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PLOIDY EFFECTS ON PROTEIN, IN VITRO DRY MATTER DISAPPEARANCE, AND POTASSIUM/(CALCIUM + MAGNESIUM) EQUIVALENT RATIO IN TALL FESCUE FORAGE[1]

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Abstract

Use of higher ploidy levels to improve concentrations of protein and digestible matter in forage grass might adversely affect other plant characteristics. Tall fescue (*Festuca arundinacea* Schreb.) lines with 21, 42, or 84 chromosomes were used in a greenhouse study to evaluate the effects of ploidy level on forage in vitro dry matter disappearance (IVDMD), crude protein, K, Ca, and Mg concentrations, and the K/(Ca + Mg) ratio (calculated on an equivalent basis). Protein and IVDMD increased with higher ploidy. The K/(Ca + Mg) equivalent ratios were 1.35, 1.48, and 1.61 for the 21-, 42-, and 84-chromosome lines, respectively. This increase in ratio with increase in ploidy occurred because K concentrations (primarily in cell contents) increased more than Ca and Mg concentrations. Although all ratios obtained in the 25°C greenhouse were below the critical value of 2.2 that is associated with increased occurrence of grass tetany, the study suggests that increasing the ploidy level of forage grass may increase its protein and IVDMD concentrations, but may also increase its K/(Ca + Mg) ratio and the potential to induce grass tetany under some field environments.

Additional index words: ***Festuca arundinacea*** **Schreb., Forage quality, Grass tetany, Tissue culture.**

TALL FESCUE (*Festuca arundinacea* Schreb.) is a widely grown cool-season grass for which improved forage quality is a continuing objective of plant breeders (3). In 1944, Sullivan (7) suggested that higher ploidy level would result in higher cell content/cell wall ratios that might contribute to higher nutritive value of the forage. However, it has been difficult to evaluate forage quality effects of ploidy level while minimizing effects of genetic and environmental variables.

In 1985, Kasperbauer and Eizenga (6) used induced endomitotic divisions in tissue culture followed by plant regeneration to obtain 21-, 42-, and 84-chromosome lines from a 21-chromosome, cytologically verified haploid plant. Thus, they obtained unique materials with which to study ploidy effects on forage characteristics.

Although the early work of Sullivan (7) suggested that higher ploidy levels should result in more succulent forage that is higher in soluble dry matter and lower in structural constituents, possible unfavorable effects of increased ploidy level also need examination. Grass tetany, or hypomagnesemia, is a widely studied, complex metabolic disorder of ruminants that involves the K/(Ca + Mg) ratio in tall fescue and other forage grasses during cool seasons (2, 4). We hypothesized that K, Ca, and Mg concentrations might differentially change with modification of the cell content/cell wall ratio and that such differences might be associated with ploidy level. The present study was conducted to determine ploidy effects on concentrations of protein, in vitro dry matter disappearance (IVDMD), K, Ca, and Mg, and the K/(Ca + Mg) equivalent ratio in leaf blades of 21-, 42-, and 84-chromosome tall fescue lines, when all were grown under the same environment.

Materials and Methods

The 21-, 42-, and 84-chromosome lines were all regenerated from somatic tissue from the same cytologically verified haploid plant as described by Kasperbauer and Eizenga (6). The procedure minimizes somaclonal variation other than ploidy. The 21-, 42-, and 84-chromosome lines were increased through tillering. When sufficient tillering had occurred, ramets were potted and grown in 5-L pots containing a commercial potting soil mixture in a 25°C greenhouse during the winter and spring months. All pots were fertilized with diluted water soluble 20-20-20 (Peters Fertilizer Co., Fogelsville, PA)[3] on the same schedule. A randomized complete block design with five replicates was used. The plants received 16 h of supplemental light each day from Sylvania Gro-Lux wide-spectrum (FR96T12/GRO/VHO/WS) fluorescent lamps. The supplemental light began before sunrise, continued all day, and ended after sunset. The photosynthetic photon flux density (PPFD) of the supplemental light was about 110 μmol m^{-2} s^{-1}. The PPFD received by plants was much higher on sunny days.

Plants were cut back to 2.5 cm on 14 March, and leaf samples were harvested on 3 May and 7 July 1983. Only green leaf blades were sampled. Samples were quick frozen, freeze dried, ground to pass a 0.5-mm mesh screen and stored in darkness at −50°C until they were analyzed. Crude protein concentrations were determined by the Kjeldahl N procedure, and the method of Tilley and Terry (8) was used to determine IVDMD. The samples were analyzed for K, Ca, and Mg using atomic absorption spectrophotometry. The K/(Ca + Mg) ratios were calculated on an equivalent basis (2) to evaluate the relative potential of the three ploidy levels to cause grass tetany.

Results and Discussion

Leaf IVDMD, protein, K, Ca, and Mg concentrations for the 21-, 42-, and 84-chromosome lines are presented in Table 1. Increasing the ploidy level increased the concentrations of IVDMD and protein as predicted by the work of Sullivan (7). Also, all three of the mineral elements were higher in the higher ploidy samples.

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[3] Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA or the South Carolina Agric. Exp. Stn. and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

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Table 1. Leaf IVDMD, crude protein, K, Ca, and Mg concentrations as influenced by ploidy level in tall fescue.

	Somatic chromosome no.		
	21	42	84
	g/kg dry matter		
IVDMD	695 ± 6†	715 ± 7	729 ± 5
Crude protein	219 ± 4	227 ± 3	239 ± 8
K	32.2 ± 0.6	34.7 ± 0.9	41.6 ± 0.7
Ca	6.8 ± 0.1	6.6 ± 0.5	7.4 ± 0.2
Mg	3.3 ± 0.1	3.3 ± 0.1	3.6 ± 0.1

† Values are means ± SE.

The increase in K concentration with increased ploidy was more pronounced than the increase in Ca and Mg concentrations (Table 1). This differential change can be explained by the function and predominant location of these cations within the plant cell. In general, K is found in the cell contents while much of the Ca is associated with cell wall or other structural components. Therefore, as cell size (and the cell content/cell wall ratio) increases, the concentration of K would be expected to increase more than the concentration of Ca and Mg. The effect of this differential change in cation concentration relative to the potential for the forage to induce grass tetany in grazing cattle (*Bos taurus*) is reflected by a significant increase in the K/(Ca + Mg) ratio.

The three ploidy levels differed significantly [LSD (0.05) = 0.12] in K/(Ca + Mg) ratio. The ratios were 1.35, 1.48, and 1.61 for the 21-, 42-, and 84-chromosome lines, respectively. Although the highest value, 1.61, was well below the critical value of 2.2, which is associated with increased occurrence of grass tetany (1), all values might be proportionately higher in plants grown at lower temperatures (4). The increase associated with higher ploidy was consistent with hypothesized effects of increased ploidy level on cation balance. However, because the K/(Ca + Mg) equivalent ratio and the occurrence of grass tetany are higher during cool, wet seasons (1), the potential effects of higher ploidy levels on forage quality might differ with season.

We conclude that although higher ploidy levels in tall fescue may result in higher succulence (5), protein concentration, and digestibility, plant breeders should be aware that increased ploidy level might also result in higher K/(Ca + Mg) equivalent ratios. Nevertheless, the effects of ploidy on equivalent ratios should be further tested under field conditions during different seasons, especially in early spring.

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