Foliar Nutrient Analysis

A Strategic Tool

Rob Brockley, RPF(Ret)

Prepared for Fertilization Program Web Meeting
March 5, 2015

Foliar analysis as a planning tool

- Foliar analysis can be used to:
  - confirm N deficiency
  - identify secondary nutrient deficiencies (e.g., S, B)
  - make appropriate fertilizer prescriptions
  - assess post-fertilization nutrient uptake and foliar nutrient balance

Foliar analysis should be used strategically

- Foliar sampling should only be undertaken on candidate sites that satisfy other forest- and stand-level selection criteria
- Strategically allocate foliar sampling expenditures

How to use foliar sampling strategically

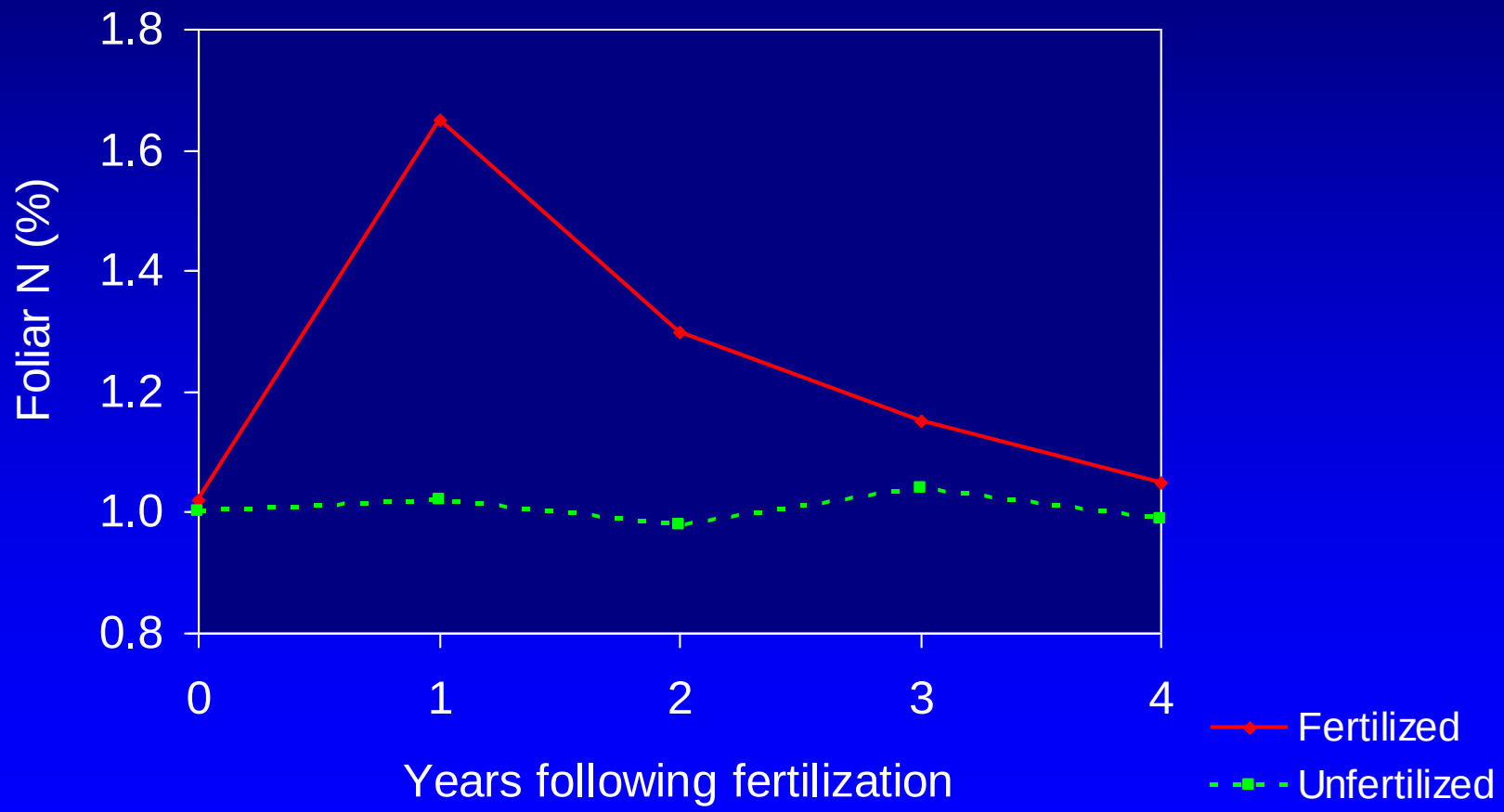
- Utilize foliar nutrient data and/or fertilization growth response results from similar nearby stands
- Stratify candidate blocks into homogeneous combinations (species, age, BEC, stand history, stand conditions) and collect representative composite foliage samples from each major combination
- Operational fertilization projects comprised of a small number of large and uniform blocks will require a relatively small amount of foliar sampling

Is foliar sampling required prior to re-fertilization?

Factors to consider:

- Was foliar sampling undertaken prior to the initial fertilization?
- If so, was the stand N deficient? Were there any secondary deficiencies?
- Is it a mixed-species stand?
- How well did stand respond to e initial fertilization?
- How long has it been since the initial fertilization?

Typical pattern of foliar %N following N fertilization



Foliar Sampling Protocol

- Sample during the dormant season
- Sample current year's foliage
- Collect foliage from the top 1/2 of live crown
- Collect foliage from representative trees
- Collect foliage from at least 20 trees per stand or stratum
- For routine diagnoses, combine equal amounts of foliage from individual trees into one composite sample per stratum
- Keep samples cool until foliage is dried

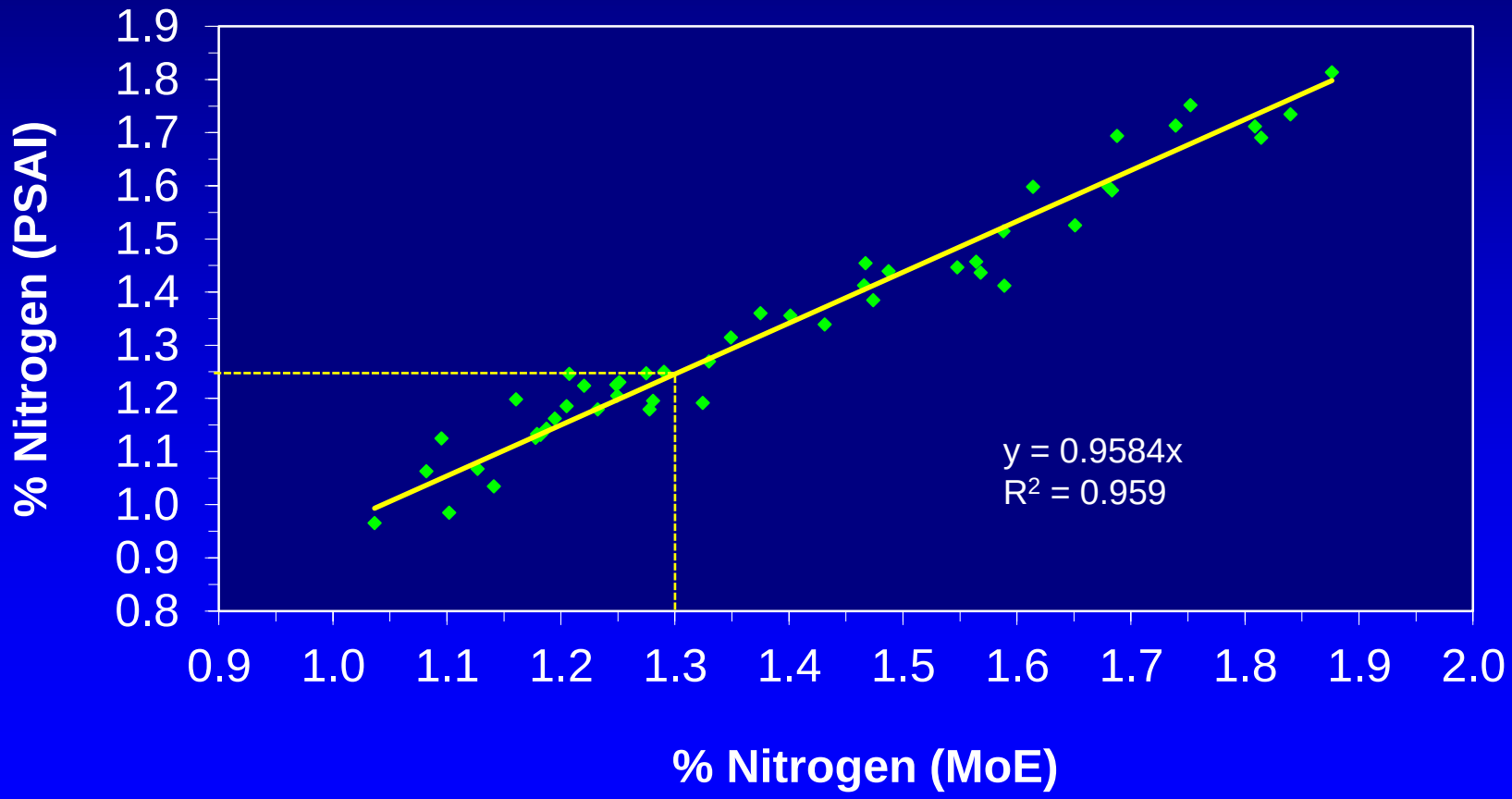
Foliar sampling protocol

Brockley, R.P. 2001. Foliar sampling guidelines and nutrient interpretative criteria for lodgepole pine. B.C. Min. For., Victoria, BC. Extension Note 52.

http://www.for.gov.bc.ca/hfd/pubs/Docs/En/En52.htm

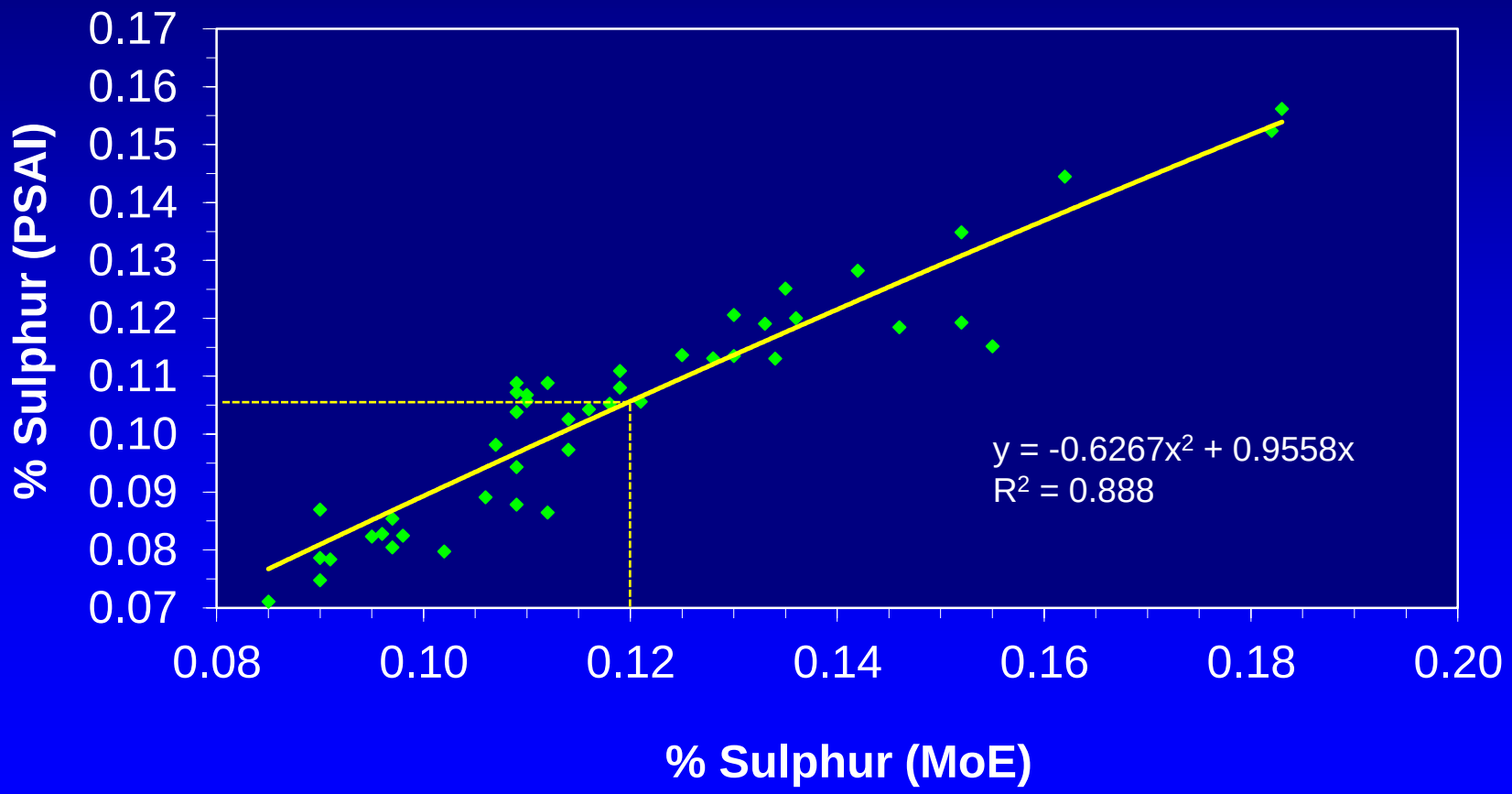
Laboratory foliar N comparison

PSAI vs. MoE



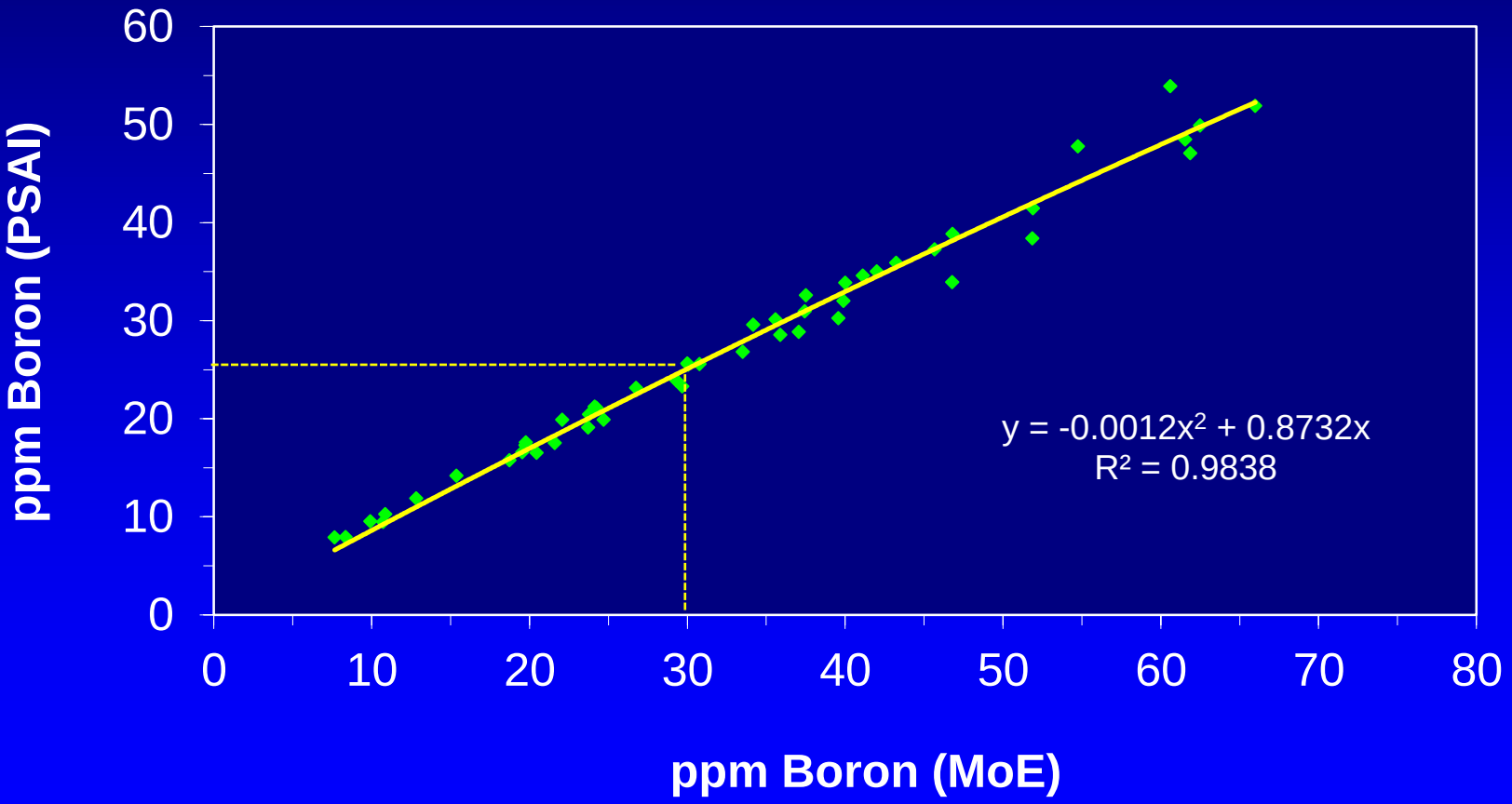
Laboratory foliar S comparison

PSAI vs. MoE



Laboratory foliar B comparison

PSAI vs. MoE



Accounting for differences in laboratory analytical methodology

- Differences may be large enough to affect interpretation
- Nutrient interpretative criteria do not account for differences in methodology
- Foliar data should be “normalized” prior to interpretation
- An Excel spreadsheet is available to facilitate foliar data “normalization”

http://www.for.gov.bc.ca/hcp/fia/landbase/standards/fertilization_program_information.htm

“Normalization” of laboratory foliar nutrient data

	PSAI			MoE	
Element	Raw data	Normalized		Raw data	Normalized
N (%)	1.200	1.200			
P (%)	0.145	0.138	= 0.9492x		
K (%)	0.450	0.413	= (0.1714x^2) + (0.8504x)		
Ca (%)	0.185	0.148	= (0.3592x^2) + (0.7346x)		
Mg (%)	0.110	0.113	= 1.0249x		
S (%)	0.091	0.091			
SO_4 (ppm)	75.0	75.0			
B (ppm)	15.0	15.0			
N:S	13.2	13.2			
N:P	8.3	8.7			
N:K	2.7	2.9			
N:Ca	6.5	8.1			
N:Mg	10.9	10.6			

“Normalization” of laboratory foliar nutrient data

	PSAI		MoE	
Element	Raw data	Normalized	Raw data	Normalized
N (%)	1.200	1.200	1.200	1.150 = 0.9584x
P (%)	0.145	0.138	0.145	0.145
K (%)	0.450	0.413	0.450	0.450
Ca (%)	0.185	0.148	0.185	0.185
Mg (%)	0.110	0.113	0.110	0.110
S (%)	0.091	0.091	0.091	0.082 = $(0.9558x) – (0.6267x^2)$
SO_4 (ppm)	75.0	75.0	75.0	101.7 = $(1.4164x) – (0.0008x^2)$
B (ppm)	15.0	15.0	15.0	12.8 = $(0.8732x) – (0.0012x^2)$
N:S	13.2	13.2	13.2	14.1
N:P	8.3	8.7	8.3	7.9
N:K	2.7	2.9	2.7	2.6
N:Ca	6.5	8.1	6.5	6.2
N:Mg	10.9	10.6	10.9	10.5

Interpreting foliar nutrient data

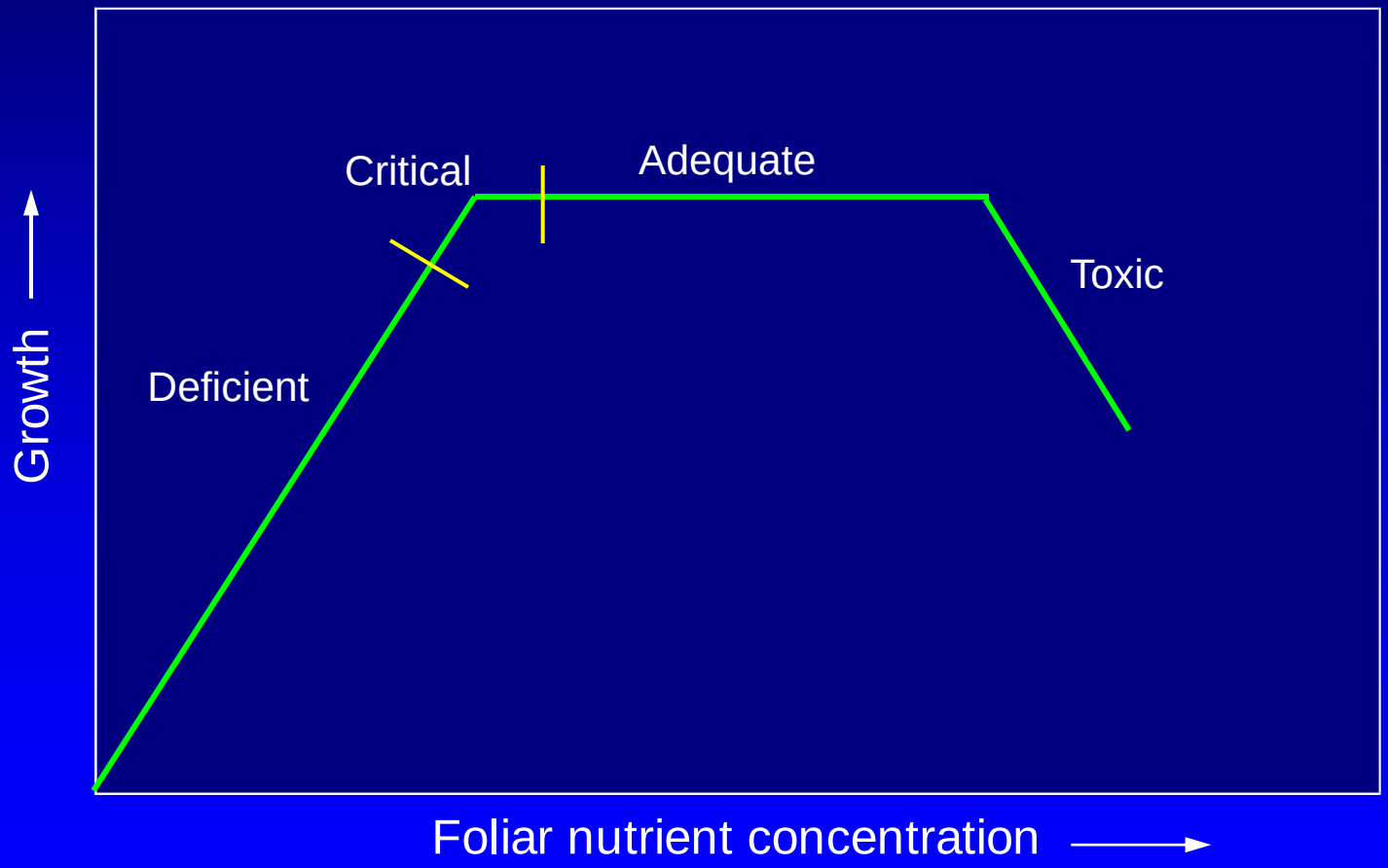


Table 1—Interpretation of macronutrient concentrations in current year's foliage of five commercial conifer species of the Pacific Northwest. Modified from Ballard and Carter (1986).

Element	Interpretation	Foliar Concentration (% dry mass basis)				
		Douglas-fir	Lodgepole pine	Western hemlock	White spruce	Western redcedar
Nitrogen	Very severely deficient	< 1.00	< 1.00	< 1.00	< 1.05	< 1.10
	Moderate to severe deficiency	1.00-1.20	1.00-1.15	1.00-1.20	1.05-1.25	1.10-1.30
	Slight to moderate deficiency	1.20-1.35	1.15-1.35	1.20-1.35	1.25-1.45	1.30-1.45
	Adequate	> 1.35	> 1.35	> 1.35	> 1.45	> 1.45
Phosphorus	Severely deficient	< 0.08	< 0.09	< 0.11	< 0.10	< 0.10
	Moderately deficient	0.08-0.10	0.09-0.12	0.11-0.15	0.10-0.14	0.10-0.13
	Slightly deficient	0.10-0.15	0.12-0.15	0.15-0.25	0.14-0.16	0.13-0.16
	Adequate	> 0.15	> 0.15	> 0.25	> 0.16	> 0.16
Potassium	Very severely deficient	< 0.35	< 0.35	< 0.40	< 0.25	< 0.35
	Moderate to severe deficiency	0.35-0.45	0.35-0.40	0.40-0.45	0.25-0.30	0.35-0.40
	Slight to moderate deficiency	0.45-0.65	0.40-0.55	0.45-0.65	0.30-0.50	0.40-0.80
	Adequate	> 0.65	> 0.55	> 0.65	> 0.50	> 0.80
Calcium	Severely deficient	< 0.15	< 0.06	< 0.06	< 0.10	< 0.10
	Moderate to severe deficiency	0.15-0.20	0.06-0.08	0.06-0.08	0.10-0.15	0.10-0.20
	Slight to moderate deficiency	0.20-0.25	0.08-0.10	0.08-0.10	0.15-0.20	0.20-0.25
	Adequate	> 0.25	> 0.10	> 0.10	> 0.20	> 0.25
Magnesium	Severely deficient	< 0.06	< 0.06	< 0.06	< 0.05	< 0.05
	Moderate to severe deficiency	0.06-0.09	0.06-0.08	0.06-0.08	0.05-0.08	0.05-0.09
	Slight to moderate deficiency	0.09-0.12	0.08-0.10	0.08-0.10	0.08-0.12	0.09-0.14
	Adequate	> 0.12	> 0.10	> 0.10	> 0.12	> 0.14

from Carter (1992)

Revised foliar nutrient interpretative criteria (2012)

Information sources:

- Previously published interpretative criteria
- Published foliar nutrient and growth response data from *Pinus*, *Picea* and *Pseudotsuga* fertilization studies
- Unpublished foliar nutrient and growth response data from BC fertilization studies

Revised foliar nutrient interpretative criteria

Macronutrients

Element	Interpretation	Foliar concentration (% dry weight)		
		Pl	Sx	Fd
N	Severely deficient	< 1.00	< 0.90	< 1.00
	Mod. to severely deficient	1.00 – 1.15	0.90 – 1.10	1.00 – 1.15
	Slightly to mod. deficient	1.15 – 1.30	1.10 – 1.30	1.15 – 1.30
	Adequate	> 1.30	> 1.30	> 1.30
P	Severely deficient	< 0.08	< 0.10	< 0.11
	Mod. to severely deficient	0.08 – 0.10	0.11 – 0.12	0.11 – 0.13
	Slightly to mod. deficient	0.10 – 0.12	0.12 – 0.14	0.13 – 0.15
	Adequate	> 0.12	> 0.14	> 0.15
K	Severely deficient	< 0.30	< 0.40	< 0.45
	Mod. to severely deficient	0.30 – 0.35	0.40 – 0.45	0.45 – 0.55
	Slightly to mod. deficient	0.35 – 0.40	0.45 – 0.50	0.55 – 0.60
	Adequate	> 0.40	> 0.50	> 0.60

Revised foliar nutrient interpretative criteria

Macronutrients cont'd

Element	Interpretation	Foliar concentration (% dry weight)		
		Pl	Sx	Fd
Ca	Severely deficient	< 0.06	< 0.10	< 0.10
	Mod. to severely deficient	0.06 – 0.08	0.10 – 0.15	0.10 – 0.15
	Slightly to mod. deficient	0.08 – 0.10	0.15 – 0.20	0.15 – 0.20
	Adequate	> 0.10	> 0.20	> 0.20
Mg	Severely deficient	< 0.04	< 0.04	< 0.06
	Mod. to severely deficient	0.04 – 0.06	0.04 – 0.06	0.06 – 0.08
	Slightly to mod. deficient	0.06 – 0.08	0.06 – 0.08	0.08 – 0.10
	Adequate	> 0.08	> 0.08	> 0.10
S	Severely deficient	< 0.06	< 0.06	< 0.06
	Mod. to severely deficient	0.06 – 0.08	0.06 – 0.08	0.06 – 0.08
	Slightly to mod. deficient	0.08 – 0.10	0.08 – 0.10	0.08 – 0.10
	Adequate	> 0.10	> 0.10	> 0.10

Revised foliar nutrient interpretative criteria

Sulphate-S and Boron

Element	Interpretation	Foliar concentration (ppm dry weight)		
		Pl	Sx	Fd
SO_4-S	Severely deficient	< 40	< 60	< 100
	Mod. to severely deficient	40 – 60	60 – 80	100 – 150
	Slightly to mod. deficient	60 – 80	80 – 100	150 – 200
	Adequate	> 80	> 100	> 200
B	Severely deficient	< 3	< 3	< 3
	Probable deficiency	3 – 6	3 – 6	3 – 6
	Possible deficiency	6 – 12	6 – 12	6 – 12
	No deficiency	> 12	> 12	> 12

Revised March 2012

Revised foliar nutrient interpretative criteria

Nutrient ratios

		Nutrient ratio		
Element	**Interpretation**	**Pl**	**Sx**	**Fd**
N:P	Moderate to severe P deficiency	> 13	> 11	> 11
	Slight to moderate P deficiency	11 – 13	10 – 11	10 – 11
	Possible slight P deficiency	10 – 11	9 – 10	9 – 10
	No P deficiency	< 10	< 9	< 9
N:K	Moderate to severe K deficiency	> 4.5	> 4.0	> 3.5
	Slight to moderate K deficiency	3.5 – 4.5	3.0 – 4.0	2.5 – 3.5
	Possible slight K deficiency	2.5 – 3.5	2.0 – 3.0	2.0 – 2.5
	No K deficiency	< 2.5	< 2.0	< 2.0
N:S	Severe S deficiency	> 25	> 25	> 25
	Moderate to severe S deficiency	20 – 25	20 – 25	20 – 25
	Slight to moderate S deficiency	15 – 20	15 – 20	15 – 20
	No S deficiency[a]	< 15	< 15	< 15

[a] Sulphur deficiency will likely be induced by N fertilization if N:S > 13

Revised foliar nutrient interpretative criteria

Nutrient ratios cont'd

Element	Interpretation	Nutrient ratio		
		Pl	Sx	Fd
N:Mg	Moderate to severe Mg deficiency	> 30	> 30	> 30
	Slight to moderate Mg deficiency	20 – 30	20 – 30	20 – 30
	Possible slight Mg deficiency	15 – 20	15 – 20	15 – 20
	No Mg deficiency	< 15	< 15	< 15

Some basic interpretative rules

- Confirm that standardized foliar sampling protocol was used
- Confirm what laboratory was used for nutrient analysis
- “Normalize” foliar data prior to interpretation
- Assess S status in the following order of importance:
  SO_4 > N:S > S
- N:P, N:K, and N:Mg ratios are more important than absolute levels of P, K, or Mg