

Perspective of barley drought tolerance; methods and mechanisms comparable to other cereals

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ABSTRACT

Despite recent agricultural advances, climate play key role in today's agricultural production. In fact, due to the recent climate change yield of many crops reduce marginally, especially due to the temperature increase, uncertainty of monsoon and uneven distribution of precipitation. Barley is one hope to mitigate these challenges as possess natural potential which is not common in most of the cereals and its wild relatives also. It is also alternate flour to wheat (especially hull less barley varieties). Barley is C₃ plant, the layer of green grain i.e. pericarp, in particular act as C₄ photosynthesis and hence contribute more as comparable to other cereals as in pericarp of barley large amount of carbon fixation takes place due to PEP carboxylase. Barley possesses all the physiological, morphological and biochemical traits to withstand during water stress. New germplasm and molecular tools make it possible to develop better variety faster for drought or salinity tolerance, but challenges still remain due to complexity of drought and salinity tolerance. The mechanism of drought tolerance can best studied under the heading of barley. In this paper, we will review progress on drought and saline tolerance in barley.

Keywords: Barley, Drought and salinity tolerance.

Barley (*Hordeum vulgare* L.) is the leading cereal crop ranks next only to wheat, rice and maize among the cereals cultivated worldwide. In India, barley is important cereal crop cultivated in rabi season, after wheat in both area and production. It has been widely used in different purposes such as, stable food for mankind, cheap ingredient in whisky and beer production industry and feed for animals. It can grow on wide range of environmental conditions than any other cereals and spread in tropical to sub-tropical areas. Barley is self pollinated, diploid crop and vegetatively completely similar to that of other cereals, particularly to wheat except the auricle which are conspicuous on the leaf in case of barley.

Natural adaptations of barley to drought compare to other cereals

Barley is the most drought and salinity tolerant than any other cereal crops and that's why it is an ideal model crop to study the genetic and mechanism of drought in cereal crops. Generally the mechanisms of drought tolerance are well-knowingly classified into three categories first is drought escape, second one drought avoidance and third drought tolerance Li *et al.* (2007). Drought escape is defined as the ability of a plant to complete its life cycle before serious soil and plant water deficits develop. Drought avoidance is the ability of plants to maintain relatively high tissue water potential despite a shortage of soil-moisture, whereas drought tolerance is the ability to withstand water-deficit with low tissue water potential. Number of traits that have been investigated for drought tolerance include (1) physiological/biochemical traits, such as osmotic adjustment capacity, proline content, stomatal conductance, plant water status, water-soluble carbohydrates, epidermal conductance, canopy temperature, relative water content, leaf turgor pressure, ABA content, transpiration efficiency, water use efficiency and carbon isotope discrimination; and (2)

developmental/morphological traits, such as leaf emergence, leaf area index, leaf waxiness, stomatal density, tiller development, flowering time, maturity rate, cell membrane stability, and root characteristics. However, despite of this, yield and yield stability under drought are still considered as the most important parameters for drought tolerance.

When barley crop are under the drought stress, a number of physiological responses have been observed and reported by number of scientists. Now we go through individual traits mechanism related to drought under the heading of the barley. In some cultivated cereals particularly in barley osmotic adjustment has been found to be one of the most effective physiological mechanisms underlying plant resistance to water deficit Turner & Jones (1980) and Blum, (1988). Osmotic adjustment, as a process of active accumulation of compatible osmolytes in plant cells exposed to water deficit, may enable (1) a continuation of leaf elongation, though at reduced rates (2) stomatal and photosynthetic adjustments (3) maintained root development and soil moisture extraction Morgan and Condon (1986); (4) delayed leaf senescence Hsiao *et al.* (1984); (5) better dry matter accumulation and yield production for crops in stressful environments Boyer (1982) and Blum (1988). Recently, mapping the single gene and/or quantitative trait loci (QTLs) for osmotic adjustment in cultivated cereals has been conducted in wheat Morgan and Tan (1996), rice Lilley *et al.* (1996) and barley Teulat *et al.* (1998).

Accumulation of glycine betaine is one mechanism for barley response to drought or salt stress. Ishitani *et al.* (1995) reported a gene up-regulated by drought stress and encoding an enzyme of known function - betaine aldehyde dehydrogenase (BADH). This enzyme is the last step in the betaine synthesis pathway. The mRNA level of BADH increased significantly when barley was subjected to

drought or saline conditions. Sorbitol has a role in osmoregulation. The enzyme aldose reductase involved in the accumulation of sorbitol was regulated by ABA Bartels *et al.*, (1991).

Transcripts for the biosynthesis of jasmonate were highly up regulated by drought, which is well-known as a signal in pathogen defence and under drought conditions. These genes included jasmonate induced proteins (JIPs) and a methyl-jasmonate inducible lipoxygenase. Lipoxygenase and fatty acid-oxidase may be in the signal transduction pathway that is regulated by jasmonates. Two arginine decarboxylases are induced by drought, which may be involved in the synthesis of polyamines that are observed in many stressed plants Ozturk *et al.*, (2002).

Another one mechanism is the carbon isotope discrimination ratio of the floral parts, leaves, and stems of barley and oat plants were measured to determine, net CO₂ fixation by PEP carboxylase makes a significant contribution to total carbon fixation in these tissues. There are numerous reports of certain tissues or organs from C₃ plants having characteristics typical of C₄ photosynthesis. In simple words though the barley is C₃ plant, the layer of green grain i.e. pericarp, in particular act as C₄ photosynthesis and hence contribute more as comparable to other cereals as in pericarp of barley large amount of carbon fixation takes place due to PEP carboxylase. For example, high levels of activity of enzymes typical of C₄ plants have been found in the seed pod of *Vicia faba* L. and in the pericarp of barley Duffus and Rosie, (1973), and in the green organs of the wheat ear and oat panicle (Wirth *et al.*, 1977). If these enzymes, notably PEP carboxylase, were to function as they do in the C₄ pathway of photosynthesis, and if in so doing they made a significant contribution to net carbon gain in these organs, we would expect the $\delta^{13}C$ value of these plant parts to differ from those characteristic of the leaves of C₃ plants.

Drought is the single most important factor limiting yield. Yet, compared to other cereals, barley is well adapted due to better water-use efficiency and mechanisms of drought escape, avoidance and tolerance. Three strategies have been considered in relation to the optimum environment for selection Byrne *et al.*, (1995). The first strategy is based on selection where growing conditions are optimum or near-optimum. The second strategy assumes that the optimum environment(s) for selection should be as representative as possible of the target population of environments Blum, (1988). The third strategy, the alternate use of optimum and stressed conditions has been used to select genotypes that yield well in both conditions Calhoun *et al.*, (1994). Ceccarelli *et al.* (1998) demonstrated that the most effective way to improve productivity of barley grown in drought conditions is to use locally adapted germplasm and select in the target environment(s).

Achievements and Challenges:

Breeding for drought resistance based on direct selection for grain yield in the target environment (empirical or pragmatic breeding) appears intuitively to be the most obvious solution, this approach faces two major problems; a) the precision of the yield trials conducted under drought conditions, and b) the existence of several target environments, each characterized by its own specific type of drought and combination of stress (Ceccarelli and Grando, 2002). Breeding for drought resistance based on putative traits, in other words, traits associated with drought resistance, but easier to select for than grain yield has been very popular, but the progress is still slow. In the case of barley, the traits more consistently associated with higher grain yield under drought include growth habit, early growth vigour, earliness, plant height under drought, long peduncle, and short grain filling duration. However, most of traits were controlled by multiple genes and environments played an important role in the expression of specific traits. Identification of molecular markers for these traits provided tools for directly selection of drought tolerance. In several studies, it has shown that the developmental genes are key factors in the determination of yield potential under drought condition Baum *et al.*, (2003) Teulat *et al.*, (2001b). These genes include photoperiod response, basic vegetative period, earliness and vernalization. These genes have been well characterized and tagged using molecular markers Boyd *et al.*, (2003). Molecular markers, especially the candidate genes regulated by drought can be used to characterize the germplasm Maestri *et al.*, (2002). In addition, genes controlling plant height on chromosome 3H and 5H are obviously target loci for selection of drought tolerance using molecular markers. The other candidate loci included the major QTLs on chromosome 6H and 7H for OA, RWU and DIS. Extensive research has been devoted to the characterization of genes induced or up-regulated by drought. The up-regulation of a drought-induced barley gene (HVA1) improved tolerance to drought and salinity in rice grown under controlled conditions Xu *et al.*, (1996). Encouraging as these results are, there is widespread skepticism that up-regulation of one or more genes encoding structural proteins may not lead to meaningful results in terms of field tolerance to drought.

By account of additional features, such partially act as C₄ plant (pericarp) which help the panicle during actual grain filling stage, the comparable yield of barley increases in drought condition. Besides this the Osmotic adjustment, as a process of active accumulation of compatible osmolytes in plant cells exposed to water deficit play key role in drought as it may enable the plant a continuation of leaf elongation, though at reduced rates, stomatal and photosynthetic adjustments, maintained root development soil moisture extraction and delayed leaf senescence. Though, drought is the single most important factor limiting yield. Yet, compared to other cereals, barley is well adapted due to better water-use efficiency and mechanisms of drought escape, avoidance and tolerance.

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