



# **Nutrition and Growth Results from Multinutrient Fertilization**

Peter G. Mika

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## Screening Trials

Individual tree trials, with treatments randomly assigned

- 5+ trees/treatment per site
- sampled for foliar response (nutrients, needle weight)
- measured for diameter and height at time of treatment and two years later

Fertilizer treatments:

Control, N only, Best Guess, Complete

Weed control with Pronone

# Treatment Rates

- N Only: 200 to 300 lbs N/a as urea
- Best: N, S (90 lbs/a), B (3 to 5 lbs/a), often K (170 lbs/a), often Cu (10 lbs/a)
- Complete: N, K, S, Mg (10 lbs/a), B, Cu, Zn (10 lbs/a), Fe (3 to 5 lbs/a)
- Pronone: 3 lbs/a Hexazinone 10G



# Number of Sites with Foliar/Growth Data by Species and Treatment

Species	Treatment							
	Control	N Only	Best	Complete	Pronone	Pronone + Complete	Pronone + Complete (low N)	Pronone + Complete (no N)
DF	36/31	36/31	36/31	18/13	13/12	13/12		13/12
GF	12/12	12/12	12/12					
LP	22/18	22/18	22/18	21/17	18/17	18/17	5/5	18/17
PP	35/29	34/29	34/29	34/29	29/28	30/28	9/9	29/28
WL	5/4	5/4	5/4	4/3				
WP	3/3	3/3	3/3					

# Number of Sites with Foliar/Growth Data by Species, Rock Type and Vegetation Series

Species	Rock Type										
	Extrusive		Intrusive			Metamorphic			Unconsolidated		
						Weathering Potential					
						high	medium	low			
	Vegetation Series										
	DF	GF	DF	GF	WRC	GF	WRC	WRC	WRC	GF	WRC
DF		9/9		1/0	5/4		7/5	8/8	2/2	3/3	1/0
GF					2/2		5/5	3/3	1/1		1/1
LP	2/2	3/3		5/5	2/1	1/1	1/0			4/4	4/2
PP		15/14	2/2	5/4	3/2	1/1	2/0	1/1		4/4	2/1
WL		1/1			1/1			1/1		1/1	1/0
WP					1/1			2/2			

# Initial Tree Size

Species	Number of Sites	Initial DBH (in)			Initial Height (ft)		
		mean	minimum	maximum	mean	minimum	maximum
DF	31	3.10	0.72	5.54	18.6	5.5	33.2
GF	12	3.76	2.38	4.90	22.1	16.1	28.9
LP	18	3.24	0.99	5.20	17.1	7.8	23.1
PP	29	3.73	0.83	6.55	15.1	4.2	26.4
WL	4	2.54	2.07	3.53	18.5	14.2	24.2
WP	3	3.44	2.60	4.03	19.8	14.8	24.9

# Statistical Analysis Foliar Nutrient Data

Data fit to an analysis of variance model where tree nutrient concentration is a function of:

Tree Species

Site

Fertilizer Treatment

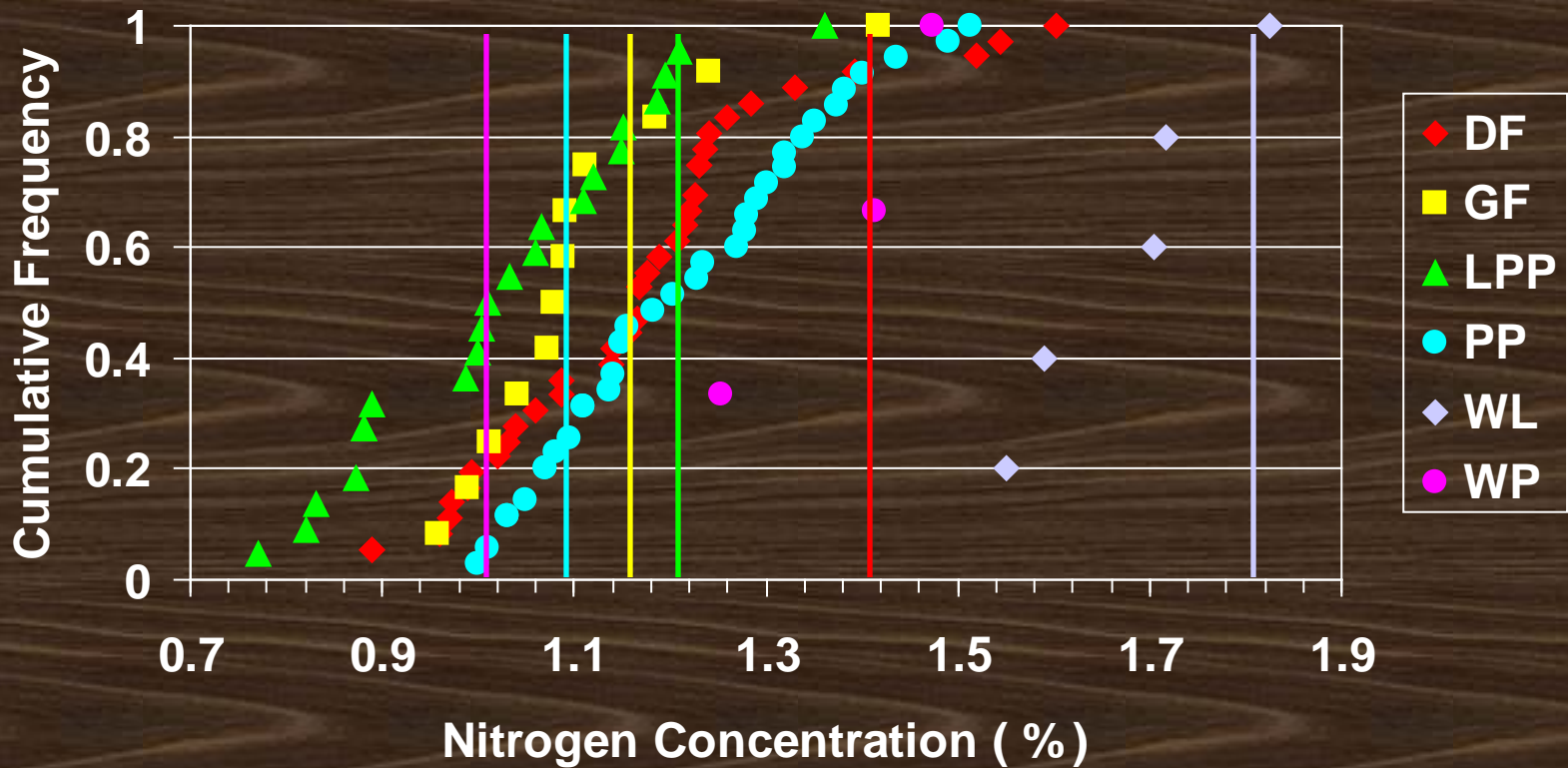
Species X Fertilizer Treatment

# Nutrient Critical Values

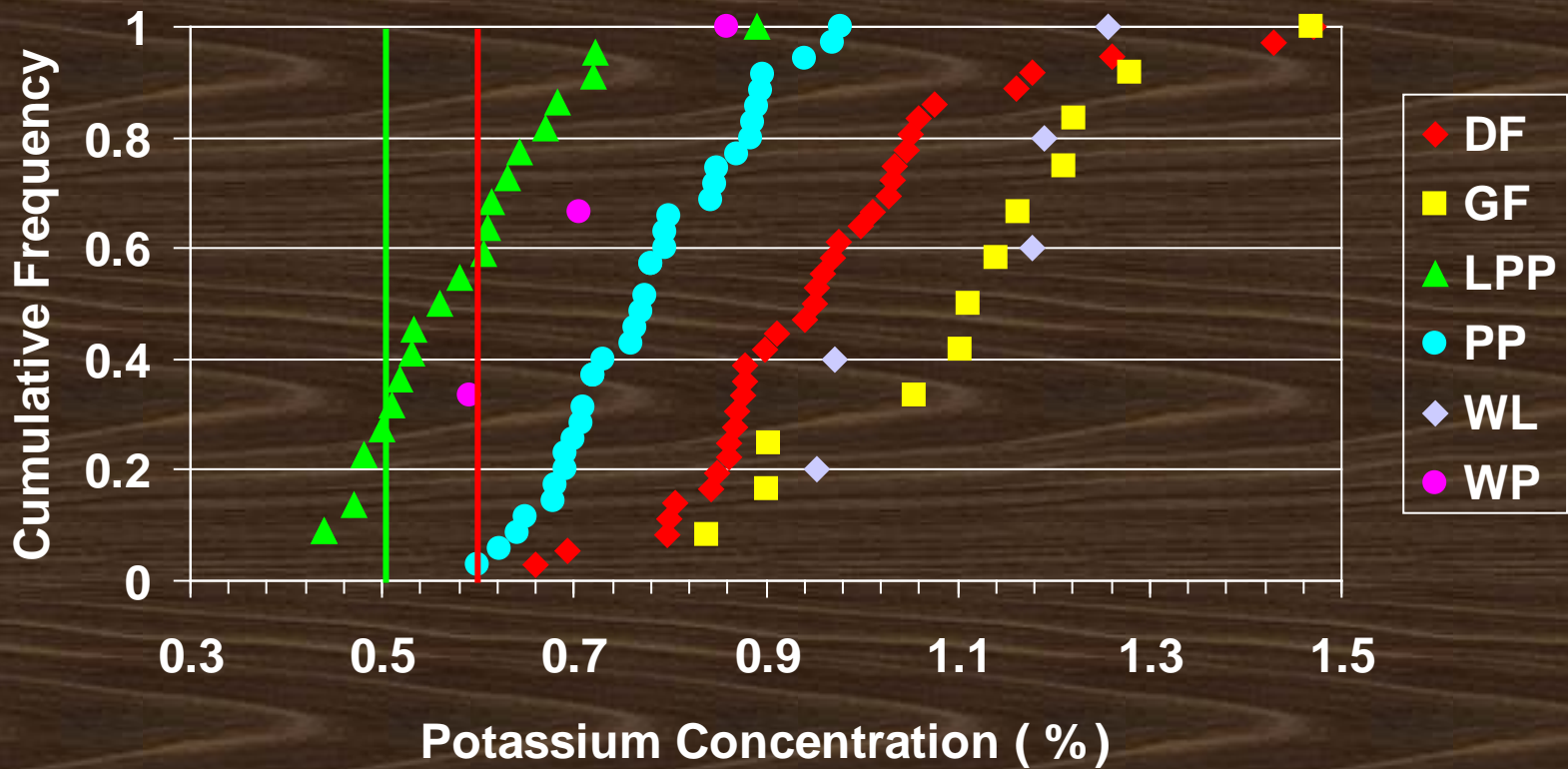
	Tree Species					
Nutrient	DF	GF	LPP	PP	WL	WP
N (%)	1.4	1.15	1.2	1.1	1.8	1
K (%)	0.6	0.58	0.5	0.48	0.5	0.7
P (%)	0.12	0.15	0.12	0.08	0.18	0.15
S (%)	0.11	0.08	0.09	0.08	0.12	0.2
Ca (%)	0.15	0.12	0.08	0.05	0.13	0.3
Mg (%)	0.08	0.06	0.09	0.05	0.15	0.1
Fe (ppm)	25	50	58	50	126	40
Zn (ppm)	10	10	52	30	5	15
Cu (ppm)	2	3	2.7	3	5.4	5
B (ppm)	10	10	4.3	20	36	10



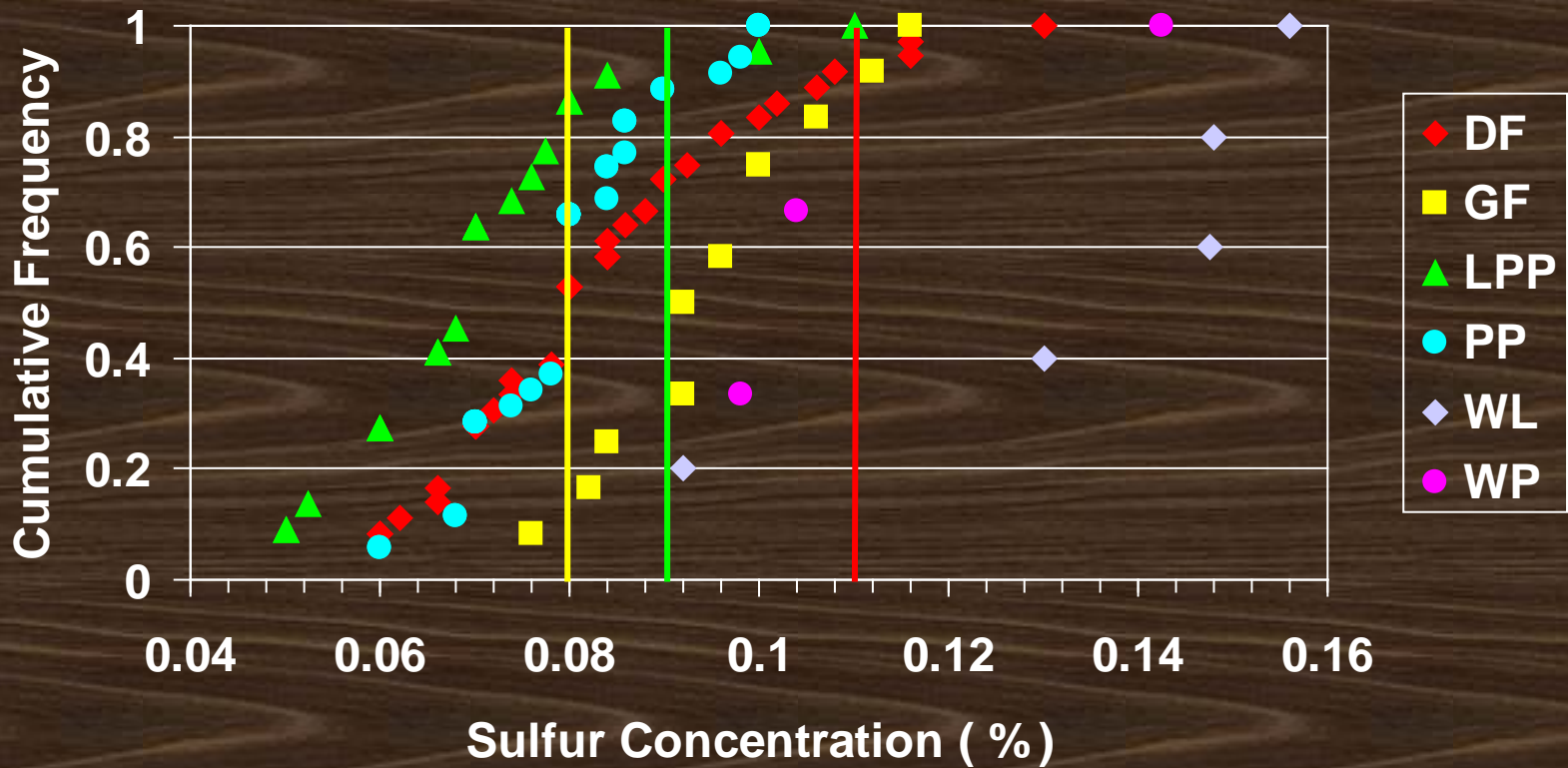
# Nitrogen Concentration Distribution by Species



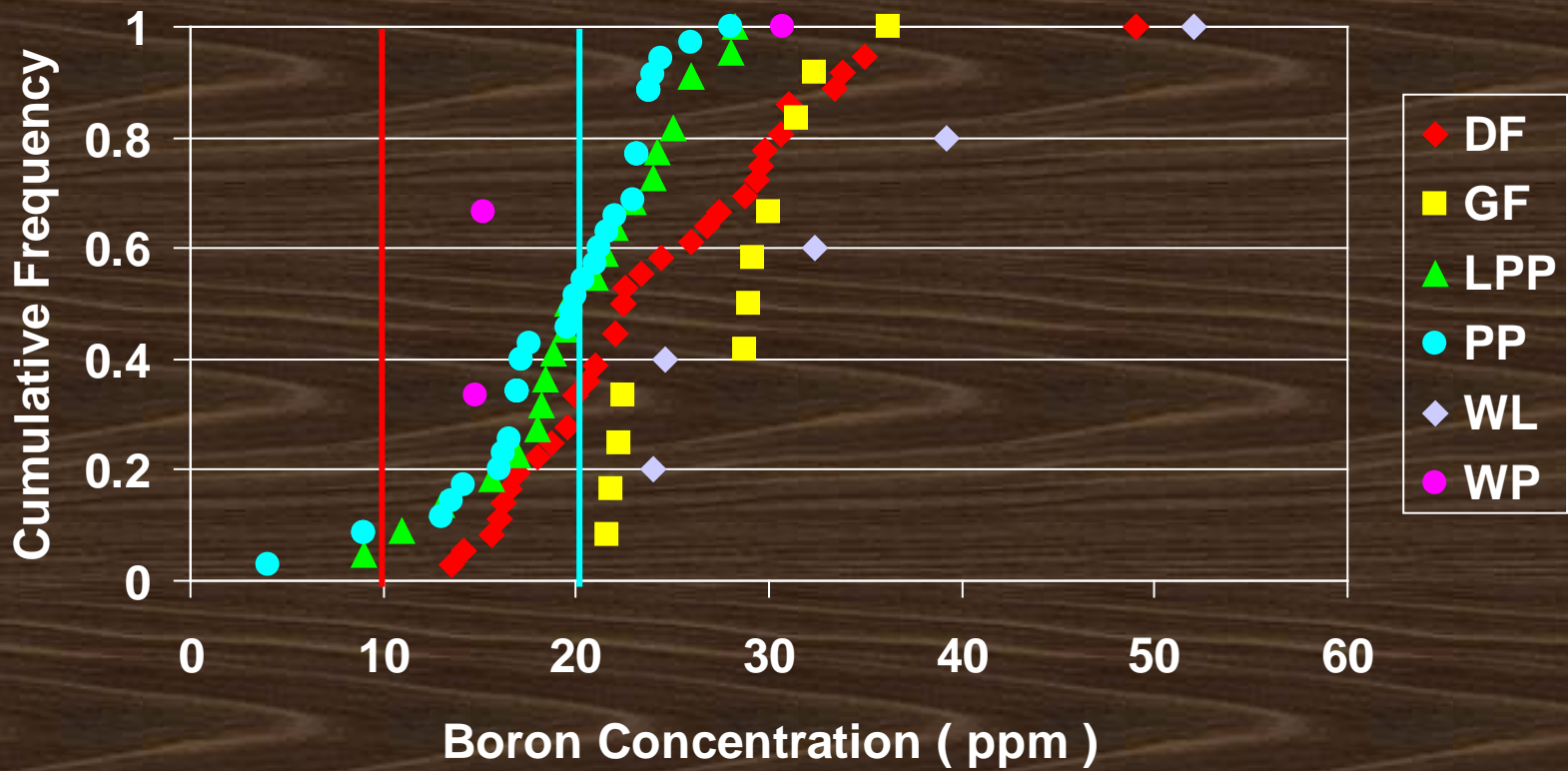
# Potassium Concentration Distribution by Species



# Sulfur Concentration Distribution by Species

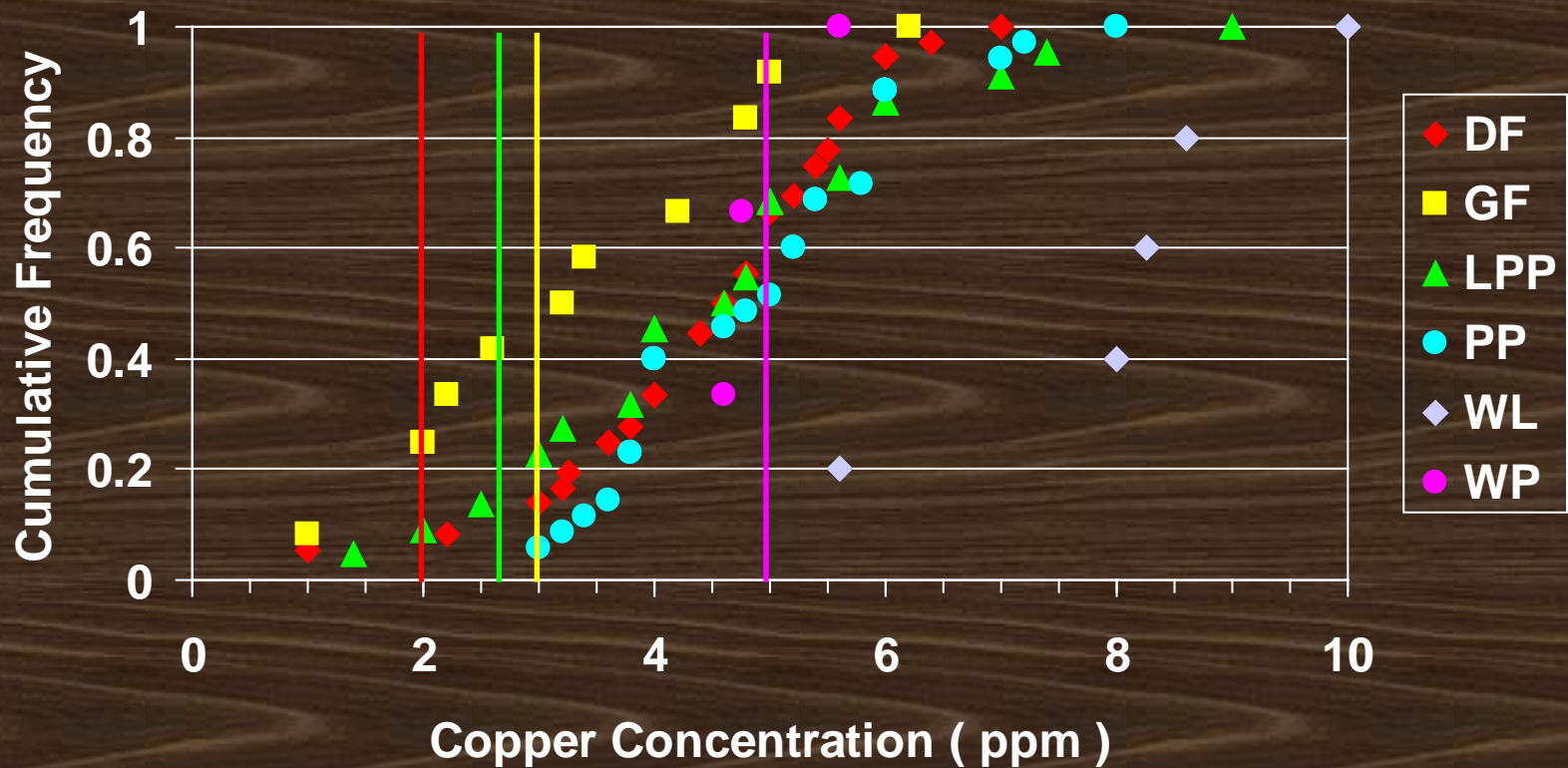


# Boron Concentration Distribution by Species

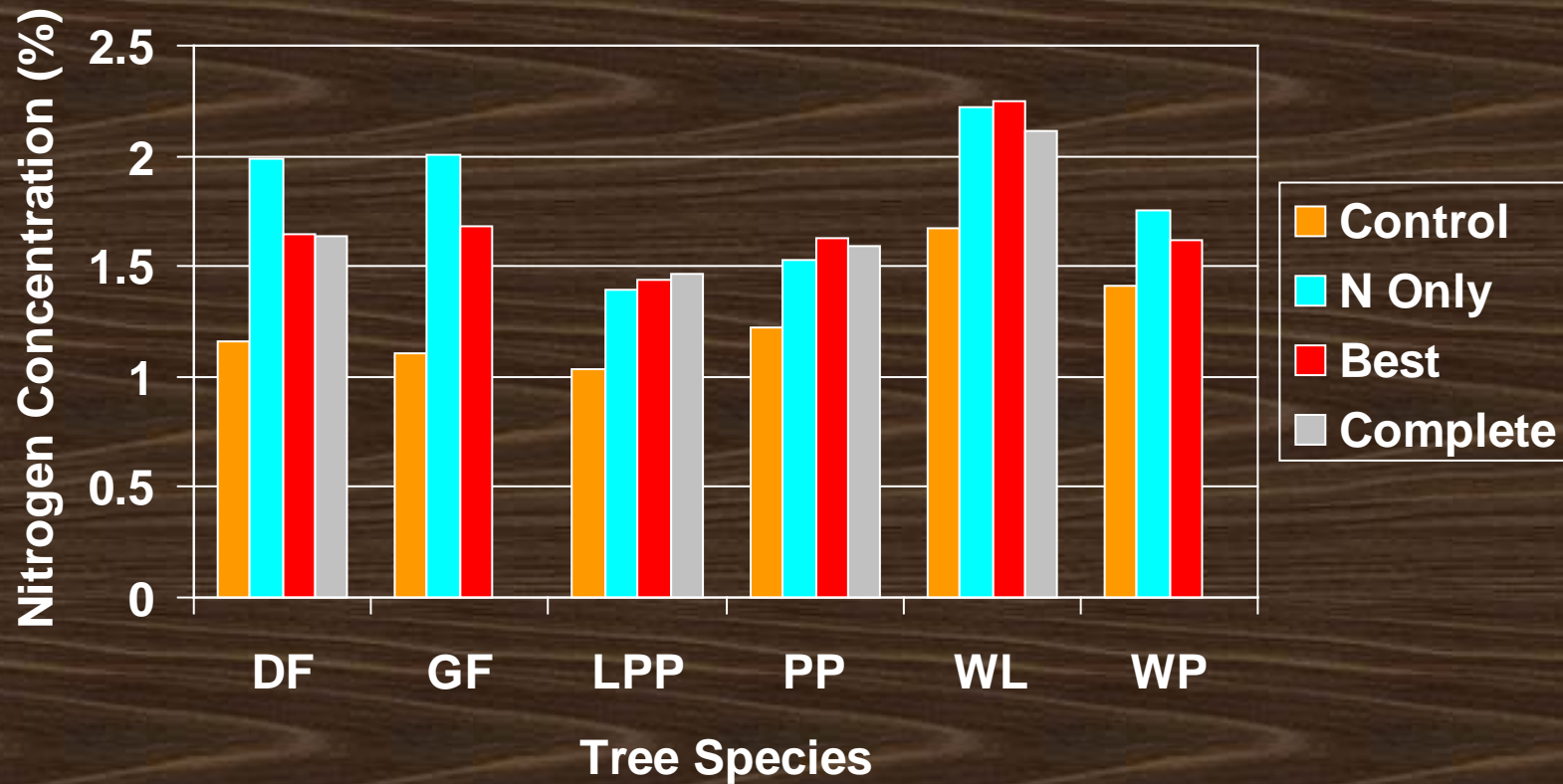




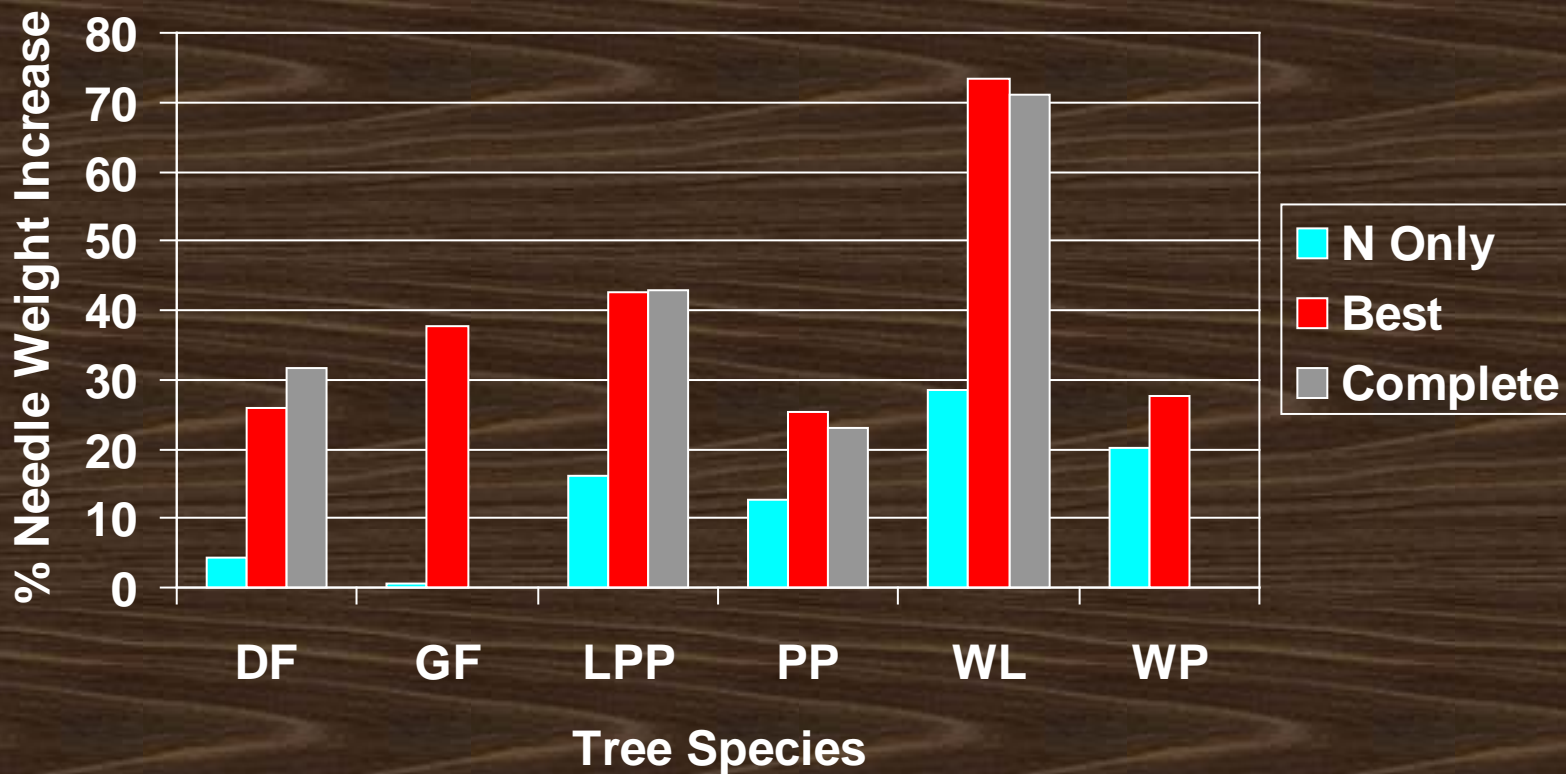
# Copper Concentration Distribution by Species



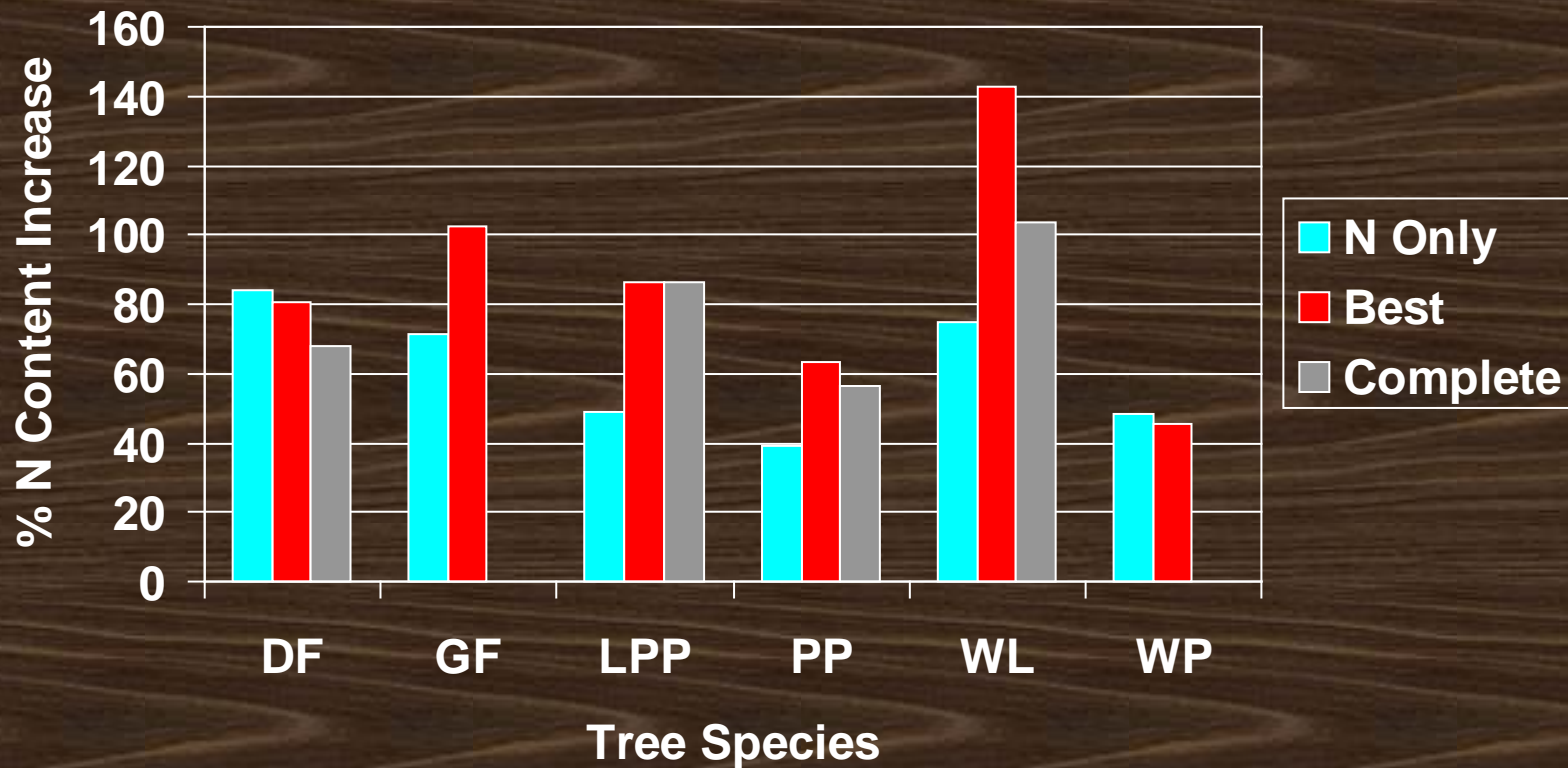
# Fertilizer Treatment Effects on Foliar Nitrogen Concentration by Species



# Increase in 1-Year Needle Weight Over Control Rate by Treatment and Species

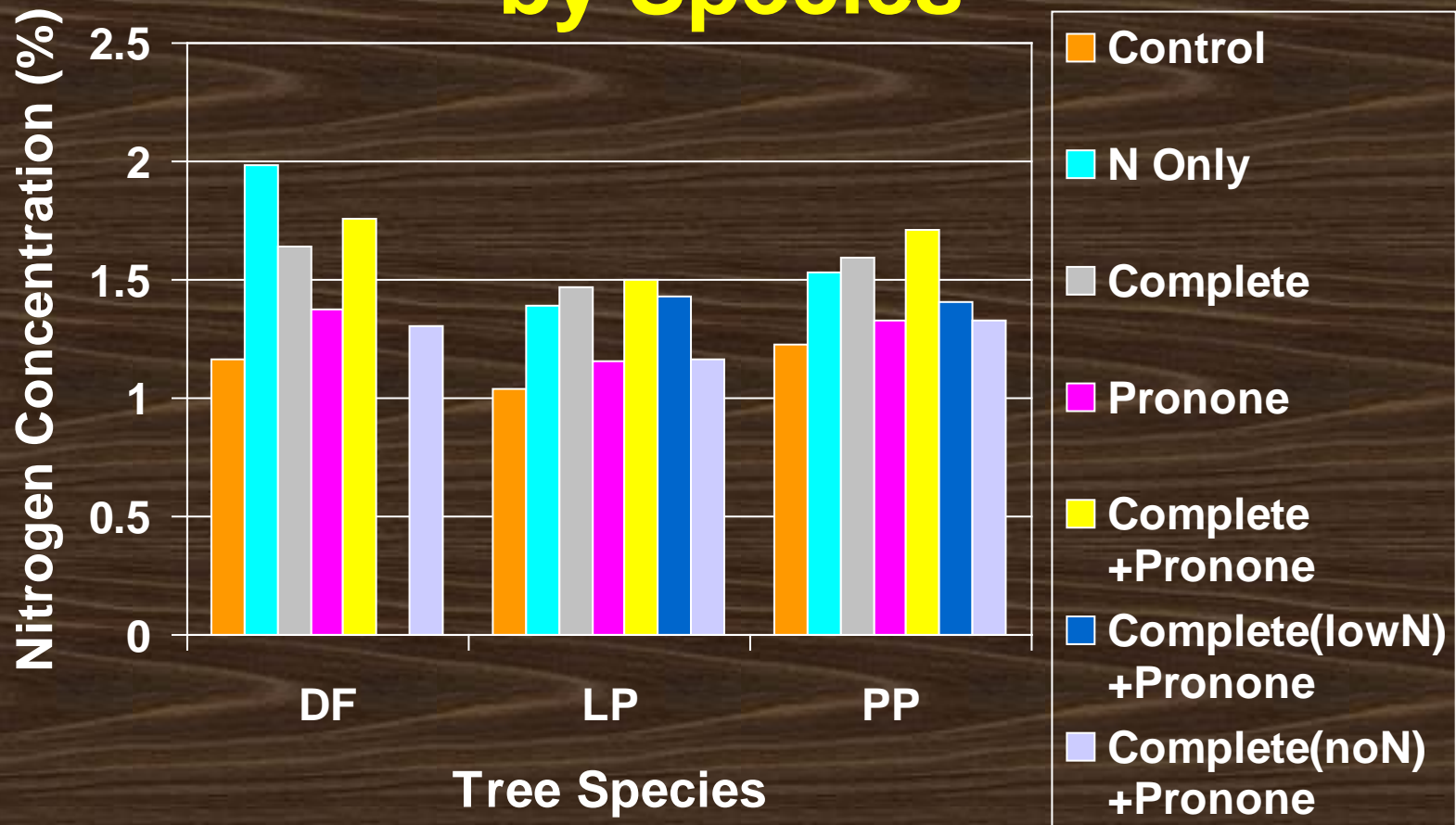


# Increase in Nitrogen Content Over Control Rate by Treatment and Species

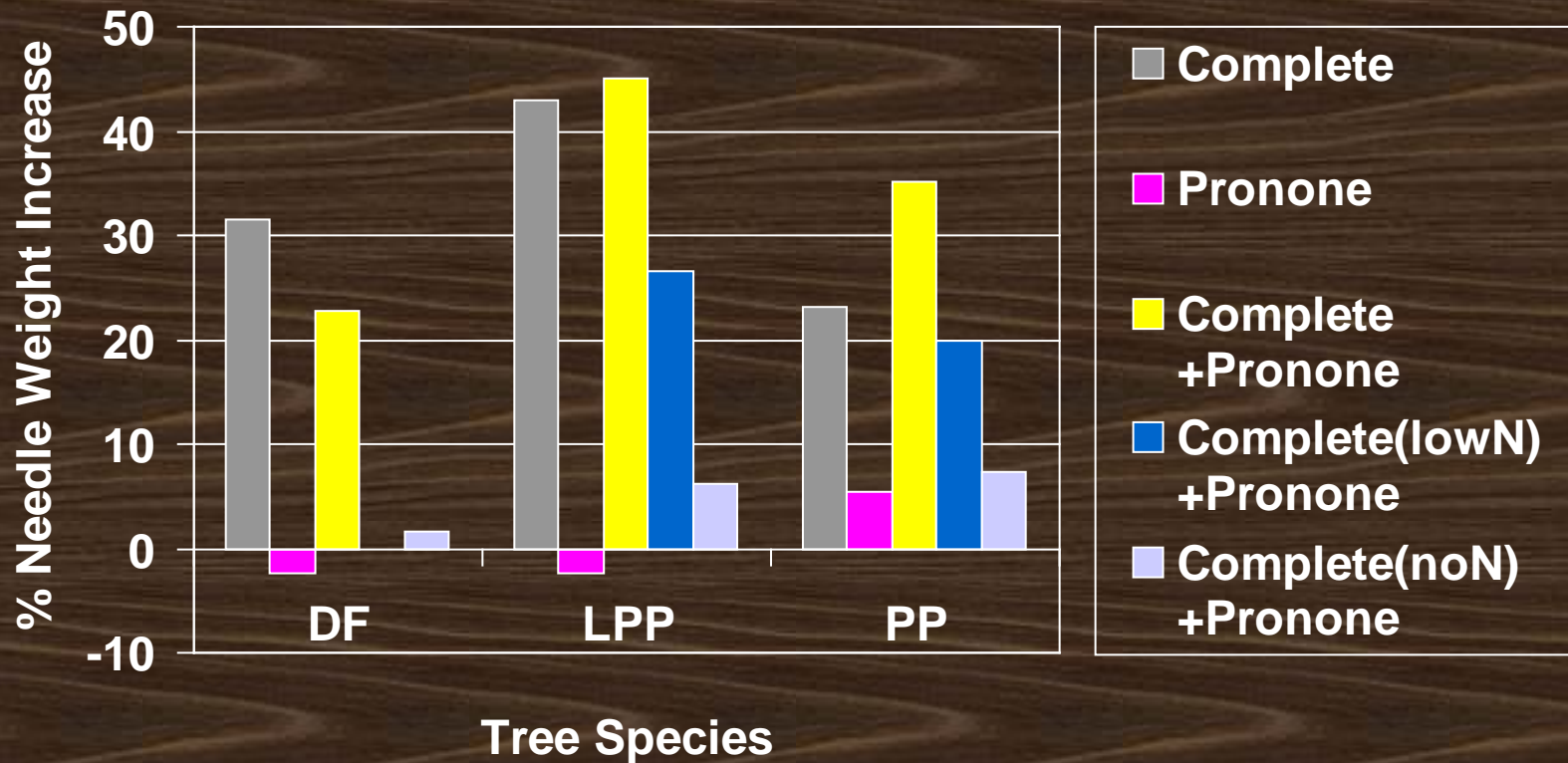




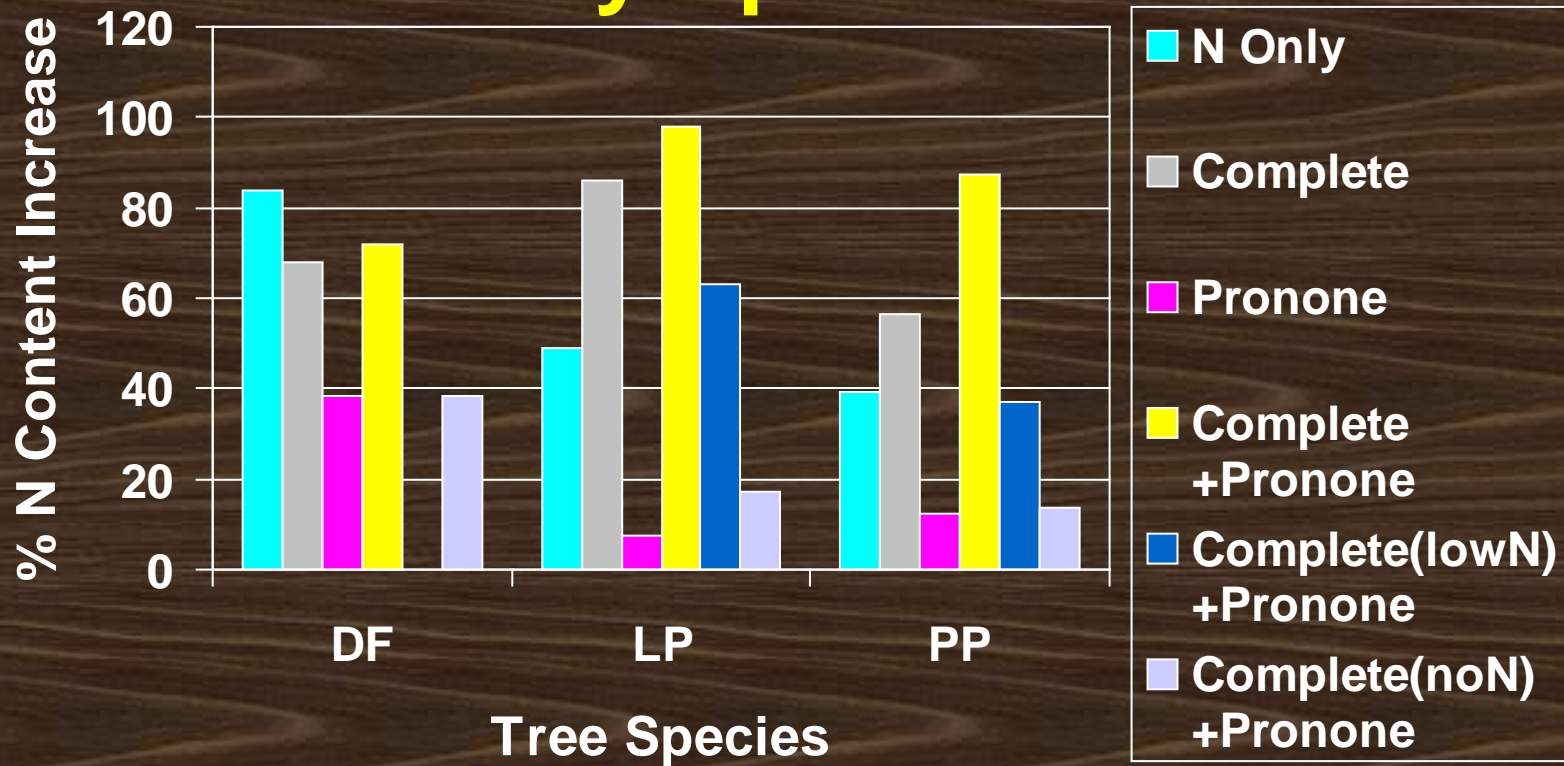
# Fertilizer and Weed Control Treatment Effects on Foliar Nitrogen Concentration by Species



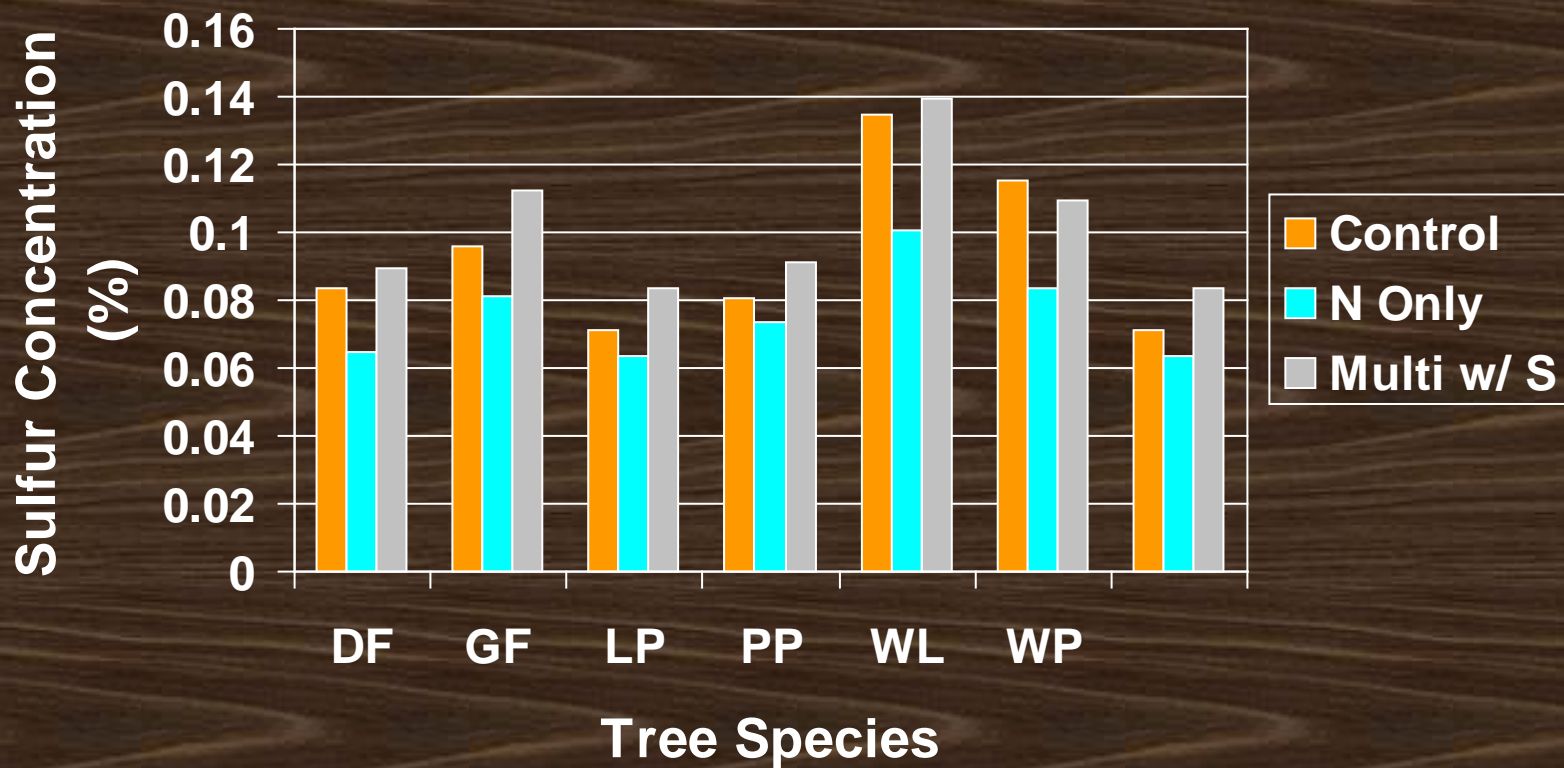
# Increase in 1-Year Needle Weight Over Control Rate by Weed Control and Fertilizer Treatments



# Fertilizer and Weed Control Treatment Effects on Foliar Nitrogen Content by Species

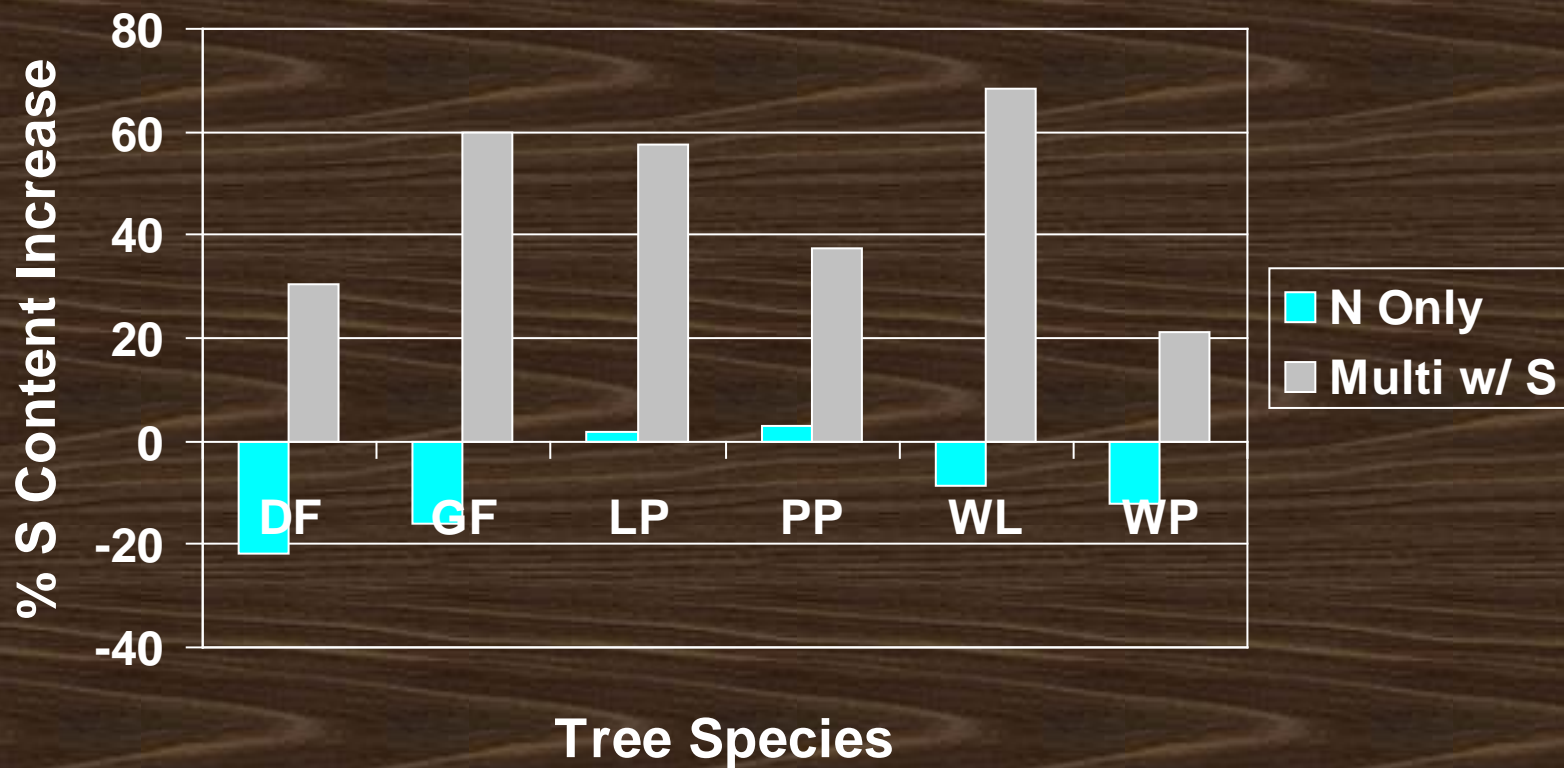


# Fertilizer Treatment Effects on Foliar Sulfur Concentration by Species

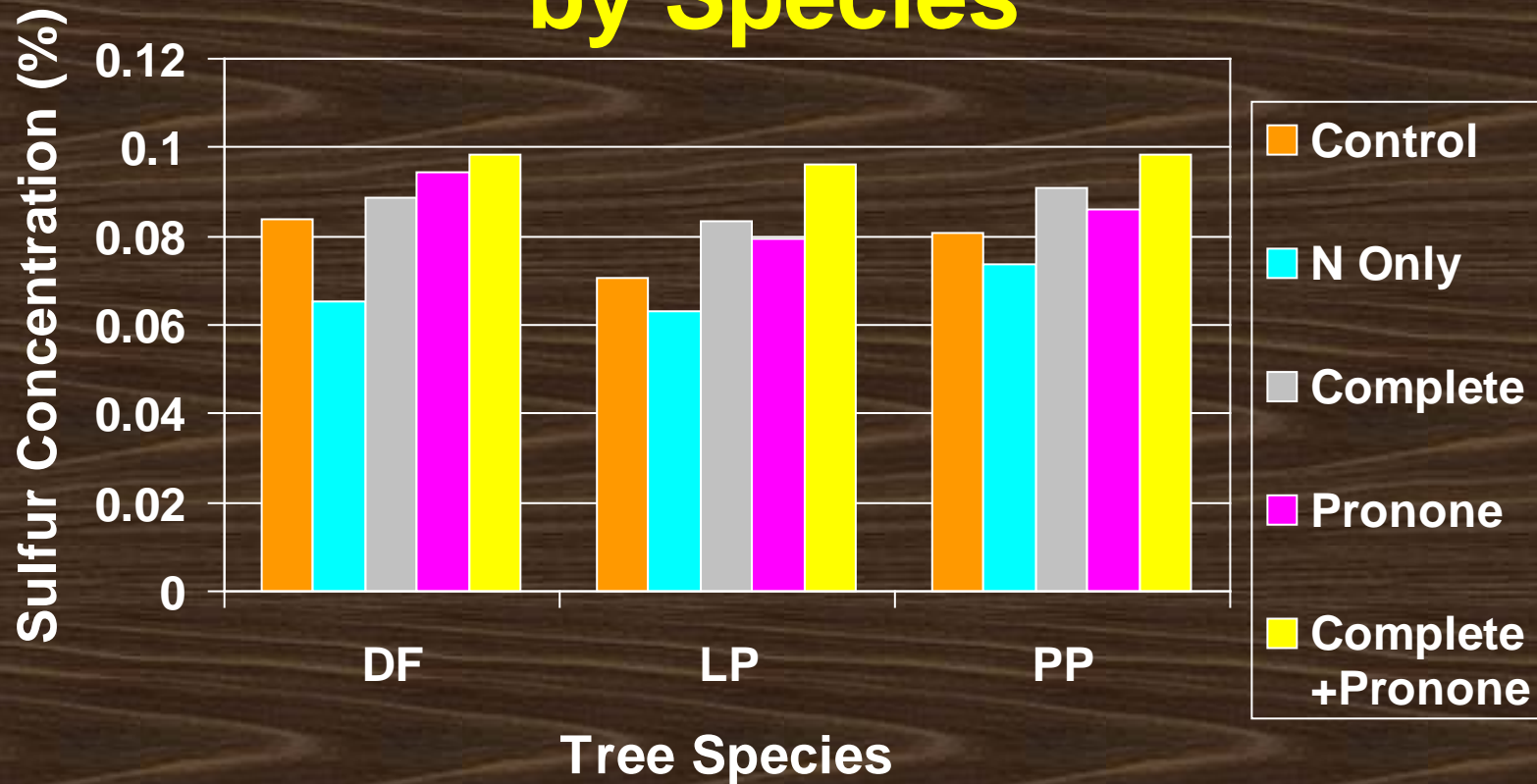




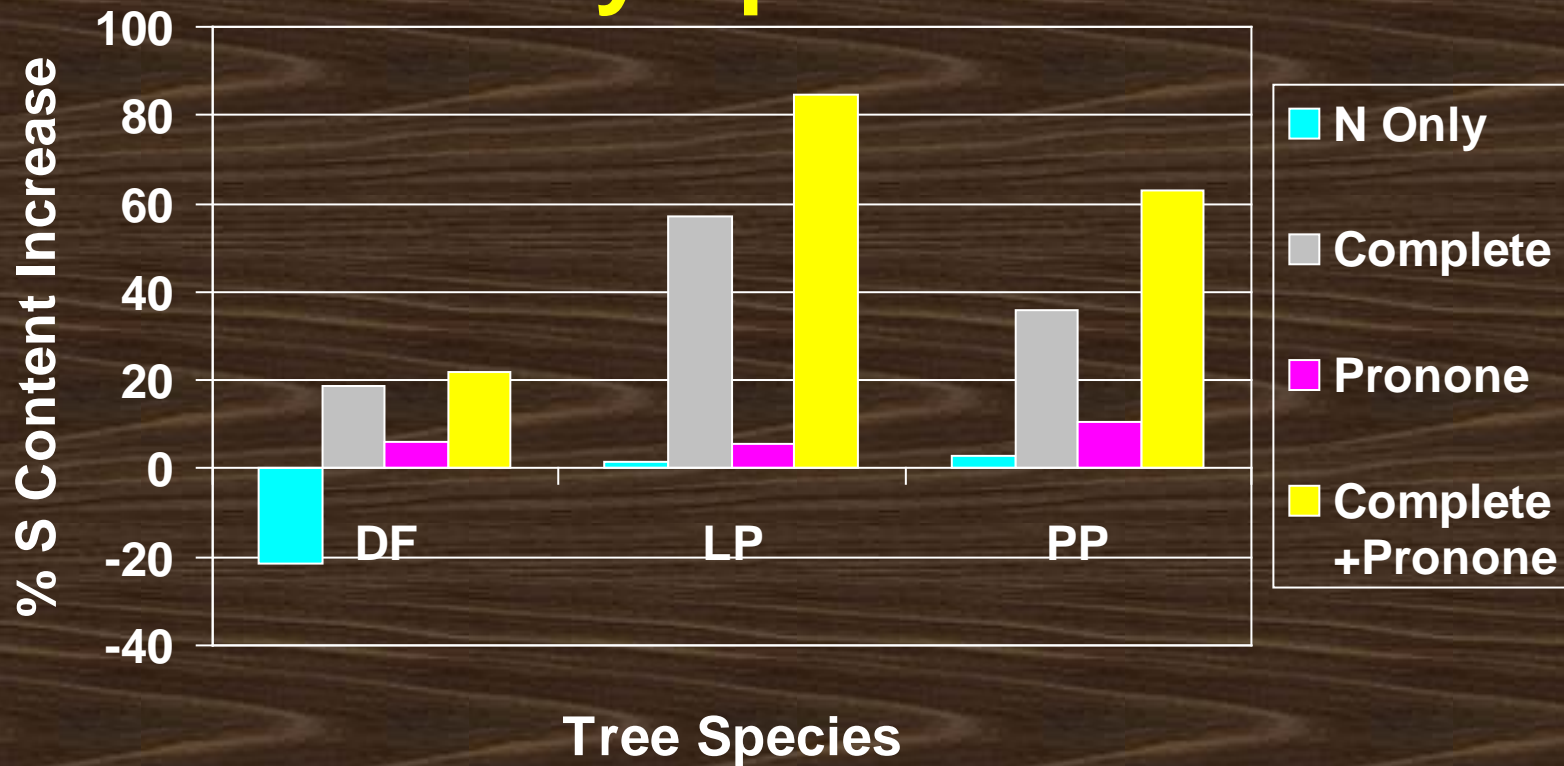
# Increase in Sulfur Content Over Control Rate by Treatment and Species



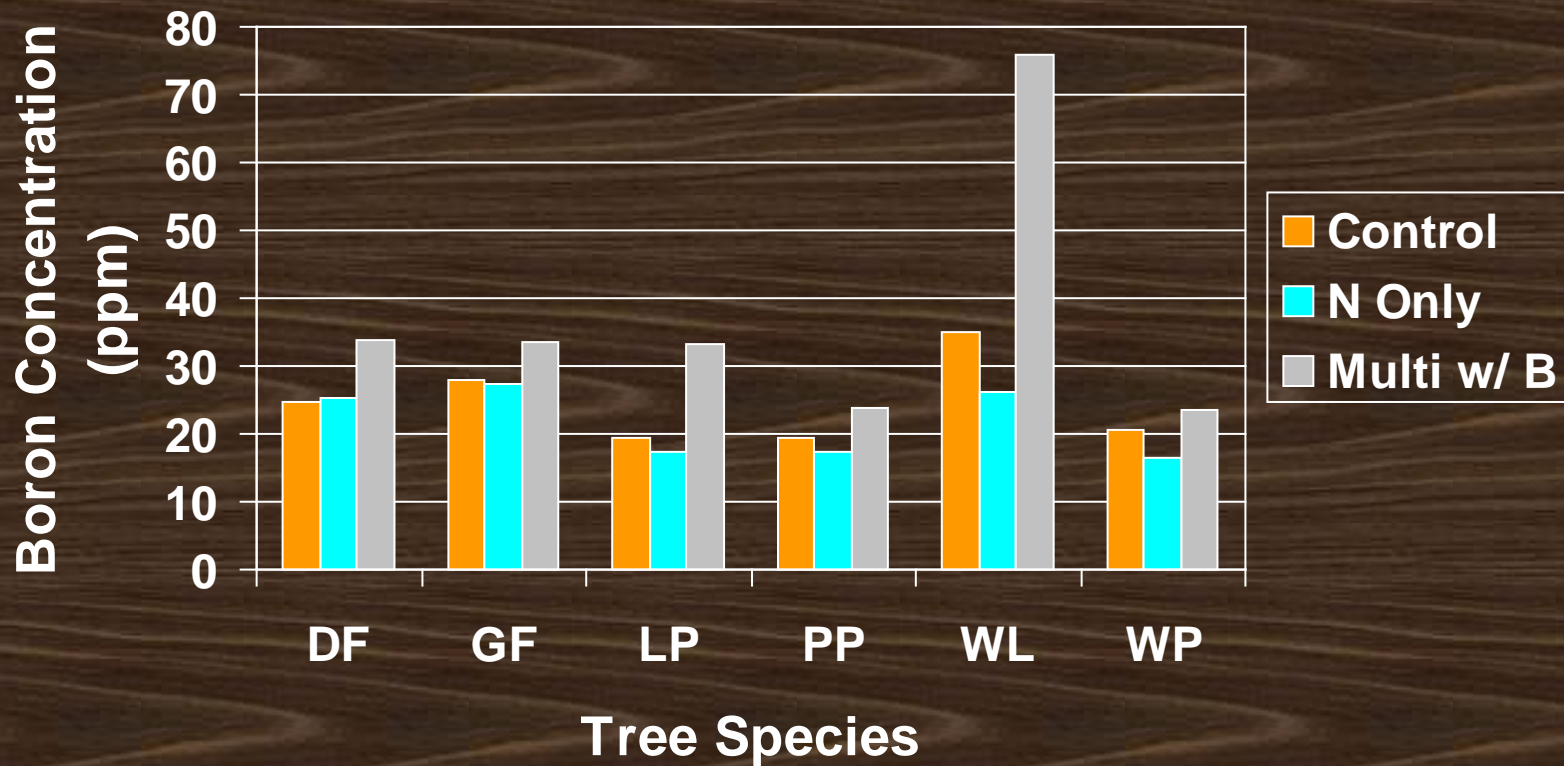
# Fertilizer and Weed Control Treatment Effects on Foliar Sulfur Concentration by Species



# Fertilizer and Weed Control Treatment Effects on Foliar Sulfur Content by Species

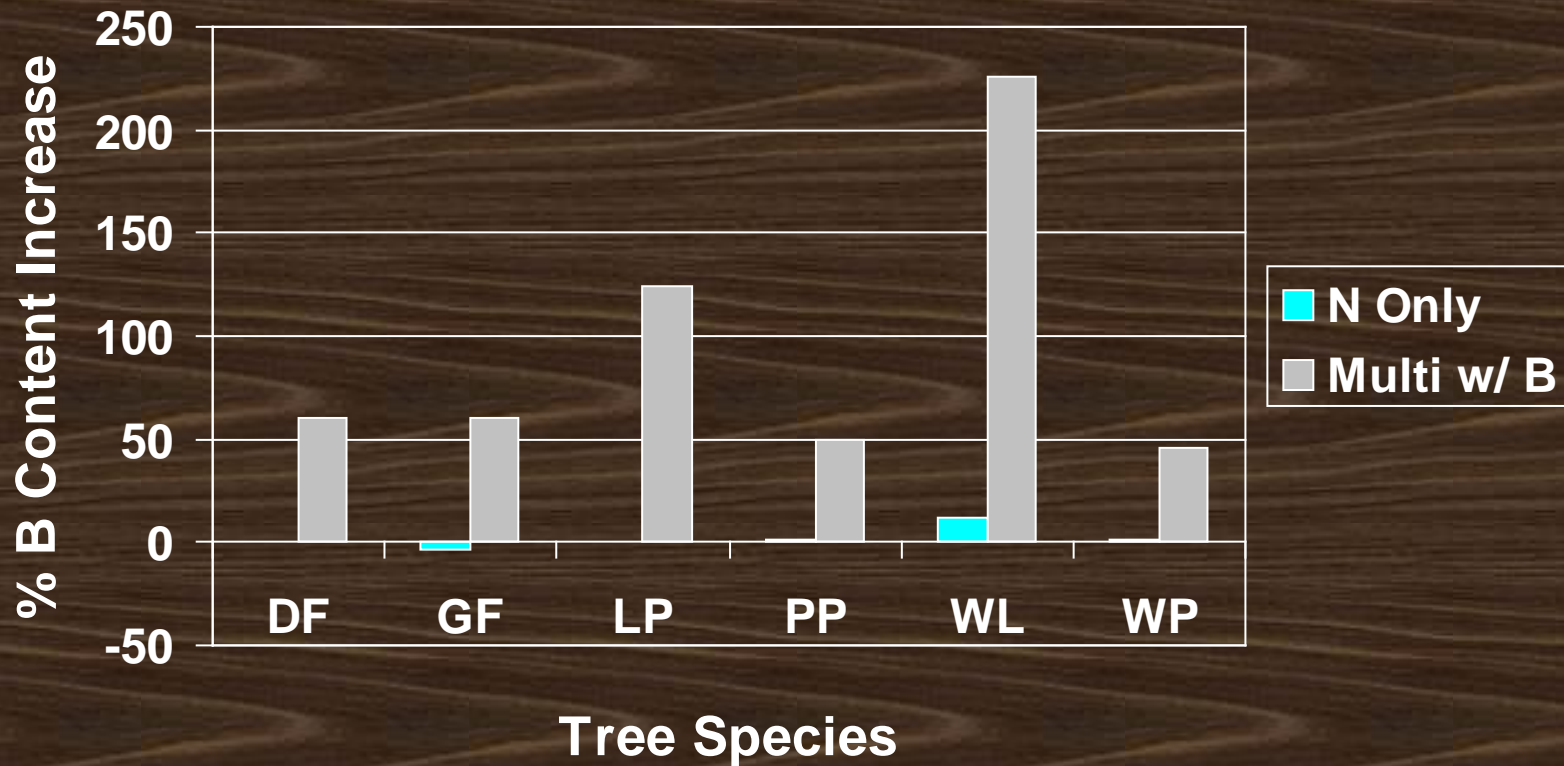


# Fertilizer Treatment Effects on Foliar Boron Concentration by Species

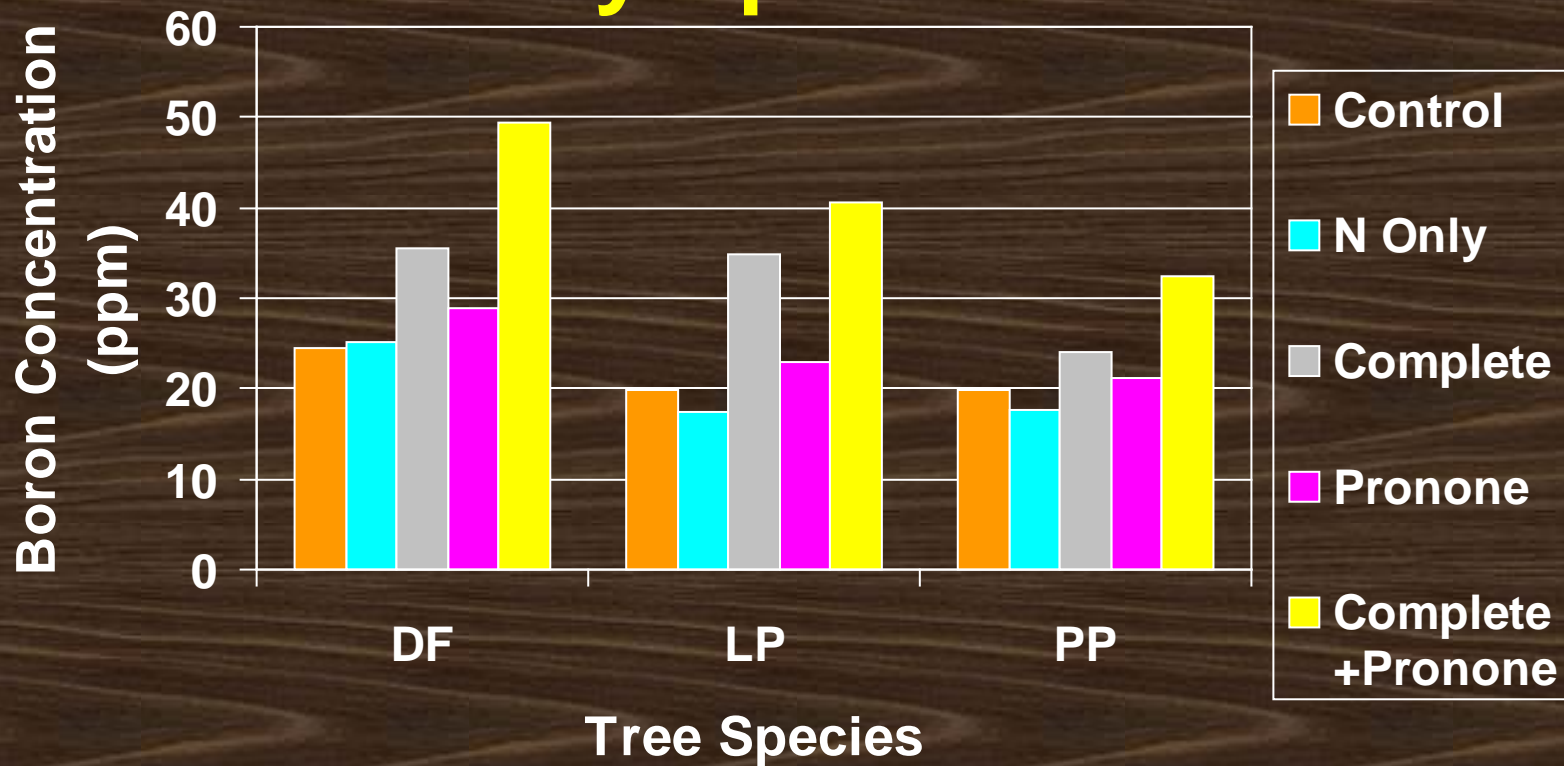




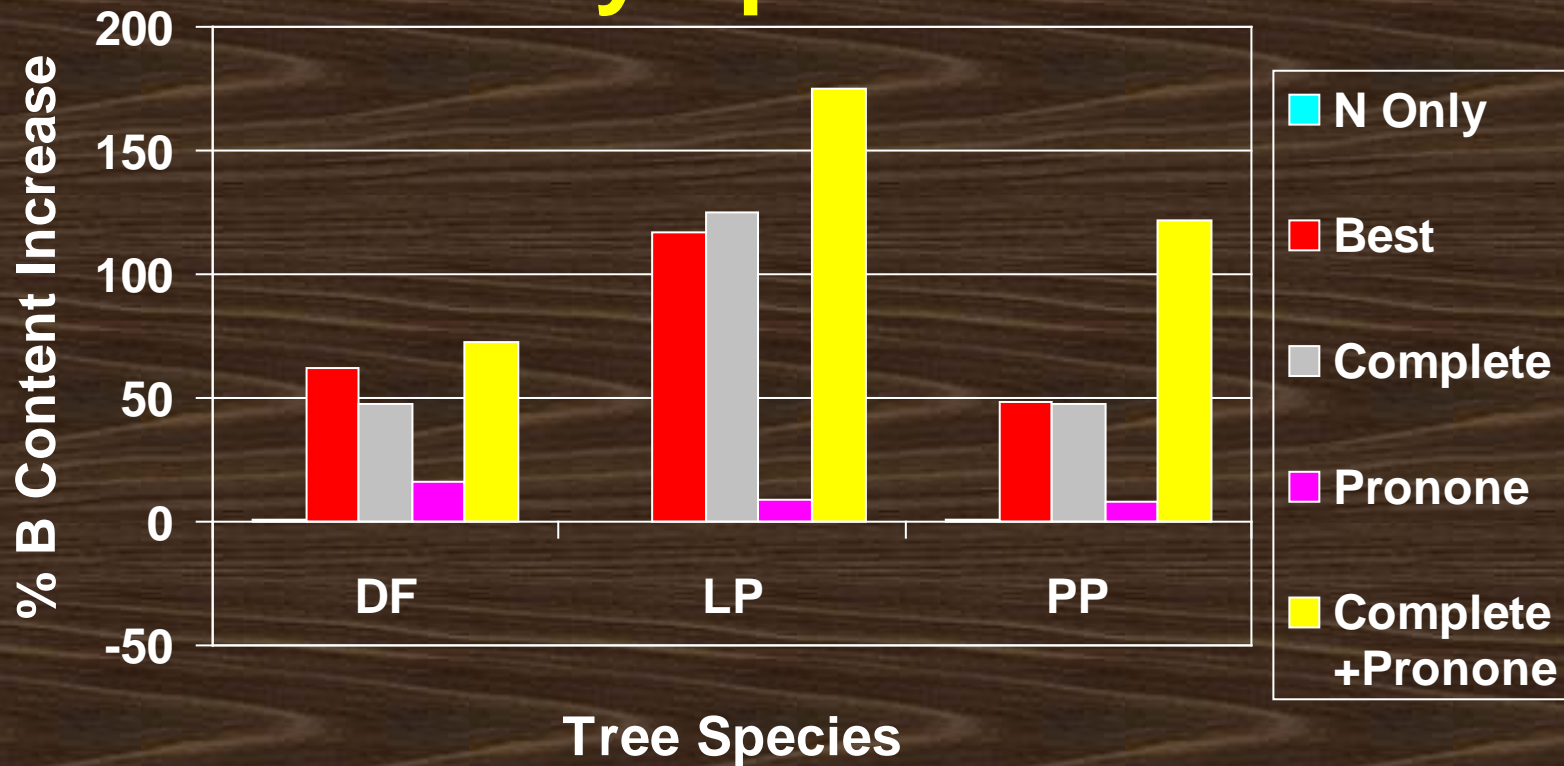
# Increase in Boron Content Over Control Rate by Treatment and Species



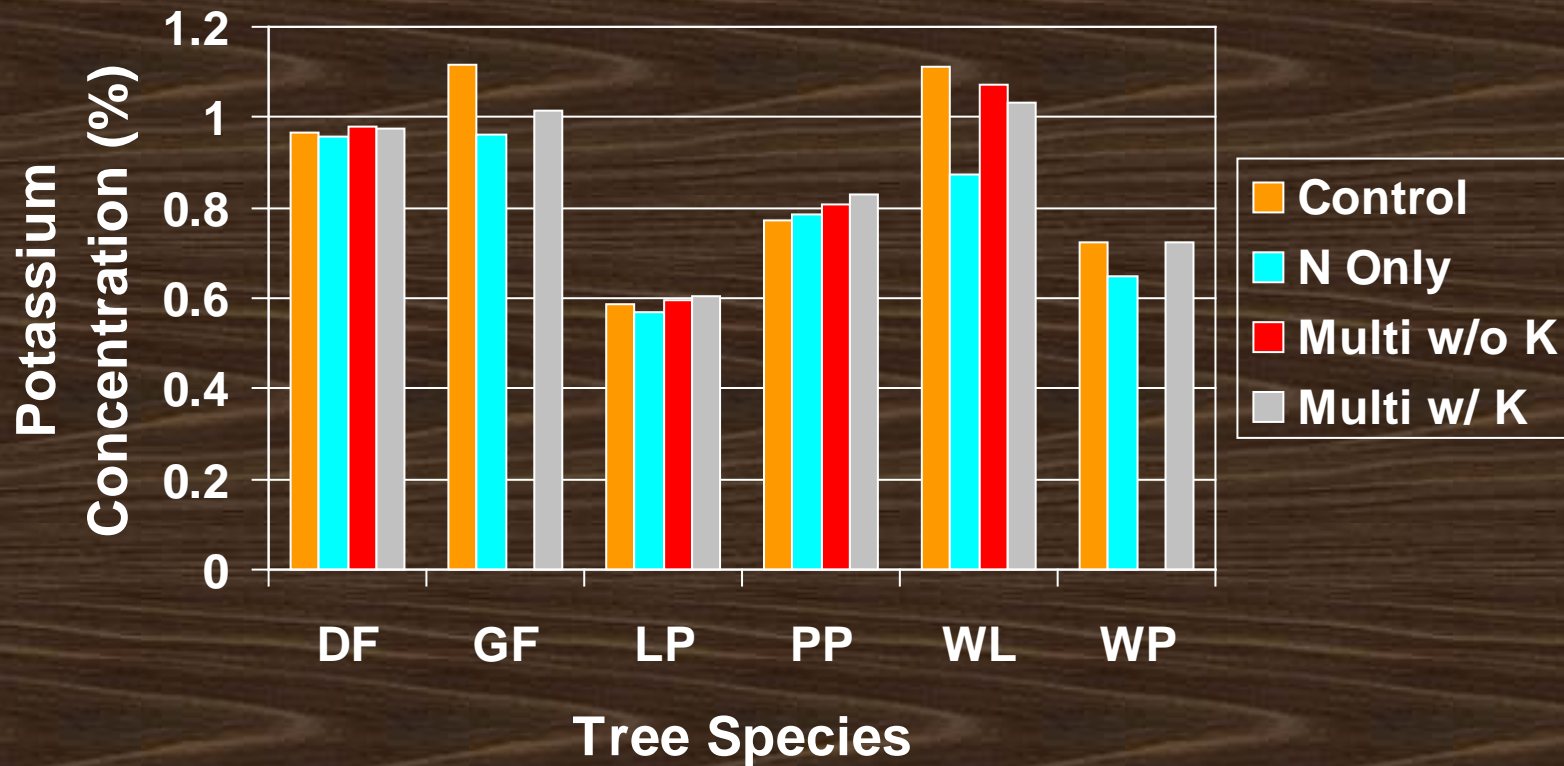
# Fertilizer and Weed Control Treatment Effects on Foliar Boron Concentration by Species



# Fertilizer and Weed Control Treatment Effects on Foliar Boron Content by Species

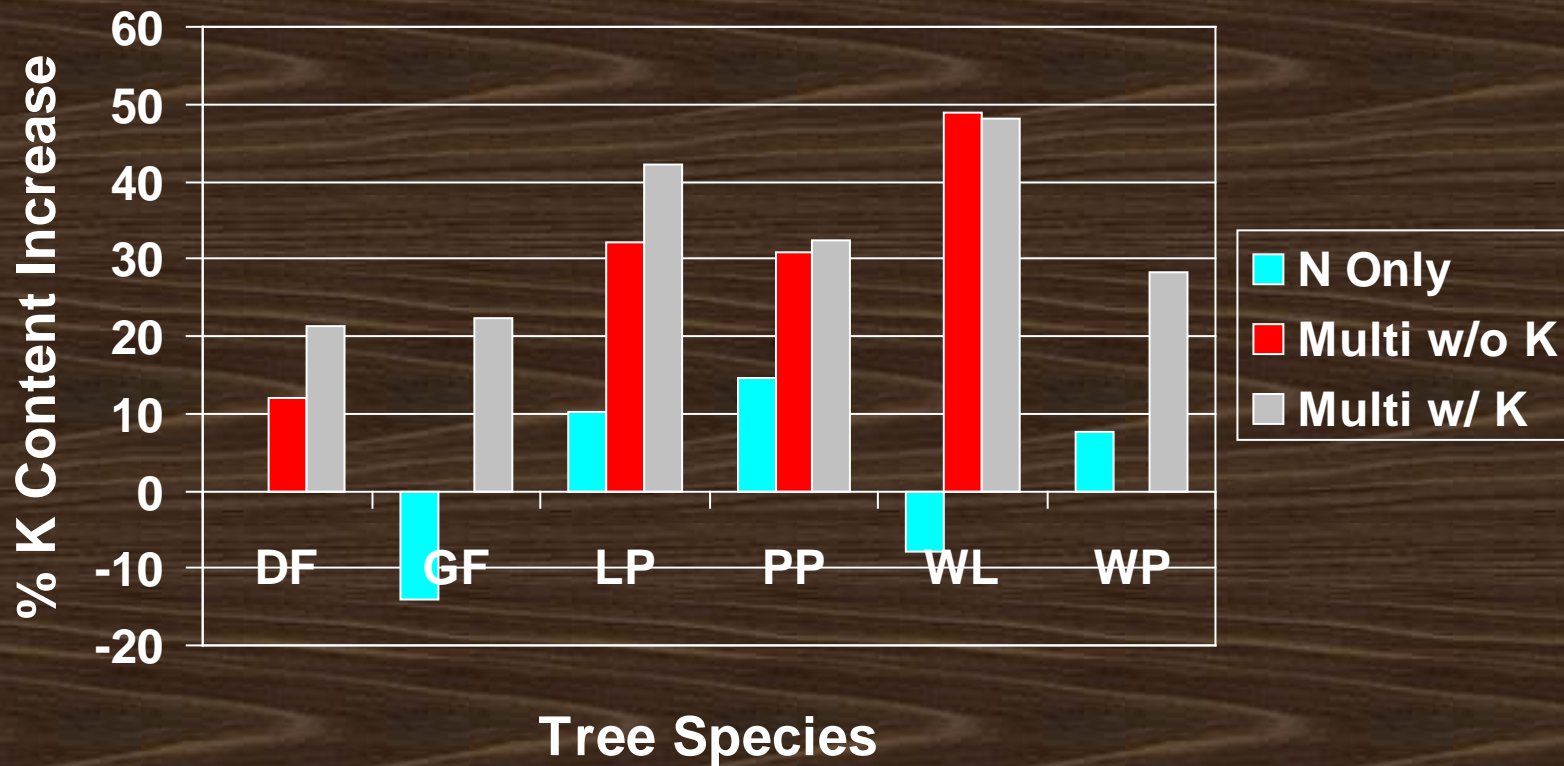


# Fertilizer Treatment Effects on Foliar Potassium Concentration by Species

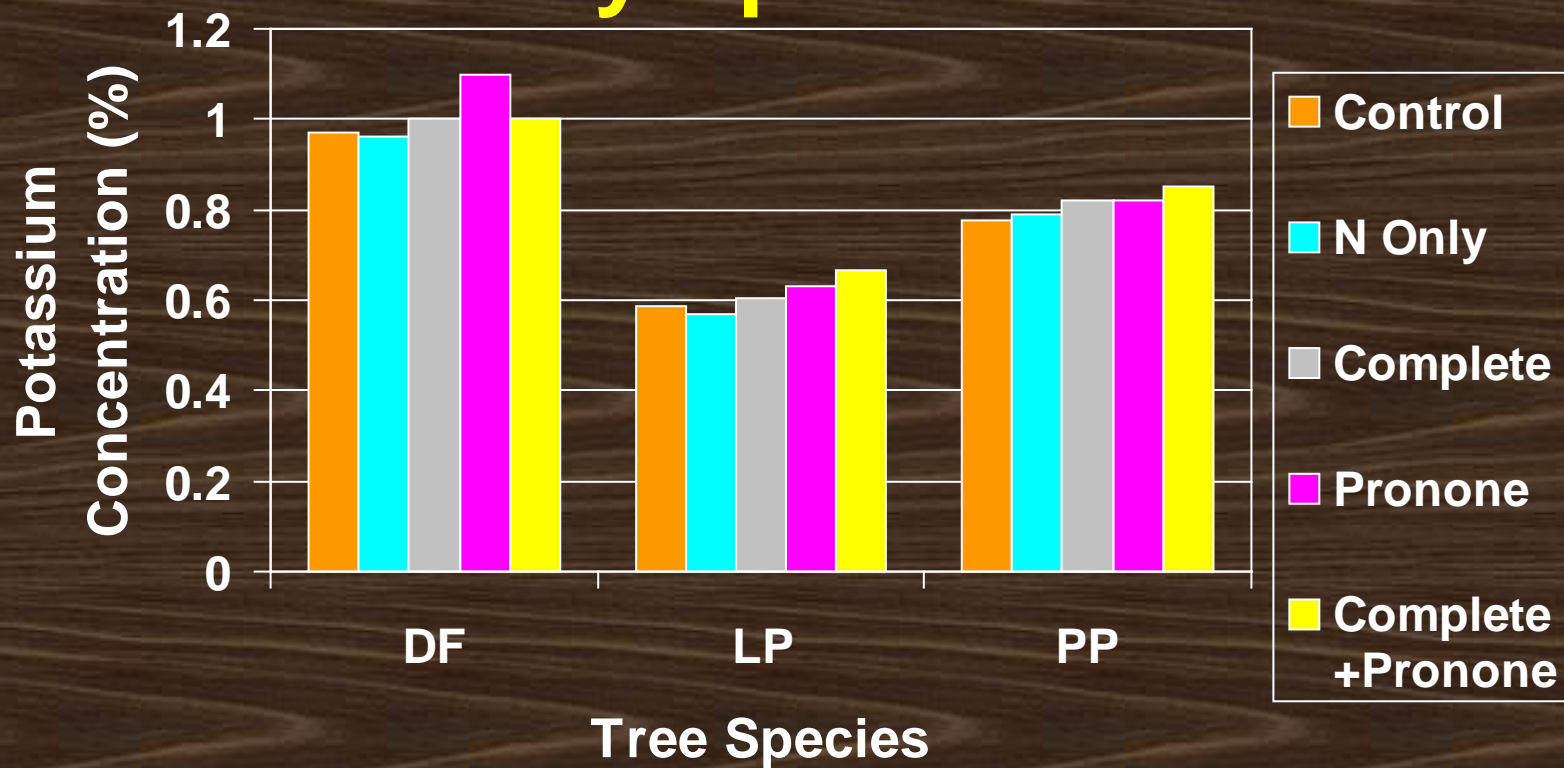




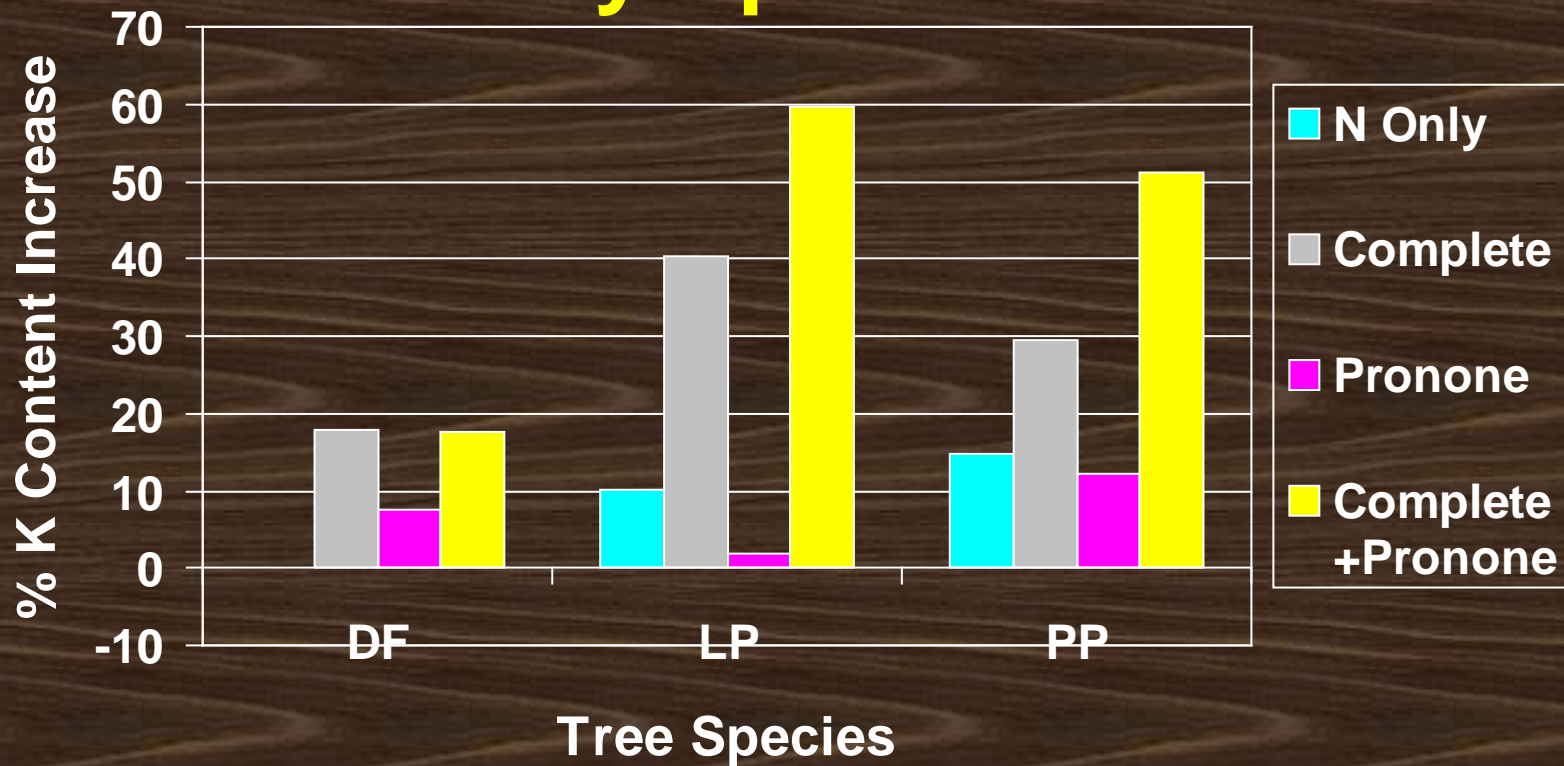
# Increase in Potassium Content Over Control Rate by Treatment and Species



# Fertilizer and Weed Control Treatment Effects on Foliar Potassium Concentration by Species



# Fertilizer and Weed Control Treatment Effects on Foliar Potassium Content by Species



# Foliar Nutrients

- N, S, and B all showed classic deficiency behavior when applied together.
- No strong evidence for deficiency of other nutrients applied (K,Mg,Fe,Zn,Cu)
- Multinutrient treatments appear to improve tree nutrient uptake, thereby increasing content for all nutrients
- A multinutrient treatment may allow higher application rates of N to be more effective

# Statistical Analysis Growth Data

Data fit to an analysis of covariance model where 2-year growth is a function of:

Tree Species

Site

Initial Tree Size

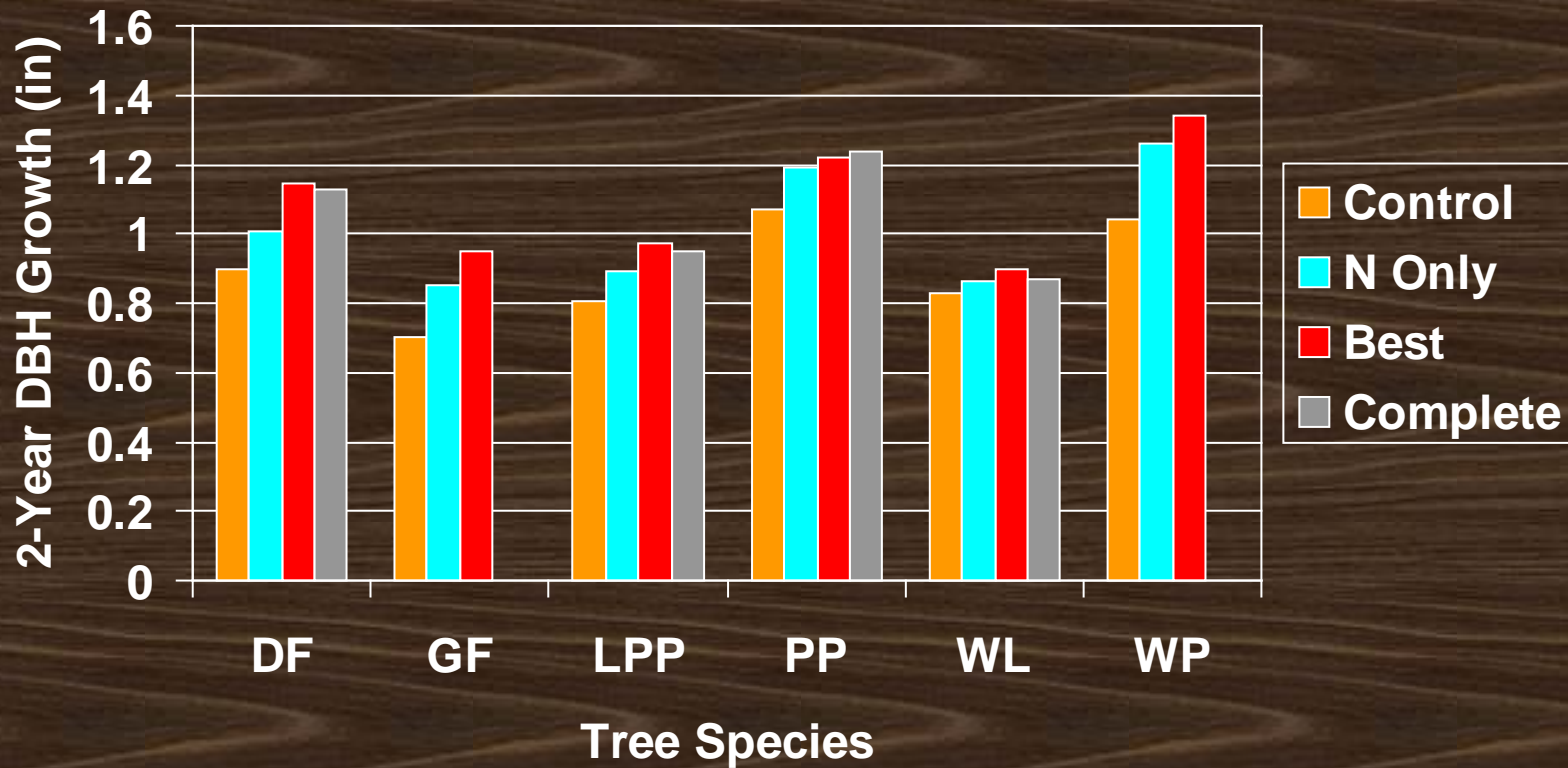
Fertilizer Treatment

Species X Fertilizer Treatment

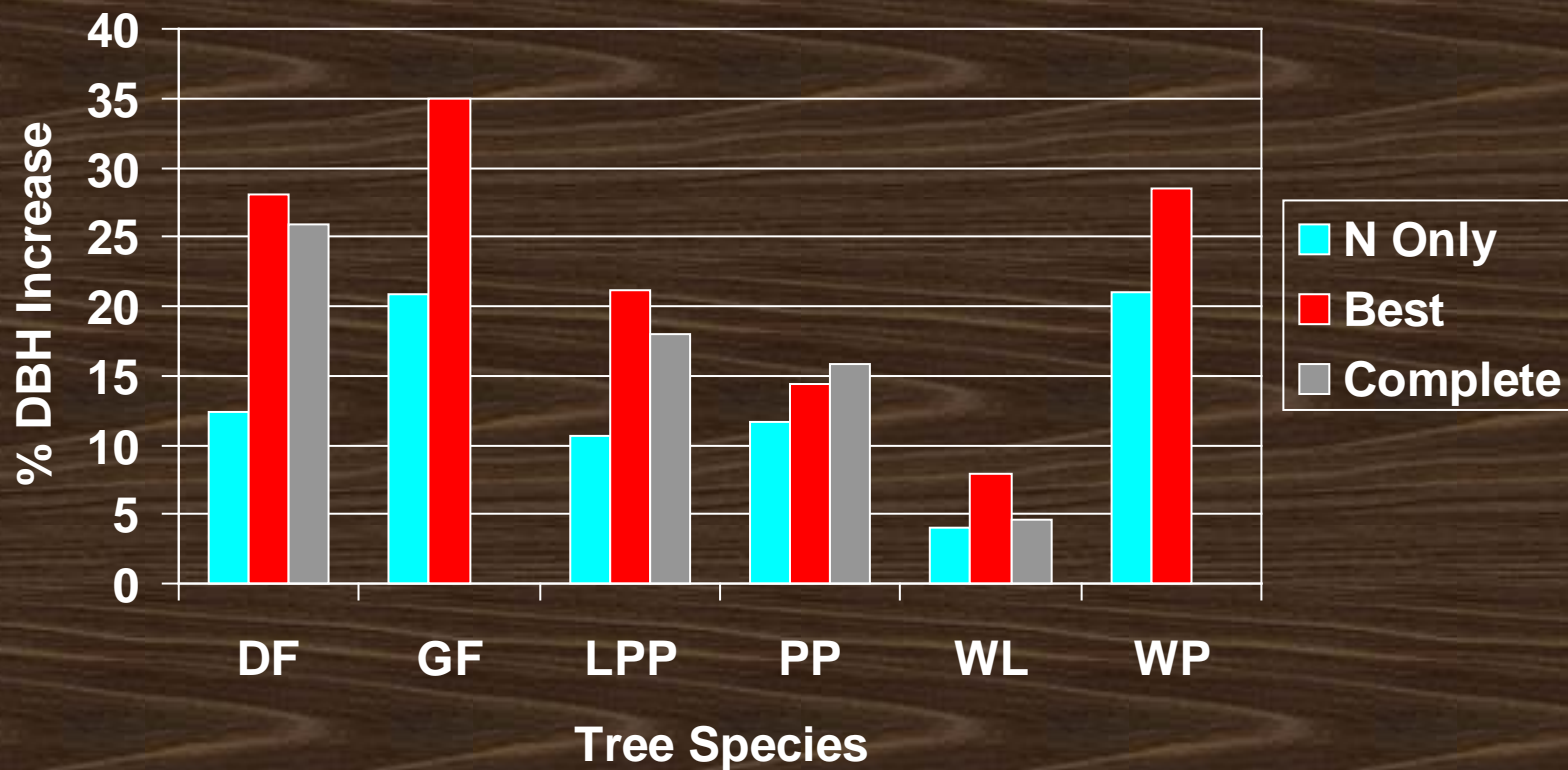
A more complex model including rock type and/or vegetation series was used to look at response differences by rock or vegetation type



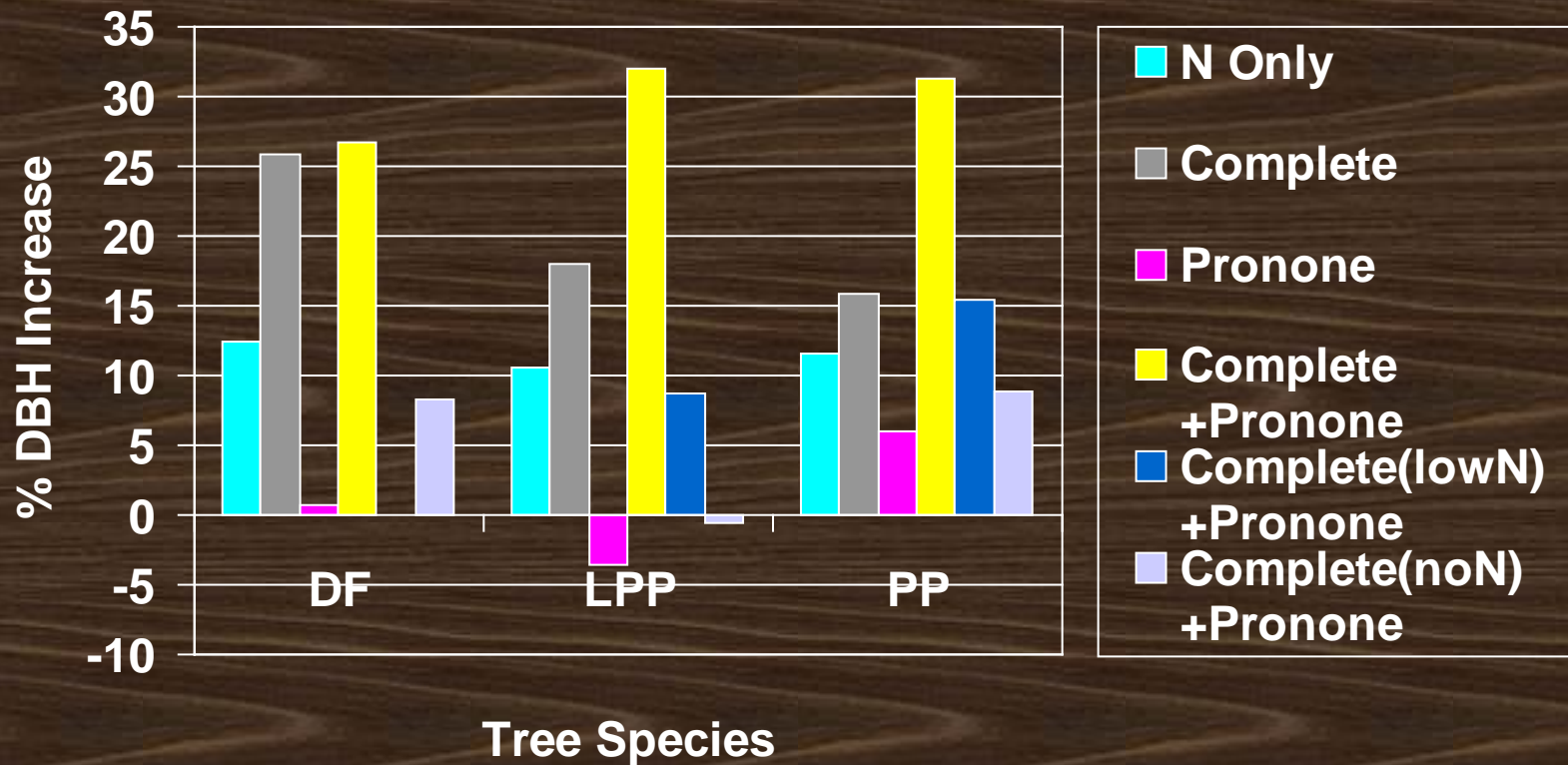
# Fertilizer Treatment Effects on 2-Year DBH Growth by Species



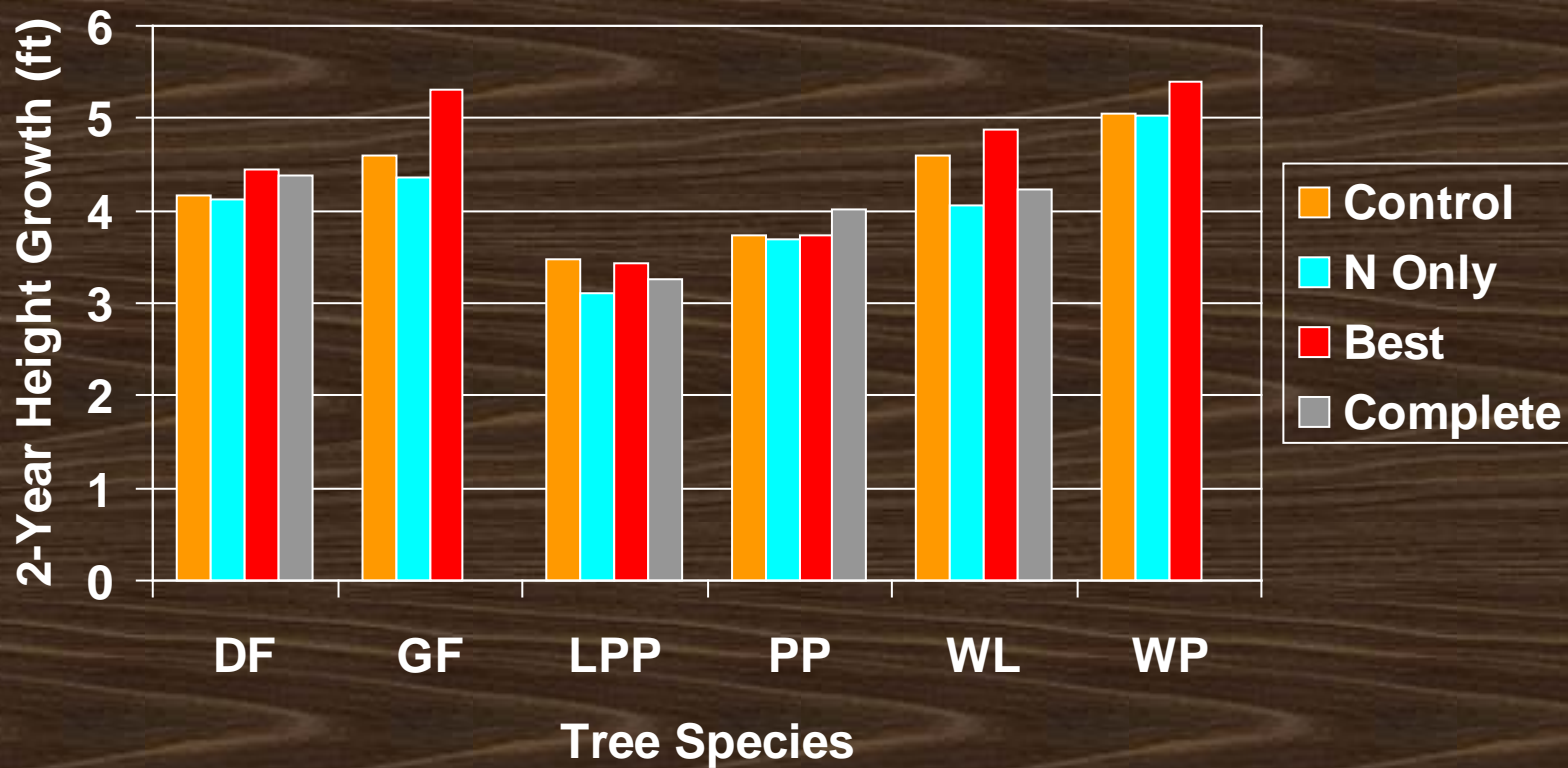
# Increase in 2-Year Diameter Growth Over Control Rate by Treatment and Species



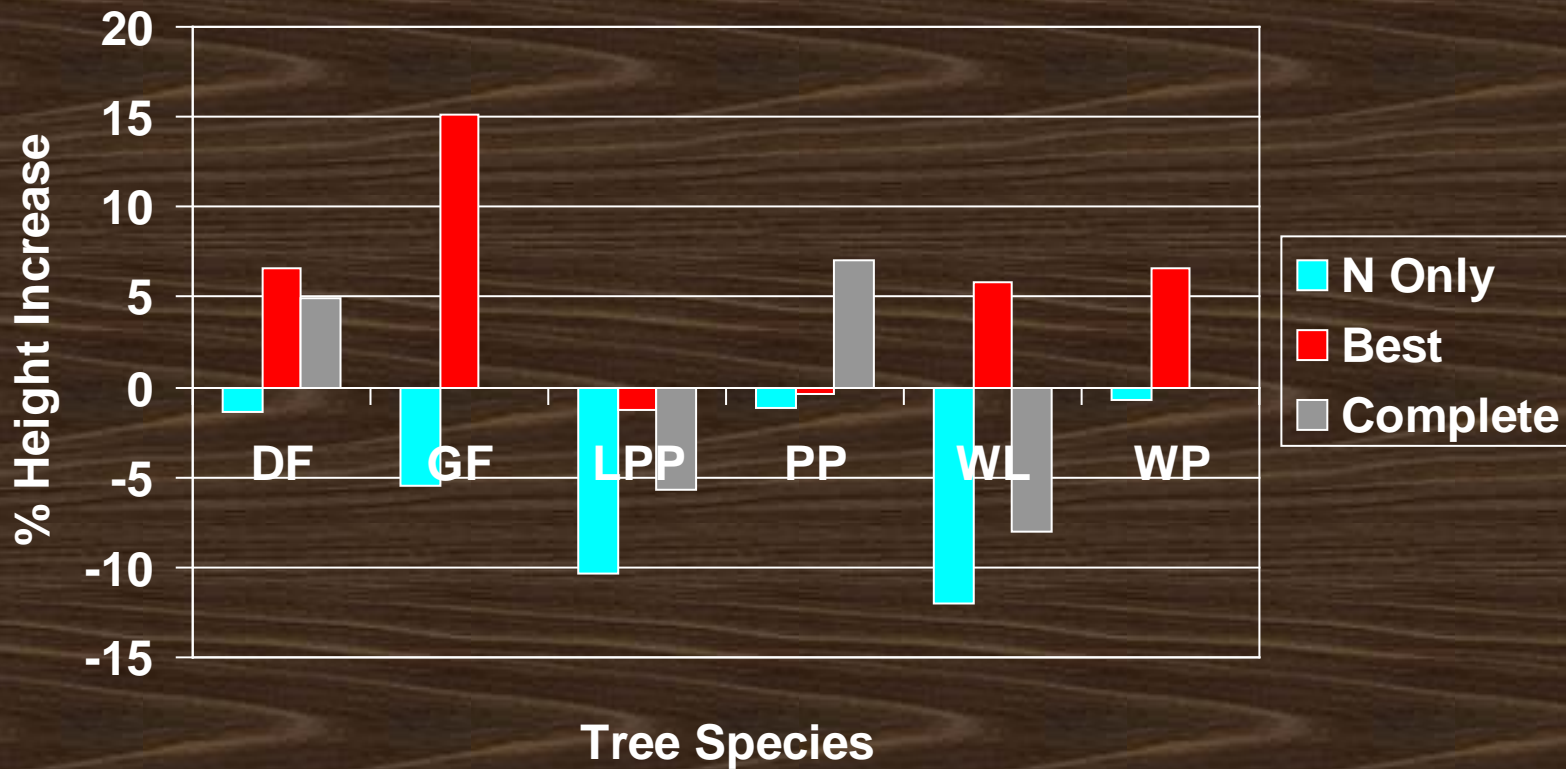
# Increase in 2-Year Diameter Growth Over Control Rate by Weed Control and Fertilizer Treatments



# Fertilizer Treatment Effects on 2-Year Height Growth by Species

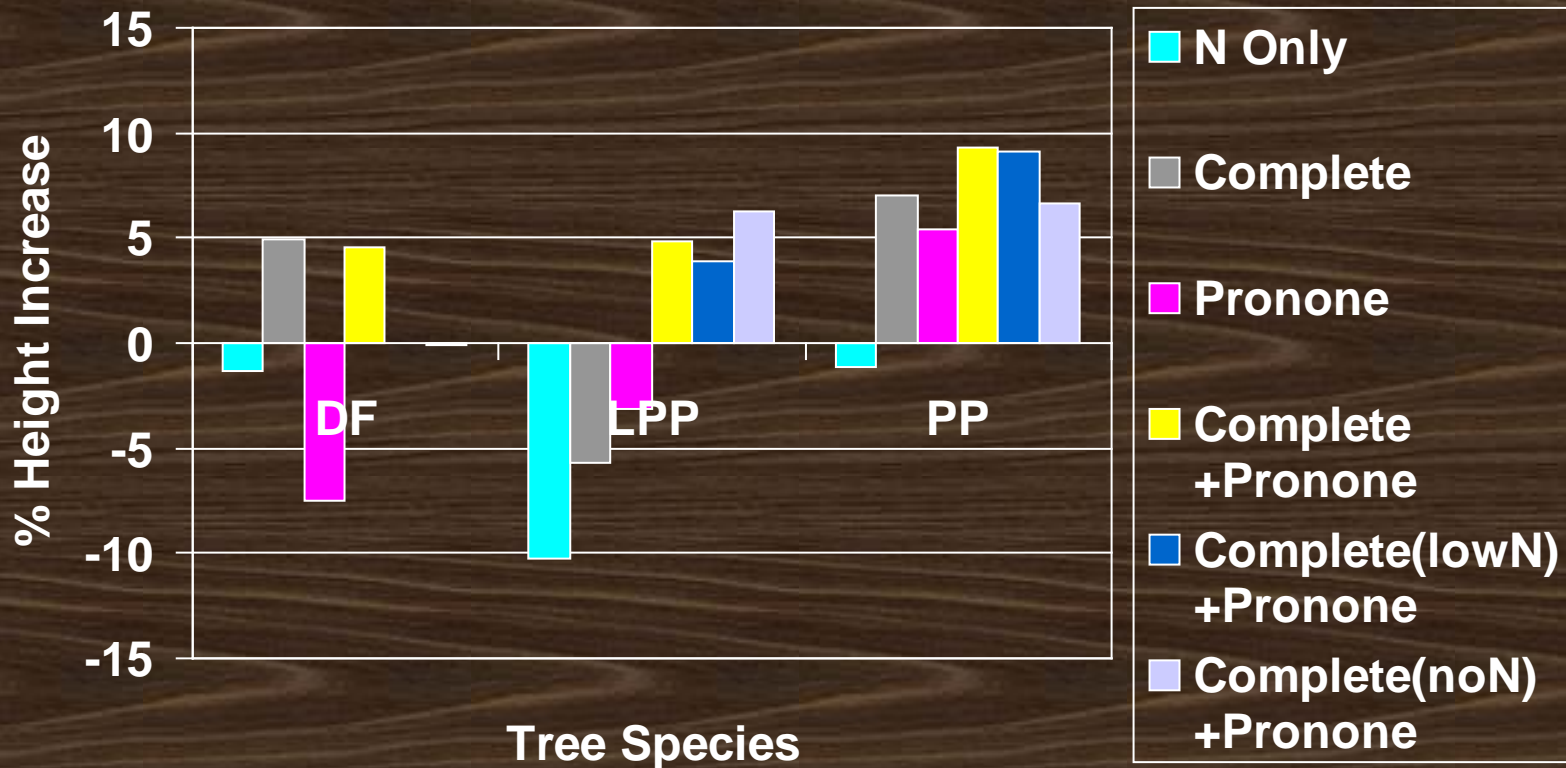


# Increase in 2-Year Height Growth Over Control Rate by Treatment and Species

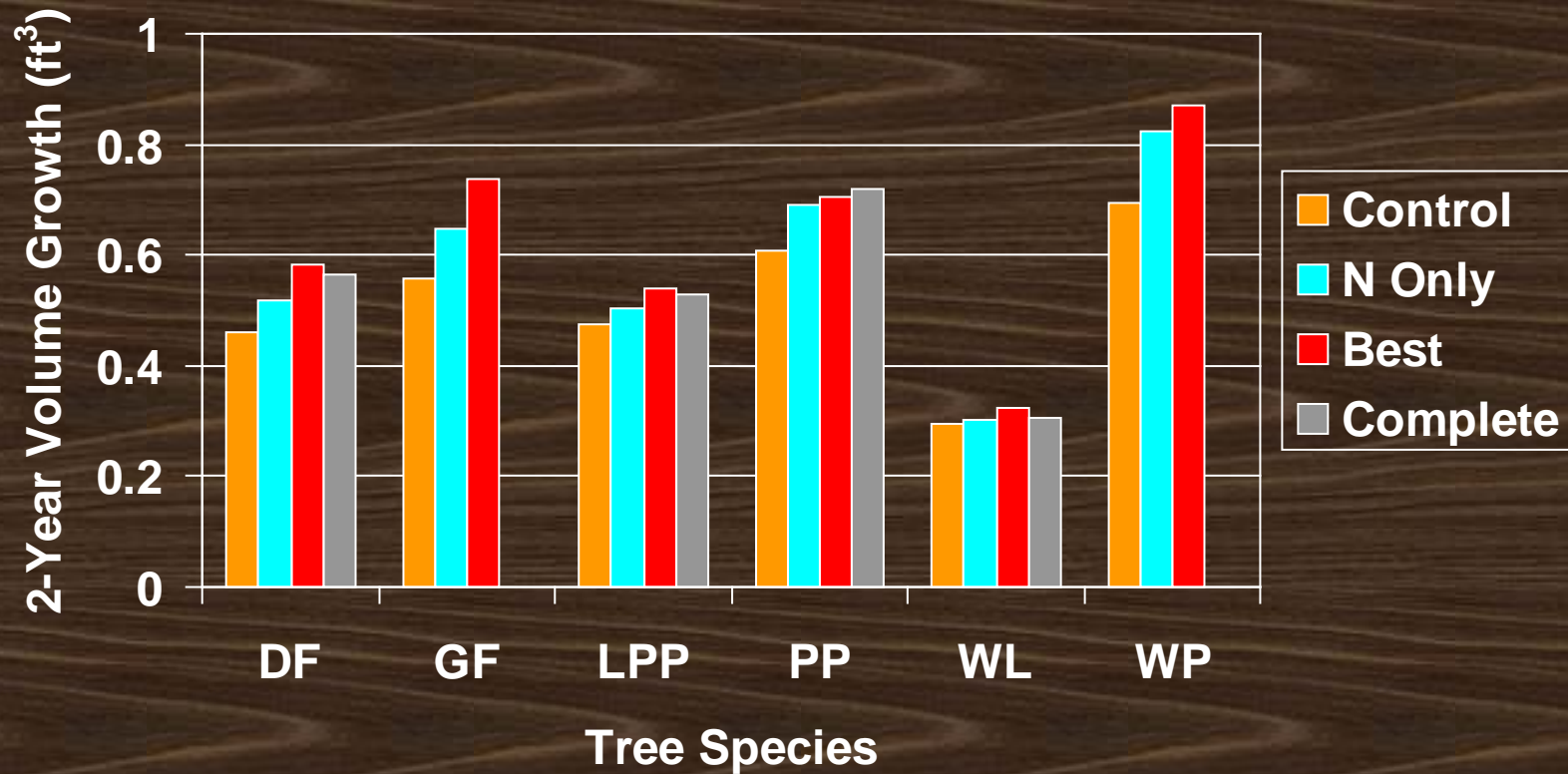




# Increase in 2-Year Height Growth Over Control Rate by Weed Control and Fertilizer Treatments



# Fertilizer Treatment Effects on 2-Year Volume Growth by Species

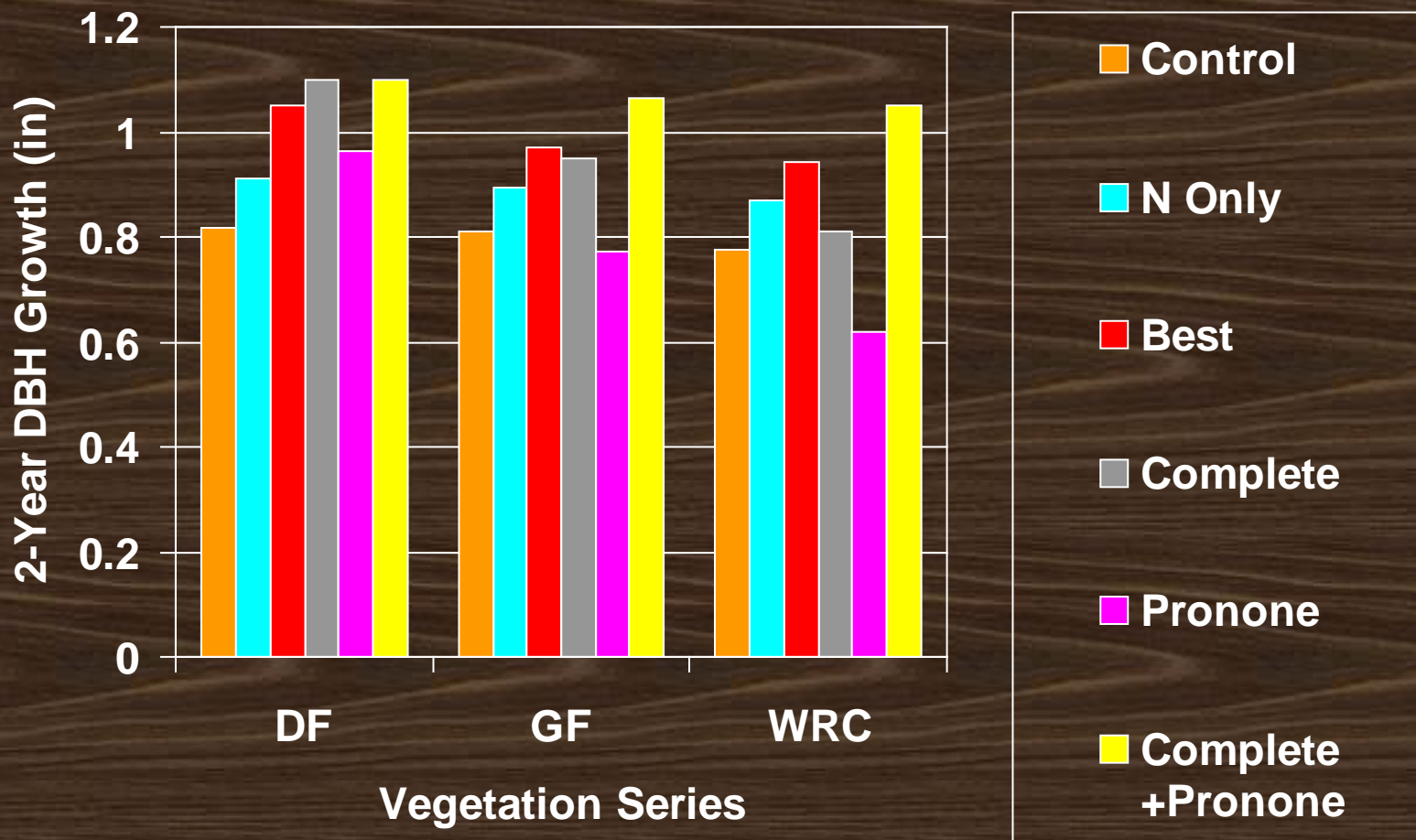


# **Treatment Differences across Vegetation and Rock Types**

# Distribution of Sites with Growth Data by Species, Rock Type, and Vegetation Series

Species	Rock Type										
	Extrusive		Intrusive			Metamorphic			Unconsolidated		
						Weathering Potential					
						high	medium	low			
	Vegetation Series										
	DF	GF	DF	GF	WRC	GF	WRC	WRC	WRC	GF	WRC
DF		9			4		5	8	2	3	
GF					2		5	3	1		1
LP	2	3		5	1	1				4	2
PP		14	2	4	2	1		1		4	1
WL		1			1			1		1	
WP					1			2			

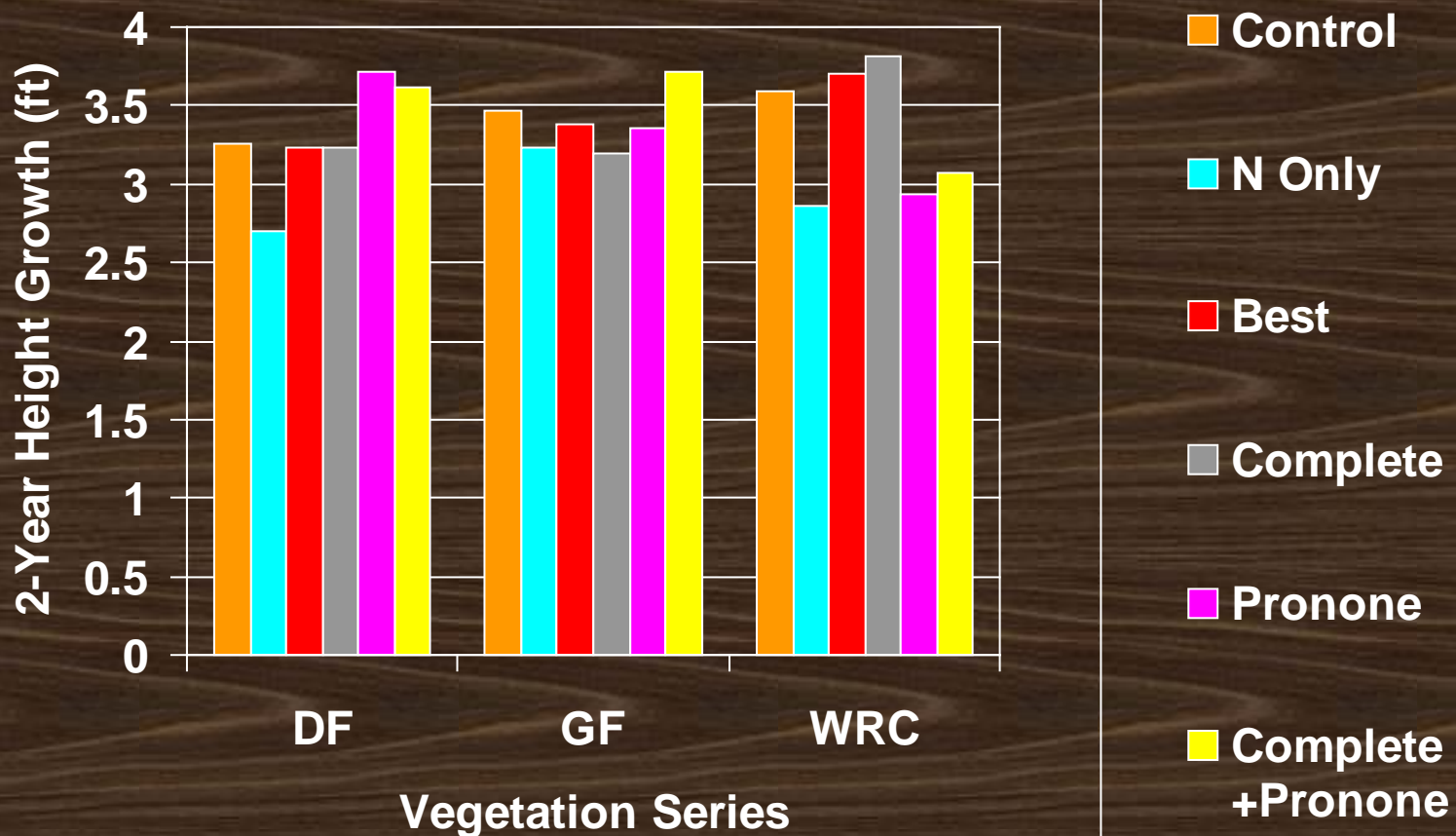
# Fertilizer Treatment Effects on 2-Year DBH Growth by Vegetation Series Lodgepole Pine





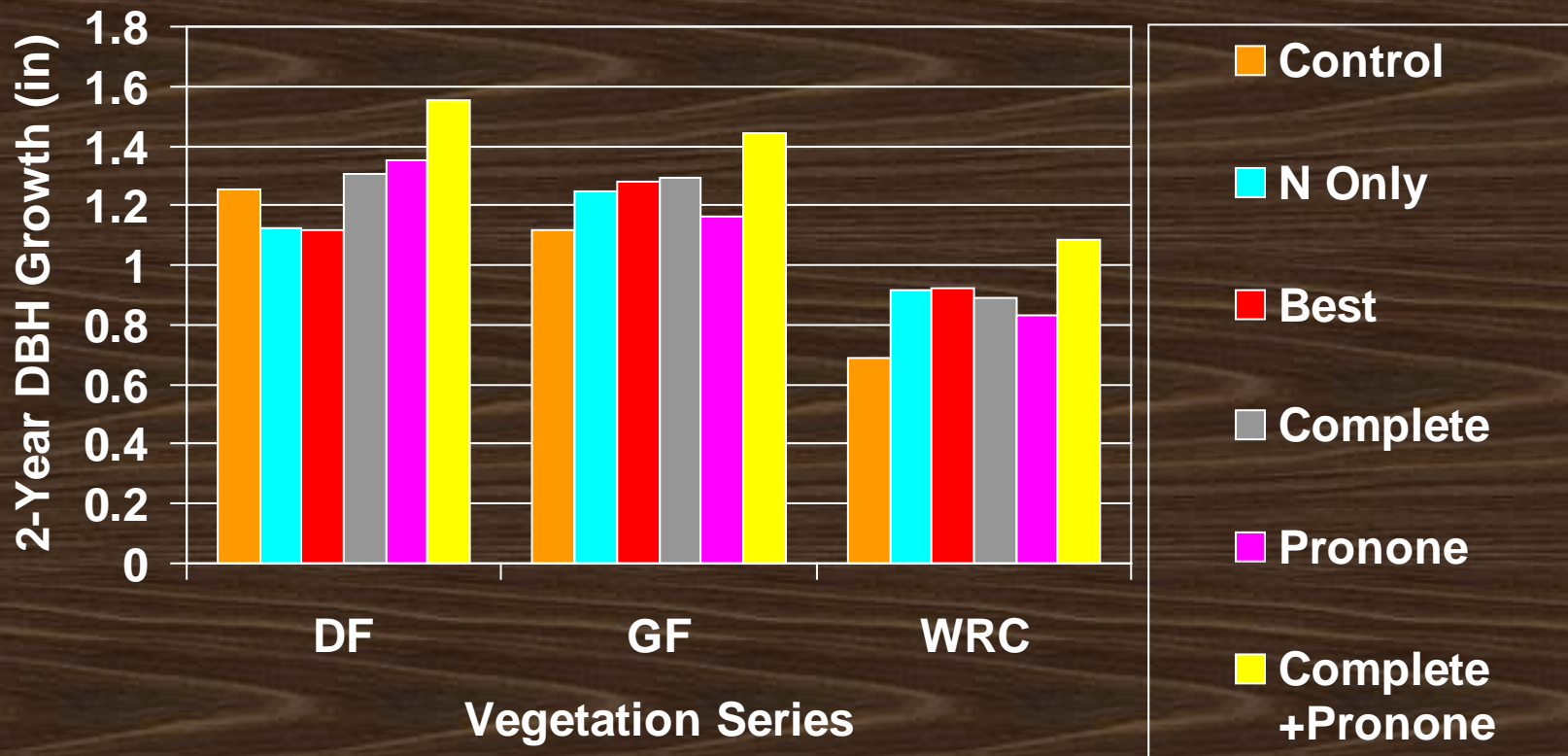
# Fertilizer Treatment Effects on 2-Year Height Growth by Vegetation Series

## Lodgepole Pine



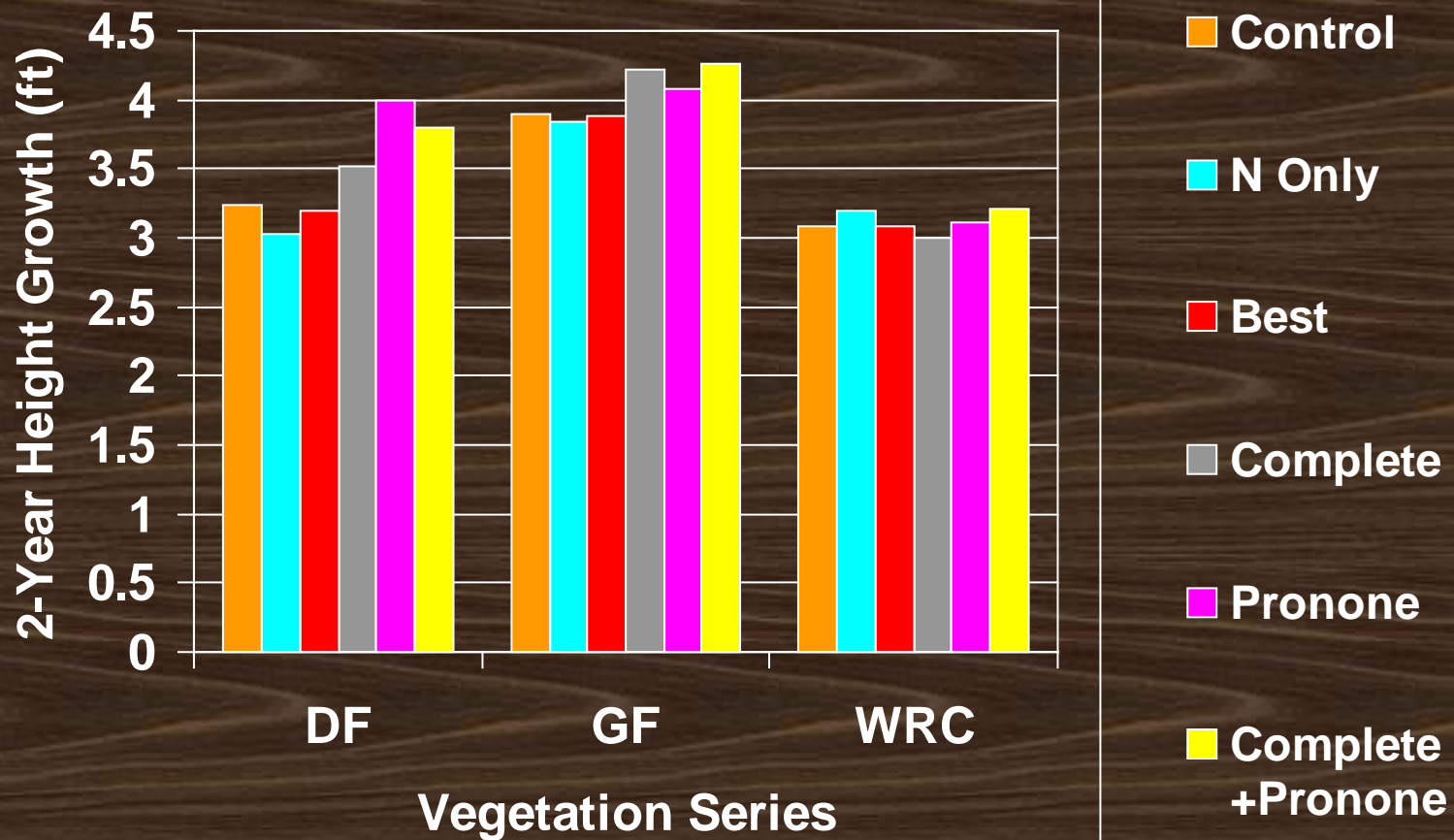
# Fertilizer Treatment Effects on 2-Year DBH Growth by Vegetation Series

## Ponderosa Pine

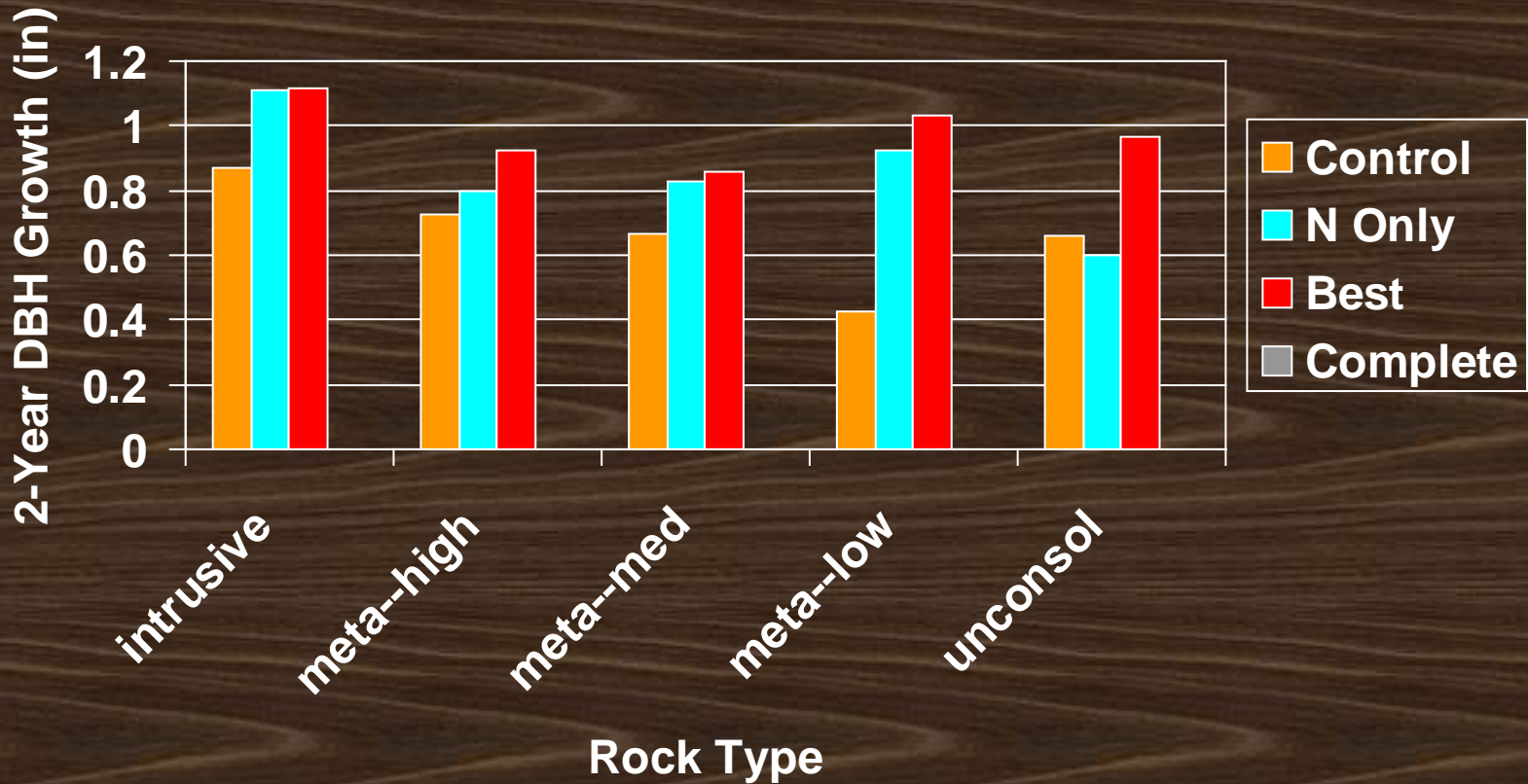


# Fertilizer Treatment Effects on 2-Year Height Growth by Vegetation Series

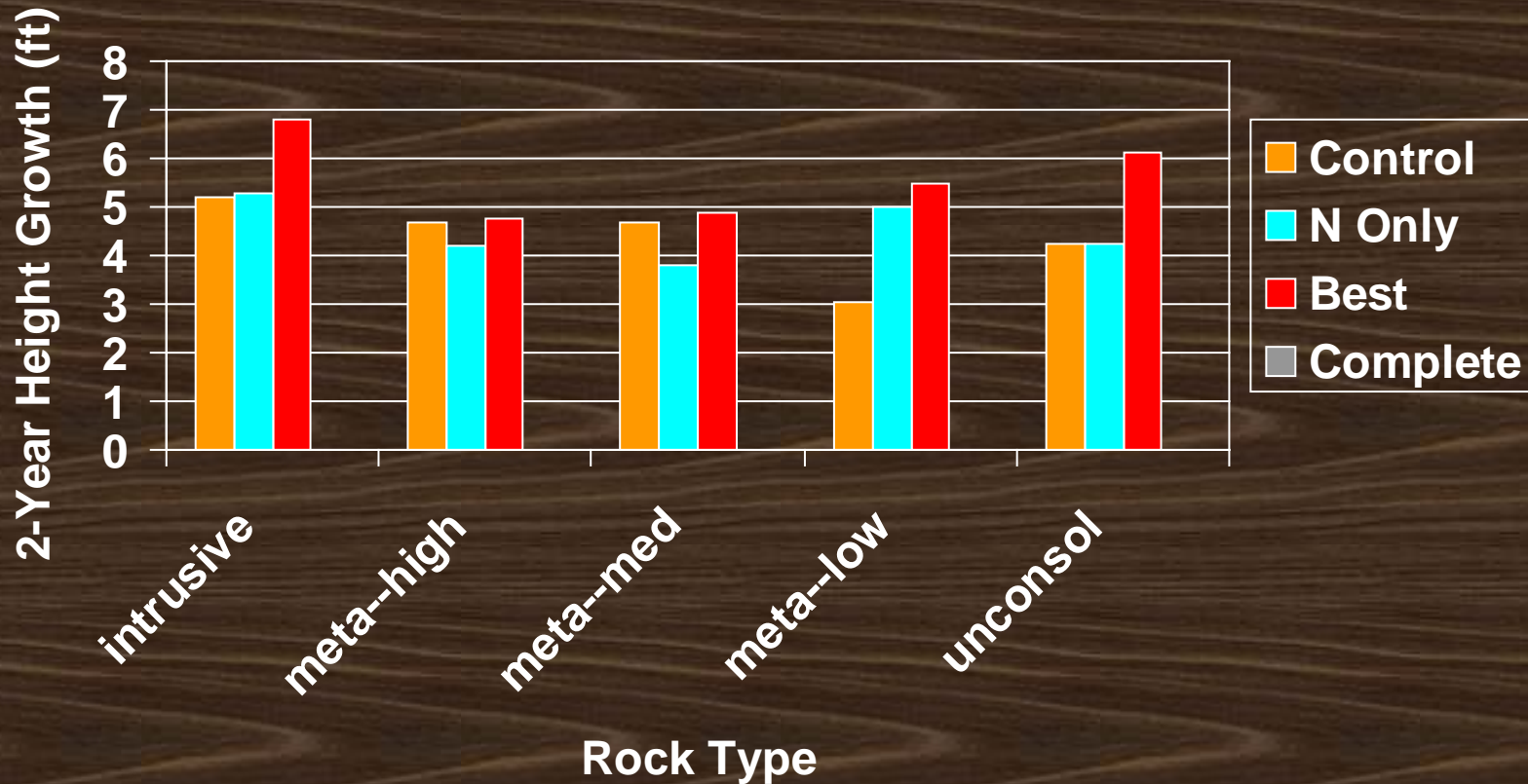
## Ponderosa Pine



# Fertilizer Treatment Effects on 2-Year DBH Growth by Rock Type Grand Fir

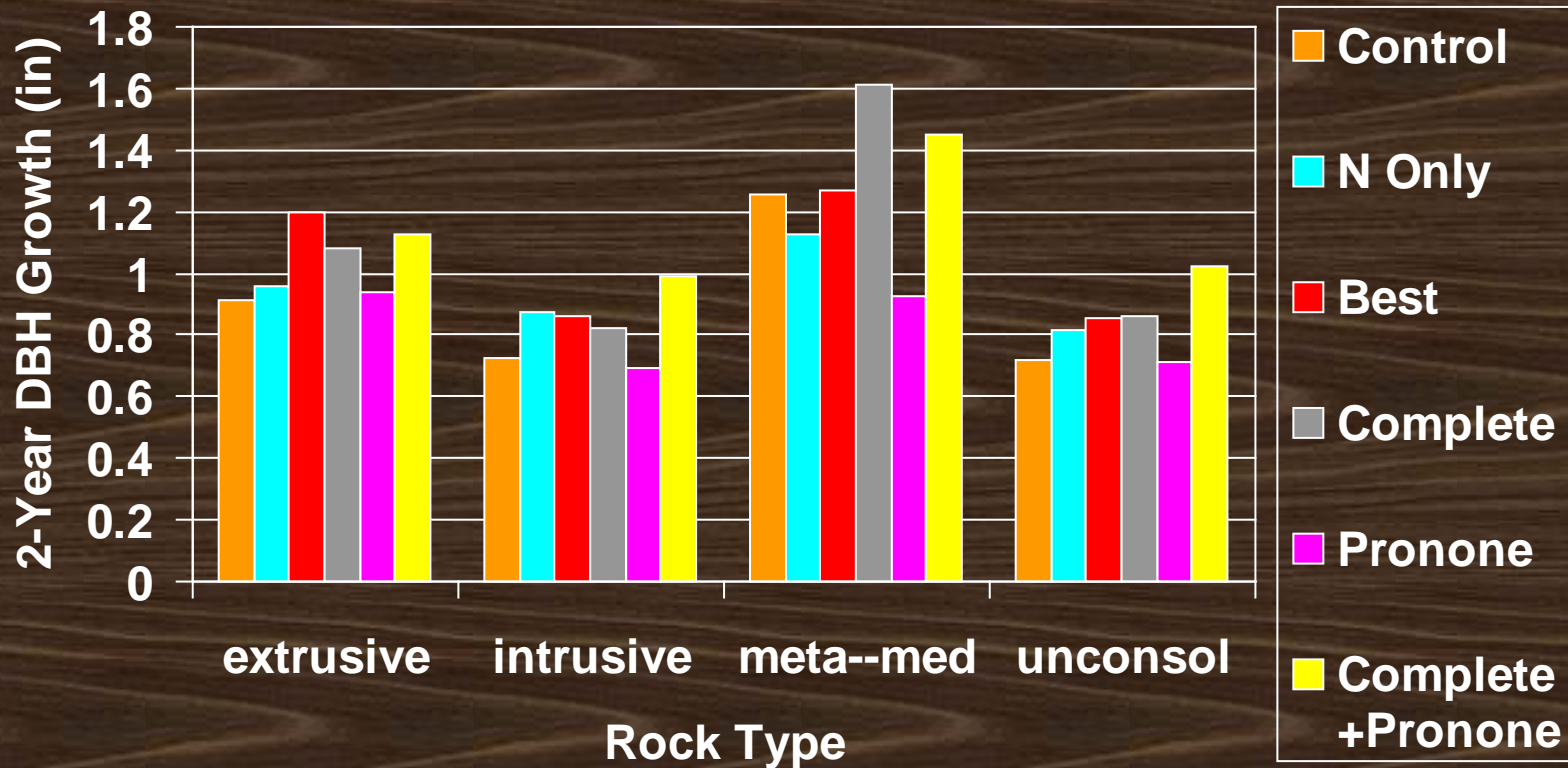


# Fertilizer Treatment Effects on 2-Year Height Growth by Rock Type Grand Fir

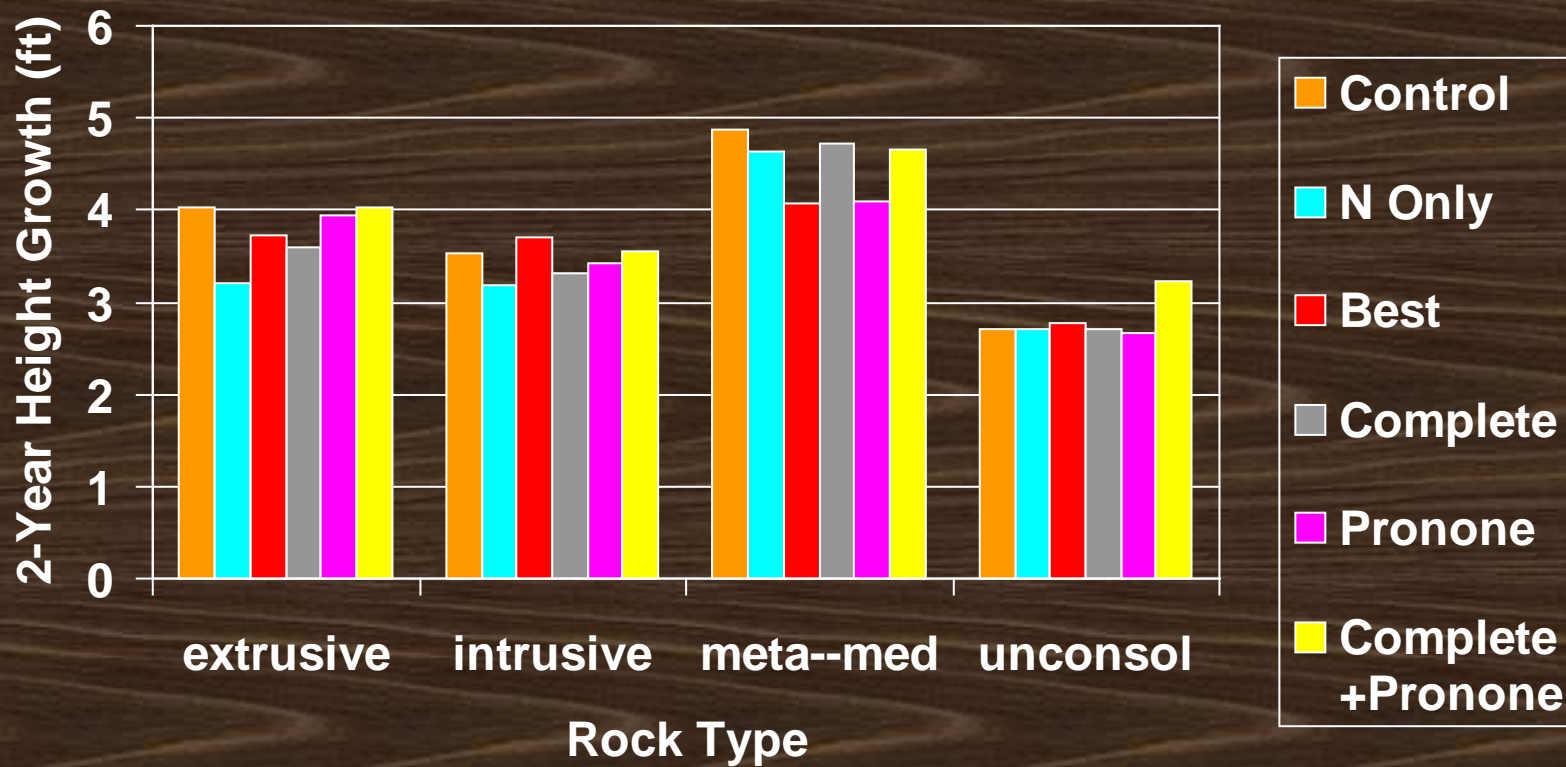




# Fertilizer Treatment Effects on 2-Year DBH Growth by Rock Type Lodgepole Pine



# Fertilizer Treatment Effects on 2-Year Height Growth by Rock Type Lodgepole Pine



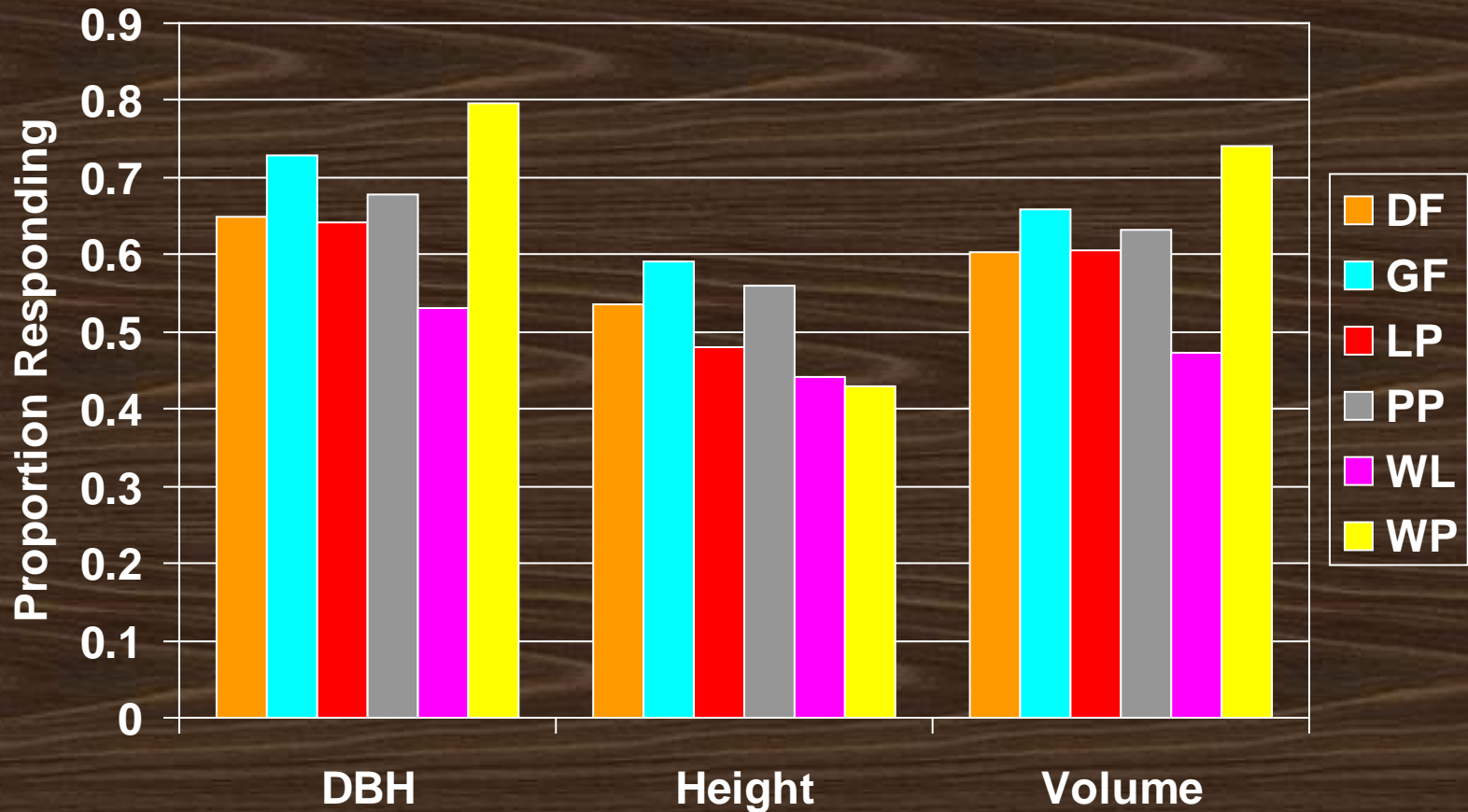
# DBH Growth

- N only treatments produced a 10 to 15% increase in diameter growth while multinutrient treatments boosted diameter growth by 15 to 35%.
- Multinutrient treatments combined with weed control improved response for LP and PP.
- Response varied by rock type for GF and LP, although the rock types with different behavior had few samples.
- Treatment differences between vegetation series were mostly confined to effects of Pronone.

# Height Growth

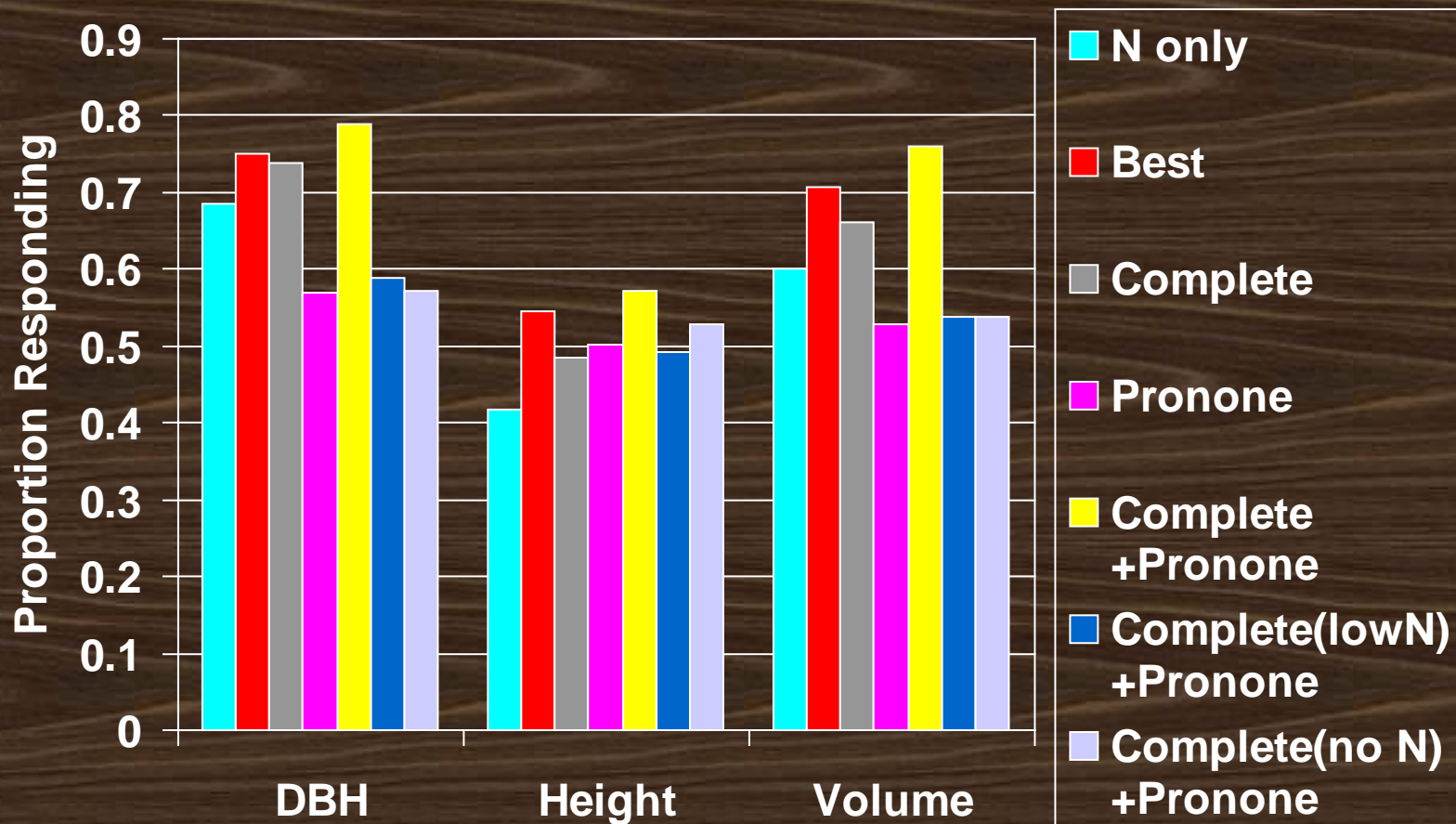
- N only treatments can decrease height growth. GF, LP, and WL appear most susceptible to this.
- Multinutrient treatments maintained or increased height growth.
- Weed control increased height growth on dry sites.

# Proportion of Trees Responding By Species





# Proportion of Trees Responding By Treatment



# Advantages of Multinutrient Fertilization

- Better nutrient balance in foliage
- Enhanced nutrient uptake of all nutrients
- Better diameter, BA, and volume growth
- Maintained or increased height growth
- Better consistency in response