Effects of Elevated Concentrations of Carbon Dioxide on Seedling Growth of Mesquite and Huisache

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Abstract—Plants such as mesquite (Prosopis glandulosa) and huisache (Acacia smallii) generally show positive growth responses to higher CO$_2$ concentrations. Growth of the two legumes was measured at five day intervals over 30 days from seedling emergence at 380, 700, and 1,000 ppm CO$_2$. Root elongation increased with CO$_2$ concentration in mesquite. Shoot mass of both species responded positively to elevated CO$_2$. Positive responses to CO$_2$ enrichment were evident within one week after emergence. Predicted increases in atmospheric CO$_2$ could increase seedling establishment and survival of these invasive shrubs, and ultimately contribute to a further change in the species composition of Southwestern rangelands.

Atmospheric concentrations of CO$_2$ are predicted to double (to about 700 ppm) by the middle of the next century. Plants possessing the C$_3$ photosynthetic pathway generally exhibit positive growth responses to superambient concentrations, while species with the C$_4$ photosynthetic pathway usually respond less to higher CO$_2$ (Mayeux and others 1991; Johnson and others 1993). This difference in response to CO$_2$ between C$_3$ and C$_4$ plant types may contribute to modify the species and growth form composition of rangelands across the Southwest (Polley and others 1994). Because most brush species are C$_3$ plants, while warm-season grasses are of the C$_4$ type, the predicted changes in CO$_2$ concentration should be selectively advantageous to invasive shrubs.

Once established, woody species may persist for a century or more unless controlled by humans. Gibbons and others (1992) found that only a small percentagge of the mesquite (Prosopis glandulosa) that germinated survived into the second year. However, this small percentage of surviving seedlings was adequate to convert productive grassland into a mesquite-dominated ecosystem. Mesquite and huisache (Acacia smallii) have invaded vast areas of the Southwest in recent years, and in many cases completely dominate the landscape. Also, in cases where mechanical or chemical controls have reduced or eliminated stands of these plants, rapid recolonization of the site by seedlings quickly returns the area to its former vegetative composition (Gibbons and others 1992).

We determined effects of elevated CO$_2$ concentrations on shoot and root growth of mesquite and huisache seedlings, effects that may contribute to alter the competitiveness of these species on rangelands in the future.

Materials and Methods

Seedlings of both mesquite and huisache were grown in split PVC tubes 145 cm (5 ft) long in glasshouses maintained at atmospheric CO$_2$ concentrations of 380, 700, and 1,000 ppm. No supplemental lighting was provided. The split PVC tubes (held together with duct tape) facilitated easy removal of the entire tap root. The soil medium was amended with complete nutrient solution. Seedlings were harvested at 5 day intervals over 30 days following emergence. At harvest, shoot and root dry mass and length of taproots were determined.

Results

Plots of log total biomass vs. aboveground biomass indicated that CO$_2$ concentration did not modify allometric relationships between aboveground and total growth in young seedlings of either species (data not shown). However, the ratio of aboveground to total biomass decreased with age regardless of CO$_2$ concentration (fig. 1).

Rooting depth of huisache did not respond to CO$_2$, and was consistently lower than that of mesquite (fig. 2). Mesquite rooted more deeply at elevated CO$_2$ levels than at the current concentration. Rates of root depth extension for mesquite averaged 3.67 cm day$^{-1}$ at the 380 ppm CO$_2$ level and 4.52 cm day$^{-1}$ at elevated concentrations.

In mesquite, total biomass at the elevated CO$_2$ concentrations was greater throughout the experiment (fig. 3), with differences being statistically significant at day 30. For huisache, differences between atmospheres were not as pronounced (fig. 4), but trends were for greater biomass at elevated CO$_2$ concentrations.
Figure 1—Means of the ratio of aboveground biomass to total biomass of mesquite and huisache seedlings after 10 to 30 days growth averaged across three CO2 levels (Huisache: $r^2 = 0.63$, $P < 0.0001$, $n = 75$; Mesquite: $r^2 = 0.58$, $P < 0.0001$, $n = 75$).

Figure 2—Rooting depth of mesquite and huisache seedlings (averaged over sampling days 5-30) at three CO2 levels. Bars headed with the same letter are not significantly different ($P < 0.05$) by Student-Newman-Kuei's Test ($n = 35$).

Figure 3—Means of total biomass of mesquite seedlings at zero to 30 days post-emergence grown at three CO2 levels (at 380 ppm, $r^2 = 0.95$, $P < 0.0001$, $n = 35$; at 700 and 1,000 ppm, $r^2 = 0.95$, $P < 0.0001$, $n = 70$).

Figure 4—Means of total biomass of huisache seedlings at zero to 30 days post-emergence grown at three CO2 levels (Single regression for all atmospheres, $r^2 = 0.84$, $P < 0.0001$).
Discussion

The response of mesquite seedlings to CO₂ enrichment was quite dramatic. Root and total biomass were increased as much as 38% at elevated CO₂. Positive responses to elevated CO₂ were evident in about a week. Positive responses were noted for huisache, but were not as impressive as those measured on older plants (H. B. Johnson, unpublished results). Differences in shoot mass present on days 15 and 20 between huisache plants grown at elevated CO₂ and the current level were not present at later harvests. We believe that this may reflect a temporary lag in growth at the elevated CO₂ levels, where the earlier abscission of cotyledons and lower leaflets precedes a burst of leaf initiation and growth. We have observed that leaf and cotyledon longevity may be shorter at elevated CO₂. Senescence of the cotyledons and lower leaves represents a significant shift in relative masses of seedling structures that further complicated growth analyses of these young plants.

Obviously, the root lengths we observed in the tube system represent maximum potential elongation, but are indicative of the significant amount of resources both species invest in deep rooting.

Further experimentation is required to determine responses of mesquite and huisache to elevated CO₂ where competition, water and heat stress, herbivory, and other complicating factors are also present.

References