Tolerances of Sagebrush, Rabbitbrush, and Greasewood to Elevated Water Tables

DAVID C. GANSKOPP

Abstract

Knowledge of the effects of saturated soils and flooding on Wyoming big sagebrush *(Artemisia tridentata wyomingensis),* green rabbitbrush *(Chrysothamnus viscidiflorus),* and black greasewood *(Sarcobatus vermiculatus)* can enhance our understanding of their distribution. The responses of these 3 species to elevated water tables were studied on 4 contours bordering an expanding lake in southeast Oregon during the 1983 and 1984 growing seasons. When plants were initially selected for study, contours were 0, 10, 20, and 40 cm above the lake surface. Continued expansion of the lake flooded the lower contours and elevated the water tables under the upper contours. Wyoming big sagebrush rapidly succumbed to surface flooding and elevated water tables within 10 cm of the surface. Green rabbitbrush behaved similarly, but responses lagged about 1 week behind sagebrush. Black greasewood tolerated surface flooding for 40 days before effects were apparent. Water tables within 25 to 30 cm of the surface had no effect on greasewood. Given adequate topography and water supplies, water spreading techniques could be used to control Wyoming big sagebrush and green rabbitbrush.

Wyoming big sagebrush (*Artemisia tridentata* Nutt. subsp. *wyomingensis* Beetle and Young) and black greasewood (*Sarcobatus vermiculatus* (Hook.) Torr.) are dominant or codominant shrubs on large expanses of western rangelands (Tisdale and Hironaka 1981, Franklin and Dyrness 1973, Romo 1985). Green rabbitbrush (*Chrysothamnus viscidiflorus* (Hook.) Nutt.), typically a minor shrub component in climax communities, may also dominate areas where fire, overgrazing, or other disturbances have reduced the competitive ability of the accompanying vegetation (Young and Evans 1974). These 3 species, either singularly or collectively, shape the character and competitively control large areas within the Great Basin.

Due to the importance of these shrubs in the region, land man-agers must consider the biotic and abiotic factors affecting their establishment, health, or distribution. Water relations play a particularly prominent role in influencing the distribution of plants in this arid region, and abundances of water are typically not a concern. Several workers have noted, however, that excessive soil moisture is detrimental to big sagebrush *(Artemisia tridentata)* (U.S. Dept. Agr., Forest Serv. 1937, Branson 1956, Vallentine 1971) and speculated that anaerobic conditions in some soils prevent successful colonization of big sagebrush (Fosberg and Hironaka 1964). Lunt et al. (1973) found root growth of big sagebrush hindered by oxygen concentrations of 5% or less and observed low rates of recovery of big sagebrush after weakened plants were returned to ambient oxygen concentrations. These same workers speculated big sagebrush was excluded from fine textured and poorly drained soils by its high oxygen requirements.

Greasewood has been classified as a phreatophyte (Robinson 1958), and Romo (1985) found water tables ranging from 3.5 to 15 m below greasewood dominated communities in Oregon. No information was found, however, regarding tolerances of greasewood or green rabbitbrush to saturated soils or low oxygen concentrations in the rooting zone. Given this lack of information, the objective of this study was to evaluate the relative tolerances of Wyoming big sagebrush, greasewood, and green rabbitbrush to elevated water tables and surface flooding.

Study Area and Methods

Studies were conducted on 6 locations bordering Malheur Lake in Harney County, Oregon. Elevations were approximately 1,245 meters. Harney Basin is internally drained and annually receives between 20 and 30 cm of precipitation. The historic meander of Malheur Lake encompasses approximately 25,000 ha; however, above-normal precipitation between 1978 and 1984 expanded the lake to 68,000 ha, inundating large areas of shrub-steppe vegetation in the process. Three study sites, approximately 2 km apart, were evaluated during the 1983 growing season. Rapid expansion of the lake in 1984 blocked access to the original study areas and 3

new sites were selected for replication of the experiment in 1984.

Each site supported a mixed overstory of Wyoming big sagebrush, black greasewood, and green rabbitbrush. Understories were dominated by cheatgrass (*Bromus tectorum* L.) with traces of Thurber's needlegrass (*Stipa thurberiana* Piper) and needle-and-threadgrass (*Stipa comata* Trin. & Rupr.). At each location, shrub vigor was evaluated along 4 contours. Contours were, respectively, 0, 10, 20, and 40 cm above the lake surface when studies were initiated in late May of each year. Twenty individuals of each species were permanently marked with numbered aluminum tags along each of the 4 contours. Shrubs along the first contour were selected by walking the water's edge and tagging those individuals whose stems were just being touched by surface water. Elevations of shrubs above the water line on the remaining 3 contours were established by standing at the base of each stem and backsighting through a level to a marked stadia rod held at the water's edge. Decadent, diseased, or damaged plants were excluded from these evaluations.

Water tables were monitored by augering holes on each contour and inserting perforated pipe to a 60 cm depth. Subsurface fluctuations in water tables were then measured with a dipstick to the nearest 0.5 cm. Vigor of shrubs and water table levels were monitored on a weekly basis as the water continued to rise, and on a biweekly basis when water levels stabilized or began to recede.

Four classes of plant vigor were recognized and each given a numerical score. These were: 3 = plant apparently healthy and foliage of normal color, 2 = foliage chlorotic or yellow, 1 = foliage chlorotic and wilted, and 0 = all foliage dried and brittle. Plants were assumed to be dead when assigned a score of 0. At each location vigor scores for each species on each contour were totaled by observation date and the total viewed as a single observation for data analysis. With 20 units contained in each sum, the value of an observation ranged between 0 and 60. Mean values were employed for simplification of data presentation.

Statistical design was a strip plot using a factorial combination of 4 contours, 3 species, and 12 (1983) or 13 (1984) evaluation dates in 3 replications. In 1984, highway construction efforts interrupted the flow of water to 1 study area. Data from that area were not included in the analysis.

Stepwise multiple linear regression was used to examine the relationship between the vigor indices of each species (dependent variable) and 6 independent variables which were: water levels, number of days of exposure to water, an interaction term of water levels $\times$ number of days of exposure; and due to the curvilinear nature of the response variable, the square of the 3 previous variables. The 1983 and 1984 regression lines for each species were compared following procedures of Neter and Wasserman (1974).

Statistical significance was accepted at $P<0.05$.

Results and Discussion

During both years of study, water tables continued to rise after research sites were established (Fig. 1). Water tables were more elevated and remained above initial levels for a longer period of
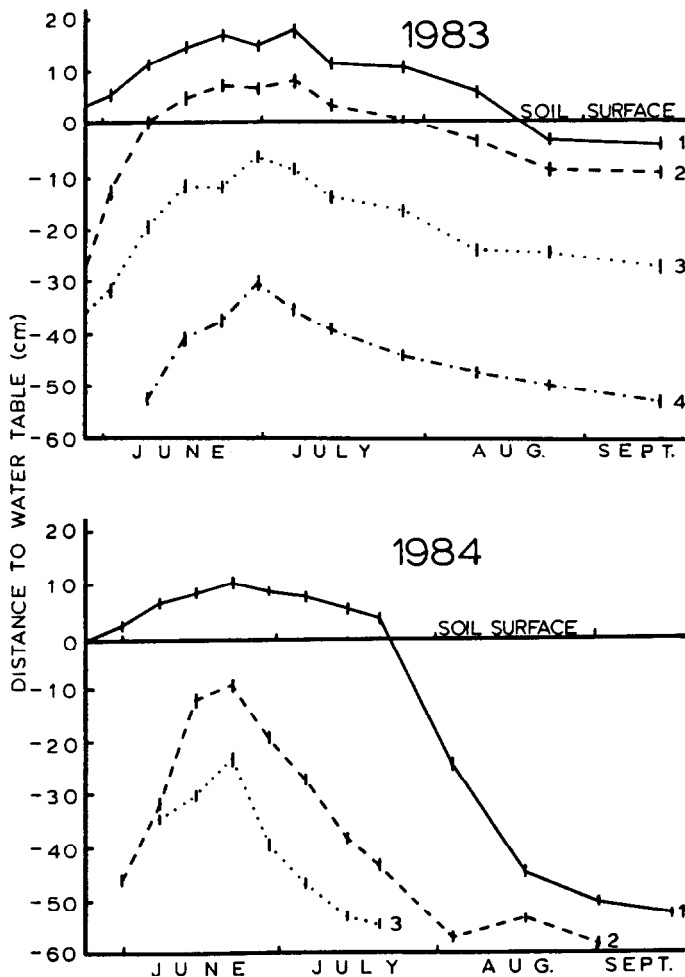

Fig. 1. *Proximity of water tables to soil surface on 4 contours initially established at 0 (——), 10 (------), 20 (········), and 40 cm (· — · — · —) above rising floodwaters in 1983 and 1984.*

Table 1. Strip plot analysis of variance of shrub vigor using a factorial combination of 4 contours, 3 species, and 12 (1983) or 13 (1984) evaluation dates. Error 1 = replication $\times$ species + replication $\times$ contour + replication $\times$ contour $\times$ species. Error 2 = Replication $\times$ date. Error 3 = difference.

Source of variation	1983 study			1984 study		
	Degrees of freedom	Mean square	F value	Degrees of freedom	Mean square	F value
Total	431	689		311	533	
Replications	2	660	1.17	1	883	9.18*
Contour	3	20932	37.04**	3	21925	163.30**
Species	2	34824	61.63**	2	15715	227.82**
Species $\times$ contour	6	1625	2.88*	6	2631	27.34**
Error 1	22	565		11	96	
Date	11	7467	201.38**	12	1911	182.92**
Error 2	22	37		12	10	
Date $\times$ species	22	872	19.99**	24	226	14.33**
Date $\times$ contour	33	432	9.90**	36	384	24.32**
Date $\times$ contour $\times$ species	66	211	4.84	72	89	5.63**
Error 3	242	43		129	16	

*significant at $P<0.05$; **significant at $P<0.01$.

time in 1983 than in 1984. The first or lowermost contours were inundated for 75 days in 1983 and only 60 days in 1984. The second contours experienced surface flooding in 1983 for approximately 63 days and only elevated water tables within 9 cm of the surface in 1984. The third contours experienced elevated water tables but no surface flooding during both years of study. Water moved into the monitored profile of the highest contours during 1983, but was not detected within these levels in 1984.

All interactions and main effects were judged significant ($P<0.05$) in the analysis of variance for both years of study (Table 1). Main effects of date, contour, and species made the greatest contribution to the sums of squares for both years. Differences between years in the extent and duration of flooding of the contours altered the responses obtained within the structure of the experiment, but the relative rankings and sensitivity of the 3 species were identical between years.

Wyoming big sagebrush was most affected by surface flooding or elevated water tables (Fig. 2). Declines in vigor were immediate,
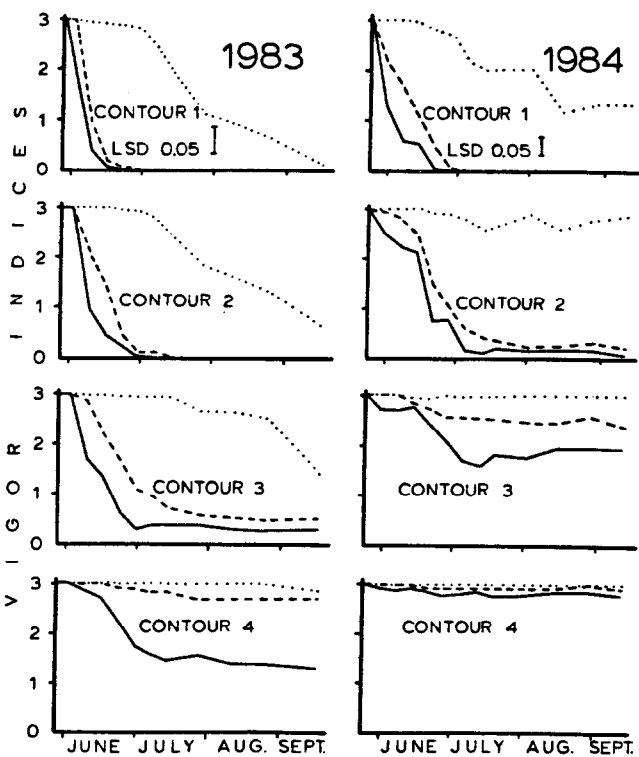
and surface flooding resulted in nearly complete mortality of sagebrush within 21 to 28 days of inundation. Water tables within 6 to 10 cm of the soil surface killed many big sagebrush plants and reduced those remaining to a wilted condition. These plants failed to recover, as they did not initiate growth in the subsequent spring. Where water tables rose within 20 to 30 cm of the surface, sagebrush foliage became chlorotic, and leaves on some branches wilted slightly. These plants did recover, however, and were able to initiate new growth the following spring.

Vigor of inundated green rabbitbrush paralleled that of Wyoming big sagebrush with the primary difference between the 2 species being a 1-week lag in the response of rabbitbrush. Twenty-eight to 35 days of surface flooding caused complete mortality of rabbitbrush. Water tables within 6 to 10 cm of the surface caused wilting and some mortality during the growing season. Again, the remaining plants failed to recover and were classified as dead the following spring. Where water tables peaked at 20 to 30 cm below the surface, vigor of rabbitbrush was reduced to a chlorotic condition. These plants were not permanently harmed by this exposure.

Black greasewood was the most tolerant of elevated water tables of the 3 species examined. Greasewood endured 40 to 42 days of surface flooding before any significant ($P<0.05$) visible effects were apparent. Within this period, portions of the crowns of many plants were submerged. Inundated foliage perished immediately, but foliage above the water's surface maintained a normal appearance. Not all inundated plants died within the monitored growing season, but all were classified as dead the following spring.

The subsurface water tables of contour 3 were endured by greasewood for 90 days before a significant ($P<0.05$) decline in vigor occurred in 1983. Water peaked within 6 cm of the soil surface in early July and slowly receded as the growing season progressed. These plants were all dead in the following spring. In 1984 the water table of contour 2 was within 9 cm of the surface. Greasewood became slightly chlorotic in early July. The water table had begun to recede by this time, however, and greasewood appeared to fully recover. Water tables within 25 to 30 cm of the surface had no visible effect on the vigor of black greasewood in either year.

For all 3 species, stepwise multiple linear regression illustrated that plant vigor was most strongly correlated to an interaction of duration and degree of flooding (Table 2). The interaction term of days × water level was the first variable to enter the models in 5 out of 6 regressions. Black greasewood, in 1983, was the only exception, and in this case the days × water level squared and the days × water level terms were the only variables to contribute significantly ($P<0.05$) to the model. No other independent variable showed a consistent order of entry into the models.

Coefficients of determination were consistently greater for 1983 models than for 1984 regressions. The lower R^2's of the 1984 data were probably due to the greater fluctuations or extreme rise and fall of the water tables on the various contours (Fig. 1). Within species, comparisons between 1983 and 1984 models were signifi-

Fig. 2. *Vigor indices of Wyoming big sagebrush (——), green rabbitbrush (------), and greasewood (·········), on 4 contours exposed to elevated water tables in 1983 and 1984. Vigor indices are: 3 = healthy, 2 = leaves chlorotic, 1 = leaves wilted, and 0 = leaves and twigs dried and brittle.*

Table 2. Coefficients of determination (R^2) and regression coefficients of models relating plant vigor to water table levels, duration of exposure, and an interaction term of days × water level.

					Regression coefficients				
Species	Year	R^2	Days	Water level	Days × water level	Days²	Water level²	(Days × water level)²	Intercept
Wyoming big sagebrush	1983	0.99	0.204₃[1]		−0.072₁			0.194E−04₂	54.54
Wyoming big sagebrush	1984	0.55	−0.163₂		−0.038₁				55.64
Green rabbitbrush	1983	0.91		1.200₃	−0.025₁		0.062₂		58.19
Green rabbitbrush	1984	0.55			−0.407₁	−0.001₂			58.81
Black greasewood	1983	0.96			0.593E−02₂			−0.131E−04₁	59.92
Black greasewood	1984	0.65	0.205₄		−0.026₁	−0.239E−02₂	0.017₃		58.38

[1]Subscripts denote order of variable entry into the model in stepwise multiple linear regression. All coefficients are statistically significant ($P<0.05$).

cantly different ($P<0.05$) in all cases. More definitive models expressing responses of these species to elevated water tables or saturated soils could be derived if this experiment was conducted under controlled conditions. Rates of transpiration or photsynthesis would also provide more accurate indices of plant health or vigor than strictly visible indications of plant stress.

Although the exact cause of plant stress or mortality was not determined in this project, the general assumption is that oxygen requirements of intolerant plants are not met in saturated soils (Fosberg and Hironaka 1964, Lunt et al. 1973). Other researchers have noted that crop species exposed to excessive irrigation and accompanying anaerobic conditions have accelerated flows of potassium from their roots (Vlamis and Davis 1944, Rosen and Carlson 1984), increased exudation of easily decomposed substances, and build ups of mucilage and microbial populations on root surfaces (Grineva 1961, Trolldenier and von Rheinbaben 1981, Trolldenier and Hecht-Buchholz 1984). Most likely, interacting combinations of several factors are responsible for reduced plant vigor in saturated soils.

Conclusions

Wyoming big sagebrush and green rabbitbrush were more susceptible to elevated water tables then black greasewood. The vigor of big sagebrush showed immediate and drastic reductions in response to surface flooding. Reductions in vigor of green rabbitbrush paralleled, but lagged approximately 1 week behind Wyoming big sagebrush. Greasewood tolerated surface flooding for approximately 40 days before exhibiting visible effects, and appeared to be unharmed by water tables within 25 to 30 cm of the soil surface. These different tolerances may explain some of the spatial separation exhibited between greasewood and the more commonly associated green rabbitbrush and Wyoming big sagebrush.

Where topography and precipitation patterns or water supplies are adequate, water spreading techniques may be used to control Wyoming big sagebrush and green rabbitbrush. Two weeks of surface flooding during the growing season would probably suffice for complete control, as both species were unable to regain their health after they reached a wilted condition. Control of black greasewood by water spreading is probably not feasible, as approximately 60 days of surface flooding were required to reduce its vigor to a wilted condition. Short-term flooding or briefly elevated water tables have little if any effect on black greasewood.

Literature Cited

Branson, F.A. 1956. Range forage production changes on a water spreader in southeastern Montana. J. Range Manage. 9:187-191.

Fosberg, M.A., and M. Hironaka. 1964. Soil properties affecting the distribution of big and low sagebrush communities in southern Idaho. Amer. Soc. Agron., Spec. Pub. No. 5, Plant physiology and soil-range relationships.

Franklin, J.E., and C.T. Dyrness. 1973. Natural vegetation of Oregon and Washington. USDA Forest Serv. Gen. Tech. Rep. PNW-8.

Grineva, G.M. 1961. Excretion by plant roots during brief periods of anaerobiosis. Fixiolojiya Rastenii. 8:686-691. Trans. in Amer. Inst. Bio. Sci. 8:544-552.

Lunt, O.R., J. Letey, and S.B. Clark. 1973. Oxygen requirements for root growth in three species of desert shrubs. Ecology 54:1356-1362.

Neter, J., and W. Wasserman. 1974. Applied linear statistical models. Richard D. Irwin, Inc., Homewood, Ill.

Robinson, T.W. 1958. Phreatophytes. U.S. Geol. Surv. Water Supply Paper 1423.

Romo, J.T. 1985. Water relations in *Artemisia tridentata* subsp. *wyomingensis, Sarcobatus vermiculatus,* and *Kochia prostrata.* Ph.D. Thesis, Oregon State Univ., Corvallis.

Rosen, C.J., and R.M. Carlson. 1984. Influence of root zone oxygen stress on potassium and ammonium absorption by myrobalan plum rootstock. Plant and Soil 80:345-353.

Tisdale, E.W., and M. Hironaka. 1981. The sagebrush-grass region: a review of the ecological literature. For., Wildl. and Range Exp. Sta., Univ. of Idaho. Bull. 33.

Trolldenier, G., and W. von Rheinbaben. 1981. Root respiration and bacterial population of roots. In: Effect of nitrogen source, potassium nutrition and aeration of roots. Z. Pflanzenernaehr. Bookenkd. 114:336-377.

Trolldenier, G., and Ch. Hecht-Buchhloz. 1984. Effect of aeration status of nutrient solution on microorganisms, mucilage, and ultrastructure of wheat roots. Plant and Soil 80:381-390.

U.S. Dep. Agr. Forest Serv. 1937. Range plant handbook. Government Printing Office, Washington.

Vallentine, J.F. 1971. Range developments and improvements. Brigham Young Univ. Press. Provo, Utah.

Vlamis, J., and A.R. Davis. 1944. Effects of oxygen tension on certain physiological responses of rice, barley and tomato. Plant Physiol. 19:33-51.

Young, J.A., and R.A. Evans. 1974. Population dynamics of green rabbitbrush in disturbed big sagebrush communities. J. Range Manage. 27:127-132.