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Nitrogen and Sulfur Impacts on the Cold Desert Biome

FORREST A. SNEVA

Highlight

N and S fertilizers decreased production and composition of native perennial grasses but increased that of annual species. N and S increased sagebrush establishment in wet years, but high mortality on fertilized plots in dry years reduced the overall impact to a low level. Current and residual year response of crested wheatgrass to N and S varied widely with crop year precipitation and its year-sequence. Fertilization can increase crested wheatgrass yields for the spring and summer grazing period. However, management manipulations need to be field-tested to minimize deliterious impacts of dry years, early spring grazing — fertilizer interactions, and to maximize grazing returns in the favorable years.

Grass is the principal renewable product of semiarid rangeland but efficient utilization and efficient means of increasing its production are needed.

Studies of response to fertilizer were initiated at the Squaw Butte Experiment Station in 1952. Since then, we have collected data that relate kinds, times, frequencies, and level of fertilization with production, quality, physiology, and phenology of native and introduced grasses, residual nitrogen in the soil, and the establishment and survival of the major brush species. This paper is an extraction of information from past and ongoing research that helps answer the question, "Can nitrogen (N) and sulfur (S) fertilizers increase the productivity of the cold desert biome?"

The Area

Squaw Butte Experiment Station, situated 68 km west of Burns in southeastern Oregon, is typical of the cold desert biome that extends into Idaho, Nevada, California, and Utah. This vast area is characterized by low annual and highly variable amounts of precipitation (200 to 380 mm), elevation ranging from 750 to 1,830 m, and temperature extremes of 38 to −38 C. Big and low sagebrush (*Artemisia tridentata* and *A. arbuscula*) with juniper (*Juniperus occidentalis*) counterparts shadow their herbaceous companions, bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*), Thurber's needlegrass (*Stipa thurberiana*), squirreltail (*Sitantion hystrix*), and Junegrass (*Koeleria cristata*), over much of this range. On misused or degraded ranges, downy bromegrass (*Bromus tectorum*) becomes a principal or sole component of the site. Total removal of existing native competition permits establishment of crested wheatgrass (CW) (*Agropyron desertorum*) in all but the drought years.

Experimental Procedure

Ammonium nitrate was the principal source of N used except for studies that compared fertilizer sources when urea and ammonium sulphate were also included. More recent studies have used Ortho ANS[1] (ammonium nitrate formulated with 6% sulfur). Gypsum was the principal source of S except in combination with N when ammonium sulphate was used.

The fertilizer was broadcast on the soil surface in early fall except when comparing dates of application (fall vs. winter vs. spring). Rates of N ranged from 11 to 90 kg/ha annually, 45 to 179 kg/ha biennially, 67 kg/ha every third year, and 134 kg/ha was monitored as a one-time treatment. Except in studies using Ortho ANS, sulfur was applied at 31 and 56 kg/ha, only at the beginning of individual studies.

Herbage was harvested in the spring, summer, and fall, depending upon the objectives of each study. Samples were oven dried and the data are reported as oven dry or air dry (10% moisture). Samples of herbage or roots were analyzed for N, S, K, Ca, P, and carbohydrates when required to fulfill objectives. Soil moisture depletion was monitored using plaster of Paris blocks and an electrical resistance meter. Residual N in the soil was determined by analyses for NH_4-N and NO_3-N. Changes in sagebrush numbers were followed by counting plants < 15 cm, > 15 cm but < 46 cm, and > 46 cm tall.

Results

Native grass

Production of grasses on a fair condition range after sagebrush was controlled with 2,4-D varied widely in response to N (Fig. 1). Most levels of N reduced yield in an extremely dry year (1955), whereas 67 kg/ha of N increased yield 200% in a very wet year (1957). Mean yield across years from 34 kg/ha of N was 86 kg/ha. In a companion study located on a poor condition site with brush for the same years, the mean herbage increase from the 17 kg/ha rate was 7 kg/ha; N at 34 kg/ha decreased yield.

During the 1971-1977 period of dry to normal precipitation, neither N nor N plus S caused large changes in total grass yield (Table 1). Sulfur alone depressed total yield. Bluebunch wheatgrass was the

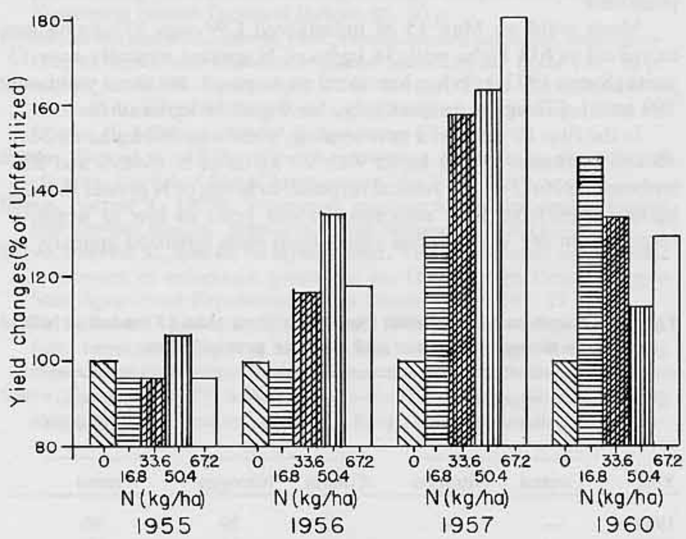

Fig. 1. Herbage yield response to annual N fertilization on a native range sprayed in 1952 for brush control.

The author is Range Scientist, Agricultural Research Service, U.S. Department of Agriculture. Squaw Butte Experiment Station, Burns, Oregon.

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[1]Mention of a trademark or propietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

Table 1. Herbage yield as influenced by nitrogen or nitrogen plus sulfur (6-year mean), as percent of check (0-0).

	Nitrogen — Sulphur[1] (kg/ha)							
Species	0-0	0-56	22-2[2]	22-56	67-0[3]	67-56	134-0[4]	134-56
Agsp	100	68	95	70	90	72	76	83
Feid	100	158	83	72	37	40	43	83
Stth	100	84	159	65	47	47	77	18
Kocr	100	78	85	65	89	55	46	49
Brte	100	115	145	389	247	287	377	292
Total	100	82	105	102	102	87	96	95

[1]Sulfur applied in first year only (1971).
[2]Nitrogen applied annually (1971 to 1976).
[3]Nitrogen applied first and third year.
[4]Nitrogen applied first year only.

largest contributor to this depression. Yields of all perennial grasses were generally depressed more by N plus S than by N alone and by the less frequent application. Fertilizer treatments increased yield of downy bromegrass to nearly 4 times that on control plots.

Sagebrush

Nitrogen had little effect upon the mortality of mature sagebrush (> 46 cm tall). Numbers of seedling sagebrush (< 15 cm) increased in years of higher than normal summer precipitation, and in those years, N caused further significant increases in numbers of seedlings established (Table 2), (Hyder and Sneva 1961). Fertilizer-N significantly increased the mortality of these small plants in subsequent years.

In 1972 to 1977, responses of sagebrush to N plus S were studied on a CW seeding in which sagebrush had invaded. Sagebrush establishment was low except in 1976, when heavy rains in July and August (10 cm) caused high establishment of seedlings with significant increases on plots fertilized with N plus S (Table 3). The next year (1977), a drought year, mortality of seedlings was high, but greatest mortality occurred on fertilized plots.

Introduced grasses

The responses of introduced grasses to N have been evaluated in field tests (Sneva and Hyder 1965; Hedrick *et al.* 1964). However, because CW is the primary grass used to improve rangeland in the temperate semiarid areas, only the results with that grass will be presented.

Mean yield on May 15 of unfertilized CW was 332 kg/ha but increased to 614 kg/ha with 34 kg/ha of N applied annually over 13 years (Sneva 1973a). When harvested on August 1, the mean yield was 799 and 1,477 kg/ha, respectively, for 0 and 34 kg/ha of N.

In the first 10 years of a new seeding, yield was 560 kg/ha on May 15 and increased to 896 kg/ha with 22 kg/ha of N (Sneva and Rittenhouse 1976) (Fig. 2). Annual response to levels of N greater than 22 kg/ha varied from high responses in wet years to low or negative responses in dry years. Mean yields from plots fertilized annually or

Table 2. Numbers of sagebrush (No./140m²) less than 15 cm tall as influenced by nitrogen fertilizer and summer precipitation.

	Improved[1] native range		Native[2] range		May-June precipitation
Year	Control	Nitrogen	Control	Nitrogen	(mm)
1954	—	—	22	29	50
1955	1	0	18	18	33
1957	8	58	168	908	83
1959	12	6	34	72	42
1960	6	2	40	43	54

[1]Brush controlled in 1952 with 2,4-D.
[2]Poor Condition.

Table 3. Numbers of sagebrush (No./19 m²) less than 15 cm tall as influenced by nitrogen and sulfur fertilization.

	Nitrogen (kg/ha)[1]			
Year	0	20[2]	60[3]	120[4]
1972	0.4	1.8	0.8	0.7
1974	1.2	1.4	0.5	0.6
1975	5.0	3.2	8.5	11.0
1976	6.8	53.7	69.6	56.4
1977	4.0	42.0	48.2	28.2

[1]Ammonium nitrate plus 6% sulfur.
[2]Applied annually.
[3]Applied first and third year.
[4]Applied first year only (1971).

biennially were not greatly different. At the most efficient rate (22 kg/ha) the concentration of herbage-N increased only in dry years. Consistent increases in herbage-N were obtained from N rates above 22 kg/ha. Nitrogen, though maintaining higher yields, did not arrest the herbage yield decline as seedings aged. Mineral (P, K, and Ca) yield in the herbage varied from year to year but was not influenced by N. Sulfur in the herbage was increased with N fertilization.

Under fertilized grasses, soil moisture was depleted rapidly (Sneva et al. 1958) and the rate of depletion increased as the rate of N increased. Residual yield varied from no response following a wet first year to a strong response following a dry first year (Fig. 3).

Fertilizer decreased the concentrations of carbohydrates in the roots of grasses in the spring (Hyder and Sneva 1961). No significant accumulations of NO_3-N were found in soils under CW following 14 years of annually applying N at 22 and 34 kg/ha (Sneva 1977).

Urea-N was slightly more effective than ammonium nitrate in increasing yield but no difference was measured among fall, winter, and spring applications (Sneva 1973b).

Sulfur alone did not improve the herbage yield of CW. Sulfur applied with N caused additional yield increases but not at all locations

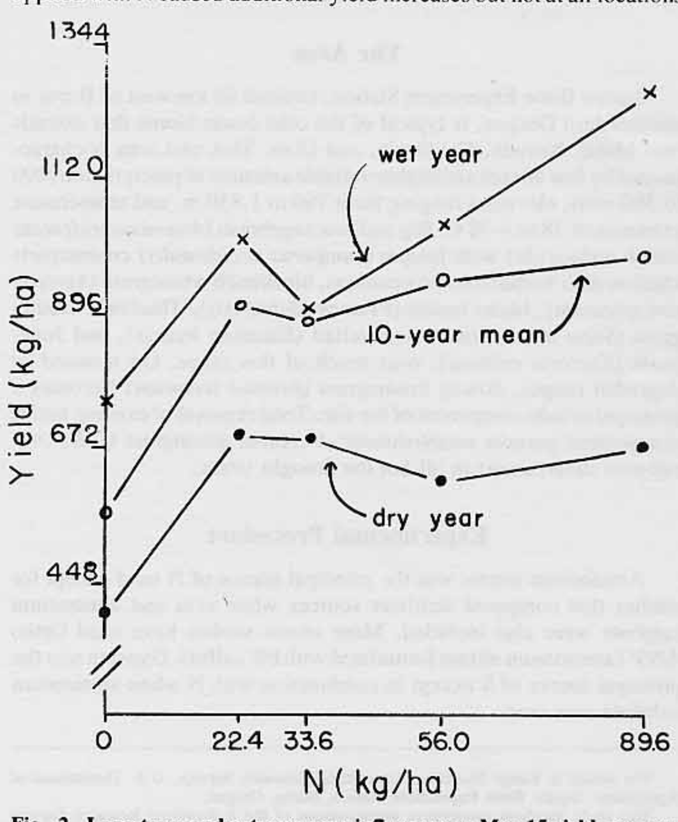

Fig. 2. Long-term and extreme year influences on May 15 yield response of crested wheatgrass to annual applications of N.

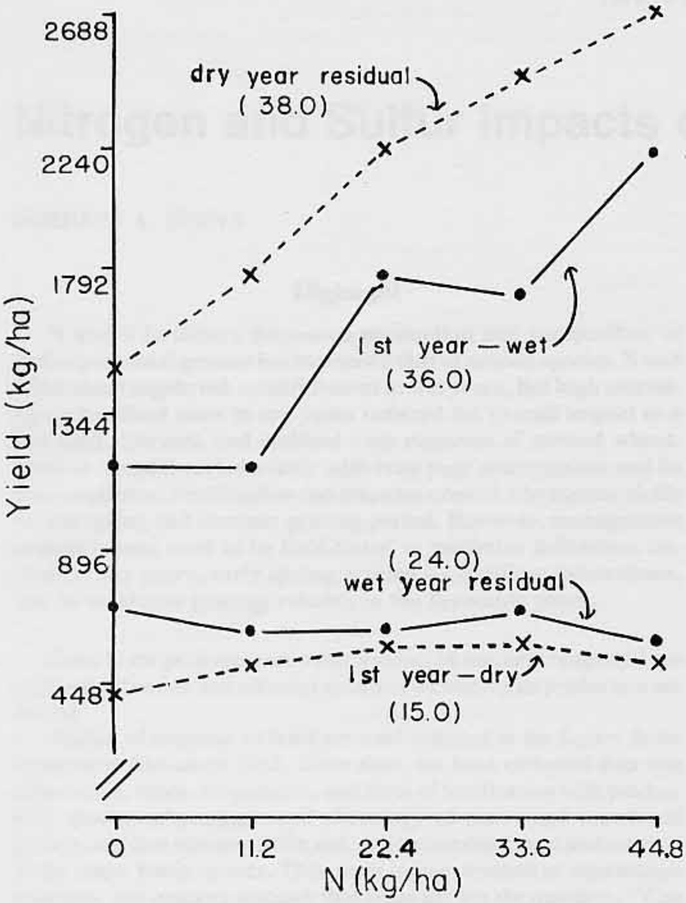

Fig. 3. Crested wheatgrass yield as influenced by N in wet and in dry years and yield responses to residual N in the second year (crop-year precipitation in cm noted in parenthesis).

tested and not in all years. In 2 years on a S-responsive site, the mean CW yield on May 15 was 336, 672, and 896 kg/ha for no fertilizer, N, and N plus S, respectively. In that study, spring production from N plus S was so great that the grasses were unable to complete their maturation cycle before soil moisture exhaustion. On S-responsive sites, N produced plants with excessively wide N:S ratios (> 13 to 1). With S, N:S ratios were < 11 to 1. Plant concentrations of N were lower in plants fertilized with N plus S than in those fertilized with N alone. Application of 31 kg/ha of S in 1972 continues at this time, 1977, to provide an adequate supply of S to grasses fertilized annually with 28 kg/ha of N.

Discussion

Responses of native and introduced plants to fertilization were strongly influenced by year and by year-sequence. The current year effect is principally due to the amount of precipitation received, but early spring yields are partially dependent on temperature as well. Because of the high variability among years, short-term research will rarely provide adequate information to judge the feasibility of fertilization practices on semiarid rangelands.

Fertilization on semiarid ranges will have a greater chance of returning economic benefit when one is fully aware of the tremendous year effect and manages the range so as to maximize the returns in wet years and minimize possible losses in dry years. To do so will require management to be more flexible and to make a greater number of decisions on predictive estimates. However, even with optimum efficiency in purchasing fertilizer and making decisions in the time of its use, fertilizer will not necessarily be a practice that returns economic benefit.

The results from N fertilization of native range do not suggest this practice as a tool for improving cold desert native ranges. The increase of weedy annuals and the associated decrease of the perennials is especially disconcerting. I believe this indicates the kinds of legumes we need for the semiarid range — those that provide high quality forage but have a low N transfer rate. The net effect of N on sagebrush was small, but N appears to encourage sagebrush establishment when moisture is present. Those attempting to establish sagebrush on harsh sites and seeking quick ground cover may find N to be an asset.

Nitrogen can increase the production of CW in early spring. On some soils, in combination with S, the increase was phenomenal. Increased production in early spring means earlier grazing, a need experienced by nearly all livestock operators on semiarid range. Unfortunately, the stresses upon the grass plant by fertilization and magnified by herbage removal by grazing during the root growth period are great. Mismanagement in a fertilization program could be extremely damaging. To reduce damage of the plant stand, the manager needs: (1) a guide for stocking rate and turn-in date; (2) criteria for judging turn-off date; and (3) alternate year pastures to enhance root growth. While recent studies provide much of the data needed to select fertilizer years, and to estimate production and stocking rates, the integration of all these data has yet to be field-tested. Nitrogen fertilization offered the greatest return per kg of N when applied for mid- or late-season grazing; even so, the economic return was marginal. The possibility exists, however, that secondary benefits from fertilization for these seasons may exceed costs when such pastures are used to increase the efficiency in breeding conception or in range supplementation programs for producing limited-grain fattened beef. Here again, adequate field-grazing trials are lacking for proper evaluation.

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