Table 1. Summary of observed variation in thermally-relevant leaf traits with canopy height and/or between sun and shade leaves

trait	symbol	units	response	forest type(s)	reference(s)
Leaf anatomy and morphological traits					
leaf mass per area (or inverse of specific leaf area)	LMA (or $1/SLA$)	$g \cdot cm^{-2}$	↑ with height	TeB, TrB, BoN	Coble and Cavaleri 2014, Mau et al. 2018, Sack et al. 2006, Chin and Sillett 2019
			↑ with light	TeB, TrB, BoN	Coble and Cavaleri 2014, Mau et al. 2018, Sack et al. 2006, Wyka et al. 2012
leaf density	$density$	$g \cdot cm^{-3}$	↑ with height	TeB	Coble and Cavaleri 2014
			↑ with light	TeB, TrB	Coble and Cavaleri 2014, Marques et al. 2000
			≈ with light	BoN	Wyka et al. 2012
leaf area	LA	cm^2	↓ with height	TeB, TrB, BoN	Kusi and Karasi 2020, Cavaleri et al. 2010, Kenzo et al. 2016, Gebauer et al. 2015
			↓ with light	TrB, TeB, BoN	Kusi and Karasi, 2020, Sack et al. 2006, Gebauer et al. 2015
stomatal density	$D_{stomata}$	mm^{-2}	↑ with height	TrB, TeB, BoN	Marenco et al. 2017, Kafuti et al. 2020, Van Wittenberghe et al. 2012, Sack et al. 2006, Chin and Silette 2017
			↑ with light	TeB, TrB	Sack et al. 2006, Kafuti et al. 2020, Marenco et al. 2017
length of minor veins/unit area	VLA_{min}	$mm \cdot mm^{-2}$	↑ with height	TeB	Zhang et al. 2019
			↑ with light	TeB	Zhang et al. 2019
leaf thickness	$LeaThi$	μm	↑ with height	TrB, TeB, BoN	Weerasinghe et al. 2014,Coble and Cavaleri 2014, Van Wittenberghe et al. 2012, Oldham et al. 2010, Marenco et al. 2017
			↑ with light	TeB, BoN, TrB	Coble and Cavaleri 2014, Wyka et al. 2012, Marenco et al. 2016, Weerasinghe et al. 2014
trichome density	$trichome$	mm^{-2}	↑ with height	TrB	Ichie et al. 2016
			↑ with light	TeB, TrB	Gregoriou et al. 2007, Ichie et al. 2016, Levizou et al. 2005, Liakoura 1997
blade inclination angle (vertical)	ϕB	∘	↑ with height	TeB, TrB	Niinemets et al. 1998, Ishida et al. 1998, Fauset et al. 2018
			↑ with light	TeB, TrB	Millen and Clendon 1979, Ishida et al. 1998, Niinemets et al. 1998, Fauset et al. 2018
pinnate lobation	$lobation$	cm^2	↑ with height	TeB	Sack et al. 2006
			↓ with height	TeB	Kusi and Karasi, 2020
			↑ with light	TeB	Kusi and Karasi 2020, Sack et al. 2006
drip tip length	$driptip$	cm	↓ with height	TrB	Panditharathna et al. 2008
			↓ with light	TrB	Panditharatna et al. 2008
upper cuticle thickness	CT	μm	↑ with height	TrB, BoN	Panditharathna et al. 2008, Chin and Sillett 2019
			↑ with light	TrB, TeB	Panditharathna et al. 2008, Marques et al. 2000, Baltzer and Thomas 2005
adaxial leaf wettability (as drop contact angle)	DCA_{ad}	∘	↑ with height	TeB	Van Wittenberghe et al. 2012
	$durationofsurfacewetness$	%	↓ with height	TrB	Dietz et al. 2007
	DCA	∘	↑ with light	TeB	Van Wittenberghe et al. 2012
			↑ with height	TrB, TeB, BoN	Kenzo et al. 2015, Coble et al. 2016, Scartazza et al. 2016, Duursma and Marshall, 2006, Harley et al. 1996
Leaf biochemical and physiological traits					

Table 1. Summary of observed variation in thermally-relevant leaf traits with canopy height and/or between sun and shade leaves *(continued)*

trait	symbol	units	response	forest type(s)	reference(s)
Nitrogen per leaf area	N_a	$g \cdot m^{-2}$	≈↑ with light	TrB, TeB, BoN	Weerasinghe et al. 2014, Hernandez et al. 2020, Scartazza et al. 2016, Coble et al. 2016, Harley et al. 1996, Duursma and Marshall, 2006.
			≈↓ with height	TrB, TeB, BoN	Weerasinghe et al. 2014, Kenzo et al. 2015, Coble et al. 2016, Scartazza et al. 2016, Harley et al. 1996, Turnbull et al. 2003
Nitrogen per leaf mass	N_m	$mg \cdot g^{-1}$	≈↓ with light	TrB, TeB, BoN	Chen et al. 2020, Kenzo et al. 2015, Coble et al. 2016, Scartazza et al. 2016, Harley et al. 1996, Wyka et al. 2012
			↑ with height	TrB, TeB, BoN	Weerasinghe et al. 2014,van de Weg et al. 2012, M.A Cavaleri et al. 2008, Mau et al. 2018
Phosphorous per leaf area	P_a	$g \cdot m^{-2}$	↑ with light	TrB, Te, BoN	Weerasinghe et al. 2014, Wyka et al. 2012
			≈↓ with height	TrB	Weerasinghe et al. 2014, Chen et al. 2020, Mau et al. 2018
Phosphorous per leaf mass	P_m	$mg \cdot g^{-1}$	≈ with light	TrB, TeB	Weerasinghe et al. 2014, Chen et al. 2020, Mau et al. 2018
			↑ with height	TrB, TeB	Koniger et al. 1995, Scartazza et al. 2016, Niinemets et al. 1998
xanthophyll cycle pigments	VAZ	μmolm^{-2}	↑ with light	TeB, TrB	Scartazza et al. 2016, Mastubara et al. 2009
			↓ with height	TrB, TeB	Harris and Medina 2013, Hansen et al. 2001
chlorophyll content	chl	$mg \cdot cm^{-2}$	↓ with light	TrB, TeB	Marques et al. 2000, Poorter et al. 1995, Hansen et al. 2001
			↑ with height	TeB, TrB	Scartazza et al. 2016, Poorter et al. 1995
b carotene and lutein	$bcarotene$ and $lutein$	μmolm^{-2}	↑ with light	TeB, TrB	Scartazza et al. 2016, Koniger et al. 1995
			↑ with height	TeB, TrB	Scartazza et al. 2016, Poorter et al. 1995
chlorophyll a/b ratio	$chla/b$	$mol \cdot mol^{-1}$	↑ with light	TeB, TrB	Scartazza et al. 2016, Poorter et al. 1995, Matsubara et al. 2009, Niinemets et al. 1998
			↑ with height	BoN, TeB, TrB	Duursma and Marshall, 2006, Coble et al. 2017, Kenzo et al. 2015
carbon isotope composition	$\delta^{13}C$	‰	↑ with light	BoN, TeB, TrB	Duursma and Marshall, 2006, Coble et al. 2016, Kenzo et al. 2015
			↓ with height	TeB	Scartazza et al. 2016
intercellular C_{O_2} concentration	C_i	μmol $\cdot mol^{-1}$	↓ with light	TeB	Scartazza et al. 2016
			≈ with height	TrB	Poorter et al. 1995, 2000
PAR absorptance	ABS	% nm	≈↑ with light	TrB	Poorter et al. 1995, 2000
			↓ with height	TrB	Poorter et al. 1995, 2000
absorptance efficiency per unit biomass	ABS	$\% \cdot g^{-1}$	↓ with light	TrB	Poorter et al. 1995, 2000
			↓ with height	TrB	Poorter et al. 1995, 2000
PAR transmittance	$transmittance$	%	↓ with light	TrB	Poorter et al. 1995, 2000
			≈ with height	TrB	Poorter et al. 1995, 2000
reflectance	$reflectance$	%	≈ with light	TrB	Poorter et al. 1995, 2000

Table 2. Summary of observed variation in leaf metabolism and thermal responses across the vertical gradient and/or betwee
sun and shade leaves

trait	symbol	units	response	forest type(s)	reference(
Stomatal conductance					
max stomatal conductance	$g_{s_{max}}$	$molm^{-2}s^{-1}$	↑ with height	TrB, TeB, BoN	Kafuti et Wittenber Roberts e 1997
			↓ with height	BoN, TrB	Ambrose e et al. 201
			↑ with light	BoN, TrB, TeB	Zeifel et a 2019, Her Urban et
stomatal conductance limitation with temperature	g_s	$molm^{-2}s^{-1}$	↑ with height	TrB, BoN	Hernandez al. 2001
			↑ with light	BoN, TrB	Zeifel et a al. 2020
stomtatal conductance at optimal temperature	g_s at T_{opt}	$molm^{-2}s^{-1}$	≈↑ with height	TeB	Carter an
			≈↑ with light	TrB	Slot et al.
Photosynthesis					
boundary-layer conductance	g_a	$mmol^{-2}s^{-1}$	↑ with height	TrB	Roberts e
	g_{bV}	mms^{-1}	↑ with height	BoN	Martin et
			↑ with light	TrB	Roberts e
	g_{bV}	mms^{-1}	≈ with light	BoN	Martin et
maximum photosynthetic capacity (area-based)	$A_{max_{area}}$	μmol $\cdot m^{-2} \cdot s^{-1}$	↑ with height	TeB, TrB	Carter an Kosugi et al. 2015,
			≈↓ with height	TeB (F.sylvatica)	Bachofen
			↑ with light	TeB, TrB, BoN	Hamerlyn Kosugi et 2017, Mau al. 2007,
maximum photosynthetic capacity (mass-based)	$A_{max_{mass}}$	$nmol \cdot g^{-1} \cdot s^{-1}$	≈ with height	TrB	Rijkerse e al. 1999
			≈ with light	TeB, TrB, BoN	Wyka et a 2000, Ishi
maximum light-saturated net photosynthesis	A_{sat}	μmol $\cdot m^{-2} \cdot s^{-1}$	↑ with height	TeB, TrB	Scartazza Weerasing
			↑ with light	TeB, TrB	Scartazza 2019
A_{sat} at optimum temperature	A_{opt}	μmol $\cdot m^{-2} \cdot s^{-1}$	≈↑ with height	TeB, TrB	Carter an et al. 201
			↑ with light	TrB	Slot et al.
Respiration					
optimum temperature for photosynthesis	T_{opt}	°C	≈ with height	TrB, TeB	Miller et a Cavaleri 2
			≈ with light	TrB, TeB	Hernandez al. 2019, 2018
photosynthetic light compensation point	LCP	μ mol m^{-2}	↑ with height	TeB, BoN, TrB	Bachofen Medina 20
			↑ with light	TrB, TeB, BoN	Slot et al. and Knap al. 2020
maximal carboxylation rate(area-based)	$V_{cmax_{area}}$	$\mu mol \cdot m^{-2}s^{-1}$	↑ with height	TeB, TrB	Scartazza al. 2012,
			↑ with light	TeB,TrB, BoN	Scartazza al. 2012, Urban et
maximal carboxylation rate(mass-based)	$V_{cmax_{mass}}$	$nmol \cdot g^{-1} \cdot s^{-1}$	≈ with height	TrB, TeB	van de We Scartazza
			≈ with light	TrB, TeB	van de We Scartazza
VOC production					
		nmol $C_{O_2}g^{-1}s^{-1}$	≈↓ with light	TeB	Legner et
V_{cmax} at optimum temperatue	$V_{cmax}(T_{opt})$	$\mu mol \cdot m^{-2}s^{-1}$	≈↑ with height	TeB	Carter an

Table 2. Summary of observed variation in leaf metabolism and thermal responses across the vertical gradient and/or betwee
sun and shade leaves *(continued)*

trait	symbol	units	response	forest type(s)	reference(
			≈ with light	TrB	Hernandez
electron transport rate(area-based)	$J_{max_{area}}$	$\mu mol \cdot m^{-2} s^{-1}$	↑ with height	TeB, TrB	Scartazza al. 2012 v
			↑ with light	TeB,TrB	Scartazza al. 2012,
					Hernandez
electron transport rate(mass-based)	$J_{max_{mass}}$	$nmol \cdot g^{-1} \cdot s^{-1}$	≈ with height	TrB, TeB	van de We
					Scartazza
			≈ with light	TrB, TeB	van de We
					Scartazza
		$nmol \cdot e^{-1} g^{-1} s^{-1}$	≈↓ with light	TeB	Legner et
J_{max} at optimal temperature	$J_{max}(T_{opt})$	$\mu mol \cdot m^{-2} s^{-1}$	≈ with light	TrB	Hernandez
leaf temperature	T_L	°C	↑ with height	TrB, TeB	Fauset et 2018, Ishi Rey-Sanch Hamerlyn
			↓ with height	BoN	Muller et 1999
			↑ with light	TrB, TeB	Fauset et 1999, Rey Miller et a and Knap
			≈ with light	BoN	Muller et
thermal time constant (in relation to increasing gs)	t	s	↓ with height	TrB, TrS	Fauset et 2019
			↓ with light	TrB	Fauset et
photosynthetic heat tolerance	T_{50}	°C	↑ with height*	TrS	Curtis et.
			≈↑ with light	TrB, TeB	Slot et al. and Knap
critical temperature beyond which Fv/Fm declines	T_{crit}	°C			
			≈↑ with light	TrB, TeB	Slot et al.
high-temperature CO_2 compensation point	T_{max}	°C	≈ with height	TrB	Weerasing
			≈ with light	TrB	Slot et al.
respiration rate at 25°C	R	$\mu molCO_2 m^{-2} s^{-1}$	↑ with height	TeB, BoN, TrB	Turnbull e al. 2017,
		$\mu molCO_2 kg^{-1} s^{-1}$	≈ with height	TeB, BoN, TrB	Turnbull e 2001
			↑ with light	BoN, TrB	Araki et a 2001
dark respiration (area-based)	R_{dark_a}	$\mu molm^{-2} s^{-1}$	↑ with height	TrB, TeB	Weerasing et al. 201 Scartazza
			↑ with light	TrB, TeB, BoN	Weerasing et al. 201 2019, Han 1994, Urb
dark respiration (mass-based)	R_{dark_m}	$nmol \cdot g^{-1} \cdot s^{-1}$	≈ $uparrow$ with height	TrB	van de We et al. 201
			≈ with light	TrB	van de We et al. 201
dark respiration at reference T	$R_{dark}(T_{ref})$	$\mu mol \cdot m^{-2} s^{-1}$	↑ with height	TrB, TeB, BoN	Weerasing et al. 201 Turnbull e
		$\mu mol(kgleaf)^{-1} s^{-1}$	↑ with height	TrB, TeB, BoN	Weerasing et al. 201 Turnbull e
		μ mol (kg N) $^{-1} s^{-1}$	↑ with height	TeB, BoN	Bolstad et al. 2003
		$\mu mol \cdot m^{-2} s^{-1}$	↑ with light	TeB, TrB	Bolstad et Weerasing al. 2019
temperature sensitivity of R_{dark}	Q_{10}	$°C^{-1}$	≈ with height	TrB, TeB, BoN	Weerasing Bolstad et 2017*
		$°C^{-1}$	≈↑ with height	TeB, BoN	Harley et al. 2003

Table 2. Summary of observed variation in leaf metabolism and thermal responses across the vertical gradient and/or betwee sun and shade leaves *(continued)*

trait	symbol	units	response	forest type(s)	reference(
			≈↓ with light	TrB, TeB, BoN	Weerasing Bolstad et 2017*
			↑ with light	TeB	Harley et
light respiration	R_L	$\mu mol \cdot m^{-2} s^{-1}$	↑ with height	TrB	Weerasing
			↑ with light	TrB	Weerasing
activation energy of respiration	E_0	$kJ \cdot mol^{-1} K^{-1}$	≈ with height	TrB, TeB, BoN	Weerasing Turnbull e Griffin 20
			≈ with light	TrB	Weerasing al. 2019
isoprene emission rate (in emitting species)	I	nmol $m^{-2} s^{-1}$	↑ with height	TeB	Harley et 1997
			↑ with light	TeB	Niinemets Harley et Monson, 2
monoterpenoid emissions	MT	$\mu g m^{-2} s^{-1}$	↓ with height	TeB	(FIX SPE Maimprag
			↓ with light	TeB	(FIX SPE Maimprag

*composite climatic stress variable from canopy temperature, vapour pressure deficit, and relative humidity is higher in lower canopy