Nitrogen - Sulfur Relations in Nordan Crested Wheatgrass (Agropyron desertorum) and its Response to Nitrogen and Sulfur Fertilizer

Forrest A. Sneva

ABSTRACT: The response to a sulfur (S) application of 28.5 pounds per acre in combination with 25, 50, and 75 pounds per acre (28, 56, 84 kg/ha) nitrogen (N) applied annually to an established stand of Nordan crested wheatgrass was compared with that receiving the same rates of N only. In the first growing season mean herbage N:S ratios of 8:1 were maintained under all levels of N fertilization with S present; however, in its absence, N:S ratios ranged from 9:1 in the controls to 15:1 in plants fertilized with 75 pounds per acre (84 kg/ha) N. Yield of herbage, herbage N, and herbage S was increased with N fertilization in the subsequent six years but with S also present further and significant ($P<0.05$) increases were measured during the second, third, and fourth growing seasons following the initial application. Soil S increases in the upper 10 inches (25 cm) due to S additions were evident only in the first growing season. These results suggest that crested wheatgrass under N fertilization programs may suffer from S deficiencies which can be corrected with periodic applications of S.

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INTRODUCTION

Nitrogen (N) is recognized as a limiting factor to the production of crested wheatgrass (Agropyron ssp.) growing on semiarid soils. As such, nitrogen fertilization research within the Intermountain sagebrush province has been extensive over the past three decades. Schmisseur and Miller (1978) cite 18 papers presenting nitrogen response data applicable to their economic analysis of fertilization on seeded sagebrush lands.

Sulfur (S) deficiencies in the Pacific Northwest were recognized by Cheney and others in 1956, and clarified further by Woodhouse in 1964. Wheatgrass response to sulfur fertilization was examined by Hyder and Sneva in eastern Oregon in 1952-53 (unpublished data - Squaw Butte Experiment Station); by Eckert and others (1961) in northern Nevada; and by Kay and Evans (1965) in northeastern California. In all three studies there was little or no response to sulfur alone or in combination with other elements considered. However, in all three locations stands of the seeded grass were three years or less in age. Subsequently, Sneva and Rittenhouse (1976) reported strong response to sulfur in combination with nitrogen in some years on aged stands or those on soils that had been growing improved species for several decades. Elsewhere in the Pacific Northwest, Pumphrey and Hart (1973) and Geist (1976) reported positive production response from both nitrogen and sulfur additions to soils derived from volcanic ash at higher elevations in northeastern Oregon.

This study is a phase of research conducted to examine the N:S relations within native and introduced vegetation of the big sagebrush (Artemisia tridentata) ecosystem in eastern Oregon. Specifically I examined the N:S relations in crested wheatgrass in the first year following N fertilization with and without S. In the following six years I monitored herbage yield, N, and S concentrations in the herbage when nitrogen treatments were annually repeated but with no additional sulfur applied.

Locale

The study site was in a 5 acre (2 ha) nursery on the Squaw Butte Experiment Station approximately 39 miles (65 km) west of Burns in eastern Oregon. The site, originally dominated by big sagebrush and bunchgrasses, was seeded to an unknown crested wheatgrass selection in the mid-1940's. The area was subsequently plowed and seeded to Nordan crested wheatgrass (A. desertorum [Link] Schultes) in 1966. The stand was in good condition, had previously received no irrigation or fertilization, and had been grazed or mowed annually after maturity.

The soil has been described by Eckert (1957). These residual or alluvial soils developed from basalt or rhyolite parent material. Textures range from loam or sandy loam in the surface layer to

Forrest A. Sneva is Range Scientist (Ret.), USDA Agricultural Research Service, Squaw Butte Experiment Station, Burns, Ore.

sandy clay loams in the sub-surface layers. An indurated restrictive layer cemented by silica or calcium is present between the 18 to 30 inch (46 to 76 cm) depth. Surface layers normally contain less than 1 percent organic matter and the pH ranges from 6.4 to 7.0.

Procedures

Plots 6 X 18 feet (1.8 x 5.5 m) were established in the fall of 1970 and fertilizer treatments applied on 28 January 1971. Treatments were no fertilizer, ammonium nitrate and ammonium sulphate alone and in combination to provide levels of 25, 50, and 75 pounds per acre (28, 56, and 84 kg/ha) of actual N only, and those same N levels plus 28.5 pounds per acre (32 kg/ha) S. Sulfur was applied only to N treated plots in the first year. Plots were subsequently fertilized annually with ammonium nitrate commencing in the fall of 1971 through 1976. Rates of N fertilizer were randomly allocated to subplots within randomly assigned main plots (N vs N plus S) with 3 replicates of treatments.

In 1971, herbage from 13 linear feet (3.7 m) of drill row within each subplot was harvested on 30 April, 14 May, 2 June, 11 June, and 14 July. These samples were oven dried and prepared for N and S analyses. Soil samples (three 0.75 inch diameter (1.9 cm) cores per sub-plot) of the surface 10 inches (25 cm) were obtained on 15 July and similarily handled and prepared for analyses. Nitrogen and sulfur analysis followed that of Association of Official Agricultural Chemists (1965).

In subsequent years herbage yield was estimated by harvesting 24 feet^2 (2.2 m^2) within each plot. Following oven drying and weighing this sample was prepared for nitrogen and sulfur analysis. Yield sample dates were 12 July 1972, 14 May 1973, 29 July 1974, 8 August 1975, 27 August 1976 and 12 July 1977. The surface 10 inches (25 cm) of subplot soils were sampled as previously described above on 14 July 1972 and 10 July 1973, and analyzed for nitrogen and sulfur.

Data analyses were for a split-split plot over years with treatment mean differences tested with Duncan's multiple range test. Nitrogen-sulfur ratios were transformed by angles prior to analysis.

RESULTS AND DISCUSSION

First Year Response

Crop-year precipitation (Sept.-June, inc.) for 1971 was 107 percent of the long term median amount. Temperature during April, May, and June was slightly below the long term mean with average monthly maximum temperatures of 12, 18 and 19° C, respectively. Thus, responses measured in that year are inferred to be relatively free of strong climatic influences.

All main effects, and first and second order interactions (except the latter for N:S ratios) were significant ($P<0.05$) sources of variation in the analyses for N and S concentrations and their ratios. These relations are presented in Figures 1 to 3.

Mean N concentrations ranged from 1.5 in the controls to about 2.5 percent when fertilized with 75 pounds per acre (84 kg/ha) N, with highest concentrations associated with N only treatments (Fig. 1a). Mean concentrations decreased in the controls from about 2 to less than 1 percent from 30 April to 14 July, as compared with a more rapid decline (3.5 to 1.5 percent) for the same period in grass fertilized with 75 pounds N per acre (84 kg/ha). Concentrations of N in grasses receiving inbetween fertilizer rates showed proportional rates of decline (Fig. 1b). Mean N concentrations on 30 April were the same in grasses fertilized with N or N plus S, but as the grasses matured the N declined most rapidly in grasses fertilized with N plus S (Fig. 1c). This difference is shown more clearly in Figure 1d which also shows a greater consistency in linear trend with rate of N in those plants fertilized with N only as they matured.

Mean S concentrations in herbage were increased with S fertilization; however, it also increased slightly with an increase in the N level of fertilization (Fig. 2a). Sulfur concentrations ranged from about 0.15 to about 0.3 percent. Like N concentration, S declined as the plants matured, the rate influenced by the level of N fertilization (Fig. 2b). Sulfur decline differed from that of N in that the rate of decline was most rapid up to 2 June; thereafter the rate slowed (Fig. 2c). In the presence of S, the two highest levels of N consistently caused high levels of S concentrations in plants, but the lowest level of N fertilization was inconsistent in that effect as the grasses matured (Fig. 2d). Also, when fertilized with N only, the response of S concentrations to level of N was extremely inconsistent as plants matured.

Nitrogen-Sulfur ratios in plants fertilized with S remained at 8:1, but ratios in grasses receiving no S increased from 9:1 to 15:1 as N rate increased (Fig. 3a). The N:S ratios generally declined as plants matured but this was influenced by nitrogen level (Fig. 3b). The decline in N and S ratios was similar in plants fertilized with N or with N plus S, but the ratios of plants fertilized with S were three to six units lower than those fertilized with only N (Fig. 3c).

Residual Response

The residual years (1972 to 1977) were dry with crop-year precipitation ranging from 64 to 94 percent of the long term median amount of 10 inches (25 cm), averaging 81 percent. Temperature in April was cooler than the long term mean in all years but 1977. May temperature was above its normal in 1972, 1973 and 1976 while in June temperature exceeded its normal in all years but 1976. The yield results obtained in those years reflect responses associated with years of below normal precipitation but with a non-consistent temperature pattern during the growing season months.

In the six residual years the mean yield of crested wheatgrass averaged 165 gm per 24 feet^2 (2.2 m^2) with N alone. It was further increased ($P>0.05$) by 10 percent on plots initially fertilized with S. A typical response to N occurred with 25 pounds per acre (28 kg/ha) of N causing a 68 percent increase in yield above the control, with increasing N rates causing no further increases. Crested wheatgrass response to 25 pounds per acre (28 kg/ha) of N was

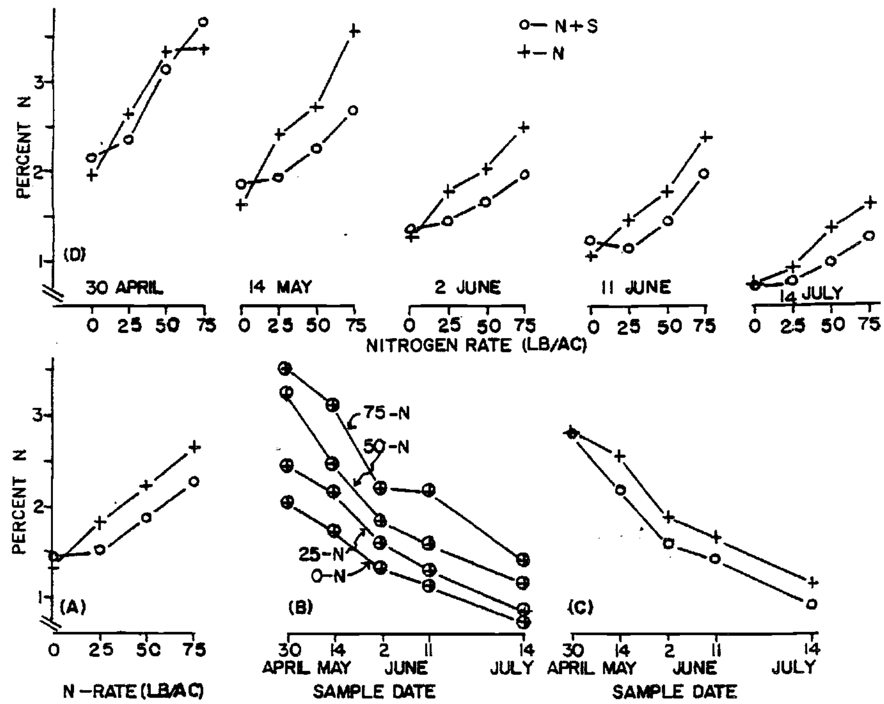

Figure 1.--Mean concentrations of N in crested wheatgrass in the first growing season following S fertilization of 28.5 pounds per acre (32 kg/ha) and N at rates indicated.

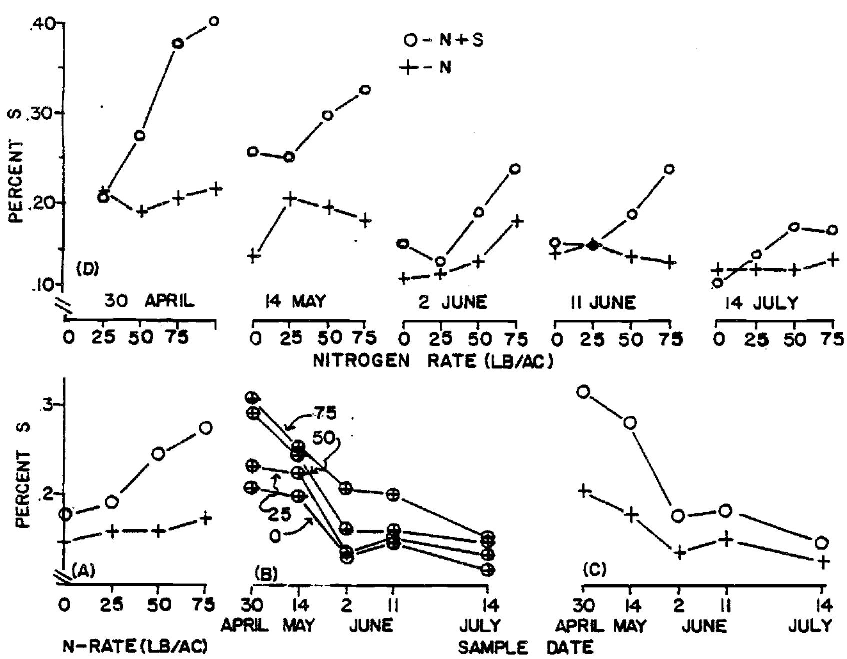

Figure 2.--Mean concentrations of S in crested wheatgrass in the first growing season following S fertilization of 28.5 pounds per acre (32 kg/ha) and N at rates indicated.

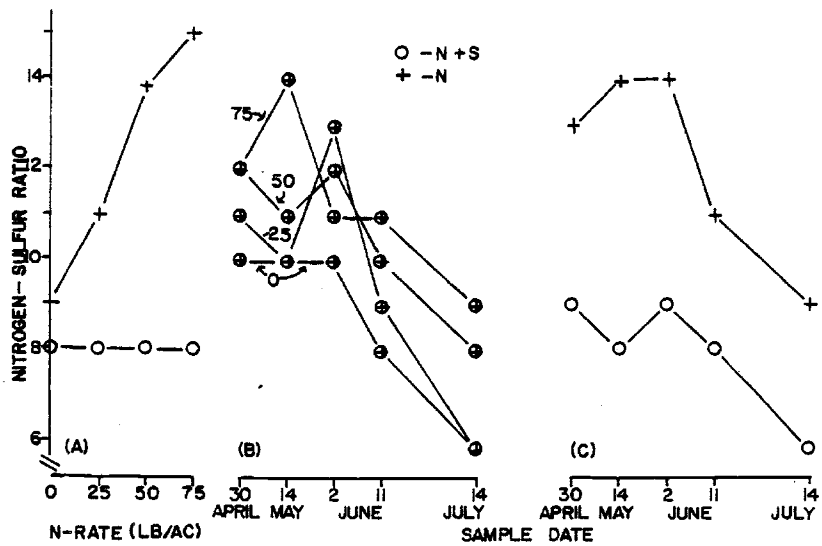

Figure 3.--Mean N:S ratios in the first growing season following S fertilization of 28.5 pounds per acre)32 kg/ha) and N at rates indicated.

consistent, relative to year variation, whereas yields declined across years at the two highest levels of N (Fig. 4a), causing a significant interaction. Similarily, in the presence of S, yields of crested wheatgrass were increased in the first three years above that fertilized with N alone. In the last three years there was no difference in yield from plots fertilized with N alone compared to that initially fertilized with N and S and thereafter only with N (Fig. 4b). The results suggest that the effects of the single application of S in the first year may have diminished by the fourth growing season.

The six year mean herbage yield increase of 10 percent induced by the addition of S, while statistically non-significant, is believed to be real and underestimates S response. Nitrogen additions to crested wheatgrass results in greater production in the spring and advances the depletion of available soil moisture (Sneva and Rittenhouse, 1976). In the present study crested wheatgrass growth in the presence of both N and S was so great that grasses receiving both elements rarely completed phenological development due to early soil moisture exhaustion. Thus, herbage loss due to decomposition and leaf shatter prior to harvest was high on plots receiving both fertilizers. The early harvest date in 1973 on 14 May, which was in error, severely damaged plants in the sampled area on plots receiving both N and S fertilizer, requiring subsequent sampling of those plots to eliminate that area. Also yields in 1973 from the N and S fertilized plots on 14 May were equal to that of mature yields of nearby plots harvested on August 1.

Mean N concentrations in crested wheatgrass were not influenced significantly by S, but increased ($P<0.05$) from 1.5 in the control to 2.2 percent in grasses fertilized with 25 pounds per acre (28 kg/ha N. Concentrations were further increased about 23 percent ($P<0.05$) with 50 or 75 pounds per acre (56 or 85 kg/ha) N. The year effect was strong with mean concentrations significantly different ($P<0.05$), ranging from 1.3 to 3.4 percent. The kind of fertilizer and the rate of N fertilizer interacted with years and these interactions are presented in figures 4c and 4d. Though significant these interactions are not particularly meaningful.

Nitrogen yield in the harvested herbage was similarily influenced by N level and years, with the year x N level and the year x kind of fertilizer interactions also significant ($P<0.05$). Nitrogen yield more than doubled with 25 pounds per acre (28 kg/ha) N (1.7 vs 3.8 gm per 24 feet^2 (2.2 m^2), and increased an additional 28 percent with N additions of 50 and 75 pounds per acre (56 and 84 kg/ha). Nitrogen yield ranged from 3.0 to 5.3 gm per 24 feet^2 (2.2 m^2) with the latter occurring in 1973. The significant interactions (Fig. 5a and 5b) of both concentration and yield of N are in part due to the early harvesting in 1973, because N concentrations are much higher at that time as compared with concentrations at maturity. However, there is still evidence of differences particularly as one compares the responses in the first three years with those of the last three years.

Mean S concentration in crested wheatgrass over the six years significantly ($P<0.05$) increased about 13 percent from the initial application of S. Interestingly, herbage S concentrations increased from plots fertilized with or without S although the increase was not as great from plots receiving no sulfur. Years interacted significantly with level of N (Fig. 5c) and with kind of fertilizer (Fig. 5d), but as with N concentrations these interactions

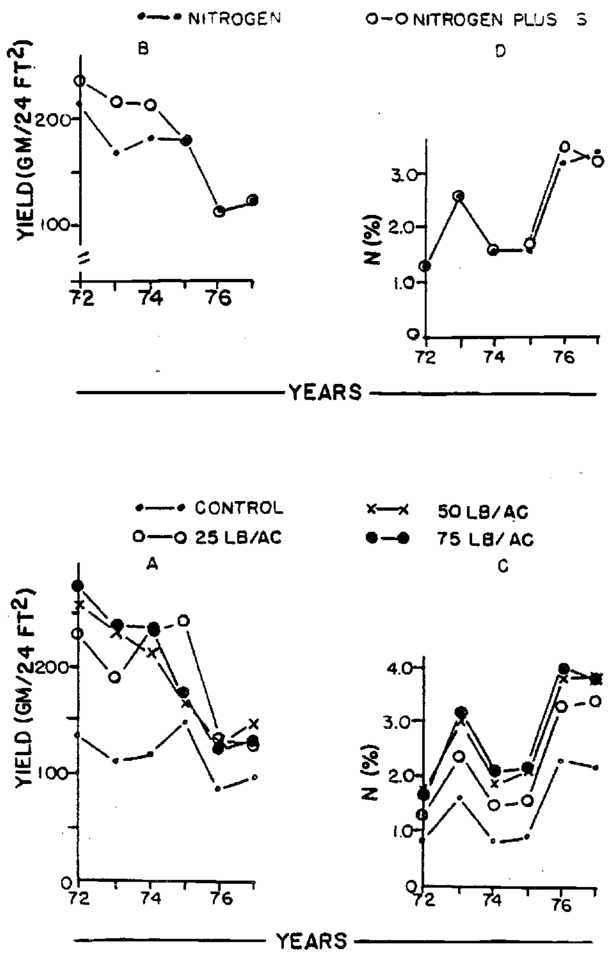

Figure 4.--Mean herbage yield and N concentrations in crested wheatgrass fertilized with 28.5 pounds per acre (32 kg/ha) S in the winter of 1971 only, with N levels as indicated applied annually.

were not strong and no particular significance is attached to them.

Sulfur yield in the herbage of crested wheatgrass fertilized with N more than doubled ($P<0.05$), but differences between mean S concentrations in plants receiving S or no S (0.354 vs 0.444 percent) were non-significant. Sulfur concentrations varied significantly ($P<0.05$) among years from 0.286 to 0.464 percent with all first and second order interactions involving years significant ($P<0.05$). Sulfur yield in herbage from plots fertilized at the 25 pounds per acre (28 kg/ha) N fluctuated similarily across years as did S yields in herbage from the controls (Fig. 5e). However, at the two highest levels of N fertilization the relative year response diminished in time. The year x kind of fertilizer interaction (Fig. 5f) occurred because yield in plants initially fertilized with S was higher than yield in plants not fertilized, but in the last three years those differences diminished. Comparing figure 5f with 5d and 4b, it seems clear that herbage yield response (rather than S concentrations) is primarily responsible for the results obtained.

The initial application of 28.5 pounds per acre (32 kg/ha) S on 27 January 1971 significantly increased the level of sulfur in the upper 10 inches (25 cm) of soil from 3.4 to 7.5 ppm when sampled on 15 July 1971. Subsequent samplings in July 1972 and 1973 revealed no differences in soil S between plots fertilized with S or those receiving no S.

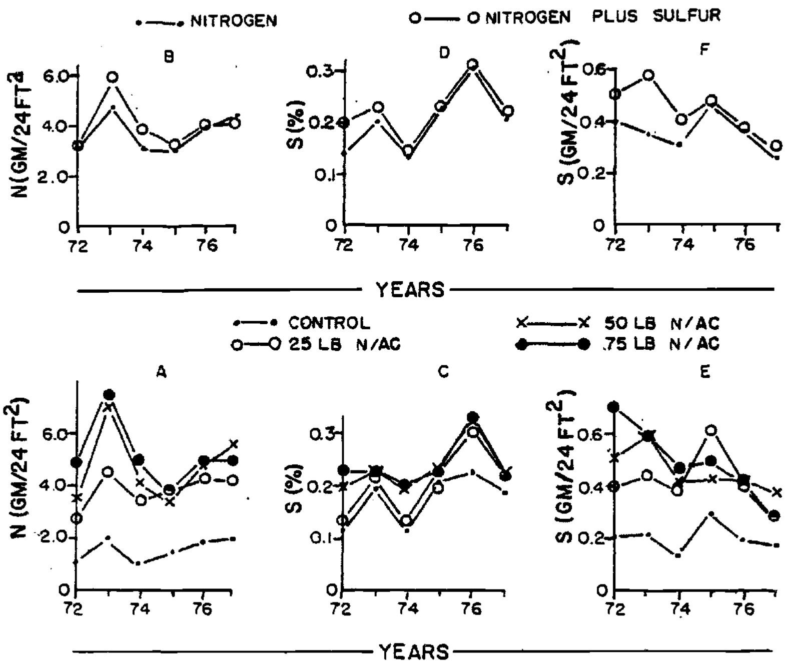

Figure 5.—Mean N and S concentrations in crested wheatgrass fertilized with 28.5 pounds per acre (32 kg/ha) S in the winter of 1971 only, with N levels as indicated applied annually.

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