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Effect of ridge-covering mulching materials on hormonal changes, antioxidative enzyme activities and production of maize in semi-arid regions of China

Keyuan Chen[a,b,1], Shahzad Ali[c,1], Yanyun Chen[a,b,*], Manzoor[d], Amir Sohail[e], Amanullah Jan[d], Inamullah[d], Shah Fahad[d]

[a] College of Life Science, Ningxia University, Yinchuan, Ningxia 750021, China
[b] Key Laboratory for Restoration and Reconstruction of Degraded Ecosystem in Northwestern China of the Ministry of Education, United Center for Ecology Research and Bioresource Exploitation in Western China, Ningxia University. Yinchuan, Ningxia 750021, China
[c] School of Science and Technology, Qingdao University, Shangdong, Qingdao 266071, China
[d] Department of Agronomy, The University of Agriculture, Peshawar, Pakistan
[e] Department of PBG, The University of Agriculture, Peshawar, Pakistan

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ABSTRACT

The objectives of this study was to investigate the effect of different ridges covered mulching materials on maize production under different simulated rainfall levels and the relationship with anti-oxidant enzyme activities in leaves and hormonal changes in grains. In the present study, conventional flat cultivation (CK) was compared with several ridge covered mulching materials (PM: plastic film, BM: biodegradable film, SC: soil crust ridges) under 320 mm and 430 mm simulated rainfall levels. The results clearly indicated that the effect of ridge covering mulching materials on antioxidant enzyme activities and hormonal changes of maize were significantly related to precipitation levels. At 430 mm rainfall level, PM significantly promoted indole-3-acetic acid, zeatin + zeatin riboside and abscisic acid contents and decreased ethylene, and gibberellic acid contents in superior, middle and inferior seeds as compared with CK_{430} treatment. At 430 mm rainfall level, PM significantly increased soil water storage, characteristics of ear, antioxidant enzyme activities in leaves, hormonal changes in seeds and reducing lipid peroxidation which led to increased (43.1%) grain yield of maize than that of CK_{430} treatment. At 430 mm rainfall level and ridges covered with plastic film significantly increased the activities of peroxidase (33.5%), catalase (76.0%) and superoxide dismutase (43.6%) at grain filling stage, while activity of malondialdehyde (MDA) concentration in leaves significant rise and reached up to maximum (16.7 μmol g^{-1} FW) value at maturity stage under conventional flat planting. Based on these results, we conclude that the PM treatment with 430 mm simulated rainfall significantly increased the soil water storage, adjusting antioxidant enzyme activities in leaves, debasing lipid peroxidation and balance of hormones in the grains as a result improve maize productivity under semi-arid regions of China.

1. Introduction

Maize (*Zea mays* L.) is the fundamental cereals crop in dry-land farming system of northwest China, and rainfall is the key source of water for corn productivity (Shao et al., 2007). However, rainfall in these areas does not match with the growth stages of maize crop. Limited and unpredictable rainfall lead to produce drought stress during different growth stages of corn as a result negatively affected corn productivity (Zhang et al., 2007). Hence, the key to improving corn productivity is to maximize preservation and consumption of the soil moisture and to improve water use efficiency (WUE) of corn crop (Ren et al., 2008).

Previous studies showed that ridge furrow precipitation collecting technique has been used in semi-arid regions of China to address the problems of water scarcity (Li and Gong, 2002). Ridge covered with plastic mulch and furrow planting had significantly improved soil moisture, increase soil temperature, decrease soil evaporation and enhance WUE of corn crop (Zhu et al., 1988). Previous research works showed that plastic and biodegradable mulch significantly increase grain yield which may be interrelated with soil moisture, evaporation

* Corresponding author at: College of Life Science, Ningxia University, Yinchuan, Ningxia 750021, China.
E-mail address: nxchenyy@163.com (Y. Chen).
[1] These authors have contributed equally to this research work.

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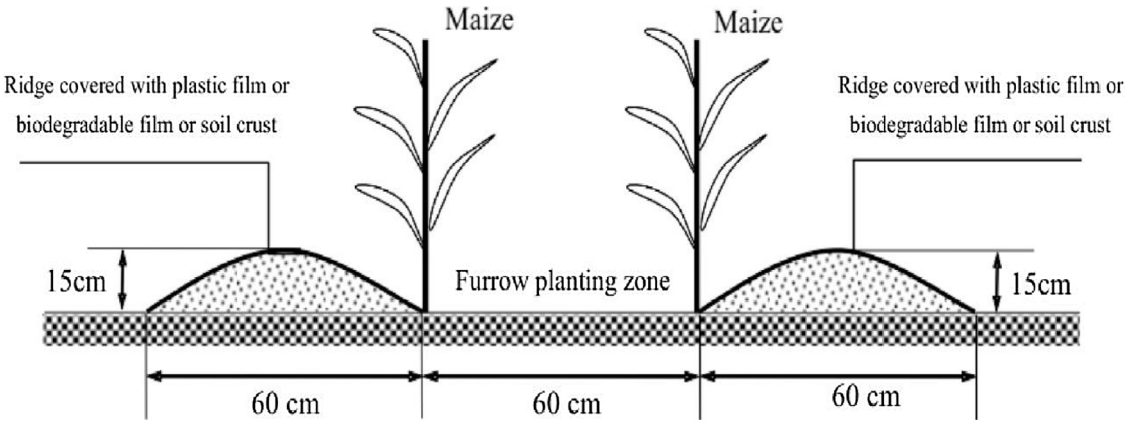

Fig. 1. A Schematic diagram of the field layout showing (a) RFRH system (Ridge covered with plastic film mulch or biodegradable film mulch or soil crust ridge).

and fertility status of soil (Moraru and Rusu, 2010). However, the antioxidant metabolism and hormonal changes are the fundamental to increase or decrease seed yield of corn crop. While it is essential to find out whether and how ridge covered mulch materials under simulated precipitation conditions affects the antioxidant metabolism activities and biochemical mechanism of corn corp. However, no research work is available concerning the influence of various mulching materials under simulated precipitation levels on the antioxidant enzymes activities of corn crop and the essential biochemical mechanism.

Maize yield in northwest China suffers during severe water deficiency, which occurs during April to mid-September, leading to reduce the grain yield of corn crop (Adda et al., 2005). Hence, it has become an important subject to elucidate the probable reactions and adjustment of corn crop under drought conditions. Pervious studies suggested that water deficiency can cause oxidative stress which leads to improved active oxygen species (AOS) in plant cells as a result damaging the cellular permeability (Wang et al., 2002). As a reaction plants develop antioxidant enzymes activities such as superoxide dismutase (SOD), peroxidase (POD) and catalase (CAT) can be produced to remove those AOS concentrations of O_2 and H_2O_2. Malondialdehyde (MDA) concentration, determine of lipid peroxidation, is encourage to buildup of large AOS under water deficiency condition (Dhanda et al., 2004). The reaction mechanisms of reactive oxygen species (ROS) to water stress are very complex. Thus this issue has not yet been understood clearly.

Plant hormonal changes play a key role in the regulatory seed filling in cereals crop. Gao et al. (2000) revealed that zeatin (Z) and zeatin riboside (ZR), indole-3-acetic acid (IAA) and abscisic acid (ABA) all improve quickly during the early seed development stage of maize and then decrease slowly until mature. Higher ABA and lower ethylene (ETH) in corn seeds considerably correlated with maximum seed filling (Yang and Zhang, 2006). The IAA content was found to be maximum in superior seeds than in inferior seeds in the early seed filling stage of maize (Xu et al., 2007). The gibberellic acid (GAs) in corn seeds is also significantly associated with the seed filling rate (Yang et al., 2001). Previous research works have revealed that hormonal changes obviously influence corn seed filling process. Yet, the association between hormonal changes in corn seeds and antioxidant enzymes activities induced by simulated rainfall levels with ridge covering mulch materials remains unclear.

Many earlier research works have been showed that the top seeds of corn were more susceptible to drought than that of basal seeds (Gao and Li, 2005). Ren et al. (2008) confirmed that furrow planting and rainwater collection with ridge significantly improve grain yield at 340 mm rainfall level. However, non significant variation was indicated for maize yield between two planting models at 440 mm rainfall level. In the present study, various ridge covering mulch materials and different precipitation levels during the growth stage of maize were used, and the hormonal changes in the grains during filling and antioxidant enzymes activities were measured. The objective of the study was to investigate the relationship between the effect of various ridge covering mulch materials and different precipitation levels during the maize growth stage and to determine how the changes in endogenous hormones in the developing grains and adjusting antioxidant enzyme activities in leaves of maize under plastic film mulching.

2. Materials and methods

2.1. Study site description

The field research was carried out in 2014 and 2015 Yinchuan in Guyuan city, and Ningxia Province with 34°20′N, 108°24′E, and 466.7 m above sea level. The weather conditions of study area were warming temperate with average air temperature 12.9 °C, maximum and minimum temperatures were 42 °C and −17.4 °C. The total annually sunlight period was 2196 h and the frost free period was 220 days. The annual average precipitation was 550 mm. The rainfall amount during 2014 and 2015 were 313 mm and 330 mm, respectively. The mean bulk density of field soil is 1.37 g cm^{-3}, the available N, P and K contents were 41.3 mg kg^{-1}, 8.56 mg kg^{-1}, and 100 mg kg^{-1}, respectively. The organic matter content (OM) and pH of 0–20 cm soil depth was 10.39 g kg^{-1} and 7.73, respectively.

2.2. Research design, treatments and management

The trial was conducted at the large-scale rain-shelter with water proof sheds. The internal shed dimensions were 32 m (length) × 15 m (width) × 3 m (height). The treatments consisted of three different ridges covering mulch materials, plastic film mulch (PM); biodegradable film mulch (BM); soil crust ridges (SC) and flat cultivation (CK). Two simulated rainfall levels, 320 and 430 mm, were used during various crop growth stages. Ridge to ridge distance was 60 cm with 25 cm height. A double row of corn was planted in furrows (Fig. 1). The length and width of each plot was 5 m × 4.42 m with 3 m deep. The plastic and biodegradable films were mulch on the ridge surface with the edges buried under in 3–5 cm depth soil. The soil crust ridges (SC) was compacted manually with wooden blocks.

The corn variety, (Zhengdan 958) was sown at a rate of 75 000 plants ha^{-1}. The grains were hand planted on 2 June in 2014 and 4 June in 2015 with a row to row distance is 60 cm and plant to plant distance is 20 cm. Nitrogen and phosphorus were applied at the rate of 230 kg N ha^{-1} and 115 kg P ha^{-1} in the form of urea and DAP fertilizer. Half of the N and full P fertilizer were applied at the time of sowing, and the remaining half of N was applied at jointing stage. In the present study, the use of a simulated precipitation (SP) to provide the crop water requirements, during natural precipitation and snowing the shelter was closed to avoid precipitation during maize growing season.