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Sources of tolerance to terminal drought in the chickpea (*Cicer arietinum* L.) minicore germplasm

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ABSTRACT

Chickpea cropping system is largely rainfed and terminal drought is a major constraint to its productivity. Currently available drought tolerant chickpea genotypes are very few. Considering that a large number of traits are collectively needed to confer yield under drought, there is a need to identify more genotypes to introduce diversity in drought tolerance breeding programs. The minicore ($n = 211$) chickpea germplasm collection has been evaluated over three years for drought tolerance index (DTI), calculated as the standard residuals, through a regression approach considering drought yield as a function of days to flowering, yield potential and the residual or drought response, in the short season environment of South-India. The minicore collection accessions exhibited large range of variations for days to 50% flowering (26–78 d) and maturity (70–120 d), shoot biomass (1500–4940 kg ha^{-1}) and seed yield (210–2730 kg ha^{-1}) under drought. The heritability for the shoot biomass and seed yields under drought stress (shoot biomass 0.118–0.461; seed yield 0.511–0.795) were relatively higher than that under optimally irrigated environment (shoot biomass 0.232–0.447; seed yield 0.322–0.631). Both the seed yield under drought and DTI showed significant accession × year interaction. A categorization of the DTI using a cluster analysis has revealed five major groups with 5 accessions in highly tolerant group, 78 in tolerant, 74 in moderately tolerant, 39 in sensitive and 20 in highly sensitive groups. ICC 4958, a previously identified drought tolerant genotype, was among the moderately tolerant while Annigeri, a well-adapted cultivar, was in the tolerant group. Though the heritability of DTI was slightly lesser than that of the yield, the DTI represented terminal drought tolerance *per se*, and was independent of phenology and yield potential influences.

1. Introduction

Globally, chickpea is the third most important pulse crop with a production of 9.3 M t from an area of 11.7 M ha (FAO STAT, 2007). About 90% of this crop is grown rainfed under receding soil moisture conditions in the postrainy season after the main rainy season by resource-poor farmers (Kumar and Abbo, 2001) with intensities and distribution of crop season rainfall varying from almost nil (Johansen et al., 1994) to >400 mm (Berger et al., 2004). Terminal drought stress of varied intensities is, therefore, a primary constraint to chickpea productivity. In the current scenario of water limitation, there is little scope to increase the irrigated areas of this crop. Moreover, the slow and steady migration of this crop towards lower latitudes in India (Gowda et al., 2009) and rainfed low input environments such as Australia, Myanmar, Canada and south eastern Africa, the chances of exposure of the crop to higher drought intensities and warmer environments constantly increases. In recent years, early maturing varieties that escape terminal drought and heat stress were developed by the breeders and were adopted by farmers with considerable success (Kumar and Abbo, 2001). However, drought escape fixes a ceiling on the potential yield and cannot utilize the opportunities, as and when available, of extended growing periods (Blum, 1988; Ludlow and Muchow, 1990; Bolanos and Edmeades, 1996). Therefore for achieving high and stable yields under drought, it is necessary to develop drought tolerant/avoiding varieties, i.e. capable of using more water and better (Ludlow and Muchow, 1990; Johansen et al., 1997).

Drought tolerance is a generic term for a highly complex phenomenon of plant responses. In a practical sense, it is the relative ability of the crop to sustain adequate biomass production and maximize crop yield under increasing water deficit through out the growing season, rather than the physiological aptitude for plant survival under extreme drought shock (Serraj and Sinclair, 2002), which has a limited economic interest for the farmers. This has led to a focus on escape and avoidance strategies such as breeding early maturing varieties (Kumar and Abbo, 2001) and selecting for large root systems that can sustain better productivity under

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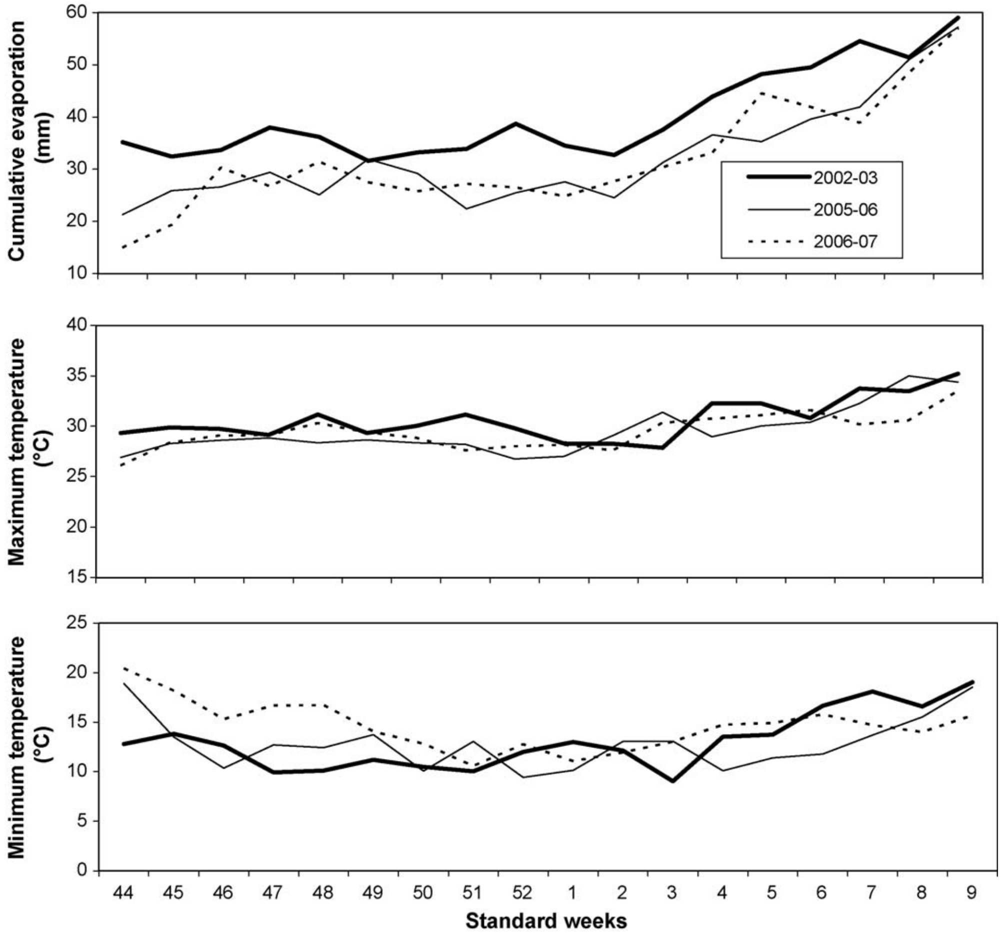

Fig. 1. Weather during the crop growing seasons (November to February) of 2002–03, 2005–06 and 2006–07.

opportune environments (Saxena et al., 1995; Singh et al., 1995; Kashiwagi et al., 2005). Drought tolerant genotypes, on the basis of yield under drought, have been identified in the past by screening accessions of chickpea germplasm that were known to come from drought-prone areas (Saxena, 1987, 2003; Saxena et al., 1993). However, the extent of genotypic variation for drought tolerance available in the germplasm bank is not clear. Yet, it is desirable to have greater genetic options and diversity for better breeding success. The establishment of the minicore collection (10% of the core collection and 1% of entire collection) of chickpea germplasm representing most of the genetic diversity available in the entire collection (Upadhyaya and Ortiz, 2001) offered an opportunity to tap new sources of terminal drought tolerance in a more systematic manner.

Chickpea yields are highly prone to large genotype by environment (G × E) interactions (Saxena, 1987; Krishnamurthy et al., 1999, 2004; Berger et al., 2004, 2006; Kashiwagi et al., 2008a). Several traits are expected to play a collective role in adaptation to terminal drought (Ludlow and Muchow, 1990; Saxena and Johansen, 1990; Johansen et al., 1997; Soltani et al., 2000) and these traits are less likely to be influenced by G × E. Under such circumstances, a better strategy of breeding for drought tolerance is to select for traits, which can be more readily related to crop performance under particular environment, rather than yield. To mention some of them are early growth vigor, harvest index, larger root system (as seen in ICC 4958), twin pods for rapid remobilization (JG 62), smaller pinnules (ICC 10448) or fewer pinnules (ICC 5680) for less transpirational demand (Saxena, 2003). However, prior to consideration for breeding, the magnitude of contribution of these traits in the target environments need to be ascertained and confirmed to be significant for prioritization. Such contributions were established to be major in terminal drought-prone chickpea (Kashiwagi et al., 2006) or for sorghum and maize (Sinclair and Muchow, 2001; Hammer et al., 2009) for traits like larger and deeper root system and for the rate of partitioning (Krishnamurthy et al., 1999), while for others, such estimations are still required. Therefore the key characteristics for selection still remain to be biomass and the yield.

Yield under drought can be explained by traits that are fully independent of the response of genotypes to the drought environment. As mentioned above, crop duration in chickpea plays a critical role and so, while selecting germplasm for “drought tolerance”, it is important to properly separate attribute that are inherent to a given line (constitutive traits) from those that only reflect a genotype’s response to stress (adaptive traits). Also crop duration is a major characteristic that contributes to G × E interactions in chickpea (Berger et al., 2004, 2006). In the past a drought tolerance index (DTI), based on the seed yield under drought after removal of the known contributory effects of drought escape (flowering time) and yield potential, has been successfully employed to assess the drought response in pearl millet and chickpea under terminal drought-prone conditions (Bidinger et al., 1987, Saxena, 1987, 2003), and has pointed to several processes explaining DTI differences under stress, i.e. seed setting and grain filling.

The objective of this study was to assess the extent of variation available in the chickpea minicore germplasm collection for drought tolerance, assessed with the DTI, and identify contrast-