Nonstructural Carbohydrates in Cool- and Warm-Season Perennial Grasses Adapted to Shaded Conditions

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Introduction

Forages frequently experience shaded conditions. Shading may occur during periods of cloudiness; from neighboring plants, especially when grown in swards with mixtures differing in height; from companion crops commonly used during seedling establishment; or lower plant parts may be shaded by upper plant parts. Additionally, there is increased interest in incorporating forage systems within agroforestry programs where forages may be shaded by associated trees. Shading has both direct and indirect effects on forage quality in that it can alter morphological development and yield. Cool-season (C_3) species are usually better adapted to shading than warm-season (C_4) species. Generally, growth rates and herbage yield of forages decrease with increasing shade. Morphological plasticity allows plants to maximize growth and to increase persistence under shaded conditions. Exposure to prolonged periods of shade causes most forages to modify proportioning of biomass among plant parts so that the potential for photosynthetic active radiation interception is maintained or increased and root growth is decreased. Shading often reduces tillering; however, stem length is often greater for plants adapted to shade. Shaded grass leaves typically are longer and thinner than when grown in full sunlight.

Shading usually has a smaller effect on forage quality than on morphology or yield. Nitrogen concentration is much more responsive than other quality characteristics. Shading usually increases N concentration substantially, especially in leaves. Most studies have also reported that shading decreases cell-wall concentration of forages. The hemicellulose fraction may be less sensitive to shading than are cellulose and lignin fractions. There is limited information about the effect of prolonged shading on nonstructural carbohydrates of forages. This study was conducted to compare the response of perennial C_3 and C_4 grass species to prolonged shading.

Materials and Methods

Four grass species, differing in photosynthetic type, were grown under three levels of solar radiation. The C_3 species were ‘Kentucky 31’ tall fescue and ‘Vantage’ reed canarygrass and the C_4 species were ‘Cave-in-Rock’ switchgrass and ‘Kaw’ big bluestem. Polypropylene fabric shades were suspended about 1 m above the soil surface to impose shade treatments of 37 and 70% sunlight beginning in early May during the 2 years of study. A nonshaded control received 100% sunlight. In late May or early June the first of three samplings was taken. Subsequent sampling occurred at 3-week intervals. Freeze-dried samples were solubilized and hydrolyzed for determination of nonstructural carbohydrates. Fractions were collected of water-soluble carbohydrates (monosaccharides), acid-extractable carbohydrates (sucrose plus short-chain fructosans), and α-amylase soluble carbohydrates (starch and other long-chain polymers). Sugar concentrations as glucose/fructose equivalents were determined by using an autoanalyzer. The three fractions were totaled and identified as total nonstructural carbohydrates (TNC).

Results and Discussion

Plants adapted to shade had lower TNC concentrations than those adapted to full sunlight, although differences were not statistically significant for nonlaminar herbage (stems and sheaths) of big bluestem and switchgrass (Fig. 1). The response was much greater in the two C_3 grasses (reed canarygrass and tall fescue) than in the C_4 grasses (big bluestem and switchgrass). Approximately one-third of the TNC was water soluble. Water-soluble carbohydrate concentration was less sensitive to shading than total nonstructural carbohydrates. In fact, the response in switchgrass, and nonlaminar herbage of reed canarygrass and tall fescue was nonsignificant. Acid-extractable carbohydrates also comprised about one-third of the TNC. Here the response was not significant for switchgrass or big bluestem but was significant for reed canarygrass and tall fescue. Shading reduced the α-amylase soluble carbohydrates only in the nonlaminar herbage of reed canarygrass and tall fescue.

Conclusions

Nonstructural-carbohydrate concentration was much more sensitive to shading in the two C_3 species than in the C_4 species. The greater plasticity in TNC concentration of cool-season species to shading than in warm-season species may be part of the mechanism that allows cool-season species to be better adapted to prolonged shading.

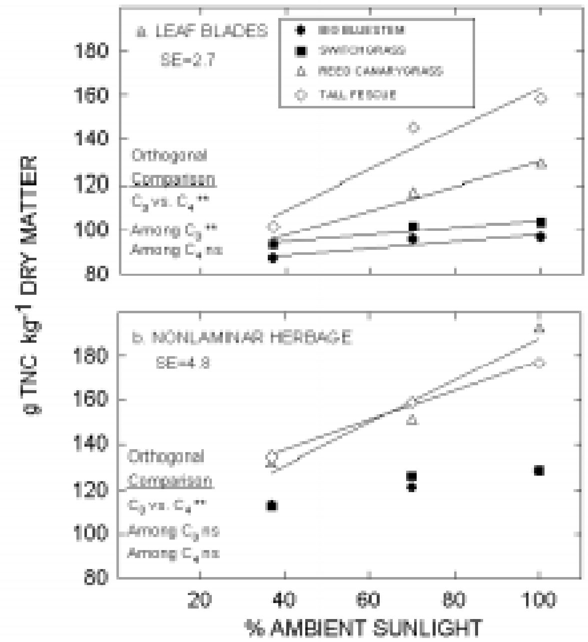

Figure 1. Total nonstructural carbohydrates in C_3 and C_4 perennial grass species adapted to different levels of sunlight

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