Influence of Summer Rainfall on Root and Shoot Growth
of a Cold-Winter Desert Shrub, *Atriplex confertifolia*

Ken C. Hodgkinson**, Pat S. Johnson, and Brien E. Norton
Department of Range Science, Utah State University, Logan, UT 84322, USA

Summary. The influence of irrigation and nitrogen fertilization in early summer on root and shoot growth of *Atriplex confertifolia*, a C₄ shrub species, was examined in a cold-winter desert community in northern Utah. Soil water and xylem pressure potentials were monitored during the summer period.

At the time of watering the surface soil (0–30 cm) was dry but there were turgid fine roots in this horizon. Watering of the soil reduced plant water stress from −30 to −15 bars (dawn values) indicating that roots near the surface were capable of absorbing water, and induced root growth in the 0–30 cm zone. The addition of N to the water treatment did not further increase root production. However, watering and watering + N fertilizer failed to stimulate shoot elongation or any dry weight increase of shoots. This shoot dormancy during summer is not typical of C₄ plants and is probably associated with adaptation to the cool arid environment.

Introduction
Aridlands are characterized by low and discontinuous precipitation (Noy-Meir, 1973). The effectiveness of precipitation events in activating biological processes and in plant biomass build-up, would be expected to vary, and would depend on such factors as prevailing temperature, and the intensity and duration of the precipitation event. This stochastic nature of precipitation in desserts is important in the timing of growth responses in plants and is justifiably included in simulation models of desert ecosystems (Goodall, 1967).

In warm arid environments where temperatures in the winter are not low enough to cause soil water to freeze, it would appear that the perennial plants make growth during the summer months as long as rainfall events exceed a threshold amount (Went, 1949; Adams and Strain, 1969). All or the majority of the perennial plants in these warm arid zone communities possess the C₄
or the CAM photosynthetic pathways and they are capable of rapid growth during periods of high solar radiation and high air temperatures. For example, *Atriplex nummularia*, a C₄ shrub found in the arid areas of southern Australia, maintains a very high growth rate during the summer period provided water and nutrients are non-limiting (Jones et al., 1970).

In cool arid environments such as in the North American Great Basin, there are some species that possess the C₄ photosynthetic pathway. An example is the perennial shrub *Atriplex confertifolia* (Torr. and Frem.) (Welkie and Caldwell, 1970). This species is able to tolerate low temperature of winter months (−30°C) when the soil is frozen and snow covers the ground. Field studies at Curlew Valley indicate that most of the annual growth occurs in the cool spring months when soil moisture is high from melting snows (Caldwell et al., 1977).

Temperatures during the summer months are high (up to 40°C) in Curlew Valley and rainfall is low and erratic. However, some heavy rainfalls do occur during the summer particularly from thunderstorm activity. Since *A. confertifolia* possesses the C₄ photosynthetic pathway it would be expected that this species would grow actively during the summer months provided soil moisture was adequate for growth, like other C₄ species growing in warmer environments. The optimum temperature for photosynthesis of this species is 35°C or slightly higher (Caldwell et al., 1977) and at 50°C active net photosynthesis has been measured (Caldwell, 1972). However, preliminary experiments by MacMahon et al., (personal communication) suggest that supplementary watering of this shrub each week during summer does not induce new shoot growth.

Several explanations can be put forward for this apparent lack of response to additional soil water during the summer months. First, absorption of water following summer showers may be insufficient to promote active photosynthesis because of lack of viable roots in the wetted zone.

Second, the surface horizon that becomes wet may be deficient in available nutrients, especially nitrogen, thereby limiting the growth response. Third, active photosynthesis may occur following summer rains but the majority of the photosynthate may be basipetally partitioned into new root structures. Fourth, there may be no measurable growth response, because this species exhibits summer dormancy.

To test the above hypotheses a field experiment was conducted in Curlew Valley, northern Utah. Selected plants received supplementary water with and without nitrogen and the growth response of the shoots and roots was monitored. Also the spatial distribution of roots was determined for a community of *A. confertifolia*.

**Materials and Methods**

1. **Supplementary Water and Nitrogen Experiment**

This study was conducted in Curlew Valley of northern Utah (113°5′W, 41°5′N) 17 km southwest of the township of Snowville at the IBP Desert Biome Validation Site. The shrub-steppe community