Seedbed Density - Soil Fertility Relationships in Conifer Seedling Growth

Albert L. Leaf and Norman A. Richards*

The significance of seedbed density and nursery soil fertility as prime considerations in producing good quality seedlings is well known in forest nursery literature.

A point that is less clear is the answer to what is a good quality seedling. Such a seedling needs a healthy top of sufficient size with ample foliage, accompanied by a vigorous root system and ability to rapidly regenerate new roots when outplanted. Though there are numerous seedling grading systems based on morphological and physiological criteria as well as outplanting performance, there is yet to be developed real seedling grading standards for various species .

Nurserymen of long experience have been able to arrive at grading guides based on seedling dimensions that may be related to seedlings that do reasonably well on most outplanting sites. These are guides rather than standards, in part because of the subjective aspect in the grading, and in part because measures of seedling morphological characteristics do not guarantee seedling establishment and growth success over a wide range of outplanting site conditions. Generally these guides, determined in various fashions, imply that a large seedling, within limits of handling, that is well balanced in height and caliper, and shoot and root, is a desirable seedling.

Nursery soil fertility status is related with seedbed density in the production of good quality seedlings. A soil of relatively low fertility requires a lower seedbed density to produce satisfactory seedlings. Stated another way, there is a direct relationship between seedbed density and soil fertility in the production of good quality seedlings . Concern for both variables is necessary to maintain high production of good quality seedlings per unit area of seedbed. Another aspect of this relationship is the time factor. Careful control of seedbed density and soil fertility may permit shorter rotations to produce good quality seedlings.

The following discussion is based on a study at the College of Forestry nursery at Syracuse that deals with 10 conifer species grown under approximately six seedbed densities in a nursery subjected to similar soil management conditions The data are limited by the conditions in the nursery, but do imply the effects of seedbed density within species and a comparison between species.

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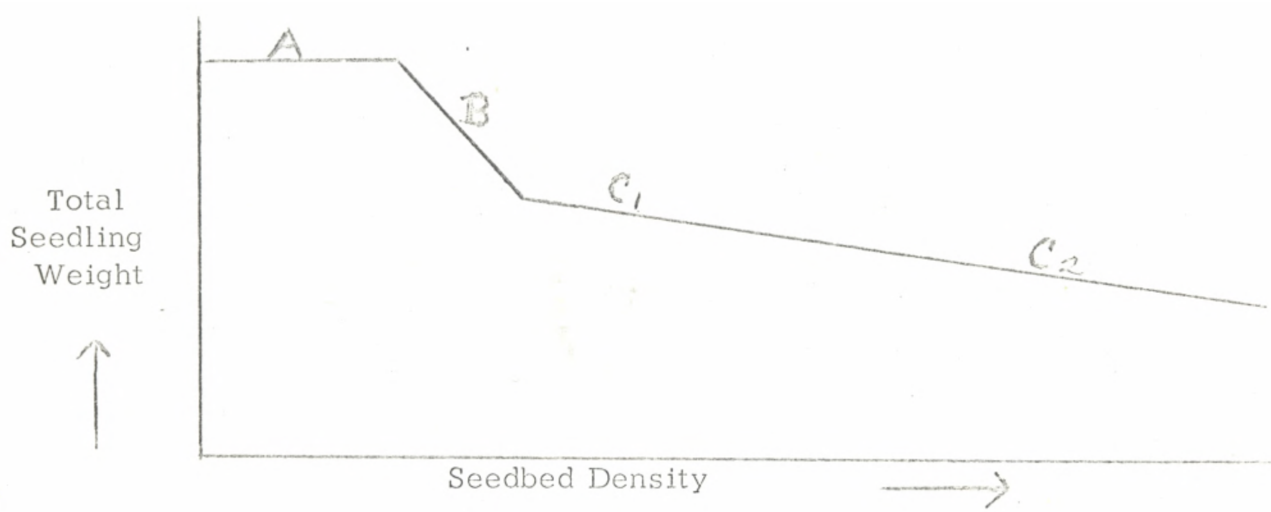
The soil conditions p this nursery include:

Texture: 83 - 87% sand, 7 - 9% silt, 5 - 7% clay
pH: 5.7 - 6.9
Organic Matter: 4.7 - 6.0%
Total N: 0.115 - 0.165%
Available P: 16 - 26 ppm
Exchangeable K: 35-64 ppm
Exchangeable Ca: 1480 - 1830 ppm
Exchangeable Mg: 76 - 96 ppm

In the autumn, prior to establishing this study the area received 200 pounds per acre of amonium sulfate, 500 pounds per acre powdered sulfur, and a top dressing of peat moss at 8 cubic feet per 200 square feet. This was all rototilled into the soil before seeding. Just prior to the beginning of the second year of growth of the seedlings a top dressing of 5-10-5 was applied at the rate of one pound per seedbed. Irrigation water .supplemented precipitation throughout' this study so the soil received one inch of water per week during the growing season. These conditions represent a favorable nursery soil for the 10 species studied.

Figures 1 through 10, all with the same x and y axis scales, indicate the effects of seedbed density on the average seedling root, stem, foliage and total seedling weights per square foot. It is readily apparent that there is an inverse relation between seedling weight dimensions and yields per square foot of seedbed in relation to seedbed density. And it is also readily apparent that there are considerable differences between species in the magnitude of this relationship.

Ideally, over the full range of seedbed densities, the curve of total seedling weight over seedbed density would demonstrate three zones:



Zone A - Seedbed density not affecting seedling weight. Seedbed density not fully stocked until inflection point between zones A and B are reached.

Zone B - Increased density resulting in sharp decrease in total seedling weight due largely to decreased branching. At inflection between zones B and C an unbranched seedling results.

Zone C - Increased density resulting in gradual decrease in total seedling weight due largely to reduced caliper in C_1 and also reduced height in C_2.

Not all 10 species show all zones in the attached curves because of the choice of densities used and growth characteristics of the species .

The data of balsam fir and Douglas fir depict zones C only because these two species normally are not branched as 2-0 stock. The data for Japanese larch also depicts zone C because at 23 seedlings per square foot zones A and B have already been surpassed. All the other species except black spruce depict zones B and C because even at the low densities studied, zone A has been surpassed. Only black spruce depicts all three zones. In general the inflection between zones B and C occurred below 40 seedlings per square foot for the pines and above 40 seedlings per square foot for the spruce. Black spruce shows zone A ending at 40 seedlings per square foot.

Also, many species showed a leveling of yield per square foot with higher densities, i.e. black spruce at about 40 seedlings, Japanese larch at about 70 seedlings, Douglas fir at about 80 seedlings per square foot, etc. However, blue spruce and white pine showed increasing yield per square foot to about 100 seedlings or more.

The changes in density had a marked effect on the proportions of foliage, stem and root tissue of the seedlings. The proportion of seedling top to root weights remained relatively uniform regardless of density, tops ranging from 55 to 85 percent of the total dry weights depending on species (balsam fir 55 - 60% and Scotch pine 80 - 85% of total seedling weights), while the proportion of foliage to stem varied with species and density. Japanese larch, balsam fir, blue spruce, and white spruce showed the foliage proportion increased with increasing density, while Douglas fir, red pine and white pine showed the reverse trend.

As indicated in Table 1, average seedling heights of extremes in density at 1-0 and 2-0 were not a good indication of changes in seedling weights with density. Average caliper appeared to be a better indicator of the average seedling's reduced weight with increasing density. However, neither height nor caliper illustrated the striking change in seedling dimensions as average dry weight. For example, black spruce seedling weight was reduced more than 500 percent within the density extremes while Norway spruce was reduced to one-third, and Scotch pine, blue spruce, white pine, red pine and white spruce were reduced to about one-half of their low density weight at the highest density tested in each case.

On a per unit area basis, Table 2 shows the total seedling dry weight production in pounds per acre. If the nurserymen were producing only tonnage of dry matter, one would favor the higher densities which produced approximately two to over three times that of the lowest densities under the conditions tested. In a few cases, i.e. Scotch pine, blue spruce and Douglas fir, as much as seven to eight tons of total dry weight per acre were produced. The highest production obtained was with Japanese larch at over 12 tons of total dry weight per acre in the 2-0 rotation.

Though data is available on the uptake of N, P, K. Ca, and Mg in concentration and content by seedling tissue components (roots, stem, foliage) with striking differences apparent within species at various seedling densities and between species, it might suffice here to discuss total uptake of each element at the extremes in densities on a pounds per acre basis. First, as expected, lower amounts of each element were taken up at the lowest densities with eat variations between species. For example, black spruce and balsam fir took up the least N at low densities; Scotch pine and, particularly, Japanese larch took up the greatest quantity of N at the highest densities. In general, there is a relationship between total dry matter production and N uptake, with about 60 to 125 pounds of dry weight produced per pound of N taken up, varying with species.

Also, in general the relationship of increased P, K, Ca and Mg uptake with increased total dry matter production held as with N. For example, the 12 tons per acre dry matter of Japanese larch at the highest density also showed the greatest uptake of all nutrient elements tested. General nutrient uptake ranked as follows:

N K Ca P N Mg

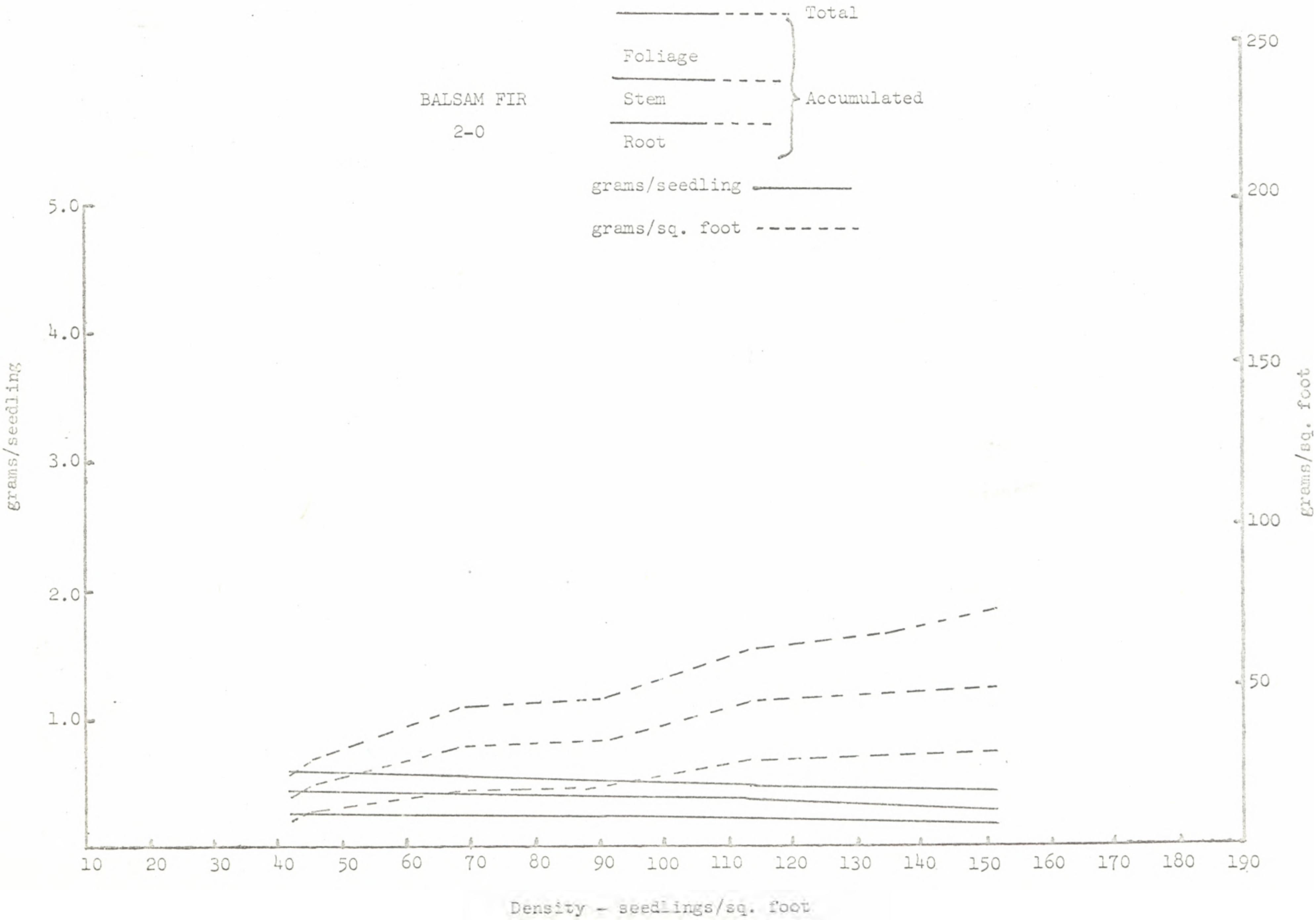
The relationship of K to Ca uptake changed ranking within species because of density, i.e. Douglas fir and red pine, and between species:

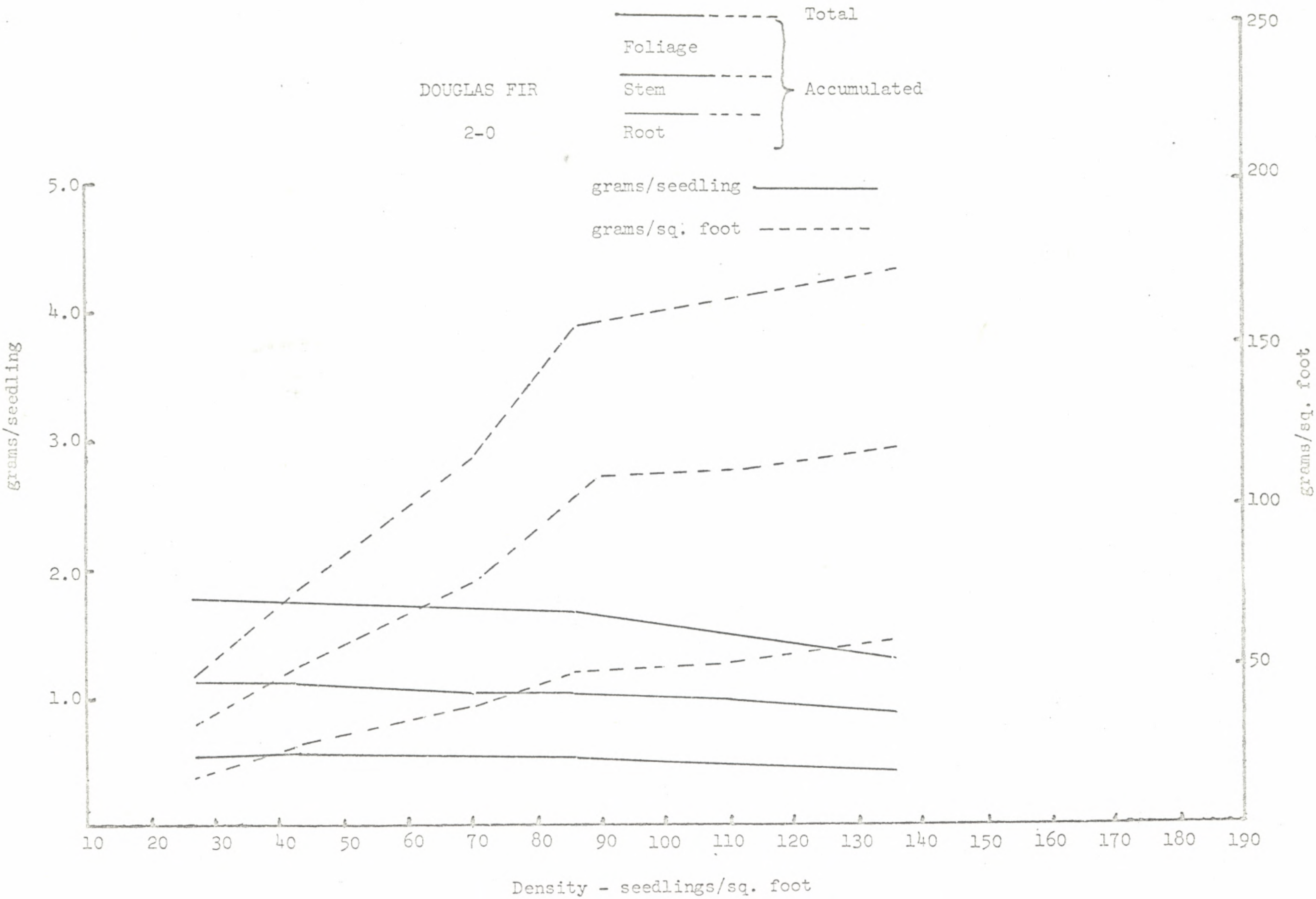
K Y Ca in Scotch pine and Japanese larch, and
Ca > K in black spruce, blue spruce, balsam fir, white pine, white spruce and Norway spruce.

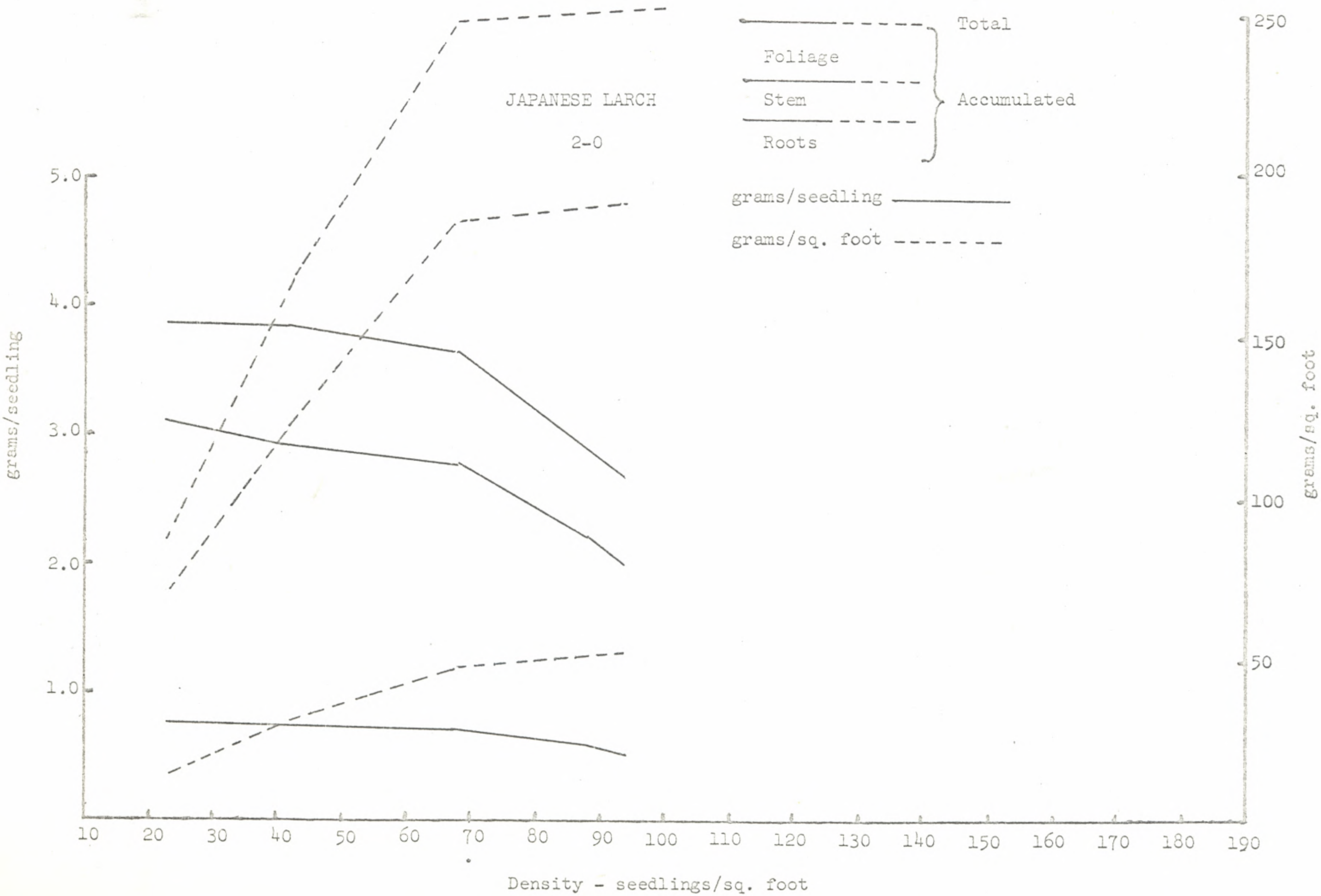
While 60 to 125 pounds of total dry matter production was produced per pound of N uptake, the proportion for Ca and K was about 100 to 200 pounds of total dry matter per pound of element. For P the ratio of pounds of dry matter per pound of element uptake was about 250 to 700, and for Mg the values for dry matter ranged from 600 to 1100. Thus , it is apparent that there were general relationships depending upon the element being considered, but that variation between species was great in this regard.

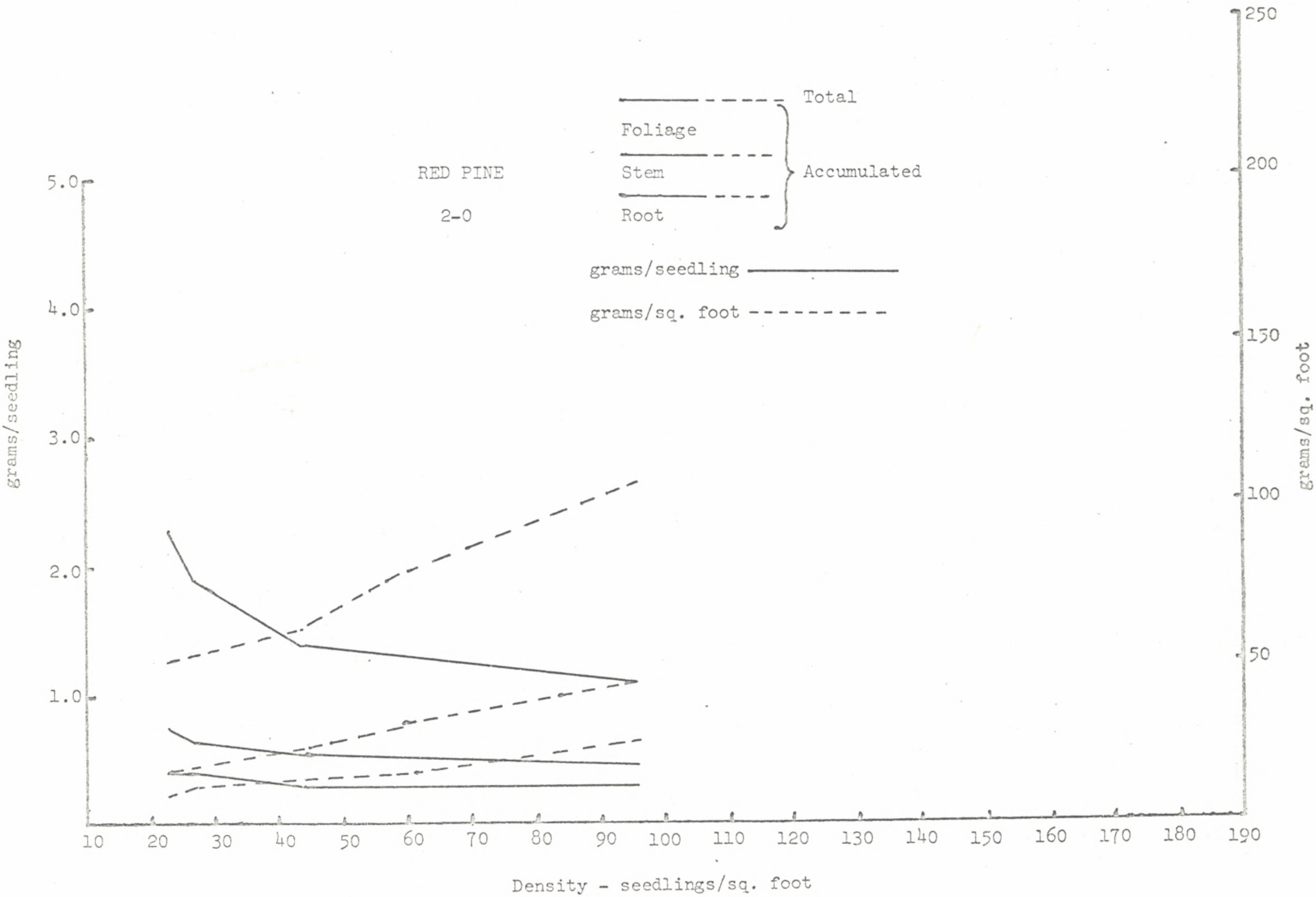
The major concern with the results of the tissue chemical analysis in this discussion, however, should center upon that uptake to produce good quality seedlings rather than maximum dry matter production. For example, it is more important that 30 to 60 pounds of N is taken up to produce good quality white and red pine than the fact that about 100 to 150 pounds of N is taken up to produce almost 100 seedlings per square foot of poor quality of these species. It would take lower rates of fertilizer additions to the nursery to produce 20 to 40 good quality seedlings per square foot than to produce 50 to 150 poor seedlings.

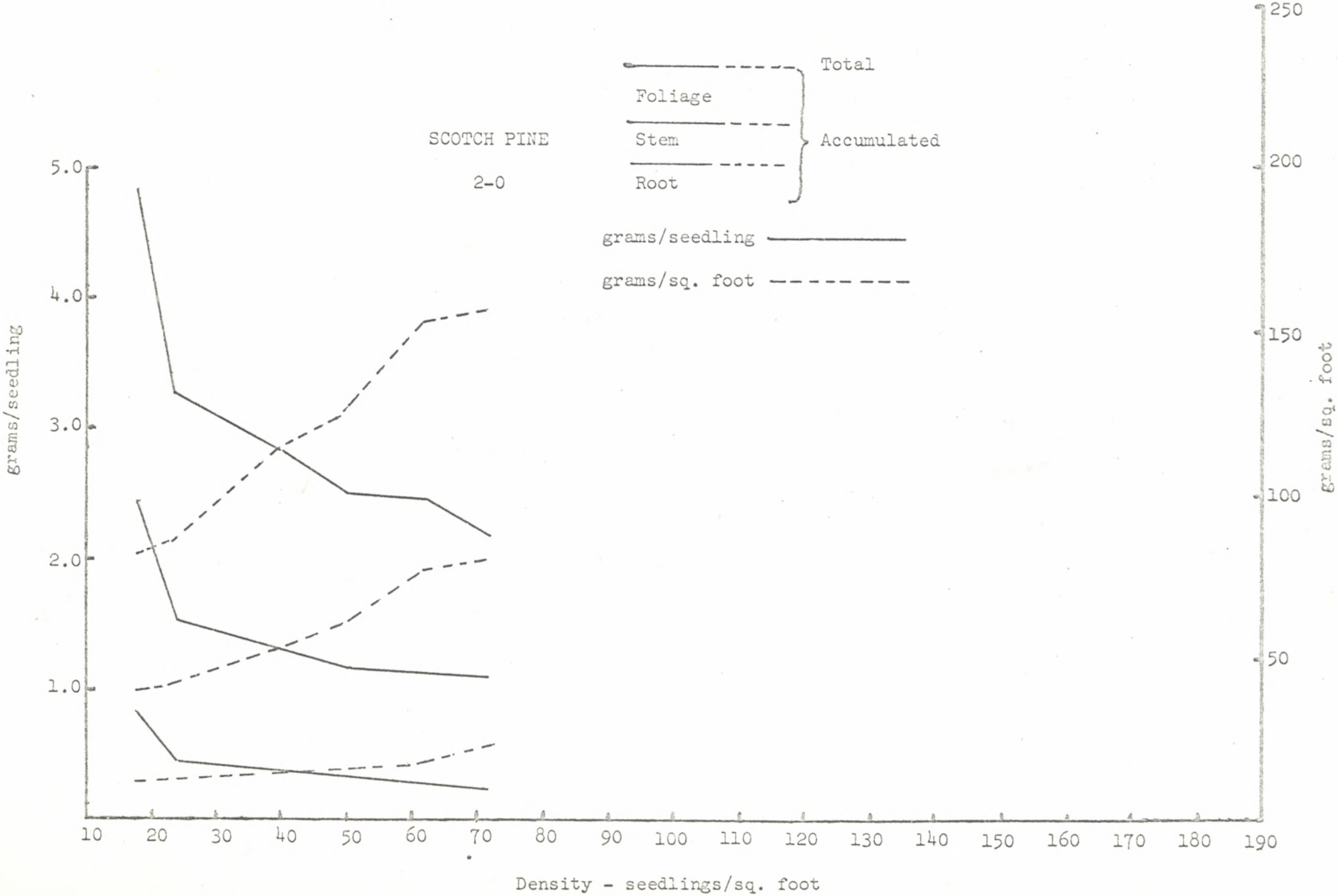
A point that impressed us while conducting this study in a nursery with high soil productivity was the low density values in which sharp changes in seedling weight occurred. It is suggested that in nurseries with less productive soil, these sharp changes in seedling weight may be even more significant. This raises the possibility that, at least for several species, relatively low seedling densities should be maintained for high quality seedling production. More work is needed to better describe the proper seedbed density—soil fertility relationships to obtain the balance between high production and good quality seedlings.


BALSAM FIR
2-0
Total
Foliage
Stem
Root
Accumulated
grams/seedling
grams/sq. foot
5.0
4.0
3.0
2.0
1.0
250
200
150
100
50
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
Density - seedlings/sq. foot

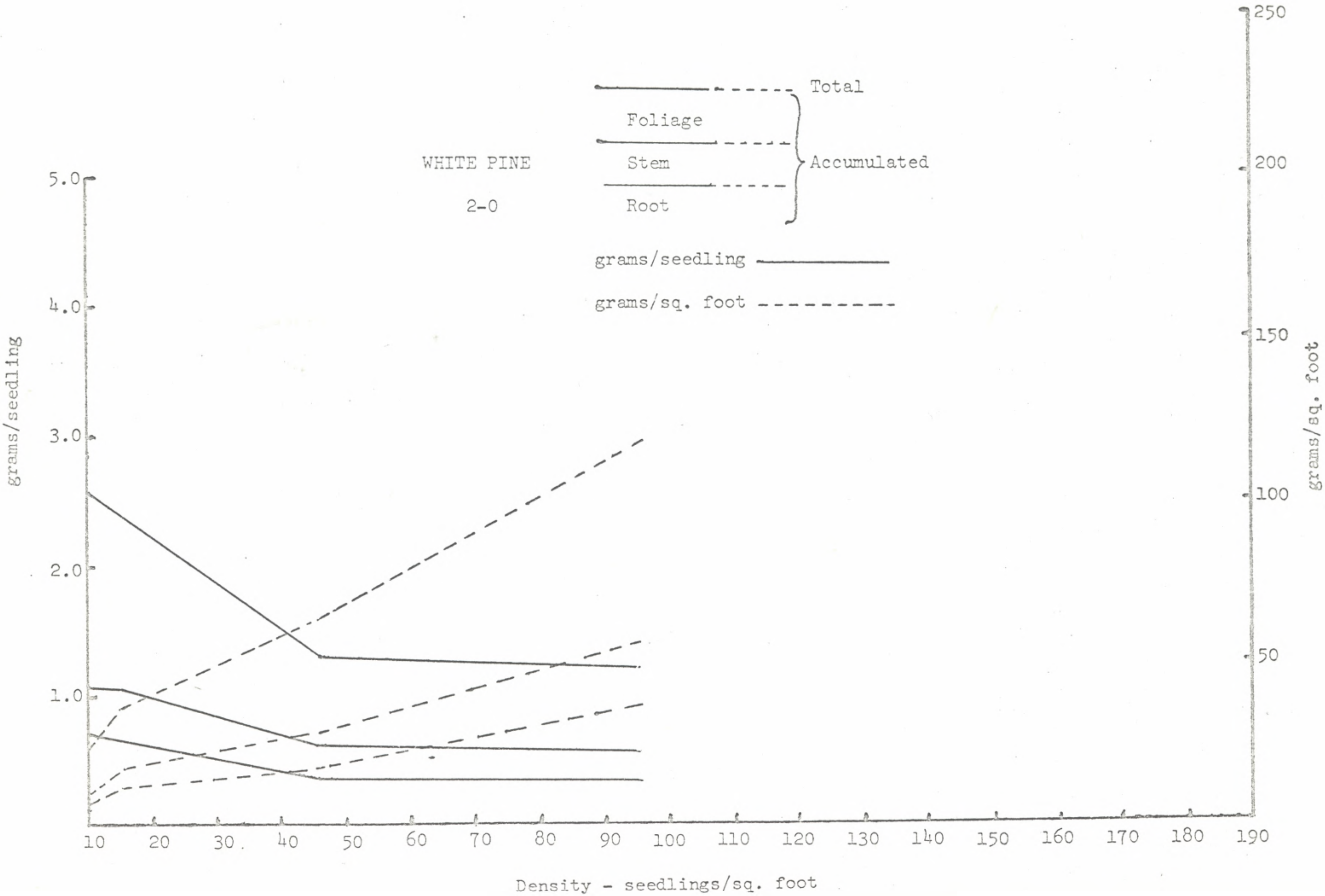

DOUGLAS FIR
2-0
Total
Foliage
Stem
Root
Accumulated
grams/seedling
grams/sq. foot
5.0
4.0
3.0
2.0
1.0
250
200
150
100
50
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190
Density - seedlings/sq. foot

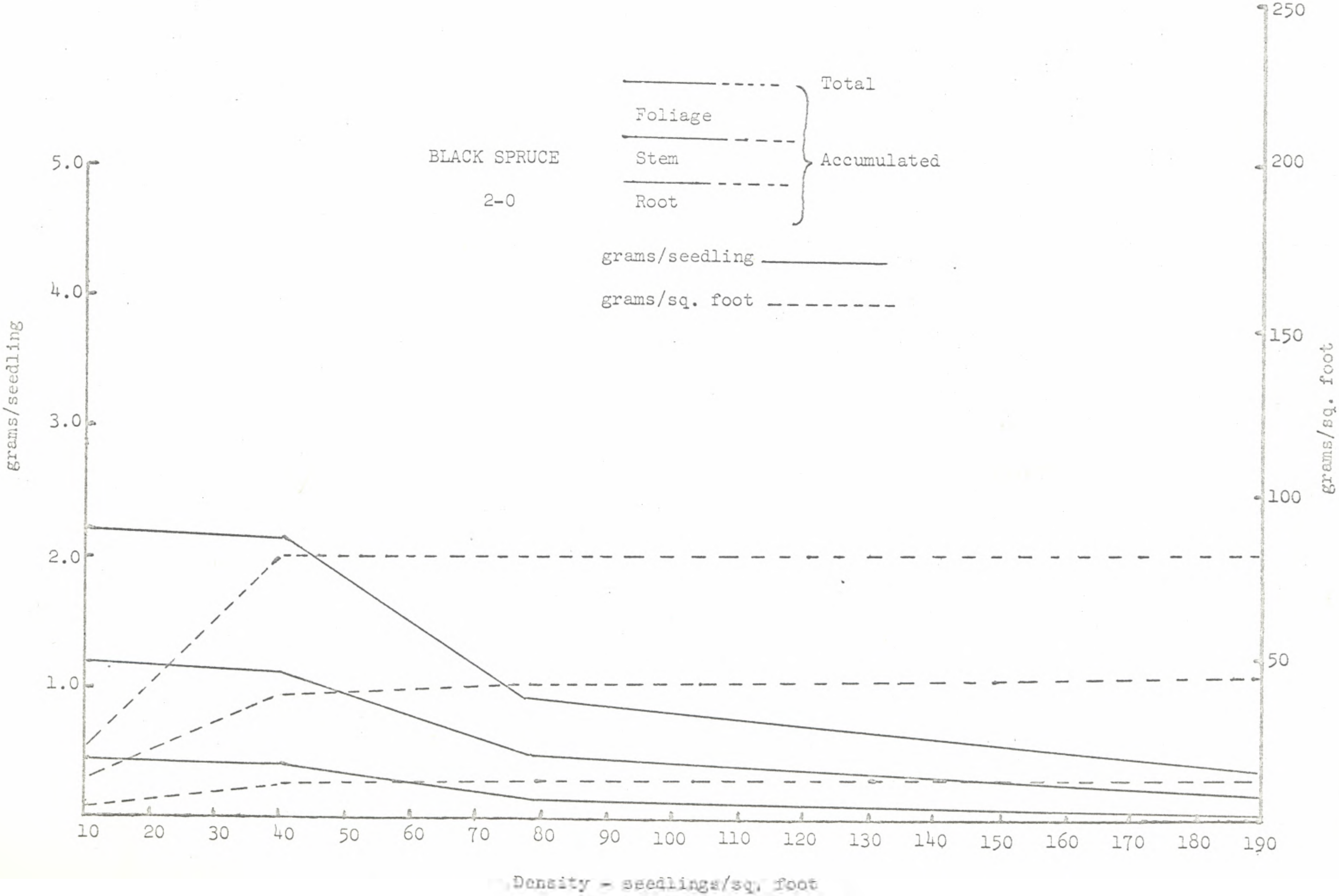

JAPANESE LARCH
2-0
Total
Foliage
Stem
Roots
Accumulated
grams/seedling
grams/sq. foot
5.0
4.0
3.0
2.0
1.0
grams/seedling
250
200
150
100
50
grams/sq. foot
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
Density - seedlings/sq. foot

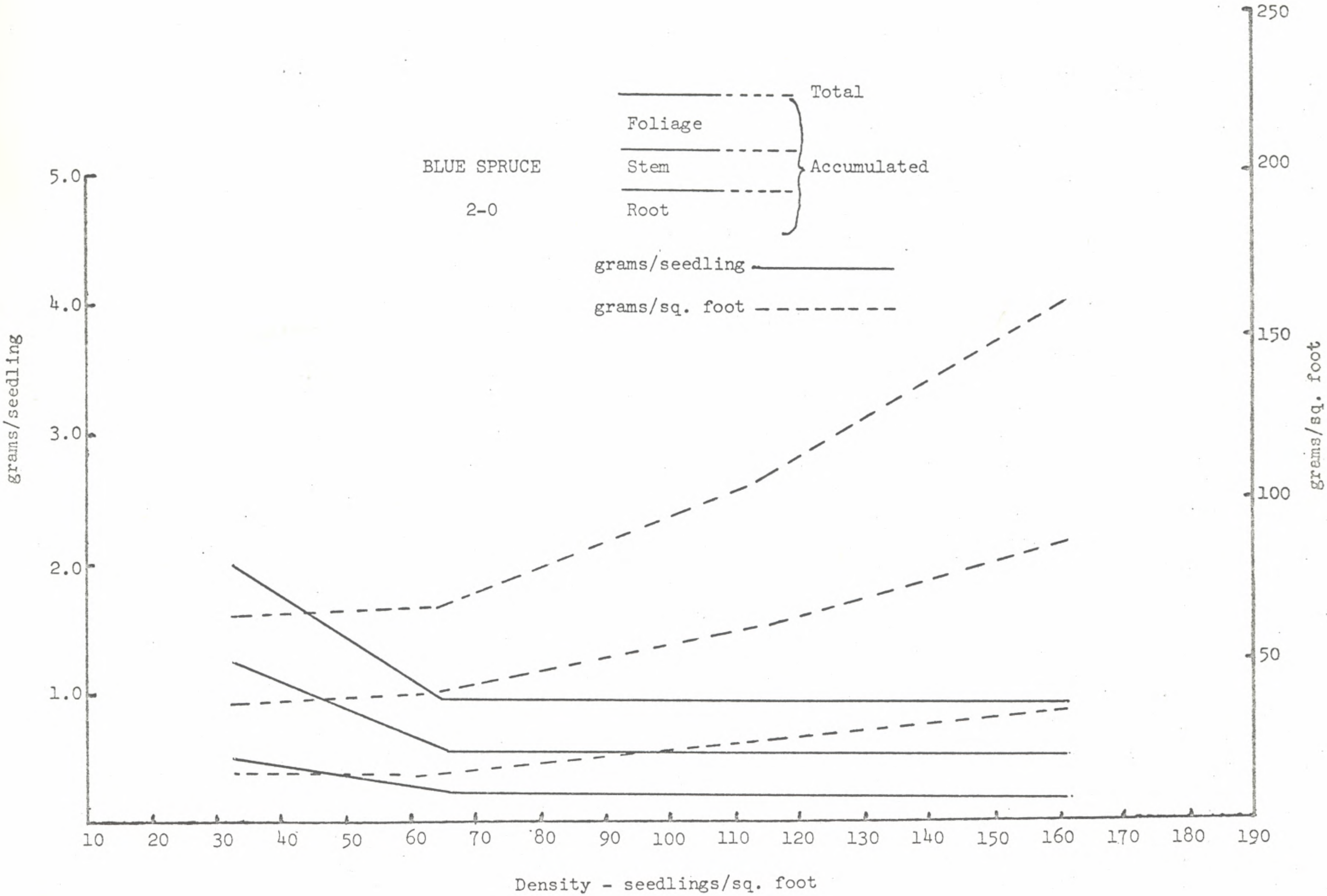

RED PINE
2-0
Total
Foliage
Stem
Root
Accumulated
grams/seedling
grams/sq. foot
5.0
4.0
3.0
2.0
1.0
250
200
150
100
50
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
Density - seedlings/sq. foot

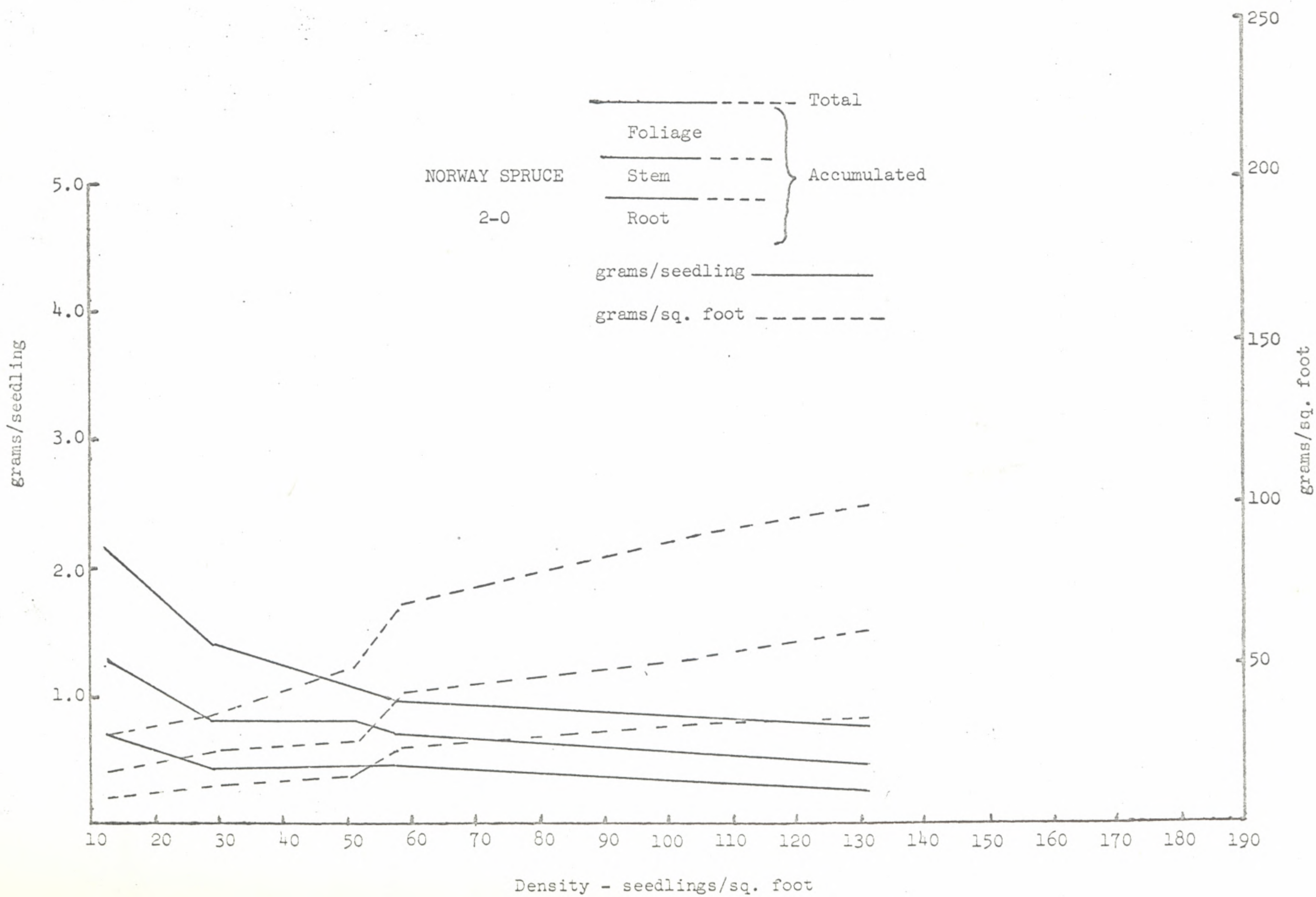


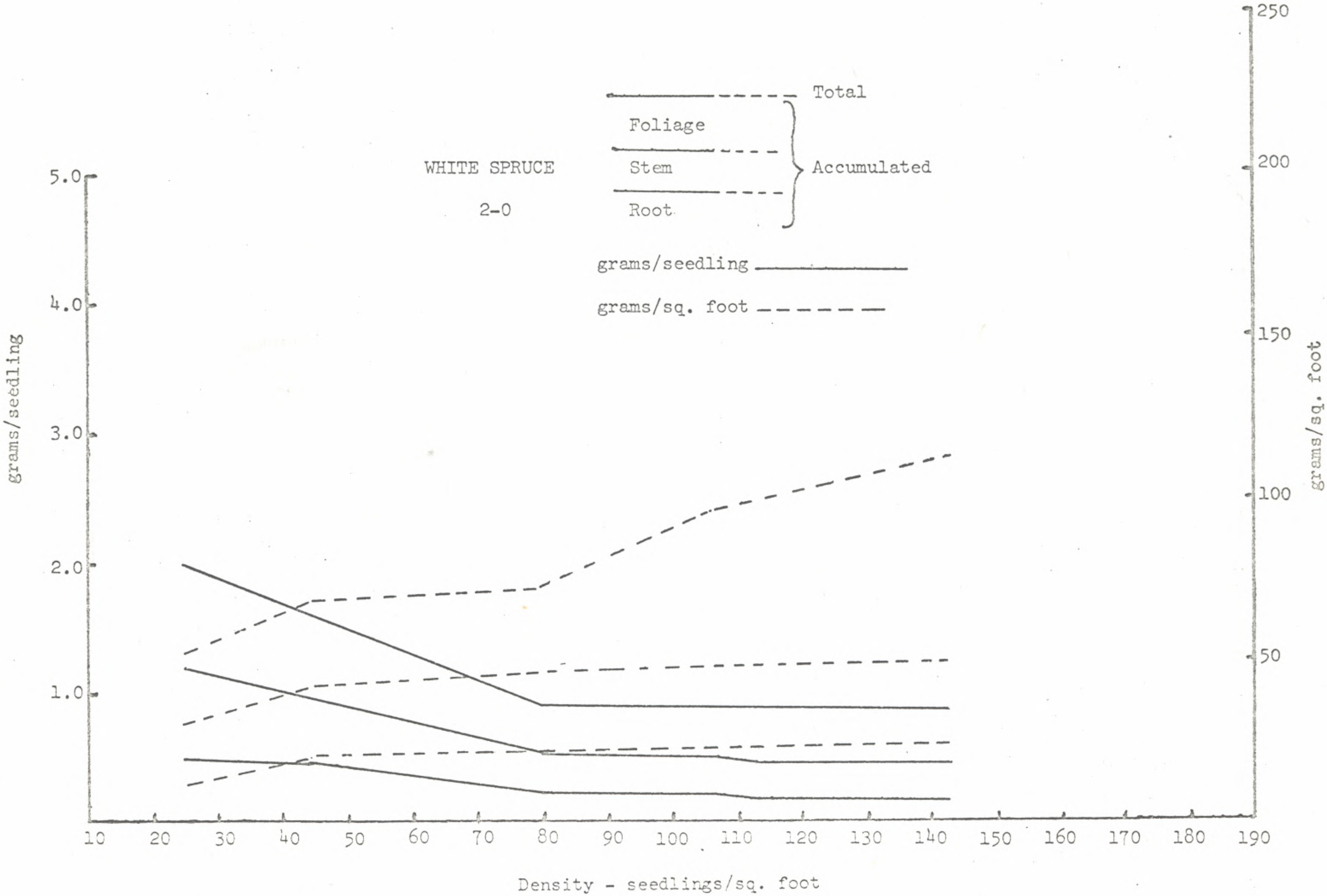
SCOTCH PINE
2-0
Total
Foliage
Stem
Accumulated
Root
grams/seedling
grams/sq. foot
grams/seedling
grams/sq. foot
5.0
4.0
3.0
2.0
1.0
250
200
150
100
50
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
Density - seedlings/sq. foot


WHITE PINE
2-0
Total
Foliage
Stem
Root
Accumulated
grams/seedling
grams/sq. foot
5.0
4.0
3.0
2.0
1.0
grams/seedling
250
200
150
100
50
grams/sq. foot
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
Density - seedlings/sq. foot


BLACK SPRUCE
2-0
Total
Foliage
Stem
Accumulated
Root
grams/seedling
grams/sq. foot
5.0
4.0
3.0
2.0
1.0
250
200
150
100
50
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190
Density - seedlings/sq. foot


BLUE SPRUCE
2-0
Total
Foliage
Stem
Root
Accumulated
grams/seedling
grams/sq. foot
5.0
4.0
3.0
2.0
1.0
grams/seedling
250
200
150
100
50
grams/sq. foot
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
Density - seedlings/sq. foot


NORWAY SPRUCE
2-0
Total
Foliage
Stem
Root
Accumulated
grams/seedling
grams/sq. foot
5.0
4.0
3.0
2.0
1.0
grams/seedling
250
200
150
100
50
grams/sq. foot
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
Density - seedlings/sq. foot


WHITE SPRUCE
2-0
Total
Foliage
Stem
Root
Accumulated
grams/seedling
grams/sq. foot
grams/seedling
grams/sq. foot
5.0
4.0
3.0
2.0
1.0
250
200
150
100
50
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
Density - seedlings/sq. foot

AVE. HEIGHTS AND CALIPER OF

EXTREME DENSITIES, ONLY

Species	Heights		Caliper
Density	1-0	2-0	2-0
	cm		mm
BALSAM FIR			
42	6	30	2
152	6	25	2
DOUGLAS FIR			
27	10	36	3
136	13	37	2
JAPANESE LARCH			
23	44	73	4
94	30	56	4
RED PINE			
23	6	35	3
96	5	29	2
SCOTCH PINE			
18	16	46	5
72	17	42	3
WHITE PINE			
10	5	27	4
96	7	31	2
BLACK SPRUCE			
10	15	41	3
190	13	32	1
BLUE SPRUCE			
33	12	40	3
162	10	35	2
NORWAY SPRUCE			
13	11	34	3
132	11	35	2
WHITE SPRUCE			
25	13	36	3
143	12	34	2

YIELDS OF EXTREME DENSITIES

OF 2-0 SEEDLINGS

Species - Density	Total Dry Weight	N	P	K	Ca	Mg
	----------------	pounds	per	acre	------------	
BALSAM FIR						
42	2,197	30	5	13	18	2
152	6,917	84	18	42	68	9
DOUGLAS FIR						
27	4,466	49	17	26	26	5
136	16,514	159	29	96	108	17
JAPANESE LARCH						
23	8,469	96	28	55	33	8
94	24,194	279	66	180	138	25
RED PINE						
23	5,157	66	7	33	25	7
96	10,184	109	24	62	76	14
SCOTCH PINE						
18	8,449	118	20	61	51	11
72	15,096	205	34	115	86	18
WHITE PINE						
10	2,256	31	7	13	18	4
96	11,382	157	30	70	82	14
BLACK SPRUCE						
10	2,093	30	5	15	20	3
190	7,923	69	19	53	63	9
BLUE SPRUCE						
33	6,640	85	11	42	54	8
162	15,411	154	30	99	131	14
NORWAY SPRUCE						
13	2,714	45	7	17	26	3
132	9,454	74	19	45	77	11
WHITE SPRUCE						
25	5,026	57	12	25	45	6
143	12,602	118	29	64	97	15