Influence of Temperatures, Water Stress, and Nitrogen Treatments on Chlorophyll and Dry Matter of Western Wheatgrass

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Highlight: Western wheatgrass (Agropyron smithii Rydb.) raised from seeds was given four treatments under three temperature regimes in environment controlled growth chambers. Dry matter and chlorophyll (a + b) were determined in the shoots of these plants at 20 day intervals for 100 days. Dry matter and chlorophyll production was greater from irrigated and irrigated-plus-fertilized plants under each temperature regime than it was from control or fertilized plants. This response was more pronounced at the intermediate temperature regime (24/13°C) than at the lower (13/7°C) or the higher temperature regimes (30/18°C). The maximum chlorophyll increase of irrigated and irrigated-plus-fertilized plants was 350% and 395% at 24/13°C while in the control and fertilized plants the increase was 251% and 176%, respectively. A positive linear relationship was found between dry matter and chlorophyll of all the plants under the three temperature regimes.

Primary production in a grassland ecosystem is dependent, besides other factors, upon the photosynthetic efficiency of the plant species found in the plant community. Photosynthesis provides metabolic energy not only for plant processes, but also for the consumer and decomposer subsystems. Chlorophyll content of plants has been used by many workers as an indicator of productivity in both native and seeded plant communities (Bray, 1960; Braugham, 1960; Aruga and Monis, 1963; Madison and Anderson, 1963), but the correlation with production under field conditions is usually poor. This is because of the differences in orientation of leaves to incident solar radiation and to the pattern of chlorophyll in leaves at each level of community organizations (Loomis and Williams, 1969). Bray (1960) reported a significant positive correlation between chlorophyll content and herbaceous stand height. Recently Mall et al (1973) reported a positive relationship between chlorophyll content and both the height and dry matter weight of various dominant species in a diverse herbaceous community. However, Gabrielson (1948) reported that, in plants with foliage leaves, the energy yield was not proportional to the chlorophyll concentrations. Similar results were found by Oelke and Andrews (1966) in sweet corn.

These reports indicate that the relationship between chlorophyll concentration and dry matter production in the field is a species characteristic and is dependent upon community structure and environmental factors.

The study reported here was undertaken to investigate the interrelationship between chlorophyll and dry matter production of western wheatgrass (Agropyron smithii Rydb.) under various temperature, water, and nitrogen treatments.

Methods and Materials

Western wheatgrass plants used in this study were raised from seeds. Three plants were transplanted in each of 144 plastic pots (12.7 cm high, 12.7 cm diameter) containing soil potting mixture consisting of native grassland soil, peat moss, and sand (4:1:1). Four treatments: control, irrigated, fertilized, and irrigated-plus-fertilized were each replicated twice at each of three temperature regimes. Growth chambers were maintained at 13/7°C, 24/13°C, and 30/18°C day/night temperature alternating with 12-hour photoperiod at 90 watts/m² light intensity. The temperature regimes selected for this study were those normally operative in the native shortgrass prairie ecosystem.

A set of 48 pots (4 treatments x 2 replicates x 6 sampling dates) was placed in each of the three growth chambers consisting of 12 pots per treatment and remained there for 2 weeks before the treatments were applied. At the end of 2 weeks, 12 pots in each chamber received nitrogen fertilizer at the rate of 150 kg N/ha in the form of ammonium nitrate, 12 continued to receive enough water daily to maintain the soil at field capacity (0 to -0.8 bars), 12 received water plus nitrogen fertilizer (at rate noted above), and 12 received no supplemental treatment.

The control and fertilized plants had to be irrigated at 3- to 4-day intervals to prevent them from extreme drought conditions. The water potential in these pots averaged -7 to -10 bars, a condition common in the native shortgrass prairie. Sampling began 1 week following the initiation of treatments. Subsequent samples were taken on 20-, 40-, 60-, 80-, and 100-day intervals. On each sampling date eight pots from each chamber (two from each treatment) were removed and from...
these all the shoots were clipped, chopped into small pieces, mixed thoroughly, and weighed. An aliquot of the mixed sample was frozen immediately for pigment analysis and the remaining shoot material was dried at 100°C for 4 hours and then at 70°C until a constant weight was obtained. Pigment analysis included analysis for chlorophyll \(a\) and \(b\) and total chlorophyll. An aliquot of 1 to 5 grams of frozen material was ground in a Waring blender containing 150 ml of 80% acetone. The chlorophyll-containing liquid was filtered through Watman's No. 52 hardened filter paper. The residue was blended in 100 ml acetone twice, and the filtered liquid from the three blending and filtering processes was combined and brought to volume with acetone in a 500-ml flask. Chlorophyll \(a\) was read at 663 nm, chlorophyll \(b\) at 645 nm, and total chlorophyll at 652 nm using Gilford micro-sample spectrophotometer, 300 N.

Results

Effects of Various Treatments on Dry Matter (g/pot)

Dry matter of shoots of western wheatgrass increased with time under the four treatments at all the temperature regimes until the 80th day and then began to decline until the final harvest (Fig. 1). A greater amount of dry matter during this period was recorded at the intermediate temperature regime (24/13°C) than at the lower (13/7°C) or at the higher temperature (30/18°C) regimes. At 13/7°C, the increase in dry matter of control, fertilized, irrigated, and irrigated-plus-fertilized plants was 102%, 61%, 181%, and 221%, respectively. During the same period the increase in dry matter of plants under 24/13°C from the above four treatments was 158%, 112%, 284%, and 333%, respectively. At 30/18°C the increase from control and fertilized plants was similar to that under 13/7°C while from irrigated and irrigated-plus-fertilized plants, the increase was of smaller magnitude than that under 24/13°C or 13/7°C.

Following the peak growth, the dry matter of all the plants under the three temperature regimes began to decline at different rates from the four treatments. At 13/7°C, maximum decrease (22%) in dry matter was recorded from control plants and minimum (15%) from irrigated-plus-fertilized plants. Decrease in dry weight at 30/18°C was greater from control plants (32%) as compared to irrigated plants (17%). At 24/13°C the maximum decrease was 24% from irrigated-plus-fertilized plants and minimum of 15% from irrigated plants. Generally, the plants under 24/13°C accumulated greater amounts of dry matter than those under 13/7°C or under 30/18°C.

Effects of Various Treatments on Chlorophyll [(a + b) - mg/pot]

The chlorophyll contents of plants at 13/7°C and 30/18°C peaked on the 60th day while those under 24/13°C peaked on the 80th day, at the same time that dry matter peaked (Fig. 2). Similar to the increases in dry matter of plants under 24/13°C, the increase in chlorophyll content of these plants at this temperature was greater than those at 13/7°C or at 30/18°C. Thus the increase in chlorophyll at 13/7°C from control, fertilized, irrigated, and irrigated-plus-fertilized plants was 250%, 113%, 263%, and 291%, respectively, while at 24/13°C the increase in chlorophyll contents of plants from the same treatments was 251%, 176%, 350%, and 395%, respectively. The increase in chlorophyll contents of plants at 30/18°C from the four treatments was considerably smaller than those at 24/13°C or 13/7°C except for the fertilized plants, which recorded an identical increase at both 13/7°C and 30/18°C.

Following the maximum production of chlorophyll the percent decreases were relatively greater in plants at 30/18°C than in those at 13/7°C or 24/13°C. Maximum decrease at 30/18°C was 53% from control plants and minimum 31% from irrigated plants at 13/7°C, the maximum was 50% from control and minimum was 28% from irrigated-plus-fertilized plants. At 24/13°C the maximum decrease was 46% from control and the minimum 21% from irrigated plants. Both chlorophyll \(a\) and \(b\) increased between 0 and 80 days in all the plants; however, the magnitude of increase from the irrigated and irrigated-plus-fertilized plants was greater than from the control or the fertilized plants at the three temperature regimes. The amounts of chlorophyll \(a\) and \(b\) from all the treated and untreated plants at 13/7°C and 24/13°C were greater than from those at 30/18°C. This was also true for total chlorophyll contents \((a + b)\). Chlorophyll \(a\) was always abundant in all the plants as compared to chlorophyll \(b\). Similar results for western wheatgrass have been reported by Rauzi and Dobrenz (1970). The percentage increase in dry
weight and chlorophyll \((a+b)\) of western wheatgrass over the control plants from the four treatments under the three temperature regimes is given in Table 1. Greater increases in dry matter and chlorophyll were recorded at 13/7°C; next at 24/13°C; and least at 30/18°C from irrigated and irrigated-plus-fertilized plants. The fertilized plants at each of the three temperature regimes accumulated small amounts of dry matter and chlorophyll. Earlier it was stated that plants at 24/13°C accumulated greater amounts of these constituents as compared to plants at 13/7°C or 30/18°C. This was true between the period from the initiation of the treatments to their respective peak growth. The percentage increase in dry weight and chlorophyll over the control plants at 24/13°C appears to be smaller than that recorded at 13/7°C. This is because of the greater amounts of these constituents from the control plants at 24/13°C. For example, the dry weight and chlorophyll contents of control plants at the time that these increases were recorded were 34% and 36% greater at 24/13°C than those at 13/7°C, respectively.

### Discussion

Results indicate that the dry matter and chlorophyll \((a+b)\) of western wheatgrass exhibited proportional fluctuations at three different temperature regimes for each of the four treatments.

The irrigated and the irrigated-plus-fertilized plants accumulated significantly greater amounts of dry matter and chlorophyll at each of the three temperature regimes than did the control and the fertilized plants. Additional water, alone or in combination with nitrogen fertilizer, enhanced chlorophyll synthesis as well as photosynthetic efficiency. This confirms that water may be a limiting factor under natural field conditions. Adequate soil water in the presence of adequate plant nutrients in the soil resulted in greater accumulation of carbon-containing compounds at 24/13°C than at 13/7°C or 30/18°C. The interaction between the intermediate temperature regime (24/13°C) and additional water and nutrients appears to have enhanced the energy harvesting and energy conversion efficiency of western wheatgrass. Increase in dry matter production with nitrogen fertilization and added water have been reported for many other forage plants (Klages and Ryerson, 1965; Baker and Jung, 1968; Power and Alessi, 1971; Hunst, 1973). Cool season grasses like western wheatgrass with the C₃ photosynthetic pathway usually respond better to nitrogen fertilizers (Williams, 1953). The increase in nitrogen content of foliage of western wheatgrass at 24/13°C may be caused by stimulation of N-uptake at this temperature. At the high temperature regime of 24/13°C, respiratory activity seems to increase. This provides additional energy for nitrogen and phosphorus uptake. Watschke et al. (1970) reported similar observations with Kentucky bluegrass (Poa pratensis L.). Although the concentration of chlorophyll (mg/g dry wt) during the period between the first sampling date and the peak growth was greater at 13/7°C from irrigated and irrigated-plus-fertilized plants, the total amount of chlorophyll (mg/pot) was greater at 24/13°C from these treatments. For example, at 13/7°C the total chlorophyll \((a+b)\) from irrigated plants was 6.26 mg/g dry matter and from irrigated-plus-fertilized plants it was 5.97 mg/g dry matter. From the same two treatments, the chlorophyll production at 24/13°C was 5.82 and 5.72 mg/g dry matter, respectively. The increased production of chlorophyll (mg/pot) at 24/13°C is attributed to greater production of shoot biomass and at 13/7°C to greater concentration of chlorophyll (mg/g dry matter). There seems to be a comparatively faster decline in dry matter and chlorophyll contents of irrigated and irrigated-plus-fertilized plants at 13/7°C and 24/13°C. Western wheatgrass is a cool
Fig 3. Interrelationship between dry matter and chlorophyll (a + b) of western wheatgrass from four treatments at three temperature regimes (1 = 13/7 °C; 2 = 24/13 °C; 3 = 30/18 °C).
Drought is a significant factor affecting the productivity of western wheatgrass (Triticum aestivum L.). The results of this study provide encouraging indications that both chlorophyll and dry matter contents can be estimated when some of the abiotic factors under field conditions are known. This hypothesis indeed warrants further investigations on coupling abiotic factors with chlorophyll and dry matter production under field conditions. Also, management strategies such as irrigation or fertilization of western wheatgrass at appropriate times for maximum production can be planned on the basis of information such as temperature regimes during the growing season. Cooler parts of the growing season appear to benefit western wheatgrass from addition of nitrogen fertilizers.

Literature Cited


Williams, J. S. 1953. Seasonal trends of minerals and protein in prairie grasses. J. Range Manage. 6:100-108.