Growth in the Greenhouse of Grasses and Shrubs on Soils from Shadscale and Sagebrush Areas[1]

A. C. HULL, JR.

Range Conservationist, Crops Research Division Agricultural Research Service, U. S. Department of Agriculture Logan, Utah

Salt-desert shrub lands often are characterized by soils high in salts which in excess hinder plant growth. To determine whether salt-desert shrub soil under shadscale (*Atriplex confertifolia* (Torr. & Frem.) S. Wats.) would grow seeded plants in the greenhouse, 6 species were seeded on shadscale topsoil and on big sagebrush (*Artemisia tridentata* Nutt.) topsoil.

Range seedings on good sagebrush lands have been successful while many failures have resulted from seedings on salt-desert shrub lands (Plummer *et al.*, 1955). Better range management undoubtedly will be the solution for improvement of most salt-desert shrub areas. However, where soil and moisture are above average and where good forage plants are too sparse for natural revegetation, seeding may speed restoration.

Gates *et al.* (1956) worked on

[1]*Cooperative with Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture and the Utah Agricultural Experiment Station, Logan. Special thanks for greenhouse facilities, and to Wesley Bitters and Glenn Carnahan, former students who assisted with soil and greenhouse work.*

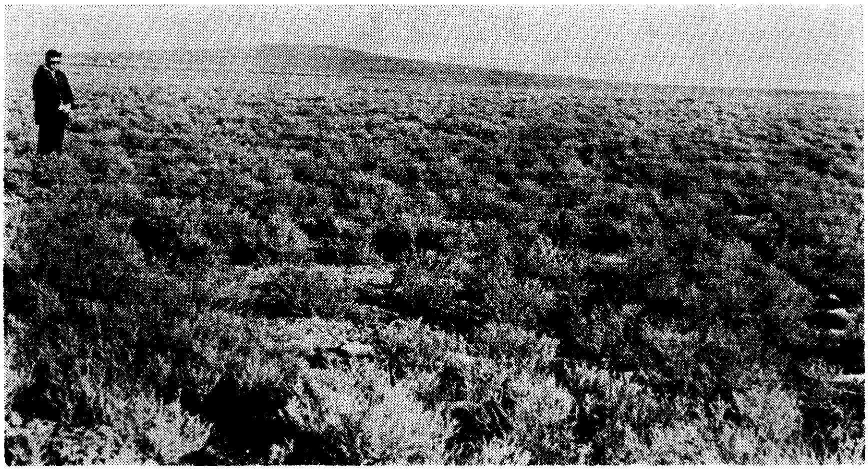

FIGURE 1. Shadscale area where soil samples were taken.

soil-plant relations in the sagebrush, shadscale, winterfat, Nuttall saltbrush, and greasewood types in northern Utah. Two shadscale and six sagebrush areas were near Snowville. Gates *et al.* (1956) concluded that total soluble salts, saturation extract conductivity, exchangeable sodium, soluble sodium, and ⅓-atmosphere moisture percentage were the only soil characteristics which differed significantly between vegetation types. The authors felt that soils occupied by the various species differed significantly, but the field work and soil analyses failed to identify soil differences which limited plant growth to a single species on any area.

Experimental Procedures

Soils for testing were collected on shadscale (Figure 1) and sagebrush areas 17 miles southwest of Snowville, Utah. The areas of collection showed little evidence of major vegetation change as the result of past use. Soils at all depths had a silty texture. Characteristics of the two soils (Table 1) are in general agreement of those of Gates *et al.* (1956).

Three seeding studies were carried out in the greenhouse:

1. Six species with five replicates were seeded ½-inch deep in gallon cans in soils taken from depths of 0-6 inches under sagebrush and from depths of 0-6, 6-18, and 18-36 inches under shadscale (Table 2). Some soils received the treatments listed below:
   (a) No treatment: Soil without amendments.
   (b) Fertilizer: Peat moss—60 tons per acre, nitrogen—50 pounds N per acre plus .01 pound per pound of peat moss, phosphorus—100 pounds P_2O_5 per acre.
   (c) Gypsum: 2,000 pounds per acre.
   (d) Fertilizer in treatment b and gypsum in treatment c combined.

   Three species, Russian wildrye (*Elymus junceus* Fisch.), four-winged saltbush (*Atriplex canescens* (Pursh) Nutt.), and halogeton (*Halogeton glomeratus* C. A. Mey.) were tested only on treatments a and b.
2. Crested wheatgrass was grown in shadscale soil in cans 18 inches deep; some were watered from the top and some from the bottom.
3. Crested wheatgrass and grown in shadscale soil in glass-faced boxes to observe root reactions to different watering systems.

Cans and boxes were weighed and enough water added to keep plants growing well but to avoid leaching.

Results

Species seeded in different soils

Four of the six species emerged well from the top six inches of soils from sagebrush and shadscale areas. Differences in emergence from shadscale and sagebrush topsoils and normal and amended topsoils were not significant. No seedlings emerged from shadscale soils taken from depths of 6-18 and 18-36 inches. Poor emergence of shadscale and halogeton seedlings resulted from poor germination. After emergence, species

Table 1. Some characteristics of soil at different depths under shadscale and sagebrush southwest of Snowville, Utah.

Vegetation and soil depth (inches)	pH (saturated paste)	Soluble salts (percent)	Saturation extract (EC x 10^3)	Exchangeable sodium (percent)	Organic matter (percent)	Moisture percent at 15 atms	Moisture percent at ⅓ atms	Moisture percent at saturation
Shadscale:								
0-6	8.1	.05	1.0	7	1.8	10	25	34
6-18	7.5	1.4	26.6	38	1.7	15	43	58
18-36	7.7	2.2	34.4	72	1.2	19	55	71
Sagebrush:								
0-6	7.9	.04	.8	2	2.3	10	22	35
6-18	7.6	.2	6.8	14	1.2	9	21	34
18-36	8.3	.5	10.5	33	.6	8	28	44

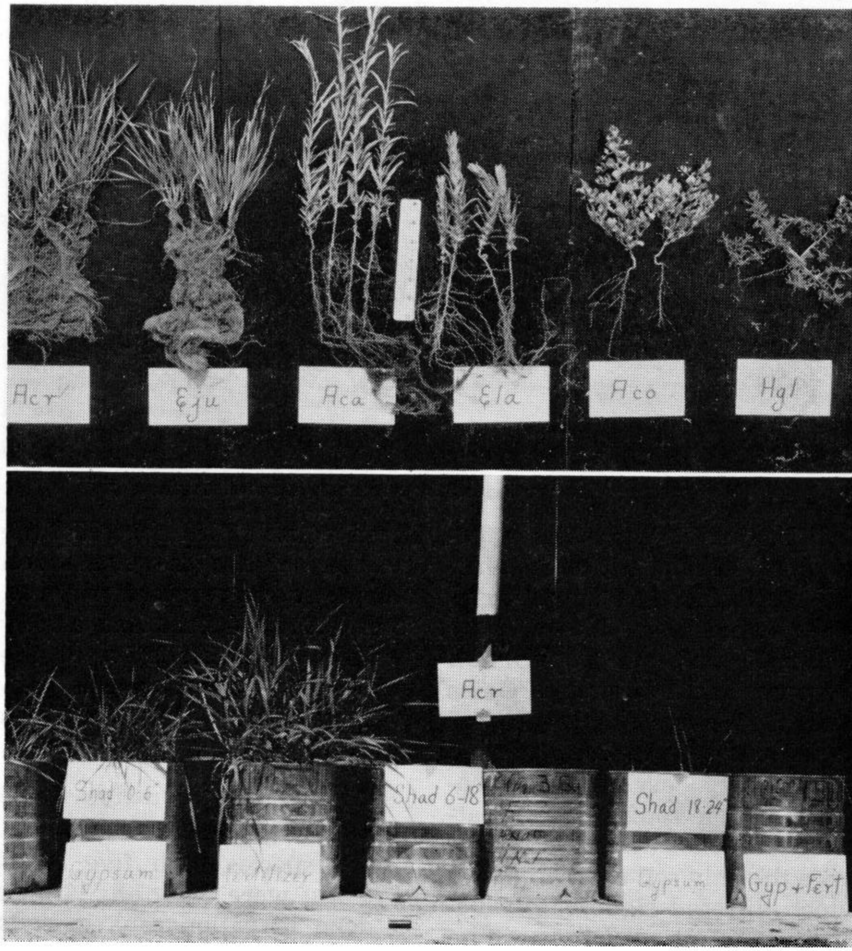

FIGURE 2. A. Six typical plants after removal from shadscale soil. Left to right, crested wheatgrass, Russian wildrye, four-winged saltbush, winterfat, shadscale, and halogeton. B. Crested wheatgrass grew well in sagebrush and shadscale topsoil but did not emerge in shadscale soils taken from depths of 6-18 and 18-36 inches. Crested wheatgrass transplant, such as shown in the second can from the right, soon died.

with excess plants were thinned to 5 per can. Shadscale did not have enough plants, so transplants brought the number up to 5 per can. At the end of 9 weeks, plants were clipped at a ¼-inch height and soil washed from the roots (Table 3 and Figure 2).

Because treatments were not uniform, two analyses were run. Duncan's (1955) multiple range was used to determine which comparisons were significant. All differences called significant are at the one percent level. Halogeton produced only a few plants and was not included in the analyses.

In the first analysis, five species were compared on two soils with two treatments; check and fertilizer. There was not a significant difference due to soils. Fertilizer increased top growth significantly but did not effect root growth. Top and root growth of species differed significantly. Top growth of crested wheatgrass, Russian wildrye, four-winged saltbush, and winterfat (*Eurotia lanata* (Pursh) Moq.) was significantly better than that of shadscale. Root growth of crested wheatgrass and Russian wildrye was significantly better than the other species, whereas four-winged saltbush and winterfat root growth were significantly better than shadscale. A strain of crested wheatgrass selected for salt tolerance produced significantly more roots on shadscale topsoil than regular crested wheatgrass. There was no difference on sagebrush topsoil.

In the second analysis three species and three fertilizers were compared on shadscale soils. Top growth from fertilizer treatments were erratic and showed no significant difference. In root growth the check and fertilizer plots were similar but the check yielded significantly more than the fertilizer and gypsum combined or gypsum alone, and fertilizer yielded more than gypsum. Comparing species, crested wheatgrass and winterfat produced significantly more top growth than shadscale. Crested wheatgrass produced significantly more root growth than winterfat, which in turn produced significantly more than shadscale.

Newly germinated crested wheatgrass plants were transplanted on the regular and the amended shadscale soil from the 18- to 36-inch depth. Plants died within two days. Two-month-old vigorously growing crested wheatgrass plants were transplanted and died in two weeks. Large clumps of crested wheatgrass which were transplanted

Table 2. Species seeded with number of seeds and seedling emergence on shadscale and sagebrush topsoils.

Species seeded	Seeds per can	Seedlings merged Shadscale soil	Sagebrush soil
Crested wheatgrass	12	9.8	9.5
Russian wildrye	12	7.7	6.1
Winterfat	36	21.8	19.3
Four-winged saltbush	60	15.7	15.5
Shadscale	48	1.0	.7
Halogeton	24	3.3	2.0

Table 3. Average air-dry yield in grams per can of 5 species grown in shadscale and sagebrush topsoil in the greenhouse.

Species and treatment	Shadscale soil Tops	Shadscale soil Roots	Sagebrush soil Tops	Sagebrush soil Roots
Crested wheatgrass (salt tolerant)				
Check	11.8	23.6	12.7	19.7
Fertilizer	21.6	25.7	17.5	24.2
Fertilizer and gypsum	16.5	19.5	—	—
Gypsum	8.1	13.8	—	—
Russian wildrye				
Check	12.2	20.2	11.6	14.5
Fertilizer	15.7	27.1	16.0	18.9
Four-winged saltbush				
Check	11.3	10.1	11.2	9.3
Fertilizer	22.4	14.1	19.8	12.5
Winterfat				
Check	12.2	10.5	11.5	10.5
Fertilizer	14.0	10.5	14.2	10.5
Fertilizer and gypsum	9.8	8.1	—	—
Gypsum	10.8	8.9	—	—
Shadscale				
Check	11.2	9.5	10.4	9.6
Fertilizer	0	0	0	0
Fertilizer and gypsum	0	0	—	—
Gypsum	0	0	—	—

also died, but more slowly. Thus shadscale soil from the 18- to 36-inch depth not only prevented seedling emergence, but caused death of crested wheatgrass transplants (Figure 2).

From soil analyses the subsoil had more soluble salts, higher conductivity, cation-exchange capacity, sodium, moisture percentage at ⅓-atmosphere, and clay than the topsoil.

Soil watered from the top and bottom

Shadscale soil was collected in the field in two-inch layers and layers were placed in their original positions in cans seven inches in diameter and 18 inches deep. Some cans were watered from the top, some from the bottom, and some half from the top and half from the bottom with the same amounts of water. Crested wheatgrass was seeded with 15 seeds per can. No plants emerged in cans watered from the bottom. Fourteen plants per can emerged in cans watered from the top and in cans watered half from the bottom and half from the top with no difference between treatments. Emerged plants were thinned to six per can. The average air-dry yield of tops in grams per can were: watered from top—7.1, watered half from top and half from bottom—2.4, and watered from bottom—0.

Soil samples were taken by 6-inch depths as soil was put into the cans and as the study was terminated (Table 4). Watering from the top made little difference. Watering from the bottom moved the salts from the bottom to the top of the profile. Sodium moved slightly toward the top. The surface salt concentration was sufficient reason for failure.

Root growth in glass-faced boxes

Shadscale soil was collected in two-inch layers to a depth of 20 inches. It was placed in glass-faced boxes two inches thick, 17 inches wide, and 20 inches deep. Three plants of crested wheatgrass were transplanted in each box. One box was watered from the top and one from the bottom, both with the same amount of water. In the box watered from the top, all plants were vigorous and roots soon reached the bottom. Where watered from the bottom, two plants died when roots reached the four- to 6-inch level. Roots of the third plant reached the 16- to 18-inch depth. This plant was in poor vigor and weighed 0.2 gram as compared with 2.3 grams for plants in the box watered from the top.

Discussion and Summary

Shadscale topsoil and subsoil and sagebrush topsoil from Snowville, Utah, were brought

Table 4. Characteristics of shadscale soils at different depths before and after watering.

Time of sampling and depth	pH of 1:5 Mixture	Soluble salts (percent)	Saturation ext. (EC x 10^3)	Exchangeable sodium (percent)
Before watering:				
0-6 inches	8.4	.2	4.7	5
6-12 inches	8.4	.5	15.3	9
12-18 inches	8.6	1.3	28.6	43
After watering from top:				
0-6 inches	9.1	.2	4.5	8
6-12 inches	9.2	.3	6.5	12
12-16 inches	9.2	.6	14.3	24
16-18 inches	8.8	1.4	26.5	25
After watering from bottom:				
0-6 inches	8.9	1.4	39.0	10
6-12 inches	9.8	.2	3.2	27
12-18 inches	9.9	.1	1.6	22

into the greenhouse and seeded to grasses and shrubs. Topsoils were equal in growing plants. In shadscale soil taken from depths of 6-18 and 18-36 inches no plants emerged and crested wheatgrass transplants died, even when amendments were added. This soil had a saturation extract of 26 mmhos per centimeter (EC x 10^3) at 6-18 inches and 34 mmhos at 18-36 inches. The salts and sodium in the subsoil could account for lack of seedling emergence and death of transplants.

Magistad (1945) stated that excessive concentrations of soluble salts in the root zone would restrict or prevent plant growth. Hayward and Bernstein (1958) confirmed this and indicated that few grasses can withstand a saturation extract of over 12 mmhos. The extreme for the most resistant is 18 mmhos.

It is possible that seeded plants may commence growth in shadscale topsoil and die as roots reach the subsoil. The unfavorable environment in subsoil for seeded species suggests that more research is needed before we shall be able to successfully seed salt-desert shrub ranges.

Dewey (1960) showed that wheatgrass species and strains vary considerably in their tolerance to salt. Two strains of crested wheatgrass, grown in shadscale topsoil, showed a significant difference in root yields. Strain differences of adapted grasses and shrubs should be considered when seeding salt-desert shrub lands.

Peat moss, nitrogen, and phosphorus combined increased top and root growths as compared with gypsum. The best top yields were from four-winged saltbush, crested wheatgrass, Russian wildrye, winterfat, and shadscale, in that order. Shadscale produced significantly less top growth and roots than any other species. Crested wheatgrass and Russian wildrye produced significantly more root growth than other species.

Watering from the bottom in cans and boxes moved salts upward in the soil, reduced root and top growths, and sometimes killed crested wheatgrass plants. Upward movement of salts occurs in the field as soils dry out.

LITERATURE CITED

DEWEY, DOUGLAS R. 1960. Salt tolerance of twenty-five strains of Agropyron. Agron. Jour. 52: 631-635.

DUNCAN, DAVID B. 1955. Multiple range and multiple F tests. Biometrics 11: 1-42.

GATES, D. H., L. A. STODDART AND C. W. COOK. 1956. Soil as a factor influencing plant distribution on salt deserts of Utah. Ecological Mono. 26: 155-175.

HAYWARD, H. E. AND L. BERNSTEIN. 1958. Plant growth relationships on salt-affected soils. Bot. Rev. 24: 584-637.

MAGISTAD, C. C. 1945. Plant growth relations on saline and alkali soils. Bot. Rev. 11: 181-230.

PLUMMER, A. PERRY, A. C. HULL, JR., GEORGE STEWART, AND JOSEPH H. ROBERTSON. 1955. Seeding rangelands in Utah, Nevada, southern Idaho, and western Wyoming. U.S. Dept. Agr. Handbook 71, 73 pp.