Photosynthetic rates and vegetative production of Sorghastrum nutans in response to competition at two strip mines and a railroad prairie

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Abstract

The effect of differing environmental conditions on competition for resources was investigated by a comparison of net photosynthetic rate ($P_N$) and vegetative production of Indian grass [Sorghastrum nutans (L.) Nash. ] at two strip mine sites with differing reclamation histories, and a railroad prairie site where this species occurs naturally. The treatment for a competition experiment consisted of tying back all species of neighboring plants around a target plant, and measuring its $P_N$ and vegetative performance during the growing season. Environmental variables at each site were also measured during the growing season. Soil bulk density and pH were higher at the two mine sites than at the prairie site, and soil texture, nutrients, and water potential were different at each of the three sites. $P_N$ of target plants compared closely among the three sites, and were lowest for plants at the railroad prairie. The competition experiment indicated that lower canopy leaves were most affected by competition for photosynthetically active radiation (PAR) at all sites. Significant differences in $P_N$ of upper canopy leaves were found between treatment and control plants at one of the mine sites. This site had higher soil water potentials and higher soil levels of P and K than the other mine site or the railroad prairie. Target plants at the other mine site experienced a low competition for PAR, likely due to lower soil moisture availability and therefore lower aboveground productivity. The largest differences in $P_N$ and irradiance between upper and lower canopy leaves occurred in target plants with neighbors at the railroad prairie, likely due to inter-specific competition. Vegetative production of the target plants also reflected the environment.
at each site, but did not reflect $P_N$ differences between treatments. $S. mutans$ is well adapted to the varying environment at these three sites, and aboveground competition for radiant energy was probably not as limiting for this C$_4$ grass as belowground competition.

**Additional key words:** biomass; gas exchange; inflorescence; irradiance; seasonal course; soil texture; tillers.

**Introduction**

Plant stress has been defined as "external constraints which limit the rate of dry matter production of all or part of the vegetation" (Grime 1979). These "external constraints" can include: soil infertility, nutrients or heavy metal toxicity, competition with other plants, drought, shade, limited space, poor soil structure and/or texture, excess heat or cold, excess water, herbivory, and disease. Plants must adapt to stress from both the environment and competition with other plants for limited resources.

Net photosynthetic rate ($P_N$) has been measured as an indicator of plant status because gas exchange requires an adequate amount of certain nutrients such as nitrogen, and responds to water and irradiance in the environment. Plants with the C$_4$ photosynthetic pathway are more efficient under high irradiances, and a higher percentage of C$_4$ plants occur in areas with higher temperatures, higher irradiances, and lower precipitation (Barnes et al. 1983). In general, $P_N$ would be expected to be lower in response to plant competition, and we have shown in a greenhouse experiment that the C$_4$ grass *Sorghastrum nutans* has reduced $P_N$ under increasing competition regardless of the competitor species (Gibson and Skeel 1996). The C$_4$ plants, however, produce more dry matter per unit of nitrogen, and therefore tend to be better competitors than C$_3$ plants in low nitrogen environments that often exist in the field (Brown 1978).

Measuring competition in the field can be challenging because plants compete for many interacting resources that are difficult to separate. The most common method is by vegetation removals where one or more species are removed around a target plant (Gurevitch 1986, Duralia and Reader 1993). Since plants can potentially compete with all other plants around them in their community, diffuse competition experiments are sometimes more appropriate to study the effect on a particular species (Mitchley 1987).

Strip mines are one example of an environment that may be stressful to plant development. The stresses of reclaimed strip mines can include a lack of soil structure, low organic matter, low nutrients, heavy metals, and soil compaction (Thomas and Jansen 1985). Species trials on native prairie plants have evaluated their success in strip mine reclamation (Anderson and Birkenholz 1980, Kuenstler et al. 1980, Bonfieti and Asby 1984, Ashby et al. 1989). Most of these studies, however, have focused on aboveground yield. Our field study focused on how individual plants respond both morphologically and physiologically, and how competition affects these responses.