Sweetpotato Cultivar Responses to Interactive Effects of Temperature, Drought, and Carbon Dioxide

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Introduction & Rationale

- Plants are highly sensitive toglobal climate change such as atmospheric carbon dioxide (CO_2), temperature, and soil moisture content which affect on crop growth, development, and yield.
- Abiotic stresses either alone or in combination affect all aspects of plant growth and development including storage roots development and yield.
- According to the Agriculture Department's Risk Management Agency (RMA), nearly $12.3 billion were paid to U.S. producers for losses incurred in 2013 year due to drought, high temperatures and failed irrigation, and combined.
- We hypothesize that sweetpotato growth and development will be modified by abiotic stresses such as temperature and drought and changes in projected atmospheric carbon dioxide concentration (CO_2) will modify that response.
- We expect cultivars vary in their response to these stresses.
- Understanding genotypic variability to multiple abiotic stresses is important for appropriate field management adjustments.

Objective

- To examine the morpho-physiological differences among three contrasting sweetpotato cultivars, Beauregard, Hatteras, and LA 1188, for heat and drought stress either alone or in combination.
- And, to see if elevated carbon dioxide projected to be in the future climate modifies those responses to abiotic stresses.

Materials and Methodology

- The experiment was conducted in sunlit plant growth units known as Soil-Plant-Atmosphere-Research (SPAR) units at MSU, during 15th July to 3rd Oct 2016.
- Plant slips of Beauregard (BG), Hatteras (HT) were obtained from Research and Extension Center, Pontotoc, MS and Louisiana 1188 (LA-1188) of LSU, LS.
- The slips were planted in large (PVC) pots, 20 cm diameter x 35 cm tall, into soil: sand mix (1:3), and every SPAR unit had 18 pots in two rows, 9 per row and 6 plants per cultivar in randomly.
- All treatments were imposed at planting with the exception of irrigation treatments which were imposed at 36 days after transplanting (DAP) and continued to 83 DAP.
- Irrigation for the drought stressed treatments were measured based on the evapotranspiration and soil moisture content measured in all units.

Treatment:

Four Levels of Combinations	Eight Treatments
1. Two levels of CO_2 (410 and 760 µmol mol^{-1}).	1. Control 2. +DS 3. +T 4. +CO_2
2. Two levels of temperature (30/28 and 38/30°C).	
3. Two levels of drought stress [well-watered, 100% and 50% evapotranspiration (ET].	5. +DS+T 6. +T+CO_2 7. +DS+CO_2
4. Control treatment consisted of 30/28°C, 410 µmol mol^{-1} (CO_2), and well-watered plants.	8. +DS+CO_2+T

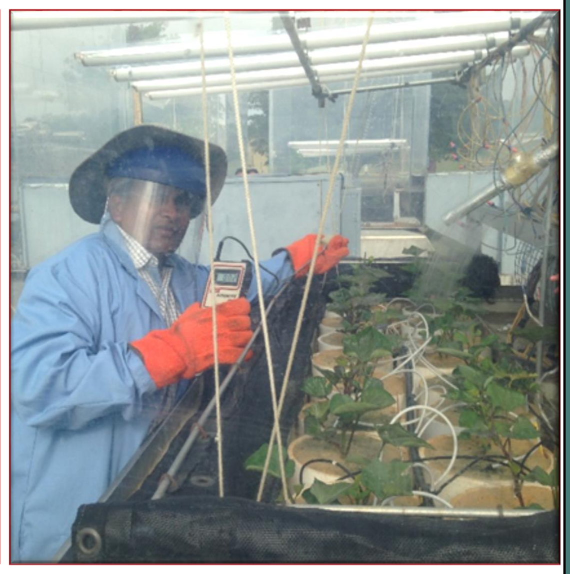


Table-1. The treatments, mean day/night temperature, day CO_2 and Soil moisture content day/ night for each unit.

Treatments	Mean Temperature/°C	CO_2 Concentration µmol mol^{-1}	Soil moisture content,m^3 m^{-3}
Control	26.54±0.077	416.76±0.79	0.220669
+DS	25.26±0.098	418.81±0.96	0.142323
+T	31.25±0.12	417.25±0.7	0.186718
+CO_2	26.65±0.210	759.39±1.03	0.217537
+DSX+T	32.40±0.080	441.48±1.26	0.153544
+TX+CO_2	31.70±0.081	734.74±2.34	0.215819
+DSX+CO_2	25.11±0.068	757.96±1.19	0.150463
+DSX+CO_2X +T	32.23±0.094	757.92±1.04	0.148956

Measurements:

- **Physiological parameters**
  - Net photosynthesis
  - Stomatal conductance
  - Transpiration
  - Leaf water potentials
  - Pigments, CMT, etc.
  - Canopy evapo-transpiration
- **Growth and development parameters**
  - Vine length
  - Leaf area
  - Storage and pencil root numbers
  - Biomass components
  - **Soil moisture content**

Data analysis:

- To test the significance of treatment effects on crop growth development, and physiological parameters, ANOVA was performed using the general linear model PROC GLM procedure in SAS.
- Sigma Plot 11.0 was used to plot the graphs.

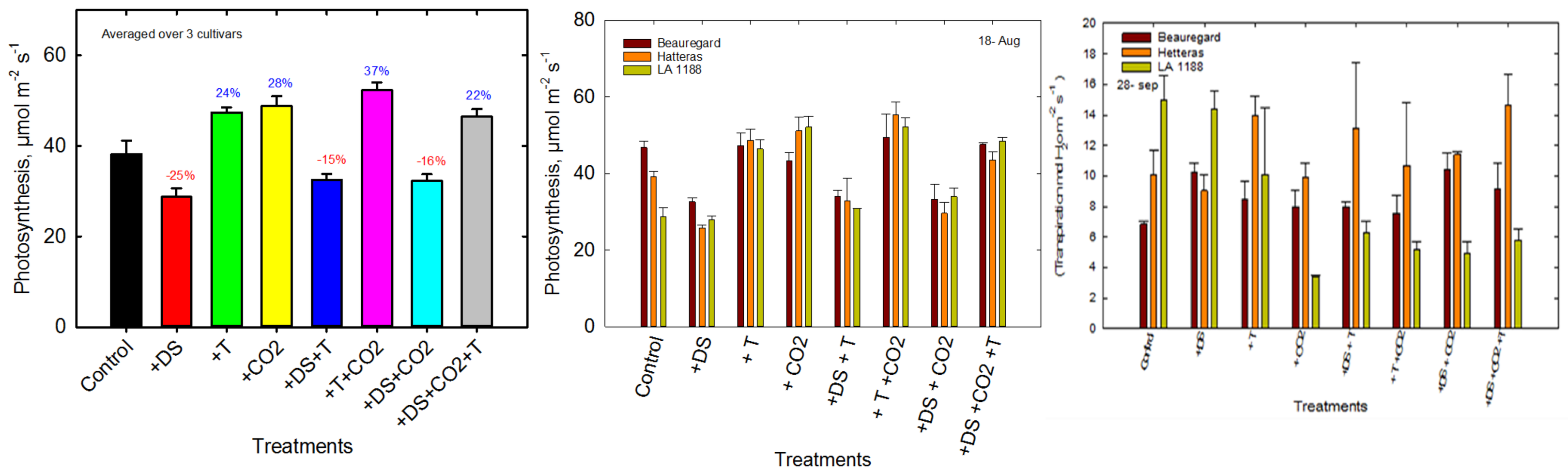
Results and Discussion

Table.2 The analysis of variance across the treatment of temperature (T), carbon dioxide concentration (CO2), Drought (DS) and cultivars (CUL: Beauregard, Hatteras, and LA 1188) and their interaction on Sweet potato morpho- physiological, photosynthetic and biochemical trait differences among three contrasting cultivars. Long vine length (LVL), long vine node No (LVNN), leaf area (LA), dry leaf weight (DLW), dry stem weight (DSW), dry root weight (DRW), total storage root weight (TSRDW), Storage root No (SRN), pencil root No (PNR), photosynthesis (PHO), stomatal conductance (COND), leaf internal CO2 (CI), florescence ratio (FV/FM), electron transport (ETR), transpiration (TRP), cell membrane thermobility (CMT), (CORO) total chlorophyll (TChl).

Source of variation	LVL	LVNN	LA	DLW	DSW	DRW	TSRDW	SRN	PRN	PHO	CON	CI	Fv/Fm	ETR	TRP	CMT	TChl
Control	*	***	NS	NS	*	NS	***	***	**	***	NS	NS	NS	NS	NS	***	NS
+DS	NS	NS	NS	NS	**	***	**	***	**	*	NS	NS	*	NS	*	***	NS
+ T	NS	NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS
+ CO_2	***	**	***	***	**	***	NS	NS	NS	***	*	NS	***	NS	NS	NS	**
+DS + T	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
+ T +CO_2	***	NS	NS	NS	NS	NS	NS	NS	*	***	NS	NS	NS	NS	NS	NS	**
+DS + CO_2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	**
+DS +CO_2 +T	***	NS	NS	NS	NS	NS	NS	**	*	NS	NS	***	NS	NS	***	NS	*

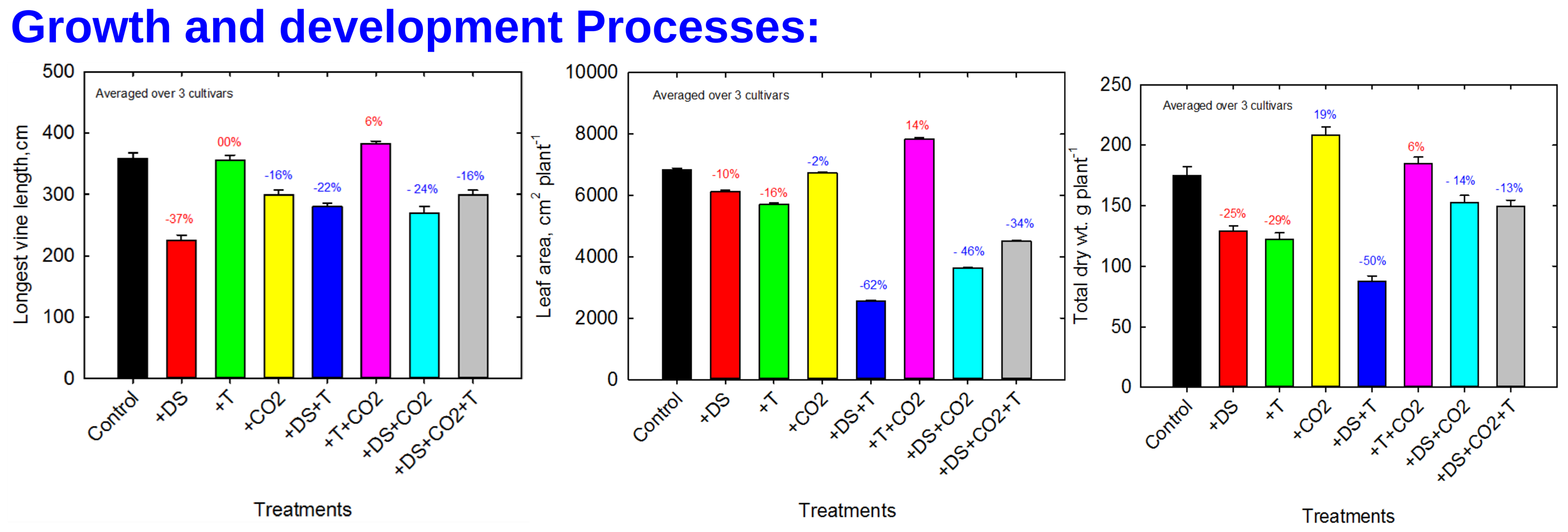
† Significance levels are indicated by ***,**,* and NS representing P<0.001, P<0.05, P<0.001 and P>0.05,

Photosynthesis Processes:

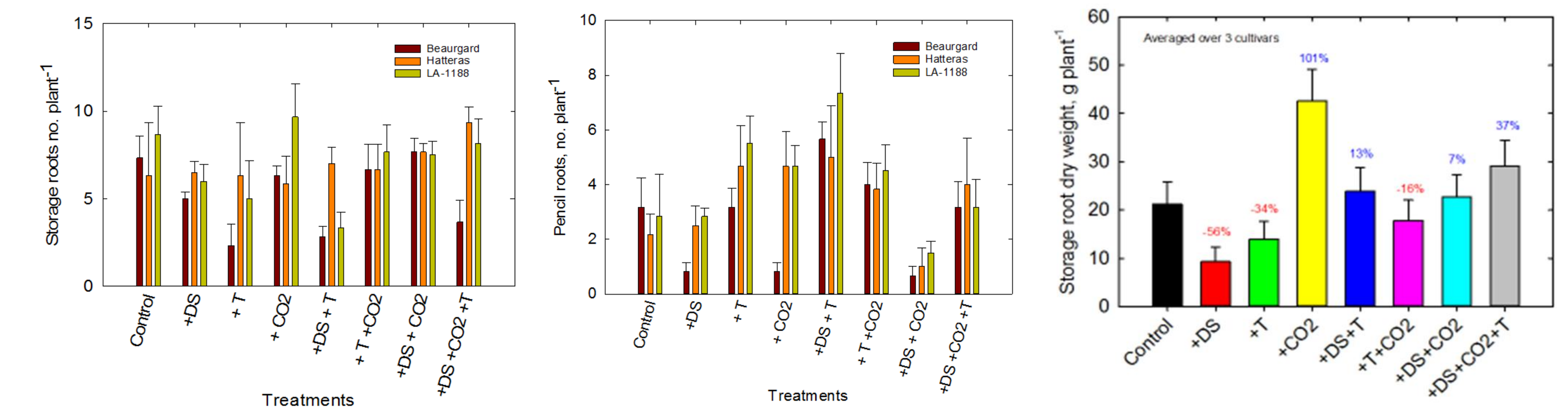


- Drought stress either alone or in combination resulted lower photosynthesis compared to control or their respective control treatments.
- Elevated CO_2 and high temperature increased photosynthesis either alone or in combination of other treatments.
- Elevated CO_2 and + T + CO_2 combination treatments decreased by 20% to 30% in LA cultivar against control.

Growth and development Processes:



- Vine length and Node numbers exhibited no significant variability among cultivars with treatments.
- Plants were grown under + T condition, 15% of node no.s increased among the other treatments, either alone, or in combination
- Significant interactions were found among treatment and cultivars for leaf area, combination of +DS + T; +DS + CO_2; and +DS +CO_2+T, reduced against control.
- Total dry weight was suppressed under all treatments, except +CO_2 and +T+CO_2 combination treatments increased against control.



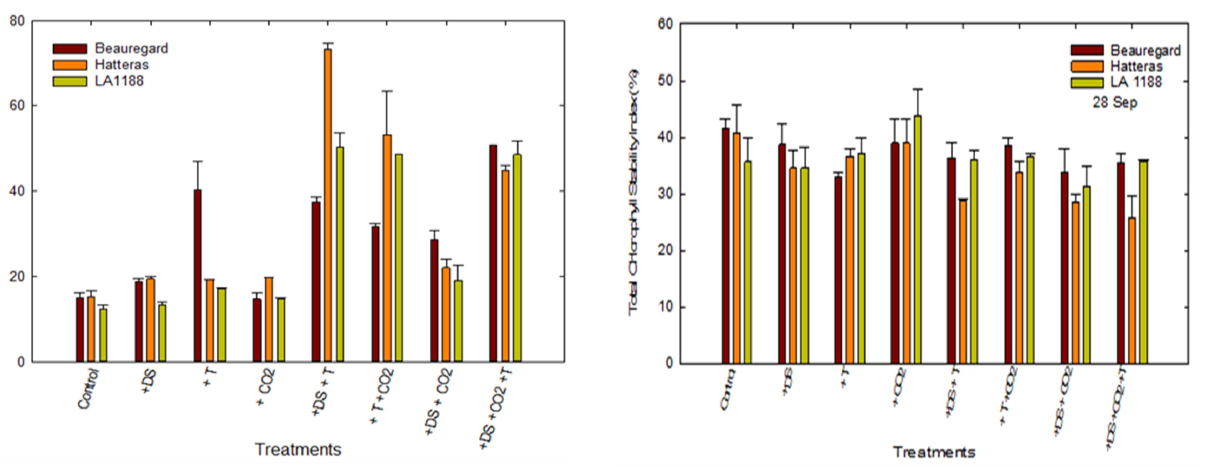
- Significant interactions were observed among treatments and cultivars for storage roots and Pencil roots production .
- Drought stress either alone or in combination resulted fewer storage roots and more pencil roots
- Plants grown under high temp resulted less storage root weight; while elevated CO_2 decreased the damaging effects of high temp and drought stress in some certain cult.

Table 3..Significance and No significance levels between all the treatment vs three cultivars (BG, HT and LA 1188).

Source of variation	LVL	LVNN	LA	DLW	DSW	DRW	TSR DW	SRN	PRN	PH0	CON	TRP	CMT	PHE	CAR	TChl
Beauregard	375.3 ***	56.6 NS	6556 NS	28.96 NS	74.3 NS	5.98 ***	59.82N S	5.24 NS	4.04 ***	33.20 NS	0.4 ***	11.6 NS	24.4N S	67.1 NS	6.2N S	37.7 ***
Hatteras	276.7 NS	59.5 NS	5302 NS	22.96 NS	66.9 NS	5.48 ***	51.08N S	3.56 ***	3.47 NS	32.13N S	0.39 NS	8.5 NS	22.5N S	58.2 NS	5.8N S	36.4 ***
LA-1188	274.2 NS	57.5 NS	5487 NS	22.50	64.5 NS	3.24 NS	50.02N S	5.12 NS	2.68N S	30.45N S	0.26 NS	7.9 NS	19.4N S	50.4 NS	5.8N S	33.46 NS

† Significance levels are indicated by ***,**,* and NS representing *P<0.001, P<0.05, P<0.001 and P>0.05,* respectively.

Biochemical Processes:



- Maximum relative injury (40-70%) was observed under multiple combination treatments against single combination treatments.
- The average chlorophyll stability index ranged from 60 to 70% in all treatment combinations and did not show huge variation among the treatment vs cultivars

Table 4. Total Stress Response Index (TSRI) and Classification

Treatments	Cultivars			
Combined stress response index (CSRI)	Beauregard	Hatteras	LA 1188	Mean
+DS	-1.87	-1.34	-0.58	-1.26
+ T	-2.95	2.26	-4.6	-1.76
+ CO2	0.01	1.08	2.07	1.05
+DS + T	-4.32	0.23	-5.69	-3.26
+ T +CO2	-0.16	5.46	0.91	2.07
+DS + CO2	0.12	7.82	-1.79	2.05
+DS + CO2 + T	-3.44	8.4	-3	0.65
Total stress response index (TSRI)	-12.61	23.92		-12.67
TSRI Classification	Sensitive	Tolerant	Sensitive	

- Total stress response index for each cultivar, developed from the cumulative sum of response indices of vegetative, photosynthetic and biochemical parameters varied among the three cultivars.
- Cultivar Hatteras was classified as stress tolerant and Beauregard and LA 1188 were classified as sensitive

Summary and Conclusions:

- Temperature and drought stress affected all aspects of plant growth and development including storage roots development and yield.
- Elevated CO_2 had a positive impact on photosynthesis and leaf area and its decreased the damaging effects of high temperature and drought stress
- High temperature (+T), drought stress (+DS), and with combination (+DSX+T) conditions, Beauregard & Louisiana 1188 cultivars showed a significant reduction in their storage root production by 80-90% and formed more pencil roots.
- Future studies should test several cultivars, lines under multiple stress conditions either alone or in combination to identify tolerance.

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