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The Effects of Water Stress on Phenology and
Carbohydrate Storage in the Shortgrass Prairie

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Western wheatgrass (Agropyron smithii Rydb.) and blue grama (Bouteloua gracilis (H.B.K.) Steud.) are important range forage species of the short-grass prairie region. Moisture is a crucial environmental factor on these semi-arid grasslands. An insight into soil moisture availability differences among soil textural groups and related effects on plant phenology and carbohydrate reserves may be useful for determination of plant survival limits on soils to be surface mined.

Seasonal trends of carbohydrates and phenology (Runyon, 1943; Benedict and Brown, 1944; Donart, 1969; Trlica and Cook, 1971; Trlica and Cook, 1972; Fisser et al., 1976), water stress and carbohydrate reserves (Plaut and Reinhold, 1965; Sosebee and Wiebe, 1971; Trlica and Singh, 1974) and water stress and phenology (Slatyer, 1957; Love and West, 1972; DePuit and Caldwell, 1973) have been studied but little attention has been collectively focused on water use as it influences the dynamics of plant growth and nutrient storage in relation to soil textural classification.

Materials and Methods

Nine study areas were located on an area to be surface mined near Gillette, Wyoming. Three study areas were located on clayey soils,

Three leaf samples from each plant were placed in the press in less than 40 seconds after excision from the plant. Pressure was applied at a rate of 5 to 6 pounds per square inch per second until water appeared at the cut edge of the leaf. Data were later converted to bars.

The following morning, roots of each sampled plant were removed to a depth of 35 centimeters, washed and placed in dry ice to reduce enzymatic activity. Samples were oven-dried at 80°C for 24 hours, and ground in a Willy Mill to pass through a 40-mesh screen. Total nonstructural carbohydrates (TNC) were obtained by combining the enzyme extraction (Weinman, 1947) and the anthrone assay method (Yemm and Wills, 1954). Data were expressed in milligrams (TNC) per gram of dry root material weight.

Results and Discussion

Western Wheatgrass

Western wheatgrass shows a seasonal variation in LWP of -6 to -32 bars, -6 to -30 bars and -4 to -41 bars, respectively, for each textural class (Fig. 1). The lowest LWP values were recorded on June 15 corresponding with a low in TNC and an increase in photosynthetic area. TNC and LWP increased and both corresponded with the initiation of flowering on July 1. During the next sampling period (July 15) LWP increased and TNC decreased and were related to seed formation on all soil types. Seed development and plant maturity were earlier on sandy soils although LWP values were somewhat lower than those recorded on the heavier soils. The difference was attributed to lower nutrient availability on coarse soils (Schalaterar and Hironaka, 1972), particularly nitrogen and phosphorus (Singleton and Cline, 1974); and the use of surface moisture from periodic thunderstorms which moistened the soil profile to a depth of 10 cm in coarse textured soils while only 2 to 3 cm on the finer textured soils.

There were no statistically significant differences ($P < 0.05$) for LWP, phenology or TNC among soil types for western wheatgrass. However, correlation coefficients (r) for LWP and TNC used to measure the degree of association between variables, were 0.87, 0.82 and 0.53, respectively, for each soil type (Table 2). The lower value for the loam textural group was possibly due to rainfall distribution. The three loamy study areas, varied from 1 to 3 km south of the remaining sites, received 15% less precipitation and were 2°C warmer during the month of July. Correlation coefficients for LWP and phenology were 0.97, 0.92 and 0.92 indicating a strong relationship between these factors on all soil textural groups.

Table 2. Correlation Coefficients Through Twelve Time Periods of Leaf Water Potential (LWP), Total Nonstructural Carbohydrates (TNC) and Phenology by Soil Textural Classes For Western Wheatgrass and Blue Grama.

Correlation Components	Western Wheatgrass			Blue Grama		
	Clay	Sand	Loam	Clay	Sand	Loam
LWP - TNC	0.87	0.82	0.83	0.72	0.88	0.98
LWP - Phenology	0.97	0.92	0.92	0.86	0.88	0.95

Blue Grama

Leaf water potential measurements varied from -5 to -47 bars, -6 to -50 bars and -4 to -62 bars for the soil types (Fig. 2). Vegetative phenology did not change during the 1st and 2nd sampling periods, whereas LWP decreased and TNC levels increased. Statistical evaluation indicated no difference in storage levels for the three soil types, but TNC levels were consistently 4 to 7% higher on the coarse soils, where initial green-up was 2 to 3 weeks earlier than on the finer textured soil.

Total nonstructural carbohydrates increased slightly whereas LWP nearly doubled on all soil types after the 1st sampling period in July. Plants on clayey soils developed faster even though LWP was higher. The difference was attributed to a reduction in moisture penetration in the soil profile, the affinity of clay particles for water, and possibly genetic variability among plants.

There were no significant differences in LWP, phenology or TNC among soil types. Correlation coefficients for LWP and TNC were 0.72, 0.88 and 0.98, respectively, for the soil types (Table 2). These values seem to indicate a selectivity of the species for texture (Tomanek, 1964; Noller, 1968) when compared with above ground biomass estimates of 82, 89, 116 kg/ha for the respective soil types. Correlation coefficients for LWP and phenology were 0.86, 0.88 and 0.95 following a similar trend.

Leaf water potential was significantly different ($P < 0.05$) between the two species on the last sampling date, storage of reserves was different on the 2nd sampling date, whereas phenological development was similar throughout the sampling period. Differences in LWP and TNC were related to the different photosynthetic processes by which each species fixed carbon dioxide.

Carbon fixation in western wheatgrass was by the Calvin-Bensen cycle (RuDP carboxylation) where the formation of a 3-carbon chain was the first photosynthetic product. Carbon fixation in blue grama involves a combination of the Calvin-Bensen cycle and the Hatch-Slack pathway (β -carboxylation) where the first photosynthetic products were 4-carbon compounds (primarily malic and aspartic acids). Although the phenological progression was similar for both species, during the sampling period, blue grama matured three to four weeks later than western wheatgrass on all soil textural types.

Summary and Conclusions

A study was conducted in 1976 in northeastern Wyoming to determine seasonal variation in leaf water potential, phenological development and total nonstructural carbohydrates and how various soil textural groups affected plant water use, morphology and storage of nutrients in western wheatgrass and blue grama. Leaf water potential, phenological development and total nonstructural carbohydrates were similar on all soil textural types for both grasses. Root reserves were lowest on June 15 for western wheatgrass with the elongation of leaves (3rd leaf) whereas LWP was highest. Reserves were rapidly accumulated in early July and maximum levels occurred with the initiation of flowering. During the following sampling period LWP increased (more negative) whereas the level of reserves increased. Plants on loamy soils matured somewhat earlier during the latter portion of July, but individuals on sandy soils matured more rapidly in late August. Reserves in blue grama gradually increased as LWP increased in all soil types. Seed formation was generally constant on soil types, with maturation dates slightly earlier on clayey soils.

The study was designed to provide baseline data which can be used as a guide to determine plant stability after reseeding on surface mined areas. Currently a bond of \$4000 to \$8000 per acre is required of mining operators by the state of Wyoming to insure plant stability after 5 years, but stability is based solely on production and adequacy of sampling before and after mining. With additional information on leaf water potential, plant phenology, total nonstructural carbohydrates and statistical methodology in correlation one parameter could be measured and others predicted to more accurately determine species adaptability.

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