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RESEARCH ARTICLE

Effect of Elevated Temperature on Growth Parameters of Foxtail Millet *(Setaria italica)*

Dhanuja.R, S.Panneerselvam, Ga.Dheebhakaran and S.Kokilavani
Department of Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore - 641003

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ABSTRACT

Foxtail millet is a short duration crop grown in the arid and semi-arid regions of the world. The increasing global temperature may lead to a shift in cropping pattern across the world. Hence it is essential to understand the effect of elevated temperature on foxtail millet, as it is predominantly grown crop in the underdeveloped countries of the world. A study was conducted to investigate the effect of elevated temperature on the growth parameters of foxtail millet in Open Top Chamber at Tamil Nadu Agricultural University during 2017-2018. The experiment included exposing four different phenological stages of foxtail millet to three temperature levels. The Study revealed that the growth parameters such as plant height, leaf area and dry matter production decreased with increase in temperature. Thus the temperature rise had a negative impact on the growth parameters of foxtail millet.

Keywords: *Foxtail millet, Plant height, Leaf area, Dry matter production.*

INTRODUCTION

Minor millets are small-seeded hardy crops that can be grown in drier regions with erratic rainfall nature. It has been proved to be suitable for people suffering from a metabolic disorder and hence known as Nutrient millet. Foxtail millet (Setaria italica) is a self-pollinated short duration crop cultivated from ancient times in the arid and semi-arid regions of the world. It ranks second in world's total millets production. It is adaptable to a wide range of soil, climatic condition and topography. In India, foxtail millet is grown over an area of 9800 ha producing about 56,000 tonnes of grains with an average productivity of 565 kg/ha. In Tamil Nadu, it is grown over an area of 700 ha with a production of 1000 tonnes (Hariprasanna et al., 2017). Global temperatures have elevated in the past 100 years by an average of 0.86oC. An increase of 0.2ºC in the average temperature has been projected to occur over the next decade. Extreme temperatures affect the plants by damaging the cells and changing the initiation and length of plant development periods. The altering climate is expected to worsen abiotic factors globally and adaptation strategies need to be established for target crops to specific environments (Mcclean et al., 2011).

MATERIAL AND METHODS

The pot culture study was carried out in Agro Climate Research Centre, Tamil Nadu Agriculture University, Coimbatore during 2017-2018 under controlled condition in Open Top Chamber (OTC) and the crop variety CO (Te) 7 of Tamil Nadu Agricultural University was used for the study. Five replications were maintained with three plants per pot following Completely Randomized Design (CRD). Eleven treatments were maintained at two temperature conditions (+2 and +4°C) and under the ambient condition for the study as listed below:

T^1 : Ambient temperature throughout the growth period

T^2 : +2°C than the ambient throughout the growth period

T^3 : + 4°C than the ambient throughout the growth period

T^4 : +2°C than the ambient during the seedling stage only (7 to 22 DAS)

T^5 : +4°C than the ambient during the seedling stage only (7 to 22 DAS)

T^6: +2°C than the ambient during the vegetative stage only (23 to 45 DAS)

T^7 : +4°C than the ambient during the vegetative stage only (23 to 45 DAS)

T^8 : +2°C than the ambient during the flowering stage only (46 to 55 DAS)

T^9 : +4°C the ambient during the flowering stage only (46 to 55 DAS)

T^{10} : +2°C than the ambient during the maturity stage only (56 to 90 DAS)

T^{11} : +4°C than the ambient during the maturity stage only (56 to 90 DAS)

*Corresponding author's e-mail: dhanujarajendran16@gmail.com

Crop management practices like irrigation, weeding, nutrient management and pest management practices were practiced as recommended for pot culture.

The growth parameters which were considered for this study are plant height, leaf area and Dry Matter Production (DMP). These parameters were recorded for three phenological stages viz., Vegetative, Flowering and grain filling stages for all the eleven treatments. Height of the plant was recorded from the base of the plant to the tip of the topmost leaf. The mean values were calculated and were expressed in cm. Destructive samples were taken at respective stages to determine leaf area per plant using a Leaf area meter (LICOR, Model LI 3000) and expressed as cm2/plant. Dry matter production was calculated from the destructively sampled plants which were uprooted, shade dried, oven dried at a temperature of 80°C for 72 hours, weighed and expressed in grams (g).

RESULTS AND DISCUSSION

Data pertaining to plant height, dry matter production and leaf area at different temperature treatments (+2ºC, +4ºC) during vegetative, flowering and grain filling stages are presented in Table 1, Table 2 and Table 3 respectively.

Table 1. Effect of elevated temperature on plant height of foxtail millet

Treatment	Temperature		Plant height (cm)		
	Elevation	Exposure Stage	Vegetative	Flowering	Grain filling
T_1	0ºC	Throughout	77.9	104.4	130.3
T_2	+2ºC	Throughout	33.2	48.7	101.3
T_3	+4ºC	Throughout	15.0	18.1	38.3
T_4	+2ºC	Seedling	51.4	67.2	104.0
T_5	+4ºC	Seedling	43.0	53.0	100.8
T_6	+2ºC	Vegetative	64.3	78.6	103.2
T_7	+4ºC	Vegetative	49.6	67.2	101.4
T_8	+2ºC	Flowering	75.8	89.4	118.1
T_9	+4ºC	Flowering	76.5	92.1	120.4
T_{10}	+2ºC	Grain filling	77.6	97.3	127.3
T_{11}	+4ºC	Grain filling	75.2	103.2	115.6
	SEd		1.48	1.67	3.36
	CD(p 0.05)		3.66	3.45	6.97

Plant height

The plant height ranged from 15 to 77.9 cm, from 18.1 to 104.1 cm and from 38.3 to 130.3 cm during vegetative, flowering and grain filling stages respectively. During the vegetative stage, the maximum height was recorded in T1 (control) and the minimum height was recorded in T3. During the flowering stage, the maximum height was recorded in T1 (control) and the minimum height was recorded in plants exposed to +4oC more than ambient (T3) which was followed by plants exposed to +2oC more than ambient (T2). During grain filling, the maximum height was recorded in T1 (control) followed by T10 and T11 which received elevated temperature of +2oC and +4oC during grain filling stage respectively. The minimum height was recorded in T3.

The plant height of foxtail millet was increased only up to a threshold temperature level and beyond which the height showed a decreasing trend irrespective of the treatments. Drastic reduction in plant height was observed in treatments that received temperature stress from the time of sowing. This was supported by a study done in wheat where high temperature lead to drastic reductions in growth (Wahid et al., 2007). The major impact of high temperature on shoot growth was through a severe reduction in the first internodal length resulting in reduced plant height (Hall, 1992). In wheat, heat stress at the sowing lead to a reduction in plant height (Riazuddin et al., 2010).

Dry matter production (DMP)

During the vegetative stage, the DMP ranged from 4.5 to 37.3 g/plant. The maximum DMP was recorded in T1 (control) and the minimum DMP was recorded in T3 which was followed by T2. During the flowering stage, the DMP ranged from 8.23 to 45.3 g/plant. The maximum DMP was recorded in T1 (control) and the minimum DMP was recorded in T3 which was followed by T2. During the grain filling stage, the DMP ranged from 17.3 to 57.2 g/plant. The maximum DMP was recorded in T1 (control) followed by T10. The minimum DMP was recorded in T3 followed by T2 and T11.

In the present study, it is observed that the dry

Table 2 Effect of elevated temperature on dry matter production of foxtail millet

Treatment	Temperature		Dry matter production (g/plant)		
	Elevation	Exposure Stage	Vegetative	Flowering	Grain filling
T_1	+0°C	Throughout	37.3	45.3	57.2
T_2	+2°C	Throughout	20.8	34.2	41.0
T_3	+4°C	Throughout	4.45	8.23	17.3
T_4	+2°C	Seedling	35.5	37.5	45.0
T_5	+4°C	Seedling	24.4	36.5	44.5
T_6	+2°C	Vegetative	35.8	38.8	45.3
T_7	+4°C	Vegetative	24.5	37.0	44.9
T_8	+2°C	Flowering	37.0	40.8	53.8
T_9	+4°C	Flowering	37.0	41.9	54.8
T_{10}	+2°C	Grain filling	37.3	44.9	55.3
T_{11}	+4°C	Grain filling	37.2	45.2	41.9
	SEd		0.5	1.15	0.75
	CD(p 0.05)		1.04	2.39	1.55

matter production was maximum in crops grown under ambient condition and was minimum in crops grown under +4°C and +2°C elevated temperatures. This may be due to a reduction in plant height, leaf area, growing duration and growing degree days. Every plant requires an optimum temperature for plant growth and development beyond which there was no growth (Hatfield et al., 2011; Hatfield and Prueger, 2015).

Table 3. Effect of elevated temperature on leaf area of foxtail millet

Treatment	Temperature		Leaf area (cm^2/plant)		
	Elevation	Exposure Stage	Vegetative	Flowering	Grain filling
T_1	0°C	Throughout	15.4	31.9	71.2
T_2	+2°C	Throughout	10.4	11.8	22.8
T_3	+4°C	Throughout	1.2	3.5	12.3
T_4	+2°C	Seedling	12.4	20.1	48.2
T_5	+4°C	Seedling	9.76	16.6	46.9
T_6	+2°C	Vegetative	13.6	20.3	48.6
T_7	+4°C	Vegetative	14.0	17.4	46.8
T_8	+2°C	Flowering	15.3	21.7	43.6
T_9	+4°C	Flowering	15.3	20.5	41.5
T_{10}	+2°C	Grain filling	15.4	31.8	66.4
T_{11}	+4°C	Grain filling	15.3	31.8	67.0
	SEd		0.26	0.47	1.22
	CD($p \leq 0.05$)		0.54	0.97	2.52

Leaf area

The leaf area ranged between 1.2 and 15.4 cm2, 5 and 31.9 cm2 and 12.3 and 71.2 cm2 during vegetative, flowering and grain filling stage respectively. During the vegetative stage, the maximum leaf area was recorded in T1 (control) and the minimum leaf area was recorded in T3 which was followed by T5. During the flowering stage, the leaf area was maximum in T1 (control) and the minimum leaf area was recorded in T3 which was followed by T2. During grain filling stage, the leaf area was maximum in T1 (control) followed by T11 and T10 which received elevated temperature of +4°C and +2°C during grain filling stage respectively and the minimum leaf area was recorded in T3.

Leaf area is an important growth parameter

that had influenced the photosynthetic rate thereby affecting yield. In this study, it had been observed that the leaf area decreased with increase in temperature. Here the maximum value of leaf area was observed in ambient condition and the minimum values were observed in crops grown under +2ºC and +4ºC elevated temperatures. The reason for this reduction was due to the narrowing of leaves when exposed to a higher temperature. This is a defense mechanism shown by plants to reduce photo-oxidative damage thereby reducing Reactive Oxygen Species production. It was observed that under high-temperature stress, the plant growth was reduced by reducing the leaf structure by decreasing the cell wall extension (Tangpong et al., 2009).

CONCLUSION

Foxtail millet variety Co (Te)7 grown under ambient condition were taller while the plants exposed to +4oC elevated temperature throughout the crop period were shorter under all stages. Morphological characteristics like leaf area and dry matter production were also found to be reduced under elevated temperatures. The reduction is more in +4oC elevated temperature than +2oC temperature elevation. It is concluded from the present investigation that under elevated temperature level, the foxtail millet growth was adversely affected as compared to foxtail millet raised under ambient temperature conditions. The negative impact was greater under the elevated temperature of +4°C than +2°C.

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