UNIVERSIDAD DE LOS ANDES
MERIDA VENEZUELA

Freezing avoidance in tropical Andean bamboos

CENTRO JARDÍN BOTÁNICO DE MÉRIDA

Francisca Ely
Sayuri Kiyota

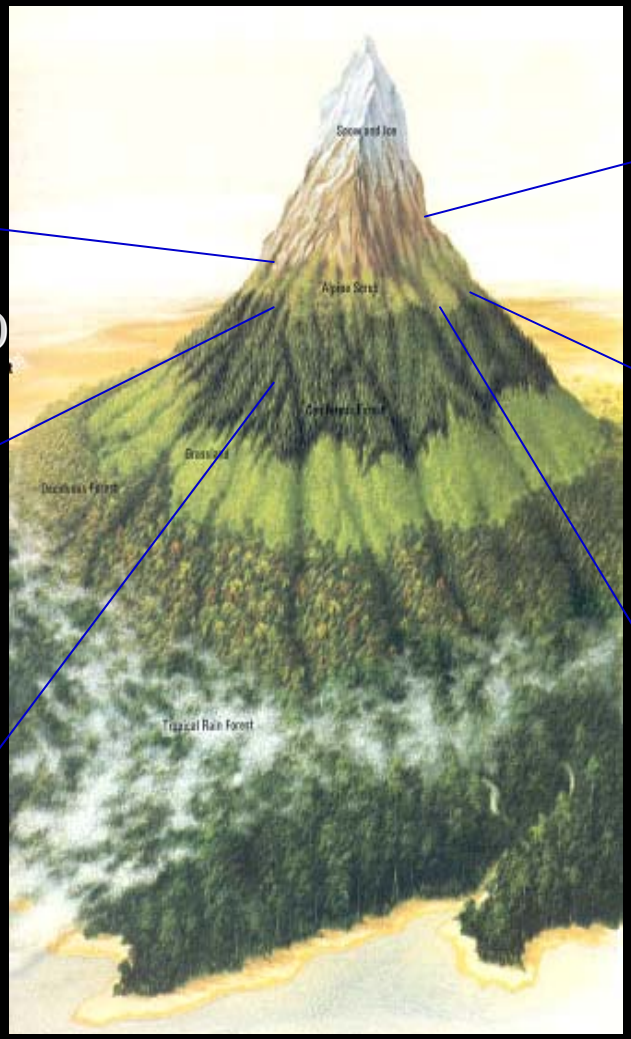
Instituto de Ciencias Ambientales y Ecológicas

Fermín Rada

Tropical Andes

Paramo proper (3000-3800)

Superparamo (3800-4300 m)



Bosques parameros (2800-3300)

Subparamos (2550-2800 m)

Dry subparamos

Cloud forests (1800-2800 m)

Swampy subparamos

Viny bamboos (1800-2900 m)

Chusquea purdieana

Chusquea serrulata

Shrublike bamboos (2670-3650 m)

Chusquea spencei

Dwarf shrublike bamboos (3800-4010 m)

Chusquea guirigayensis

Chusquea angustifolia

We know that in tropical Andes

- Above treeline limits (3000 m asl) air and soil temperatures can fluctuate very abruptly on a daily basis, with freezing temperatures occuring any night of the year
- Many species that do not grow above treeline limits because they do not resist freezing temperatures.
- Those that do must either avoid or tolerate freezing

In the Venezuelan paramo plants we have examples of both strategies

Frost avoiders (no ice nucleation occurs) through supercooling or accumulation of osmotically active solutes and carbohydrates

Frost tolerant withstanding ice formation in intercellular spaces

Right and above: *Coespeletia timotensis* and *Espeletia schultzii. Left, below: Polylepis sericea*

Above: *Cortaderia* (right), *Ruilopezia atropurpurea* (left), below: *Arenaria* (left), *Draba* (midle), *Castilleja fissifolia*

It is very likely that freezing temperatures have conditioned the distribution of woody bamboos in the tropical Andes

- We know that temperate Japanese bamboos of the genera *Sasa* and *Sasamorpha* are frost avoiders through deep supercooling (-22 to -15 °C)[1]
- We do not know how tropical Andean bamboos deal with freezing temperatures

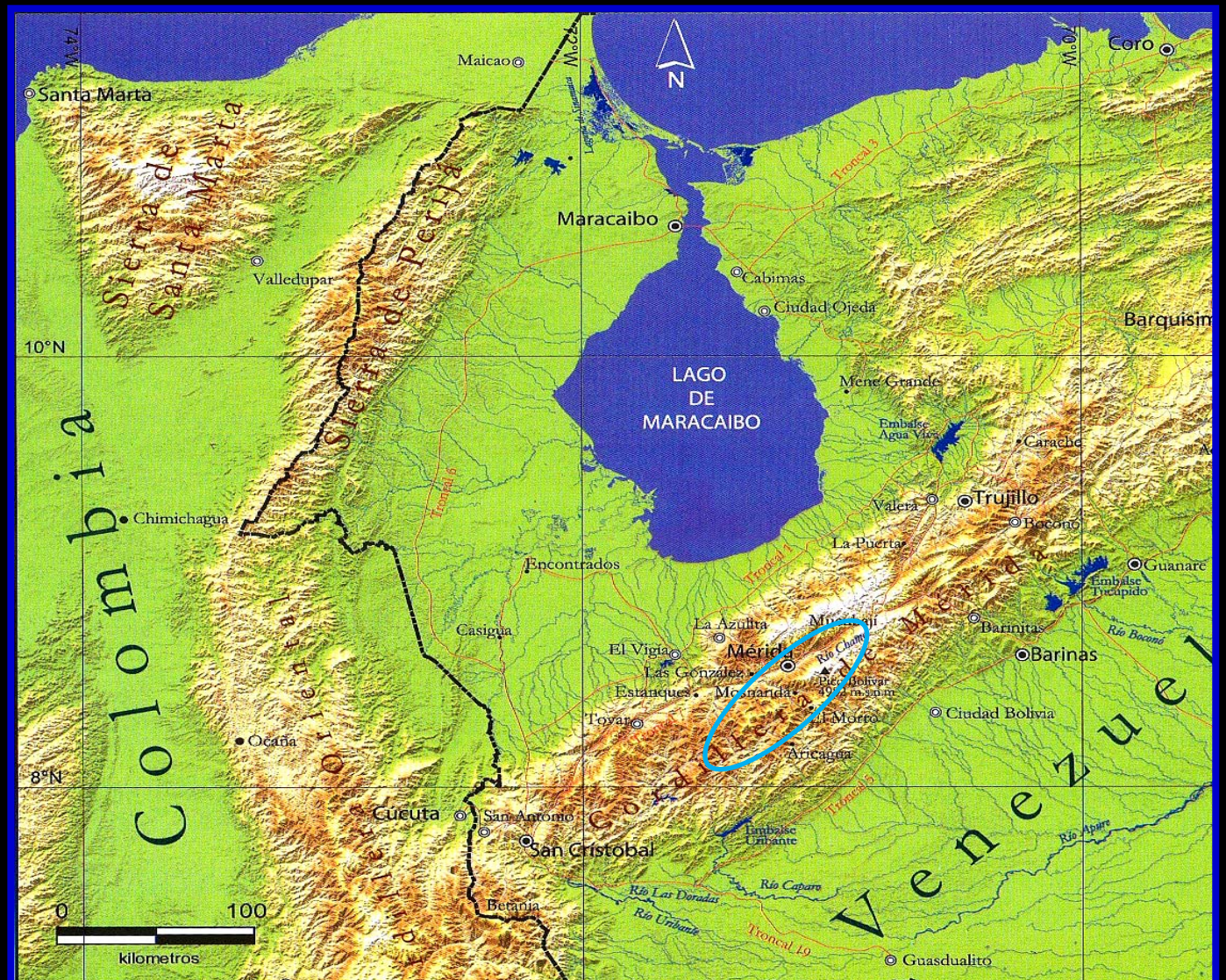
Main questions addressed in this study:

1. Firstly, how do tropical Andean bamboos respond to freezing temperatures?
2. Are the species of lower elevations frost avoiders and those of higher elevations frost tolerant?
3. Does freezing resistance increase in woody bamboos along the altitudinal gradient?

Hypothesis

- Cloud forest viny bamboos and subparamo shrublike bamboos (<3000 m) do not resist freezing temperatures
- Paramo bamboos (3000-3600 m) are frost avoiders in which supercooling capacity increases with altitude
- Dwarf shrublike bamboos associated to superparamos (3800-4010 m) could be frost tolerant like tussock grasses

Study site


Colombia
Venezuela
Sierra de Perijá
Sierra Nevada de Santa Marta
Cordillera de Mérida
LAGO DE MARACAIBO
Maracaibo
Santa Marta
Maicao
Valledupar
Chimichagua
Ocaña
Cúcuta
San Antonio
San Cristobal
Betania
Encontrados
Casigua
Cabimas
Ciudad Ojeda
Mene Grande
Coro
Barquisim
Caracha
Trujillo
Valera
Bocono
La Puerta
Guanare
Barinitas
Barinas
La Azulita
El Vigia
Mérida
Las Gonzalez
Estanques
Monarida
Tovar
Aricagua
El Morro
Ciudad Bolivia
Guasdualito
Embalse Agua Viva
Embalse Tucupido
Embalse Uribante
Río Bocono
Río Apure
Río Caparo
Río Las Doradas
Río Uribante
Troncal 1
Troncal 3
Troncal 5
Troncal 8
Troncal 19
10°N
8°N
74°W
70°W
N
0
100
kilometros

husquea purdieana

Chusquea serrulata

Chusquea spencei

Chusquea guirigayensis

Chusquea angustifolia

and soil temperatures were determined with portable dataloggers (15 min)

af samples were collected from n=5 culms (separated 10 m) during wet and dry

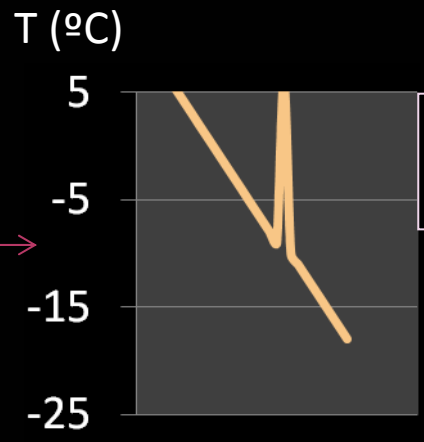
ns of 2008-2010

ms were cut at ground level, placed in water, cut again and then allowed to

acellular ice nucleation temperatures were determined registering herm formation temperatures

leaf samples ced in sealed ntaining constantan ouples

2- These were placed in a regfigerated bath temperatures were diminished from 5 to -25°C at a rate of 7.5°C/h



3- Exotherm temperature was monitored

% Injury temperature was determined using the electrolyte leakage hod (Ishikawa 1984, Lindén 2002)

samples were ed to the same process sly described

2- Every 5°C intervals, 3 samples were withdrawn each time and submerged in 15 mm^3 deonized water

5- Samples were submerged again in original containers **Final electric conductivity** was measured after 48 h

3- Initial electric conductivity was measured in µs.
A rise in electric conductivity due to electrolyte leakage, (mostly of K ions) as a consequence of tissue rupture once freezing occurs

4- Immediately after, total

Results

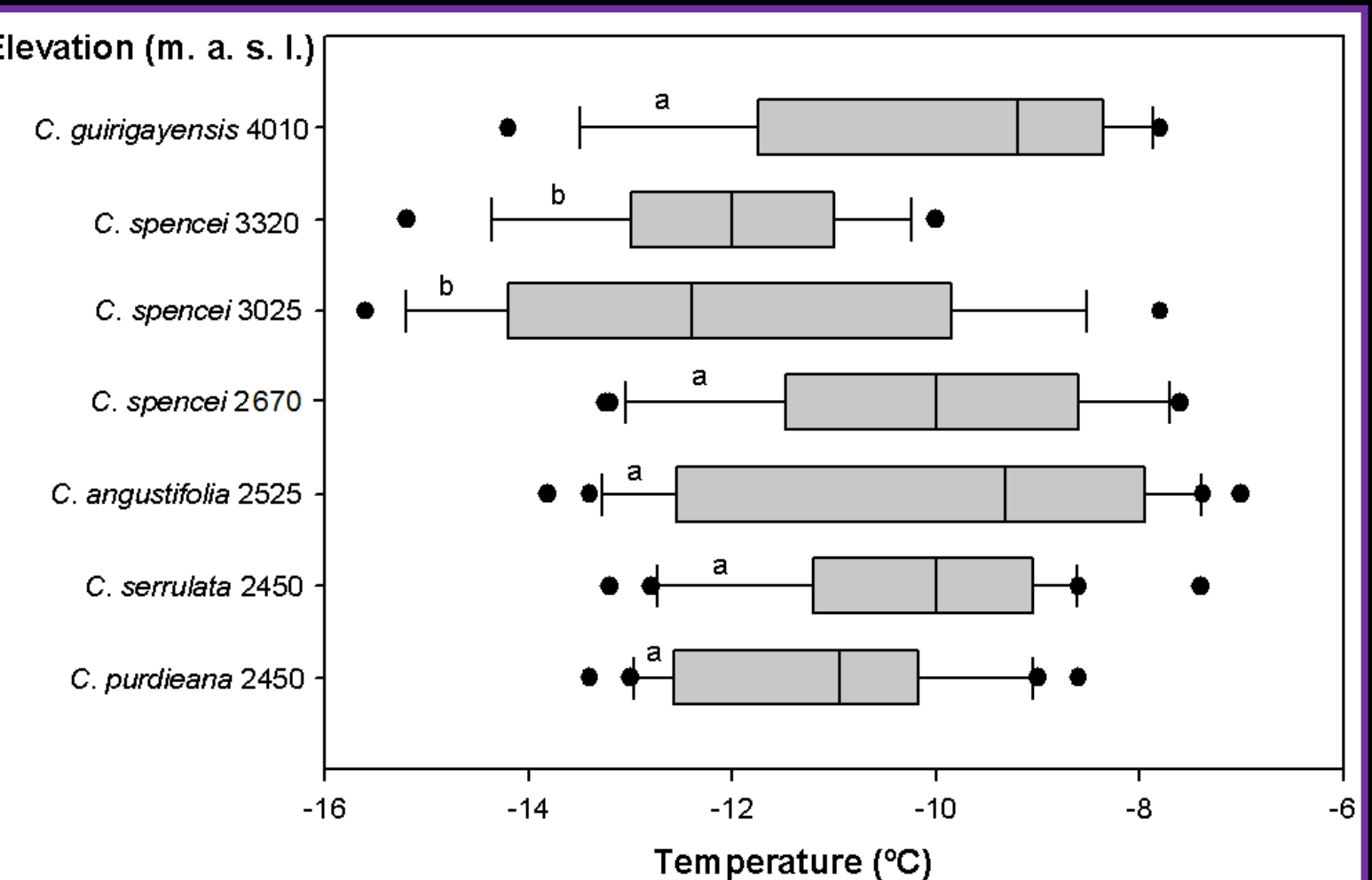
Study sites	Air temperatures (ºC)		
	Average	Minimum	Maximum
Monte Zerpa (2450 m)	13	8.03 (6,53)	17.06 (20)
Las Piñuelas (2525 m)	14	8.5 (4.6)	20 (25)
Las Coloradas (2670 m)	12	9.0 (7.0)	17 (21)
La Culata (3025 m)	9.25	4,3 (-0.16)	-------- 18.8
La Aguada (3320 m)	7.6	2.3 (-0.68)	--------- (20±0.06)
Piedras Blancas (4010 m)	6.2± 0.04	2.0	15

Extracellular ice nucleation temperatures and 50 % injury temperatures

Species	Exotherm formation temperature (°C)	50 % Injury temperature (°C)
C. purdieana (Monte Zerpa 2450 m)	**(-9.0) -11.0[a] (-13.4)**	**(-10.8) -11.5[a] (-12.4)**
C. serrulata (Monte Zerpa 2450 m)	**(-9.0) -10.5[a] (-13.0)**	**(-9.6) -10.1[a] (-11.9)**
C. angustifolia (Las Piñuelas 2525 m)	**(-7.4) -10.8 [a] (-13.8)**	**(-11.4) -12.3[a] (-13.1)**
C. spencei (Las Coloradas 2670 m)	**(-7.6) -10.6[a] (-13.3)**	**(-8.4) -10.2[a] (-13.7)**
C. spencei (La Culata 3025 m)	**(-7.9) -12.1[b] (-15.6)**	**(-9.8) -12.0[b] (-13.5)**
C. spencei (La Aguada 3320 m)	**(-10.4) -12.0[b] (-15.0)**	**(-9.8) -12.2[b] (-15.9)**
C. guirigayensis	**(-8.0)**	**(-9.0)**

lts

dless of their life-form and habitat all of these bamboos shared very
r supercooling temperatures, with the exception of genets of *C. spencei*
3000 m



We conclude that:

- All five species avoide intercellular ice formation through a moderate supercooling, regardless of their life-form, plant height and habitat
- Supercooling capacity values were higher in these *Chusquea* species than those reported for other treeline-paramo woody species[1], and comparable to those reported for giant rosettes of the genus *Espeletia*[2]

[1]Rada et al. 1985, 2009; Cavieres et al. 2000.

[2]Goldstein et al. 1985, Rada et al. 1987.

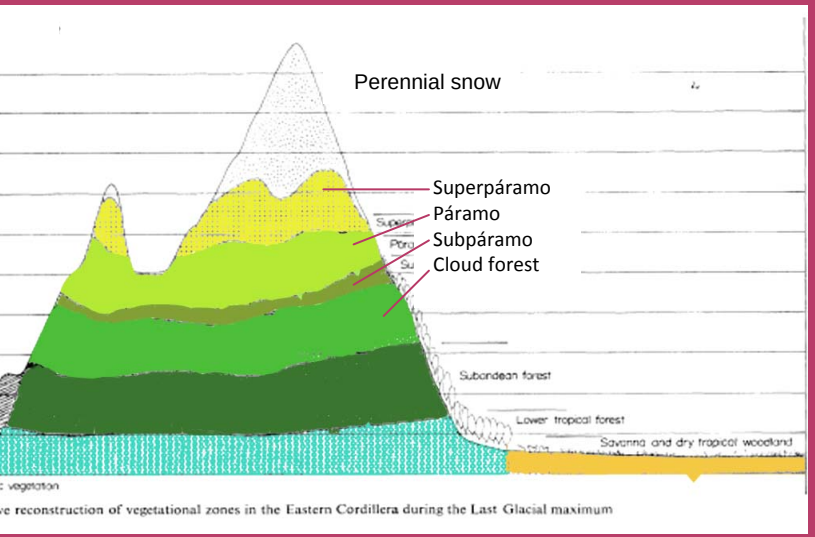
- Neither intercellular ice nucleation nor 50 % injury temperatures varied significantly between the species situated at the upper (4010 m) and lower limits (2450 m) of this gradient
- Only *C. spencei* presented a slight increase in its supercooling capacity with increasing altitude
- *C guirigayensis* despite its small size and more frequent exposure to freezing temperatures as low as -4°C, for longer intervals, responds to freezing temperatures in the same manner as the

It is important to take into account that

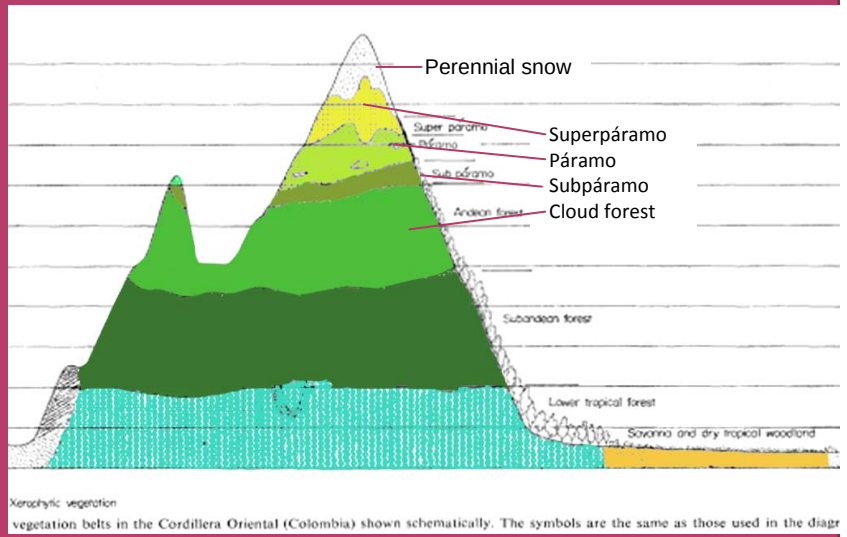
ent species distribution is the result of past climatic and geological events rmark 1979)

mo and cloud forest boundaries have suffered repeated displacements since the acier era (Van der Hammen 1974, 2000, Salgado-Labouriau *et al.* 1977, 1992)

emperatures in the tropical Andes have increased in these past 30 years



ve reconstruction of vegetational zones in the Eastern Cordillera during the Last Glacial maximum



vegetation belts in the Cordillera Oriental (Colombia) shown schematically. The symbols are the same as those used in the diagr

- Freezing resistance mechanisms differ amongst herbaceous grasses and bamboos, the first are frost tolerant[1] whilst the second are frost avoiders[2], regardless of their latitudinal and altitudinal distribution
- Although tropical and temperate bamboos are frost avoiders, they differ in their supercooling capacity (-22 to -15 ºC vs -12.1 to -10.3)

[1]Ashworth & Pearce 2001; Márquez *et al.* 2006; Liu & Osborne 2008.

[2] Ishikawa 1984; Sakai & Larcher 1987; Tanaka 2002.

- The altitudinal distribution of these five *Chusquea* species is not conditioned by freezing temperatures, but more likely by other environmental factors not taken in account in the present study.