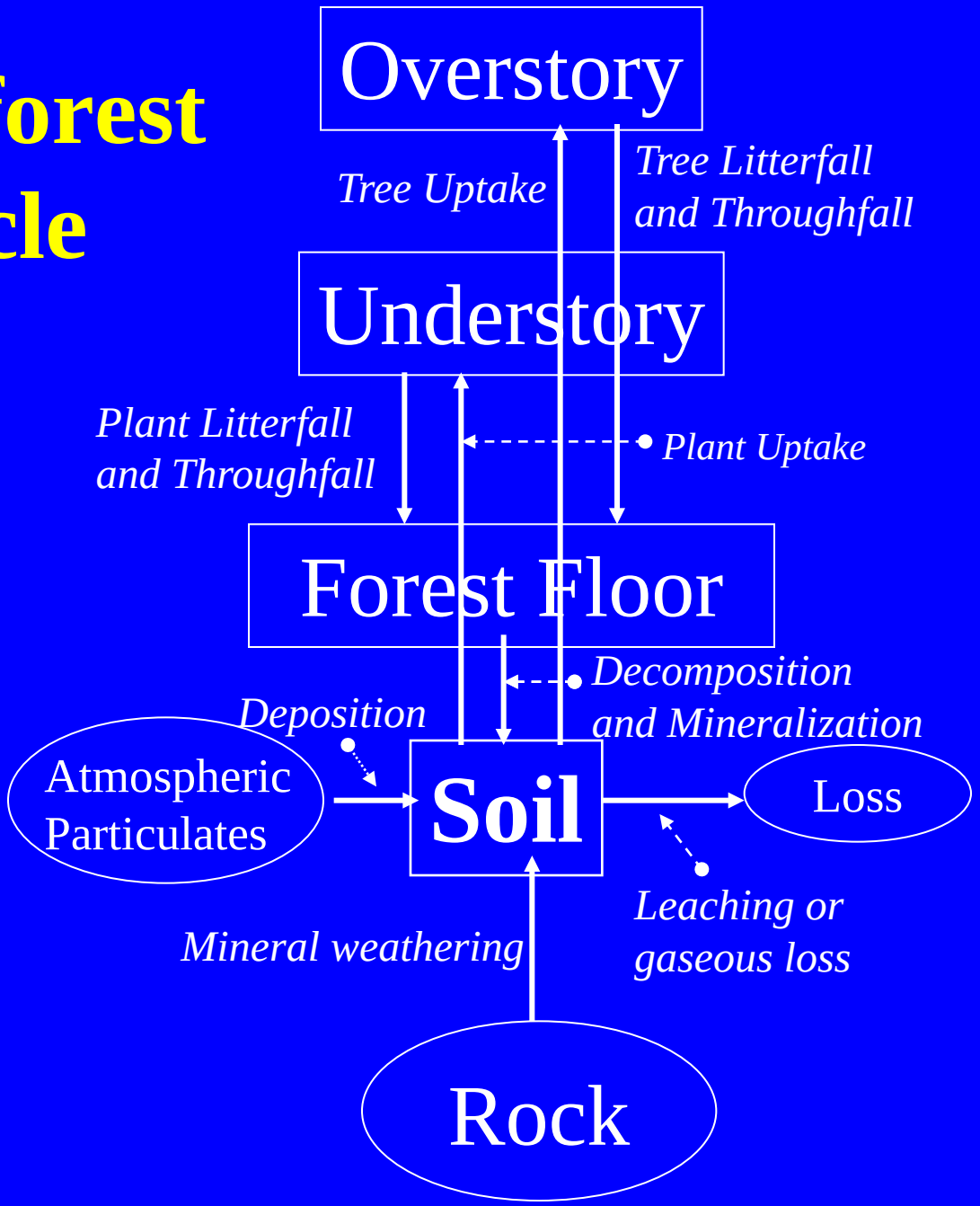
Nutrient Budget Model Update

Peter Mika

2004 IFTNC Annual Meeting

Modeling the forest nutrient cycle



The Overstory

- Components
  - Foliage
  - Fine Branches (<0.25”)
  - Coarse Branches (>=0.25”)
  - Stem
    - Wood versus Bark
    - Merchantable versus Unmerchantable
- Needed information
  - Biomass
  - Nutrient concentration

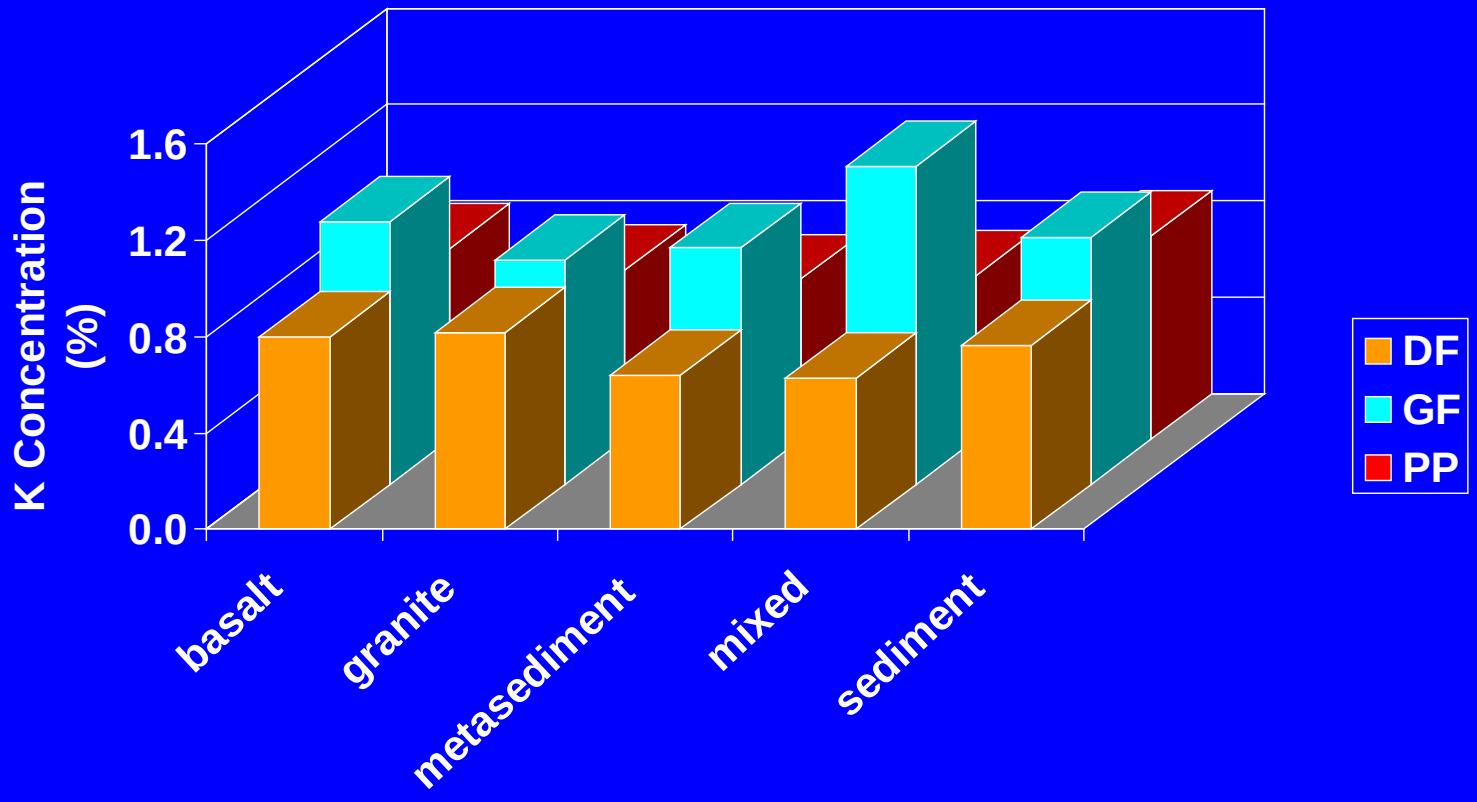
Information in FVS

- Wood
  - Known: CFV, total and merchantable
  - Needed: wood density, nutrient concentrations
- Bark
  - Known: wood/bark ratios by species
  - Needed: bark volumes, bark density, nutrient concentrations
- Crown
  - Known: biomass of foliage, fine branches, and coarse branches
  - Needed: nutrient concentrations

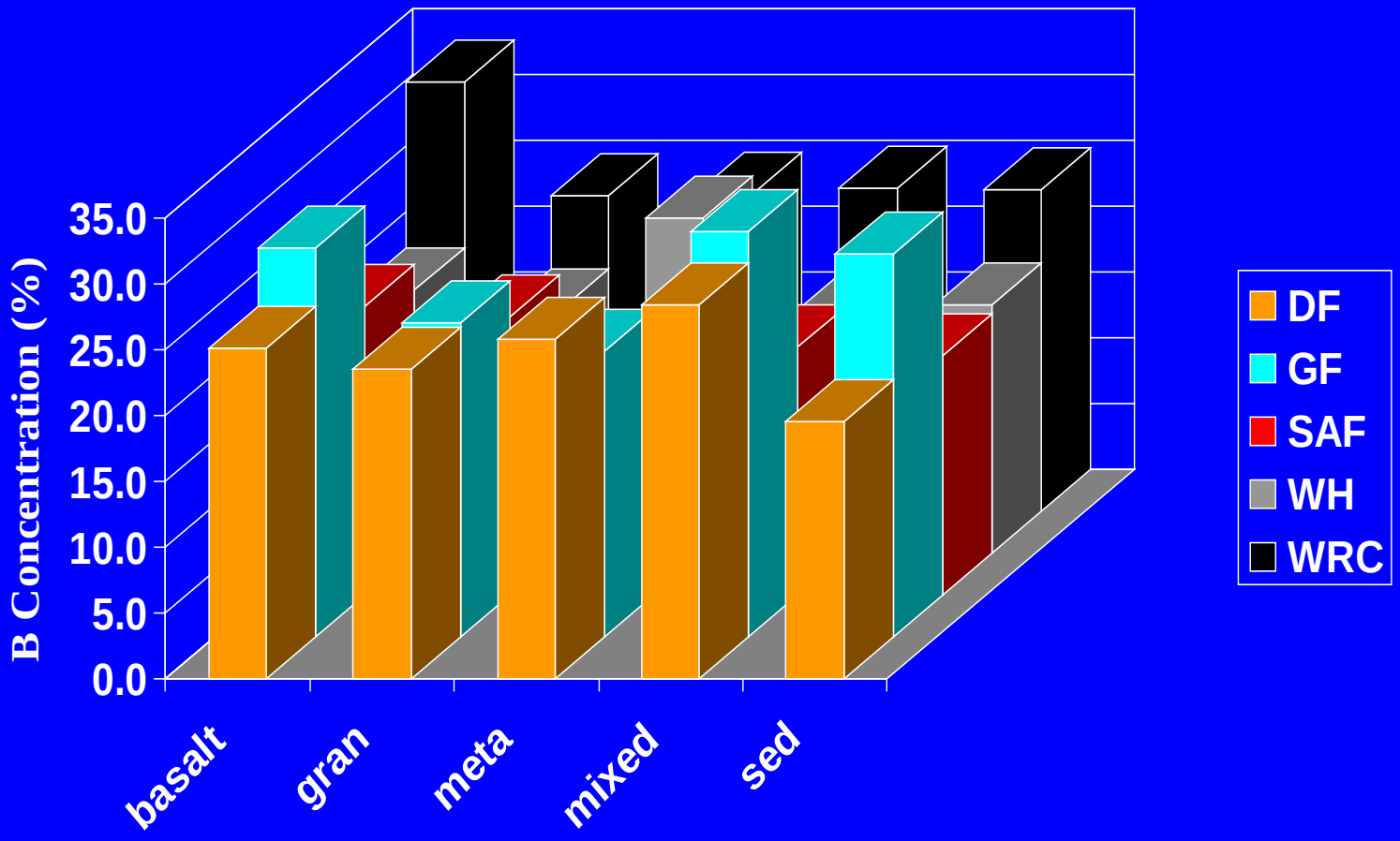
What do we know?

- Tissue nutrient concentration
  - Variation among species
  - Variation across sites
    - Habitat type
    - Rock type
  - Variation within crowns
    - By position (ie. upper, mid, and lower crown)
    - By age (ie. new foliage, older foliage)

Foliar K Concentration By Rock Type and Species on GF Vegetation Series



Douglas-fir Foliar B Concentration by Rock Type and Vegetation Series



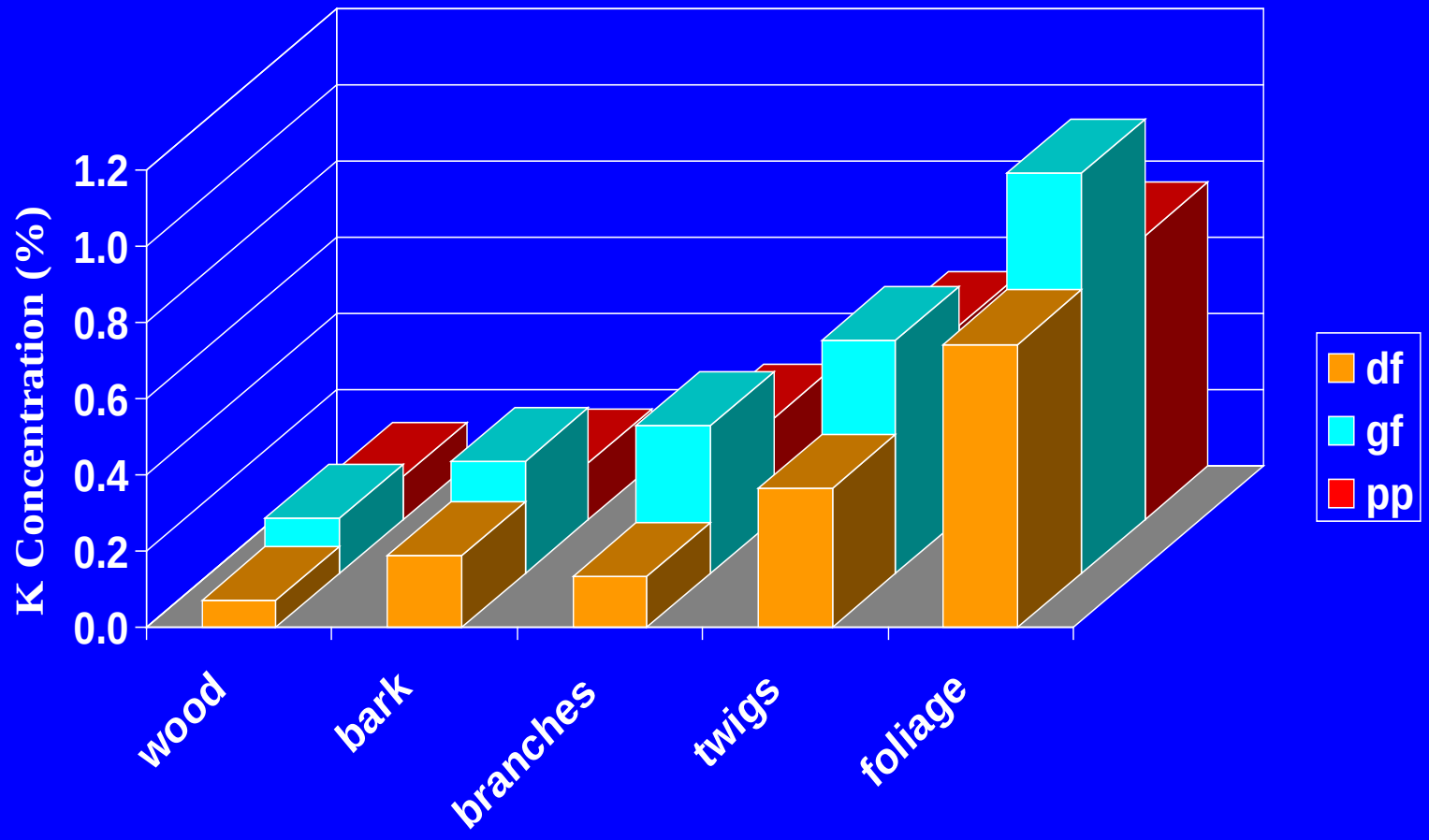
What information does the IFTNC have?

- Foliar nutrient concentration data
  - Species we have sampled across rock and vegetation types
    - DF, GF, PP, LPP
  - Species we have sampled somewhere
    - WRC, WL
  - Species we have never sampled
    - WWP, ES, SAF, WH, MH

What other information does the IFTNC have?

- Branch, Bark, and Wood Chemistry
  - Species we have sampled in detail
    - DF, PP, GF
  - Species we have sampled somewhere
    - LPP, WRC, WL
  - Species we have never sampled
    - WWP, ES, SAF, WH, MH

K Concentration by Species and Overstory Component



Model Calculations

- Crown

  Foliage biomass (from FVS) X nutrient concentration = nutrient content

  Same for fine and coarse branches

- Wood

  Wood volume (from FVS) X wood density X nutrient concentration = nutrient content

- Bark

  Bark volume = f(wood volume (from FVS), bark/wood ratio (from FVS)

  Bark volume X bark density X nutrient concentration = nutrient content

FVS Input: Keywords and Tree List

```
SCREEN
STDIDENT
IFTNC366   HEPPNER NOTHIN
MGMTID
THINBBA
DESIGN                    10.0       99.0        3.0
STDINFO          105       520         40          1          8         22
INVYEAR       1997.0
NUMCYCLE         1.0
GROWTH            0.         2.         0.         2.
SPECPREF      1997.0          4.      9999.
SPECPREF      1997.0          3.       999.
SPECPREF      1997.0         10.        99.
THINBBA       1997.0        150.
TREEDATA        15.0
3664 44      11PP  156  0 93      122 0 0 0 0 0 010 528952000
3664 45      11PP  200  2102      274 0 0 0 0 0 010 528952000
.
.
.
3666123      11PP   29  1 16       65 0 0 0 0 0 012 528952000
3666124      11PP   44  2 19       41 0 0 0 0 0 012 528952000
 -999
PROCESS
STOP
```

FVS Input: Keywords

```
SCREEN
STDIDENT
IFTNC366    HEPPNER NOTHIN
MGMTID
THINBBA
DESIGN                      10.0       99.0        3.0
STDINFO          105         520         40          1          8         22
INVYEAR       1997.0
NUMCYCLE         1.0
GROWTH             0.          2.          0.          2.
SPECPREF      1997.0          4.       9999.
SPECPREF      1997.0          3.        999.
SPECPREF      1997.0         10.         99.
THINBBA       1997.0        150.
NUTRIENT           1           2
TREEDATA        15.0
```

Guidance for FVS can be obtained at www.fs.fed.us/fmsc/fvs/index.php

FVS Input: Keywords

	Rock Type	Veg Series
NUTRIENT	1	2
Codes:	1=Basalt	1=Douglas-fir
	2=Granite	2=Grand Fir
	3=Metasediment	3=Subalpine Fir
	4=Mixed	4=Western Hemlock
	5=Sediment	5=Western Redcedar

Guidance for FVS can be obtained at www.fs.fed.us/fmsc/fvs/index.php

FVS Input: Tree List

```
3664 44      11PP  156   0 93      122 0 0 0 0 0 010 528952000
3664 45      11PP  200  2102       274 0 0 0 0 0 010 528952000
.
.
.
3666123      11PP   29   1 16       65 0 0 0 0 0 012 528952000
3666124      11PP   44   2 19       41 0 0 0 0 0 012 528952000
 -999
PROCESS
STOP
```

FOREST VEGETATION SIMULATOR VERSION 6.21 -- INLAND EMPIRE PROGNOSIS RV:12.23.02

STAND ID: IFTNC366 MGMT ID: THIN HEPPNER NOTHIN

SUMMARY STATISTICS (PER ACRE OR STAND BASED ON TOTAL STAND AREA)

	START OF SIMULATION PERIOD									REMOVALS				AFTER TREATMENT				
YEAR	AGE	NO OF TREES	BA	SDI	CCF	TOP HT	QMD	TOTAL CU FT	MERCH CU FT	MERCH BD FT	NO OF TREES	TOTAL CU FT	MERCH CU FT	MERCH BD FT	BA	SDI	CCF	TOP HT	RES QMD
1997	40	253	238	362	212	93	13.1	7341	6510	35667	122	2455	2153	11382	150	222	118	93	14.5

OVERSTORY NUTRIENT COMPONENTS (lbs/acre)

STAND ID: IFTNC366 MGMT ID: THIN

ROCK TYPE: Basalt VEGETATION SERIES: Grand Fir

Amount in standing crop before any cut

Year	Nutr	Foliage	Small Branches	Coarse Branches	Total Crown	Unmerch Bark	Merch Bark	Unmerch Wood	Merch Wood
1997	Bio	10892.1	5372.1	32638.6	48902.9	2902.1	52295.5	25542.8	201348.7
	N	115.967	37.661	100.118	253.745	8.023	142.093	11.115	84.511
	K	74.368	21.159	78.945	174.472	5.518	101.330	25.582	194.076
	P	18.025	6.003	20.071	44.100	1.835	33.599	9.946	78.110
	Ca	84.249	34.984	144.372	263.605	13.615	254.251	36.057	276.233
	Mg	13.622	5.845	24.340	43.807	1.470	26.350	10.405	79.226
	S	9.156	2.752	8.773	20.682	0.546	9.868	2.698	21.196
	Mn	3.797	0.781	3.200	7.778	0.277	5.332	0.681	5.096
	Fe	0.954	1.044	3.257	5.255	0.220	3.838	1.698	13.060
	Zn	0.251	0.248	1.253	1.752	0.094	1.727	0.376	2.810
	B	1.758	0.078	0.287	2.122	0.023	0.424	0.105	0.818
	Cu	0.024	0.092	0.935	1.052	0.074	1.162	0.264	2.047

FVS Output: Stand Summary

SUMMARY STATISTICS (PER ACRE)

START OF SIMULATION PERIOD

YEAR	AGE	NO OF TREES	BA	SDI	CCF	TOP HT	QMD	TOTAL CU FT	MERCH CU FT	MERCH BD FT
1997	40	253	238	362	212	93	13.1	7341	6510	35667

REMOVALS				AFTER TREATMENT				
NO OF TREES	TOTAL CU FT	MERCH CU FT	MERCH BD FT	BA	SDI	CCF	TOP HT	RES QMD
122	2455	2153	11382	150	222	118	93	14.5

FVS Output: Initial Nutrient Contents

OVERSTORY NUTRIENT COMPONENTS (lbs/acre)

STAND ID: IFTNC366 MGMT ID: THIN

ROCK TYPE: Basalt VEGETATION SERIES: Grand Fir

Amount in standing crop before any cut

Year	Nutr	Foliage	Small Branches	Coarse Branches	Total Crown
1997	Bio	10892.1	5372.1	32638.6	48902.9
	N	115.967	37.661	100.118	253.745
	K	74.368	21.159	78.945	174.472
	P	18.025	6.003	20.071	44.100
	Ca	84.249	34.984	144.372	263.605
	Mg	13.622	5.845	24.340	43.807
	S	9.156	2.752	8.773	20.682
	Mn	3.797	0.781	3.200	7.778
	Fe	0.954	1.044	3.257	5.255
	Zn	0.251	0.248	1.253	1.752
	B	1.758	0.078	0.287	2.122
	Cu	0.024	0.092	0.935	1.052

FVS Output: Initial Nutrient Contents

OVERSTORY NUTRIENT COMPONENTS (lbs/acre)
STAND ID: IFTNC366 MGMT ID: THIN
ROCK TYPE: Basalt VEGETATION SERIES: Grand Fir

Amount in standing crop before any cut

Year	Nutr	Unmerch Bark	Merch Bark	Unmerch Wood	Merch Wood
1997	Bio	2902.1	52295.5	25542.8	201348.7
	N	8.023	142.093	11.115	84.511
	K	5.518	101.330	25.582	194.076
	P	1.835	33.599	9.946	78.110
	Ca	13.615	254.251	36.057	276.233
	Mg	1.470	26.350	10.405	79.226
	S	0.546	9.868	2.698	21.196
	Mn	0.277	5.332	0.681	5.096
	Fe	0.220	3.838	1.698	13.060
	Zn	0.094	1.727	0.376	2.810
	B	0.023	0.424	0.105	0.818
	Cu	0.074	1.162	0.264	2.047

FVS Output: Removal Amounts

```
In year 1997  Material Removed:  TPA cut = 122.
                                 CFV cut = 2454.71
                       Merchantable CFV cut = 2153.40
                    Yarding losses:    TPA =       0.
                                       CFV =        0.00
                       Merchantable CFV =        0.00
```

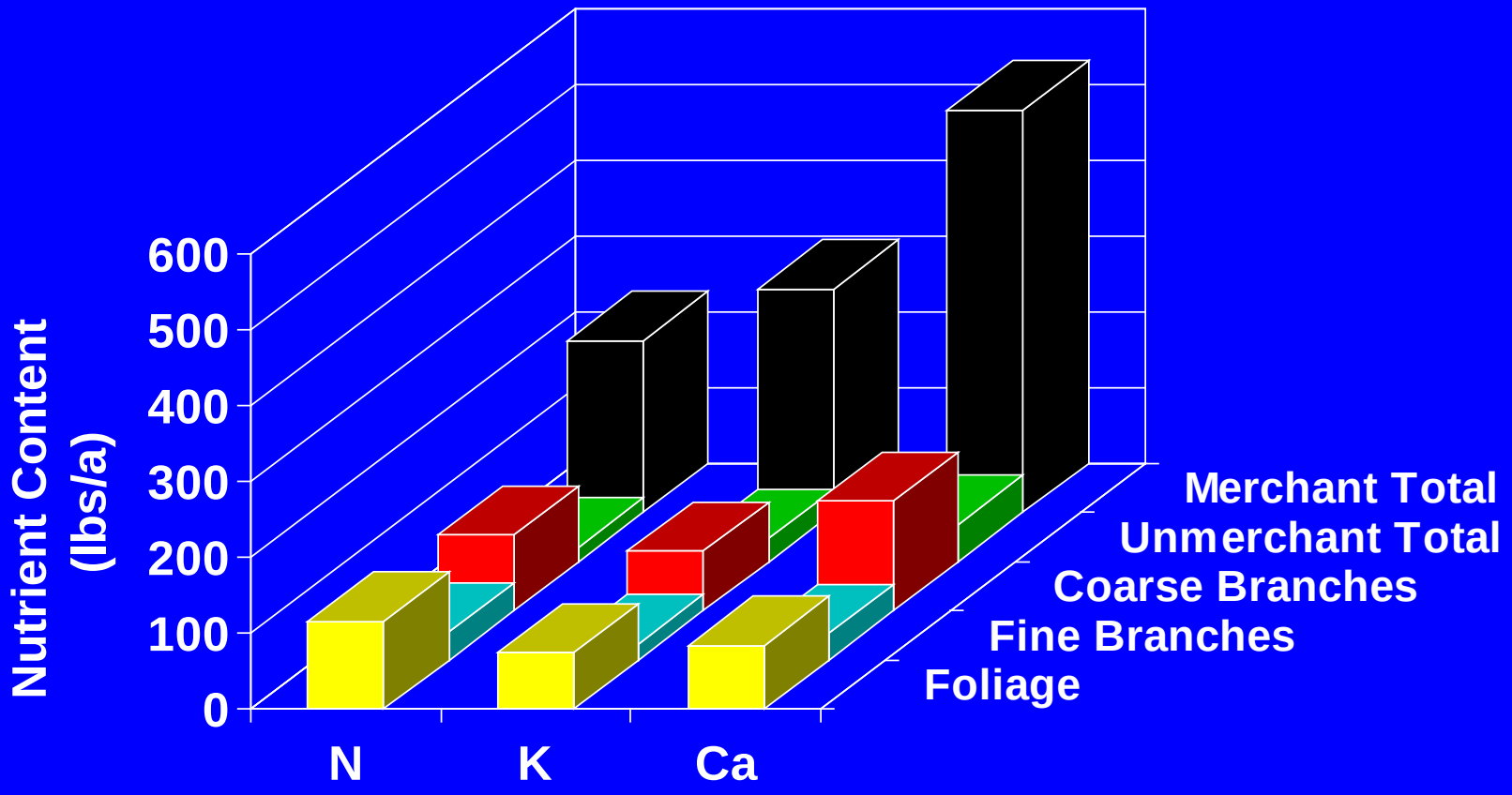
FVS Output: Nutrient Content of Removals

		Amount removed in cut			
Year	Nutr	Foliage	Small Branches	Coarse Branches	Total Crown
1997	Bio	5124.9	2900.4	12491.8	20517.1
	N	53.394	20.055	42.824	116.272
	K	35.181	11.877	33.432	80.490
	P	8.113	3.368	8.854	20.335
	Ca	50.711	20.626	68.662	139.999
	Mg	6.538	3.185	8.988	18.711
	S	4.195	1.471	3.618	9.284
	Mn	1.653	0.469	1.620	3.742
	Fe	0.450	0.608	1.187	2.245
	Zn	0.101	0.131	0.437	0.668
	B	0.787	0.043	0.110	0.940
	Cu	0.011	0.050	0.300	0.360

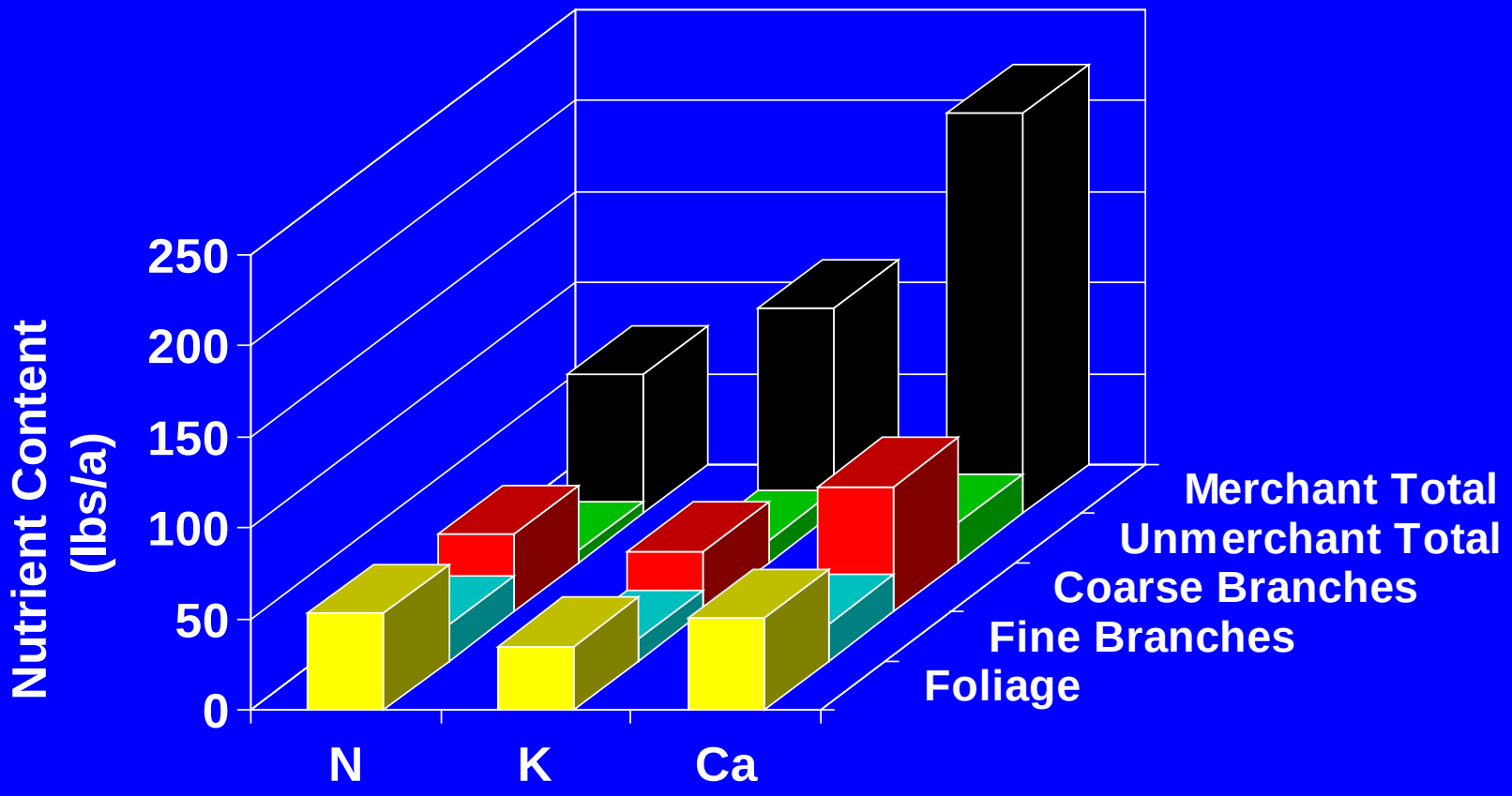
FVS Output:
Nutrient Content of Removals

		Amount removed in cut			
Year	Nutr	Unmerch Bark	Merch Bark	Unmerch Wood	Merch Wood
1997	Bio	1335.6	19838.0	9594.3	68617.9
	N	3.456	51.632	3.496	24.796
	K	2.878	44.391	9.768	68.478
	P	0.924	13.993	3.695	26.396
	Ca	7.771	122.135	13.882	97.739
	Mg	0.685	10.441	3.063	21.833
	S	0.264	4.037	1.007	7.189
	Mn	0.194	3.243	0.297	2.055
	Fe	0.091	1.393	0.516	3.692
	Zn	0.046	0.662	0.106	0.752
	B	0.011	0.167	0.040	0.287
	Cu	0.015	0.231	0.084	0.603

Nutrients in Original Stand



Nutrients in Material Removed



Nutrient Variation by Crown Class: Data Sources

- Mallory Creek Nutrient Budget Study
  (DF/GF stand on WRC series, metasediment)
  - Foliage and branch chemistry by crown position
- Heppner USFS Fuels Reduction Study
  (PP/DF/GF stand on GF series, basalt)
  - PP, DF, and GF sampled on unthinned portion
  - PP and DF sampled on thinned portion
  - Foliage chemistry by crown position

Nutrient Variation by Crown Class: Analysis Approach

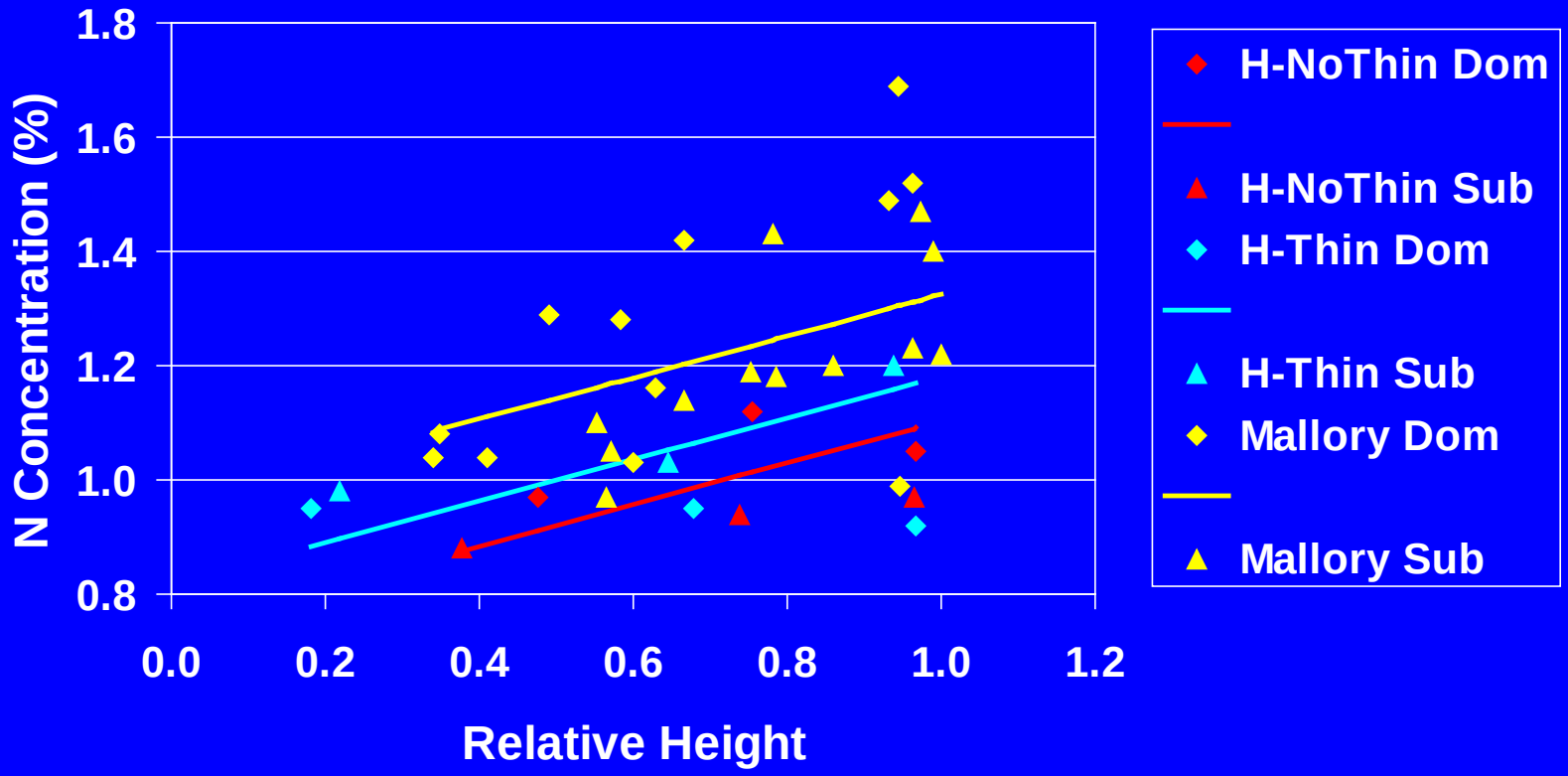
- Look at within-canopy variation in nutrient concentration for new and old foliage and fine and coarse branches.
- Model nutrient concentration of a particular tissue as a function of species, crown class (dominant or subdominant), and height of sample.

Nutrient Variation by Crown Class: Analysis Results

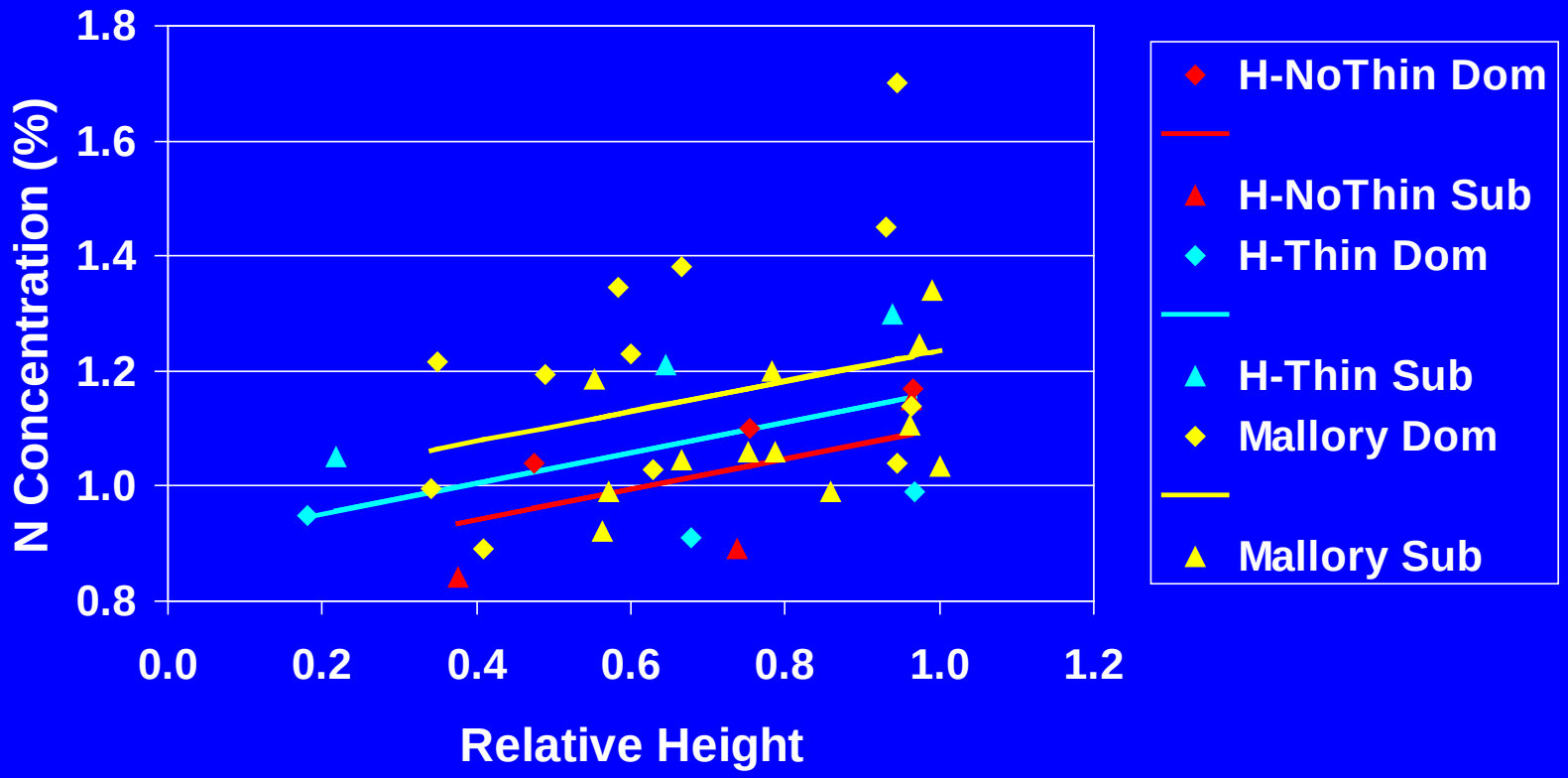
- Most nutrient concentrations showed significant linear correlation with sample height.
  - Slopes usually differed by species but mostly not by crown class
- Relative height (=sample height/tree height) was generally a better predictor than actual height.
- Final model:

$$conc = \mu + Species_i + B_i \times Relative\ Height$$

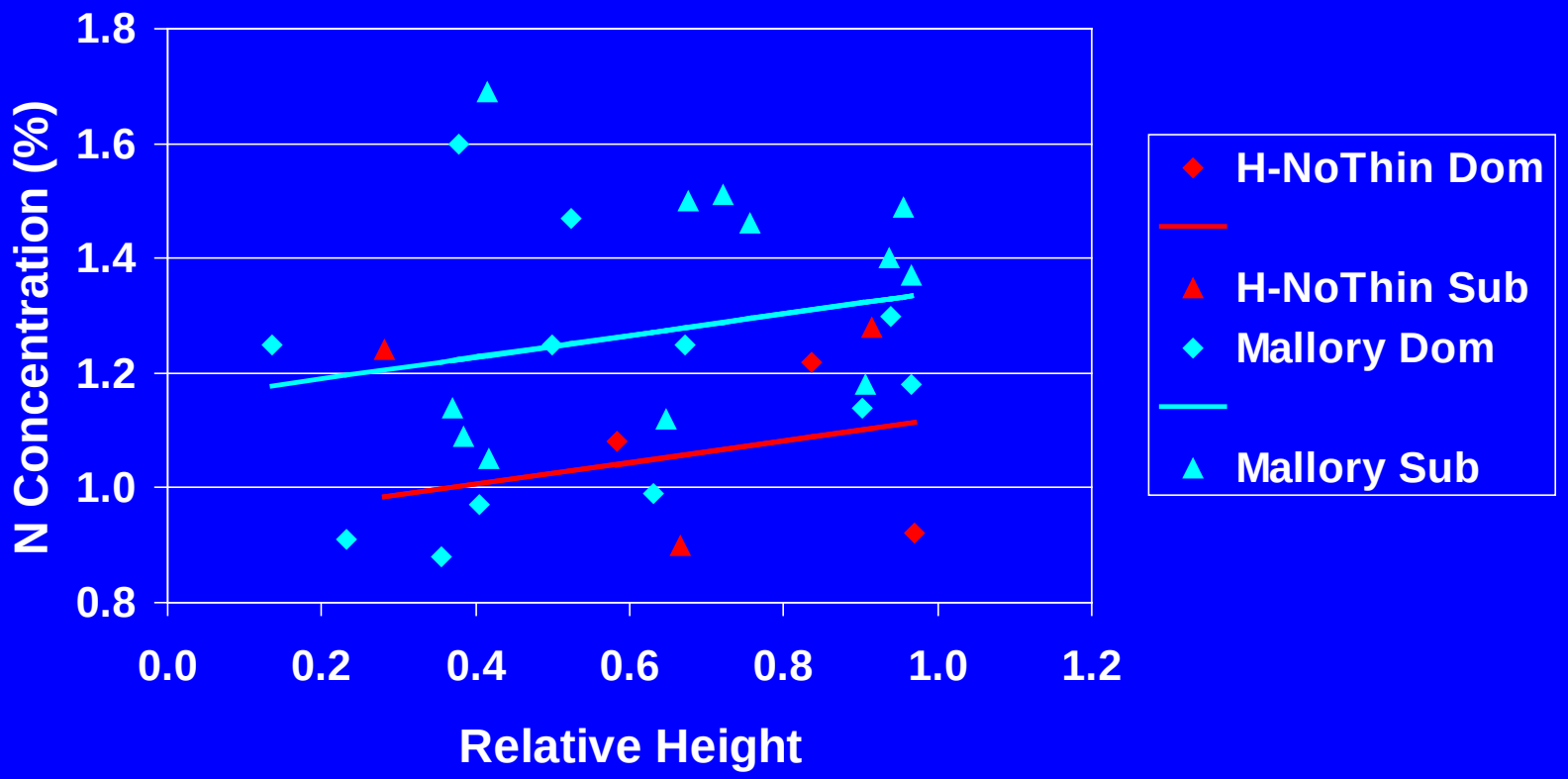
Dominant vs. Subdominant DF New Foliage N Concentration



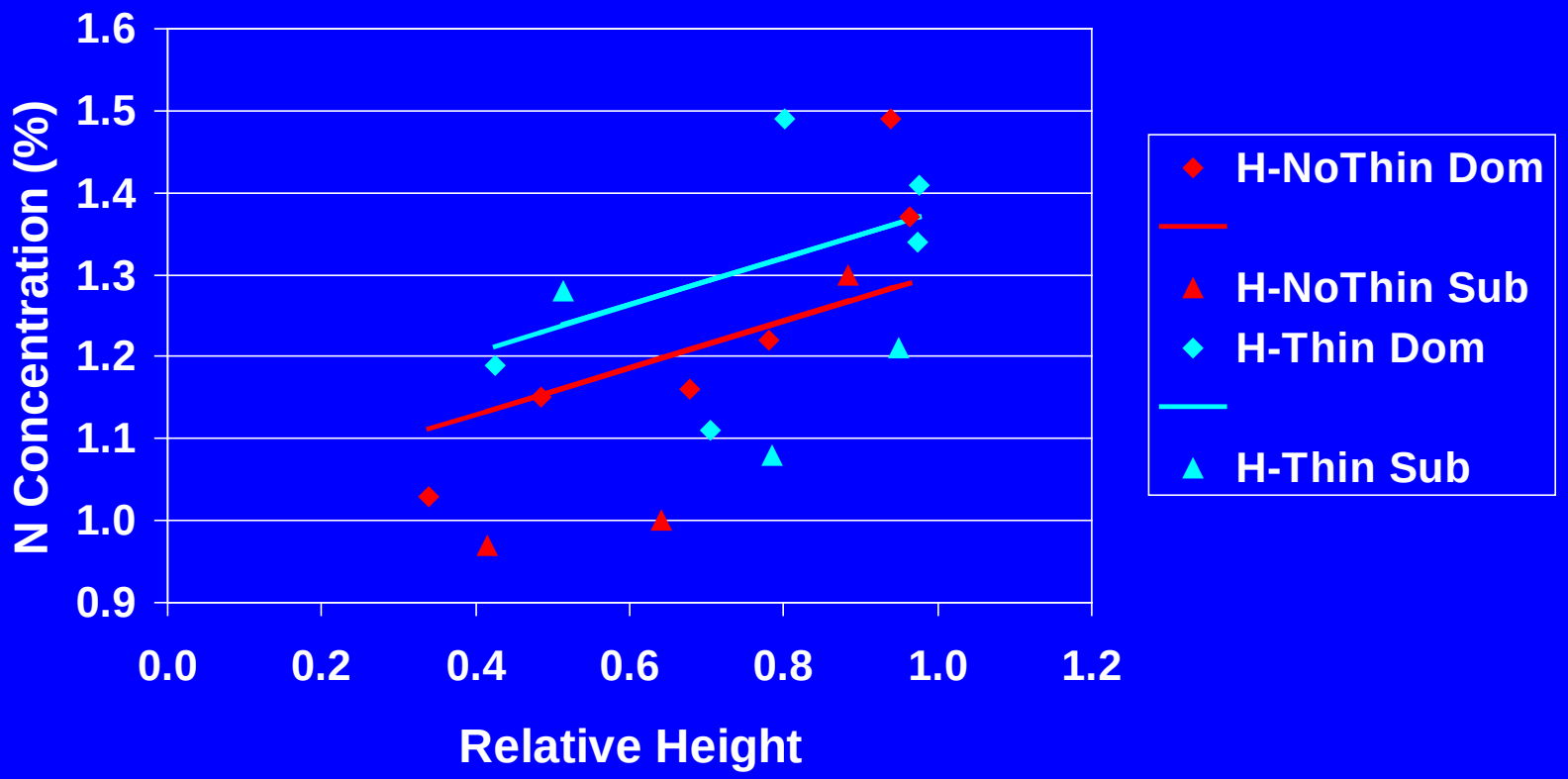
Dominant vs. Subdominant DF Old Foliage N Concentration



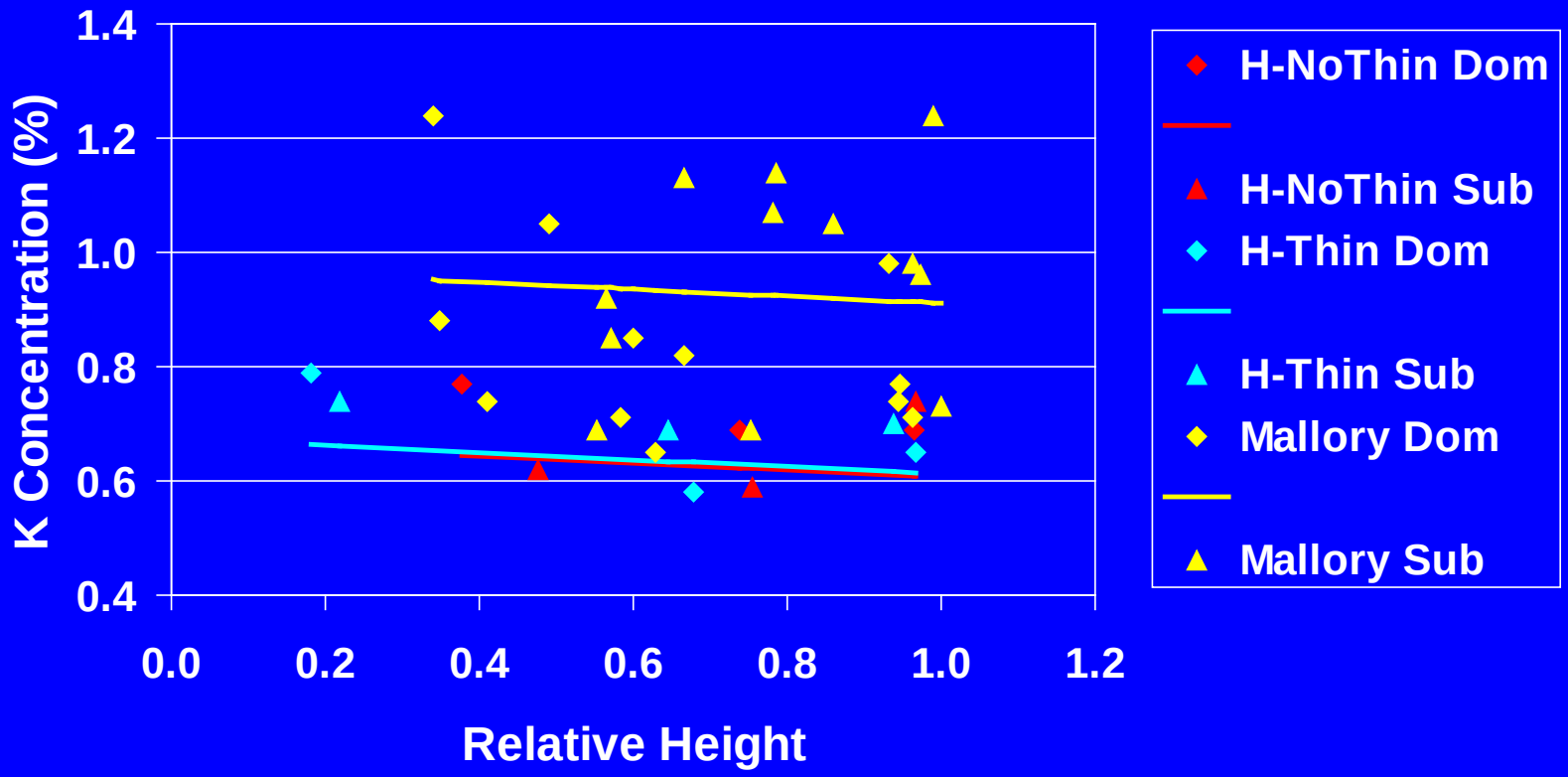
Dominant vs. Subdominant GF New Foliage N Concentration



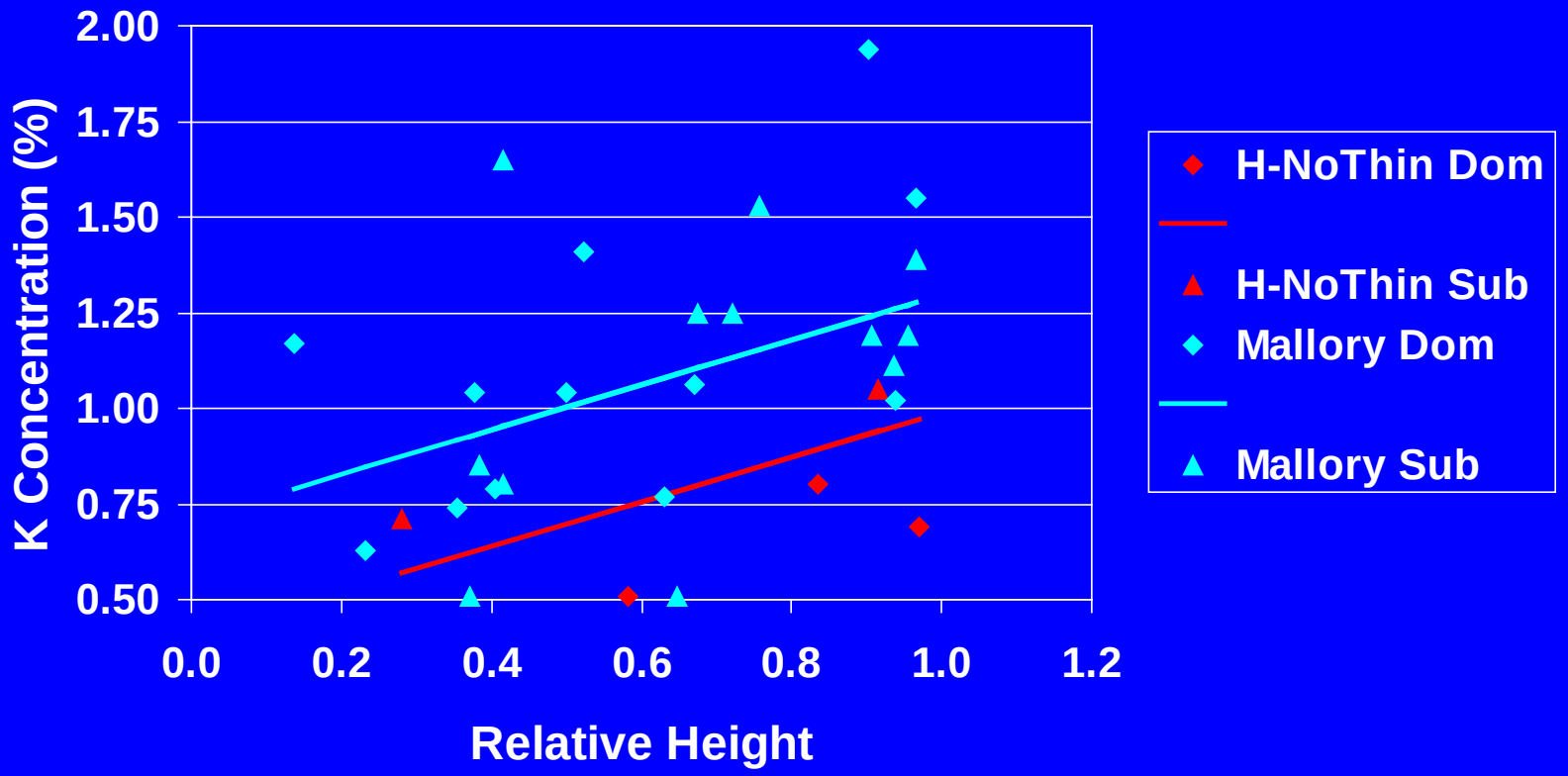
Dominant vs. Subdominant PP New Foliage N Concentration



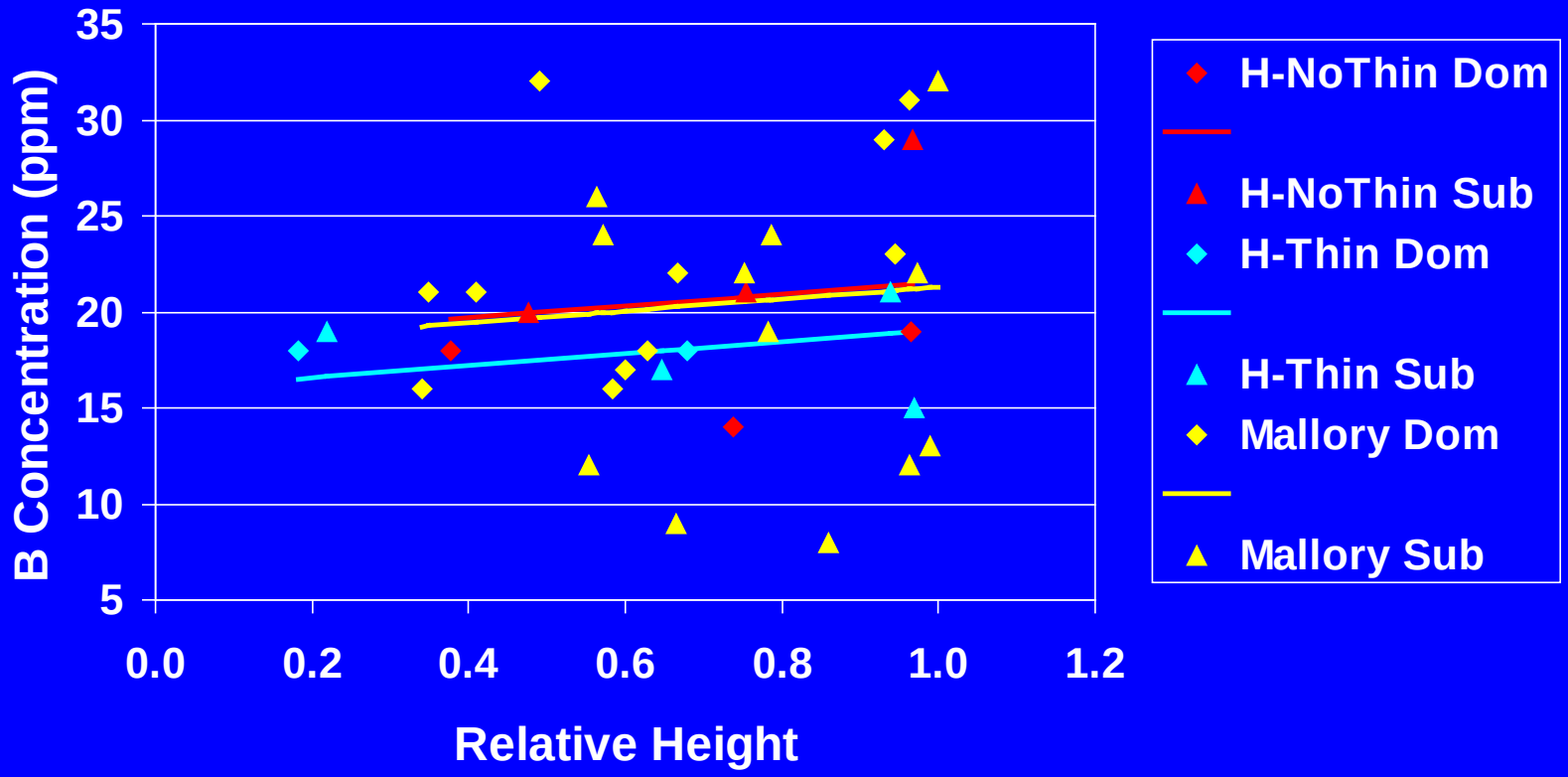
Dominant vs. Subdominant DF New Foliage K Concentration



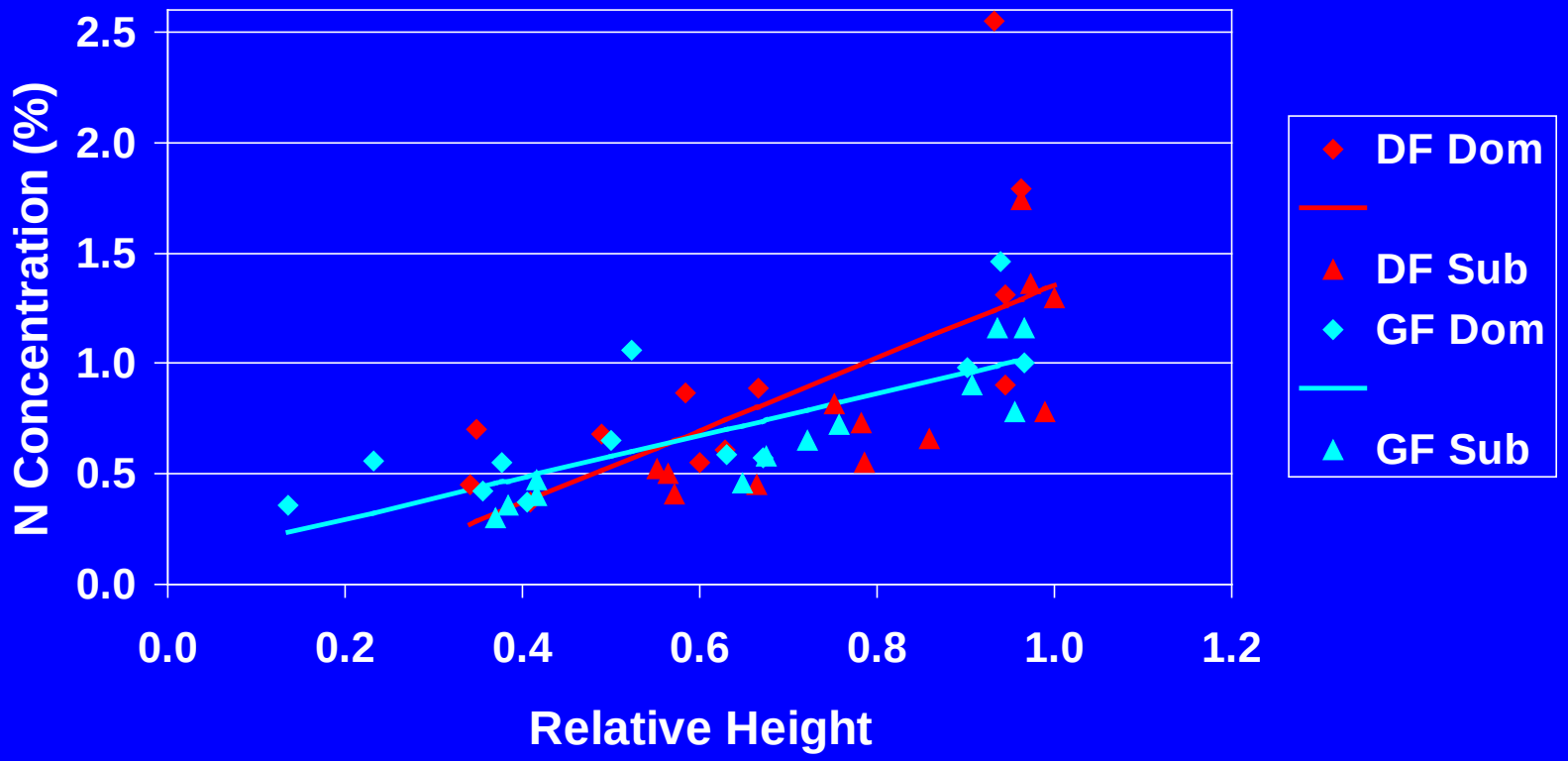
Dominant vs. Subdominant GF New Foliage K Concentration



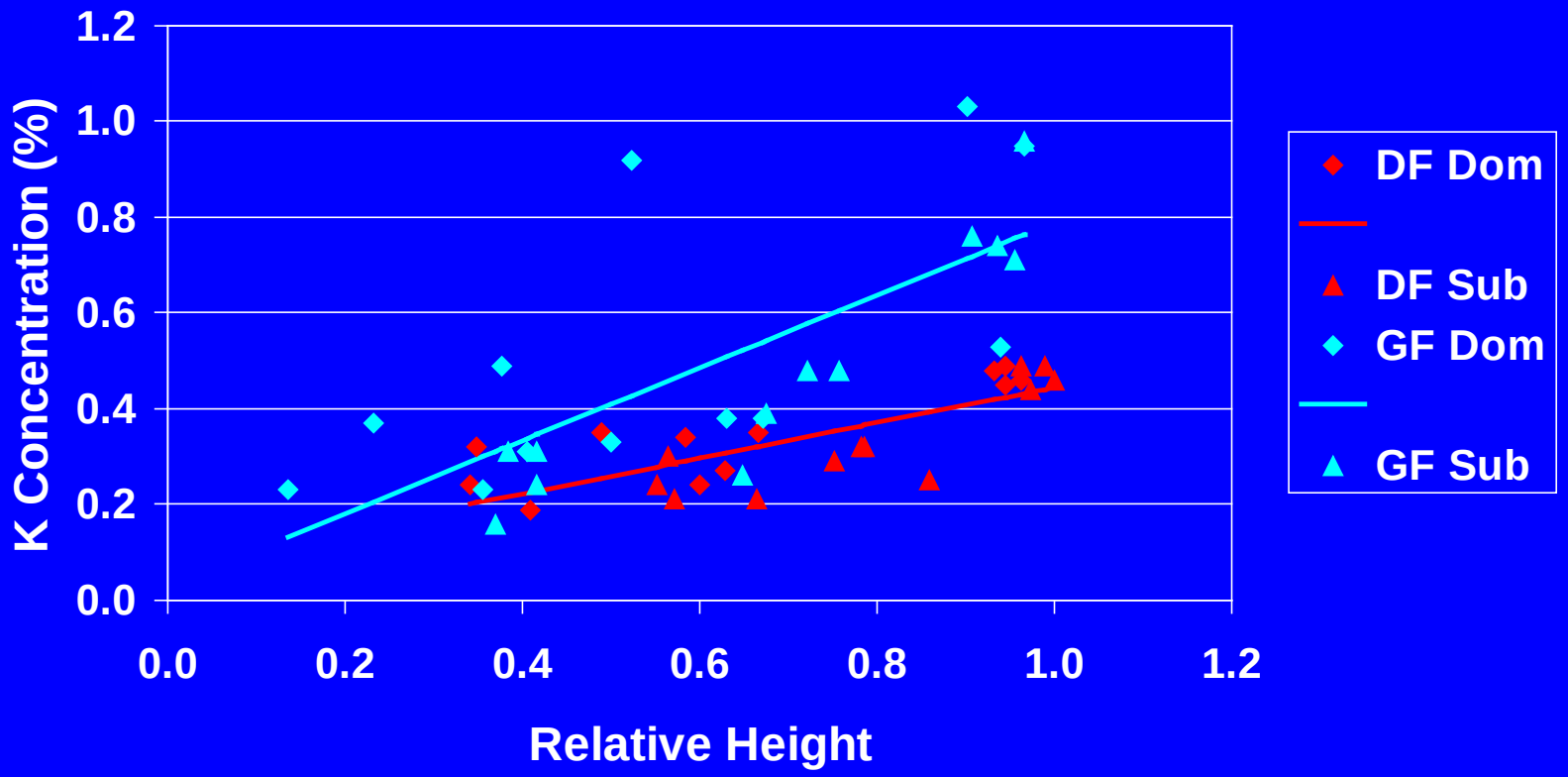
Dominant vs. Subdominant
DF New Foliage B Concentration



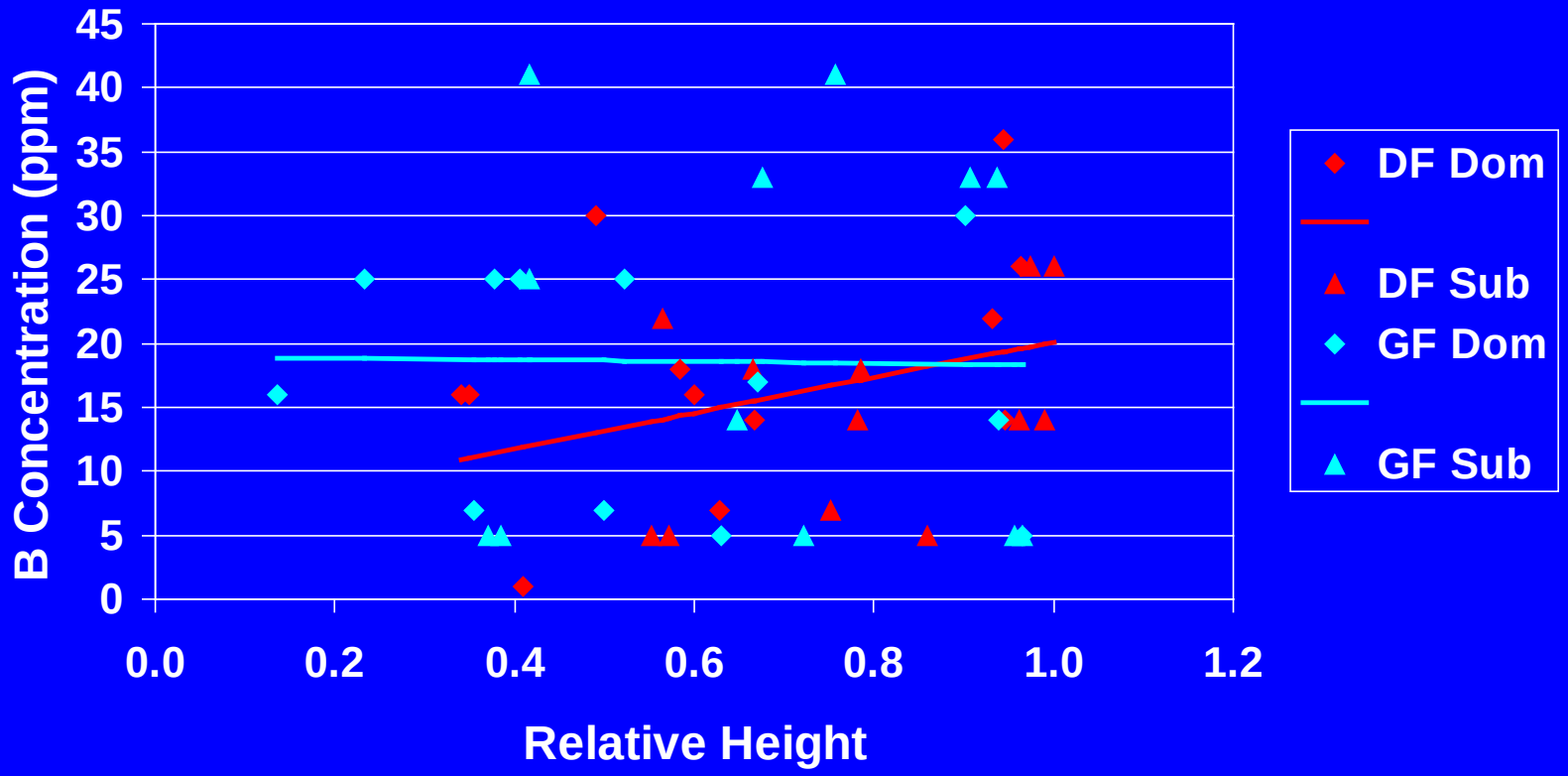
Dominant vs. Subdominant Secondary Branch N Concentration



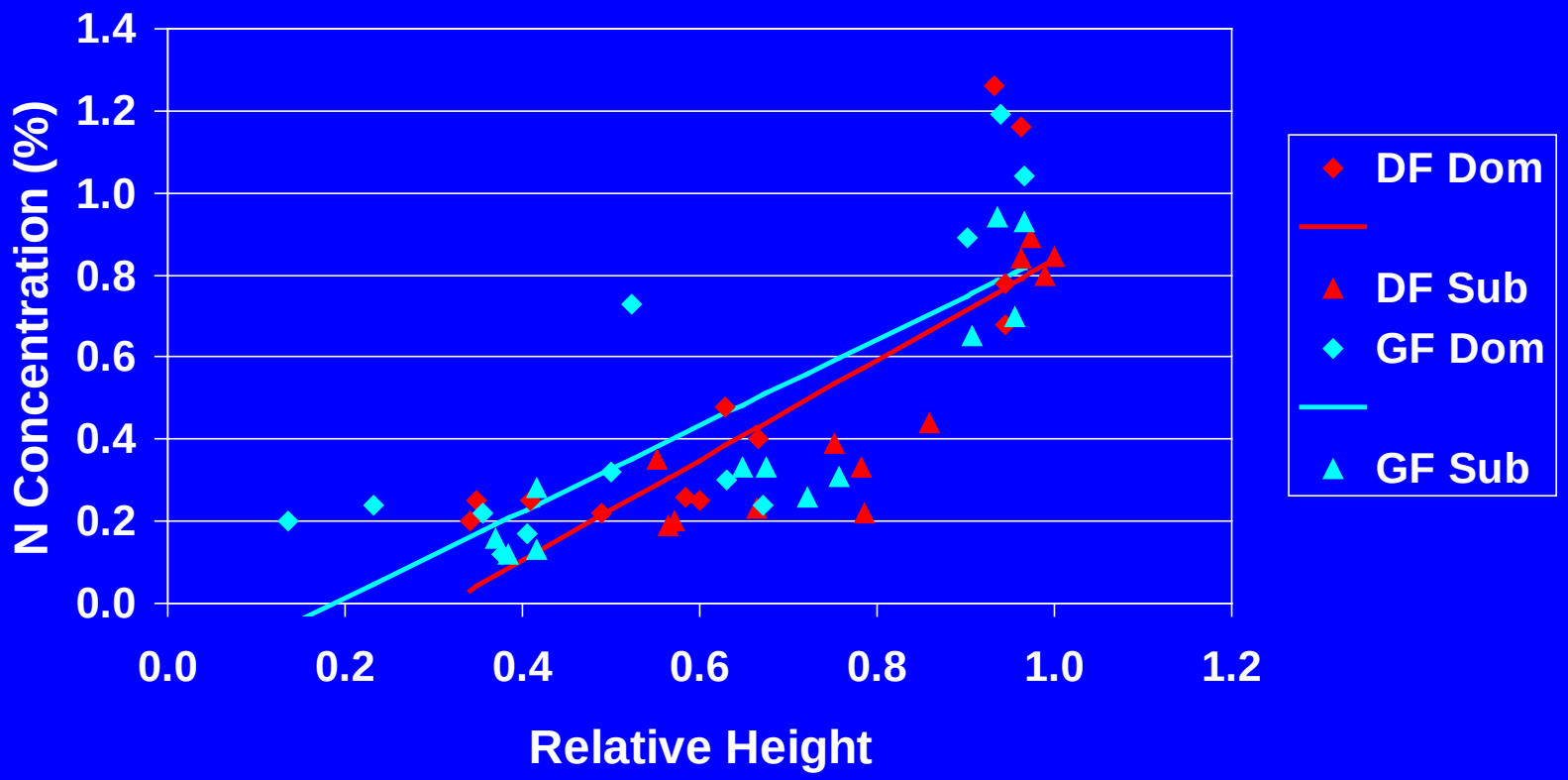
Dominant vs. Subdominant Secondary Branch K Concentration



Dominant vs. Subdominant Secondary Branch B Concentration



Dominant vs. Subdominant Primary Branch N Concentration



Nutrient Variation within Crowns: General Trends

	Relationship to Height		
Tissue	Increase	Decrease	No Trend
Foliage and Secondary Branches	N, P, S, Zn Mg and K in GF	Mn and Ca in GF	B, Fe, Cu K, Ca, Mg, and Mn in DF and PP
Primary Branches	N, P, S, K Ca, Mg, and Mn in GF Zn in DF	Fe Cu and Zn in DF	Mn and Ca in DF Cu in GF

Additional Data

- Foliage, branch, bark and wood (in lab)
  - DF and PP from control and NK-fertilized plots on two Forest Health sites
  - DF, PP, and GF branch samples from the Heppner fuels reduction study
- Forest floor, litter traps, clip plots (in lab)
  - Control and NK-fertilized plots from two Forest Health sites
  - Control, whole-tree removal and bole-only removal on two Forest Service LTSP plots
- Soil ion-exchange capsules
  - Forest Health and LTSP plots
  - Analysis complete; to be presented

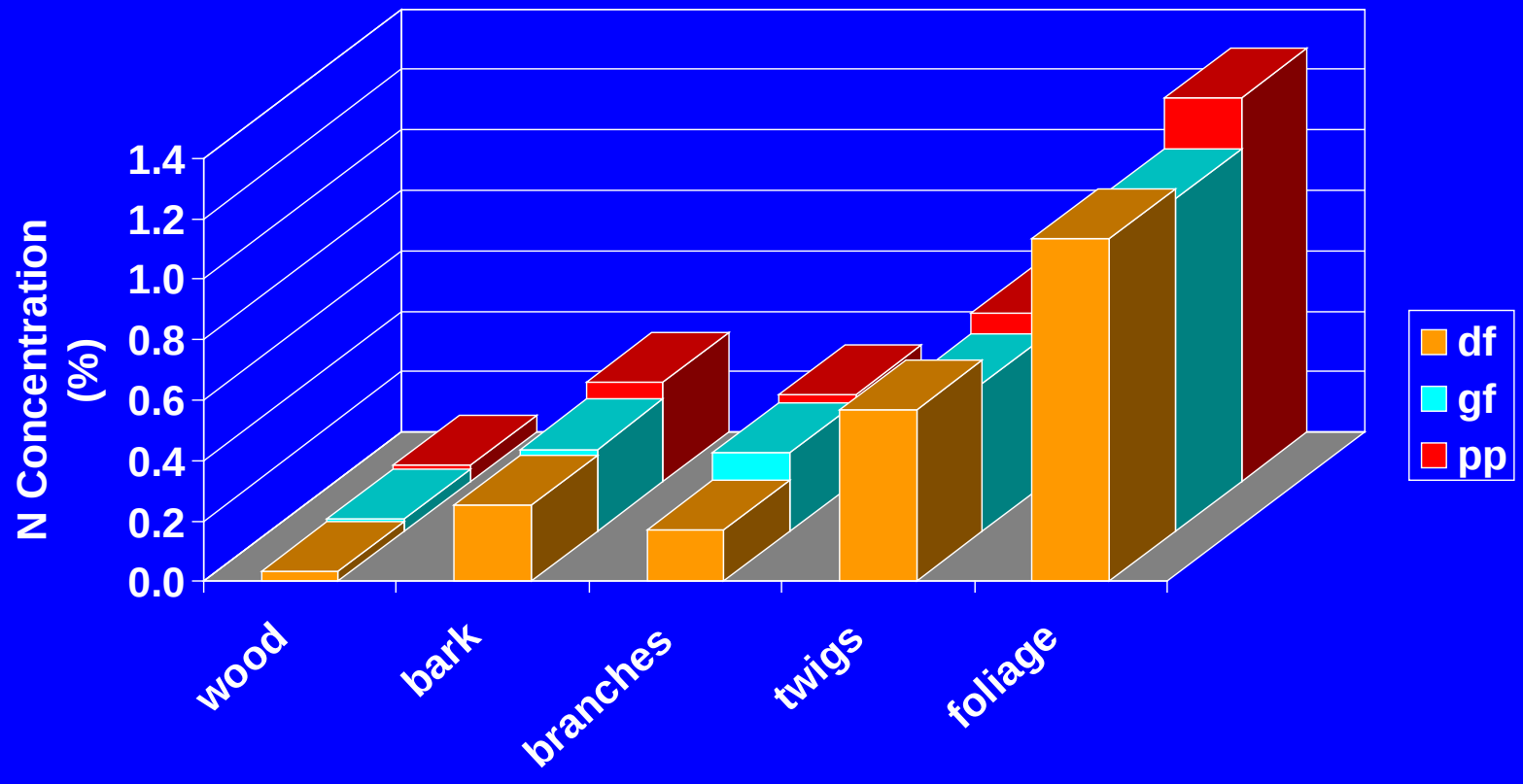
Additional Work

- Incorporate the height-nutrient concentration relationship into our tree nutrient bookkeeping model
- Develop a bookkeeping model of nutrient movement through slash, possibly using the fire extension of FVS
- Develop a better understanding of nutrient changes in the soil following various treatments
- Evaluate physiological process models for incorporating a relationship between soil nutrition and stand productivity into a nutrient budget model

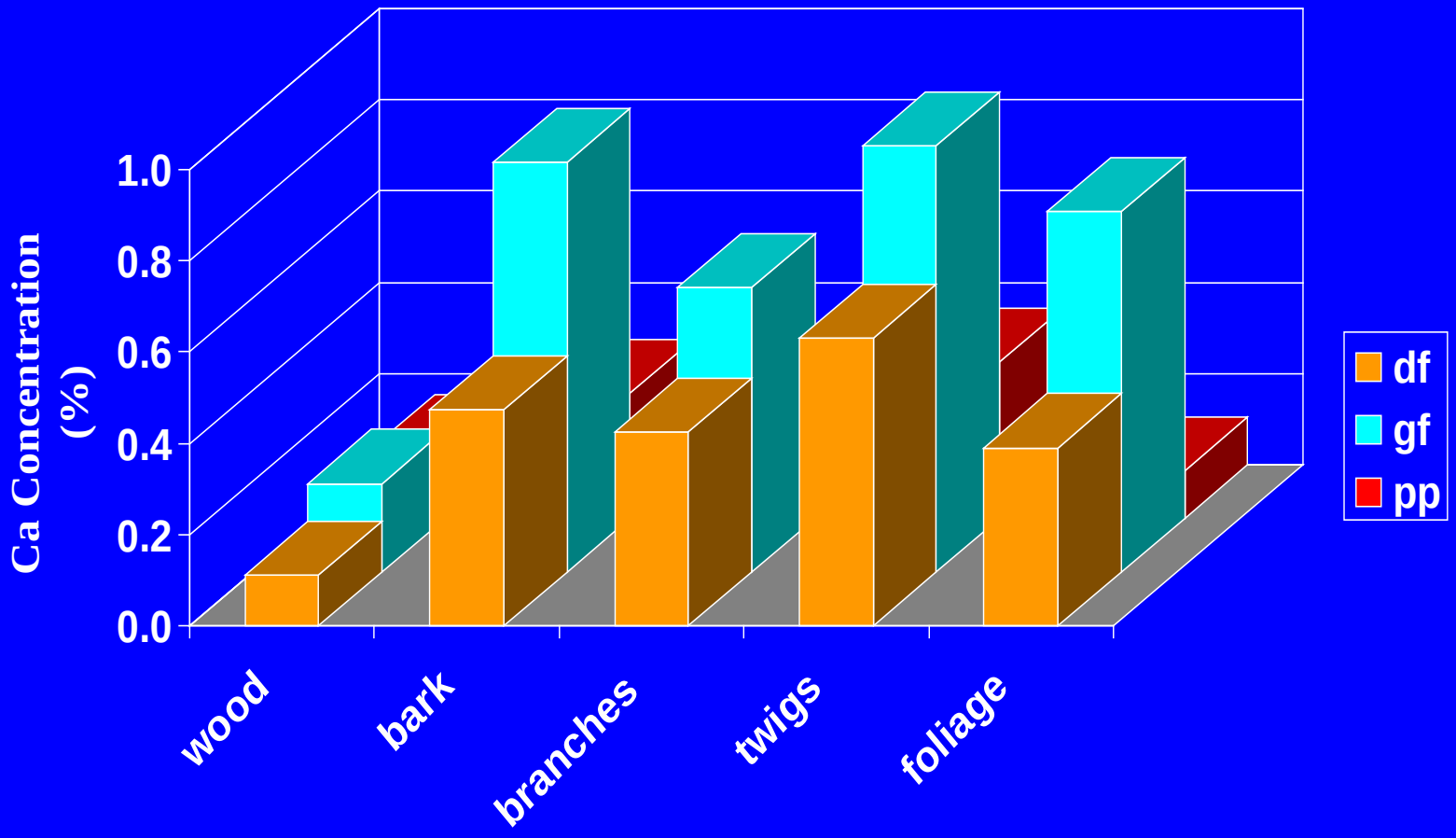
Sites Sampled for Foliar Nutrients

	Tree Species													
	DF					PP		GF				LPP		
	Vegetation Series													
ock Type	DF	GF	RC	WH	AF	DF	GF	GF	RC	WH	AF	DF	GF	A
asalt	15	25	5	3		6	12	5	1	2	1		1	1
ranite	11	9	3	1	1	4	2		1			1		3
etasediment	8	6	12	2		3	1	1	2					
ixed	17	4	4	1	1	3	4		1			1	1	1
ediment	4	3					2							

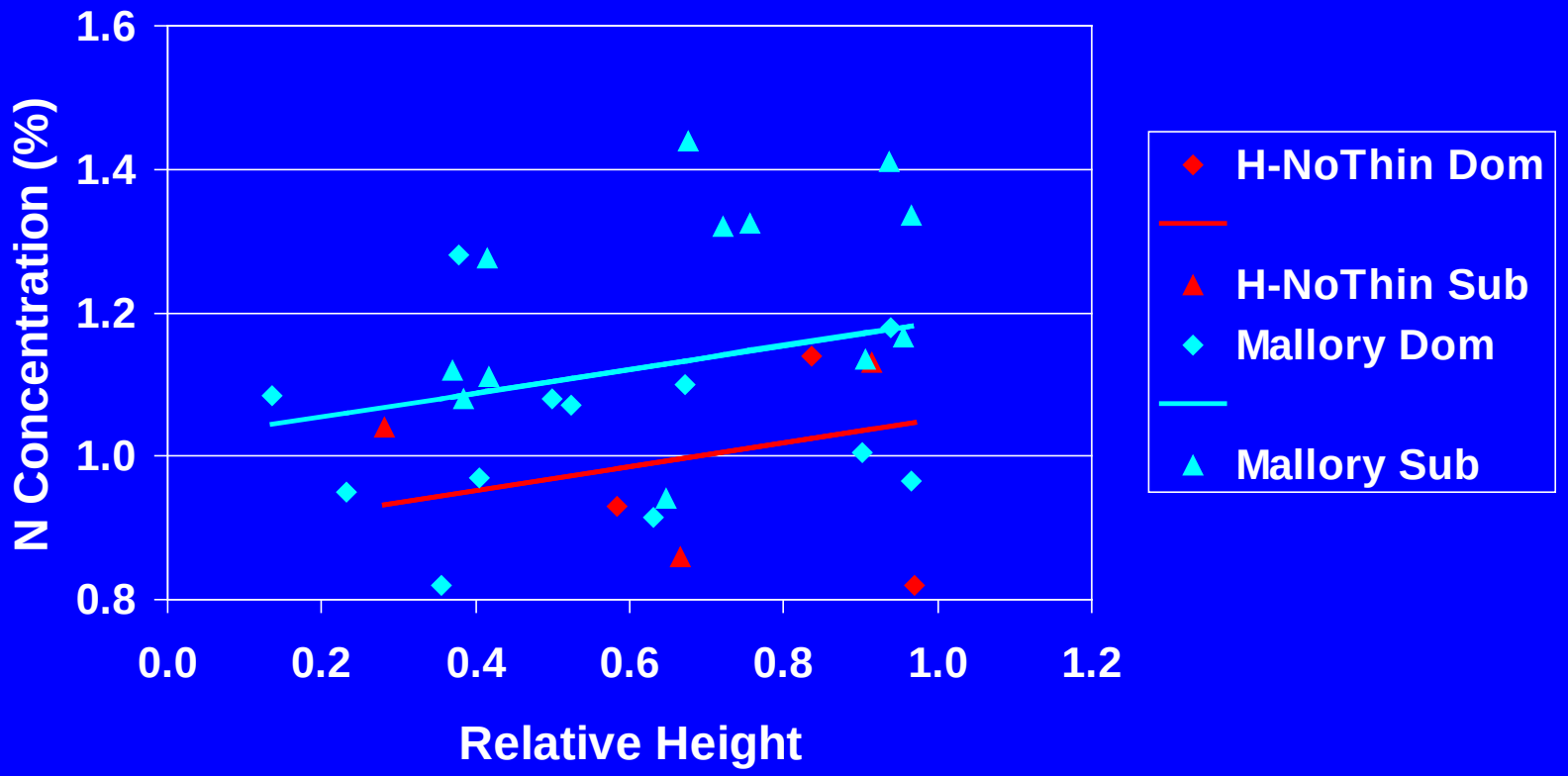
N Concentration by Species and Overstory Component



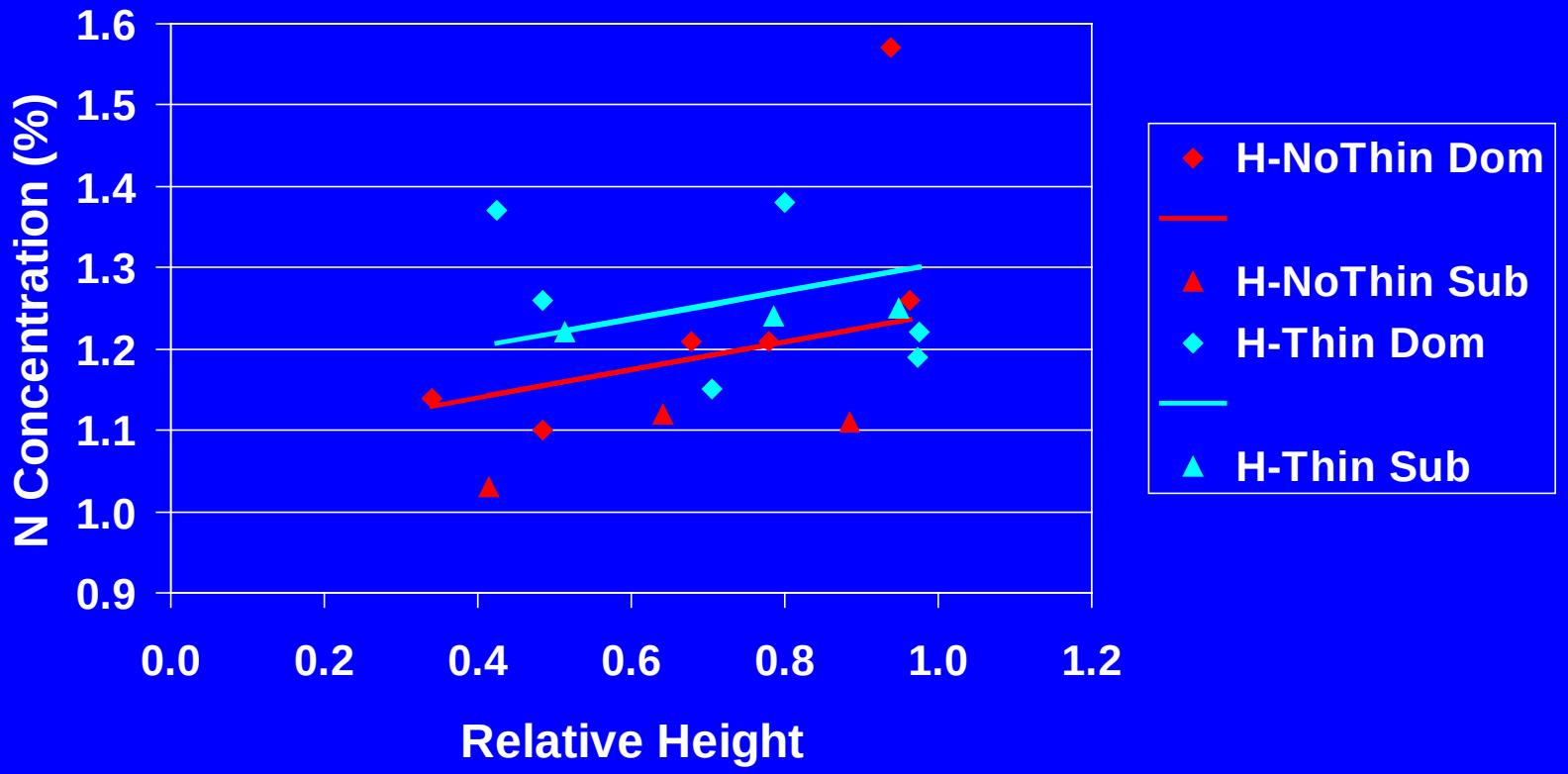
Ca Concentration by Species and Overstory Component



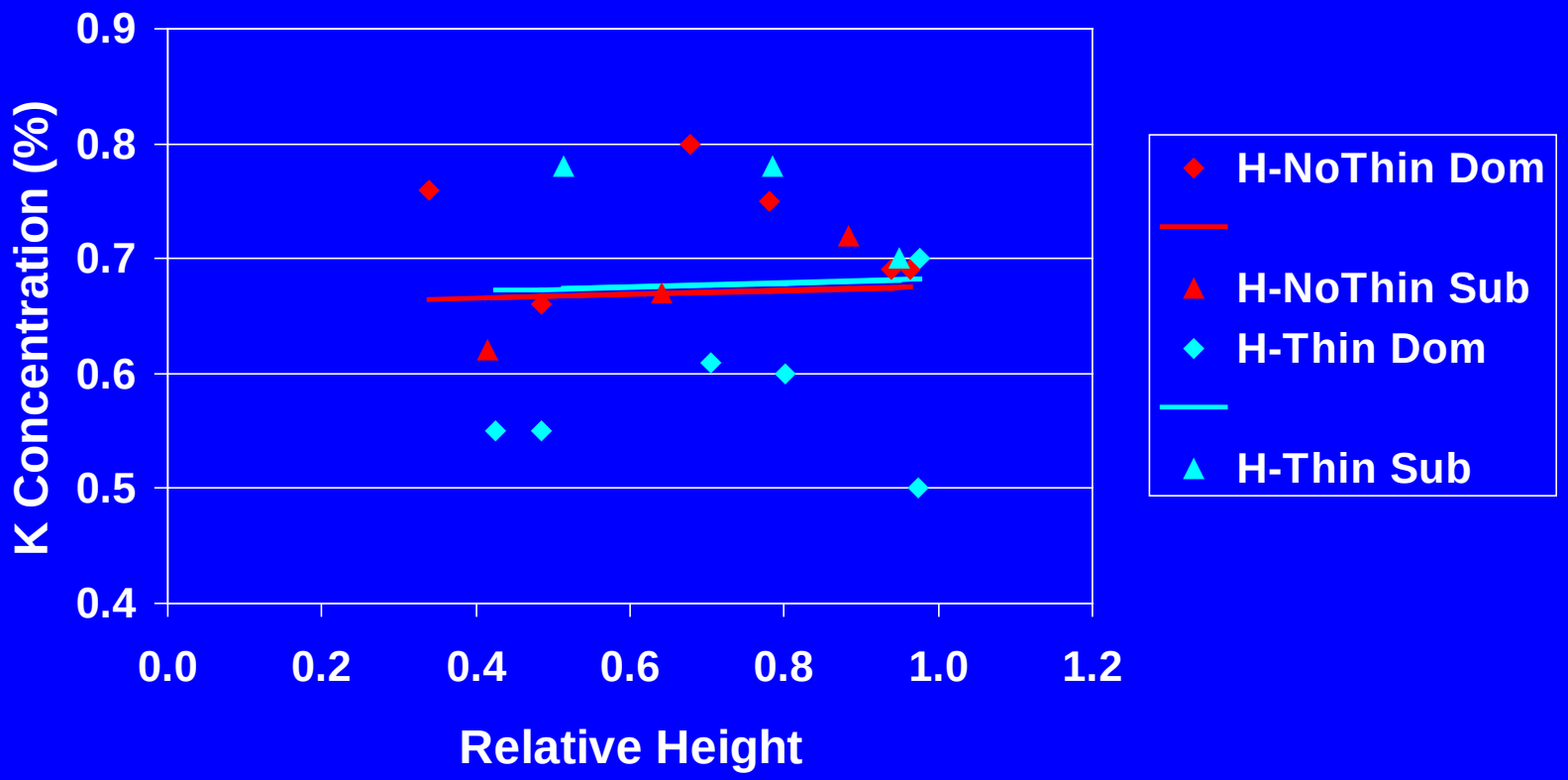
Dominant vs. Subdominant GF Old Foliage N Concentration



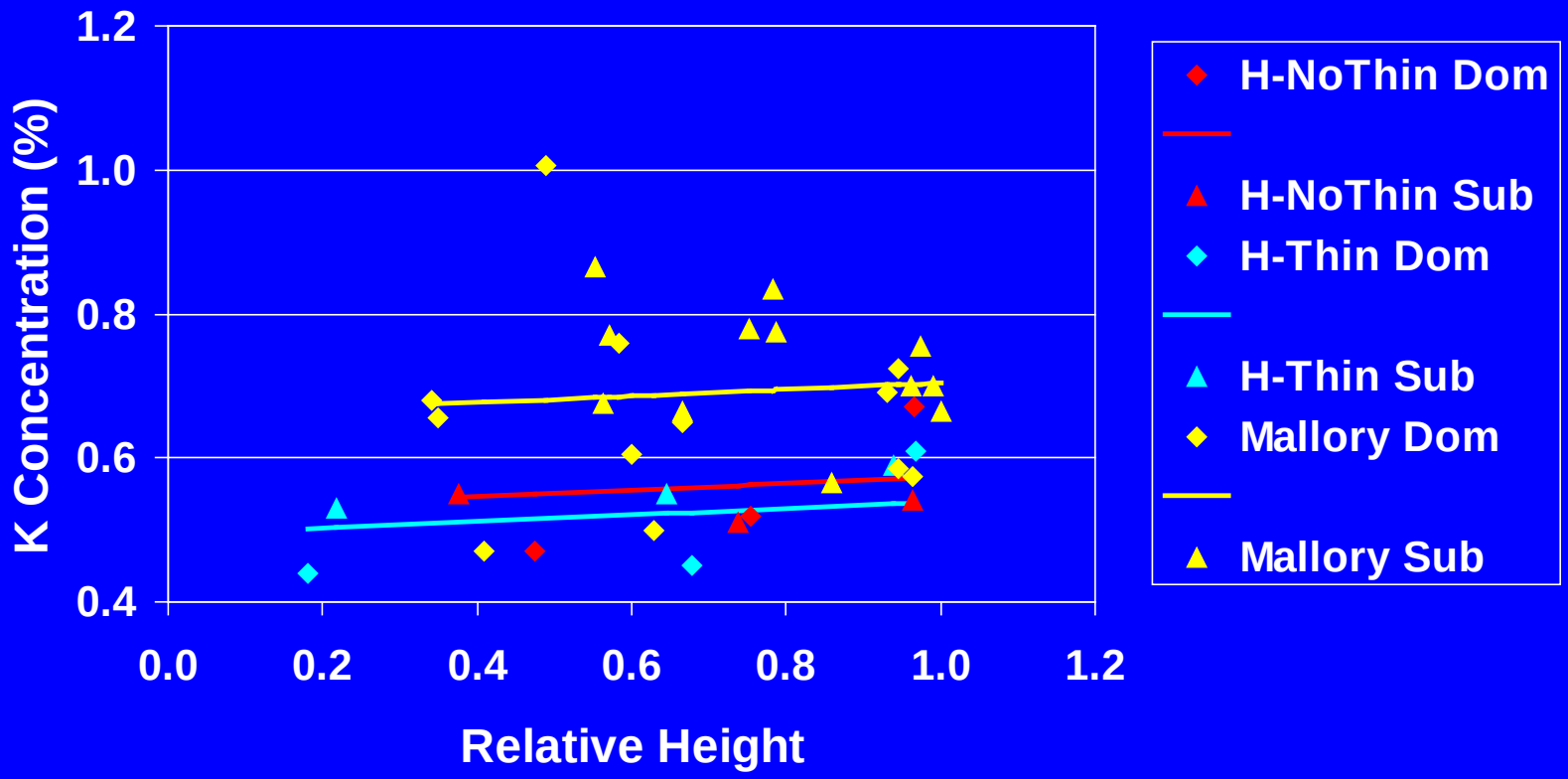
Dominant vs. Subdominant PP Old Foliage N Concentration



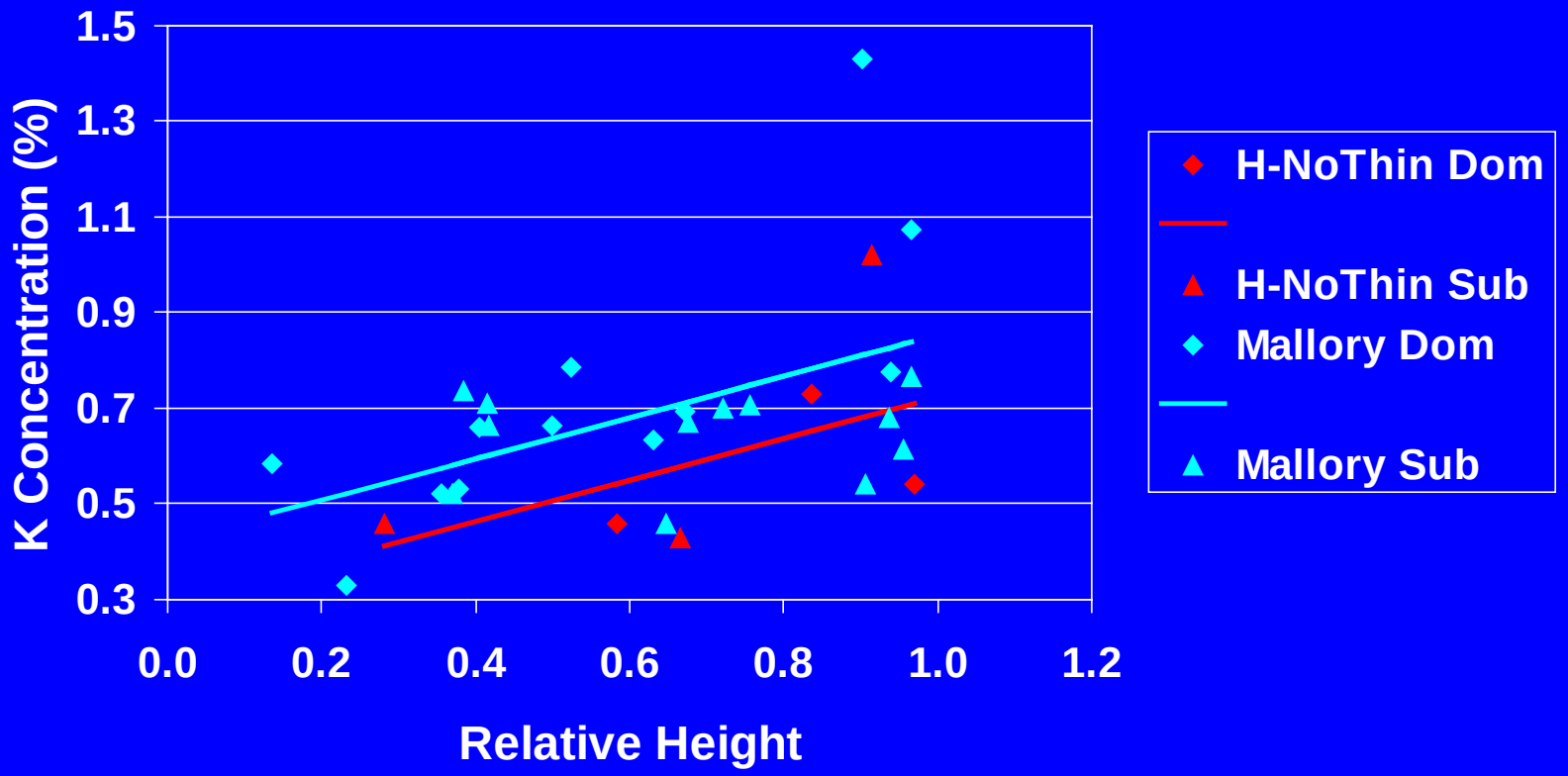
Dominant vs. Subdominant PP New Foliage K Concentration



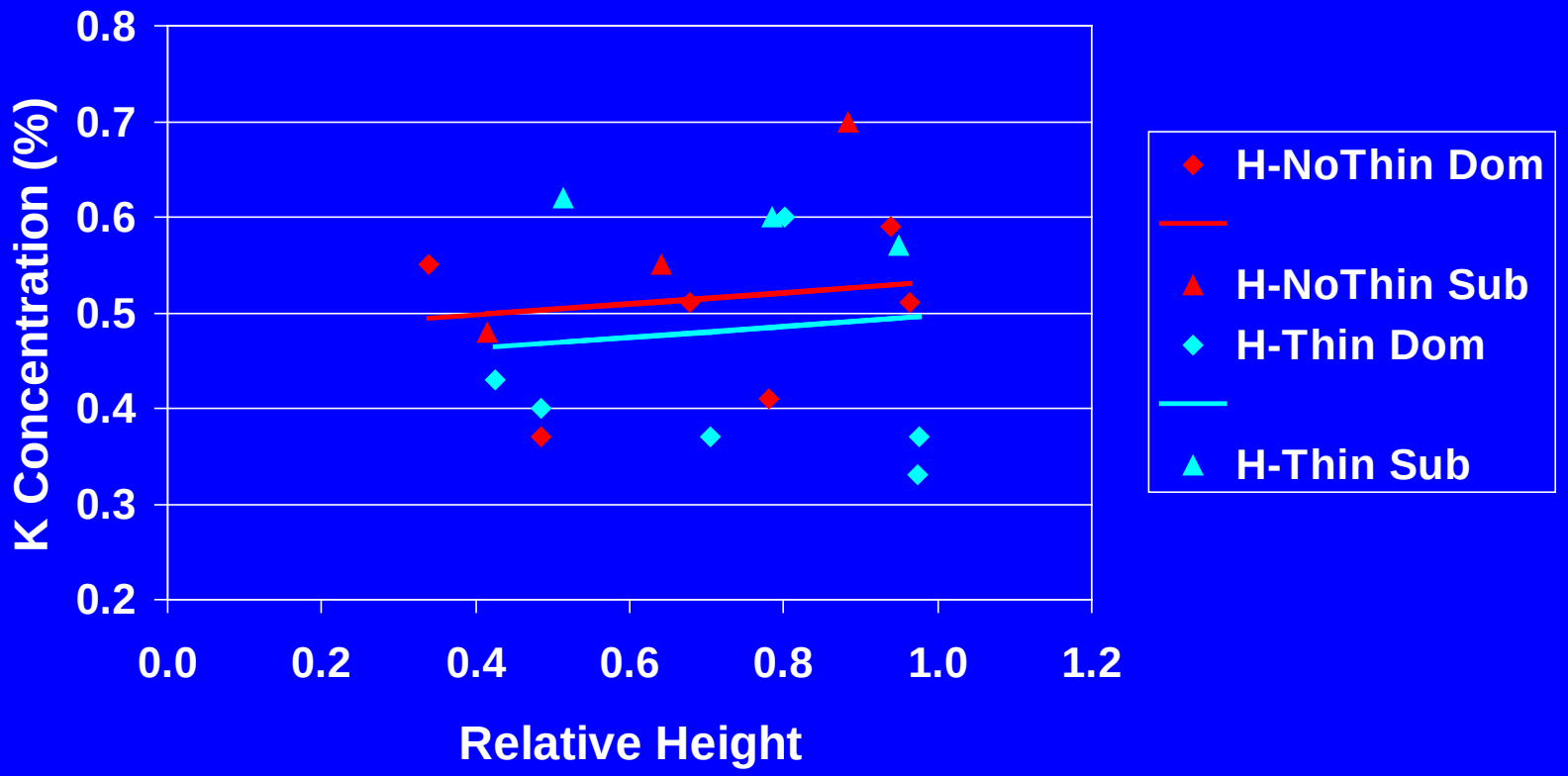
Dominant vs. Subdominant DF Old Foliage K Concentration



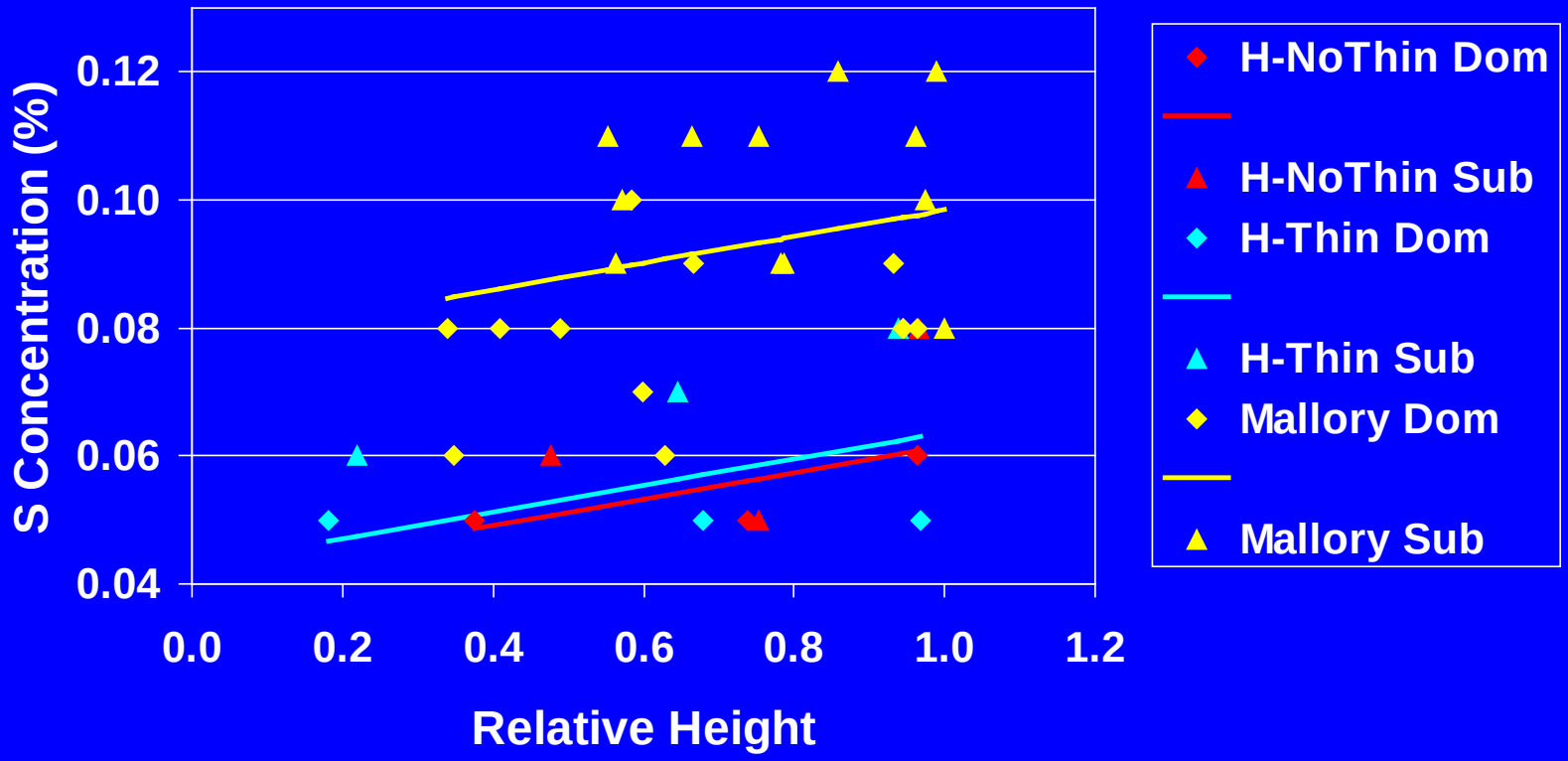
Dominant vs. Subdominant GF Old Foliage K Concentration



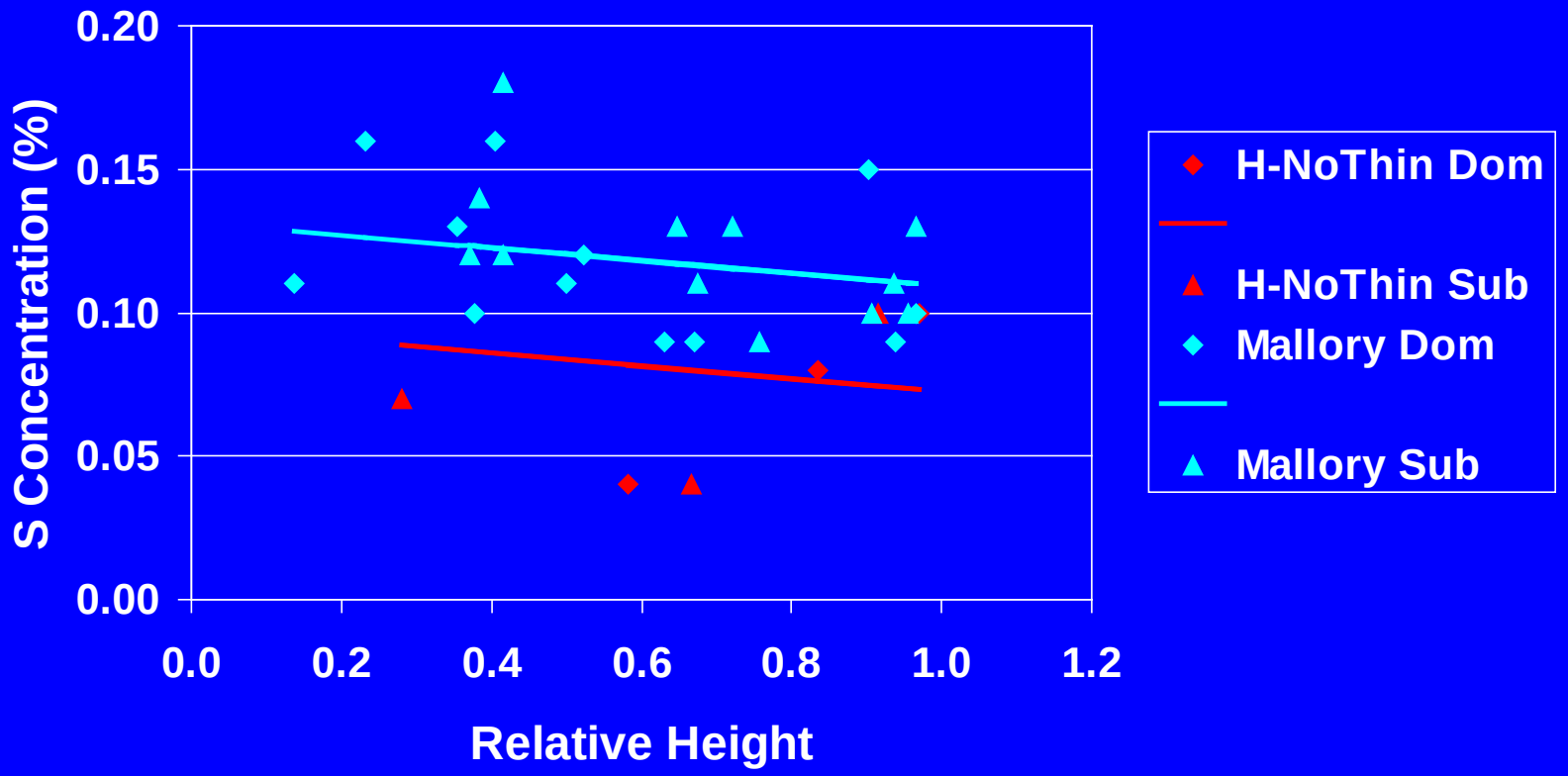
Dominant vs. Subdominant PP Old Foliage K Concentration



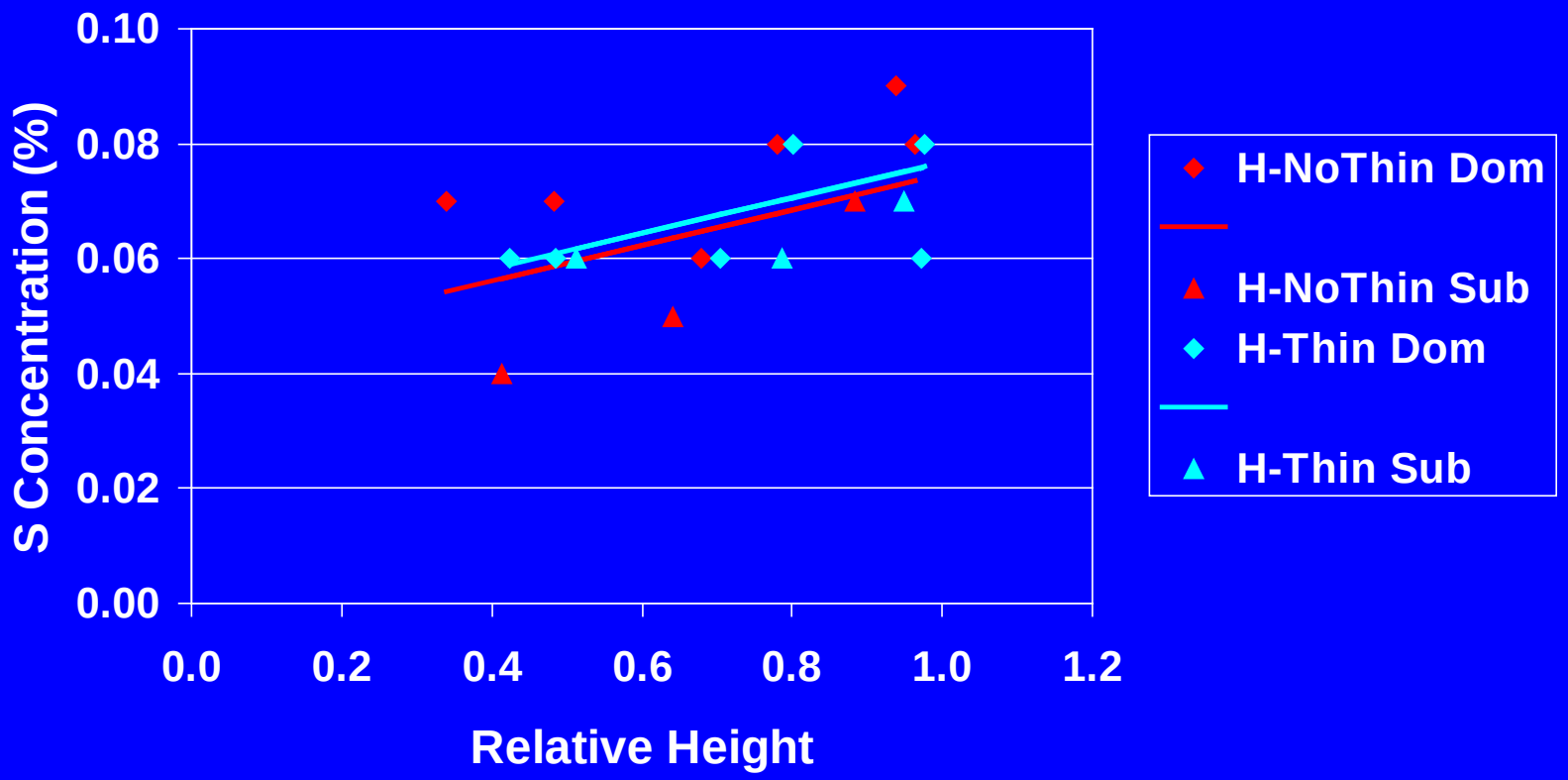
Dominant vs. Subdominant DF New Foliage S Concentration



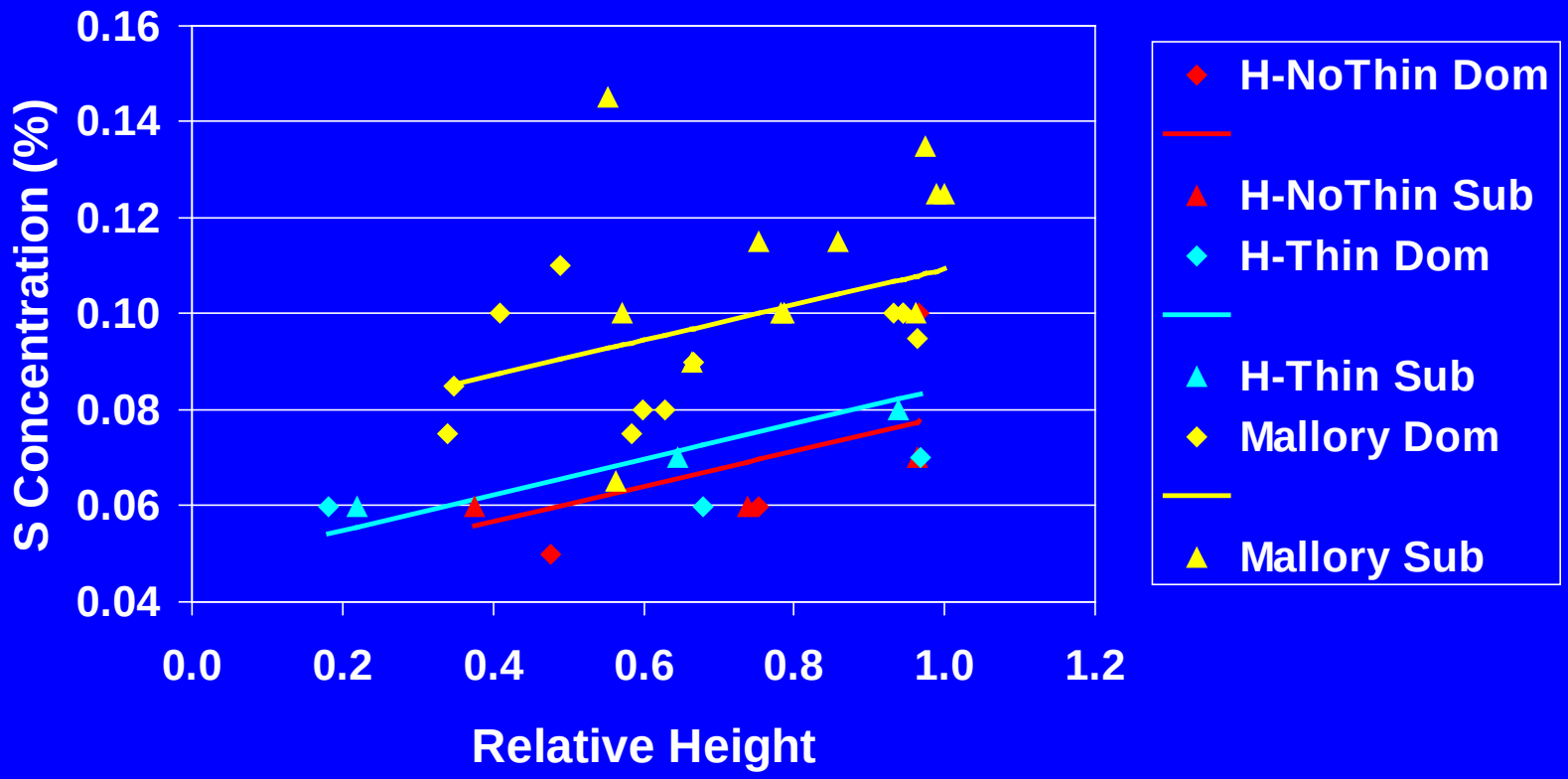
Dominant vs. Subdominant GF New Foliage S Concentration



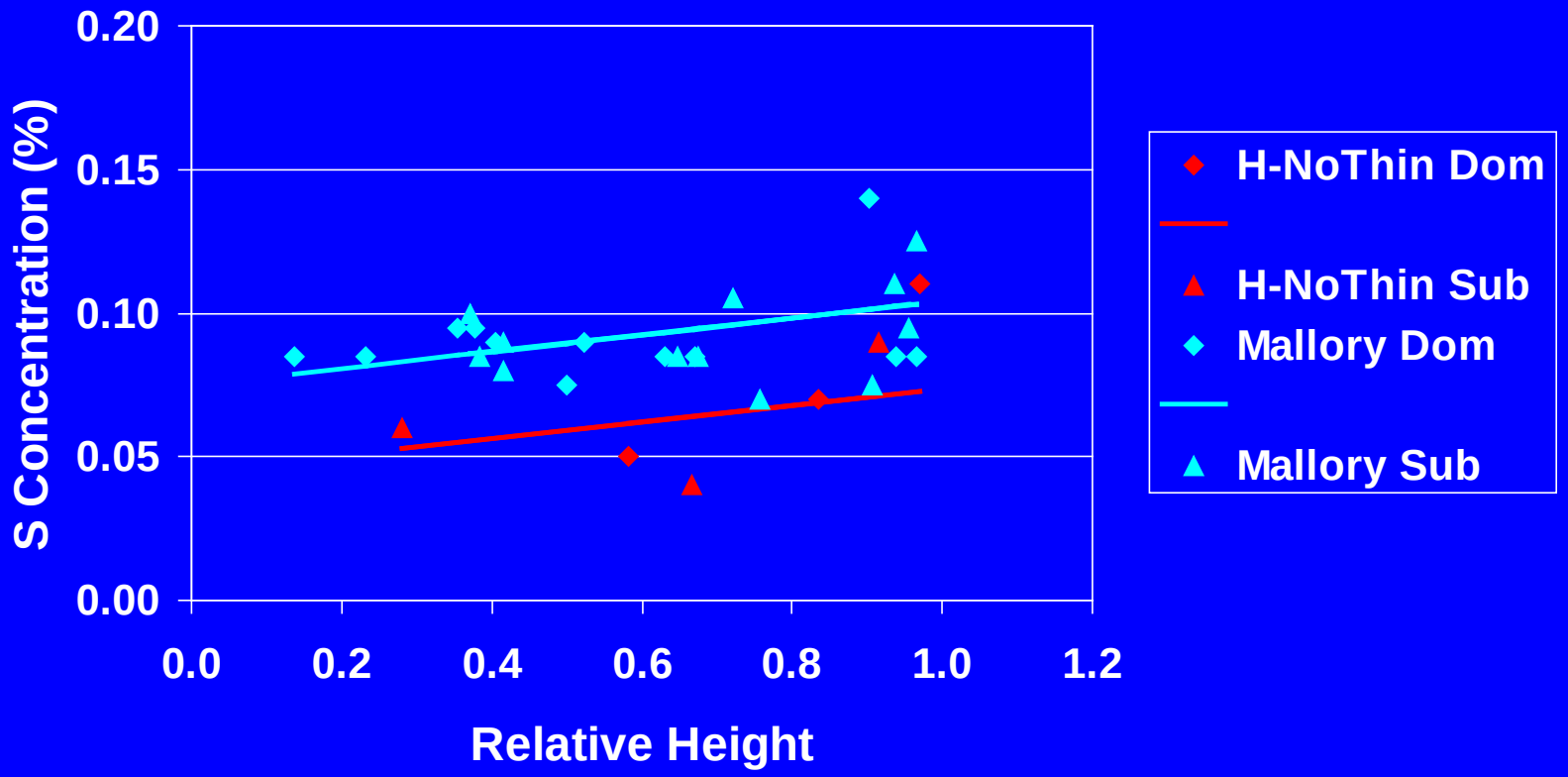
Dominant vs. Subdominant PP New Foliage S Concentration



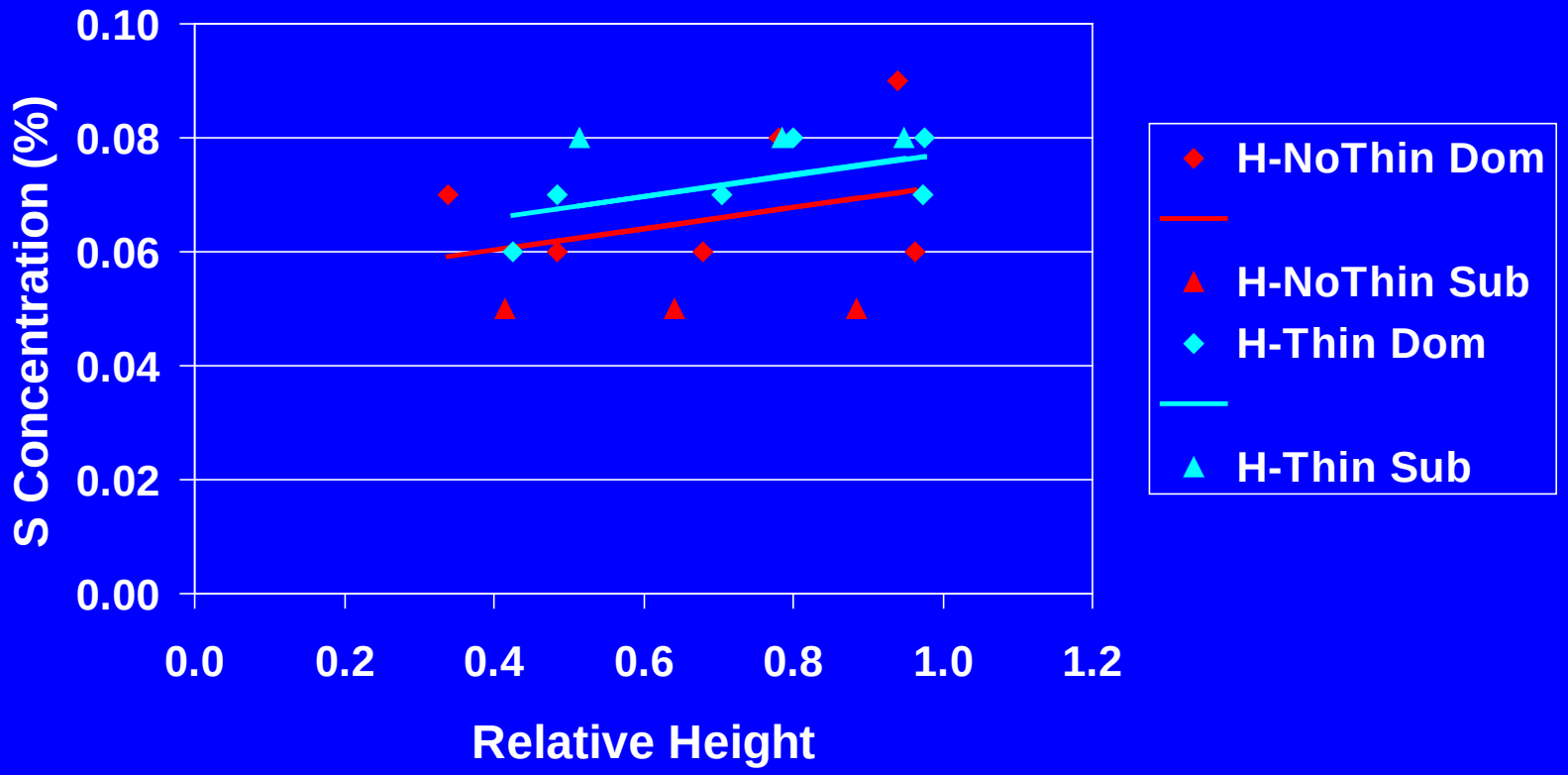
Dominant vs. Subdominant DF Old Foliage S Concentration



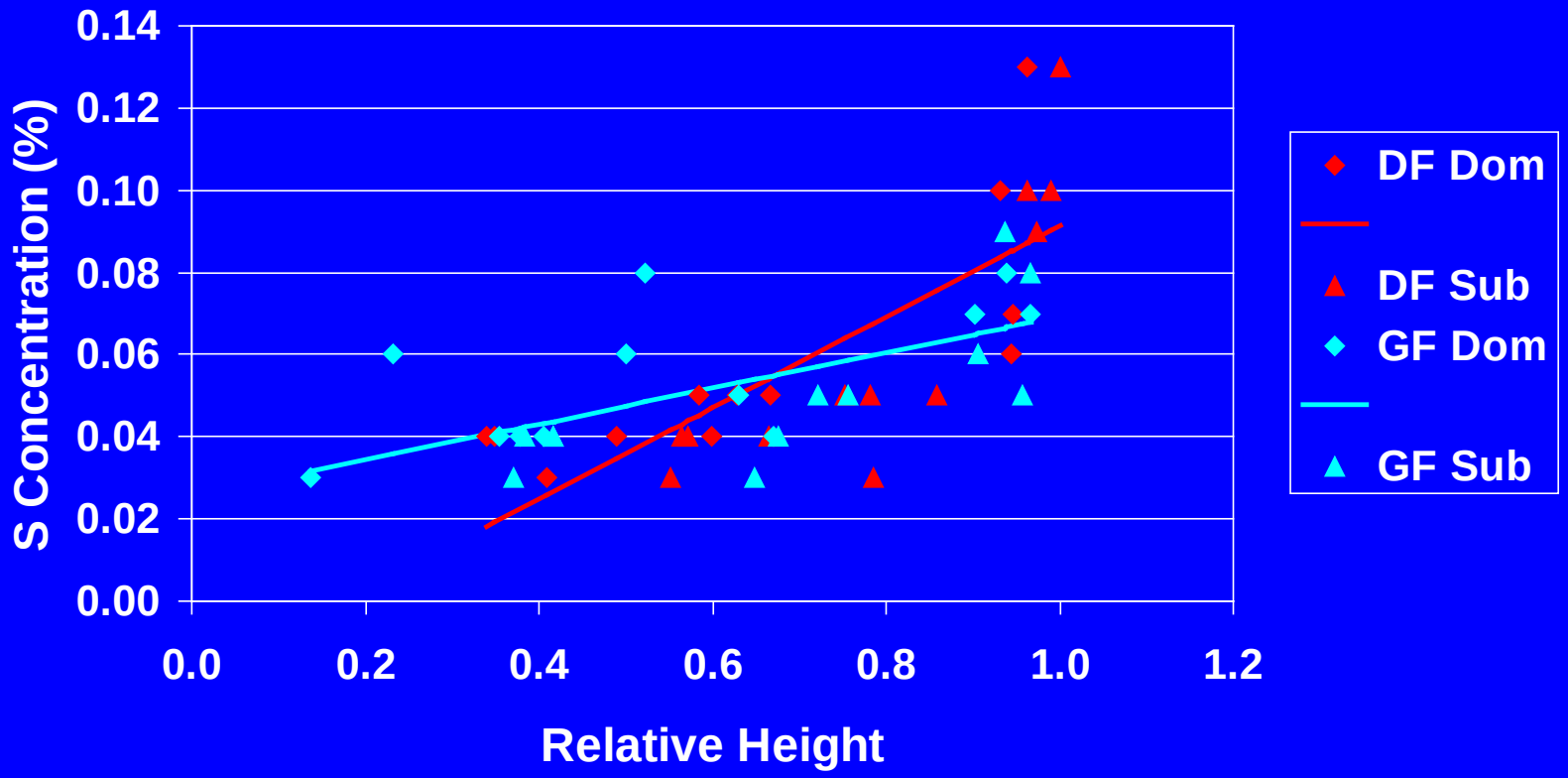
Dominant vs. Subdominant GF Old Foliage S Concentration



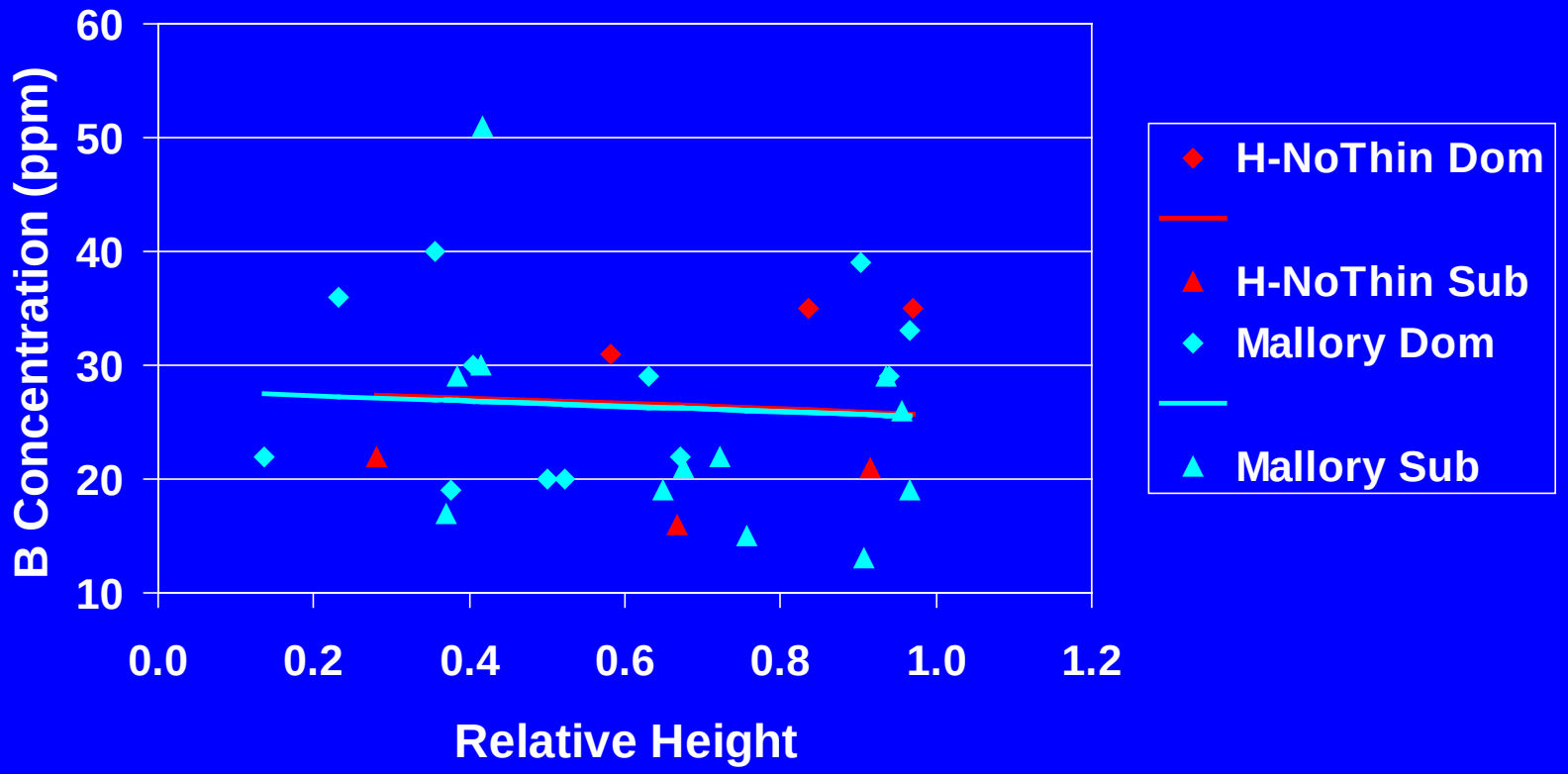
Dominant vs. Subdominant PP Old Foliage S Concentration



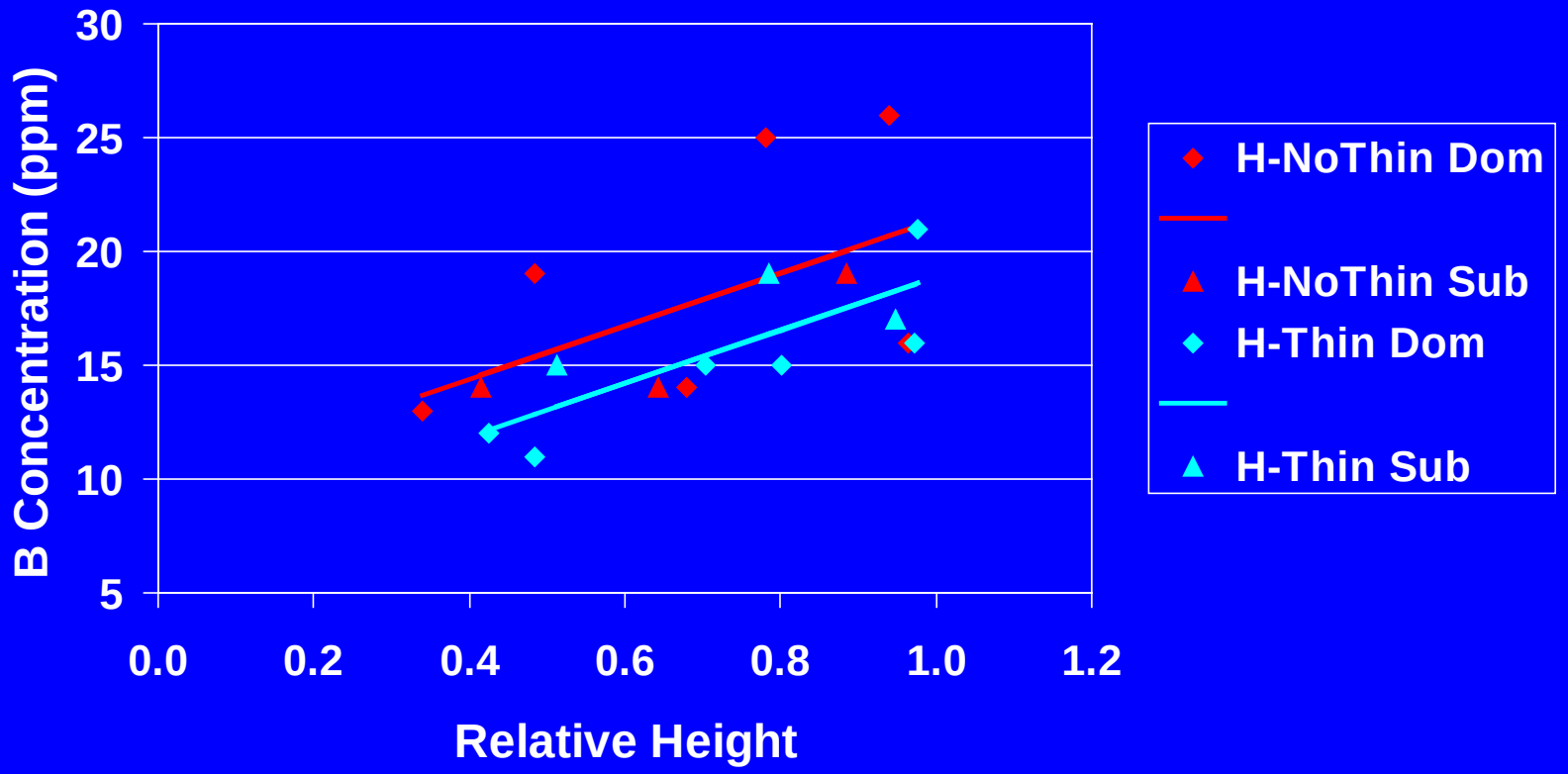
Dominant vs. Subdominant Secondary Branch S Concentration



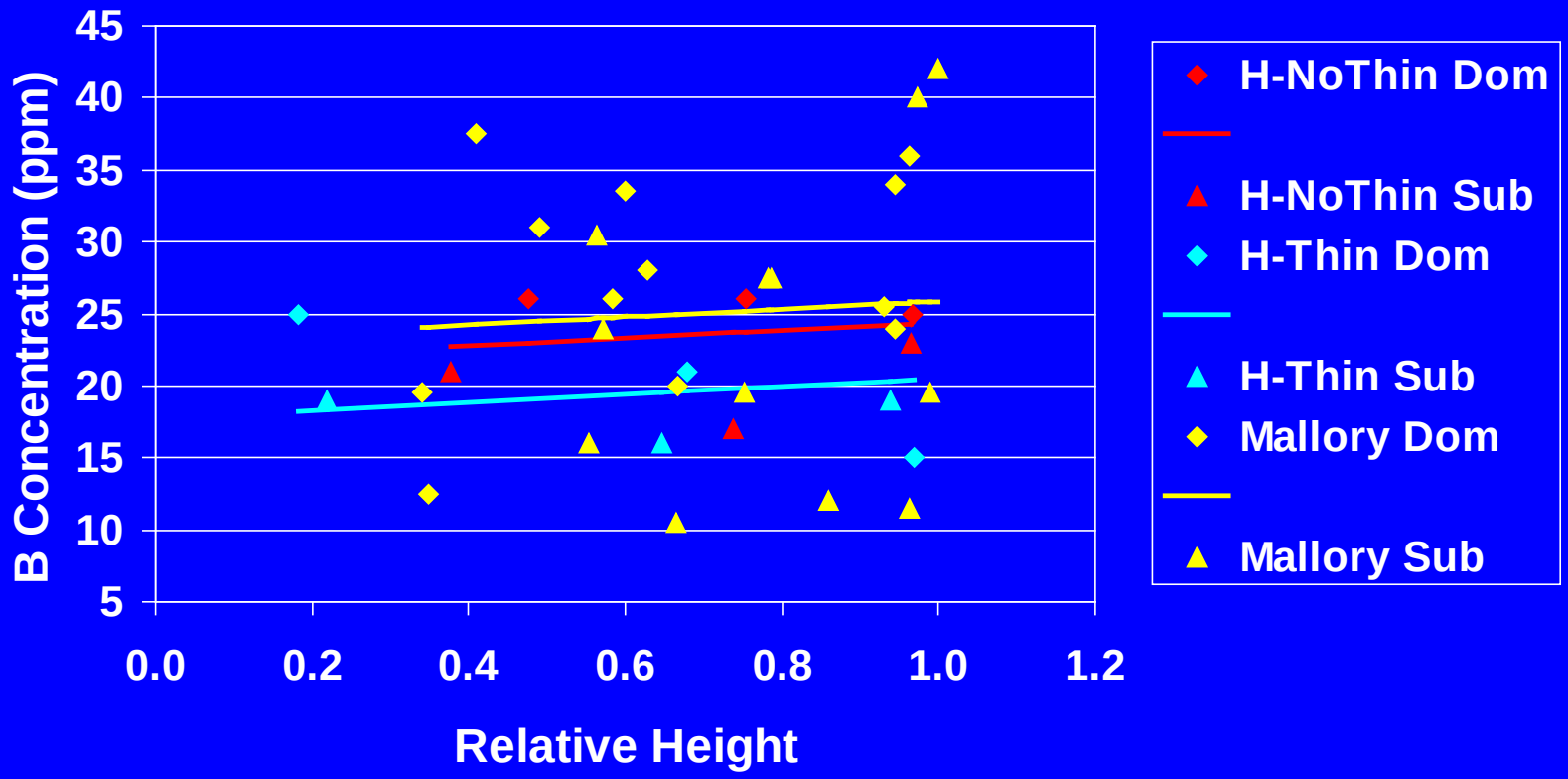
Dominant vs. Subdominant GF New Foliage B Concentration



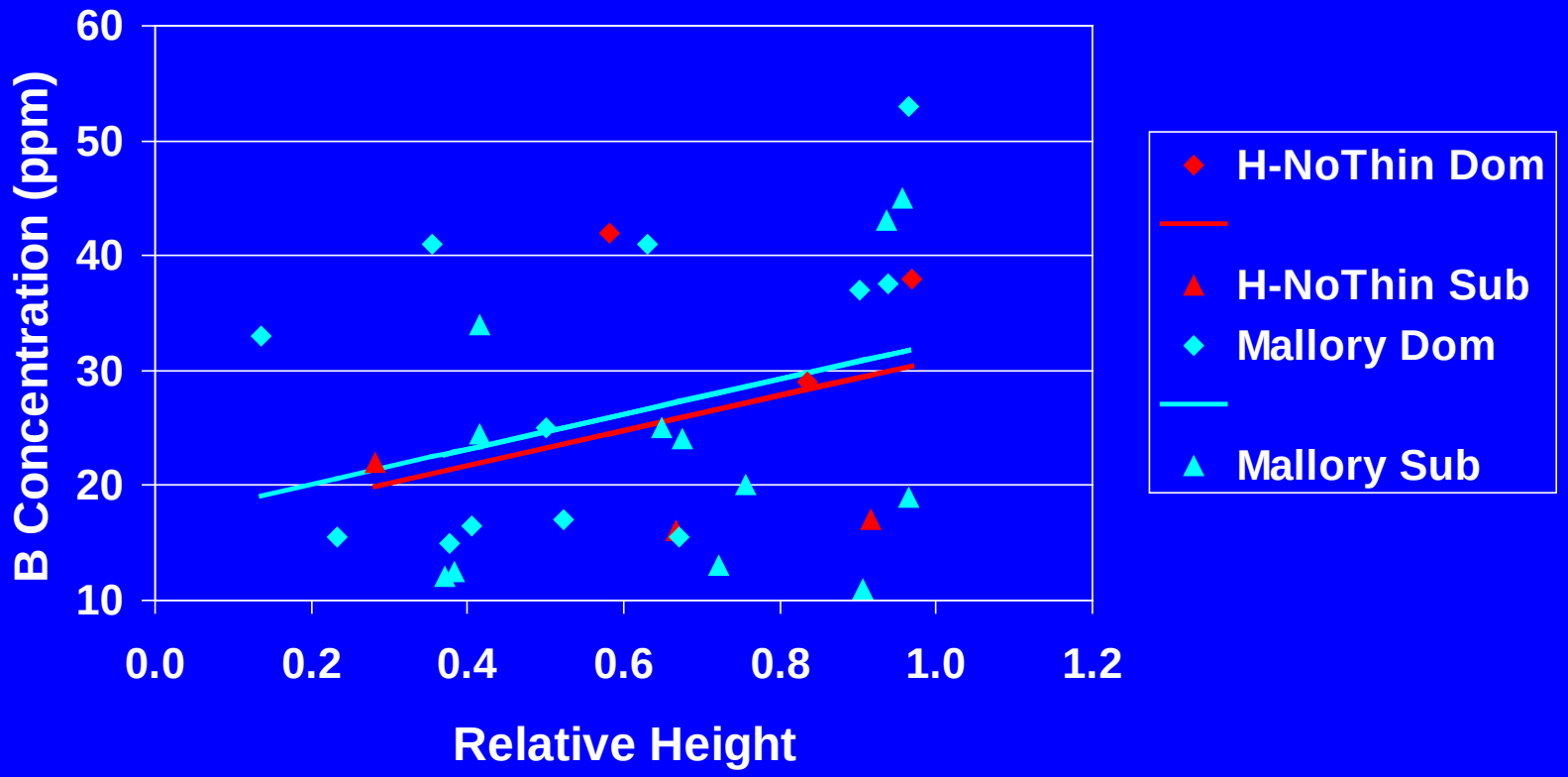
Dominant vs. Subdominant PP New Foliage B Concentration



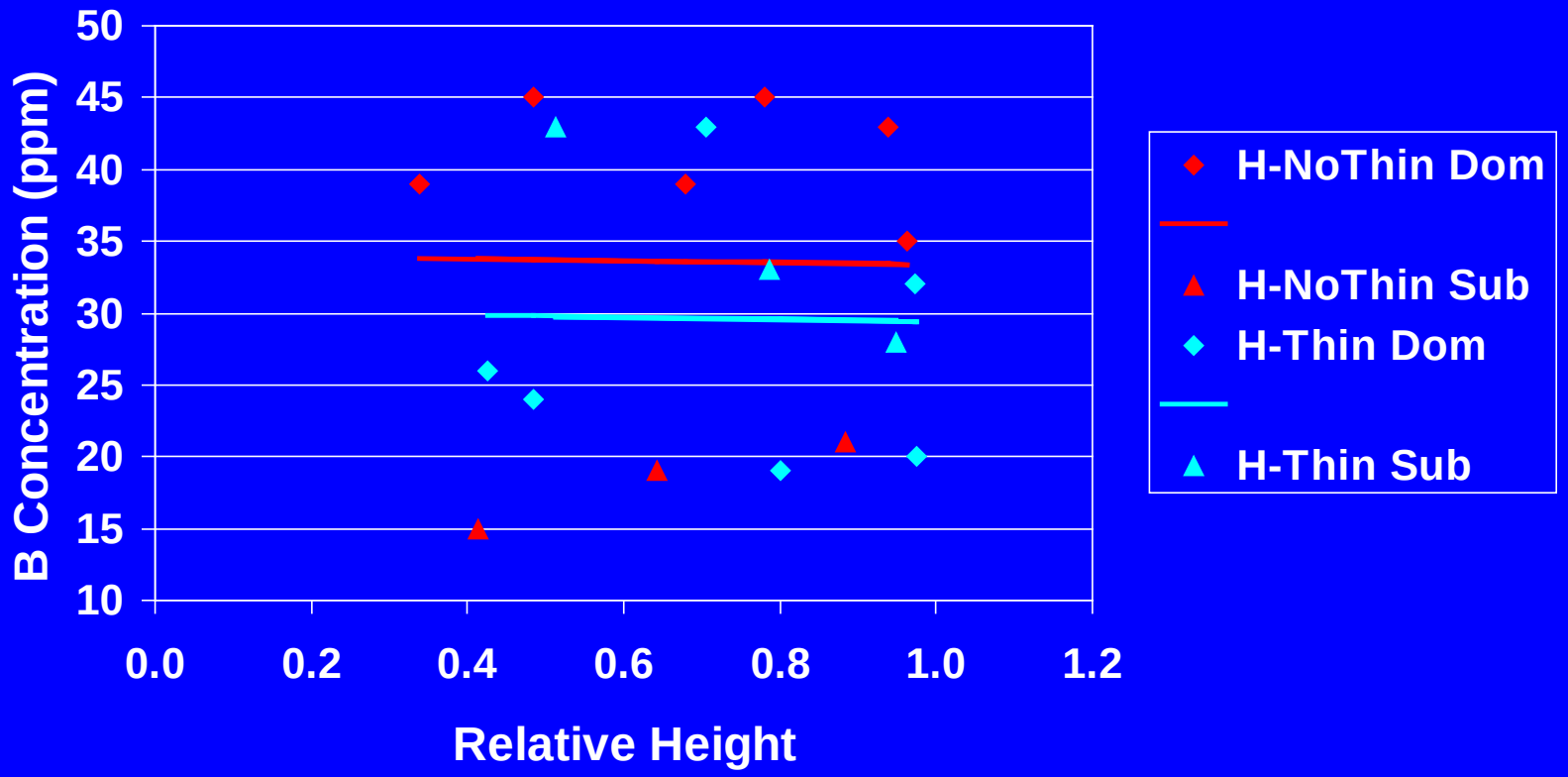
Dominant vs. Subdominant DF Old Foliage B Concentration



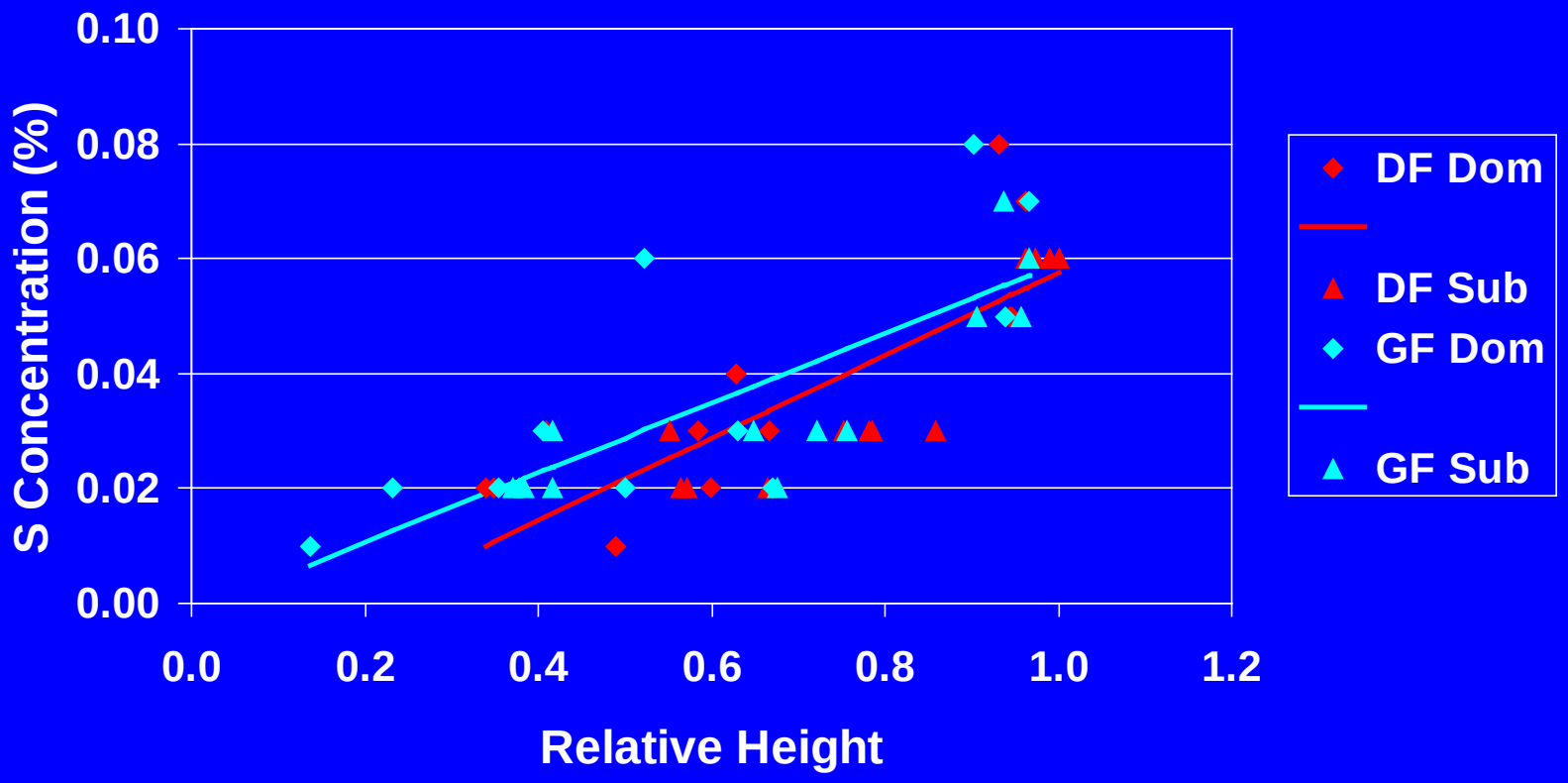
Dominant vs. Subdominant GF Old Foliage B Concentration



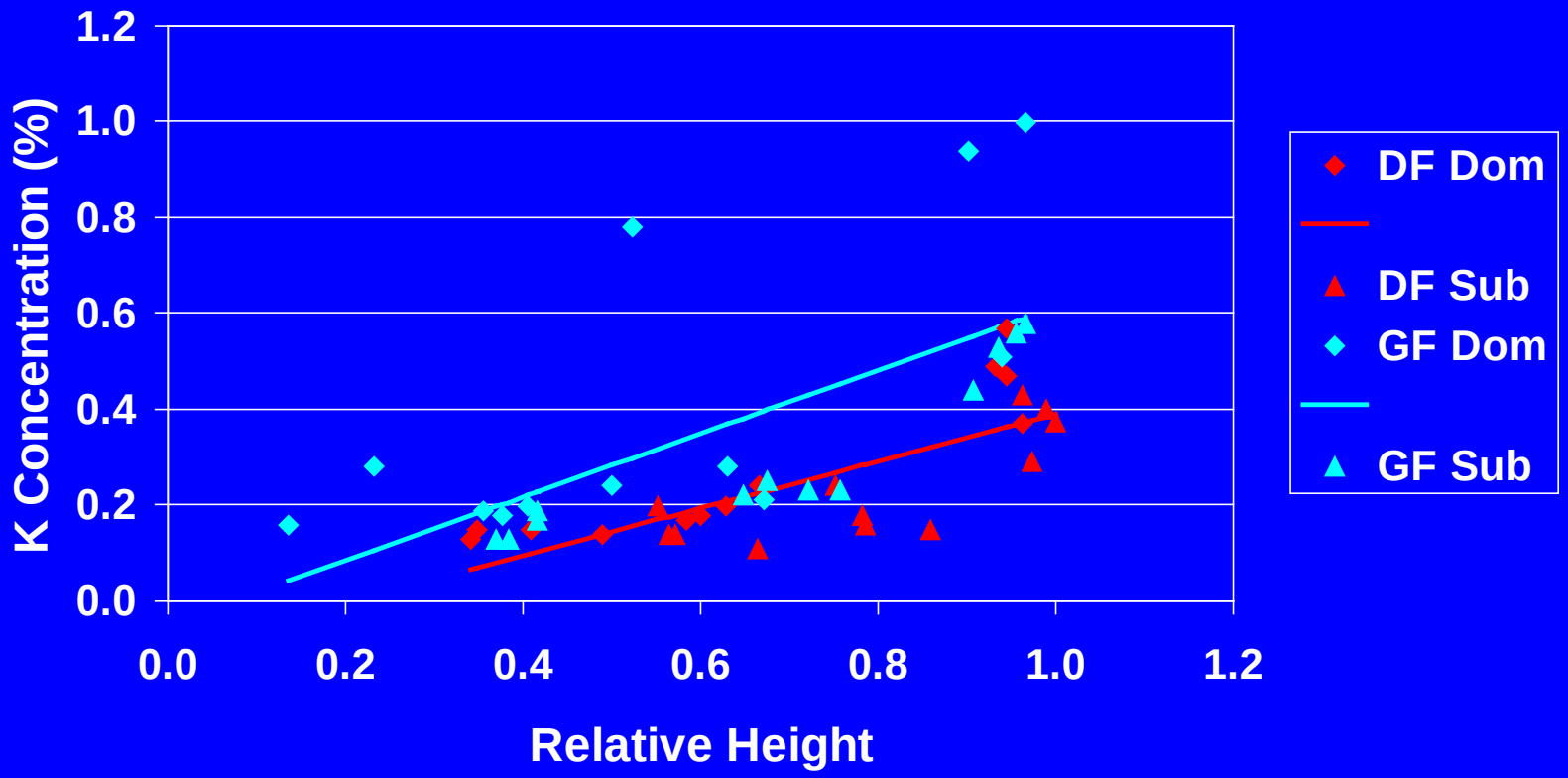
Dominant vs. Subdominant PP Old Foliage B Concentration



Dominant vs. Subdominant Primary Branch S Concentration



Dominant vs. Subdominant Primary Branch K Concentration



Dominant vs. Subdominant Primary Branch B Concentration