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Role of leaf architecture under drought stress conditions in wheat (*Triticum aestivum* L.)

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Abstract

Understanding the physiology and genetic control of drought tolerance mechanisms using physiological and agronomical tools assist breeding programs seeking to improve crop plants. Physiological studies help to establish the precise screening techniques necessary to identify traits which are related to plant productivity. The selection of physiological traits has the potential to improve grain yield under drought in wheat. Therefore, understanding the physiological responses of crops in leaf anatomy, waxiness and pubescence under drought, and the underlying complex genetic control of different mechanisms of drought tolerance, is crucial to enhance screening for drought tolerance. Several strategies have been devised to overcome the problem of drought stress. In this connection, a few of the drought screening test have been identified for their use in breeding program. There is a strong coordination between various physiological responses in leaf architecture of crop plants to drought and their tolerance mechanisms.

Key words: drought, leaf architecture, leaf anatomy, leaf waxiness and pubescence

Introduction

The world population is expected to reach about 9 billion by the end of the 21st century and consequently the demand for wheat will increase by approximately 40% by 2020 (Rosegrant *et al*., 1995) and 60% by 2050 (Dixon *et al*., 2009). The demand for wheat specifically in developing countries is expected to raise even further more (FAOSTAT, 2006). The main way to maintain an adequate supply of food for future generations is by either expanding the land area, or by improving water availability and management leading to improve yield stability. The potential for expansion in agricultural land area is limited due to urbanization and industrialization. Therefore, the increased productivity under the available land and the given environment can come from economically sustained methods of crop improvement and judicial use of available moisture. Improving crop management and breeding techniques requires a detailed understanding of crop plants at various levels (organ, cell and gene), their environment and the G x E interaction. Direct indices like that of breeding for abiotic stresses are not available with breeders for developing genotypes under drought situations (Singh *et al*., 2015). Drought is accepted as the major abiotic stress reducing

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yield of wheat and other crops in water-limited areas. There has been a substantial increase in the number of physiologically oriented studies on drought tolerance during the past 20 years. Some of these physiological studies involve leaf architectural traits.

Leaf architecture traits

Leaf anatomy

The leaf structure and features which are play important role in the drought condition include leaf area, variation in leaf cuticle thickness, leaf water potential, leaf rolling, leaf waxiness, early maturity and prolonged stomatal closure leading to a reduced total seasonal evapo-transpiration, (Fischer and Wood, 1979), leaf canopy temperature, cell osmotic adjustment, cell membrane stability and maintenance of photosynthesis through persistent green leaf area (stay green) (Fig. 1). The traits like ion linkage, relative water content (RWC) (Malik and Wright, 1995), excised leaf water retention capacity (ELWRC), seedling survivability and canopy temperature have been considered as major physiological traits for study under drought stress.

Leaf Area Index

Many aspects of plant growth are affected by drought stress, one of them is leaf expansion, which is reduced due to the sensitivity of cell growth to water stress. The leaf is the first organ to show visible signs of drought which provide a cheap and easy to manipulate trait for selection under water deficit. Water stress also reduces leaf production and promotes senescence and abscission (Karamanos, 1980), resulting in decreased total leaf area per plant. Reduction in leaf area reduces crop growth and thus biomass production. Seed production, which is positively correlated with leaf area (Rawson and Turner, 1982), may also be reduced by leaf area reductions induced by drought stress. According to the hypothesis lower leaf area index can maintain leaf water potential at a higher level during the growth of the crop, thus reducing water stress.

Leaf waxiness, pubescence

Leaf waxiness or glaucousness, the waxy bloom on the surface of leaves and other plant parts, has been shown to be associated with grain yield in wheat in dryland field environments (Johnson *et al*., 1983). Glaucous lines of wheat had increased yields under drought conditions over their non-glaucous isogenic pairs (Johnson *et al*., 1983). Glaucousness and/or pubescence increases surface reflectance to lower the surface temperature of photosynthetic tissue (Richards *et al*., 1986). The quantity of epicuticular waxes has showed an association with water loss through the cuticle and disease susceptibility (Clarke *et al*., 1994). In water-stressed plants, the effect of glaucousness could be greater due to its effect on reduction of leaf temperature (Richards *et al*., 1986), which would reduce both residual and stomatal water loss. The visual rating of germplasm collections under dry growing conditions for glaucousness would be an effective means of identifying genotypes worthy of further study (Clarke *et al*., 1992).

Leaf rolling and thickness

Leaf rolling is a result of other avoidance mechanisms which result in high leaf water potential (Fukai and Cooper, 1995). Leaf rolling reduces the leaf area exposed to light reducing the activity of chlorophyll and the process of photosynthesis exhibit negative relationship with chlorophyll content and harvest index. Rolling of leaves leads to subsidized activity chlorophyll through lessened exposure to sunlight, which in turn results in low photosynthesis and ultimately poor grain yield. It is an important trait for shedding radiant energy and is likely to result in cooler leaf temperatures, less transpiration, and lower respiratory losses. It may also be important for maximizing photosynthesis and transpiration efficiency by unrolling in the morning when the plant has a high leaf water potential and vapor pressure deficit is low, and rolling when conditions become more unfavorable (Richards et al., 2002).

Stay green

Leaf senescence comprises a series of biochemical and physiological events which include the final stage of development, from the fully expanded state until death. During leaf senescence, the photosynthetic apparatus is dismantled and nutrients are exported to young tissues or storage organs. Genetic variation exists for foliar senescence and genotypes and plants with leaves which remain green for longer than normal are defined stay-green. Over fifty years ago it was realised that the diversity in yield for most crops is mainly a consequence of variation in the duration, rather than the rate of photosynthetic activity (Watson, 1952), and so, delayed leaf senescence (i.e., stay-green) has long been considered to be a desirable trait in cereal breeding. So, the ability to maintain green leaf area duration during the grain filling is one of the important physiological traits that have an implication on yield potential related to increasing assimilate (i.e. Source) availability. The leaf senescence also depends on the wheat species. Thus, under water stress, the flag leaf senescence in the durum wheat variety occurs much sooner than in bread wheat variety reported by (Mekliche *et al*., 1992; Gate *et al*., 1992). This leads to the decrease in the 1000 grain weight eventually because of decrease in grain filling duration due to the acceleration of the flag leaf senescence reported by Day and Intalap (1970).

(a)

(b)

(c)

(d) (e) (f)

Figure 1. Leaf architecture traits of wheat genotypes under drought stress conditions a. leaf rolling b. Normal and unrolled leaves c. waxiness on stem and leaves d. ground cover and mulching e. stay green trait g. tip sterility

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