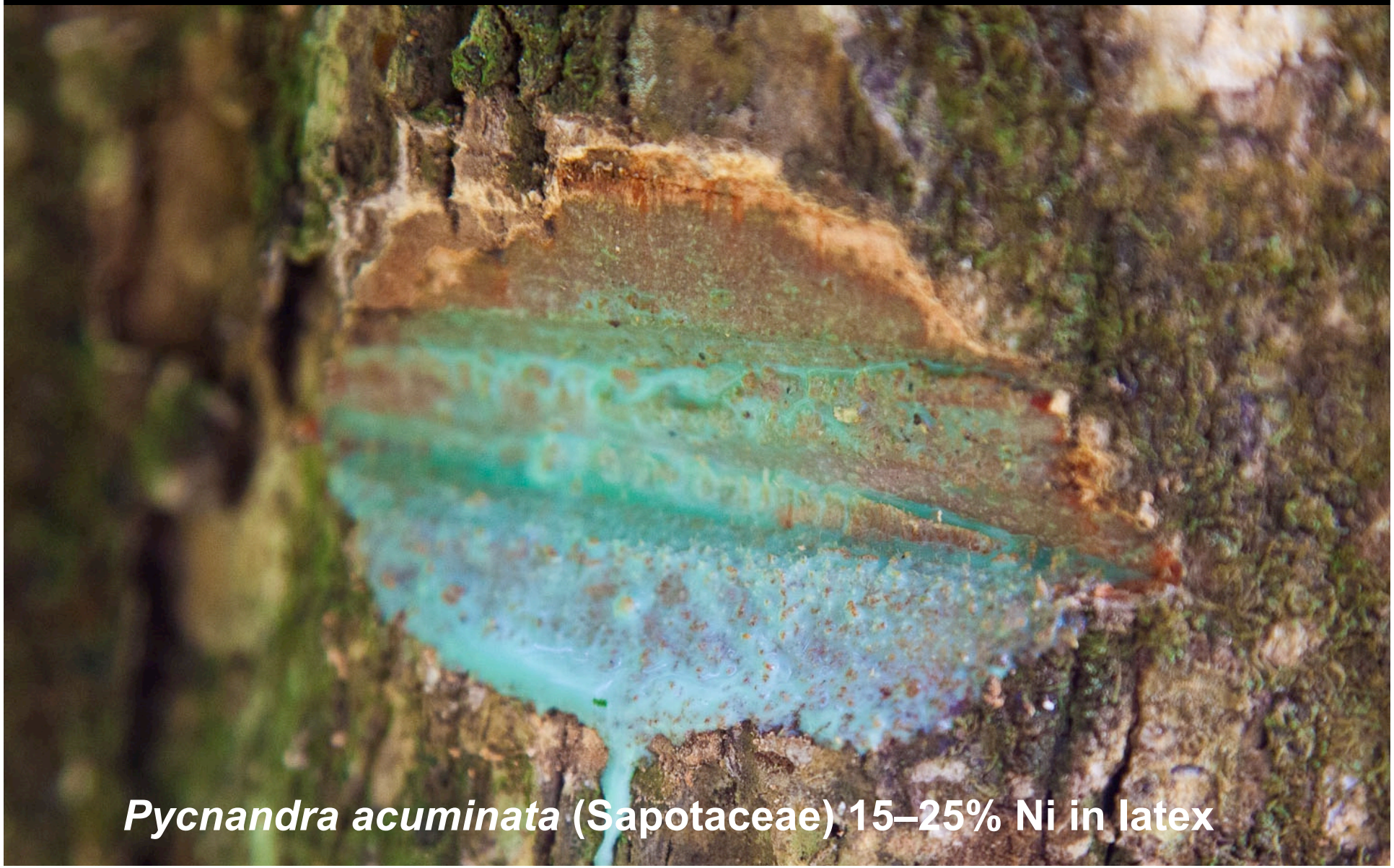
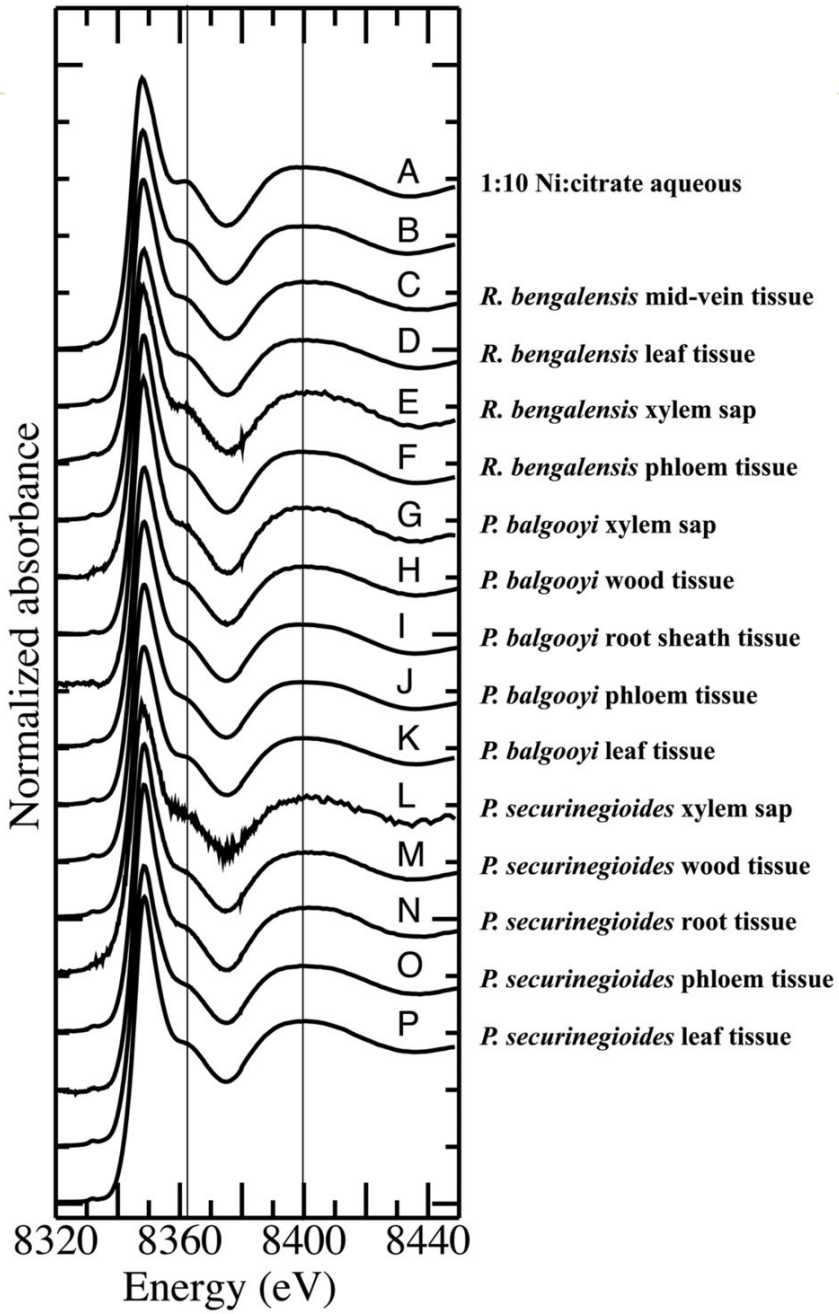
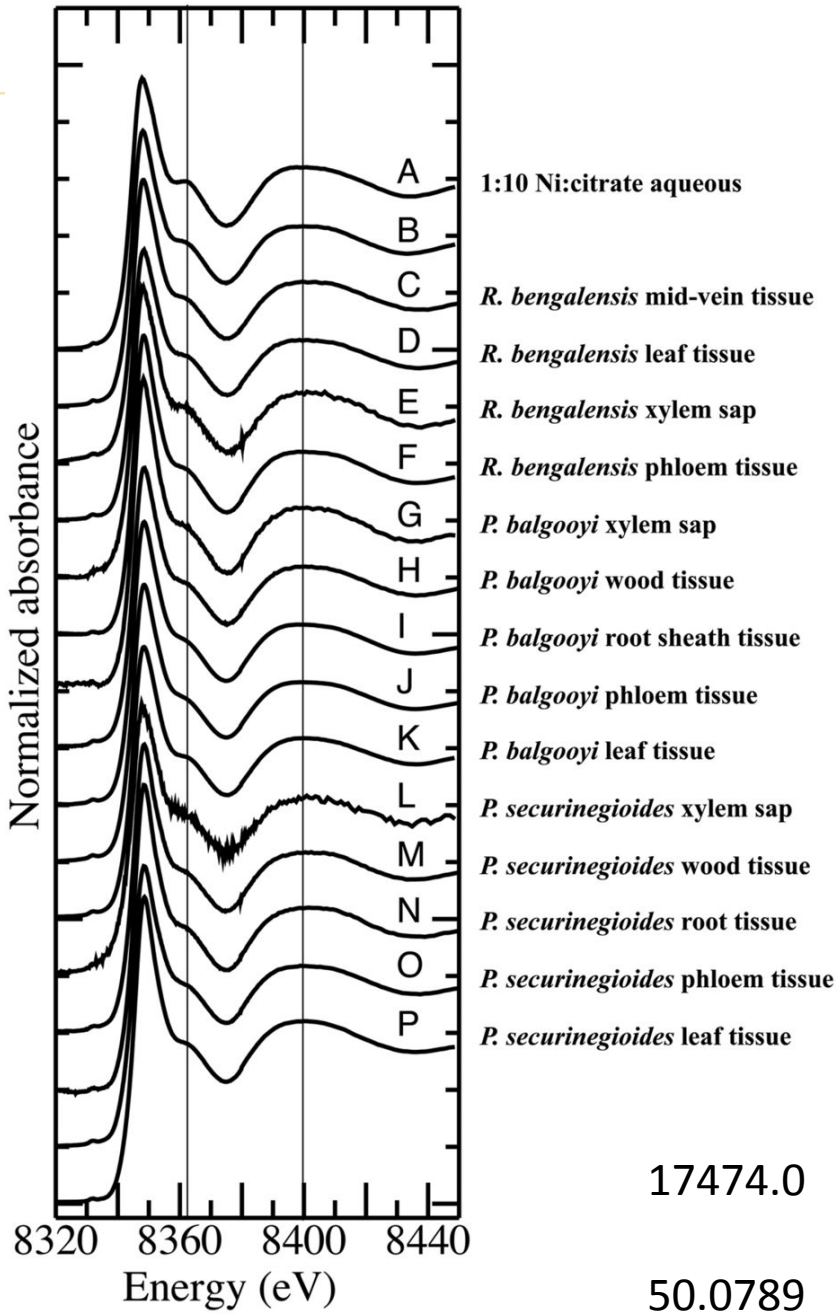
XRF and XAS of Ni hyperaccumulating plants

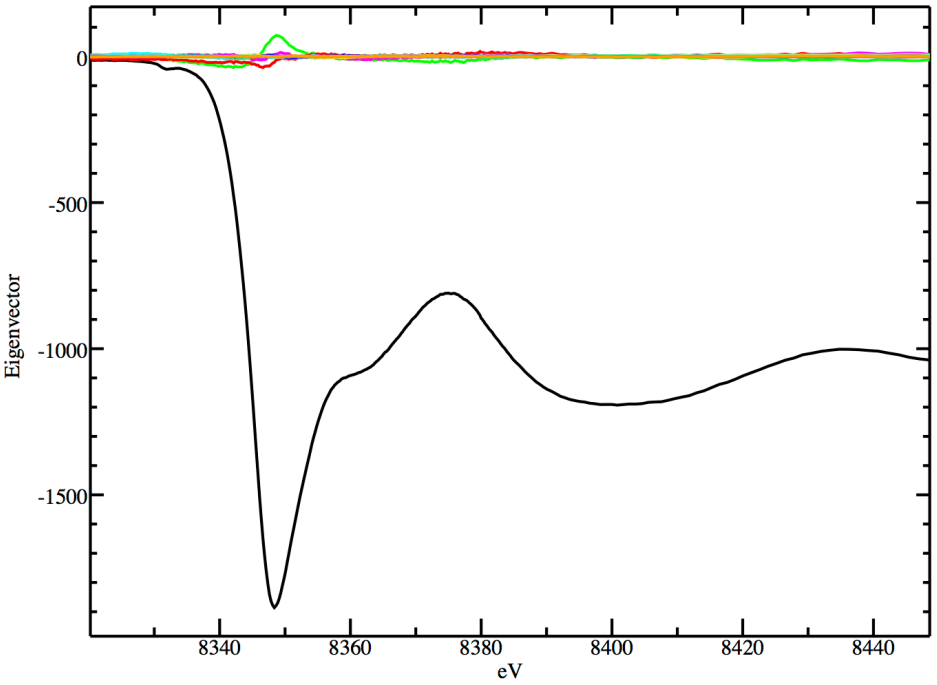
Hugh H. Harris – The University of Adelaide



Cryogenic collection in the field

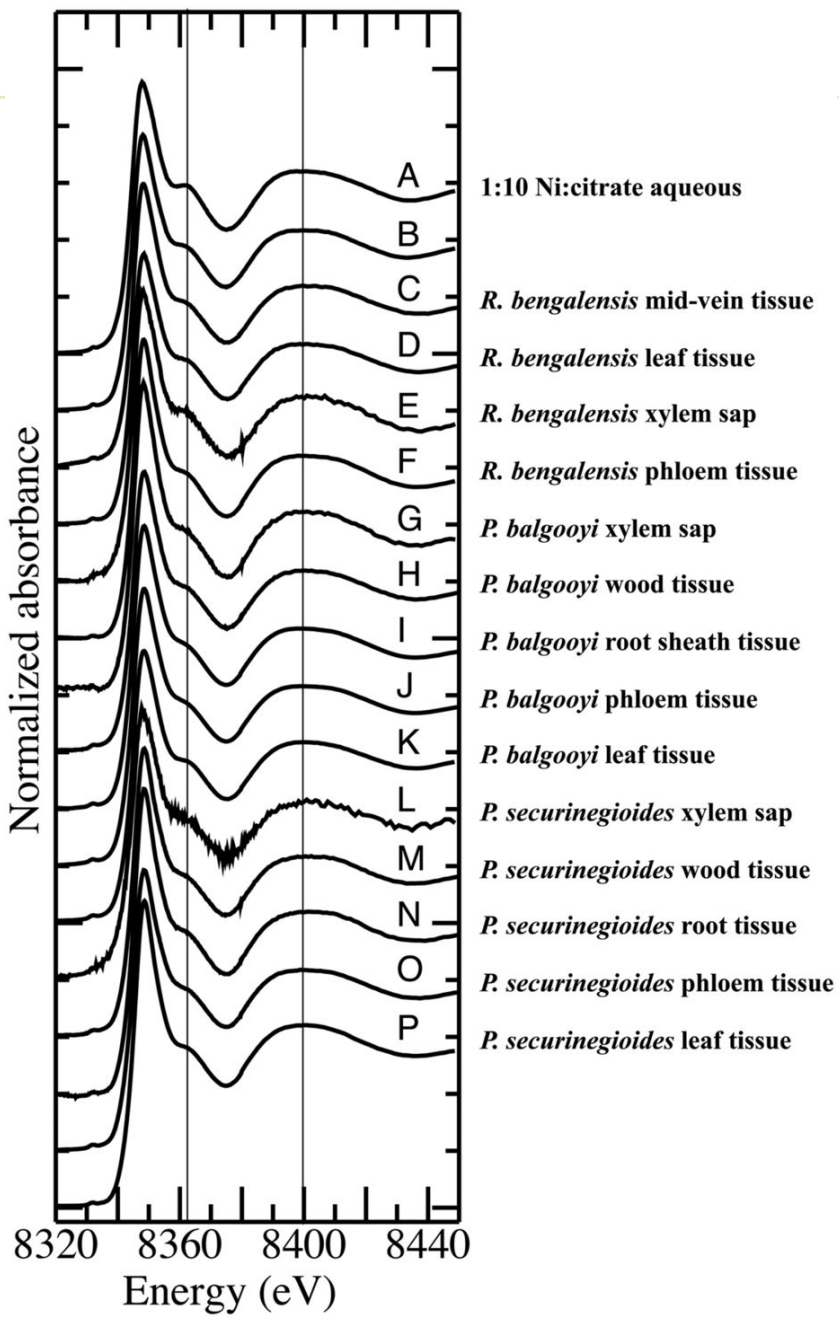

Normalized absorbance
8320
8360
8400
8440
Energy (eV)
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
1:10 Ni:citrate aqueous
R. bengalensis mid-vein tissue
R. bengalensis leaf tissue
R. bengalensis xylem sap
R. bengalensis phloem tissue
P. balgooyi xylem sap
P. balgooyi wood tissue
P. balgooyi root sheath tissue
P. balgooyi phloem tissue
P. balgooyi leaf tissue
P. securinegioides xylem sap
P. securinegioides wood tissue
P. securinegioides root tissue
P. securinegioides phloem tissue
P. securinegioides leaf tissue





PCA Eigenvalues

17474.0	347.606	213.705	95.0008	73.3990
50.0789	43.7364	31.5538	27.5475	21.6209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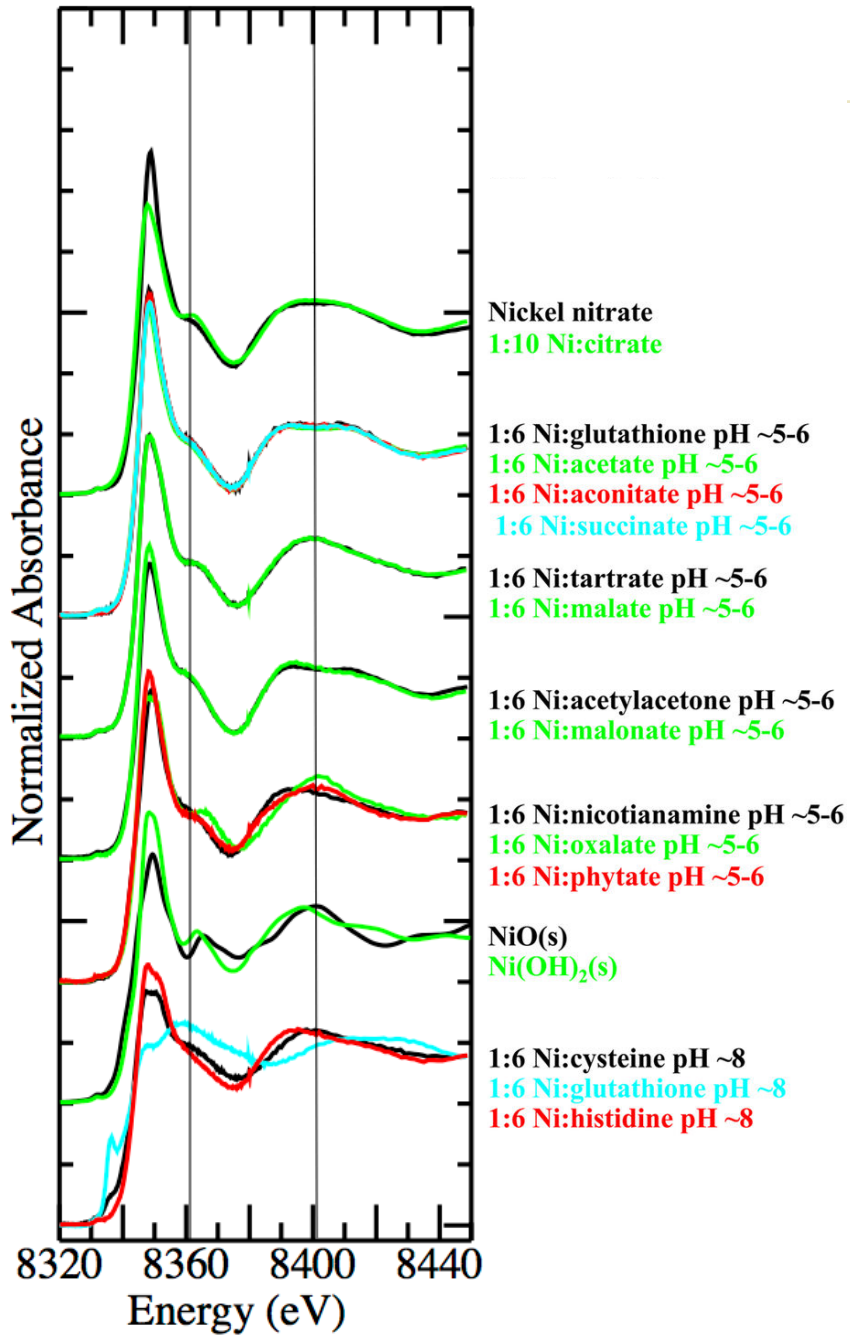
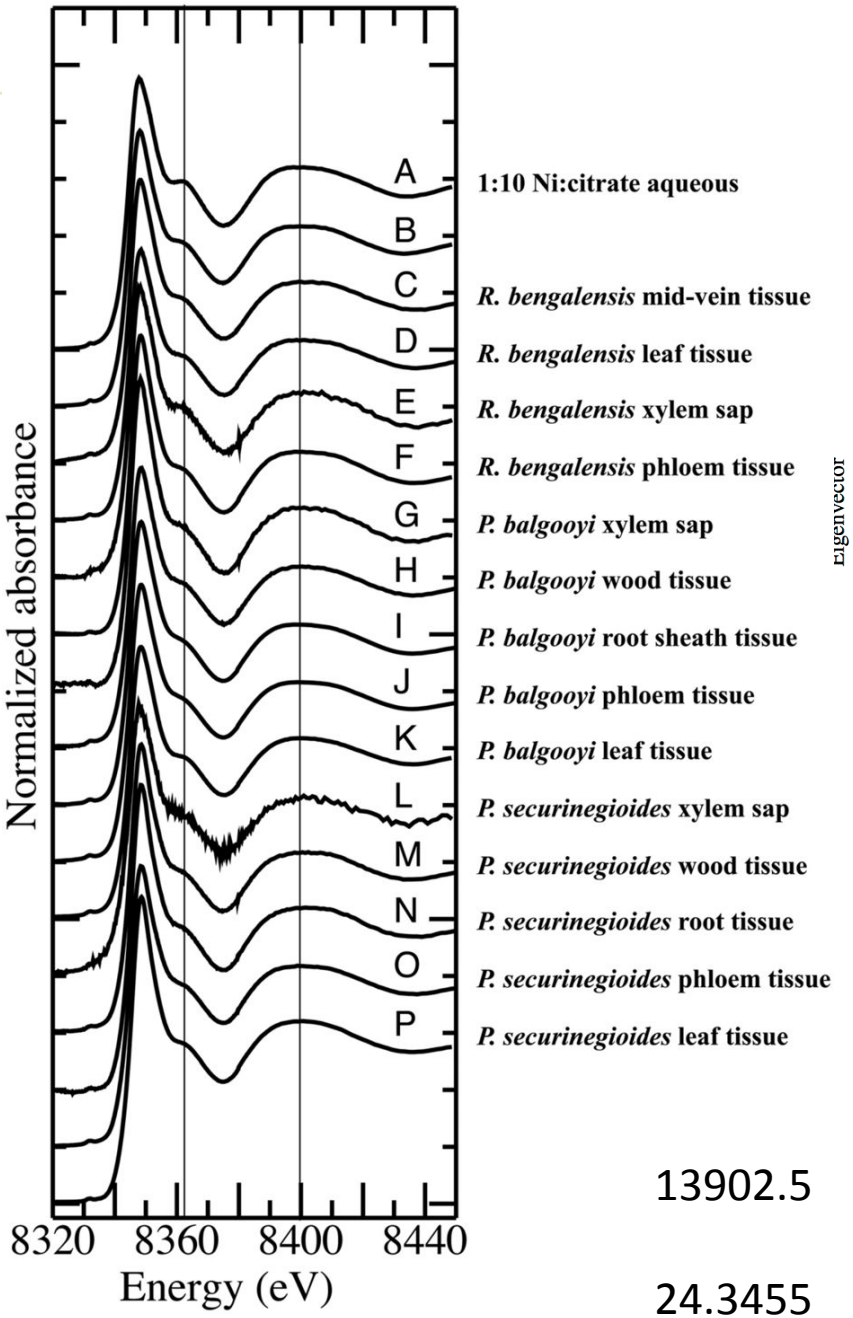
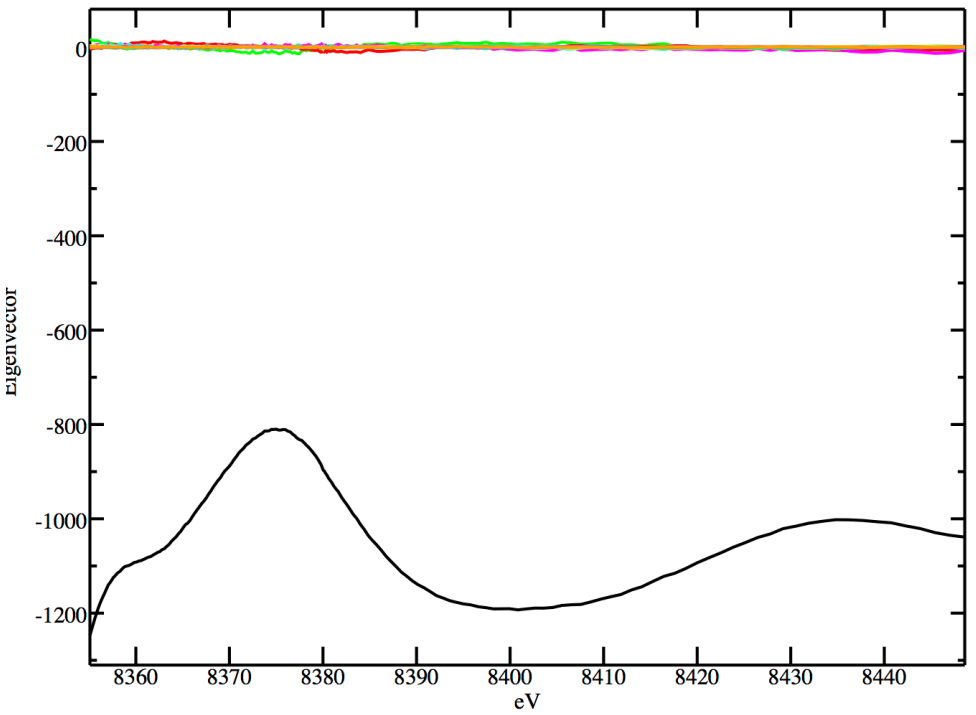
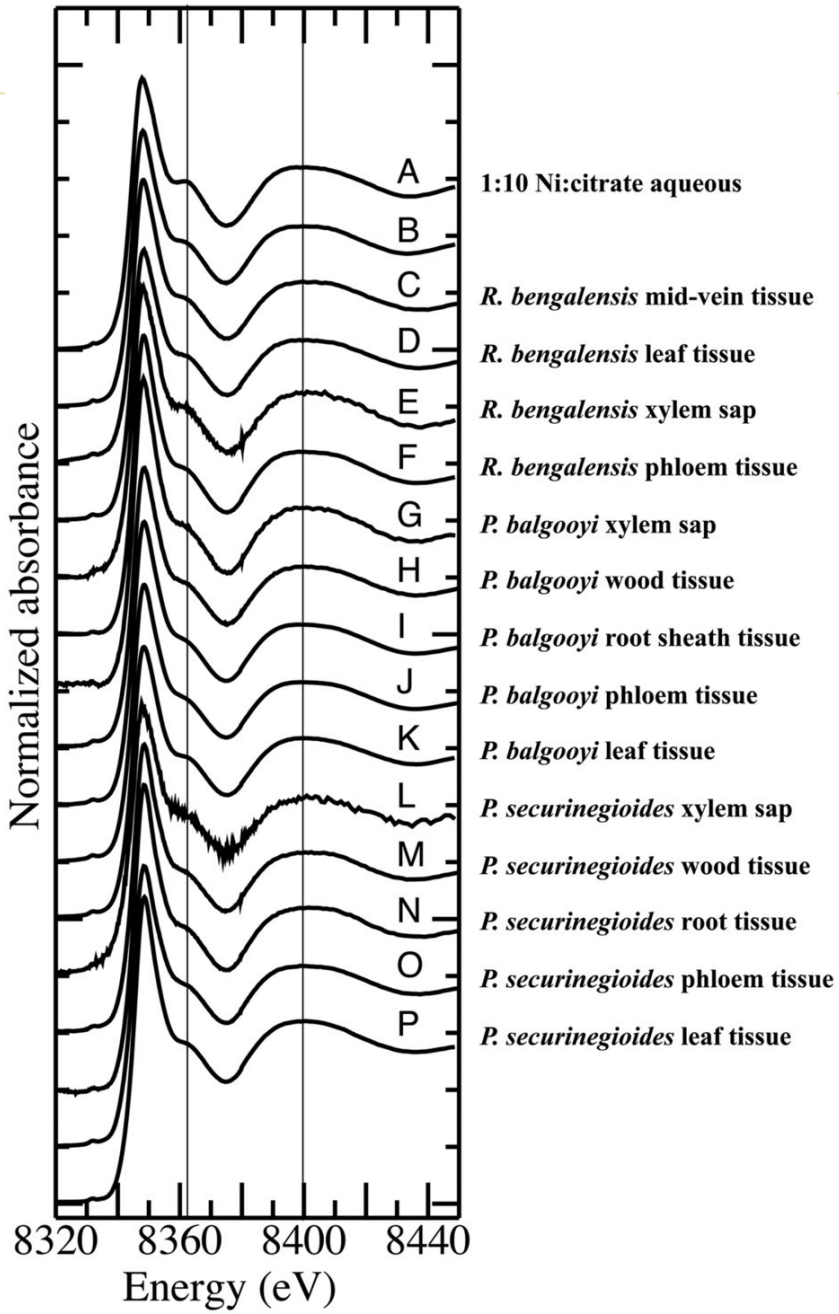

Normalized Absorbance
8320
8360
8400
8440
Energy (eV)
Nickel nitrate
1:10 Ni:citrate
1:6 Ni:glutathione pH ~5-6
1:6 Ni:acetate pH ~5-6
1:6 Ni:aconitate pH ~5-6
1:6 Ni:succinate pH ~5-6
1:6 Ni:tartrate pH ~5-6
1:6 Ni:malate pH ~5-6
1:6 Ni:acetylacetone pH ~5-6
1:6 Ni:malonate pH ~5-6
1:6 Ni:nicotianamine pH ~5-6
1:6 Ni:oxalate pH ~5-6
1:6 Ni:phytate pH ~5-6
NiO(s)
Ni(OH)2(s)
1:6 Ni:cysteine pH ~8
1:6 Ni:glutathione pH ~8
1:6 Ni:histidine pH ~8





PCA Eigenvalues

13902.5	94.4778	83.5268	53.3202	31.2594
24.3455	19.3124	13.6464	2.40461	9.40211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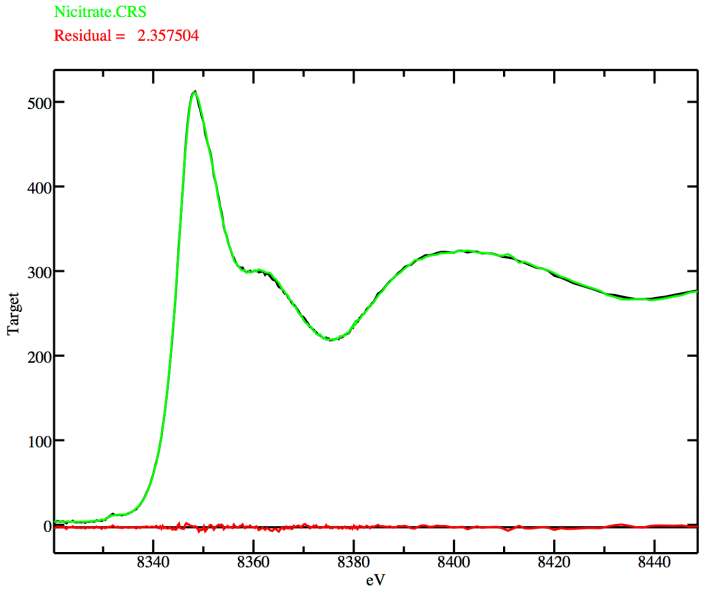
Nicitrate.CRS
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Target
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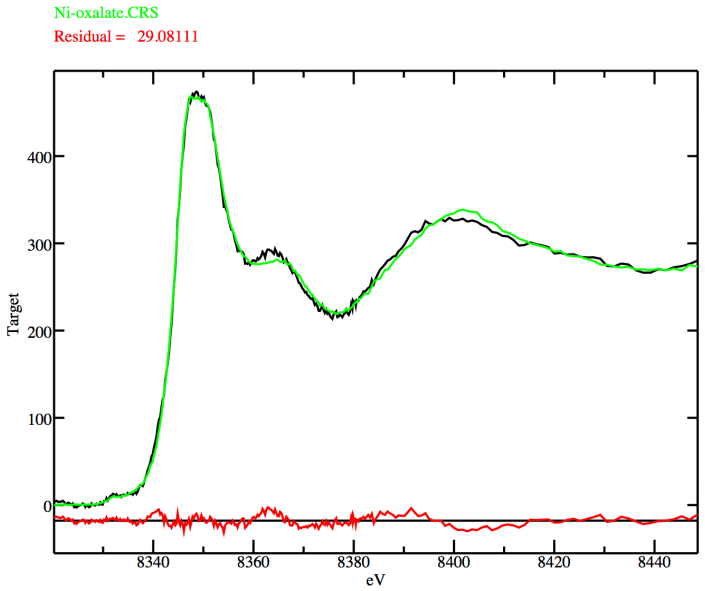
400
300
200
100
0
8340
8360
8380
8400
8420
8440
eV


Ni-oxalate.CRS
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Target
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300
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100
0
8340
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8400
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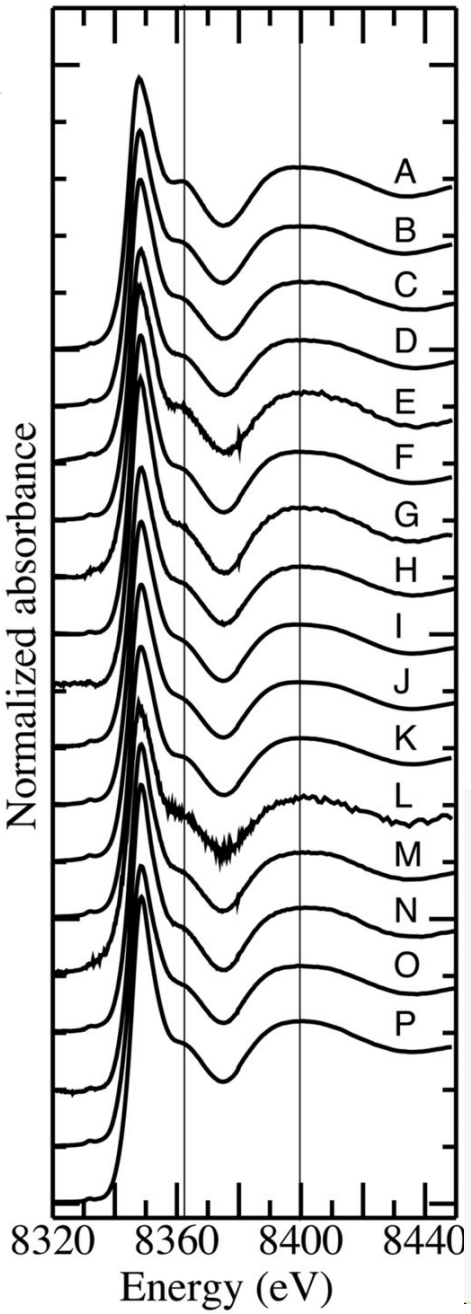
8440
eV



1:10 Ni:citrate aqueous

***R. bengalensis* mid-vein tissue**

***R. bengalensis* leaf tissue**

***R. bengalensis* xylem sap**

***R. bengalensis* phloem tissue**

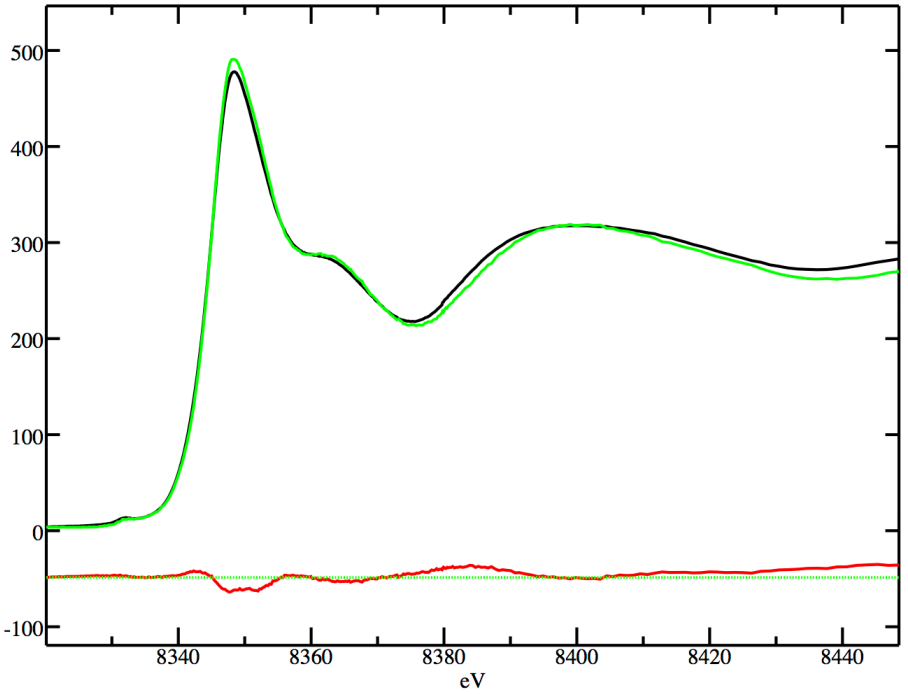
***P. balgooyi* xylem sap**

***P. balgooyi* wood tissue**

***P. balgooyi* root sheath tissue**

***P. balgooyi* phloem tissue**

***P. balgooyi* leaf tissue**

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Fit complete
( Info =  7 )
File Pbal_leaf.CRS                                          Edge
Energy range (eV) :   8320.00     -   8450.00
 #   Fraction       e.s.d.       eV-shift       e.s.d.     i i File
  1   0.449847      0.579123E-01   0.00000       0.00000     0 1 Nicitrate.CRS
X 2   0.00000      0.366091E-01   0.00000       0.00000     1 1 Ni-aconitate.CRS
  3   0.527237      0.581220E-01   0.00000       0.00000     0 1 Nitartrate.CRS
X 4   0.00000      0.329582E-04   0.00000       0.00000     1 1 NiNO3_05mm.CRS

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     No. of variables      :       2
     No. of data points    :     326
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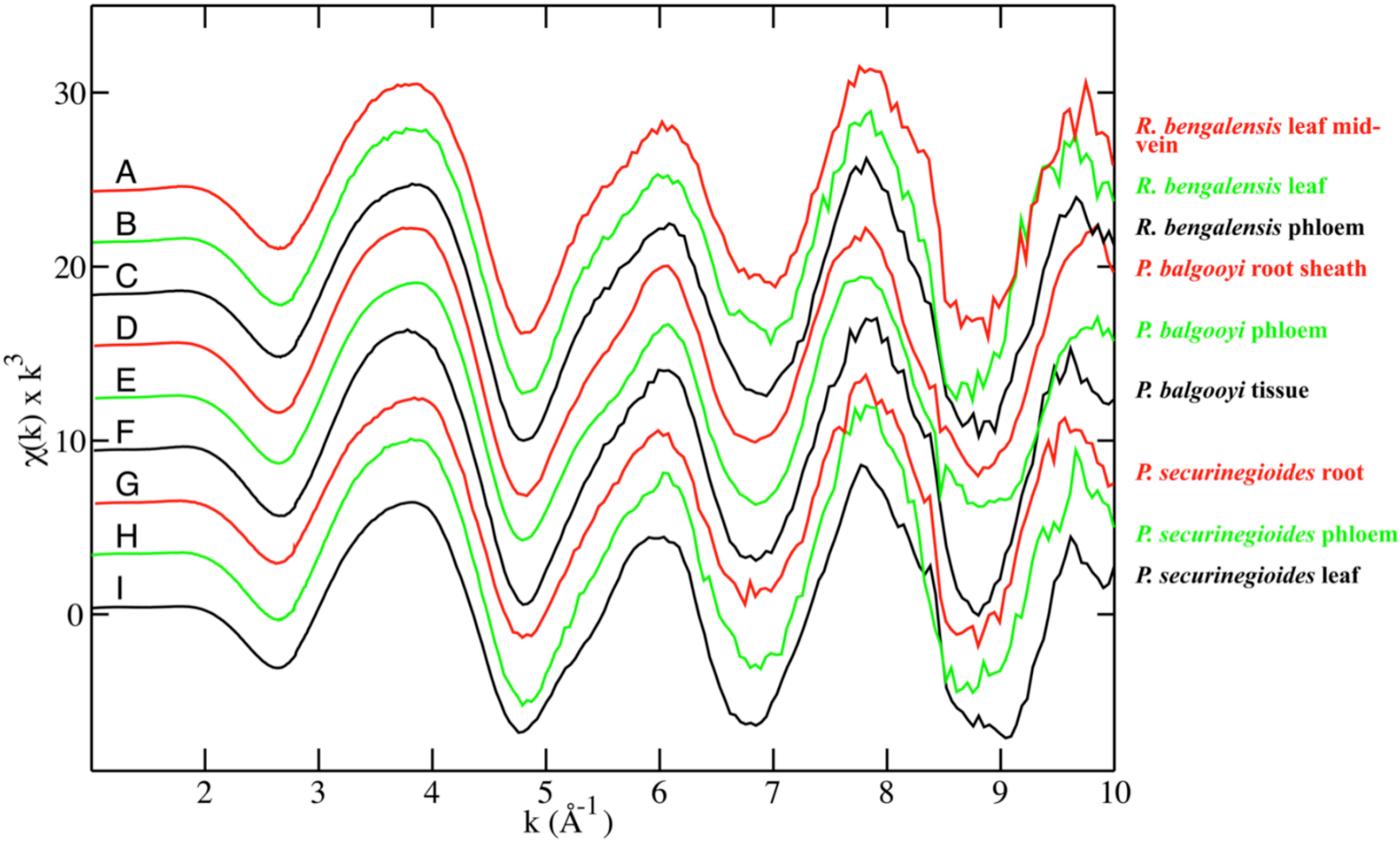
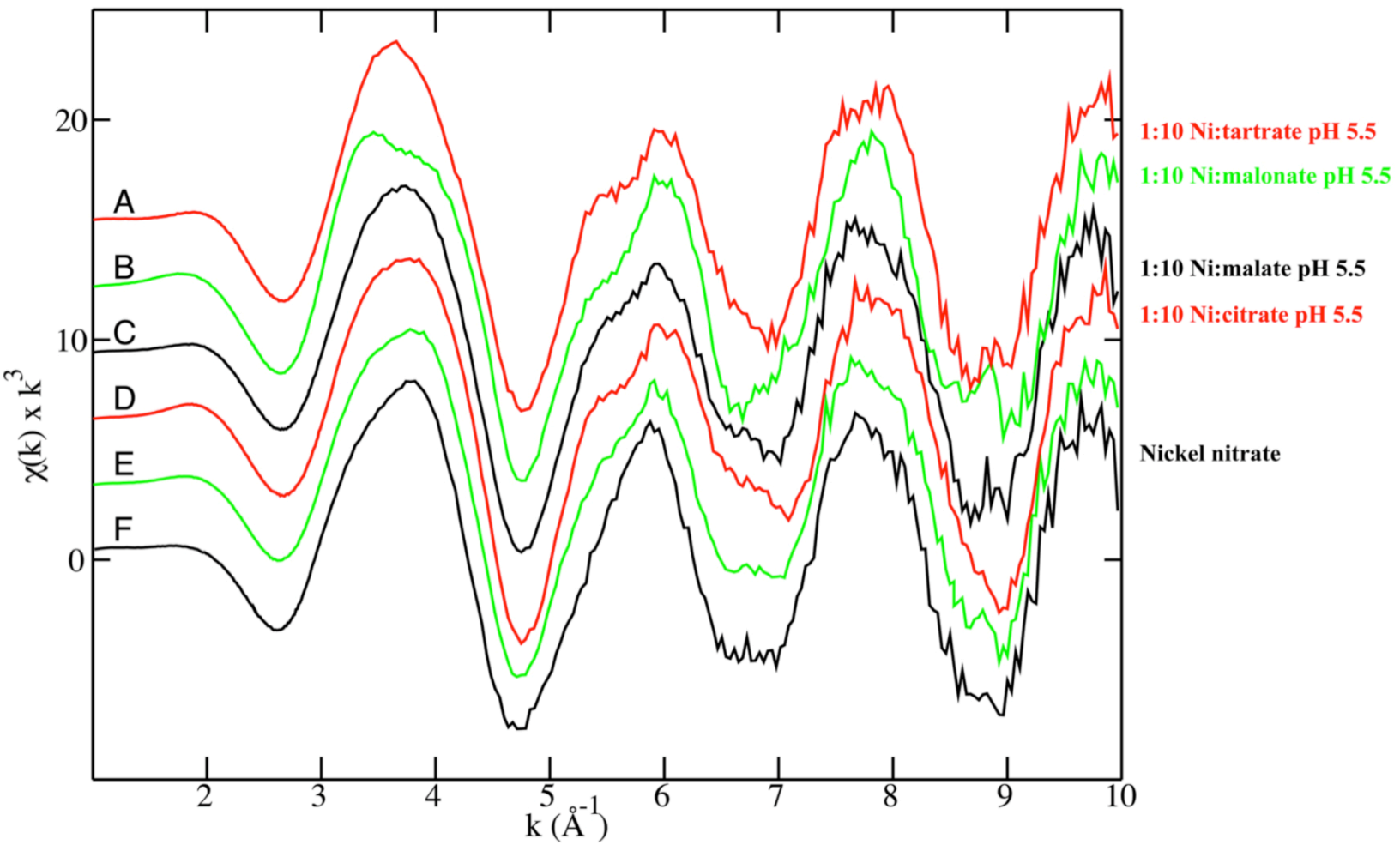


Supplementary Figure 1. Ni K-edge extended X-ray absorption structure for **A**, *Rinorea bengalensis* leaf mid-vein tissue; **B**, *Rinorea bengalensis* leaf tissue; **C**, *Rinorea bengalensis* phloem tissue; **D**, *Phyllanthus balgooyi* root sheath tissue; **E,** *Phyllanthus balgooyi* phloem tissue; **F**, *Phyllanthus balgooyi* leaf tissue; **G**, *Phyllanthus securinegioides* root tissue; **H**, *Phyllanthus securinegioides* phloem tissue; **I**, *Phyllanthus securinegioides* leaf tissue.

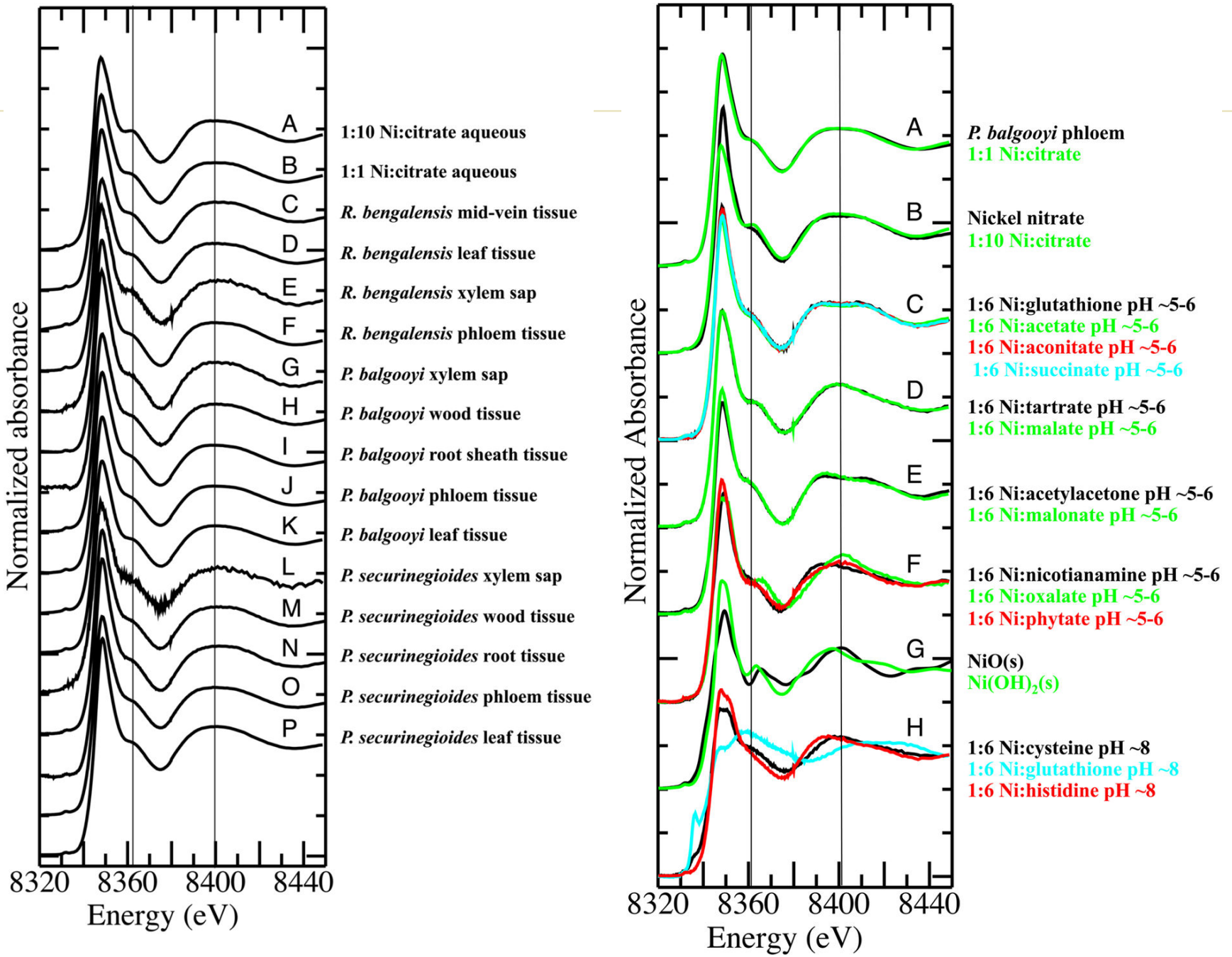


Supplementary Figure 2. Ni K-edge extended X-ray absorption structure for **A**, 1:10 Ni:tartrate in aqueous solution at pH 5.5; **B**, 1:10 Ni:malonate in aqueous solution at pH 5.5; **C**, 1:10 Ni:malate in aqueous solution at pH 5.5; **D**, 1:10 Ni:citrate in aqueous solution at pH 5.5; **E**, 1:1 Ni:citrate in aqueous solution at pH 5.5; **F**, Ni:nitrate in aqueous solution (*i.e.* $[Ni(H_2O)_6]^{2+}$.

Species	Part	Sample	Malate	Citrate	Fructose	Glucose	Sucrose	Catechin
			μg g^{-1} (dry weight)					
Phyllanthus balgooyi	Phloem tissue	1	0.8	121.7	0.4	0.5	13.9	5.9
Phyllanthus balgooyi	Phloem tissue	2	0.5	81.6	0.4	0.4	10.4	3.9
Phyllanthus balgooyi	Phloem tissue	3	0.5	102.5	1.6	1.1	62.4	3.2
Phyllanthus balgooyi	Phloem sap	1	12.8	480.0	2.3	2.7	4.9	n.d.
Phyllanthus balgooyi	Phloem sap	2	14.1	285.6	2.1	1.5	6.7	n.d.
Phyllanthus balgooyi	Phloem sap	3	14.4	314.8	1.5	0.7	11.9	n.d.
Phyllanthus securinegioides	Phloem tissue	1	1.1	12.1	0.5	0.4	40.7	1.7
Phyllanthus securinegioides	Phloem tissue	2	1.4	14.0	0.4	0.4	43.1	1.7
Phyllanthus securinegioides	Phloem tissue	3	1.2	14.9	0.6	0.5	50.9	1.9
Rinorea bengalensis	Phloem tissue	1	3.8	70.9	19.4	16.2	186.0	n.d.
Rinorea bengalensis	Phloem tissue	2	3.0	34.4	18.1	13.9	141.5	n.d.
Rinorea bengalensis	Phloem tissue	3	3.6	41.7	17.7	15.5	135.2	n.d.

Results obtained with quantitative GC-MS.

Mass Balance *Phyllanthus balgooyi* phloem sap							
	Anions μg g^{-1} (dry weight)						
Sample	**Cl^-**	**NO_3^-**	**PO_4^{3-}**	**SO_4^{2-}**	**Sum anions wt%**	**Citrate wt%**	
1	1295	700	711	4167	0.69	81.3	
2	1280	863	1178	903	0.42	79.2	
3	1097	369	593	599	0.27	68.9	
	Cations μg g^{-1} (dry weight)						
Sample	**K^+**	**Mg^{2+}**	**Ni^{2+}**	**Ca^{2+}**	**Co^{2+}**	**Sum cations wt%**	**Total balance wt%**
1	649	821	145560	1300	1869	15.1	96.4
2	1211	810	168514	1871	1449	17.4	96.6
3	1532	595	154944	1960	557	16.1	85.0
Results obtained with ICP-AES, High Performance Liquid Chromatography (HPLC) and ion chromatography.							



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Acknowledgements

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AUSTRALIA

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