Available online at www.sciencedirect.com
Agricultural Sciences in China
2006, 5(4): 291-298
SCIENCE DIRECT
April 2006

Effects of Water Stress on the Protective Enzyme Activities and Lipid Peroxidation in Roots and Leaves of Summer Maize

GE Ti-da[1], SUI Fang-gong[1], BAI Li-ping[2], LU Yin-yan[1] and ZHOU Guang-sheng[2]

[1] *Department of Agronomy, Laiyang Agricultural College, Laiyang 265200, P.R.China*
[2] *Laboratory of Quantitative Vegetation Ecology, Institute of Botany, Chinese Academy of Sciences, Beijing 100093, P.R.China*

Abstract

A systematic study was conducted to determine the effects of water stress on the activities of protective enzymes and lipid peroxidation in maize. The results showed that, under water stress, the activities of superoxide dismutase (SOD), catalase (CAT), and peroxidase (POD) in leaves and roots increased sharply at prophase and metaphase growth stages, such as, male tetrad stage, but then declined towards the physiological maturity. The protective enzyme activities in roots were lower than those in leaves. The content of malondialdehyde (MDA) increased according to the severity of water stress. The content of MDA in roots was lower than that in leaves. The activities of protective enzymes and lipid peroxidation in roots were positively related to that in leaves with most of the correlation coefficients being significant. The content of soluble proteins in roots and leaves decreased with increasing drought stress. The ear characteristics deteriorated and the economic yields of maize decreased significantly under water stress. The main factors that caused reduction of yields were the decrease in the number of ear kernels and 100-kernel weight.

Key words: maize, water stress, protective enzyme activities, lipid peroxidation

INTRODUCTION

Maize (*Zea mays*), as the main food, is an economical and forage crop. It is one of the most important crops throughout the world. With the population expansion in China, the demand for crop supply has increased correspondingly, so it is urgent to improve maize yields even under the unfavorable conditions. Depending on different soil water status, biochemical changes to various extents, occurred in maize grains. Moreover, unfavourable dry weather may have potentially deleterious consequence on crop quality and agricultural production. Reasons may be the high temperature and changes in precipitation patterns, especially reduction in precipitation. These may possibly be the results of the projected global environmental changes during the crop growth period. Furthermore, in the semiarid zone in northern China, maize production suffers during severe drought, which often occurs from mid-April to September, leading to direct economic loss. Therefore, it has become a hot issue to elucidate the possible responses and adaptation of plants to drought.

Numerous studies have demonstrated that adverse conditions (water deficiency) can induce membrane damage, increase membrane permeability and the accumulation of free radicals in plants. As a reaction to the adverse conditions, anti-oxidative enzymes and small molecule substances can be produced to remove those active oxygen radicals (Sun *et al.* 2003; Wang *et al.* 2002). In many plants, it was found that the free radicals could not be removed thoroughly because of too

This paper is translated from its Chinese version in *Scientia Agricultura Sinica*.
GE Ti-da, MSc, Tel: +86-535-2922477; Correspondence SUI Fang-gong, E-mail: fgsui@lyac.edu.cn

high amount of free radicals or the weakening of the anti-oxidative enzyme system. Therefore damage to the plant cells may occur when the plant suffers from water deficiency (Iturbe-Ormaetxe *et al.* 1998). The response mechanisms of reactive oxygen scavenging system and lipid peroxidation to drought stress are very complex, as they are not only dependent on plant genotype and stress intensity, but also there are different modes of enzyme reactions. Therefore this problem has not yet been understood clearly. Other studies about water stress reactions of maize mainly reported about experiments where maize was exposed to short-time and sudden water stress (Smirnoff 1998), and about the crops in fields where drought stress has occurred gradually, during the whole development stages of maize. In the case of sudden or staggered stress (Wang *et al.* 1995), it may lead to the irreversible damage to membrane and components in cells, whereas in the case of gradual stress it led the plants to endure more severe stress probably because it did not lead to serious damage to the components in cells.

In the experiment described here, the drought conditions were therefore applied for the whole growing season, to broaden the experimental conditions as described in the literature. The effects of water stress on the protective enzyme activities and on lipid peroxidation in maize roots and leaves at different soil drought stress levels, from third leaf stage to maturity under field conditions, have been discussed in this paper. The main objective of this study is to understand the possible responses and adaptations of maize to drought and the function of some physiological and biochemical processes. By this study, the development of scientific strategies in order to alleviate negative effects of climatic changes, for example, water deficiency or global warming may be supported.

MATERIALS AND METHODS

Plant materials and treatments

Field experiments of summer maize in concreted plots (plot area 4 m^2, depth 1.5 m, concrete isolation around each plot) were carried out in the summer seasons of 2002 and 2003 (both from June to October) at Laiyang Agricultural College, Shandong Province in northern China. The basic properties of the fluvo-aquic medium loam soil were: soil water-holding capacity (gravimetric): 25%, bulk density: 1.34 g cm^{-3}, orgaic matter: 1.04%, available N: 72.54 mg kg^{-1}, available P: 24.58 mg kg^{-1}, and available K: 65.72 mg kg^{-1}.

The maize cultivar Nongda 108, a main type of high yield cultivar in northern China was subjected to different soil water treatments of 80±5% (full water supply, treatment F), 60±5% (light water stress, treatment L) and 40±5% (serious water stress, treatment S) relative water content from third leaf stage to maturity by controlling irrigation. During rain the trial area was covered with a mobile rain shelter. The water was supplied before maize emergence was identical in each plot. Plants were thinned to 21 plants per plot about three weeks after emergence. The date of fertilizer applications and field management were the same for all treatments. The trial design was a completely randomized plot design with three replications.

Soil water content was measured between 0-100 cm soil depth at 20 cm intervals by a neutron probe (503DR, ICT, USA). Additionally, soil samples were taken between 0-20 cm soil depth and oven dried at 65°C for water content determination. The probe was calibrated with volumetric soil samples. One aluminum access tube was installed to a depth of 1.5 m in the central row of each plot. A water meter was used to control the irrigation water supply. To maintain the aimed soil water content the plots were irrigated about every three to seven days (Fig.1). The amount of irrigation water (W) was calculated according to the following equation:

$$W = \gamma H A (W_u - W_0)$$

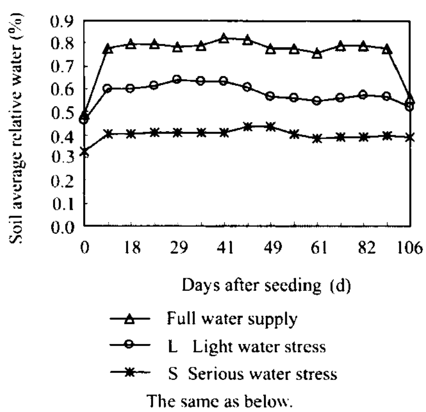

Fig. 1 Soil relative water content during maize development under different drought treatments (average of two growth periods).