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Plant Moisture Stress Patterns in *Eurotia lanata* and *Atriplex confertifolia*[2]

Introduction

There are *a priori* reasons to expect that plants might have different tolerances to varying degrees of water stress and that their natural distribution might be a reflection of their relative abilities to withstand low water potentials. As a case in point, Waring's (1970) pressure bomb measurements of plant moisture stress have greatly helped to explain the distribution of mesophytes in southwestern Oregon. If such measurements are useful in subhumid environments, it is logical that they may be even more valuable in assessing site differences and explaining the distribution of desert species.

The effects of soil moisture on xerophyte growth are difficult to interpret in deserts where the additional influence of salinity on total soil moisture stress exists. Furthermore, it recently has been shown that much of the growth of desert shrubs occurs when soil moisture is below the permanent wilting percentage for agronomic species (Chew and Chew, 1965; Gasto, 1969).

Water status measurements in the plant seem to be a more direct assessment of ecological relationships than soil moisture data. The ease of using the pressure bomb, the close correlation of bomb data with water potential (Wiebe *et al.,* 1970; Detling and Klikoff, 1971), and the physiological relevance of water potential encouraged us to test the utility of this approach in helping to explain plant distribution in a cool-desert situation. We did so by measuring plant moisture stress in *Eurotia lanata* (Pursh.) Moq. (winterfat) and *Atriplex confertifolia* (Torr. & Frem.) Wats. (shadscale) during two growing seasons and correlating these data with phenology and climatic conditions.

Methods

Internal moisture stress was measured by the apparatus designed by Waring and Cleary (1967). The results are expressed, for convenience, in positive atmospheres, rather than a negative measurement as used by Scholander *et al.* (1965) and Pierpont (1967).

The studies were made several km north of the Great Salt Lake in Curlew Valley, northwestern Utah, using plants from three different stands, all at the 1350 m contour.

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Site 1. *E. lanata* community in the valley bottom.

Site 2. Mixed *E. lanata* and *A. confertifolia* community, about 0.2 km to the west of site 1.

Site 3. *A. confertifolia* community about 0.2 km to the west of site 2.

The vegetation and soil chemical and physical characteristics of this study area have been described by Gates *et al.* (1956) and Mitchell *et al.* (1966).

Data were collected from April-November, 1968 and from March-October, 1969, usually at weekly intervals. An exception was the six-week period during September to mid-October 1969 when data were missed because of illness of the senior author. On each occasion, 10 plants from the *E. lanata* stand, 10 plants from the *A. confertifolia* stand, and five plants of each species from the mixed stand were measured. Mature plants were selected at random, and their general condition was noted. The samples were taken between 10:00 a.m. and 2:00 p.m. each day. Standards of measurement established by Scholander *et al.* (1965) and Waring and Cleary (1967) were followed.

Diurnal pressure bomb readings were made in May, 1969, in order to assess the degree of fluctuation in plant moisture stress during the course of a day. The measurements were made at hourly intervals during the day and at suitable intervals during the evening. Only plants from the monospecific stands were measured.

Climatic data on rainfall, air temperature, relative humidity, wind speed, and radiation were collected from a nearby weather station. Soil moisture measurements during 1968 were made with a neutron probe.

Results

Mean plant moisture stress values for each species and stand are depicted in Figures 1 (1968) and 2 (1969). Diurnal moisture values for May 12-13, 1969 are recorded in Table 1.

TABLE 1. Diurnal plant moisture stress variation in *Eurotia lanata* and *Atriplex confertifolia* at Curlew Valley, May 12-13, 1969.

	Time of Day	Plant Moisture Stress (atm) Mean of Ten Plants *E. lanata*	 *A. confertifolia*
	1700 hours	27.7	32.7
	1800	29.7	27.8
(sunset)	2030	27.0	22.3
	2230	16.5	22.4
(sunrise)	0603	20.3	17.1
	0800	22.5	22.4
	0900	30.0	22.8
	1000	31.0	30.0
	1100	32.5	29.3
	1200	32.4	33.1
	1300	32.8	27.6
	1400	30.9	28.0

Growing season rainfall and weekly maximum temperatures, the most relevant climatic parameters, are recorded in Figures 1 and 2. Soil moisture data are found in Table 2. Phenological sequences are shown in Table 3.

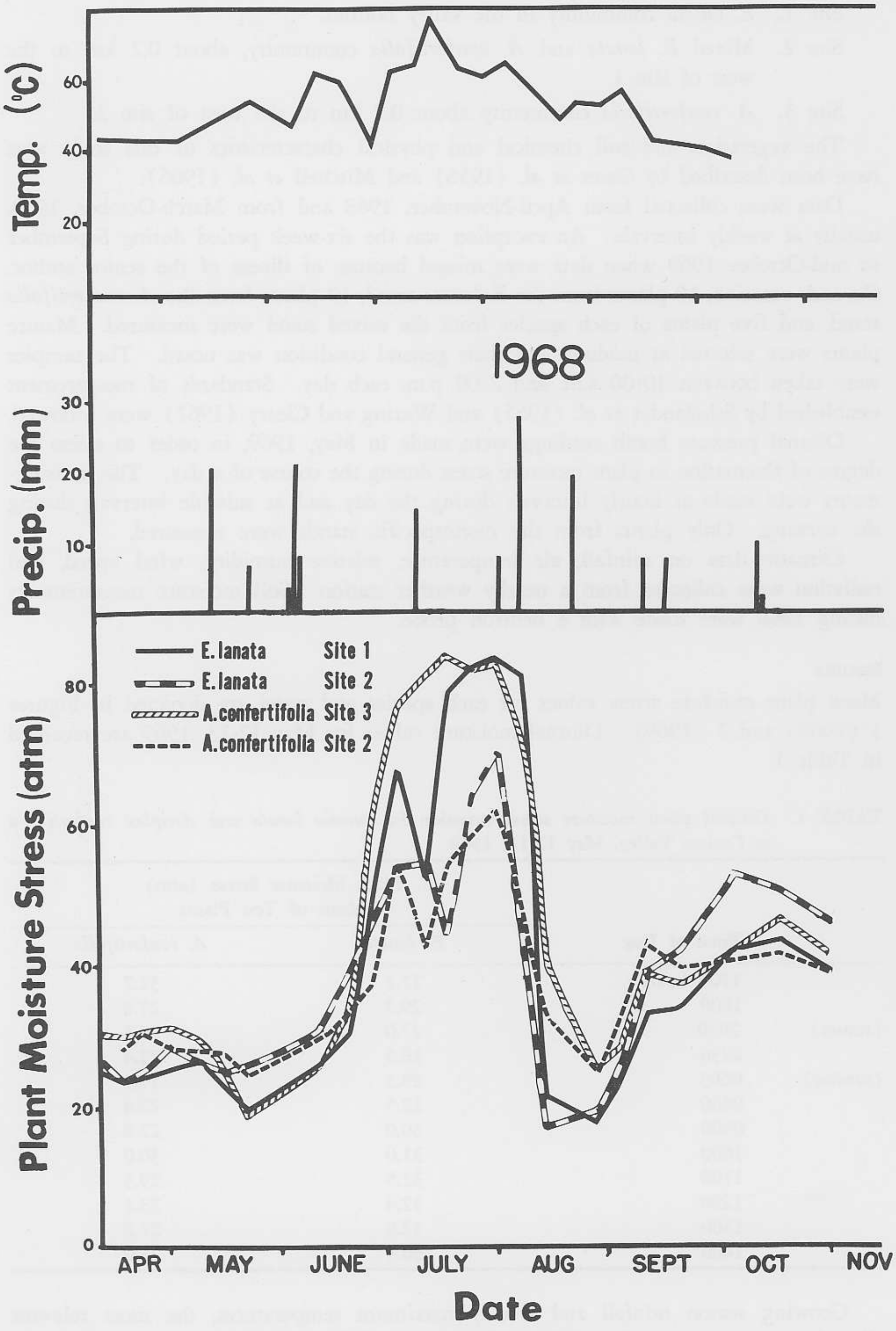

Figure 1. Trends of mean plant moisture stress taken during the 1968 growing season with concomitant precipitation events and weekly maximum temperatures.

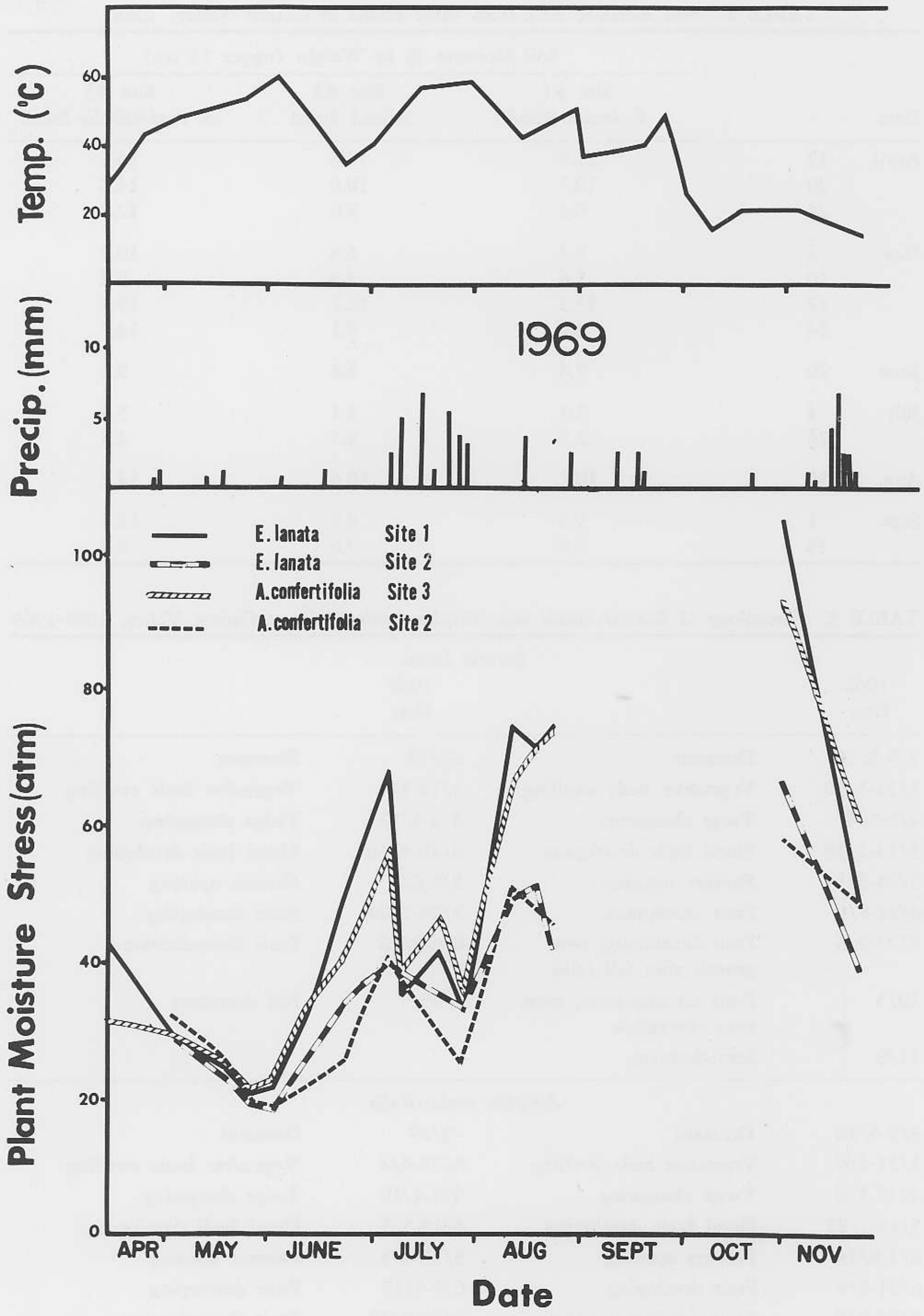

Figure 2. Trends of mean plant moisture stress taken during the 1969 growing season with concomitant precipitation events and weekly maximum temperatures.

TABLE 2. Soil moisture data from three stands at Curlew Valley, 1968.

Date		Soil Moisture % by Weight (upper 15 cm) Site #1 *E. lanata* Stand	Site #2 Mixed Stand	Site #3 *A. confertifolia* Stand
April	12	11.4	11.4	16.5
	20	10.7	10.0	14.5
	27	9.4	9.0	12.5
May	3	8.2	6.4	10.9
	10	5.6	4.8	9.2
	17	12.3	12.7	19.5
	24	8.4	9.1	14.7
June	20	7.4	6.3	9.1
July	4	3.3	3.1	5.9
	26	2.7	2.7	4.5
Aug.	13	10.2	10.6	14.2
Sept.	1	9.3	8.9	12.5
	19	6.6	7.6	8.6

TABLE 3. Phenology of *Eurotia lanata* and *Atriplex confertifolia* at Curlew Valley, 1968-1969.

1968 Date		1969 Date	
	Eurotia lanata		
3/0-3/16	Dormant	–3/14	Dormant
3/21-3/30	Vegetative buds swelling	3/14-4/4	Vegetative buds swelling
4/6-5/4	Twigs elongating	4/4-4/19	Twigs elongating
5/11-5/18	Floral buds developing	4/20-5/10	Floral buds developing
5/25-6/14	Flowers opening	5/5-6/3	Flowers opening
6/21-8/9	Fruit developing	5/24-7/24	Fruit developing
8/23-9/6	Fruit developing; new growth after fall rains	8/4-9/16	Fruit dissemination
10/5	Fruit dissemination, some twig elongation	9/23	Fall dormancy
11/9	Semi-dormant		
	Atriplex confertifolia		
3/9-3/16	Dormant	–3/29	Dormant
3/21-4/6	Vegetative buds swelling	3/29-4/4	Vegetative buds swelling
4/13-5/4	Twigs elongating	4/4-4/19	Twigs elongating
5/11-5/25	Floral buds developing	4/19-5/5	Floral buds developing
6/1-6/14	Flowers opening	5/10-6/3	Flowers opening
6/21-8/9	Fruit developing	6/9-7/17	Fruit developing
8/23-9/6	Fruit developing; new growth after fall rains	7/24-9/23	Fruit dissemination
10/5	Fruit dissemination, swelling of vegetative buds	9/30	Fall dormancy
11/9	Some elongation of fall twigs		

Discussion

Plant moisture stress data for *E. lanata* and *A. confertifolia* during 1968 (see Figure 1) show a definite correlation with seasonal changes in temperatures and rainfall. The highest values for both species in all stands occurred in July and August when the maximum temperatures for the year were recorded. The lowest values for both species in all stands occurred in May and the latter part of August, following 19.3 mm of rain in May and over 50.0 mm in August. At the onset of the growing season in early spring, all moisture stress values were relatively low and rose to a peak in summer during the period of flowering and fruiting (see Table 3). They decreased after the early fall rains, when new vegetative growth appeared, and rose again during the dry part of the fall. Almost every depression in Figure 1 can be accounted for on the basis of rain. Heavy rainfall generally resulted in reduced plant moisture stress, but storms of 8 mm or less had little effect on plant moisture stress. The storm of July 11 may have failed to depress the plant moisture stress at Site #3 because of less effective moisture infiltration into the saltier, finer-textured surface soils rooting this community (Gasto, 1969). None of the sites is more than 0.4 km apart at the same elevation, so greatly different rainfalls are unlikely.

Plant moisture stress data collected in 1969 also show a definite correlation with seasonal progressions of temperature and phenology as altered by rainfall. If the 1968 data are typical, it is likely that peak stresses occurred during the unseasonably hot and dry period of September and early October, 1969. Again, the least plant moisture stress for both species in all stands occurred in the late spring after heavy rainfall.

The plant moisture stress values recorded in this paper compare favorably with Scholander *et al.* (1965) who measured a negative sap pressure value of –80 atm for *Larrea tridentata,* and a recently reported plant moisture stress value of –128 atm for *Atriplex obovata* (Branson *et al.,* 1969). Detling (1969) recorded maxima of approximately –85 bars for *Suaeda fruticosa* and *S. depressa* at a slightly lower elevation along the southern shore of the Great Salt Lake.

Table 1 shows that both *E. lanata* and *A. confertifolia* vary considerably in moisture stress during a 24-hour period. On May 12, 1969, both species showed increases in plant moisture stress until sunset, when stress decreased, and reached a minimum sometime during the night. After sunrise on May 13, plant moisture stress gradually increased and reached a maximum about noon. Plant moisture stress values varied only slightly between 9:00 a.m. and 2:00 p.m. Readings were discontinued at 2:00 p.m. due to rain.

The results indicate that plant moisture stress in both species follows an expected pattern of increase to a maximum sometime during the early or later afternoon. The values decrease before sunset to a minimum during the night and rise again after sunrise. Plant moisture stress, at least during this period of the year, varies comparatively little during the part of the day when the weekly readings were collected. Unless a daily minimum value is required, this system of data collection seems satisfactory.

It is disappointing that the difference in distribution pattern between *E. lanata* and *A. confertifolia* in this study situation cannot be explained by data collected on plant moisture stress. Both species show similar patterns of variation in moisture stress, although *E. lanata* in the monospecific stand displayed more over-all variation than *A. confertifolia* in its monospecific stand. When both species growing in a mixed stand were measured, they also showed a similar pattern of variation. Moreover, more variation occurs between samples of a species in mixed and monospecific stands than between the two species. The only thing that can be said with confidence is that the site conditions of the mixed stand were associated with less plant tissue moisture tension than that of the monospecific stands. The variability of the data makes statistical analysis of questionable value. Coefficients of variation for both species at all sites ranged from 13.8 to 22.1 percent from the dryest to wettest periods of the growing season.

We conclude from the literature that a decrease in soil moisture and/or an increase in salinity of the soil will cause a corresponding decrease in plant water potential (increased plant tissue moisture tension) (Slayter 1967). The soil in which *A. confertifolia* was rooted had higher moisture content and soil salt content (Gasto, 1969), yet these plants showed less moisture tension than the *E. lanata* rooted in soil with lower moisture (Table 2). Detling (1969) had similar difficulty trying to explain the differing habitats of two *Suaeda* species on the basis of plant tissue moisture tension.

It is possible that halophytes are not amenable to this approach because of unique salt metabolism and occurrence in soils of differing soil moisture tension characteristics from that of glycophytes. Another possibility is that the sites studied have species-to-site relationships which are so far removed from pristine conditions that the present distribution of plants could be mostly a reflection of disturbance. Although the study area has not been grazed by domestic animals for the last eight years the area was grazed heavily for the bulk of the previous century. Some ecophysiological differences could be minor or indeterminate until competition reestablishes the species into their quasi-original niche separation. Research is currently underway to explore these and other possibilities. The holocoenotic principle is undoubtedly operating, requiring a consideration of the interaction of many factors to explain successfully why these plants occur where they do.

Summary

Pressure bomb measurements of diurnal and seasonal plant moisture stress in *Eurotia lanata* and *Atriplex confertifolia* were made during the 1968 and 1969 growing seasons in Curlew Valley, Utah. Highest values were recorded in early to mid afternoons of the driest, hottest periods. Rainfalls of more than eight mm generally resulted in immediate reduction of stress values. Differences in plant distribution patterns could not be explained by differences in plant moisture stress data.

Literature Cited

Chew, R. M., and A. E. Chew. 1965. The primary productivity of a desert shrub (*Larrea tridentata*) community. Ecol. Monogr. 35: 355-375.

Branson, F. A., R. F. Miller, and J. F. McQueen. 1969. Soil moisture as a determinant of arid land plant distribution. Abstracts of International Conference on Arid Lands in a Changing World, University of Arizona, Tucson.

Detling, J. K. 1969. Photosynthetic and Respiratory Response of Several Halophytes to Moisture Stress. Ph.D. Thesis, University of Utah, Salt Lake City, 78 p. Dissert. Abst. #70-3802.

————, and L. G. Klikoff. 1971. Comparison of two field techniques for determination of water potential in two halophytes. Amer. Midl. Nat. 85: 235-238.

Gasto, J. M. 1969. Comparative Autecological Studies of *Eurotia lanata* and *Atriplex confertifolia*. Ph.D. Thesis, Utah State University. 278 p. Dissert. Abstr. #70-2397.

Gates, D. H., L. A. Stoddart, and C. W. Cook. 1956. Soil as a factor influencing plant distribution on salt deserts of Utah. Ecol. Monog. 26: 155-175.

Mitchell, J. E., N. E. West, and R. E. Miller. 1966. Soil physical properties in relation to plant community patterns in the shadscale zone of northwestern Utah. Ecology 47: 627-630.

Pierpont, G. 1967. Direct measurement of internal moisture deficits in trees. Forestry Chronicle 43: 145-148.

Scholander, P. F., H. T. Hammel, Edda D. Bradstreet, and E. A. Hemmingsen. 1965. Sap pressure in vascular plants. Science 148: 339-346.

Slatyer, R. O. 1967. Plant-water relationships. Academic Press, New York. 366 p.

Waring, R. H., and B. D. Cleary. 1967. Plant moisture stress: evaluation by pressure bomb. Science 155: 1248-1254.

Waring, R. H. 1970. Forest plants of the eastern Siskyous: Their environment and vegetational distribution. Northwest Science 43: 1-17.

Wiebe, H., R. W. Brown, T. W. Daniel, and E. Campbell. 1970. Water potential measurements in trees. BioScience 20: 225-226.

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