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Response of Bermuda grass (*Cynodon dactylon*) growth under elevated temperature and moisture stress condition

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Abstract
Future climate scenarios indicated that, during the second part of this century Indian agriculture would suffer with elevated temperature and moisture stress. Weeds are one of the important biotic factor, compete the crop for its resources. It is very difficult to eliminate weeds completely from agricultural system. Weeds respond very quickly to stress and adopt easily than crops. In this context an investigation was carried out at Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore during 2015 -16 to understand weeds response to climate change for preparing ourselves to manage them during future climate scenarios. Experiment was carried out as pot culture in climate control chamber under CRD with 10 treatments and three replications. Each treatment was a combination of one temperature and one moisture level. Three temperature levels *viz.*, ambient (0°C), +2°C and +4°C increase over the ambient. Two moisture levels *viz*., supply of moisture at 100 percent of evaporation (M_{100}) and 60 percent of evaporation (M_{60}) occurred previous day. The results inferred that, the problematic weed *Cynodon dactylon* had high acclimatization capacity and produced more growth under elevated temperature up to +4°C, with sufficient moisture. The C_4 pathway of Bermuda grass helps that weed to utilise the moisture and temperature more efficiently even during stress and produce more growth. Moisture stress with increased temperature had negative effect on growth, but induced the early flowering and more seed production in *Cynodon dactylon*. It is concluded that, in future elevated temperature, during the rainy season, the crop production would suffer with *Cynodon dactylon* menace. Hence, necessary protection measures to be planned during rainy season and precaution measures to be planned during moisture stressed summer to control the weeds before seed setting.

Keywords: Bermuda grass, elevated temperature, moisture stress, crop

Introduction
Climatic changes and increasing climatic variability are likely to aggravate the problem of future food security by exerting pressure on agriculture. Climate change, plants may be more often subjected to high temperatures and low soil moisture during the growing season in spring and summer (Knapp *et al.*, 2008) [12]. The recent Intergovernmental Panel on Climate Change (IPCC, 2013) [9] assessment report V indicated that, climate scenarios predict an increase of annual mean temperatures by 1.5 – 4^0C by the end of 21th century. There is increasing evidence that climate change will result in more extreme weather events including an increased frequency of severe droughts and extreme rainfall (Walck *et al.*, 2011) [18].
Weeds are ubiquitous in nature and invade both crop and non-crop lands. When present in crop fields, weeds compete with the crops for nutrients, soil moisture, solar radiation and space; hence reduce their productivity and quality. If not interrupted, co-occurrence of weeds with crops continues (Dass *et al.*, 2017) [6] It has been reported that, out of total loss of agriculture production from several pests in India, weed account for about 37%, insect for 29%, diseases for 22% and other pests for 12% (Yaduraju, 2006) [19]. In India weed management consume 30–50 percent share of the total cost of cultivation (Bhan, 1997) [3]. Holm *et al.* (1977) [8] *Cynodon dactylon* is treated as the second most important weed in the world after *Cyperus rotundus* a status justified by its occurrence in virtually every tropical and sub-tropical country and in virtually every crop in those countries. *Cynodon dactylon* as a serious weed its affect in 57 countries and 40 crops. It has good drought tolerance because of a deep root system, is well adapted to sandy soils and can tolerate close continuous grazing. They are establishing vegetatively (sprigged) because of very poor seed production (Taliaferro *et al.*, 2004) [17]. *Cynodon dactylon* is very drought tolerant by virtue of rhizome survival through drought

induced dormancy over a period up to 7 months. After dormancy, it has the ability to re sprout easily from stolons and rooted runners. *Cynodon dactylon* recovers quickly after fire and can tolerate at least several weeks of deep flooding (Cook *et al.,* 2005) [5]. *Cynodon dactylon* is a stoloniferous grass widely naturalized in tropical and subtropical regions of the world. This species is a C_4 grass included in the Global Compendium of Weeds and it is listed as one of the most "serious" agricultural and environmental weeds in the world (Holm *et al*., 1977) [8].

Weeds have been conquers and will remain dominant in climate change conditions also since, they have vast adaptive capacity and greater diversity. Climate change may aggravate the weed density, their phenology and invasiveness. rising temperature, changing in rainfall pattern are the distinct consequences of climate change, which leads to deleterious changes in the crop-weed competition, Under rising temperature, plants with C_4 photosynthesis pathway (mostly weeds) have a competitive advantage over crop plants possessing the more common C_3 pathway (Yin and Struik, 2008) [20]. The physiological plasticity of weeds and their greater intraspecific genetic variation compared with most crops could provide weeds with a competitive advantage in a changing environment. Controlling weeds is likely to be more difficult and expensive under climate change (Naidu, 2015) [14]. Weeds have more adaptability to stress conditions than crops. Hence, it is important to understand the thriving capacity of weeds under future projected climate, particularly to elevated temperature and moisture stress. With this back ground, the study titled "Assessing acclimatization capacity of problematic weeds under future climate scenarios.

Material and Methods

The pot culture experiments titled "Assessing acclimatization capacity of problematic weeds under future climate scenarios" were conducted at Climate Control Chamber (CCC) of Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore during 2015 – 2016 to evaluate the acclimatization capacity of problematic weed (*Cynodon dactylon*) under elevated temperature and moisture stress. The latitude and longitude of the experiment location are 11^0N and 77^0E, respectively. The mean altitude is 426.7m above mean sea level and Coimbatore comes under Western agro climate zone of Tamil Nadu**.** Coimbatore is climatically categorized as Semi-Arid Tropic (SAT) climate with an average annual rainfall of 695.9 mm distributed in 46.5 rainy days. The long period average annual mean maximum and minimum temperatures are 31.7^0C and 21.3^0C respectively. The normal annual mean relative humidity is 84.8 percent during morning 07.22 hours LMT and 49.3 percent during evening 14.22 hours LMT. The average mean bright sunshine hour is 7 per day and solar radiation is 311.4 cal/cm^2/day.

The study was conducted with 10 treatments and three replication in Completely Randomized Design. Each treatment was a combination of one temperature and one moisture level. The temperature levels were varied as ambient (0ºC), two degree (+2ºC), four degree (+4ºC) increase over the ambient temperature. The moisture levels were, supply of moisture at 100 percent of evaporation (M_{100}) and 60 percent of evaporation (M_{60}) occurred previous day. Trial was conducted for three generations of weeds and the temperature and moisture levels were varied generation to generation as per treatment.

Treatment Details

The treatment combinations were T_1 (+2^0C + M_{100} for all the three generation), T_2 (+2^0C + M_{100} for 1st and 2nd generations, +4^0C + M_{100} for 3rd generation), T_3 (+2^0C + M_{100} for 1st generation and +4^0C + M_{100} for 2nd and 3rd generation), T_4 (+4^0C + M_{100} for all the three generation), T_5 (+0^0C + M_{100} for all the three generation), T_6 (+2^0C + M_{60} for all the three generation), T_7 (+2^0C + M_{60} for 1st and 2nd generations, +4^0C + M_{60} for 3rd generation), T_8 (+2^0C + M_{60} for 1st generation and +4^0C + M_{60} for 2nd and 3rd generation), T_9 (+4^0C + M_{60} for all the three generation) and T_{10} (+0^0C + M_{60} for all the three generation).

Irrigation

Irrigation with good water was done to the pots on the basis of pan evaporation reading as per treatment schedule. The loss of water through evaporation was calculated every day and equal water was poured in the pots for 100 percent moisture level. In 60 percent moisture stress treatment, quantity of water equal to 60 percent of open pan evaporation was poured. The calculation method was as followed. Diameter of pot - 25 cm; Area of pot: 0.049 sqm. 1mm of water in 1square meter =1 litre. Hence, for 1mm in 0.049sq m = 49 ml. If pan evaporation reading is 5 then water required for 100% level pots =5 x 49ml =245ml and for 60% = 147 ml.

Results and Discussion

The data observed at 15 planting/Cutting (DAP/C) for the effects of different treatments on *Cynodon dactylon* plant height (cm), number of branch and number of leaves per plant are depicted in table 1. The mean values recorded at 15 DAP/C were ranged (plant height- 5.9 to 12.2 cm, 16.2 to 41.5 cm and 13.2 to 23.4 cm), (number of branch- 1.0 to 2.6, 7.1 to 10.9 and 4.7 to 11.7) and (number of leaves -7.4 to 10.4, 34.9 to 54.1 and 28.7 to 35.3) during 1st, 2nd and 3rd generations, respectively. The mean value of leaf area per plants (cm^2) at 15 DAP/C were ranged from 6.8 to 9.7 cm^2, 30.5 to 50.7 cm^2 and 23.3 to 30.8 cm^2 during 1st, 2nd and 3rd generations are depicted in figure 1. It was observed that, the treatment T_4 (+4^0C with M_{100}) had significantly higher plant height (8.2 to 39.3 cm), number of branches (2.1 to 11.7), number of leaves (10.4 to 54.1) and leaf area (9.7 to 50.7sq.cm) than all other treatments.

The data on plant height (cm), number of branch and number of leaves per plant observed at 30 DAP/C are depicted in table 2. The mean values recorded at 30 DAP/C were ranged (plants height -18.9 to 29.2 cm, 26.9 to 45.1 cm and 29.1 to 43.6 cm), (number of branch per plant - 7.0 to 13.4, 22.3 to 29.7 and 20.3 to 35.7) and (number of leaves - 40.2 to 70.9, 113.4 to 150.8 and 111.3 to 133.7) during 1st, 2nd and 3rd generations respectively. The mean value of leaf area per plant at 30 DAP/C were ranged from 36.9 to 66.2 cm^2, 106.0 to 151.2 cm^2 and 96.8 to 124.7 cm^2 during 1st, 2nd and 3rd generations, respectively are depicted in figure 2. It was observed that, the treatment T_4 (+4^0C with M_{100}) had significantly higher plant height (24.7 to 45.1cm), number of branches (12.6 to 35.7), number of leaves (64.6 to 150.8) and leaf area (63.5 to 151.2sq.cm) than all other treatments.

The results indicated that, in general, the above growth factors of *Cynodon dactylon* were increased with increase in temperature (+2^0C or +4^0C) and the growth was significantly more if the plant had no moisture stress (M_{100}). The maximum growth was observed in treatment number T_4 (+4^0C +M_{100}, for all the generation) followed by T_3 (+4^0C +M_{100}, from 2nd generation onwards). There was significantly lower growth viz., height, branches, leaves and leaf area were observed in the treatment number T_{10}, which was ambient temperature (0^0C) with moisture stress (M_{60}) followed by T_5, ambient temperature without moisture stress (M_{100}). The results inferred that, the *Cynodon dactylon* weed had induced by elevated temperature to put forth more growth under no moisture stress conditions. The studies of Singh and Singh Ohe (2000) [16] and Ohe *et al*. (2007) [15] in rice, supported this phenomenon that the plant grew taller when temperature was more beyond threshold level of crop requirement due to triggered mechanism of plant enzymes with higher temperature and the energy of the plant was oriented towards increasing the plant height. On other hand, Kanno *et al.* (2009) [10] and Kima *et al.* (2011) [11] reported that the rice plant had more number of tillers with higher dry matter production when the crop was grown under open condition as compared to growing rice under controlled chamber with the elevated temperature. But in this study, the *Cynodon dactylon,* at elevated temperature (+4^0C) and no moisture stress condition recorded plant height, leaf area higher than the controlled condition.

Hence, the *Cynodon dactylon* would have better opportunity than rice in future climate scenario of increasing temperature. Even under moisture stress condition, the elevated temperature of +4^0C produced more growth than the ambient +2^0C and ambient temperature conditions, which confirmed the more tolerance of *Cynodon dactylon* to increased temperature level. Mahasneh *et al.*, 2014 [13], has also reported that the Bermuda grass (*Cynodon dactylon)* is a fast-growing, popular turf grass widely grown in warm climates all over the world and the grass is a highly suitable turf grass in Saudi Arabia due to its high tolerance to hot and dry conditions. In overall, the generation in which the plant was exposed to elevated temperature of +4°C, from there onwards, the plant produced more growth than earlier generation and lower temperature exposed treatments. Carter and Peterson (1983) [4] and Ziska and Bunce (1997) [21] reported that the C_4 plants are more effective compared to that of C_3 plants at higher temperatures and C_4 is always getting more advantage at elevated temperature. Hence, being a C_4 photosynthetic pathway plant, the *Cyodon dactylon* has produced more growth than at ambient temperature.

Among the moisture levels, the moisture stress condition (M_{60}) recorded significantly lower plant growth parameters viz., plant height, branches, leaves and leaf area per plant than 100 percent moisture supplied treatments. The study by Akram *et al.*, 2007 [1], also confirmed that the growth decreasing effect was more at the lowest water regime in *Cynodon dactylon.* Ares *et al.* (2000) [2]; Heschel and Riginos (2005) [7] reasoned that despite drought conditions, the plants avoid drought by maintaining high fitness through decreasing leaf size and stomatal conductance to water vapour in response to limited water availability.

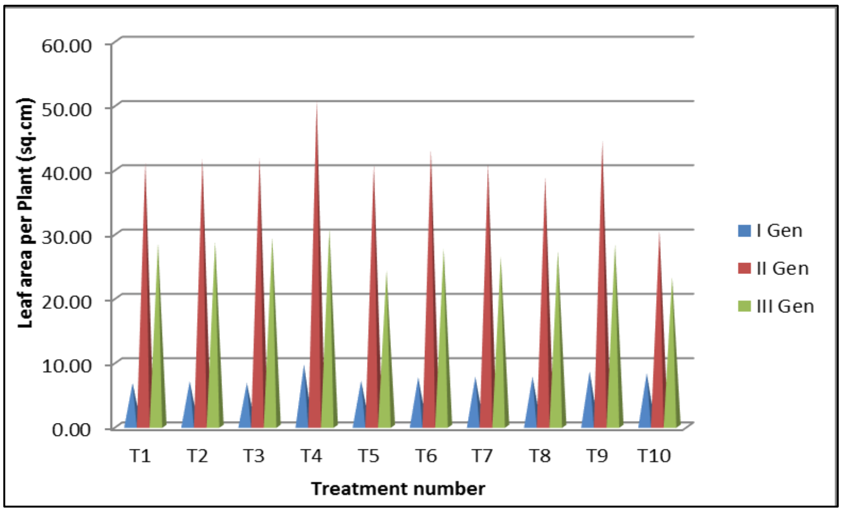

Fig 1: Effect of elevated temperature and moisture stress on Leaf area per plant of *Cynodon dactylon* (cm^2 /Plant) on 15 days

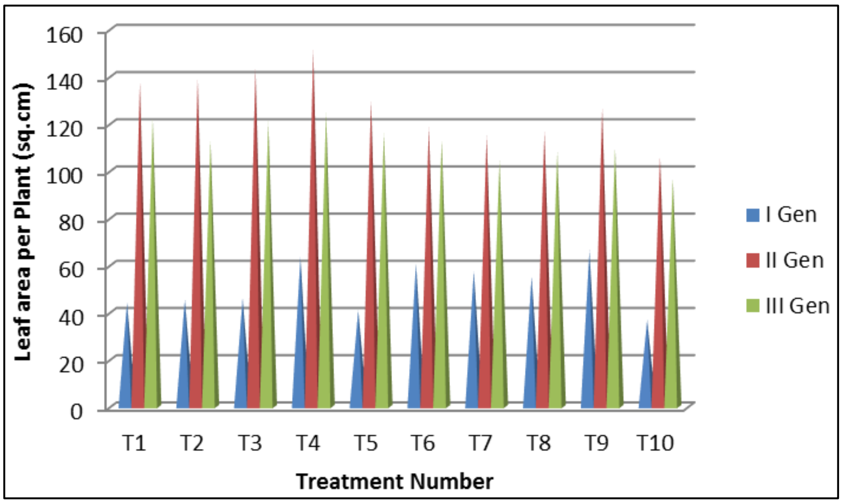

Fig 2: Effect of elevated temperature and moisture stress on Leaf area per plant of *Cynodon dactylon* (cm^2/Plant) on 30 days

Table 1: Effect of elevated temperature and moisture stress on plant height, No of branches and No. of leaves per plant of *Cynodon dactylon* on 15 days

Treatment details				I Generation			II Generation			III Generation		
No.	**I Gen**	**II Gen**	**III Gen**	**Plant height cm**	**No. of branches per plant**	**No. of leaves per plant**	**Plant height cm**	**No. of branches per plant**	**No. of leaves per plant**	**Plant height cm**	**No. of branches per plant**	**No. of leaves per plant**
T_1	+2ºC + M_{100}	+2ºC + M_{100}	+2ºC + M_{100}	6.34	1.11	7.44	24.13	8.16	44.56	20.01	8.33	33.33
T_2	+2ºC + M_{100}	+2ºC + M_{100}	+4ºC + M_{100}	6.48	1.01	7.67	25.8	8.56	44.78	20.37	8.33	33.33
T_3	+2ºC + M_{100}	+4ºC + M_{100}	+4ºC + M_{100}	6.27	1.89	7.44	29.1	8.16	45.33	19.94	9.67	34.33
T_4	+4ºC + M_{100}	+4ºC + M_{100}	+4ºC + M_{100}	8.14	2.11	10.44	39.27	10.89	54.11	23.44	11.67	35.33
T_5	0ºC + M_{100}	0ºC + M_{100}	0ºC + M_{100}	5.92	1.11	8.11	16.2	7.22	45.78	15.36	6.33	29.33
T_6	+2ºC + M_{60}	+2ºC + M_{60}	+2ºC + M_{60}	7.88	1.78	8.44	28.13	9.33	46.78	18.06	6.33	32.33
T_7	+2ºC + M_{60}	+2ºC + M_{60}	+4ºC + M_{60}	7.27	1.11	8.67	32.1	9.11	45.11	16.76	7.67	31.33
T_8	+2ºC + M_{60}	+4ºC + M_{60}	+4ºC + M_{60}	7.8	1.78	8.89	35.67	8.22	44.11	17.39	8.67	33.33
T_9	+4ºC + M_{60}	+4ºC + M_{60}	+4ºC + M_{60}	12.24	1.89	9.78	41.5	10.44	50.11	20.16	9.33	34.33
T_{10}	0ºC + M_{60}	0ºC + M_{60}	0ºC + M_{60}	8.08	2.56	9.6	17.6	7.11	34.89	13.22	4.67	28.67
		Mean		7.642	1.635	8.648	28.95	8.72	45.556	18.471	8.1	32.564
		SEd		0.359	0.069	0.399	0.853	0.371	2.008	0.89	0.43	1.46
		CD (P = 0.05)		0.74884	0.14393	0.83227	1.7793	0.7739	4.1885	1.8565	0.8969	3.0454

Table 2: Effect of elevated temperature and moisture stress on plant height, No of branches and No. of leaves per plant of *Cynodon dactylon* on 30 days

Treatment details				I Generation			II Generation			III Generation		
No.	**I Gen**	**II Gen**	**III Gen**	**Plant height cm**	**No. of branches per plant**	**No. of leaves per plant**	**Plant height cm**	**No. of branches per plant**	**No. of leaves per plant**	**Plant height cm**	**No. of branches per plant**	**No. of leaves per plant**
T_1	+2ºC + M_{100}	+2ºC + M_{100}	+2ºC + M_{100}	19.66	7.33	45.67	41.7	25.67	139.44	39.7	28.33	133.0
T_2	+2ºC + M_{100}	+2ºC + M_{100}	+4ºC + M_{100}	18.89	7.56	46.78	43.4	26.08	139.8	38.03	29.00	122.0
T_3	+2ºC + M_{100}	+4ºC + M_{100}	+4ºC + M_{100}	19.39	12.78	47.56	44.93	28.82	145.4	42.34	30.33	131.7
T_4	+4ºC + M_{100}	+4ºC + M_{100}	+4ºC + M_{100}	24.73	12.56	64.56	45.13	29.67	150.78	43.61	35.67	133.7
T_5	0ºC + M_{100}	0ºC + M_{100}	0ºC + M_{100}	20.22	6.98	43.7	26.93	22.67	136.3	33.16	24.67	131.33
T_6	+2ºC + M_{60}	+2ºC + M_{60}	+2ºC + M_{60}	28.42	10.12	62.78	36.2	24.27	120.33	34.58	25.0	123.33
T_7	+2ºC + M_{60}	+2ºC + M_{60}	+4ºC + M_{60}	28.78	10.07	60.56	40.93	23.89	118.67	33.91	26.33	115.67
T_8	+2ºC + M_{60}	+4ºC + M_{60}	+4ºC + M_{60}	28.56	9.86	59.56	42.93	26.22	123.78	37.58	28.0	123.33
T_9	+4ºC + M_{60}	+4ºC + M_{60}	+4ºC + M_{60}	29.24	13.44	70.89	42.93	26.33	133.11	40.48	27.67	124.0
T_{10}	0ºC + M_{60}	0ºC + M_{60}	0ºC + M_{60}	26.3	10.44	40.2	27.8	22.33	113.4	29.07	20.33	111.33
		Mean		24.419	10.114	54.226	39.288	25.595	132.1	37.246	27.533	124.94
		SEd		1.12	0.943	2.66	1.779	1.26	5.967	1.74	1.22	6.14
		CD (P = 0.05)		2.3362	1.967	5.5485	3.7108	2.6282	12.44	3.6295	2.5448	12.807

Conclusion

The problematic weed (*Cynodon dactylon*) showed high acclimatization capacity and its growth rate was more under elevated temperature up to +4ºC, with sufficient moisture. Hence, in future under elevated temperature condition in both rainy and dry season, the crop production will suffer with weed menace. Therefore, necessary measures should be taken up to control *Cynodon dactylon* to protect crop field from weed invasion. It can also be conclude that temperature and moisture stress tolerant gene can be transfer to other agricultural crops through genetic engineering for developing tolerant crop variety for future climate scenarios.

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