The Forest Health/Nutrition Experiment: 6-year Growth and Mortality Responses for Individual Species

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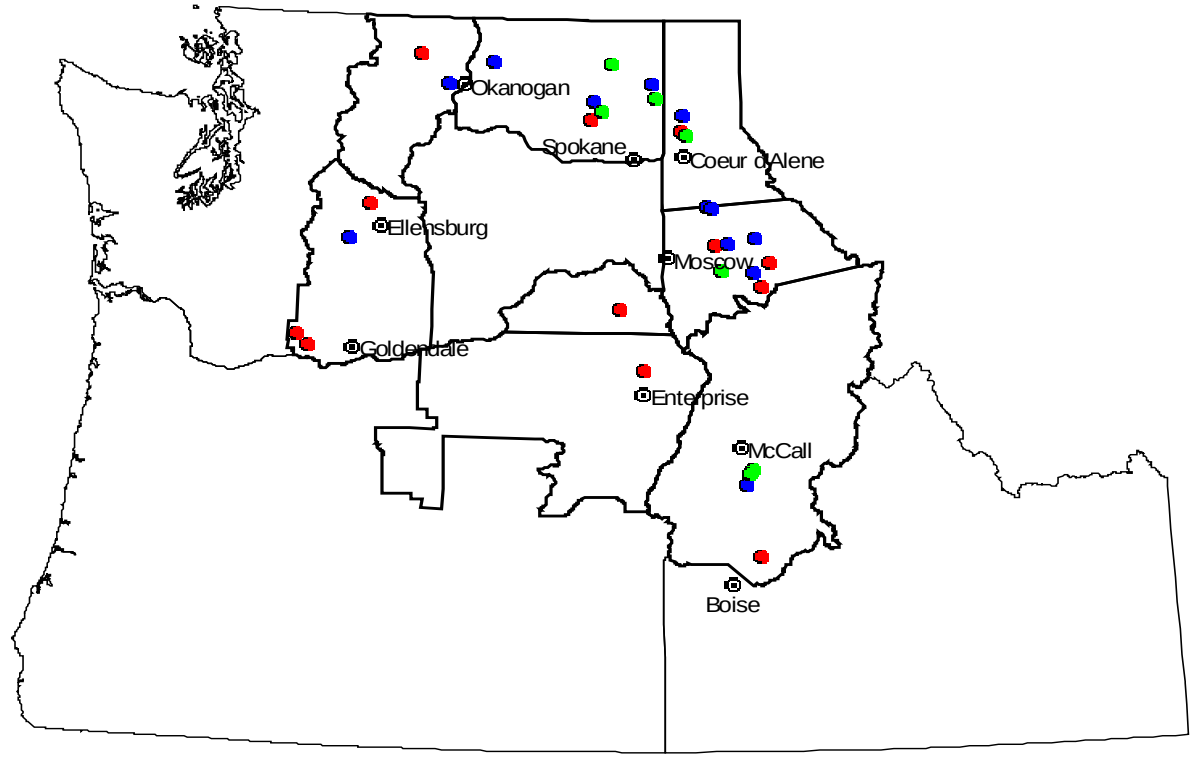
2004 IFTNC Annual Meeting

IFTNC Forest Health / Nutrition Experimental Locations (1994-1996)



Design of the experiment

- Sites stratified by 4 rock types and 3 vegetation types
- A core N and K 4-treatment experiment at all sites
- Additional fertilizer treatments tailored to site conditions
- Large experimental plots to monitor mortality

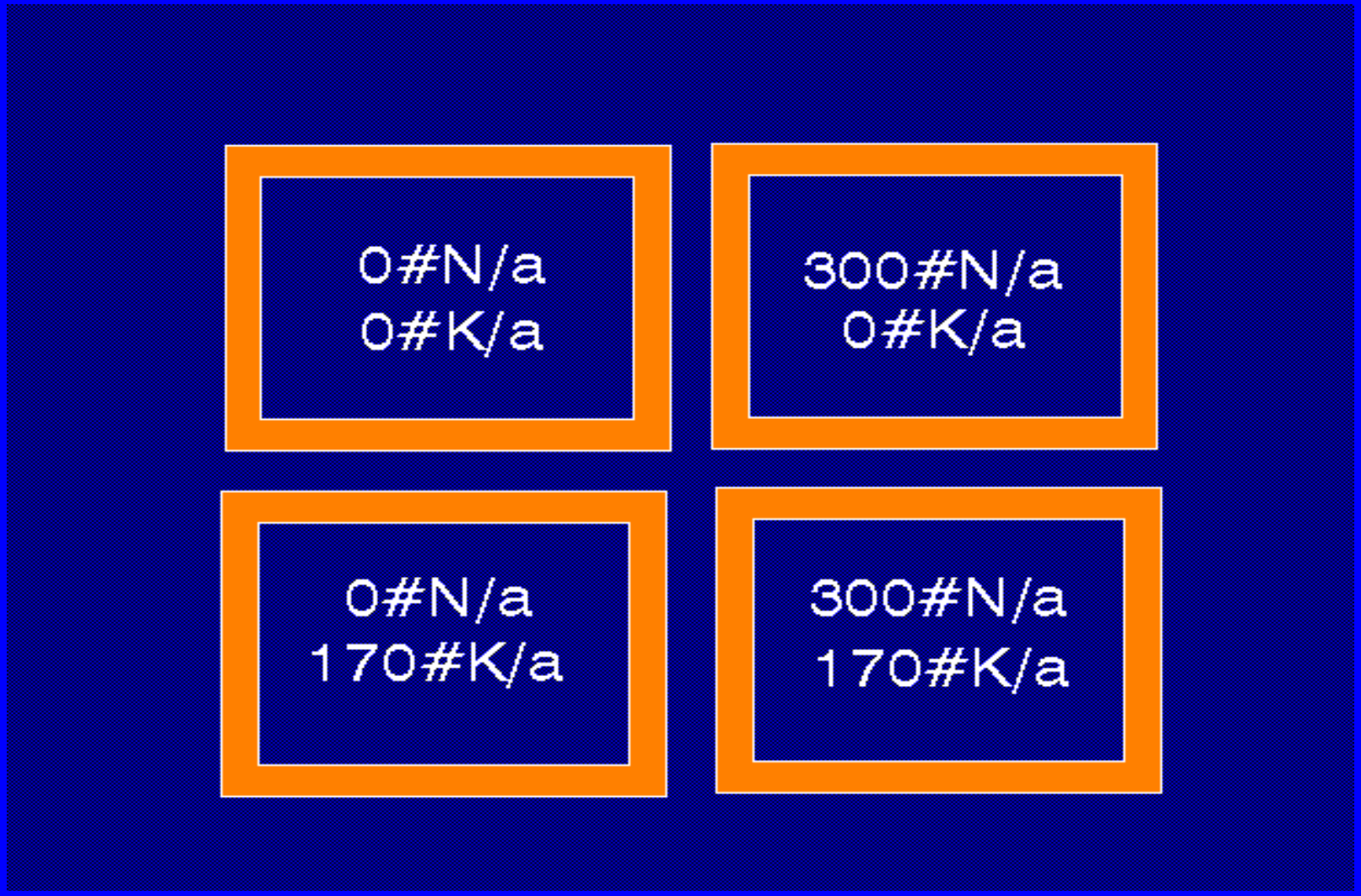
Sites Established: 1994-1996

by Rock Type and Vegetation Series

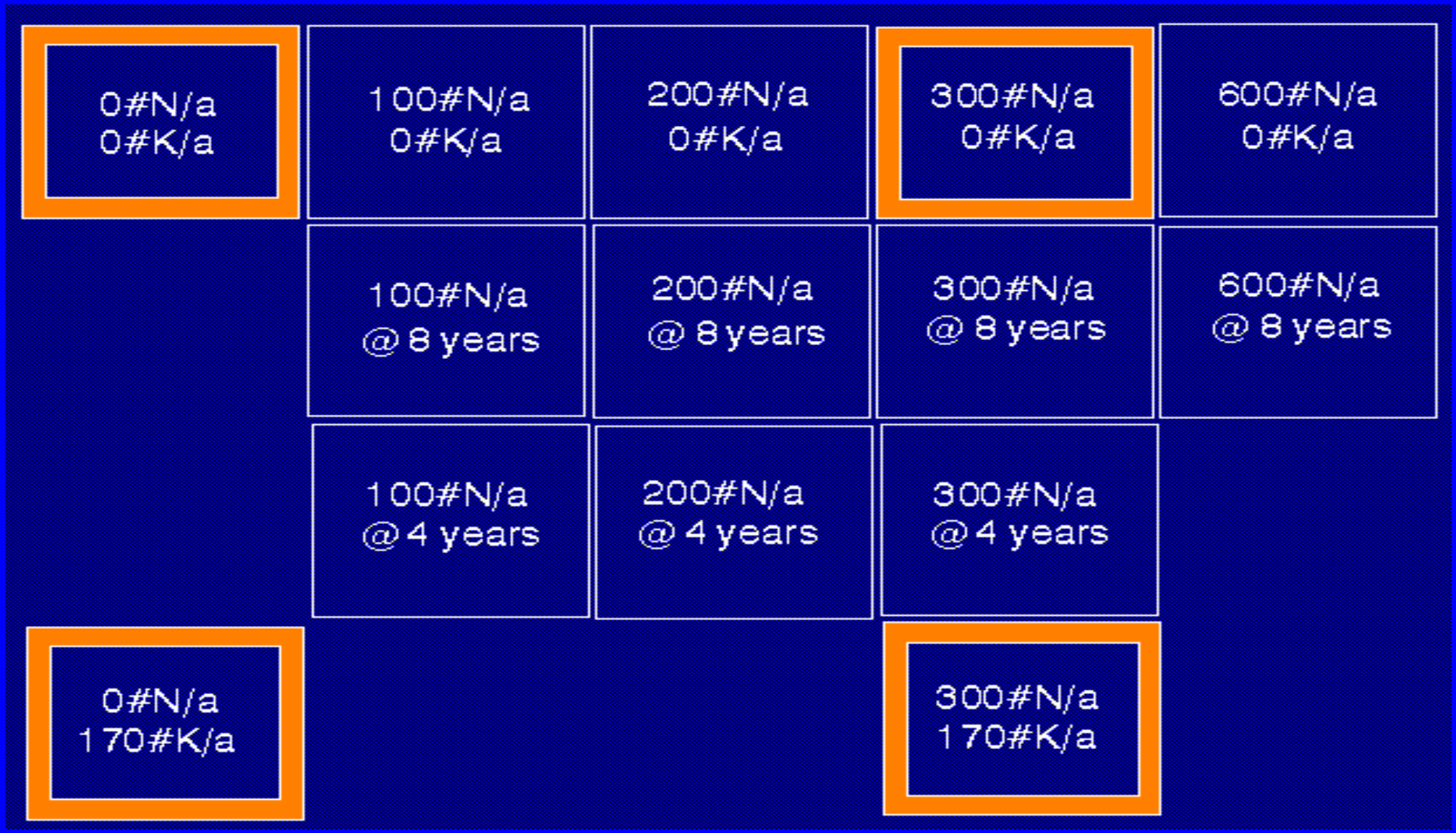
	Douglas-fir	Grand fir	Cedar/ Hemlock	TOTAL
Granite	K,B (1) K (2) N,B (1)	K (4)	K (2)	10
Basalt	N (1) R (2)	K (3)	N (1) R (2)	9
Metamorphic		K (1)	K (3)	4
Mixed	N (2)	K (2)	K (1) N (3)	8
TOTAL	9	10	12	31

N-Rate (N), Repeated N-Rate (R), N-K Response Surface (K), Bark Beetle (B)

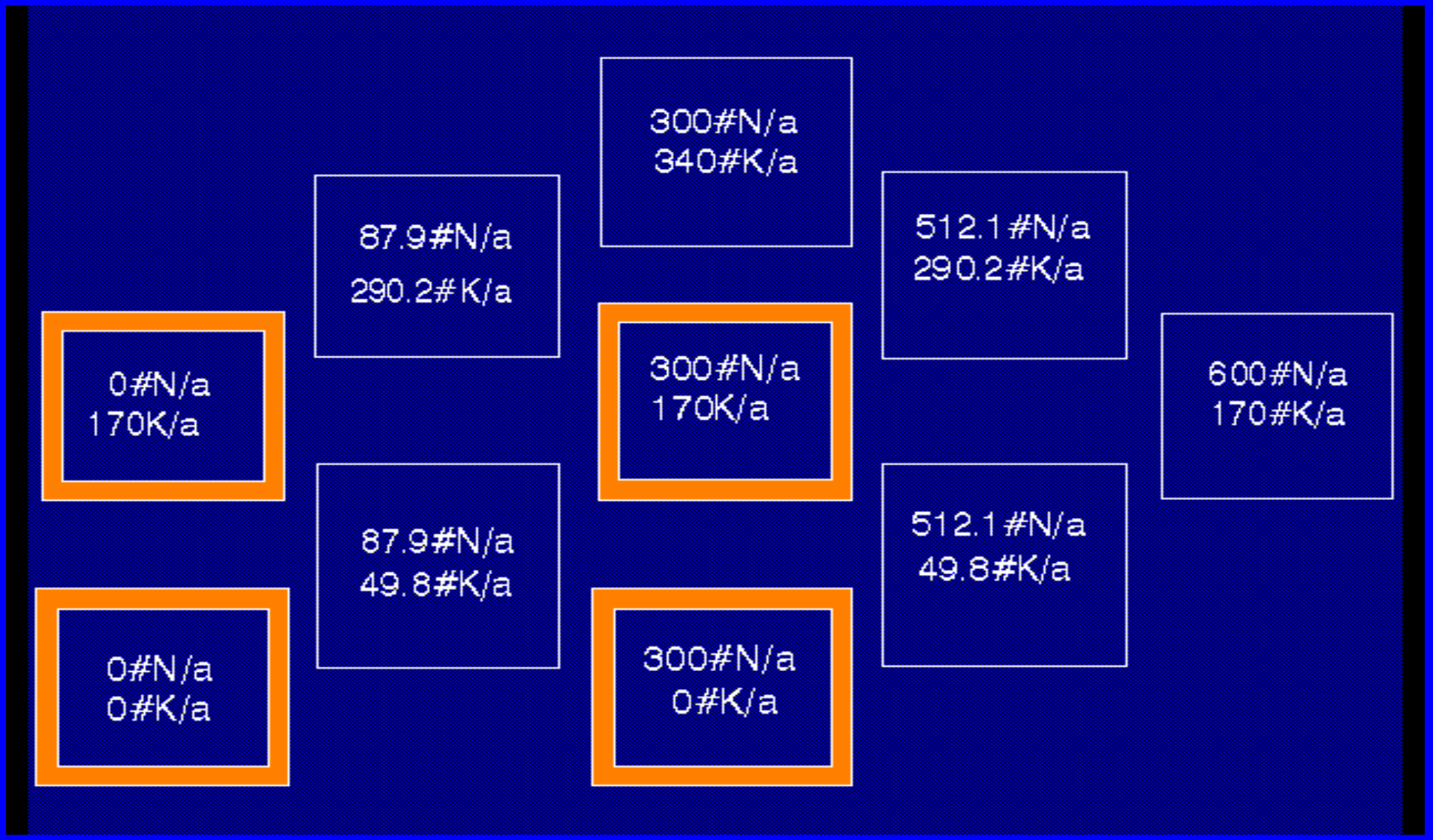
Core Design



Nitrogen Rate Design



N-K Response Surface Design

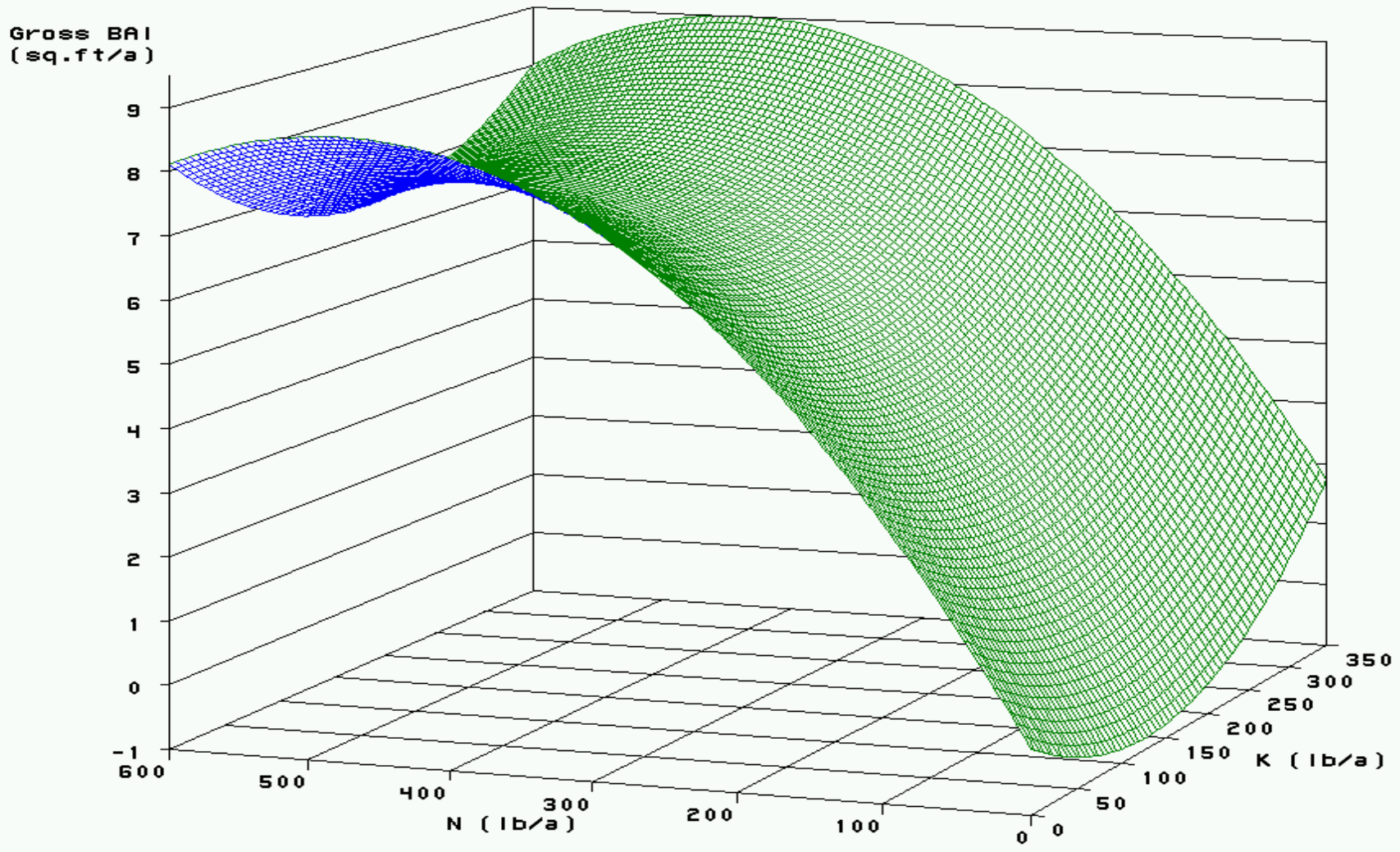


Topics for Today:

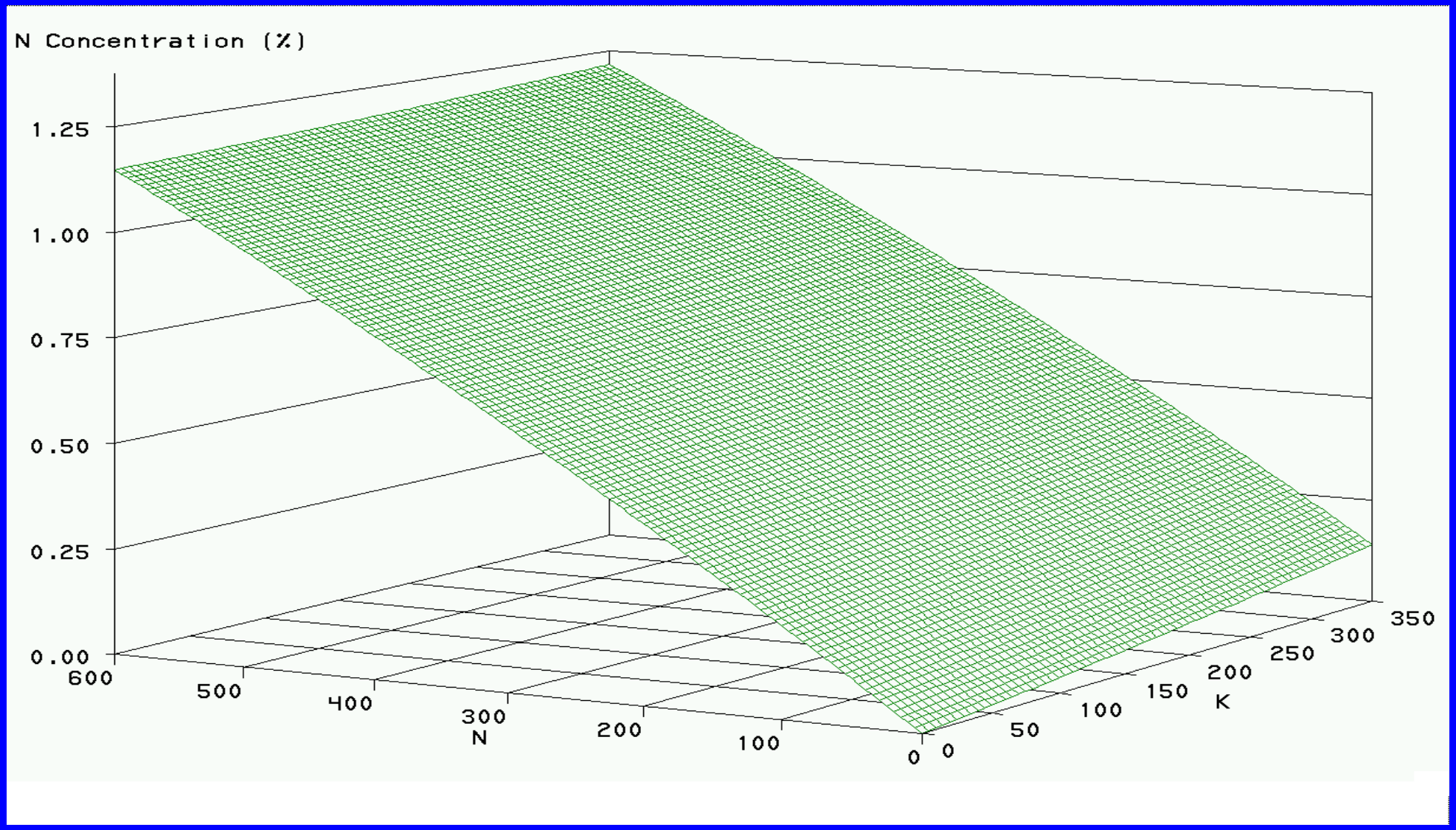
- Fertilizer Effects on Species-specific 6-year BA Growth
  - N and K Effects on relative growth: N and K response surface
  - S Effects (KCl vs. K_2SO_4) and Micronutrient Effects (B, Cu, Mo, Zn) on relative growth: ANOVA comparison of means

- Fertilizer Effects on Species-specific 6-year Mortality
  - N and K Effects on mortality: N and K response surface
  - S Effects (KCl vs. K_2SO_4) and Micronutrient Effects (B, Cu, Mo, Zn) on mortality: ANOVA comparison of means

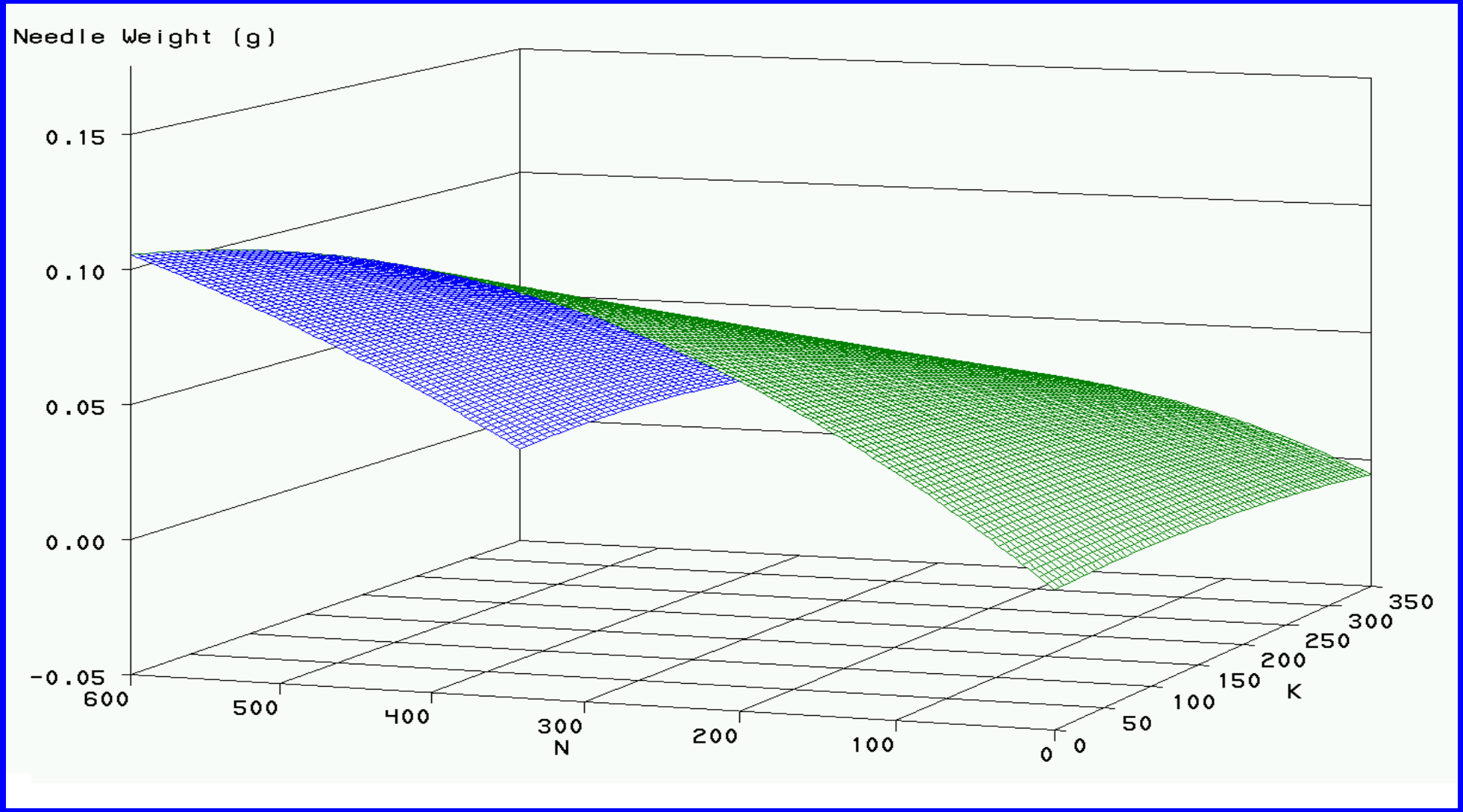
N and K fertilizer effects on 6-year gross BA growth



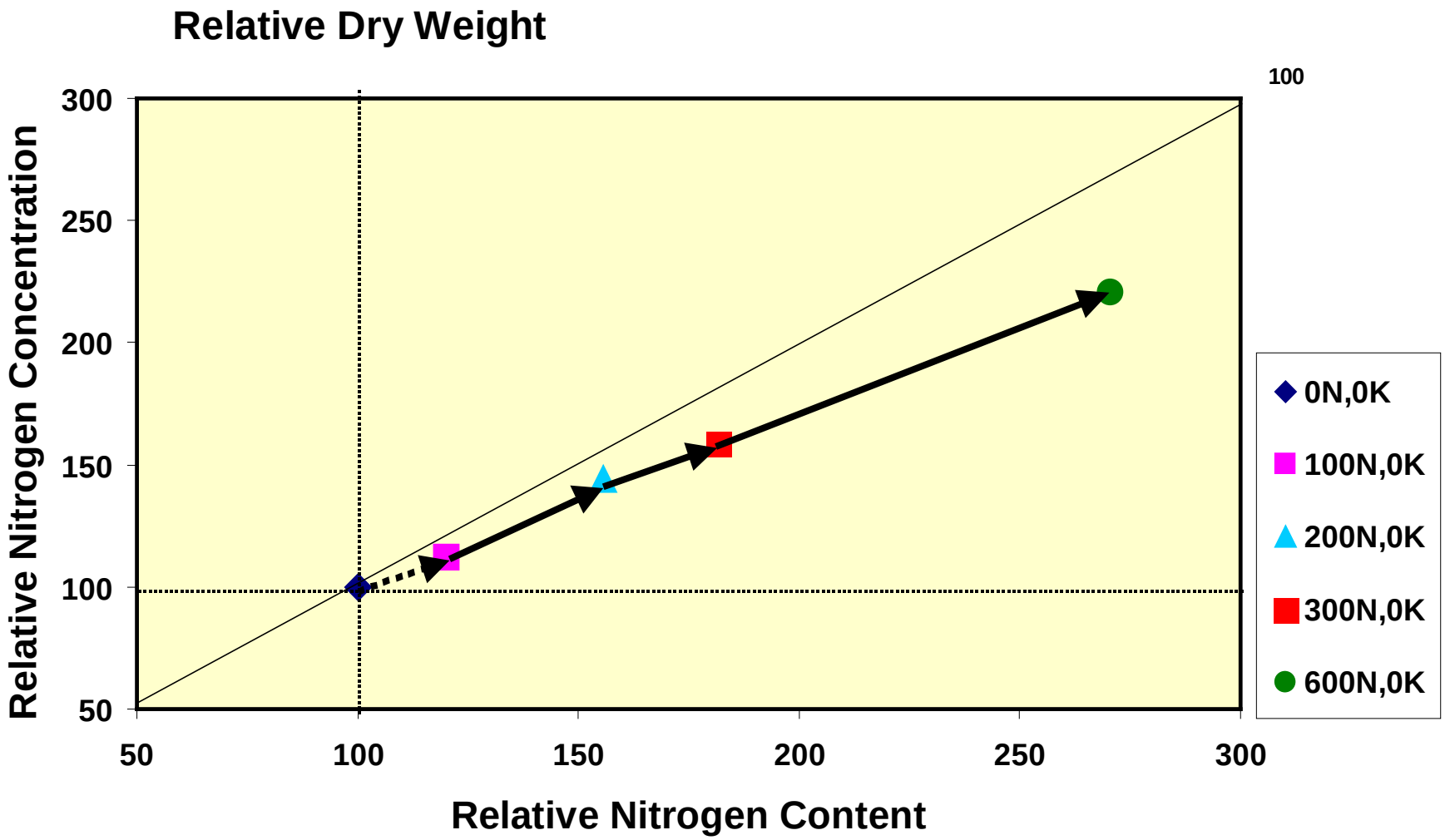
N and K Fertilizer Effects: Douglas-fir Nitrogen Concentration



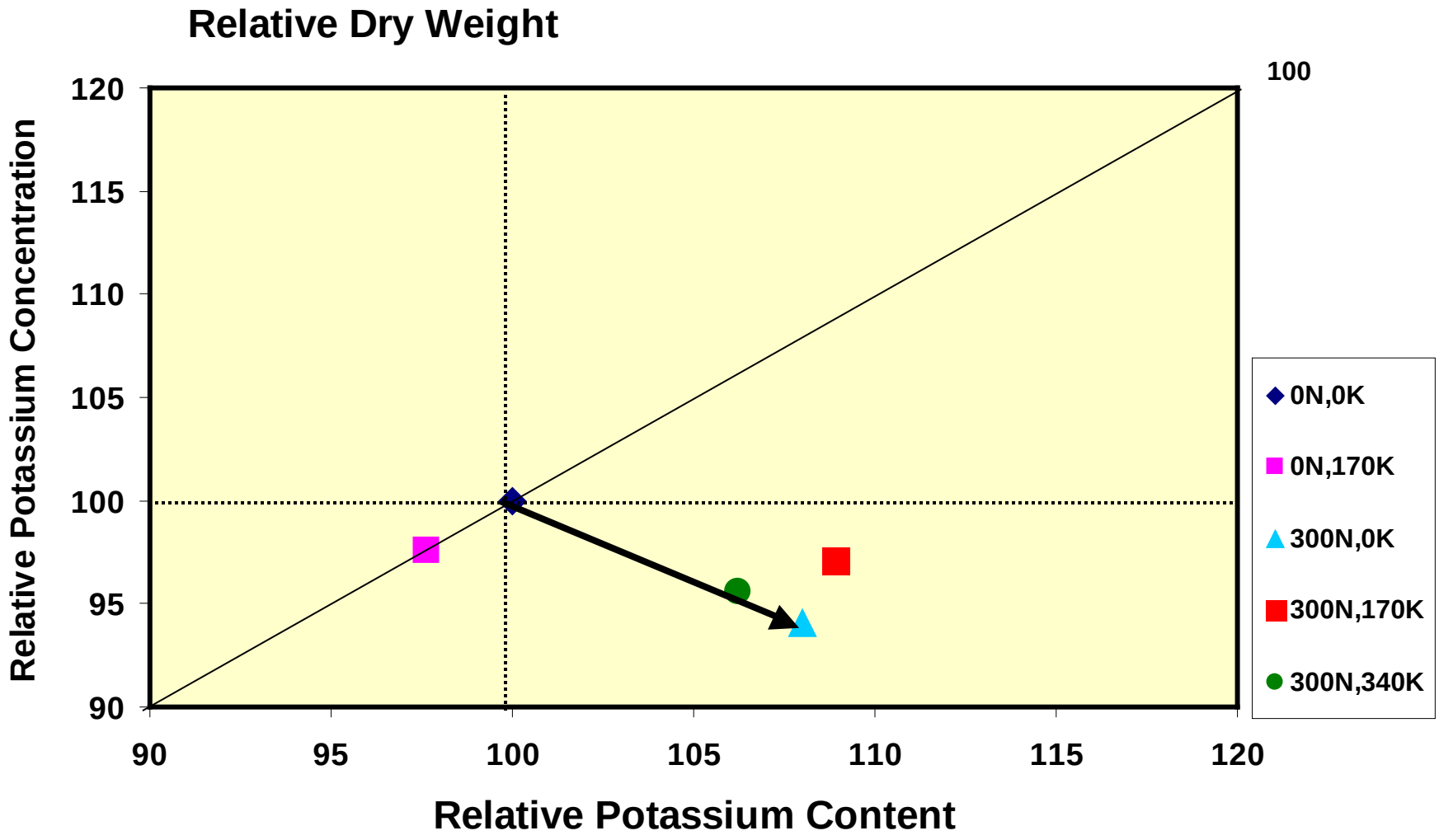
N and K Fertilizer Effects: Douglas-fir Needle Weight



Douglas-fir: All Rock Types



Douglas-fir: All Rock Types



Foliar Chemistry Vector Analysis Results: N and K

Species	Results	Prognosis:
DF	N deficiency even for high N rates K dilution	Growth response to N even at high N rates No growth response to K
GF	N deficiency but only for moderate N rates K deficiency?	Growth response to low N rates but negative response to high N rates Perhaps some growth response to K
PP	N deficiency but only for moderate N rates K dilution	Growth response to low N rates but declining response at high N rates No growth response to K

Species-specifc Growth Analysis: N and K

Only plots with ≥1.0 ft^2/a initial BA of a species were used
(DF: 29 sites, 335 plots GF: 21 sites, 177 plots PP: 22 sites, 167 plots)

Dependent variable = intrinsic growth rate (IGR)
$= \int dS/S = [\ln(S_2) - \ln(S_1)]/\Delta t$. Therefore $S_2 = S_1 e^{\Delta t\ IGR}$

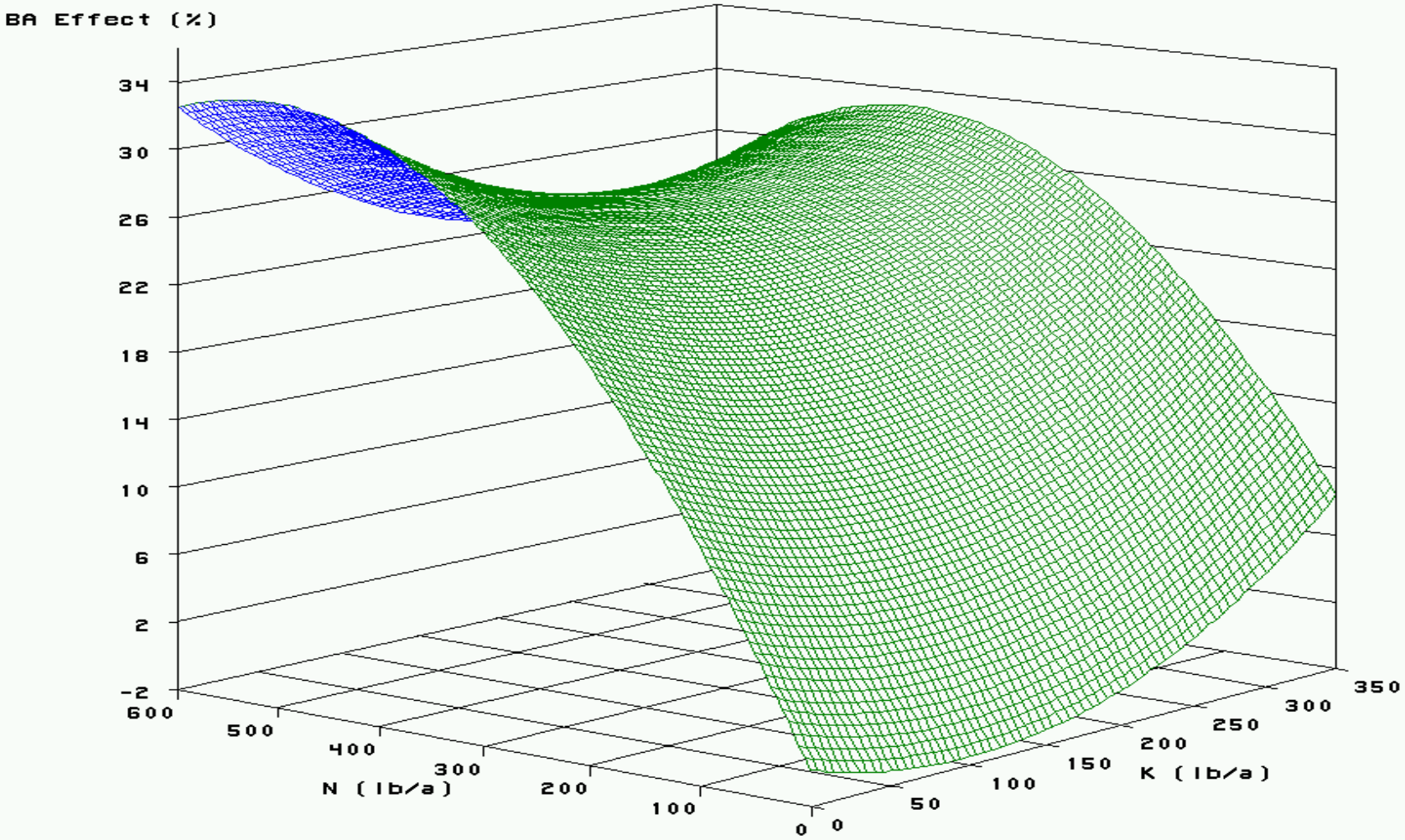
N and K fertilizer effects estimated using a species-specific quadratic response surface model:

$$IGR = \mu + Site + \beta 1 * N + \beta 2 * N^2 + \beta 3 * K + \beta 4 * K^2 + \beta 5 * NK$$

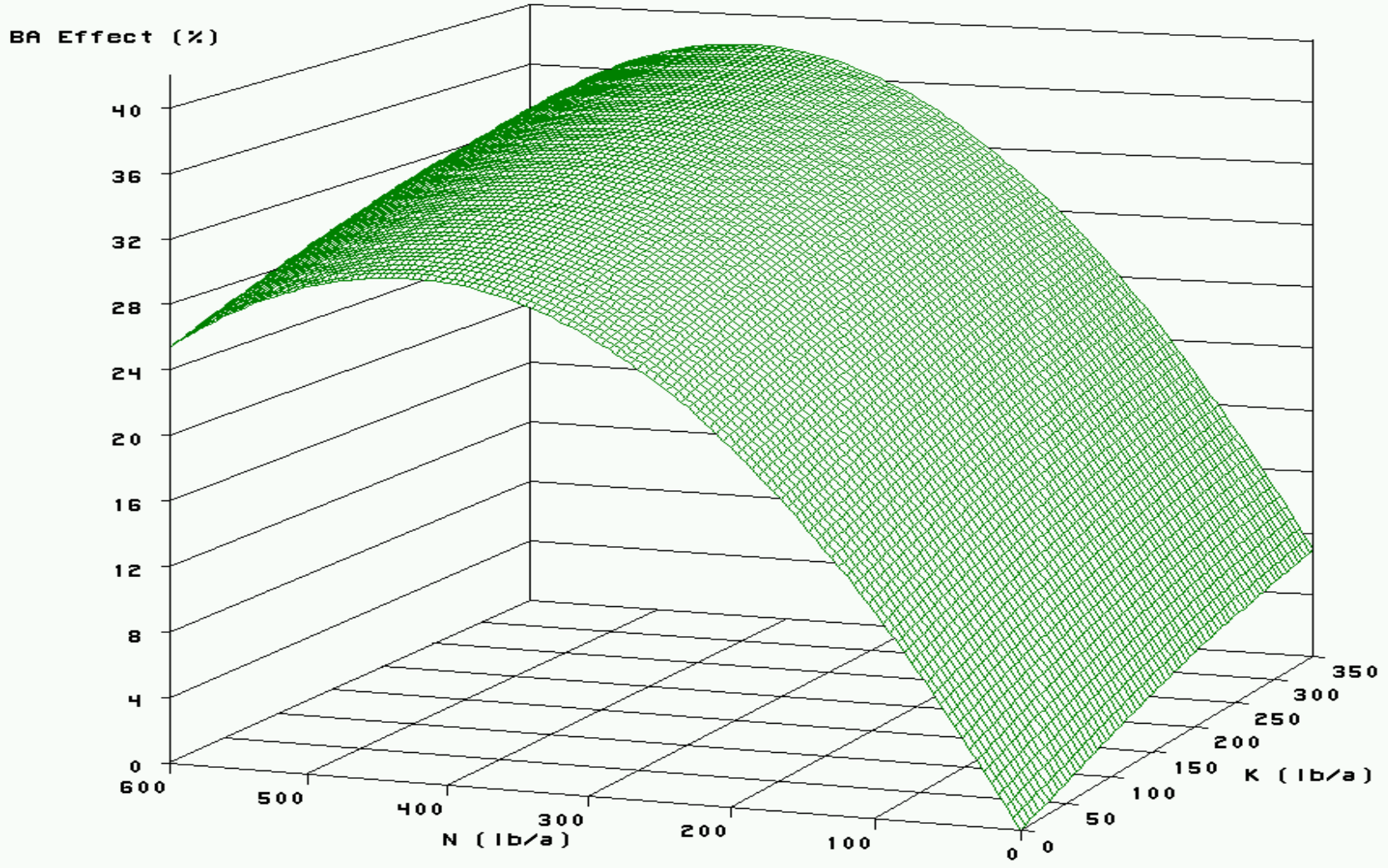
Graphed response = fertilizer growth effect as a % of control growth $= 100 * (S_t - S_c)/(S_c - S_0)$

$$= 100 * (e^{\Delta t\ IGRt} - e^{\Delta t\ IGRc})/(e^{\Delta t\ IGRc} - 1)$$

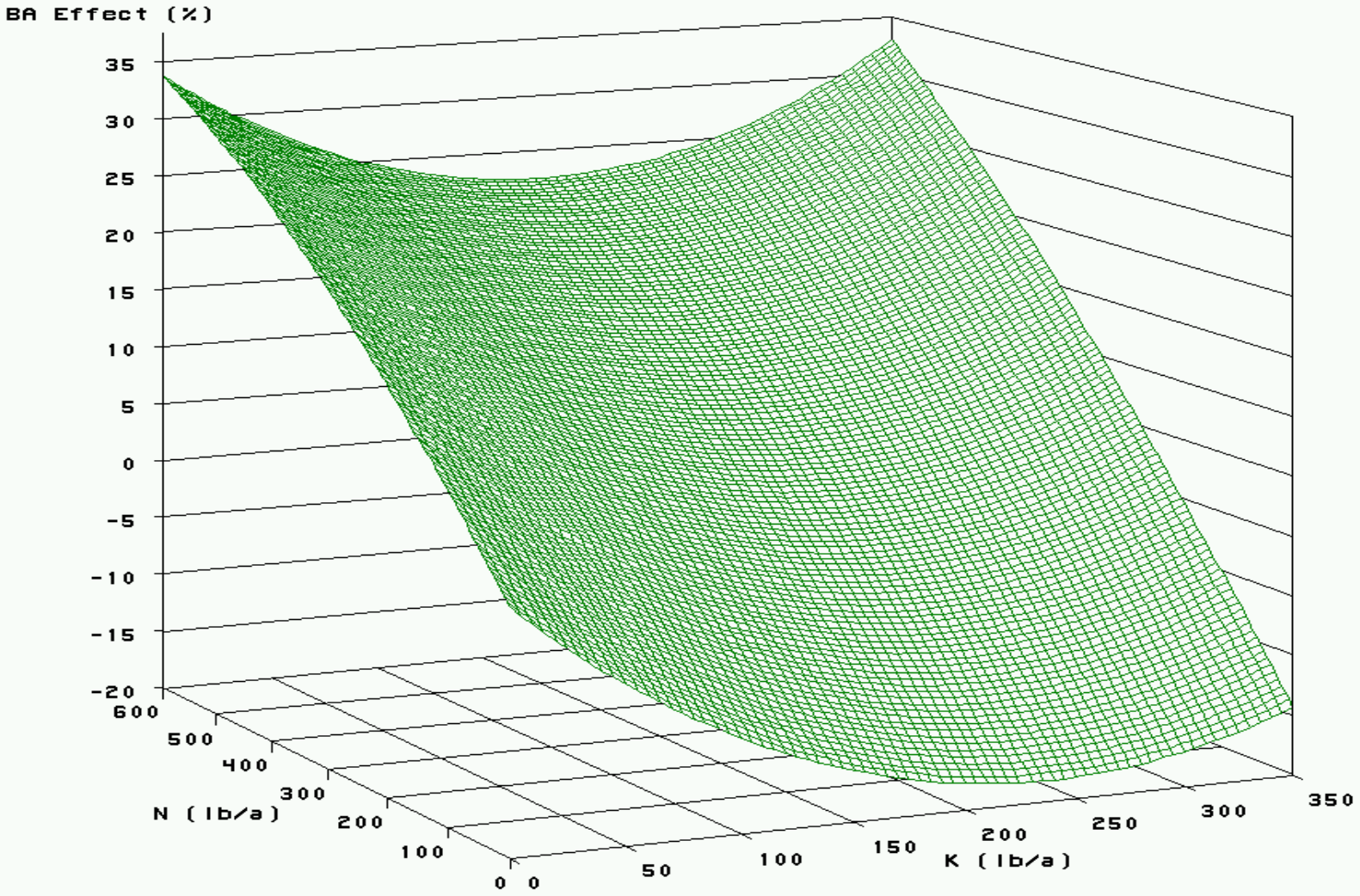
N and K fertilizer effects in Douglas-fir: 6-year BA Response



N and K fertilizer effects in Grand Fir: 6-year BA Response



N and K fertilizer effects in Ponderosa Pine: 6-year BA Response



Distribution of Species-specific growth data by rock type and vegetation series

		Tree Species		
Series	Rock Type	DF	GF	PP
DF	Basalt	35	1	27
	Granite	49	0	40
	Metasediment	0	0	0
	Mixed	7	0	9
GF	Basalt	41	33	22
	Granite	48	19	29
	Metasediment	22	10	9
	Mixed	1	1	28
WRC/WH	Basalt	35	35	0
	Granite	27	24	0
	Metasediment	35	33	1
	Mixed	35	21	2

Foliar Chemistry Vector Analysis Results: S and micros (B, Mo, Cu, Zn)

Species	Results	Prognosis:
DF	S deficiency	Growth response to S
	No micro deficiencies	No growth response to micros
GF	S deficiency	Growth response to S
	No micro deficiencies	No growth response to micros
PP	S toxicity?	No growth response to S, perhaps some growth decline
	Micro deficiencies	Growth response to micros Unable to determine which (B, Mo, Cu, Zn) is responsible

Sulfur and Micronutrient Analysis

S Fertilizer Effects (KCl vs. K_2SO_4) and Micronutrient Effects (B, Cu, Mo, Zn) estimated with ANACOVA using only those sites where K_2SO_4 was applied.

DF (13 sites, 169 plots), GF (11 sites, 95 plots),

PP (10 sites, 86 plots)

Model:

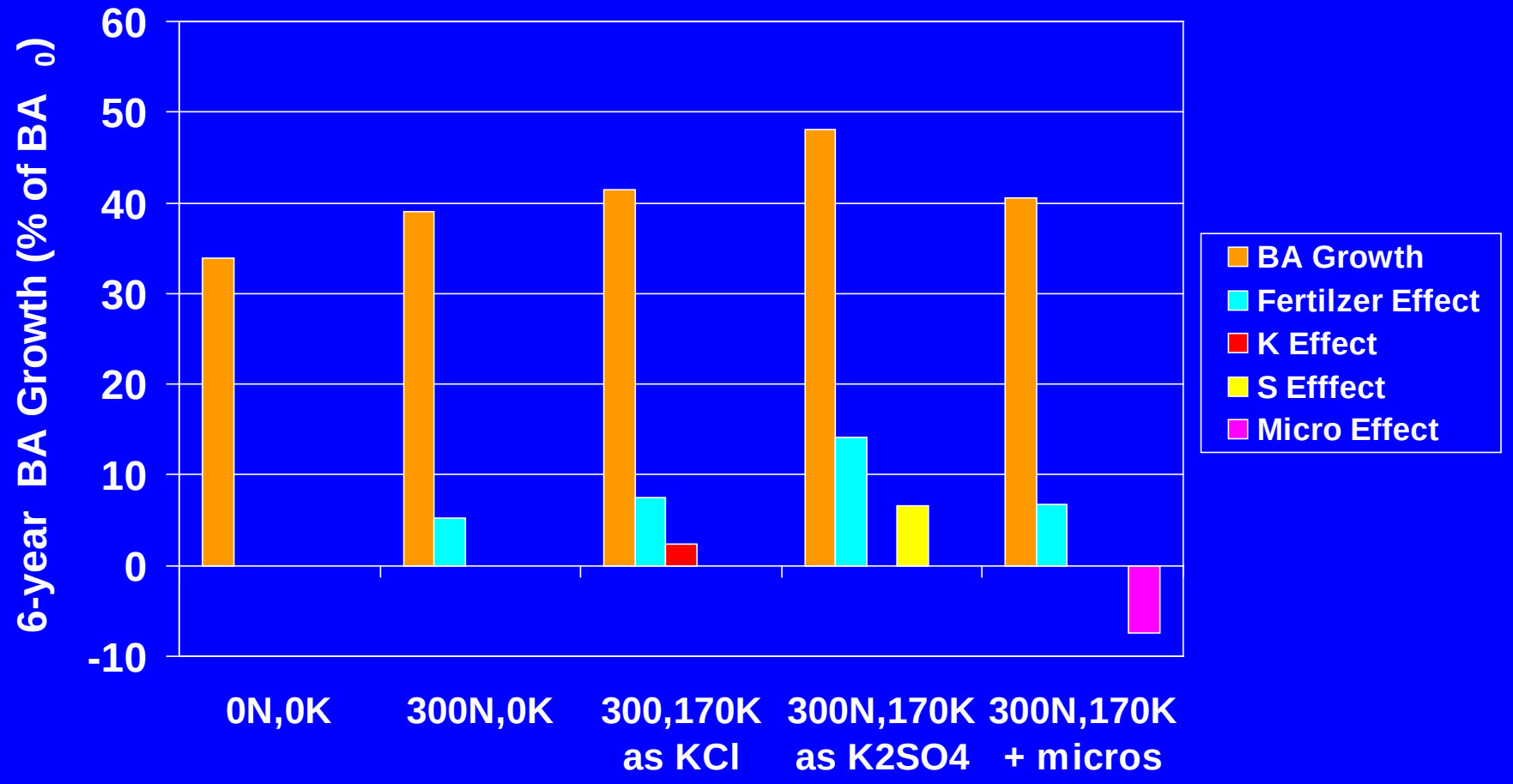
$$IGR = \mu + Site + \beta 0 * BA_0 * Species + \beta 1 * Treatment * Species$$

Graphed response is % increase=100*growth/starting condition

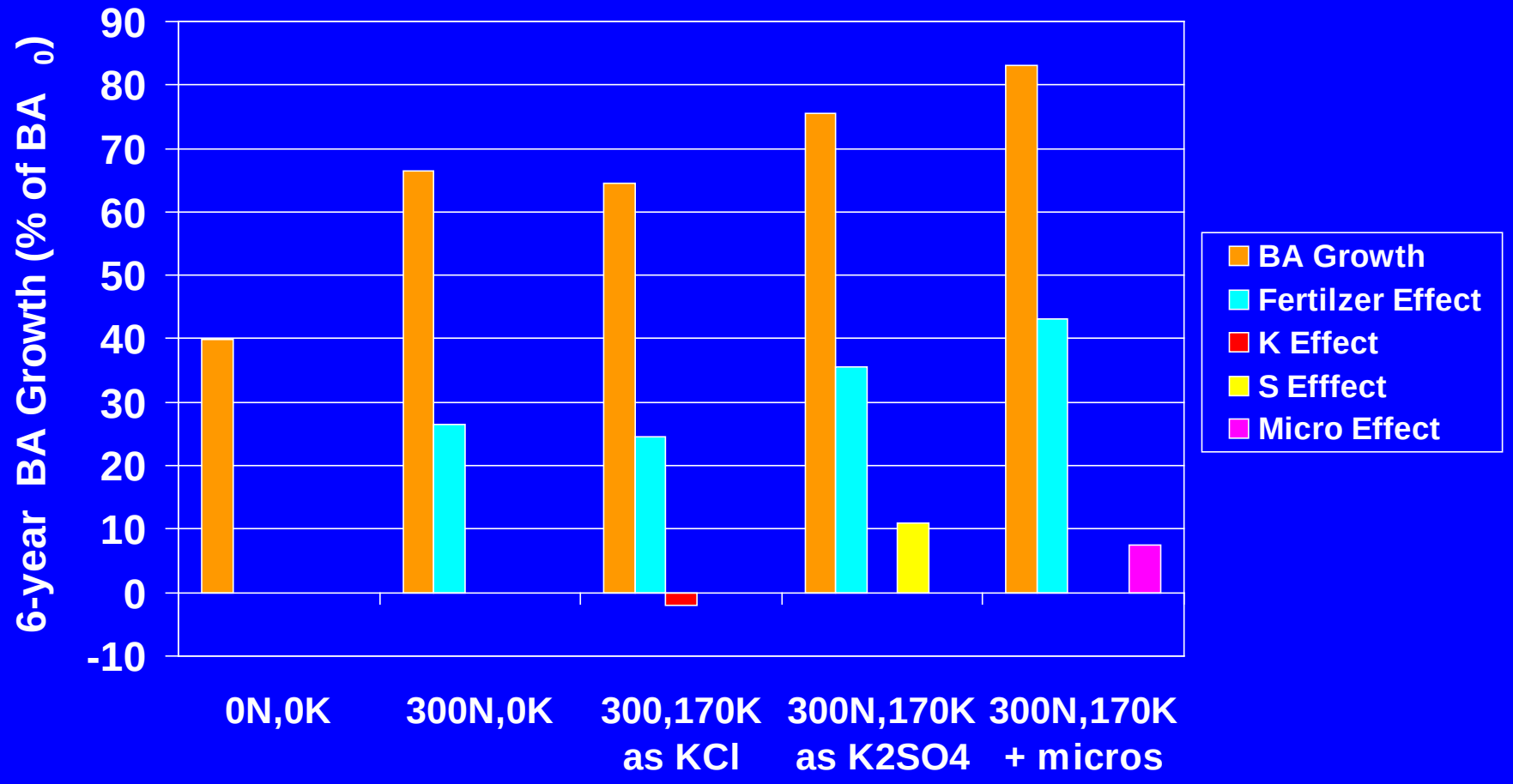
$$= 100 * (S_2 - S_1)/ S_1 = 100 * (S_1 e^{\Delta t\ IGR} - S_1)/ S_1$$

$$= 100 * (e^{\Delta t\ IGR} - 1)$$

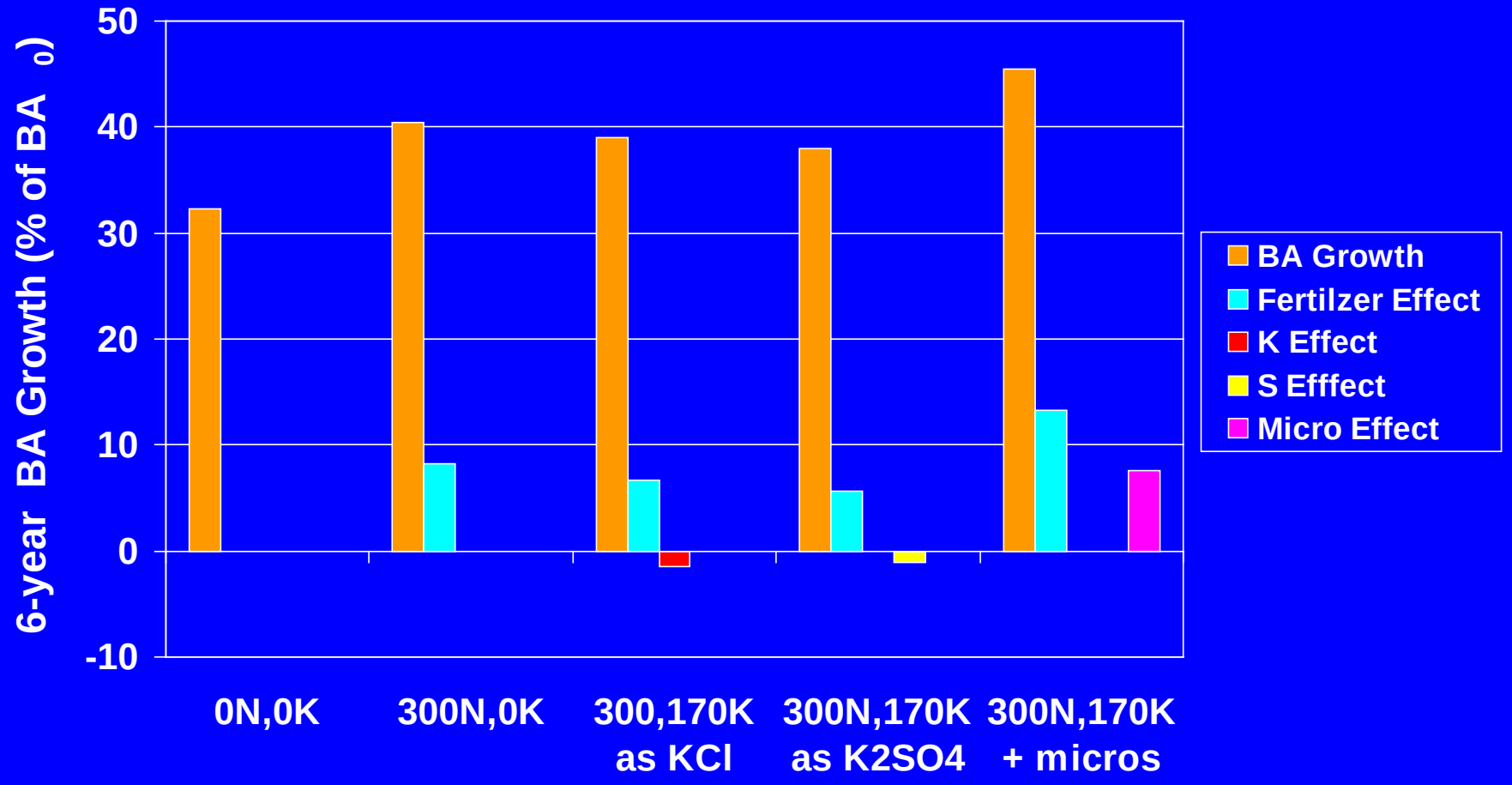
KCl, K_2SO_4, and Micronutrients Effects: 6-year BA Response — Douglas-fir



KCl, K_2SO_4, and Micronutrients Effects: 6-year BA Response — Grand Fir



KCl, K_2SO_4, and Micronutrients Effects: 6-year BA Response — Ponderosa Pine



Summary of Results: Growth

- Response was proportionate to N rate at lower rates, but increases declined at N rates above 300 lbs./a, particularly in GF.
- K fertilizer additions did not significantly affect growth in DF or GF, although PP growth appeared to decline with increasing K rate
- SO_4 increased response in GF and, to a lesser extent, DF but not in PP.
- Micronutrients produced a growth response in PP but not DF or GF.

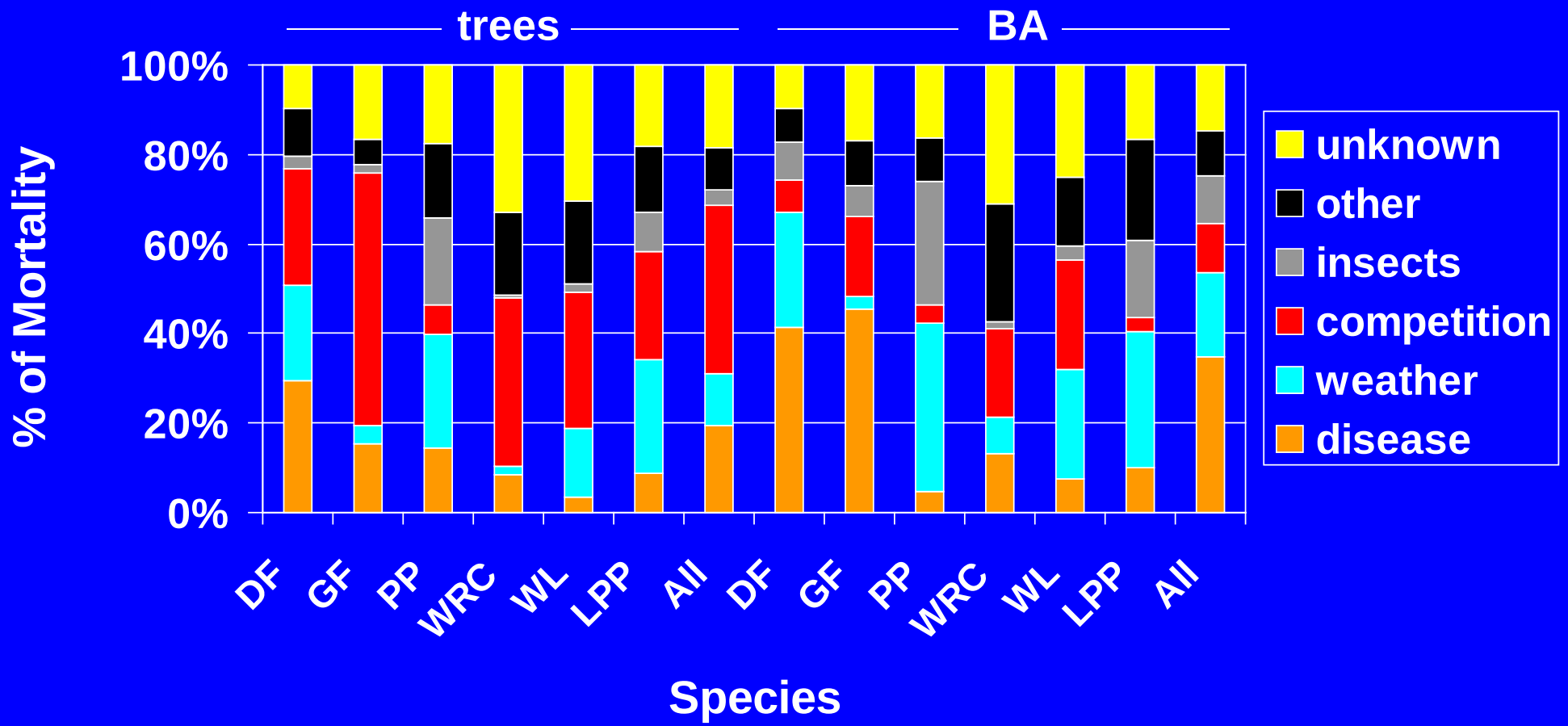
Vector Analysis

Agreement between foliage vector analysis predictions and actual growth responses was good.

6-year Mortality Distribution

	Trees			Basal Area (ft^2)		
Species	live at year 0	dead at year 6	% of original	live at year 0	dead at year 6	% of original
DF	24113	834	3.46	7927.7	153.7	1.94
GF	18302	1069	5.84	3729.6	137.1	3.68
PP	8189	165	2.01	2579.7	51.2	1.98
WRC	10770	273	2.53	837.7	6.1	0.73
WL	1927	71	3.68	633	13.1	2.07
LPP	3090	151	4.89	399.7	22.9	5.73
WH	791	22	2.78	154	3.3	2.14
WWP	555	69	12.43	46.4	5	10.78
ES	719	44	6.12	28.6	1.3	4.55
SAF	26	7	26.92	1.5	0.8	53.33
HW	170	22	12.94	20.9	1.2	5.74
All	68652	2726	3.97	16359	395.7	2.42

Mortality Causes : Trees and BA



Species-specifc Mortality Analysis: N and K

Only plots with ≥1.0 ft^2/a initial BA of a species were used (DF: 29 sites, 335 plots GF: 21 sites, 177 plots PP: 22 sites, 167 plots)

Dependent variable = LPMBA = ln(% BA mortality + 1)

= ln(100 ∗ initial BA_s of dead trees/total initial Ba_s + 1)

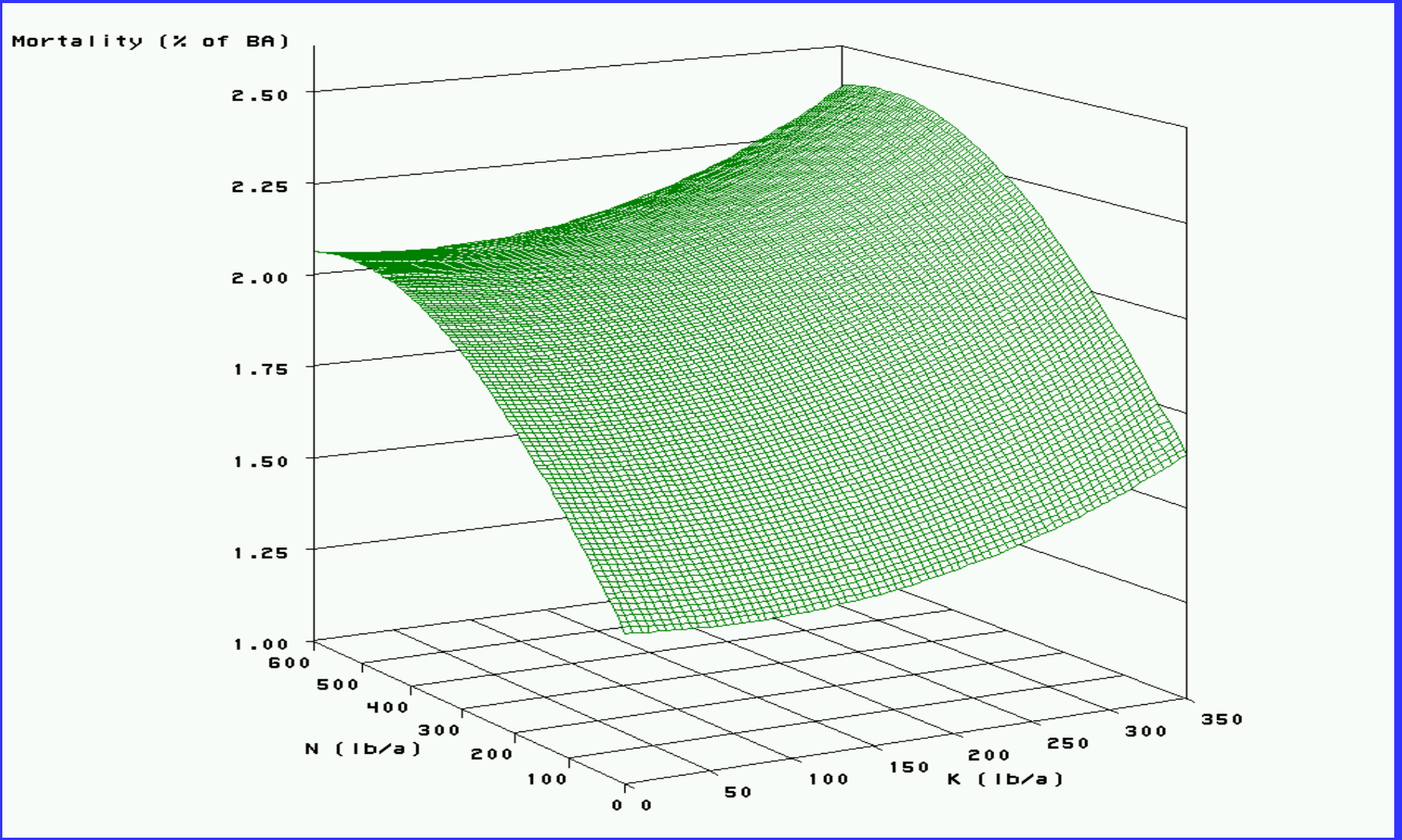
N and K fertilizer effects estimated using a species-specific quadratic response surface model:

$$LPMBA = \mu + Site + \beta1*N + \beta2*N^2 + \beta3*K + \beta4*K^2 + \beta5*NK$$

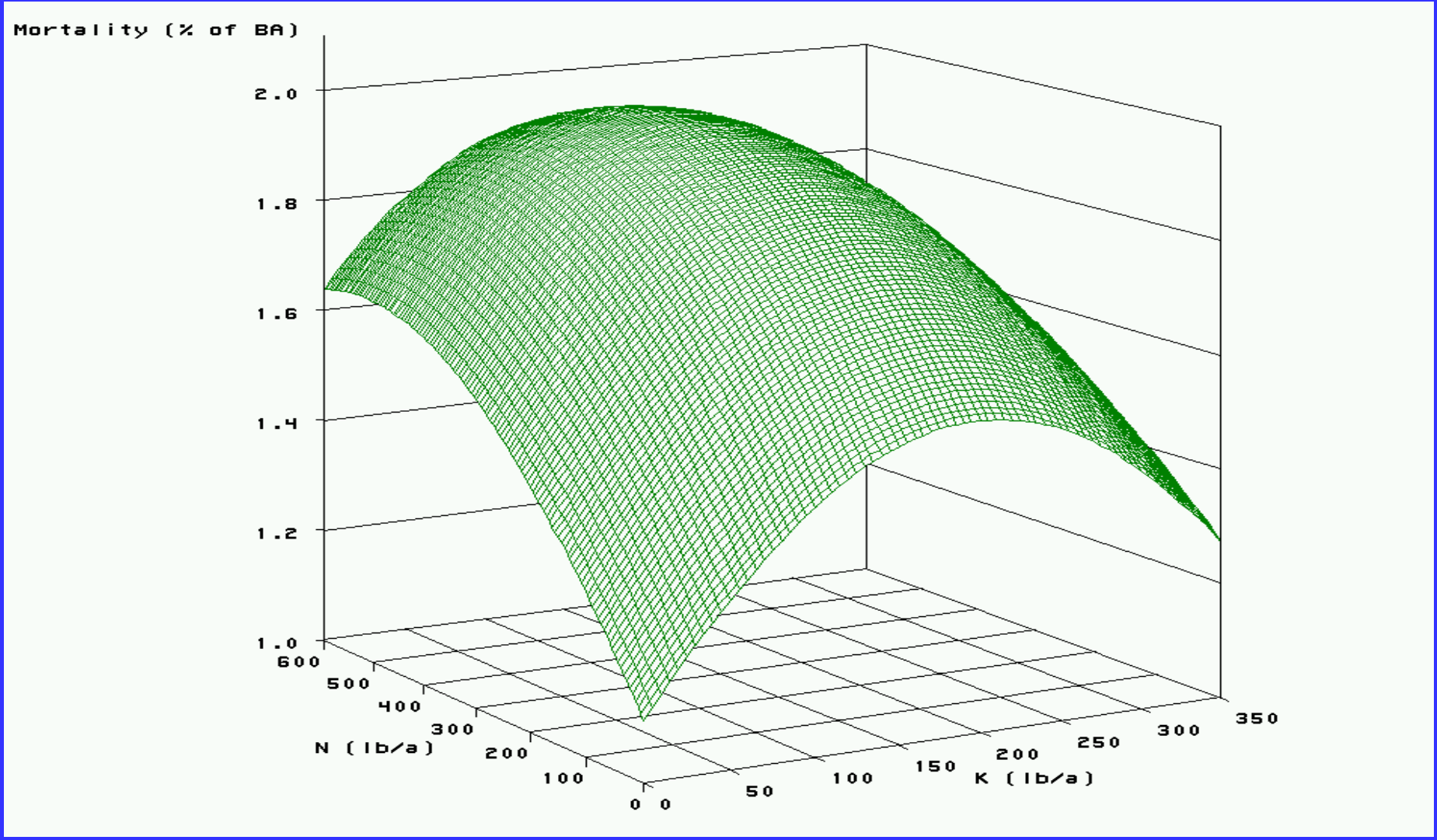
Graphed response = mortality as a % of initial BA

$$= e^{(LPMBA + \sigma^2/2)} - 1$$

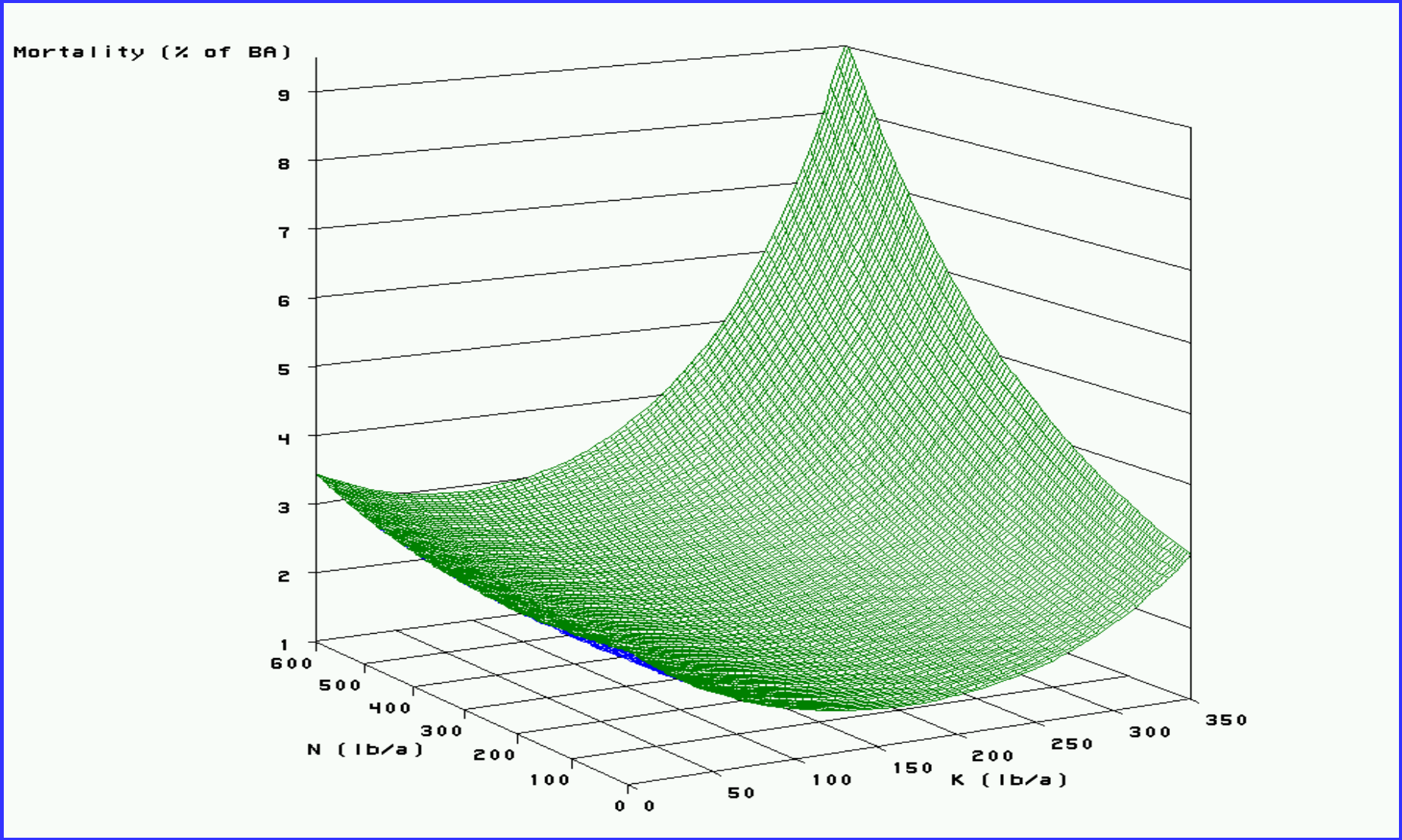
N and K fertilizer effects on 6-year mortality (% of BA)



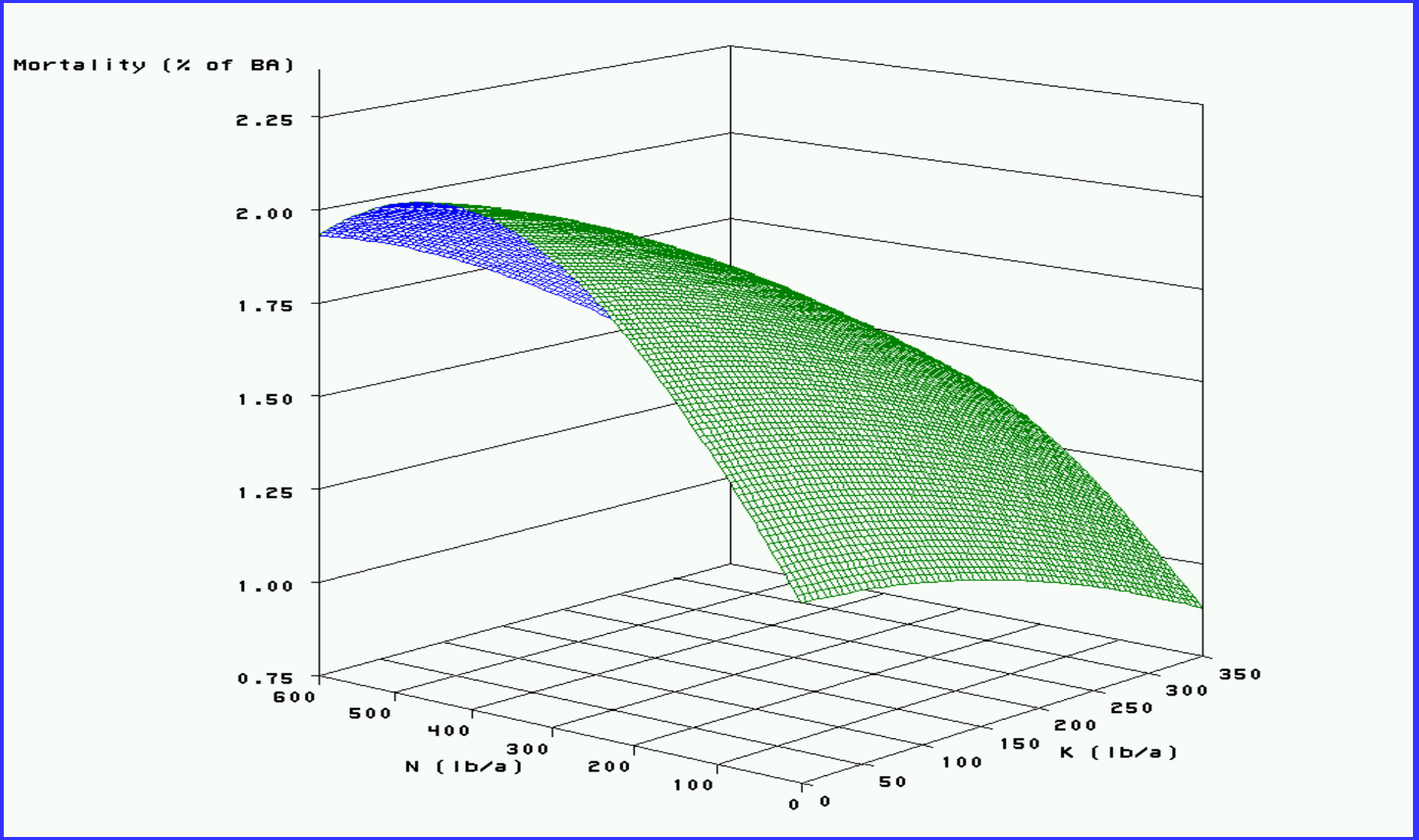
N and K fertilizer effects on 6-year mortality (% of BA) in Douglas-fir



N and K fertilizer effects on 6-year mortality (% of BA) in Grand Fir



N and K fertilizer effects on 6-year mortality (% of BA) in Ponderosa Pine



Species-specifc Mortality Analysis: S and micros

Only plots with ≥1.0 ft^2/a initial BA of a species were used (DF: 29 sites, 335 plots GF: 21 sites, 177 plots PP: 22 sites, 167 plots)

Dependent variable = LPMBA = ln(% BA mortality + 1)

= ln(100 ∗ initial BA_s of dead trees/total initial BA_s + 1)

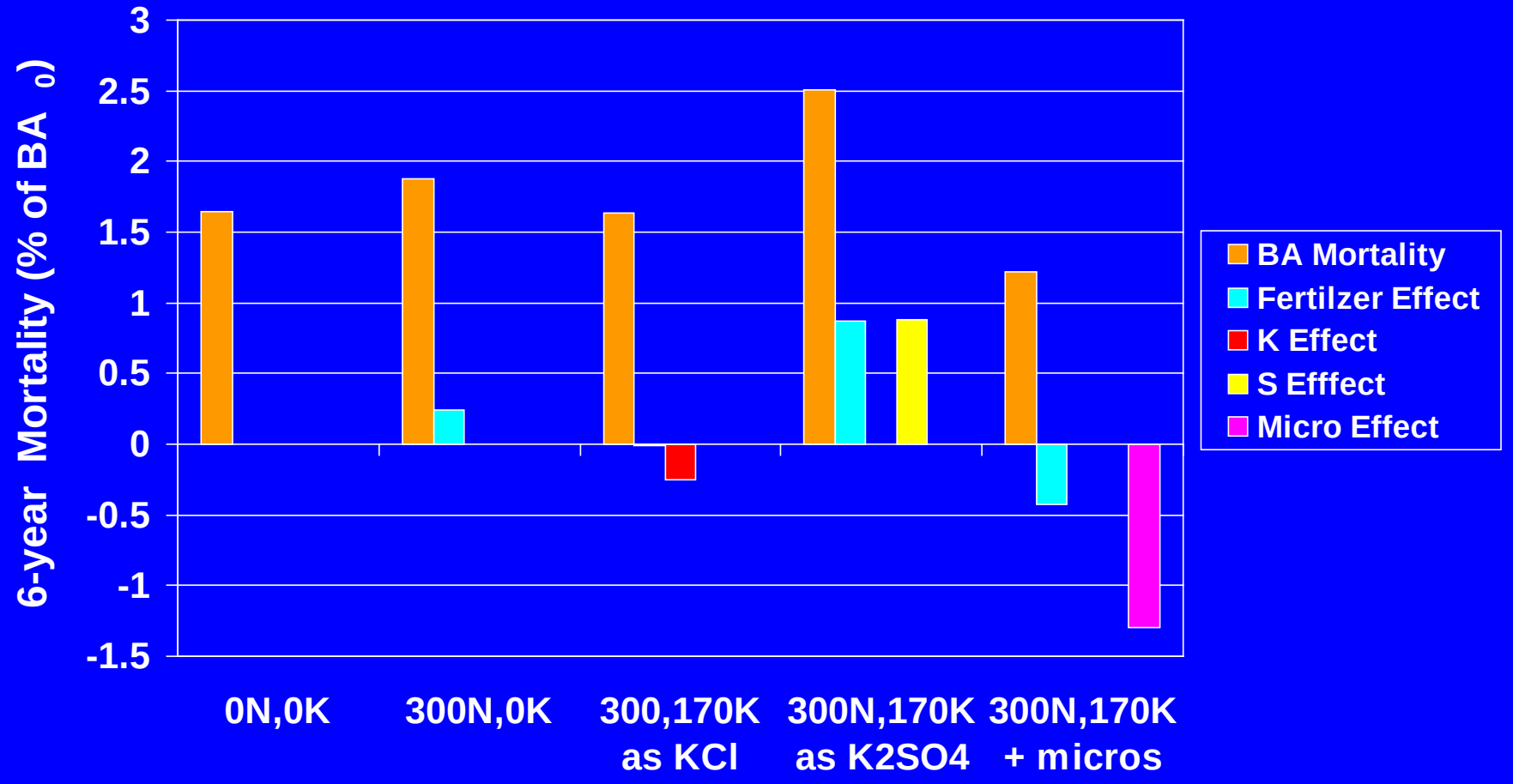
S and micros fertilizer effects estimated using a species-specific ANOVA model:

$$LPMBA = \mu + Site + Treatment$$

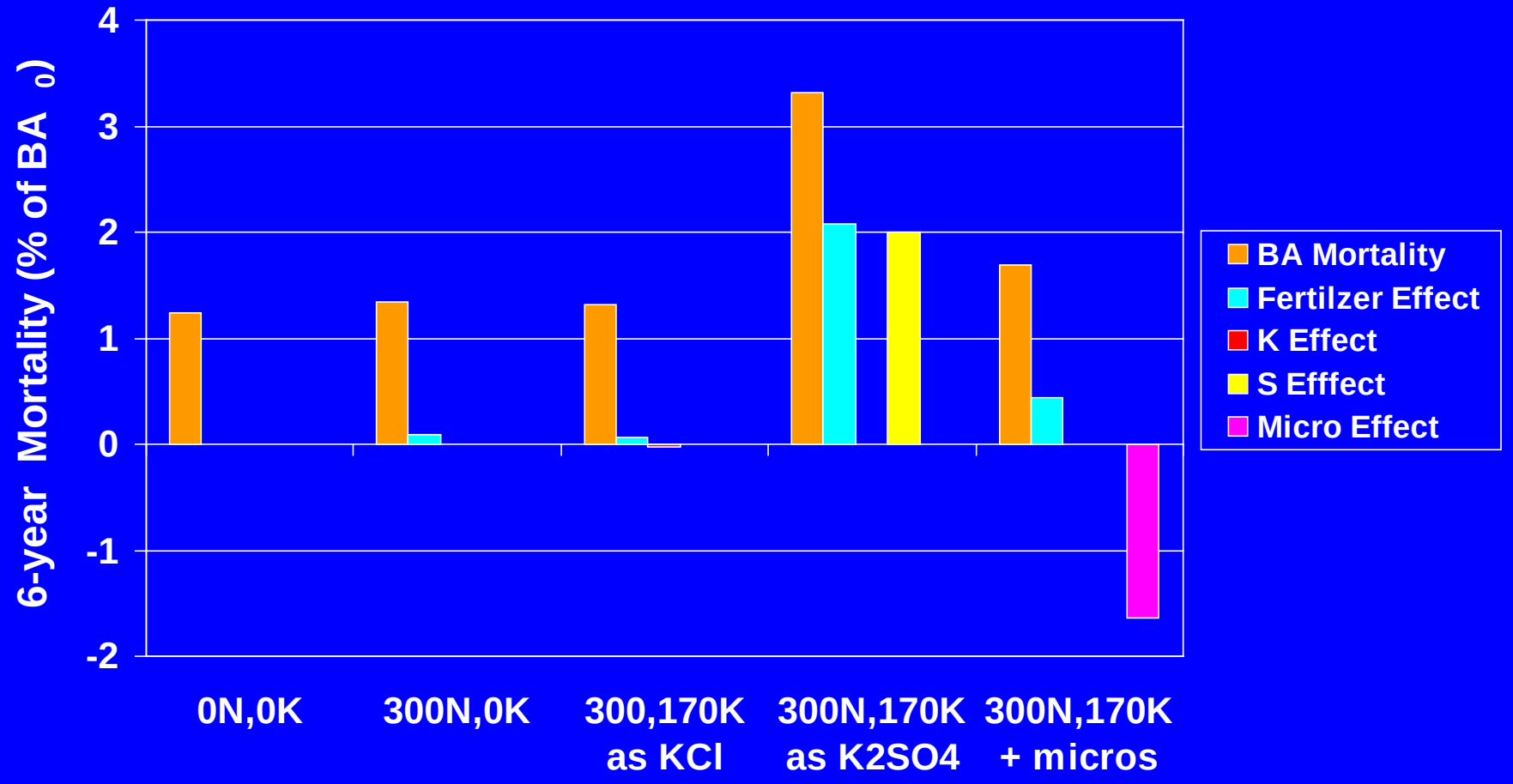
Graphed response = mortality as a % of initial BA

$$= e^{(LPMBA + \sigma^2/2)} - 1$$

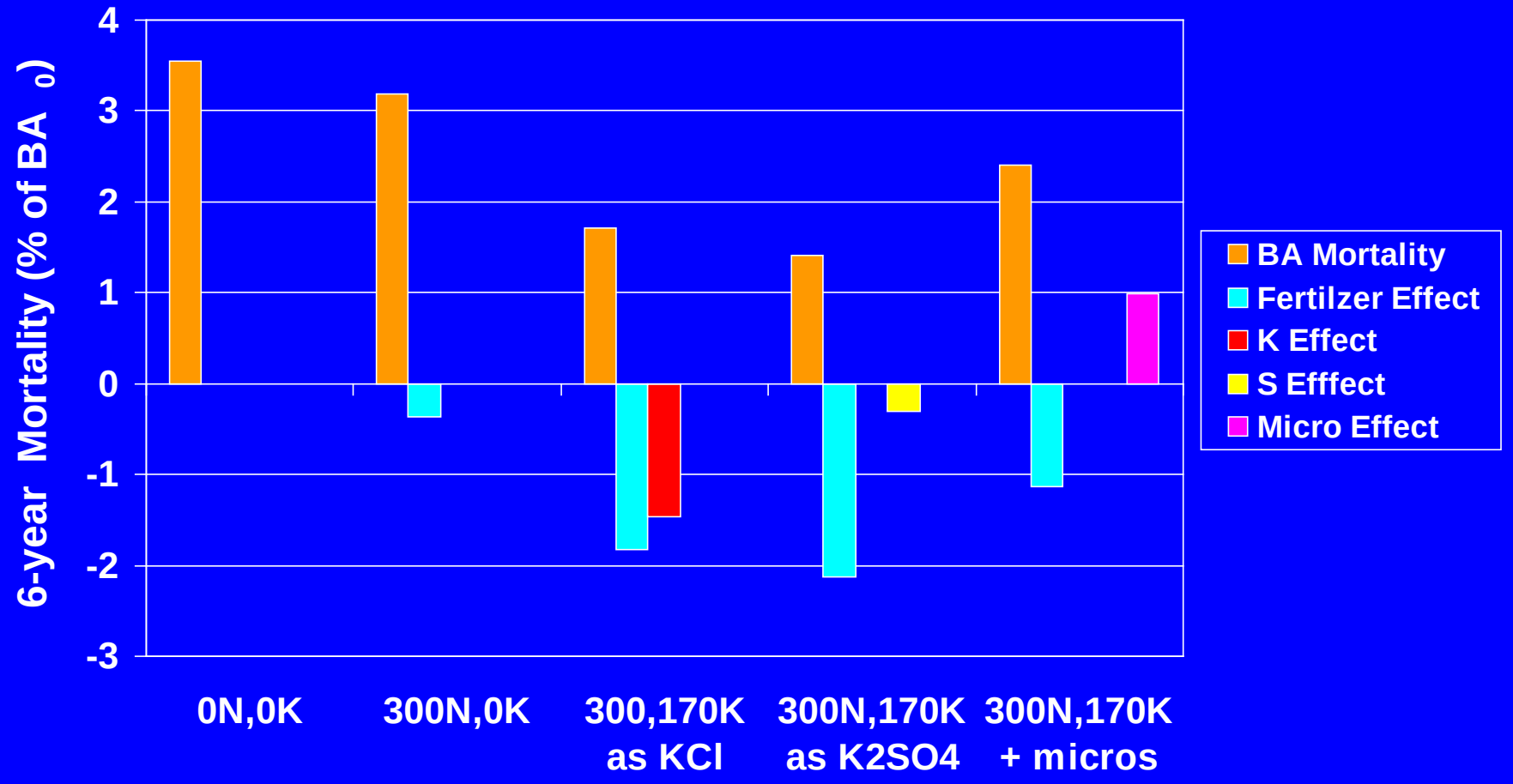
KCl, K_2SO_4, and Micronutrients Effects: 6-year BA Mortality — All Species



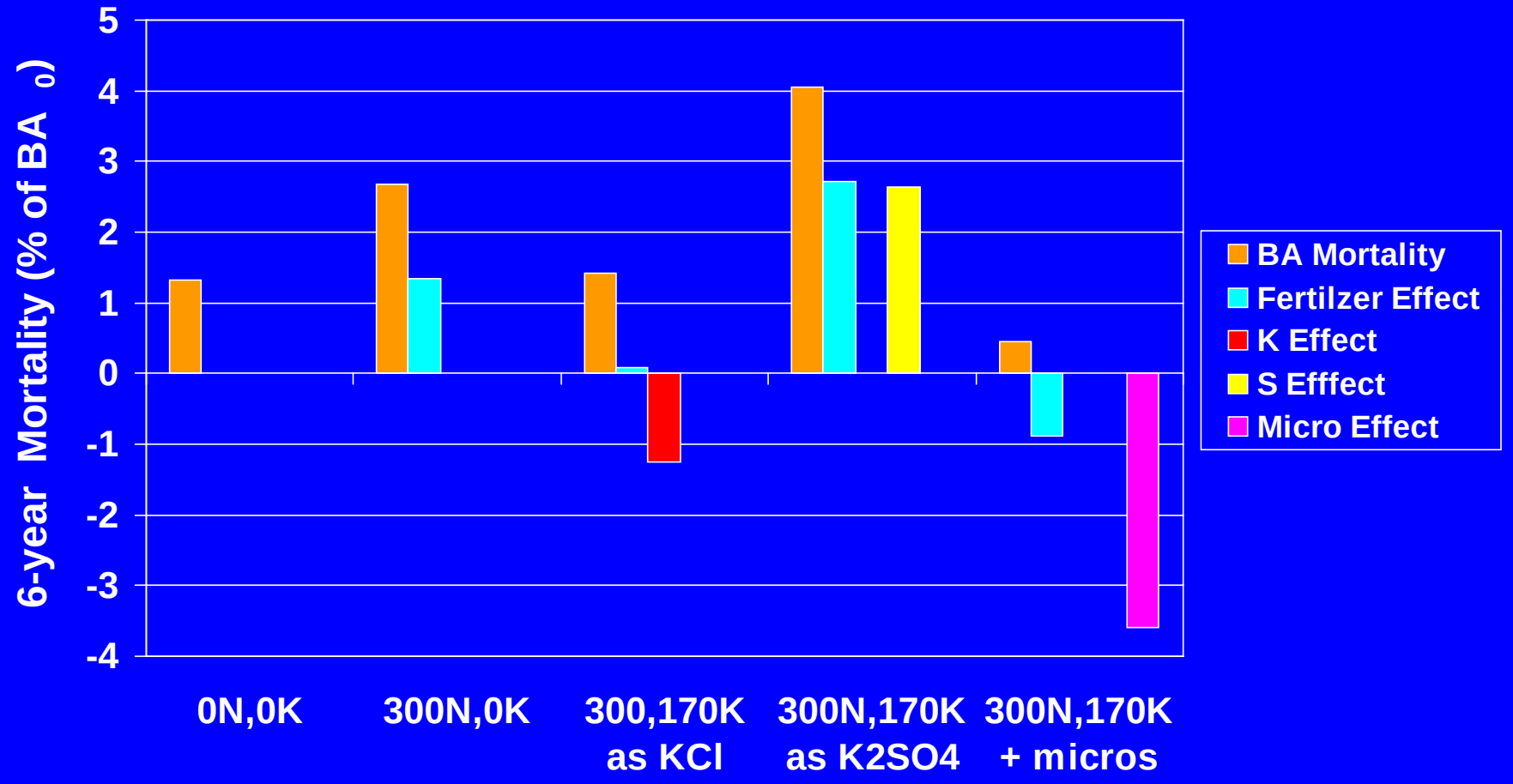
KCl, K_2SO_4, and Micronutrients Effects: 6-year BA Mortality — Douglas-fir



KCl, K_2SO_4, and Micronutrients Effects: 6-year BA Mortality — Grand Fir



KCl, K_2SO_4, and Micronutrients Effects: 6-year BA Mortality — Ponderosa Pine



Summary of Results: Mortality

- N fertilizer increased mortality in DF and PP, but not in GF.
- K fertilizer additions appeared to decrease mortality in GF and PP, but not in DF.
- SO_4 increased mortality in DF and PP, but not in GF.
- Micronutrients lowered mortality in PP and DF, but not in GF.