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To the Graduate Council:

I am submitting herewith a thesis written by Stephen Walker Radford entitled "Factors Involved in the Maintenance of the Grassy Balds of the Great Smoky Mountains National Park." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Botany.

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FACTORS INVOLVED IN THE MAINTENANCE OF THE GRASSY BALDS
OF THE GREAT SMOKY MOUNTAINS NATIONAL PARK

A Thesis

Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Stephen Walker Radford

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TABLE OF CONTENTS

SECTION	PAGE
I. INTRODUCTION.	1
II. PARTICULARS OF THE REGION	2
III. THE STUDY AREAS	5
Andrews Bald.	5
Spence Field.	5
Gregory Bald.	6
IV. MATERIALS AND METHODS	8
V. RESULTS	12
Climatic Studies.	12
Transplant Studies.	28
Growth Rate Studies	29
Seedling Studies.	35
VI. DISCUSSION.	52
VII. CONCLUSIONS	56
LITERATURE CITED.	57
APPENDIXES.	59
A. SUMMARY WEATHER DATA FOR ANDREWS BALD	60
B. SUMMARY WEATHER DATA FOR SPENCE FIELD	61
C. SUMMARY WEATHER DATA FOR GERGORY BALD	62
D. SUMMARY WEATHER DATA FOR NEWFOUND GAP	63
E. SUMMARY WEATHER DATA FOR PARK HEADQUARTERS.	64
F. VALUES FOR THE PARAMETERS OF THE CLIMATIC POLYGONS.	65

SECTION	PAGE
G. COMPARATIVE AGES AT DBH OF <u>ABIES FRASERI</u> FOR THE MID-POINTS OF DIAMETER CLASSES	67
H. ANDREWS TRANSPLANTS	68

LIST OF TABLES

TABLE		PAGE
I.	Andrews Bald - Soil Transplants	10
II.	Values of Components of Regression Equations of Temperatures. .	22
III.	Values of Components of Regression Equations of Ages and Diameters of <u>Abies Fraseri</u>	34
IV.	Comparison of Growth Rings of Selected Large Diameters of <u>Abies Fraseri</u> in Each of Four Locations on Andrews Bald . . .	36
V.	Seedling Densities (with Corresponding Standard Error and Standard Deviation) from Several Areas on Andrews Bald. . . .	44
VI.	Shrub Density on Andrews Bald	50
VII.	Summary Weather Data for Andrews Bald	60
VIII.	Summary Weather Data for Spence Field	61
IX.	Summary Weather Data for Gregory Bald	62
X.	Summary Weather Data for Newfound Gap	63
XI.	Summary Weather Data for Park Headquarters.	64
XII.	Values for the Parameters of the Climatic Polygons.	65
XIII.	Comparative Ages at DBH of <u>Abies Fraseri</u> for the Mid-Points of Diameter Classes	67

LIST OF FIGURES

FIGURE		PAGE
1.	Average monthly temperatures for five stations in the Great Smoky Mountains National Park.	13
2.	Average maximum temperatures for five stations in the Great Smoky Mountains National Park.	14
3.	Average minimum temperatures for five stations in the Great Smoky Mountains National Park.	15
4.	Relation of maximum temperatures at Newfound Gap and Andrews Bald	16
5.	Relation of minimum temperatures at Newfound Gap and Andrews Bald	17
6.	Relation of maximum temperatures at Newfound Gap and Spence Field.	18
7.	Relation of minimum temperatures at Newfound Gap and Spence Field.	19
8.	Relation of maximum temperatures at Newfound Gap and Gregory Bald	20
9.	Relation of minimum temperatures at Newfound Gap and Gregory Bald	21
10.	Climatic polygon for June, 1967. Comparison of climates of Andrews Bald, Spence Field, and Gregory Bald	23
11.	Climatic polygon for July, 1967. Comparison of climates of Andrews Bald, Spence Field, and Gregory Bald	24
12.	Climatic polygon for August, 1967. Comparison of climates of Andrews Bald, Spence Field, and Gregory Bald	25

FIGURE

PAGE

13.	Climatic polygon for September, 1967. Comparison of climates of Andrews Bald, Spence Field, and Gregory Bald	26
14.	Climatic polygon for October, 1967. Comparison of climates of Andrews Bald, Spence Field, and Gregory Bald	27
15.	Relation of diameter to age in a population of <u>Abies fraseri</u> invading the open portion of Andrews Bald	30
16.	Relation of diameter to age of <u>Abies fraseri</u> in the spruce-fir forest in the northern surrounding portion of Andrews Bald. .	31
17.	Relation of diameter to age in a stand of <u>Abies fraseri</u> on the eastern margin of Andrews Bald.	32
18.	Relation of diameter to age in a stand of <u>Abies fraseri</u> on the western margin of Andrews Bald.	33
19.	Regression of ages and diameters with 5% confidence limits of <u>Abies fraseri</u> on Andrews Bald using logarithmically transformed data and the corresponding anti-logs.	37
20.	Age distribution of <u>Abies fraseri</u> in four locations on Andrews Bald.	38
21.	Seedlings of <u>Abies fraseri</u> under 5 inches in height compared with those between 5 inches and 3 feet on each side of Andrews Bald.	39
22.	Seedlings of <u>Ribes</u> sp. under 5 inches in height compared with those between 5 inches and 3 feet on each side of Andrews Bald.	40

FIGURE

PAGE

23. Seedlings of Rhododendron sp. under 5 inches in height
compared with those between 5 inches and 3 feet on each
side of Andrews Bald. 41
24. Seedlings of Vaccinium sp. under 5 inches in height compared
with those between 5 inches and 3 feet on each side of
Andrews Bald. 42
25. Seedlings of Picea rubens under 5 inches in height compared
with those between 5 inches and 3 feet on each side of
Andrews Bald. 43

I. INTRODUCTION

The National Park Service, realizing that the montane treeless areas (grass balds) endemic to the Southern Appalachian Mountains were being rapidly overgrown by woody species where not grazed, burned, or managed, wanted to determine "if management of the balds is justifiable and if so what procedures would accomplish the aim without initiating a sequence of changes worse than those resulting from no management." (Park Service Contract)

Before a bald management program can be logically considered, factors involved in the natural maintenance must be determined. This particular study was conducted to examine possible factors. An intensive climatic documentation of two of the grassy balds and one field was undertaken, soil and vegetational transplants between forest and bald were made, growth rates of Abies fraseri, (peripheral old-growth as well as that of the newly invading species) were determined and successional trends studied. Permanent seedling plots were established for initial counts of woody seedlings and for later determination of survival rates, germination and survival of Picea rubens Sarg. were followed through one growing season, and possible shrub invasion was examined. Climatic data were gathered from three areas within the Great Smoky Mountains National Park: Andrews Bald, Gregory Bald, and Spence Field. The other phases of the study were carried out on Answers Bald.

II. PARTICULARS OF THE REGION

For an operational definition consider a "grass bald" to be a naturally occurring, high mountain area dominated by grasses and sedges within an otherwise forested region. Areas of this type are located in the southern section of the Blue Ridge Province (Fenneman, 1938), specifically in portions of southern Virginia, western North Carolina, eastern Tennessee, and the northern portion of Georgia. Other grassy areas of recent origin in the region offer comparative data, but cannot be called "true balds" according to Mark (1958).

Of the 34 true balds studied by Mark (1958), two were surrounded by coniferous forests, 14 by hardwoods, and 18 were ecotonal. Concerning the balds associated with hardwoods, Whittaker (1956), Camp (1942), and Cain (1942) agreed that tree stature decreased "up the slopes and along the ridges toward the balds, (where) the change from forest to bald is abrupt." Mark (1958) studied the growth rates of hardwood trees in the vicinity of Round Bald¹ and found that the rates reflected the severity of the conditions under which they grew and "they appeared to be growing at or near their upper altitudinal limit." Growth rates of spruce and fir, when they occur next to or on a bald, indicated that "the bald environment (was) within their tolerance range." (Mark, 1958).

¹Round Bald is an ecotonal bald located along the North Carolina-Tennessee state line.

The balds probably receive well over 80 inches of rainfall a year with September and October the driest months and droughts at these times not infrequent. A temperature decrease of 2.23° F. per 1,000 feet rise in elevation has been calculated (Shanks, 1954); so the balds should average 8° F. to 12° F. cooler than the base of the mountain. Often the balds are completely enclosed by fog which, during the warm season, increases humidity and decreases solar radiation and thus reduces transpiration. Wind velocities, as would be expected, are highest on the bald itself. Bald environments are generally extreme, but no more so than nearby recently deforested areas. (Mark, 1958).

The parent rocks of the grassy bald soils are fine-grained conglomerates, coarse to fine sandstones, and silty or argillaceous slates and phyllites (King, 1964). According to Mark (1958), though, "no correlation (exists) between distribution of balds and . . . certain rock types." Mark also studied the possibility that soil differences might provide an explanation for the distinctive bald vegetation. Because all the soils were either sandy loams or loamy sands there could be little or no correlation of bald occurrence with soil texture. He found only slight variation in color of the A_1 and soil depth between the balds and their surrounding forests. Soil profiles were also very similar in other morphological and in chemical characteristics. Bald soils were found to be slightly less acid than the adjacent forests; any exceptions, he felt, were effects of vegetational differences rather than a cause of them. No consistent differences could be found in organic matter content between bald and forest, but the content of forest soils tended to be

higher. His very limited examination of the microfungus composition of Gregory Bald tentatively showed "that the microfungus flora . . . is very similar to that found in forested areas and not typical of the prairies of North America." Bruhn (1964) pointed out the confusion in the literature concerning the classification of the bald soils.

Herbaceous species, largely Danthonia compressa², dominate the vegetational cover with Potentilla canadensis and Rumex acetosella also consistently found. Invasion of balds by woody plants, both potential overstory and shrub species, has been estimated to be somewhere between 0.009 and 0.015 acres per year per acre of clear bald (Bruhn, 1964). Amelanchier laevis, Crataegus macrosperma v. roanensis, and species of Vaccinium are characteristic of the woody invasion (Mark, 1958). To this list Bruhn added three species: Abies fraseri, Quercus rubra, and Acer rubrum.

²Nomenclature follows that of Fernald (1950).

III. THE STUDY AREAS

Andrews Bald

Gilbert (1954), Mark (1958), and Bruhn (1964) have all included Andrews Bald, Spence Field, and Gregory Bald in their studies and have provided detailed vegetational descriptions in their papers. Briefly, Andrews Bald, at an elevation of approximately 5,700 feet, is located on a southwest facing slope on Forney Ridge approximately one and one-half miles from the Clingman's Dome parking area. An ecotonal bald, Andrews is bordered on the north and west by spruce-fir forest and on the south and east by hardwood forest. Since there is no known historical account of its clearing, Andrews is assumed to be a "true bald" - one of natural origin. Bruhn estimated the bald that year to include 9.17 acres.

One striking feature of the bald is that the invading woody species almost always occur around a rock, thus creating small "islands" of vegetation. (Bruhn, 1964).

According to Bruhn (1964), since the cessation of grazing in 1931, spruce and fir have invaded the bald from above with fir in much larger numbers. Bruhn found Amelanchier laevis to be the third most common invading tree species on Andrews, also noting that there was little invasion from the hardwood forest below and that little invasion from Rhododendron, Vaccinium, and Viburnum along the steeper margin of the bald (east and south) was occurring.

Spence Field

Spence Field is located along an east-west ridge (5,000 feet) separating Tennessee from North Carolina. Bruhn reported the area to

be 29.84 acres. The entire area is enclosed by hardwoods and is believed by some to have been cut from a then existing beech forest (Gilbert, 1954). However, Bruhn stated that Spence Field is an extension of Thunderhead Bald which is on a ridge immediately east. The reported cutting according to Bruhn was simply a widening of narrow portions of the "original" area.

The surrounding forest is composed largely of stunted Quercus rubra and Fagus grandifolia. The northeastern corner of Spence Field has become the site of active tree invasion since grazing was stopped in 1933. Gilbert (1954) noticed that the general character of this end differed from the rest of the bald in that there were numerous rock outcrops. Rhododendron spp. and Kalmia latifolia border on the southern edge and are invading bare areas thought to have been created by heavy grazing.

Typical "grassy bald" species are found in the open portions: Danthonia compressa, Rubus canadensis, Potentilla canadensis, Rumex acetosella, Amelanchier laevis, Vaccinium constablaei, and Crataegus macrospermum var. roanensis among others. Pine is a recent invader according to Bruhn.

Gregory Bald

Gregory Bald is situated on the Tennessee-North Carolina line "about half a mile to the west of the intersection of Gregory Ridge with the state line ridge in a summit position at an elevation of 4,948 feet." (Bruhn, 1964). All reports indicate Gregory to be a natural opening (Bruhn, 1964 and Gilbert, 1954). Bruhn estimated the

present area of the bald to be 11.71 acres. Grazing was stopped in 1936.

The surrounding forest is largely Quercus rubra with Fagus grandifolia and Betula lutea becoming more numerous toward the lower, western end. Rhododendron spp. and Kalmia latifolia are invading the severely eroded areas on the bald. Invasion on Gregory is 50 per cent greater than on Spence Field or Andrews. The higher rate was due, according to Bruhn, to the rapid invasion of low-bush blueberry. She noted the recent increase in pine, but there was generally very little invasion by potential overstory trees. There are fewer rock outcroppings on Gregory Bald than on the other areas.

IV. MATERIALS AND METHODS

For the comparison of bald environments, one medium-sized Cotton-belt weather instrument shelter was placed in each of three areas: Andrews Bald, Gregory Bald, and Spence Field. Each shelter contained a clock driven hygrothermograph (U.S.W.B. Spec. no. 405.8202) with a 31 day recording cycle, a sling psychrometer (U.S.W.B. Spec. no. 450.1016), and a set of maximum-minimum thermometers (U.S.W.B. Spec. no. 450.1016). Not inside the shelter, but in the immediate area was an anemometer with a totalizing mechanical counter reading up to 10,000 miles, and a rain and snow gauge (U.S.W.B. Spec. no. 450.2301) with a capacity of 20 inches. A 7-day recording pyreheliograph with springwound clock drive was attached to the top of the Andrews Bald and Spence Field shelters. The shelters and corresponding instruments were flown in by helicopter on March 27, 1966, and enclosed by barbed-wire fencing. Even with the fence, the equipment suffered damage. Care was taken to place the stations in the most exposed positions, and the shelters were oriented to face the North.

Instruments on Andrews Bald and Spence Field were read weekly and those on Gregory Bald biweekly throughout 1966, 1967, and the observations are continuing. Servicing trips involved reading the anemometer, rain gauge, maximum-minimum thermometers, determining relative humidity with the sling psychrometer, and servicing the pyreheliograph and hygrothermograph. Soil temperatures were taken at 1", 3", 6", 12", and 18" levels near the shelter with a telethermometer composed of a portable registering unit and a temperature sensitive probe.

Transplant studies, begun during May, 1967, on Andrews Bald, involved exchanging a series of soil cores 1 foot in diameter and 1 foot in depth with accompanying vegetation between bald and forest. Table I is a listing of the actual transplants; 2A, 2B, 7A, and 7B served as controls. Cores which constituted controls were excavated and returned to the holes from which they were dug. Records were kept on the names and growth of original species, and the appearance of any new species throughout the 1967 growing season.

On Andrews Bald growth rates of individuals of Abies fraseri were studied from increment cores from one hundred trees. Twenty-five cores were taken at d.b.h. from the fir trees in 1/5 acre plots in each of four different locations: the eastern hardwood forest margin, the bald itself, the western spruce-fir forest margin, and the spruce-fir forest. Stratified random sampling was used to select the locations of the plots as well as the trees to be studied.

Permanent .01 acre seedling plots were established along three compass lines in order that plots would fall in each of the following areas: the spruce-fir forest, the margin of the spruce-fir forest, the bald, the eastern margin of the mixed hardwood and conifer forest, the eastern mixed forest, the southern margin of the deciduous forest, and the southern deciduous forest. Stratified random sampling was employed in the spacing of the plots along the compass lines in order that the plots fall in the "marginal" areas as well as in the forest and bald. The random numbers table was used to determine on which side and at what distance from the line the plots would be placed. New plots were added in each area until no new species of woody seedlings were encountered,

TABLE I
ANDREWS BALD - SOIL TRANSPLANTS

Description of Transplant	Plot Number
Bald soil and vegetation moved to forest	1A
Forest soil and vegetation moved to Bald	1B
Bald soil excavated and reset in same hole	2A
Forest soil excavated and reset in same hole	2B
Bald left unexcavated in original site and devegetated	3A
Forest left unexcavated in original site and devegetated	3B
Bald excavated and reset in same hole and devegetated	4A
Forest excavated and reset in same hole and devegetated	4B
Bald excavated and transferred to Univ. Tenn. Greenhouse	5A
Forest excavated and transferred to Univ. Tenn. Greenhouse	5B
Sterile greenhouse soil placed in hole on Bald	6A
Sterile greenhouse soil placed in hole in forest	6B
Bald plot left untouched, but marked	7A
Forest plot left untouched, but marked	7B
Bald soil excavated, sterilized, and reset	8A
Forest soil excavated, sterilized, and reset	8B
Bald soil excavated, devegetated, placed in forest	10A
Forest soil excavated, devegetated, placed on Bald	10B
Bald soil excavated, sterilized, placed in forest	11A
Forest soil excavated, sterilized, placed on Bald	11B

and centers of the plots were marked with aluminum rods. Seedlings of woody species were counted and those of one plot in each of the five areas were marked with colored, plastic pick-up sticks. Plots were also placed along a compass line through a burned area in the spruce-fir forest, and a bog in the southwest corner of Andrews Bald in the same manner as above. For the purposes of this study any woody plant under 3 feet tall was considered a seedling, and two subcategories were used: those seedlings 5 inches or less and those between 5 inches and 3 feet. It was assumed that plants in the first category could be compared with those of the second category to give an indication of apparent mortality.

The same .01 acre plots were used to measure the density of the shrub layer in a search for invasion trends of this life form.

Germination rates of seeds of Picea rubens Sarg. from the Adirondack Mountains, sterilized in 50 per cent Clorox for approximately 30 minutes and rinsed in sterilized water for removal of indigenous fungal spores, were determined in laboratory experiments. Seeds treated in the same manner were then planted in five locations on Andrews Bald - 100 in each of the following: hardwood forest, hardwood forest-bald margin, bald, spruce-fir forest-bald margin, and spruce-fir forest.

V. RESULTS

Climatic Studies

Values for daily maximum and minimum temperatures were read from the hygrothermograph charts taken from Andrews Bald, Spence Field, and Gregory Bald, and monthly averages for each were calculated for the period April, 1966, to October, 1967, using the formula below:

$$\frac{\sum_{1-30} \left(\frac{\text{daily maximum} + \text{daily minimum}}{2} \right)}{30}$$

These values were then compared with corresponding data recorded by the National Park Service at Park Headquarters and Newfound Gap (see Figures 1, 2, 3, and actual monthly values in Appendixes A, B, C, D, and E).

Monthly minimum and maximum air temperatures for Andrews Bald, Spence Field, and Gregory Bald were compared with Newfound Gap (Figures 4, 5, 6, 7, 8, and 9) and for each set of points a least squares fit was obtained. Statistics for the linear regression of the form $y = a+bx$ appear in Table II. The coefficients of correlation (r) were significant at the 1 per cent level. This allows one to predict with accuracy the temperatures of the balds, given the temperatures for Newfound Gap.

Values for rainfall, wind velocity, and solar radiation from the three areas for the study period (Appendixes A, B, and C), together with the temperatures discussed above and vapor pressure deficit, were used as parameters for climatic polygons (Hutchinson, 1940; Jackson and Newman, 1967). The polygons graphically represent monthly comparisons of the relative differences among the climates of Andrews Bald, Spence Field, and Gregory Bald (see Figures 10, 11, 12, 13, and 14).

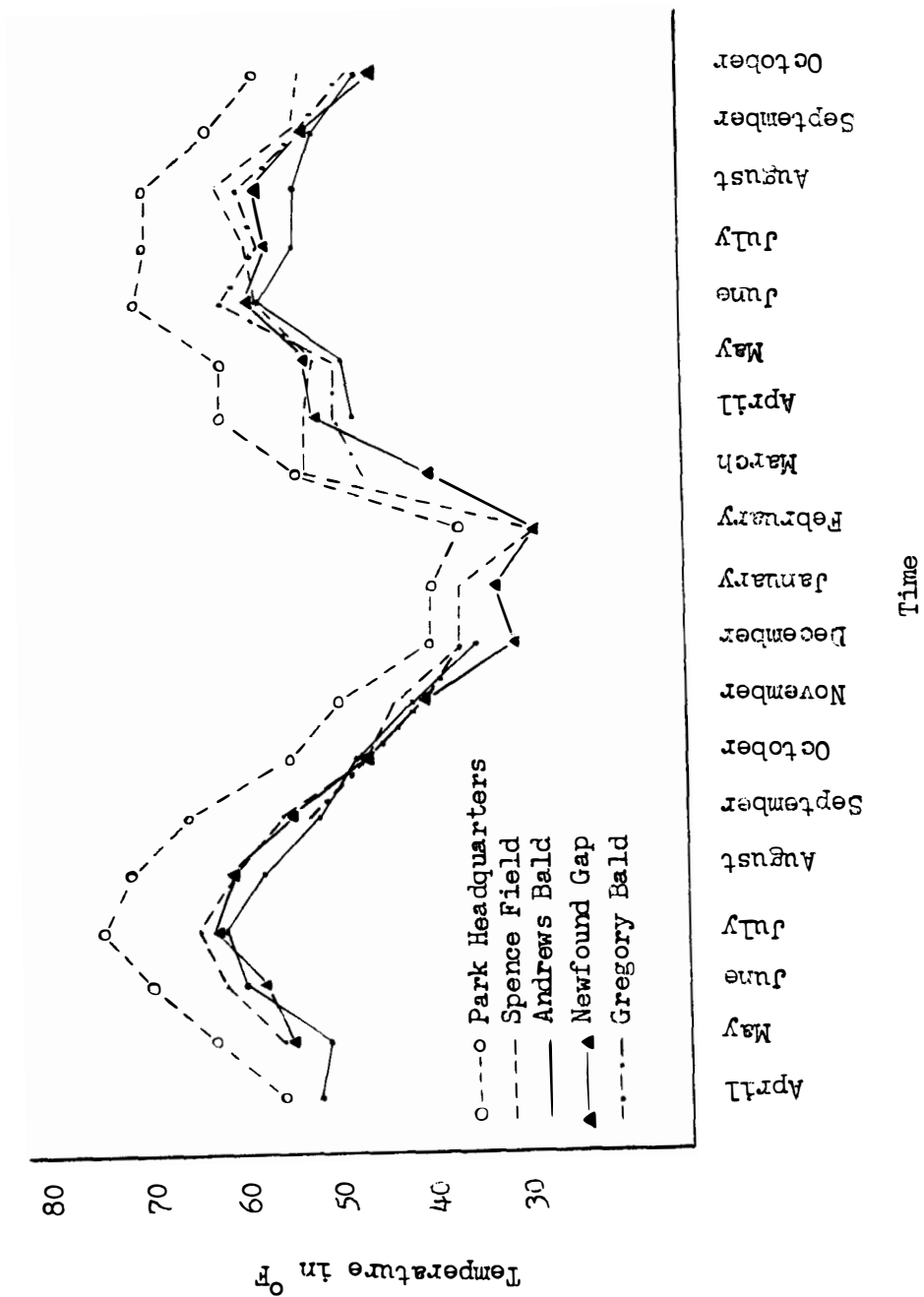


Figure 1. Average monthly temperatures for five stations in the Great Smoky Mountains National Park.

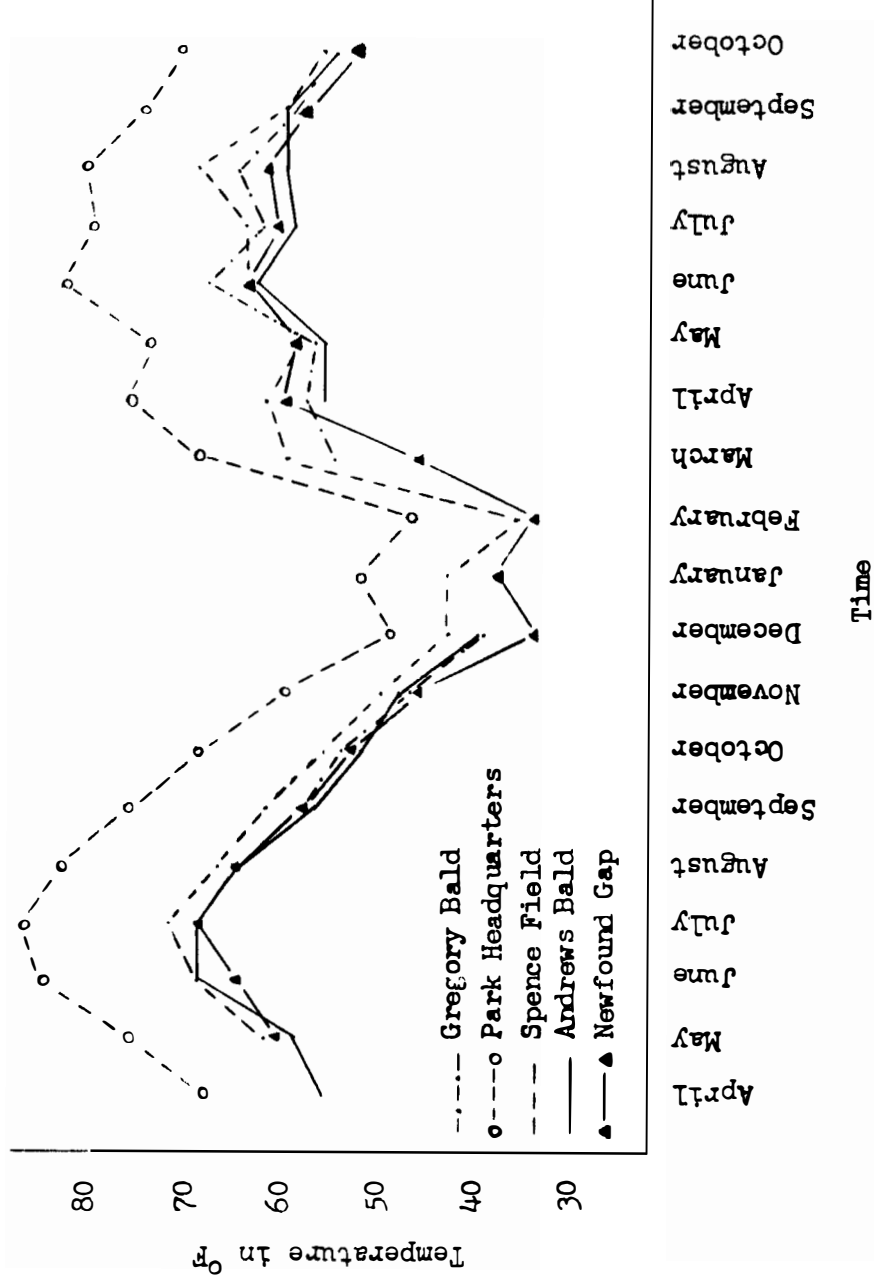


Figure 2. Average maximum temperatures for five stations in the Great Smoky Mountains National Park.

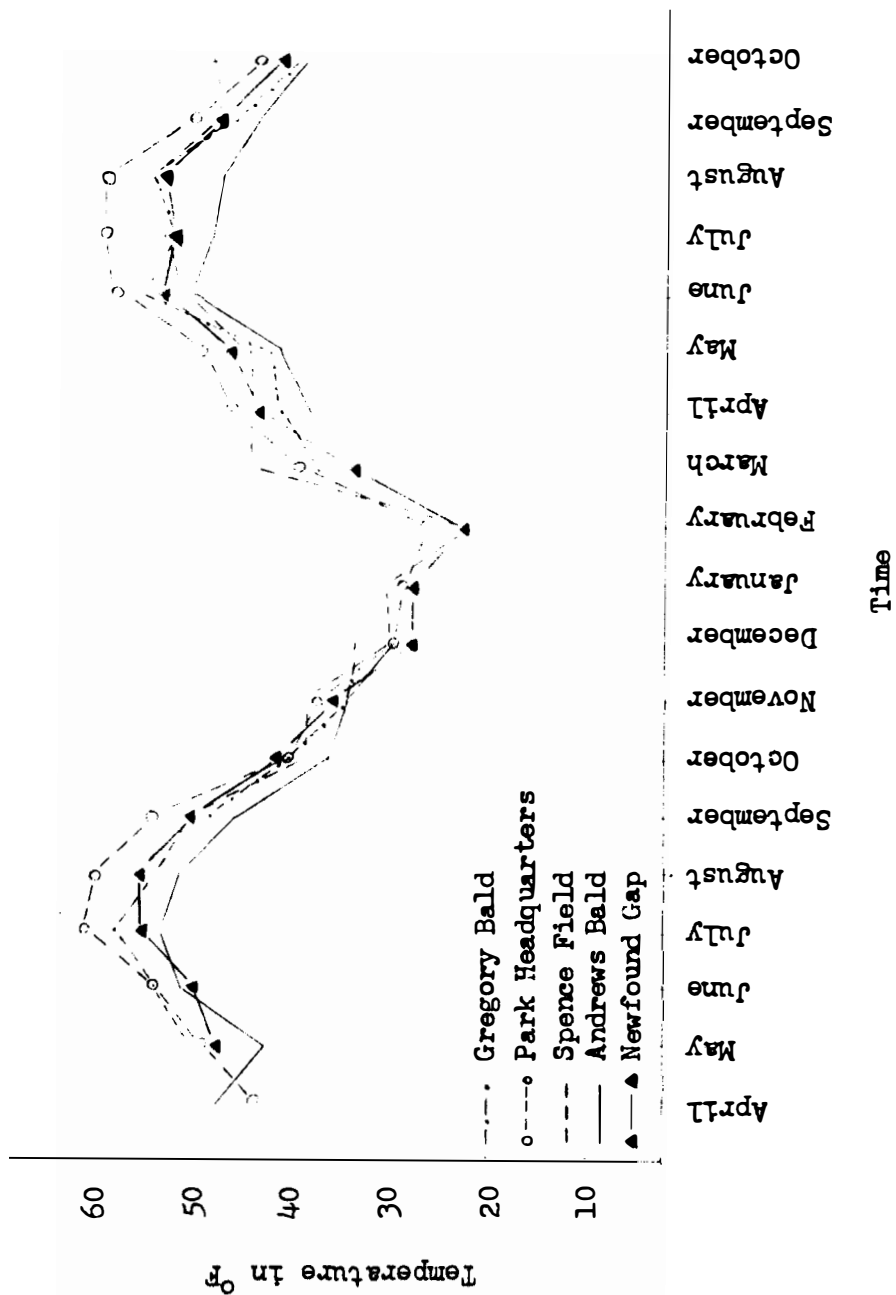


Figure 3. Average minimum temperatures for five stations in the Great Smoky Mountains National Park.

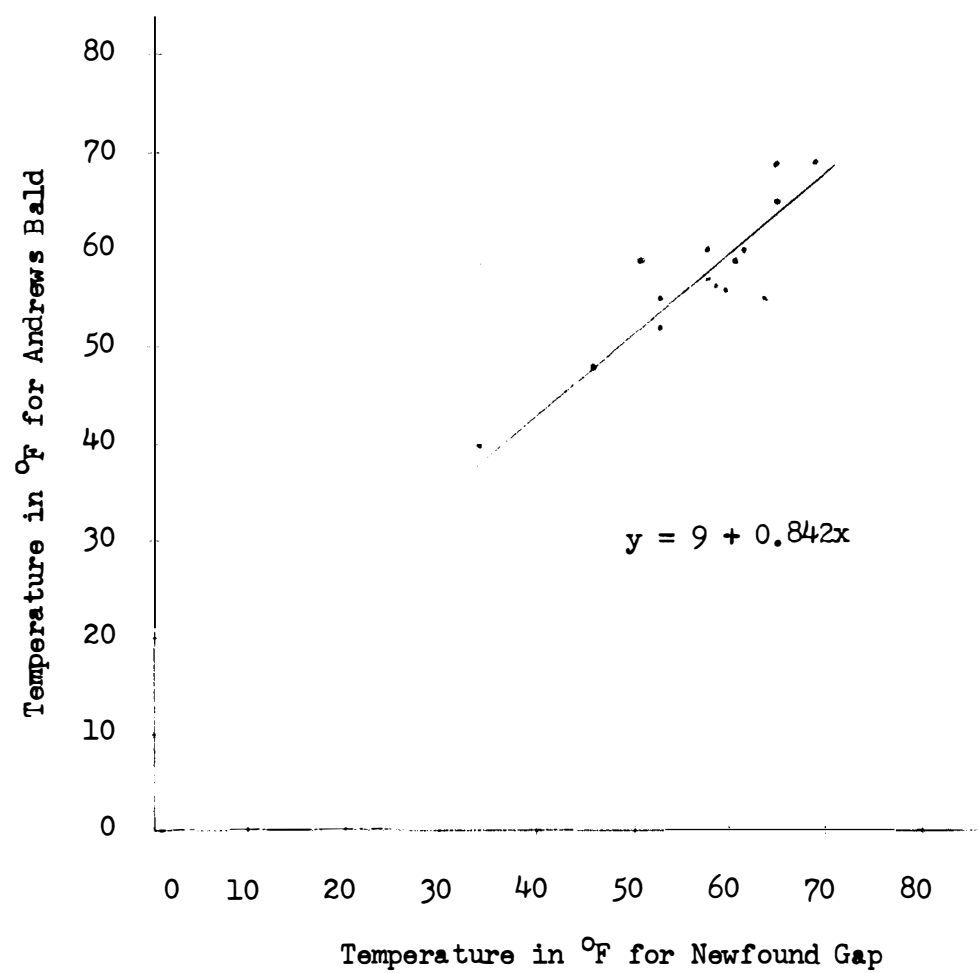


Figure 4. Relation of maximum temperatures at Newfound Gap and Andrews Bald.

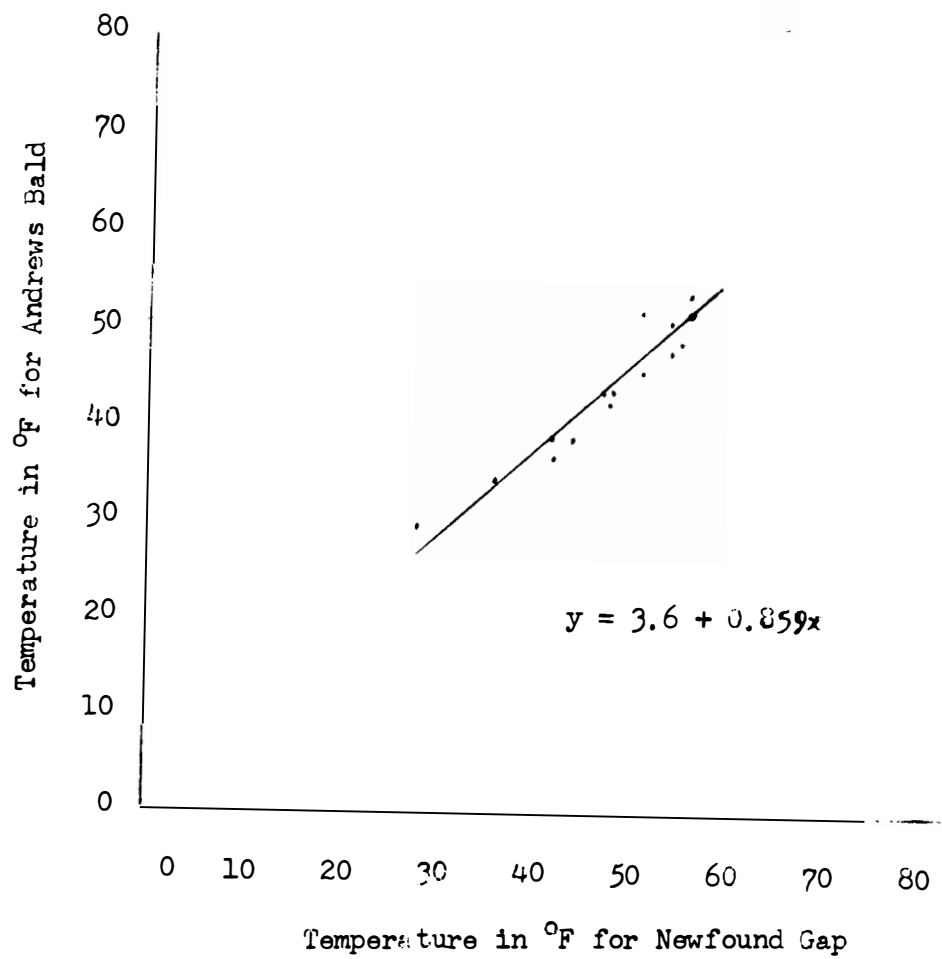


Figure 5. Relation of minimum temperatures at Newfound Gap and Andrews Bald.

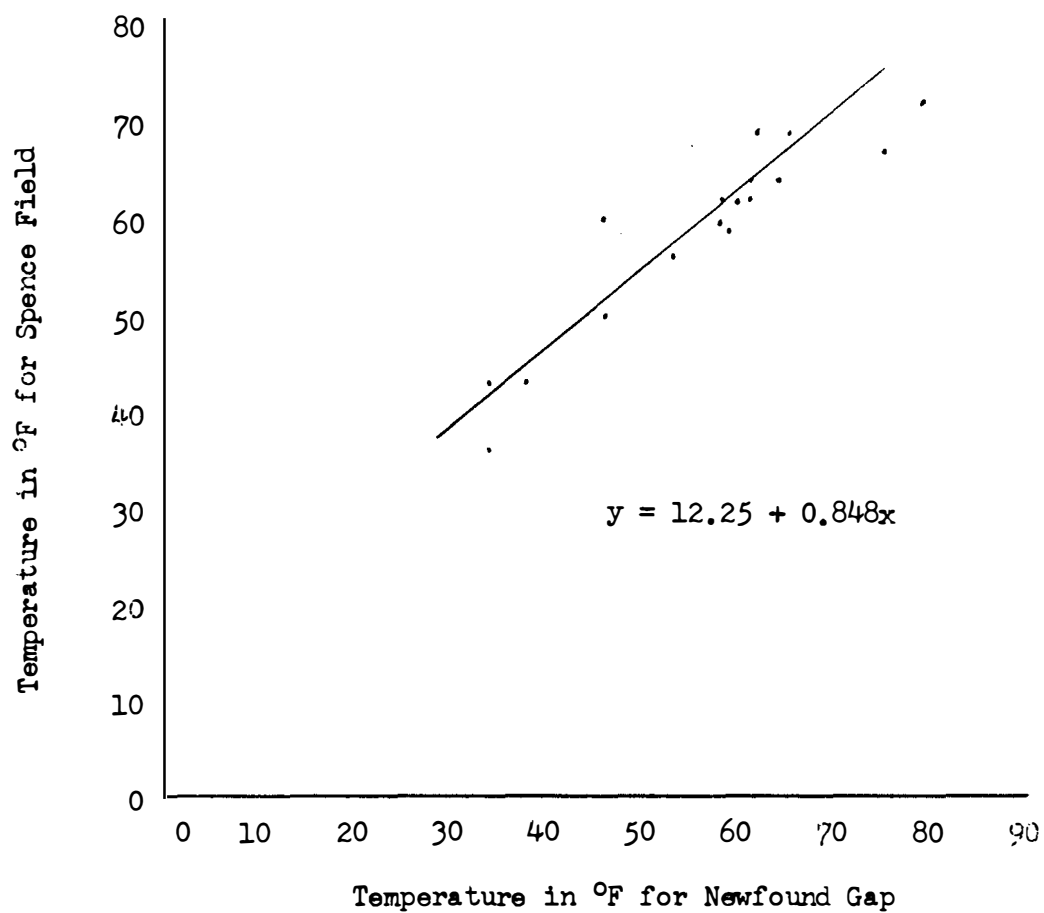


Figure 6. Relation of maximum temperatures at Newfound Gap and Spence Field.

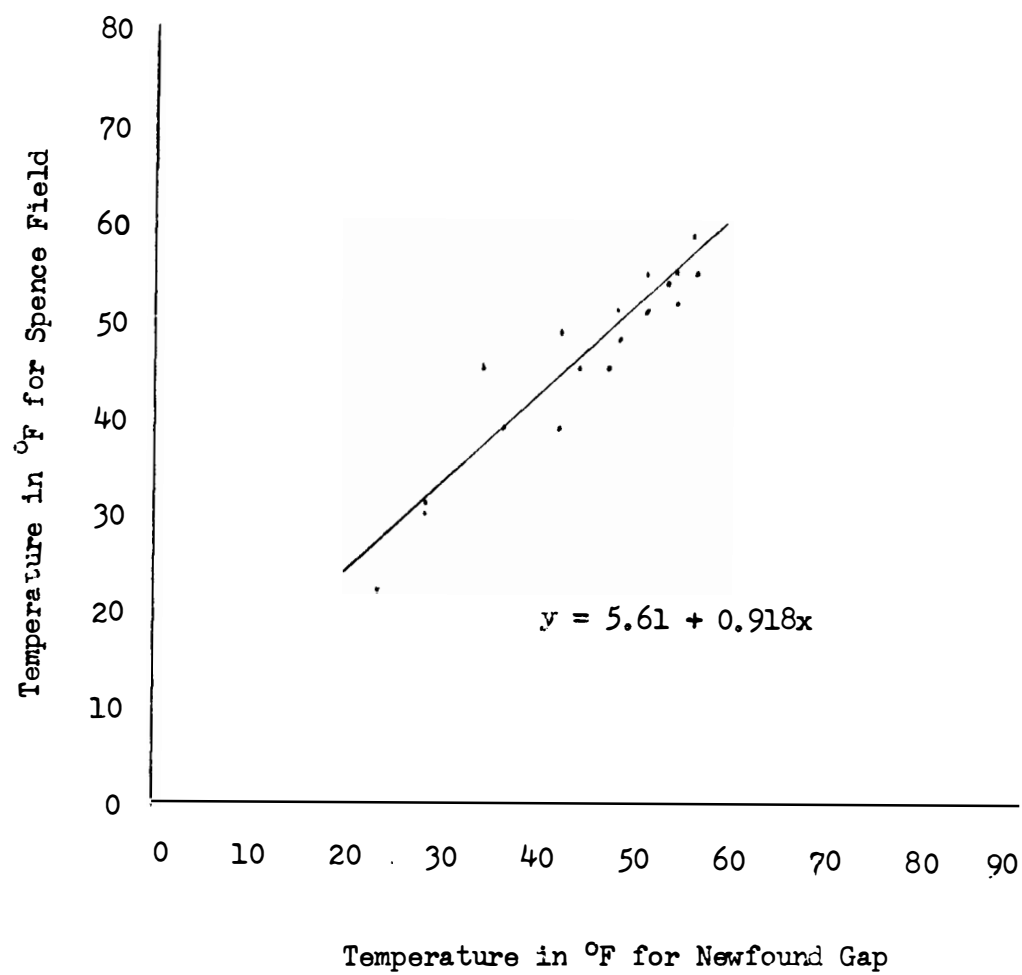


Figure 7. Relation of minimum temperatures at Newfound Gap and Spence Field.

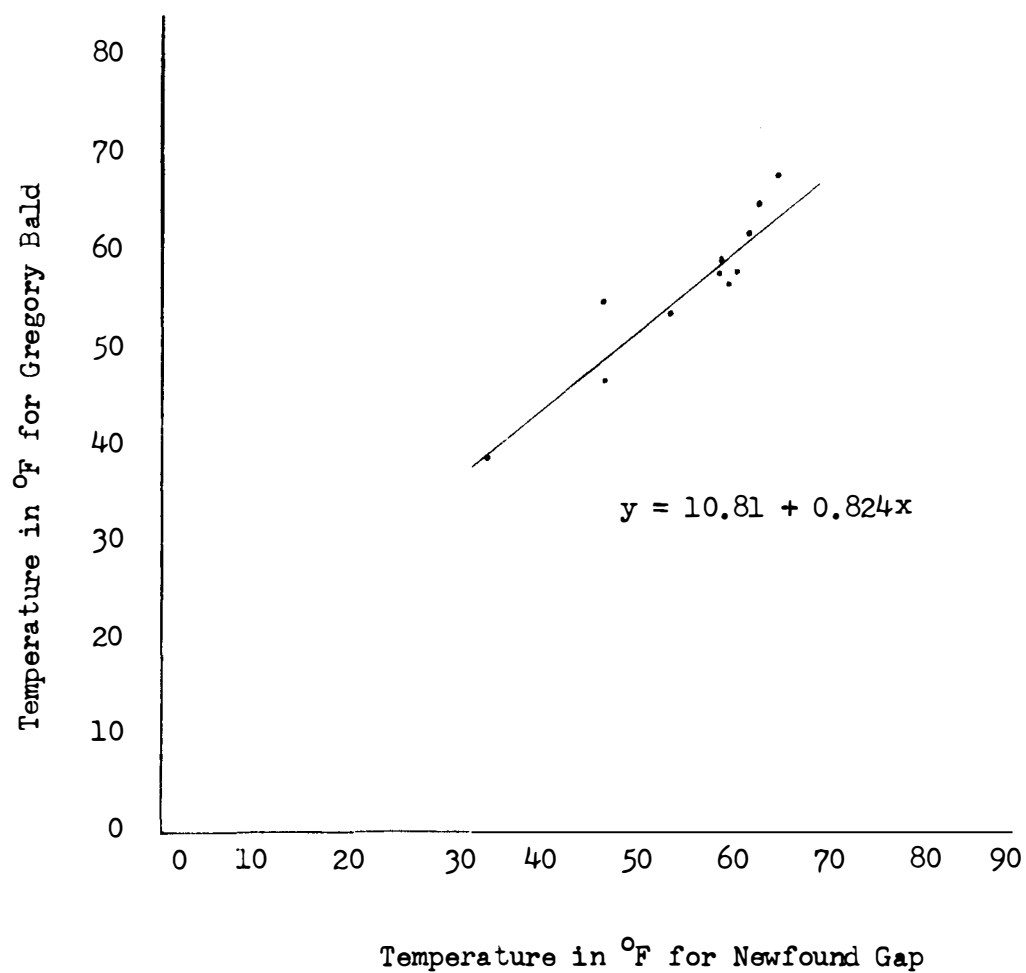


Figure 8. Relation of maximum temperatures at Newfound Gap and Gregory Bald.

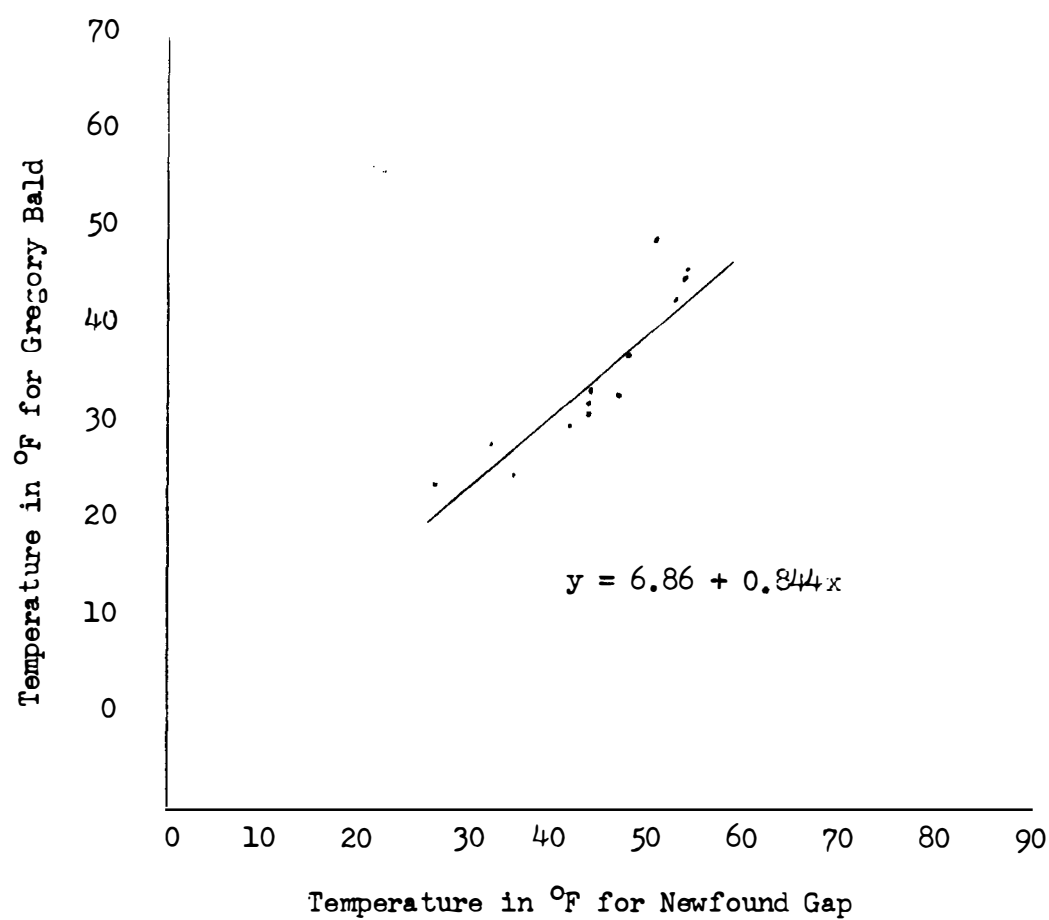


Figure 9. Relation of minimum temperatures at Newfound Gap and Gregory Bald.

TABLE II
VALUES OF COMPONENTS OF REGRESSION
EQUATIONS OF TEMPERATURES

y	x	a	b	r
Minimum				
Andrews	Newfound Gap	3.6	0.859	0.956**
Spence	"	5.61	0.918	0.944**
Gregory	"	6.86	0.844	0.943**
Maximum				
Andrews	"	9	0.842	0.954**
Spence	"	12.25	0.848	0.952**
Gregory	"	10.81	0.824	0.931**

**(P $\leq$ 1%)

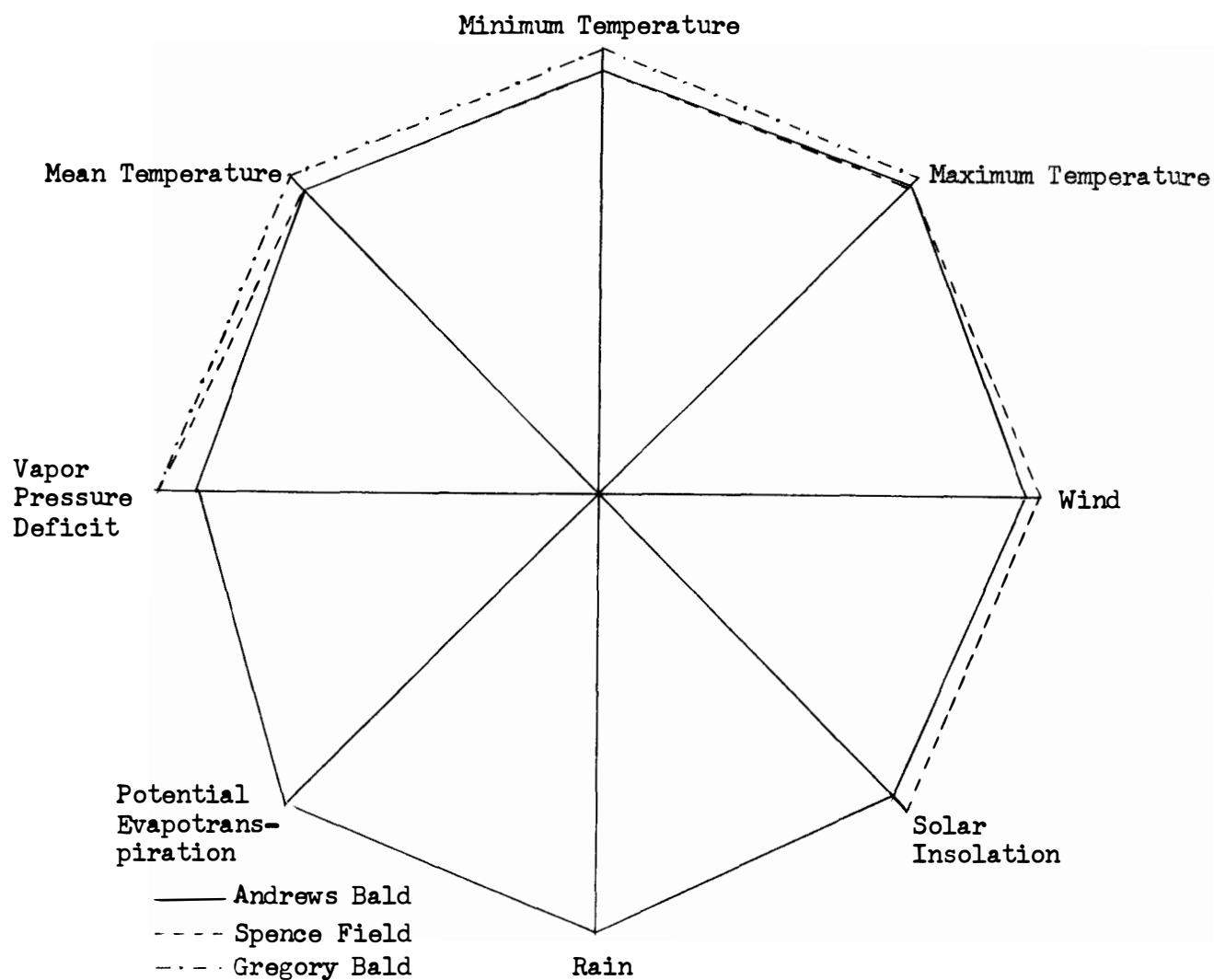


Figure 10. Climatic polygon for June, 1967. Comparison of climates of Andrews Bald, Spence Field, and Gregory Bald.

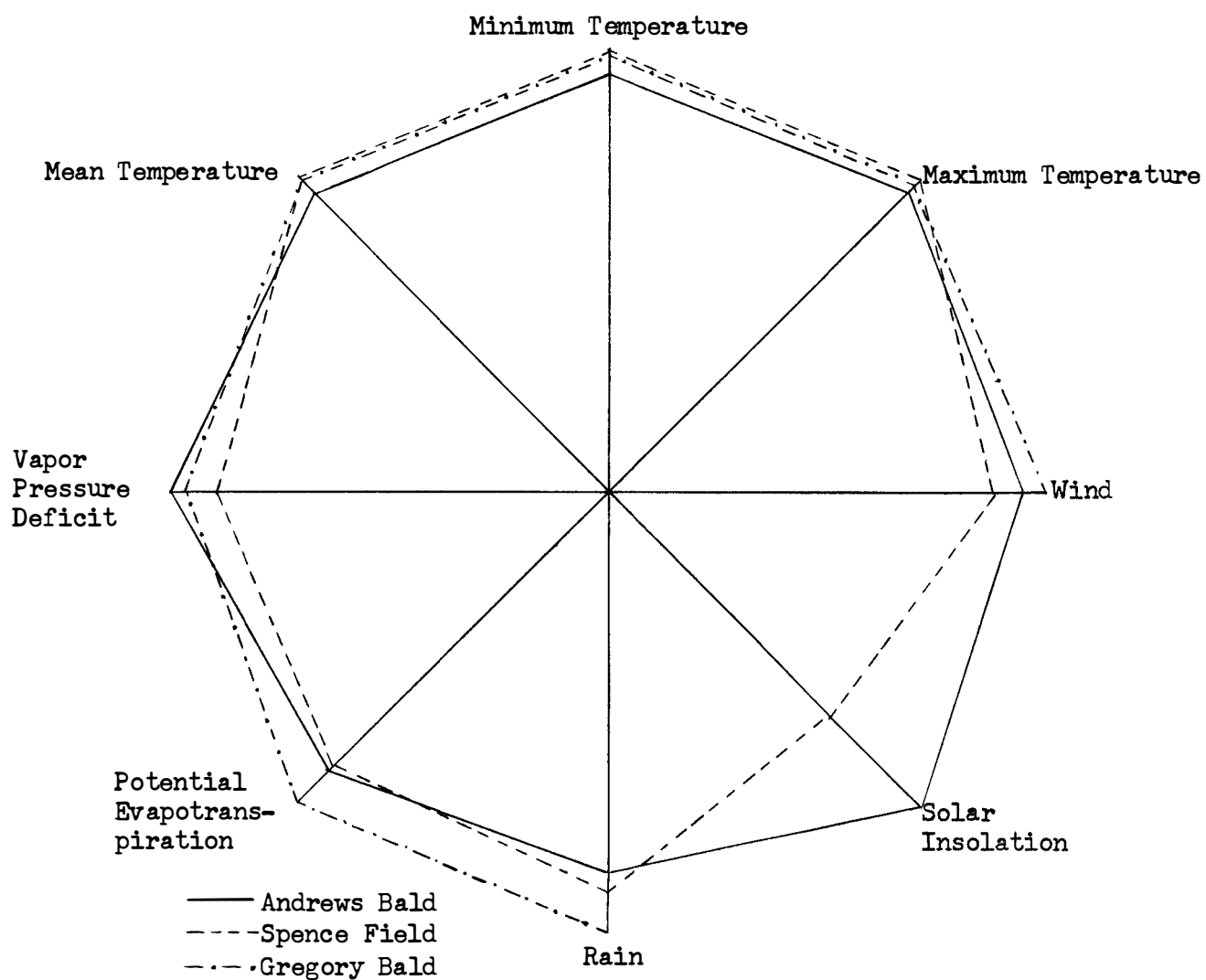


Figure 11. Climatic polygon for July, 1967. Comparison of climates of Andrews Bald, Spence Field, and Gregory Bald.

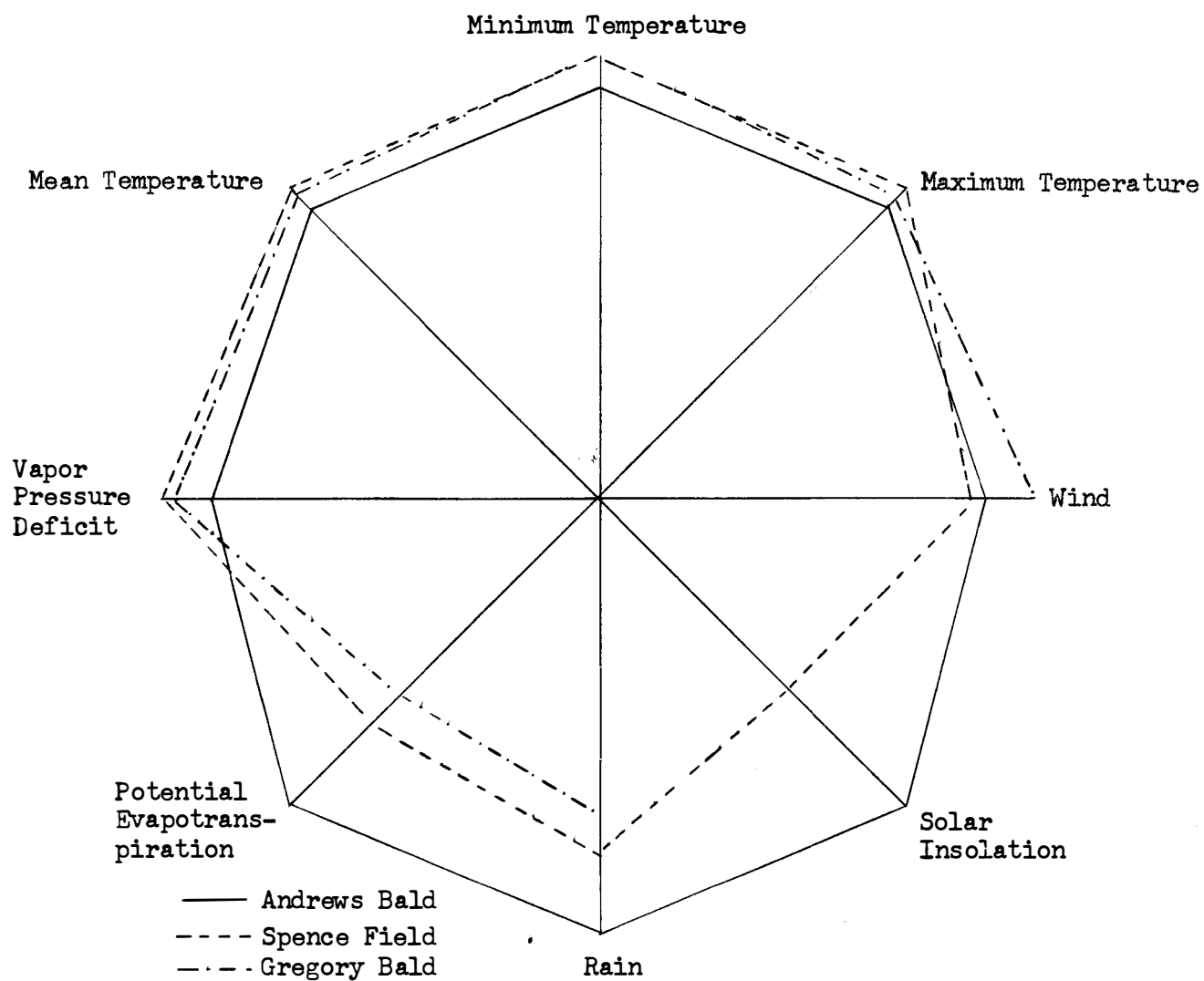


Figure 12. Climatic polygon for August, 1967. Comparison of climates of Andrews Bald, Spence Field, and Gregory Bald.

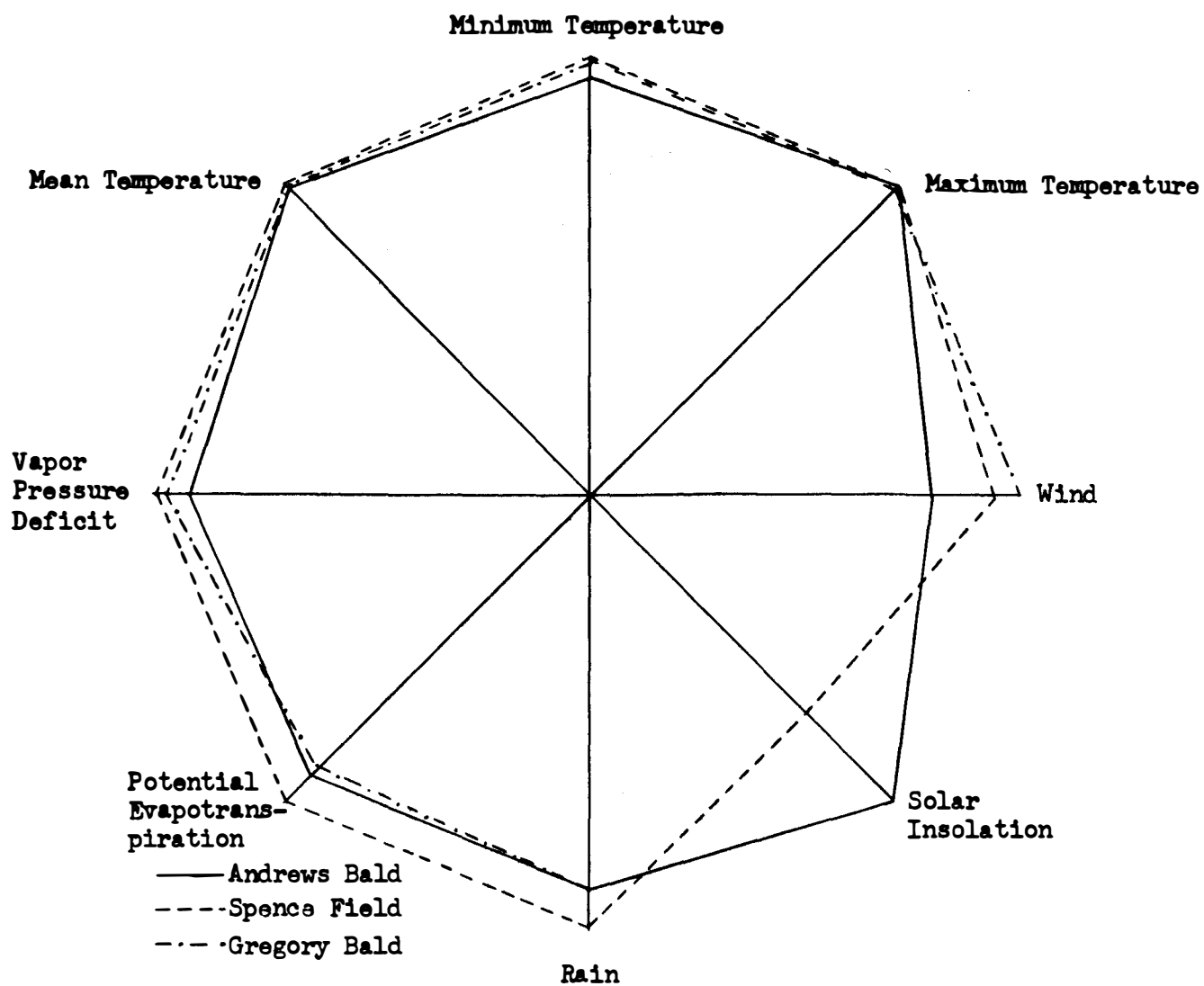


Figure 13. Climatic polygon for September, 1967. Comparison of climates of Andrews Bald, Spence Field, and Gregory Bald.

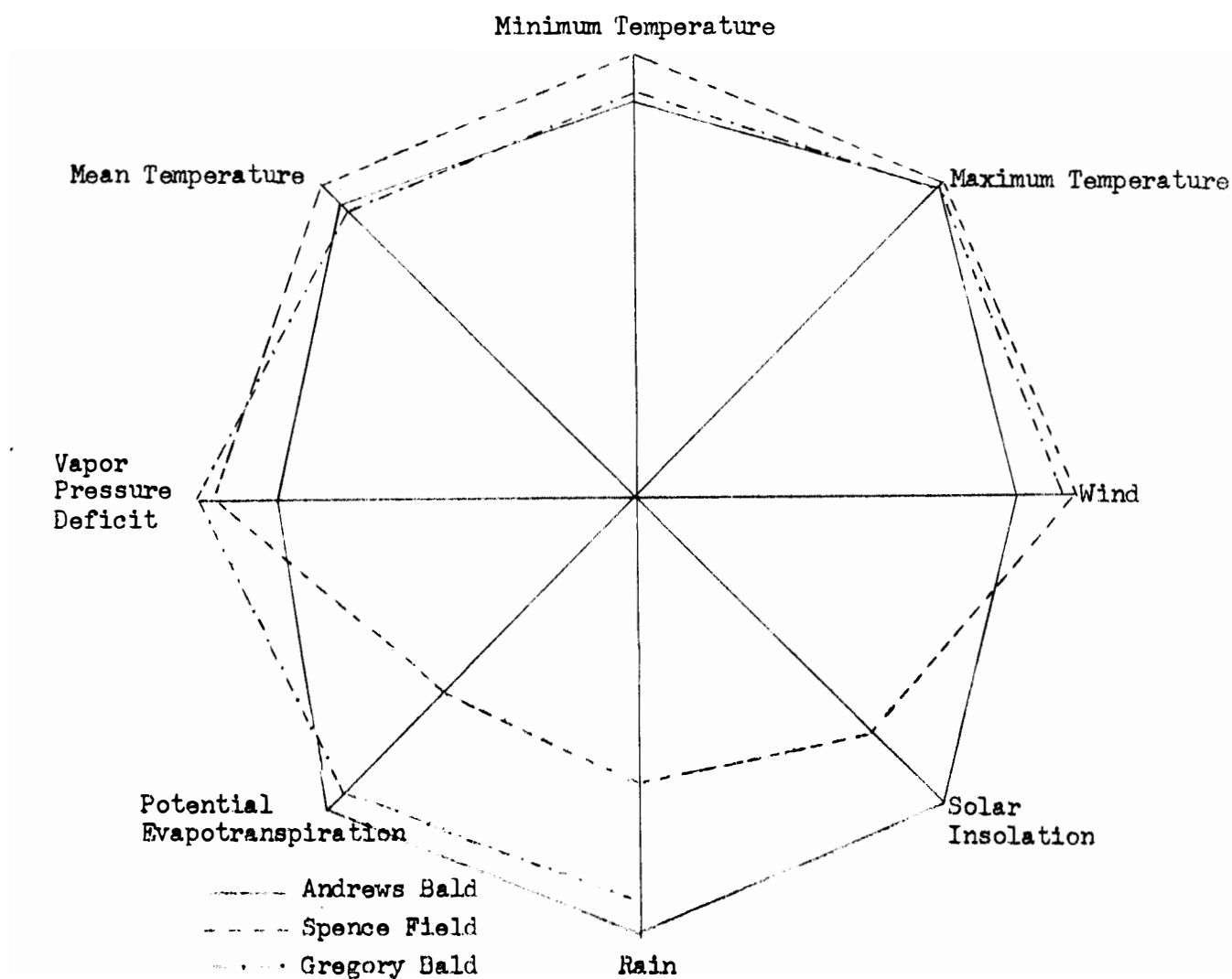


Figure 14. Climatic polygon for October, 1967. Comparison of climates of Andrews Bald, Spence Field, and Gregory Bald.

The graduation of the axial scales was based on square roots of the relative values in order to "make the areas of the polygons more nearly directly proportional to the relative conditions represented in a given environment" (Jackson and Newman, 1967). Polygons were constructed for five months in the 1967 growing season for which data were most complete (see Appendix F). Vapor pressure deficit was used as a parameter rather than the relative humidity since the v.p.d. is much more indicative of the potential rate of evaporation (Oosting, 1956).

Transplant Studies

The notes taken on the initial vegetational composition of the transplants (see Table I, page 10, for list of transplants) and its change through the 1967 growing season (Appendix H) show that the most dramatic observations were the senescence and death of Danthonia compressa and Potentilla sp. on the bald plot that was moved to the forest (Plot 1B) and of the fir seedlings on the forest plot moved to the bald (Plot 1B). However, those fir seedlings protected by tall grass clumps did survive the growing season. The fir seedlings of a second (Plot 1B) all died when transplanted to bald conditions presumably because these seedlings were unprotected from extremes of weather. Control Plots 2A and 2B indicate that the results of the transplant study cannot be attributed to the transplanting procedures and control Plots 7A and 7B serve to show that conditions of the 1967 growing season were sufficiently "normal" to allow for growth and development of bald and forest species. Bared areas on the bald tend to return to the grassy condition fairly slowly (Plot 4A) and Plot 3A, treated in the same fashion but left unexcavated, showed the

same slow regrowth, thus ruling out excavation as a factor. Other areas on the bald, devegetated by small rodents (Bruhn, 1964) have remained bare for several growing seasons.

The spruce-fir forest plot when excavated, reset, and devegetated remained in that condition (Plot 4B) as did Plot 3B, which was devegetated but not excavated. Again, excavation was not a factor. A plot of forest soil (Plot 5B) when returned to The University of Tennessee greenhouse was covered with Carex sp. and seedlings of Betula lutea Michx. within a month. Forest soil (Plot 10B) under bald conditions soon showed the same response, but the numbers of Carex sp. was greatly reduced. Runners of Potentilla sp. were slowly invading the plot at the end of the season. A devegetated bald plot when moved to the forest (Plot 10A) soon supported several species, including a Potentilla sp., Danthonia compressa, and a Rumex sp.

Sterilized soil cores (Plots 6A, 6B, 8A, 8B, 11A, 11B) remained devegetated.

Growth Rate Studies

Preliminary plotting of the ages and diameters of Abies fraseri in each of the four areas sampled on Andrews Bald indicated possible curvilinear relationships. For each group of points a least squares fit was calculated with logarithmic transformed data, and ages and diameters of the trees of each area were compared (Figures 15, 16, 17, and 18). Regression statistics were recorded (Table III), the coefficients of correlation being highly significant ($P < .01$).

A comparison of growth rings for the last four years for Abies

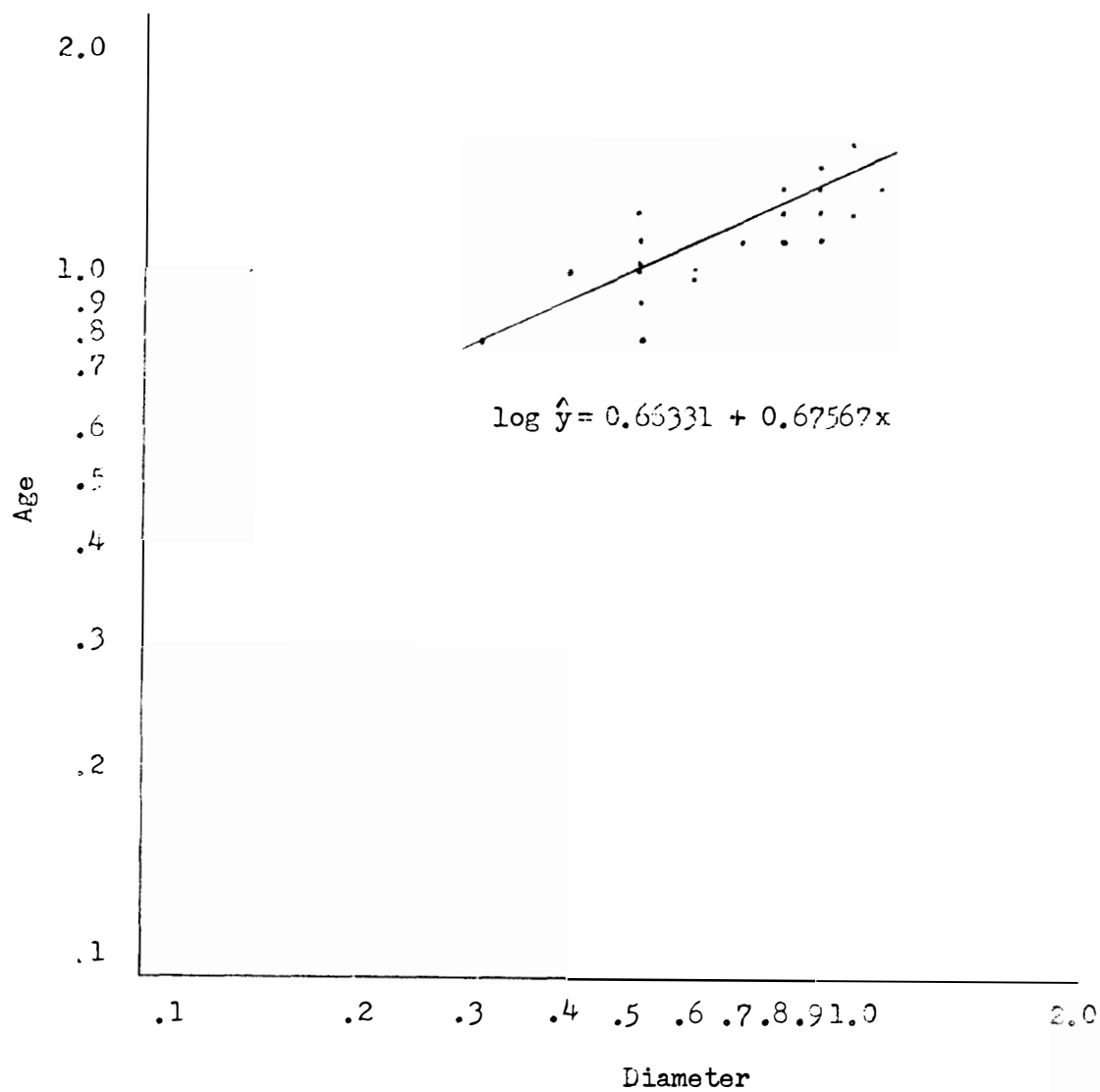


Figure 15. Relation of diameter to age in a population of Abies fraseri invading the open portion of Andrews Bald.

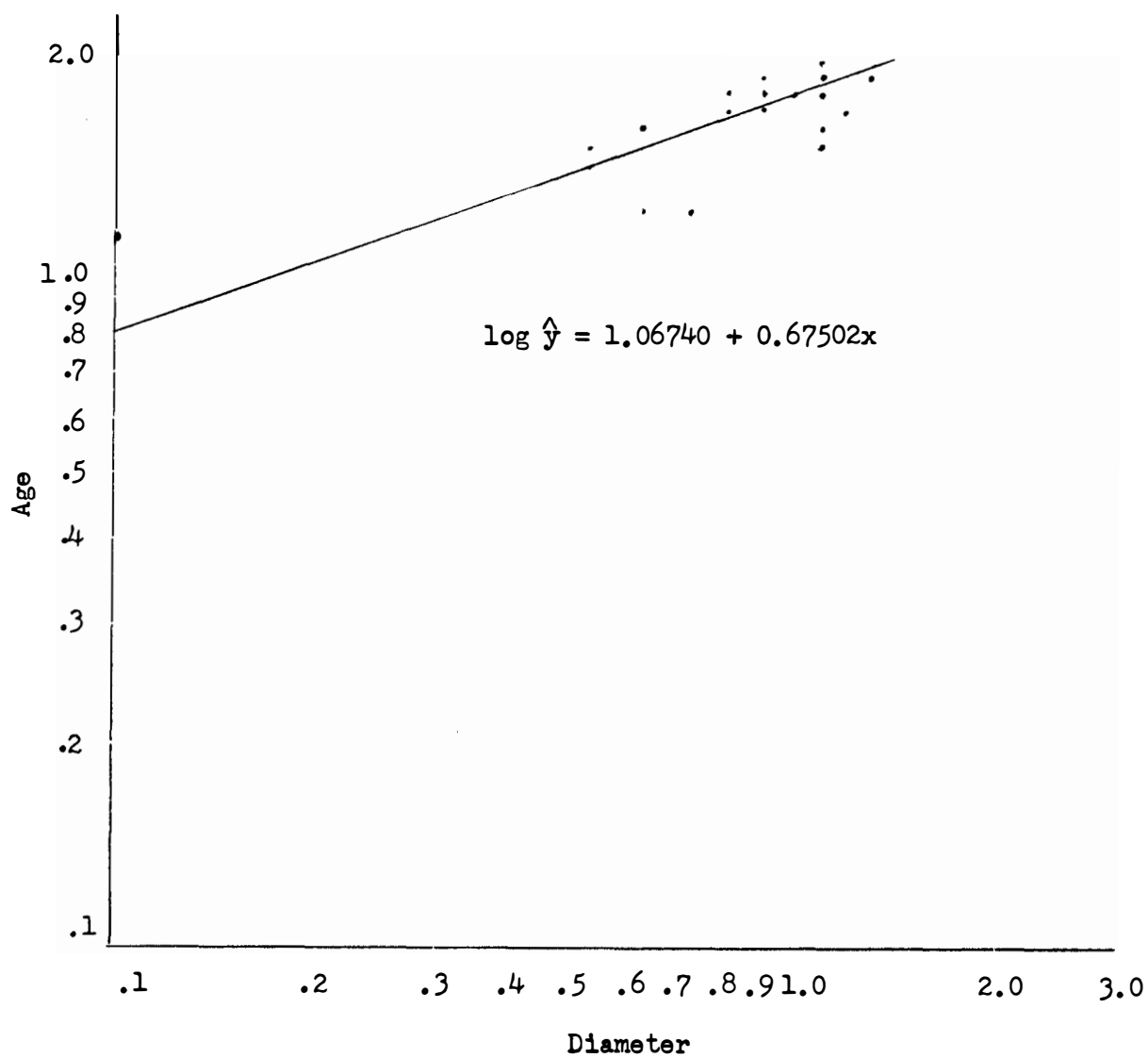


Figure 16. Relation of diameter to age of *Abies fraseri* in the spruce-fir forest in the northern surrounding portion of Andrews Bald.

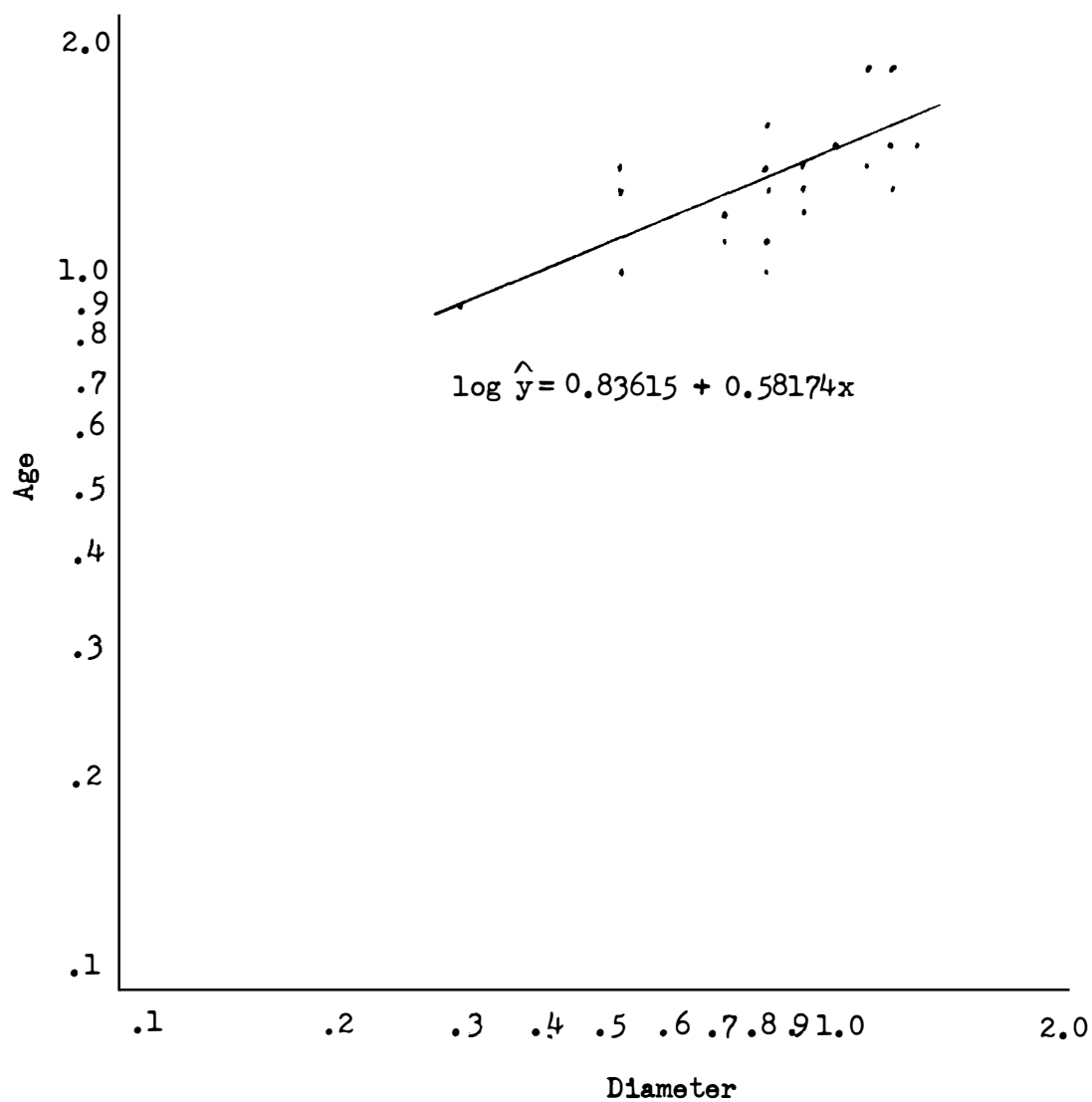


Figure 17. Relation of diameter to age in a stand of Abies fraseri on the eastern margin of Andrews Bald.

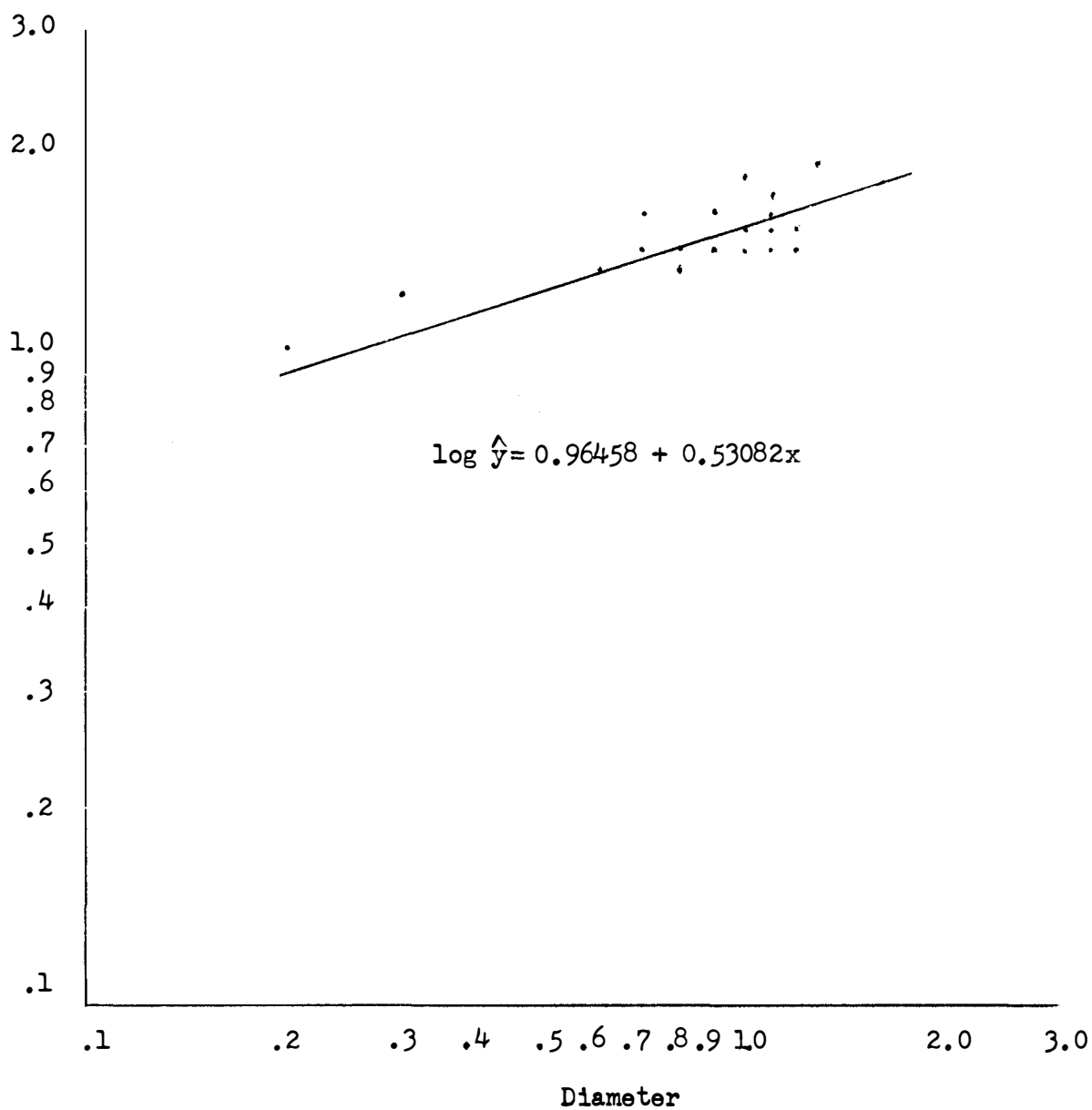


Figure 18. Relation of diameter to age in a stand of Abies fraseri on the western margin of Andrews Bald.

TABLE III
VALUES OF COMPONENTS¹ OF REGRESSION
EQUATIONS OF AGES AND DIAMETERS OF
ABIES FRASERI

Location of Sampled Trees	A	b	r	SEb
Spruce-fir forest	1.06740	0.67502	0.770844	0.1456
Eastern margin-mixed stand	0.96458	0.53082	0.68352	0.1050
Bald	0.66331	0.67567	0.86545	0.0813
Western spruce-fir margin	0.83615	0.58174	0.74498	0.1180

¹In logarithmic form.

fraseri (Table IV) in each of samples areas indicate that given comparable canopy exposure, growth rates on the bald appear to be at least as good as those of margin or forest. The actual growth pattern of fir trees growing on Andrews Bald is presented in Figure 19.

For convenience, trees of each of the four 1/5 acre plots were placed in diameter classes. The age of the mid-points of the classes was calculated using the specific regression equation for the trees in each area. Though statistically hard to defend, values for the numbers of trees in each diameter class from the 1/5 acre plots were taken to be representative of larger populations. The four areas were then compared for successional trends (Figure 20).

Seedling Studies

The permanent .01 acre seedling plots were placed so that comparisons of three margins could be made. Seedling density for both the seedlings under 5 inches and those between 5 inches and 3 feet on the western spruce-fir side, the deciduous southern side, and the mixed-forest (both deciduous and conifer) eastern side were calculated (Figures 21, 22, 23, 24, 25, and Table V).

Counts of woody seedlings on a "grassy area" in the spruce-fir forest which was created in 1925 by a forest fire (A. Stupka, pers. comm.) showed slower woody invasion trends than on Andrews Bald except for Vaccinium sp. which appears to be slowly encroaching. Surprisingly few Pin Cherries (Prunus pennsylvanica) and other species normally connected with secondary succession in spruce-fir areas (Brown, 1941) were encountered. The herbaceous cover was unusual, with Carex

TABLE IV
COMPARISON OF GROWTH RINGS OF SELECTED LARGE DIAMETERS
OF ABIES FRASERI IN EACH OF FOUR
LOCATIONS ON ANDREWS BALD

DBH	1967	1966	1965	1964
Spruce-Fir Forest				
19.0	0.075	0.075	0.050	0.075
16.3	0.075	0.061	0.061	0.061
14.0	0.100	0.075	0.050	0.050
12.5	0.175	0.150	0.125	0.135
12.8	0.125	0.125	0.100	0.125
Western Spruce-Fir Margin				
22.3	0.125	0.086	0.060	0.060
15.0	0.125	0.125	0.075	0.125
15.7	0.250	0.225	0.175	0.225
16.3	0.125	0.100	0.090	0.175
13.3	0.235	0.210	0.200	0.210
Bald				
8.5	0.210	0.196	0.200	0.225
7.8	0.236	0.197	0.145	0.175
9.5	0.175	0.175	0.145	0.150
7.1	0.125	0.175	0.175	0.200
8.5	0.100	0.100	0.100	0.100
Eastern Mixed Forest Margin				
17.8	0.175	0.173	0.135	0.148
11.9	0.107	0.160	0.061	0.100
13.0	0.125	0.100	0.100	0.100
14.3	0.025	0.080	0.075	0.050
14.3	0.159	0.133	0.133	0.150

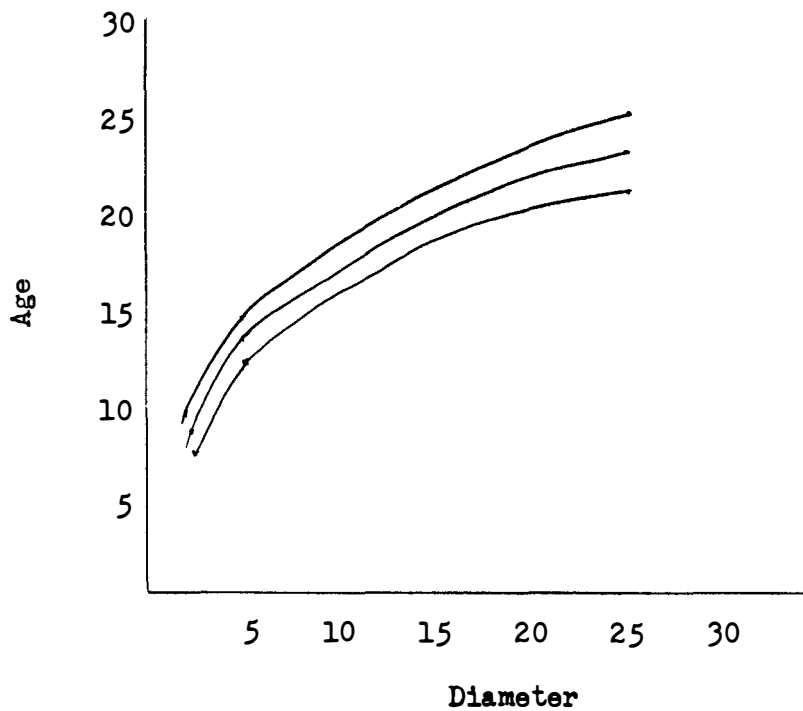
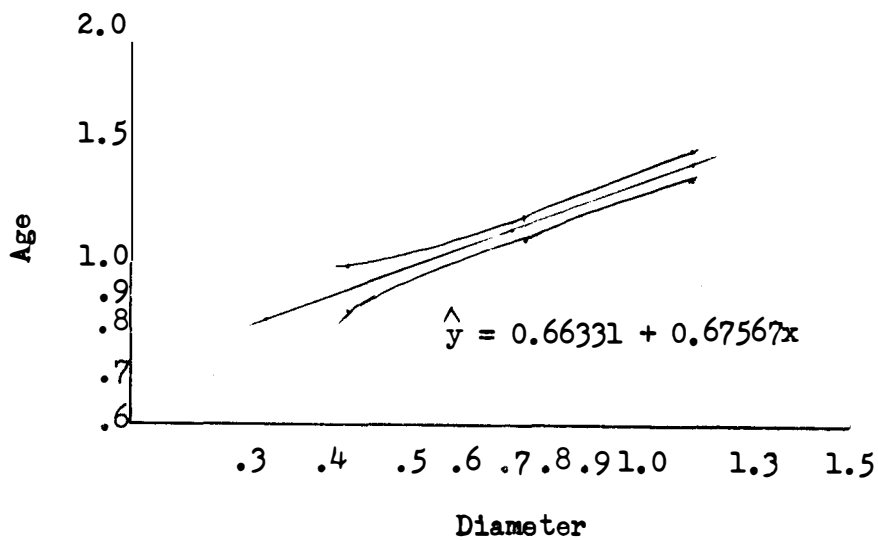


Figure 19. Regression of ages and diameters with 5% confidence limits of Abies fraseri on Andrews Bald using logarithmically transformed data and the corresponding anti-logs.

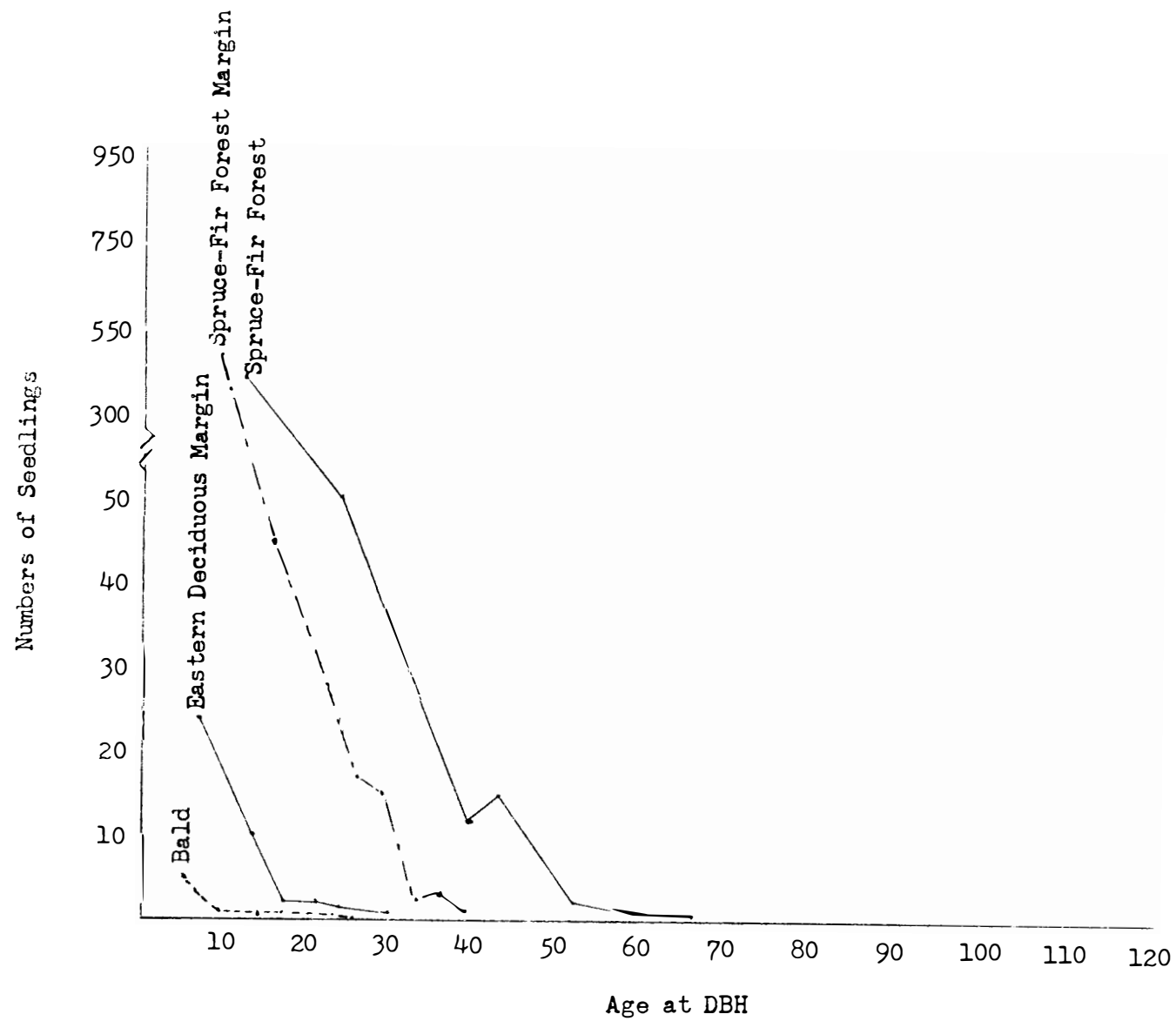


Figure 20. Age distribution of *Abies fraseri* in four locations on Andrews Bald.

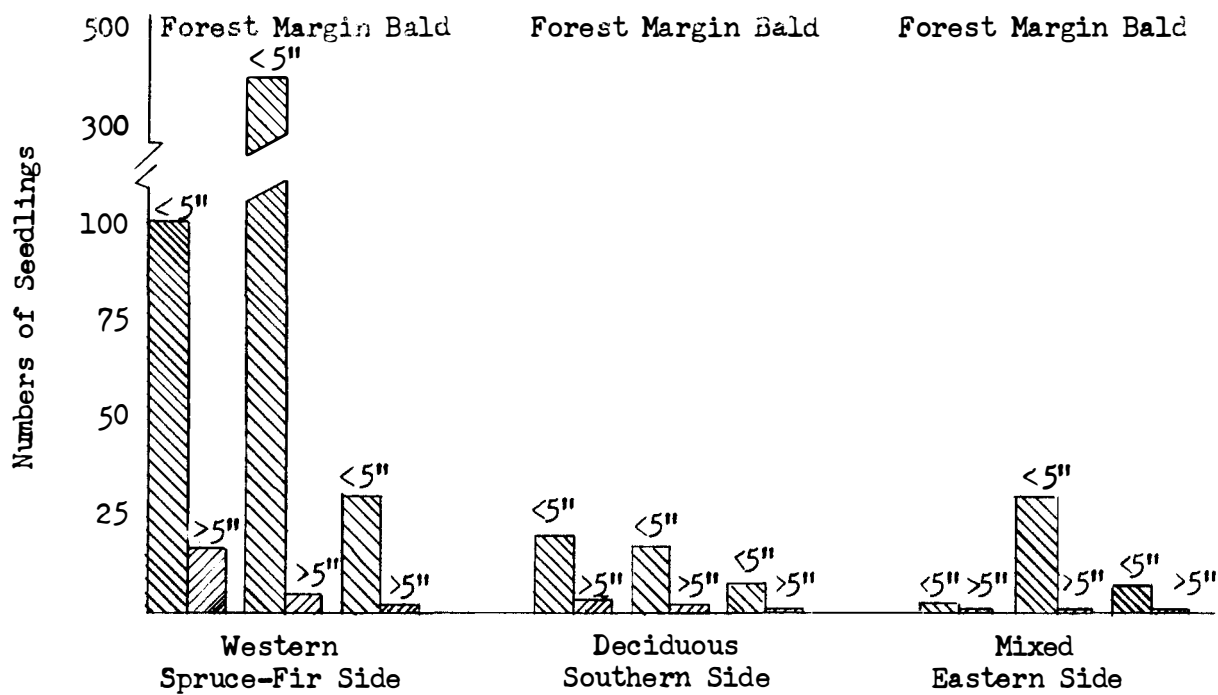


Figure 21. Seedlings of *Abies fraseri* under 5 inches in height compared with those between 5 inches and 3 feet on each side of Andrews Bald.

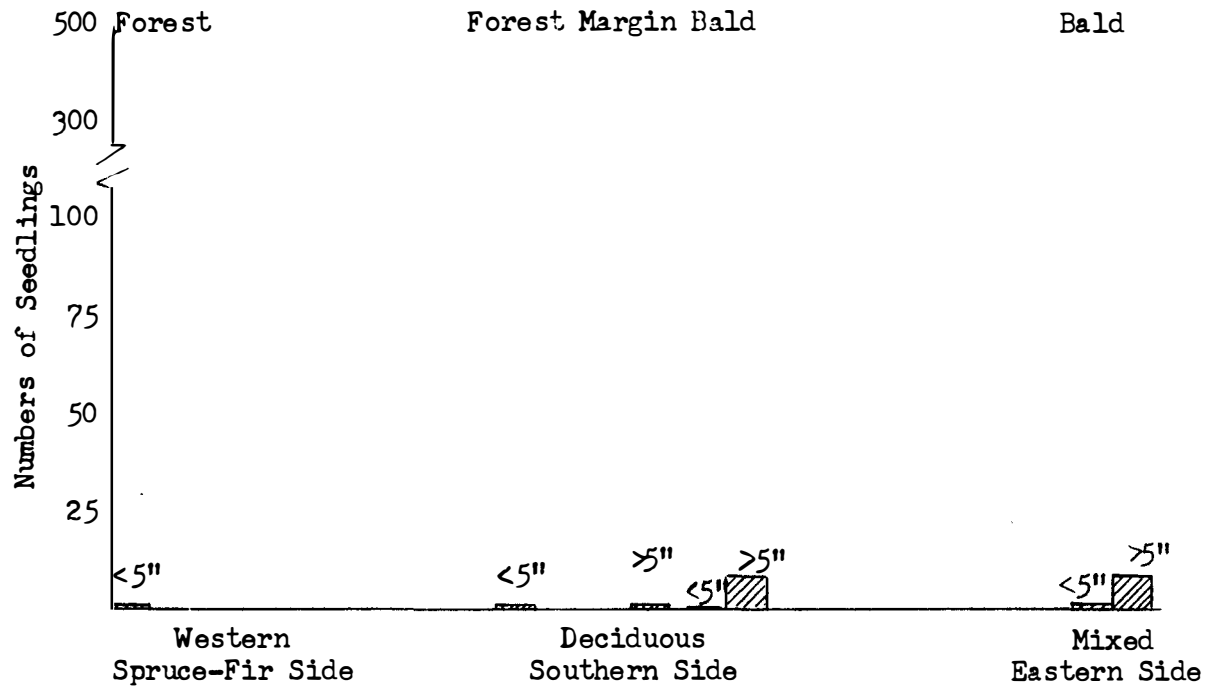


Figure 22. Seedlings of *Ribes* sp. under 5 inches in height compared with those between 5 inches and 3 feet on each side of Andrews Bald.

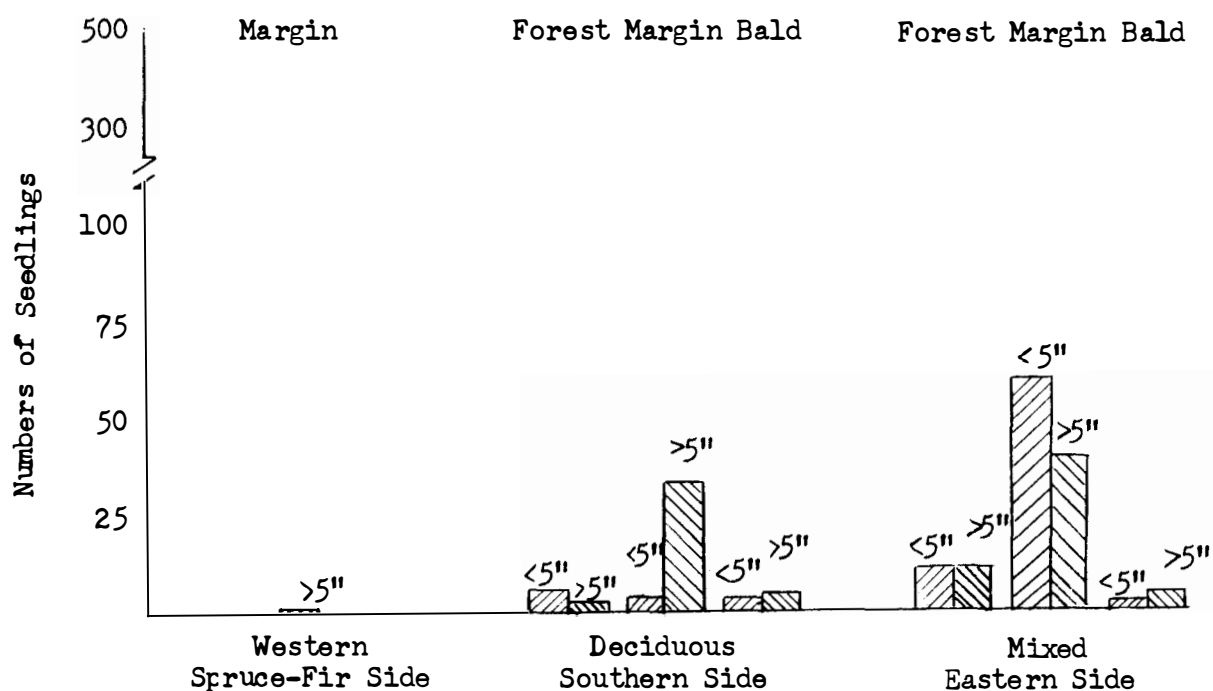


Figure 23. Seedlings of *Rhododendron* sp. under 5 inches in height compared with those between 5 inches and 3 feet on each side of Andrews Bald.

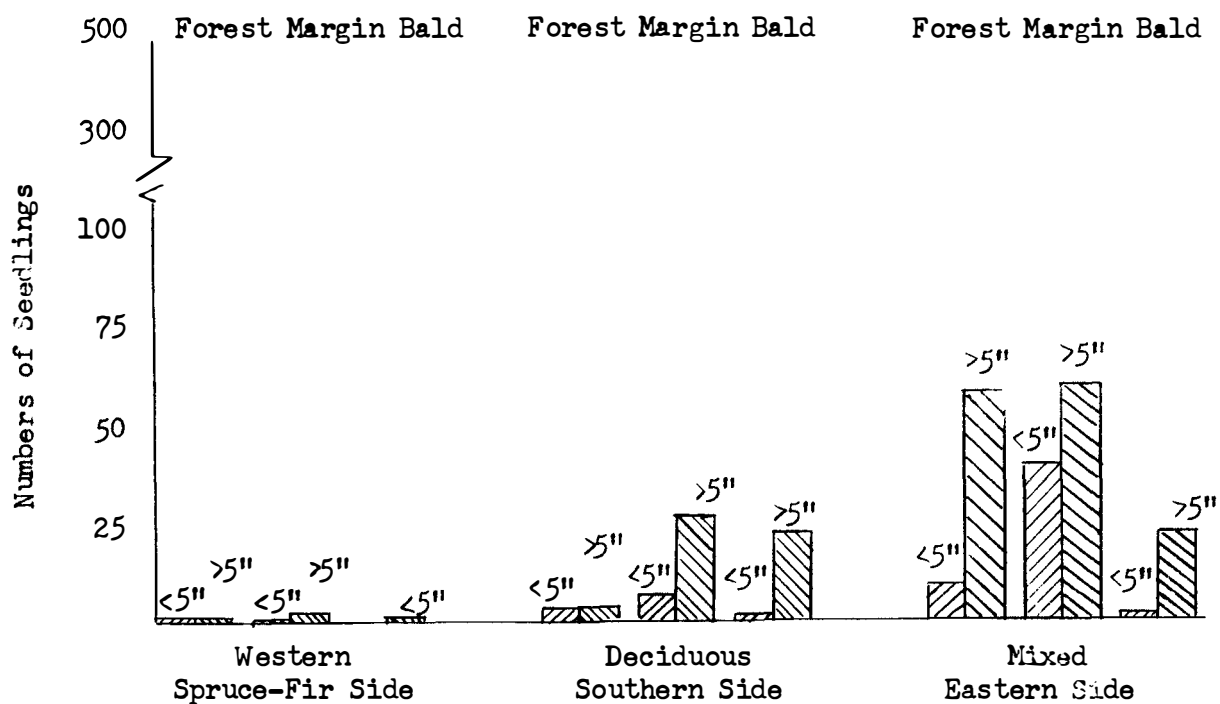


Figure 24. Seedlings of *Vaccinium* sp. under 5 inches in height compared with those between 5 inches and 3 feet on each side of Andrews Bald.

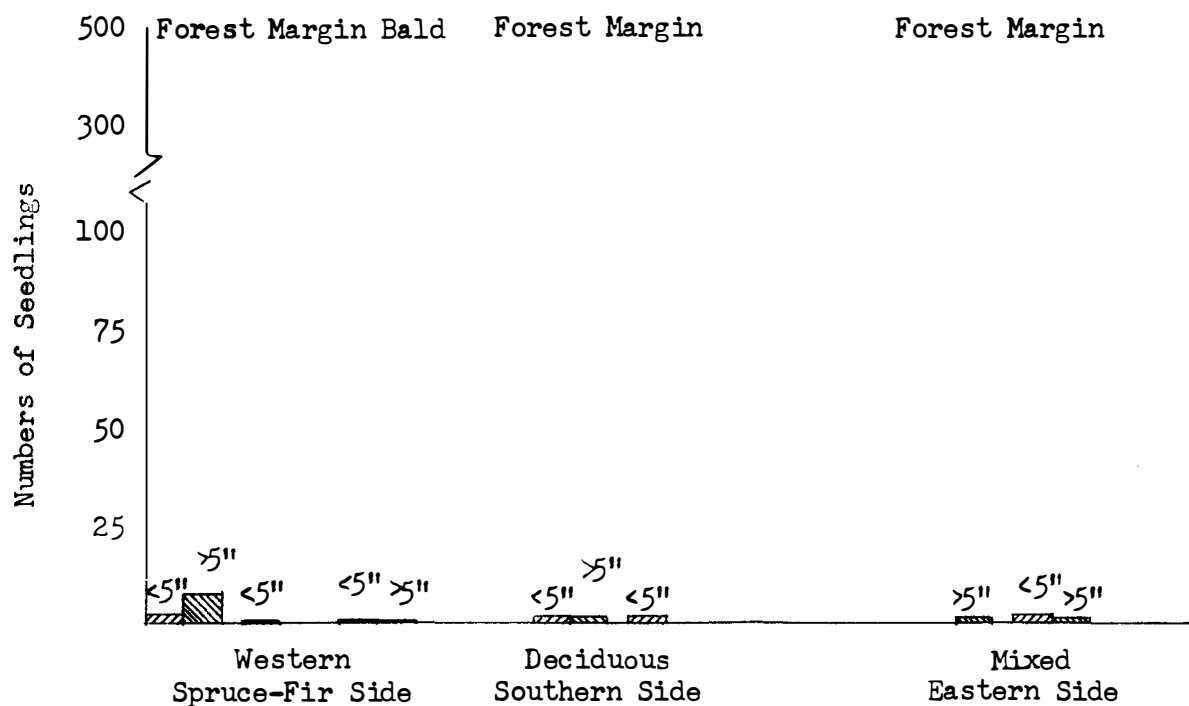


Figure 25. Seedlings of *Picea rubens* under 5 inches in height compared with those between 5 inches and 3 feet on each side of Andrews Bald.

TABLE V

SEEDLING DENSITIES (WITH CORRESPONDING STANDARD ERROR AND STANDING DEVIATION)
FROM SEVERAL AREAS ON ANDREWS BALD

Species	Density		s		Sx		Density		s		Sx	
	5"	5" 3'	5"	5" 3'	5"	5" 3'	5"	5" 3'	5"	5" 3'	5"	5" 3'
	Spruce-Fir Forest						Spruce-Fir Margin					
<u>Abies fraseri</u>	103.20	16.50	74.60	19.82	30.45	8.10	416.20	5.60	167.70	5.15	75.00	2.30
<u>Betula lutea</u>	19.30		23.10		9.42			.20		.50		.20
<u>Picea rubens</u>	2.50	7.60	1.70	12.27	.71	5.00	0.50		.90		.40	
<u>Vaccinium</u> sp.	.83	.50	1.30	.84	.54	.33	.20	1.80	.90	3.47	.40	2.40
<u>Viburnum</u> sp.	.16		4.10		1.60							
<u>Ribes</u> sp.	.33		8.10		3.31							
<u>Amelanchier</u> sp.							11.00		17.46		7.40	
<u>Rhododendron</u> <u>calendulaceum</u>							.40	1.20	.23	2.60	.32	1.20
<u>Rhododendron</u> sp.								.40		.90		.40

TABLE V (continued)

Species	Density		s		Sx		Density		s		Sx	
	5"	5" 3'	5"	5" 3'	5"	5" 3'	5"	5" 3'	5"	5" 3'	5"	5" 3'
	Southern Deciduous Margin						Southern Deciduous Forest					
<u>Abies fraseri</u>	17.6	1.2	13.00	1.60	5.80	.23	19.6	3.2	18.4	2.4	8.20	1.1
<u>Betula lutea</u>	.6	1.8	.97	3.90	.44	1.70	1.0		1.4		.60	
<u>Picea rubens</u>	1.2		1.20		.50		.6	.5	.6	1.4	.25	.6
<u>Vaccinium</u> sp.	6.0	26.6	6.60	39.00	3.00	1.70	3.8	3.6	3.4	5.4	2.20	2.4
<u>Viburnum</u> sp.	3.6	3.6	6.48	4.60	2.90	2.10	1.0	1.2	1.0	2.7	.45	1.2
<u>Ribes</u> sp.		.6		1.35		.60						
<u>Amelanchier</u> sp.	1.8	.8	1.70	1.20	.24	.50						
<u>Rhododendron calendulaceum</u>		3.4		3.60		1.60	6.8	4.8	5.8	4.3	2.60	1.9
<u>Rhododendron</u> sp.	8.6	33.4	7.80	67.00	3.50	29.50	5.6	3.6	10.9	4.3	4.90	1.9
<u>Acer rubrum</u> L.	.4	.2	.70	.50	.90	.27	.4		.9		.40	
<u>Fagus grandifolia</u> Ehrh	2.2		4.89		2.20		11.0	9.8	4.7	5.2	2.10	2.3
<u>Ilex montana</u> T. & G.	.6	.6	.97	.97	.44	.44						
<u>Crataegus macrosperma</u> Ashe	.8	.8	1.20	1.40	.50	.60						
<u>Kalmia latifolia</u>	.4	.8	.75	1.20	.35	.50						
<u>Quercus rubra</u> L.	.2		.50		.27							

TABLE V (continued)

Species	Density		s		Sx		Density		s		Sx	
	5"	5" 3'	5"	5" 3'	5"	5" 3'	5"	5" 3'	5"	5" 3'	5"	5" 3'
	Eastern Mixed Margin						Eastern Mixed Forest					
<u>Abies fraseri</u>	29.50	1.00	28.21	1.15	14.11	.57	2.80	1.00	9.10	2.00	4.50	1.00
<u>Betula lutea</u>	2.30	1.20	2.05	1.42	1.02	.70	14.00		22.18		11.09	
<u>Picea rubens</u>	2.50	1.50	3.43	3.00	1.71	1.50		.25		.50		.25
<u>Vaccinium</u> sp.	40.00	61.50	35.13	48.70	17.53	24.40	9.50	58.00	7.41	65.70	3.70	33.30
<u>Viburnum cassinoides</u>	3.00	2.50						1.00				
<u>Amelanchier</u> sp.	.75											
<u>Rhododendron</u> sp.	60.40	39.20	40.00	35.66	20.00	17.85	11.30	11.50	15.13	14.79	7.54	7.41
<u>Prunus pennsylvanica</u>								.25				
<u>Sorbus americana</u> (Marsh)	2.50	.25										
<u>Acer rubrum</u> L.							.25	1.50				
<u>Fagus grandifolia</u> Ehrh							.25	1.00				
<u>Cornus alternifolia</u> L.f.							.25	.50				

TABLE V (continued)

Species	Density		s		Sx		Density		s		Sx	
	5"	5" 3'	5"	5" 3'	5"	5" 3'	5"	5" 3'	5"	5" 3'	5"	5" 3'
	Burn						Bog					
<u>Abies fraseri</u>	.50		.27		.34		597.0	2.0	472.4	2.80	334.00	2.0
<u>Betula lutea</u>							15.5		20.5		14.49	
<u>Vaccinium</u> sp.	12.80	89.60	25.50	124.1	10.40	50.4	1.5	8.0	2.1	11.30	1.50	8.0
<u>Viburnum</u> sp.	.16	.82										
<u>Rhododendron calendulaceum</u>								.5		.23		.5
<u>Sorbus americanus</u>	.83											
<u>Acer rubrum</u> L.							.2					

TABLE V (continued)

Species	Density		s		Sx		Density		s		Sx	
	5"	5" 3'	5"	5" 3'	5"	5" 3'	5"	5" 3'	5"	5" 3'	5"	5" 3'
	Bald Deciduous Side						Bald Spruce-Fir Side					
<u>Abies fraseri</u>	7.0	.8	10.90	1.8	6.00	.8	31.75	.12	23.2	.35	8.2	.13
<u>Betula lutea</u>	.2											
<u>Picea rubens</u>							.60		1.2		.4	
<u>Vaccinium</u> sp.	1.0	22.6	2.20	32.9	1.00	19.2		.25		.70		.25
<u>Viburnum</u> sp.		.6										
<u>Ribes</u> sp.	.2	8.8	.01	19.2	.20	8.6						
<u>Amelanchier</u> sp.	.4	.2										
<u>Rhododendron</u> sp.	2.4	4.2	4.9	9.4	2.20	4.2						
<u>Prunus pennsylvanica</u>								.25				
<u>Crataegus macrosperma</u> Ashe	2.4	4.4	2.2	6.1	.98	2.7						

intumescens var. Fernaldei and Agrostis perennans (Walt) Tuckerm. dominating.

Seeds of Picea rubens Sarg. from the Adirondack Mountains were treated in the laboratory with 50 per cent Clorox and germinated on 1 per cent agar. Germination rates ranged from 2 per cent to 60 per cent, with a 2 per cent and a 30 per cent rate obtained from plates wrapped in polyethylene. A 42 per cent and a 60 per cent rate were obtained from plates without the protective wrapping.

Germination rates in field plantings of seeds sterilized as above varied from 19 per cent on the bald to 1 per cent in the spruce-fir forest with a 7 per cent rate on the spruce-fir margin, a 4 per cent on the southern deciduous margin, and an 11 per cent rate in the hardwood forest. None of the seedlings survived the growing season. Leaf litter destroyed those in the hardwood forest and on its margin. Inability to compete with grass that rapidly invaded the seed bed on the spruce-fir margin appeared to be the reason for their death. Seedlings, which were fully exposed to the climatic extremes of the bald, were uprooted and destroyed apparently by hard-driving rain.

Density of the various taxa of the shrub layer was determined from the same .01 acre plots discussed above (Table VI). Species of Rhododendron and Vaccinium dominated the southern deciduous and eastern margins.

The threat of the balsam wooly aphid (Chermes picea Ratz) to Fraser fir in the Great Smoky Mountain National Park is great. Recent surveys have shown that 35 acres were infested in 1963 and this figure has increased to approximately 2,280 acres today. Traps on Andrews Bald

TABLE VI
SHRUB DENSITY ON ANDREWS BALD

Species	Spruce Fir Forest	Spruce Fir Margin	Bald Spruce Fir Side	Southern Deciduous Forest	Southern Deciduous Margin	Bald Southern Side	Eastern Mixed Forest	Eastern Mixed Margin	Bog	Burn
Vaccinium sp.	2	5.6	9.3	6.2	41	5.6	38.2	38.5	11.5	64.3
Ribes sp.	0	0	.5	.2	1.4	7	0	.7	0	0
Kalmia latifolia L.	0	0	0	0	2.2	0	0	0	0	0
Rhododendron calendulaceum	0	1.2	.5	9.2	23.4	0	0	0	1	0
Rhododendron sp.	.5	5.6	0	9	125.2	3.4	4.7	117.7	0	0
Veburnum sp.	0	0	0	1.6	4.4	1.2	0	2	0	12.6

in the summer of 1967 indicated that the firs there were still free of infection, but their destruction is within the realm of possibility (pers. comm. with Jim Wiggins of the Great Smoky Mountains National Park).

VI. DISCUSSION

Bald environments are more extreme than the adjacent forests as Mark (1958) pointed out, but how do weather conditions compare among the balds? Mean temperatures for Andrews Bald, Spence Field, and Gregory Bald are very close for the entire study period as are the maximum and minimum temperatures. Comparisons by means of climatic polygons for the 1967 growing season showed the climates of the three "grassy areas" to be very similar. Solar insolation values for July and August indicate possible differences between Spence Field and Andrews Bald, but careful note must be made of the number of days involved in the calculations of each mean.

The close correspondence of the temperatures for Andrews Bald, Spence Field, Gregory Bald, and Newfound Gap during the growing season was pointed out in Figures 1, 2, and 3, pages 13, 14, and 15. Comparison of Park Headquarters with Newfound Gap shows that Newfound Gap averages 10° to 12° F. lower than Park Headquarters; a relationship pointed out by Shanks (1954).

Standard errors computed for the regression coefficients of the age-diameter relationships of Abies fraseri in each of the four areas on Andrews Bald indicated that the regression coefficients were not significantly different. For the marginal and forest regressions, the variation around the regression line was greater than that for the bald due to the unaccounted for effect of stand density and small sampling size. Regression coefficients for the margins and forest, then, cannot be indicative of growth rates of fir. But, since most of the trees on the bald were

included in the sampling, and since age at DBH is more closely related to chronological age for fir grown in the open, bald conditions, the regression coefficient is indicative of growth rate there; and there was, in fact, a high correlation ($r = .86545$) between the ages and diameters on the Bald.

Observations on the width of tree rings taken (in the forest and margin) from cores at DBH of large diameter fir trees with their crowns represented in the canopy and from cores of the open grown trees on the bald give an estimate of their growth rates. That the trees on the bald appear to be growing as well as trees in the forest with comparable exposure in the canopy agrees with Brown (1953) and Mark (1958).

Results from the climatic and growth rates studies as outlined above appear to support the hypothesis of Billings and Mark (1957) that balds occupy potential spruce-fir zones.

That the extremes of the bald environment are destructive at the seedling level is pointed out by the transplants. Those seedlings not protected from climatic extremes did not survive the transplanting through one growing season. This agrees with Mark (1958) who felt that the tolerance limits of tree seedlings were approached and perhaps exceeded "under the severe environmental conditions" of the bald. Observations concerning other factors affecting seedling survival can be made after examining the plots in the spring of 1968. Seeds of grasses and sedges are present in spruce-fir forest soils and germinate on transplanting to the bald or greenhouse. This strongly suggests that destruction of the canopy over a wide enough area to create a "bald"

would be followed by quick grass proliferation which in turn offers competition to potentially re-invading fir or spruce seedlings.

Field plantings of Picea rubens Sarg. dramatically demonstrate the effects of bald weather conditions on seedlings. All of the seedlings in the bald plot were uprooted, apparently by a combination of wind and rain. Those on the margins, covered by deciduous leaves, were dead at the end of the season. That there was only 1 per cent germination in the spruce-fir forest was due presumably to the depth of planting and the very wet, unaerated soil of the plot. According to Griffin (1965), Picea rubens Sarg. from the Adirondack Mountains should survive outside its natural range in proportion to original germination and this is "favored by shallow plantings." From the laboratory work it could be conjectured that the polyethylene covers on the petri plates simulated increased planting depths thus the low germination rates while unwrapped plates had higher percentages.

If the age distribution pattern (Figure 20, page 38) for the spruce-fir forest can be taken as representative of a forest regenerating itself, then the margins are not only maintaining themselves, but slowly encroaching on the bald. The low germination and survival rates on the bald are pointed out, as is a period possibly critical to seedlings that reach 8 years of age, about the time they would rise above protective vegetation and rocks.

From comparisons of fir seedlings under 5 inches with those between 5 inches and 3 feet, it appears that survival rates are higher in the forest than on the margin where 5 in 400 might survive. Survival rate on the bald seems proportionally higher, but this is due to a

reduced number of seedlings in the 5 inch category as compared with margin and forest. Rhododendron sp. compared in this manner appears to be more than maintaining itself on the southern and eastern sides of Andrews Bald, and in fact, appears to be slowly invading the bald. Vaccinium sp. also appears to be actively invading the eastern edge of Andrews Bald as seedling survival seems to be quite high. Spruce seedlings were conspicuous by their absence. Other woody species, while reproducing, were not present in sufficient numbers to be called active invaders.

Studies of stem densities bear out the seedling trends--Rhododendron sp. and Vaccinium sp. appear to be dominant invaders on the southern and eastern margins.

Survival for seedlings of Rhododendron sp. and Vaccinium sp. appear to be higher than Abies fraseri; and if the balsam wooly aphid does destroy the existing fir, then Andrews Bald can only become a heath bald.

For those balds surrounded by deciduous forest, lack of a coniferous seed source in all probability explains their bald condition. A warming trend, however, would allow invasion of the balds by woody species that are normally excluded by the climatic conditions of a "spruce-fir" zone.

VII. CONCLUSIONS

The three grass balds studied (and in all probability the other grassy balds) lie in potential spruce-fir zones. Invasion of the balds by woody species has been documented by several investigators and is not contested here. That the invasion is extremely slow has been shown (Bruhn, 1964). The present study indicates that factors preventing total re-invasion of the balds are operating at the seedling level. Other investigators have suggested that competition with the grass (Wells, 1937; Gilbert, 1954), severity of the bald environment at a level critical to seedlings (Billings and Mark, 1957), exceeded tolerance limits of the tree taxa (Mark, 1958), possible moisture deficiencies, lack of seed source, and possible elimination of biotypes (Mark, 1958) either separately or together are responsible for bald maintenance. In the case of the balds surrounded by hardwoods which are at upper limit of their tolerance, a lack of coniferous seed source obviously prevents bald invasion. From this study it appears that a combination of factors are involved where seed source is available. Those seeds germinating in the grass must compete with the grass and very few survive past the 5 inch level. Conifer seedlings and presumably deciduous seedlings exposed to the bald climate soon die, but if the seedling should have the protection of a rock or pre-existing vegetation, survival is almost assured.

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LITERATURE CITED

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APPENDIXES

APPENDIX A

TABLE VII

SUMMARY WEATHER DATA FOR ANDREWS BALD

Year	Month	Maximum °F/Days	Minimum °F/Days	Mean °F/Days	Rainfall Inches	Wind Miles/Day	Solar Radiation (gm cal/cm ²)/Days
1966	April	56/7	48/7	52/7			207.59/7
	May	59/26	43/26	51/26			
	June	69/14	52/14	60/14	10.55		411.52/13
	July	69/31	54/31	62/31	4.70		400.64/28
	August	65/21	52/21	58/21	10.89		312.19/29
	September	57/28	46/28	52/28	6.14		220.05/9
	October	52/25	37/25	48/25	6.69		265.24/8
	November	48/8	35/8	42/8	.22		176.82/24
	December	40/3	30/3	35/3	5.48		235.71/3
1967	January						
	February						
	March						286.57/7
	April	56/26	39/26	48/26			370.02/22
	May	56/31	42/31	49/31	8.09		252.61/14
	June	65/29	51/29	58/29	12.45	100.67	267.49/5
	July	59/6	49/6	54/6	8.71	123.7	293.33/21
	August	60/16	48/16	54/16	8.90	100.1	223.86/27
	September	60/25	44/25	52/25	3.64	83.7	251.76/26
	October	55/19	39/19	47/19	4.76	140.0	249.06/30

APPENDIX B

TABLE VIII

SUMMARY WEATHER DATA FOR SPENCE FIELD

Year	Month	Maximum °F/Days	Minimum °F/Days	Mean °F/Days	Rainfall Inches	Wind Miles/Day	Solar Radiation (gm cal/cm ²)/Days
1966	April						
	May	62/18	51/18	56/18			
	June	69/30	55/30	62/30	1.65		383.82/13
	July	72/31	59/31	65/31	8.24		352.36/27
	August	67/31	55/31	61/31	10.47		221.40/14
	September	62/30	51/30	56/30	5.70		231.77/29
	October	56/31	39/31	47/31	5.65		262.10/21
	November	50/23	39/23	44/23	5.88		112.23/11
	December	43/19	30/18	37/18	4.09		109.31/12
1967	January	43/12	31/12	37/12			
	February	36/5	22/5	29/5			253.52/7
	March	60/6	45/6	53/6			287.20/6
	April	62/26	45/26	53/26			314.64/15
	May	59/31	45/31	52/31			303.69/13
	June	64/30	52/30	58/30	.83*	109.1	287.66/18
	July	64/31	54/31	59/31	9.37	106.0	152.64/24
	August	69/31	55/31	62/31	5.77	93.8	83.59/22
	September	60/25	48/25	54/25	4.42	115.3	129.24/20
	October	56/28	49/28	53/28	2.01	190.4	144.03/25

*Figure includes only 15 days.

APPENDIX C

TABLE IX

SUMMARY WEATHER DATA FOR GREGORY BALD

Year	Month	Maximum °F/Days	Minimum °F/Days	Mean °F/Days	Rainfall Inches	Wind Miles/Day
1966	April					
	May					
	June					
	July					
	August					
	September	58/20	49/20	53/20	6.00	
	October	54/29	41/31	47/29	7.20	
	November	47/27	35/27	41/27	2.69	
	December	39/5	34/4	37/4		
1967	January					
	February					
	March	55/12	38/12	47/12		
	April	58/30	42/30	50/30		
	May	57/15	43/15	50/15		
	June	68/13	56/13	62/13		
	July	62/27	53/27	58/27	11.44	140.56
	August	65/31	55/31	60/31	4.61	128.9
	September	59/30	47/30	53/30	3.71	134.79
	October	55/29	40/29	48/29	3.98	178.19

APPENDIX D

TABLE X

SUMMARY WEATHER DATA FOR NEWFOUND GAP¹

Year	Month	Maximum °F	Minimum °F	Mean °F	Rainfall Inches
1966	April				
	May	61	48	55	4.42
	June	65	51	58	3.04
	July	69	56	63	11.19
	August	65	56	61	11.79
	September	58	51	55	6.13
	October	53	42	47	7.32
	November	46	36	41	9.56
1967	December	34	28	31	9.40
	January	38	28	33	5.48
	February	34	23	29	7.22
	March	46	34	40	5.01
	April	60	44	52	4.00
	May	59	47	53	8.26
	June	64	54	59	7.79
	July	61	53	57	14.05
	August	62	54	58	7.54
	September	58	48	53	4.60
	October	53	42	46	5.03

¹All averages based on complete monthly readings taken by National Park Service.

APPENDIX E

TABLE XI

SUMMARY WEATHER DATA FOR PARK HEADQUARTERS¹

Year	Month	Maximum °F	Minimum °F	Mean °F	Rainfall Inches
1966	April	68	44	56	5.72
	May	76	50	63	3.12
	June	85	55	70	6.43
	July	87	62	75	7.23
	August	83	61	72	12.64
	September	76	55	66	2.99
	October	69	41	55	4.36
	November	60	38	50	5.56
	December	49	30	40	2.15 rain 3.00 snow
1967	January	52	29	40	2.57
	February	47	27	37	5.57
	March	69	40	54	2.99
	April	76	47	62	2.97
	May	74	50	62	6.84
	June	83	59	71	5.04
	July	80	60	70	12.21
	August	81	60	70	5.36
	September	75	51	63	3.20
	October	71	44	58	2.23

¹All averages based on complete monthly readings taken by National Park Service.

APPENDIX F

TABLE XII

VALUES FOR THE PARAMETERS OF THE CLIMATIC POLYGONS

	Hygro- thermo- graph Maximum °F/*	Hygro- thermo- graph Minimum °F/*	Hygro- thermo- graph Mean °F/*	Rainfall Inches/*	Relative Humidity Mean %/*	Solar Insolation ¹ (gm cal/cm ²)/*	Anemometer ¹	Vapor Pressure Deficit	Potential Evapotrans- piration
	June								
Andrews	65/9.8	51/9.5	58/9.7	12.45/10	85/9.9	267.49/9.6	100.67/9.6	1.92/9.1	25/10
Spence	64/9.7	52/9.6	58/9.7		82/9.7	287.66/10	109.1/10	2.304/9.9	
Gregory	68/10	56/10	62/10		86/10			2.344/10	
	July								
Andrews	59/9.6	49/9.5	54/9.6	8.71/8.7	85/9.8	293.33/10	123.7/9.4	1.912/10	18.5/9.1
Spence	64/10	54/10	59/10	9.37/9.1	88/10	152.64/7.2	105.99/8.7	1.536/8.9	18.0/8.9
Gregory	62/9.8	53/9.9	58/9.9	11.44/10	86/9.9		140.56/10	1.792/9.7	22.5/10
	August								
Andrews	60/9.3	48/9.3	54/9.3	8.90/10	87/9.9	223.86/10	100.1/8.8	1.40/8.9	19.0/10
Spence	69/10	55/10	62/10	5.77/8.1	88/10	83.59/6.1	93.76/8.5	1.758/10	10.0/7.3
Gregory	65/9.7	55/10	60/9.8	4.61/7.2	87/9.9		128.9/10	1.664/9.7	8.0/6.5

TABLE XII (continued)

	Hygro- thermo- graph Maximum °F/*	Hygro- thermo- graph Minimum °F/*	Hygro- thermo- graph Mean °F/*	Rainfall Inches/*	Relative Humidity Mean %/*	Solar Insolation ¹ (gm cal/cm ²)/*	Anemometer ¹	Vapor Pressure Deficit	Potential Evapotrans- piration
September									
Andrews	60/10	44/9.6	52/9.8	3.64/9.1	83/10	251.76/10	83.71/7.9	1.70/9.3	8.0/9.2
Spence	60/10	48/10	54/10	4.42/10	82/9.9	129.24/7.1	115.3/9.3	1.944/10	9.5/.10
Gregory	59/9.7	47/9.9	53/9.9	3.71/9.2	82/9.9		134.79/10	1.872/9.8	7.5/8.9
October									
Andrews	55/9.9	39/8.9	47/9.4	4.76/10	80/10	249.06/10	140.00/8.6	1.664/8.2	10.5/10
Spence	56/10	49/10	53/10	2.01/6.5	79/9.9	144.03/7.6	190.39/10	2.241/9.5	4.0/6.2
Gregory	55/9.9	40/9.1	48/9.5	3.98/9.2	71/9.4		178.19/9.7	2.497/10	9.5/9.5

*The second number in each case represents the square root of the relative value and is the point actually plotted.

¹Numerators represent daily averages.

APPENDIX G

TABLE XIII

COMPARATIVE AGES AT DBH OF ABIES FRASERI
FOR THE MID-POINTS OF DIAMETER CLASSES

Mid-points of Diameter Classes		Age of Trees on the Bald		Age of Trees in Spruce-Fir Forest		Age of Trees on Western Spruce-Fir Margin		Age of Trees on Eastern Mixed Forest Margin	
Anti-log	Log	Anti-log	Log	Anti-log	Log	Anti-log	Log	Anti-log	Log
1.05	0.02119	4.764	0.67763	12.08	1.08170	9.441	0.97583	7.047	0.84848
3.05	0.48430	9.572	0.98054	24.77	1.39431	16.67	1.22166	13.12	1.11789
5.05	0.70329	13.77	1.13850	38.83	1.54213	21.78	1.33790	17.58	1.24528
7.05	0.84819	17.22	1.23641	43.65	1.63995	26.00	1.41482	21.38	1.32958
9.05	0.95665	20.42	1.30969	51.64	1.71316	29.65	1.47239	24.72	1.39267
11.05	1.04336	23.33	1.36828	59.16	1.77169	32.66	1.51842	27.73	1.44311
13.05	1.11561	26.12	1.41709	66.07	1.82046	36.06	1.55677	30.55	1.48514
15.05	1.17754	28.77	1.45894	72.78	1.86238	38.90	1.58964	33.19	1.52117
17.05	1.23172	31.62	1.49555	79.43	1.89884	41.50	1.61841	35.73	1.55269
19.05	1.27989	33.73	1.52809	85.31	1.93135	44.06	1.64397	38.11	1.58071
21.05	1.32325	36.06	1.55739	91.41	1.96062	46.45	1.66699	40.36	1.60594
23.05	1.36267	38.37	1.58403	97.05	1.98723	48.75	1.68791	42.56	1.62887
25.05	1.39881	40.55	1.60844	102.8	2.01162	50.93	1.70710	44.67	1.64989
27.05	1.43217	42.76	1.63098	108.1	2.03414	53.09	1.72480	46.67	1.66930
29.05	1.46315	44.87	1.65192	113.5	2.05506	55.08	1.74125	48.64	1.68732
31.05	1.49206	46.88	1.67145	118.9	2.07457	57.15	1.75660	50.58	1.70414

APPENDIX H

ANDREWS TRANSPLANTS

Transplant	Location	Treatment	Dates	Observations
1A	Bald	Moved to forest	6/6/67	5 clumps of <u>Danthonia compressa</u> .
			7/3/67	Same
			7/15/67	5 clumps grasses - dying down significantly.
			7/28/67	8 <u>Potentilla canadensis</u> , grass 50% dead.
			8/6/67	<u>Potentilla canadensis</u> has flowered - older grasses chlorosed and grass vigor is diminishing - some have fruited.
			8/28/67	Few fruits on grass, otherwise same as above.
			9/14/67	<u>Potentilla canadensis</u> .
			10/1/67	Grass dying.
			11/2/67	Grass very dead.
1B	Forest	Moved to balds	5/6/67	19 <u>Abies fraseri</u> seedlings < 5", moss.
			7/3/67	19 <u>Abies fraseri</u> , moss.
			7/15/67	Same, moss (turning brown).
			7/28/67	Same
			8/6/67	Same
			9/14/67	Moss dying, 4 fir in good shape, 1 dead, 15 dying, grass still alive.
			10/1/67	3 fir alive, all else dead.
			10/28/67	15 fir, 4 fir dying, moss dying, 7 or 8 grass growing.
			11/2/67	Only the 3 fir protected by grass cover were still alive.
			11/7/67	Gone.

Another 1B set up: 1 spruce and as of August 6, 1967, the spruce was dead and the fir was turning brown.

APPENDIX H (continued)

Transplant	Location	Treatment	Dates	Observations
2A	Bald	Dug and reset	5/6/67	<u>Danthonia compressa</u> , <u>Potentilla canadensis</u> .
			7/3/67	Same
			7/15/67	App. 124 <u>Danthonia compressa</u> , 1 <u>Rubus canadensis</u> , 6 <u>Potentilla canadensis</u> , 1 unknown #1, 1 unknown #2.
			7/28/67	1 <u>Rubus canadensis</u> , grass dying a little.
			8/6/67	Grass dying somewhat, 1 <u>Rubus canadensis</u> , 6 <u>Potentilla canadensis</u> , 1 <u>Viola</u> sp., app. 75 <u>Danthonia compressa</u> .
			8/28/67	Same
			9/14/67	Same
			10/1/67	No <u>Rubus canadensis</u> - dead, <u>Potentilla canadensis</u> , <u>Viola</u> sp. turning brown.
			11/2/67	Same
2B	Forest	Dug and reset	6/21/67	<u>Abies fraseri</u> .
			7/3/67	Same
			7/15/67	3 <u>Solidago</u> sp., 3 fir.
			7/28/67	6 <u>Aster</u> sp., 3 fir.
			8/6/67	4 <u>Aster</u> sp. (others eaten), 3 fir.
			8/28/67	Same
			9/14/67	3 fir, 4 <u>Aster</u> sp.
			10/1/67	3 fir, 1 <u>Aster</u> sp.
			11/2/67	Fir still alive and okay - no transplant damage.
3A	Bald	Devegetated	5/6/67	Begun.
			7/15/67	No plants.
			7/28/67	2 <u>Potentilla canadensis</u> .
			8/6/67	2 small grass, 2 <u>Potentilla canadensis</u> .
			8/28/67	Same
			9/14/67	3 grasses, <u>Potentilla canadensis</u> .
			10/1/67	Grass germinating, no <u>Potentilla canadensis</u> .
			11/2/67	Same

APPENDIX H (continued)

Transplant	Location	Treatment	Dates	Observations
3B	Forest	Devegetated	6/21/67 7/15/67 7/28/67 8/6/67 8/28/67 9/14/67 10/1/67	Begun. No plants. Same Same Same Same Same, covered with litter.
4A	Bald	Dug, reset, and devegetated	5/6/67 7/15/67 7/28/67 8/6/67 8/28/67 9/14/67 10/1/67 11/2/67	Begun. 43 <u>Danthonia compressa</u> , 4 <u>Potentilla canadensis</u> . 5 <u>Potentilla canadensis</u> , 52 <u>Danthonia compressa</u> . Same, 1 <u>Rubus canadensis</u> . Moss beginning, otherwise same. Part exposed to sun almost overgrown with grass - otherwise same. 2 <u>Rubus canadensis</u> , <u>Potentilla canadensis</u> (3 or 4), covered with grass, some moss. Same
4B	Forest	Dug, reset, and devegetated	5/6/67 7/15/67 8/6/67 8/28/67 9/14/67 10/1/67	Begun. No plants. Same Same Same Same

APPENDIX H (continued)

Transplant	Location	Treatment	Dates	Observations
5A	Bald	Moved to green-house	5/6/67	<u>Potentilla canadensis</u> , <u>Rubus canadensis</u> , <u>Danthonia compressa</u> , <u>Rumex acetosella</u> , <u>Angelica triquinata</u> .
			7/12/67	Same
			8/9/67	1 <u>Angelica triquinata</u> (3 stems), 1 <u>Rubus canadensis</u> , 30-40 <u>Potentilla canadensis</u> , grass cover with healthy fruits.
			9/3/67	Same
5B	Forest	Moved to green-house	6/2/67	Unknown
			7/12/67	Same, unknown germinating, grass germinating.
			8/9/67	<u>Aster</u> sp. healthy 10-12, grass from top and side, 5 birch seedlings.
			9/3/67	<u>Aster</u> sp. flowering, 8 birch seedlings, grass healthy, growing from 3 inches from top.
			11/2/67	Same
6A	Bald	Sterilized and placed on bald	5/6/67	No plants.
			7/3/67	Same
			7/28/67	Same
			8/6/67	3 or 4 grass.
			8/28/67	Same, grass, <u>Potentilla canadensis</u> , runners falling across.
			9/14/67	5 or 6 grasses, covered with moss, protected from sunlight.
			10/1/67	2 or 3 grasses, covered with moss.

APPENDIX H (continued)

Transplant	Location	Treatment	Dates	Observations
6B	Forest	Sterilized and placed on bald	6/21/67 7/15/67 7/28/67 8/6/67 8/28/67 9/14/67 10/1/67	Begun. No plants. Same Same Same Same Same
7A	Bald	None	5/6/67 7/3/67 7/15/67 7/28/67 8/6/67 8/28/67 9/14/67 10/1/67 11/2/67	<u>Danthonia compressa</u> , <u>Potentilla canadensis</u> , <u>Viola</u> sp., unknown #2. Same 350 <u>Danthonia compressa</u> , 9 <u>Potentilla canadensis</u> , 3 <u>Viola</u> sp., 2 <u>Angelica triquinata</u> . Normal. Same Same Same <u>Angelica triquinata</u> gone, all else same. Same
7B	Forest	None	5/6/67 7/3/67 7/15/67 7/28/67 8/6/67 9/14/67 10/1/67	<u>Abies fraseri</u> , moss, unknown #3. Same 11 <u>Aster</u> sp., 12 fir. Same Same Same, except <u>Aster</u> sp. dying. <u>Russula</u> sp., same, many moss (<u>Polytrichum</u>)

APPENDIX H (continued)

Transplant	Location	Treatment	Dates	Observations
8A	Bald	Dug, sterilized, reset	6/24/67 7/15/67 8/6/67 8/28/67 9/14/67 10/1/67	Begun. No plants. Same, dead grass, <u>Potentilla canadensis</u> creepers encroaching. 2 <u>Potentilla canadensis</u> runners rooted. Same Same
8B	Forest	Dug, sterilized, reset	6/21/67 7/15/67 7/28/67 8/6/67 8/28/67 9/14/67 10/1/67	Begun. No plants. Same Nothing. Same Same Same
10A	Bald	Dug, reset, and devegetated	5/6/67 7/3/67 7/15/67 7/28/67 8/6/67 8/28/67 9/14/67 10/1/67	No plants. Same 4 grasses, 1 <u>Rumex acetosella</u> . 7 <u>Rumex acetosella</u> , 10 grasses, 1 <u>Potentilla</u> <u>canadensis</u> . 7 <u>Rumex acetosella</u> , 1 <u>Potentilla canadensis</u> . 5 <u>Rumex acetosella</u> , 2 <u>Potentilla canadensis</u> , spindly grass. Same 3 <u>Rumex acetosella</u> , 3 <u>Potentilla canadensis</u> , few grass.

APPENDIX H (continued)

Transplant	Location	Treatment	Dates	Observations
10B	Forest	Dug up, reset, devegetated	5/6/67 7/15/67 7/28/67 8/6/67 8/28/67 9/14/67 10/1/67 11/2/67	Begun. No plants on top, grass growing out sides, 2 <u>Solidago</u> sp. Same 1 grass growing from top in protected area, 2 <u>Aster</u> sp. in protected area, <u>Potentilla</u> <u>canadensis</u> runners covering area. Same <u>Potentilla canadensis</u> rooting, grass from side, no <u>Aster</u> sp., birch seedling. Grass from sides, <u>Potentilla canadensis</u> runners resting, (birch seedling probably fire cherry). Same
11A	Bald	Dug, sterilized, reset in forest	6/24/67 7/28/67 8/6/67 8/28/67 9/14/67 10/1/67	Begun. No plants. Nothing. Same Same Same
11B	Forest	Dug, sterilized, reset on bald	6/24/67	Begun.