CO_2 EXCHANGE OF THE ABOVEGROUND AND BELOWGROUND COMPONENTS OF KLEINGRASS (*PANICUM COLORATUM* L.) DURING DROUGHT IN THE NORTHERN CHIHUAHUAN DESERT

WILLIAM B. SISSON

Jornada Experimental Range, USDA, Agricultural Research Service,
Las Cruces, New Mexico, USA

SUMMARY

The effect a 52 day drought had on the diel whole-plant carbon balance of kleingrass (*Panicum coloratum* L.) growing in the northern Chihuahuan desert was determined. Whole-plant CO_2 inputs (photosynthesis) and outputs (belowground and aboveground respiration) were measured on day 52 of the drought (June 23, 1981) and 2 days following 1.12 cm of precipitation that occurred on June 24, 1981.

Although net photosynthesis rates were severely depressed on June 23, a positive whole-plant carbon balance was determined prior to and following the rain. On a whole-plant basis,.002 g C/g DW/day was gained on June 23 and .015 g C/g DW/day on June 26. Respiration of the belowground components (roots plus root crown) was very low (.004 g C/g DW/day) due to the suberized condition of the entire root system. The ability of roots to change from a nonsuberized state to a suberized condition when soil dries reduces the root maintenance cost and, therefore, may enable a plant to maintain a large root biomass during drought.

KEY WORDS: drought, carbon balance, desert, photosynthesis, root respiration.

INTRODUCTION

High temperatures, low annual precipitation and frequent droughts limit the number of plant species able to inhabit desert environments, as well as the productivity and distribution of those plant species present. Although many plant species possess morphological and physiological adaptations that aid in coping with this environment, high rates of net CO_2 assimilation and growth usually occur during brief time periods coincident with favorable moisture and temperature (e.g. Öquist, 1983; Kemp, 1983).

Perennial grasses inhabiting the northern Chihuahuan desert initiate spring growth in April or May (Kemp, 1983). Growth to mid-July is primarily dependent upon soil moisture stored the previous fall and winter because precipitation during the spring and early summer is low (2.6 cm; April through June; 52 year average). During 1981, no precipitation occurred for 52 days prior to June 24, when 1.12 cm of rain was received. The present study assesses the effect severe plant water stress prevalent on June 23 had on the diel (24 hour) whole-plant carbon balance of kleingrass (*Panicum coloratum* L.) growing *in situ*. Similar analyses of the whole-plant CO_2 flux were made 2 days following the precipitation of June 24.

METHODS

The study was conducted in June 1981 on mature kleingrass plants growing on the Jornada Experimental Range (approximately 32° 34′N, 104° 48′W) near Las Cruces, New Mexico, USA. The plants were grown from seed within an experimental plot established in 1975. Average annual precipitation on the study site is 22.1 cm, with 1.2 cm occurring in June.

Net photosynthesis and dark respiration rates of individual leaf blades, and leaf sheaths plus stem were measured with an open gas circulation system (Sisson, 1981). Respiration rates of intact, attached roots were measured with a root gas exchange system (Sisson, 1983). Individual roots on the south side of the plant and at a soil depth of 15 to 40 cm were located by removal of soil until the entire, intake root was exposed. The root was examined to ensure it was undamaged and attached to the plant, rinsed with water, blotted dry, sealed into a 6-ml polyurethane cuvette equipped with inlet and outlet ports, and covered with approximately 20 cm of soil. Only roots that appeared completly suberized were found on several excavated plants. Respiration rates were determined on a 6- to 10-cm portion of the suberized roots approximately 5- to 15-cm from the root crown. Respiratory activity of individual root crowns from field-grown plants was measured by manometric techniques following the procedure described by Sisson (1983).

A plant, representative of those on the study site, was destructively sampled in June 1981 to quantify biomass partition of the above- and belowground components. An attempt to remove the entire root system of the plant was made by sieving all soil within a radius of approximately 2 m from the plant base to a soil depth of approximately 2 m.

RESULTS

JUNE CO_2 EXCHANGE

The absence of precipitation on the study site for 52 days prior to initiation of the study resulted in severe plant water stress. The dry soil conditions prevalent on June 23 resulted in a predawn and midday (solar noon) leaf water potential of -1.52 and -2.59 MPa, respectively, and partial leaf rolling was evident by leaves within the canopies of most kleingrass plants by 0800 hours. All kleingrass plants possessed some or all leaves in a rolled-up condition by solar noon. Although positive gains in CO_2 occurred throughout the photoperiod, leaf net CO_2 assimilation rates were severely depressed (Fig. 1B). Precipitation amounting to 1.12 cm occurred on June 24 and substantially increased leaf net CO_2 assimilation rates on June 26 (Fig. 1B), the first cloudless day following the rain. The predawn and midday (solar noon) mean leaf water potential on June 26 was -0.90 and -2.04 MPa, respectively, and no leaf rolling was evident throughout the photoperiod. Nevertheless, the progressive decline in net CO_2 assimilation rates through the photoperiod suggested water stress may have repressed photosynthetic activity. Net CO_2 assimilation rates were similar on both June 23 and 26 after 1700 hours. Diurnal leaf sheath plus

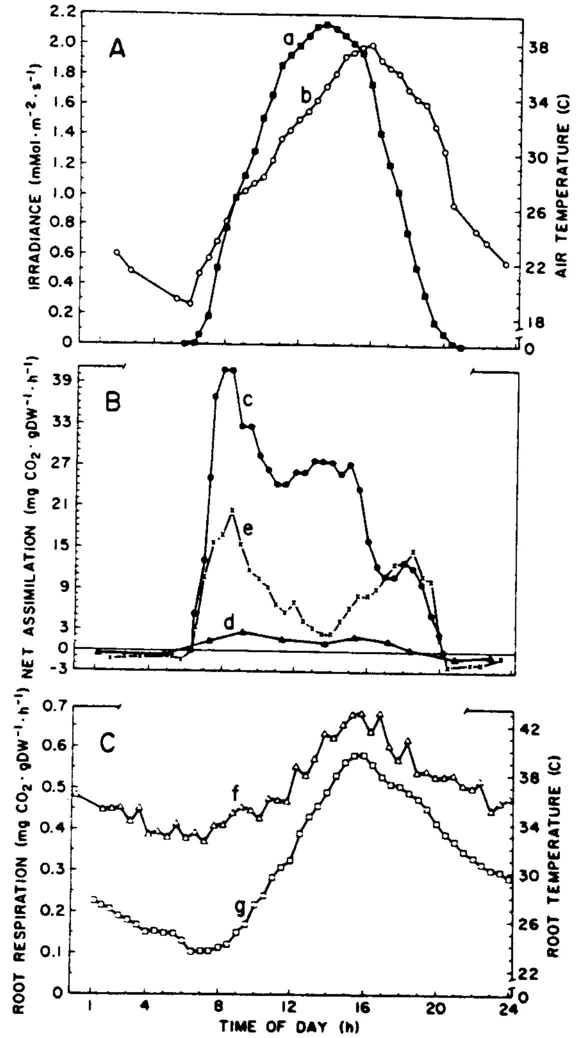

Fig. 1. Diel net photosynthesis and dark respiration (B) of kleingrass (*panicum coloratum* L.) leaf sheaths and stems (d) and leaf blades prior to (e) (x---x) (June 23, 1981), and following (c) (●---●) (June 26, 1981) 1.12 cm precipitation (June 24, 1981) on the study site during cloudless days in the northern Chihuahuan desert. Irradiance (a) and air temperature (b) (A) values represent the mean of June 23 and 26, 1981. Average temperatures (g) and respiration rates (f) (C) of two suberized roots determined on June 23 and 26, 1981. Hours are Mountain Daylight Time (MDT + 88 min = mean solar time).

stem net CO_2 assimilation rates were essentially identical on June 23 and 26 (Fig. 1B) suggesting the precipitation of June 24 had little or no effect on the photosynthetic rates of these plant components.

The root biomass component of kleingrass plants was comprised entirely of suberized roots during June. Diel root respiration rates were essentially identical on June 23 and June 26, and, therefore, average rates are depicted in Fig. 1C. Diel respiratory activity of these roots was highly temperature dependent: maximum and minimum respiration rates coincided with high and low root temperatures, respectively. A Q_{10} of 1.48 results when based on the diel mean minimum and maximum root temperatures and the associated root respiration rates.

CARBON BALANCE

Dry weights of the components of a plant removed from the soil were used to calculate a carbon balance of a whole-plant growing *in situ* during June 23 and 26 (Table 1).

Table 1. Dry weights (g), diel carbon exchange and carbon balance of the aboveground and belowground components of a kleingrass (*Panicum coloratum* L.) plant removed from the soil in the northern Chihuahuan desert during June 1981.

	Dry weight (g)	g C/day (June 23)	g C/day (June 26)
Leaf blades	5.3	.126	.441
Leaf sheath + stem	2.5	.009	.009
Crown	3.4	-.020	-.020
Roots	14.7	-.048	-.048
Total weight	25.9		
Carbon balance		.067	.382

A positive carbon balance was calculated during both periods. Relative to the whole-plant carbon gain on June 23 (.067 g C/day), a 6-fold increase in carbon was gained on June 26 (.382 g C/day).

DISCUSSION

Initiation of growth by kleingrass during the dry, cool months of April and May resulted in a dependence for growth on soil moisture from precipitation the previous fall and winter. By June 23, following 52 days devoid of precipitation on the study site, soil moisture was apparently depleted resulting in severe plant water stress as evidenced by a predawn and midday (solar noon) leaf water potential of -1.52 and -2.59 MPa, respectively, leaf rolling prior to solar noon, and substantially depressed diurnal net CO_2 assimilation rates (Fig. 1B). This reduction in photosynthetic capacity resulted in a net gain of only .017 g C/g DW of the aboveground biomass on June 23. Considering the high soil temperatures (Fig. 1C), the dependency of root respiration rates on temperature (Sisson, 1983), and the high proportion of root biomass relative to shoot biomass (root:shoot = 2.3), a negative whole-plant carbon balance might have been predicted. The belowground biomass was, however, comprised entirely of suberized roots possessing very low respiration rates (Fig. 1C). On the basis of the entire root system, only .003 g carbon was respired on June 23 per g dry weight. This low root respiratory activity, coupled with a low but positive aboveground carbon gain, resulted in a positive whole-plant carbon balance (.067 g C/day; Table 1). The 1.12 cm of precipitation on June 24 substantially increased the net CO_2 assimilation rates, and consequently, the whole-plant carbon gain on June 26 (.382 g C/day; Table 1). On a whole-plant basis, .002 and .015 g C/g DW/day were gained prior to (June 23), and following (June 26) the precipitation, respectively.

The ability of roots to change from a nonsuberized condition with high respiration rates (Sisson, 1983) to a suberized state when soil dries (Portas and Taylor, 1976) considerably reduces the cost of maintaining a plant's root system during drought. This would be particularly true for plants in the northern Chihuahuan desert during the typically dry, hot months of May and June. During drought, therefore, a relatively large root biomass (root:shoot > 1) can be maintained with low respiratory costs without reducing the distribution of roots in the soil for subsequent water uptake when soil moisture becomes available.

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