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Variations in Growth and Pigment Compositon of Sunflower Varieties under Early Season Drought Stress

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Abstract: Experiments were conducted in pot culture the plants were allowed to grow up to 30 DAS on alternative day irrigation. On 30th to 50th day (Before flowering period) all the potted plants were grown under poly house. Altering the irrigation intervals was imposed drought stress as follows. One set of 60 pots were irrigated at 3 days interval and another two set of pots at 4 days and 5 days interval up to 50th DAS. The root length of the sunflower all the cultivar increased while stem length, total leaf area, fresh and dry weights decreased under drought stress in all the sunflower cultivars. The total chlorophyll and carotenoid content decreased under drought stress in all the sunflower cultivars. Among the cultivars, the S-275 cultivar had the lowest pigmentation when compared to other cultivars. Drought stress significantly reduced the total chlorophyll and carotenoid content.

Key words: Water deficit stress, Growth, Yield, Sunflower, Pigment

INTRODUCTION

Water stress tolerance is seen in almost all plant species but its extent varies from species to species. Water deficit stress is a global issue to ensure survival of agricultural crops and sustainable food production [1]. Conventional plant breeding attempts have changed over to use physiological selection criteria since they are time consuming and rely on present genetic variability [2]. Currently, protection of plants from abiotic stresses through application of plant growth regulators (PGR) attracts more attention [3, 4]. Tolerance to abiotic stresses is very complex, due to the complexity of interactions between stress factor and various molecular, biochemical and physiological phenomena affecting plant growth and development [5]. High yield potential is the target of most crop breeding, not superior drought resistance and in many cases high yield potential can contribute to yield in moderate stress environment [6].

Plant experiences drought stress either when the water supply to roots becomes difficult or when the transpiration rate becomes very high and these two conditions often coincide under arid and semiarid climates. Although the general effects of drought on plant growth are fairly well known, the primary effects of water deficit at the biochemical and molecular levels are not well understood [1]. Accumulation of proline has been advocated as a parameter of selection for stress tolerance [4]. Proline accumulation can be met with the stresses such as temperature, drought and starvation [7]. High levels of proline enabled the plant to maintain low water potentials. By lowering water potentials, the accumulation of compatible osmolytes, involved in osmoregulation allows additional water to be taken up from the environment, thus buffering the immediate effect of water shortages with in the organism [8].

Water stress tolerance is seen in all plant species but its extent varies from species to species. Improving the

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efficiency of water use in agriculture is associated with increasing the fraction of the available water resources that is transpired, because of the unavoidable association between yield and water use [9]. For the last few decades, several scales of physiological works have been conducted under drought stress in crop plants [1, 10, 11].

Mechanisms of drought tolerance, not yet clear, can be to some extent explained by stress adaptation effectors that mediate ion homeostasis, osmolyte biosynthesis, toxic radical scavenging, water transport and long distance response coordination [12]. Tolerance to a biotic stresses is very complex, due to the complexity of interactions between stress factor and various molecular, biochemical and physiological phenomena affecting plant growth and development [5]. High yield potential is the target of most crop breeding, not superior drought resistance and in many cases high yield potential can contribute to yield in moderate stress environment [6].

MATERIALS AND METHODS

Collection of Seeds: Economically important oil seed crop sunflower (*Helianthus annuus* L.) belonging to the family Asteraceae was selected for the present investigation. Five cultivars viz., Asgrow SH 3322 (SH 3322), Agsun 110 (A-110), Kaveri 618 (K-618), SH 416 and Sunbred 275 (S-275) of sunflower were obtained from Kaveri Seeds Pvt. Ltd. andhra Pradesh, India and used for the experiments. The experiments were conducted at the Botanical Garden and Stress Physiology Laboratory, Department of Botany, Annamalai University, Tamil Nadu, India.

The potted plants were raised during the months of February-May, 2005-2007. The seeds were surface sterilized with 0.2% Mercuric chloride solution for five minutes with frequent shaking and thoroughly washed with tap water. The experiment was laid out in a Completely Randomized Block Design (CRBD). Plastic pots of 40 cm diameter and 45 cm height size were used for the study. The pots were filled with 10 kg of soil mixture containing red soil; sand and farm yard manure at 1:1:1 ratio and 440 pots were arranged in completely randomized block design. One set of 110 pots were kept as control and other 3 sets of 330 pots were used for drought stress treatments. The sunflower seeds were sown and the seedlings were thinned to 1 per pot on 10 days after sowing (DAS). The plants were allowed to grow up to 30 DAS. On 30^{th} to 50^{th} day (Before flowering period) all the potted plants were grown under poly house. The control plants were irrigated an alternative days. Mild stress (irrigation once in 3 days) moderate stress (irrigation once in 4days) severe stress (irrigation once in 5days) from 30^{th} to 50^{th} DAS. After the drought period all the pots to be irrigated an alternate days up to harvest. Plants were uprooted randomly 50^{th}, 60^{th} and 70^{th} DAS, washed carefully and estimating growth parameters, pigment.

STATISTICAL ANALYSIS

Experimental data were analyzed in SPSS-11 statistical package. Two factorial design with @seven replicates (Growth Parameters) and three replicates (Biochemical) in all the treatments and control.

Growth Parameters:

Root and Stem Length: Root and stem length were recorded on 50, 60 and 70 DAS. Below the point of root-stem transition to the tap root and the length of lateral roots were taken as total root length. The length between stem tip and point of root stem transition region was taken as stem length. The root length and the stem length were expressed in centimeters per plant.

Total Leaf Area: The total leaf area of the plants was measured using LICOR Photo Electric Area Meter (Model LI-3100, Lincoln, USA) and expressed in cm^2 per plant.

Fresh Weight and Dry Weight: After washing the plants in the tap water, fresh weight was determined by using an electronic balance (Model-XK3190-A7M) and the values were expressed in grams. After taking fresh weight, the plants were dried at 60°C in hot air oven for 72 hours. After drying, the weight was measured and the values were expressed in grams.

Biochemical Analysis:

Chlorophyll and Carotenoid: Chlorophyll and carotenoid were extracted from the leaves and estimated by the method of Arnon [13].

Carotenoid content was estimated using the formula of Kirk and Allen [14] and expressed in milligrams per gram fresh weight.

RESULTS AND DISCUSSION

Morphological Parameters (Tables 1,2,3,6)

Root Length: The root length increased to a larger extent with all drought treatment. Five day interval drought (DID) increased the root length to a higher level in all cultivars than the 3 and 4 DID treatments.

Table 1: Drought stress induced changes in Stem length (values are the mean of seven replicates expressed in cm plant^{-1}) of five cultivars of sunflower

Growth Stages	Treatments	SH-3322	A-110	K-618	SH-416	S-275
50 DAS	Control	66.22^{b}	66.16^{b}	68.60^{a}	63.50^{c}	61.06^{d}
	3 DID	53.34^{h}	55.32^{f}	58.60^{e}	52.29^{i}	47.70^{m}
	4 DID	48.63^{l}	50.44^{j}	54.28^{g}	48.12^{m}	43.93^{o}
	5 DID	43.23^{p}	45.22^{n}	49.22^{k}	42.44^{q}	36.99^{r}
60 DAS	Control	84.23^{e}	89.32^{b}	91.32^{a}	86.14^{c}	79.43^{h}
	3 DID	73.23^{m}	79.90^{g}	84.94^{d}	75.76^{k}	66.92^{q}
	4 DID	70.49^{o}	77.21^{j}	81.60^{f}	72.51^{n}	63.93^{r}
	5 DID	67.03^{q}	73.85^{l}	77.81^{i}	69.46^{p}	59.96^{s}
70 DAS	Control	87.75^{f}	92.64^{c}	94.67^{a}	89.89^{e}	82.55^{i}
	3 DID	82.76^{i}	89.52^{e}	93.59^{b}	85.62^{g}	74.64^{l}
	4 DID	80.98^{j}	87.66^{f}	91.36^{d}	83.98^{h}	73.02^{m}
	5 DID	78.76^{k}	85.76^{g}	89.12^{e}	81.97^{i}	70.28^{n}

Group a has the highest and group s has the lowest stem length.

DAS-Days After Sowing

DID-Days Interval Drought

Table 2: Drought stress induced changes in whole plant fresh weight (values are the mean of seven replicates expressed in gram per plant) of five cultivars of sunflower

Growth Stages	Treatments	SH-3322	A-110	K-618	SH-416	S-275
50 DAS	Control	76.58^{d}	81.60^{b}	85.31^{a}	79.56^{c}	72.36^{e}
	3 DID	61.66^{gh}	67.91^{f}	74.45^{d}	65.74^{g}	55.86^{i}
	4 DID	55.32^{i}	61.76^{gh}	66.78^{f}	58.33^{h}	50.07^{j}
	5 DID	48.69^{k}	58.08^{h}	59.17^{h}	51.14^{j}	41.99^{l}
60 DAS	Control	106.5^{d}	111.6^{b}	115.3^{a}	109.5^{c}	102.3^{e}
	3 DID	88.13^{i}	95.93^{g}	102.9^{e}	93.45^{g}	82.61^{b}
	4 DID	85.12^{j}	92.28^{gh}	99.12^{f}	88.45^{i}	78.19^{k}
	5 DID	80.31^{k}	87.60^{i}	93.94^{h}	83.61^{j}	73.00^{l}
70 DAS	Control	126.5^{d}	131.6^{b}	135.3^{a}	129.5^{c}	122.3^{e}
	3 DID	118.0^{f}	126.8^{d}	133.5^{a}	123.6^{e}	109.9^{h}
	4 DID	115.6^{g}	124.5^{e}	130.8^{b}	121.1^{f}	107.0^{hi}
	5 DID	112.2^{h}	120.1^{f}	126.0^{d}	117.3^{fg}	103.0^{j}

Group a has the highest and group l has the lowest fresh weight.

DAS-Days After Sowing

DID-Days Interval Drought

Table 3: Drought stress induced changes in whole plant dry weight (values are the mean of seven replicates expressed in gram per plant) of five cultivars of sunflower

Growth Stages	Treatments	SH-3322	A-110	K-618	SH-416	S-275
50 DAS	Control	12.63^{c}	15.35^{b}	18.31^{a}	14.31^{b}	11.57^{c}
	3 DID	9.13^{e}	11.56^{d}	14.53^{b}	10.64^{d}	7.99^{f}
	4 DID	8.80e	10.41^{de}	12.88^{d}	9.29^{e}	7.09^{f}
	5 DID	6.90^{f}	8.97^{e}	11.29^{c}	8.15^{e}	5.85^{g}
60 DAS	Control	23.63^{c}	26.35^{b}	29.31^{a}	25.31^{b}	20.57^{d}
	3 DID	18.17^{e}	20.95$_{d}$	24.60^{c}	19.70^{d}	15.36^{ef}
	4 DID	17.48^{e}	20.27^{d}	23.37^{c}	18.86^{de}	14.42^{f}
	5 DID	16.38^{e}	19.16^{d}	21.76^{d}	17.77^{e}	13.39^{f}
70 DAS	Control	25.60b^{c}	28.30^{b}	31.23^{a}	27.40^{b}	22.67^{d}
	3 DID	23.37^{d}	26.59^{bc}	28.05^{a}	25.38b^{c}	20.22^{e}
	4 DID	23.09^{d}	26.10^{bc}	27.46^{ab}	24.93^{c}	19.53^{e}
	5 DID	22.26^{d}	25.55^{bc}	26.45^{b}	24.02^{c}	18.69^{f}

Group a has the highest and group g has the lowest dry weight.

DAS-Days After Sowing

DID-Days Interval Drought

Table 4: Drought stress induced changes in total chlorophyll content (expressed in mg/gm fresh weight) of five cultivars of sunflower

Growth Stages	Treatments	SH-3322	A-110	K-618	SH-416	S-275
50 DAS	Control	0.341^{b}	0.374^{b}	0.419^{a}	0.362^{b}	0.317^{c}
	3 DID	0.270^{d}	0.308^{c}	0.361^{b}	0.294^{c}	0.243^{e}
	4 DID	0.260^{d}	0.296^{cd}	0.344^{b}	0.278^{d}	0.233^{e}
	5 DID	0.246^{e}	0.282^{d}	0.327^{c}	0.265^{d}	0.212^{f}
60 DAS	Control	0.688^{d}	0745^{b}	0.787^{a}	0.713^{c}	0.616^{f}
	3 DID	0.575^{h}	0.636^{e}	0.709^{c}	0.601^{g}	0.500^{k}
	4 DID	0.551^{i}	0.622^{f}	0.680^{d}	0.578^{h}	0.530^{j}
	5 DID	0.524^{j}	0.590^{g}	0.646^{d}	0.549^{i}	0.507^{j}
70 DAS	Control	0.900^{d}	0.947^{b}	0.989^{a}	0.915^{c}	0.818^{gh}
	3 DID	0.830^{f}	0.901^{d}	0.959^{b}	0.862^{e}	0.723^{k}
	4 DID	0.771^{j}	0.836^{fg}	0.894^{d}	0.797^{i}	0.662^{l}
	5 DID	0.783^{j}	0.858^{e}	0.918^{c}	0.814^{hi}	0.664^{l}

Group a has the highest and group l has the lowest total chlorophyll content.

DAS-Days After Sowing

DID-Days Interval Drought

Table 5: Drought stress induced changes in Carotenoid content (expressed in mg/gm fresh weight) of five cultivars of sunflower

Growth Stages	Treatments	SH-3322	A-110	K-618	SH-416	S-275
50 DAS	Control	0.085^{g}	0.114^{d}	0.143^{a}	0.124^{b}	0.071^{h}
	3 DID	0.063^{i}	0.092^{f}	0.120^{c}	0.097^{e}	0.052^{j}
	4 DID	0.060^{i}	0.087^{fg}	0.114^{d}	0.090^{f}	0.049^{j}
	5 DID	0.058^{i}	0.085^{f}	0.111^{d}	0.089^{f}	0.047^{k}
60 DAS	Control	0.166^{e}	0.193^{c}	0.225^{a}	0.182^{d}	0.156^{f}
	3 DID	0.132^{i}	0.165^{e}	0.200^{b}	0.149^{g}	0.121^{j}
	4 DID	0.125^{ij}	0.157^{f}	0.190^{c}	0.142^{h}	0.114^{k}
	5 DID	0.138^{h}	0.152^{fg}	0.184^{d}	0.139^{h}	0.111^{l}
70 DAS	Control	0.206^{d}	0.135^{i}	0.267^{a}	0.222^{c}	0.193^{de}
	3 DID	0.168^{g}	0.119^{j}	0.246^{b}	0.200^{d}	0.155^{h}
	4 DID	0.163^{gh}	0.117^{j}	0.241^{b}	0.195^{de}	0.151^{h}
	5 DID	0.158^{h}	0.112^{j}	0.230^{c}	0.178^{f}	0.141^{i}

Group a has the highest and group l has the lowest carotenoid content.

DAS-Days After Sowing

DID-Days Interval Drought

Table 6: Drought stress induced changes in Total leaf area (values are the mean of seven replicates expressed in gram per plant) of five cultivars of sunflower

Growth Stages	Treatments	SH-3322	A-110	K-618	SH-416	S-275
50 DAS	Control	348.60	369.56	393.33	356.46	326.46
	3 DID	338.96	297.43	326.56	282.36	239.50
	4 DID	246.56	274.33	304.50	290.06	223.43
	5 DID	233.26	247.26	294.20	243.00	206.06
60 DAS	Control	477.53	497.93	526.53	485.40	459.53
	3 DID	404.53	446.33	488.46	413.60	384.33
	4 DID	397.46	436.03	470.06	407.66	372.20
	5 DID	377.40	420.30	455.40	400.33	360.40
70 DAS	Control	508.40	530.60	585.60	517.30	490.53
	3 DID	470.60	511.00	579.46	487.60	438.26
	4 DID	461.20	500.60	571.33	478.40	431.13
	5 DID	444.60	489.53	564.06	471.13	421.53

Group a has the highest and group g has the lowest dry weight.

DAS-Days After Sowing

DID-Days Interval Drought

Among the cultivars the root length was increased to higher level in K-618 cultivar followed by A-110, SH 416, SH 3322 and S-275 cultivars. Drought stress increased the root length in Pearl millet [15], sunflower [16], Triticum aestivum [17], Cannabis sativa [18], The development of root system may increases the water uptake under drought stress.

Stem Length: Drought stress inhibited the shoot growth significantly in all sunflower cultivars. Among the drought treatments, 5 DID treatment highly affected the stem length than the other two treatments. Among the cultivars S-275 was most affected by the drought. Which was followed by SH-3322, SH-416, A-110 and K-618 cultivars. Stem length decreased in Eucalyptus seedlings under drought stress [19]. Similar results were observed in avocado [20], soybean [21], Populus species [22], Abelmoschus esculentus [23] and olive [24].

Total Leaf Area: Total leaf area decreased under drought stress significantly in sunflower cultivars. Among the drought treatments 5 DID reduced the total leaf area to a higher level than the other two treatments. Among the cultivars, the total leaf area was significantly reduced in S-275 cultivar by the drought stress to a larger extent. Water stress decreased total leaf area in Eragrotis curvula [25] and in Sorghum [26]. Similar results were observed under drought stress in wheat [27], cowpea [28], maize [29] and Abelmoschus esculentum [23, 30]. Reduction in shoot growth and increase in root growth shows the drought adoptive energy balances in sunflower.

Whole Plant Fresh Weight: Drought stress decreased the whole plant fresh weight in all sunflower cultivars significantly. The 5 DID drought treatment most affected the whole plant fresh weight than the other two treatments. Among the cultivars the whole plant fresh weight was very low in S-275 cultivars under drought. The whole plant fresh weight was reduced under drought condition in wheat [31]. Similar results were observed in higher plants like Vicia faba [32], cowpea [28], Pearl millet [15] sunflower [16, 33] and Catharanthus roseus [34]. The reduction in fresh weight under drought condition might be due to suppression of cell expansion and cell growth due to the low turgor pressure and partial root drying caused a significant reduction in shoot biomass when compared to control as observed in wheat [10, 27].

Whole Plant Dry Weight: The whole plant dry weight was reduced by drought stress in all sunflower cultivars. Among the drought treatments 5 DID treatment reduced the whole plant dry weight than the other two treatments. Among the cultivars the whole plant dry weight was very highly decreased in S-275 cultivar the reduction was low in the cultivar K-618 as compared to its control. Drought stress decreased the plant biomass in Lupinus albus [35] Arachis hypogaea [36], Asteriscus maritimus [37], wheat [38, 39] and in Abelmoschus [23]. Decreased total dry weight may be due to the considerable decrease in plant growth, photosynthesis and canopy structure as indicated by leaf senescence during drought stress in wheat [27]. Severe water stress may result in arrest of photosynthesis, disturbance of metabolism and finally drying [40].

Pigment Composition (Table 4,5)

Total Chlorophyll and Carotenoid: Drought stress caused decrease chlorophyll content when compared to their control in all the cultivars of sunflower. Among these cultivars, S-275 showed more reduction in the chlorophyll with 5 DID treatment and an lower reduction was observed in K-618 cultivars. A reduction in chlorophyll content was reported in drought stressed Helianthus annuus [16], Wheat [41] and Soybean [42].

The carotenoid content decreased in all the drought stressed sunflower cultivars when compared to their control. Reduced carotenoid content under drought was reported in Cherry [43], sunflower [44], Wheat [41] and Soybean [42].

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