# Effect of Fertilizer on Pinegrass in Southern British Columbia[1]

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## Highlight

**Response to fertilizers of pinegrass dominated vegetation on Gray Wooded soils was tested in pot and field trials. Ammonium nitrate applied at 100 and 200 kg N/ha increased the yield, nutritive value, and palatability of pinegrass; this increase was accentuated when S in the form of gypsum was applied with N. Response to P, K, and a solution of micro nutrients was negligible. Most of the applied S and all of the applied N were depleted from the upper root zone by the end of the second growing season. At the higher rates of application, only 14% of the N was recovered by pinegrass. This value was even smaller at the lower rates of application. Sulfur considerably improved the ability of pinegrass to respond to N fertilization and 23% of the N was recovered when 100 Kg S/ha was applied with the N. Soils were analyzed for $NO_3$-N, $SO_4$-S, field moisture and organic C. These two elements and organic C were found to be mainly concentrated near the soil surface, which experienced the greatest fluctuation in moisture content.**

Pinegrass (*Calamagrostis rubescens* Buckl.) is the principal species for summer grazing over 15 million acres of forest land in southern interior British Columbia. In spite of extensive utilization of pinegrass, its response to fertilizer application has not been studied.

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Grazing studies on pinegrass-dominated range have been made in the Douglas-fir (*Pseudotsuga menziesii* (Merb.) Franco) zone of interior British Columbia (McLean, 1967). A decline in daily gain of cattle, as the season advanced, was noted. Feed quality rather than feed quantity influenced these rates of gain since ample feed was available. This finding would probably hold true for most pinegrass ranges since the grass drops rapidly in its nutritive value, is fairly palatable in June, becomes very unacceptable by August, and is seldom utilized completely.

Fertilizer usage affects all three factors on which the productivity of animals on grasslands depend; yield, palatability and nutritive value (Raymond and Spedding, 1965). Fertilization has been widely tested as a way to increase herbage production of western rangelands (Black, 1968; Johnston, Smith et al., 1968; Rauzi et al., 1968; Smith et al., 1968). The improvement of palatability and nutritive value of grasses through application of fertilizers has also been reported (Cook, 1965; Johnston, Bezeau et al., 1968; Reid and Jung, 1965; Reid et al., 1966).

The object of the present study was to determine to what extent fertilizers can improve the palatability, nutritive value, and, of lesser importance, yield of pinegrass.

## Study Area and Procedures

Areas under study were located in the Douglas-fir zone of southern British Columbia, which has been described by Tisdale and McLean (1957). Pinegrass is the dominant herbaceous species and occupies about 80% of the ground area.

Soils of the Douglas-fir/pinegrass communities are mainly Gray Wooded (Dawson and Kelly, 1965); in the study area they were found to have thin L-H and Ah (A1) horizons, each less than 5-cm thick; prominent Ae (A2) horizons up to 18-cm thick, and Bt (B2t) horizons about 10-cm thick. Such Gray Wooded soils in southern British Columbia have been found to be particularly low in nitrogen (N) (Dawson and Kelly, 1965).

Three experiments were conducted; two in the field and one in a growth room.

*Experiment I.*—To determine the response of pinegrass to N, ammonium nitrate (33-0-0) was applied at three rates, 0, 55, and 165 kg N/ha (subtract 10% from kg for lbs/acre), to six replicates of a pinegrass range in a randomized complete block design on May 6, 1966. The plots, 2 × 10 m, were located about 14 miles northwest of Kamloops, in an open site within a mixed stand of lodgepole pine (*Pinus contorta* Dougl) and Douglas-fir at an elevation of 1200 m (3900 ft). Following the fertilizer application, a 1.2-m exclosure cage was placed at random on each plot. Yield and utilization by cattle, which grazed the area from early June to mid-September, was determined by clipping 1-$m^2$ quadrats from under the exclosure and at random on the grazed portion of the plots; difference in the amount of forage harvested outside and beneath the cage gave an assessment of palatability. The plots were clipped on June 24, 1966, September 22, 1966, July 12, 1967, and July 24, 1968. The forage was separated into grass, shrubs and forbs, oven dried at 90 C, and weighed. The grass was ground through a 60-mesh screen on a Wiley mill and quality was assessed by the following chemical analyses; crude protein by the Kjeldahl method, acid detergent fiber (ADF) and lignin (Van Soest, 1963), silica (Buckner et al., 1967), and soluble carbohydrates (Barnett, 1954). Soil was sampled from these plots to a depth of 35 cm on September 24, 1967, ground to pass a 2-mm sieve, and analyzed for nitrate N by the phenoldisulfonic acid method (Chapman and Pratt, 1961).

Weather records were available from a station maintained in the vicinity of the plots. The summers of 1966 and 1968 were wetter than usual, while the summer of 1967 was particularly dry.

*Experiment II.*—To confirm field results obtained with N in Experiment I, and to test whether pinegrass would respond to other elements, a potted fertilizer trial was made. Pinegrass sods were dug to a depth of approximately 25 cm and placed in 4.6-liter black plastic freezer cartons. The filled pots were weighed and soil was either added or removed, so that each pot contained approximately the same amount. The grass was clipped at approximately 2 cm, fertilized by surface application, and grown in a growth room at 20 C and 1000 ft-c with lights timed to run 16 hours on and 8 hours off. Nitrogen, Phosphorus (P), Potassium (K), and S were used at three rates 0, 100, and 200 kg/ha ($N_0$ $N_1$ $N_2$, $P_0$ $P_1$ $P_2$, etc.) Long Ashton's solution of micronutrients was applied at a rate of 75 l/ha (1 gal/acre) (Hewitt, 1966). The elements were applied in different combinations (Table 2) giving a total of 21 treatments to six replicates in a randomized complete block design. Nitrogen, P, and K were applied in the form of commercial fertilizer; 33-0-0 ammonium nitrate, 0-45-0 triple superphosphate, and 0-0-60 potassium chloride. Sulfur was applied in the form of 1 N $H_2SO_4$.

The first cut was made 30 days after fertilization followed by two more cuts at three-week intervals. Yield was measured as the total oven dry weight for the three cuts. The grass was not analyzed chemically.

*Experiment III.*—On the basis of results obtained from the growth room fertilizer trial, a 3 × 3 factorial field experiment was designed. Two sites were chosen; one in an aspen (*Populus tremuloides* Michx) stand 14 miles northwest of Kamloops, the other in a stand of lodgepole pine 40 miles southeast of Williams Lake. Ammonium nitrate and gypsum were applied at three rates; 0, 100, and 200 kg of the element/ha, ($N_0$ $N_1$, $N_2$ and $S_0$ $S_1$ $S_2$) individually and in combination to four replicates at each site, in a randomized complete block design. Fertilizer was applied to 5 × 5 m plots on May 4, 1967, and an exclosure cage was placed on each plot. Meter square plots were clipped from under the exclosure and on the grazed portion of the plots on July 12, 1967, and July 26, 1968. The samples were separated and weighed as in Experiment I. The grass was analyzed for crude protein, ADF, lignin, silica, and nitrate N (Lawrence et al., 1968). Soil was sampled to a depth of 35 cm on September 22, 1967, and in 1968 at one-month intervals, starting the first of May and ending on the first of September. The samples were analyzed for nitrate N, sulfate S (Bradsley and Lancaster, 1960) organic carbon (Walkley and Black, 1934) and moisture by the gravimetric method.

## Results

*Experiment I.*—Palatability and yield of pinegrass were increased significantly (5% level) in the summer following spring application of 165 kg N/ha (Fig. 1). The crude protein content of forage from the nitrogen fertilized plots was higher, while

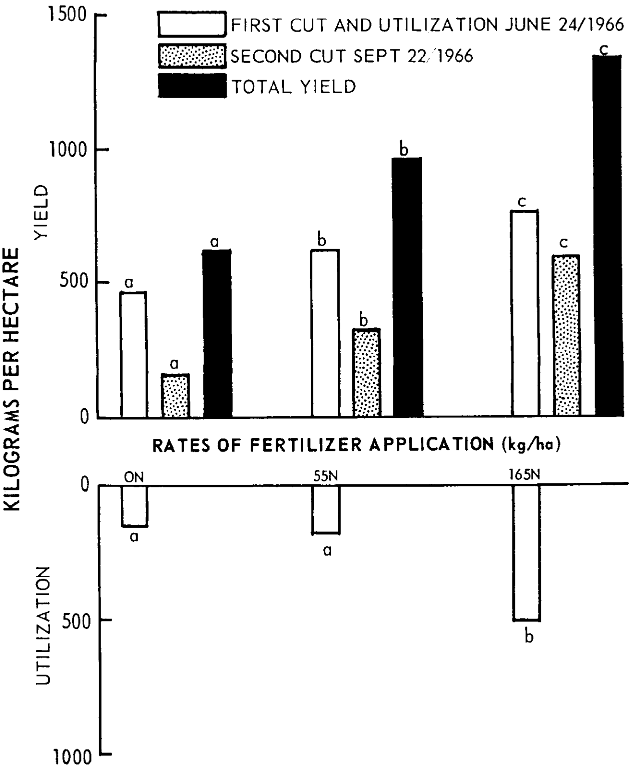


FIG. 1. Average yield (kg/ha, oven-dry), regrowth after clipping, and utilization of pinegrass which was fertilized with amonium nitrate in the spring and sampled in the summer of 1966. Same letters with columns of same pattern indicate no significant difference at .05 level by Duncan's multiple range test.

**Table 1. Chemical composition[1] (% dry matter) of pinegrass fertilized in the spring and sampled in the summer of 1966.**

| N Applied kg/ha | Crude protein | Silica | Soluble carbohydrates | ADF | Lignin |
|---|---|---|---|---|---|
| 0 | 9.7 a[1] | 9.9 a | 15.9 a | 37.9 a | 3.1 a |
| 55 | 13.4 b | 9.7 a | 14.5 b | 35.8 a | 3.2 a |
| 165 | 15.8 c | 8.4 b | 12.4 c | 33.1 a | 3.2 a |

[1] Same letters within a column indicate no significant difference between the values at .05 level by Duncan's multiple range test.

the soluble carbohydrate and silica content were lower than from the non-fertilized plots. Fertilization did not affect the ADF or lignin content (Table 1). In 1967 there was a significant residual effect on yield only at the 165 kg N/ha application. This residual fertilizer did not improve palatability or have any effect on the chemical composition of the grass. By September 1967 the nitrate content of soil from the fertilized plots was the same as that of soil from the non-fertilized plots, and by 1968 no carry-over effects of the N could be measured.

*Experiment II.*—Nitrogen increased the yield of pinegrass consistently while K and micronutrients had no measurable effect (Table 2). Sulfur in combination with N alone or with other elements increased yields in most instances but this increase was statistically significant only at the lower level of application and in combination with NPK and micronutrients. Sulfur, at the higher rate of application and with N at 100 kg/ha, had a slight herbicidal effect. This effect was not noticed when S was applied alone. Phosphorus at 200 kg/ha in combination with NKS and micronutrients, increased the yield significantly; this increase, however, was not detected at the lower rate of application.

**Table 2. Average yield[1] (gm/pot, oven-dry) of potted pinegrass treated with various fertilizer applications.**

| Treatment | Weight |
|---|---|
| $N_0\ P_0\ K_0\ S_0\ M_0$ | 3.9 ab[1] |
| $N_1\ P_1\ K_1\ S_1\ M$ | 8.3 efg |
| $N_0\ P_1\ K_1\ S_1\ M$ | 2.6 a |
| $N_1\ P_0\ K_1\ S_1\ M$ | 7.1 cdef |
| $N_1\ P_1\ K_0\ S_1\ M$ | 7.0 cdef |
| $N_1\ P_1\ K_1\ S_0\ M$ | 5.2 abcd |
| $N_1\ P_1\ K_1\ S_1\ M_0$ | 6.3 bcde |
| $N_2\ P_2\ K_2\ S_2\ M$ | 10.1 g |
| $N_0\ P_2\ K_2\ S_2\ M$ | 3.9 ab |
| $N_2\ P_0\ K_2\ S_2\ M$ | 7.8 def |
| $N_2\ P_2\ K_0\ S_2\ M$ | 9.1 fg |
| $N_2\ P_2\ K_2\ S_0\ M$ | 8.6 efg |
| $N_2\ P_2\ K_2\ S_2\ M_0$ | 8.6 efg |
| $N_1\ S_0$ | 6.3 bcde |
| $N_2\ S_0$ | 8.7 efg |
| $N_0\ S_1$ | 4.2 ab |
| $N_0\ S_2$ | 4.8 abc |
| $N_1\ S_1$ | 6.7 cdef |
| $N_1\ S_2$ | 5.8 bcde |
| $N_2\ S_1$ | 9.2 fg |
| $N_2\ S_2$ | 10.8 g |

[1] Yields having a letter in common are not significantly different at the .05 level by the Duncan's multiple range test.

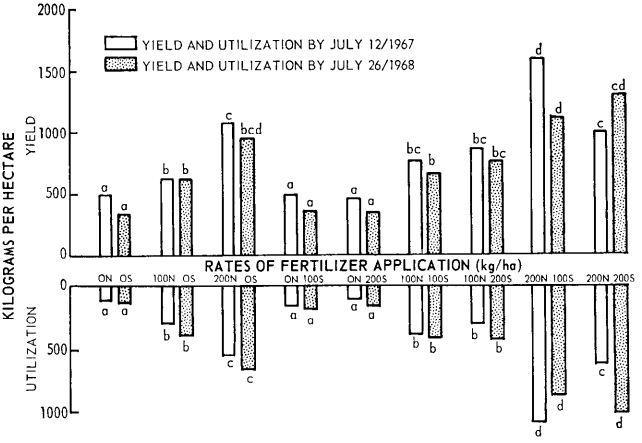


FIG. 2. Average yield (kg/ha, oven-dry) and utilization of pinegrass which was fertilized in the spring of 1967 and sampled in the summers of 1967 and 1968. Same letters with columns of same shading indicate no significant difference at .05 level by Duncan's multiple range test.

*Experiment III.*—In spite of a very dry summer, (total precipitation May 1 to September 30, 11 cm; 7-year average is 19 cm) there was a marked response in the first year to the fertilizer application. Nitrogen, alone and with S, significantly increased the yield and palatability of pinegrass (Fig. 2). Sulfur alone did not have a significant effect either on the yield or palatability, however, there was a significant N × S interaction. There was a highly significant difference (1% level) in both yield and palatability between $N_2S_1$ but not $N_2S_2$ and $N_2$. Regrowth after clipping was insignificant both years.

The amount of shrubs and forbs growing on the plots was highly variable and did not show any consistent response to the fertilizer application. The forbs, which were mainly leguminous, tended to respond more to S than to N and their palatability was improved by both elements. The shrubs were hardly grazed at all, and showed some response to both N and S, the differences, however, were non-significant. Pinegrass in all cases dominated the vegetation.

The crude protein content of pinegrass was increased significantly by the application of N, but not of S (Table 3). However, both rates of S, in combination with N, increased the crude protein significantly over that of N alone. The nitrate content was influenced by the amount of N applied and not by S and was well below levels considered toxic to cattle (Lawrence et al., 1968). The silica concentration of the plant was depressed by N and

**Table 3. Chemical composition[1] (% dry matter) of pinegrass which was fertilized in the spring of 1967 and sampled in the summers of 1967 and 1968.**

| Fertilizer kg/ha | 1967 | | | | | 1968 | |
|---|---|---|---|---|---|---|---|
| | Crude Protein | Silica | ADF | Lignin | Nitrate N | Crude Protein | Silica |
| 0 N 0 S | 8.5 a[1] | 12.5 ab | 42.0 a | 7.8 a | 114 ab | 8.8 ab | 11.3 ab |
| 100 N 0 S | 10.3 bc | 10.4 cd | 40.3 a | 7.5 a | 128 ab | 9.3 abc | 11.3 ab |
| 200 N 0 S | 14.3 e | 9.4 de | 38.4 a | 6.5 a | 820 c | 10.3 d | 11.1 ab |
| 0 N 100 S | 8.8 ab | 11.2 bc | 42.6 a | 6.3 a | 75 a | 8.8 a | 11.9 a |
| 0 N 200 S | 7.8 a | 12.9 a | 44.5 a | 6.3 a | 78 a | 8.8 a | 12.0 a |
| 100 N 100 S | 11.7 cd | 8.5 ef | 37.5 a | 6.8 a | 162 ab | 9.4 abcd | 10.5 bc |
| 100 N 200 S | 12.0 d | 8.6 ef | 39.3 a | 6.0 a | 387 b | 9.6 abcd | 10.3 bc |
| 200 N 100 S | 15.6 ef | 5.6 g | 38.5 a | 7.4 a | 1342 d | 10.1 bcd | 9.3 cd |
| 200 N 200 S | 17.0 f | 7.1 fg | 35.7 a | 5.4 a | 868 c | 10.2 cd | 8.9 d |

[1] Same letters within a column indicate no significant difference between the values at .05 level by Duncan's multiple range test.

generally was not affected by applications of S. The ADF and lignin content of pinegrass were not affected by the fertilizers.

In 1968 the highest soil moisture was recorded in early June and decreased rapidly, especially in the surface horizon, reaching a low by early August (Fig. 3). The moisture content started increasing again in September. Judging from rainfall data, this would appear to be a fairly typical pattern of soil water distribution in the upper 35 cm.

The applied N remained in the surface 10 cm, and most of the nitrates were absorbed and/or lost during the growing season following application. There was also considerable N loss during the winter (Fig. 4) and by the end of the second summer no residual effect from the applied ammonium nitrate could be detected.

The applied S was not lost from the soils as rapidly as the applied N (Fig. 5) and by the end of the second growing season residual S could still be detected.

Like N, most of the applied S was found in the surface horizons, which also were highest in organic carbon (C) content (Fig. 6).

## Discussion

Results of the experiments confirm earlier findings (Dawson and Kelly, 1965) that Gray Wooded soils of interior British Columbia are particularly low in N, since yield of pinegrass was increased considerably through the application of ammonium nitrate. The residual effect of the N depended on the amount of precipitation during the year of application.

Soil analyses revealed an N : S ratio lower than 8 : 1, which has been found to be remarkably constant in soils throughout the world (Walker, 1968). Under normal growing conditions, therefore, Gray Wooded soils could be expected to supply adequate S for plant growth, which was confirmed by the lack of response of pinegrass to application of gypsum alone. However, when ammonium nitrate was applied the ratio of N : S was increased considerably, creating an S deficiency, and a marked response to S was noted with applications of N.

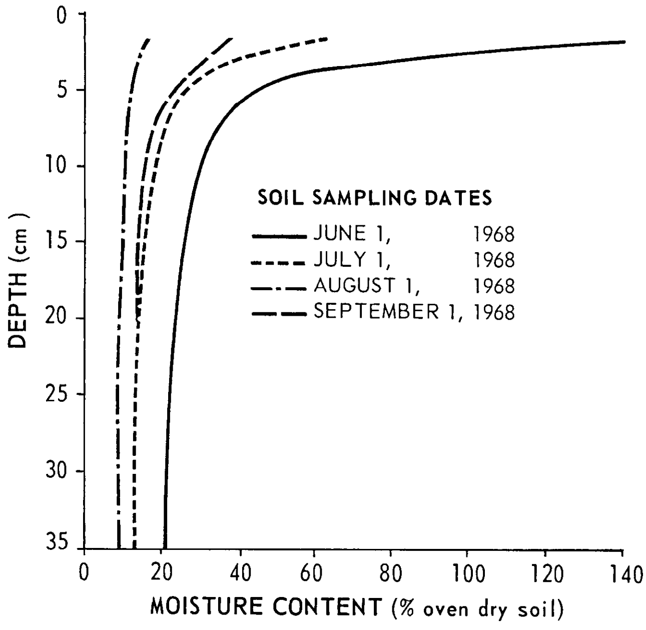


FIG. 3. Vertical distribution of soil moisture measured at monthly intervals from May to September 1968.

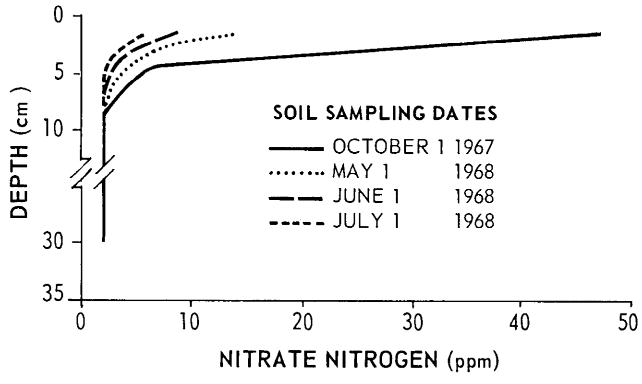


FIG. 4. Vertical distribution of soil nitrate nitrogen following an application of 200 kg N/ha in the spring of 1967.

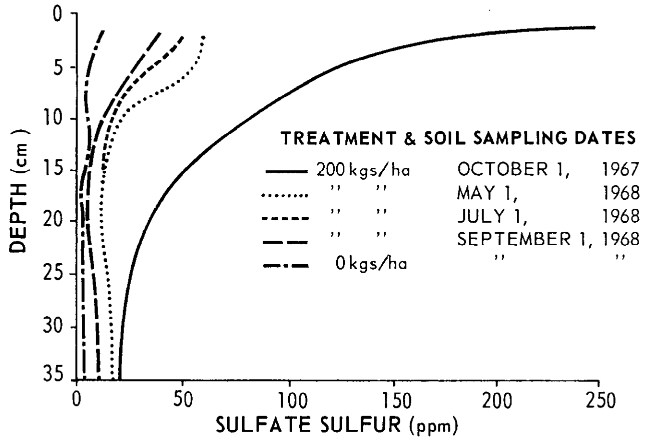


FIG. 5. Vertical distribution of soil sulfate sulfur following sulfur fertilizer treatments in the spring of 1967.

In light of the 8 : 1 ratio the rates of S used in the present study were higher than would normally be considered necessary for growth and protein formation, and the response of pinegrass to lower levels of S in combination with N remains to be tested. Furthermore, these heavy rates would be unjustifiable since a large amount of the applied S was lost especially during the winter; losses of S, however, were not as great at N.

Only 14% of the N, applied at the heavier rates, was recovered by pinegrass during the two growing seasons. At lower rates of application the recovery values were even smaller. In the experimental areas pinegrass constituted approximately 80% of the herbaceous vegetation, therefore, only about 17.5% or less of the N was recovered by the herbage (assuming the N content of the forbs to be same as of pinegrass). Presumably some of the N was absorbed by shrubs and trees, while appreciable quantities were probably lost. Various routes of soil N loss have been proposed but it is apparent in the literature that the mechanisms involved are incompletely understood. This is particularly true with regard to non-enzymatic losses in soils such as the Gray Wooded, of slight or moderate acidity (Wullstein and Gilmour, 1964).

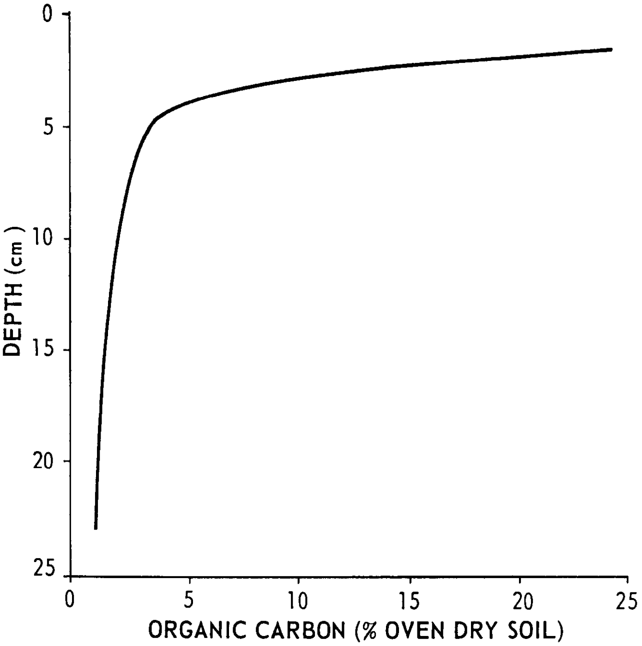


FIG. 6. Vertical distribution of soil organic carbon.

When S at a 100 kg/ha was applied with N at either rate, 23% of the applied N was recovered by pinegrass. The added S, therefore, considerably improved the ability of pinegrass to respond to N fertilization.

Pinegrass failed to regrow when cut around the middle of July, by which time much of the water in surface horizons had been exhausted (Fig. 3). The applied nitrogenous fertilizer remained concentrated in this surface horizon, and without adequate moisture pinegrass would be unable to absorb the N, which is essential for growth. It appears, therefore, that this lack of regrowth is due to a combination of lack of moisture and a deficiency of a major plant nutrient in the subsoil.

Many workers have studied the relation between chemical composition of plants and their palatability and many conflicting results have been reported as to what components influence forage preference (Heady, 1964).

The improvement of palatability of grasses by the application of nitrogenous fertilizers has been observed (Ivins, 1955) and usually there is a high positive correlation between protein and animal preference. On the other hand, herbage high in sugars was also found to be very palatable (Kare and Halpern, 1961). Reid et al., (1967) reported that acceptability and the soluble carbohydrate content of orchardgrass declined with increasing levels of N fertilization. In this study it was found that ammonium nitrate increased the crude protein and decreased the soluble carbohydrate content while greatly improving the palatability of pinegrass. The crude protein content of unfertilized pinegrass normally drops toward the end of June to below the minimum required for active growth of calves (12%), for lactating cows (8.3%) by mid-August and for maintenance (7.3%) by early September (McLean et al., 1969). The crude protein content for a large part of the grazing season is therefore inadequate. In this respect, ammonium nitrate, as well as S in combination with the N, had a definite beneficial effect on the nutritive value of the grass.

There also seems to be considerable confusion regarding palatability and digestibility (Garner, 1963). Some consider there is a close correlation between these two, while others question it. Neither N nor S, in combination or alone, had an effect on the ADF or lignin content of pinegrass, in spite of improved palatability. Similar negligible effects of fertilizers on the digestibility and lignin content of forage plants have already been reported (Knox et al., 1958; Calder and McLeod, 1968).

Silica may affect both the palatability and digestibility of forage (Jones and Handreck, 1968). Like lignin, silica is an integral part of the matrix of plant cell walls, and may similarly reduce the accessibility of cell wall carbohydrates to attack by digestive microorganisms. This aspect has as yet received little attention.

There is substantial evidence that fertilizing with N causes a decrease in the concentration of silica in plants (Jones and Handreck, 1968) and this effect has been confirmed in the present study. Such a decrease in the silica content, which normally is extremely high in pinegrass, was associated with a parallel increase in palatability but not with a noticeable decrease in fiber.

The results of these trials tend to support some workers (Heady, 1964) who feel that there is no consistent correlation between the chemical composition of forage and its preference and suggest that possibly more significant than the amount of any chemical component is the combination of chemical compounds.

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