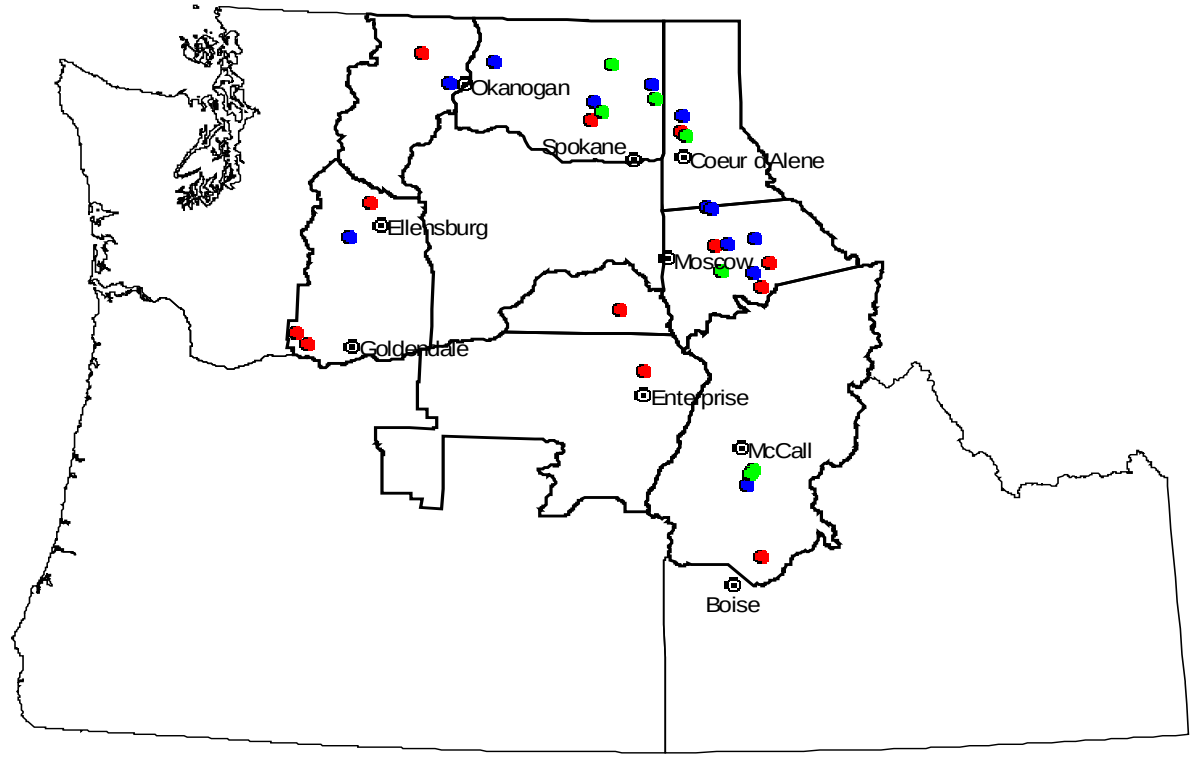
# The Forest Health/Nutrition Experiment: Eight-year Growth and Mortality Results

Peter Mika

2005 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

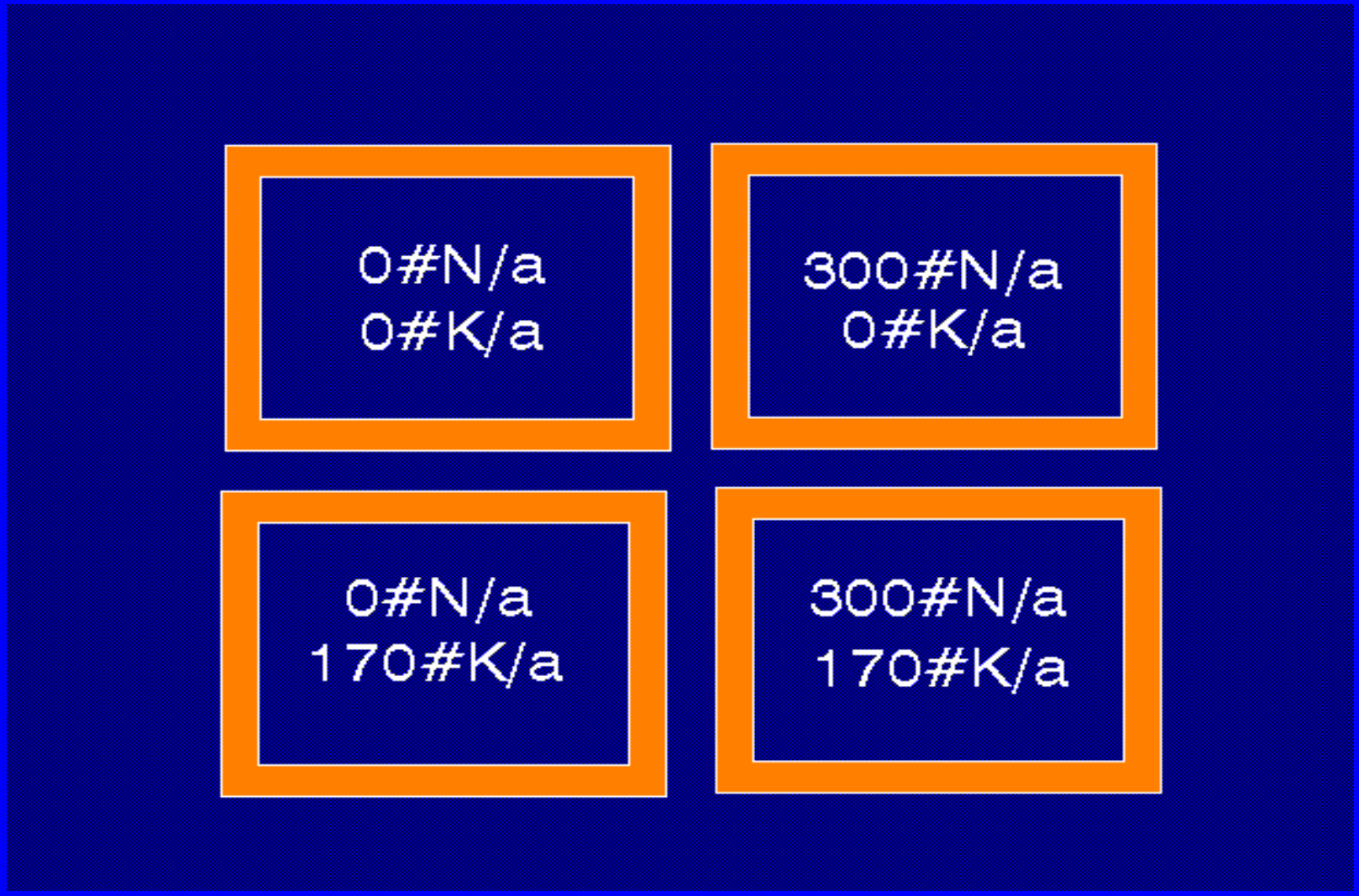
# Sites Established: 1994-1996

## by Rock Type and Vegetation Series

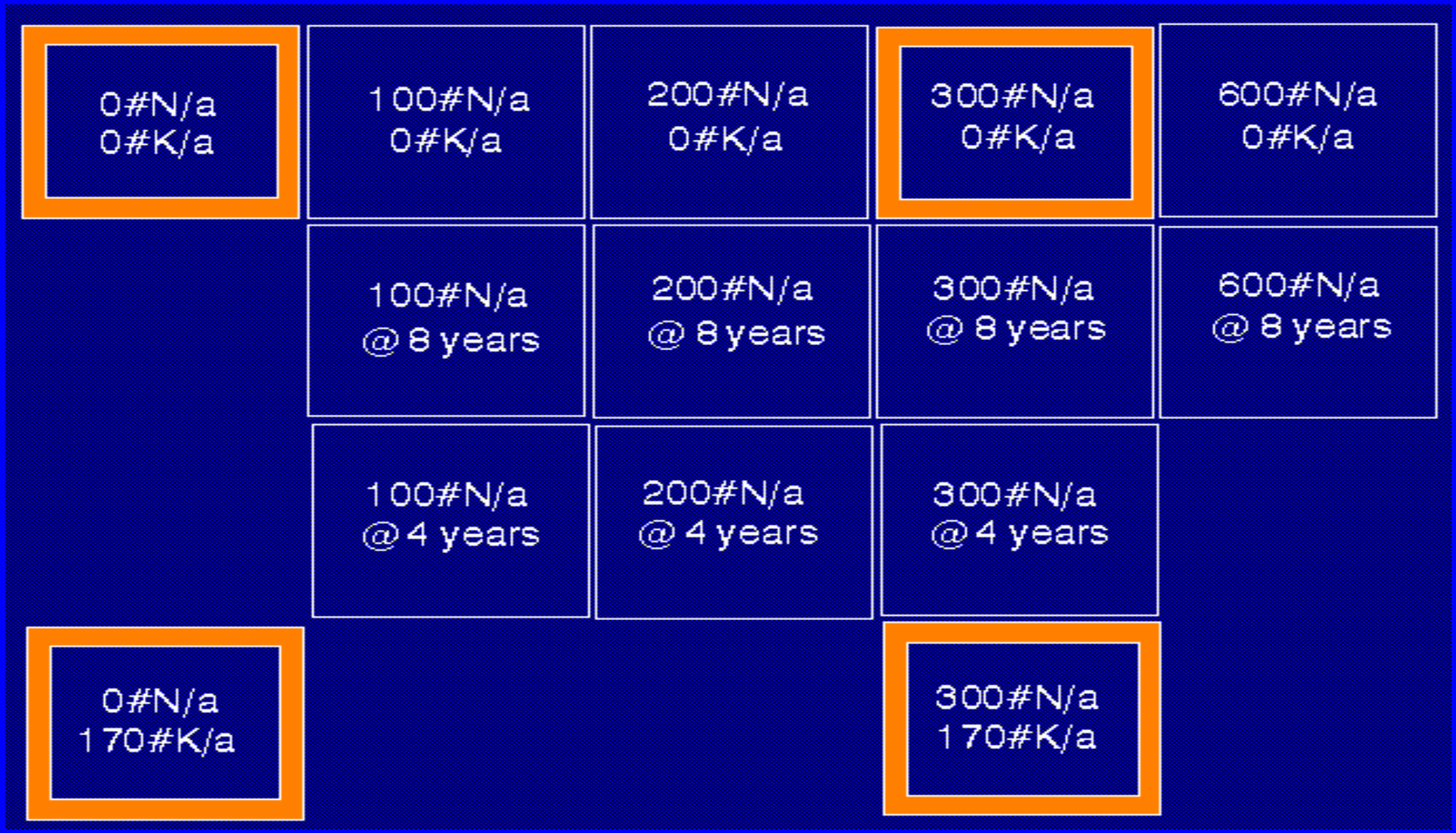
| | Douglas-fir | Grand Fir | Cedar/ Hemlock | TOTAL |
|---|---|---|---|---|
| Granite | K (3)<br>N (1) | K (4) | K (2) | 10 |
| Basalt | N (1)<br>R (2) | K (3) | N (1)<br>R (2) | 9 |
| Metamorphic | | K (1) | K (3) | 4 |
| Mixed | N (2) | K (2) | K (1)<br>N (3) | 8 |
| TOTAL | 9 | 10 | 12 | 31 |

K=N - K Response Surface, N=N Rate Trial, R=Repeated- N Trial

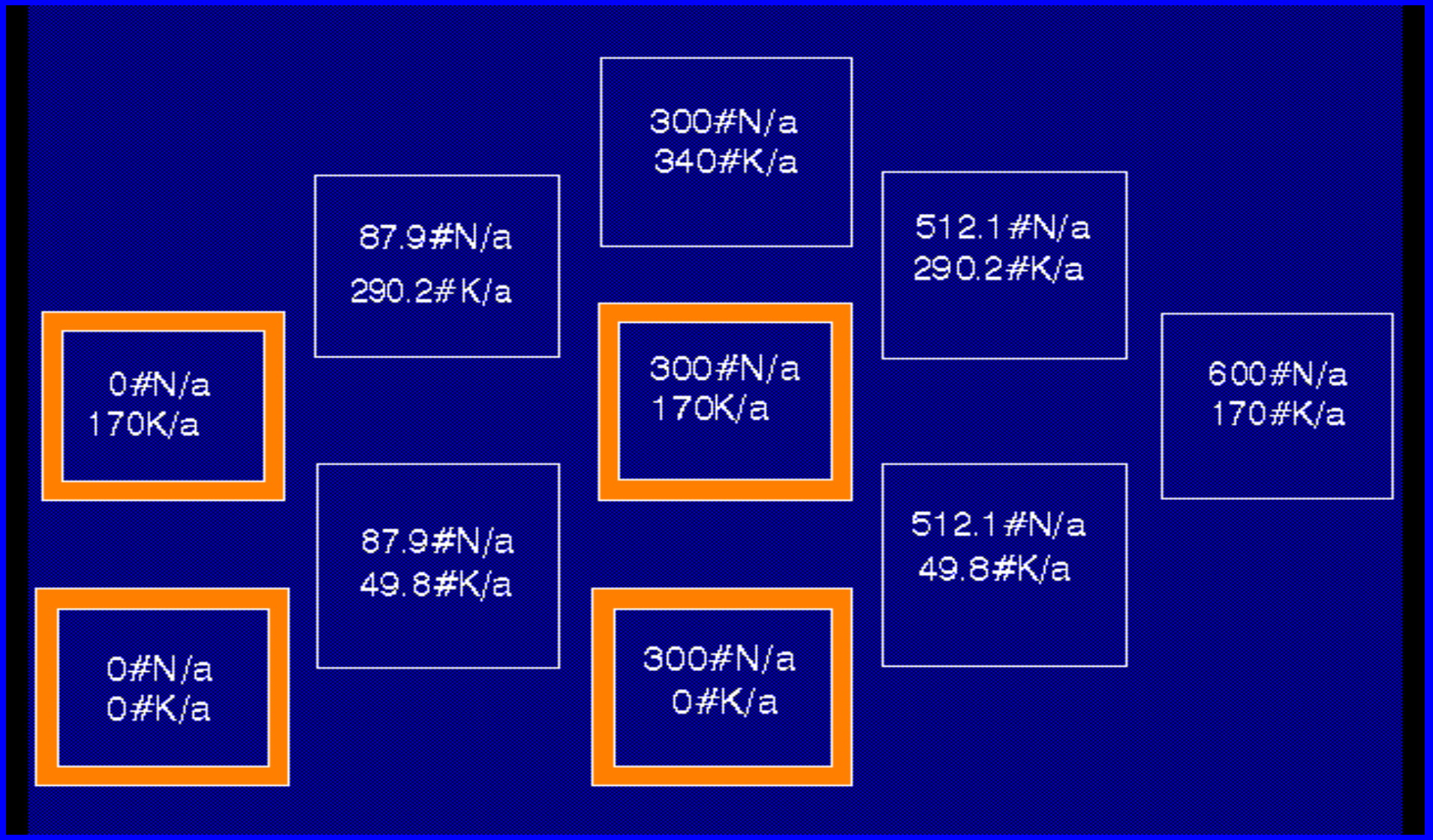
# Core Design



# Nitrogen Rate Design



# N-K Response Surface Design



# Topics for Today:

- N and K Fertilizer Effects
  - On BA and volume growth: N and K response surface
  - On mortality
    - What's dying
    - Causes of mortality
    - N and K response surfaces for mortality
- S and Micronutrient (B, Cu, Mo, Zn) Fertilizer Effects
  - Growth effects
  - Mortality effects
- Repeated N Applications
  - Growth effects
  - Mortality effects

# The Fertilizer Growth Effect Model

Multiplicative model:

$\ln(G_{trt}) = \mu + I + C + \beta_1 * N + \beta_2 * N^2 + \beta_3 * K + \beta_4 * K^2 + \beta_5 * NK$

where G = growth (8-year BA or volume increment)

I = installation effect (random)

C = covariate adjustment for initial density

N = nitrogen rate (lbs/a)

K = potassium rate (lbs/a)

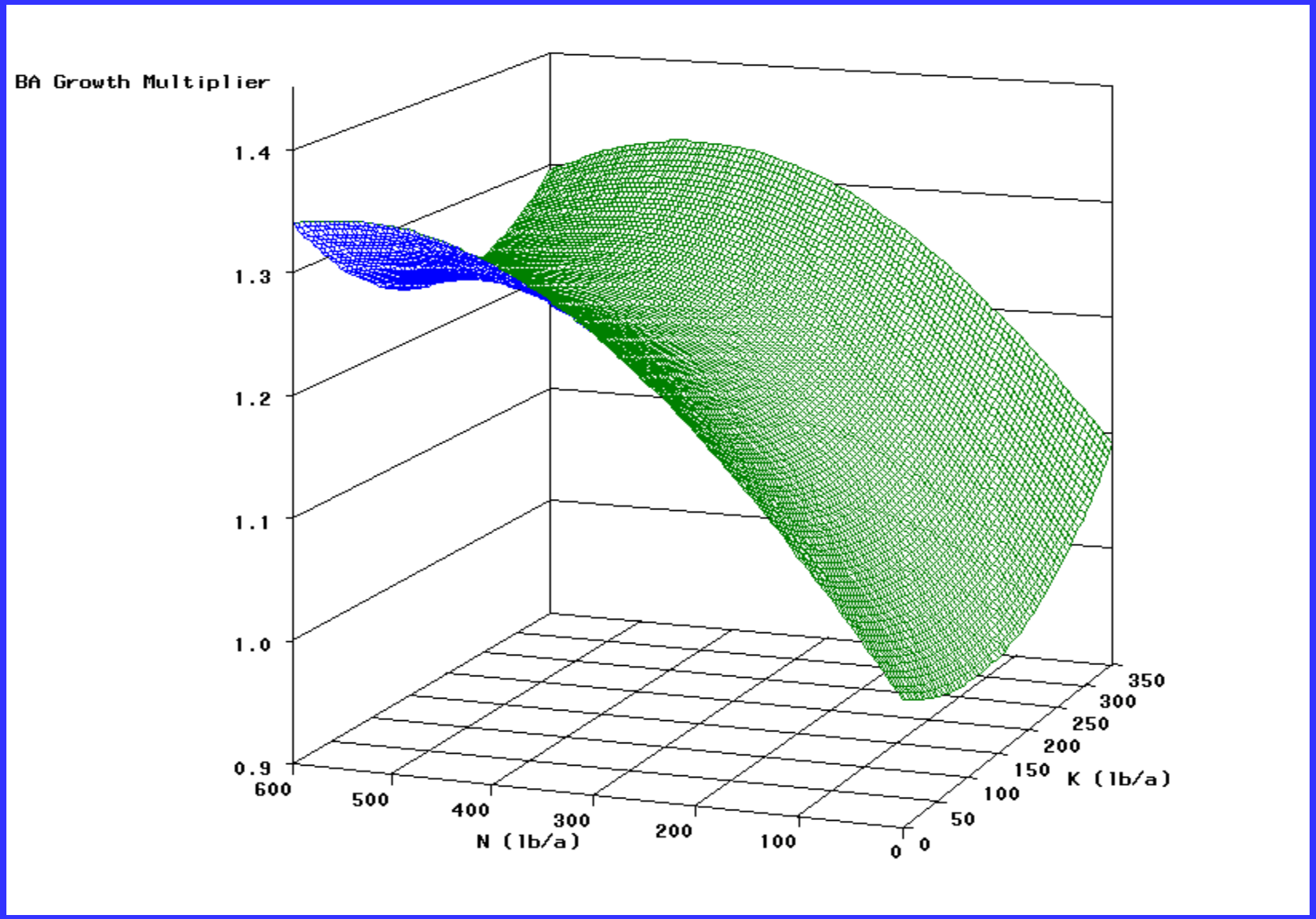
Thus, $G_{trt} = \exp(\mu + I + C + \beta_1 * N + \beta_2 * N^2 + \beta_3 * K + \beta_4 * K^2 + \beta_5 * NK)$

$= \exp(\mu + I + C) * \exp(\beta_1 * N + \beta_2 * N^2 + \beta_3 * K + \beta_4 * K^2 + \beta_5 * NK)$

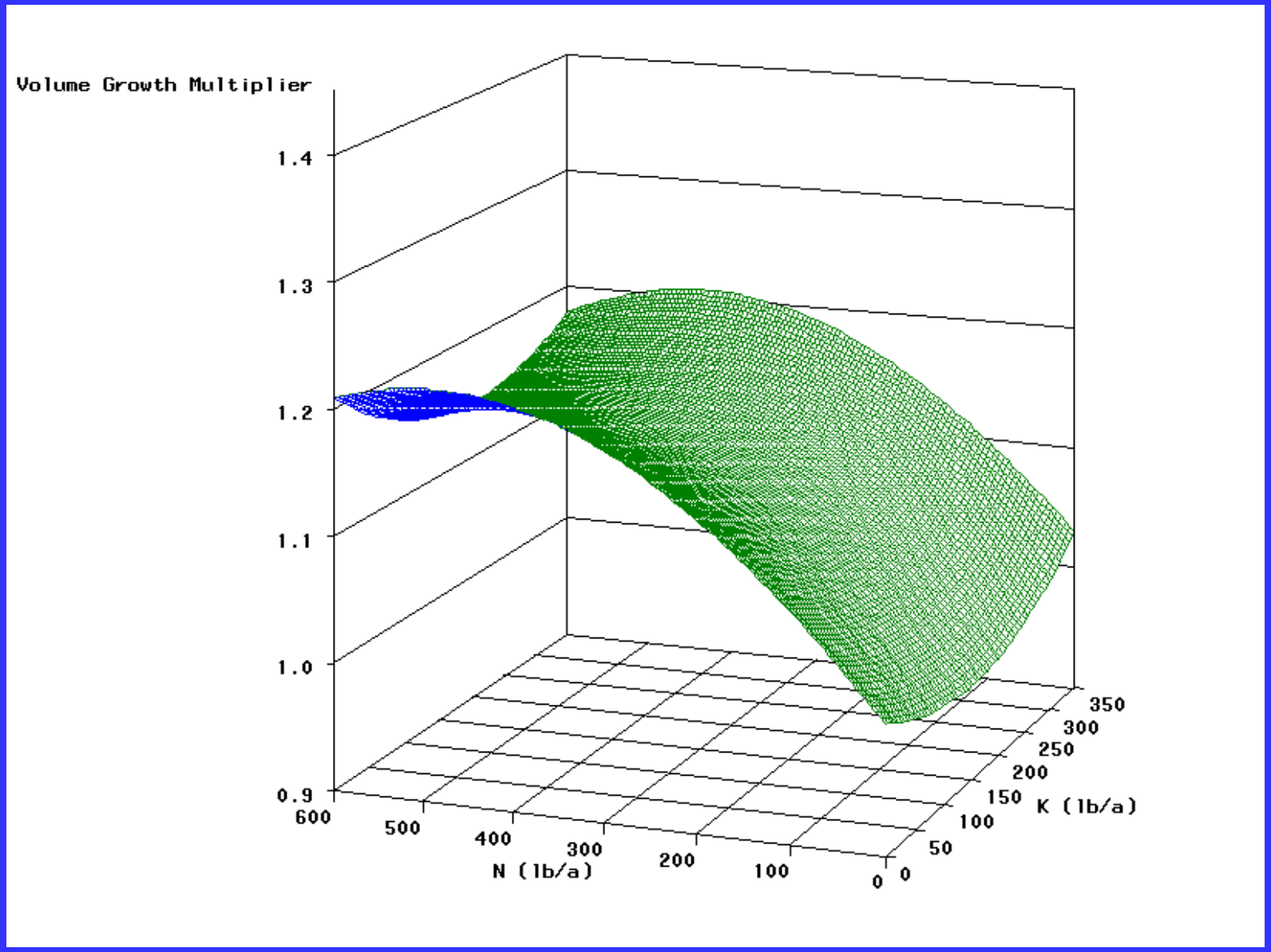
$= G_{con} *$ Fertilizer Effect

Therefore, Fertilizer Effect is a growth multiplier

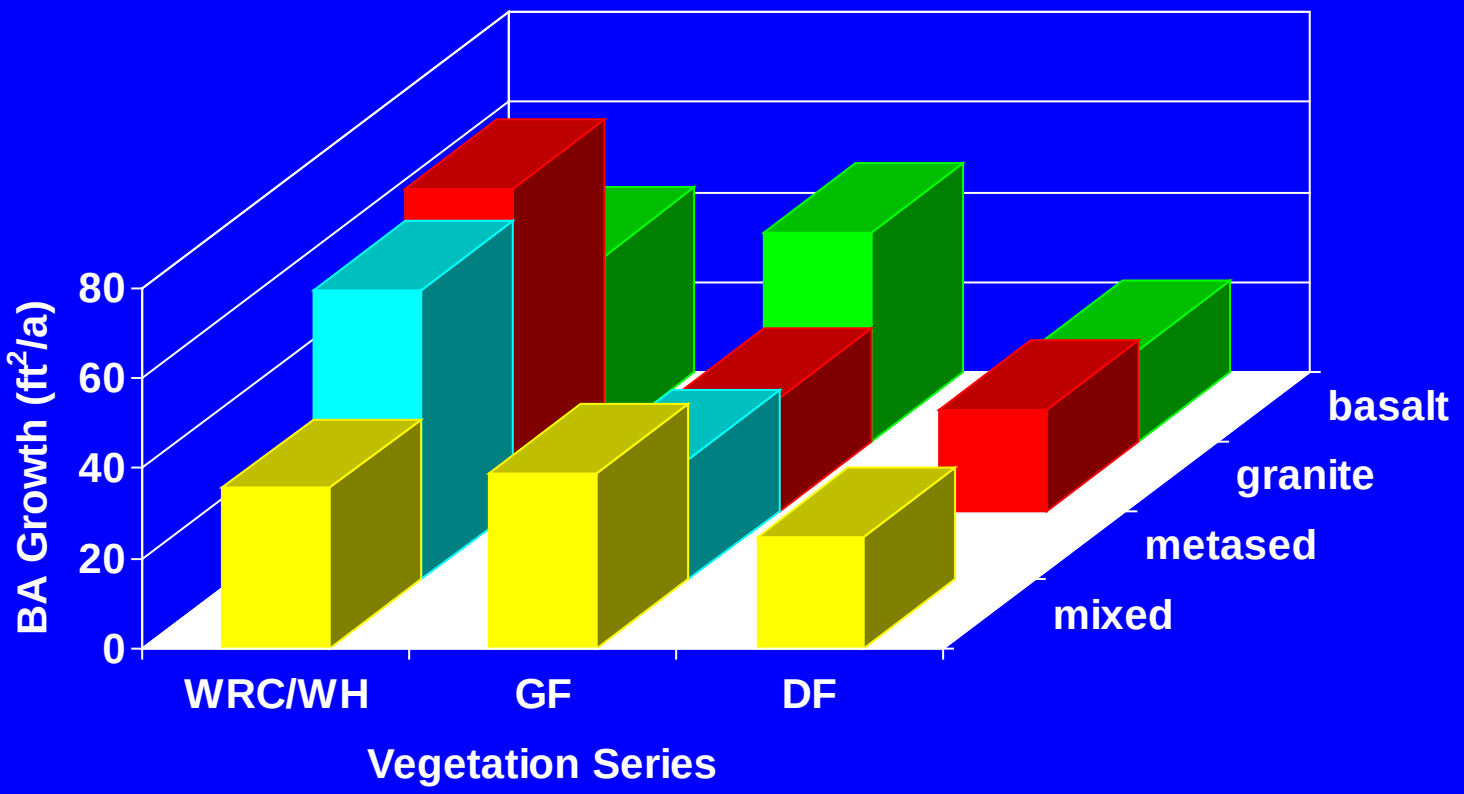
# N and K fertilizer effects on 8-year gross BA growth



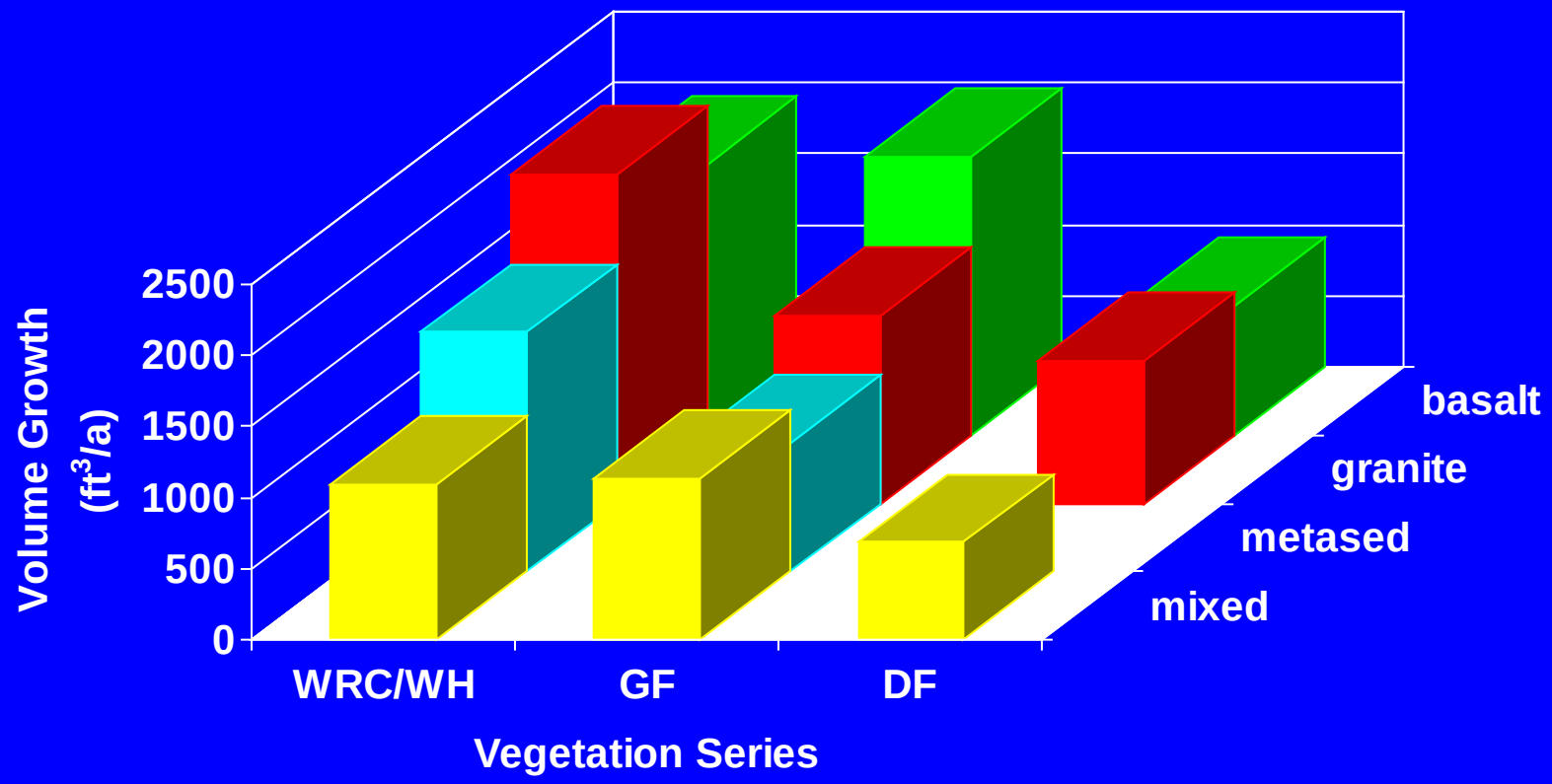
# N and K fertilizer effects on 8-year gross Volume growth



# Control Plot 8-year BA Growth ($ft^2/a$ ) by Rock Type and Vegetation Series



# Control Plot 8-year Volume Growth ($ft^3/a$ ) by Rock Type and Vegetation Series



# Site Influences on Fertilizer Growth Effects

$$\ln(G_{trt}) = \mu + V + R + V*R + I(V*R) + C$$
$$+\beta_1*N + \beta_2*N^2 + \beta_3*K + \beta_4*K^2 + \beta_5*NK$$
$$+\gamma_1*V*N + \gamma_2*V*N^2 + \gamma_3*V*K + \gamma_4*V*K^2 + \gamma_5*V*NK$$
$$+\delta_1*R*N + \delta_2*R*N^2 + \delta_3*R*K + \delta_4*R*K^2 + \delta_5*R*NK$$
$$+\xi_1*V*R*N + \xi_2*V*R*N^2 + \xi_3*V*R*K + \xi_4*V*R*K^2 + \xi_5*V*R*NK$$

where G = growth (8-year BA or volume increment)

V = vegetation series

R = rock type

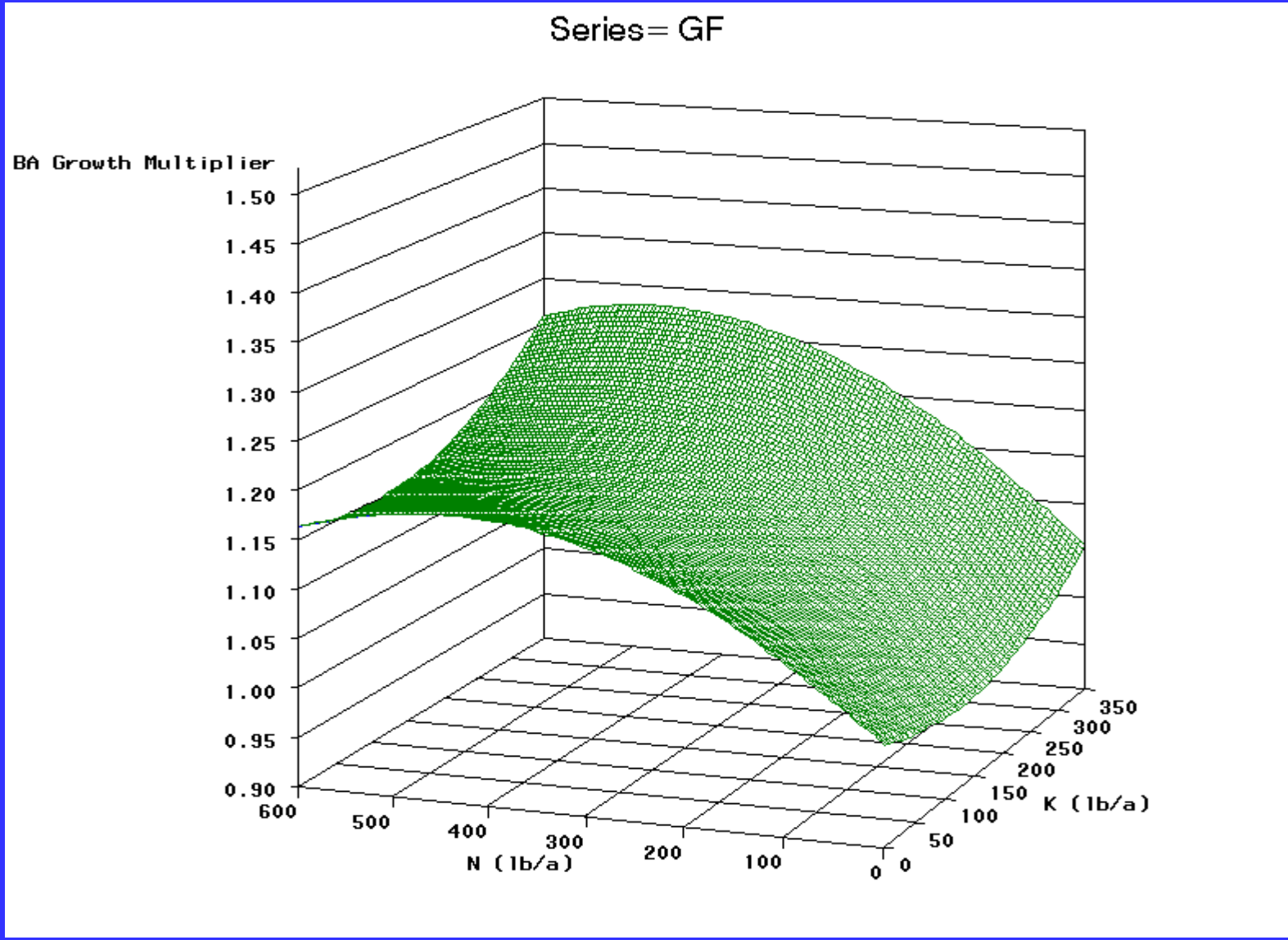
I = installation effect (nested random)

C = covariate adjustment for initial density

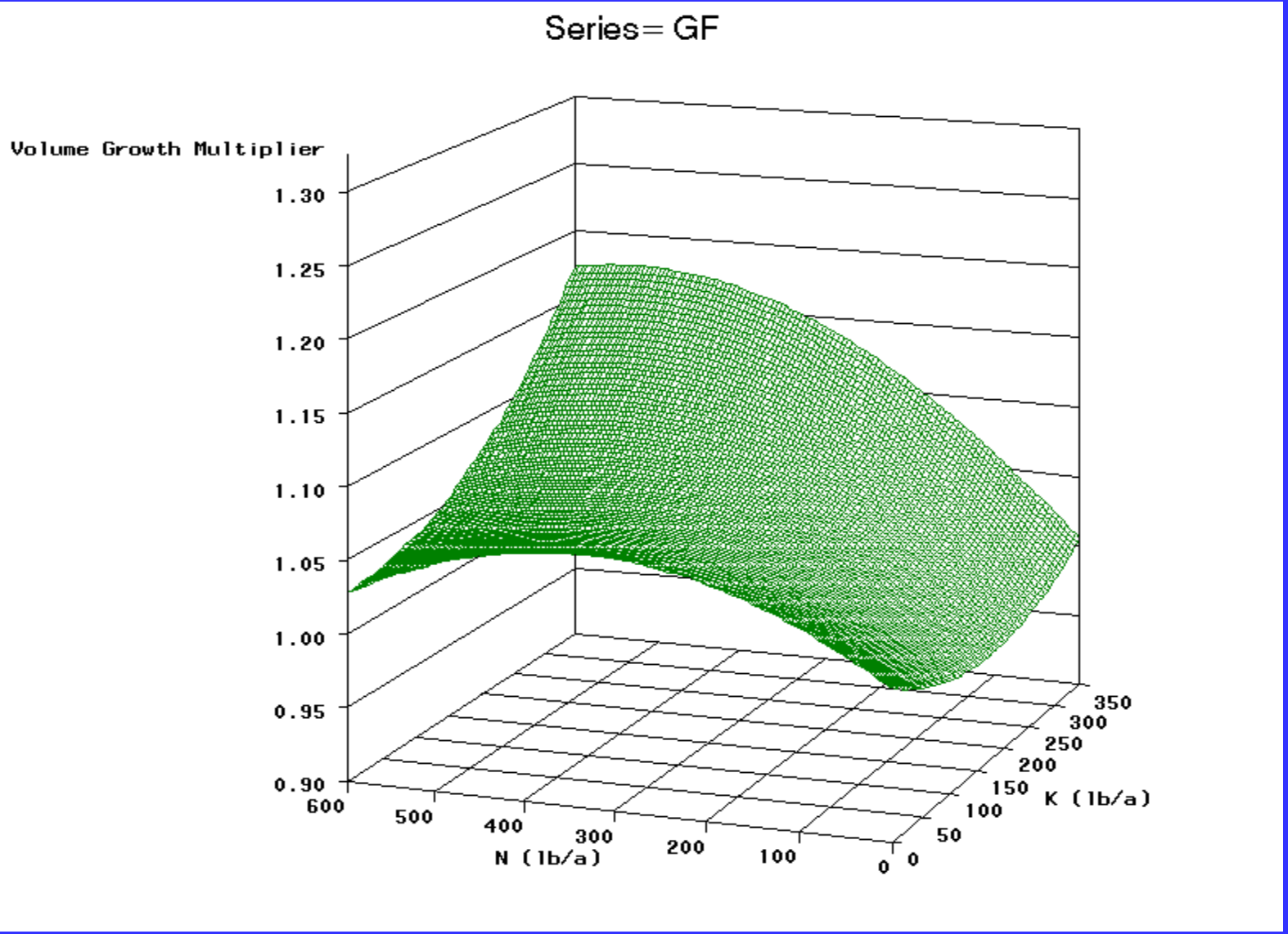
N = nitrogen rate (lbs/a)

K = potassium rate (lbs/a)

# N and K fertilizer effects on 8-year gross BA growth
# Grand Fir Vegetation Series

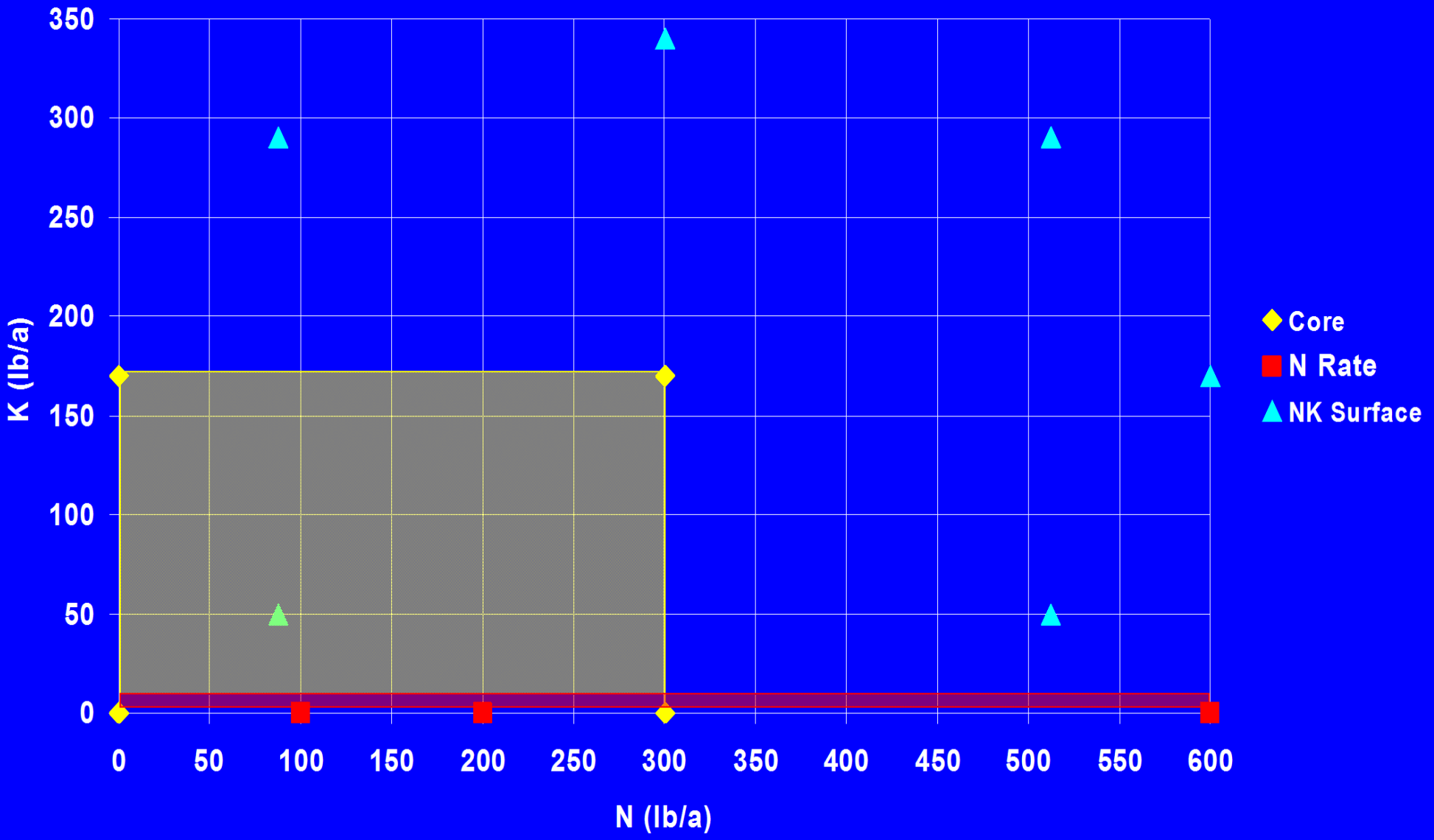


# N and K fertilizer effects on 8-year gross Volume growth Grand Fir Vegetation Series

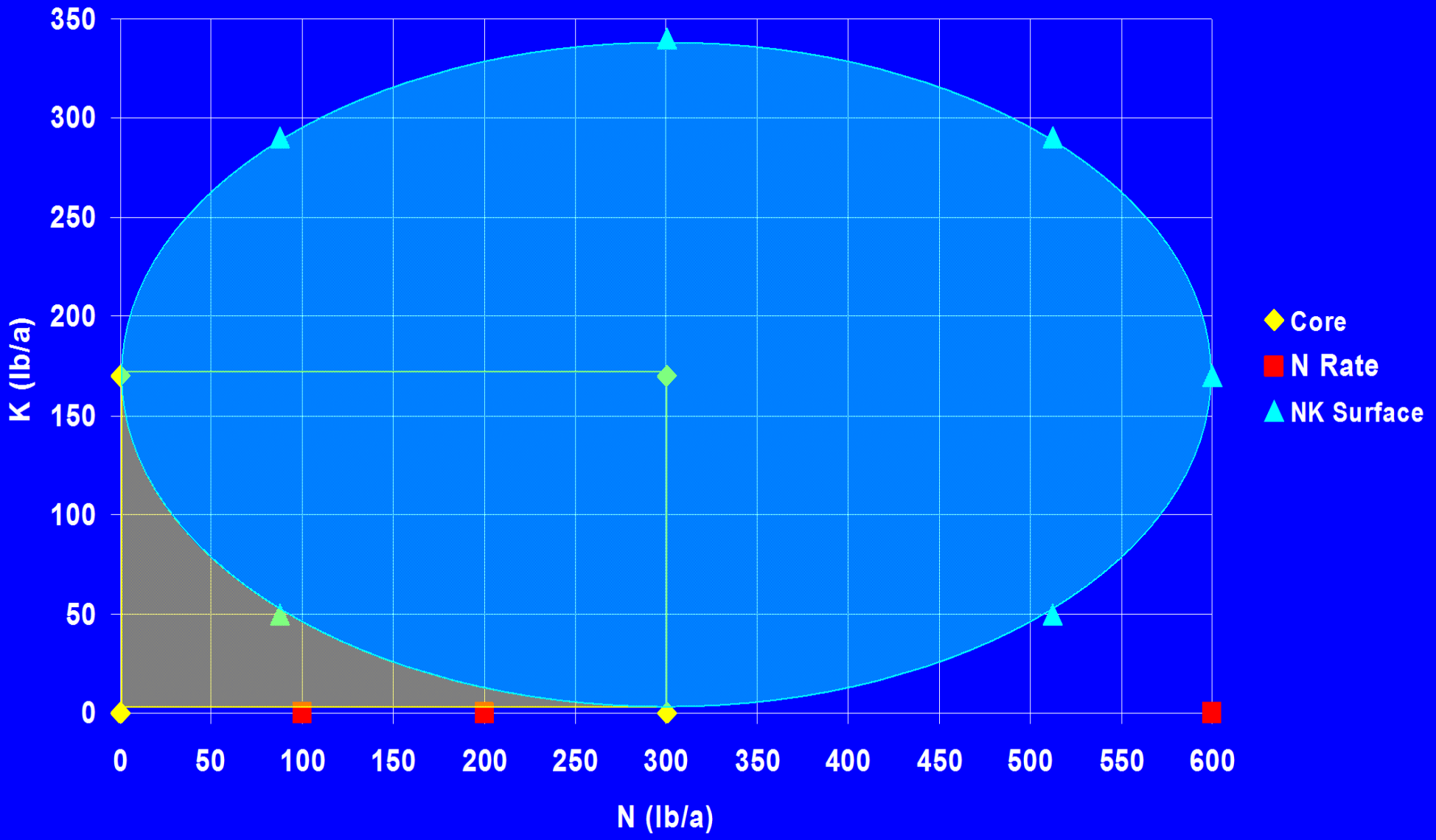


# Fertilizer Application Rates: Core Coverage

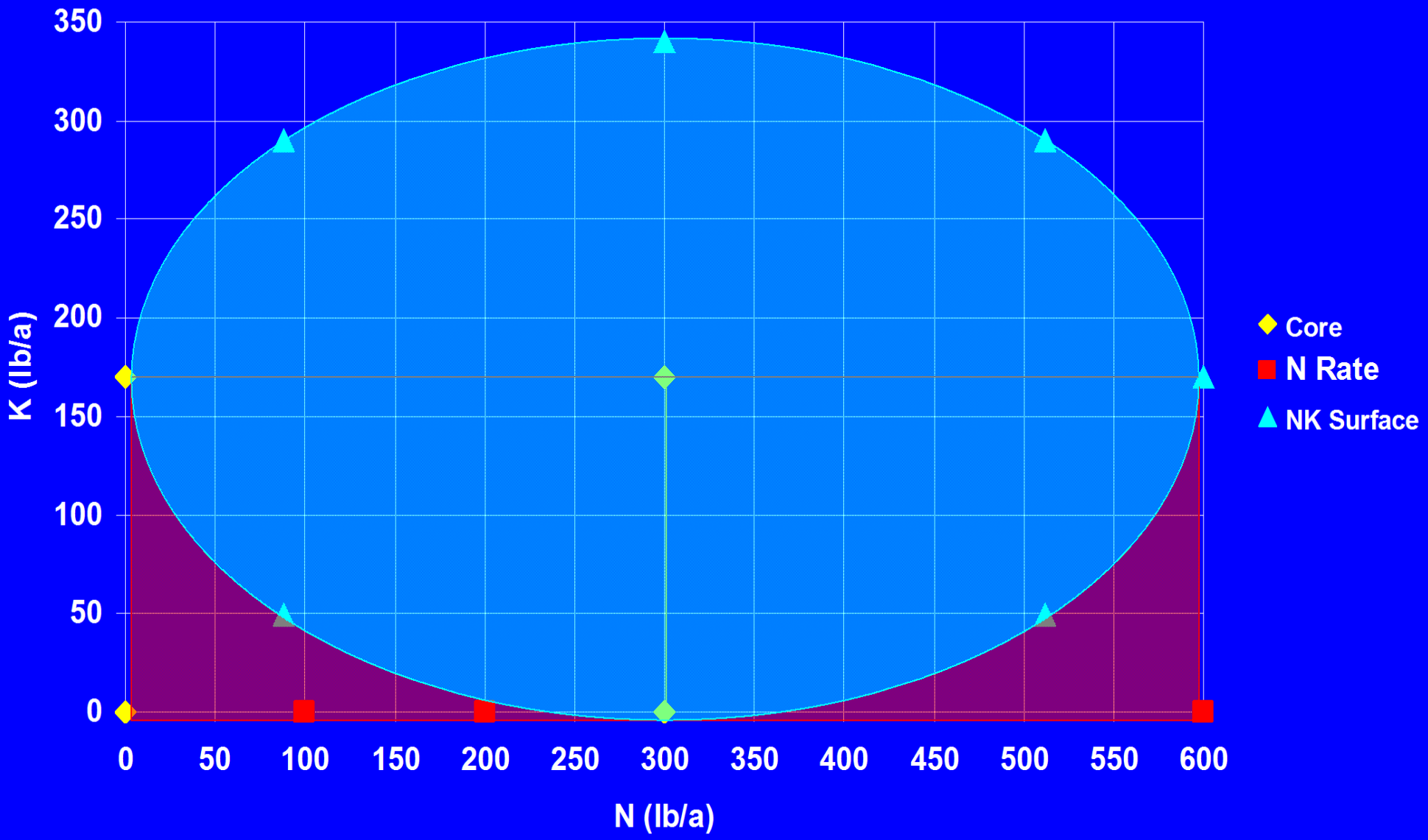
# Fertilizer Application Rates: N Rate Coverage



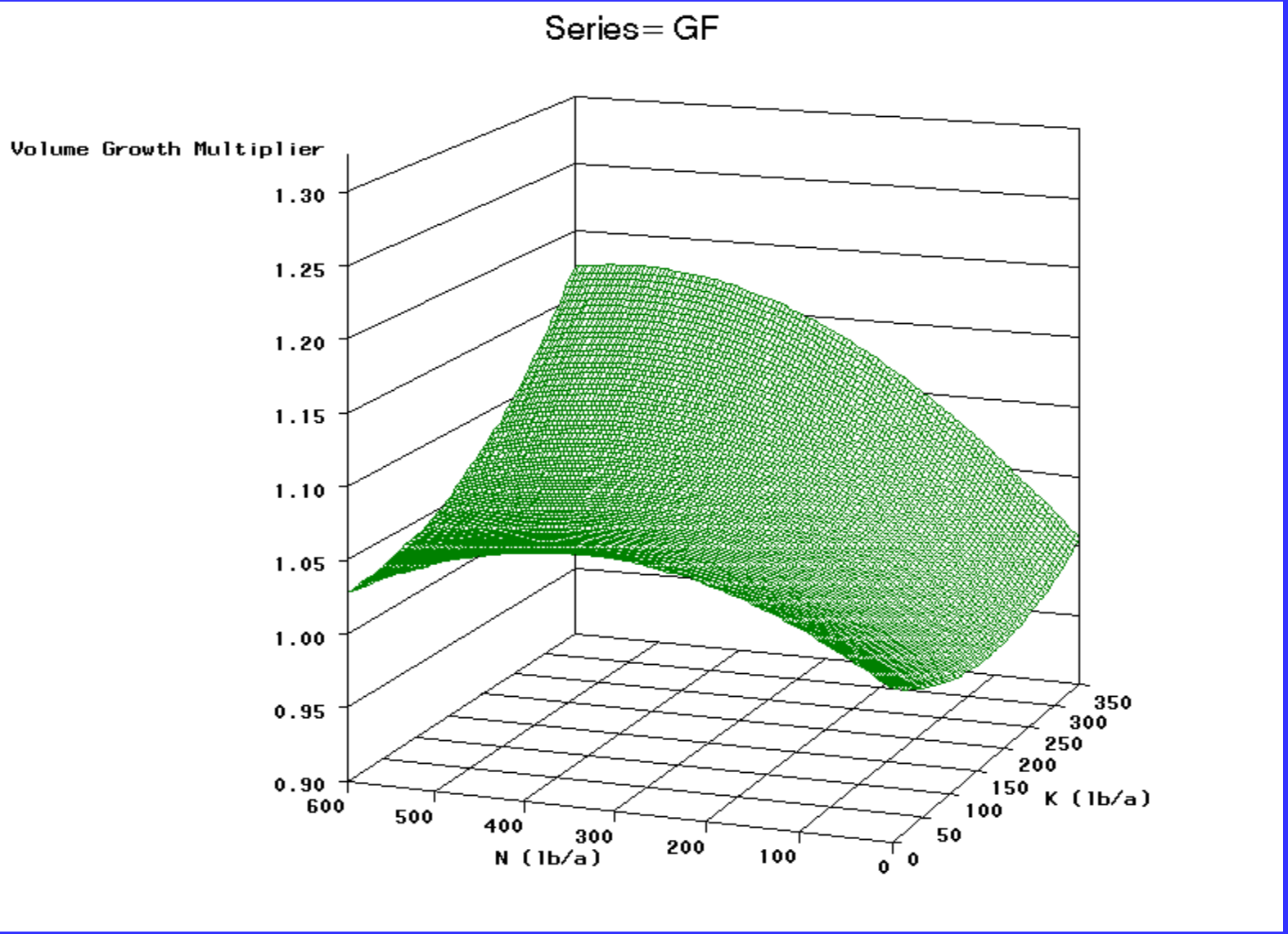
# Fertilizer Application Rates: NK Response Surface Coverage



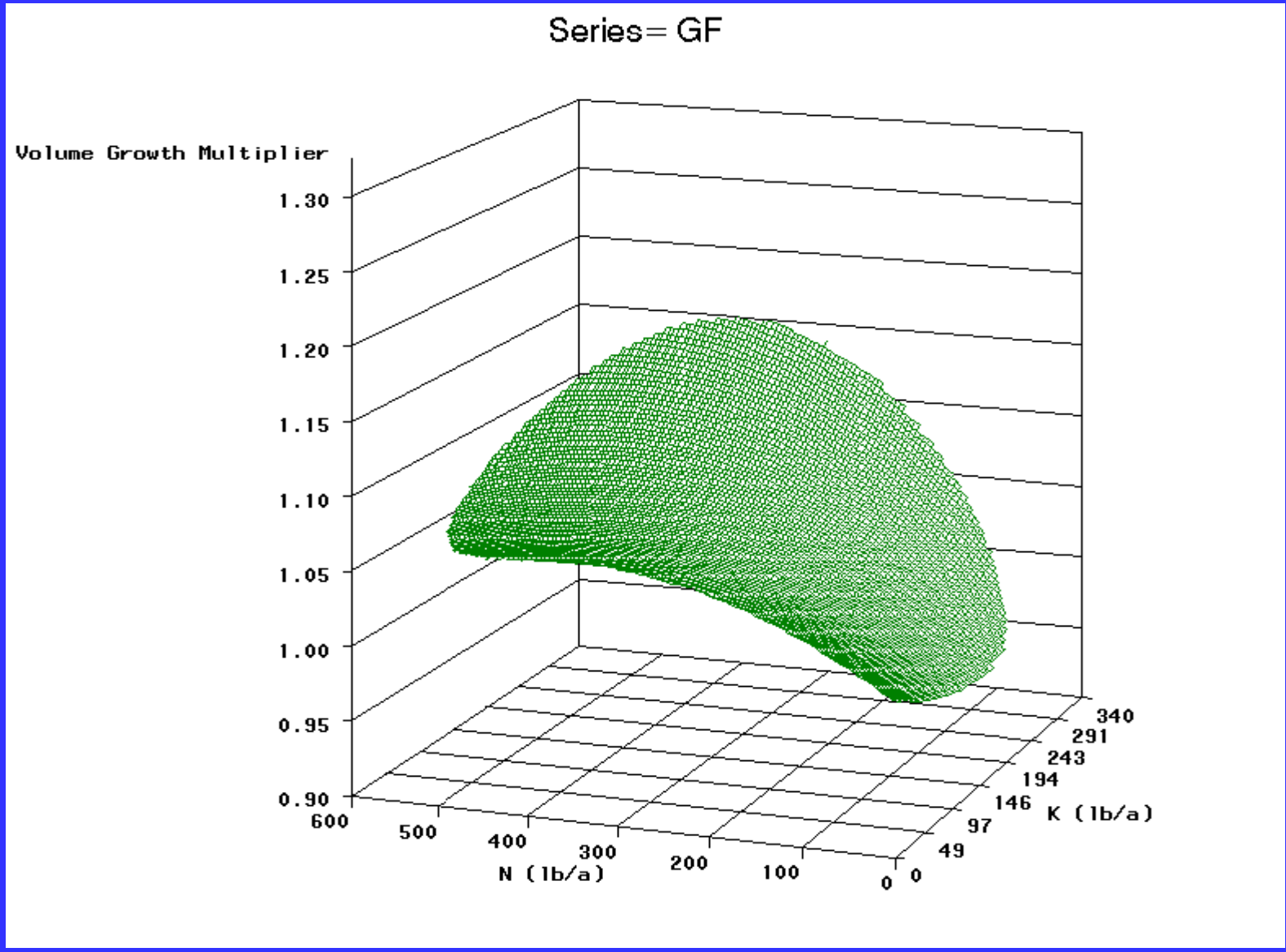
# Fertilizer Application Rates: Maximum Coverage



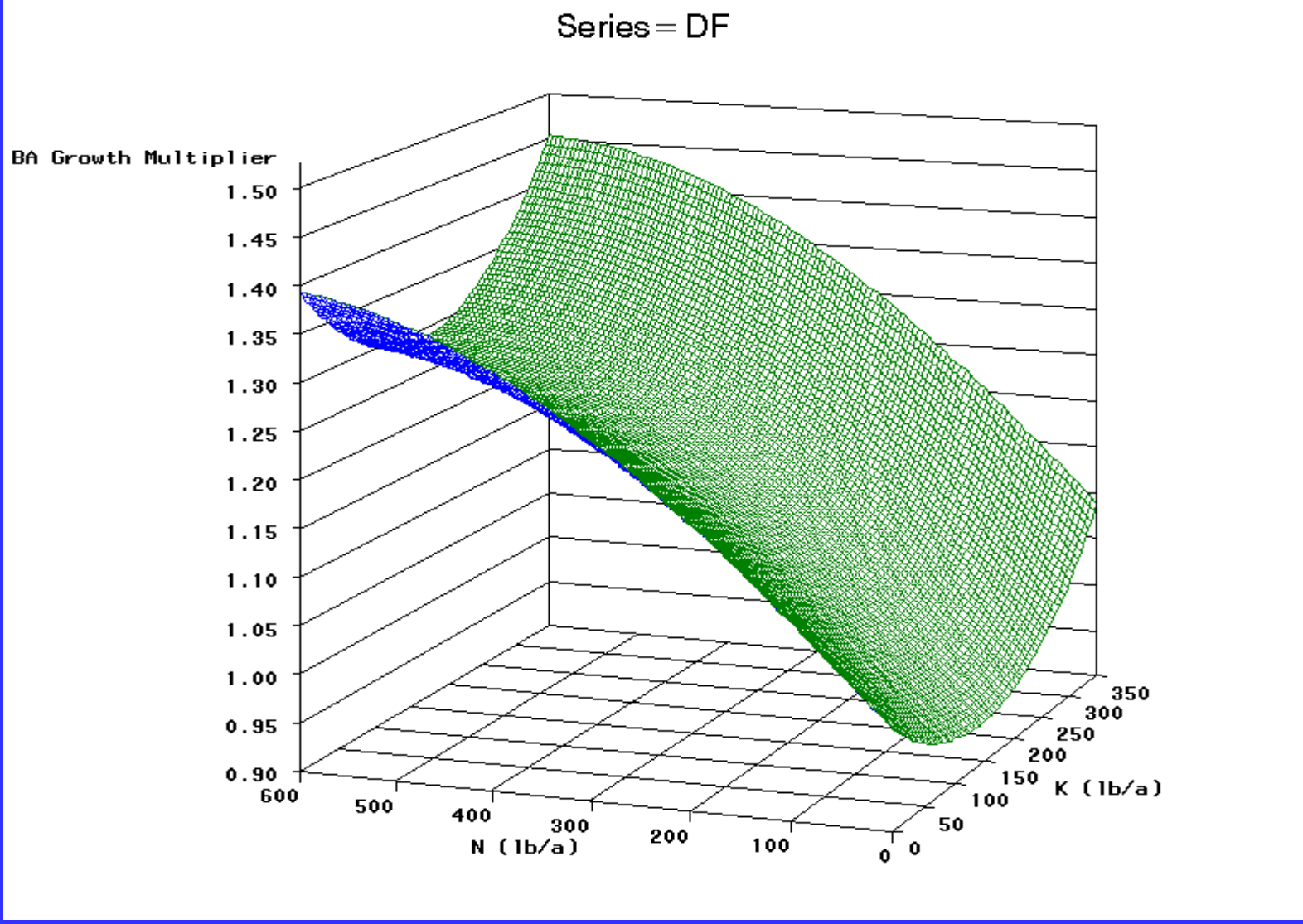
# N and K fertilizer effects on 8-year gross Volume growth Grand Fir Vegetation Series



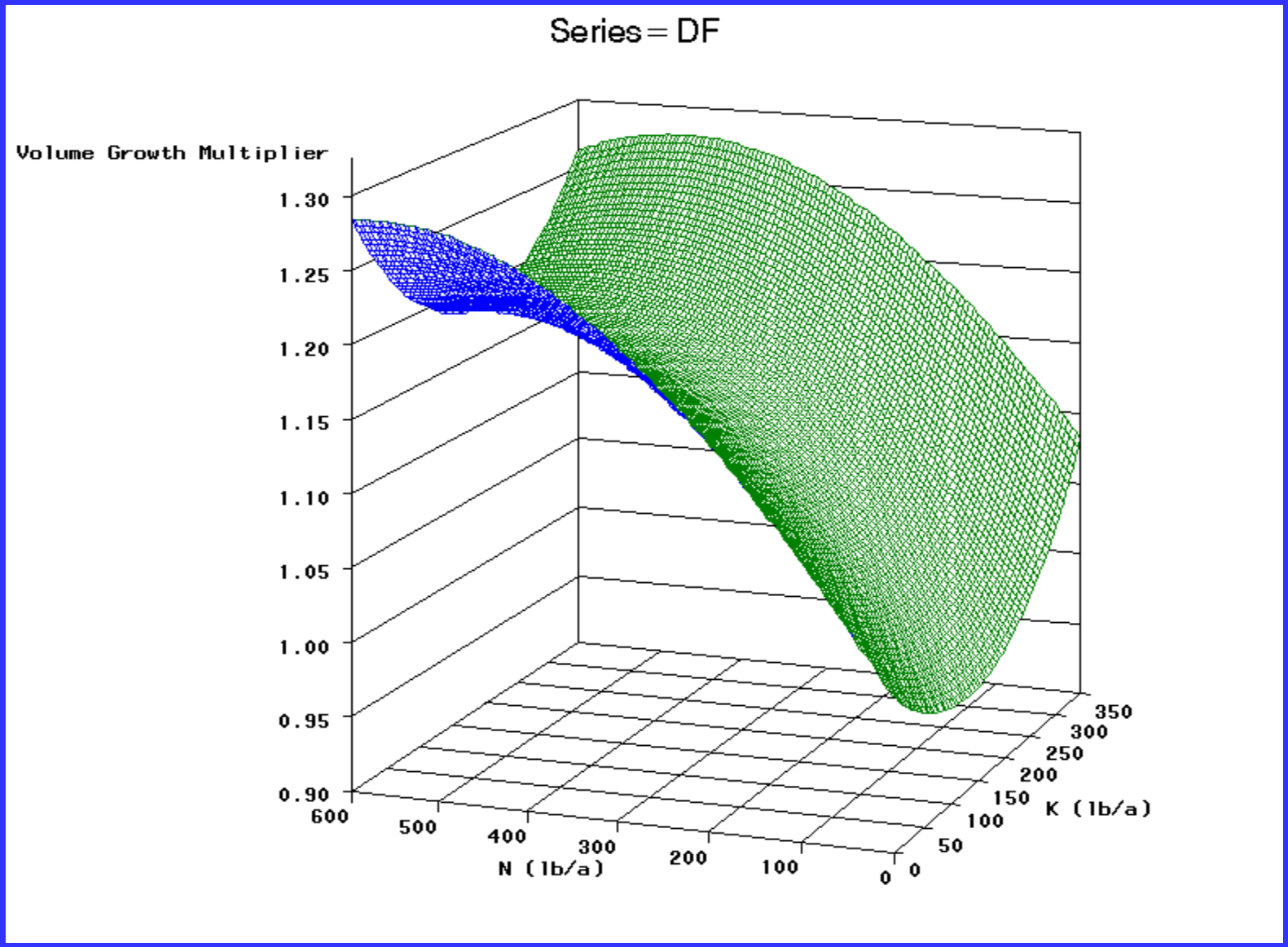
# N and K fertilizer effects on 8-year gross Volume growth
# Grand Fir Vegetation Series



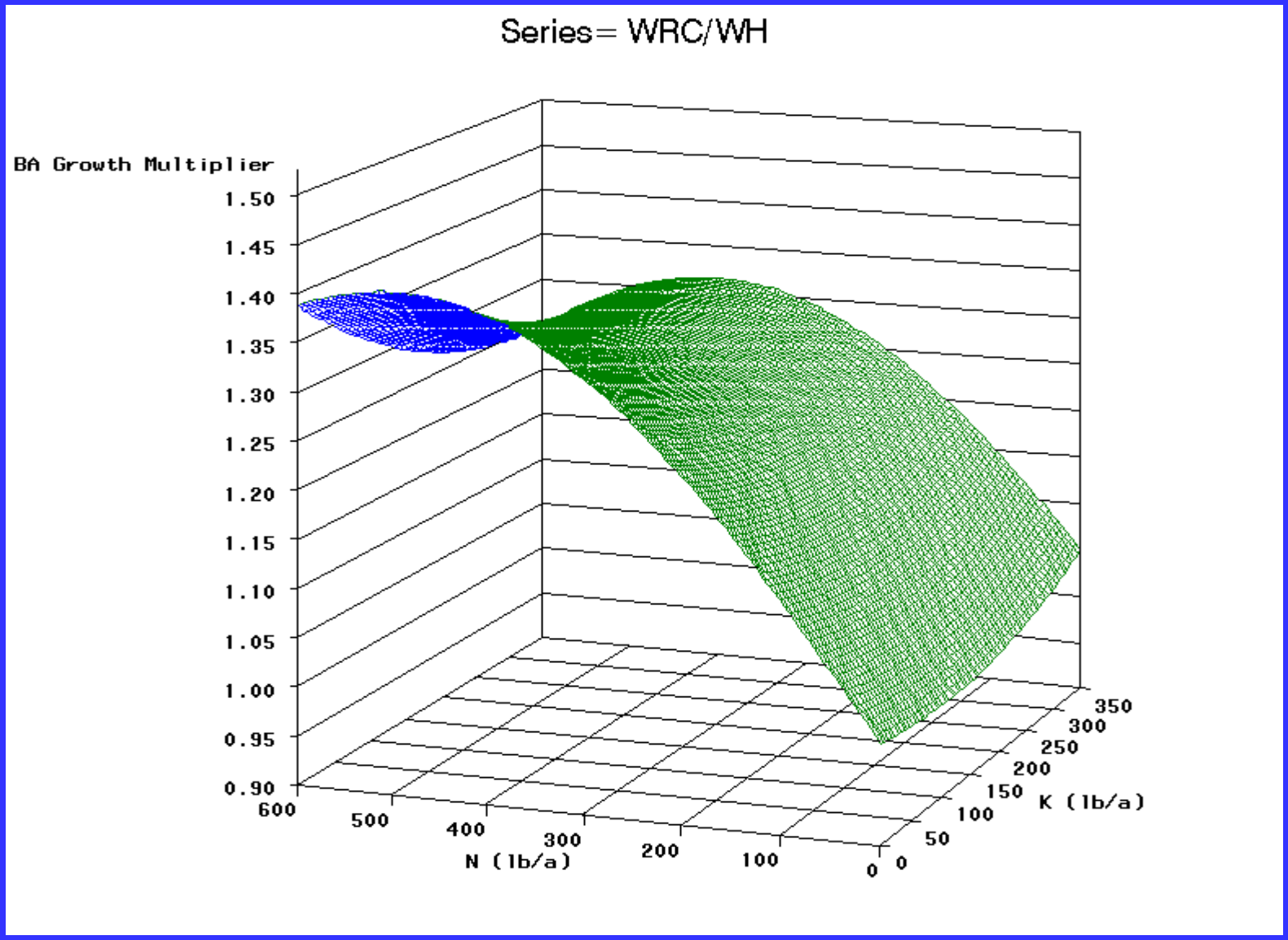
# N and K fertilizer effects on 8-year gross BA growth Douglas-fir Vegetation Series



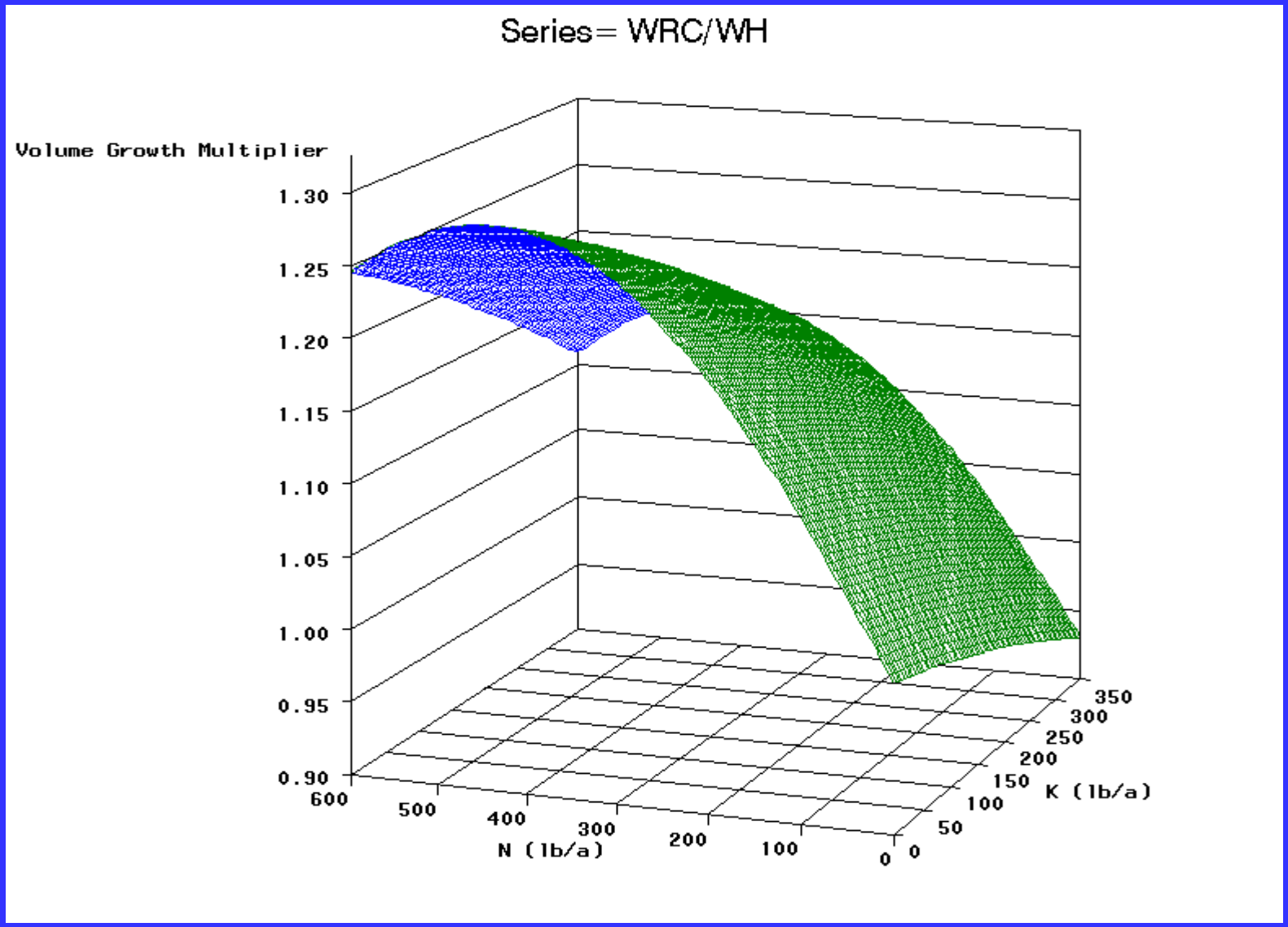
# N and K fertilizer effects on 8-year gross Volume growth Douglas-fir Vegetation Series



# N and K fertilizer effects on 8-year gross BA growth Cedar/Hemlock Vegetation Series



# N and K fertilizer effects on 8-year gross Volume growth Cedar/Hemlock Vegetation Series



# Summary: N and K Effects on Growth

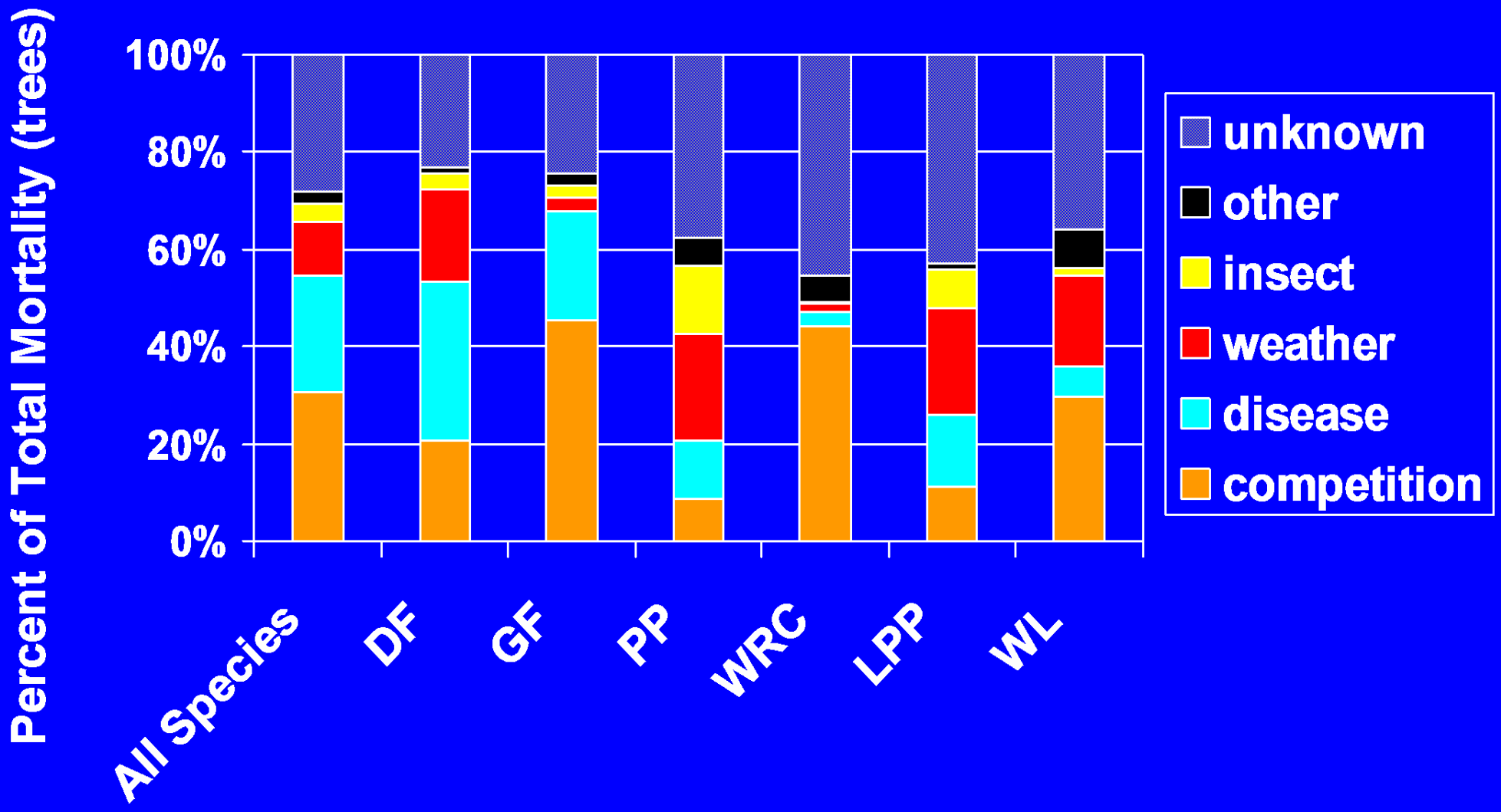
- N and K effects differed by vegetation series but not by rock type
  - Good N response on DF and WRC/WH sites, but much lower response on GF sites
  - K appeared to boost N responses on DF and GF sites, but not on WRC/WH
- Volume response was lower than BA response

# What's Dying?

| | Total Trees | Dead Trees | % Mortality |
|---|---|---|---|
| All species | 43071 | 2845 | 6.61 |
| Douglas-fir | 17115 | 968 | 5.66 |
| Grand Fir | 11310 | 1083 | 9.58 |
| Ponderosa Pine | 6367 | 207 | 3.25 |
| Western Redcedar | 3579 | 227 | 6.34 |
| Lodgepole Pine | 1711 | 154 | 9.00 |
| Western Larch | 1547 | 64 | 4.14 |

| | Mean DBH | Inner-Quartile Range |
|---|---|---|
| All trees | 6.8 inches | 3.6 to 9.2 inches |
| Dead trees | 4.5 inches | 1.1 to 6.8 inches |

# Causes of Mortality



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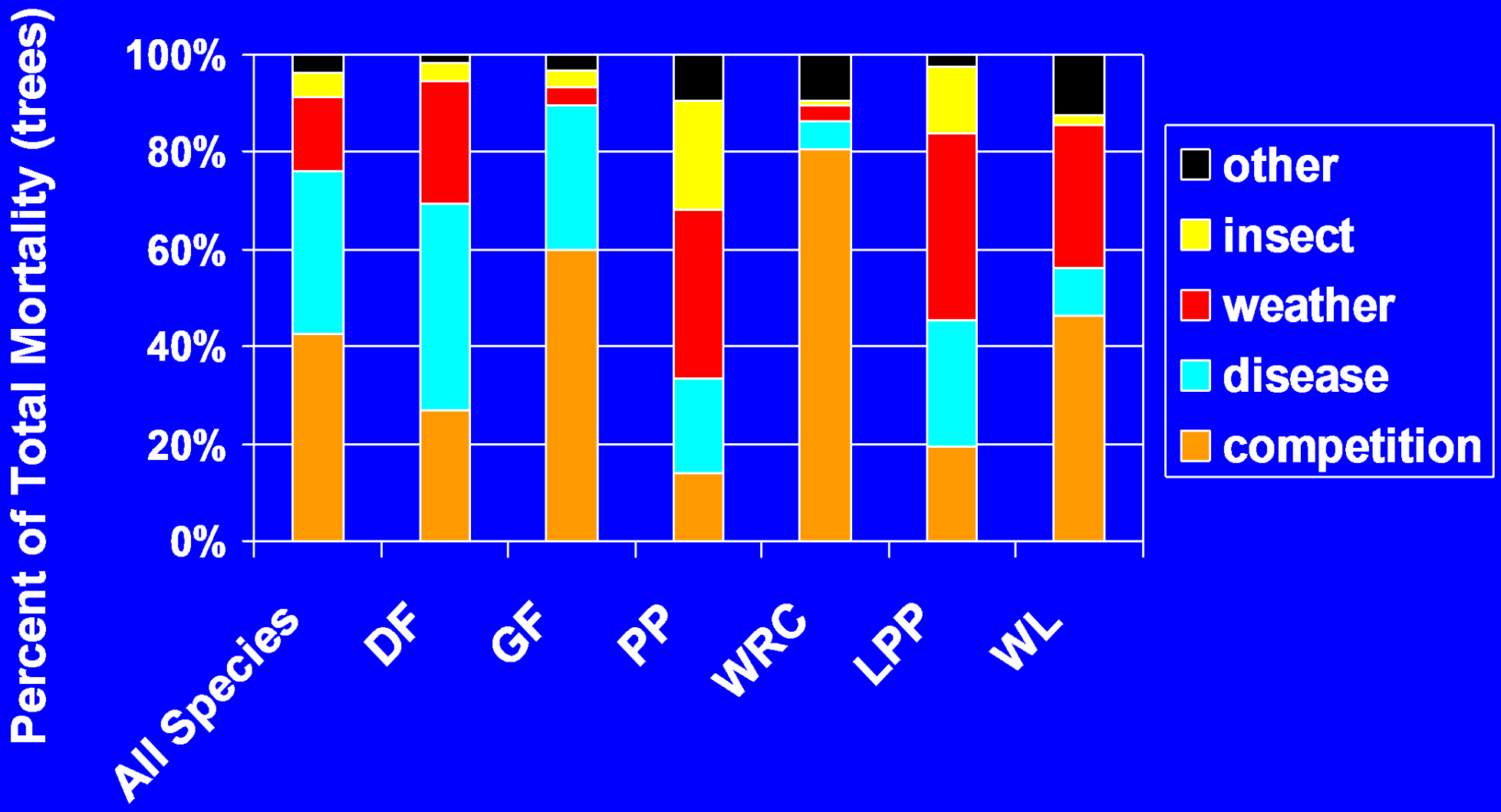
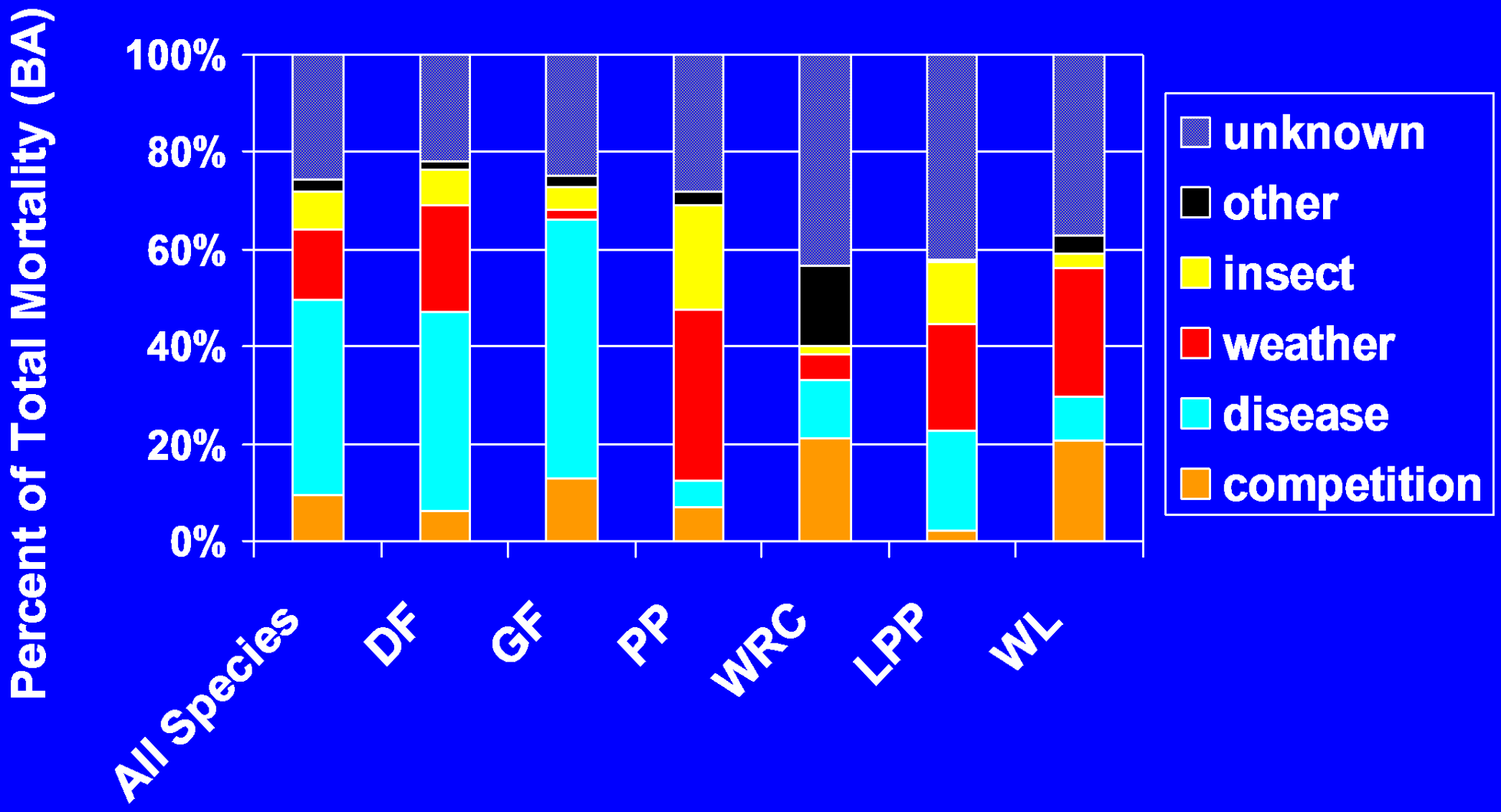


# Size of Mortality

| Mortality Cause | DBH (inches) | |
|---|---|---|
| | Mean | Inner-Quartile Range |
| Competition | 2.34 | 0.49 to 3.58 |
| Weather | 6.15 | 3.86 to 7.97 |
| Disease | 6.68 | 3.82 to 8.85 |
| Insects | 8.08 | 5.04 to 10.55 |

# Causes of Mortality



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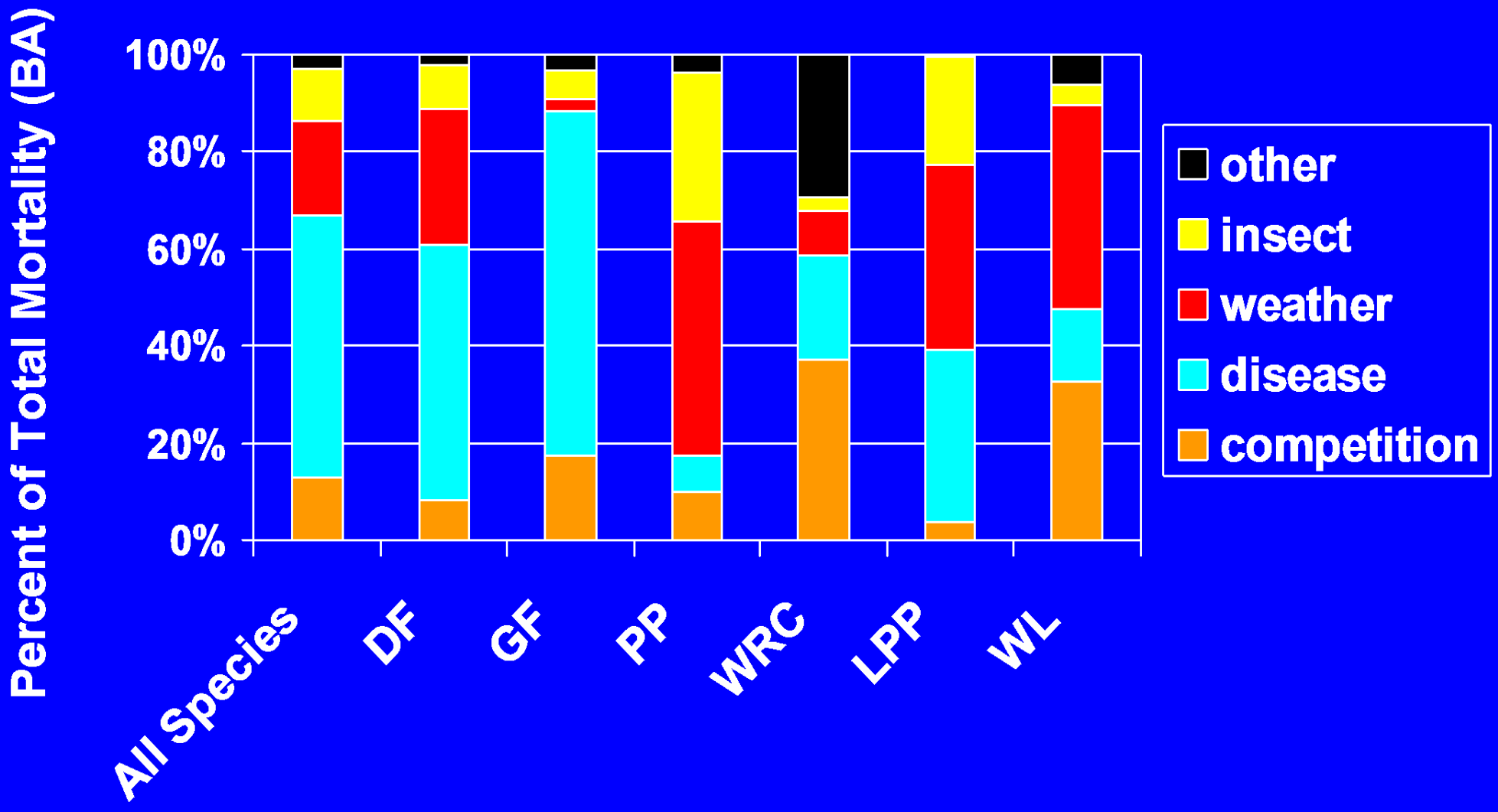
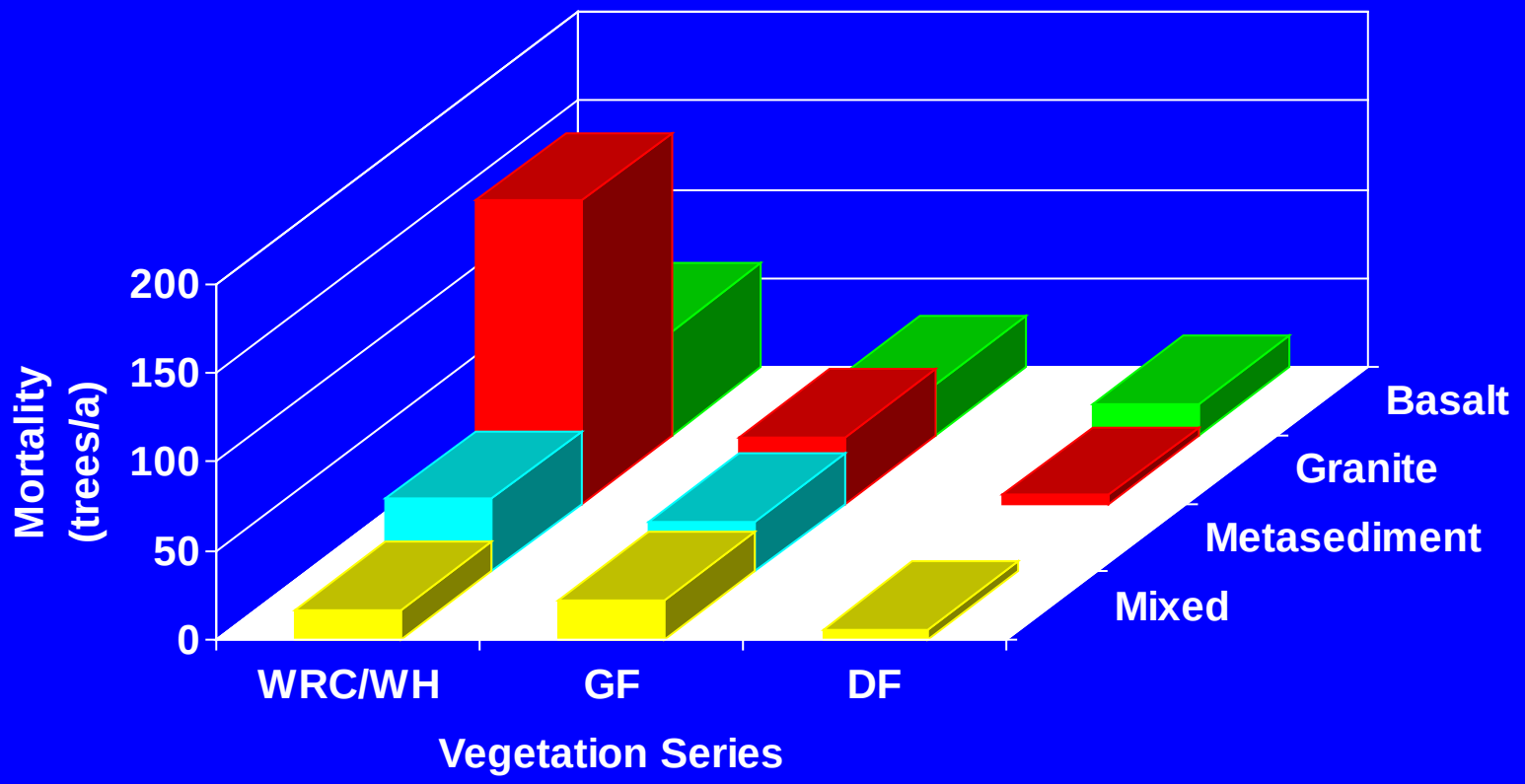
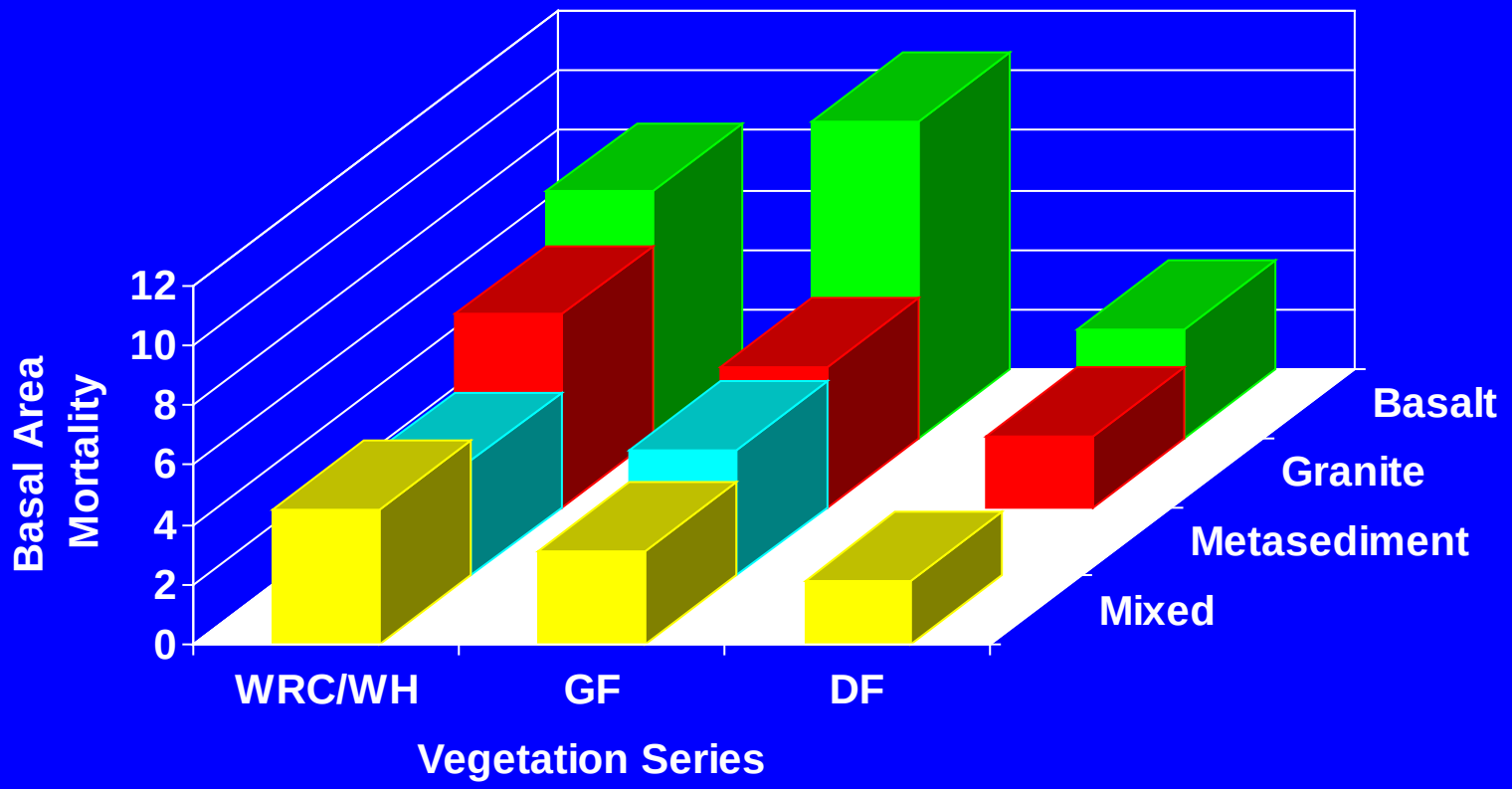


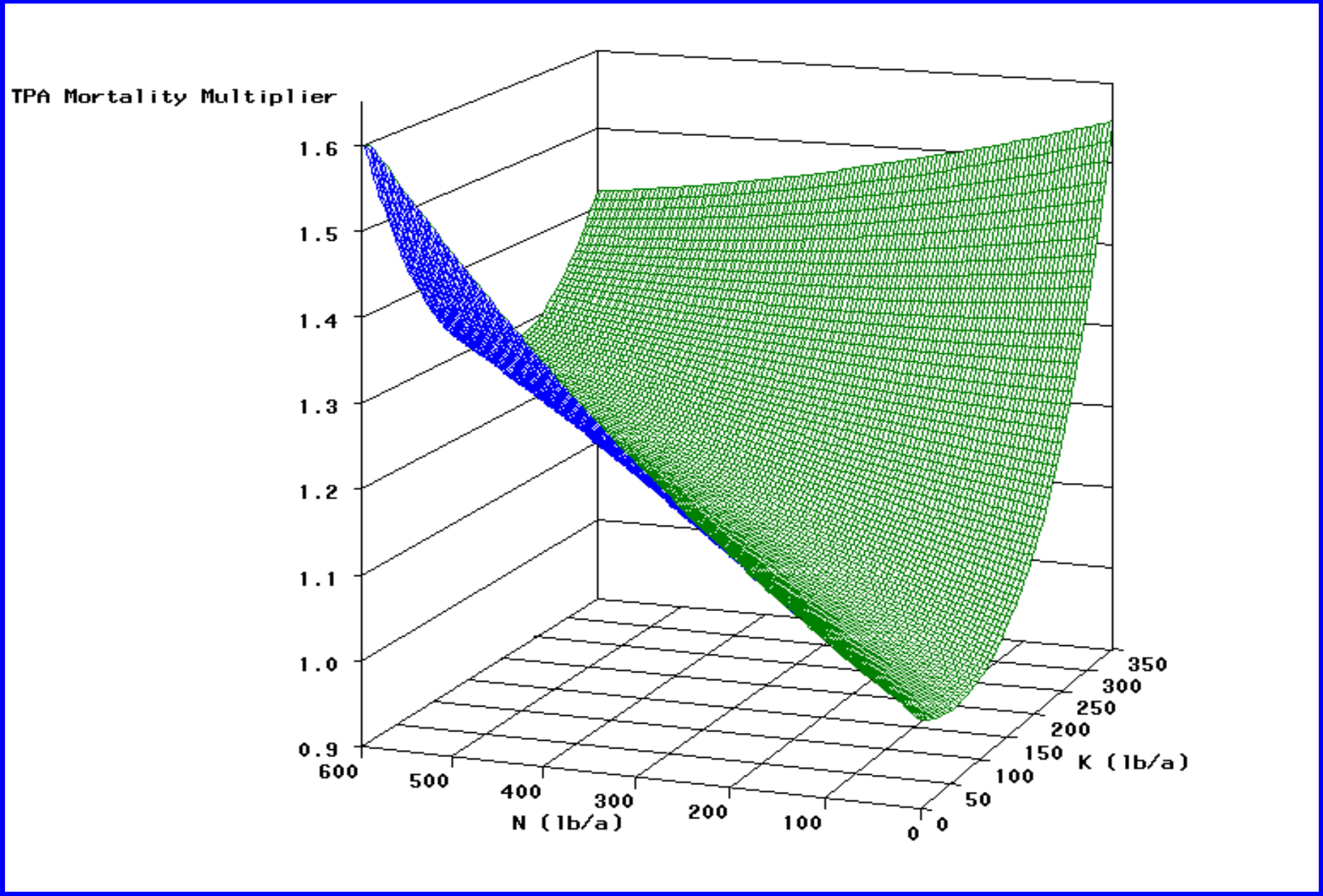
# Control Plot 8-year Mortality (trees/a) by Rock Type and Vegetation Series



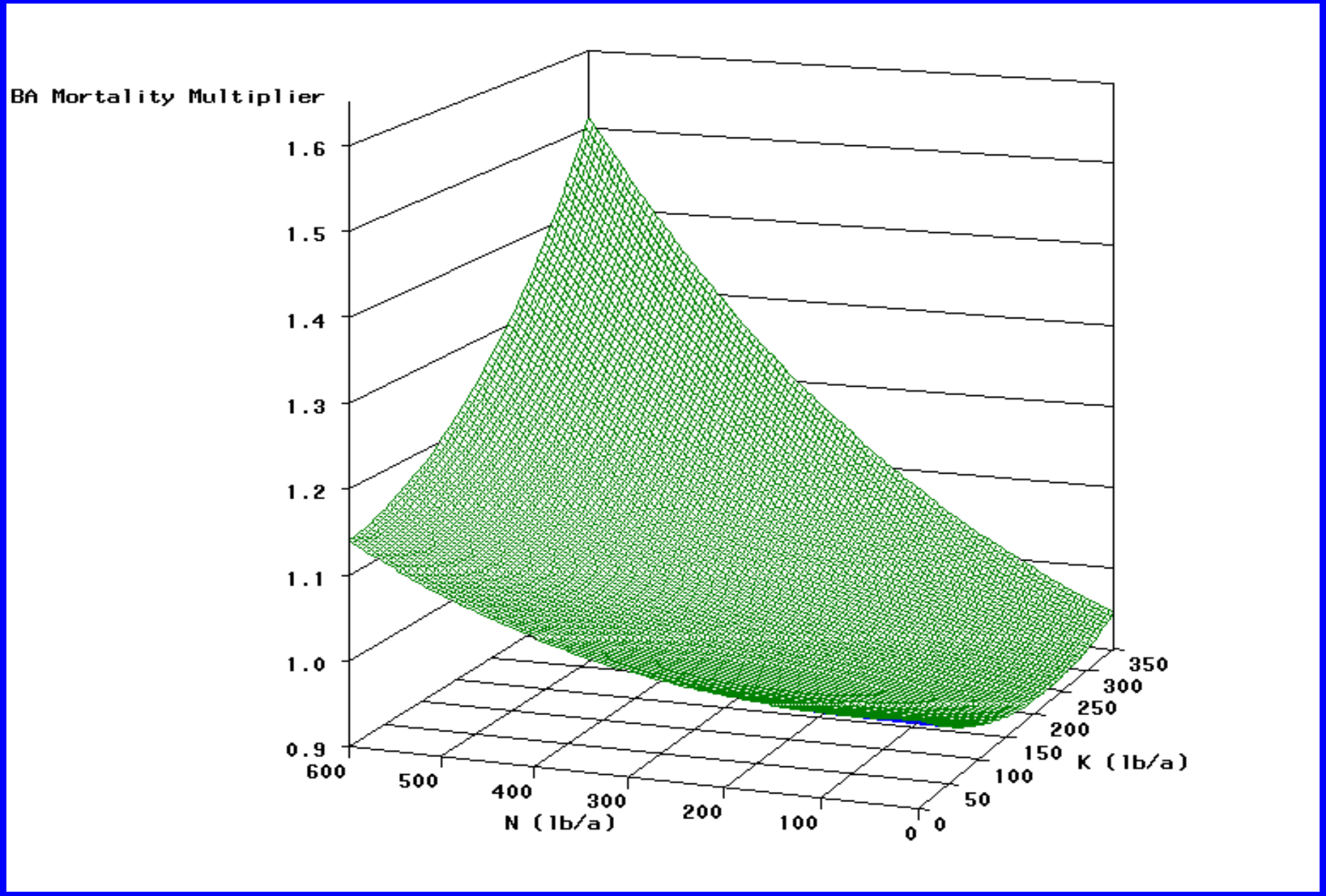
# Control Plot 8-year Basal Area Mortality ($ft^2/a$) by Rock Type and Vegetation Series



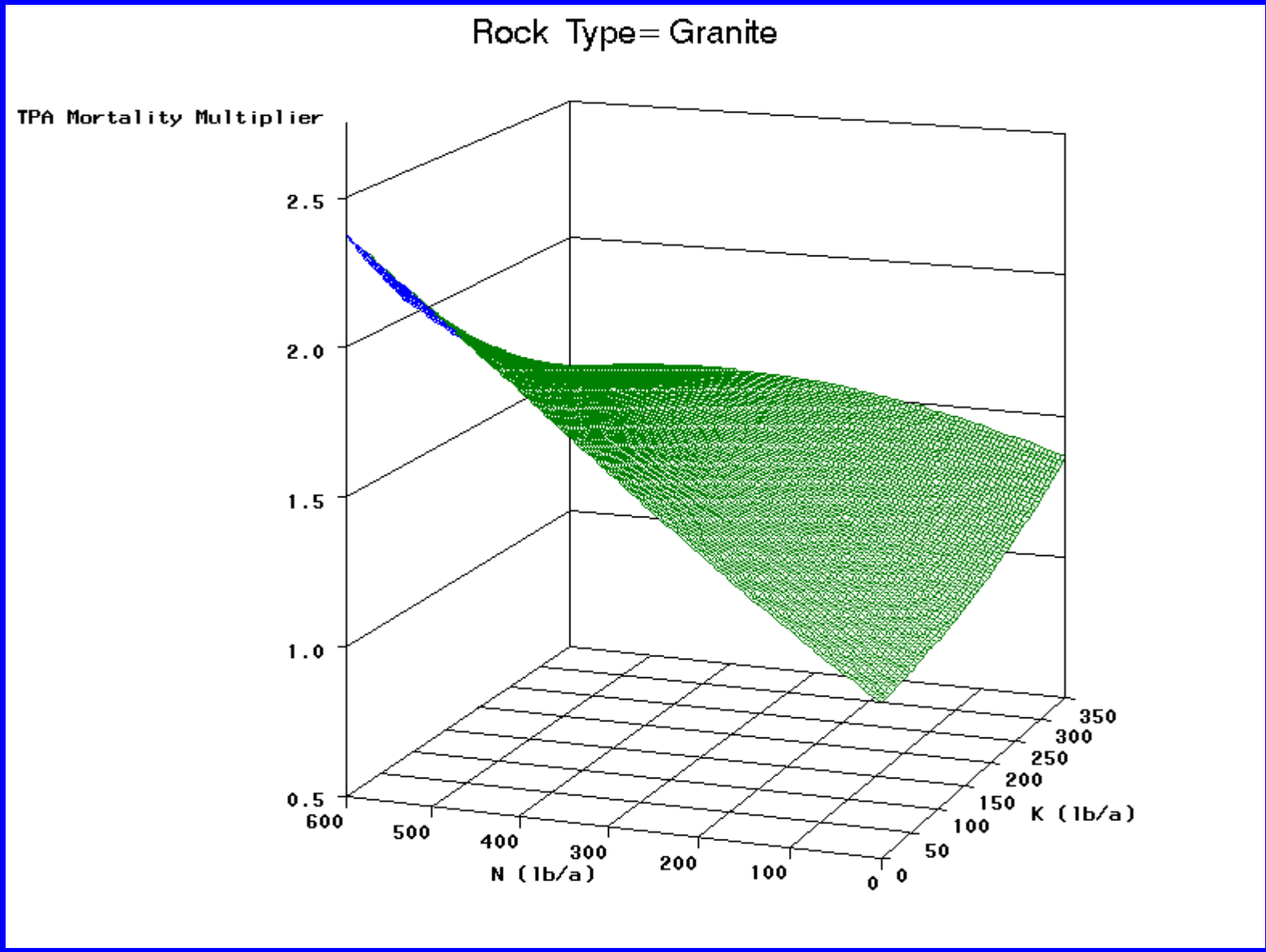
# N and K Effects on 8-year Mortality (trees/a)



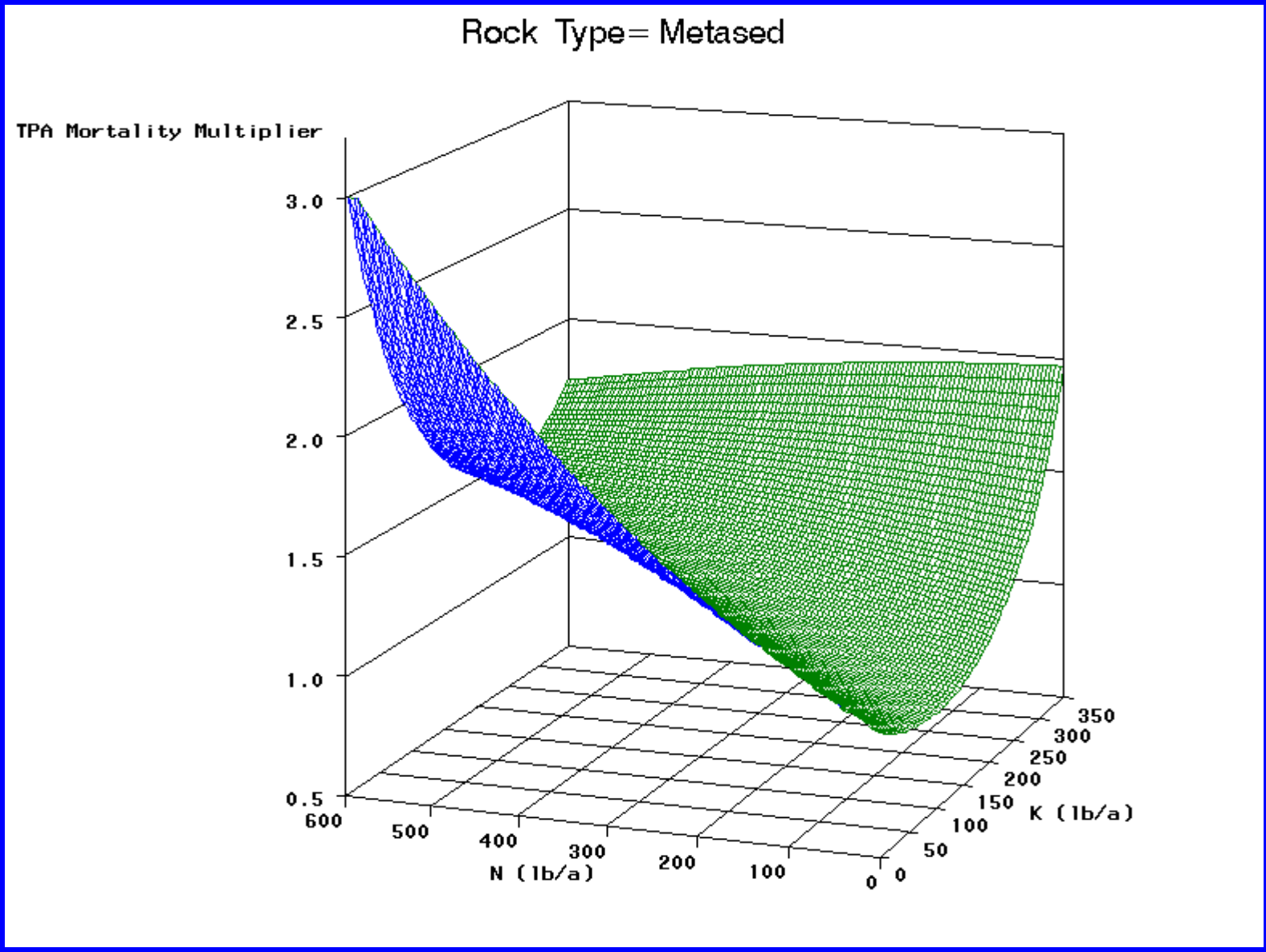
# N and K Effects on 8-year BA Mortality ($ft^2/a$)



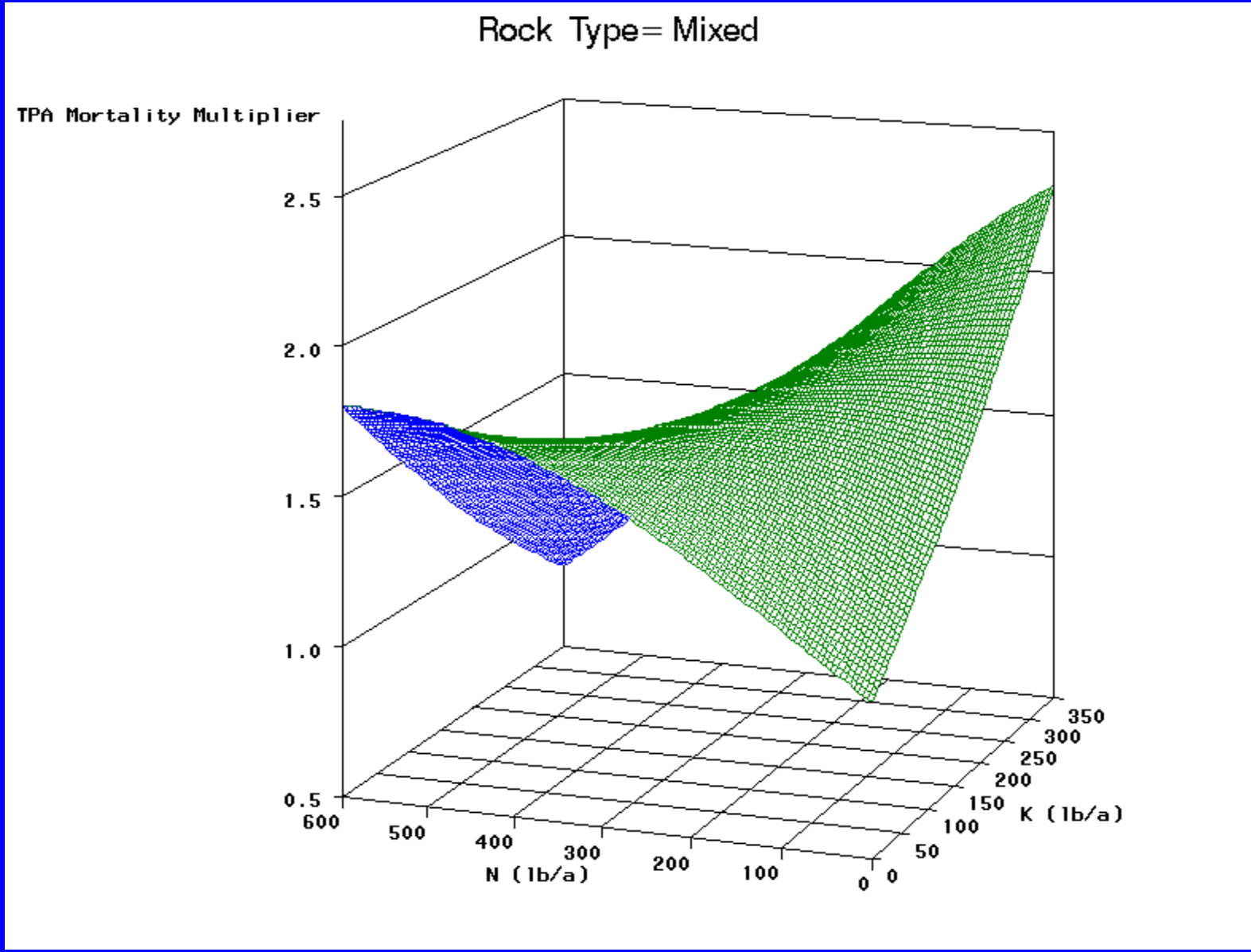
# N and K Effects on 8-year Mortality (trees/a): Granite Rock Types



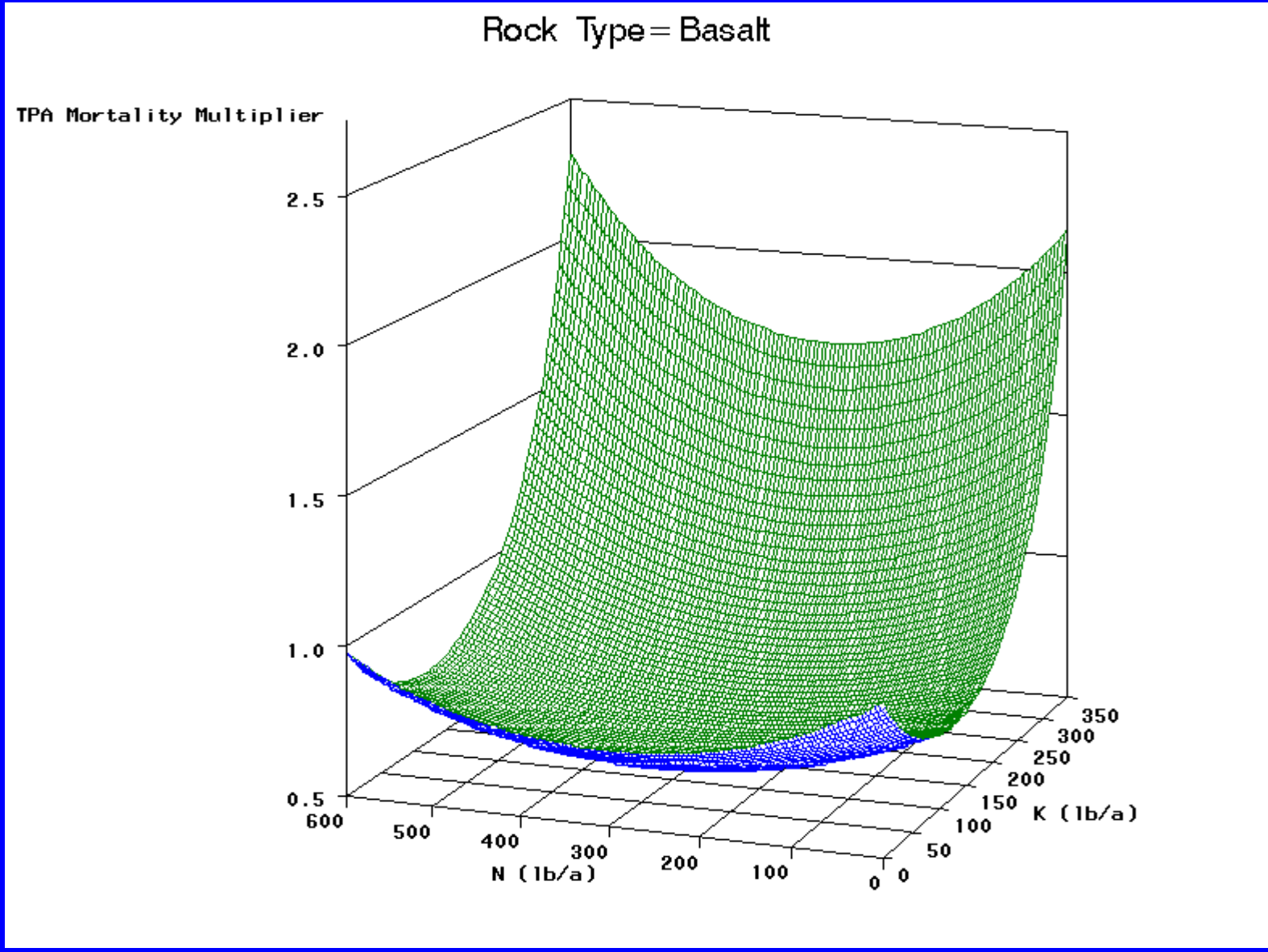
# N and K Effects on 8-year Mortality (trees/a): Metasedimentary Rock Types



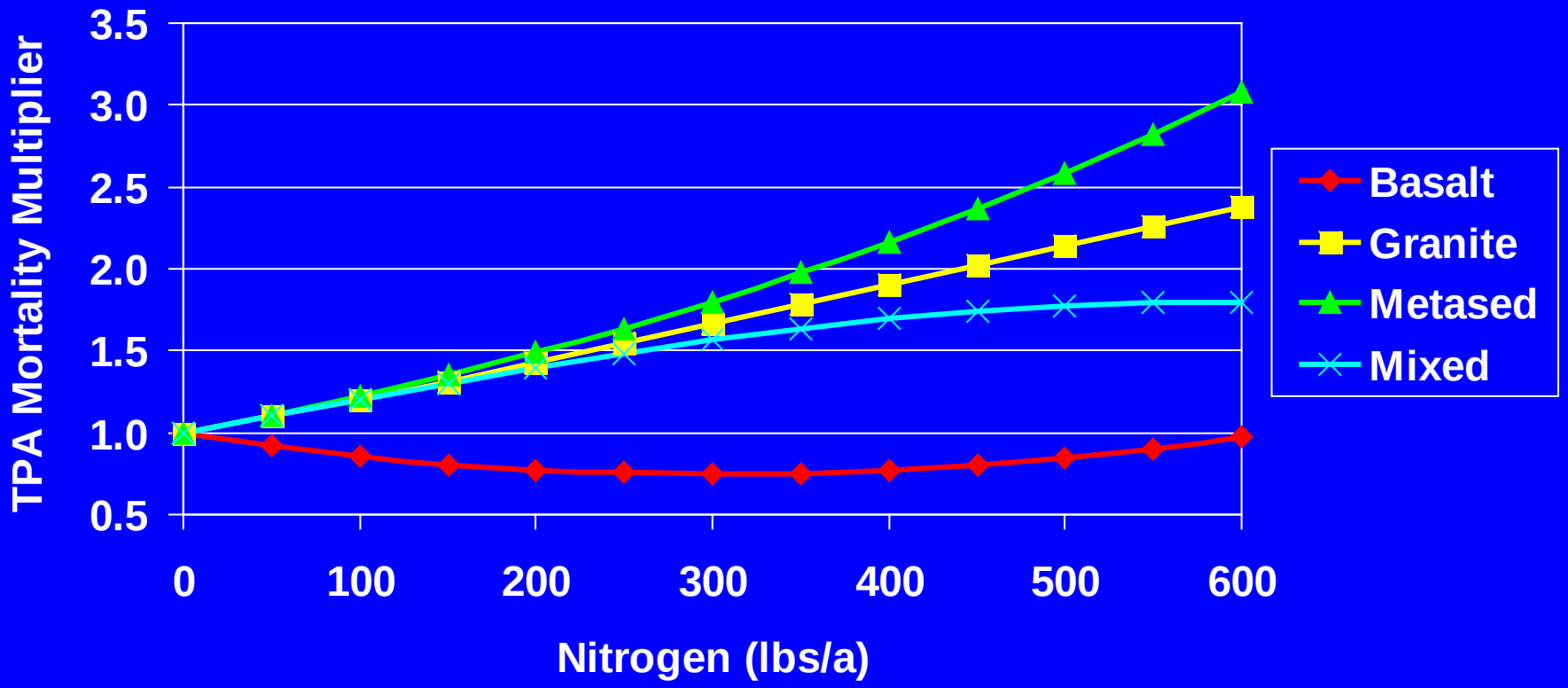
# N and K Effects on 8-year Mortality (trees/a): Mixed (Glacial Till) Rock Types



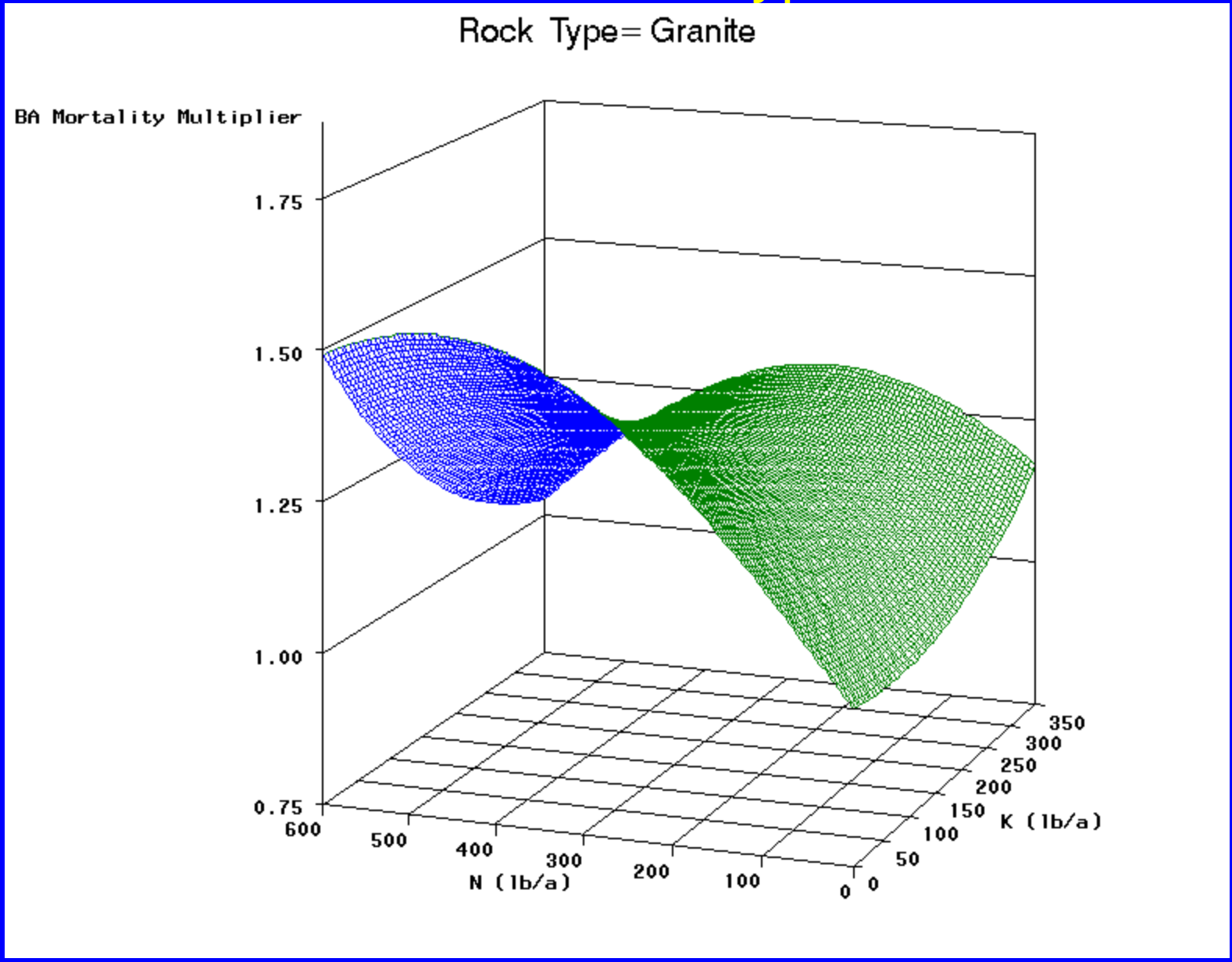
# N and K Effects on 8-year Mortality (trees/a): Basalt Rock Types



# N Effects on 8-year TPA Mortality



# N and K Effects on 8-year BA Mortality ($ft^2/a$): Granite Rock Types



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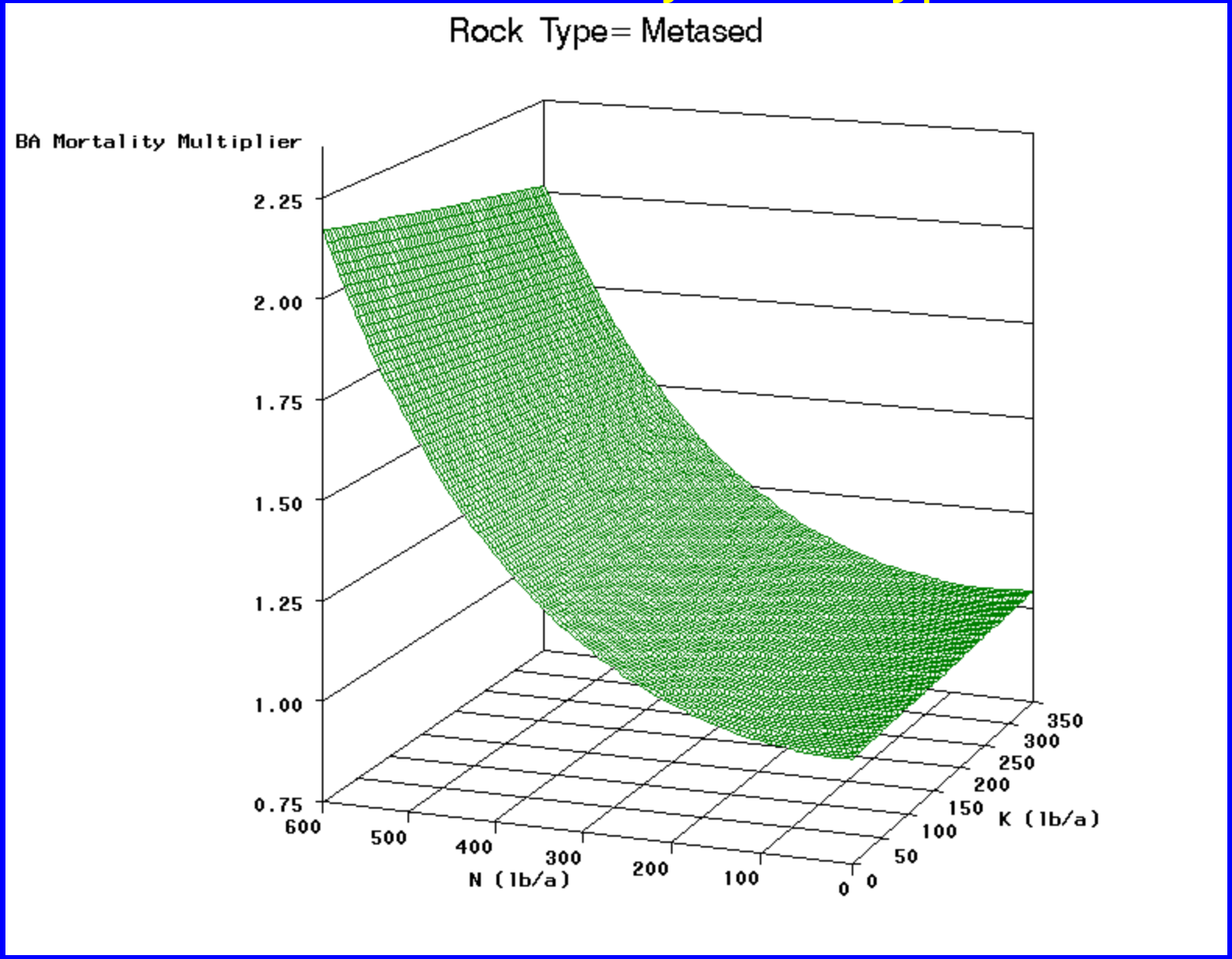
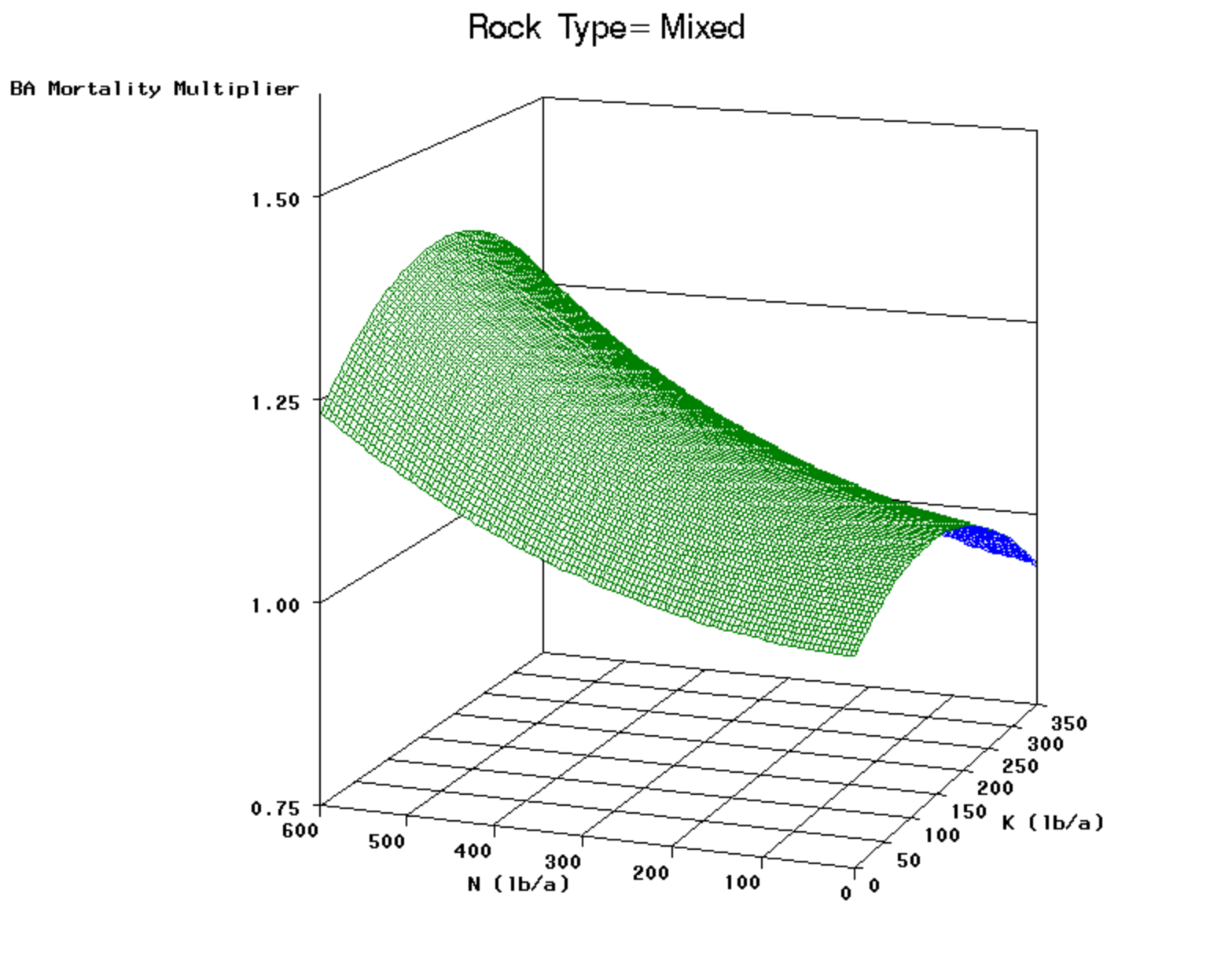
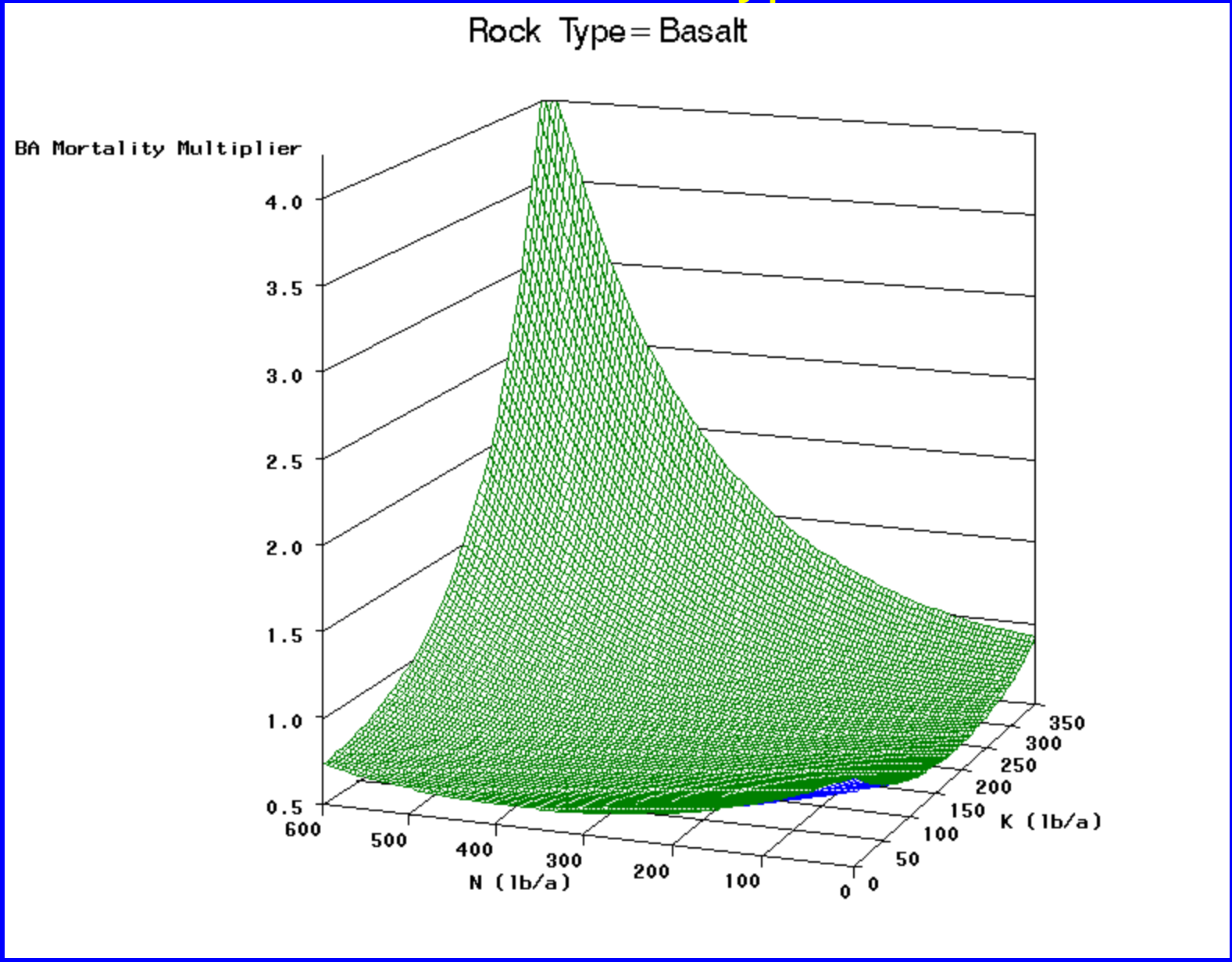


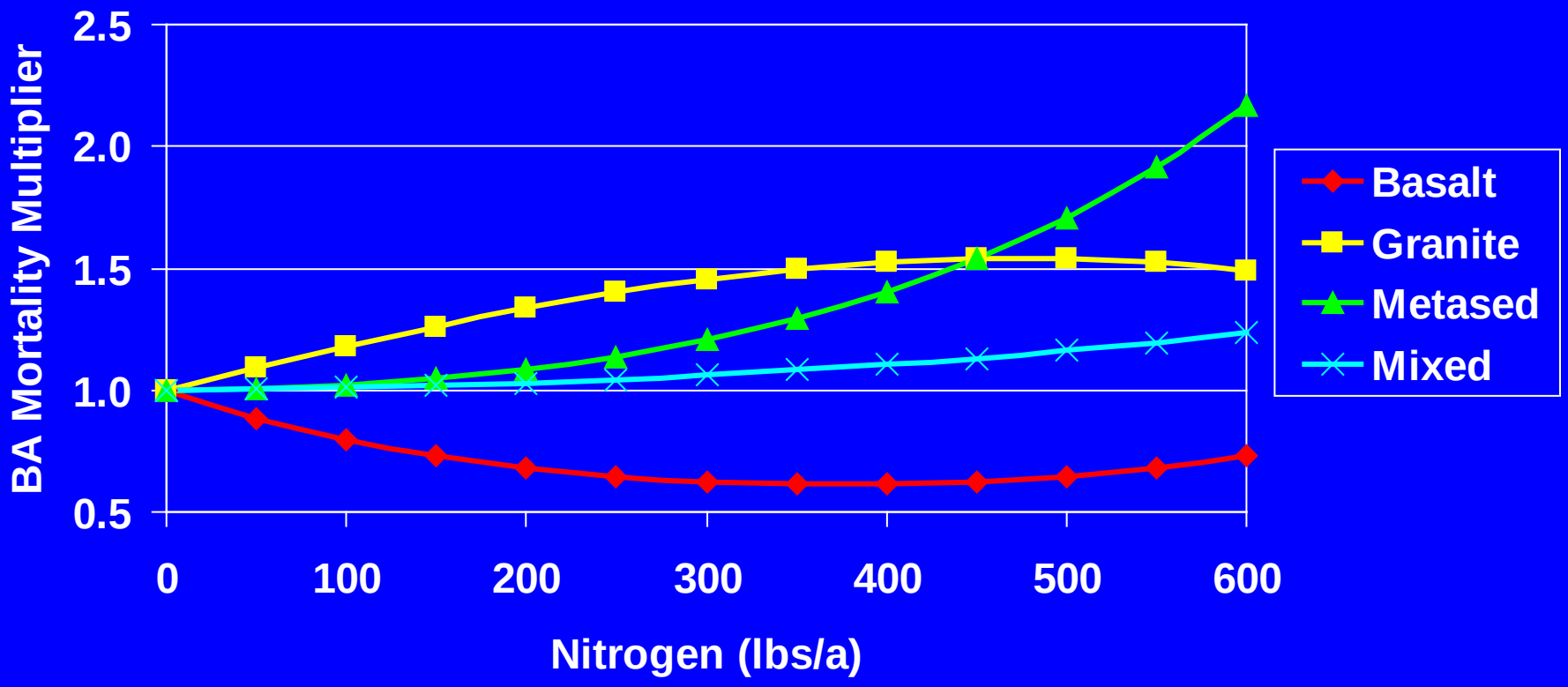
# N and K Effects on 8-year BA Mortality ($ft^2/a$): Mixed (Glacial Till) Rock Types



# N and K Effects on 8-year BA Mortality ($ft^2/a$): Basalt Rock Types



# N Effects on 8-year BA Mortality



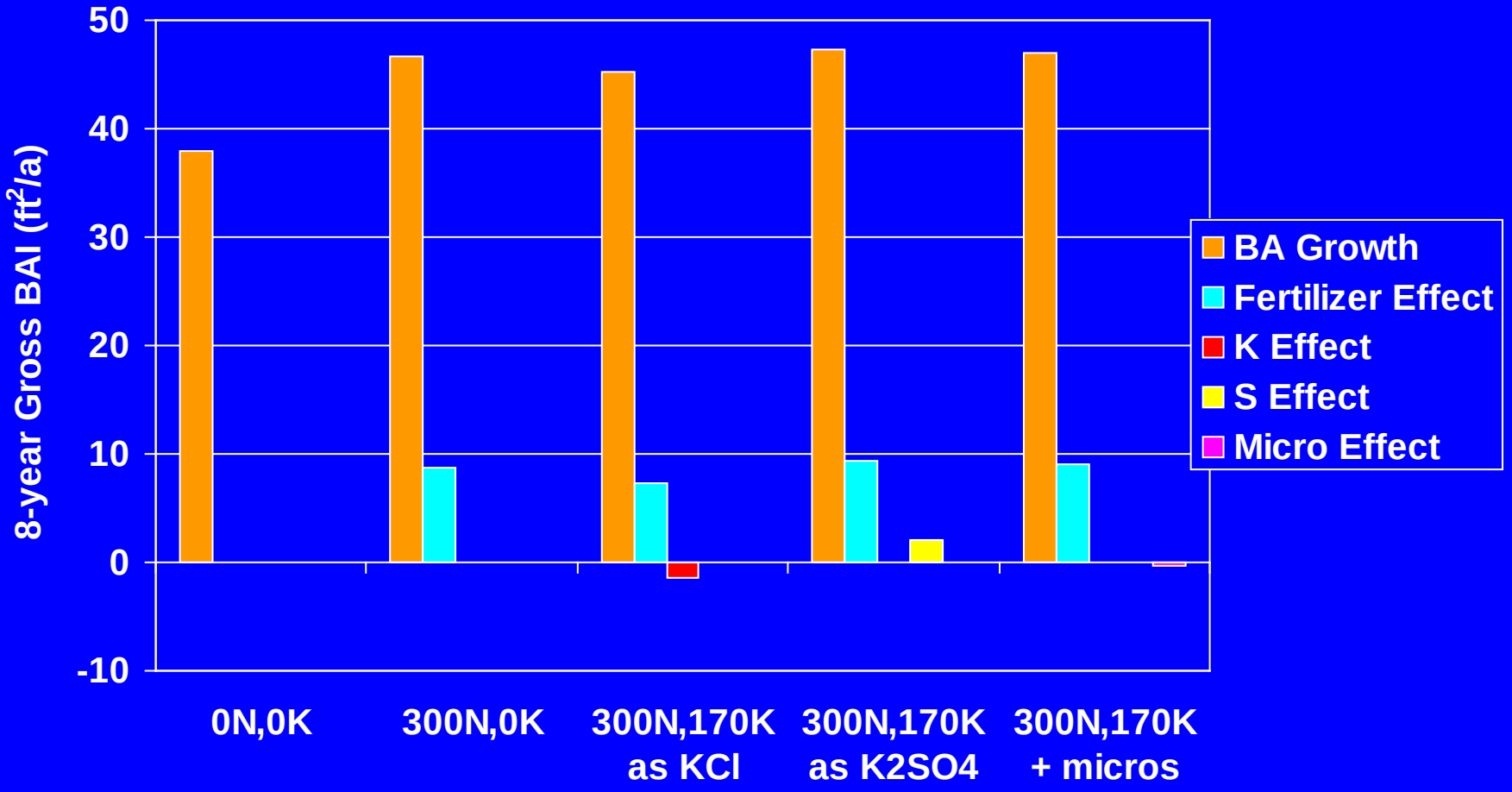
# Summary: N and K Effects on Mortality

- N fertilizers generally increase mortality, but K does not produce any consistent effect
- Rock type and vegetation series both influence background mortality rates, but fertilizer effects only appear to differ by rock type
  - On basalts, N fertilizers do not affect mortality rates, while high K applications appear to increase mortality
  - On granite and metasediment, mortality increases as the N rate increases. Addition of K tends to decrease mortality at high N rates. Mixed rock type sites follow similar patterns, although mortality rates are lower.

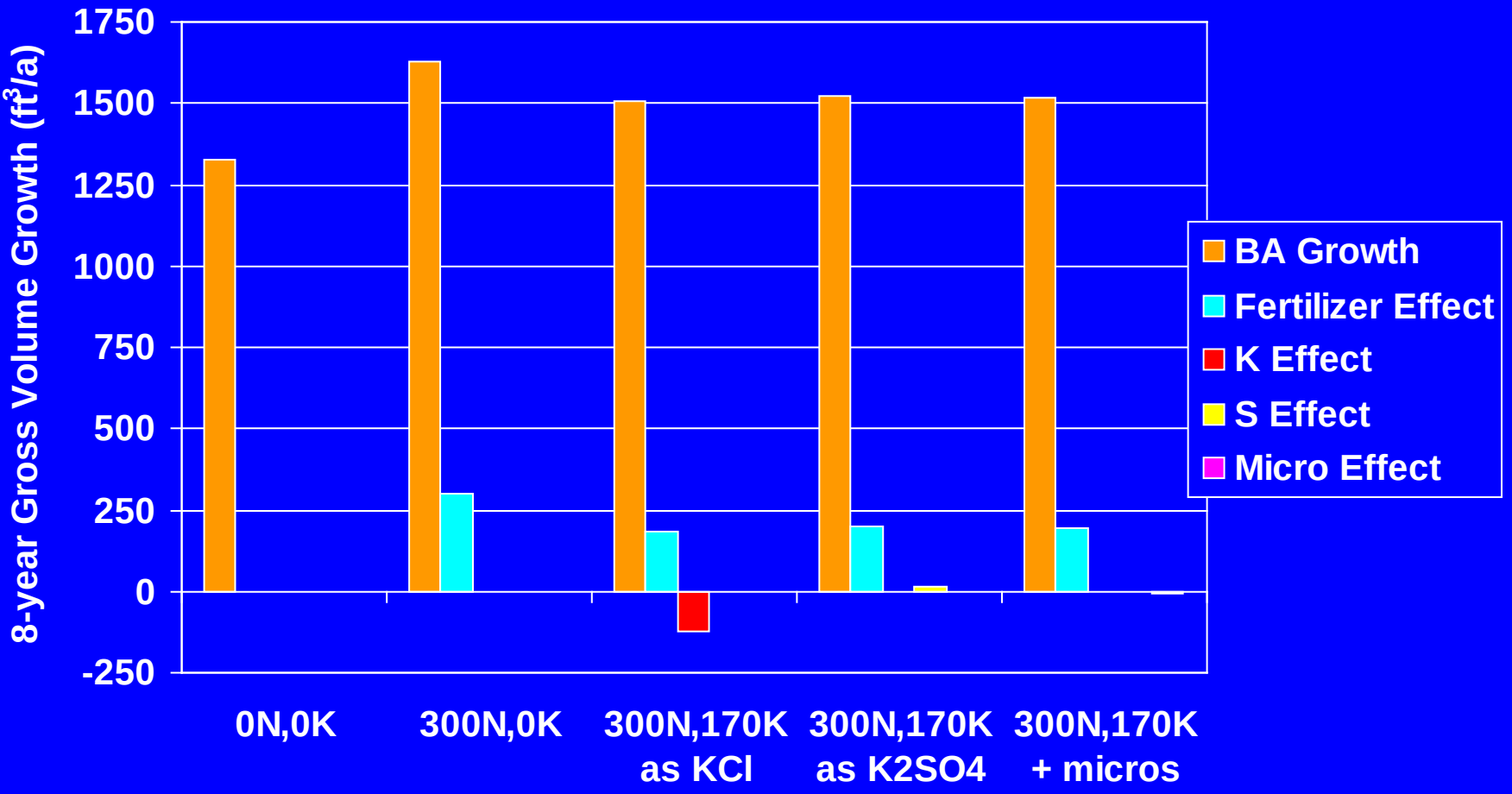
# Sulfur and Micronutrient Effects

- Analysis limited to those sites with S treatments (13 sites)
- S applied at 65 lbs/a
- Micronutrients
  - Boron (5 lbs/a), Copper (10 lbs/a), Zinc (10 lbs/a), and Molybdenum (1 lbs/a)
  - All applied together: thus cannot attribute any effects to specific elements

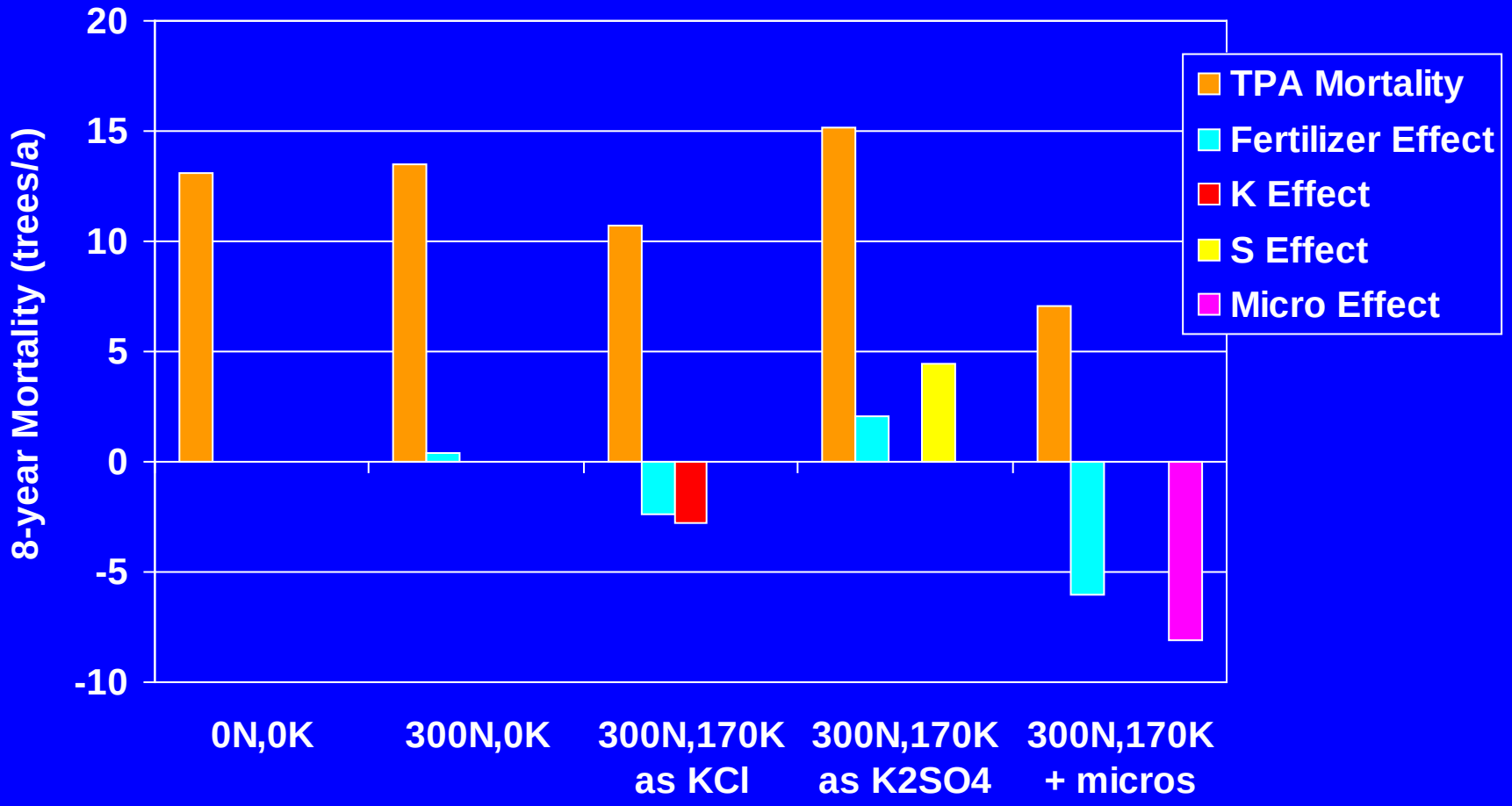
# KCl, $K_2SO_4$, and micronutrients: effects on 8-year BA Growth



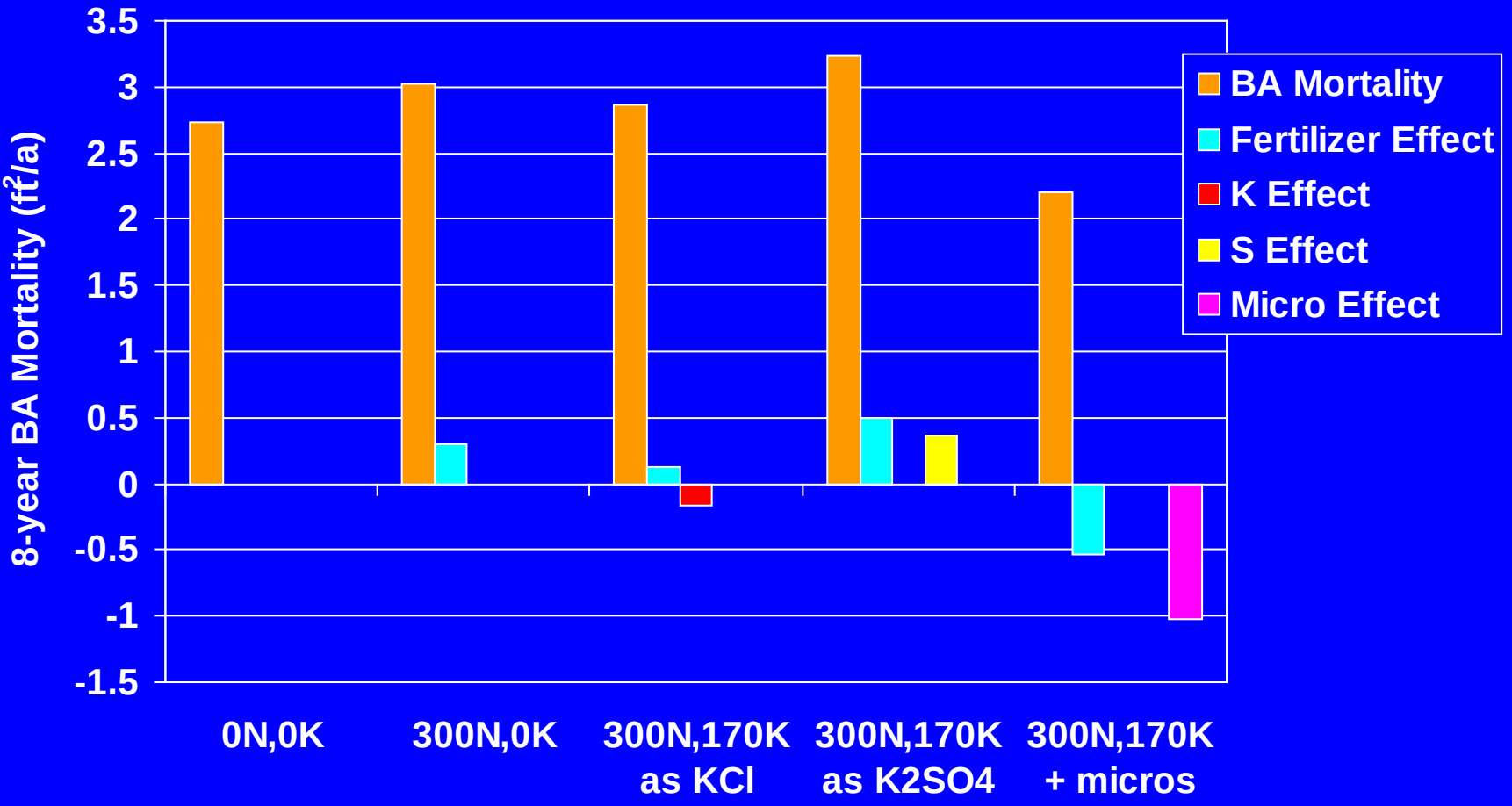
# KCl, $K_2SO_4$, and micronutrients: effects on 8-year Volume Growth



# KCl, $K_2SO_4$, and micronutrients: effects on 8-year Mortality (trees/a)



# KCl, $K_2SO_4$, and micronutrients: effects on 8-year BA Mortality ($ft^2/a$)



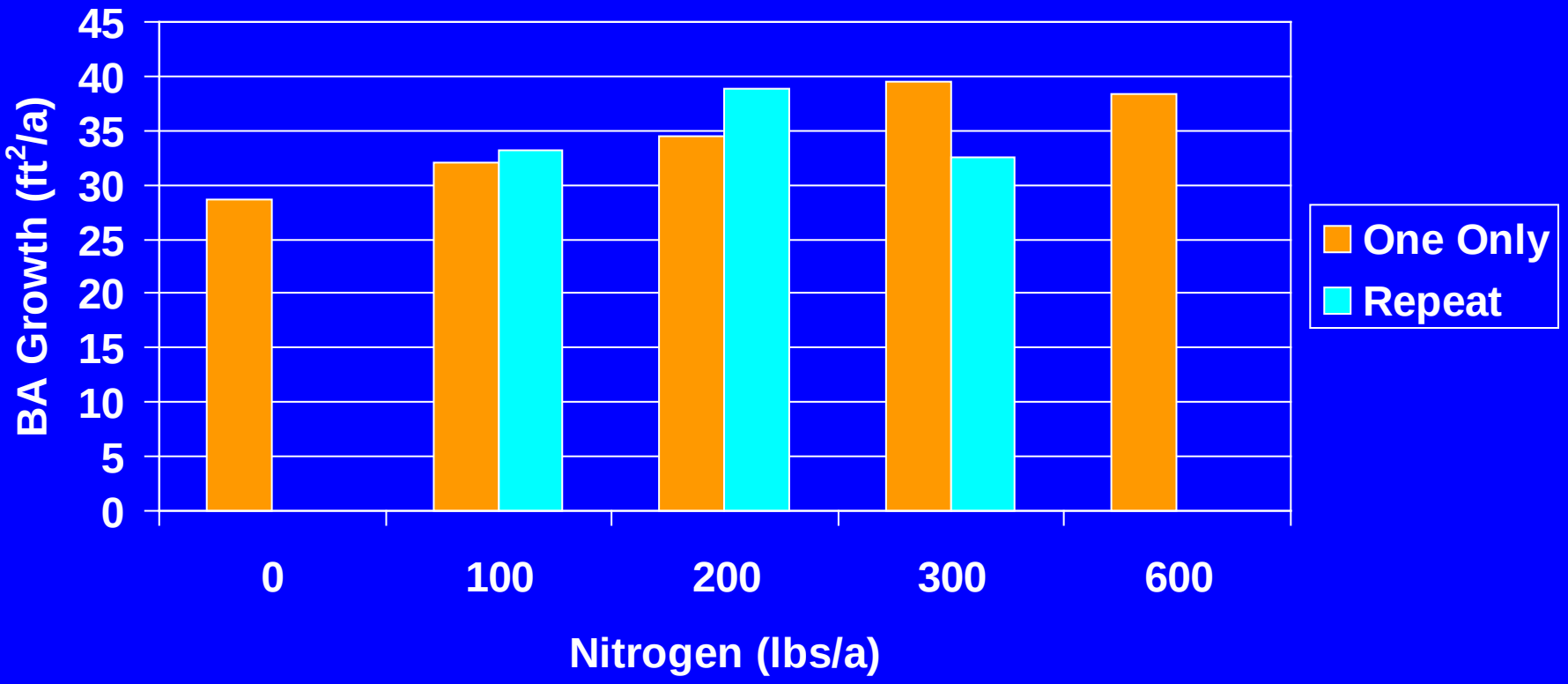
# Summary: S and Micronutrient Effects

- Sulfur, which had shown a positive effect on growth in shorter term analyses, did not appear to increase growth over an 8-year period.
- Micronutrients had no discernable effect on growth
- Mortality declined substantially when micronutrients were applied.  Sulfur appeared to increase mortality.

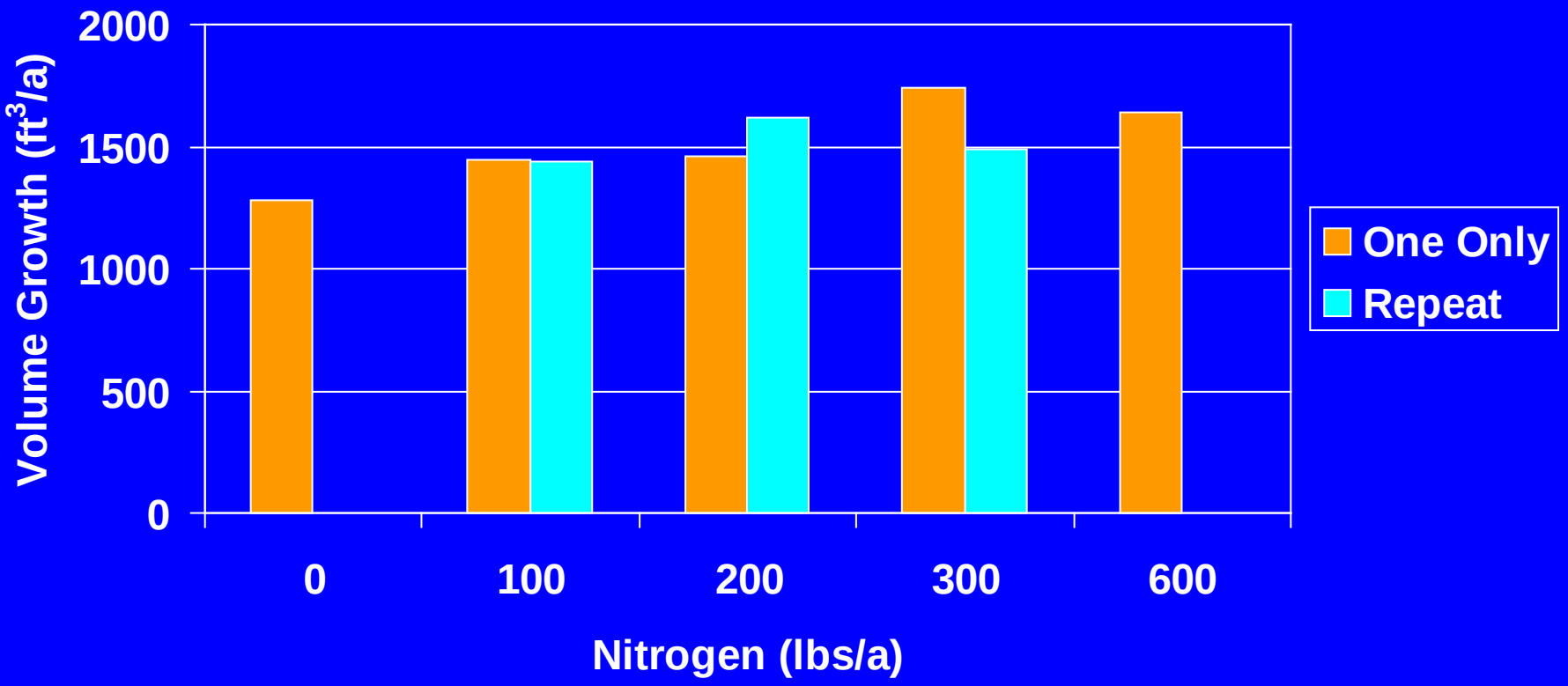
# Effects of Repeated N Applications

- 4 sites (2 DF/Basalt, 2 WRC-WH/Basalt)
- Repeat of 100, 200, or 300 lbs N/a application at 4 years on one set of plots and at 8 years on another set
- Analysis limited to those plots without any K application

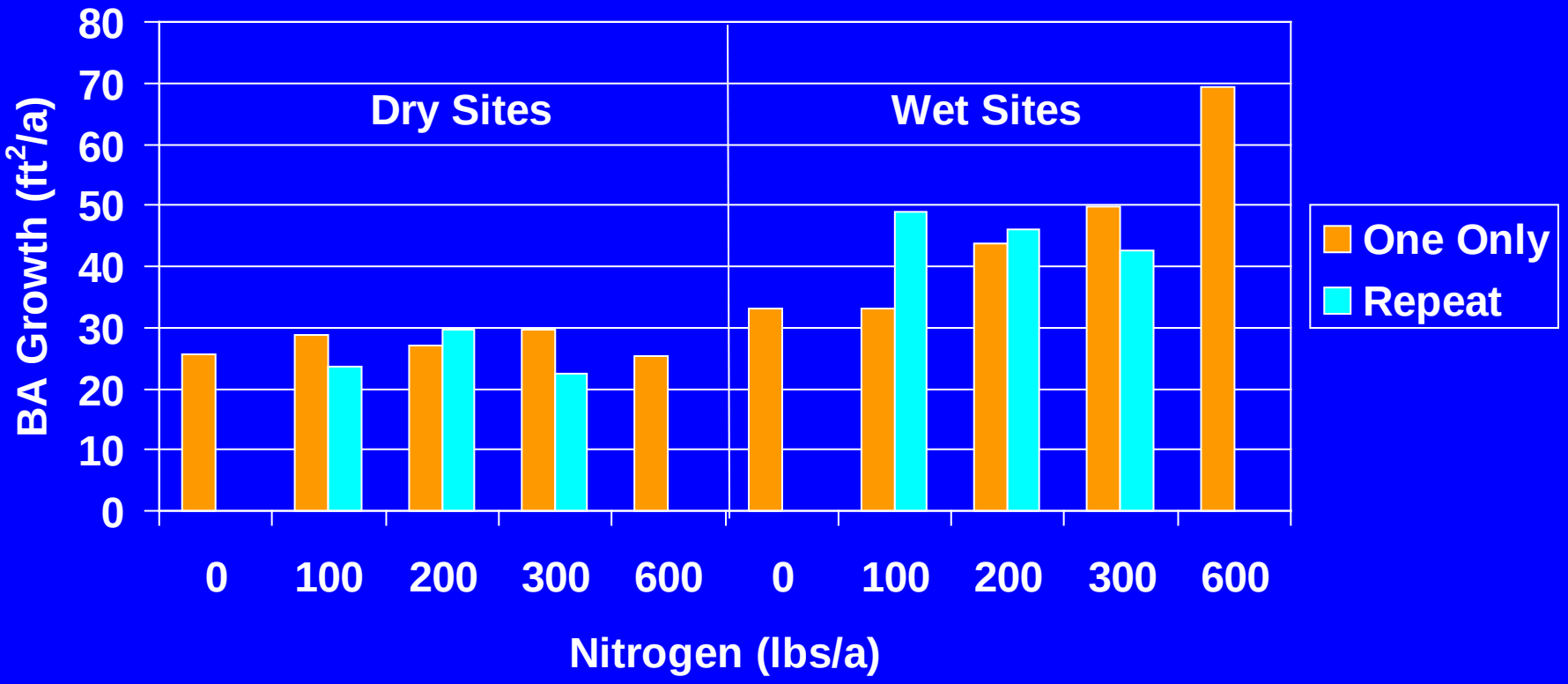
# Repeated N Application Effects: 8-year BA Growth



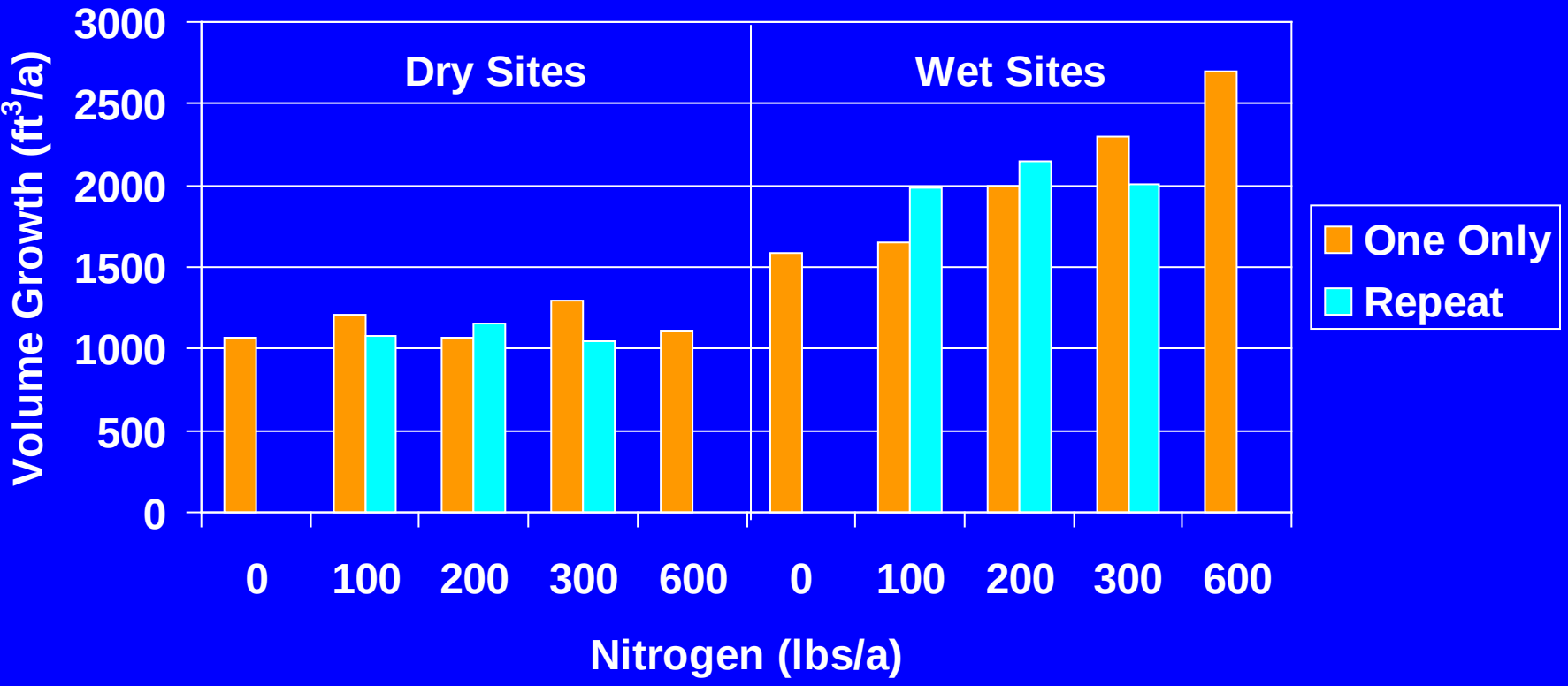
# Repeated N Application Effects: 8-year Volume Growth



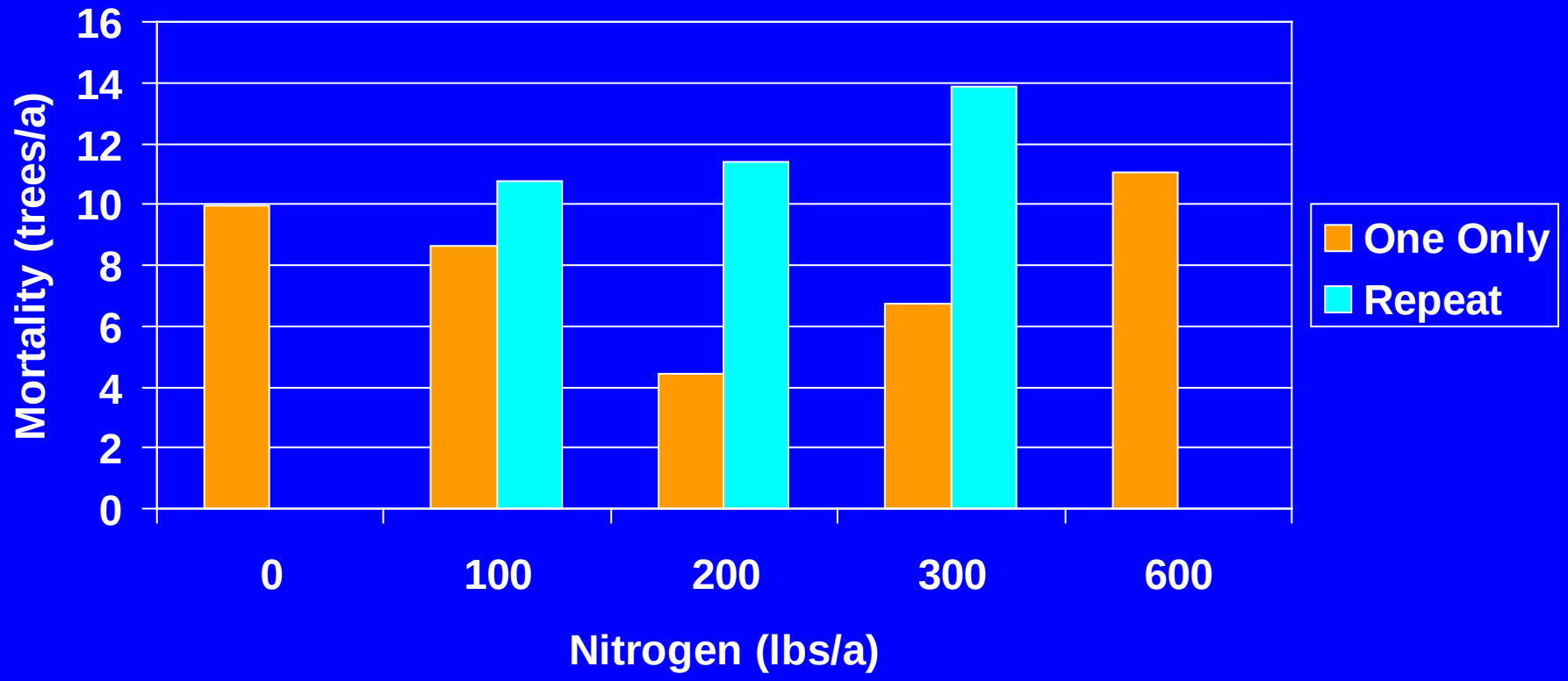
# Repeated N Application Effects: 8-year BA Growth



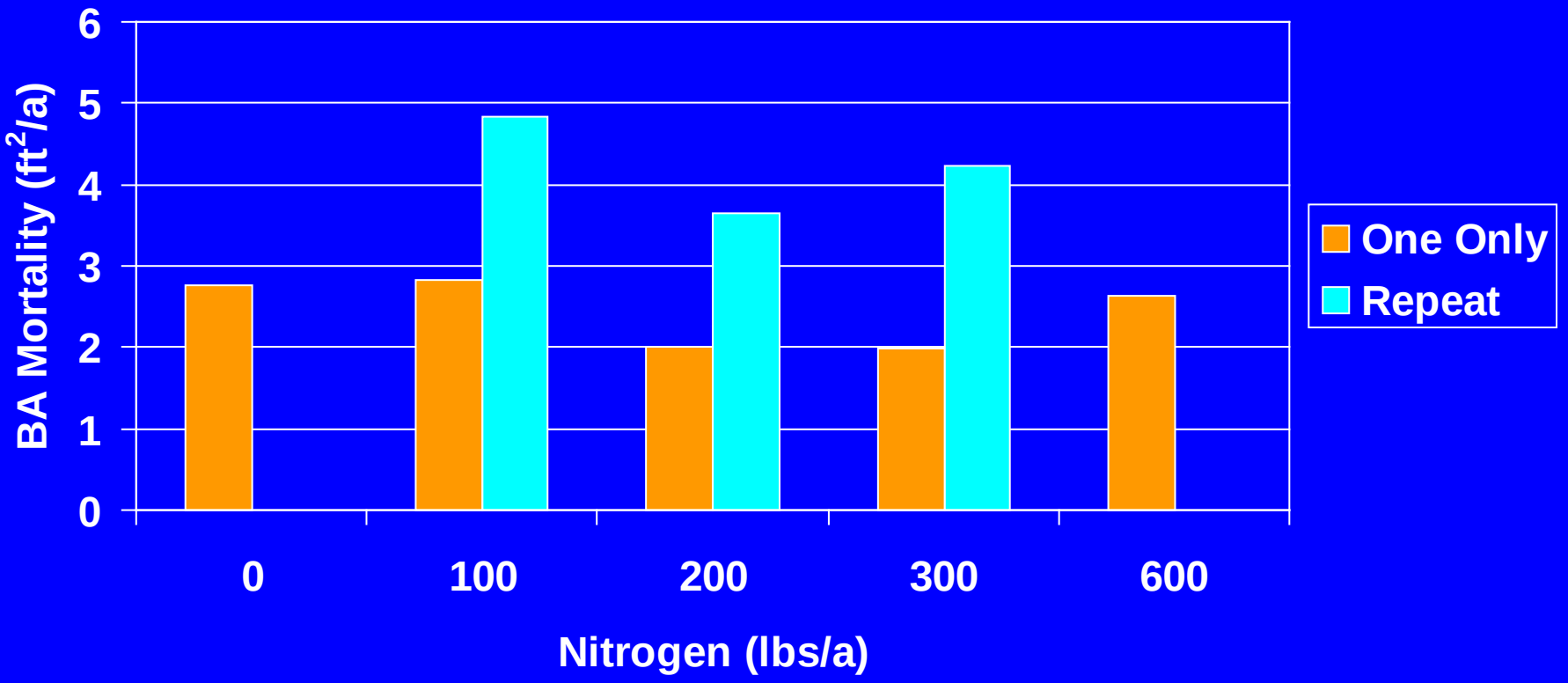
# Repeated N Application Effects: 8-year Volume Growth



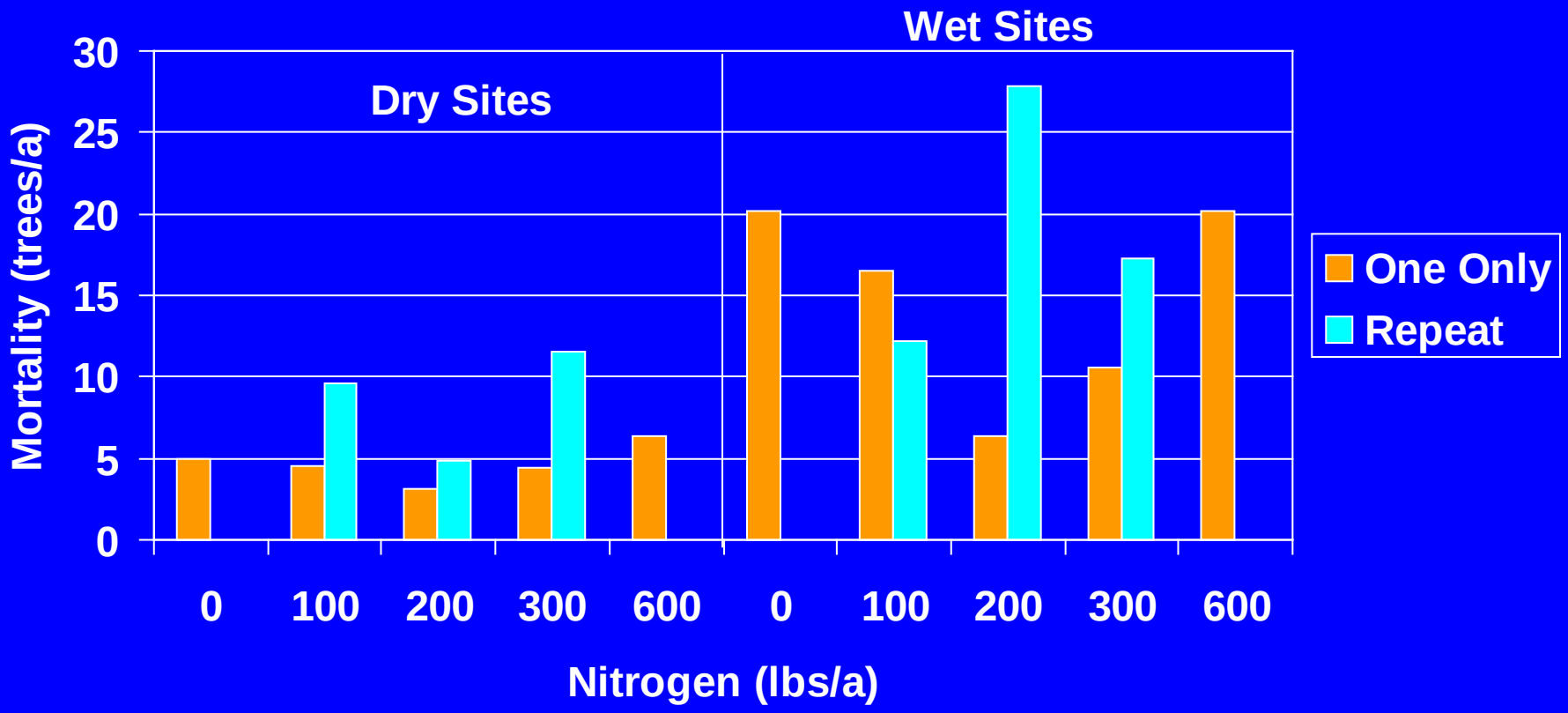
# Repeated N Application Effects: 8-year TPA Mortality



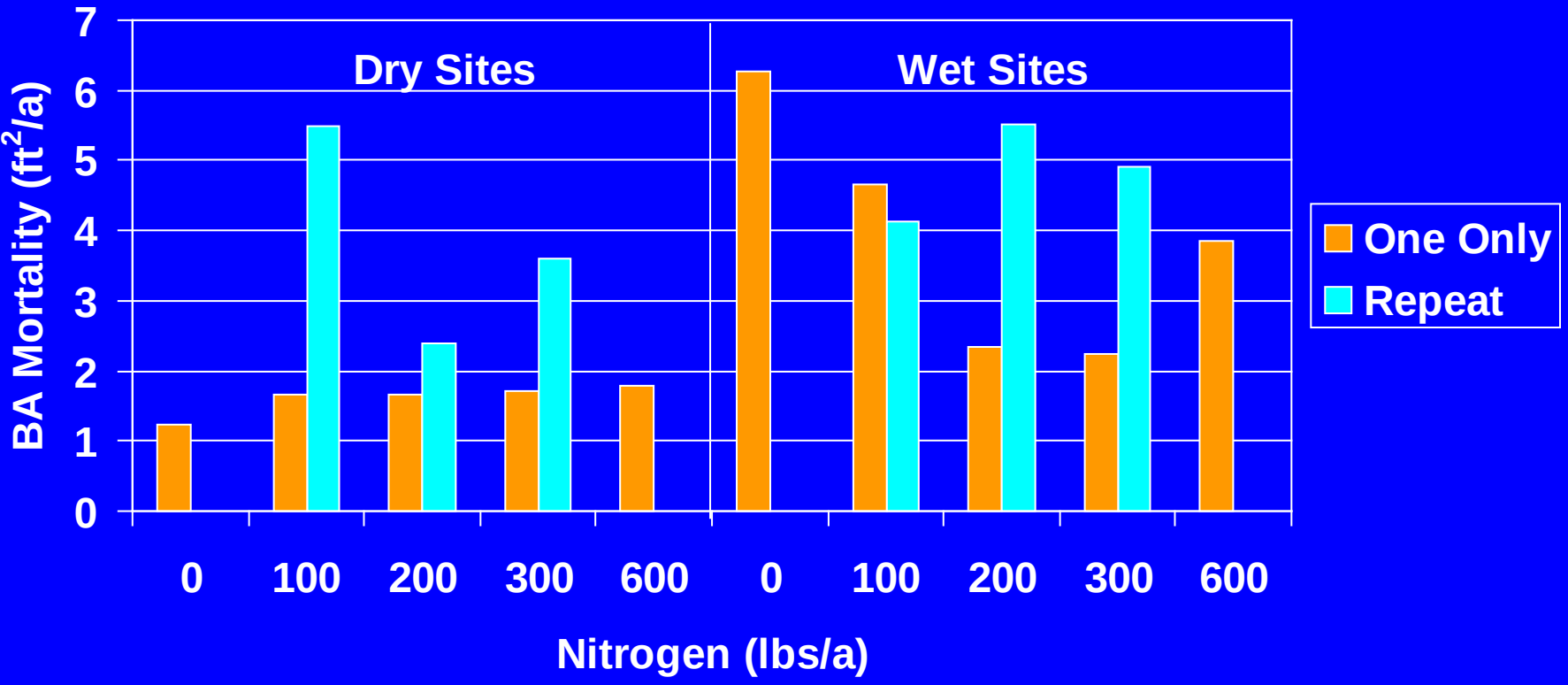
# Repeated N Application Effects: 8-year BA Mortality



# Repeated N Application Effects: 8-year TPA Mortality



# Repeated N Application Effects: 8-year BA Mortality



# Summary: Repeated N Application Effects

- Reapplication of N at 4 years did increase growth response, but only on wet sites and at low N rates (110 lbs/a). Reapplication of higher N rates did not produce additional response
- Reapplication increased mortality on both wet and dry sites. While mortality on dry sites increased with all reapplication rates, on wet sites only the higher N reapplication rates produced higher mortality