Orchardgrass Growth on Nitrogen and Sulfur Fertilized Volcanic Ash Soil

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Highlight: Growth responses of orchardgrass to additions of N and S from various sources were studied in the greenhouse on a volcanic ash soil. Sources with soluble S were superior to those with elemental S in producing faster growth, greater growth, and greater N recovery. Results indicate fertilizers with formulae of 21-0-0-24, 30-1-0-6, 27-12-0-4, or 16-20-0-15 should effectively aid rapid establishment of new orchardgrass seedlings. Rapid early growth will take optimum advantage of stored soil moisture prior to the onset of dry summers which typically occur in much of the Northwest. Grazing at late growth stages will maximize returns from applied fertilizers.

Seeding of grasses and forbs on skid trails, landings, and cutting areas is a common practice following logging in eastern Oregon. Native understory is often sparse before dense overstory canopy is removed, and seeding can speed establishment of erosion control cover where soil disturbance has occurred. These revegetated areas offer increased forage supplies for summer grazing by livestock and big game populations.

Volcanic ash soils are common in forests of the Blue and Willowa Mountains in eastern Oregon. These soils are derived from varied thicknesses of silt-sized Mt. Mazama ashfall (Harward and Youngberg, 1969). They are moderately deep, have comparatively high water-holding capacity, and occur in annual precipitation zones ranging from 45 to 125 cm. Considerable interest has been expressed in fertilizing these soils to promote better seeding success and greater vegetation productivity. Fertilization guidelines are needed for upland soils, and progress has been made toward developing such information in eastern Oregon and eastern Washington. Growth responses to nitrogen (N) and sulfur (S) addition have been found in field and greenhouse studies on several soils (Pumphrey, 1971; Pumphrey and Hart, 1973; Klock et al., 1971). Responses to N, phosphorus (P), and S added singly and in combinations have been studied on a number of soils (Geist, 1971). Plant growth responses on volcanic ash soils were particularly impressive with N and S additions. Little has been done to determine which fertilizer sources, particularly commercial types, should be used on deficient ash soils, although some preliminary field results from other studies have been obtained (Geist, 1972).

This paper describes the response of orchardgrass (*Dactylis glomerata* L.) to several sources of N and S applied on Mazama ash soil (Tolo silt loam) as a guide to fertilizer selection in revegetating areas disturbed by logging.

Methods

A bulk sample of surface soil (0 to 15 cm) was collected from the Starkey Experimental Forest and Range, 30 miles southwest of La

Grande, Ore. The soil was air dried, thoroughly mixed, passed through 6.6-mm (¼-inch) mesh screen, and 2,000-g portions were weighed into pots lined with plastic bags. Each pot was planted with 10 seeds of Latah orchardgrass and thinned to four plants at the two-leaf stage. Deionized water was added by weight to maintain a minimum stress condition of 1/10 to 1/3 bar. Plants were grown in the greenhouse a total of 265 days after planting at 22°C with a 14-hour photoperiod. Successive clippings of top growth 4 cm above the soil surface were made at 66-, 65-, 69-, and 65-day intervals. Clippings were oven dried for 24 hours at 65°C, weighed, and ground to pass a 40-mesh screen.

Nine fertilizer treatments were applied in a completely random design with four replications. Nitrogen sources lacking S were supplemented with either elemental S (0.25 to 0.5-mm size) or calcium sulfate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). The nine treatments (T) were:

T1—check, no N or S

T2—200 ppm N as ammonium nitrate (33-0-0) + 50 ppm elemental S

T3—200 ppm N as ammonium nitrate + 50 ppm S as $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$

T4—200 ppm N, 229 ppm S as ammonium sulfate (21-0-0-24)

T5—200 ppm N, 40 ppm S as ammonium nitrate sulfate (30-1-0-6)

T6—200 ppm N as urea (46-0-0) + 50 ppm elemental S

T7—200 ppm N as urea + 50 ppm S as $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$

T8—200 ppm N, 30 ppm S as ammonium phosphate sulfate (27-12-0-4)

T9—200 ppm N, 188 ppm S as ammonium phosphate sulfate (16-20-0-15)

Fertilizers were mixed into the upper layer of dry potting soils before seeding and initial watering. All pots received 25 ppm Mg and 25 ppm K as dissolved chloride salts at both 53 and 68 days postplant.

The potting soil was analyzed for organic matter (modified Walkley-Black method, Jackson, 1958), total N (Kjeldahl method, Jackson, 1958), available phosphorus (NaHCO_3 method, Watanabe and Olsen, 1965), exchangeable potassium (K), and magnesium (Mg) (U.S. Salinity Laboratory Staff, 1954), total S (Bardsley and Lancaster, 1960), and pH (1:2 in 0.01M CaCl_2).

Differences among treatments were tested by analysis of variance and means were compared by Scheffe's test at the 0.05 level (Scheffe, 1959). Tests were made on each clipping and, in the case of yield and percentage N recovery, for totals over all clippings.

Results

Soil analyses indicated an acidic reaction and relatively low levels of organic matter, nitrogen, and sulfur:

pH	5.2
Organic matter (%)	2.31
Total N (%)	0.076
Total S (%)	0.0063
N:S ratio	12
Available P (ppm)	52.6
Exchangeable K (meq/100g)	1.47
Exchangeable Mg (meq/100g)	1.21
Size classes (S, Si, C) (%)	33, 54, 13,

The N:S ratio showed the balance between the two was adequate for normal protein production. Available P was fairly high, and

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sufficient levels of exchangeable K and Mg were present for normal growth. Hence, precautionary additions of K and Mg were unnecessary.

Yield and other response variables are discussed individually, with treatment effects summarized into major group differences.

Three major groupings in response to treatments are apparent in the yield data. Significant differences in yields occurred among treatments for each clipping and for cumulative yield (Fig. 1). Statistical tests of means showed significant differences between T3-5, 7-9 and T1, 2, 6 at the first clipping. Differences in cumulative yield at the fourth clipping occurred between T1 and T2-9. Growth on T2 and 6 containing elemental S, began slowly, but a higher percentage of total growth occurred during the second through the fourth growing periods compared with T3-5, 7-9 containing sulfate - S. This caused a slight convergence in cumulative yield curves, but T3-5 and 7-9 were still almost 50% greater than T2 and 6 through the fourth clipping. Approximately 75% of the total growth was made by plants in T3-5 and 7-9 by the first clipping compared to 50% by T2 and 6, and 60% by T1.

Fig. 1. Cumulative top growth of orchardgrass (treatment code in parentheses).

The similarity in effects of certain treatments noted in yield data occurred with other response variables. They are subsequently grouped and discussed as T2 and 6 = T-group 1; T3-5, 7-9 = T-group 2.

Nitrogen concentrations (Fig. 2) were also significantly different at each of the four clippings, with T-group 1 substantially higher than the check and T-group 2 at clipping one. The means of T-group 2 were intermediate at clipping one but declined to lowest by clipping two, and plants assumed a chlorotic color. Means of T-group 1 also declined by clipping two but remained highest; the check declined slightly and assumed an intermediate position in about the midrange position. By clippings three and four, plants in T-group 1 and T-group 2 had similar N concentrations. Concentrations in check plants increased to higher N percentages than all other treatment plants by clipping three and maintained this level through four. However, yields of fertilized plants were similar to or exceeded check plants over growth periods three and four (Fig. 1).

Sulfur concentrations differed among treatments at each clipping. Concentrations of T-group 2 were higher than T-group 1 and the check at clipping one, but no concentration differences occurred among T-group 1 and the check treatment (Table 1). Sulfur concentrations of T-group 2 at clipping one generally reflected the concentrations applied initially. Concentrations of

Fig. 2. Nitrogen concentrations in orchardgrass (treatment code in parentheses).

T-group 2 declined much like nitrogen by the second clipping, then generally increased through clippings three and four. Concentrations in check plants were low and changed relatively little over the four clippings. Plants with elemental S added (T-group 1) had rather low S concentrations at the first and second clippings but increased by the third and fourth clippings. Soluble sulfur sources maintained significantly higher S concentrations than other treatments in most instances and supplied adequate sulfur throughout all growth periods.

Further clarification of N and S status of treated plants is provided by N:S ratios (Table 1). Significant differences at every clipping are again reflected in three response patterns. Check treatment values were moderate initially, then increased to a fairly high level. T-group 1 began high, then declined to moderate values. T-group 2 remained comparatively low (4-8/1) over all clippings. Thus, although the check and T-group 2 differed from T-group 1 in the first two clippings, these trends ended with only the check differing from other treatments by the final two clippings.

Table 1. Mean sulfur concentration, nitrogen to sulfur ratio, and nitrogen recovery of orchardgrass according to fertilizer treatment and clipping.

Clipping	Treatment								
	T-group 1			T-group 2					
	1	2	6	3	4	5	7	8	9
Sulfur concentration (ppm)									
First	891	875	876	2,453	4,547	2,422	3,235	2,078	4,094
Second	953	829	828	1,279	1,532	1,126	1,110	1,000	1,922
Third	1,172	1,672	1,688	3,157	3,782	2,422	2,704	2,297	4,328
Fourth	875	2,438	2,110	3,500	4,531	2,636	3,031	2,156	5,188
Nitrogen to sulfur ratio									
First	13	30	28	6	4	7	5	8	4
Second	11	18	16	5	4	6	6	7	3
Third	17	11	10	4	4	6	5	6	3
Fourth	22	9	10	4	3	6	5	7	3
Recovery of fertilizer nitrogen (%)									
First	—	36	39	62	65	58	61	60	62
Second	—	11	10	5	4	5	5	5	3
Third	—	8	5	2	2	2	2	1	1
Fourth	—	3	3	0	0	0	0	0	0
Total recovery		58	57	69	71	65	68	66	66

Fertilizer N recovery percentages were computed on the basis of N uptake over the check plants (Table 1). Most fertilizer recovery occurred in the first clipping, and the percentage recovery was significantly higher for T-group 2 than T-group 1. This relationship reversed in subsequent clippings with T-group 1 higher. Percentage recovery universally declined with each cutting, in fact, to zero by the fourth clipping in T-group 2. Total recovery, however, showed T-group 2 significantly higher than T-group 1.

Discussion and Conclusions

Nitrogen sources containing readily soluble sulfur stimulated rapid seedling growth and development more than sources supplemented with elemental S. Rapid growth would favor early plant establishment in the field before other limiting factors of a site restrict growth. Early season growth is important in the Northwest because precipitation occurs primarily in winter and spring, and a pronounced drought usually occurs in July and August. Thus, utilization of water and nutrients during the early growing season takes optimum advantage of this weather pattern.

Stewart and Whitfield (1965) reported the N:S ratio of plant protein is about 16. Thus, a tissue ratio above 16 indicates S supply is low relative to N or N supply is high relative to S, but the ratio alone does not tell whether supply of either nutrient is adequate. N:S ratios and concentrations are both helpful for interpretation of results; however, the overall adequacy of supply and success of treatments is best judged from growth data.

Ratio and concentration data for plants in T-group 1 show that S supply was inadequate relative to N during the first growth period. This imbalance was corrected the second period, but thereafter N supply was low relative to S. The initial nutrient imbalance was apparently due to the inability of microorganisms to oxidize elemental S for plant use at a rate commensurate with N supply and growth potential. Differences in growth among treatment replicates of T-group 1 indicate that oxidation rates were variable.

The low ratios associated with T-group 2 show that S supply was excessive relative to N; however, concentration and growth data indicate that supplies of both were adequate during the first growth period. Supplies of S continued high relative to N over the next three growth periods. This, coupled with reduced growth, indicates nitrogen supply was limiting growth after the first clipping.

The decline in N and S concentrations of fertilized plants from the first to the second clipping was apparently a response to the initial clipping, which removed a sizeable percentage of the applied nutrients. Luxury consumption of N and S the first growth period may have played a part in emphasizing these changes, particularly in the case of N in T-group 1.

Inadequate and imbalanced nutrient supply caused poor growth of unfertilized plants. N:S ratios of tissues indicated excessive S relative to N the first two growth periods, balanced supplies the third period, and excessive N relative to S the fourth period. Stewart and Whitfield (1965) stated that a rather constant relationship exists between soil organic N and S, further, that these nutrients are mineralized in about the same ratio as they exist in soil. Thus, since the experimental soil used had an N:S ratio of 12, we might expect unfertilized plant tissues to have consistent ratios near this value. But, tissue ratios were neither consistent nor very near 12 the last two growth periods.

Mineralization of soil N and S apparently exceeded the 12:1 ratio during the third and fourth periods.

Overall, fertilizers in T-group 2 appeared equally effective in supplying N and S for growth of orchardgrass in the greenhouse. It is clear that these fertilizers should be recommended over T-group 1 as an aid to establishing new seedlings on ash soils. No growth benefit was noted with fertilizers containing P, as might be expected, since the available soil P was originally high. Among T-group 2, one of the readily available commercial formulations (21-0-0-24, 30-1-0-6, 27-12-0-4, 16-20-0-15) should be chosen for use in the field. Criteria of selection will depend on cost, availability, and related factors. If the soil is low in available P, then one of the latter two sources mentioned should be chosen.

To realize maximum benefits in the field, grazing should be deferred till late in the season to allow maximum use of applied nutrients. Deferment is usually practiced with new seedlings but would also be beneficial when fertilizing established stands. Hedrick et al. (1965) found highest yield benefits from fertilizing grasses when clipping was delayed to the head emergent growth stage. Thus, the year of fertilization must be coordinated with season of use in cattle management plans.

Livestock and big game are particularly attracted to fertilized areas, so management plans should consider this factor also (Geist et al., 1974).

Summary

Greenhouse growth responses of orchardgrass to N and S additions from various sources were studied on a volcanic ash soil. Nitrogen sources with readily soluble sulfur produced greater initial and total growth and N recovery than N sources with elemental S. However, all N and S treatments produced more growth than the unfertilized treatment.

The results showed either 21-0-0-24, 30-1-0-6, 27-12-0-4, or 16-20-0-15 would be equally effective sources of N and S for deficient ash soils and should aid rapid establishment of new orchardgrass seedlings.

Rapid early season growth takes optimum advantage of the predominant precipitation pattern in the Northwest. Most of the precipitation commonly occurs in the winter and early spring followed by a pronounced drought in July and August.

Maximum utilization of fertilizer nutrients should be realized if grazing is deferred to late growth stages of the plant. Remember too, that fertilized forage is attractive to both livestock and big game, so animal management plans must consider both these factors.

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