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Research Article

EFFECT OF DROUGHT STRESS ON GAS EXCHANGE, CHLOROPHYLL AND YIELD CHARACTERS OF PEARL MILLET GENOTYPES

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Abstract: Plant faces several drought stress impacts on growth and development during its life period. Due to this, the agricultural production has become decreased which lead to insufficient to meet peoples economic demand during the upcoming years. Scientist has developed several mitigation strategies. In this screening of drought tolerant genotypes is important for the creation of tolerant varieties to face the problem. An experiment was conducted in pearl millet genotypes to study the physiological and biochemical changes under drought stress in glass house, Department of Crop Physiology, TNAU, Coimbatore. Drought stress was imposed at panicle emergence stage. The physiological and biochemical parameters like gas exchange parameters like transpiration and photosynthetic rate, chlorophyll characters like chlorophyll index (SPAD), chlorophyll content and chlorophyll fluorescence and yield characters were 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 performance in drought stress. Likewise, the genotype PT 5756 recorded much lower tolerance capacity to withstand under drought stress.

Keywords: *Transpiration rate, SPAD value, Chlorophyll, Pearl millet, Drought*

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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 factors 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 perils for the 21st century. Scientist [1] reports that, nowadays 36 percent of the world population was lives under the water limited condition. Climate changes may potentially show a discrepancy of water resource availability in agriculture [2]. The productivity of both rainfed and irrigated agriculture may be expected to change [3]. Sposito, (2013) [4] 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 percent 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 gram grains, iron zinc, calcium and dietary fibers [5]. Pearl millet was mostly cultivated in rainfed conditions; environmental factors play a high impression on plant growth and development. Herein, water stress impacts are more on plant developmental aspects. Pearl millet subjected to drought stress of varying degree and duration, causes substantial loss of yield. Therefore, it is important to identify the drought tolerant pearl millet genotypes with high tolerance physiological indices that can be transferred for breeding studies and crop improvement. 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 occurred, the plant physiological and yield characters was drastically affected. Chlorophyll is the major pigment which located in chloroplast and involved in photosynthetic process [6]. Kulshreshtha, *et al*., [7] 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 [8]. Hence, the experiment was planned to study the gas exchange, biochemical and yield character changes under drought stress at panicle initiation stage.

Materials and methods

The study was conducted in the Glass house, Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore. Ten Pearlmillet genotypes (PT 5456, PT 5557, PT 5609, PT 5659, PT 5702, PT 5721, PT 5748, PT 5756, PT 4903 and PT 4915) seeds were collected from the Department of Plant Genetic Resources, 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°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.

Table-1 *Effect of drought stress on gas exchange characters and physiological characters of pearl millet genotypes*

SN	Pearl millet genotypes	Photosynthetic rate (µmol CO_2 m^{-2} s^{-1})		Transpiration rate (mmol H_2O m^{-2} s^{-1})		SPAD		Chlorophyll fluorescence	
		Control	Stress	Control	Stress	Control	Stress	Control	Stress
1	PT 5456	41.11	30.45	2.93	1.54	42.18	34.33	42.18	34.33
2	PT 5557	34.51	26.74	7.01	4.39	33.13	24.08	33.13	24.08
3	PT 5609	38.46	27.70	4.72	2.15	40.73	34.17	40.73	34.17
4	PT 5659	31.49	26.09	5.44	4.33	35.14	26.41	35.14	26.41
5	PT 5702	31.75	25.08	13.07	8.76	48.46	40.67	48.46	40.67
6	PT 5721	30.43	26.81	9.44	8.19	51.73	41.01	51.73	41.01
7	PT 5748	31.97	27.44	5.49	4.37	53.07	45.43	53.07	45.43
8	PT 5756	32.91	15.62	6.4	2.10	38.71	20.62	38.71	20.62
9	PT 4903	32.48	23.06	8.04	3.46	40.16	31.8	40.16	31.8
10	PT 4915	39.85	26.46	7.72	2.75	34.16	23.73	34.16	23.73
	Mean	34.50	25.54	7.03	4.21	41.75	32.22	41.75	32.22
		SED	CD(P=0.05)	SED	CD(P=0.05)	SED	CD(P=0.05)	SED	CD(P=0.05)
	G	0.492	0.995	0.096	0.194	0.558	1.128	0.558	1.128
	S	0.220	0.445	0.043	0.087	0.249	0.504	0.249	0.504
	G*S	0.696	0.407	0.136	0.275	0.789	1.595	0.789	1.595

Table-2 *Effect of drought stress on chlorophyll characters of pearl millet genotypes*

SN	Pearl millet genotypes	Chlorophyll a(mg/g)		Chlorophyll b(mg/g)		Total chlorophyll (mg/g)	
		Control	Stress	Control	Stress	Control	Stress
1	PT 5456	1.42	0.82	0.92	0.47	2.53	1.38
2	PT 5557	0.97	0.49	0.61	0.39	1.64	0.97
3	PT 5609	1.02	0.56	0.72	0.36	1.91	1.04
4	PT 5659	1.21	0.67	0.67	0.34	1.93	1.20
5	PT 5702	1.04	0.71	0.70	0.40	1.81	1.19
6	PT 5721	1.71	1.09	0.94	0.54	2.80	1.78
7	PT 5748	1.32	0.73	0.84	0.50	2.28	1.37
8	PT 5756	0.83	0.46	0.60	0.32	1.56	0.84
9	PT 4903	1.44	0.68	0.94	0.49	2.49	1.26
10	PT 4915	1.31	0.79	0.81	0.45	2.34	1.38
	Mean	1.23	0.70	0.77	0.43	2.13	1.24
		SED	CD(P=0.05)	SED	CD(P=0.05)	SED	CD(P=0.05)
	G	0.012	0.024	0.011	0.022	0.023	0.047
	S	0.005	0.010	0.004	0.010	0.010	0.021
	G*S	0.016	0.034	0.015	0.031	0.033	0.066

Table-3 *Effect of drought stress on yield characters of pearl millet genotypes*

SN	Pearl millet genotypes	Earhead number $plant^{-1}$		Earhead length (cm)		1000 grain weight (g)		Yield (g/plant)	
		Control	Stress	Control	Stress	Control	Stress	Control	Stress
1	PT 5456	3.81	3.06	22.64	20.75	6.09	4.47	33.50	24.60
2	PT 5557	3.93	3.15	24.07	22.62	6.20	3.79	34.08	20.87
3	PT 5609	4.72	4.37	18.61	17.50	6.59	4.52	36.27	24.84
4	PT 5659	4.10	4.25	16.85	15.33	6.82	5.01	37.50	25.93
5	PT 5702	3.73	3.47	17.74	16.50	7.05	4.35	38.76	28.01
6	PT 5721	5.82	4.50	26.40	24.72	7.24	5.42	38.33	29.83
7	PT 5748	4.67	3.13	28.72	26.47	6.30	4.75	34.63	26.15
8	PT 5756	3.30	3.08	20.33	18.33	5.10	3.09	28.05	17.02
9	PT 4903	4.70	3.42	20.56	18.57	5.88	4.32	32.33	23.76
10	PT 4915	4.67	3.73	17.43	16.01	5.75	3.88	31.62	21.33
	Mean	4.35	3.62	21.33	19.68	6.30	4.36	34.50	24.23
		SED	CD(P=0.05)	SED	CD(P=0.05)	SED	CD(P=0.05)	SED	CD(P=0.05)
	G	0.06	0.12	0.23	0.48	0.08	0.16	0.33	0.67
	S	0.02	0.05	0.10	0.21	0.03	0.07	0.14	0.30
	GS	0.08	0.17	0.33	0.68	0.11	0.22	0.47	0.95

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 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, drought stress was imposed. During the drought stress, the gas exchange characters were recorded. The leaf samples were collected and analyzed the biochemical parameters. After re-watering, the drought stress was relieved. Yield parameters were estimated after harvest. The experiment was laid out in factorial completely randomized block design with three replications. Leaf gas exchange parameters were measured by using Portable Photosynthesis System (PPS) (Model LI-6400 of LICOR inc., Lincoln, Nebraska, USA) equipped with a halogen lamp (6400-02B LED) positioned on the cuvette. Totally, three measurements were taken in the same leaf. Leaves were inserted in a 3 cm2 leaf chamber and PPFD at 1200 µmol photons $m^{-2}s^{-1}$ and relative humidity (50-55%) was set. The readings were taken between 9 am to 11.30 am. Using PPS, transpiration rate and photosynthetic rate were recorded. SPAD readings were recorded by using chlorophyll meter (SPAD 502) designed by the soil plant analytical development (SPAD) section, Minolta, Japan. The Minolta SPAD-502 measures chlorophyll content as ratio of transmittance of light at wavelength of 650 nm and 940 nm. Five readings were taken from each replication and the average value computed using method described [9, 10]. The contents of chlorophyll 'a', 'b' and total chlorophyll were estimated by adopting the procedure of [11]. Chlorophyll florescence (Fv/Fm) was measured using the instrument Plant Efficiency Analyzer (Hansatech, U.K.) (PEA) as described [12]. The number of earhead per plant was calculated from the same sampling unit and average of five plants was calculated. The length of earhead per plant was calculated from the same sampling unit and average of five earhead length was calculated. The weight of thousand seeds from earhead at random from each replication in every treatment was taken and expressed in g. The grain yield g/plant was recorded after threshing, cleaning and drying the grains. It is also known as economical yield. The data on various parameters were analyzed statistically as per the procedure suggested [13].

Result and Discussion

In plants, the first response to drought is stomatal closure to avoid excessive water loss through transpiration and to protect the photosynthetic machinery. Therefore, the effect of drought stress on photosynthetic rate and transpiration rate were measured. Lower leaf water potential (ΨL) and stomatal closure caused to decrease in photosynthetic rate resulting in decreased CO_2 availability and rubisco activity [14]. In present study, the results showed drastic reduction in photosynthetic rate when the drought stress imposed during panicle initiation stage invariably in all the genotypes. As limitation of CO_2, leads to inactivation of electron transfer reactions, an excess of reducing power is frequently generated in drought plants [15]. The tolerant genotypes (PT 5721, PT 5748) recorded lower percent reduction compared to susceptible genotypes (PT 5756). The lower reduction in photosynthetic rate under drought is good indicators of drought tolerance capacity of the genotypes as reported [16]. Kutner, *et al*., [17] indicated that the rate of photosynthesis decreased mainly due to stomata closure which is also evident from the reduced stomatal conductance in sensitive genotypes. Chlorophyll fluorescence indices provide direct information on functionality and the effectiveness of photosynthesis [18]. Fluorescence yield will be high when PS II reaction centre is least damaged by photo inhibition. Fv/Fm values indicate the photosynthetic efficiency of photo system II. The high Fv/Fm ratio is proportional to quantum yield and showing high degree of photosynthesis [19]. In present investigations, the fluorescence values were declined in all the genotypes in drought conditions. Among them, the genotypes PT 5721 and PT 5748 maintained higher Fv/Fm ratio even under drought. The same genotypes also maintained photosynthetic activity with less reduction. Therefore, chlorophyll fluorescence of the leaf could be used as an indicator of photosynthetic activity [20]. The chlorophyll content meter is an indicator of the photo-synthetically active light-transmittance characteristics of the leaf, which is dependent on the unit amount of chlorophyll per unit leaf area [21]. In present study, the susceptible genotype PT 5756 showed the adverse effect of drought stress on greenness of leaf could be inferred through 46 percent reduction in chlorophyll meter readings over control. The genotypes, PT 5748 (14.39), PT 5702 (16.07) and PT 5609 (16.10) recorded less reduction in chlorophyll meter reading in drought condition. Hayatu and Mukhtar (2010) [22] showed that, at both moderate and severe water stress there was 100 percent reduction in the chlorophyll content of the stressed genotypes. Consequently, this trait could be well used as selection criteria for identifying drought tolerant crops. The sensitivity to water deficit is particularly acute during the reproductive development because reproduction involves several processes that are extremely vulnerable to a change in plant water status. Mirbahar, *et al*., [23] reported that drought stress occurred during flowering reduced the earhead length. The present study showed similar results wherein reduction in earhead length was observed under drought stress compared to control. In case of earhead length, the genotypes, PT 5721 and PT 5702 were observed lower percent decrease over control and thus, considered as drought tolerant genotypes while PT 5756 recorded higher percent over control. Kilic and Yagbasanlar (2010) [24] reported that maturity date and spike length represent useful selection for screening drought tolerance in early generations in wheat. Under drought stress, 1000 grain weight was shown to be reduced. The current study shows that, PT 5721 and PT 5748 showed the lowest reduction percent under drought stress environment in tube experiment study. Therefore, it can be concluded that plants under drought stress during panicle initiation stage causes reduction in grain weight due to alternation in source sink relationship in plants. Kilic and Yagbasanlar (2010) [24] have reported that the 1000 grain weight and grain yield of wheat is reduced in drought and terminal heat stress conditions. The millet crop was commonly grown under arid and semi arid environmental conditions. The crops highly face the water scarcity problem during its reproductive stage particularly flowering and grain developmental stages [25]. This may highly influence the grain yield potential of the plants. Scientist reported that, the crop faces stress at their earhead emergence stage, which strongly shows the reduction in pollination and fertility performance. This may evolve the grain yield reduction under the drought stress conditions. The current shows that, the genotype PT 5721 shows 22 percent yield reduction and PT 5748 recorded 24 percent reduction in yield during tube experiment. This result supported as [26] who studied in pearl millet indicated that seed yield in stress and non-stress environments were 828 to 1136 kg ha^{-1} and 3123 to 3942 kg ha^{-1} respectively. Bray, *et al*., [27] reported that drought stress at seed filling stage reduced seed yield up to 50 percent. Under drought stress, plant's ability to absorb and transfer materials is disturbed which affects yield [28]. However, the tolerant potential should be helped to withstand under drought stress condition. The selection of high yielding varieties was a best one. The scientist reported that, superior ear girth, ear length, more tiller number, high seed density was given the positive correlation with the yield performance [29].

Conclusion

The experiment concluded that, the ten different pearl millet genotypes behave in a different way under imposed panicle initiation stage of stress. Every genotype has a different genetic character were documented.

Application of research: The study shows that; the genotype PT 5721 and PT 5748 reflected the superior performance among other genotypes. These genotypes are highly suitable for further plant breeding programmes for the production of tolerant pearl millet varieties.

Research Category: Crop Physiology

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Study area / Sample Collection: Glass house, Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore

Cultivar / Variety / Breed name: Pearl Millet PT 5721 and PT 5748

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