Environment and Ecology 37 (3B) : 1014—1018, July—September 2019
Website: environmentandecology.com ISSN 0970-0420

Effect of Drought Stress on Physiological and Biochemical Changes in Pearl Millet Genotypes

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Received 25 March 2019; Accepted 30 April 2019; Published on 17 May 2019

Abstract An experiment was conducted in pearl millet genotypes to study the physiological and biochemical changes under drought stress in glass house. Drought stress was imposed at panicle emergence stage. The physiological and biochemical parameters like Proline (µg g^{-1}), Peroxidase, Nitrate reductase activity (µmol NO_2 g^{-1} $hour^{-1}$), Electrolyte leakage (%), Chlorophyll stability index (%), Total chlorophyll content (mg/g) and osmotic adjustment was recorded. The pearl millet genotypes show significant variation under drought stress. Among the ten peal millet genotypes PT 5721 and PT 5746 shows the superior physiological and biochemical changes in drought stress. Likewise, the genotypes PT 5756 recorded much lower tolerance capacity to withstand under drought stress.

Keywords Pearl millet, Drought, Physiological parameter, Biochemical parameter.

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Introduction

Plants are sessile in nature. Hence, it experiences many biotic and abiotic stresses in its crop growth period. In this, drought is one of the most important abiotic stress factor which affects the plant developmental processes. In simple terms, drought means that inadequate water supply to the plants for completion of normal life cycle period. This effect ultimately impacts the physiological and biochemical processes of the plant which caused the reduction in yield potential.

Water scarcity is one of the serious for the 21st century. Scientist Safriel et al. (2005) reports that, nowadays 36 % of the world population was lives under the water limited condition. Climate changes may potentially show a discrepancy of water resource availability in agriculture (Hoekstra and Mekonnen 2012). The productivity of both rainfed and irrigated agriculture may be expected to change (Turral et al. 2011). Sposito (2013) stated that necessitate of new approaches based on plant and soil feedbacks to improve crop productivity.

Pearl millet is the staple food and fodder crop in Indian and African subcontinent of hottest and driest environmental areas. Around 90% of cultivated grain is consumed as food crop. It shows high nutritional value compared to other cereals. It has 22 to 25 g of proteins per 200 g grains, iron zinc, calcium and dietary fibers (Anu Sehgal and Kwatra 2006) . When pearl millet was exposed to drought stress cause several metabolic and physiological changes into the plant system. It makes the plant suffer for the production of photosynthates to meet their normal needs. When the drought stress was occur, the plant physiological and biochemical characters was drastically affected. Chlorophyll is the major pigment which located in chloroplast and involved in photosynthetic process (Rahdari et al. 2012). Kulshreshtha et al. (2009) stated that, total chlorophyll was significantly reduced under drought stress condition in sunflower. This might be due to the production of reactive oxygen species which cause degradation of the chlorophyll pigment and increased the photo-oxidation process (Anjum et al. 2011).

Drought stress makes accumulation of more free radicals which causes lipid peroxidation and membrane degradation in plants. It leads an imbalance between reactive oxygen species and antioxidant defence system which may cause oxidative stress. ROS play important role in signalling pathway in case of limited amounts. If it is present in higher amounts cause damage to different organelles membrane. The amount of lipid peroxidation determines the severity of stress condition and also exhibits the tolerant potential of plants (Chowdhury and Chowdhury (1985).

Compatible solutes are low molecular weight compounds that involved in protecting the enzymes and membrane structure from reactive oxygen species and maintain the plant cell volume against water loss. Thus, the plants adjust osmotic stress and continue the normal metabolic pathway (Heidaiy and Moaveni 2009). Scientist identified that, with incresing stress condition proline content also get increased. Proline present in plant cells and play a essential role in protein precursors in plant development and its metabolism processes, metal chelator, signalling molecule, osmolyte, anti-oxidant defence compound (Hayat et al. 2012). The enzymes like nitrate reductase activity was affected drastically. Hence the experiment was planned to study the effect of drought stress on different pearl millet genotypes.

Materials and Methods

The study was conducted in the glass house, Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore. Seeds of pearl millet lines were surface sterilized in 0.05% $NaOCl_3$ for 30 min and imbibed for 24 h in aerated 1 mM $CaSO_4$, then were placed in darkness at 28^{o}C in a germination chamber for two days. Seedlings were planted in polyvinylchloride (PVC) cylinders of dimension (13 cm in diameter and 117 cm in height) filled with soil mixture. The empty tubes were cut into two pieces and then tied up again with duck-tape to facilitate the washing of soil while taking root data. The bottom of tubes was wrapped with muslin cloth. Tubes were fitted in the stand. Two days before planting the tubes were fully irrigated and seed was sown. The plants were thinned to two seedlings per cylinder at 14 days after sowing (DAS) and later thinned to one plant per cylinder at 21 DAS. The crop was top dressed with 1.38 g N plant^{-1} (as urea) at 28 DAS. All the plants were fully irrigated until a 28 DAS. Each cylinder received 500 ml of water twice a week until 14 DAS and 500 ml on alternate days thereafter until 28 DAS. At the time of panicle emergence, watering was stopped. Thereby, stress imposed until harvest.

The proline content was estimated by acid ninhydrin protocol given by Bates et al. (1973). CSI was determined by utilizing following protocol by adopting the method of Murthy and Majumder (1962). Nitrate reductase activity was estimated in fully expanded functional leaves following the method of Nicholas et al. (1976). Total chlorophyll content were estimated by adopting the procedure of Yoshida et al. (1971). Peroxidase activity (change in absorbance value at 430 nm g^{-1} min^{-1}) was determined according to Perur (1962), Angelini et al. (1990). The osmotic potential was recorded using vapour pressure osmometer (VAPRO, 5600) (Babu et al. 1999). The data on various parameters were analyzed statistically as per the procedure suggested by Gomez and Gomez(1984). Wherever the treatment differences are found significant, critical differences were worked out at 5% probability level and the values were furnished.

Results and Discussion

Compatible solutes are low molecular weight compounds that involved in protecting the enzymes and membrane structure from reactive oxygen species and maintain the plant cell volume against water loss. Thus, the plants adjust osmotic stress and continue the normal metabolic pathway (Heidaiy and Moaveni 2009). Scientist identified that , with increasing stress condition proline content also get increased. Proline present in plant cells and play a essential role in protein precursors in plant development and its metabolism processes, metal chelator, signalling molecule, osmolyte, anti-oxidant defence compound (Hayat et al. 2012). The study result that, the tolerant genotype PT 5746 showed highest increment of proline content 24.86% under stress condition compared to control followed by PT 5721 showed 23.91% increased proline content. However, the susceptible genotype PT 5756 showed very low amount of proline content 10.95%. This may due to the variation in expression of proline among genotypes.

Plants have evolved a certain variety of antioxidant enzyme, which involved in plant defence mechaisms against stress. Peroxidase is an antioxidant enzyme which nullifies the hydrogen peroxide radical and gives the potential to withstand under stress condition. In this study shows that pearl millet genotype PT 5721 showed 14.22 % increased peroxidase content in leaves followed by PT 5746 (13.82%) (Table 1). The genotype PT 5756 showed lowest level of 4.63% peroxidase activity. Vijayalakshmi et al. (2012) study also state that, peroxidase content was drastically increased in plants under drought stress which improve the physiological mechanism for drought stress. Nitrate reductase activity gives a good estimate of the nitrogen status of plants and is correlated with growth and plant yield (Srivastava 1980) and abiotic stress tolerance under drought. The current study shows that, PT 5721 recorded lowest amount of (31.49%) reduction in NRase activity followed by PT 5746 (35.79%). However, the genotype PT 5756 recorded highest amount of (57.96%) reduction in the enzyme activity. The genotype PT 5721 recorded lowest increment of electrolyte leakage (12%) when

Table 1. Effect of drought stress on Proline (µg g^{-1}), Peroxidase (change in absorbance value at 430 nm g^{-1} min^{-1}) and Nitrate reductase activity (µmol NO_2 g^{-1} $hour^{-1}$) of pearl millet genotypes.

Sl. No.	Vernacular name	Proline (µg g^{-1})		Peroxidase activity (change in absorbance value at 430 nm g^{-1} min^{-1})		Nitrate reductase activity (µmol NO_2 g^{-1} $hour^{-1}$)	
		Control	Stress	Control	Stress	Control	Stress
1	PT 5456	176	214	7.016	7.901	1.54	0.76
2	PT 5557	180	216	8.108	8.720	1.47	0.72
3	PT 5609	194	221	7.143	7.641	1.43	0.67
4	PT 5659	179	218	6.804	7.317	1.84	1.01
5	PT 5702	170	206	7.497	8.107	1.54	0.84
6	PT 5721	184	228	7.401	8.454	1.81	1.24
7	PT 5746	181	226	7.84	8.924	1.76	1.13
8	PT 5756	146	162	6.92	7.241	1.57	0.66
9	PT 4903	163	194	7.451	8.041	1.64	0.89
10	PT 4915	162	197	7.375	8.170	1.66	0.91
	Mean	173.5	208.2	7.3555	8.0516	1.626	0.883

	G	S	GS	G	S	GS	G	S	GS
SEd	2.80	1.25	3.96	0.12	0.05	0.17	0.01	0.007	0.02
CD (p=0.05)	5.67	2.53	8.02	0.25	0.11	0.35	0.03	0.01	0.04

Table 2. Effect of drought stress on Electrolyte leakage (%), Chlorophyll stability index (%) and Total chlorophyll content (mg/g) of pearl millet genotypes.

Sl. No.	Vernacular name	Electrolyte leakage (%) Control	Electrolyte leakage (%) Stress	Chlorophyll stability index (%) Control	Chlorophyll stability index (%) Stress	Total chlorophyll content (mg/g) Control	Total chlorophyll content (mg/g) Stress
1	PT 5456	61	72	81	75	2.53	1.38
2	PT 5557	57	69	84	77	1.64	0.97
3	PT 5609	59	69	85	79	1.91	1.04
4	PT 5659	64	75	82	74	1.93	1.2
5	PT 5702	60	73	81	70	1.81	1.19
6	PT 5721	50	56	89	84	2.17	1.49
7	PT 5746	57	66	87	80	2.28	1.47
8	PT 5756	73	89	79	62	1.74	0.84
9	PT 4903	58	67	85	76	2.49	1.26
10	PT 4915	59	68	84	78	2.34	1.38
	Mean	59.8	70.4	83.7	75.5	2.084	1.222

	G	S	GS	G	S	GS	G	S	GS
SEd	0.93	0.42	1.32	1.11	0.49	1.57	0.02	0.01	0.03
CD (p=0.05)	1.89	0.84	2.68	2.25	1.00	3.18	0.05	0.02	0.07

compared to its control condition. It may be due to the reduced amount of membrane disintegrity within the cell organelles. However, the genotype PT 5756 shows high electrolyte leakage of 89% followed by PT 5609 has 64% under drought stress. The genotype PT 5456 recorded high osmotic adjustment character followed by PT 5702 and PT 5756 recorded the lowest osmotic adjustment (Fig.1).

Chlorophyll stability index (CSI) and total chlorophyll content is an important physiological parameter that impacts the ability of the plant to sustain under stress condition by improving the photosynthetic capacity under stress and measure the membrane integrity of the plants (Sayed 1999) (Table 2). Genotypes PT 5721 showed high level of 84% in stress condition followed by PT 5746 recorded 80% of CSI in stress condition. The genotype of PT 5721 observed highest amount of total chlorophyll content followed by PT 5456. The result indicates that imposed stress did not have a major negative effect on chlorophyll content of the tolerant genotypes and thus, helps to maintain photosynthetic machinery. The genotype PT 5756 recorded low amount of CSI 62 % and total chlorophyll level in drought stress. Reduced CSI in susceptible genotypes during drought stress was also observed in maize (Meenakumari 2004).

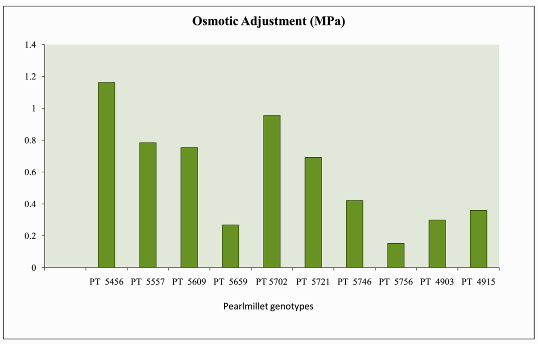

Fig. 1. Effect of drought stress on osmotic adjustment (MPa) of pearl millet genotypes.

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