Weather and Climate Extremes 7 (2015) 24–35

Contents lists available at ScienceDirect

Weather and Climate Extremes

journal homepage: www.elsevier.com/locate/wace

# Drought risk management for increased cereal production in Asian Least Developed Countries

Md. Rezaul Karim [a,b,*], Mohammed Ataur Rahman [c]

[a] College of Agricultural Sciences, IUBAT—International University of Business Agriculture and Technology, Dhaka 1230, Bangladesh
[b] Department of Soil Science, EXIM Bank Agricultural University, Bangladesh (EBAUB), Sagor Tower, Holding No: 69-69/1, Boro Indara Moor, Chapainawabganj 6300, Bangladesh
[c] Centre for Global Environmental Culture (CGEC), IUBAT—International University of Business Agriculture and Technology, Dhaka 1230, Bangladesh

ARTICLE INFO

*Article history:*
Received 6 December 2013
Received in revised form
21 September 2014
Accepted 10 October 2014
Available online 3 January 2015

*Keywords:*
Drought
Water-use efficiency
Cereal
Yield
Balance fertilization
Efficient genotype

ABSTRACT

Drought stress is a serious abiotic factor inhibiting nutrient acquisition by roots and limiting cereal crop production in Asian Least Developed Countries (LDCs). Many studies revealed that balanced fertilization can improve photosynthetic activity by stabilizing superoxide dismutase (SOD) activity, improve proline, abscisic acid (ABA) and make the crop drought tolerant with efficient root system and finally improve crop yield. To mitigate drought stress, along with the usage of resistant and efficient genotypes, soil and foliar applications of macro- and micro-nutrients are being used in Asia. According to drought sensitivity index, the efficient genotypes are found more drought-tolerant than the inefficient ones. Studies revealed that irrigation alone is not sufficient to obtain satisfactory grain yield without balanced fertilization. At drought stress, the efficient genotypes accumulate higher quantities of ABA and proline, and exhibit higher activities of SOD, as compared with inefficient genotypes through greater nutrient accumulation by their longer and thinner root systems with high efficiency. Under severe drought with low nutritional status, the rate of photosynthesis, particularly water-use efficiency (WUE) increases in the efficient genotypes than in the inefficient ones. Consequently, these physiological and morphological parameters result in better yield performance by efficient use of water. Under drought, soil application of NPK along with foliar application of zinc (Zn), boron (B) and manganese (Mn) increase grain yield as well as micronutrients concentration of the grain. The rate of photosynthesis, pollen viability, number of fertile spikes, number of grains per spike, and WUE are increased by late foliar application of these micronutrients. This indicates that, by increasing WUE foliar application of Zn, B and Mn at booting to anthesis can reduce the harmful effects of drought that often occur during the late stages of cereal production in Asian LDCs. Therefore, it can be concluded that soil application of Zn, B and Mn in early stage combined with foliar application in late stage, especially at the flowering stage, is a promising approach to alleviate drought stress. Another attractive environmental friendly approach is to select efficient and drought tolerant genotypes with a more efficient root system. These findings are of high relevance for farmers' practices, the extension service and fertilizer industry to mitigate the drought stress in Asian LDCs. A few recommendations are made for extension of scientific knowledge to find more scope in support of mitigating drought situation.



## 1. Introduction

Rice (*Oryza sativa*, L.), maize (*Zea mays* L.) and wheat (*Triticum aestivum* L.), are three cereals that feed the world, with an estimated global production of 470,854 and 655 million tons and consumption of 469,866 and 673 million tons of rice, maize and wheat, respectively in 2012–2013 (International Grain Council, 2013). FAO's latest forecast for global cereals production in 2012 stands at below last year's level, but close to the average of the past five years (FAO, 2012). This level is considerably below expectations earlier in the year, largely reflecting the impact of severe droughts in Europe and Asia. Water and nutrition are two of the major components of environmental variations and together provide limitations to successful crop production. Mineral nutrients are essential for plant growth and development through their fundamental roles in plant metabolism, while drought is prominent among the most important ecological factors that impact crop growth and productivity (Bagci et al., 2007; Passioura, 2007). Many physiological processes in plants are impaired by drought stress, including photosynthesis, enzyme activity, membrane stability,

* Corresponding author at: EXIM Bank Agricultural University, Bangladesh (EBAUB), Sagor Tower, Holding No: 69-69/1, Boro Indara Moor, Chapainawabganj 6300, Bangladesh. Tel.: +880 1684997452.
*E-mail addresses:* rezaul.karim@iubat.edu, reza_2007karim@yahoo.com (Md.R. Karim), marahman@iubat.edu (M.A. Rahman).

http://dx.doi.org/10.1016/j.wace.2014.10.004

pollen viability and ultimately growth (Flexas et al., 2004; Schoper et al., 1987; Valentovic et al., 2006; Westgate and Boyer, 1986) and several reports have demonstrated that proline and abscisic acid (ABA) accumulation in plants can enhance tolerance to abiotic stresses (Bray, 1997; De Ronde et al., 2004; Hmida-Sayari et al., 2005). Drought is a major cause of yield and quality loss in cereal crops throughout many of the world's cereal growing area, as well as Asian Least Developed Countries (LDCs) (Akanda, 2010; Bagci et al., 2007; Passioura, 2007; Sheng and Xiuling, 2004). Almost half (47%) of the terrestrial land surface in the world, equal to 6.45 billion hectares, is comprised of dry lands and are distributed among all the different regions of the earth (Fig. 1).

One billion hectares are hyper arid and 5.45 billion hectares are made up of arid, semi-arid and sub-humid areas. There are 70% (5.2 billion hectares) of dry lands around the world used for agriculture with a limited productivity where, crop yield depends on the mode of drought (UNEP, 1997). Despite the fact that rice, maize and wheat are grown in Asian LDCs, the occurrence of drought stress is a frequent phenomenon across the Asian LDCs rice, maize and wheat belts during growing season, particularly during the flowering to grain filling period (Akanda, 2010; Li, 1990). Drought has been found to be one of the major environmental factors which limits both quantity and quality of rice, maize and wheat production in Asian LDCs. Drought stress is often accompanied by a number of other environmental stress factors, including temperature, high solar radiation and wind. While the interactions of drought stress and these other stresses have generally received a reasonable amount of discussion in the literature, the interaction of drought stress and nutritional stress seems to have received little attention. Soils in the Asian LDCs are deficient in many macro- and micro-nutrients essential to plant growth and zinc (Zn), boron (B) and manganese (Mn) are no exception. Low Nutritional status of soils is widespread throughout Asian LDCs, and they commonly occur in areas where crop plants are also subjected to drought stress (Akanda, 2010). Zinc, B and Mn are involved in a wide range of physiological process within the plant cell, and several of these are also associated with tolerance to drought stress. These nutrients also play a key role in the maintenance of photosynthetic activity (Brown et al., 1993; Karim et al., 2012a), pollen viability (Karim et al., 2012a; Sharma et al., 1990), the preservation of membrane integrity (Bettger and O'Dell, 1981; Cakmak and Marschner 1988a; Welch et al., 1982) and the continuance of enzyme activity (Cakmak and Marschner, 1988b; Seethambaram and Das, 1985), as well as being an important factor in a plant's defense against reactive oxygen species, which proliferate under various stress conditions, including drought stress (Cakmak, 2000). This suggests that adequate nutrition may be important for maintaining high plant productivity in drought stress under arid and semiarid environment. This information concerning the relationship between nutrition and drought stress available in the literature, and interaction does not appear to have been studied before in Asian LDCs cereals to any depth. Therefore, the present study is designed to investigate the possible roles of nutrients in improving drought tolerance of cereals crops to nutrient supply and drought stress during early vegetative growth, flowering to grain filling stages, and the effects of these two stresses on grain yield and quality are also examined.

Drought and low nutritional status of soils often occur in combination throughout the world's cropping areas especially in Asian LDCs, and yet the possible interaction between these two stress factors has been largely overlooked. This review describes current knowledge of the independent effects of drought stress and NPK along with Zn, B and Mn nutrition on the growth, grain yield and grain quality of cereals crops. The physiological responses of plants to drought stress are discussed, together with genetic variation in these responses that exists between cereal genotypes. genotypes. Consideration is given to the various roles of these micro- and macro-nutrients as an essential plant nutrients, and some of the better-understood mechanisms responsible for genotypic variations in their efficiency are described. Particular attention is given to the effects of drought on grain yield. Finally, the possible role of NPK along with Zn, B and Mn in the provision of drought tolerance of plants under drought stress is discussed.

### 1.1. Drought stress and crop productivity

#### 1.1.1. Frequencies and impacts of droughts in Asian LDCs

Production of agricultural crops in Asian LDCs is very much influenced by drought stress that occurs during crop growth. Drought poses the most important environmental constraint to plant survival, distribution and crop productivity, causing notable economical losses. Recent plant breeding techniques have assisted this to some extent, with the selection and development of crop cultivars well adapted to the drought that exists throughout Asian LDCs. However, drought stress continues to impose limitation on crop yield, especially in cereals crops. Areas vulnerable to drought in Bangladesh are shown in Fig. 2.

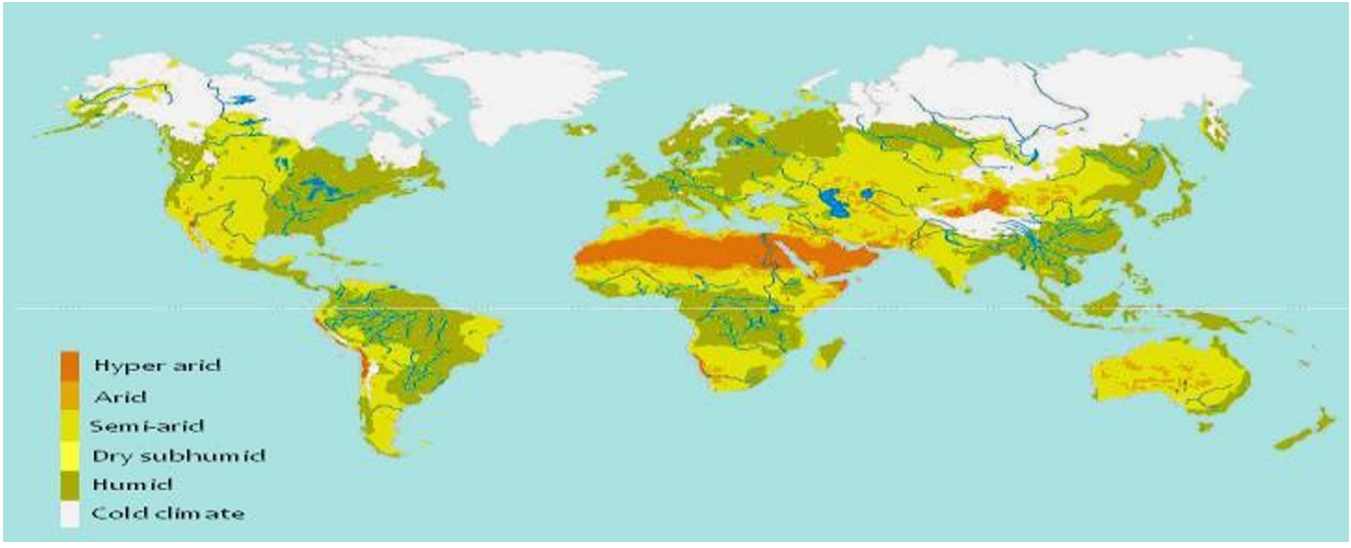


**Fig. 1.** Geographical distribution of drought affected areas in the world.