Emergence and Establishment of Basin Wildrye and Tall Wheatgrass in Relation to Moisture and Salinity

BRUCE A. ROUNDY

Abstract

Many saline, arid rangelands in the Great Basin once dominated by basin wildrye (*Elymus cinereus* Scribn. & Merr.) could again be highly productive following brush control and seeding of adapted species. The effects of spring precipitation and soil salinity on emergence and establishment of Jose tall wheatgrass [*Agropyron elongatum* (Host) Beauv. 'Jose'] and Magnar, a selected cultivar of basin wildrye, were compared in central Nevada. Both species were seeded in circular plots on a nonsaline and a moderately saline soil (electrical conductivity of the saturation extract, EC_e , of 7.0 ds $\cdot m^{-1}$) and irrigated to simulate a gradient in spring precipitation. Magnar basin wildrye required higher and more frequent irrigation and precipitation in April through June to produce an acceptable stand of seedlings (at least 2 seedlings per meter of row) on the moderately saline soil than on the nonsaline soil. Jose tall wheatgrass produced acceptable seedling stands without irrigation and excellent stands (6 seedlings per meter of row) with irrigation on both soils following a wet winter and during a dry spring. Although mature basin wildrye is well adapted to many saline, arid soils, it definitely will require supplemental irrigation to establish from seed. Tall wheatgrass is more salt tolerant and less sensitive to plant water stress at the seedling stage than basin wildrye, so it is more likely to establish on saline, arid soils without irrigation. However, mature tall wheatgrass may not persist in areas that receive less than 30 cm annual precipitation. Until more drought and salt-tolerant plant materials are available, saline, arid soils should not be seeded without supplemental irrigation.

Valley bottoms and flood plains of the Great Basin historically were important grazing lands for the livestock of early ranchers (Lesperance et al. 1978). In the late 19th century, many of the cattle grazing sagebrush (*Artemisia*)/grasslands were wintered on the extensive basin wildrye (*Elymus cinereus* Scribn. & Merr.) stands dominating many of these lowlands (Hazelton et al. 1961, Lesperance et al. 1978, Young and Evans 1981). Because basin wildrye is sensitive to spring clipping and frequent herbage removal during the growing season (Krall et al. 1971; Perry and Chapman 1974, 1975, 1976), many stands were decimated by excessive grazing (Young et al. 1975). Recovering the forage production of these lowland ranges is desirable because the ranges are extensive and in close proximity to many ranch base properties. Many areas have the potential for high forage production due to the subsurface and overland drainage water they receive and the high water-holding capacity of the associated fine-textured soils. Extensive lowlands now dominated by greasewood [*Sarcobatus vermiculatus* (Hook.) Torr.] and salt rabbitbrush [*Chrysothamnus nauseosus* ssp. *consimilis* (Greene) Hall and Clem] and lacking an understory of basin wildrye could be productive after chemical brush control (Cluff et al. 1983) and the establishment of forage species adapted to saline/alkaline and arid soils (Roundy et al. 1983).

Seedling establishment on these soils may be limited by low

water potential due to infrequent precipitation, low soil matric potentials and high soil salinity. Salts lower the osmotic potential of the soil solution and specific ions may be toxic to germinating seeds and seedlings. Precipitation in the Great Basin occurs mainly in fall, winter, and spring. As storms that provide effective precipitation become less frequent from March through June, soil water content decreases so that soil matric and osmotic potentials are decreased and soil water may be unavailable for seed germination or seedling growth (Roundy et al. 1984). Successful seeding establishment is dependent on frequency and amount of winter and spring precipitation and the ability of the seeded species to germinate and grow as soil matric and osmotic potentials decrease. Forage species most recommended for seeding saline, dry soils include Russian wildrye (*Elymus junceus* Fisch.), tall wheatgrass [*Agropyron elongatum* (Host) Beauv.], and basin wildrye (Plummer et al. 1955, 1968). Russian wildrye is difficult to establish because of poor seedling vigor (Hafenrichter et al. 1968, Vallentine 1961). Tall wheatgrass is well known for its salt and sodium tolerance (Carter and Peterson 1962, Dewey 1960, Moxley et al. 1978, Shannon 1978, Rauser and Crowle 1963) and has established well on wet saline soils, but may not persist on dry saline soils (Forsberg 1953, Ludwig and McGinnies 1978, McGinnies and Ludwig 1978, McPhie 1973). Rollins et al. (1968) and Eckert et al. (1973) reported difficulty in establishing tall wheatgrass and basin wildrye on a greasewood/rabbitbrush [*Chrysothamnus nauseosus* (Pall.) Britt.] site in central Nevada due to high salinity, sodicity, and high boron concentrations. Young and Evans (1981) suggested that many of the sites where basin wildrye occurred naturally are too dry for tall wheatgrass and too saline for crested wheatgrass [*Agropyron desertorum* (Fisch. ex Link) Schult.]. Although basin wildrye has had a reputation for low seed germination and poor seedling vigor (Young and Evans 1981), a selected cultivar, Magnar, has been released which has high and viable seed production and high germination (Evans and Young 1983).

The purpose of this study was to determine the establishment of Magnar basin wildrye and to compare it with that of Jose tall wheatgrass in relation to soil salinity and spring precipitation as simulated by irrigation in central Nevada. Simulation of spring precipitation by irrigation was intended to avoid the possibility of total seeding failure and to estimate the minimum precipitation necessary to establish these grass species on saline soils.

Methods

Two sites were chosen for their differences in soil salinity and their similarities in soil morphology and texture and their potential to support mature basin wildrye plants. The nonsaline and saline sites are both in Grass Valley, Eureka, and Lander counties, Nevada, at the University of Nevada's Gund Research and Demonstration ranch on the east side of the dry lake bed of pluvial Lake Gilbert (Young and Evans 1980). The soil of the nonsaline site is of the fine, montmorillonitic, mesic family of Typic Camborthids in a lagoon of Lake Gilbert. The soil of the saline site is a Gund silt-loam series of the fine-silty over clayey, mixed (calcareous), mesic family of Aquic Durorthidic Torriorthents on the lake plain (Peterson 1981) of Lake Gilbert. The physical and chemical prop-

Author is a range scientist, formerly with USDA/ARS, Renewable Resources, University of Nevada, Reno, 920 Valley Road; presently at the School of Renewable Natural Resources, University of Arizona, Tucson.

This study is a contribution from the USDA/ARS and the Agricultural Experiment Station, University of Nevada, Reno.

Manuscript accepted June 12, 1984.

erties of these fine-textured soils are representative of many other flood plains and valley bottoms in the Great Basin (Roundy 1984 and Roundy et al. 1984). The soil of the saline site is saline/alkaline having an average sodium adsorption ratio (SAR) of 44 and an average electrical conductivity of the saturation extract (ECe) of $8.4 \text{ dS}\cdot\text{m}^{-1}$ in the upper 30 cm with the predominant salts being sodium chloride (NaCl) and sodium sulfate (Na_2SO_4). The nonsaline soil has an average ECe of less than $0.5 \text{ dS}\cdot\text{m}^{-1}$. Both sites supported a shrub community of greasewood, salt rabbitbrush, and big sagebrush (*Artemisia tridentata* Nutt. ssp. *tridentata*) and a herbaceous understory of basin wildrye.

Brush on both sites was eliminated by applying $3.4 \text{ kg}\cdot\text{ha}^{-1}$ of 2,4-D [(2,4-dichlorophenoxy)acetic acid] in the spring and roto-beating later in the summer of 1980. The sites were fenced to exclude rabbits and livestock. In the fall of 1980 a moderately saline plot ($\text{ECe} = 7 \text{ dS}\cdot\text{m}^{-1}$) and a saline plot ($\text{ECe} = 9.7 \text{ dS}\cdot\text{m}^{-1}$) on the saline site were seeded to Magnar basin wildrye. In the fall of 1981, a moderately saline plot ($\text{ECe} = 7 \text{ dS}\cdot\text{m}^{-1}$) and a nonsaline plot ($\text{ECe} < 0.5 \text{ dS}\cdot\text{m}^{-1}$) were seeded to both Jose tall wheatgrass and Magnar basin wildrye. Grasses were seeded to 1 to 2 cm deep with a vegetable seeder calibrated for a rate of 1 seed per centimeter into circular concentric furrows, 35 cm apart and constructed by hand with a hoe to be similar to furrows made by a standard rangeland drill. The circular plots were 32 m in diameter and in 1980 were divided into 3 pie-shaped blocks seeded to Magnar basin wildrye and in 1981 were divided into 6 pie-shaped blocks seeded alternately to Jose tall wheatgrass and Magnar basin wildrye.

In the spring of each year after fall seeding, water was applied using a single sprinkler with a 4.8-mm range by 2.4-mm spreader nozzle operated at 0.2 MPa on a 60-cm riser in the center of each circular plot to create an irrigation gradient (Hanks et al. 1976). Water applied decreased almost linearly with distance from the sprinkler head. Amount of irrigation was measured in cans 14.5 cm diameter by 17.5 cm deep placed along 3 transects at 2.5, 6.5, 10.5, and 16 m from the center of each plot. Each irrigation was approximately 6 hr and added an average of 2 cm of water to the soil at 2.5 m from the plot center and no water at 16 m from the plot center. There were 5 irrigations in the spring of 1981 and 4 in 1982 with the plots being irrigated approximately every 2 weeks from May through June. The irrigation water was hauled to the plots from a nearby mountain stream and had an electrical conductivity of less than $0.5 \text{ dS}\cdot\text{m}^{-1}$. Irrigations were done at night when wind was minimal.

Seedling counts were made as early as seedlings emerged and thereafter every 2 weeks through July and again the following spring. Seedlings in a 1 m long sample of row were recorded in the concentric rows of 2.5, 6.5, 10.5, and 16 m from the plot center and in the inside and outside row bordering these rows. Six observations per block were recorded for each species at each distance from the plot center at each sampling date.

Soil samples of 1 old shrub mound and 1 interspace were collected at 3 sampling points in 1981 and at 2 sampling points in 1982, at distances of 2.5, 6.5, 10.5, and 16 m from each plot center. Samples were collected starting in April and thereafter in 2-to 4-week intervals. Samples were generally collected 2 weeks after each irrigation on the day preceding the next irrigation. Samples were taken for depth intervals of 0–1, 1–5, 5–10, 10–15, and 25–30, and were analyzed for ECe, volumetric water content, and total, matric, and osmotic soil water potential as described by Roundy (1984) and reported by Roundy et al. (1984). Other chemical and physical characteristics of these soils are reported by Roundy (1984) and Roundy et al. (1984).

Predawn leaf water potentials of seedlings receiving the highest irrigation at 2.5 m from the plot center and those receiving no irrigation at 16 m from the plot center were measured periodically using a pressure bomb (Scholander et al. 1965).

Results and Discussion

Because natural precipitation was not controlled, seedling emer-

gence and establishment results must be interpreted by taking into account the natural precipitation in relation to irrigation each year. In 1980–1981 low winter precipitation was followed by high precipitation in March, April, and May, and low precipitation in June

Fig. 1. Monthly precipitation and irrigation for 1980 to 1982 and 8-year precipitation means at the Gund research and demonstration ranch, Grass Valley, Nevada.

(Fig. 1). In 1981–1982 winter and March precipitation was high followed by low precipitation in April, May, and June. Generally, 1980–1981 could be characterized as a dry winter followed by a normal spring, whereas 1981–1982 could be considered a wet winter followed by a dry spring. Seedlings generally followed a pattern of initial emergence when temperatures became warm enough for germination in April and May, followed by mortality of some seedlings with the absence of rain. This was followed by additional seedling emergence associated with spring rains and irrigation followed by gradual mortality through the summer (Fig. 2).

Emergence

Irrigation greatly increased Magnar basin wildrye seedling emergence in the spring of 1981, but had little effect on emergence of Magnar basin wildrye or Jose tall wheatgrass in the spring of 1982 (Fig. 2 and Table 1).

Table 1. Analysis of variance of irrigation treatments (highest irrigation versus no irrigation) and salinity (moderately saline versus saline soil in 1981; moderately saline versus nonsaline soil in 1982) for maximum emerged and established seedling densities of Magnar basin wildrye in 1981 and Magnar basin wildrye and Jose tall wheatgrass in 1982.

Source of variation	Degrees of freedom	F-value	
		Maximum emerged seedlings	Established seedlings
1981 Experiment			
Irrigation (I)	1	24.3**	46.6**
Salinity (Sa)	1	3.0 NS ⁺	3.3 NS
I × Sa	1	2.9 NS	2.5 NS
1982 Experiment			
Irrigation (I)	1	3.4 NS	58.5**
Salinity (Sa)	1	1.3 NS	13.1**
Species (Sp)	1	33.9**	96.0**
I × Sa	1	1.1 NS	0.2 NS
I × Sp	1	1.6 NS	11.9**
Sa × Sp	1	0.1 NS	2.7 NS
I × Sa × Sp	1	0.1 NS	3.0 NS

**Significant at the 0.01 level.

*Not significant at the 0.05 level.

Fig. 2. Seedling density with confidence intervals ($P \leq 0.05$), daily precipitation and irrigation, and total soil water potentials (5 to 15 cm interval) for plots with Magnar basin wildrye in 1981 and Magnar basin wildrye and Jose tall wheatgrass in 1982 in Grass Valley, Nevada.

On the moderately saline plot, emergence of Magnar basin wildrye under the highest irrigation was much higher in 1981 than in 1982, but emergence of the nonirrigated rows was less in 1981 than in 1982 (Fig. 2). These trends can be explained by the different patterns of winter and spring precipitation and irrigation in 1981 and 1982 and the associated differences in the water potential of the surface soil. Due to lack of winter soil water recharge (Fig. 1), the surface soil in 1981 was initially drier than in 1982. On 8 April, total soil water potential in the upper 1 to 5 cm of the moderately saline plot averaged -820 and $-300 \text{ J}\cdot\text{kg}^{-1}$, respectively, in 1981 and 1982. Because of the initially dry seedbed in 1981, emergence did not begin until after irrigation and natural storms in mid to late April. Maximum emergence occurred in June after substantial April and May irrigations and storms (Fig. 2). In contrast, maximum emergence of Magnar basin wildrye on the moderately saline plot in 1982 occurred in April before any irrigations when temperatures were warm enough for germination and the soil was still wet from high winter precipitation. In 1981, irrigations combined with storms resulted in moisture events about 8 days apart for the irrigated rows compared with natural storms about 20 days apart for the nonirrigated rows. This resulted in about 4 times the seedling emergence on the highest irrigated rows compared with the nonirrigated rows (Fig. 2). In the absence of frequent rains, the surface soil rapidly dried out resulting in extremely low soil water potentials (Roundy et al. 1984a). The higher frequency of irrigation and storms on an initially dry seedbed in April and May in 1981 than in 1982 may have resulted in greater germination of Magnar basin wildrye seeds, resulting in greater maximum emergence on the irrigated rows in 1981 than 1982. Due to an initially wet seedbed in 1982, maximum emergence occurred before irrigation, and nonirrigated rows had higher emergence than in 1981 when the seedbed was initially much drier. These data illustrate the importance of frequent spring storms to seedling emergence following a dry winter and also show that the highest seedling emergence will be produced by frequent spring storms when temperatures are warm enough for germination.

There was no significant difference ($P \leq 0.05$) in maximum emergence in relation to soil salinity for Magnar basin wildrye or Jose tall wheatgrass seedlings (Table 1).

In 1982 Jose tall wheatgrass had higher seedling emergence than Magnar basin wildrye on both the highest irrigated and on nonirrigated rows and on both the nonsaline and moderately saline plots (Table 1 and Fig. 2). Jose tall wheatgrass has greater radicle growth at low osmotic potentials, has higher total germination and more rapid emergence at low osmotic and matric potentials than Magnar basin wildrye. Jose tall wheatgrass also germinates at lower osmotic and matric potentials than Magnar basin wildrye (Roundy et al. 1985b). Magnar basin wildrye apparently requires more frequent storms or irrigation as occurred in 1981 to equal the emergence produced by Jose tall wheatgrass following a wet winter and relatively dry spring as in 1982.

Although the saline soil in this study had boron concentrations ranging up to 100 ppm in the saturation extract, boron probably had little effect on seed germination. Both species had high germination in boron concentrations up to 450 ppm in laboratory tests (Roundy 1985a). However, boron may have reduced emergence and survival of some seedlings. Radicle growth greater than 5 mm of both species is inhibited at boron concentrations above 100 ppm and root yield of both species is reduced by half at saturation extract concentrations above 30 ppm (Roundy 1985a).

Establishment

As soil water potential decreased through the summer, seedling density decreased (Fig. 2). The highest irrigation significantly increased ($P \leq 0.05$) the number of seedlings of both species established on both the nonsaline and saline soils (Table 1 and Fig. 2). Seedling establishment generally increased with irrigation (Fig. 3).

An acceptable stand of Magnar basin wildrye seedlings (at least 2 seedlings per meter of row) on the moderately saline plot was

Fig. 3. Established seedling density of Magnar basin wildrye and Jose tall wheatgrass on nonsaline and moderately saline plots in relation to cumulative precipitation plus irrigation from April through June at Grass Valley, Nevada. Each point is the mean of 18 observations and the maximum calculated standard error of the mean was 0.8 seedlings per m of row.

produced only in 1981 and required at least 16 cm of irrigation plus precipitation from April through June (Fig. 3). Basin wildrye failed to produce an acceptable stand of seedlings in 1982 on the moderately saline plot, even at the highest irrigation (Fig. 3). The lower established density of basin wildrye in 1982 than in 1981 on the moderately saline plot was due mainly to lower emergence and somewhat to lower survival (Fig. 2). In 1981, peak seedling emergence was preceded by a series of storms in May (Fig. 1 and 2). Irrigation before and after these storms not only resulted in greater seedling emergence, but also resulted in somewhat higher survival of emerged seedlings.

In 1981, seedlings receiving the highest irrigation received 8.9 cm of water from 2 irrigations and a series of storms in May of 1981 resulted in higher total water potentials in early June in 1981 than in 1982. For example, total soil water potential of the 1- to 5-cm interval in the highest irrigated rows of the moderately saline plot averaged -560 and $-1500 \text{ J}\cdot\text{kg}^{-1}$, respectively, on June 1, 1981 and 1982. Frequent precipitation on saline soils maintains high total water potentials by increasing soil water content and by leaching salts (Roundy et al. 1984). Even though Magnar basin wildrye seedlings received 8.5 cm of water from irrigations and storms in June of 1982, they still failed to establish on the moderately saline plot. These differences in establishment in 1981 and 1982 suggest that high and frequent precipitation in May when evaporative demands are low is more effective than precipitation in June for emergence and establishment of Magnar basin wildrye on moderately saline soils.

More Magnar basin wildrye seedlings established on the nonsaline plot than on the moderately saline plot in 1982 (Table 1, Fig. 3). Precipitation plus irrigation of 14 cm in April through June produced an acceptable stand of Magnar basin wildrye seedlings on the nonsaline plot, whereas 16 cm of precipitation plus irrigation failed to produce an acceptable stand on the moderately saline plot in 1982. Greater plant water stress was associated with higher soil salinity. For example, predawn water stress of nonirrigated seedlings ranged from 290 to 2870 $\text{J}\cdot\text{kg}^{-1}$ higher on the nonsaline

than on the moderately saline soil in July 1982. The lower total water potential of the moderately saline than the nonsaline soil could generally be attributed to its osmotic potential where the matric potential of the two soils were similar (Roundy et al. 1984).

Jose tall wheatgrass produced an acceptable stand of seedlings with no irrigation, but produced excellent seedling stands (6 seedlings per meter of row) with irrigation on both the nonsaline and moderately saline plots (Fig. 3).

Greater establishment of tall wheatgrass than basin wildrye was due not only to higher emergence, but also generally to greater seedling survival. Although predawn leaf water stress of tall wheatgrass seedlings was an average of $830 \text{ J} \cdot \text{kg}^{-1}$ greater on the moderately saline than the nonsaline plot in June and July, salinity did not reduce survival of tall wheatgrass seedlings as much as it reduced survival of basin wildrye seedlings.

Magnar basin wildrye seedling survival associated with decreasing soil water potential was significantly ($P \leq 0.05$) lower on the moderately saline plot than the nonsaline plot, whereas that of Jose tall wheatgrass was similar for both plots and similar to Magnar basin wildrye on the nonsaline plot (Table 2). This difference suggests that Jose tall wheatgrass salinity tolerance is greater than that of Magnar basin wildrye. Jose tall wheatgrass has greater absolute growth of roots and shoots under decreasing osmotic potentials than Magnar basin wildrye (Roundy 1983). Because Jose tall wheatgrass has more rapid root and shoot elongation than Magnar basin wildrye in nonsaline and saline soils (Roundy 1984b), it would be expected to be more competitive and have higher establishment on nonsaline and saline soils than Magnar basin wildrye.

Table 2. Statistics for the linear regressions of seedling percentage survival on total soil water potential ($\text{J} \cdot \text{kg}^{-1}$) at the 1-15 cm depth interval for Jose tall wheatgrass and Magnar basin wildrye seedlings in 1982 on nonsaline and moderately saline soils in central Nevada.

Species	Soil	Intercept	Slope*	r^2
Tall wheatgrass	Nonsaline	99.1	0.00977 b	0.86
	Moderately saline	104.6	0.01055 b	0.90
Basin wildrye	Nonsaline	104.1	0.01126 b	0.83
	Moderately saline	100.8	0.01697 a	0.88

*Values followed by the same letter are not significantly different at the 0.05 level as determined by the slope test method of Snedecor and Cochran (1971).

†All regressions are significant at the 0.01 level.

Although basin wildrye is definitely adapted to drier, saline soils, such as those seeded in this study, high and frequent spring precipitation or irrigation is necessary to establish it from seed on these soils. This suggests that high establishment of natural basin wildrye seedlings occurs only during years of unusually high precipitation, as may be the case for other species growing in harsh environments (Noy-Meir 1973, Went 1955).

Although tall wheatgrass is able to establish on dry saline soils, as in this study, spring precipitation or irrigation can make the difference between an acceptable stand and an excellent stand on these soils. However, due to its inability to persist on many sites receiving less than 30 cm annual precipitation, tall wheatgrass may not be the best plant material to revegetate dry, saline soils. Use of irrigation or development of more drought and salt-tolerant plant materials than we presently have is necessary before many saline arid sites may be seeded successfully.

Literature Cited

- Carter, D.L., and H.B. Peterson. 1962. Sodic tolerance of tall wheatgrass. *Agron. J.* 54:382-384.
- Cluff, G.J., B.A. Roundy, R.A. Evans, and J.A. Young. 1983. Herbicidal control of greasewood (*Sarcobatus vermiculatus*) and salt rabbitbrush (*Chrysothamnus nauseosus* ssp. *consimilis*). *Weed Sci.* 31:275-279.
- Dewey, D.R. 1960. Salt tolerance of twenty-five strains of *Agropyron*. *Agron. J.* 52:631-635.
- Eckert, R.E., Jr., A.D. Bruner, and G.J. Klomp. 1973. Productivity of tall wheatgrass and Great Basin wildrye under irrigation on a greasewood-rabbitbrush range site. *J. Range Manage.* 26:286-288.
- Evans, R.A., and J.A. Young. 1983. Magnar basin wildrye-germination in relation to temperature. *J. Range Manage.* 36:395-398.
- Forsberg, D.E. 1953. The response of various forage crops to saline soils. *Can. J. Agr. Sci.* 33:542-549.
- Frelich, J.R., E.H. Jensen, and R.O. Gifford. 1973. The effect of crust rigidity and osmotic potential on emergence of six grass species. *Agron. J.* 65:26-29.
- Hafenrichter, A.L., J.L. Schwendeman, H.L. Harris, R.S. MacLauchlan, and H.W. Miller. 1968. Grasses and legumes for soil conservation in the Pacific Northwest and Great Basin States. USDA Soil Conserv. Serv. Agr. Handbook. No. 339.
- Hanks, R.J., J. Keller, V.P. Rasmussen, and G.D. Wilson. 1976. Line source sprinkler for continuous variable irrigation-crop production studies. *Soil Sci. Soc. Amer. J.* 40:426-429.
- Hazelton, B., C. Saulisberry, and H. Taylor. 1961. A range history of Nevada. *West. Livestock J.* 31:98-100.
- Krall, J.L., J.R. Stroh, C.S. Cooper, and S.R. Chapman. 1971. Effect of time and extent of harvesting on basin wildrye. *J. Range Manage.* 24:414-418.
- Lesperance, A.L., J.A. Young, R.E. Eckert, Jr., and R.A. Evans. 1978. Great Basin wildrye. *Rangeman's J.* 5:125-127.
- Ludwig, J.R., and W.J. McGinnies. 1978. Revegetation trials on a saltgrass meadow. *J. Range Manage.* 31:308-311.
- McGinnies, W.J., and J.R. Ludwig. 1978. Effects of a Natrustoll soil horizon on germination, emergence, and growth of four grasses. *Agron. J.* 70:1086-1088.
- McPhie, G.L. 1973. Three successful salt tolerant plants. *S. Aust. J. Agr.* 76:5-8.
- Moxley, M.G., W.A. Berg, and E.M. Barrau. 1978. Salt tolerance of five varieties of wheatgrass during seedling growth. *J. Range Manage.* 31:54-55.
- Noy-Meir, I. 1973. Desert ecosystems: Environment and producers. *Ann. Rev. Eco. Sys.* 4:25-51.
- Perry, L.J., Jr., and S.R. Chapman. 1974. Effects of clipping on carbohydrate reserves of basin wildrye. *Agron. J.* 66:67-69.
- Perry, L.J., Jr., and S.R. Chapman. 1975. Effects of clipping on dry matter yields of basin wildrye. *J. Range Manage.* 28:271-274.
- Perry, L.J., Jr., and S.R. Chapman. 1976. Clipping effects on dry matter and survival of basin wildrye. *J. Range Manage.* 29:311-312.
- Peterson, F.F. 1981. Landforms of the basin and range province. *Nev. Agr. Exp. Sta. Tech. Bull.* 28. Univ. Nevada, Reno.
- Plummer, A.P., A.C. Hull, Jr., G. Stewart, and J.H. Robertson. 1955. Seeding rangelands in Utah, Nevada, southern Idaho, and western Wyoming. USDA Forest Serv. Agr. Handbook. No. 71.
- Plummer, A.P., D.R. Christensen, and S.B. Monsen. 1968. Restoring big-game range in Utah. *Pub. No. 68-3*. Utah Div. of Fish and Game.
- Rausser, W.E., and W.L. Crowle. 1963. Salt tolerance of Russian wildrye grass in relation to tall and slender wheatgrass. *Can. J. Plant Sci.* 43:347-407.
- Rollins, M.B., A.S. Dylla, and R.E. Eckert, Jr. 1968. Soil problems in reseeding a greasewood-rabbitbrush range site. *J. Soil Water Conserv.* 23:138-140.
- Roundy, B.A. 1983. Response of basin wildrye and tall wheatgrass seedlings to salination. *Agron. J.* 75:67-71.
- Roundy, B.A., G.J. Cluff, J.A. Young, and R.A. Evans. 1983. Treatment of inland saltgrass and greasewood sites to improve forage production. In: S.B. Monsen and N. Shaw (eds.), *Managing Intermountain rangelands—Improvement of rangeland wildlife habitats*. Gen. Tech. Rep. INT-157. Ogden, Utah. USDA Forest Serv. Intmnt. Forest and Range Exp. Sta.
- Roundy, B.A. 1984. Estimation of water potential components of saline soils of Great Basin rangelands. *Soil Sci. Soc. Amer. J.* 48:645-650.
- Roundy, B.A. 1985b. Root penetration and shoot elongation of tall wheatgrass and basin wildrye in relation to salinity. *Can. J. Plant Sci.* (In press).
- Roundy, B.A., J.A. Young, and R.A. Evans. 1984. Surface soil and seedbed ecology in salt desert plant communities. p. 66-74. In: A.R. Tiedemann, E.D. McArthur, H.C. Stutz, R. Stevens, and K.L. Johnson (compilers). *Proceedings—symposium on the biology of Atriplex and related chenopods*. Gen. Tech. Rep. INT-172. Ogden, Utah. USDA Forest Serv. Intmnt. Forest and Range Exp. Sta.
- Roundy, B.A. 1985a. Germination and growth of tall wheatgrass and basin wildrye in relation to boron. *J. Range Manage.* (In press).

- Roundy, B.A., J.A. Young, and R.A. Evans. 1985.** Germination of basin wildrye and tall wheatgrass in relation to osmotic and matric potential. *Agron. J.* 77 (In press).
- Scholander, P.F., H.T. Hammel, F.D. Bradstreet, and E.A. Hemmingsen. 1965.** Sap pressure in vascular plants. *Science* 148:339-346.
- Shannon, M.C. 1978.** Testing salt tolerance variability among tall wheatgrass lines. *Agron. J.* 70:719-722.
- Vallentine, J.F. 1961.** Important Utah range grasses. *Utah Agr. Ext. Cir.* 67-170.

- Went, R.W. 1956.** The ecology of desert plants. *Sci. Amer.* 192:68-75.
- Young, J.A., R.A. Evans, and P.T. Tueller. 1975.** Great Basin plant communities - pristine and grazed. p. 187-212. *In:* R. Elston (ed.) Holocene climate in the Great Basin. *Occas. Pap. Nev. Archeol. Surv.* Reno, Nev.
- Young, J.A., and R.A. Evans (eds.). 1980.** Physical, biological, and cultural resources of the Gund Research and Demonstration ranch. *USDA Agr. Res. Serv., Agr. Review and Manuals. ARM-W-11, Oakland, Calif.*
- Young, J.A., and R.A. Evans. 1981.** Germination of Great Basin wildrye seeds collected from native stands. *Agron. J.* 73:917-920.