


Effects of wet N deposition on *Sphagnum capillifolium* in peatland

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Universidad Rey Juan Carlos

ExpeER Ecosystem Research

éclaire

Effects of climate change on air pollution impacts and response strategies for European ecosystems

SEVENTH FRAMEWORK PROGRAMME

Nitrogen deposition – effects on Sphagnum

Isoprene emissions

Pigments

Photosynthesis

(why are we interested?)

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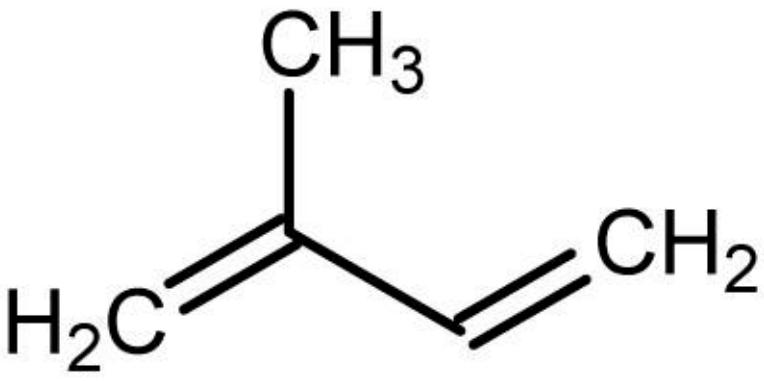
Isoprene chemical structure- it's reactive!



Isoprene C_5H_8

Monoterpenes $C_{10}H_{16}$ and sesquiterpenes C_{15} H_{24}

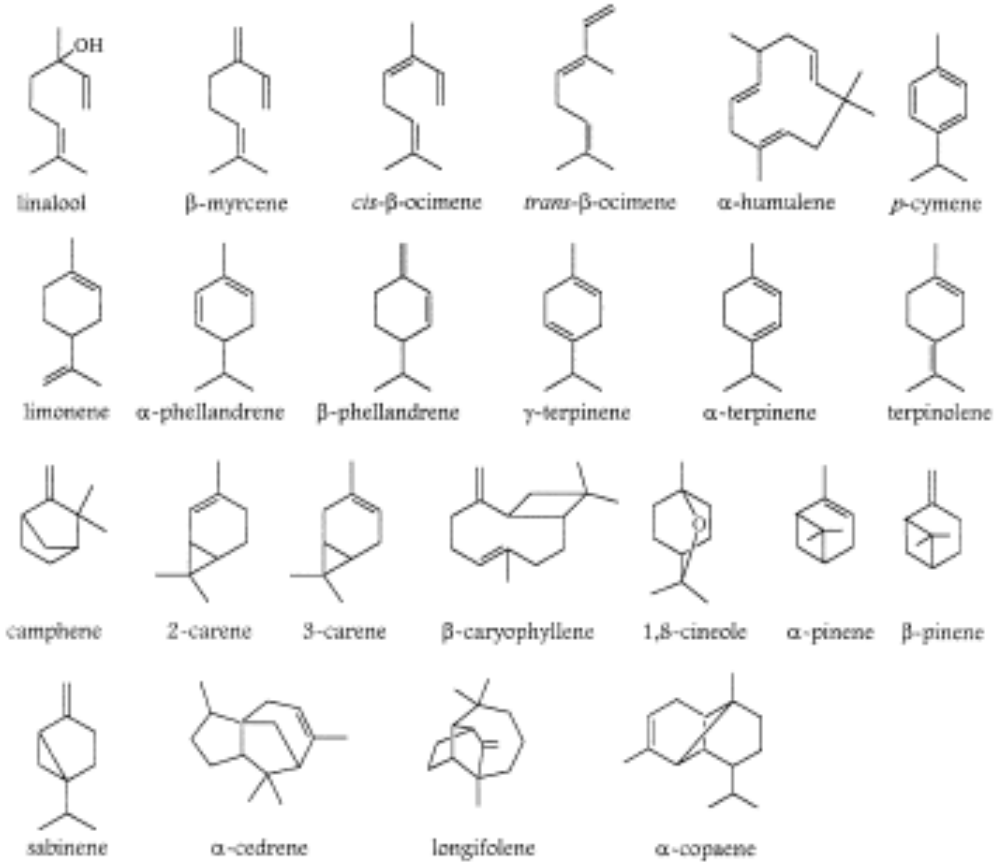


Fig. 1. The chemical structures and names of the terpenes treated in the present review.

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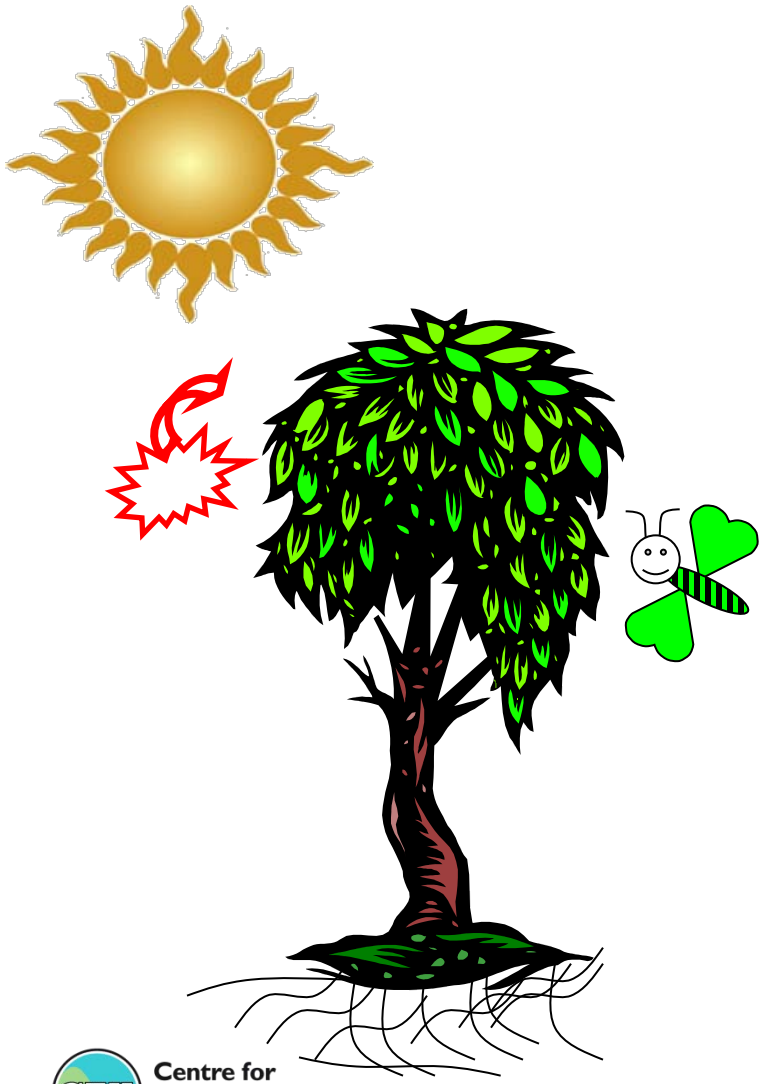
Calogirou et al 1999

Role of isoprene (and other bVOCs) in plants**



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Thermoprotection

Photoprotection

Oxidative damage protection

Photorespiration role at high temp/low O_2

Antiherbivory

Antimicrobial

Pollinator Attractant

Flowering signal

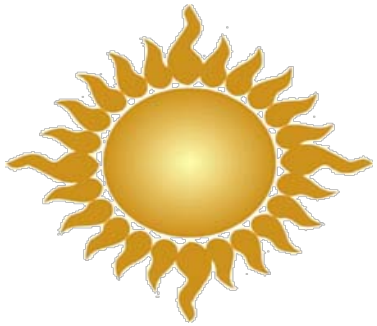
Metabolic safety valve

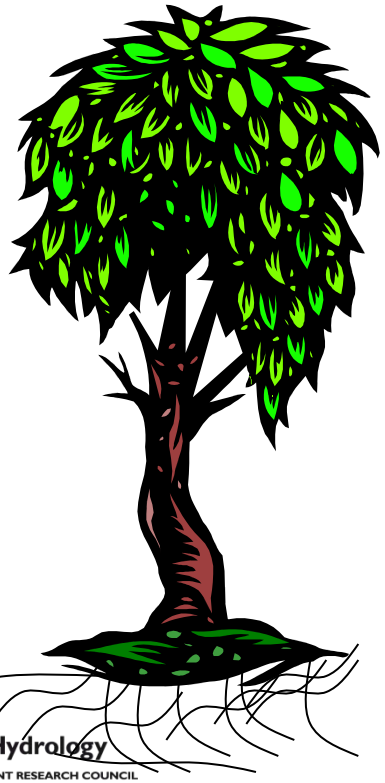
Allelopathy

AND ... can account for up to 5% photosynthetically fixed C

Role of isoprene and other bVOCs in the troposphere

emissions





Reactive with OH, O_3, NO_3

Take part in O_3 chemistry

Can produce particles

(*climate change chemistry*)

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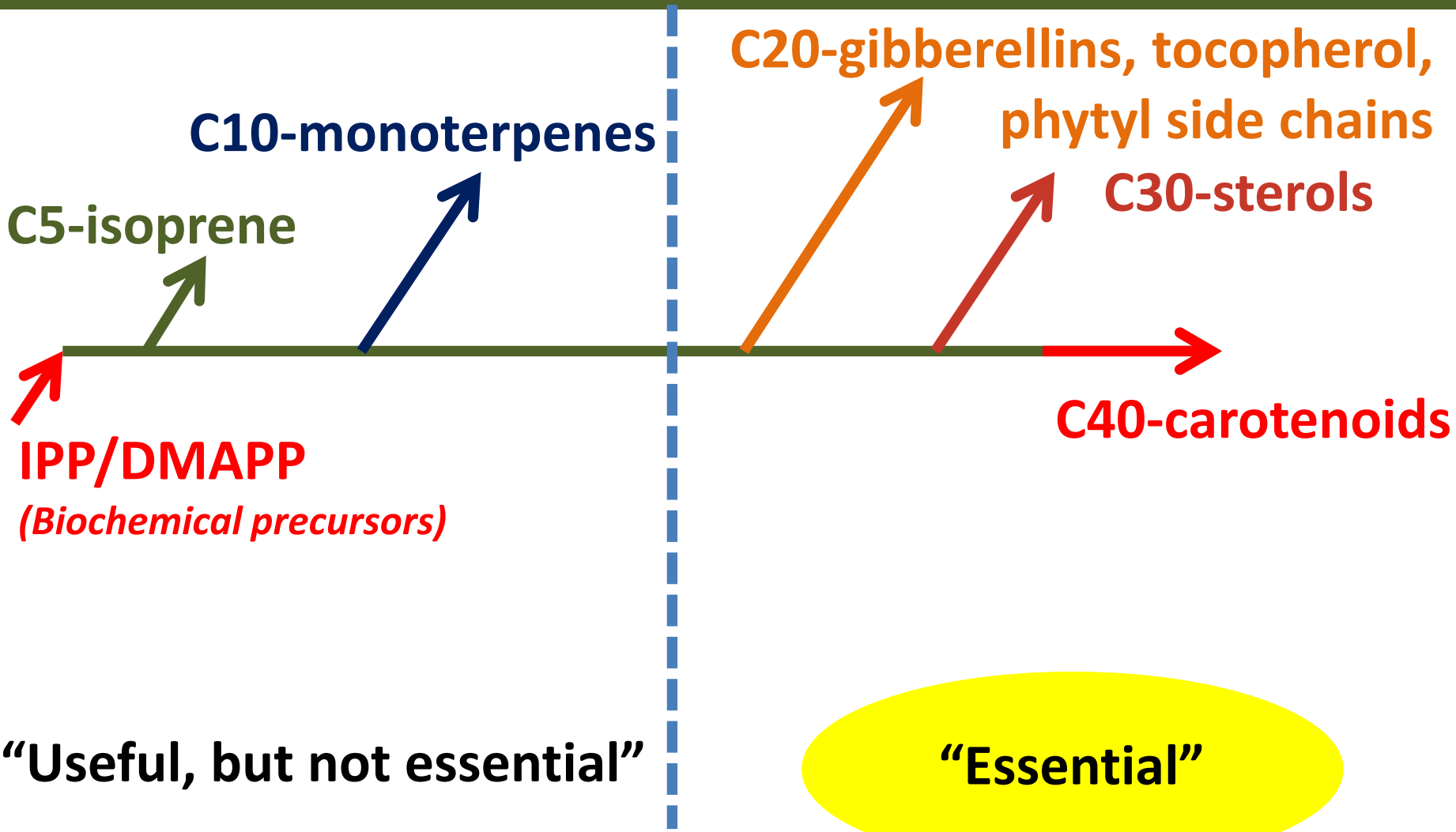
Isoprene emissions: link with pigments



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Owen and Penuelas 2005 TIPS

Research questions (many unknowns)

- Are isoprene emissions and pigment content in *S. capillifolium* affected by N deposition?
- Is there any difference in the response of two pigment types of *S. capillifolium* to N deposition ?
- Is there any relationship between carotenoid content and isoprene emission, as suggested by the "opportunistic hypothesis"?
- Is there a relationship between photosynthesis and carotenoid concentrations/isoprene emissions?

Study site: Whim Bog

Globally peat land occupies ~400x10^6 ha (3% Earth's land surface)
Northern hemisphere ~ 360x10^6 ha
(*cf ~1000 million ha forest in Europe and Russia*)

- **9 miles south of CEH, Edinburgh**
- **Transition between upland blanket bog and lowland raised bog.**
- ***Sphagnum* sp. and *Eriophorum* sp. are the main peat-forming species**
- **Treatment + met data since 2002**

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Study species: *Sphagnum capillifolium*

- Red type: open spaces, tops of tussocks
- Green type: shade provided by heather (*Calluna vulgaris*)

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Whim Bog Nitrogen deposition treatments

Automated treatments, linked to rainfall and windspeed

4 treatment blocks of wet deposition
NH_4Cl
$NaNO_3$

at **0** (control) and 8, 24, **56** kg N ha^{-1} y^{-1} above ambient
(~8 – 11 kg N ha^{-1} y^{-1})

Sampling and laboratory analyses in August 2012

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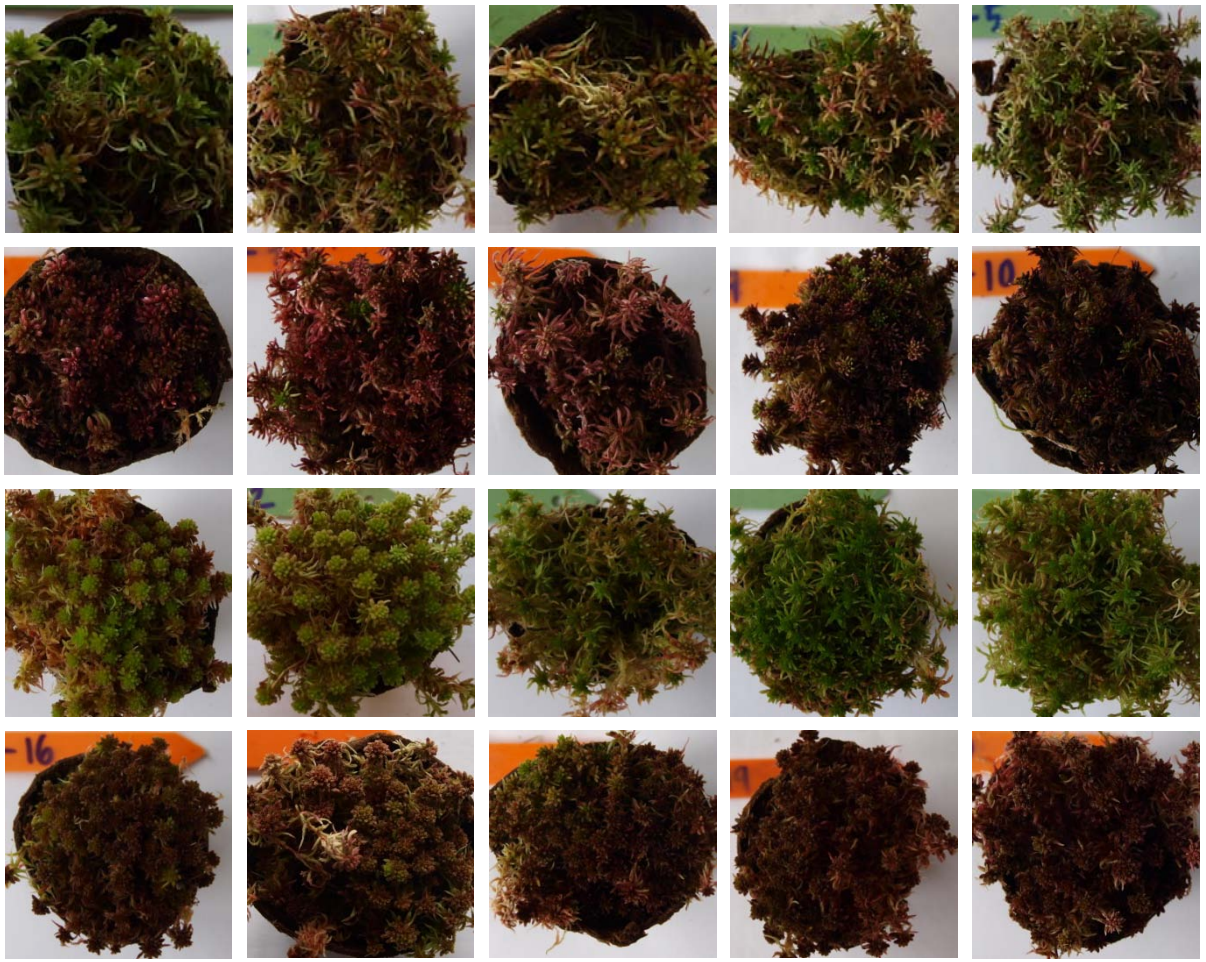
Sphagnum capillifolium samples



High NO3, green

High NO3, red

control, green

control, red

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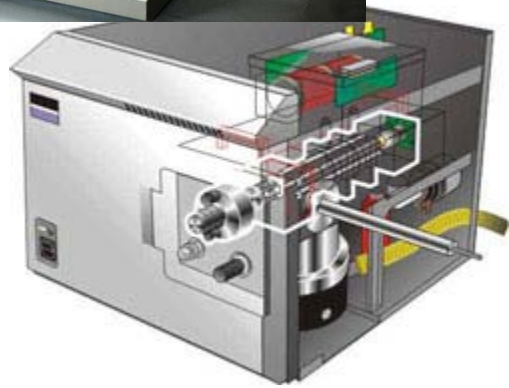
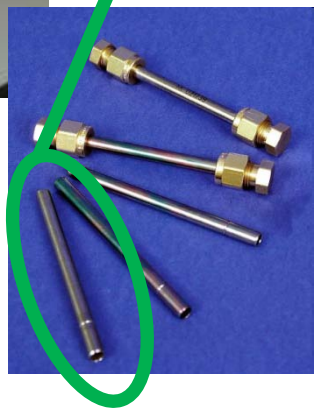
Sampling and measurements from *Sphagnum capillifolium*

- *Fv/Fm* (Handy PEA, Hansatech)
- Photosynthesis (LICOR LI-6400)
- Isoprene emissions (LICOR LI-6400 and GC-MS)
- Pigment content (HPLC, Waters)

Isoprene emissions and photosynthesis *Sphagnum capillifolium*



Analysis by GC-MS with automatic thermal desorption



5 replicates x 2 moss colours x 2 “treatments”

Quantitative
dynamic system, environmental control

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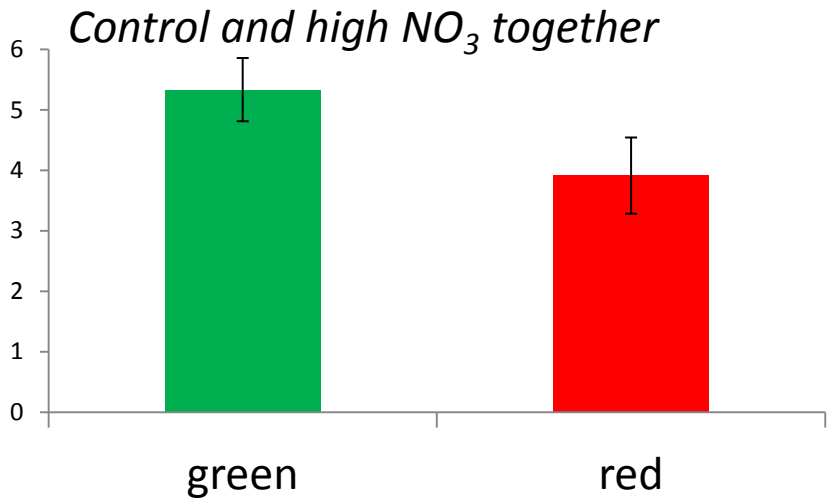
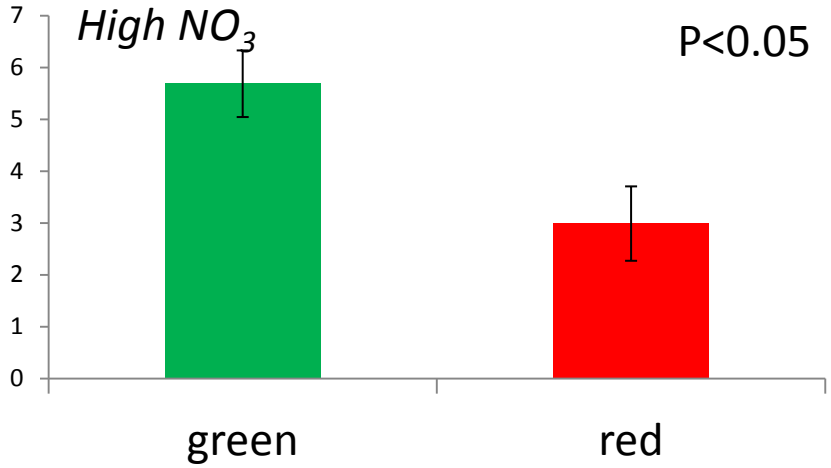
Experimental set-up of LICOR and Photograph by Emily Taylor

Sphagnum capillifolium – photosynthesis rates in red and green types

Rate of photosynthesis (µmol CO_2 kg^{-1} s^{-1})





Control alone: no significant difference between green and red types

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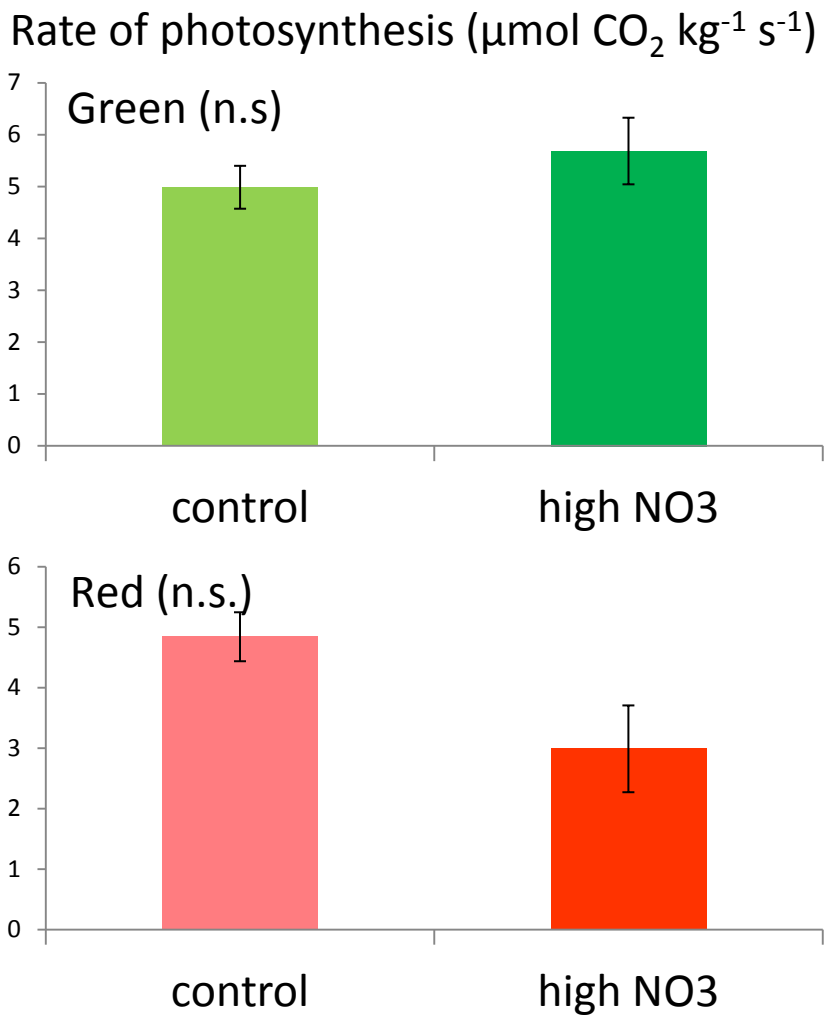
Sphagnum capillifolium – effect of high NO3 on photosynthesis rates

Red and Green together:
no significant difference between control and high NO3



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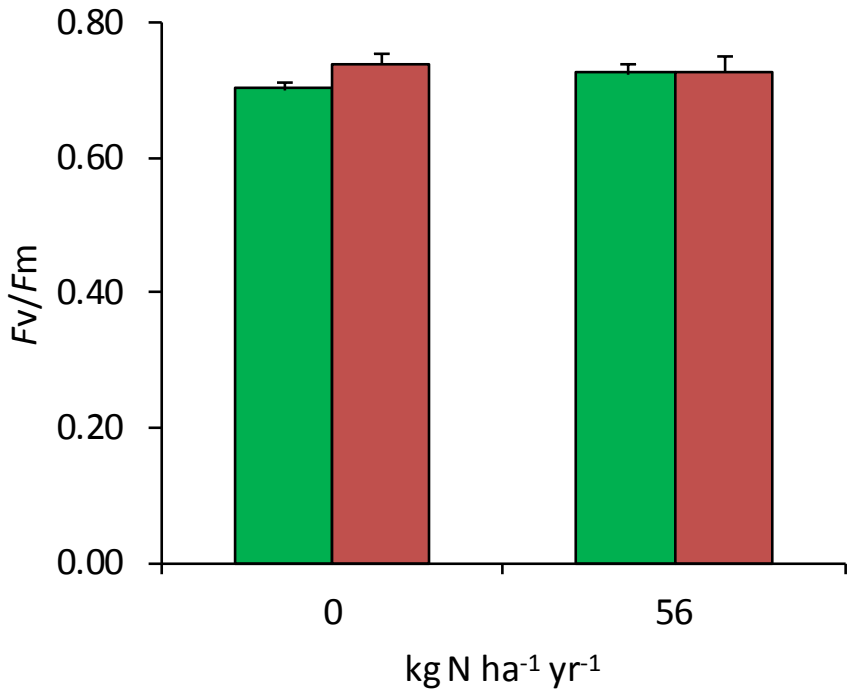
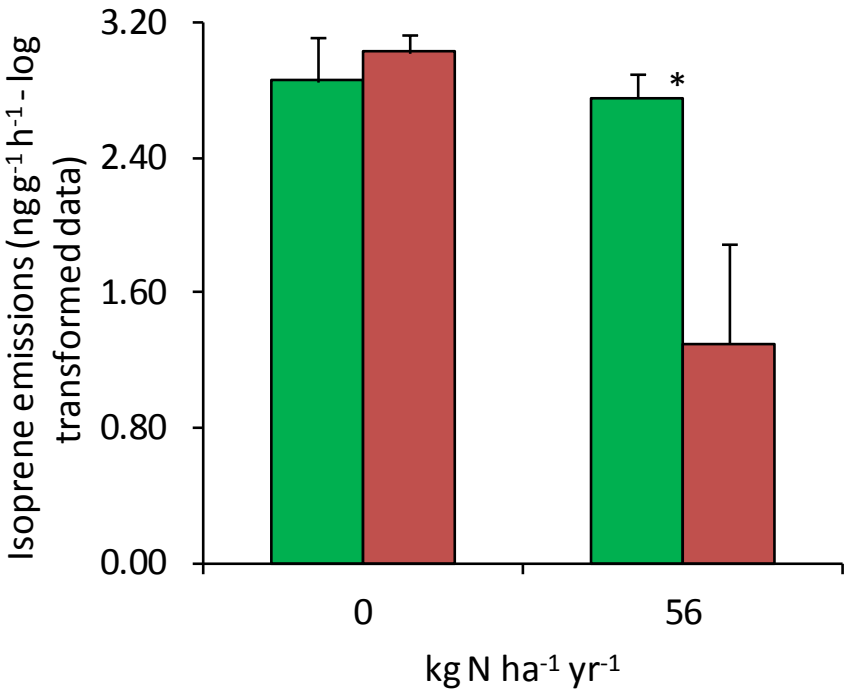
Sphagnum capillifolium – Fv/Fm and isoprene





	F v*F* m			Isoprene emissions		
	df	*F*	*P*	df	*F*	*P*
Nitrogen	1,16	0.10	0.75	1,16	9.09	<**0.01**
Colour	1,16	1.53	0.23	1,16	4.48	**0.05**
Nitrogen x colour	1,16	1.29	0.27	1,16	7.52	**0.02**

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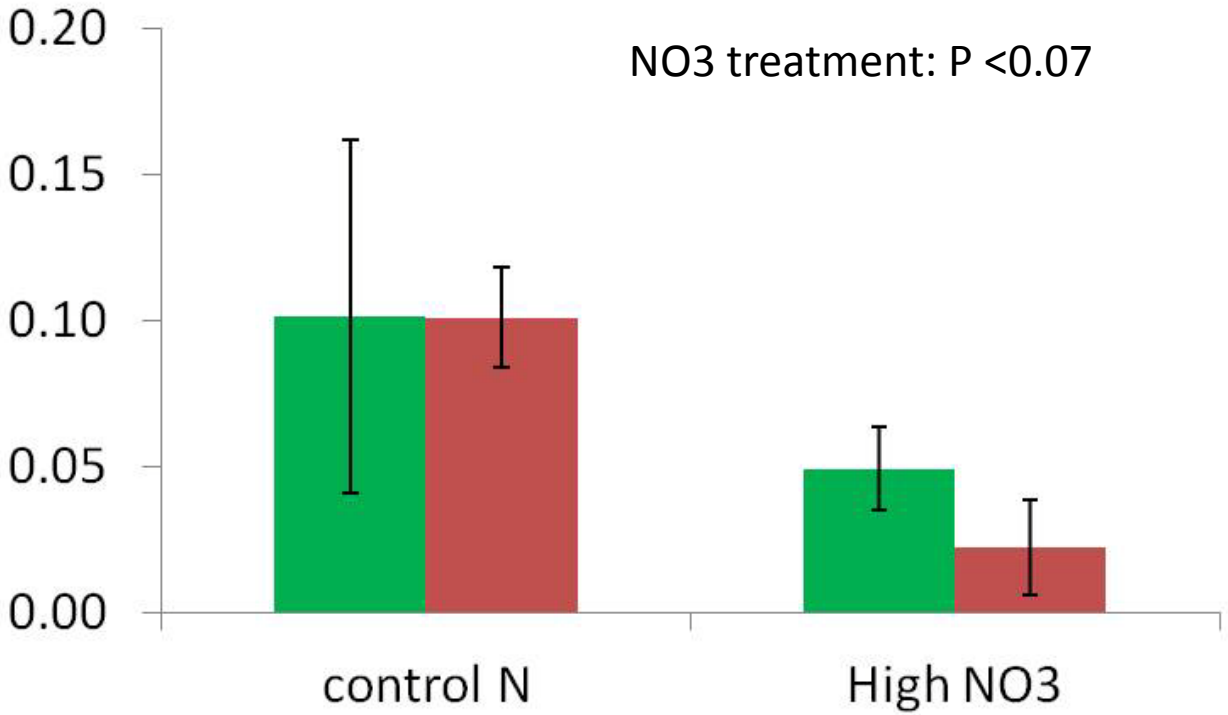
Sphagnum capillifolium – isoprene emissions as a percent of fixed photosynthetic carbon

Isoprene as %fixed C
(max ~0.34%)



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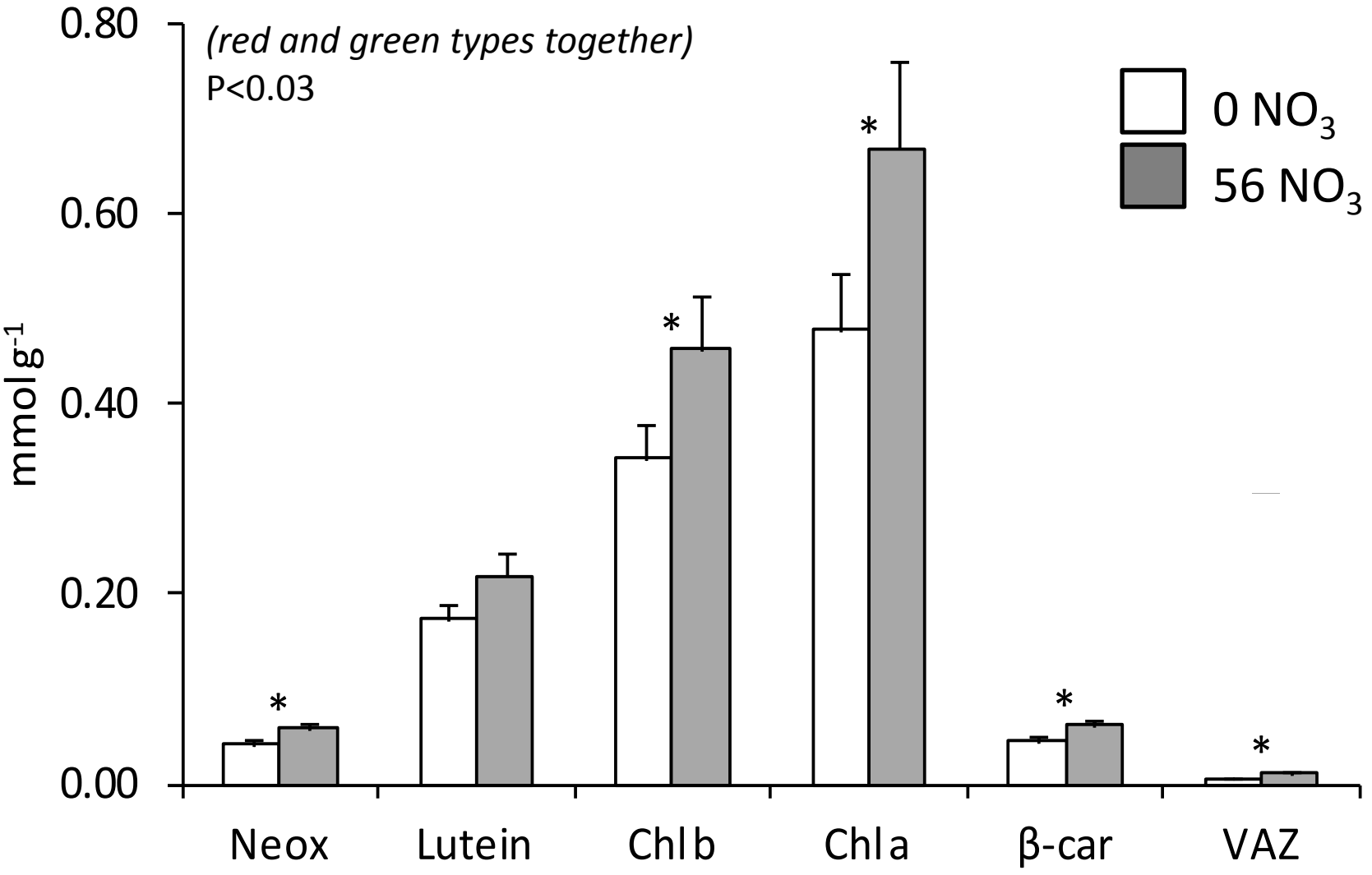
Sphagnum capillifolium – pigment content



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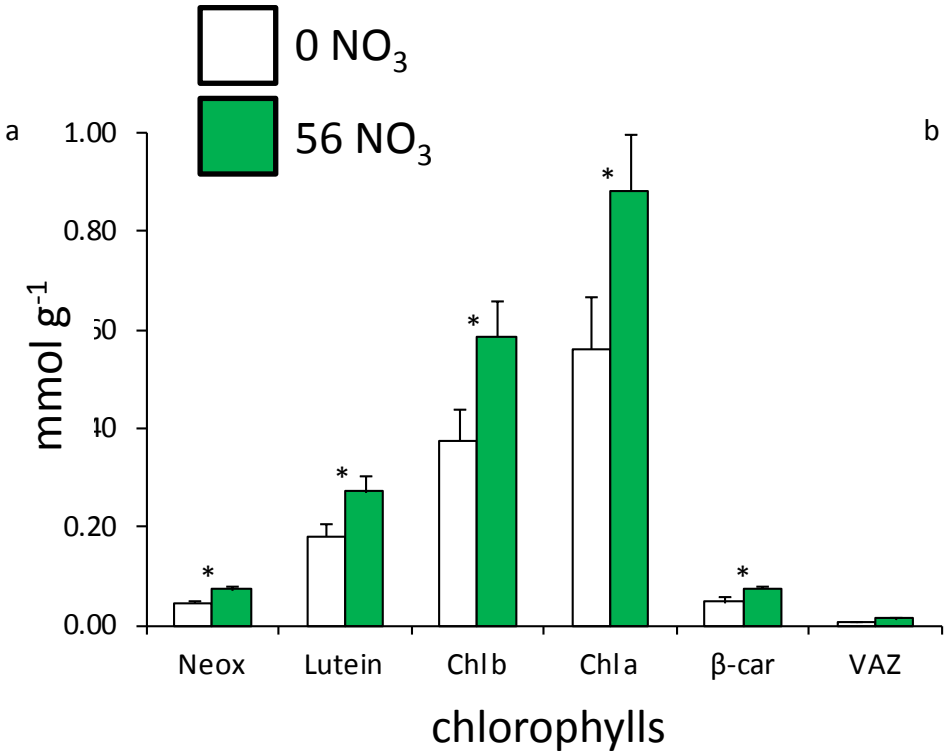
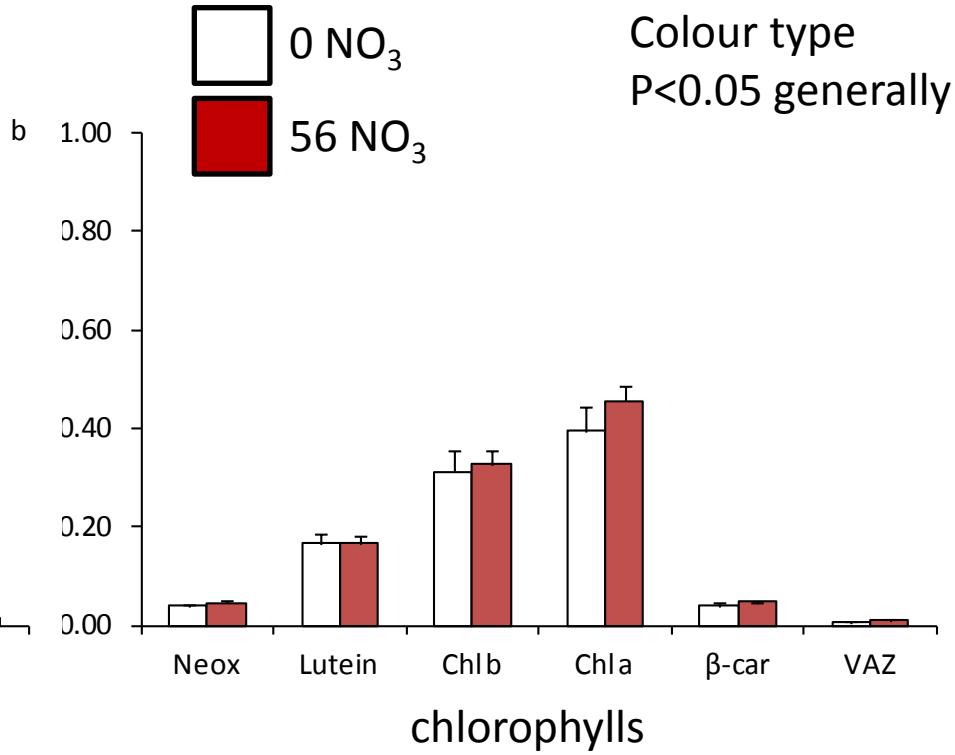
Sphagnum capillifolium – pigment content





Colour type
P<0.05 generally

	Neoxanthin			Lutein			Chlorophyll *b*			Chlorophyll *a*			β-carotene			*VAZ*		
	df	*F*	*P*	df	*F*	*P*	df	*F*	*P*	df	*F*	*P*	df	*F*	*P*	df	*F*	*P*
Nitrogen	1,16	7.20	**0.02**	1,16	4.18	0.06	1,16	5.36	**0.03**	1,16	6.48	**0.02**	1,16	7.57	**0.01**	1,16	5.53	**0.03**
Colour	1,16	6.54	**0.02**	1,16	6.97	**0.02**	1,16	10.84	**<0.01**	1,16	15.71	**<0.01**	1,16	8.17	**0.01**	1,16	1.17	0.30
Nitrogen x colour	1,16	2.56	0.13	1,16	3.86	0.07	1,16	3.98	0.06	1,16	3.03	0.10	1,16	2.78	0.12	1,16	0.34	0.57

	Chlorophyll *a*/*b*			Neox/Chl *a*+*b*			Lutein/Chl *a*+*b*			β-carot/Chl *a*+*b*			*VAZ*/Chl *a*+*b*		
	df	*F*	*P*	df	*F*	*P*	df	*F*	*P*	df	*F*	*P*	df	*F*	*P*
Nitrogen	1,16	3.94	0.07	1,16	0.53	0.48	1,16	4.56	**0.05**	1,16	0.58	0.46	1,16	2.16	0.16
Colour	1,16	20.75	**<0.01**	1,16	8.43	**0.01**	1,16	18.02	**<0.01**	1,16	2.48	0.13	1,16	2.10	0.17
Nitrogen x colour	1,16	2.33	0.15	1,16	0.24	0.63	1,16	0.29	0.60	1,16	0.15	0.71	1,16	1.23	0.28

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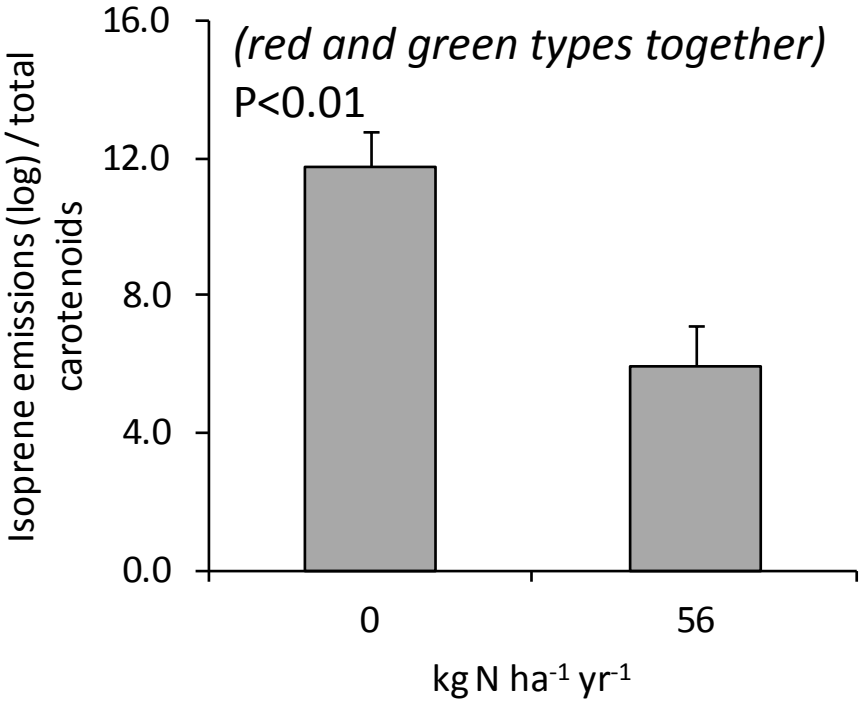
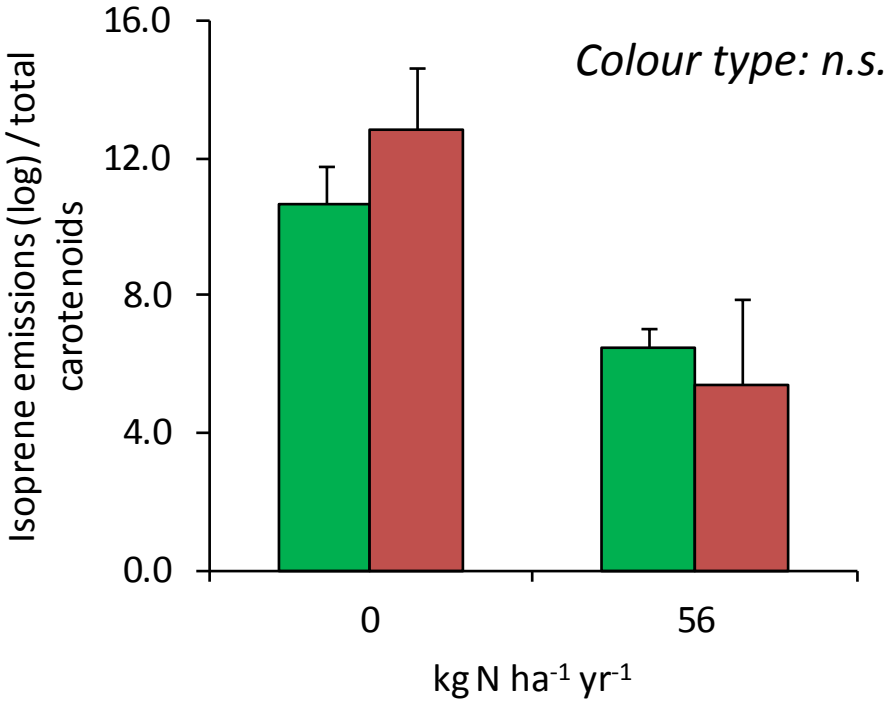
Sphagnum capillifolium – isoprene / ∑carotenoids





	Isoprene emissions			Isopre-log/carot		
	df	*F*	*P*	df	*F*	*P*
Nitrogen	1,16	9.09	**<0.01**	1,16	15.08	**<0.01**
Colour	1,16	4.48	**0.05**	1,16	0.13	0.72
Nitrogen x colour	1,16	7.52	**0.02**	1,16	1.20	0.29

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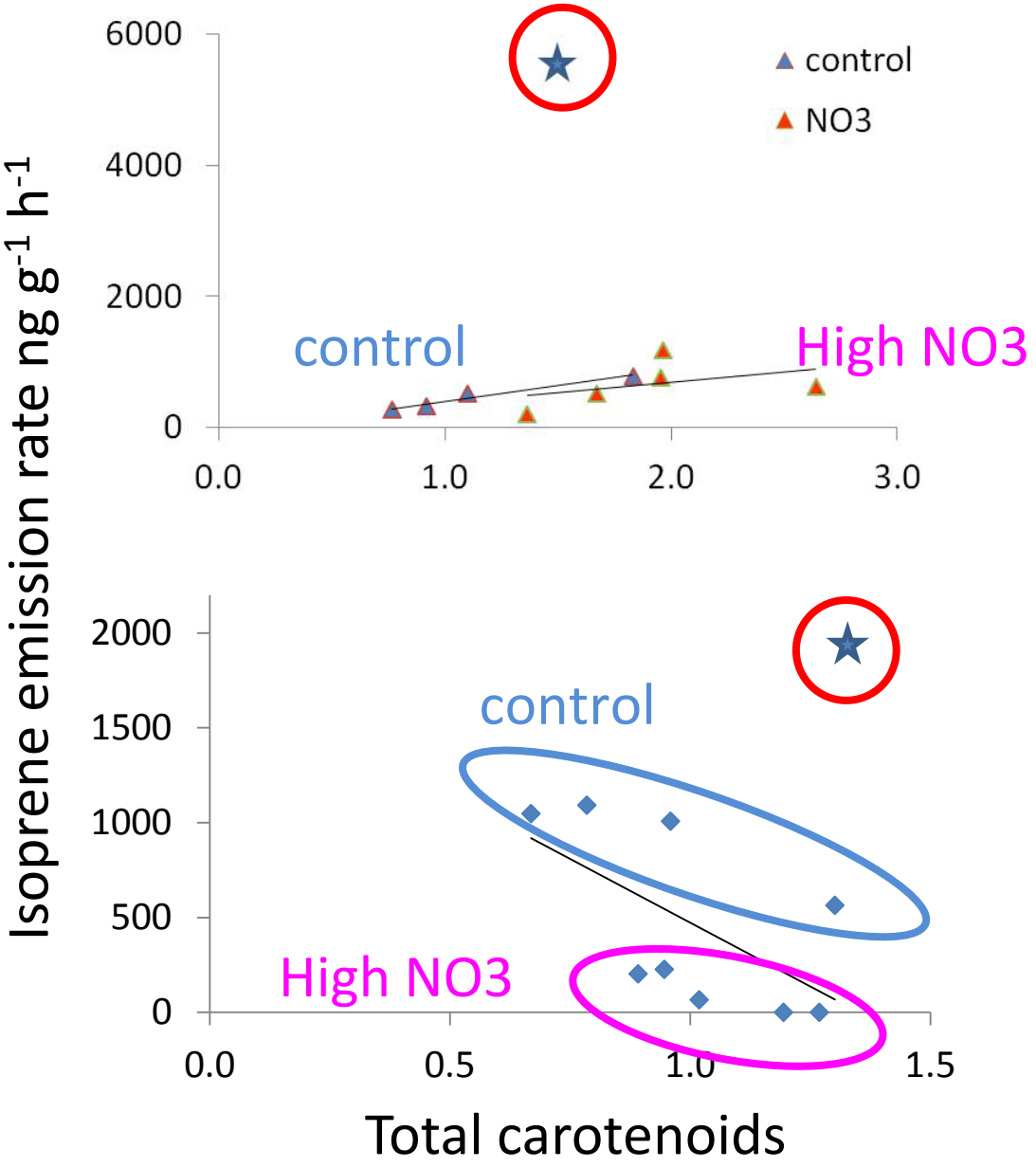
Sphagnum capillifolium – isoprene & total carotenoids

Green *Sphagnum*
P=0.07

Red *Sphagnum*
P=0.07



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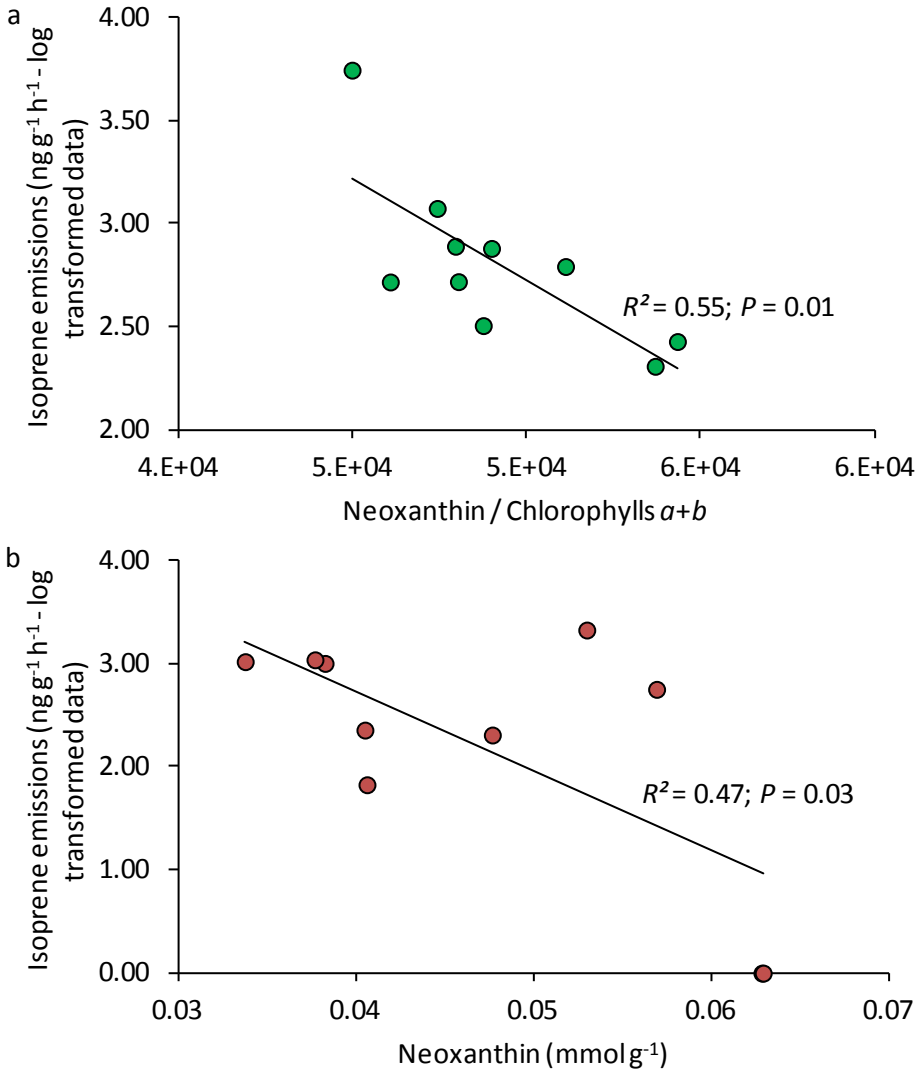
Sphagnum capillifolium – isoprene & carotenoids



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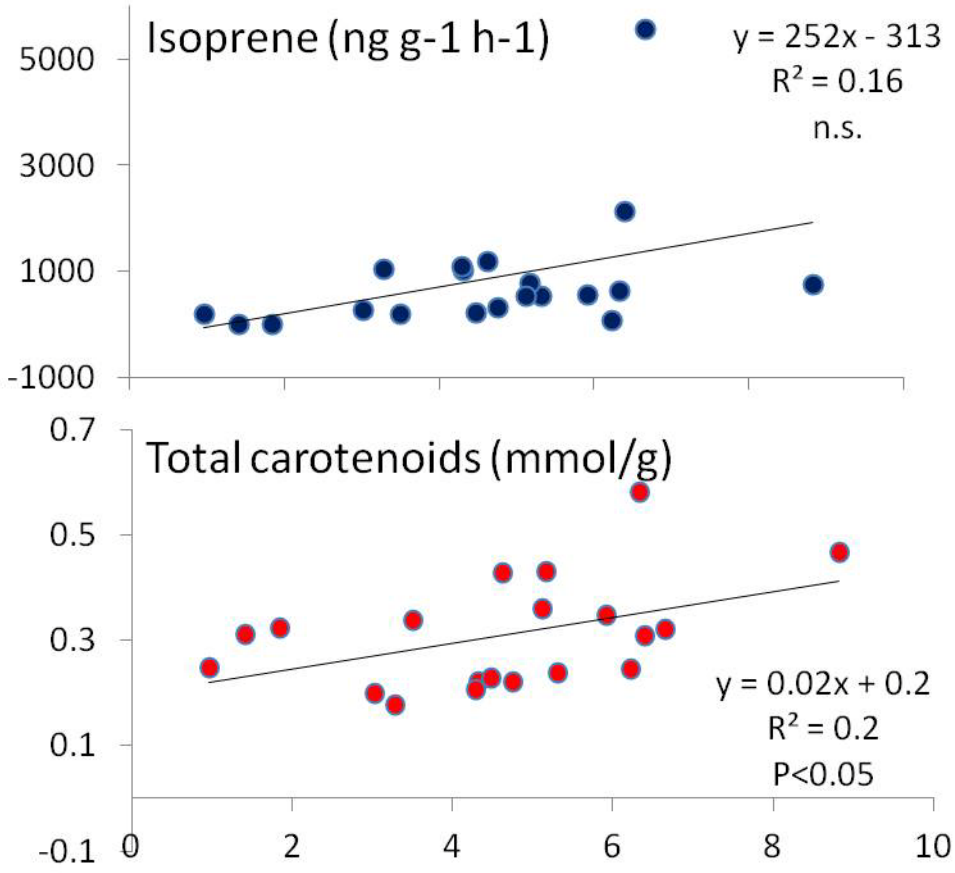
Sphagnum capillifolium – isoprene, carotenoids & photosynthesis



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Summary – colour effects on *S. capillofolium*

Photo-synthesis	Isoprene emissions	Pigments	Isoprene/ Σcarotenoids	Isoprene vs Σcarotenoids
Control: RED=GREEN NO3: RED<GREEN P<0.05	Control : RED=GREEN NO3: RED<GREEN P<0.05	Control: RED<GREEN P<0.05 NO3: RED<GREEN P<0.05	Control: RED=GREEN NO3: RED<GREEN n.s.	Control: RED –ve GREEN +ve, (P=0.07)* NO3: RED -ve GREEN +ve (P=0.07)

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Summary – NO3 effects on *S. capillofolium*

Photo-synthesis	Isoprene emissions	pigments	Isoprene/ Σcarotenoids	Isoprene vs Σcarotenoids
RED: ↓ n.s. GREEN: no effect	RED: ↓ P<0.02 GREEN: no effect	RED: ↑ n.s. GREEN:↑ P<0.05	RED: ↓ P<0.05 GREEN: ↓ P<0.05	RED: –ve curves (P=0.07)* GREEN: +ve curves (P=0.07)*

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Research questions

- Are isoprene emissions and pigment content in *S. capillifolium* affected by N deposition? YES
- Is there any difference in the response of two pigment types of *S. capillifolium* to N deposition ? YES
- Is there any relationship between carotenoid content and isoprene emission, as suggested by the "opportunistic hypothesis"? YES
- Is there a relationship between photosynthesis, carotenoids and isoprene emissions? YES

Acknowledgements

Thank you!
any questions?

(and any job vacancies for Raúl?)

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Summary

- N deposition ↑ pigment content in *S. capillifolium* ($P<0.05$ green; n.s. red)
  - increased demand for carotenoid photoprotection? (successful because Fv/Fm not sig diff)
  - need more chlorophyll to sustain level of p/s?

- N deposition ↓ isoprene emission and photosynthesis in red *S. capillifolium* ($P < 0.05$)
  - reduced substrate availability for all products of isoprenoid pathway (IPP, DMAPP), carotenoids more important so resources diverted there?

- Some degree of support for the "Opportunistic hypothesis" in *S. capillifolium*

Thank you – any questions?

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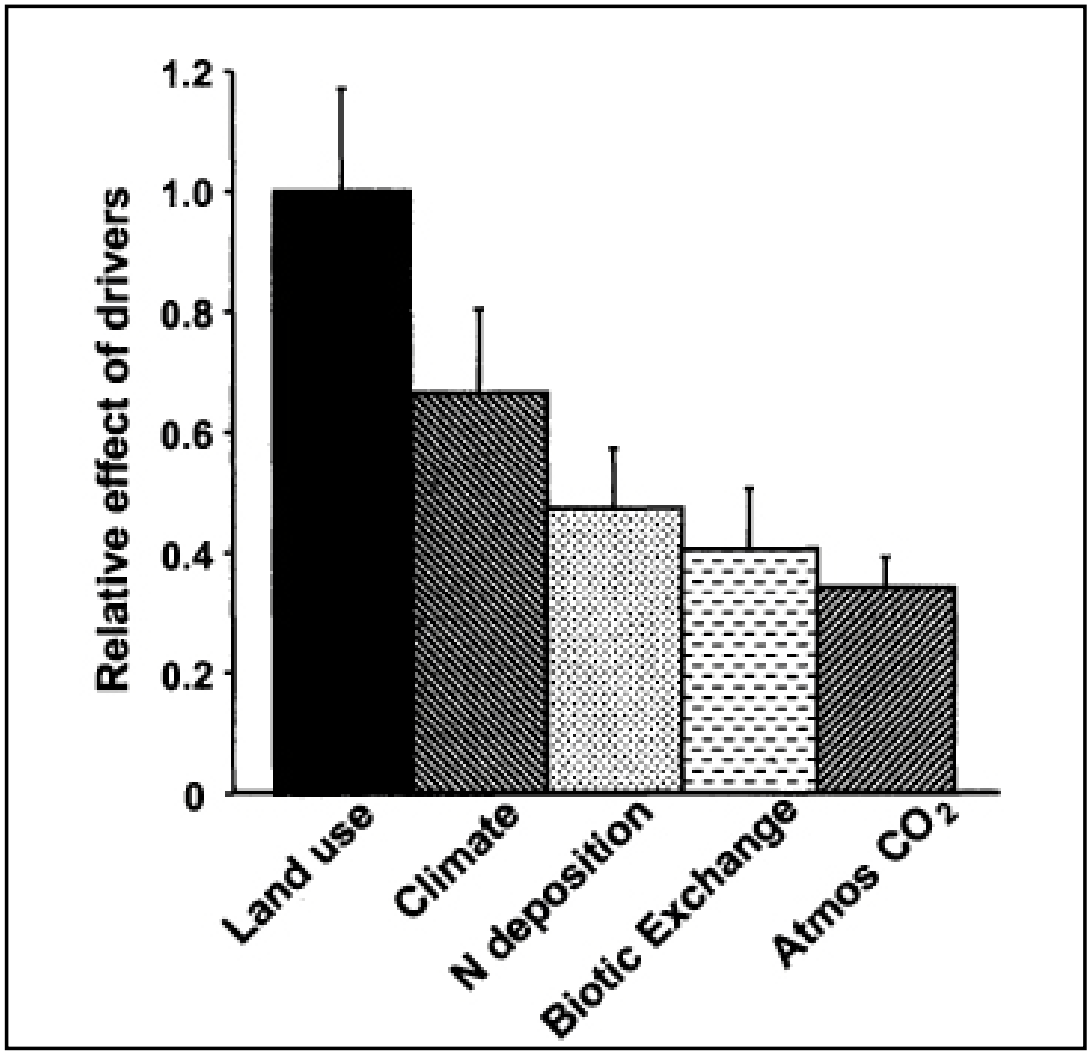
Nitrogen deposition – biodiversity loss



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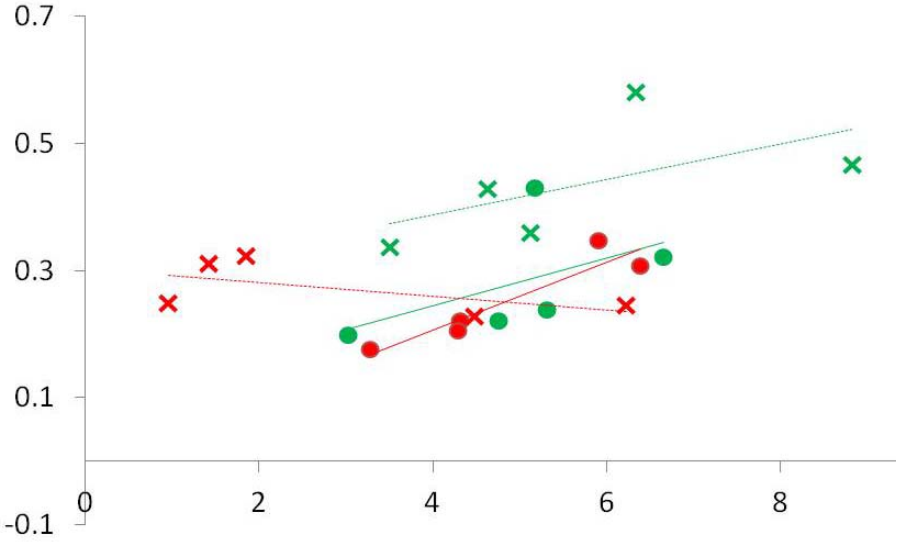
Sala et al., 2000 Science 287: 1770-1774

Sphagnum capillifolium – isoprene, carotenoids & photosynthesis

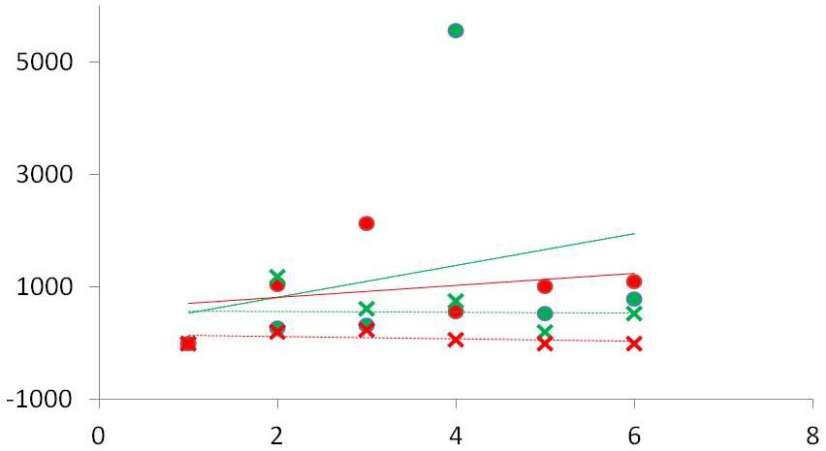
Total carotenoids (mmol/g)



Control (green type)

High NO3 (red type)

Isoprene emissions (ng g-1 h-1)



Photosynthesis rate (umol kg-1 s-1)

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Nitrogen deposition – biodiversity loss

Source	Ecosystem	Isoprene emission rate $\mu g\ m^{-2}\ h^{-1}$	Chamber T °C	Chamber PAR $\mu mol\ m^{-2}\ s^{-1}$
Tiiva et al 2007	Subarctic peatland	71	26	628
Janson et al 1999	Sphagnum fen June	62	15 – 18	cloudy
Janson et al 1999	Sphagnum fen August	459	26	sunny
Holst et al 2010	high latitude wetland site	373	20	1000
Faubert et al 2010	Subarctic peatland growing season mean emission	8		
Tiiva et al 2008	Subarctic heath growing season 1 mean emission	58		
	Subarctic heath growing season 2 mean emission	36		
Ekberg et al 2011	Northern Swedish mire: Average peak growing season wet	120	20	1000
Ekberg et al 2011	Northern Swedish mire: Average peak growing season dry	84	20	1000
THIS STUDY	Ombrotrophic bog, Scotland	0.1- 518	12-14	300 – 2300(?)
Laffineur et al 2011	Mixed forest Europe	3276	30	1000
Owen 1998	Mediterranean forest	~800		
Stewart et al 2003	South Edinburgh “hot spot”	20-80	Cool-hot	Cloudy-sunny

Nitrogen deposition

- annually:

anthropogenic fixed N ~= naturally fixed N (~120 Tg N)

- predicted to increase

- associated with uncontrolled human activities
  (e.g., energy use and food production)

Galloway et al., 2003 BioScience 53: 341-356

IPP/DMAPP – precursors of all isoprenoids

2 isoprenoid biosynthesis pathways:

(1) Mevalonate pathway (cytosol)
begins with 2 molecules of acetyl coenzyme A (acetyl coA)

(2) MEP pathway (chloroplast)
begins with 1 molecule each of pyruvate and glyceraldehyde-3-phosphate (G-3-P)

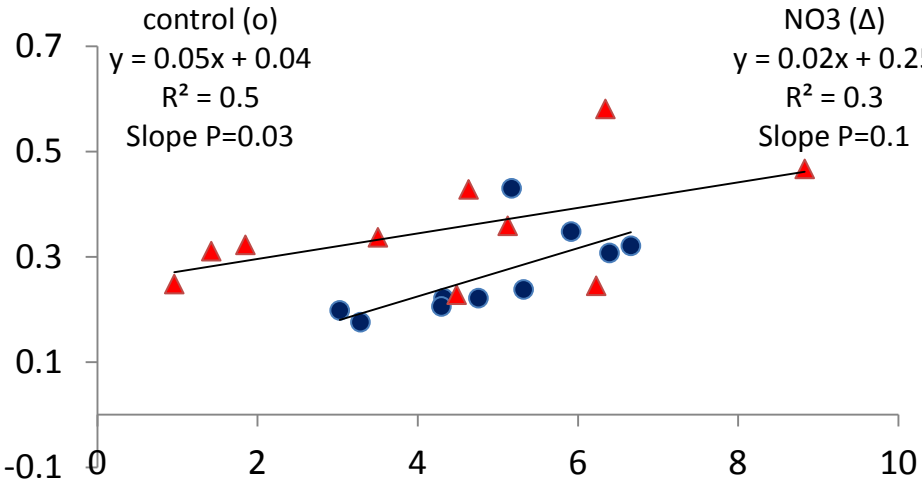
These compounds are derived from products of respiration and photosynthesis biochemistry

Effect of N-deposition and pigmentation on isoprene emissions from *Sphagnum capillifolium* – a laboratory study

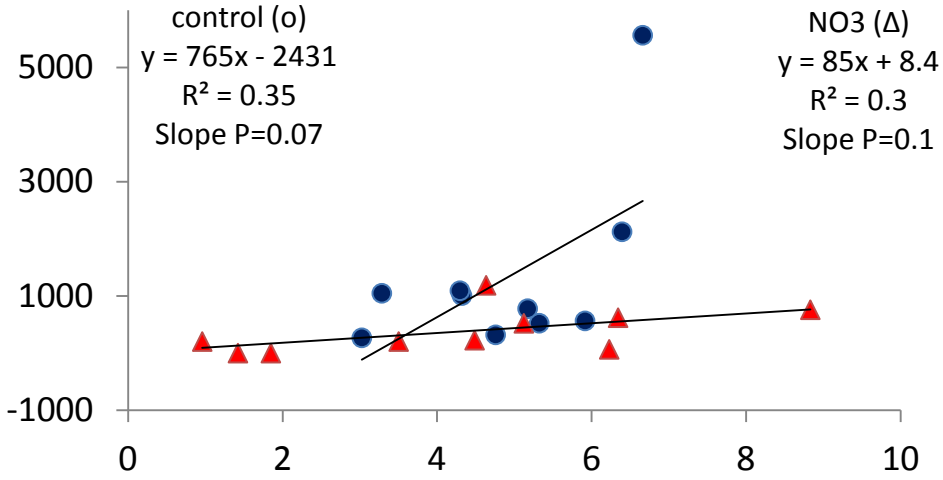
(with Lucy Sheppard and Raul Ochoa-Hueso)

Sphagnum capillifolium – isoprene, carotenoids & photosynthesis

Total carotenoids (mmol/g)



Isoprene emissions ((ng g-1 h-1))



Photosynthesis rate (umol kg-1 s-1)

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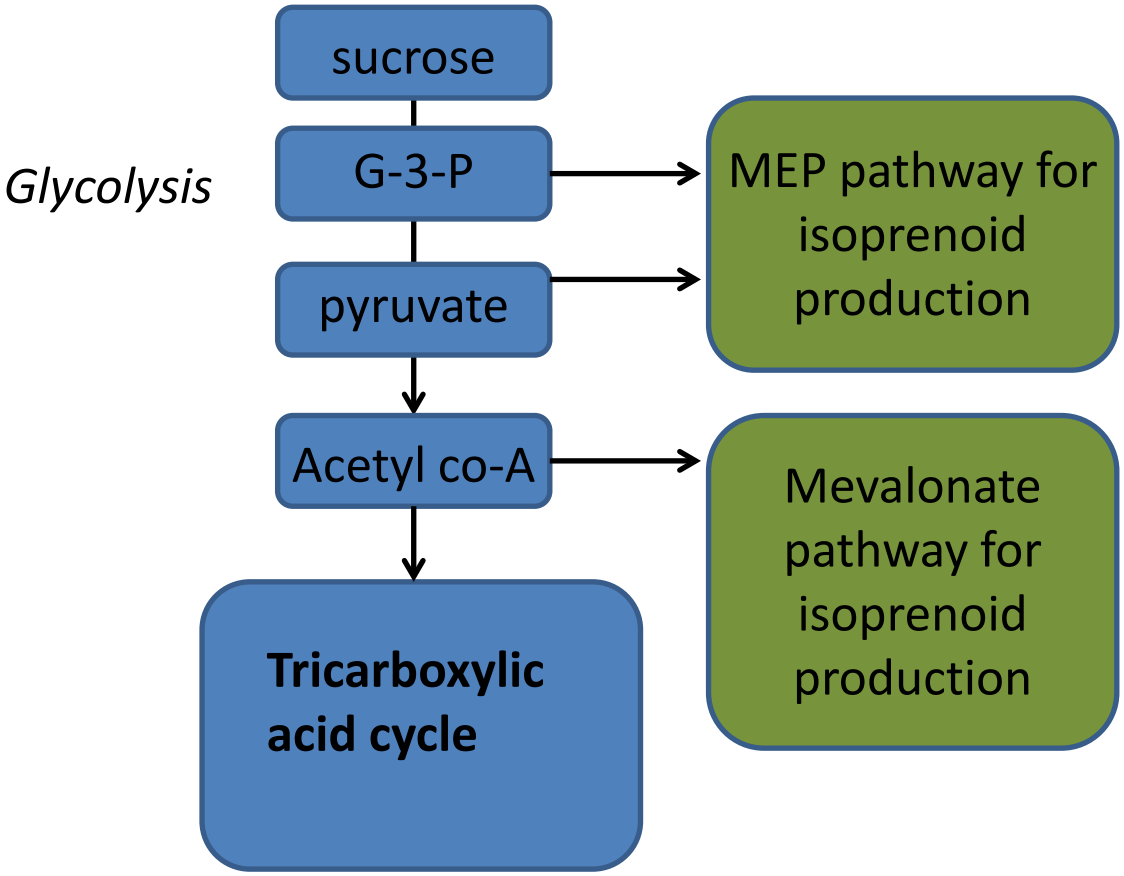
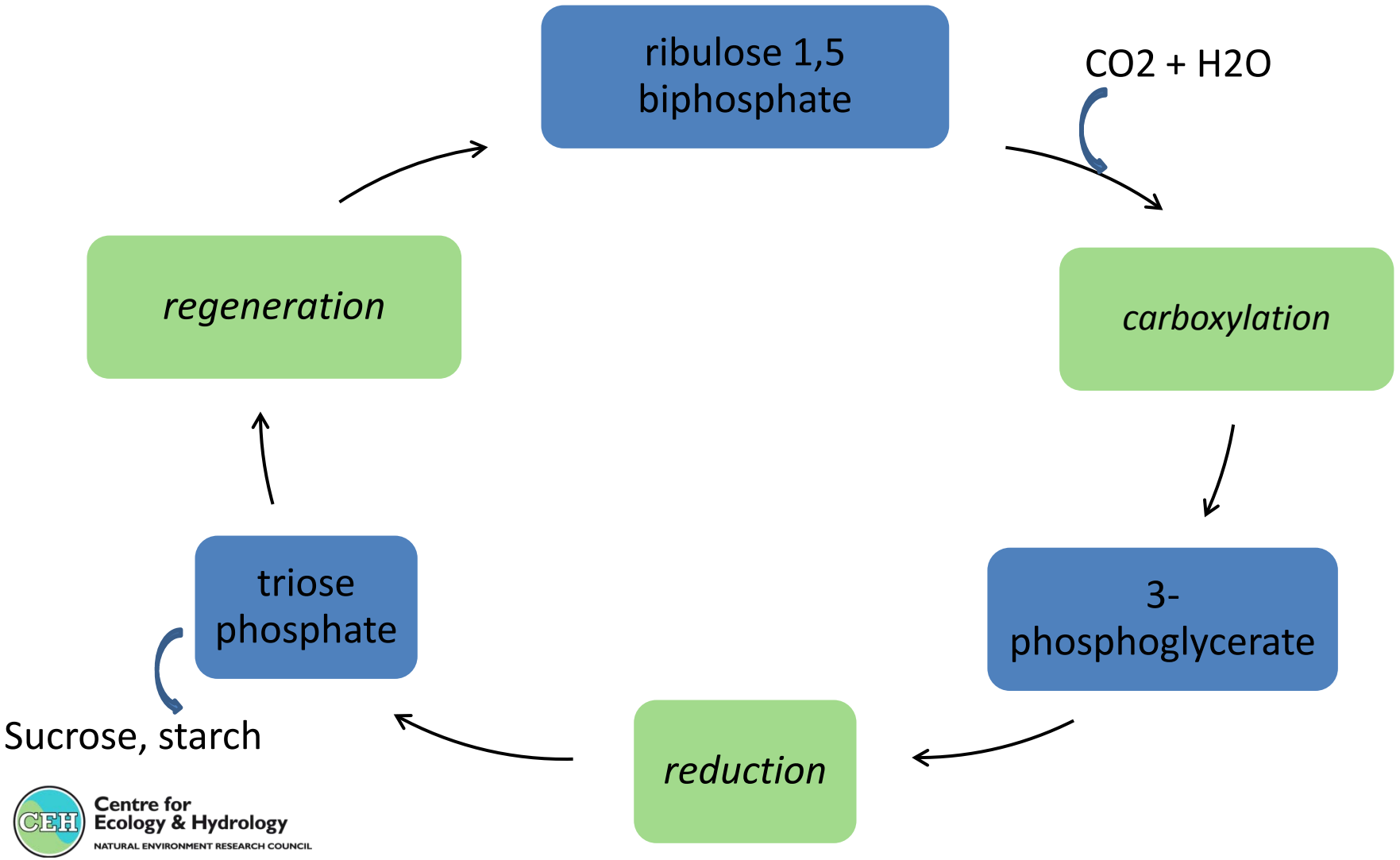
Isoprenoid precursors: link with respiration



Isoprenoid precursors: link with photosynthesis:



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Controls on isoprene emissions

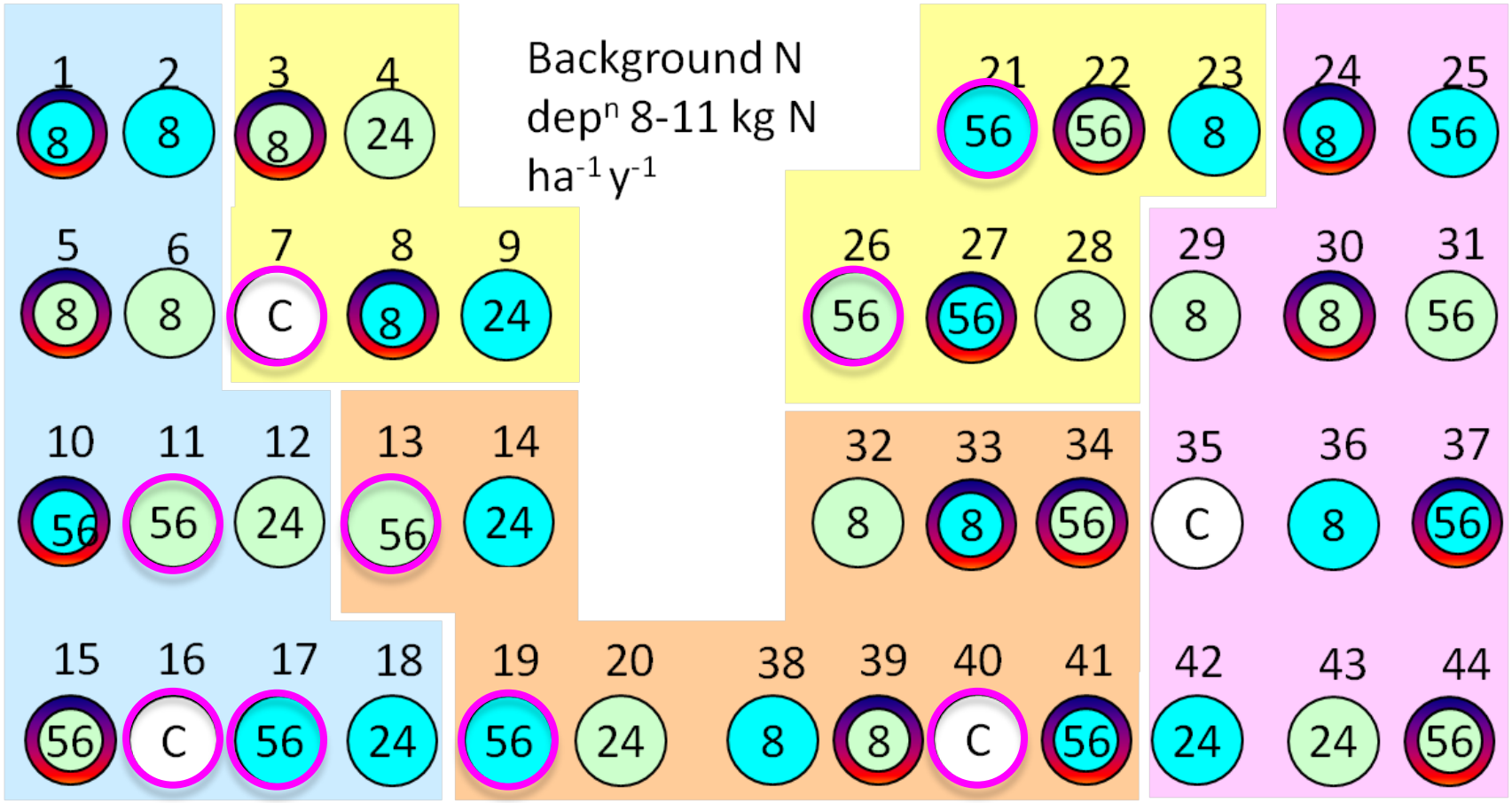
(Many)
Temperature

PAR (photosynthetic active radiation)

Plant species-specific

Important to know if/how N deposition affects emissions

Whim Bog Treatments automated, linked to rainfall and windspeed



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Lucy Sheppard

What does isoprene do?

- it confers protection to the producing plant against oxidative/thermal stress

- monoterpenes can attract pollinators/repel herbivores

- it can be important in O_3 and aerosol chemistry

- it can account for up to 5% photosynthetically fixed C

-Large literature in general *(~1800 "isoprene and (emissions or flux)" titles)*
-Paucity of work in peatlands *(~33 relevant to peatland/bog)*

Existing work on isoprene from peatlands

Web of Science search	# hits
Topic : (isoprene AND (emission* or flux*))	1649
(isoprene AND (peat* or bog*))	22 relevant[+]
Title : (isoprene or VOC* or bVOC* or volatile) and (peat* or bog* or mire* or wetland*)	12

[+]*Tiva et al (Finland)*
Faubert et al (Finland)
Ekberg et al (Sweden)
Backstrand et al (Sweden)

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