Drought Tolerance—Program-Controlled Environmental Evaluation Among
Range Grass Genera and Species

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A limiting characteristic of many range grasses is inability to withstand the environment in semiarid and arid regions. Combinations and interactions of environmental factors of the Southwest produce a climate in which drought regularly occurs. Thus, improvement of drought tolerance of range and forage grasses is an important breeding objective. The manner in which drought-tolerant grasses can be isolated then becomes the major concern of grass breeders.

Considerable variation exists in drought terminology (9). May and Milthorpe (5) presented a review and discussed characteristics of drought-resistant crop plants. Three types of drought resistance were defined. Definitions were based on internal water content and tolerance to partial drying. They stated that plant breeders have been misdirected by placing too much emphasis on the ability of plants to grow in a dry climate. The statement was not supported by data.

Recently, Leivitt (4) presented a discussion of drought and stated that avoidance and tolerance are the components of drought resistance. According to Leivitt, drought-resistance measurement should consider both components and be based on the vapor pressure deficit that causes 50% killing. However, he stated that measurement techniques are not precisely defined. Thus, the proposal is a hypothesis, and if proven will demonstrate a process or characteristic but will not identify the influencing character(s).

A comprehensive review of hardiness of plants was presented by Leivitt (4) which included discussion of mechanism of drought injury and factors influencing drought. However, isolation of a specific characteristic as an exact measure of drought tolerance has not been reported. Many factors have been correlated with drought tolerance and various methods have been used to evaluate plants for soil and atmospheric drought response (9).

Until fundamentals of drought-tolerant characteristics within species is known, it would appear that plant breeders must use isolation techniques that are general and include plant response rather than specific plant processes or adjustments. A suggested definition is, “drought-tolerant range and forage grasses for the semiarid and southwest are economically desirable plants which are able to establish, develop, and maintain themselves through drought periods by efficient and economical use of moisture.” The definition includes environmental influence, allows for the expression of the physiological processes and morphological characteristics, and accounts for efficient and economical use of moisture for growth, survival, and dry matter production. However, specific characteristics to distinguish drought tolerance are not suggested. Up to the present time no one working with forage plants has been successful in establishing a relationship between observable characteristics and drought tolerance.

Terms for the three stages of growth (establish, develop, and maintain) included in the definition are, respectively, seedling drought tolerance, young plant drought tolerance, and mature plant drought tolerance. The interaction of environmental combinations with plant growth stages from establishment to maturity suggests that drought tolerance at each stage of growth is related but may be independently expressed. The seedling stage is the period from initial embryo germination until the stored food reserves of the seed have been depleted. This stage is relative to the other stages and would be difficult to describe by time, size, etc. The young plant stage is the period from independence from stored food reserve of the seed until the plant reproduces seed. The time span of seedling and young plant stages will vary among species but should be similar within species except as influenced by environmental conditions. The mature plant stage is the period following initial reproduction through the life span of the plant. Sufficient evidence is available to state that seedling, young plant, and mature plant drought tolerance varies among grass species. Thus, plant breeders must be aware of the developmental stages, particularly when one stage is critical from the standpoint of drought injury.

Range performance of plants continues to be the standard by which investigators rate tolerance regardless of the evaluation procedure. Range survival in semiarid and arid regions is subjected to fluctuations of environmental conditions on specific sites as well as various environments at different locations. Mass screening under range conditions is then a hazardous, time consuming, and uncertain endeavor. As a result, investigators have employed artificial drought conditions to measure drought tolerance.

Seedling grass plants have been used to study drought tolerance artificially. Investigators (7, 8) have stated that the seedling stage is the most critical period for drought tolerance of perennial grasses. Literature reveals that seedling techniques have proven successful for applied and basic genetic investigations. Fryxell (1) reviewed the research of several European workers and stated that the favorable results obtained by seedling selections might be investigated on a broad scale to determine the practical and theoretical effect of seedling selection techniques for several characters including drought tolerance. Recently Herbert (3) concluded that seedling evaluation of sugarcane selections would provide a reliable estimate of yield. Haskell (2) discussed the use of seedling morphology as a plant breeding technique and suggested that the greatest potential lay in breeding of polyploids.

A review of drought tolerance evaluation techniques was presented by Wright and Streetman (9). Most research reported has dealt with drought relationship among species. Results of drought tolerance evaluation of grasses by use of artificial drought chambers have shown varying degrees of correlation with field survival. Good agreement between tolerance of various grass species in artificial soil- and atmospheric-drought and in field drought studies were reported by Schultz and Hayes (8), Mueller and Weaver (7), and McAlister (6). McAlister (6) reported considerable variability among strains or seed sources of the range grass species studied. He stated that this variability could

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