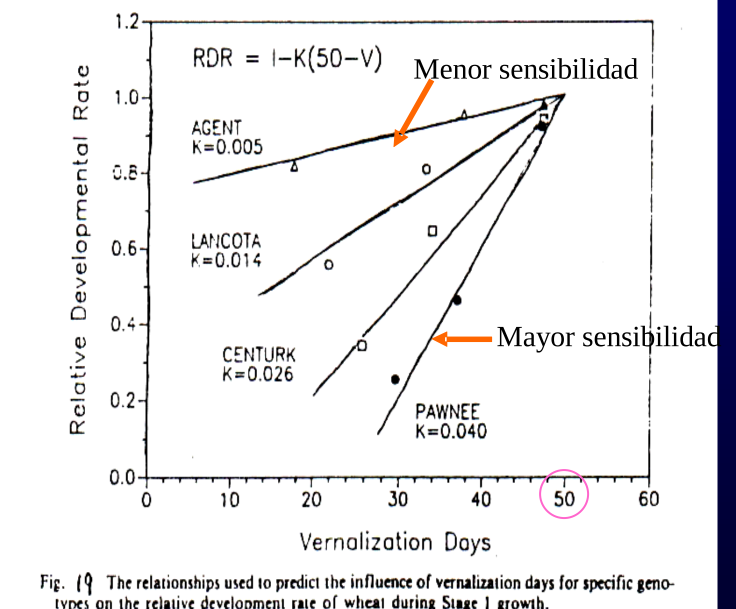
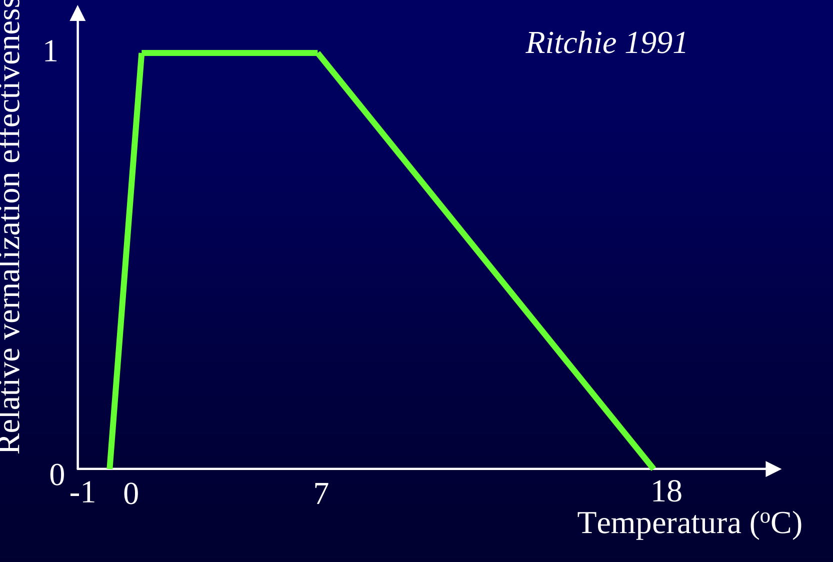


Fig. 19 The relationships used to predict the influence of vernalization days for specific genotypes on the relative development rate of wheat during Stage 1 growth.

Ritchie 1991

Vernalización



Considera el concepto de devernalización:
si el número de VD <10 y Tmax >30ºC, entonces el número de VD disminuye 0,5d por ºC
si el número de VD>10 considera que no puede ocurrir devernalización

Fotoperíodo

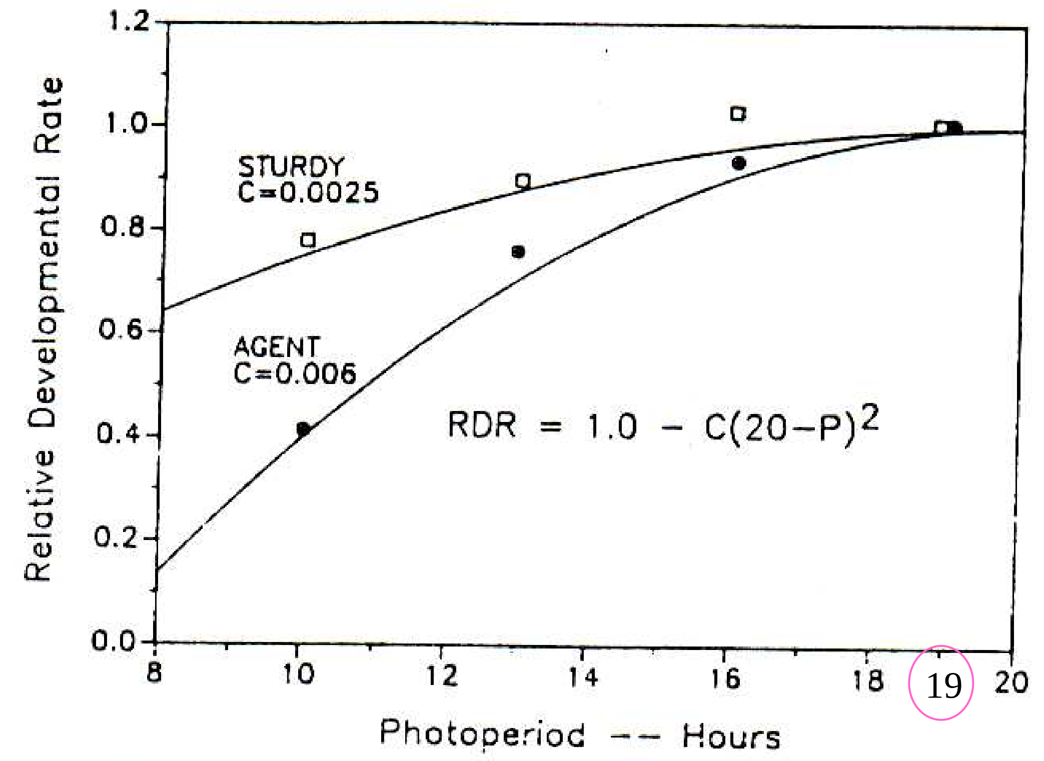


Fig. (7) The relationship used to predict the influence of photoperiod for specific genotypes or the relative development rate of wheat during Stage I growth.

Ajusta el progreso diario hacia antesis en TT en función del factor menos favorable

4. Uso de descripciones que pueden manejar interacciones fotoperíodo x temperatura

Soja: Ej. Summerfield et al. 1993 (respuesta lineal a temperatura)

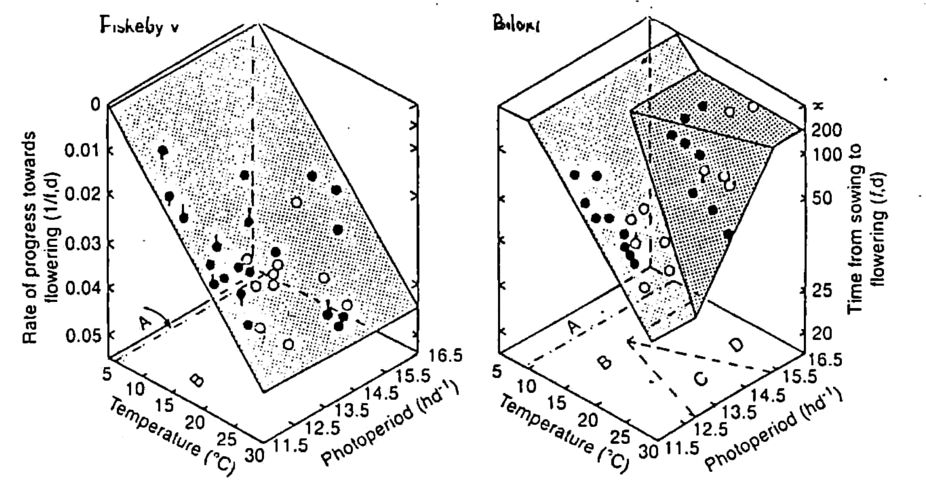


Fig. 1 Effects of photoperiod and temperature on the rate of progress from sowing towards first flowering (*left vertical scale*; transformed to days to flower on *right vertical scale*) in soyabean cultivars, 'Fiskeby V' (photoperiod-insensitive) and 'Biloxi' (photoperiod-sensitive). Results from six contrasting sites in Australia from 1986 to 1988 (●) and one in Australia and two in Taiwan in 1989–1990 (○). *Vertical lines* indicate deviations from fitted planes. Projection of the boundaries between response planes to the base (*broken lines*) show four environmental domains where progress towards flowering is *A* impossible (too cool), *B* solely temperature-dependent, *C* dependent on both photoperiod and temperature, and *D* maximally delayed by photoperiod and unresponsive to variation in either photoperiod or temperature. The fitted planes are quantified in Table 2. The boundaries between the domains are defined by T_b (between A and B), P_c (between B and C), T_p (between B and D) and P_{ce} (between C and D): see text for further explanation. (From Summerfield et al. 1993.)

<u>Trigo</u>: AFRCWHEAT (Weir et al. 1984 J. Agric. Sci., Cambridge 102)
desde emergencia a Doble lomo el progreso a floración en TT es modificada en función
de un factor derivado de la multiplicación de efectos diarios de vernalización y fotoperíodo

Angus et al. 1981, FCR 4. Trigo primaveral
Respuesta no lineal a la tempratura
Tasa de desarrollo (r) = f (T) x f (F)

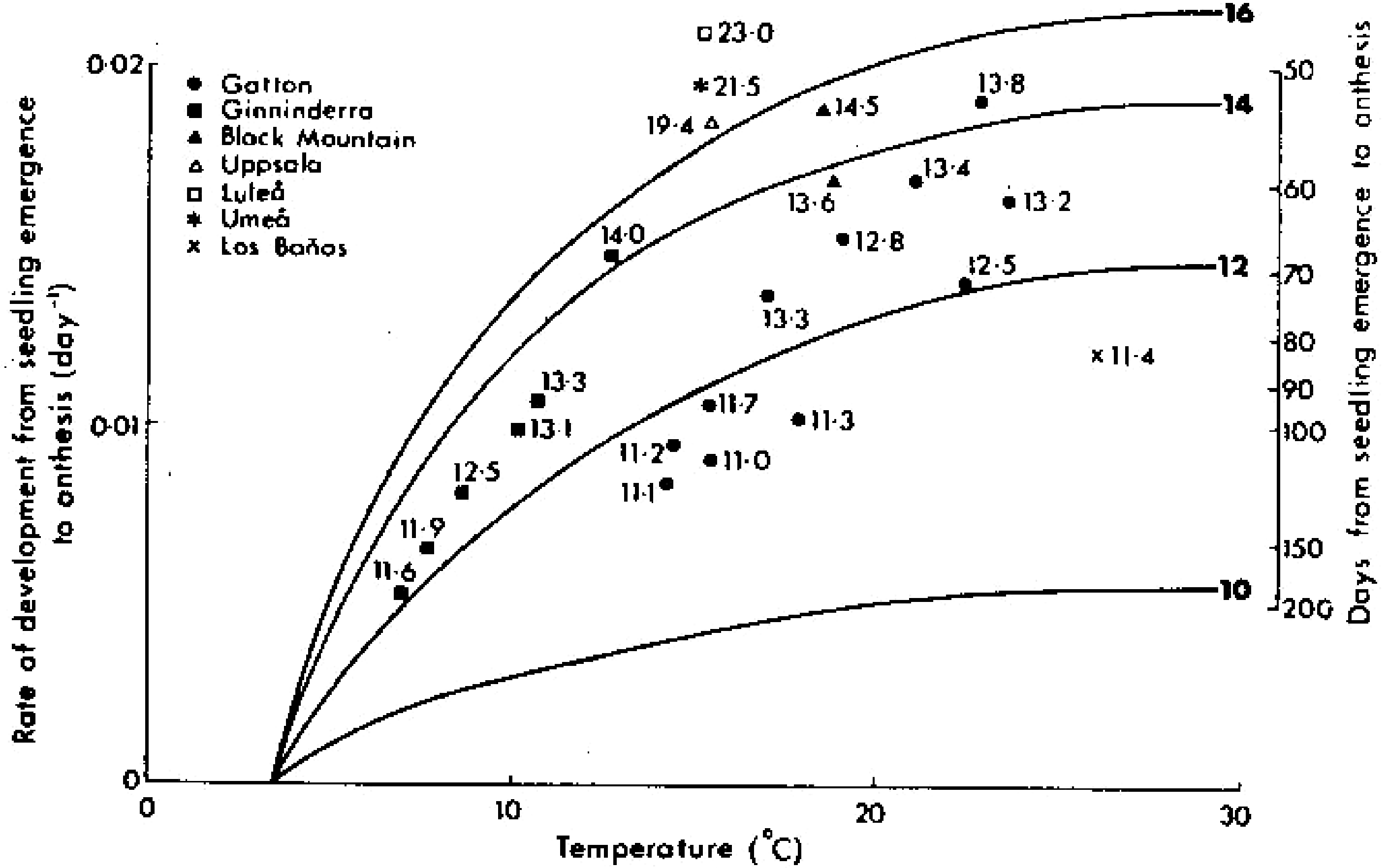


Fig. 3. Rate of development from emergence to anthesis of the wheat cultivar UQ189 in relation to mean temperature and photoperiod over the phase. The labelled value on each point refers to the mean photoperiod. The family of curves represents the model for chosen values of photoperiod.

Otros factores que alteran el desarrollo

Nutrientes

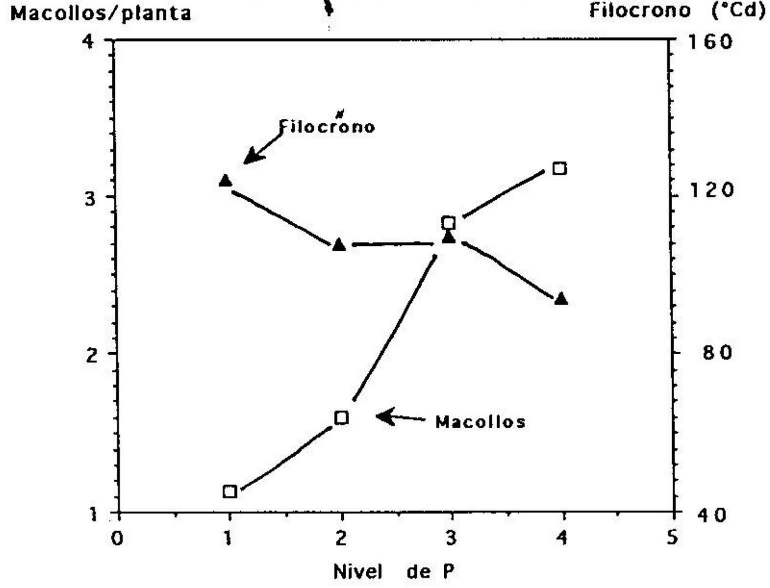
Tabla 2.1- Duración de las etapas Emergencia (Em) a Doble Lomo (DL), Espiguilla Terminal (ET) y Antesis (Ant) con diferentes combinaciones de nitrógeno y azufre. Datos correspondientes a los ensayos conducidos en containers.

Tratamiento		Duración de las subetapas (ºCdía)			
		Em – DL	DL – ET	ET – Ant	Em – Ant
N_0	S_0	522	144	655	1321
	S_1	540	134	635	1309
N_1	S_0	522	153	625	1299
	S_1	540	134	690	1364
N		ns	ns	ns	ns
S		ns	*	*	*
N x S		ns	ns	*	*

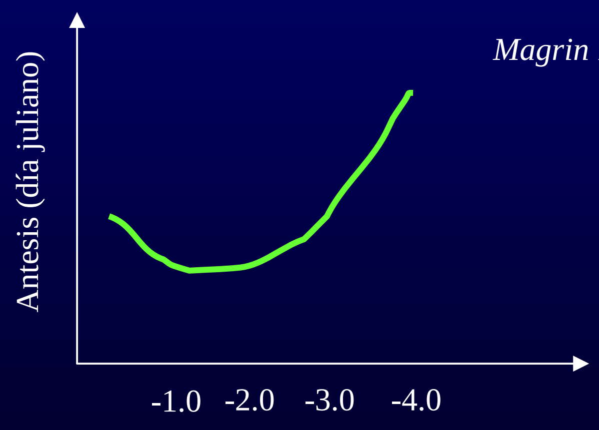
* 5% de Significancia según el test LSD.

Salvagiotti & Miralles 2005

Efectos de P sobre filocrono y macollaje de trigo (Rodriguez et al., Plant Soil 200:227, 1998.

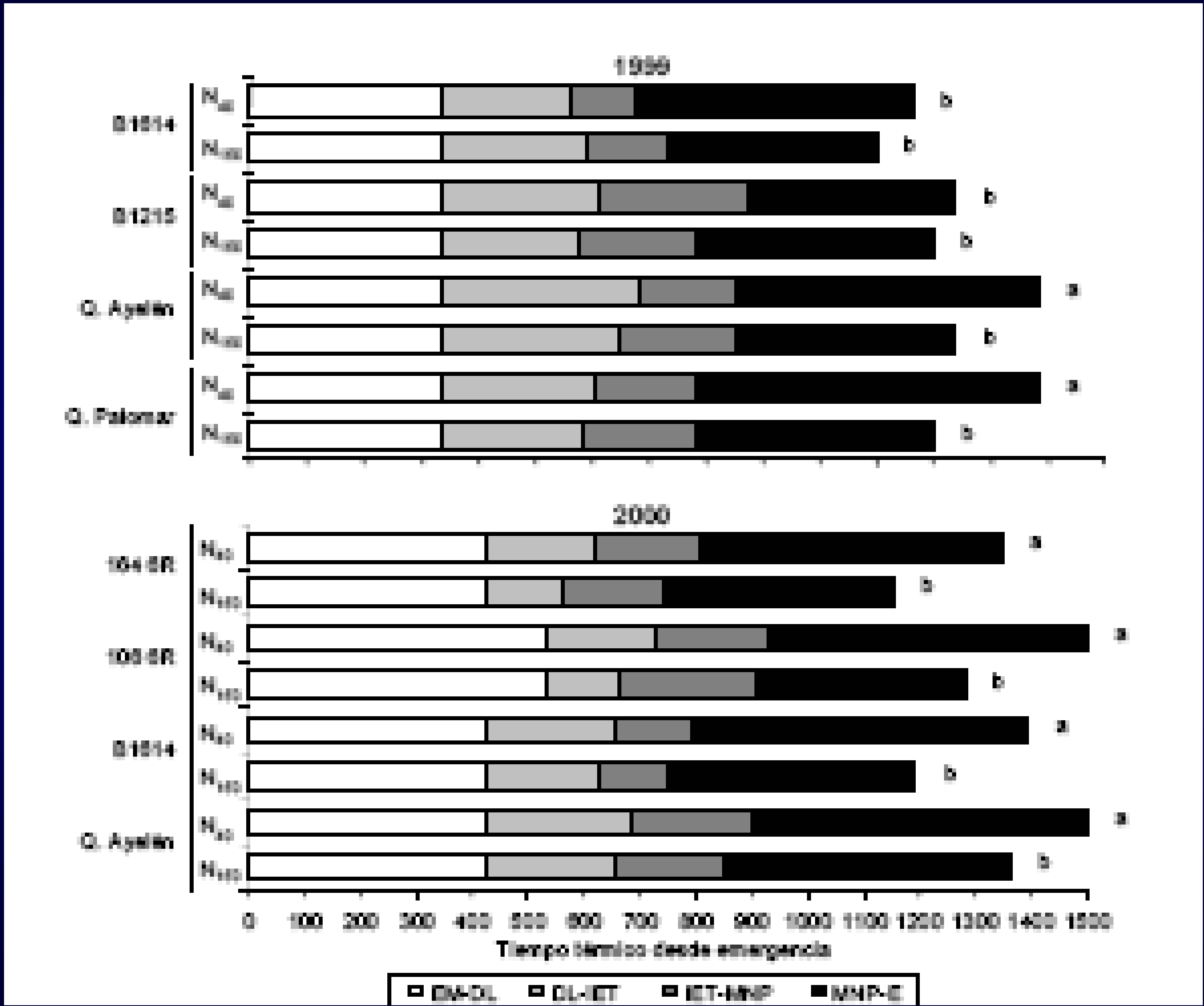


Estrés hídrico



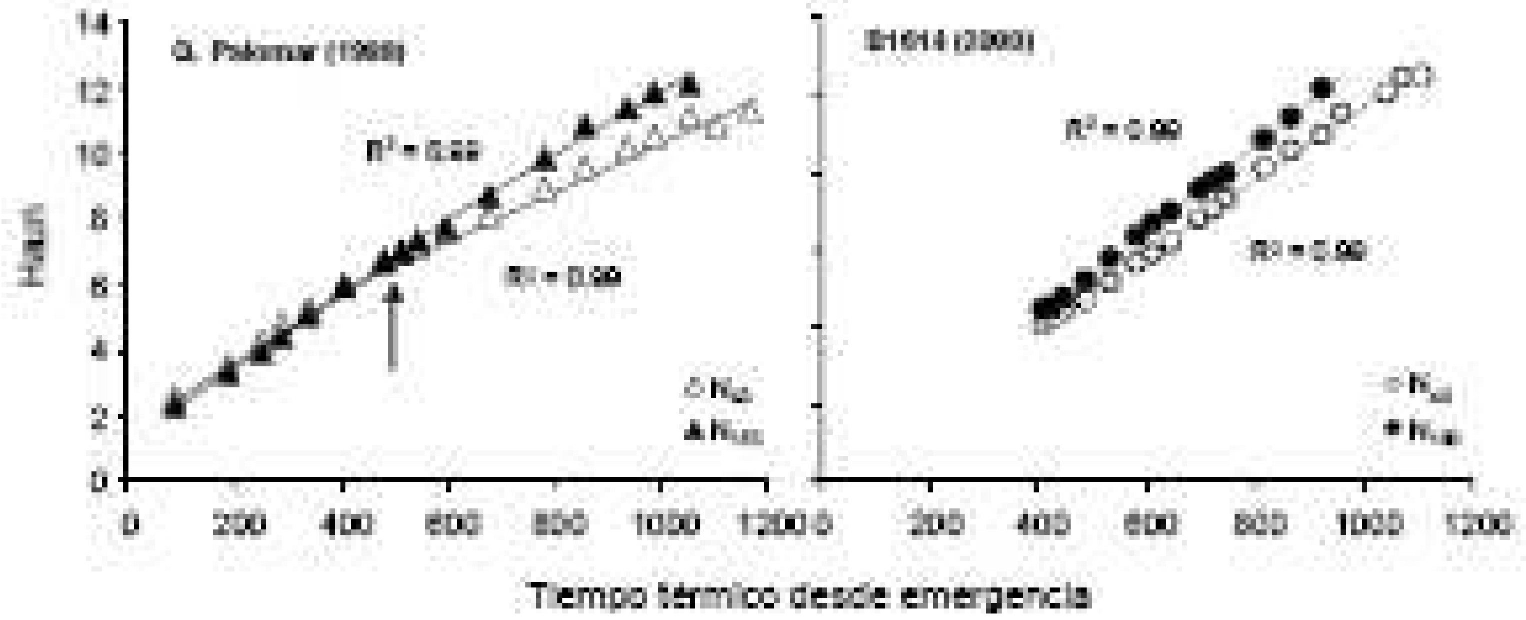
Efectos de N
Arisnabarreta & Miralles 2004
Aust J Agric Res 55
Deficiencia Nitrogeno en cebada aumento el Flocrono sin modificar el N final de hojas

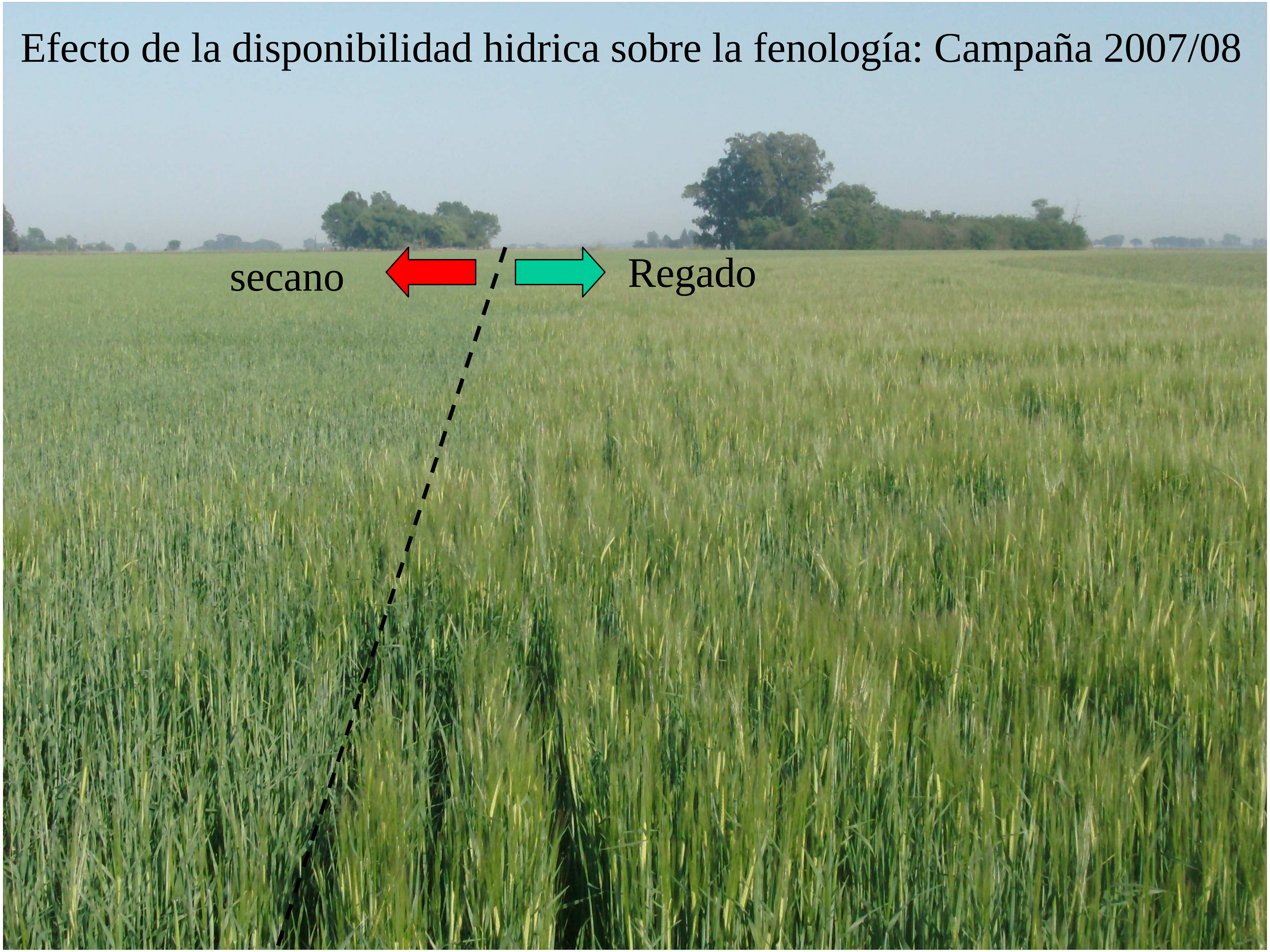
Efecto de los nutrientes sobre la fenología en cebada:

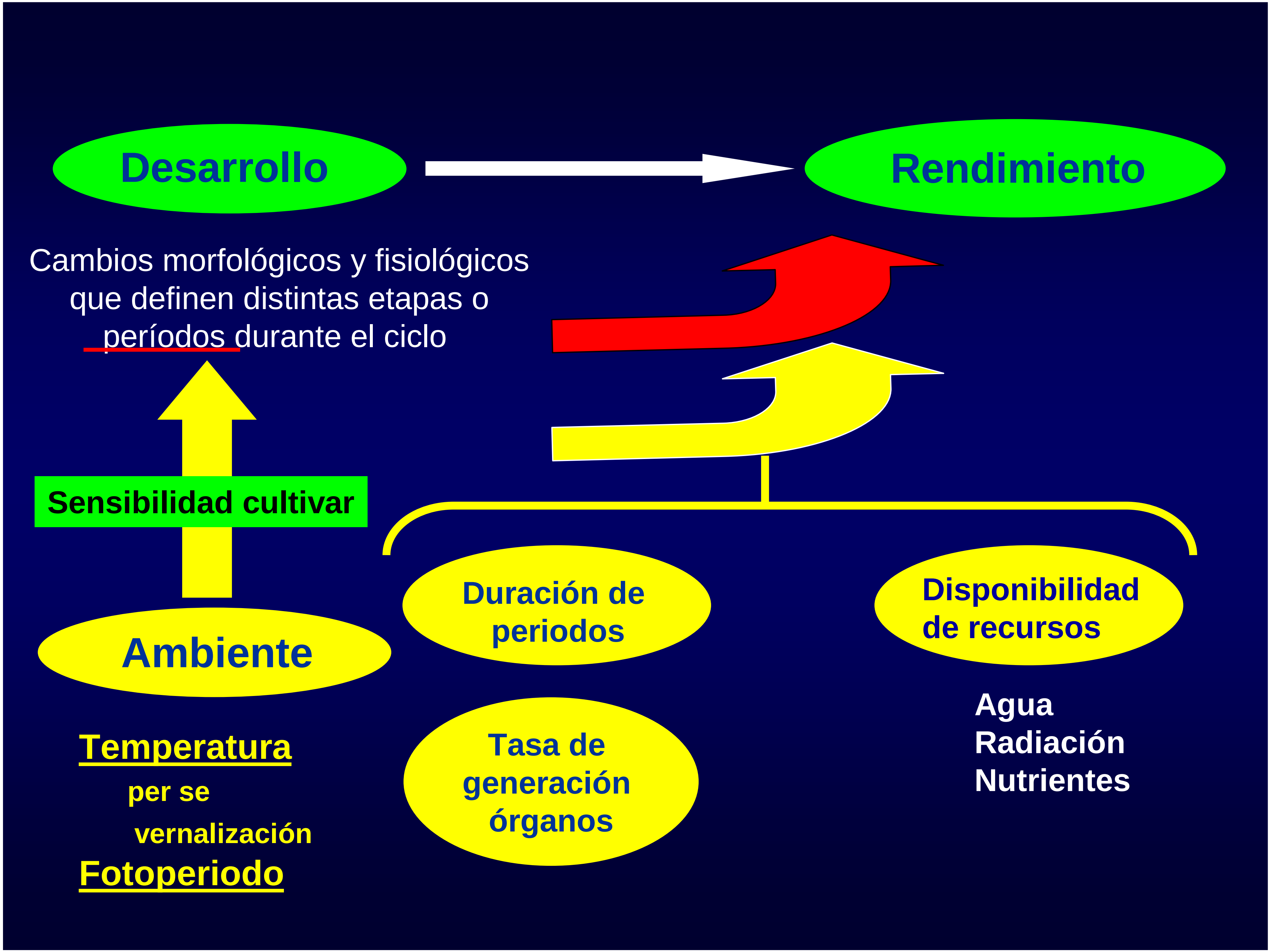


Arisnabarreta & Miralles (2004)

Efecto de los nutrientes sobre la fenología en cebada: Analisis de la tasa de aparición de hojas




Efecto de la disponibilidad hidrica sobre la fenología: Campaña 2007/08
secano
Regado



Desarrollo
Rendimiento
Cambios morfológicos y fisiológicos que definen distintas etapas o períodos durante el ciclo
Sensibilidad cultivar
Ambiente
Temperatura
per se
vernalización
Fotoperiodo
Duración de periodos
Tasa de generación órganos
Disponibilidad de recursos
Agua
Radiación
Nutrientes