Physiological and molecular changes in plants at low temperature

Cold or chilling stress

Fisiologia Molecular do stress

Anabela Bernardes da Silva

Summary

Cold or chilling stress in C4 plants :

- Acclimation to long-term chilling on leaf growth parameters and photosynthesis

Acclimation to long-term chilling in a C4 plant
Effect on leaf growth parameters

Table 1. Effect of low temperature on leaf growth parameters of *P. dilatatum* cv. Raki. Data are means (±SE) of 15–16 independent replicates.

	Leaf growth parameters					
	L_{FW} (g)	L_{DW} (g)	$\%L_{DW}$	L_A (cm^2)	L_{FW}/L_A ($g\ FW\ m^{-2}$)	SLA ($m^2\ kg^{-1}$ DW)
Control	0.4736 (±0.0240)	0.0722 (±0.0034)	15.8 (±0.7)	26.29 (±1.21)	179.5 (±1.6)	36.7 (±1.2)
Cold-acclimated	0.3746 (±0.0202)	0.0759 (±0.0051)	20.2 (±0.6)	20.38 (±1.13)	184.2 (±2.1)	27.3 (±9.0)

Table 2. Effect of low temperature on photosynthetic pigments leaf content of *P. dilatatum* cv. Raki. Data are means (±SE) of 20 independent replicates obtained in two different experiments.

	Photosynthetic pigments content ($mg\ g^{-1}$ FW)					
	Chl *a*	Chl *b*	Chl *a* + *b*	Carot	Chl *a*/*b*	Chl *a* + *b*/Carot
Control	2.21 (±0.12)	0.48 (±0.03)	2.69 (±0.14)	0.74 (±0.04)	4.62 (±0.12)	3.63 (±0.04)
Cold-acclimated	1.33 (±0.09)	0.34 (±0.03)	1.67 (±0.11)	0.66 (±0.03)	3.94 (±0.09)	2.48 (±0.07)

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Acclimation to long-term chilling in a C4 plant

Effect on photosynthesis

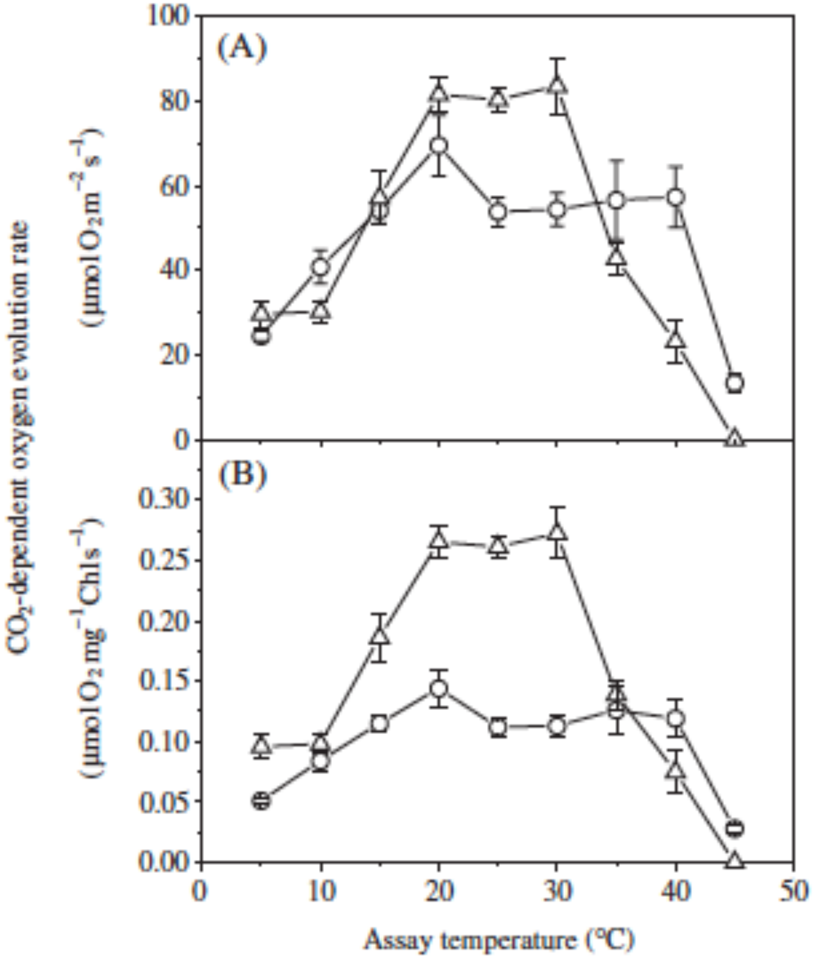

Fig. 2. Temperature response curves of CO_2-dependent oxygen evolution rates in the last fully expanded leaf of control (○) and cold-acclimated (Δ) *P. dilatatum* cv. Raki. Values are means (± SE) of 4–17 independent replicates. (A), A_{O2} (μmol O_2 m^{-2} s^{-1}) and (B), A_{O2} (μmol O_2 mg^{-1} Chl s^{-1}).

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Acclimation to long-term chilling in a C4 plant
Effect on photosynthesis

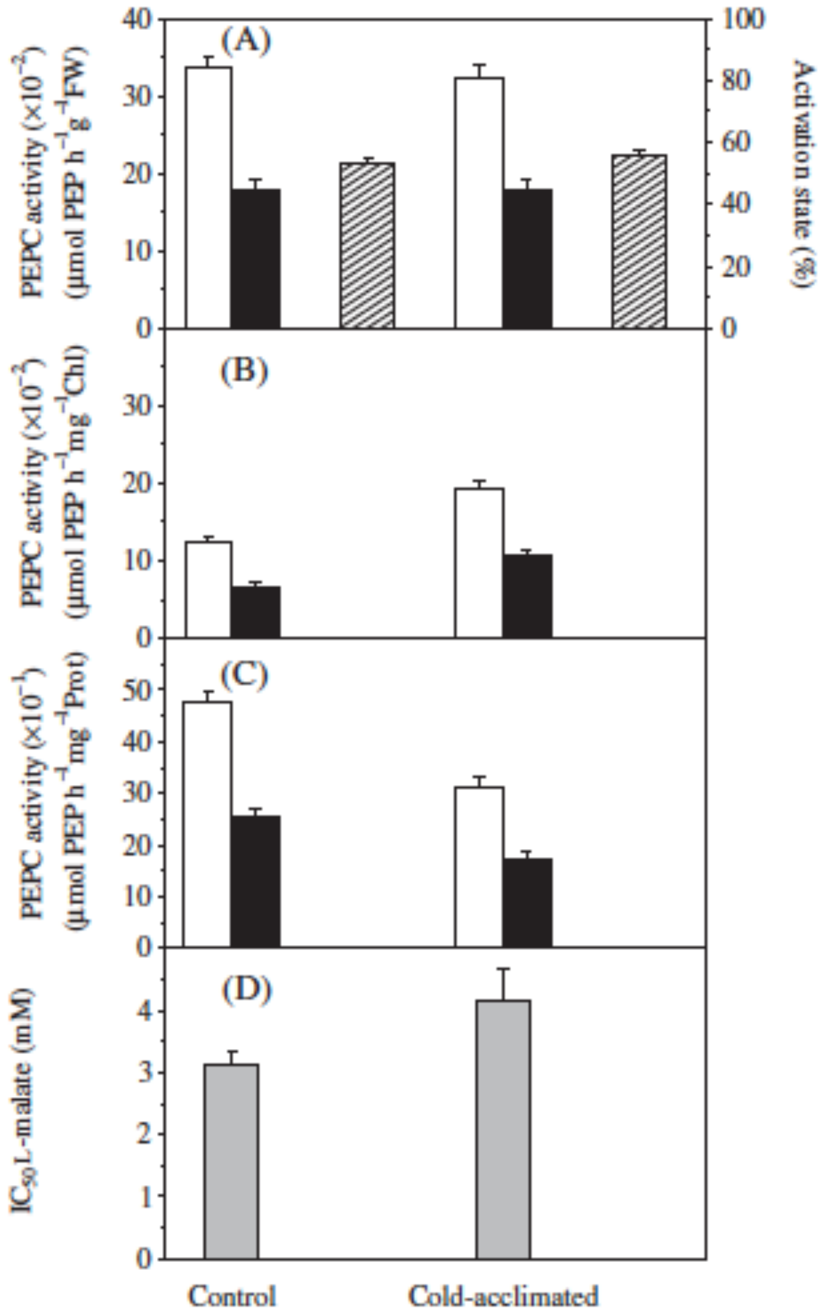

Fig. 6. PEPC activity on a fresh weight basis (A), on a chlorophyll content basis (B) and on a soluble protein content basis (C) and IC_{50} (L-malate) (D) in the last fully expanded leaf of control and cold-acclimated *P. dilatatum* cv. Raki. Columns are means (+ SE) of six independent replicates. (A)–(C) V_{max} (□), $V_{physiol}$ (■), activation state (▨); (D), IC_{50} [L-malate] (▩).

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Acclimation to long-term chilling in a C4 plant
Effect on photosynthesis

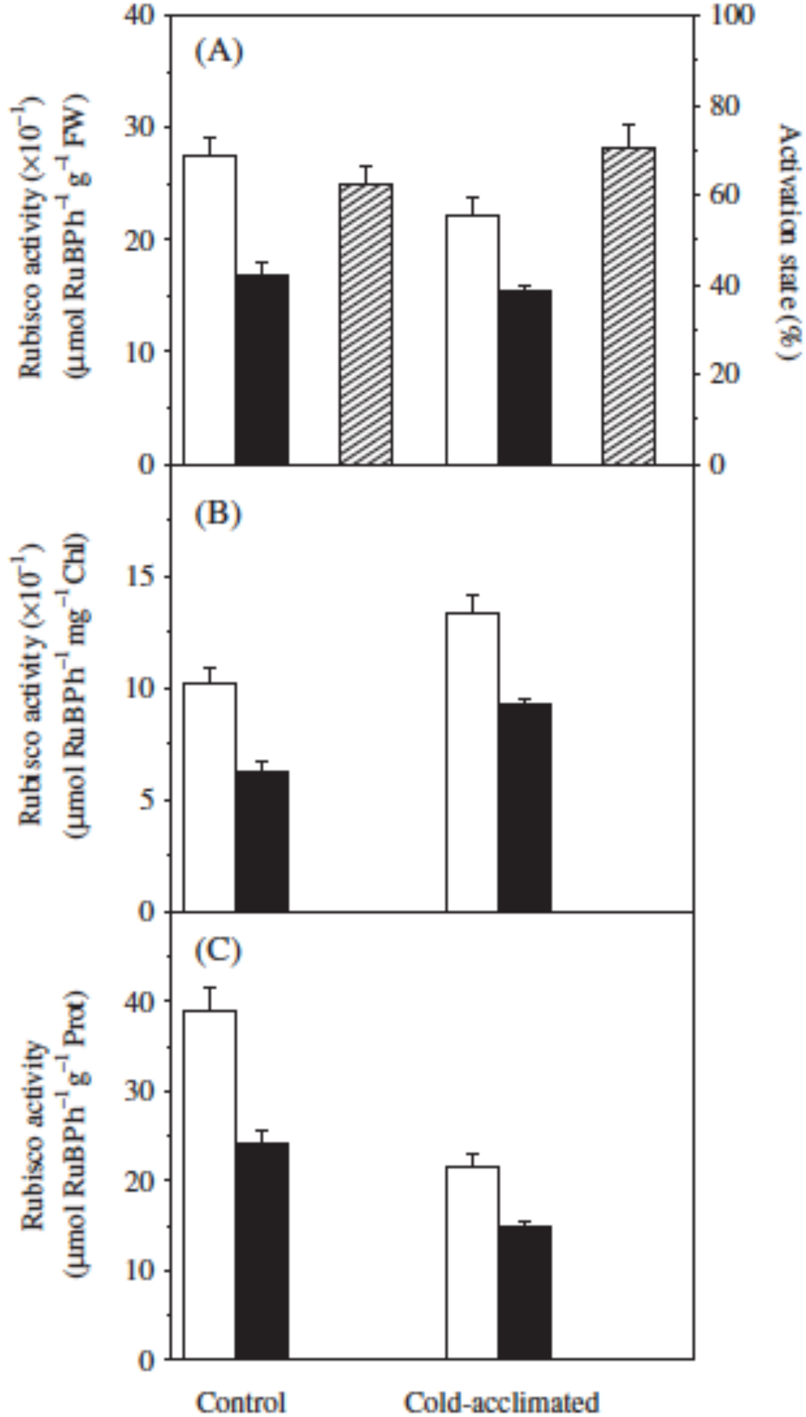

Fig. 7. Rubisco activity [V_{total} (□), $V_{initial}$ (■), activation state (▨)] on a fresh weight basis (A), on a chlorophyll content basis (B) and on a soluble protein content basis (C) in the last fully expanded leaf of control and cold-acclimated *P. dilatatum* cv. Raki. Columns are means (+SE) of six independent replicates.

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Acclimation to long-term chilling in a C4 plant
Effect on photosynthesis

Arrhenius eq. $v = A\, e^{-Ea/RT}$

$\log v = \log A - (Ea/R)(1/T)$

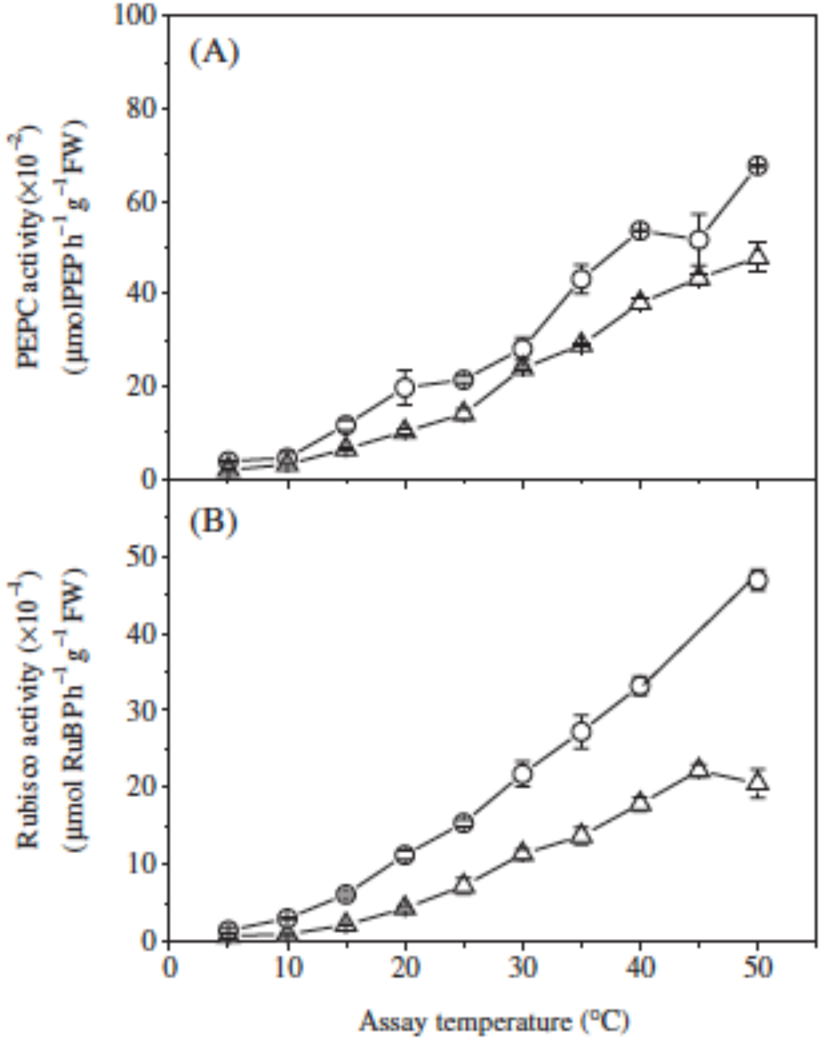

Fig. 8. Temperature curves of PEPC (V_{max}) (A) and Rubisco (V_{total}) (B) activity in the last fully expanded leaf of control (○) and cold-acclimated (Δ) *P. dilatatum* cv. Raki. Values are means (± SE) of 2–4 independent replicates.

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Acclimation to long-term chilling in C4 plants

Effect on photosynthesis

Figure 1. Emily Heaton next to a stand of giant miscanthus on Caveny Farm, Monticello, Illinois. Each mark on the post equals 1 foot.
Photo: John Caveny.

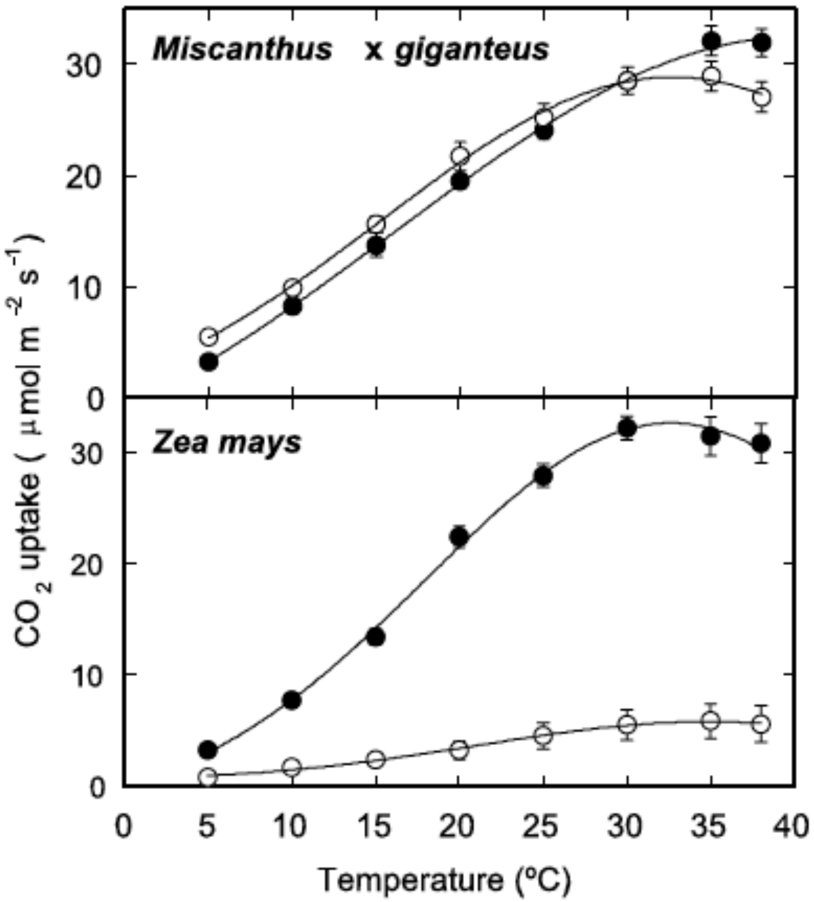

Figure 1. Temperature response of photosynthetic CO_2 uptake per unit leaf area for *M.* × *giganteus* and maize grown at 25°C/20°C or 14°C/11°C day/night temperatures. Error bars (±1 SE) of the mean (*n* = 8–15) are shown, except when smaller than the symbol size.

Naidu *et al*., Plant Physiol. 132: 1688-1697

Acclimation to long-term chilling in C4 plants

Effect on photosynthesis

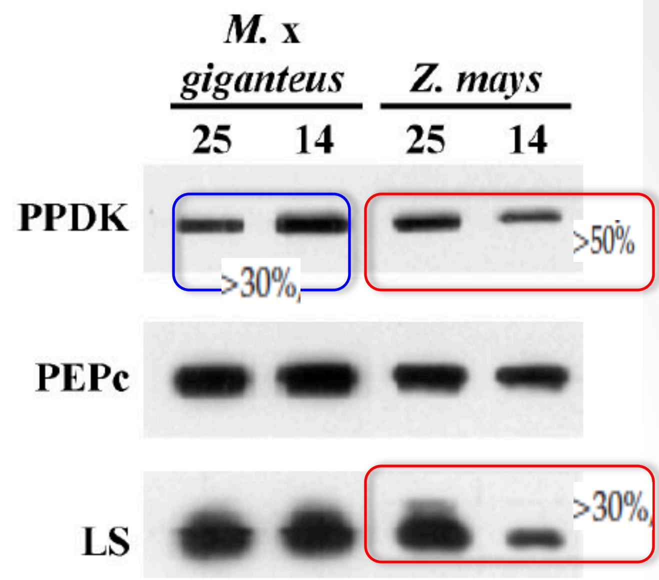

Figure 2. Sample western blot of PPDK, PEPc, and the large subunit of Rubisco (LS) extracted from *M.* × *giganteus* and maize leaves grown at 25°C/20°C or 14°C/11°C day/night temperatures. Samples were loaded on an equal leaf area basis.

Table I. *Protein content*

Means and SEs of C_4 photosynthetic protein amounts (from western blots) for three replicate leaf samples of *M.* × *giganteus* and maize plants grown and measured at 25°C/20°C or 14°C/11°C day/night temperatures. Within each replicate, values were standardized to amount of protein in 25°C maize leaves. The bottom row contains values of total soluble protein (grams per square millimeter) extracted from four replicate leaf samples for each species and temperature. Percentage of change is relative to 25°C within each species.

	Miscanthus × *giganteus*				Maize			
	25°C/14°C	14°C/11°C	Percentage of change	P value	25°C/14°C	14°C/11°C	Percentage of change	P value
PPDK	0.68 (0.172)	0.87 (0.064)	+28%	0.191	1.00 (N/A)	0.43 (0.186)	−57%	0.032
PEPc	0.91 (0.007)	0.90 (0.016)	−1%	0.500	1.00 (N/A)	0.90 (0.053)	−10%	0.032
LS	0.98 (0.016)	1.01 (0.014)	+3%	0.191	1.00 (N/A)	0.61 (0.192)	−39%	0.032
Total	3.73 (0.043)	3.82 (0.035)	+2%	0.131	3.79 (0.037)	3.12 (0.041)	−17%	0.015

Naidu *et al.*, Plant Physiol. 132: 1688-1697

Acclimation to long-term chilling in C4 plants

Effect on photosynthesis

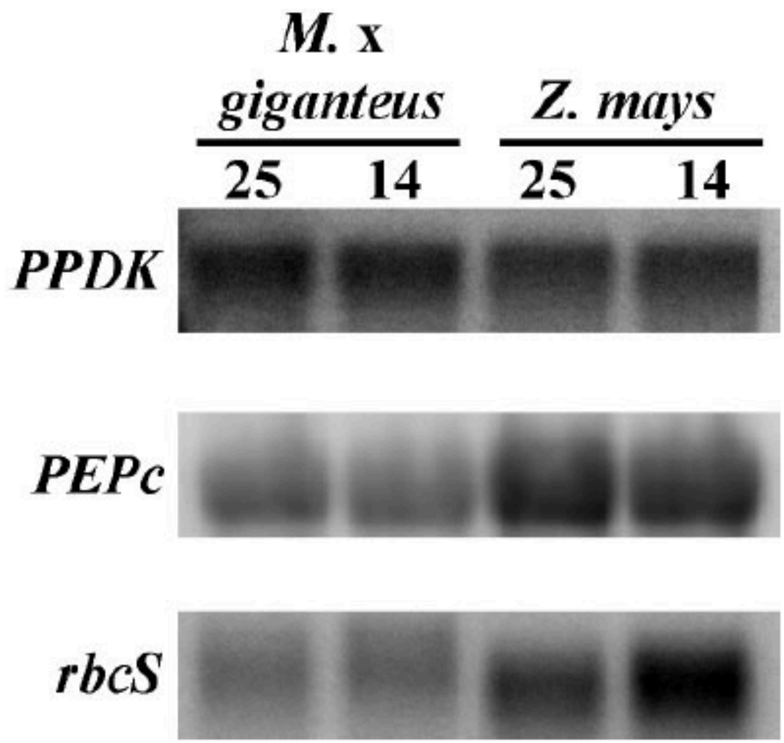

Figure 3. Northern blots of *PPDK*, *PEPc*, and the small subunit of Rubisco (*rbcS*) mRNA from *M.* × *giganteus* and maize leaves grown at 25°C/20°C or 14°C/11°C day/night temperatures.

Naidu *et al*., Plant Physiol. 132: 1688-1697

Papers to read :

Effects of long-term chilling on growth and photosynthesis of the C_4 gramineae *Paspalum dilatatum*

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Cold Tolerance of C_4 photosynthesis in *Miscanthus* × *giganteus*: Adaptation in Amounts and Sequence of C_4 Photosynthetic Enzymes[1]

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Suggestion :

Review

New Phytologist

TANSLEY REVIEWS

Tansley review

Advances and challenges in uncovering cold tolerance regulatory mechanisms in plants

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Epigenetic Control of Plant Cold Responses

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Keywords: cold stress, DNA methylation, histone modifications, vernalization genes, cold acclimation, crosstalks