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An investigation of the ecology of subalpine fir on the Markagunt Plateau in southern Utah

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AN INVESTIGATION OF THE ECOLOGY OF SUBALPINE FIR ON THE MARKAGUNT PLATEAU IN SOUTHERN UTAH

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PURPOSE OF STUDY

Management of the subalpine fir region of southern Utah is becoming increasingly important, not only for the available wood products and grazing needs, but also for watershed and aesthetic considerations. Winter recreation has also become an important management problem concurrent with the recent emphasis on skiing and snowmobiling.

It is postulated that subalpine fir (*Abies lasiocarpa* (Hook. Nutt.) becomes more susceptible to broom rust (*Melampsorella caryophyllacearum* Schroet.) not only as it ages, but also because of edaphic factors. Moisture stress and nutrient status of basalt and limestone soils were the principal factors evaluated to test this hypothesis. The aim of this research was to evaluate the kinds of sites on which subalpine fir grows and to propose management recommendations to reduce the incidence of the brooms.

INTRODUCTION--REVIEW OF LITERATURE

Subalpine Fir

Subalpine fir is a native true fir. As the common name implies, it is a timberline species which grows at altitudes from near sea level in southeastern Alaska and the Yukon to the 12,000 foot level in New Mexico and Arizona. It is the smallest and most widely distributed of the eight species of true firs native to the United States (U.S. Forest Service 1965).

Subalpine fir is easily identified from associated species, namely Engelmann spruce (Picea engelmannii (Parry) Engelm.) in Utah, by its lighter colored bark and often more narrow and distinctive spire-like form. The needles are typically flat and blunt and do not leave a persistent base on the stem when they fall. The cones are 2.5 to 4 inches long, purplish-grey to black in color, deciduous, and upright on the stems (U.S. Forest Service 1969). The bark is thin, light in color and smooth in appearance. The inner bark contains numerous tiny resin pockets which are lacking in other true firs (Franklin 1967). The tree is susceptible to fire because of its thin bark and copious resin (U.S. Forest Service 1965).

Individuals of this species are found over a broad environmental range. They are usually found on cold, dry to moist sites where precipitation falls mostly as snow and can tolerate very poor soil conditions which well suits them for their role as pioneer species (Fonda 1969; Whittaker and Niering 1965). Studies by Daubenmire (1956) show temperature to be a more important limiting factor in distribution than is moisture.

Subalpine fir is usually classified as a pioneer or invader species, but also may be an important member of stable climax communities. Franklin (1967) reported that subalpine fir invades meadows, lava flows, recent furus and other disturbed or severe sites. Ellison (1954) proposed that spruce and fir are part of the early successional state of warm, dry talus sites leading to an upland-herb plant community. Figures 1 and 2 illustrate invasion of subalpine fir onto a meadow and

Fig. 1. Small Subalpine Fir and Engelmann Spruce Invading a Meadow in Cedar Breaks at About 10,500 Feet in Elevation.

Fig. 2. Subalpine Fir and Engelmann Spruce Invading the North Slope of Brian Head, Near 11,000 Feet.

severe rocky slopes, respectively, near the selected study area. After invasion the trees are often dominant because of favorable edaphic conditions and the ability to reproduce in its own shade (Fonda 1969). Consequently this species often remains in the dominant position in the developing communities of higher elevations.

A study by Roe *et al*. (1970) showed that the Engelmann spruce-subalpine fir forest forms a relatively stable community throughout much of the central and southern Rockies which remains unless a major disturbance such as excessive logging, fire or disease occurs.

The spruce-fir forest occupies about 26 percent of the total commercial forests in Utah and dominates the high altitude areas. Either subalpine fir or Engelmann spruce can dominate such areas, although they usually occur jointly. Engelmann spruce represents 30 percent of Utah's sawtimber inventory and subalpine fir contributes only 9 percent of the harvest total (Choate 1965). This is probably because most of the stands in Utah, including those within the study area, are generally overmature.

Broom Rust

Broom rust of subalpine fir is caused by the rust fungus, *Melampsorella caryophyllacearum* Schroet., which is native to North America, Europe, and Asia (Pady 1942; Peterson 1965). This fungus is a heteroecious rust whose alternate hosts are species of *Cerastium* and *Stellaria*, both commonly called chickweed. These genera are found in Utah (the most common host is believed to be *Stellaria media*).

The rust completes its life cycle in two years (Ziller 1973). Accounts and descriptions of the life cycle of *M. caryophyllacearum* have been given by several authors including Pady (1941), Peterson (1963), Pawuk (1973), and Ziller (1973). The most conspicuous symptom expressed by the host as a result of the infection is a broom-like proliferation created by the compact growth of several small, shortened, and distorted branches (Figure 3). Needles of affected branches are also thicker, shorter, and a lighter green apparently due to reduced chlorophyll content. The infected needles grow only for a single growing season and then die, causing the entire broom to have a dead appearance during the winter months. The production of bright colored yellowish-orange aecia make the brooms particularly conspicuous from mid-summer to late fall (Pady 1941; Mielke 1957; Peterson 1963; White et al. 1969; Ziller 1973).

History of the Problem and Current Status of the Concept

Most research dealing with broom rusts and subalpine fir have dealt either with a description of the fungus or a description of the importance and ecology of fir as a lumber species. However, the environmental conditions which render fir trees most susceptible to the disease have never been thoroughly examined.

Broom rust of subalpine fir and Engelmann spruce was considered to be the same species by most early authors. It was not until the 1940's that Pady (1940, 1941) claimed they were two distinct species and wrote several articles on the subject. His concepts were later confirmed by Ziller (1970) when he performed a series of inoculation experiments with the two rusts.

While intensive management to control the disease is common in

Fig. 3. A Particularly Large Broom Rust Which Has Apparently Caused the Death of this Fir Tree in Cedar Breaks National Monument.

Fig. 4. Cedar Breaks National Monument: Exposed Limestone in the Foreground and Brian Head, Composed of Basalt in the Background.

Europe where the disease is more prominent, little or no management of this kind exists in the United States (Peterson 1963).

LOCATION AND DESCRIPTION OF THE STUDY AREA

The Markagunt Plateau is the western most portion of the Colorado Plateau system. Located in southern Utah, it is situated between Cedar City on the west and Panguitch on the east. Engelmann spruce and subalpine fir dominate the forest cover in the southwest portion where the plateau reaches its highest elevation. Familiar landmarks in this spruce-fir forest are Cedar Breaks National Monument and Brian Head Peak (Figure 4). The plateau drops sharply to the west with the valley floor less than 11 miles away. This sudden drop is also present to the south where the rising plateau gives way to narrow and deep canyons which form Zion National Park some 20 miles distant. The steep plateau edges are large limestone outcrops exposed to the constant workings of wind, water and temperature. Beautiful erosional sculpturing has resulted, such as that at Cedar Breaks. The drop in elevation is much more gradual eastward and north. Dutton (1880) claimed that the slope from east to west never exceeded 2.5 degrees. The steepness of the slope is more variable to the southeast.

In response to this gradual reduction in elevation, the dominant forest species also slowly change. Descending from west to east, the Engelmann spruce-subalpine fir forest gradually evolves into a blue spruce-white fir (Picea punges Engelm. Abies concolor Hoppes) type with pockets of Douglas fir (Pseudotsuga menziesii (Mirb.) Franc.). This forest type again gives way as the elevation decreases east and north to the Ponderosa pine (Pinus ponderosa Laws) expanse which covers much of the plateau. Since the decrease in elevation is so gradual, ecotones between forest types are often extensive in area and are difficult to define.

Although limestone is the dominant parent material in the study area, a series of rather extensive volcanic eruptions have provided parent material for a second soil type upon which the subalpine forest grows. While these eruptions have occurred throughout geologic ages, the greatest amount of basalt material present is considered to be extremely young geologically (Crockett and Nelson 1963). Dutton (1880), while exploring the Markagunt Plateau discovered a large basalt flow near Panguitch Lake he considered to be so recent that he wondered why there were no accounts of the flow occurring. The largest basalt flow in the area lies west of Duck Creek and extends almost to the plateau rim in some areas. This flow is also recent and most of it still remains as bare rock. Aspen (Populus tremuloides Michx.) and some conifers are just beginning to invade the outer edges. Limestone and basalt lave have formed the major soil types found on the plateau and will be the only two considered in this study.

The actual study area was restricted to the Engelmann spruce-subalpine fir forest cover type (Society of American Forester 1967). This area extends from the western and southern rims of the plateau, east to Duck Creek, the low point with an elevation of 8,800 feet. The highest point in elevation is Brian Head Peak at 11,307 feet.

METHODS AND PROCEDURES

Sixty-six, one-tenth acre plots were selected (Figure 5) ranging from Duck Creek Ranger Station west to Midway and north through Cedar Breaks to Brian Head, a total distance of about twenty miles. Plots were selected to include the major differences in elevation and soil types in the study area and were located approximately 0.5 mile apart. Thirty-eight sample plots were taken on limestone soil, 24 plots on basalt soil and 4 plots were taken in mixed basalt-limestone soil. These plots were used to determine the density and relative distribution of the broom rust infections on subalpine fir. The 66 sample units included 14 that were taken within Cedar Breaks National Monument.

Plant moisture stress measurements were obtained by utilizing a Waring Pressure Bomb (Scholander _et al_. 1965; Waring and Cleary 1967). These kinds of data approximate closely the tension at which moisture is held within the tissues of a plant. Plant moisture stress measurements, even though only loosely related to soil moisture stress (Knipling and Miller 1965), can be used to evaluate differences between habitats (Jones 1972; Waring and Cleary 1967).

Four subalpine fir trees were randomly selected at a given point with four twigs off each tree taken as samples. Individual trees with and without infections growing on both the basalt and limestone soils were included. Twigs were sampled rather than leaves due to the ease with which results were obtained and the greater precision in making determinations. Pressure bomb readings were done during a five month period, beginning in February before growth was apparent and continued

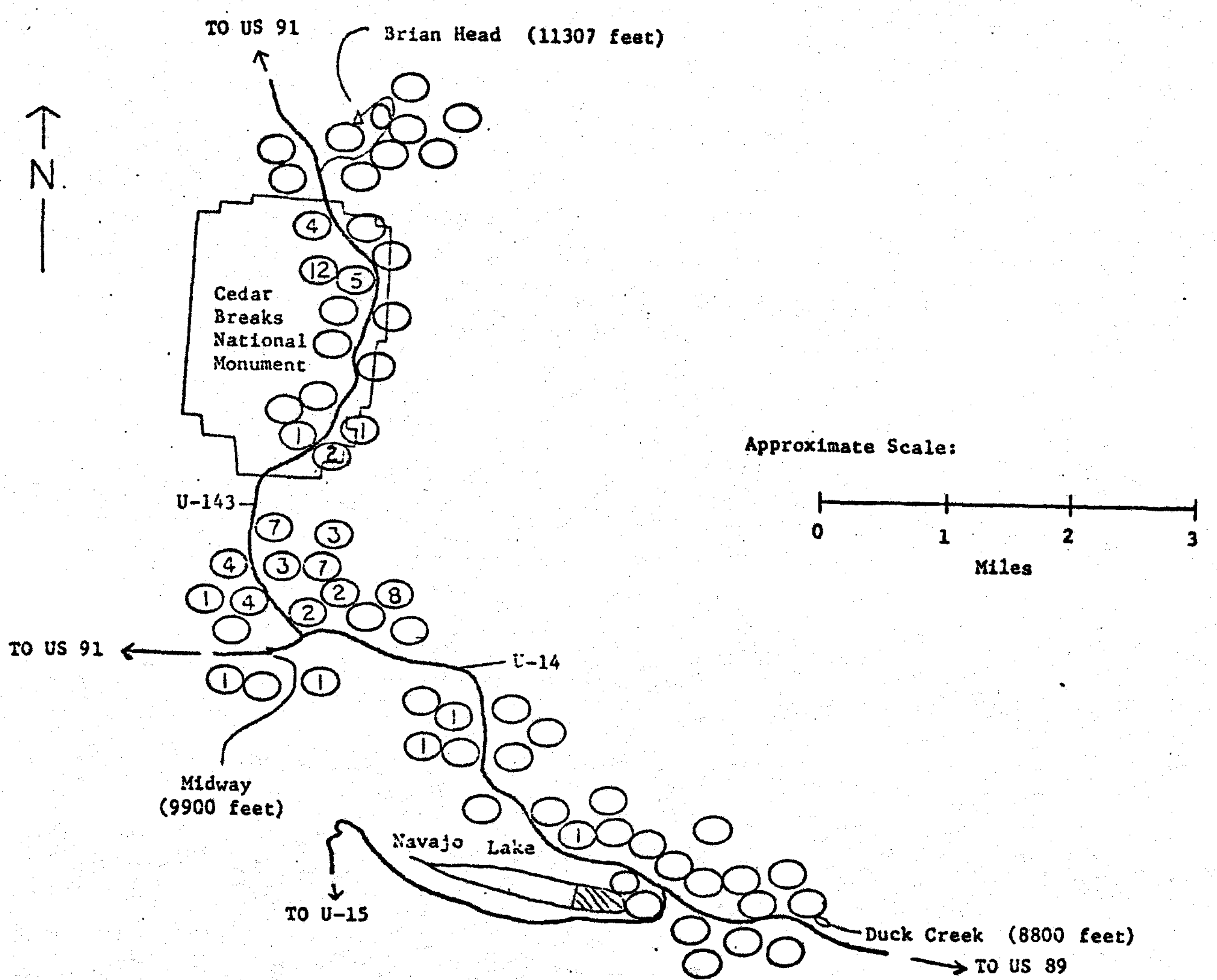

Fig. 5. Location of Sample Plots (number indicates the number of rust brooms found in each)

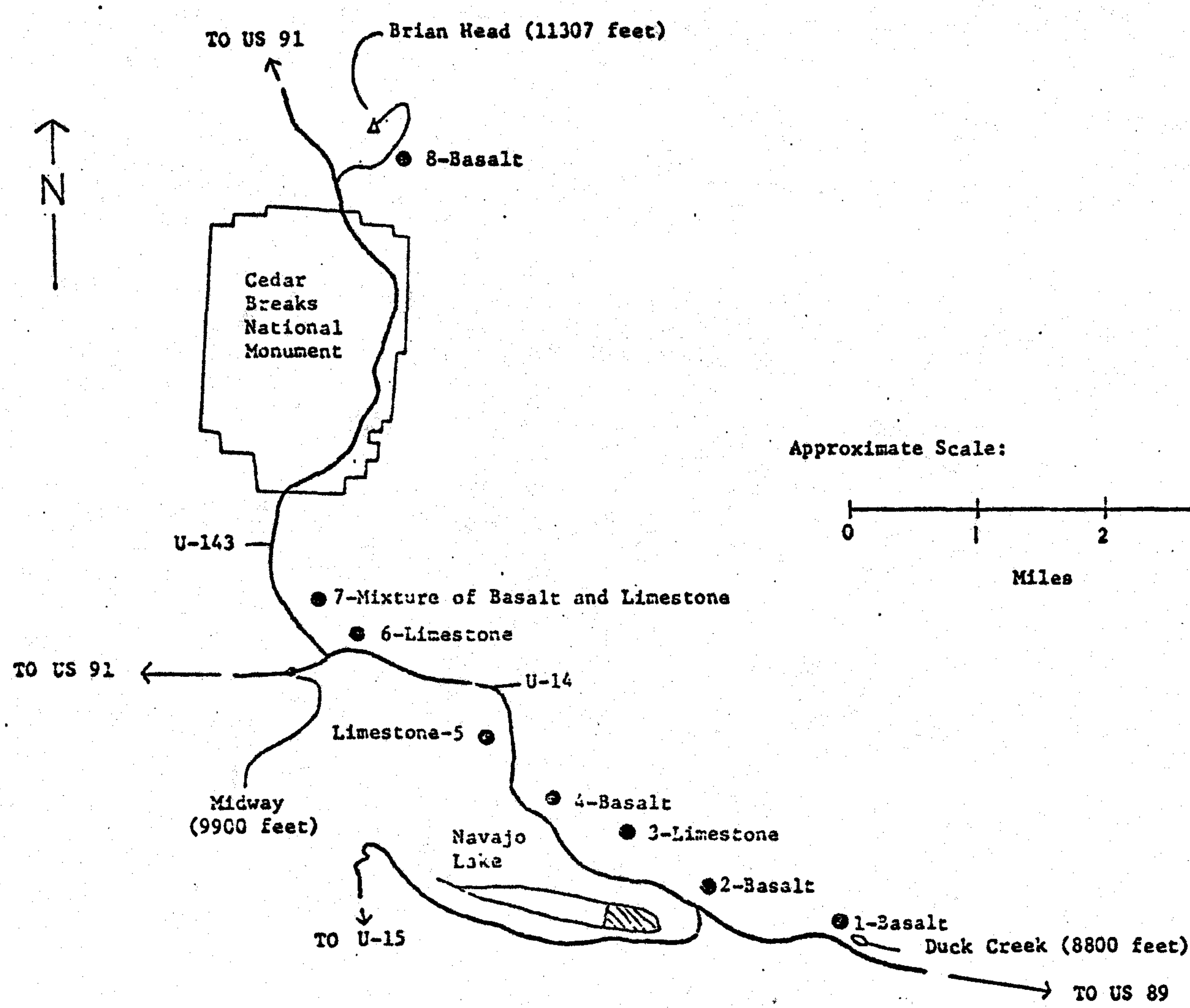

Fig. 6. Location of Soil Samples

until there was no marked difference in the readings from subalpine fir plants growing on both soil types.

Eight soil samples were taken (Figure 6) at depths of 18-24 inches and analyzed for available P, Mg, K and Ca and for soil pH. The samples represent both the basalt and limestone soils. The procedure followed to quantify these key minerals available to plants is described by Russell (1950) and Soil Science of America (1967). Atomic absorption procedures were used to determine magnesium, potassium, and calcium, and colorimetric procedures were used to determine phosphorus content of the soil. Soil pH was determined by the electrometric method using 1:1 soil paste.

RESULTS

The broom rust infections in the study area appeared to be concentrated at an elevation from 9,900 to 10,500 feet (Figure 7). Few were found at elevations below 9,900 feet and none at elevations higher than 10,500 feet.

Twenty-one on the sixty-six plots studied contained one to twelve brooms. Of the 38 plots located on limestone soil, 18 contained the rust. Two of the four plots on the mixed soil type contained rust brooms and only one plot taken on basalt soil contained the disease (Table 1). All but four of the plots containing brooms were located along the western rim of the plateau, ranging from Midway on the south to the northern boundary of Cedar Breaks National Monument (Table 2). Field observations indicated that two particularly large infection centers occurred along this line. One was widespread beginning at

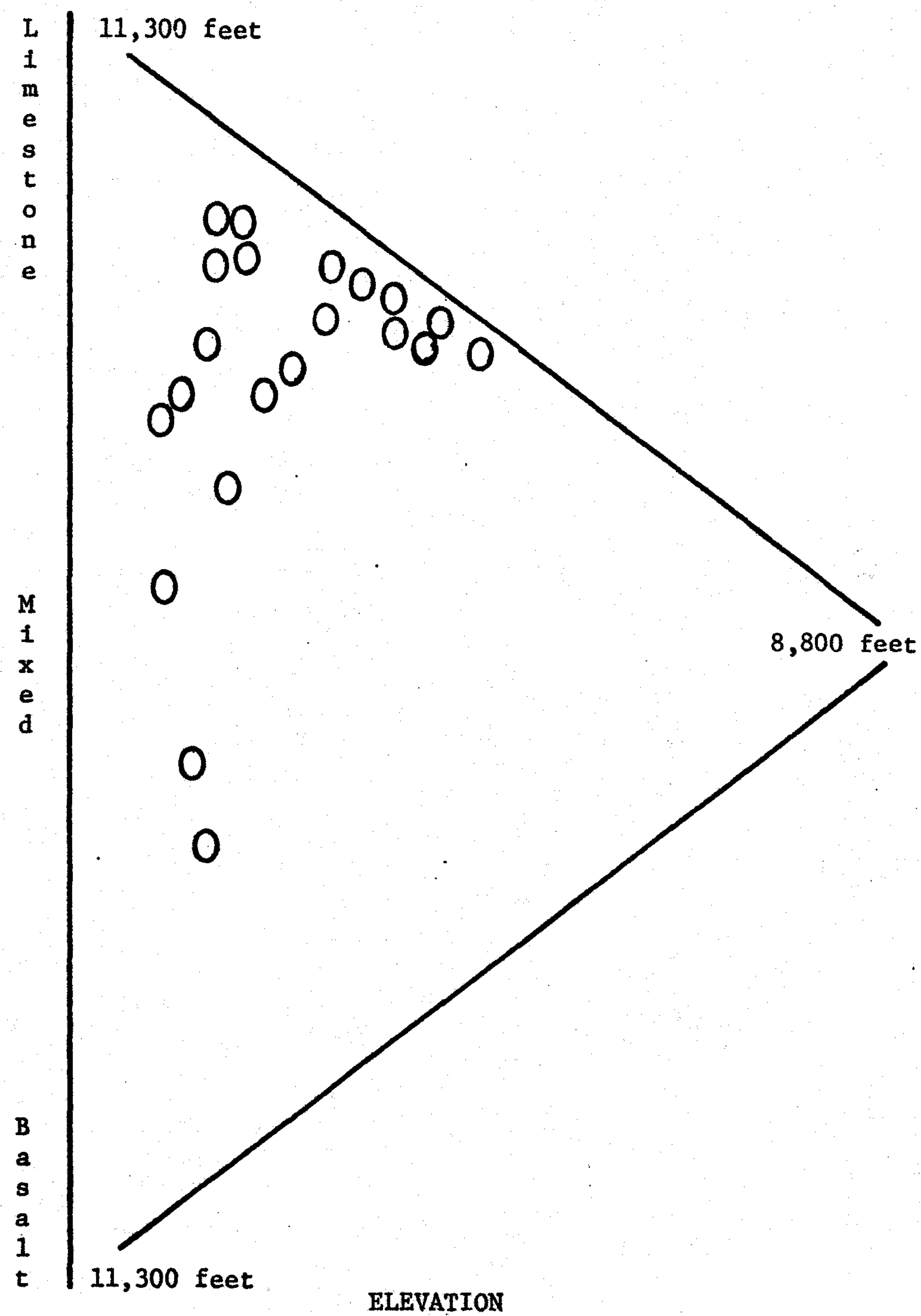

Fig. 7. Relative location of broom rust-containing plots with respect to elevation and soil type (plots contained from 1 to 12 rust brooms).

TABLE 1

A COMPARISON OF BROOM RUST OCCURRENCE ON BASALT, LIMESTONE, AND MIXED SOIL TYPES

Soil	Total Plots	Plots with Broom Rusts	
		Number	Percent
Basalt soil	24	1	4
Limestone	38	18	53
Mixed	4	2	50
TOTALS	66	21	32

TABLE 2

A COMPARISON OF BROOM RUST OCCURRENCE BETWEEN THE WESTERN RIM AND THE INTERIOR OF THE PLATEAU

Location	Total Plots	Plots with Broom Rusts	
		Number	Percent
Plots along western rim	37	17	46
Plots east into plateau interior	29	4	14
TOTALS	66	21	32

Midway and extending north for a distance of almost three miles. Thirteen plots taken in the area yielded an average of at least three brooms per plot. The second disease center was localized within the boundaries of Cedar Breaks National Monument. One of these plots contained twelve rusts. The soil parent material within the monument and near Midway is limestone.

From Midway east to Duck Creek the number of brooms per plot rapidly decreased. No rusts were observed between Navajo Lake and Duck Creek Ranger Station where basalt is the dominant parent material of the soil.

Plant Moisture Stress

Results obtained from the use of the Waring Pressure Bomb showed that for the months of February through June, plant moisture stress measured an average of 1.91 ATM's higher in subalpine fir growing on limestone soil than in those trees growing on basalt soil. The widest margin was in March when a difference of 3.35 ATM's was recorded; the least was measured in June when only 0.83 ATM's separated the two soil types (Figure 8). Although a difference was observed between the two soils when the data was evaluated with the F-test at the 5% confidence level (Bishop 1966), none of the differences were statistically significant. Therefore, it is postulated that moisture stress is not the major factor causing the broom rust infections.

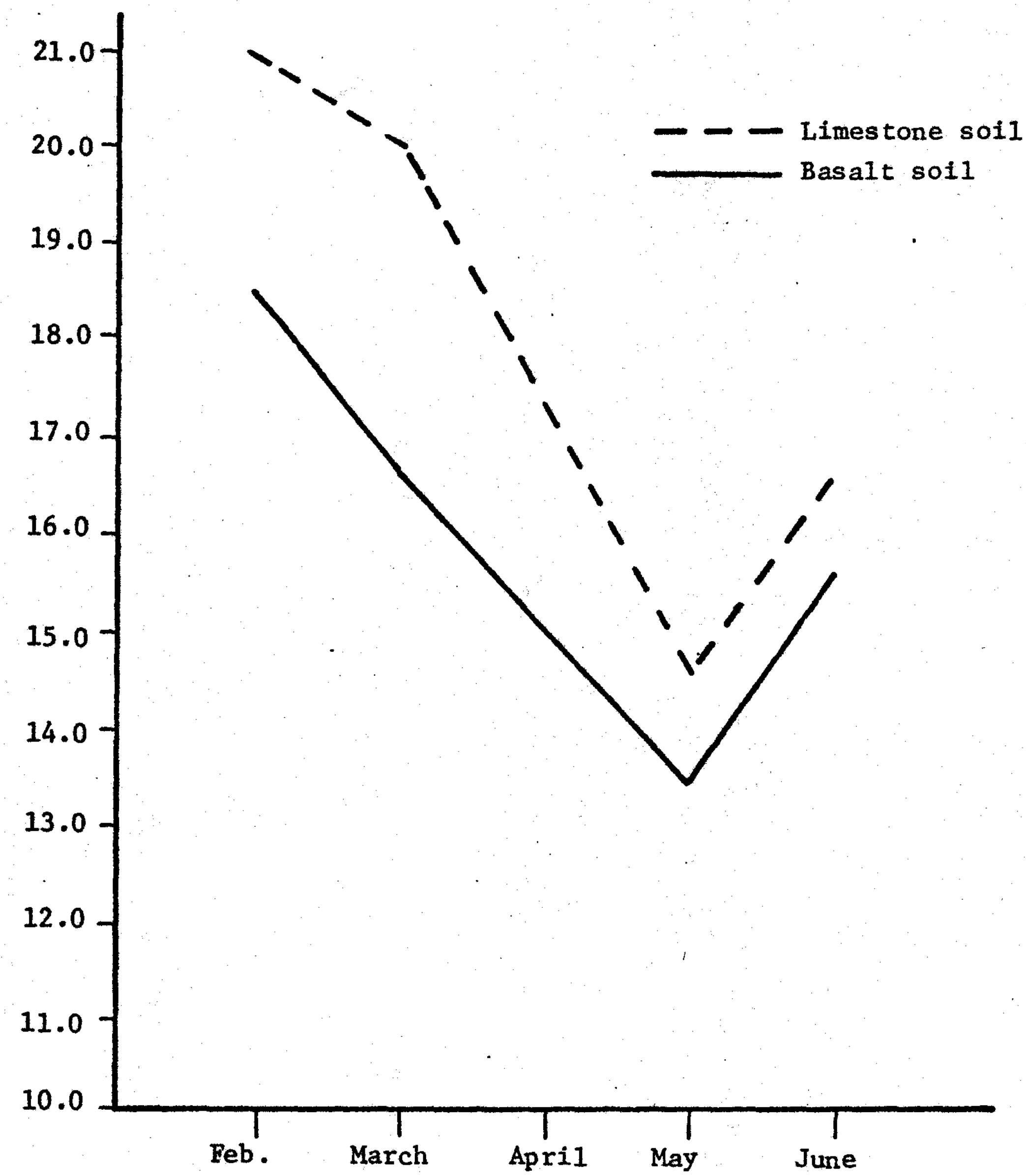

Fig. 8. Average Plant Moisture Stress Readings for Both Soil Types from February through June.

Soil pH Analyses

The pH determinations reported in Table 3 show there is a marked difference between the soils of different parent materials. The pH values for the basalt soils are typical of those for a coniferous forest (Wilde 1958). However, those for the soils derived from limestone are quite high, except for the one sample which is a degraded limestone soil. This soil is well leached. The incidence of broom rust on this site was lower than on the limestone soils having higher pH values.

Available Mineral Analyses

The results of the soil analyses are presented in Table 4 and Figures 9-12. The basalt soil contained 135 ppm of magnesium whereas the limestone soil contained only 13 ppm.

Magnesium is often found in an inverse proportion to calcium (Russell 1950), with calcium usually being more abundant. The ratio of magnesium to calcium varies from 1:1 in heavy clay soils to 1:1.31 in clay loams, and to 1:2.61 in sandy loams (U.S. Geological Survey 1971). The soils of this study are loams. The ratio of magnesium to calcium is 1:2.23 for the basalt soil and 1:0.12 for the limestone soil.

The range in the amount of phosphorus in the soil can vary from 100 to 2000 ppm; western soils may contain 700 ppm of this element (Buckman and Brady 1969). Both of the soils considered in this study contain low amounts of phosphorus. This is especially critical for the limestone soils because as the pH increases, the availability of phosphorus decreases. Those limestone soils which have pH values of 7.5 probably have limited amounts of phosphorus available for plant growth.

DISCUSSION

Broom rust is seldom mentioned as a disease of subalpine fir in literature reviewed, yet the trees in the limestone areas of the Markagunt Plateau seem to be vulnerable to this disease. While it is true that most of Utah's subalpine forests are overmature, important exceptions do occur. For example, on the Markagunt Plateau in those areas where recent lava flows have occurred, subalpine fir, and other species such as aspen are just beginning to invade. The fir trees which pioneer this new environment are hardy, disease resistant trees. This presents a sharp contrast to the subalpine fir trees often only a few feet away, growing on the relatively undisturbed limestone soil which are overmature.

It proved difficult to obtain repeatable moisture stress data when the weather was cold, i.e. below freezing. The readings in late January were irregular and were extremely high or low.

In general, moisture stress measurements taken with the pressure bomb showed no significant statistical difference between plants growing on soils derived from basalt and limestone parent materials. However, the measurements were consistently higher from trees growing on the limestone soils. This may be biologically significant because of the apparent low levels of magnesium and phosphorus in the soils derived from limestone.

TABLE 3

SOIL pH ANALYSES

Site Number	Location	Parent Material	pH
1	1 mile west of Duck Creek Ranger Station	Basalt	6.0
2	Navajo Lake Turnoff	Basalt	5.8
4	Iron-Kane County Line	Basalt	5.2
8	Brian Head Peak	Basalt	6.2
		$\overline{X}$	5.8
3	Navajo Lake Overlook	Limestone	7.1
5	Sage Valley	Limestone	5.5
6	Junction of U-14 and U-134	Limestone	7.5
		$\overline{X}$	6.7
7	2 Miles north of Site 6	Mixture of Basalt and Limestone	5.0

TABLE 4

A COMPARISON OF AVAILABLE MINERALS IN
BASALT AND LIMESTONE SOILS

Element	Basalt	Limestone	Percent Difference
	ppm		
Phosphorus	40.50	2.37	-94
Potassium	3.05	2.83	- 7
Magnesium	135.50	13.00	-90
Calcium	60.75	105.67	+74

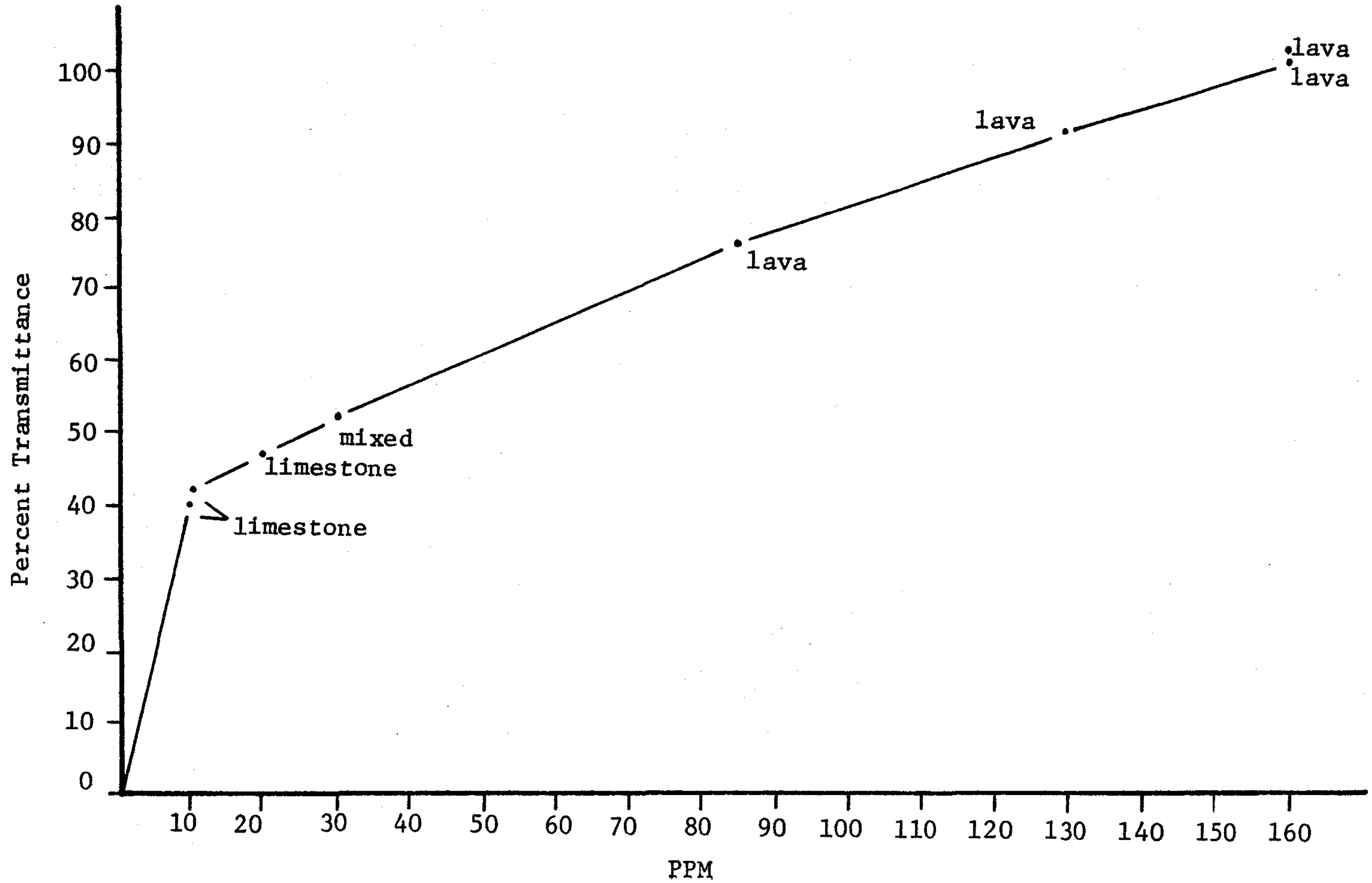

Fig. 9. Amounts of available magnesium found in both soil types

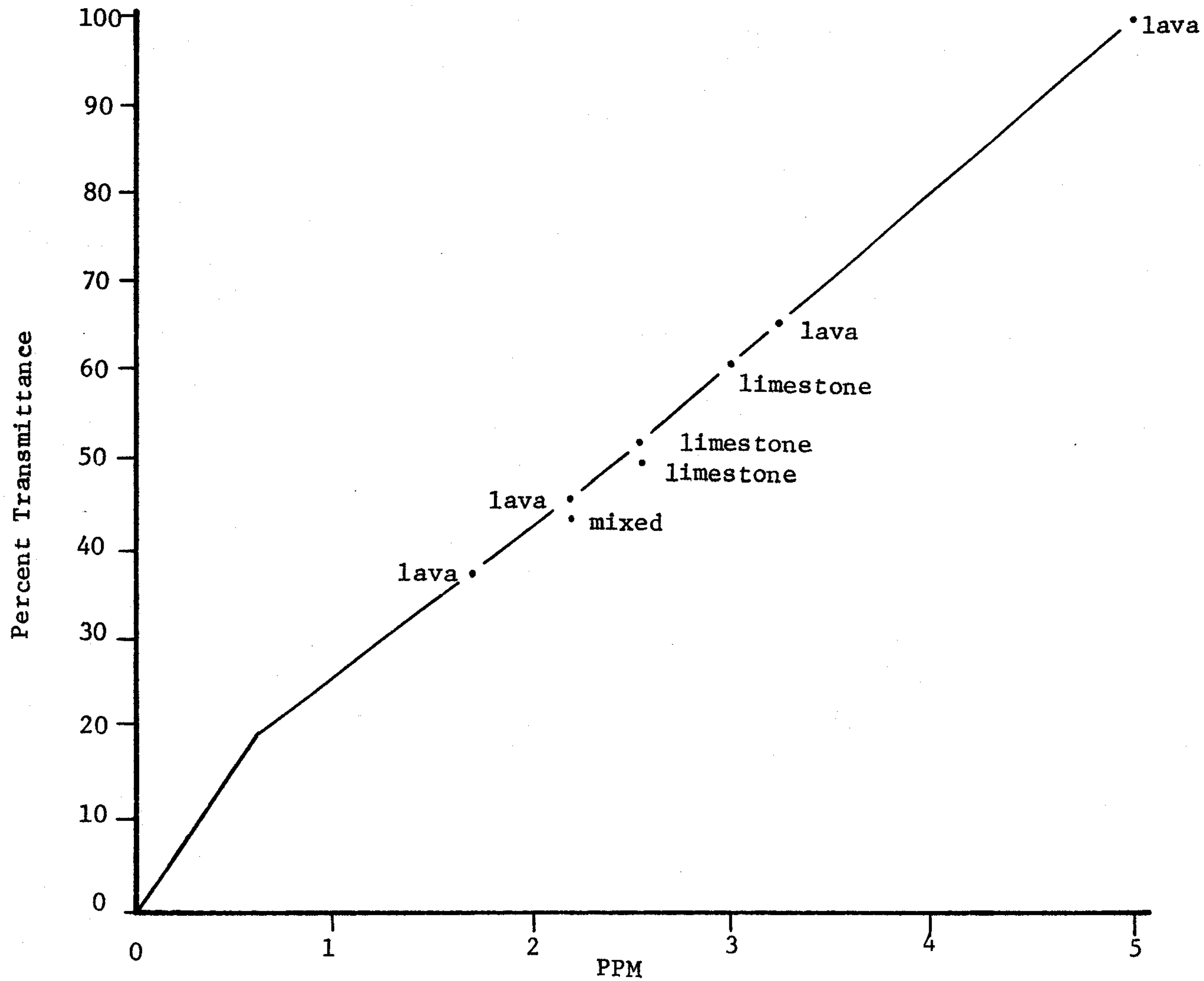

Fig. 10. Amounts of available potassium found in both soil types

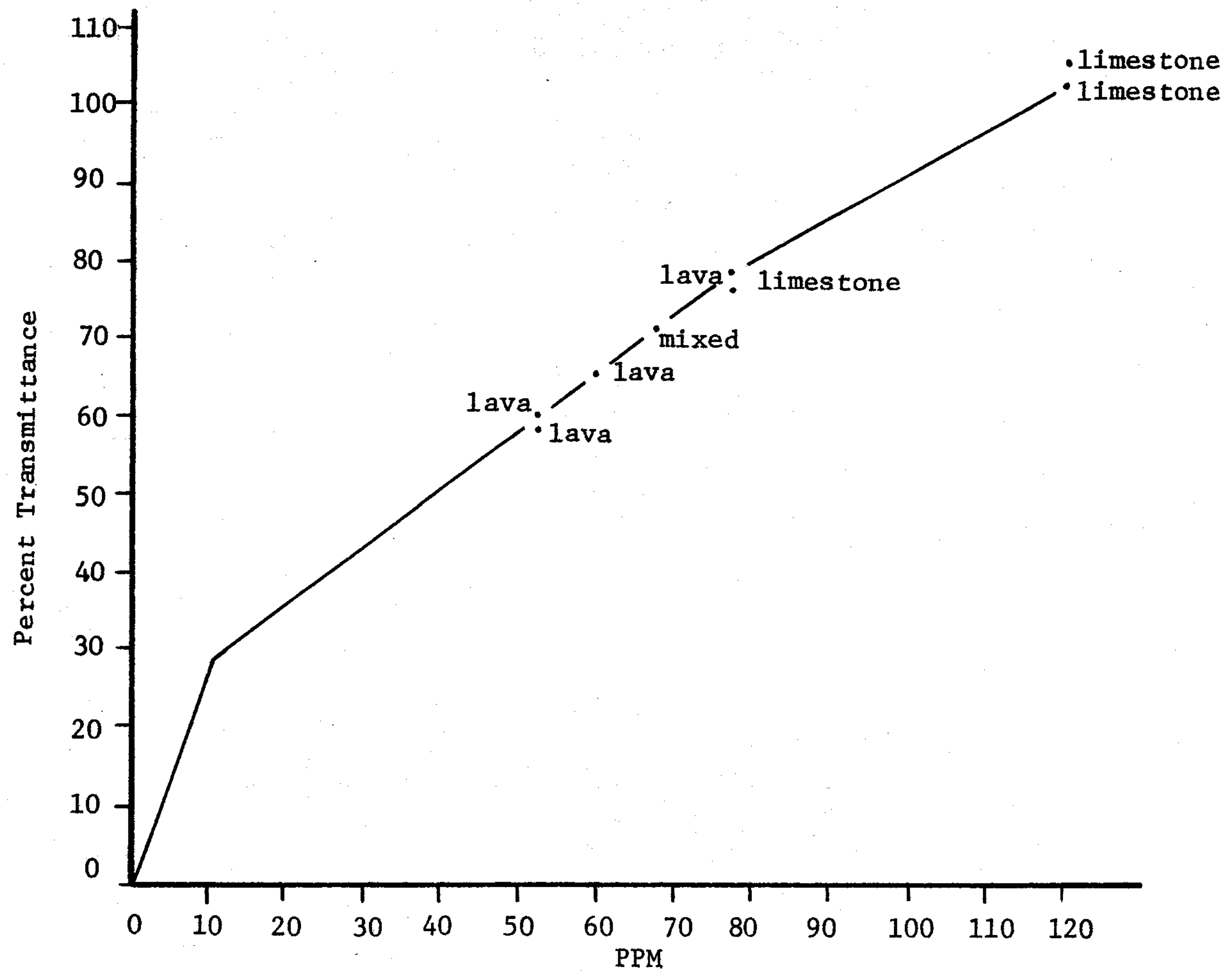

Fig. 11. Amounts of Available Calcium Found in Both Soil Types

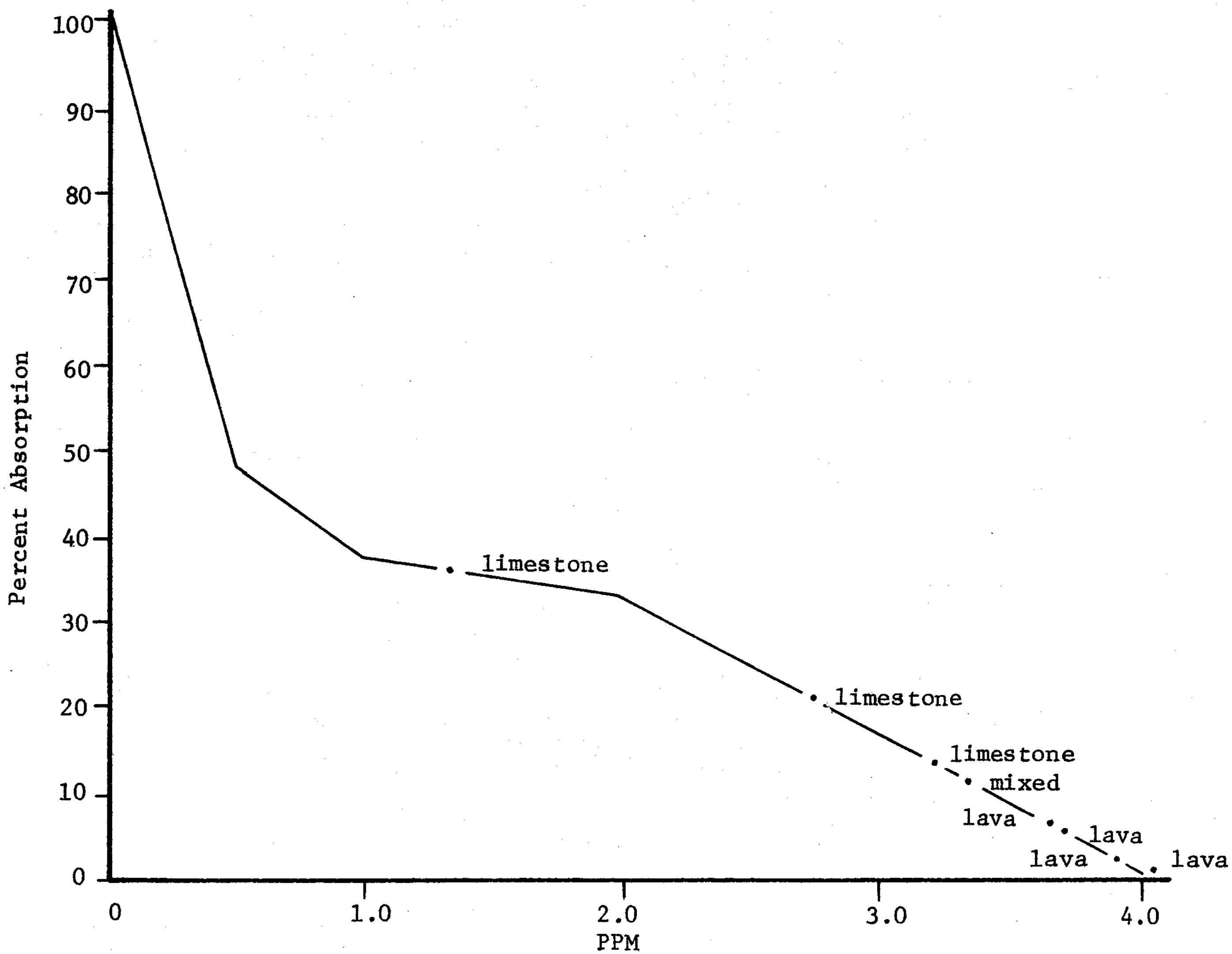

Fig. 12. Amounts of Available Phosphorus Found in Both Soil Types

The analyses of the two soils showed marked differences in the amounts of available magnesium and phosphorus. Based on criteria used for agronomic crops, the amounts of these elements present seem to be low. Often low amounts of phosphorus will cause antagonistic effects on the use of other elements. For example, low amounts of phosphorus will prevent nitrogen from being obtained in amounts adequate for growth (Buckman and Brady 1969). Correlation of plant moisture stress, and the concentration of nutrients in the plants as well as in the soil in relation to incidence of disease would be a fertile area of research.

The infected trees within Cedar Breaks National Monument are especially of concern due to the lack of specific management policies in National Parks. The incidence of broom rust in the area harbors a potential disease reservoir which could build up and eventually spread outside the park boundaries. It seems ironic that the protective policies of the National Park Service protect not only trees, shrubs, and other wild flora, but also the diseases that can destroy them.

Conversations with local Forest Service personnel, as well as the author's experience in the area, have indicated that the role of fire in the ecology of the Engelmann spruce-subalpine fir forest of the Markagunt Plateau is extremely minor. Although fuel is abundant under stands growing on limestone soils, fires in this area above 8,500 feet are rare. The importance of fire as a cleansing agent has been documented by its extensive use for rust control in the slash pine area of the Southern United States (Paul Fullmer 1974). Without this cleansing agent, some primary hosts may persist on the forest floors which are cluttered with deep layers of litter. These diseases may weaken the trees to a degree that they become more susceptible to other infections such as broom rust.

These conditions apply only to the limestone areas because the understory of the forest growing on basalt soils is still relatively free of litter and debris.

While this study raises more questions than answers, the author does suggest a possible management practice of pruning and burning of diseased branches, especially within the boundaries of the national park system. This seems practical since the disease is relatively restricted at the present time. Since the disease seldom extends beyond the distinctly visible symptom of the actual witches' broom this method would keep destruction and deformation of trees at a minimum. Eradication of chickweed, the primary host, is of no advantage since the rust spores are windblown and can travel great distances.

Although the role of subalpine fir as a timber species is relatively minor, it occupies an important position in the high elevation forest ecosystem. For example, these trees grow on steep slopes at timberline elevations where few other species can survive and they are important in preventing flooding and erosion. In many parts of the Rocky Mountains, including the Markagunt Plateau, subalpine fir forms parts of the forest that protect headwaters of many vital and important streams (U.S. Forest Service 1969). The beauty of this forest cannot be measured. The long, narrow crowns have become a familiar landmark to visitors of the subalpine forest region.

SUMMARY

The study evaluated certain factors postulated to cause subalpine fir to be susceptible to broom rust invasion on the Markagunt Plateau.

It was found that the incidence of broom rust was restricted to limestone soils which are apparently low in magnesium and phosphorous. Trees growing on basalt soils were freer from infection. Broom rust also seemed to be concentrated near the western rim of the plateau. The slightly higher plant moisture stress of limestone soils may play a role in relation to broom rust susceptibility by intensifying the effects of the low level of nutrients in the soil.

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ABSTRACT

The ecology of subalpine fir relative to broom rust was investigated. Broom rust infections were most common in trees growing on limestone soils, and seldom occurred on trees growing on basalt soils. Even though plant moisture stress was consistently higher in the plants from limestone soils, the studies indicated that moisture stress is not the major factor causing infection. The amounts of available magnesium and phosphorus were much lower in the limestone soil. It is postulated that the higher plant moisture stress of subalpine fir growing on limestone soils may aggrevate the lack of nutrients and be a contributing factor to the susceptibility of subalpine fir to broom rust. Even though the study raises more questions than it answers, management prescriptions relative to this disease can be proposed. Pruning and burning of diseased branches should be evaluated as a possible method to control broom rust on subalpine fir. This species must be better managed because of its strategic position on watersheds and recreation sites of higher elevations.