Nitrogen, potassium and forest health results – a synthesis of 10 years of data

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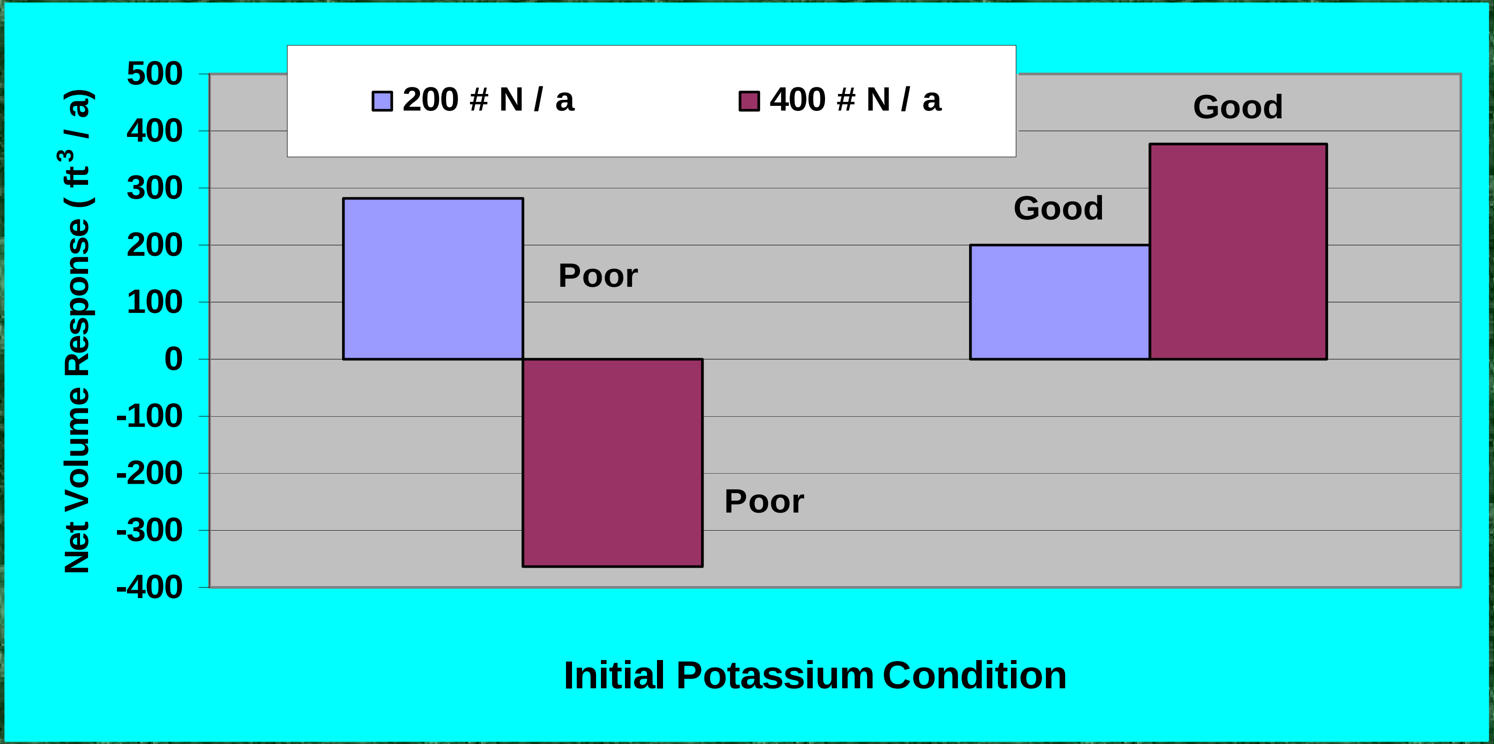
IFTNC Annual Meeting

April 8, 2008

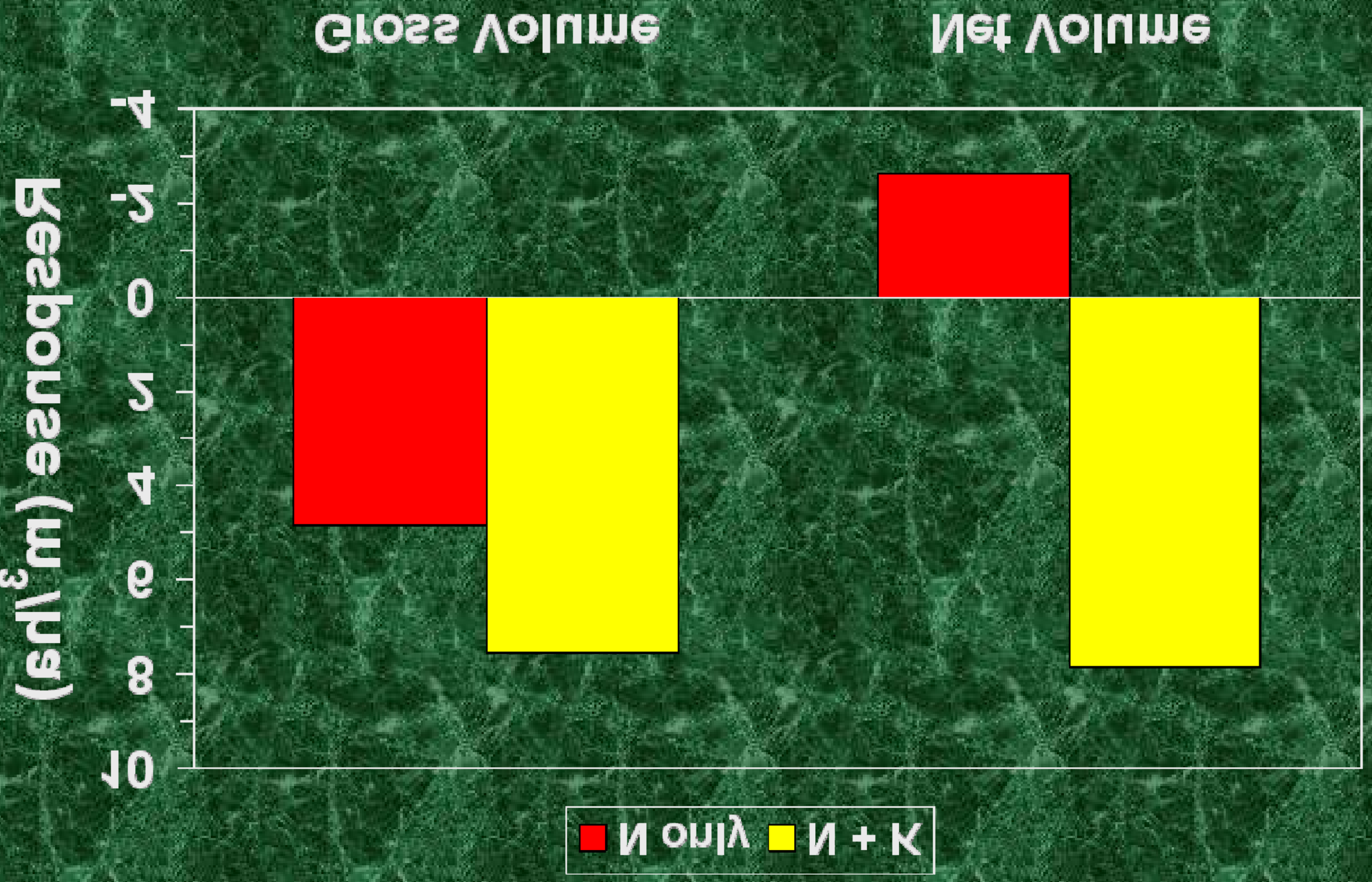
Ten-year Net Response to N Fertilization by Initial Potassium Condition for Douglas-fir



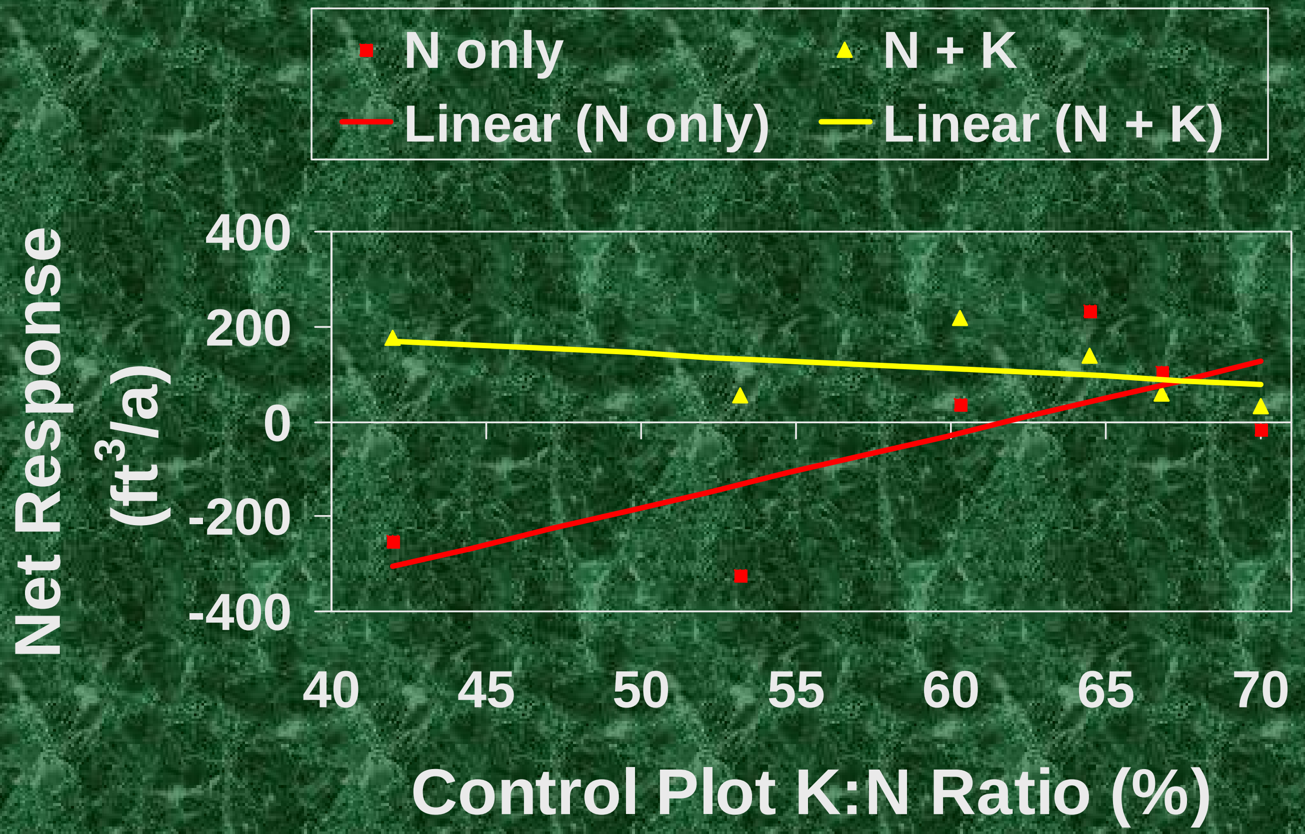
Poor: Foliar K<0.6%, K/N<50%   Good: Foliar K>0.6%, K/N>65%

4-year Volume Response

Montana Ponderosa Pine Study



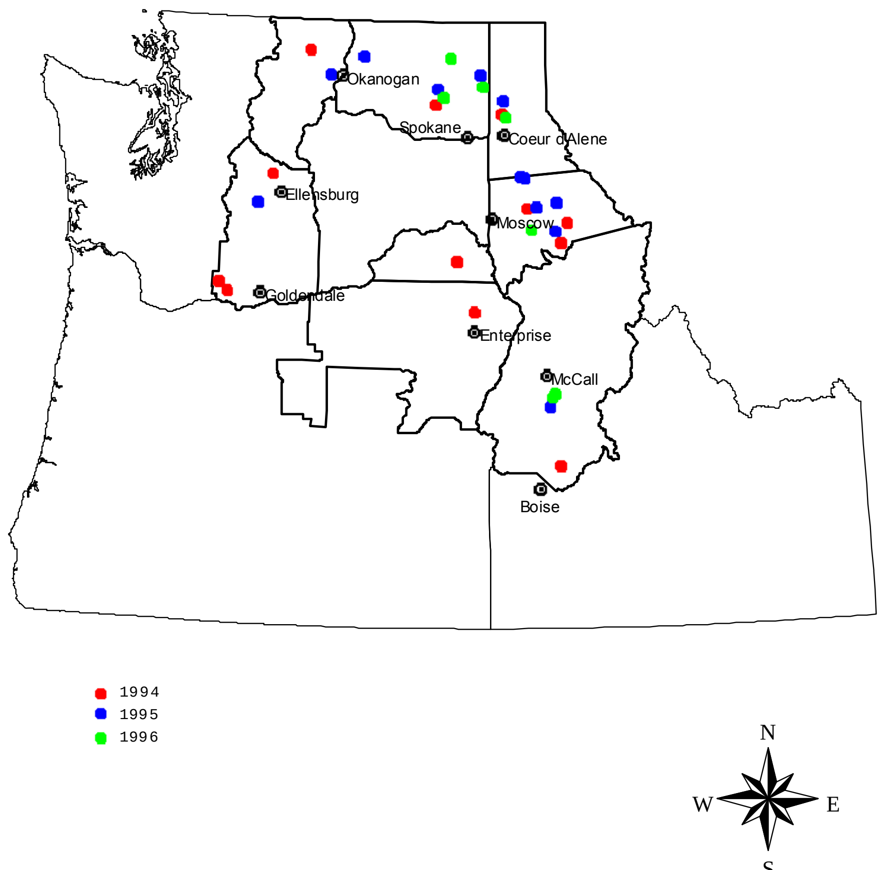
4-year Volume Response
Montana Ponderosa Pine Study



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

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



Sites Established: 1994-1996

by Rock Type and Vegetation Series

	Douglas-fir	Grand Fir	Cedar/ Hemlock	TOTAL
Granite	K (3), N (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

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

Treatments

- Core (31 sites):
  Control, 170 #K, 300#N, 170#K+300#N
- Nitrogen rate trial (12 sites):
  DF and WRC series, basalt or mixed rock types
  100#N, 200#N, 600#N
  Repeated application at 4 and 8 years at 4 sites
- N-K response surface (19 sites):
  GF series, granite and metasedimentary rock types
  Various combinations of N and K, allowing estimation of a response surface
- S and micronutrients
  65#S, 65#S+5#B+10#Cu+10#Zn+1#Mo
  Added to 300#N+170#K plot

Today's focus: N and K Fertilizer Effects

- On growth: N and K response surface
- On mortality
  - What's dying
  - Causes of mortality
  - N and K response surfaces for mortality

Topics not covered:

S and Micronutrient (B, Cu, Mo, Zn) Effects

No statistically significant effects on either growth or mortality

Repeated N applications

4-year response to 8-year application will be measured this year with results presented at next year's annual meeting

Sites Remaining: 2008

by Rock Type and Vegetation Series

	Douglas-fir	Grand Fir	Cedar/ Hemlock	TOTAL
Granite	K (3), N (1)	K (2)	K (1)	7
Basalt	N (1), R (1)	K (2)		4
Metamorphic		K (2)	K (3), N (1)	6
Mixed	N (2)	K (2)	N (2)	6
Tertiary Sediments			K (2), N (1), R (2)	5
TOTAL	8	8	12	28

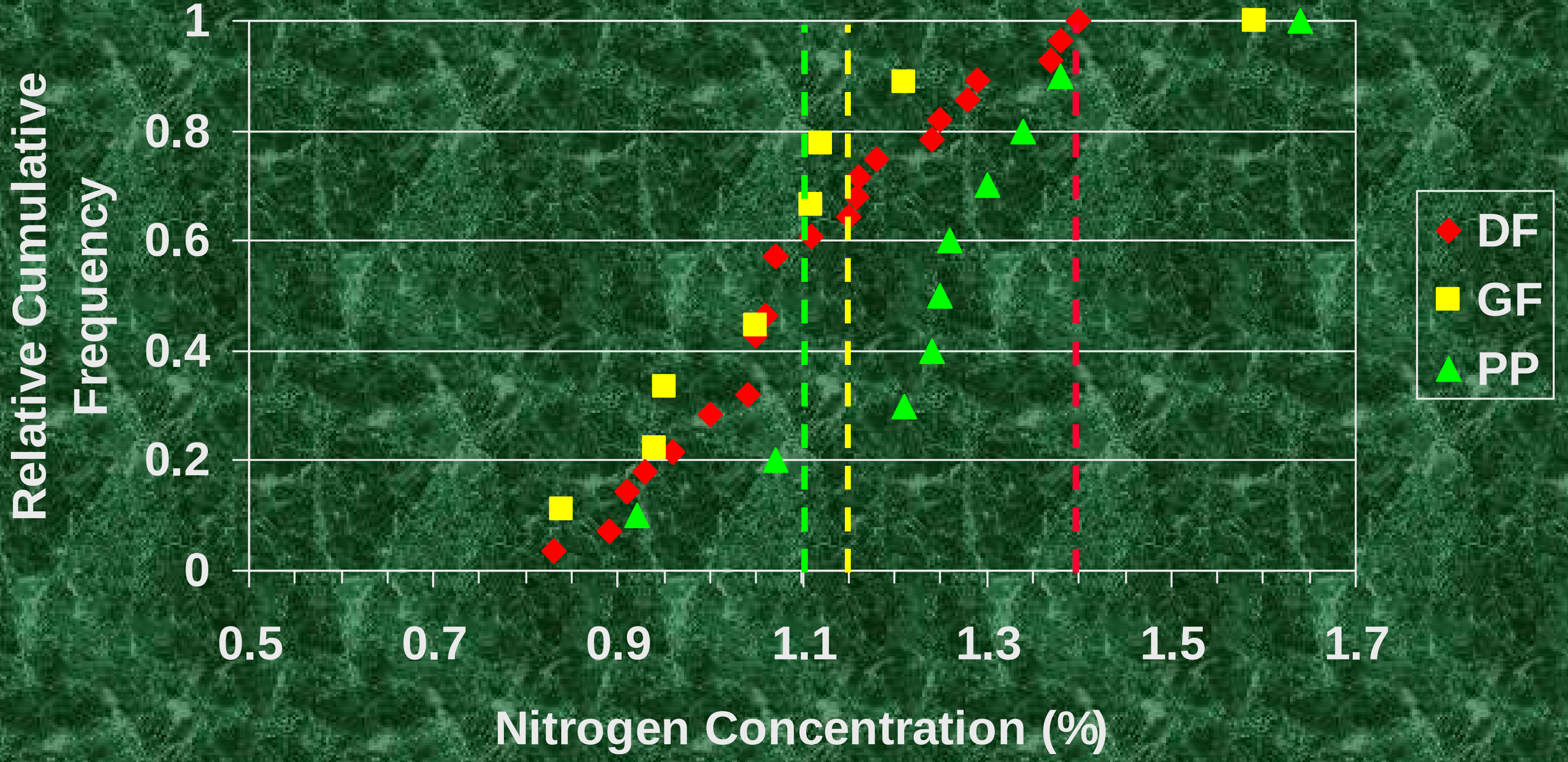
K=N - K Response Surface, N=N Rate Trial, R=Repeated- N Trial

Stand Initial Characteristics

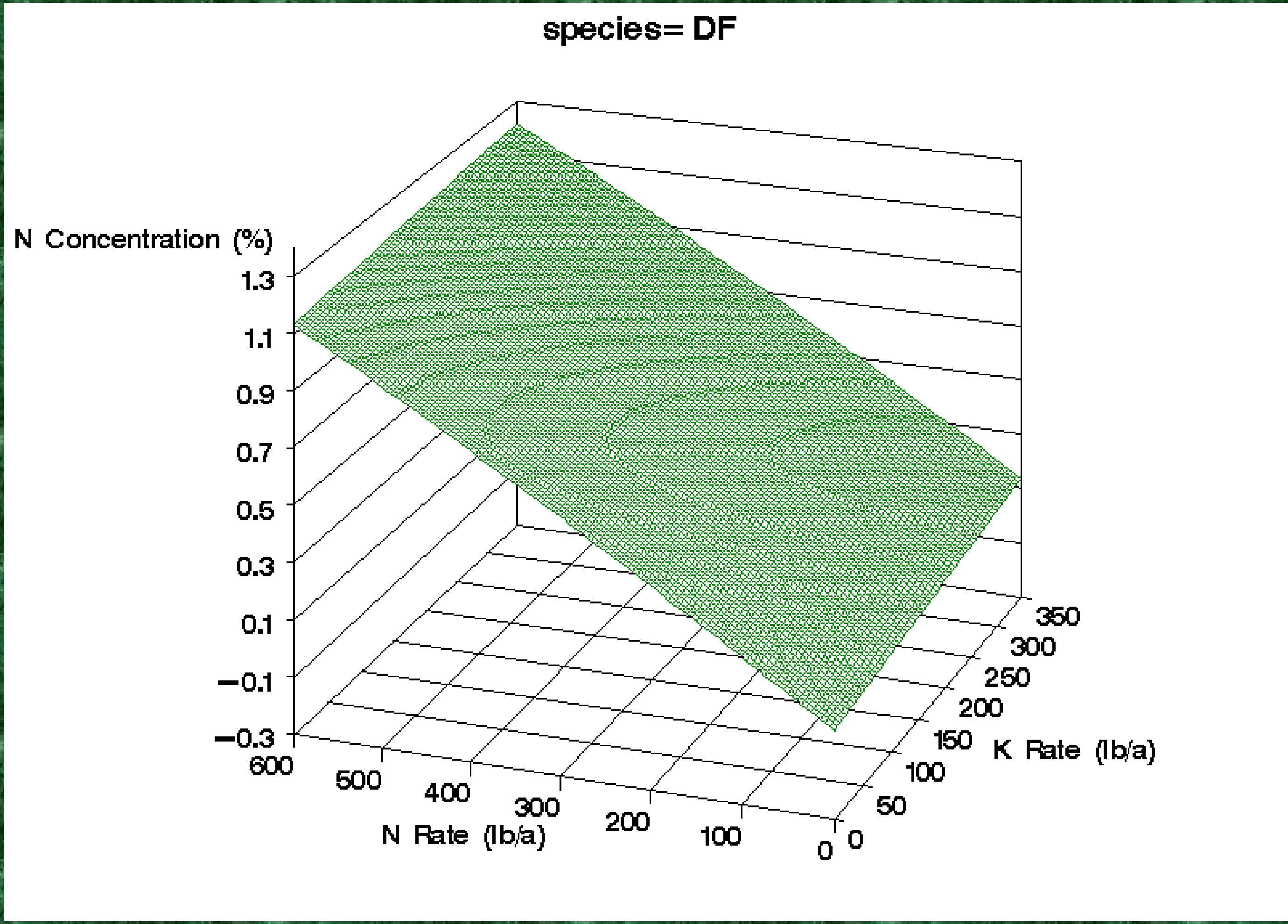
	Mean	Minimum	Maximum
Mean DBH	7.5	3.3	15.2
BA/a	96	30	290
CCF	108	33	266

Species	Composition (% of initial BA/a)		
DF	51	0	98
PP	22	0	97
GF	14	0	68

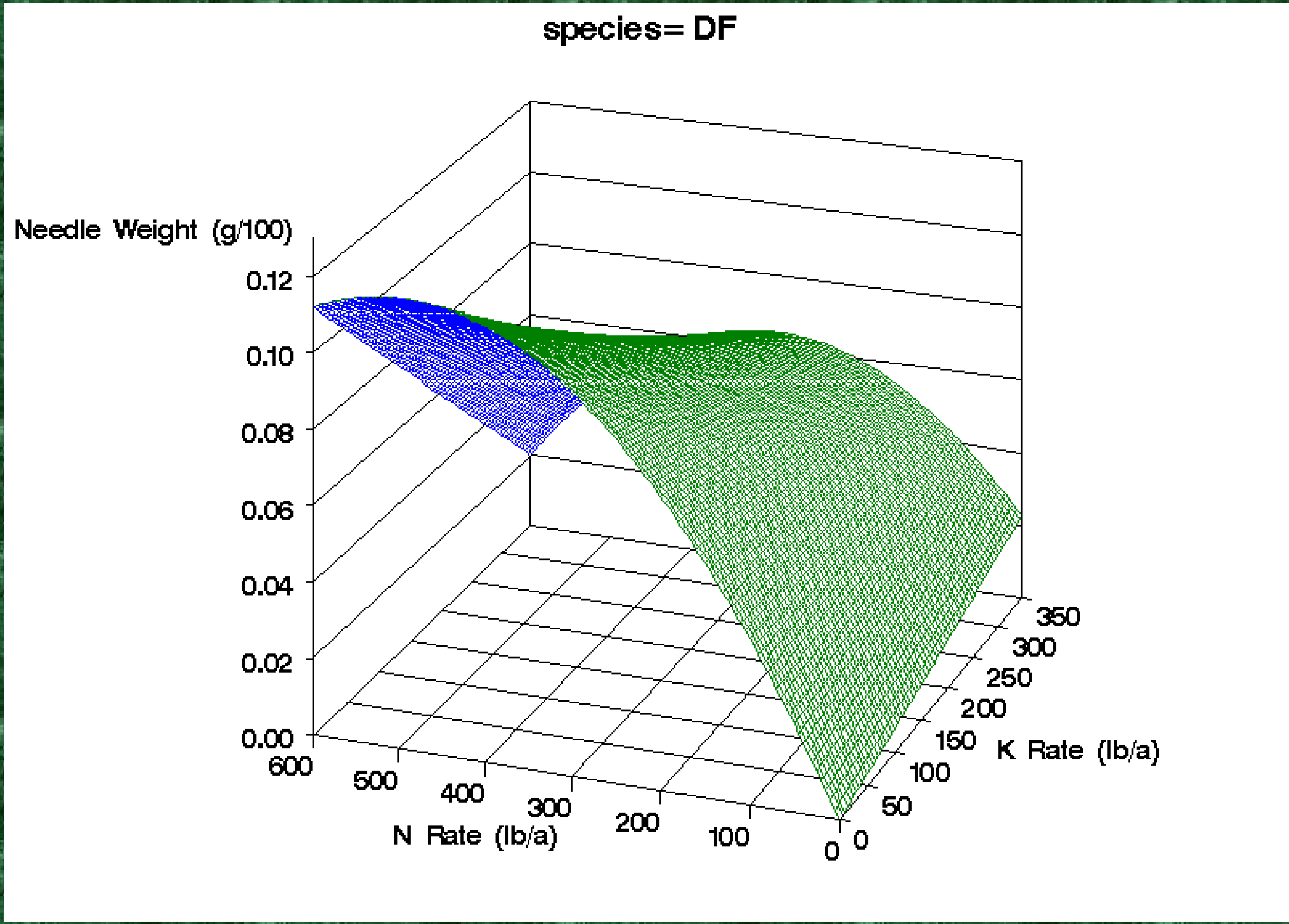
Foliar N Concentration Control-plot Distribution



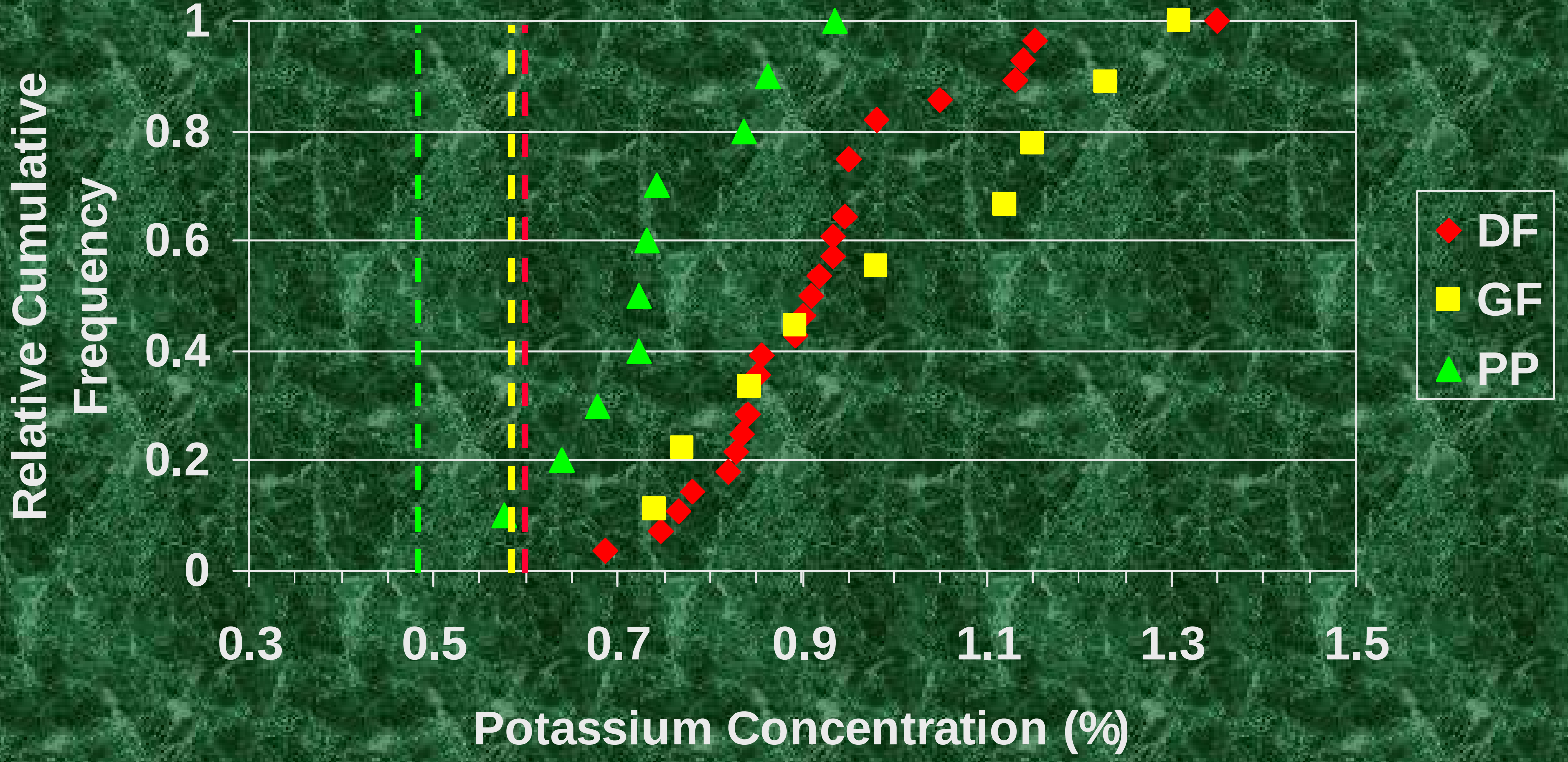
N and K Effects: DF Foliar Nitrogen



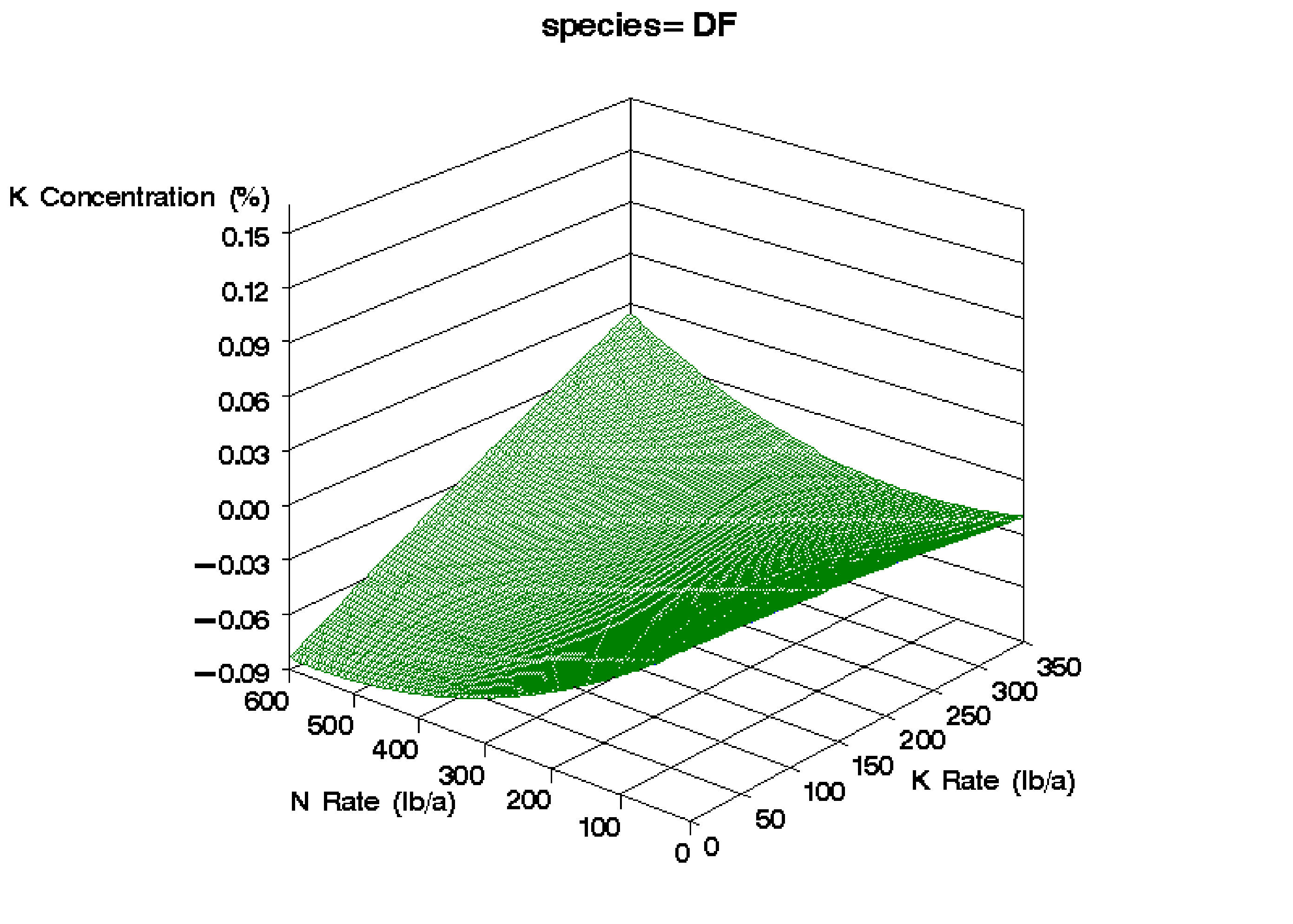
N and K Effects: DF Needle Weight



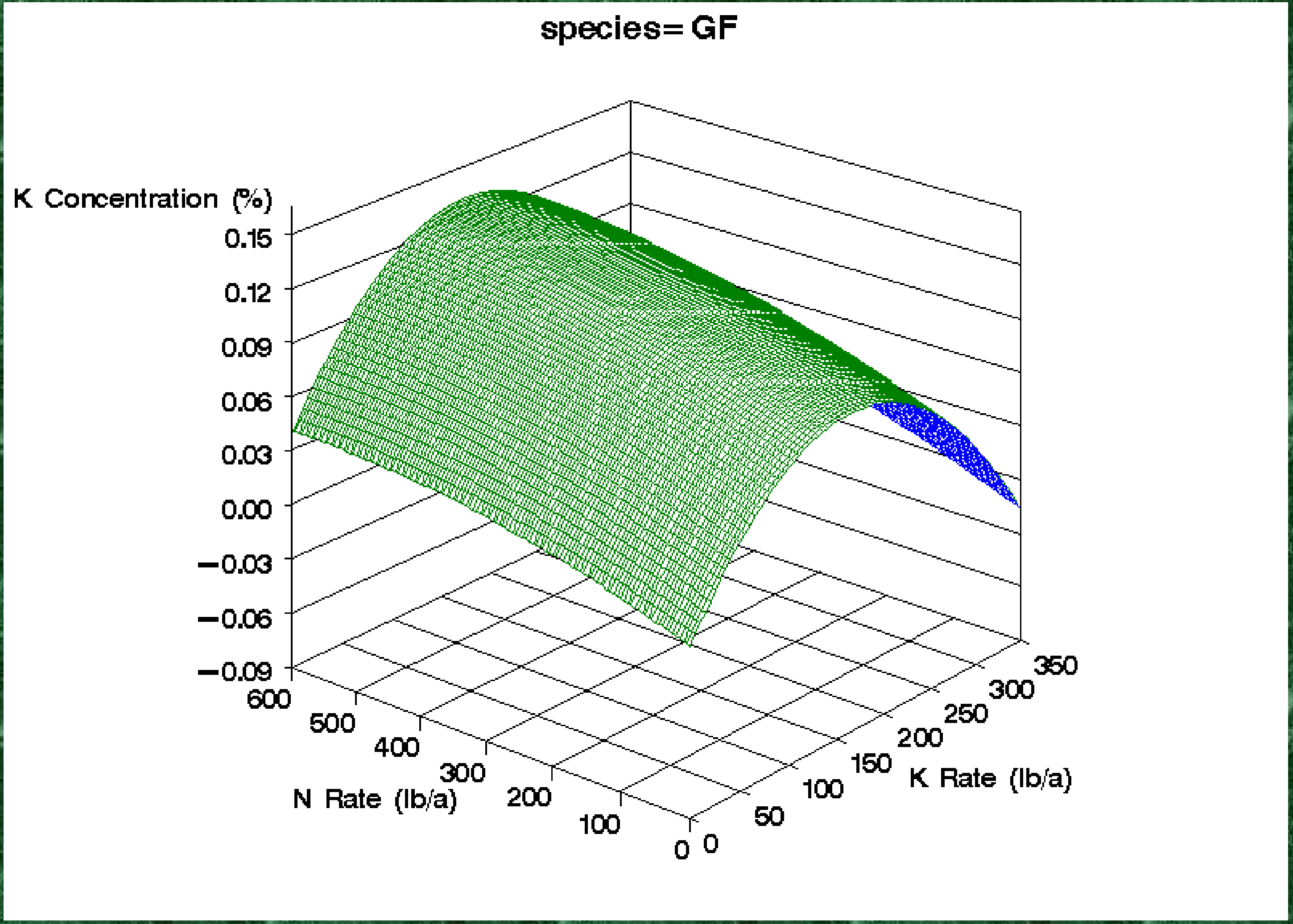
Foliar K Concentration Control-plot Distribution



N and K Effects: DF Foliar Potassium



N and K Effects: GF Foliar Potassium



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

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 (diameter, BA, or height growth/tree)

I = installation effect (random)

C = covariate adjustments for initial plot density, initial tree size, plot mortality

N = nitrogen rate (lbs/a)

K = potassium rate (lbs/a)

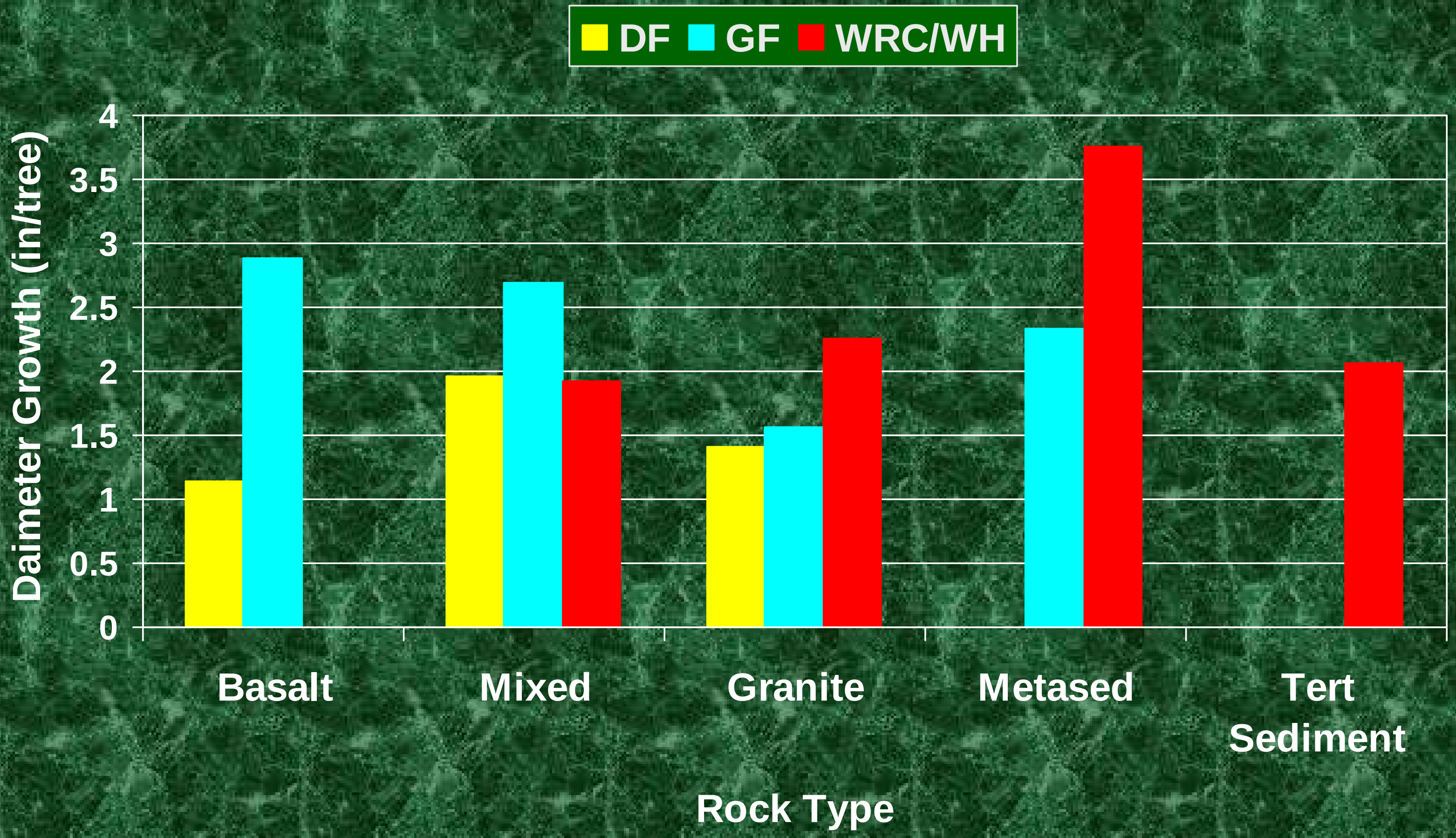
Thus, $G_{trt} = \exp(\mu+I+C+\beta_1{*}N+\beta_2{*}N^2+\beta_3{*}K+\beta_4{*}K^2+\beta_5{*}NK)$

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

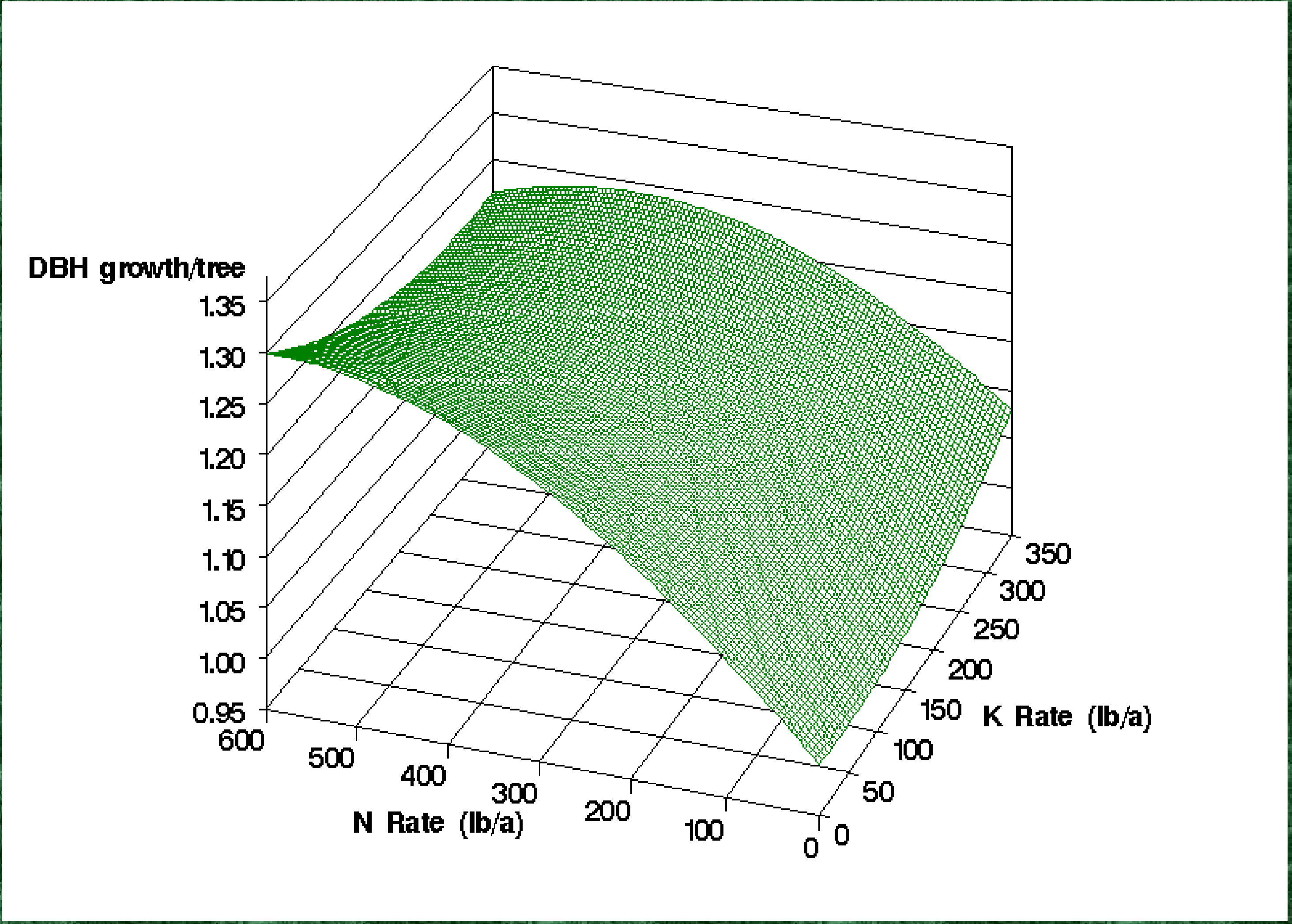
$= G_{con}{*}$Fertilizer Effect

Therefore, Fertilizer Effect is a growth multiplier

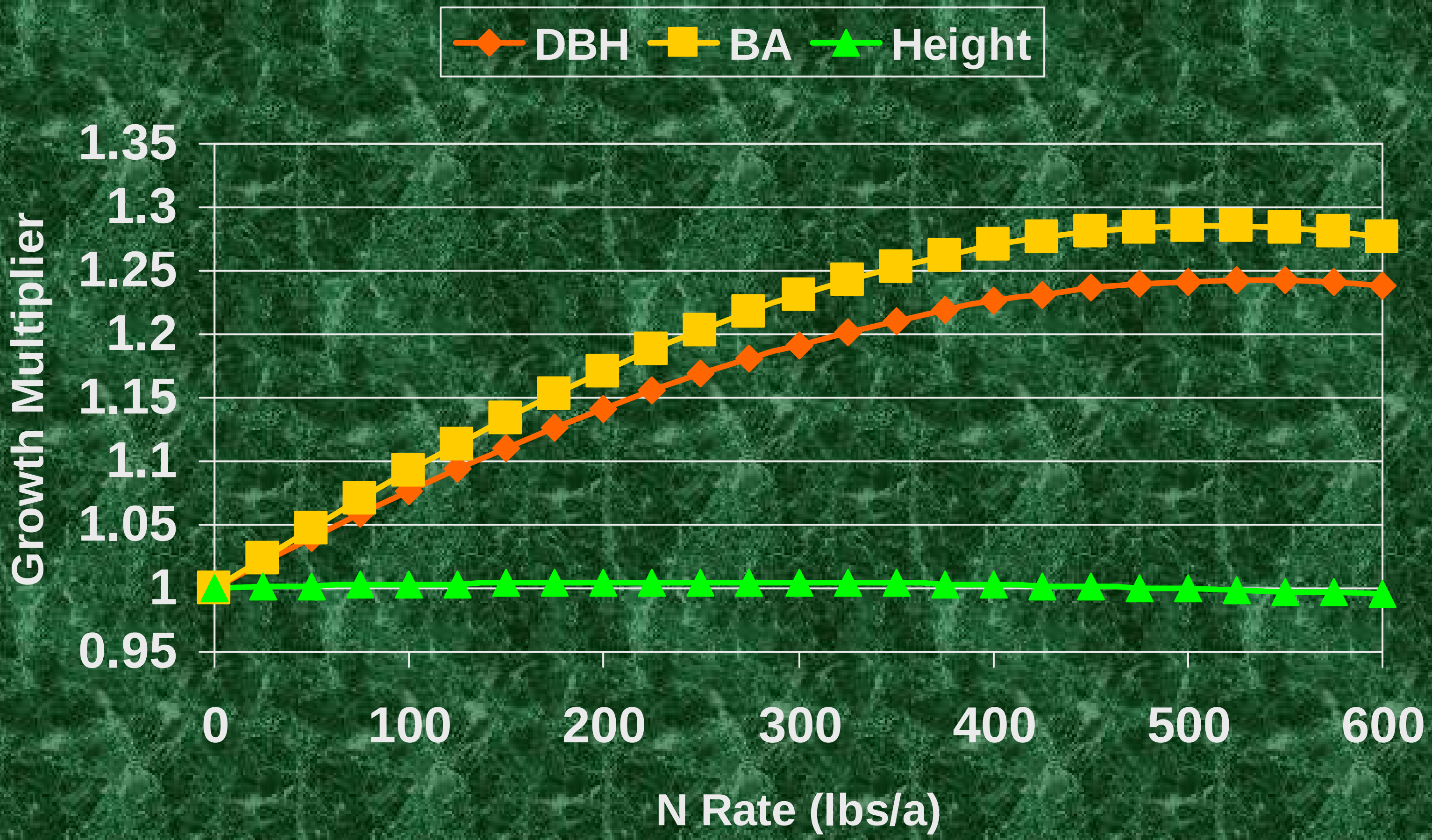
Control plot 10-year diameter growth/tree by Rock Type and Vegetation Series



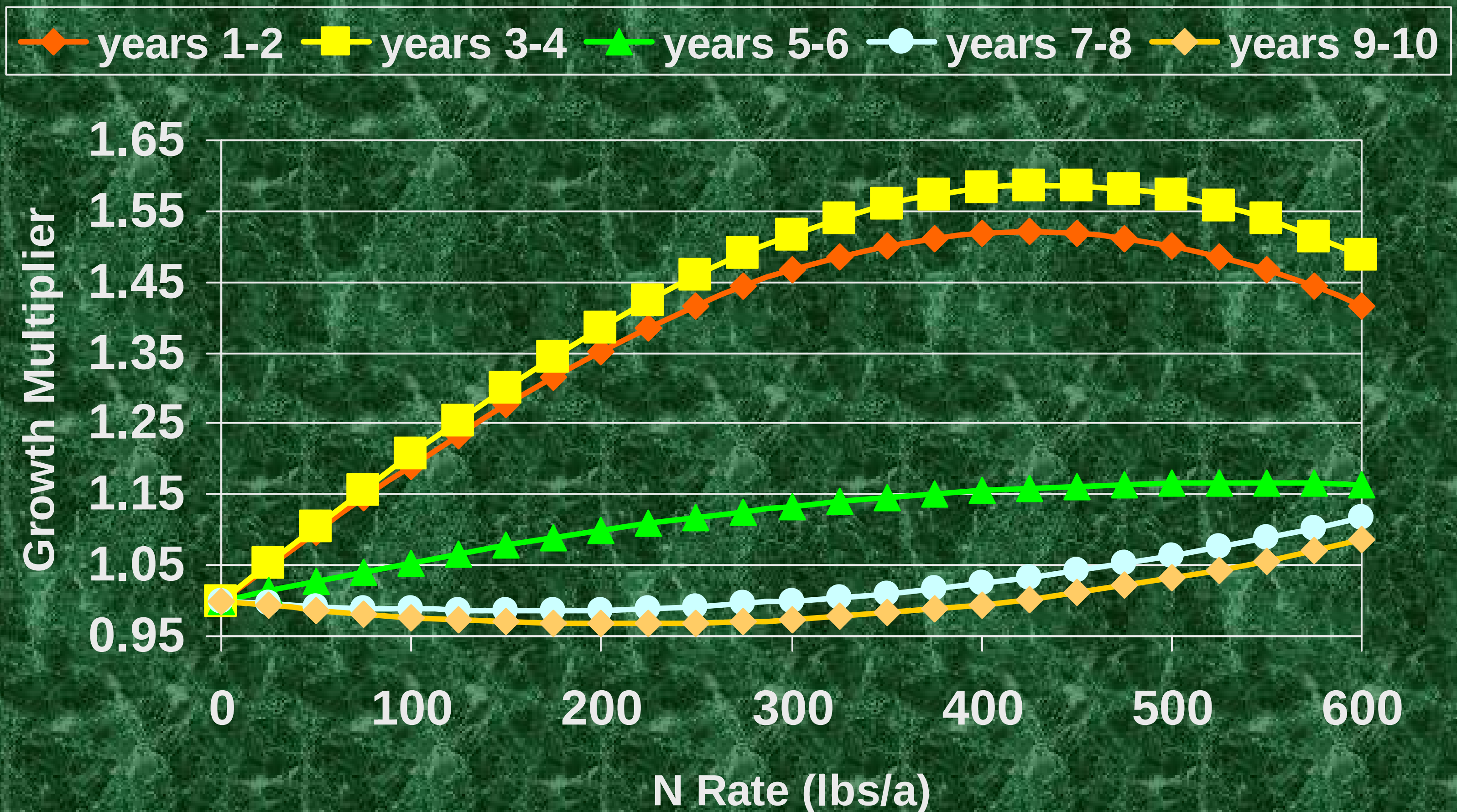
Growth multiplier: Diameter Growth/tree



Growth multipliers
N effects on per-tree growth

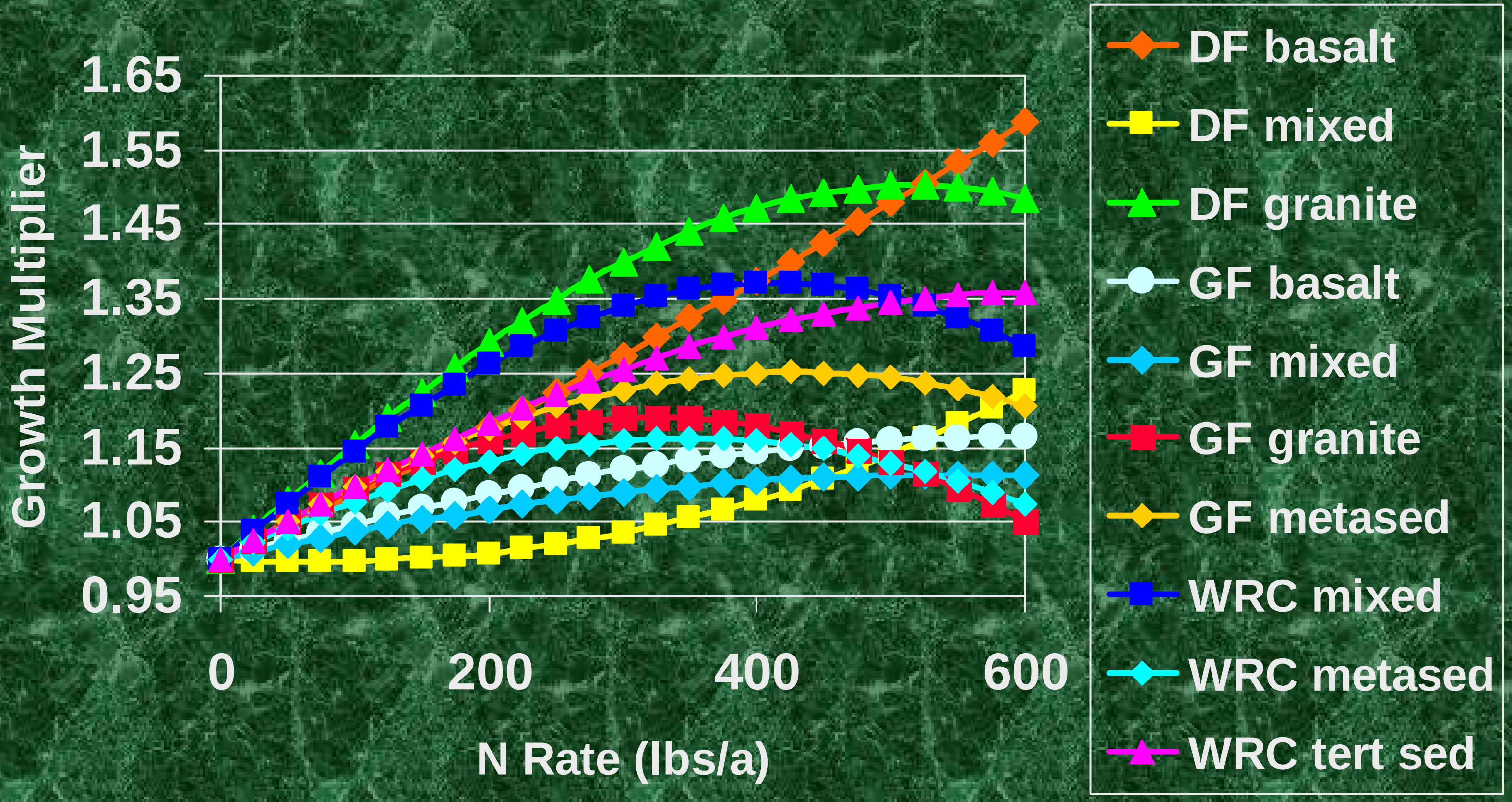


Growth multipliers: Periodic diameter growth



Growth multipliers

N effects on diameter growth/tree by vegetation series and rock type



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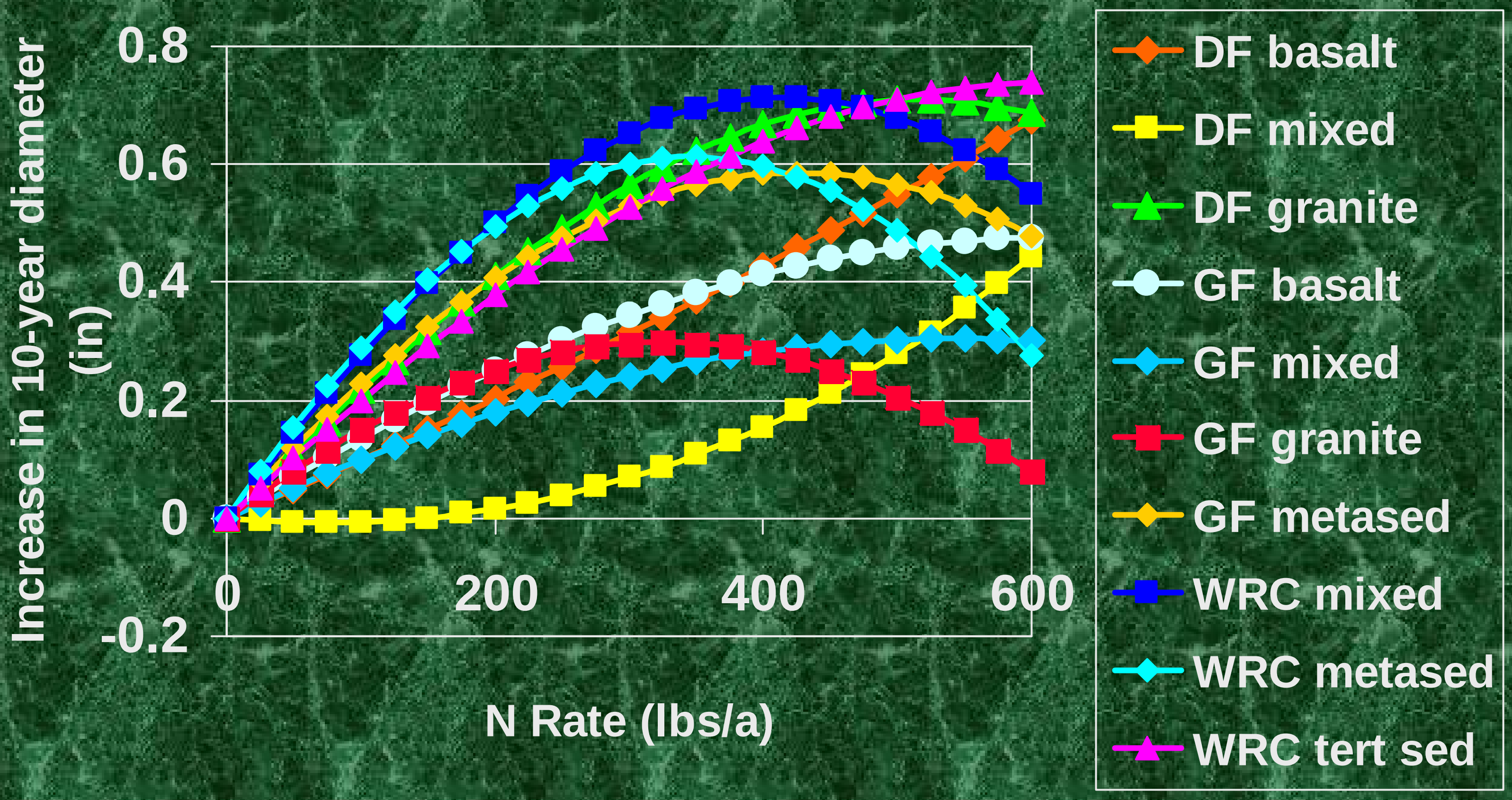

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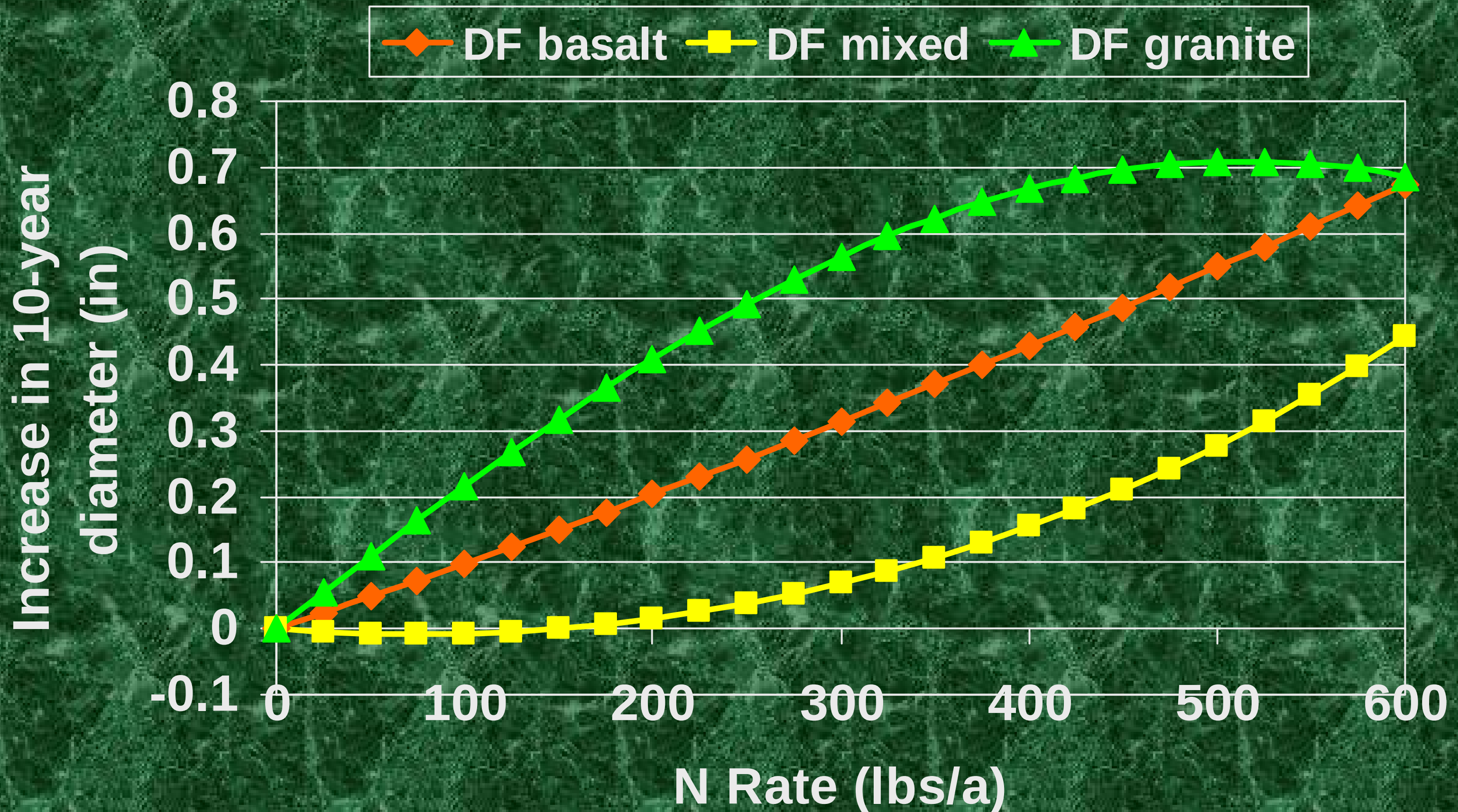

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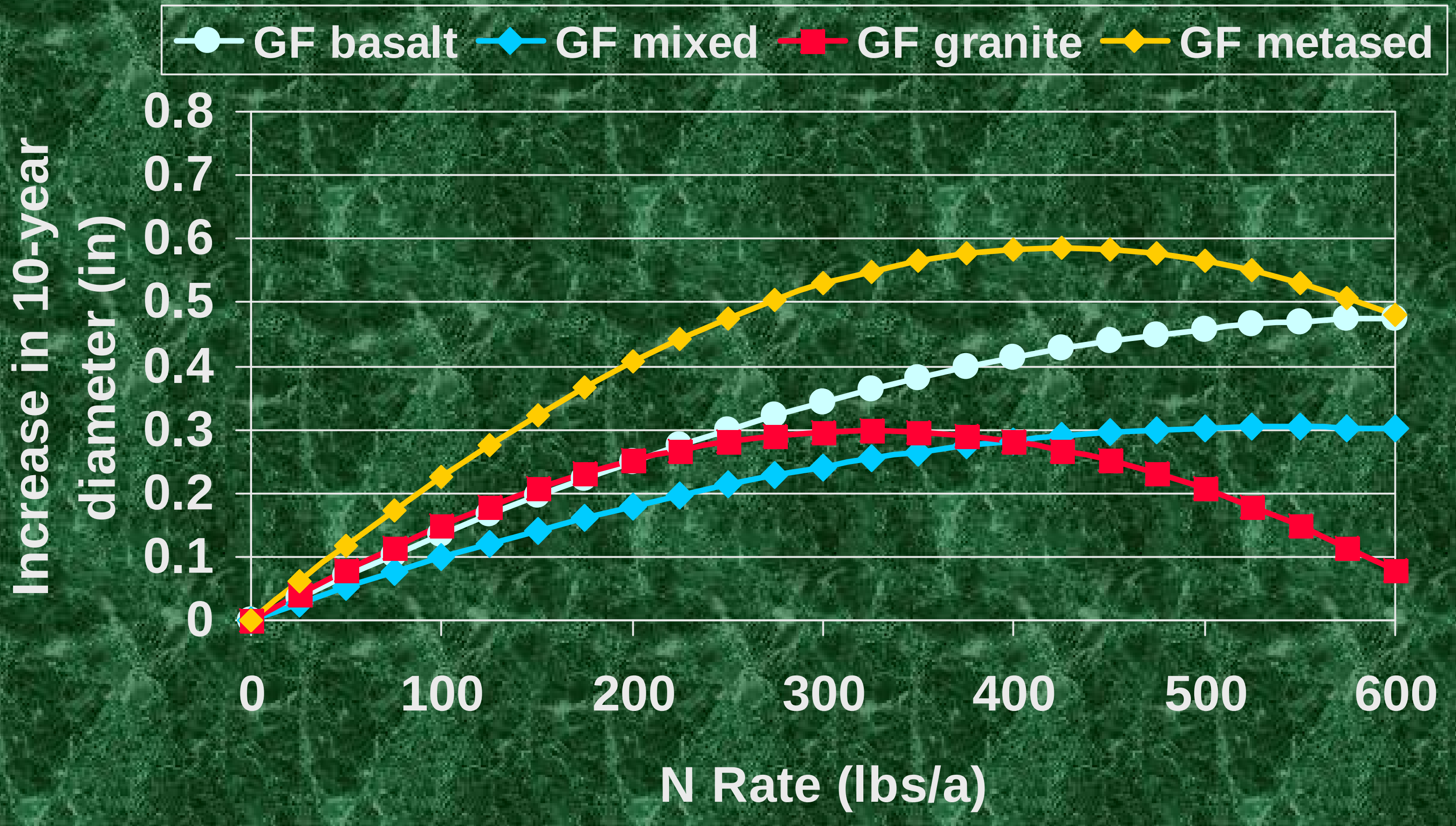

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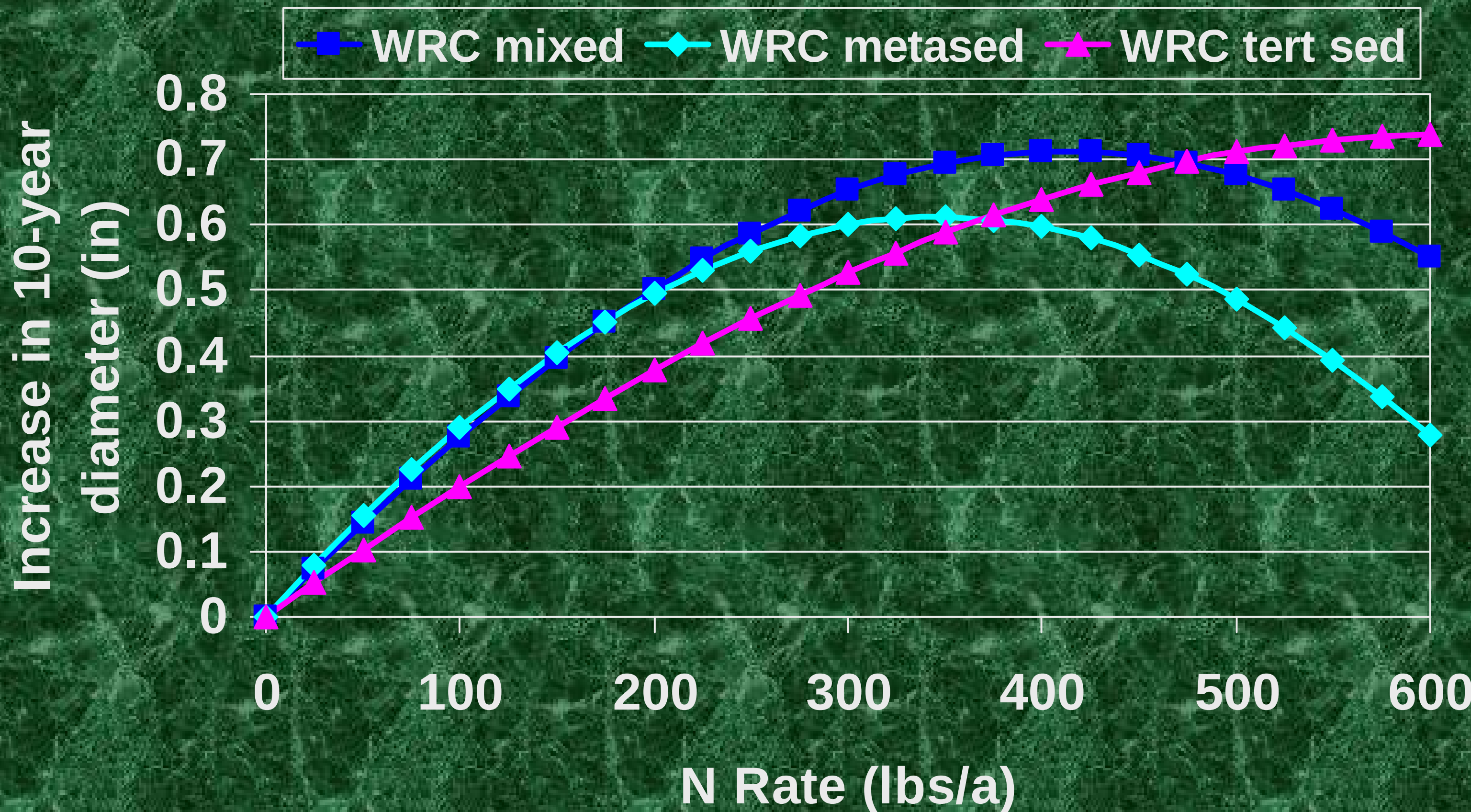
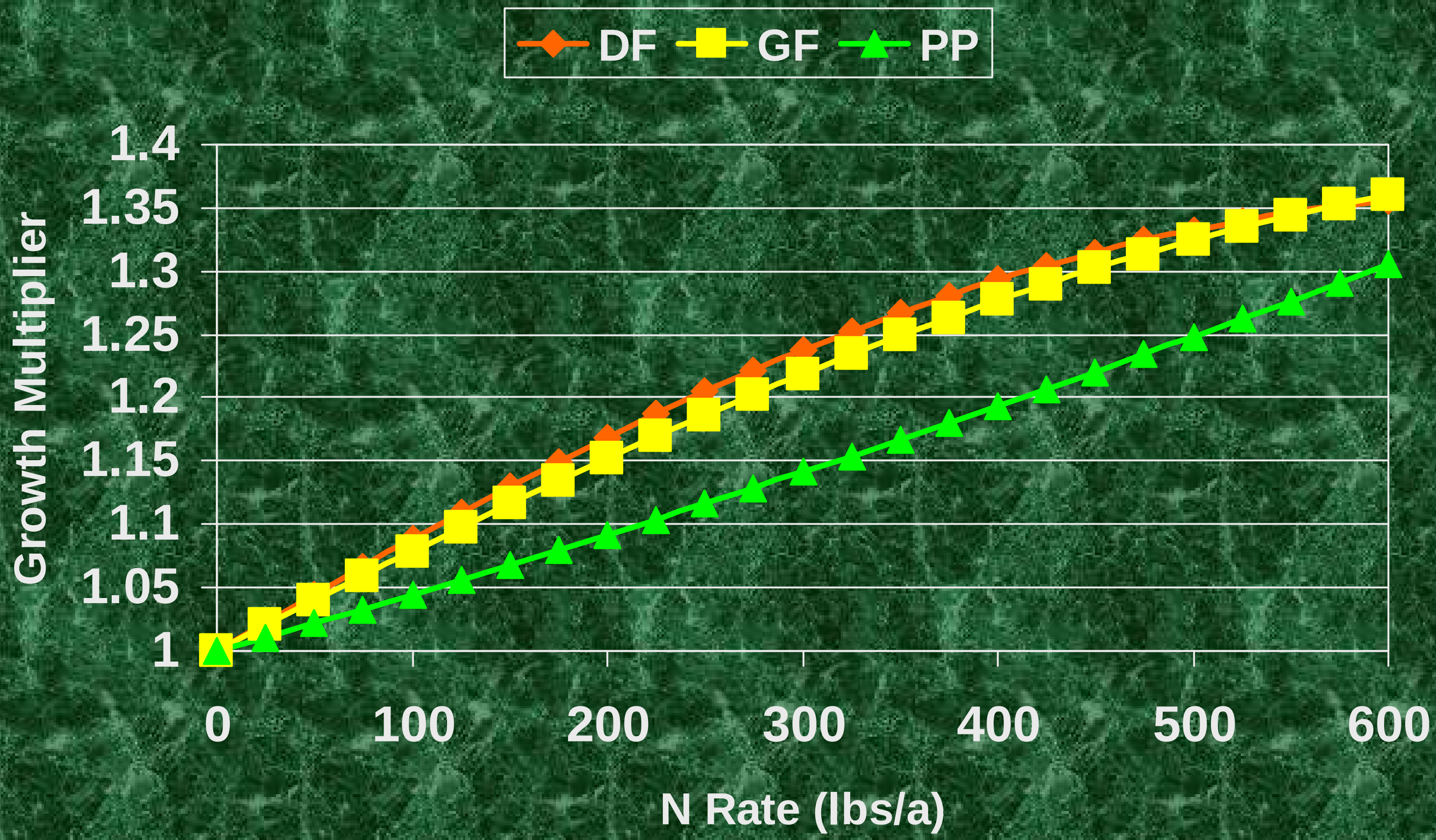


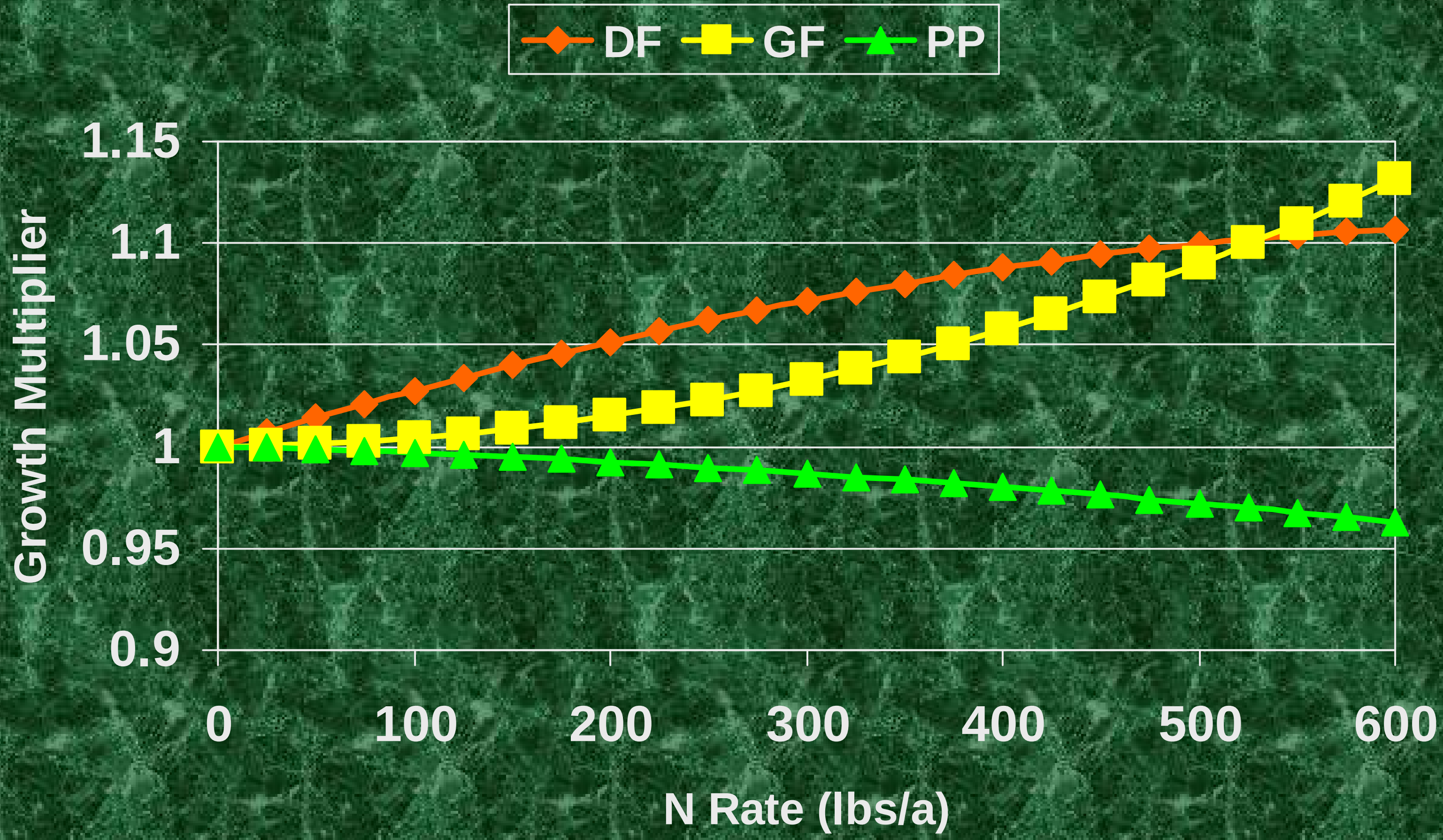
Distribution of sites with species-specific growth data

	Vegetation Series								
	DF			GF			WRC/WH		
Rock	Species								
Type	DF	GF	PP	DF	GF	PP	DF	GF	PP
basalt	2		2	2	1	1			
mixed	1		1	2	1	2	2	2	
granite	4		4	2	1	1	1	1	
metased				2	1	1	4	3	
tert sed							5	5	

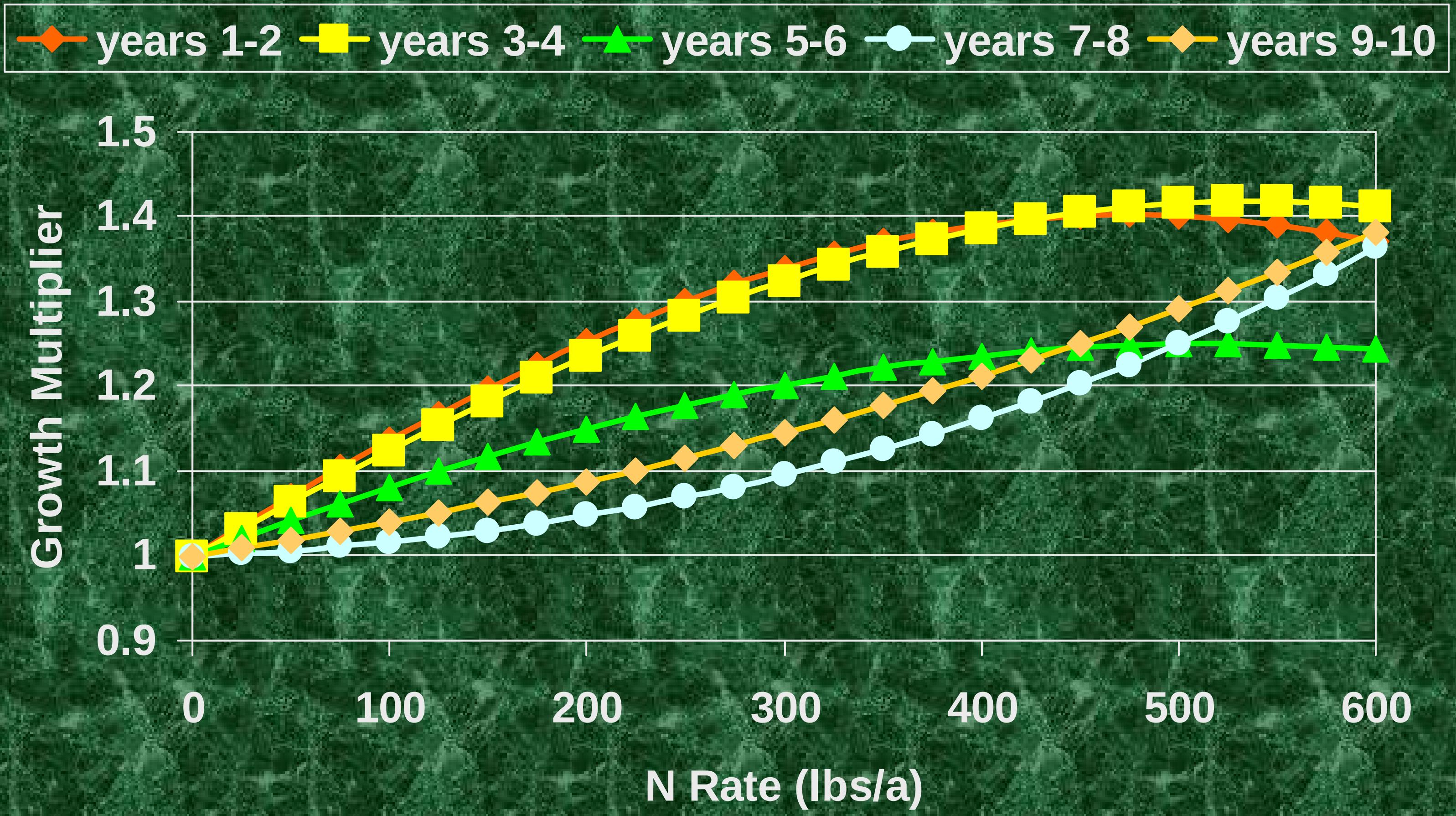
Species-specific growth multipliers: 10-year tree diameter growth



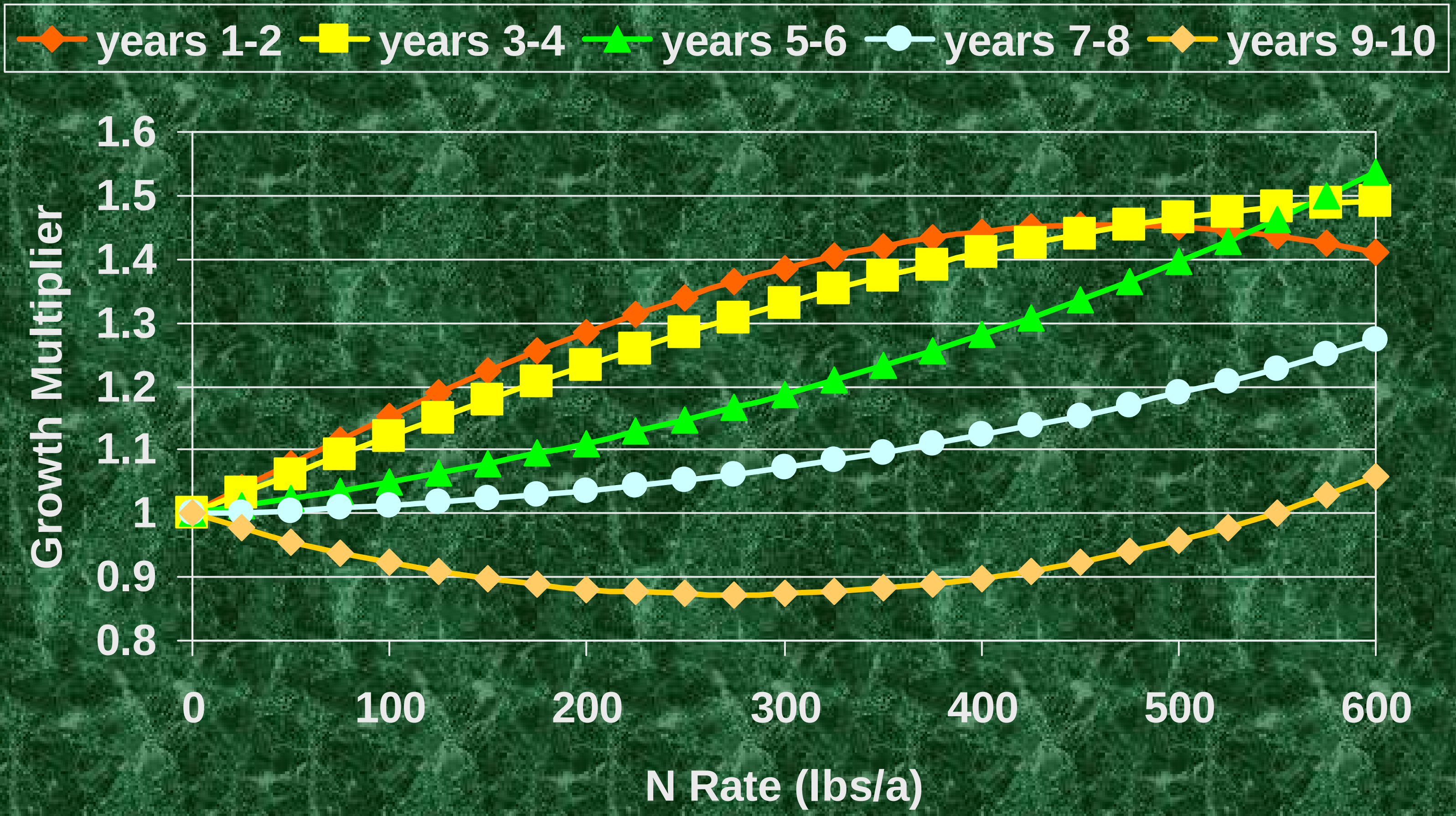
Species-specific growth multipliers: 10-year tree height growth



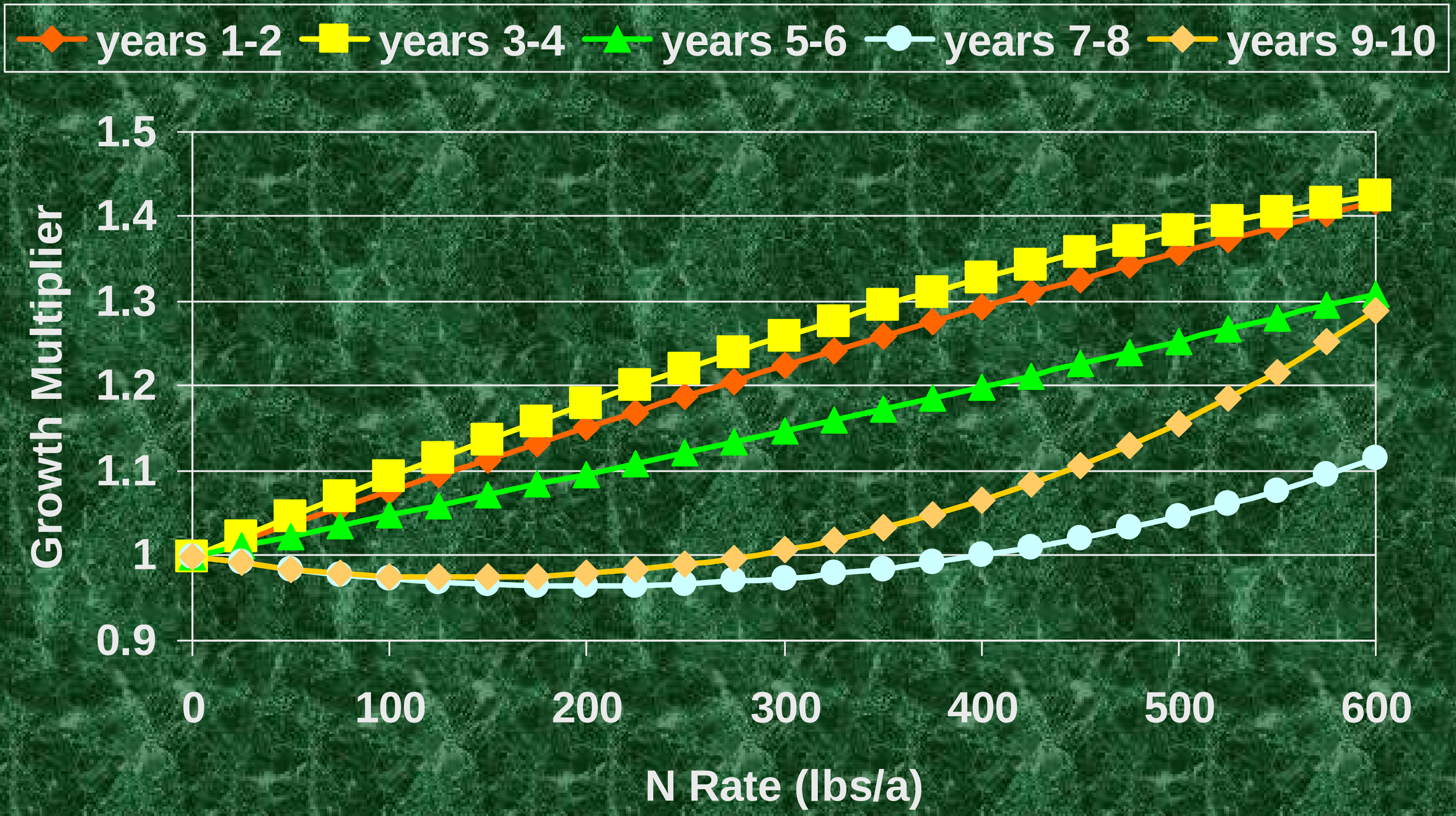
Growth multipliers: DF Periodic diameter growth



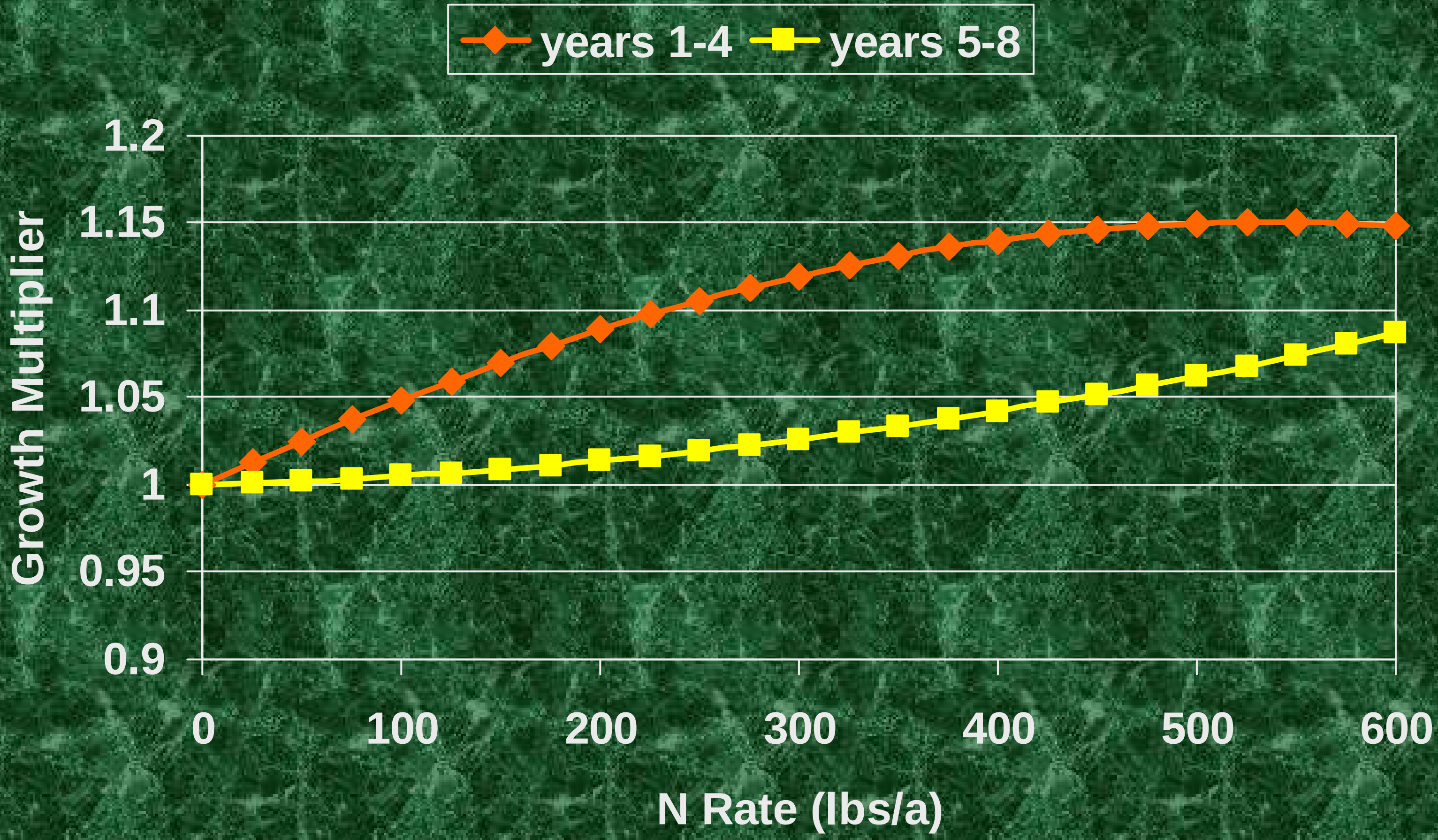
Growth multipliers: GF Periodic diameter growth



Growth multipliers: PP Periodic diameter growth



Growth multipliers: DF Periodic height growth



Summary: N and K Effects on Growth

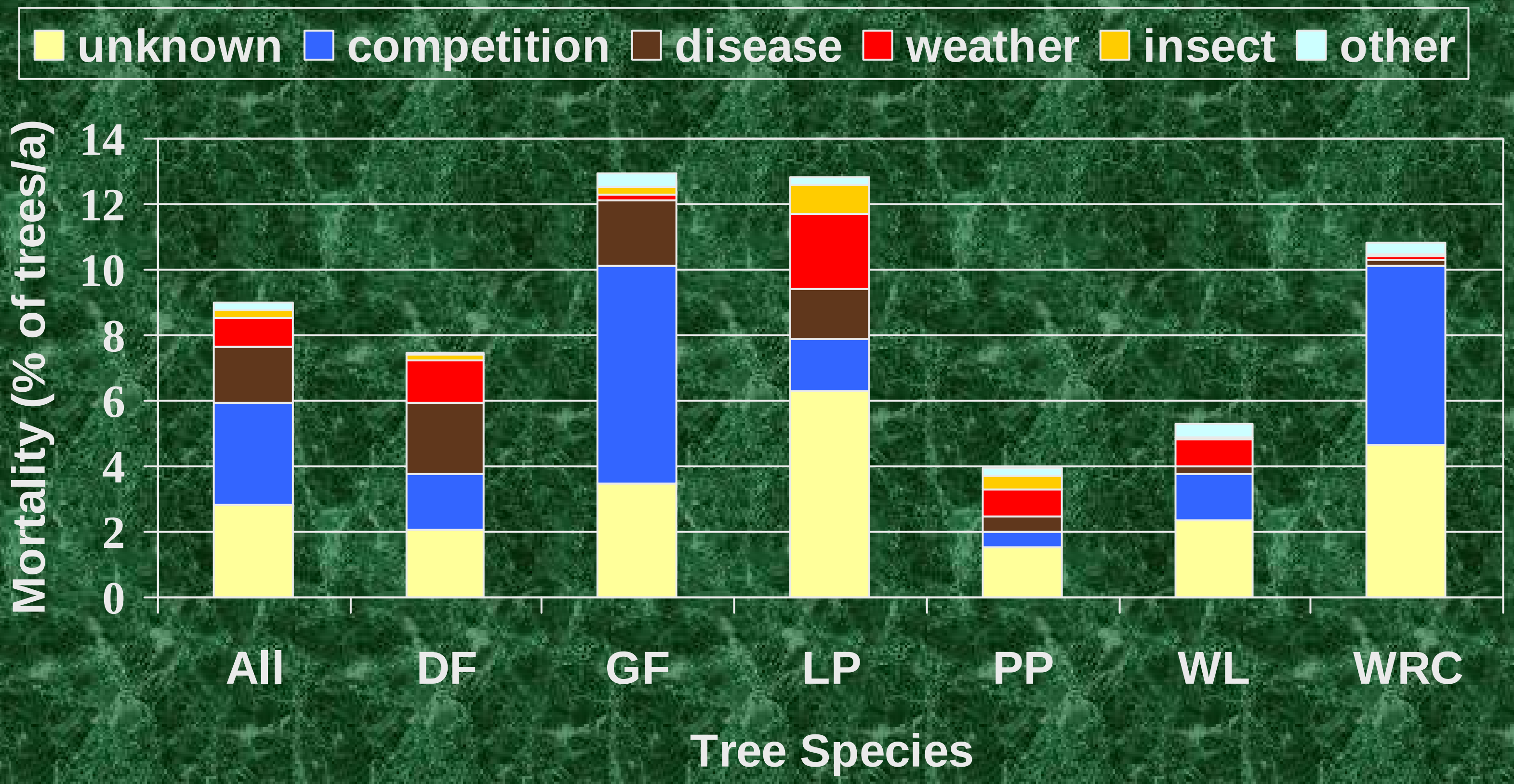
- Diameter and basal area growth showed a strong relationship to rate of N application but not to K. The effect was proportional to N rate at lower rates but declined at high N rates.
- Most of the fertilizer effect occurred within the first 4 years after treatment, but significant N effects were still present in years 5-6. High N rates extended the duration of response.
- Height growth was increased by N application, but the amount was slight and the duration of response was short.
- N effects varied by series and rock type with rock type differences more pronounced on drier vegetation series

What's Dying?

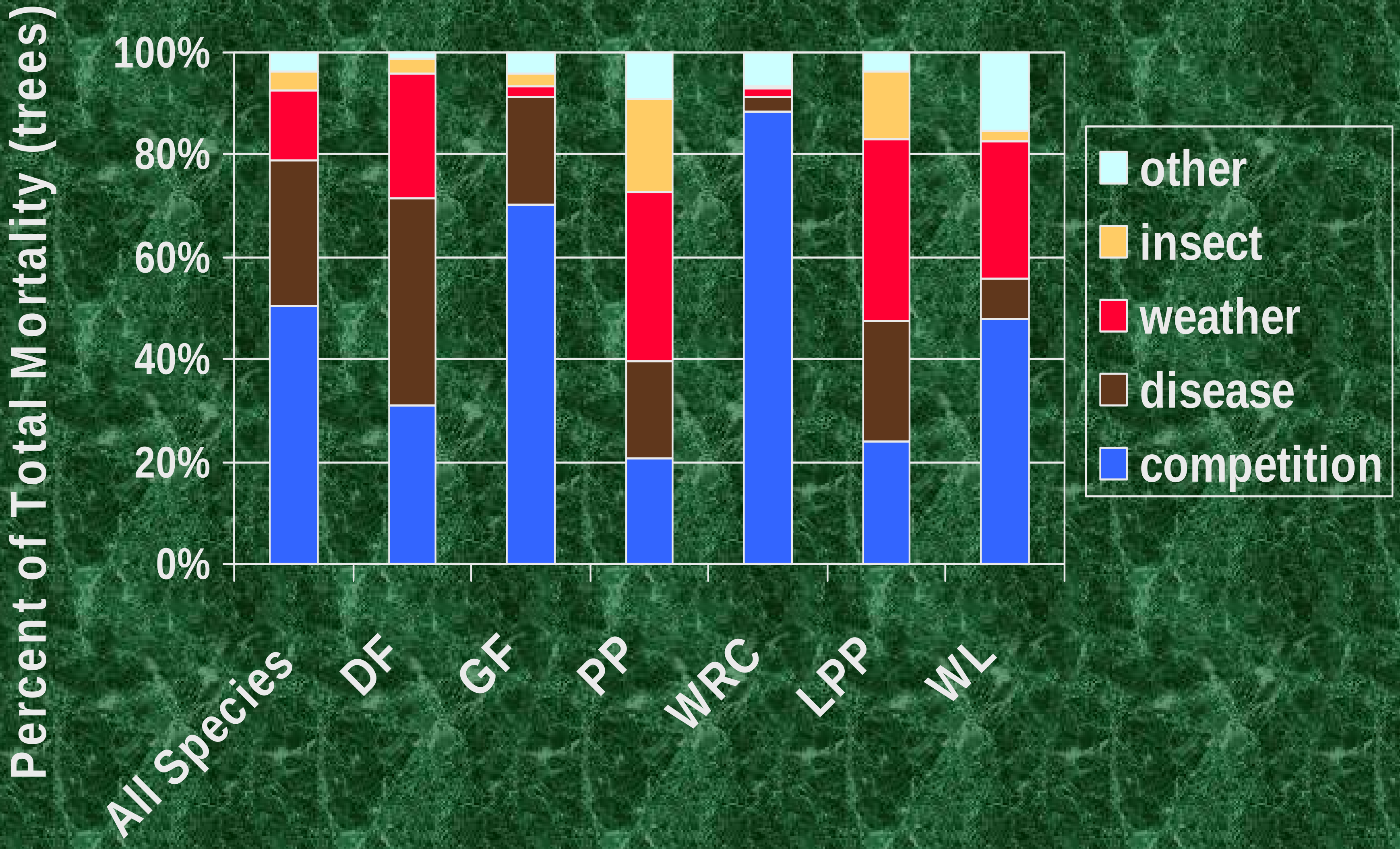
	Total Trees	Dead Trees	% Mortality
All Species	49422	4436	9.0
Douglas-fir	19504	1454	7.5
Grand Fir	12718	1645	12.9
Ponderosa Pine	7500	294	3.9
Western Red Cedar	4222	458	10.8
Lodgepole Pine	2108	270	12.8
Western Larch	1771	94	5.3

	Mean DBH	Inner Quartile Range
All Trees	6.26	3.13 – 8.55
Dead Trees	3.78	0.64 – 5.76

10-year Mortality by Cause stems/a



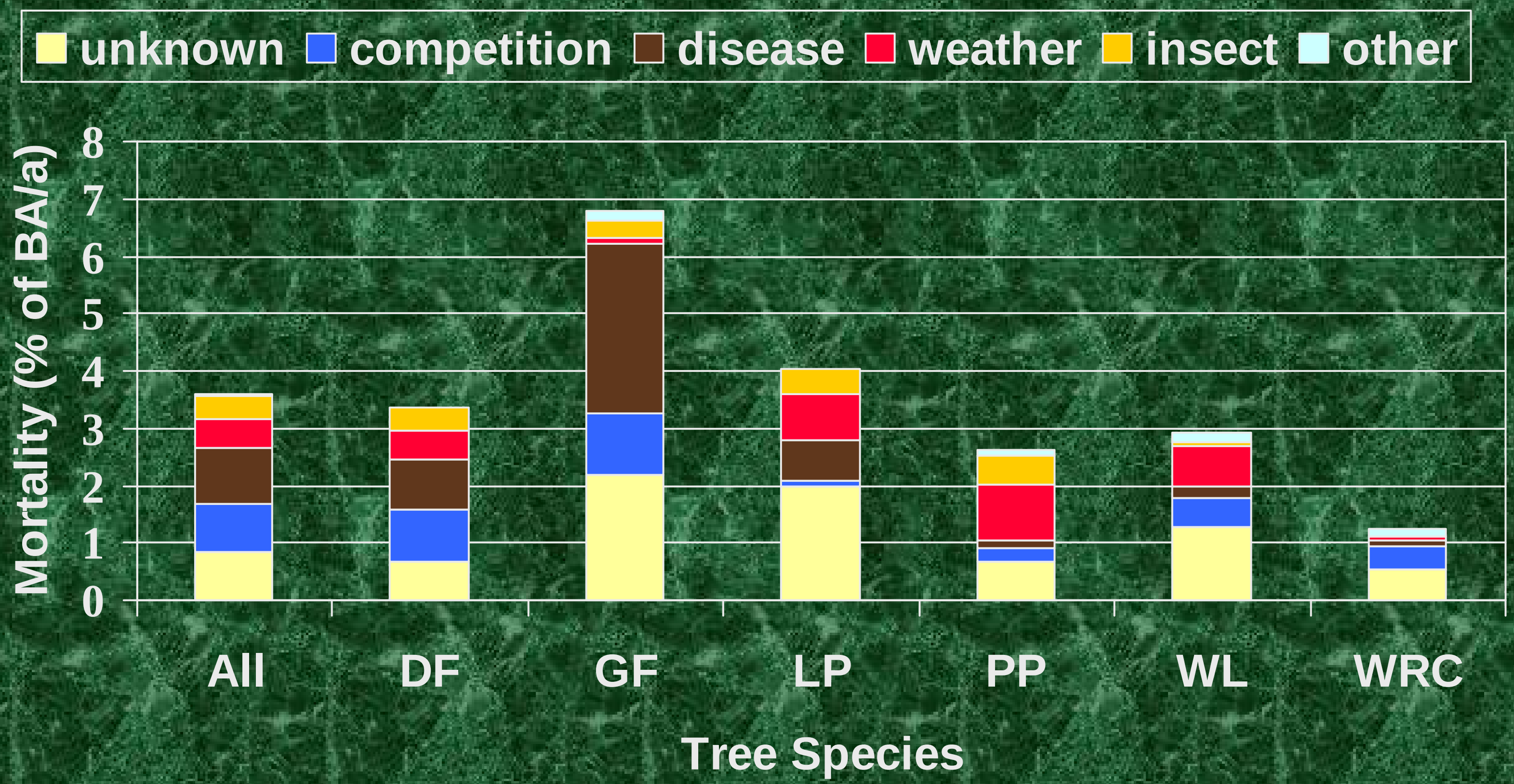
Causes of Mortality



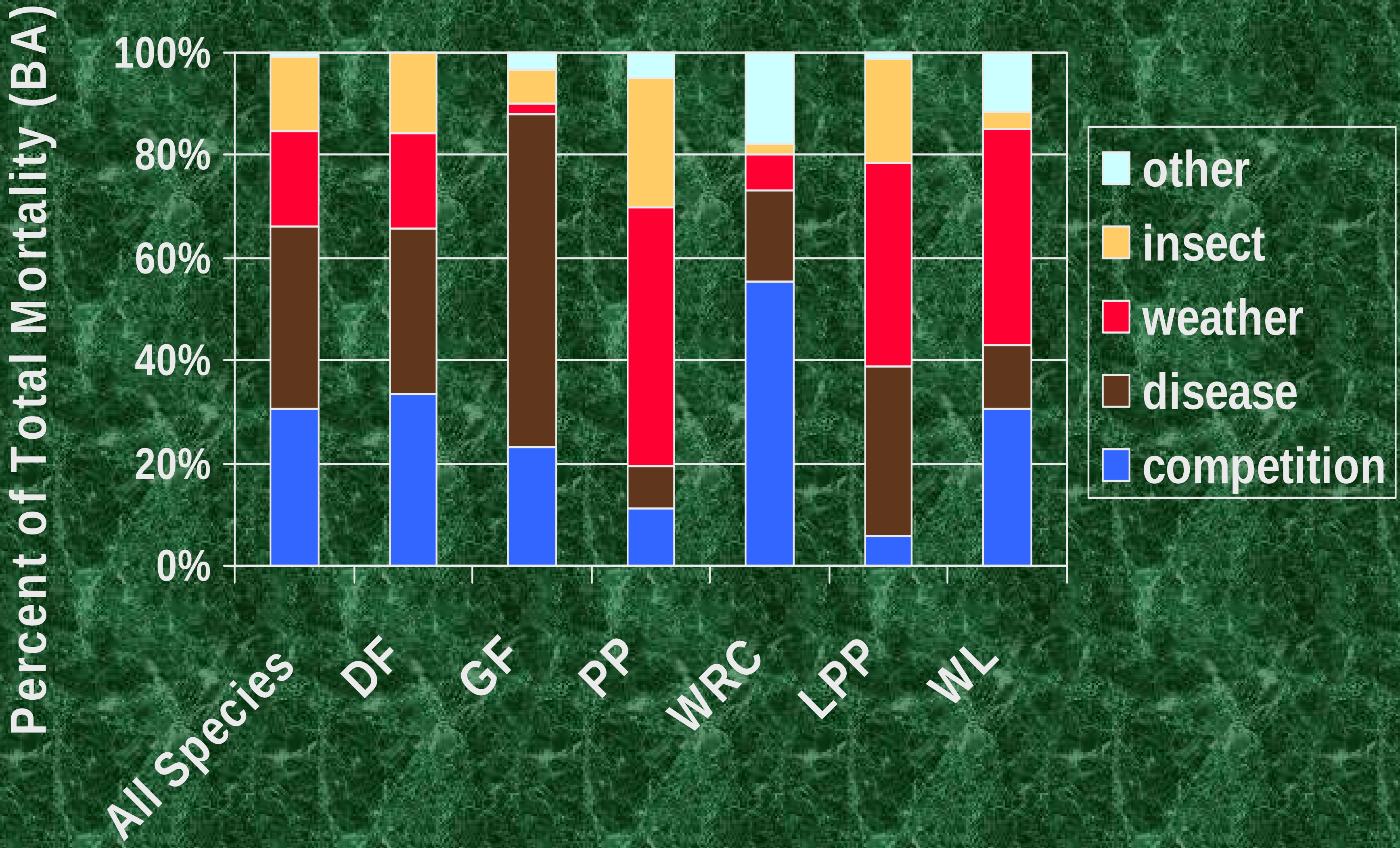
Size of Mortality

Mortality Cause	DBH (inches)	
	Mean	Inner-Quartile Range
Competition	1.95	0.43 to 2.92
Weather	5.96	3.62 to 7.86
Disease	6.03	3.34 to 7.92
Insects	7.53	4.91 to 9.61

10-year Mortality by Cause BA/a



Causes of Mortality



The Fertilizer Mortality Effect Model

Multiplicative model:

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

where M = mortality (10-year trees, BA or volume/acre)

I = installation effect (random)

C = covariate adjustments for initial plot density, plot growth

N = nitrogen rate (lbs/a)

K = potassium rate (lbs/a)

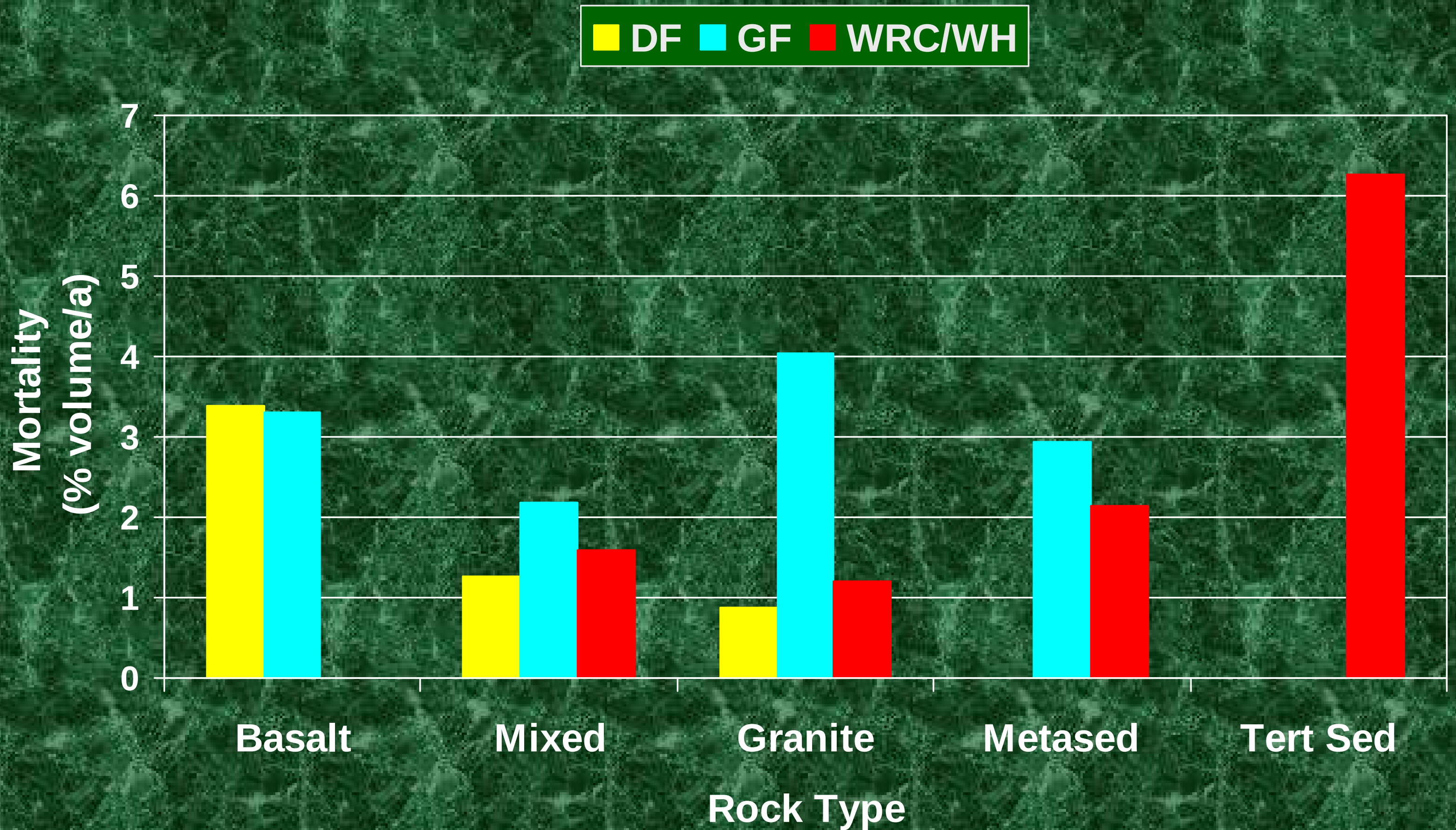
Thus, $M_{trt} = \exp(\mu+I+C+G+\beta_1{*}N+\beta_2{*}N^2+\beta_3{*}K+\beta_4{*}K^2+\beta_5{*}NK)$

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

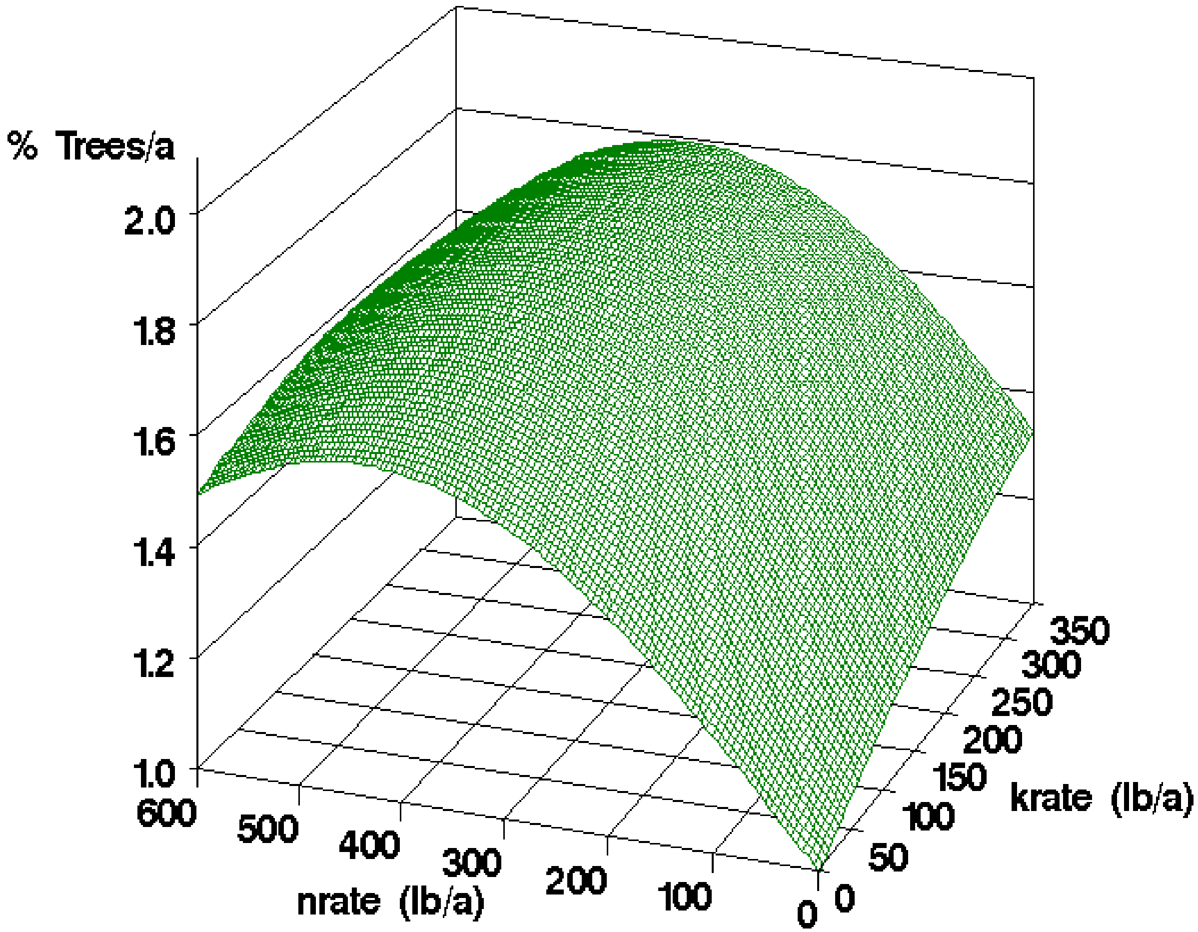
$= M_{con}$*Fertilizer Effect

Therefore, Fertilizer Effect is a mortality multiplier

Control Plot 10-year Mortality (% volume/a) by Rock Type and Vegetation Series



Mortality multiplier: % Trees/a



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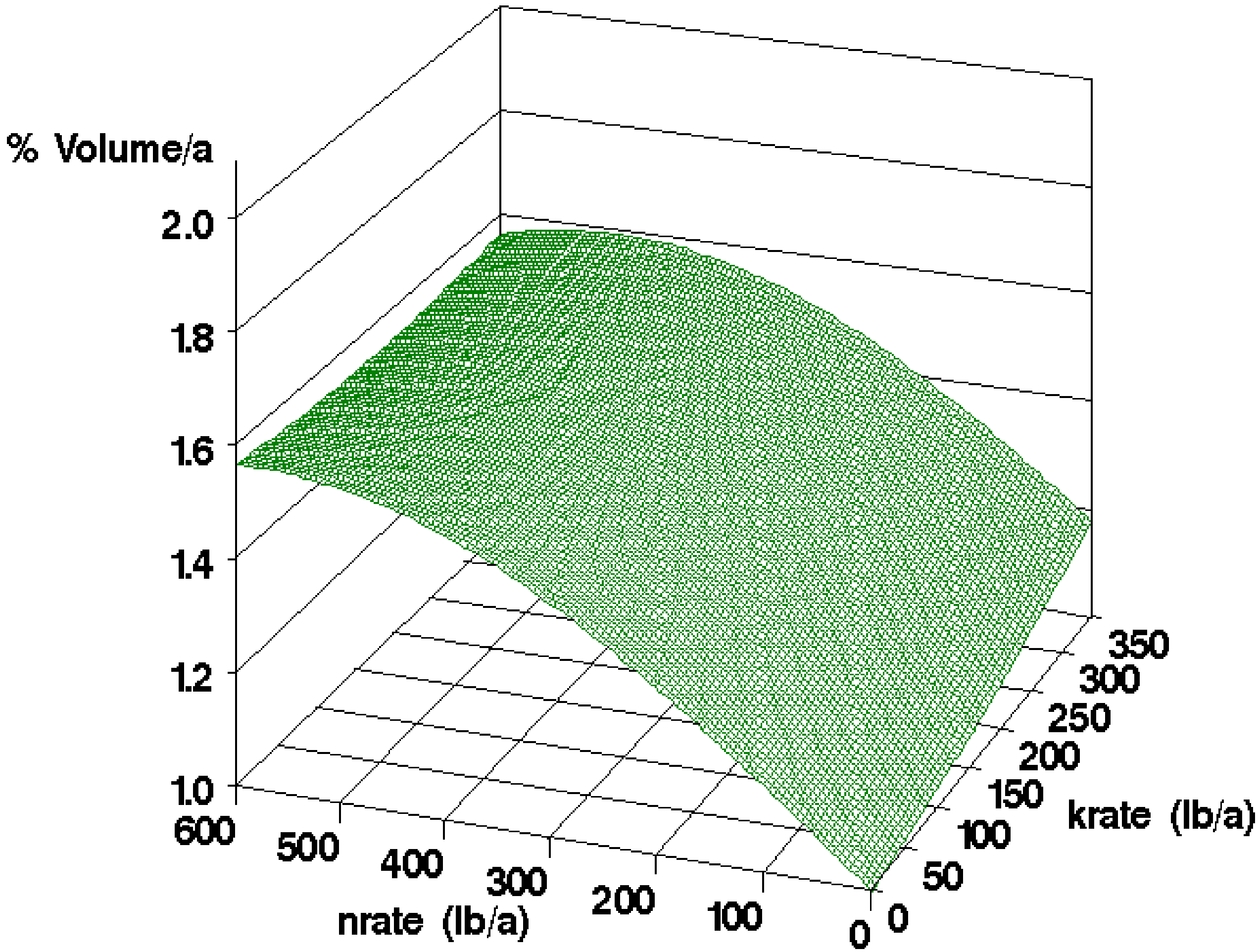
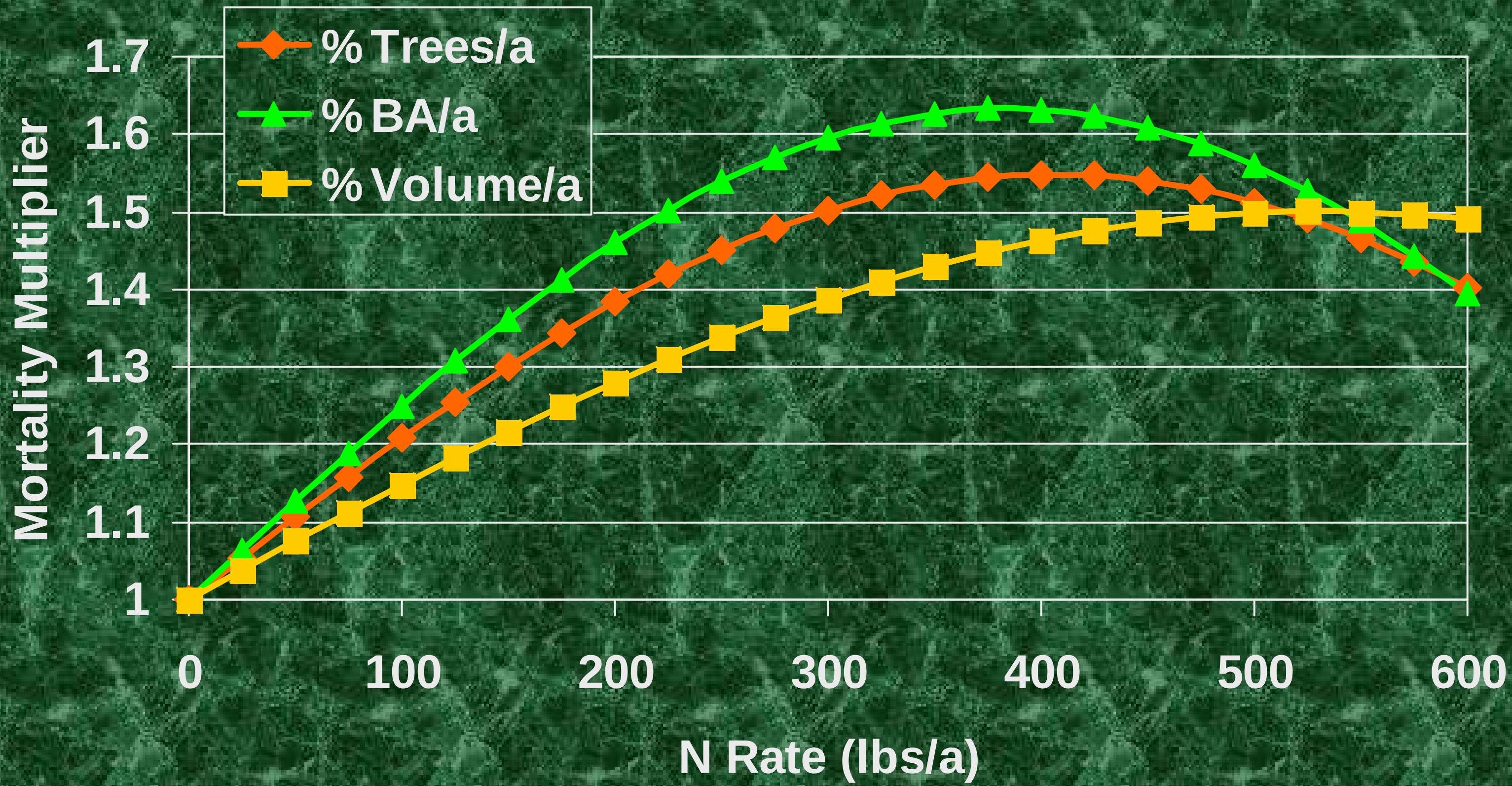


Mortality multipliers
N effects on % mortality/a



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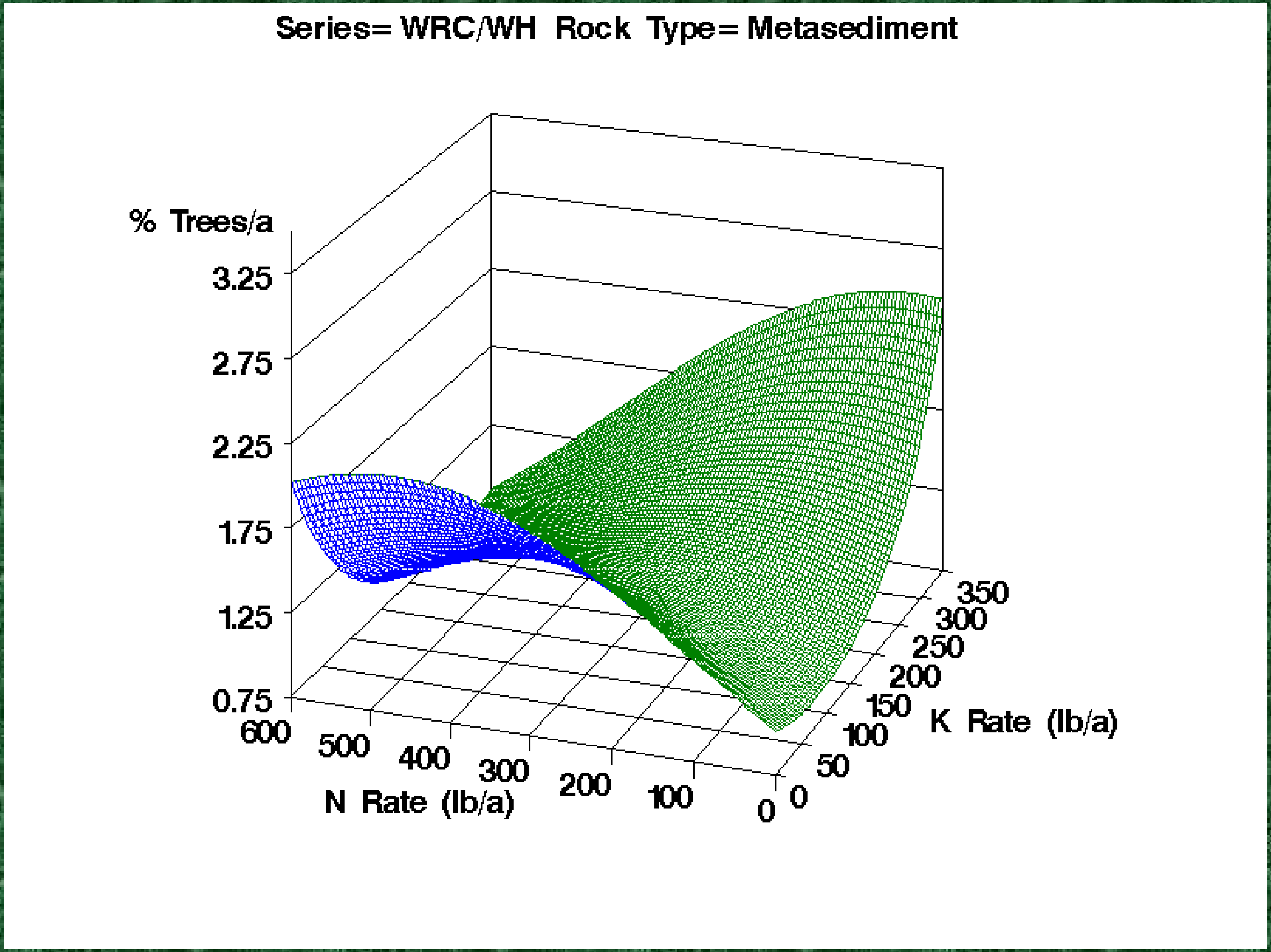

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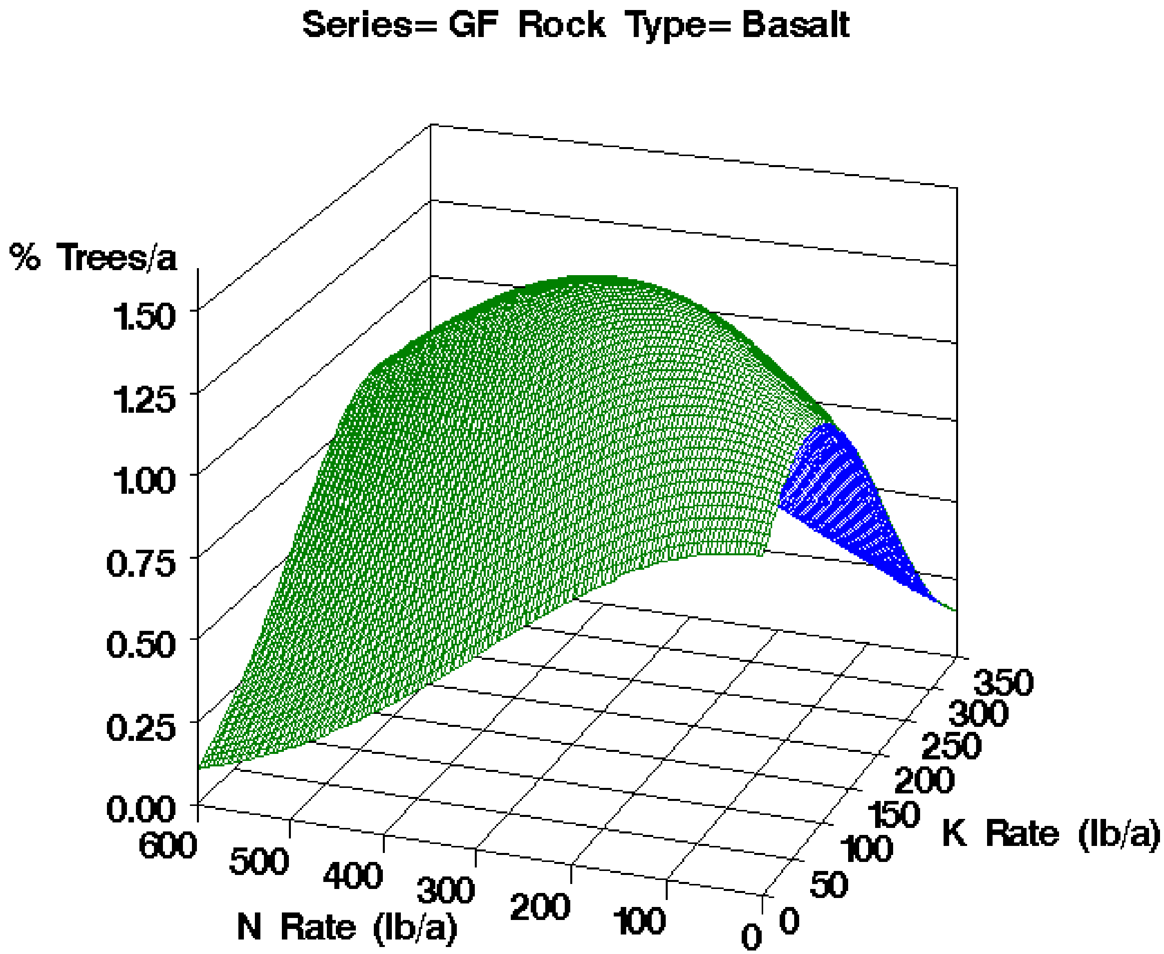
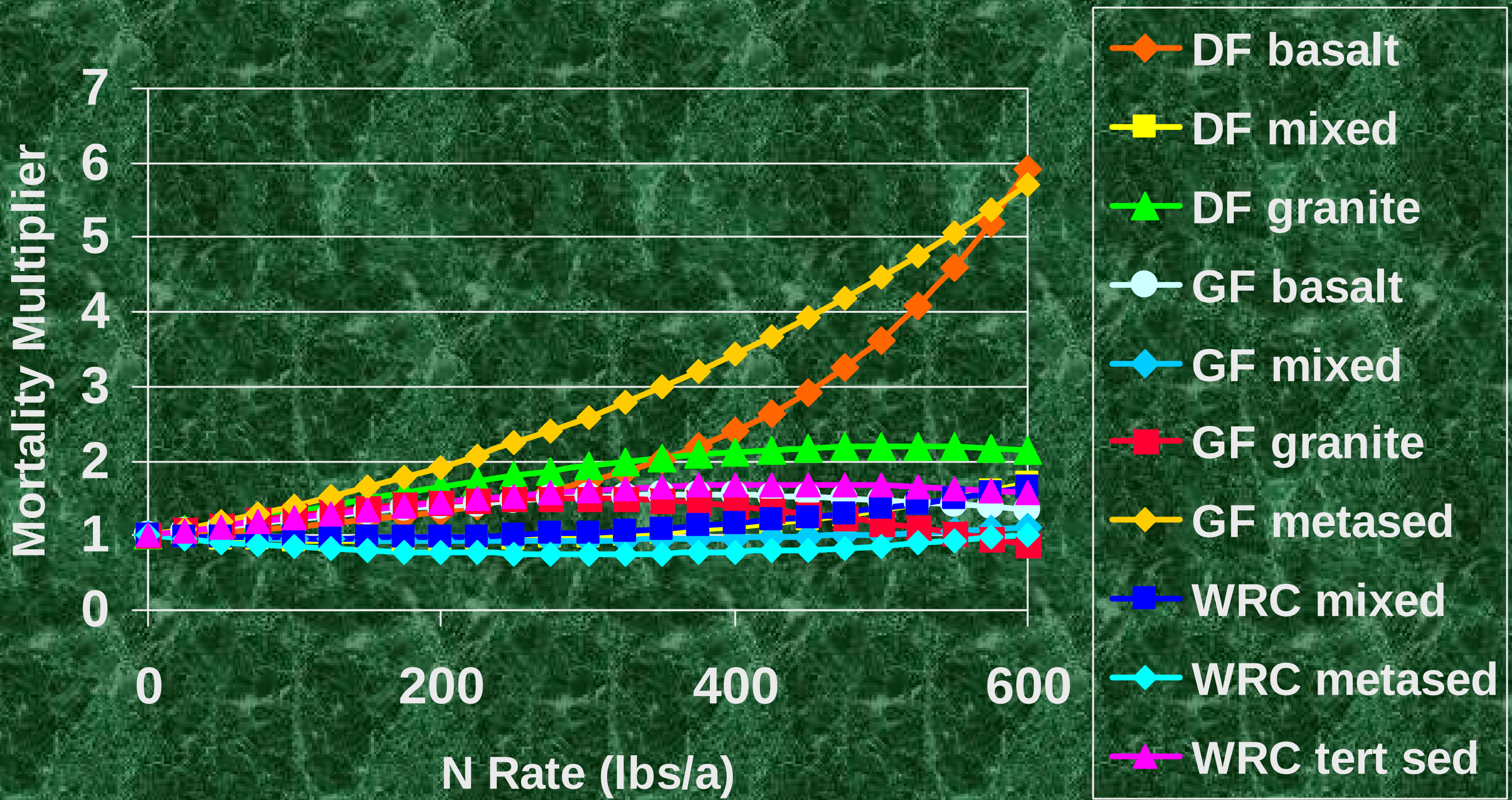


Mortality multipliers
N effects on % volume/a mortality by vegetation series and rock type



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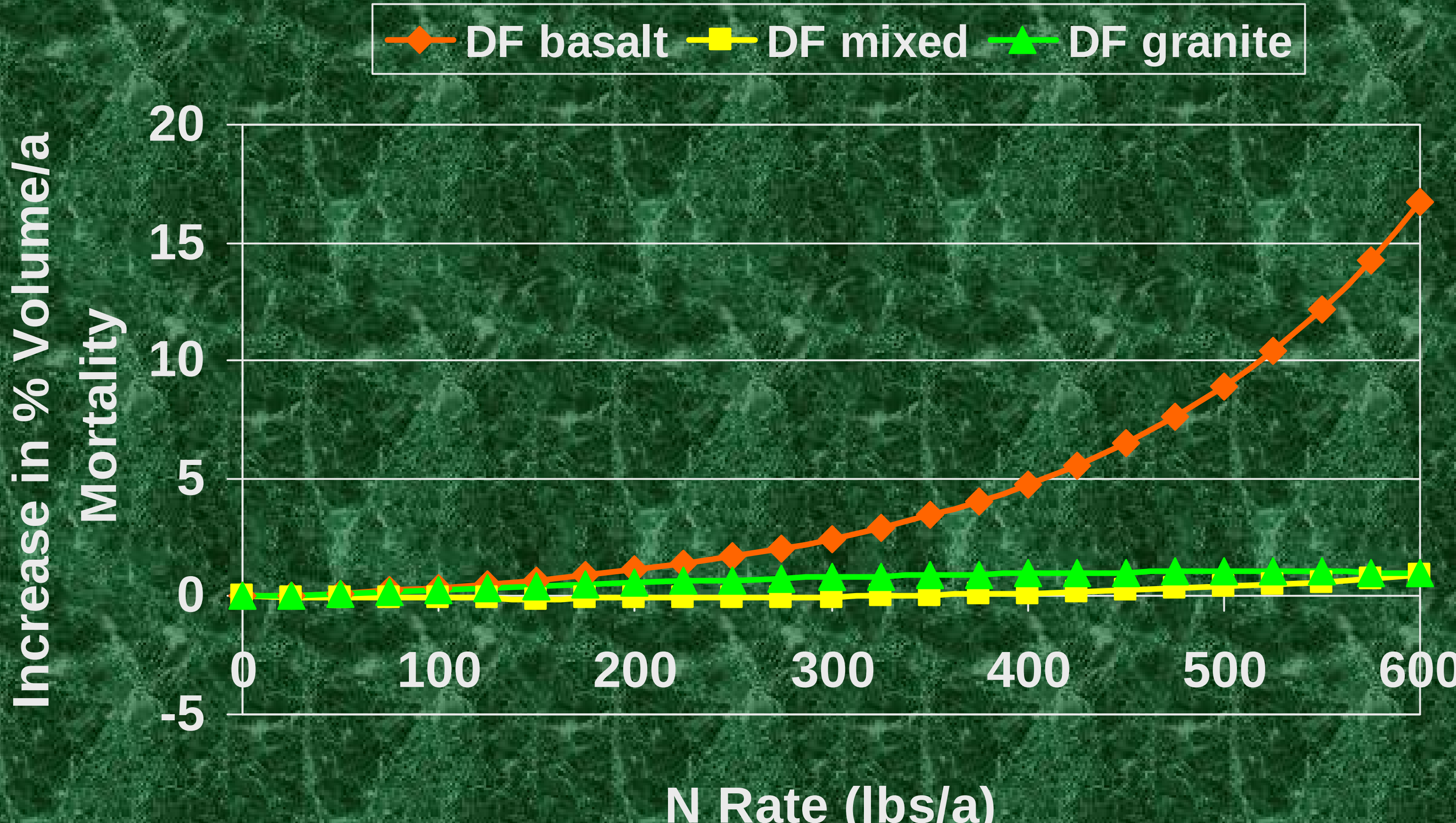

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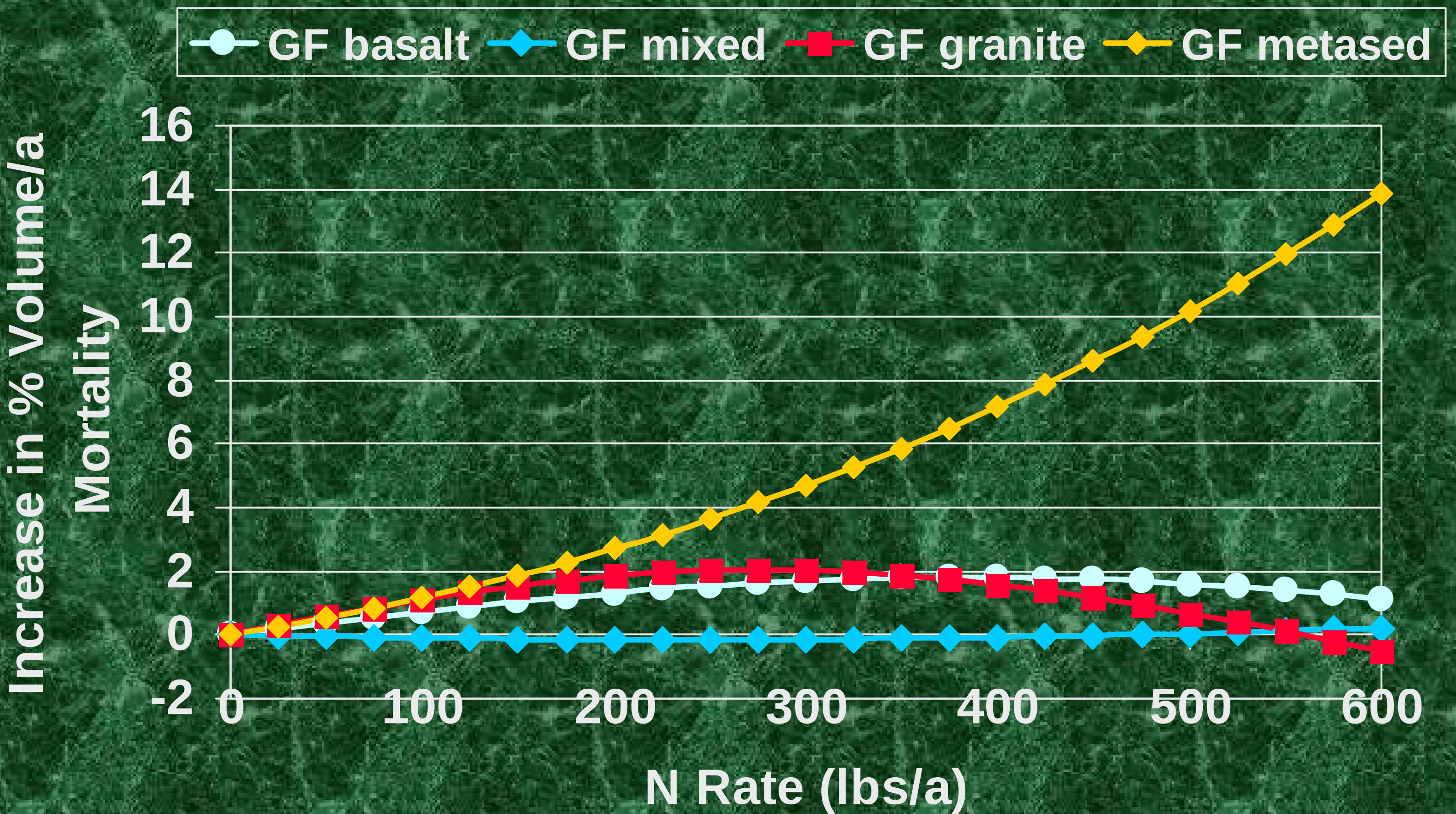

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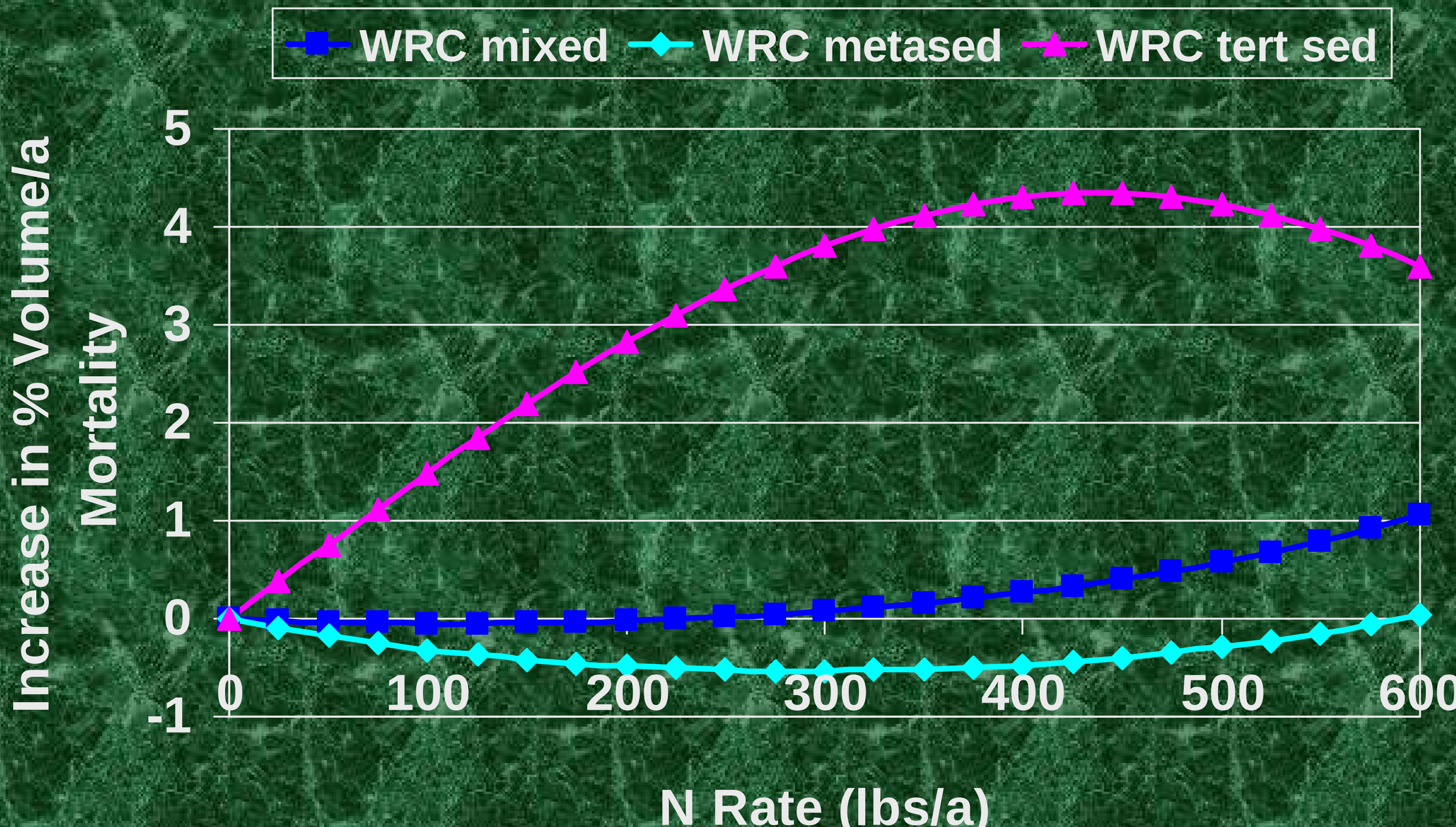

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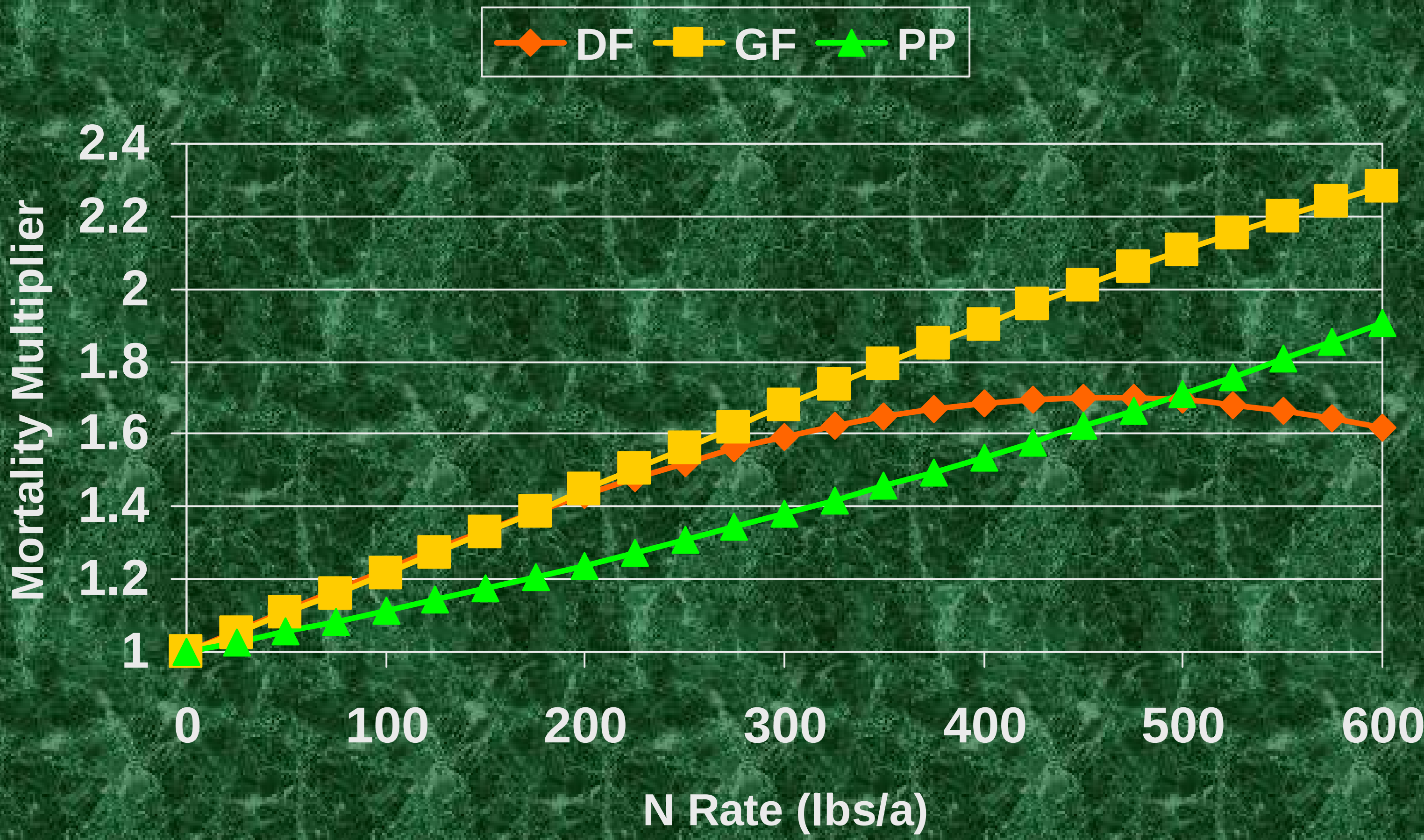
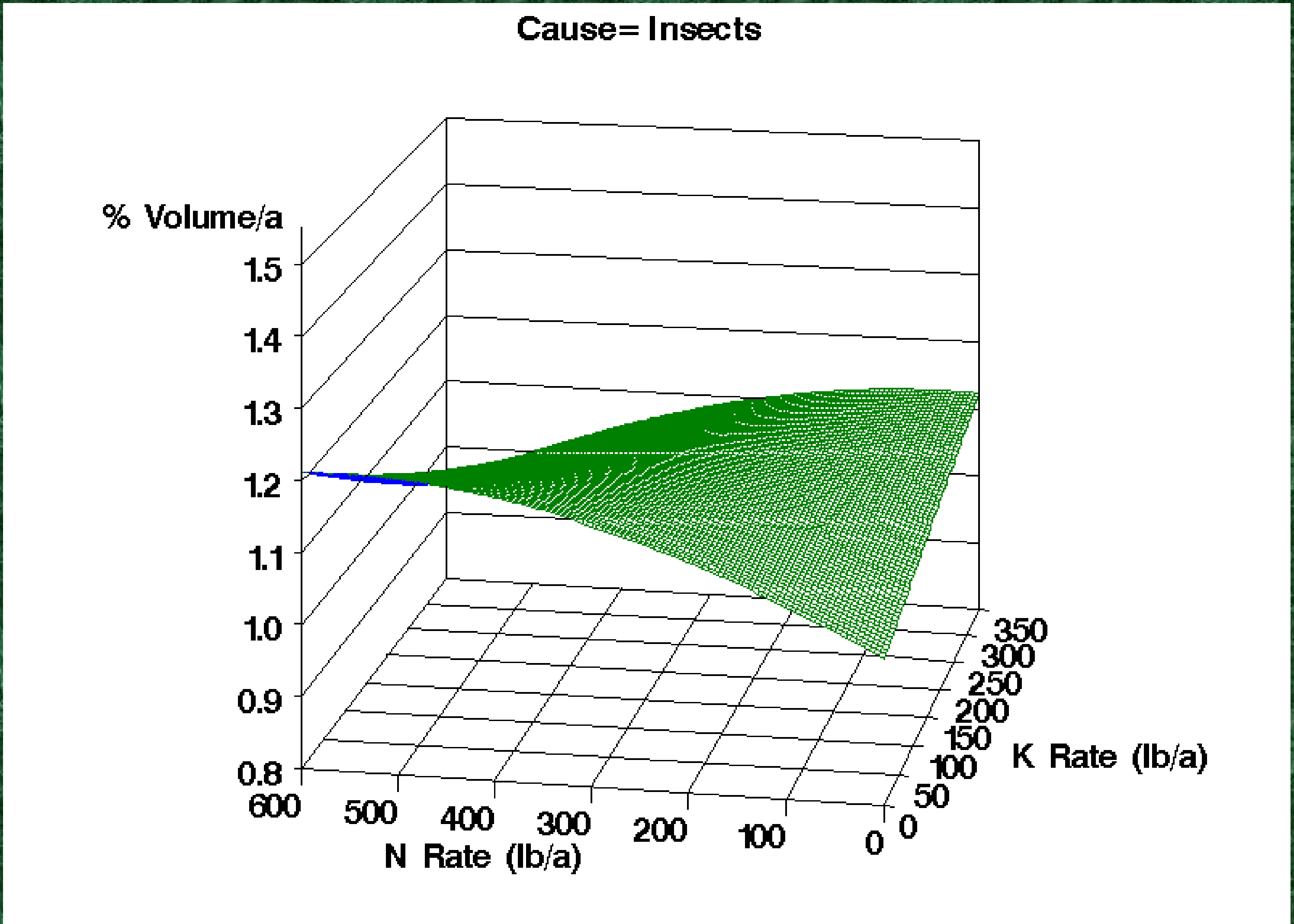


Mortality multiplier: % Volume/a



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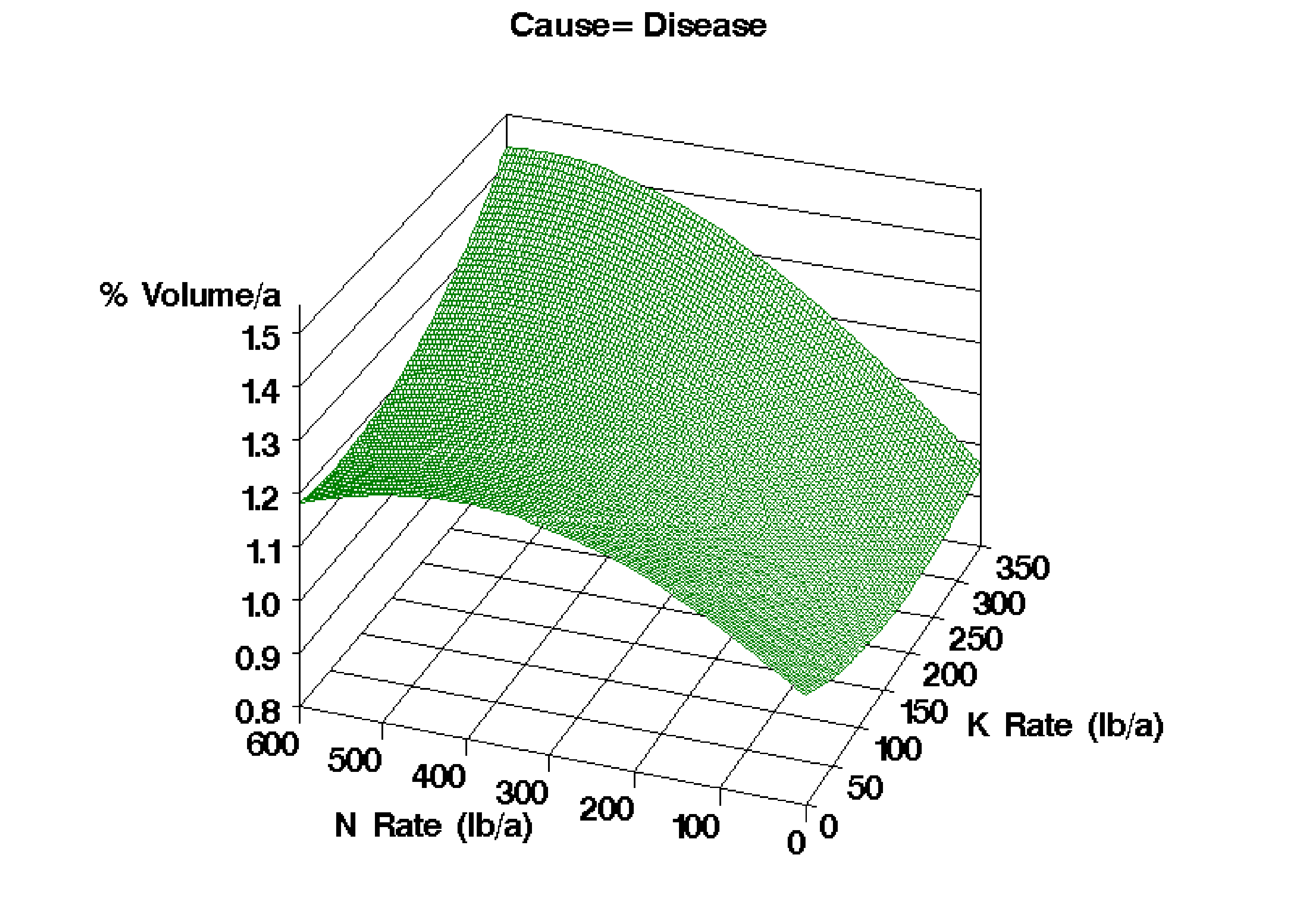
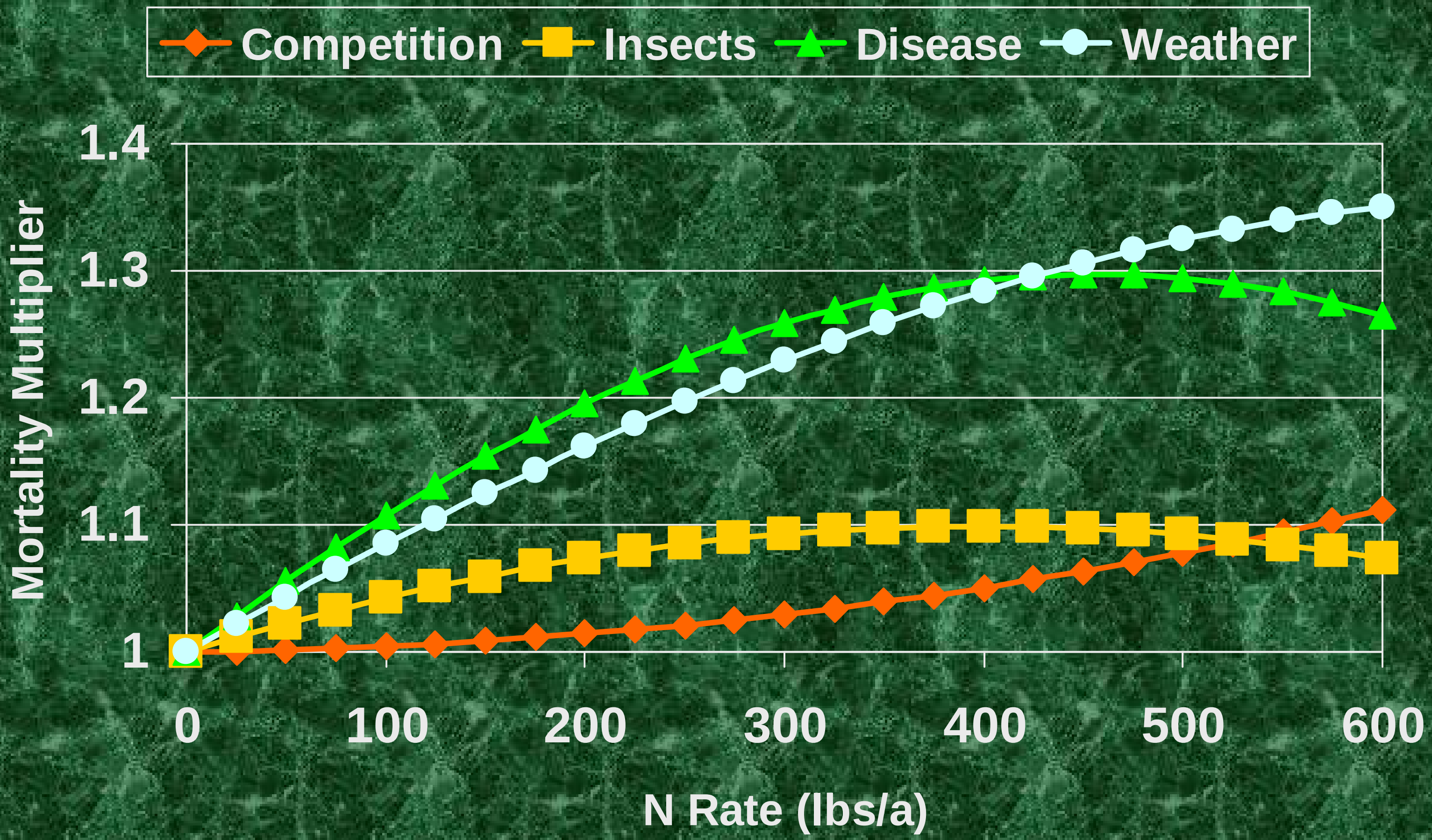


Mortality multipliers
N effects on % volume/a mortality



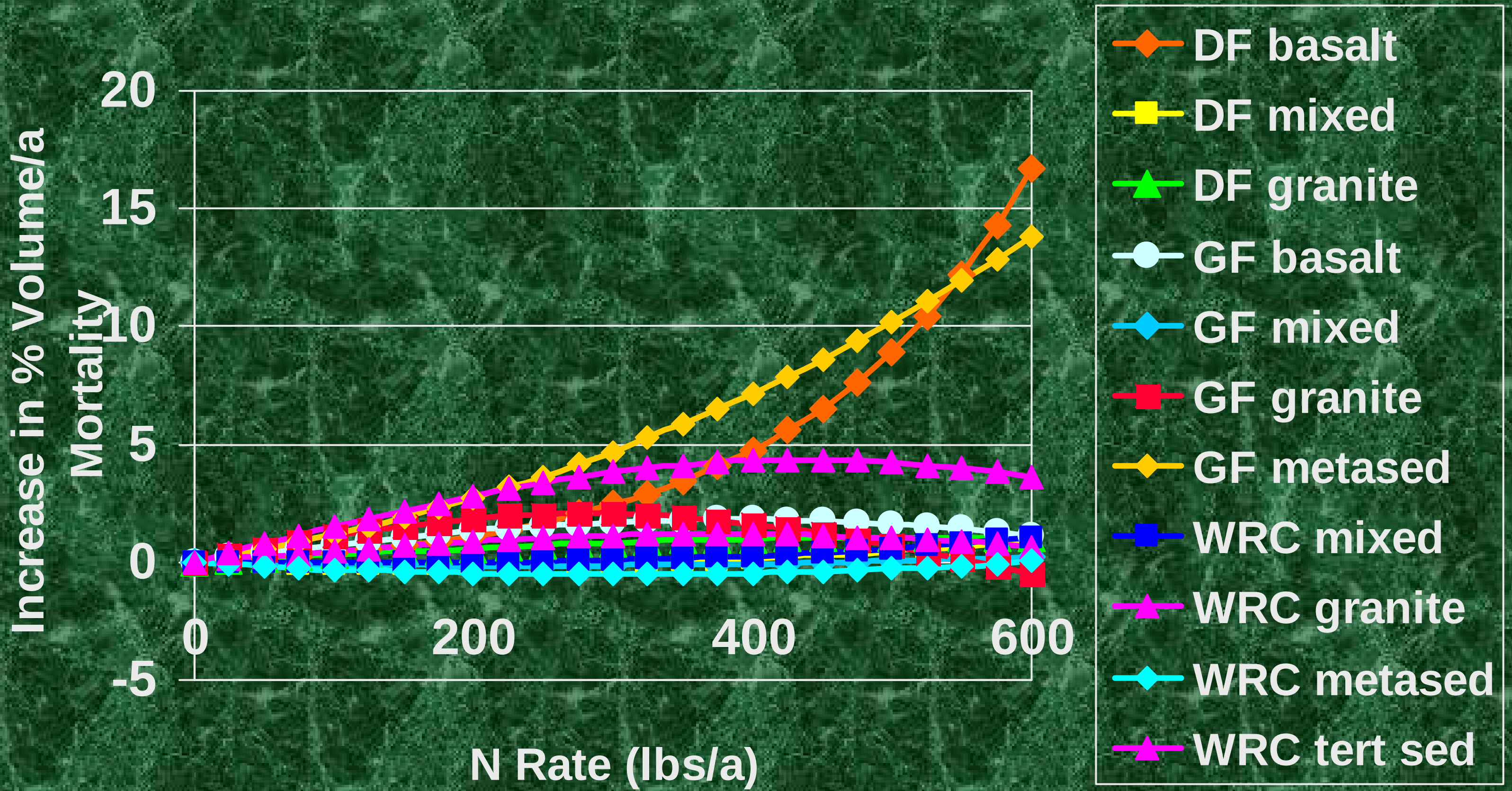
Summary of Mortality Effects

- Mortality rates were strongly linked to N application rates. Like growth, mortality increases were proportional to N rate at lower rates but declined at higher rates.
- The N rate-mortality relationship varied significantly by rock type, vegetation series, and mortality measure
- There was no evidence that K applications modified mortality rates in any consistent fashion.
- Increased mortality from N application seemed mostly caused by weather or disease agents.

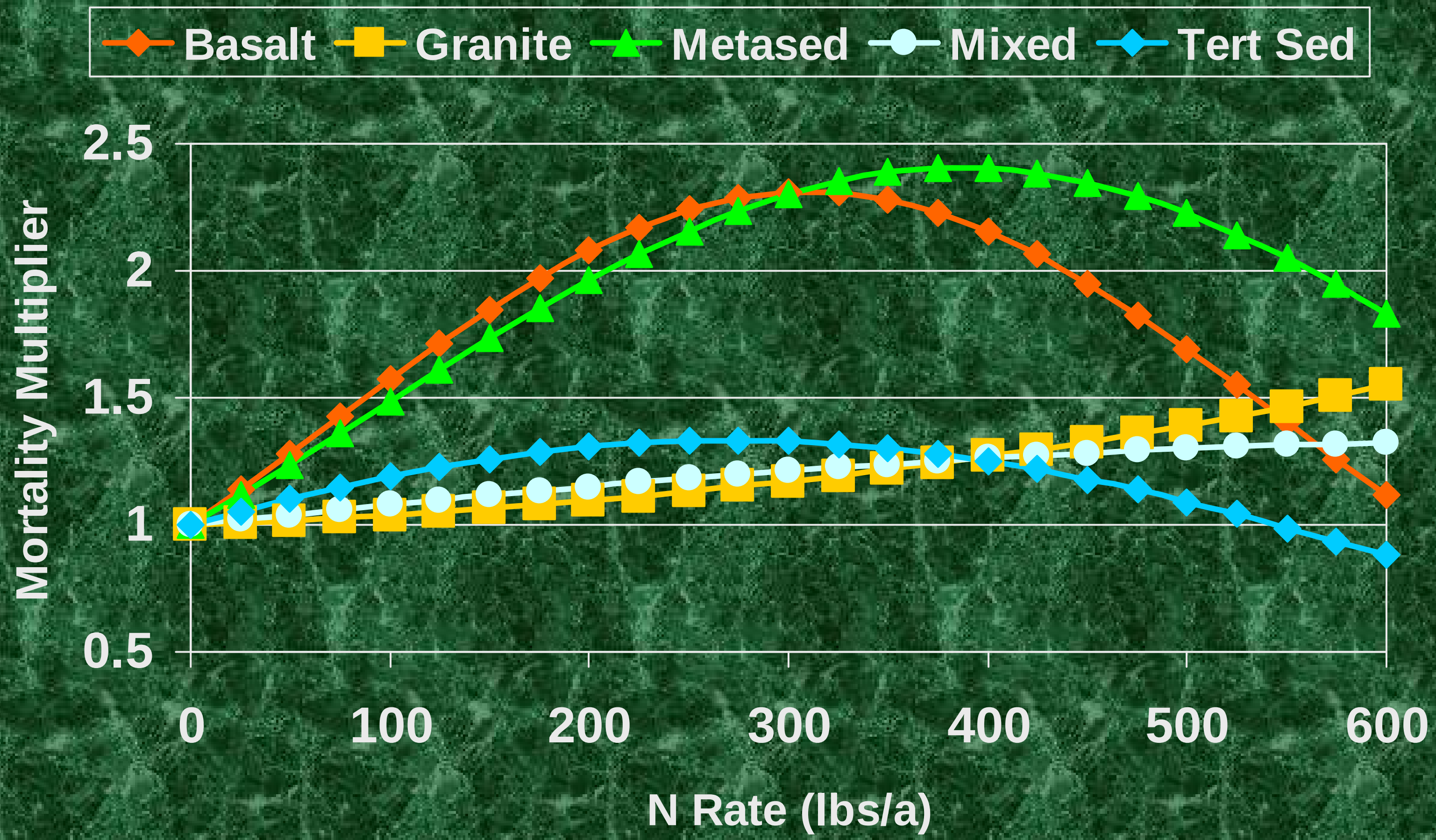
Further Work

- Repeated application analysis
- Modeling site-related effects on growth and mortality relationships to N application rate
- Examining site subsets for possible relationships of K application rate to growth and mortality

Mortality multipliers N effects on % volume/a mortality by vegetation series and rock type



Mortality multipliers
N effects on % trees/a mortality



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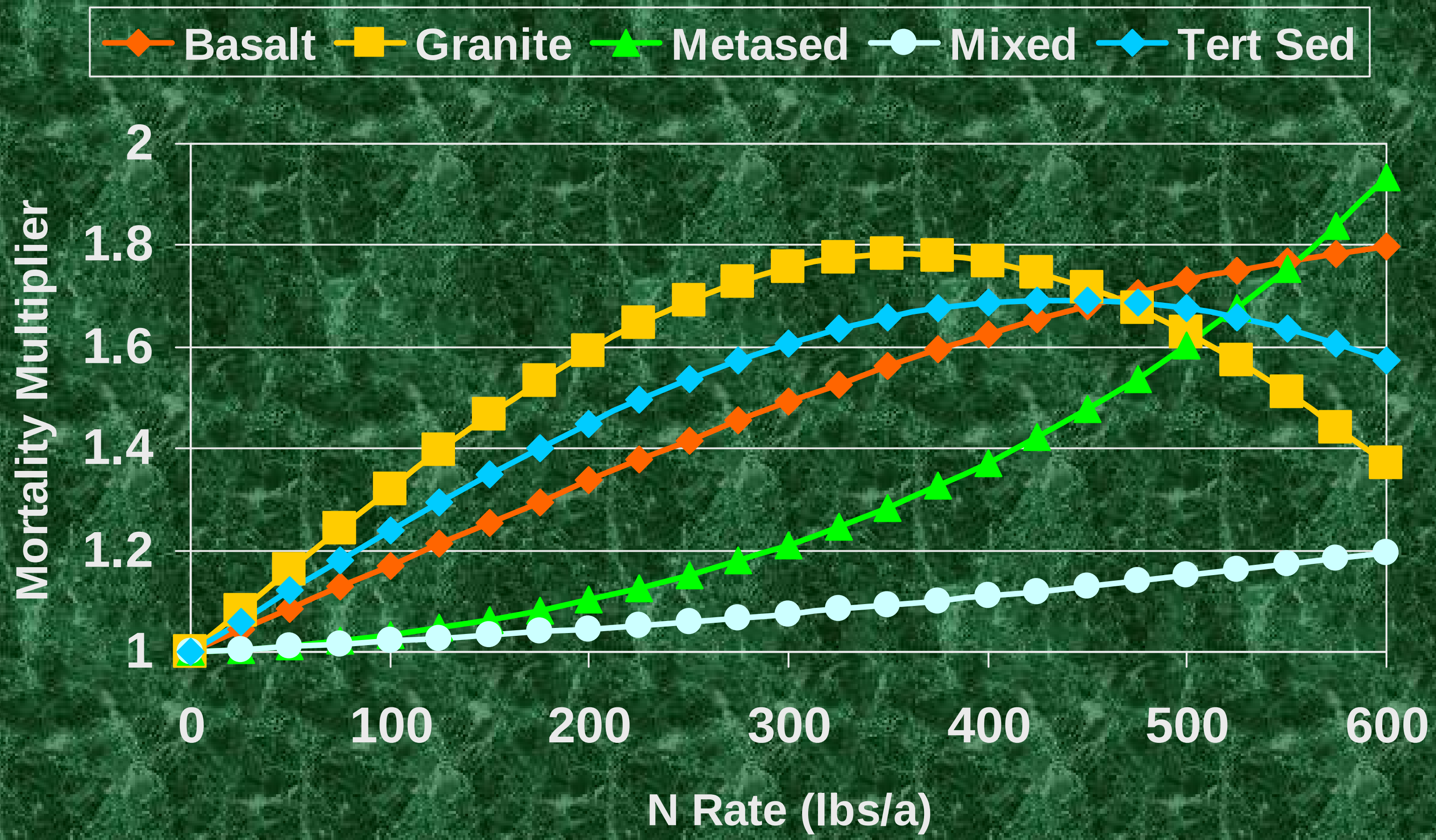

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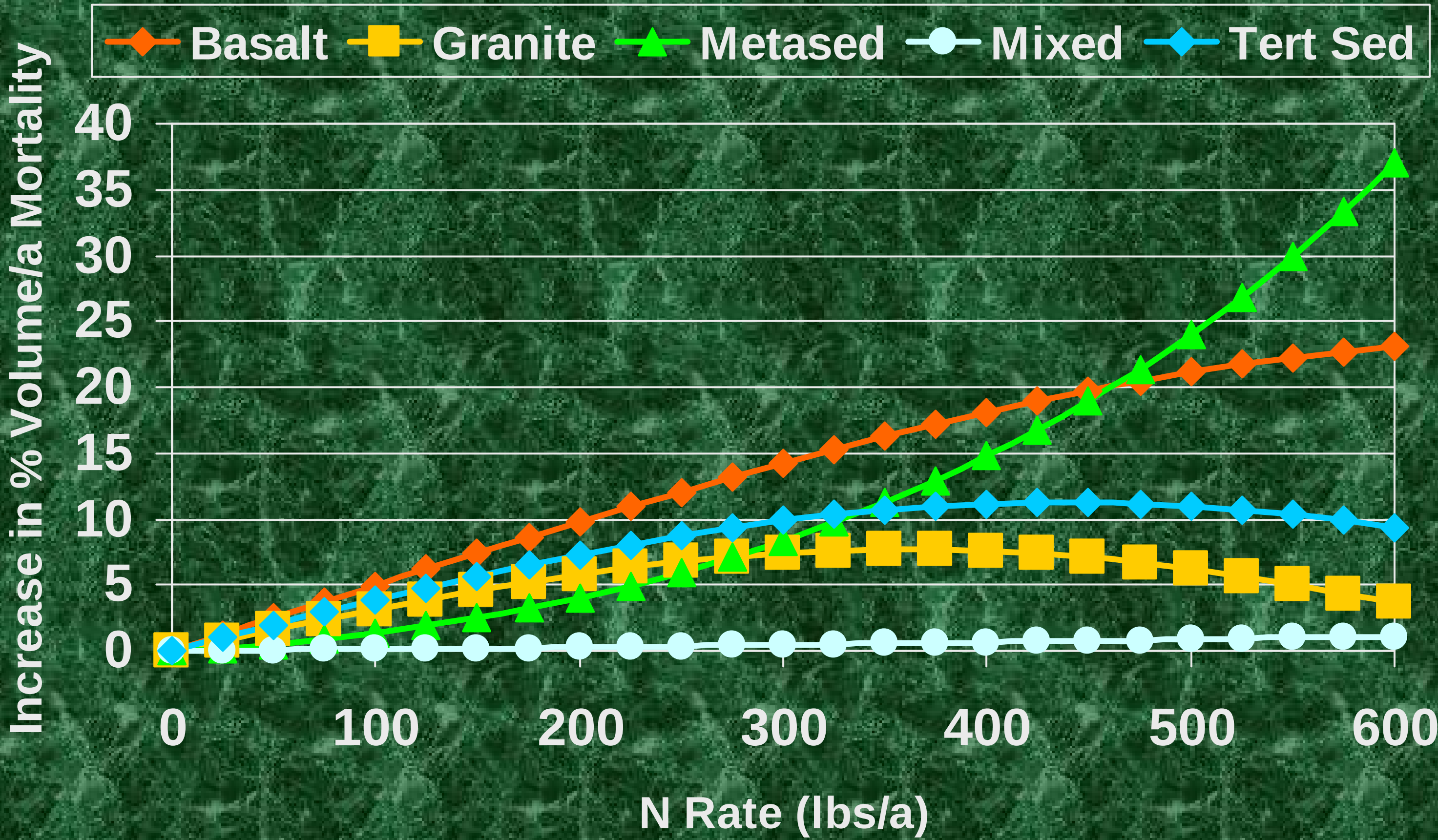

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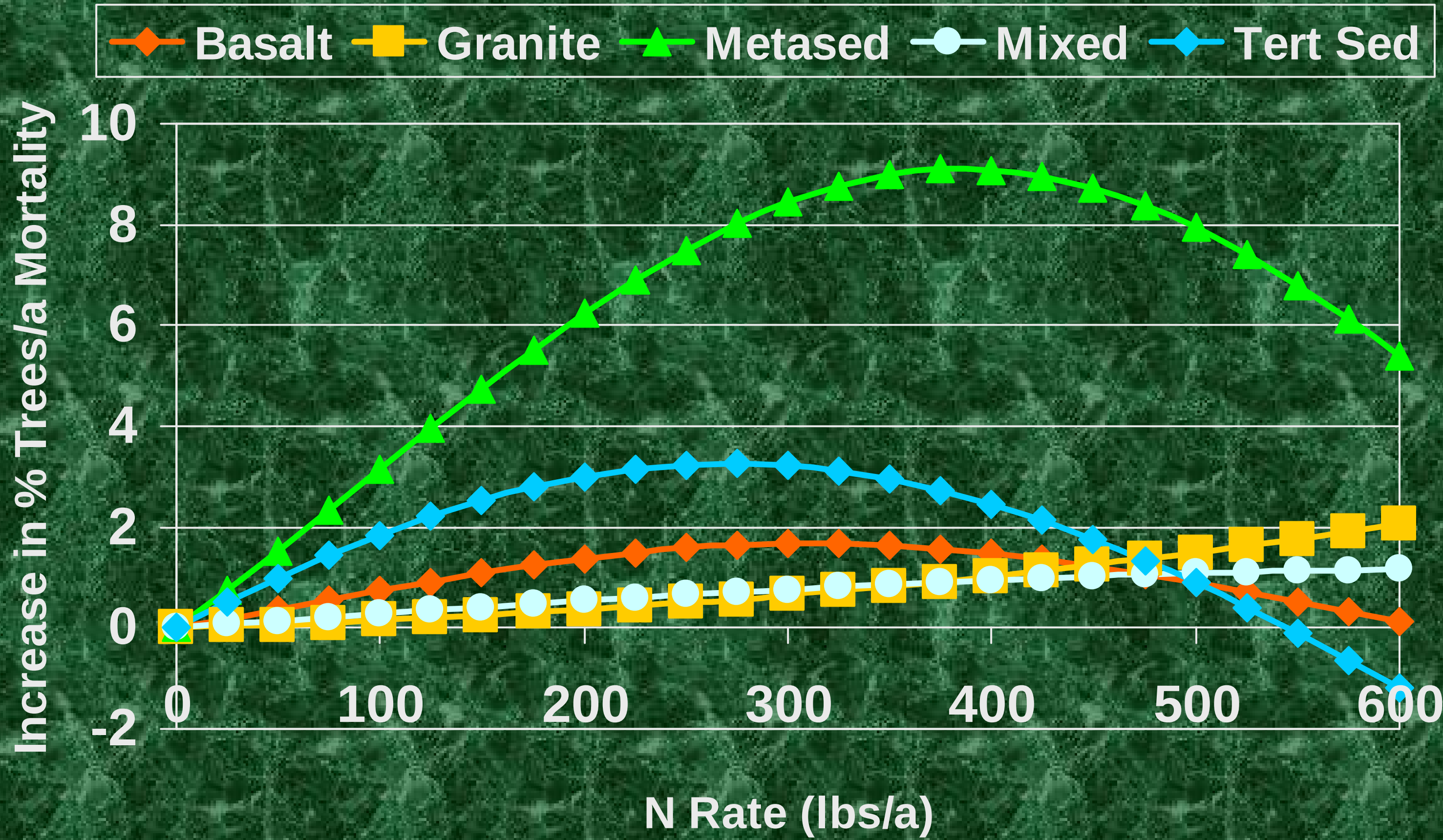

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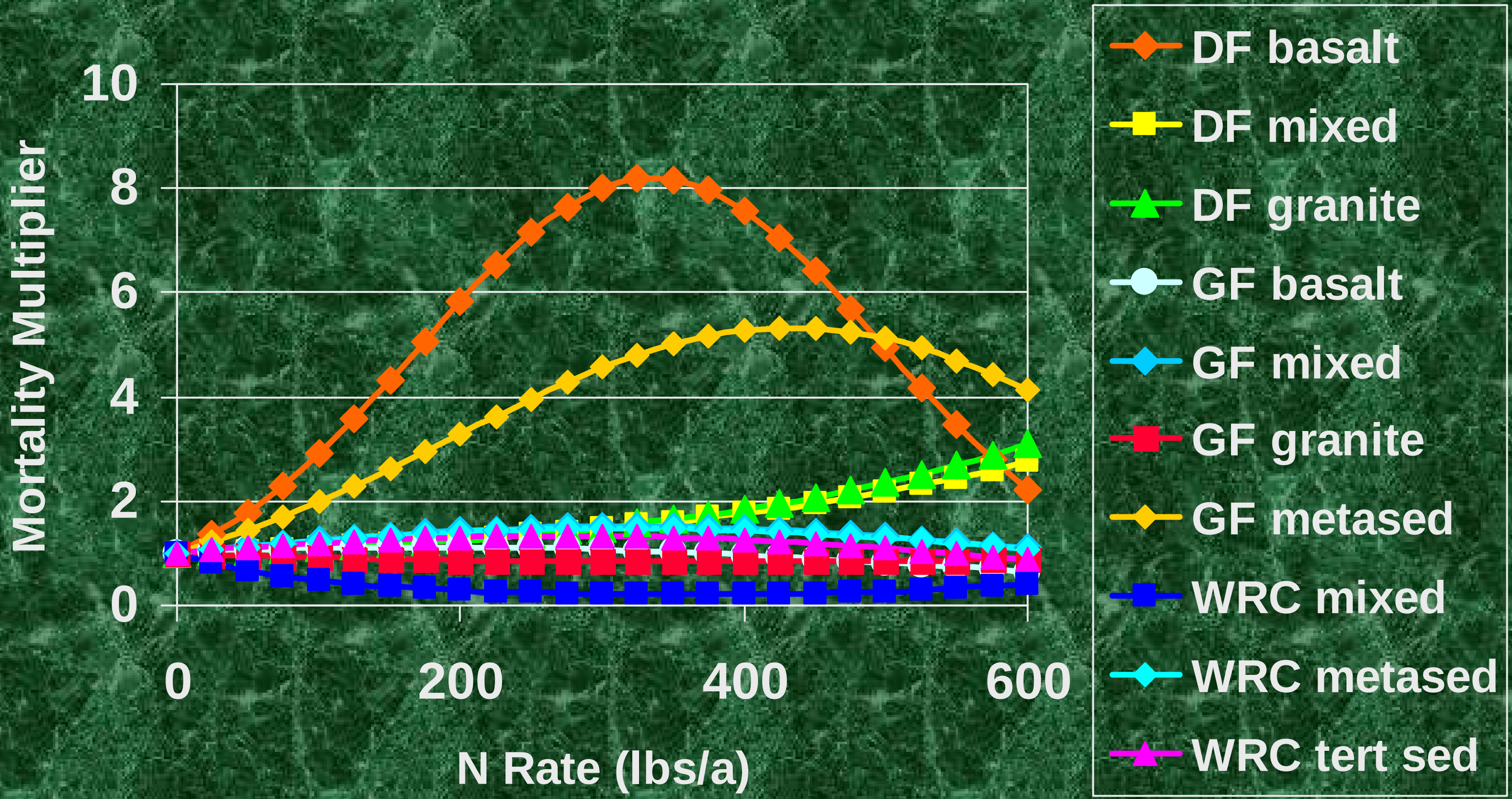
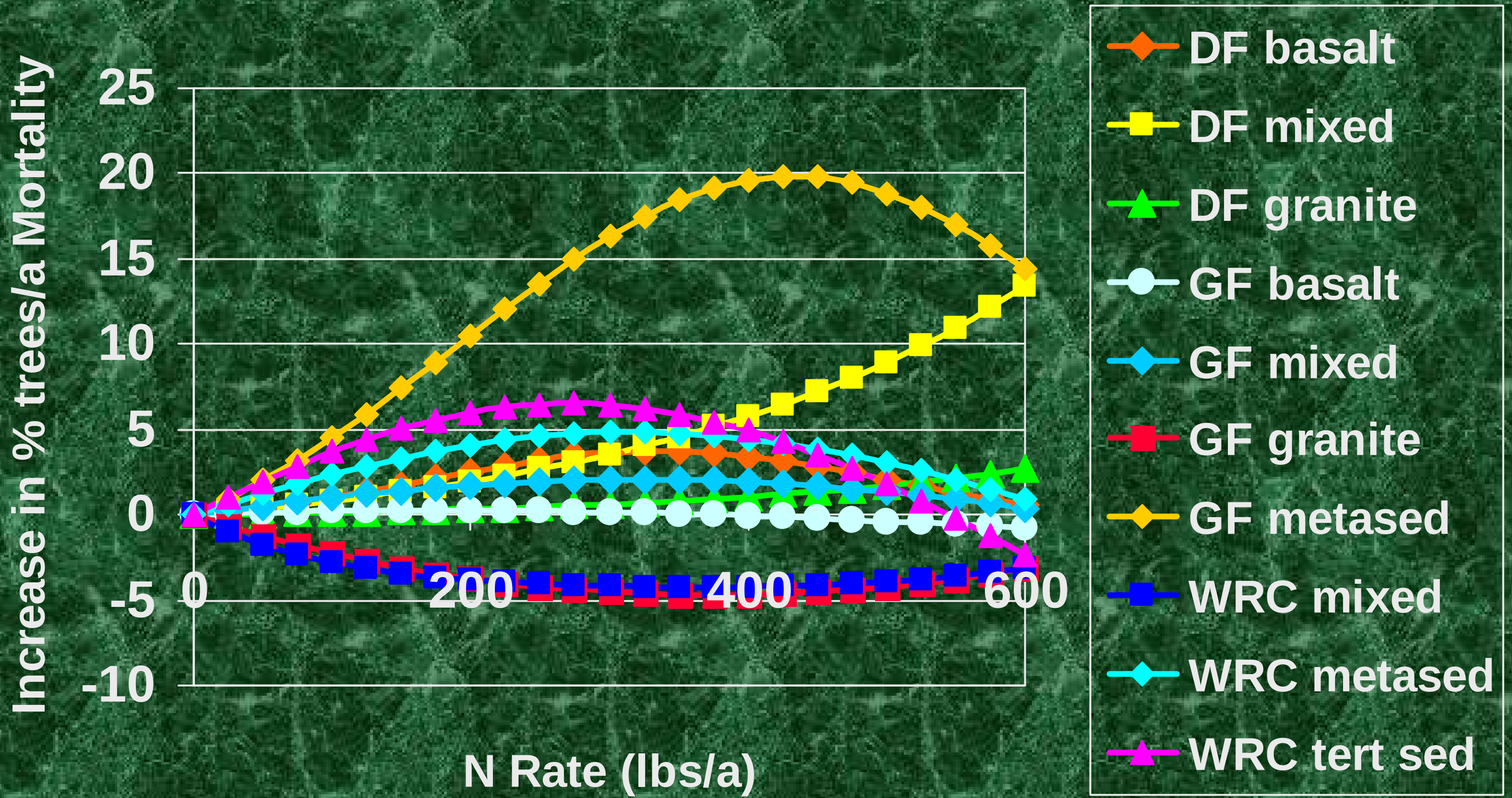


Mortality multipliers
N effects on % trees/a mortality by vegetation series and rock type



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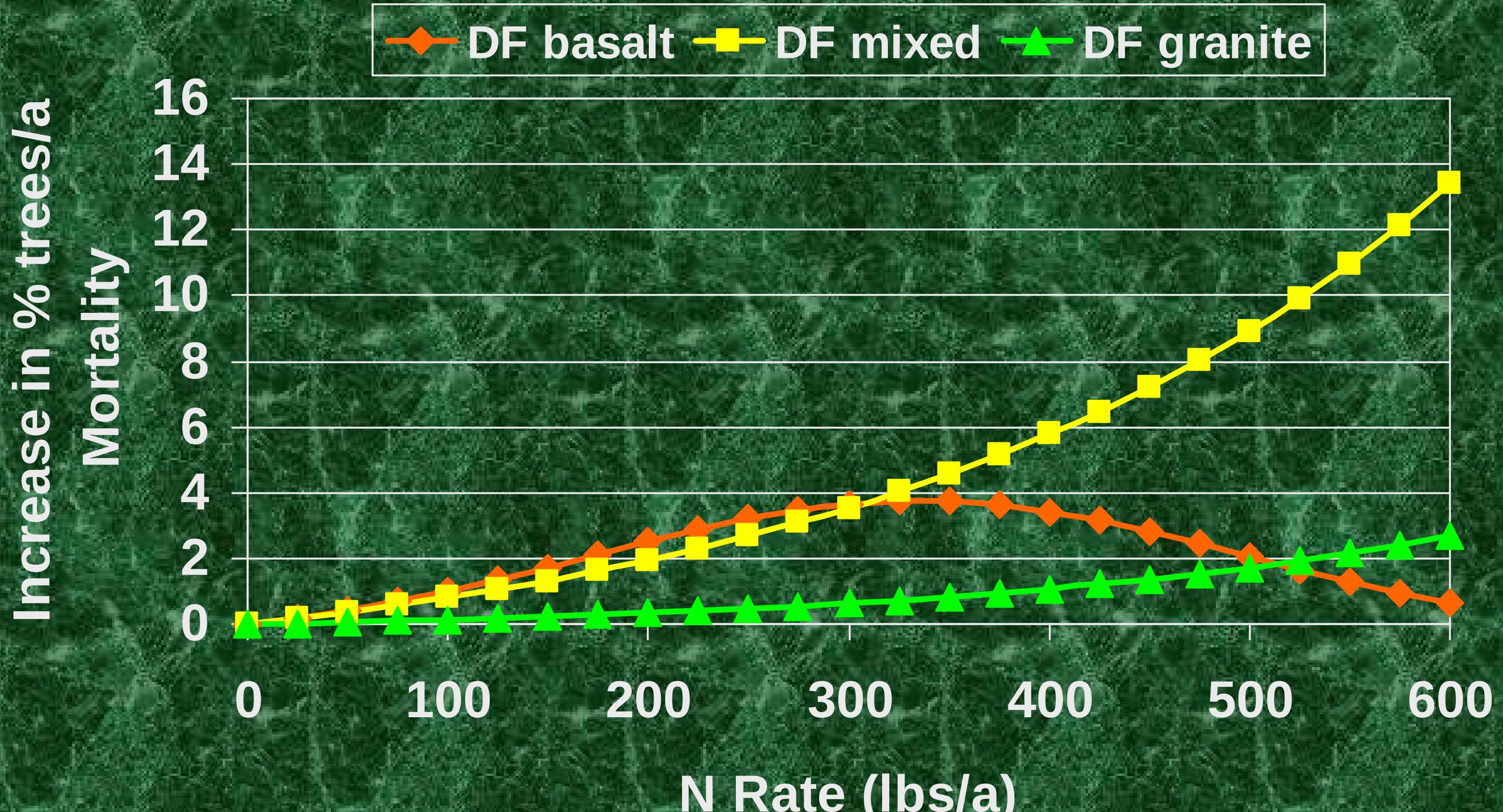

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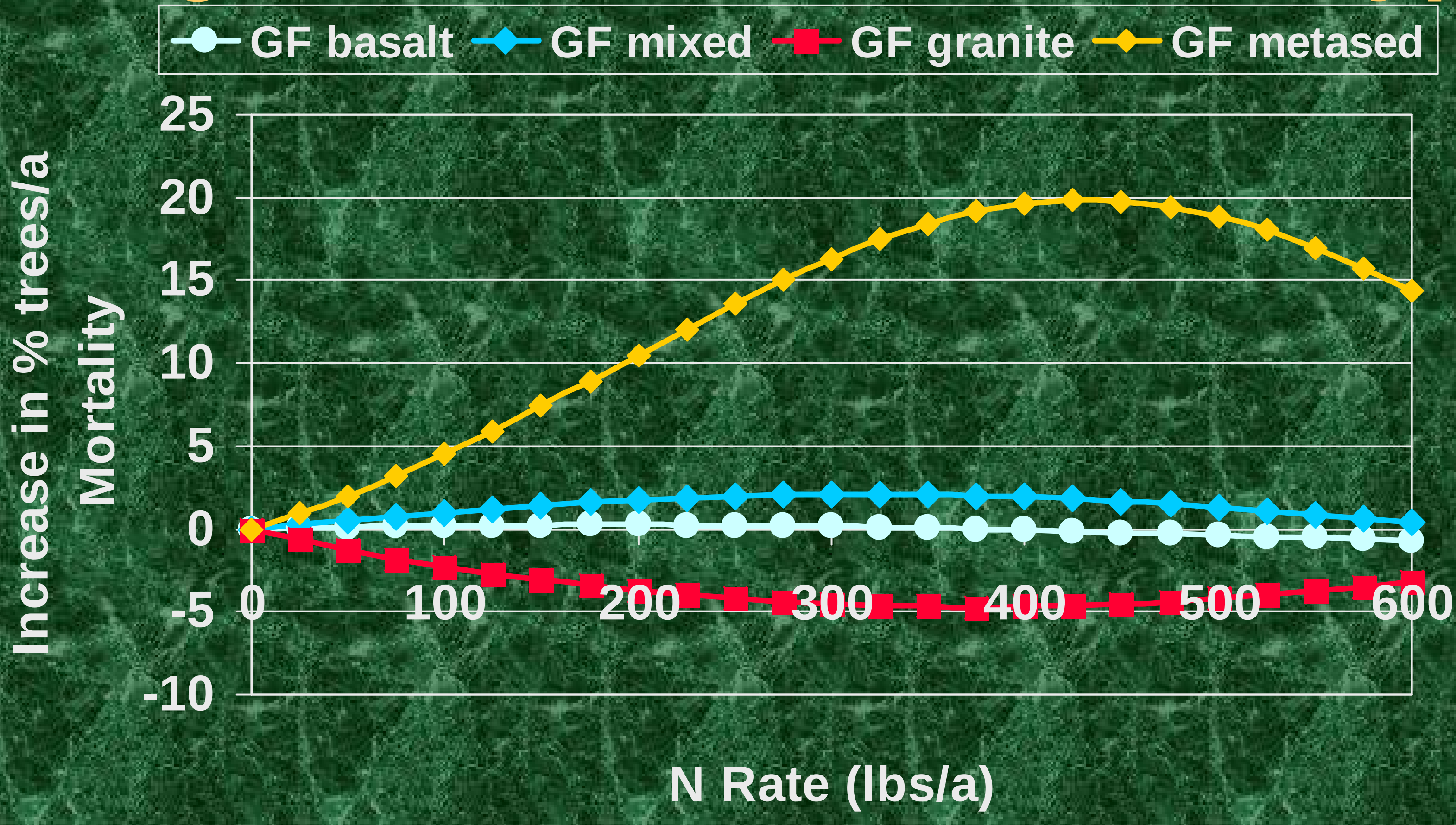

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