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DROUGHT TOLERANCE STUDIES IN WHEAT (*TRITICUM AESTIVUM* L.)

S. MAHPARA [1]*, S.T. HUSSAIN[1], J. FAROOQ[2]

*E-mail: drmaha@uaf.edu.pk, jehanzeb1763@hotmail.com

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ABSTRACT. Wheat is a foremost staple food crop of Pakistan and plays a vital role for stability of country's economy and people's food requirement. Shortage of water has remained a consistent problem for the farmers over past few years and different agronomic techniques have been introduced into the limelight. But there is an immense scope of making some genetic manipulations to improve/enhance the drought tolerance of wheat. It has been observed by many researchers that yield in drought stress conditions, is a fine fusion of the traits like days taken by crop to reach physical maturity, water use efficiency, crop water use and harvest index. Drought being one of the main limiting factors of wheat production should be highly preferred in the future wheat improvement programs.

Key words: Wheat; Stress; Drought; Genetic manipulations; Hydroponic culture technique.

INTRODUCTION

Human beings directly depend on plants to obtain their food **(**Farooq *et al.,* 2011b**)**. Wheat is the most widely grown and consumed food grain of the world **(**Farooq *et al.,* 2011a**)**. Wheat is also a very important trade commodity as one fifth of the world wheat production is traded worldwide (FAO, 2003). With progressive global climatic change and increasing shortage of water resources and worsening eco-environment, wheat production is influenced greatly (Singh and Chaudhary, 2006). The increasing yield potential has indisputable importance in solving world hunger issue. Since yield has a complex trait and is strongly influenced by the environment, severe losses can be caused by drought, a stress common in most arid and semi-arid areas. Accordingly, drought tolerance is one of the main components of yield stability and its improvement is a major challenge to geneticists and breeders. Wheat breeding programs aim to reorganize genotypes possessing improved yields,

[1] College of Agriculture, D.G. Khan, Pakistan
[2] Cotton Research Institute (AARI), Faisalabad, Pakistan

adaptation to changing climatic conditions and a balanced food quality.

The term stress has various meanings but generally it is an altered physiological condition, caused by factors that tend to disrupt the equilibrium of a plant's systems (Gaspar *et al.,* 2002). Water stress can be defined as the lack of adequate moisture necessary for a plant to grow normally and complete its life cycle (Zhu, 2002). And in developing countries 37% of the area is semi-arid in which available moisture is the primary constrained to wheat production (Dhanda *et al.,* 2002).

On the basis of climatic conditions Pakistan falls into arid and semi-arid lands. These lands constitute about 88% of the country's total geographic area of 79.6 million hectares (mha). The agriculture in these arid and semi-arid areas is mainly dependent on the scanty and erratic rainfall (Mujtaba and Alam, 2002).

Occurrence of drought and its effects

Drought stress not only affects plant growth and development but ultimately productivity in almost all the cereals, thus it is one of the most serious threats to world agriculture (Hamayun *et al.,* 2010, Subhani *et al.,* 2011). The situation demands crop breeding for drought stressed areas utilizing using traditional along with modern molecular techniques.

The genes for drought tolerance are regulated at once under drought conditions and produced the respected products that response to signal transduction, stress response and help the plant to withstand under drought stress (Zhou *et al.,* 2010). The effect of water stress on the yield and yield components of durum wheat at different growth stages have been the subject of many studies (Simane, 1993; Solomon *et al.,* 2003). Considering the entire plant, the effect of a particular stress generally causes a decrease in photosynthesis and growth. Water stress results in the closure of stomata which in turn reduces transpiration and CO_2 diffusion. In the most extreme cases, the permanent wilting point will be reached; runaway xylem cavitations occur, followed by desiccation and the death of the plant.

Leaf stomata close in response to either light (mediated by the pigment zeaxanthin), CO_2 concentration in the leaf, or organ water potential (dehydrating roots send abscisic acid to the leaves signaling them to close stomata). The main driving force of water from the soil to the leaves is the difference in water potential between the outside and the inside of the leaf. As water vapor diffuses from the inside of the leaf it passes through the stomata and into the atmosphere. This diffusion creates a negative pressure which is felt through the xylem down to the roots. The roots in turn remove water from the soil. With decreasing soil water reserves the plant closes the stomata in an effort to reduce water loss and maintain the continuous column of water that exists from the root hairs to the leaf mesophyll.

Mechanism of drought tolerance

Avoiding drought is an extremely important adaptation for survival in a water limiting environment. However, plant physiologists are generally more interested in plants that are able to tolerate drought (i.e. plants that have evolved a number of anatomical, developmental, biochemical, physiological and molecular adaptations to limit the drying out of vegetative tissues). The mechanisms for coping with drought in plants can be divided into three categories: 1) escape, 2) avoidance, and 3) tolerance. Cultivars that have the ability to escape water stress are able to complete their life cycles before the water deficits can have an extreme effect on performance. Ideally, these cultivars exhibit high rates of growth and gas exchange using the available moisture to successfully reproduce before the time when water is limited. Associated with successful escape of water stress are increased stem and root carbohydrate storage, and the ability to mobilize reserves during increasing drought. Plants may be able to tolerate moisture stress by avoiding tissue dehydration. This is done by maintaining tissue water potential as high as possible. A number of mechanisms exist by which plants can avoid dehydration by minimizing water loss. These include closing of stomata, reducing light absorbance (i.e. curling of leaves), possessing dense trichomes, which increase light reflectance, exhibiting a steep leaf angle, or by decreasing canopy leaf area by developing smaller leaves or shedding older leaves. Other ways to avoid dehydration is to maximize water uptake by increasing investment in root growth to provide the plant water from greater depth.

Lastly, tolerance of water deficiency is associated with plants that, at the cellular level, have the ability to make osmotic adjustments, have more rigid cell walls or have smaller cells. At the organ level, plants with smaller leaves have the ability to tolerate drought stress as they have a greater ability to dissipate extra solar energy as well as a greater efficacy in controlling water loss through stomata.

Success of certain crop plants under drought environments merely depends on presence of an optimum combination of these three resistance mechanisms (Malik *et al.,* 1995). Breeding for drought in past has been facilitated by conventional breeding approaches by concentrating on yield and it’s relating components (Raziuddin, 2003). Breeding for new and improved cultivars against abiotic stress needs a thorough understanding of the reactions of plant tissues and organs against the prevailing stress.

Drought effects on wheat productivity

Although wheat breeders have been successful in increasing yield under productive conditions, but success has been more difficult to achieve in production regions where environmental stresses like water stress occur (Blum, 1996; Rajram *et al.,* 1996). Exploring physiological mechanisms of water stress tolerance for different wheat genotypes is of importance to find out new drought resistant gene resources (Shao *et al.,* 2005).

Substantial losses in wheat grain yield have been reported due to water deficiency depending on the developmental stages at which crop plant experiences stress. The intensity of the response depends on the stress severity and its duration, as well as the plant developmental stage. Wheat crop needs water for the whole growth period, but there are some stages, which are more vulnerable to water shortage, and any water shortage during this period may result in significant yield losses. The shortage of irrigation water at crown root initiation, booting and early grain fill period results in significant yield losses (Anonymous, 2007). But it is considered that water stress is usually less detrimental to grain yield when occurring early in the crop cycle (Blum, 1996). Water stress at stages before anthesis can reduce number of ear heads and number of kernels per ear (Denčić *et al.,* 2000; Mary *et al.,* 2001). While water stress imposed during later stages might additionally cause a reduction in number of kernels/ears and kernel weight (Gupta et al., 2001). Zhang and Oweis (1999) reported that wheat crop was found to be more sensitive to water stress from stem elongation to heading and from heading to milking.

Less decrease in wheat yield under water stress is usually observed in water stress tolerant cultivars as compared to sensitive ones (Gáspár *et al.,* 2005). Baser *et al.* (2004) studied the effect of water stress on the yield and yield components of winter wheat and found a decrease of about 40% in yield under water stressed conditions as compared to control.

There are also several approaches to investigate morphological traits for the purpose of increasing yield under water limited conditions. Leaf rolling, induced by loss of turgor and poor osmotic adjustment represents an important drought avoidance mechanism (Richards, 1996). Under drought condition, leaf rolling decreased stomatal closure (O'Toole *et al.,* 1979b). Apart from conventional methods of selection for drought tolerance, great efforts have been made to produce genetically modified plants tolerant to drought. Genetically modified wheat showed high drought tolerance in field conditions (Kereša *et al.,* 2008).

Peduncle length has been also suggested as useful indicator of yield capacity in dry environments. Kaya *et al.* (2002) have been found a strong positive correlation between peduncle length and grain yield. In other cases, such relationship has been found inverse (Briggs and Aytenfisu, 1980) or no relationship (Villegas *et al.,* 2001) depending on the environment. The genotypes exhibited strong leaf rolling under water deficit condition had more grain yield, kernel numbers per spike and water use efficiency (Bogale *et al.,* 2011).

The economic use of water in drought prone areas is facilitated by controlling the stomatal action which reduces the losses of water by transpiration. Higher stomatal resistance reduces transpirational loss and hence can improve water use efficiency of the crop under water limited conditions (Munir *et al*., 2007). Significant genetic variation exists for these traits and has been found to be related to drought resistance (Kirkham, 1980; Martin *et al.*, 1989). Semi-dwarf wheat varieties are better adapted to moist growing conditions than dry plain areas (Briggle and Vogel, 1968).

Breeding for drought tolerance

Drought offers great challenges to plant breeders around the globe. In Pakistan, scientists are primarily working for wheat lines suitable for irrigated areas, whereas dry regions are given secondary importance. Most of the studies on drought mostly concentrated on response of natural drought in the field where drought is usually uncertain and unpredictable using conventional techniques. Mostly breeders in Pakistan rely on conventional breeding procedures like introduction, selection, hybridization and mutation. But in contrast to Pakistan, novel methods such as *in situ* and *in vitro* techniques are also used in other parts of the world.

Different stress resistant lines of different crop plants have been developed by various scientists (Ram and Nabors, 1985; O'Toole and Chang, 1979a). Mohmand and Nabors (1989; 1990; 1991) reported drought tolerant wheat somaclonal lines induced through the use of polyethylene glycol (PEG). Raziuddin (2003) proved that hydroponic culture technique can be effectively utilized for screening a large number of wheat genotypes and lines at different vegetative stages for not only drought but other abiotic stresses as well.

Summary

Pakistan is an agricultural country as this sector is occupying more than 50% of country's labor force. Wheat is most important crop of agriculture sector of Pakistan because it shares major contribution to the nation's economy and on the other hand fulfils the food and feed requirements of humans and farm animals. Wheat crop is facing problem in terms of its yield and production due to shortage of water. This shortage of water for a plant at such a level that it can affect the metabolic activities of the plant and reduce its productivity is termed as drought. In wheat crop, drought stress though affects all the growth stages of crop but yield is significantly reduced if drought stress occurs at various critical stages e.g. tillering, booting, anthesis, grain formation and grain filling. The possible mechanism by which a plant may survive of water shortage are escaping; by completing

life cycle before onset of drought, avoidance; by adopting special modification in the systems by conservation of water and finally by completely tolerating it by minimizing the dehydration losses. The breeder has a tough job to do for the development of varieties which can effectively tolerate drought stress. This review highlighted the fact that there is a need of changing the common breeding procedures, which has become too conventional to be capitalized in this modern era. New advanced screening, hybridization and selection techniques will be replaced with conventional techniques. Plant tissue culture, hydroponic culture, *in vitro*, *in situ*, somaclonal variants, protoplast culture should be utilized in the breeding for drought stress.

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