Journal of Stress Physiology & Biochemistry, Vol. 9 No. 1 2013, pp. 258-272 ISSN 1997-0838

ORIGINAL ARTICLE

Parental Drought and Defoliation Effect on Yield, Grains Biochemical Aspects and Drought Performance of Sorghum Progeny

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Received October 30, 2012

This study was designed to evaluate the effect of drought stress and drought with defoliation on yield parameters of three sorghum varieties (Giza 15, Dorado and Hybrid 113). Also, the effect of these parental stress treatments on drought performance of progeny of the most drought tolerant variety was investigated. Application of drought stress in the vegetative stage non significantly affected panicles number, grain yield and harvest index of all cultivars. Drought stress in the reproductive stage of Giza 15 and Hybrid 113 cultivars caused a two fold increase in length of lateral branch and panicles number. However, grain yield and total panicles weight were significantly reduced in all cultivars due to this stress. Application of drought with defoliation in the vegetative stage reduced shoot and straw weights, and grain yield in sorghum in comparison with drought stress only. Protein-N and polysaccharides content were decreased in parent grains in response to water stress.

The stress intensity index (SII) of progeny from drought- subjected parents was about 30-fold greater than SII of progeny from control parents. Further, SII of progeny from parents exposed to drought stress in the reproductive stage was higher than the SII of progeny from parents subjected to drought stress in the vegetative stage. A strong negative correlation appeared between the stress intensity index of the progeny and polysaccharides content of parent grains. Based on our research parental defoliation did not improve the drought resistance of sorghum progeny.

Key words: drought; defoliation; parental; polysaccharides; progeny; protein-N; sorghum

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Key words: drought; defoliation; parental; polysaccharides; progeny; protein-N; sorghum

Conditions in the parental environment can affect the performance of progenies (Amzallag, 1994; Blödner *et al*., 2007). Stressful parental environments can dramatically influence expression of traits in offspring, in some cases resulting in phenotypes that are tolerant to the inducing stress (Herman *et al*., 2012). Drought stress is one of the most important abiotic stress factors that limit plant growth and ecosystem production around the world. It is estimated that the percentage of droughty terrestrial areas will redouble by the end of 21st century (Deeba *et al*., 2012). Improving the drought tolerance of crops through the integrated efforts of plant physiologists and breeders is an important objective (McWilliam, 1989; Jaleel *et al*., 2009).

Even though a number of indirect techniques have been used for the evaluation of drought tolerance in plants, grain yield, in cereals, is the most reliable indicator because it directly represents the harvestable product (Fischer and Murrer, 1978; White *et al*., 1994). Grain yield is a result of the integration of metabolic reactions in the plants, consequently any factor influence this metabolic activity at any period of plant growth can affect this yield. The effects of drought stress on grain yield depend on the duration and intensity of drought as well as the phenological stage of the crop when drought occurs (Savin and Nicolas, 1996; Mutava *et al*., 2011). In this context, it was found that drought stress at any stage of crops growth reduced yield to some extent, though stress applied at earlier stages had the least effect (Xia, 1994; Ahmed and Suliman, 2010). This reduction, in cereals, is mainly due to the decrease of starch accumulation, because over 60% of grain dry weight is starch (Duffus, 1992; He *et al*, 2012).

Protein and carbohydrates content in grains of cereals depends on the genotype and environmental factors, mainly temperature and moisture (Fernandez-Figares *et al*., 2000). Drought stress during grain filling tend to increase grain protein content and decrease starch content (Gooding *et al*., 2003). Others, reported the decrease of both carbohydrates and proteins in cereal grains in response to drought stress (Fernandez-Figares *et al*., 2000).

Defoliation, in optimum conditions, has been shown to reduce crop yield, and yield reduction is greatest if leaf removal coincide with the pollination stage (Rajewski and Fracncis, 1991; Board, 2004; Yang and Midmore, 2004). However, the information about the dual effect of defoliation and drought stress on crops yield is limited. Reduction of the negative effect of water stress on crop yield by defoliation was observed in rice (Fukoshima *et al*., 1985) and maize (Yang and Midmore, 2004). On the other hand the results of Caviness and Thomas (1980) using soybeans plants found that the actual yield was reduced in response to defoliation in control or drought conditions as compared to their respective controls. In case of sorghum, except the data of Montes *et al*. (1993) which indicated that the effect of defoliation in improving grain yield in water limited condition depend on the level of defoliation and the stage of plant growth, no other study has been done to evaluate sorghum response to defoliation under water stress conditions.

Grain sorghum is fifth in importance among the world's cereals (wheat, rice, maize, barley, sorghum) and is characterized by its ability to tolerate and survive under condition of both continuous or intermittent drought (Doggett, 1988). The exposure of sorghum plants to salinity stress was found to induce an increase in vigour of the progeny and consequently improved the adaptation of sorghum to salinity (Amzallag, 1994). Up to date, to our knowledge, no study has investigated the effect of parental drought or drought with defoliation on sorghum progeny performance under drought conditions. So this study was undertaken to investigate the effect of drought and drought plus defoliation on yield parameters and some grains biochemical aspects of three sorghum cultivars. Further, the influence of parental drought or drought with defoliation on progeny yield was studied.

MATERIALS AND METHODS

Growth conditions

Two pot experiments were carried out in a greenhouse at the Faculty of Science, Mansoura University, Egypt

1st experiment: Three Egyptian cultivars of sorghum (Giza 15, Hybrid 113 and Dorado) were used in this study. Pure strains were obtained from the Agriculture Research Centre at Cairo. The seeds were surface sterilized with 0.001 M $HgCl_2$ solution for 3 min and washed thoroughly with distilled water. The seeds were soaked in distilled water for 3 h and then allowed to germinate in Petri dishes for 2 days on filter paper moistened with water. The germinated seeds were planted in plastic pots (4 seeds per pot, 25 cm width × 30 cm height) filled with 6 kg soil (clay :sand =2:1, v/v). The plants were subjected to natural day/night conditions (minimum/maximum air temperature and relative humidity were 29/33°C and 63/68%, respectively at midday during the experimental period). Twenty days after planting the plants were thinned to 2 per pot. In the vegetative stage (45 days from planting) and reproductive stage (at anthesis) the plants of each cultivars were divided into three treatments: 1- Control, whereas the plants were irrigated to field capacity when the soil water content was at 60% of its initial value. 2-Drought stress by withholding water until yellowing of apical leaves tips was pronounced. This required 12 days for Giza 15 and Hybrid 113 and 17 days for Dorado at the vegetative stage and 10 days for all cultivars in the reproductive stage. 3- Drought with defoliation, whereas the plants were subjected to defoliation in addition to drought stress. Defoliation was achieved by cutting the lamina of the lower plant leaves which corresponded to half of total leaves. These three treatments were replicated 12 times to give a total of 36 pots for each cultivars. After the drought stress period the plants were irrigated as control plants and were left to grow until grain maturation. Then the plants were harvested and samples were taken for yield and grain biochemical aspect analyses. After thinning and before heading, each pot received 0.5 g N as calcium nitrate and 0.5 g P as dipotassium hydrogen phosphate.

Determination of total soluble sugars

A known dry weight was submerged in 80% ethanol overnight with periodic shaking, then filtered through Whatman No. 1 filter paper, and the filtrate was made up to known volume with 80% ethanol. Total soluble sugars in this filtrate was determined spectrophotometrically by the anthrone method (Riazi et al. 1985).

Determination of Polysaccharides:

According to Naguib (1963) a known weight of the dried plant residue which remaining after extraction of soluble sugars, was heated under reflux in 1.5 N H_2SO_4 for 4 hours at 100 ^oC . The solution was neutralized, cleared with basic lead acetate (137g/l) and deleaded with Na_2HPO_4 (M/3). Then the sugars content in this solution was determined by the anthrone method (Riazi et al. 1985).

Determination of total –N:

The dry powdered tissue was heated for at least 8 hours with 0.5 g catalyst (K_2SO_4; (80 g), $CuSO_4.5H_2O$ (20 g), and SeO_2 (0.3 g), 2 ml of ammonia-free concentrated H_2SO_4 and 1ml of distilled water. After cooling, total-N was determined by the conventional Kjeldahl method of Pirie (1955).

Determination of total soluble-N:

Total soluble -N was extracted by grinding the samples powder for 30 minutes in distilled water, in a mortar, at room temperature. The extract was then quantitatively transferred to a boiling tube, brought quickly to and maintained at 80°C for 15 minutes . The insoluble residue was removed by filtration. As mentioned for total-N, catalyst, H_2SO_4 and water were added and the sample digested. Then, the total soluble-N was determined by the conventional Kjeldahl method (Pirie, 1955). Subtracting the total soluble-N from total-N gave the value for protein-N.

Estimation of stress intensity index (SII):

Stress intensity index was calculated using the formula of Fischer and Murrer (1978).

SII= 1– (grain yield in stress condition/grain yield in control condition)

Estimation of harvest index (HI):

HI = Economic yield (grain yield) / Biological yield (above ground dry matter) × 100 (Beadle, 1993).

2nd experiment

In a trial to study the possible enhancement of drought tolerance in sorghum plants, the grains produced during the first experiment by the most tolerant variety were re-cultivated under the same growth and drought conditions, in the vegetative stage, as the parent plants in a pot experiment of similar design. Yield analysis was carried out as in 1st experiment.

Statistical analysis

The experiment had a completely random and factorial design. Results were based on ten replicates for yield analysis, and three replicates for physiological parameters. The results were subjected to an analysis of variance using GLM (general Linear Model) and one way ANOVA. The least significant differences between means ($P \leq 0.05$) and the correlation coefficients were given by SPSS 15 software.

RESULTS

Changes in yield parameters of parents plants in response to drought stress in the vegetative stage:

It can be seen from table 1a that the application of drought stress in the vegetative stage reduced shoot and straw weights by about 10% and 15% of control values, respectively in Giza 15 and Hybrid 113 cultivars and non significantly affected those of Dorado cultivar. Panicles number and weight, grain yield and harvest index were non significantly affected by the applied stress in all cultivars. Drought stress increased grain biomass of Giza 15 and Hybrid 113 cultivars to 115% and 110% of control, respectively and non significantly increased that of Dorado.

Drought plus defoliation treatment markedly reduced most yield parameters including grain yield of all used cultivars in comparison with drought only (table 1a). On the other hand, no significant difference was observed between the effect of drought and drought plus defoliation on grain biomass and the harvest index.

Changes in yield parameters of parents plants in response to drought stress in the reproductive stage:

Our results (table 1b) show that drought stress in the reproductive stage of both Giza 15 and Hybrid 113 cultivars increased shoot dry weight, straw weight, length of lateral branch and panicles number to about 110%, 130%, 200% and 200% of control, respectively. On the other hand, this stress appeared to reduce shoot and straw weights to 75% of control values, and non significantly change the number of panicles per plant and the length of lateral branch in Dorado cultivar.

Drought stress, in general, reduced total panicles weight, grain yield and grain biomass of all used cultivars and the effect was more pronounced in Giza 15 and Hybrid 113 than Dorado cultivar. It is interesting to mention that the main panicle of Giza 15 and Hybrid 113 varieties exposed to water deficit stress had no grains, and the grain yield resulted from the lateral panicle. As a consequence of the changes in shoot dry mass and grain yield, the harvest index of Giza 15 and Hybrid 113 cultivars was reduced to about 70% of control values in response to drought stress in the reproductive stage. On many occasions, no significant difference was observed between the effect of drought + defoliation and drought stress on yield parameters of sorghum plants (table 1b).

Changes in stress intensity index (SII) of parents plants

It can be seen from figure 1 that Dorado had a lower stress intensity index than Hybrid 113, which in turn had a lower values than Giza 15 in response to drought stress or drought plus defoliation in the vegetative and reproductive stages. This means that Dorado was more drought tolerant than Hybrid 113, which was more tolerant than Giza 15.

The results also indicate that drought stress in the reproductive stage increased the values of the SII of all varieties to more than 200% of drought stress in the vegetative stage. So it can be conclude that sorghum plants are more sensitive to water deficit stress in the reproductive stage than in the vegetative stage of plant growth. Drought plus defoliation treatments in the vegetative stage increased the stress intensity index of all cultivars to more than 300% of drought treatment. However, this treatment in the reproductive stage slightly increased the SII than drought treatment (Fig.1).

Changes in carbohydrates and nitrogen contents of parents developing grains

The main effect of drought stress, in the vegetative stage, taken across the three sorghum varieties was to reduce polysaccharides and protein-N in the developing grains (Fig.2a). Drought plus defoliation treatment in this stage added more reduction in protein-N. Total soluble sugars and total soluble –N levels were significantly increased in grains of the most drought resistant variety, Dorado, and were reduced in those of the most drought sensitive variety, Giza 15, in response to drought stress in the vegetative stage. Concerning the effect of drought plus defoliation on total soluble sugars and soluble –N there was a varietal difference, whereas its concentration in the developing grains was increased in Giza 15 and reduced in Dorado variety in comparison with drought stress only. In control conditions, Dorado variety had a higher polysaccharides and Protein-N levels than Giza 15 and Hybrid 113 and the converse was true for total soluble sugars and total soluble-N (Fig.2a).

In a broad sense, the changes of carbohydrates and nitrogen content in response to the drought stress in the reproductive stage were not different from those observed due to drought in the vegetative stage. On many occasions the effect of drought plus defoliation on polysaccharides and protein-N was similar to the effect of drought stress only (Fig 2b).

Changes in yield parameters of Dorado progeny grown under drought conditions in the vegetative stage:

It is important to mention that sorghum is considered to be substantially self-pollinating and under field conditions the extent of cross-pollinating average is only about 6% (Doggett 1988). Under greenhouse conditions it is likely that the extent of cross pollination would be much lower and it is assumed that it would be sufficiently low to permit the assumption that the seed was true to type.

The results in table 2 shows that drought stress reduced shoot and straw weights of progeny from control parents to about 90% of control. This treatment had no significant effect on panicle weight, grain yield and grain biomass, and consequently increased the harvest index in Dorado plants. Application of drought stress on progeny from parents exposed to drought stress in the vegetative stage reduced shoot weight, straw weight, panicle weight grain yield and harvest index to 65%, 55%, 57%, 43% and 68% of control values, respectively. Administration of drought stress on progeny from parents exposed to drought stress in the reproductive stage reduced these yield parameters to 40%, 41%, 47%, 39% and 97% of control respectively. Furthermore, this treatment reduced grain biomass to 73% of control value. This means that progeny from parents exposed to drought stress in the reproductive stage suffered more reduction in all yield parameters than those from parents exposed to drought in the vegetative stage. On many occasions the effect of parental drought plus defoliation treatment on Dorado yield parameters was not different from that of parental drought treatment (table 2).

Table 1a. Effect of drought stress in the vegetative stage on yield parameters of three sorghum cultivars . Values in each column for each cultivar with the same letter (s) are not significantly different at P<0.05.

Cultivars	Treatments	Parameters						
		Shoot dwt (g)	Straw weight (g/ plant)	Panicles no./plant	panicle fwt (g)	Grain yield (g/plant)	100 grains dwt (g)	Harvest index
Giza15	Control	12.23^a	8.96^a	1.0^a	6.31^a	4.71^a	3.62^b	38.51^a
	Drought	10.81^b	7.40^b	1.0^a	5.99^a	4.59^a	4.16^a	42.46^a
	Drought+ Defoliation	08.15^c	5.70^c	1.0^a	4.46^b	3.52^b	4.15^a	43.19^a
Dorado	Control	10.43^a	7.52^a	1.0^a	5.41^a	4.31^a	3.35^a	41.32^a
	Drought	10.33^a	7.30^a	1.0^a	5.04^a	4.26^a	3.38^a	41.24^a
	Drought+ Defoliation	10.07^a	7.20^a	1.0^a	5.08^a	4.18^a	3.61^a	41.50^a
Hybrid113	Control	12.34^a	9.37^a	1.0^a	6.00^a	4.54^a	3.92^b	36.79^a
	Drought	11.31^b	8.11^b	1.0^a	5.88^a	4.45^a	4.29^a	39.34^a
	Drought+ Defoliation	10.88^b	8.00^b	1.0^a	4.42^b	3.29^b	4.25^a	30.23^b

Table 1b. Effect of drought stress in the reproductive stage on yield parameters of three sorghum cultivars . Values in each column for each cultivar with the same letter (s) are not significantly different at P<0.05.

Cultivars	Treatments	Parameters: Shoot dwt (g)	Straw weight (g/ plant)	Length of lateral branch (cm)	Panicles no./plant	Total panicles fwt (g)	Grain yield (g/plant)	100 grains dwt (g)	Harvest index
Giza15	Control	12.23^b	8.96^b	40.8^c	1.0^b	6.31^a	4.71^a	3.62^a	38.51^a
	Drought	13.39^a	11.76^a	80.5^b	2.0^a	4.56^b	3.58^b	3.39^{ab}	26.73^b
	Drought+ Defoliation	12.46^{ab}	11.33^a	95.5^a	2.0^a	4.71^b	3.28^b	3.06^b	26.32^b
Dorado	Control	10.43^a	7.52^a	46.6^a	1.0^a	5.41^a	4.31^a	3.35^a	41.32^a
	Drought	7.95^b	5.69^b	39.5^b	1.0^a	4.09^b	3.47^b	3.46^a	43.64^a
	Drought+ Defoliation	8.68^b	5.18^b	49.0^a	1.0^a	3.96^b	3.5^b	2.58^b	40.32^a
Hybrid113	Control	12.34^b	9.37^c	54.4^c	1.0^b	6.00^a	4.54^a	3.92^a	36.79^a
	Drought	13.58^a	11.95^a	118.0^a	2.0^a	5.05^b	3.54^b	2.14^b	26.07^b
	Drought+ Defoliation	11.61^b	10.09^b	86.5^b	2.0^a	4.57^b	3.33^b	3.81^a	28.68^b

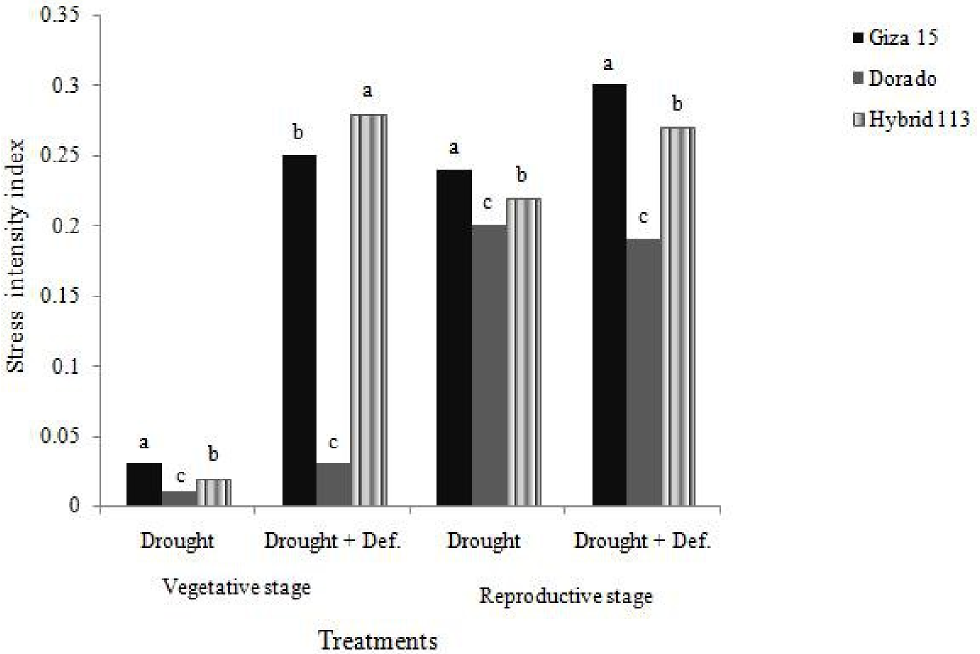

Fig.1. Changes in drought intensity index of three sorghum cultivars at vegetative and reproductive stages. Values in a group with the same letter (s) are not significantly different at P<0.05.
Abbreviation: Def. = Defoliation

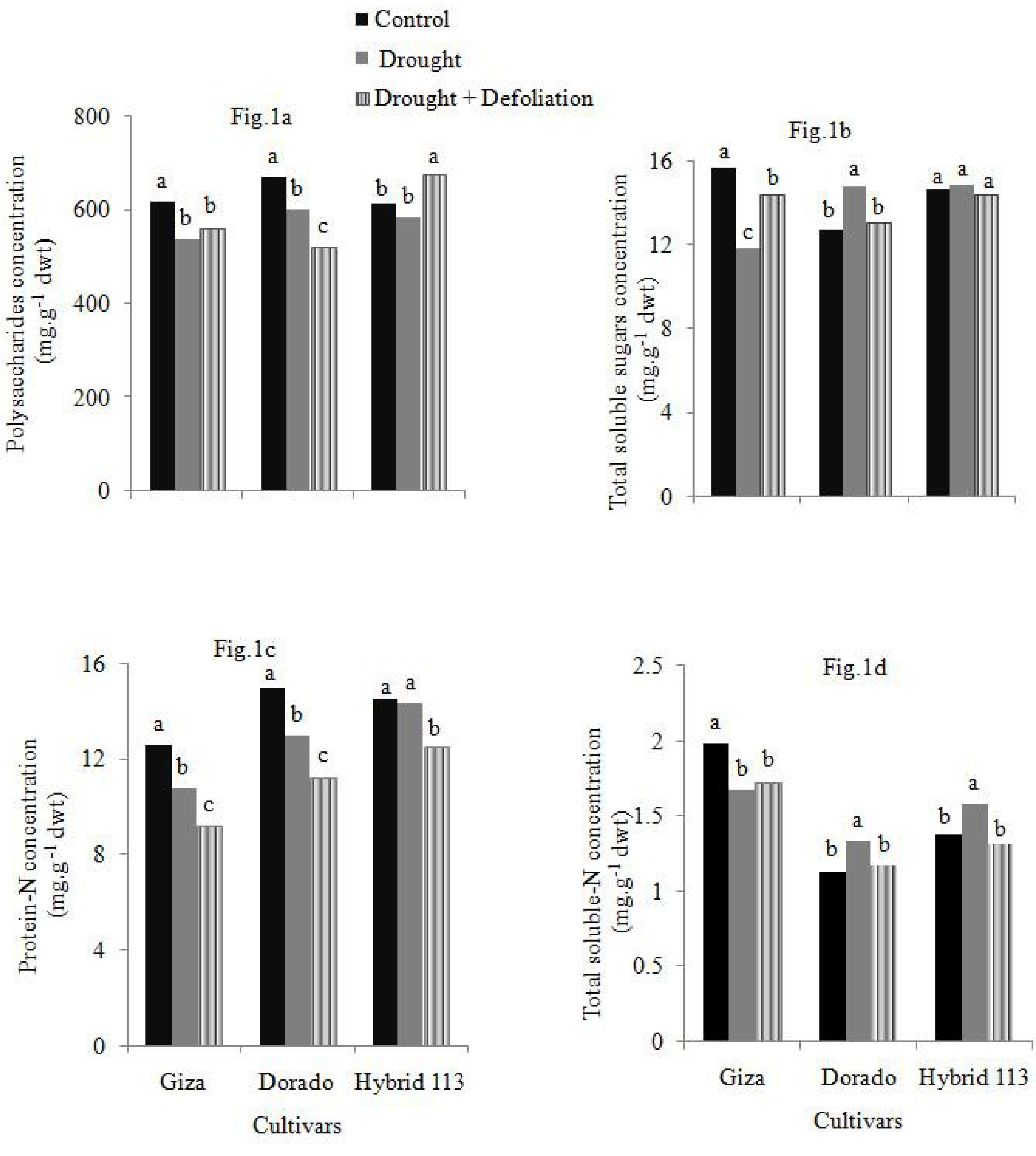

Fig.2a. Effect of drought stress in the vegetative stage on some biochemical aspects of three sorghum cultivars grains. Values in a group with the same letter (s) are not significantly different at P<0.05.

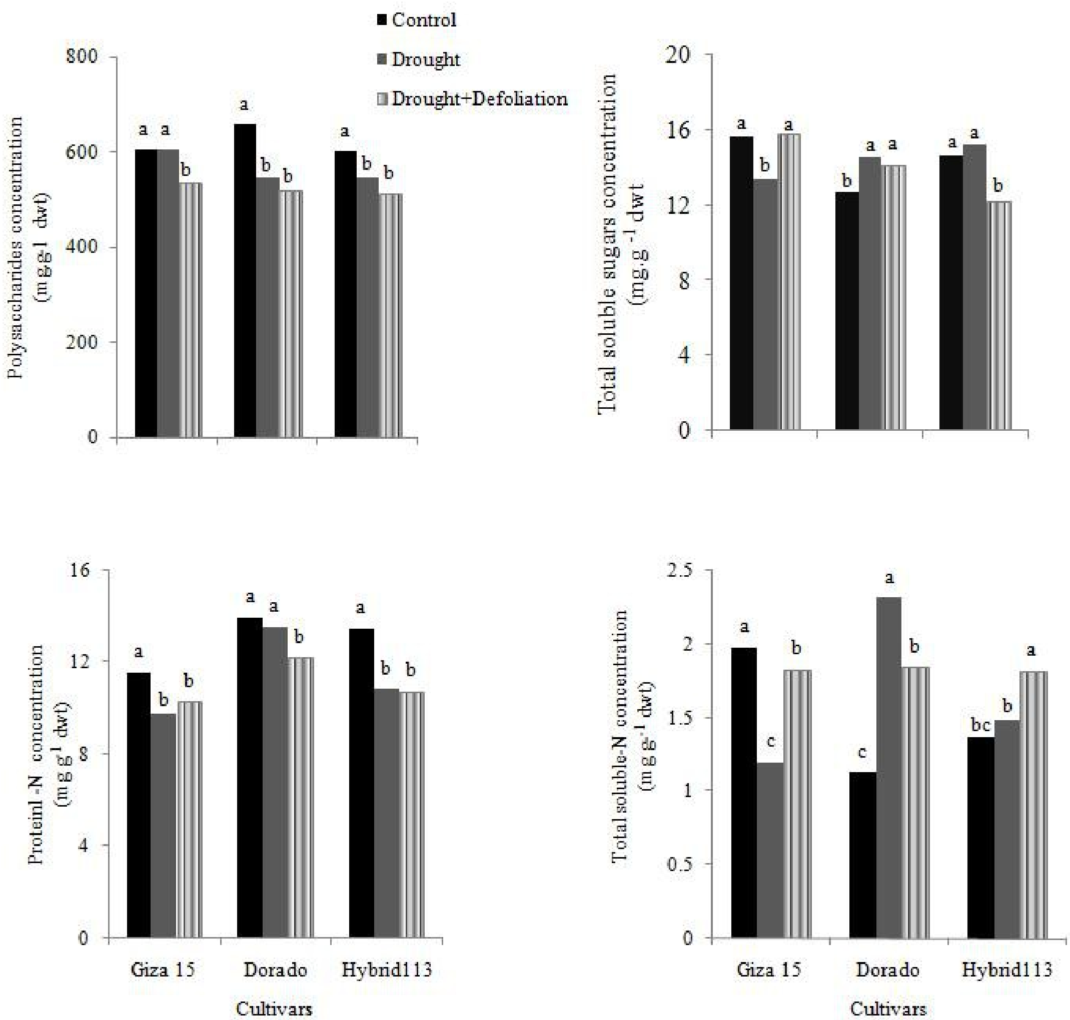

Fig.2b. Effect of drought stress in the reproductive stage on some biochemical aspects of three sorghum cultivars grains. Values in a group with the same letter (s) are not significantly different at P<0.05.

Table 2. Effect of Dorado parents treatments on yield of the offspring grown under drought conditions in the vegetative stage. Values in each column with the same letter (s) are not significantly different at P<0.05.

Parents treatments	Progeny treatments	Shoot dwt (g)	Straw weight (g/ plant)	panicle fwt (g)	Grain yield (g/plant)	100 grains dwt (g)	Harvest index	Stress Intensity index
Control	Control	9.8^{a}	8.6^{a}	5.1^{a}	4.8^{a}	2.3^{b}	49.1^{ab}	
	Drought	8.8^{b}	7.7^{b}	5.4^{a}	4.7^{a}	2.6^{a}	53.0^{a}	0.02^{c}
Drought (V)	Drought	6.3^{c}	4.8^{c}	2.9^{b}	2.1^{b}	2.2^{b}	33.4^{d}	0.55^{b}
Drought + Defoliation (V)	Drought	5.1^{d}	4.3^{c}	3.0^{b}	2.1^{b}	2.1^{b}	42.4^{c}	0.56^{b}
Drought (R)	Drought	3.9^{e}	3.5^{d}	2.4^{c}	1.9^{c}	1.7^{c}	48.1^{b}	0.61^{a}
Drought + Defoliation (R)	Drought	4.0^{e}	3.7^{d}	1.9^{d}	1.6^{c}	2.7^{a}	40.6^{c}	0.65^{a}

Table 3. Correlation coefficients between the stress intensity index of Dorado progeny and parents yield parameters.

Parameters	Correlation coefficients (r)
Shoot dwt	-0.58*
Panicle fwt	-0.71**
Grain yield	-0.61*
Grain biomass	-0.23
Harvest index	0.11
Polysaccharides content	-0.88**
Total soluble sugars	0.71**
Protein-N	-0.58*
Total soluble-N	0.56*

It can be seen also from table 2 that the highest progeny stress intensity index (SII) resulted from parents exposed to drought stress in the reproductive stage and the lowest one from control parents. It can be estimated that the stress intensity index of progeny from drought- subjected parents was about 30-fold greater than SII of progeny from control parents.

Correlation coefficients between the stress intensity index (SII) of Dorado progeny and parents yield parameters:

A strong negative correlation appeared between the SII and panicle weight (r = - 0.71) and polysaccharides content (r = - 0.88) of parent grains (table 3). The SII had a modest negative correlation with parents shoot weight, grain yield and protein content. On the other hand, the progeny SII had a positive correlation with total soluble sugars (r = 0.71) and total soluble-N (r = 0.56) of parents grains. A non significant correlation appeared between the SII and the other yield parameters (table 3).

DISCUSSION

The effect of drought stress on sorghum yield of parent plants appeared to depend on the stage of plant growth at which the stress was applied and the used cultivar. Grain yield was not affected, whereas shoot and straw weights were decreased by drought stress in the vegetative stage in Giza 15 and Hybrid 113 varieties. These results are compatible with those of Xia (1994) using faba bean (*Vicia faba* L.) and Ahmed and Suliman (2010) using cowpea (*Vigna ungiculata* L.) plants. This indicated that the straw weight was more sensitive to water deficit stress in the vegetative stage than grain yield. This reduction in dry matter production under water deficit stress was reported to be mainly due to reduction of leaf area, photosynthetic pigments and CO^2 assimilation (Younis *et al*., 2000; Jaleel *et al*., 2009) and increased photorespiration (Abogadallah, 2011; Beis and Patakas, 2012). No reduction was observed in grain yield or shoot dry mass in Dorado variety and this result with the results of the other two varieties explained the pattern of changes in the harvest index. Our results, on grain yield basis, that Dorado was more drought resistant than Hybrid 113, which in turn more resistant than Giza 15 cultivar support the findings of Younis *et al*. (2000) about these cultivars on shoot dry mass basis.

The reduction in grain yield of all used cultivars due to drought stress in the reproductive stage is consistent with the results of Craufurd and Peacock (1993) in sorghum and Ahmed and Suliman (2010) in cowpea. This reduction appeared to result from reduced grain biomass in the drought sensitive cultivars (Giza 15 and Hybrid 113) and decreased grain number in the most drought tolerant cultivar (Dorado). The observed increase of panicles number per plant in Giza 15 and Hybrid 113 in response to water deficit stress resulted from the destruction of the main panicle and activation of the growth of lateral branch and new panicle. This situation was not clear in the literature and our finding may be the first report about the effect of water deficit stress on lateral branch growth in sorghum. At this point, Dogget (1988) reported that the development of lateral branches in some sorghum varieties is often a response to stem damage. The increase in shoot and straw weights in Giza 15 and Hybrid 113 cultivars in response to drought stress in the reproductive stage appeared to be a consequence of the activation lateral branch growth after plants recovery. The decrease in grain yield and increase in straw weight in Giza 15 and Hybrid 113 varieties led to the observed reduction in the harvest index (HI) in response to drought stress in this stage. This is compatible with the results of Craufurd and Peacock (1993) who found that late drought stress (69 days after sowing) reduced HI in sorghum.

The negative effect of drought plus defoliation on sorghum yield in comparison with drought only in the vegetative stage is consistent with those obtained by Caviness and Thomas (1980) in soybean and seemed to be related to the reduction in grains number rather than grain biomass. However, no significant difference was observed between the effect of drought plus defoliation and drought stress alone on sorghum in the reproductive stage, and this is compatible with the results of Montes *et al*. (1993).

The decrease in polysaccharides and protein contents in developing grains in response to drought application at both stages are consistent with the results of Khanna-Chopra *et al*. (1994) and Fernandez-Figares *et al*. 2000). These changes could result from the reduction of CO_2 fixation (Younis *et al*. 2000), decrease of assimilates translocation from other plant parts to the developing grains (Westgate 1994) and reduction in the expression of starch and protein synthesis genes (He *et al*. 2012). On many occasions, drought plus defoliation added more reduction in polysaccharides and protein content of developing grains than drought alone. This is possibly due to alteration in source-sink ration which cause reduction in N (Asghar and Ingram, 1993) and sugars (Wang *et al*, 1996) content in developing grains compared with non defoliated plants.

Parental conditions obviously affected the resistance of sorghum progeny to drought stress. Unfortunately, parental drought and drought plus defoliation reduced the economic yield and the other yield components of Dorado progeny exposed to drought stress in comparison with drought-stressed progeny from control parents. These results were related to the observed decrease in polysaccharides and protein contents of parents grains in response to water deficit stress. From all evaluated parameters, polysaccharides content of parent developing grains appeared to be the most important factor for progeny drought tolerance. In contrast to our results, Amzallag (1994) observed that the exposure of sorghum plants (*Sorghum bicolor* L. Moench MP 610) to NaCl salinity induced an increase in vigour of the progeny to salinity and consequently improved the adaptation response of sorghum plants to salinity.

In conclusion the three used sorghum cultivars were different in their response to drought stress. Dorado cultivar was more resistant to drought stress than Hybrid 113 which in turn was more resistant than Giza 15. All cultivars were more resistant to drought stress in the vegetative stage than in the reproductive stage. The progeny from parents exposed to drought stress was less resistant to this stress than progeny from control parents. Application of drought plus defoliation did not improve the drought resistance of sorghum progeny. Although drought stress processes have been well characterized in many plants, this is may be the first study that investigate the effect of parental drought stress and parental drought with defoliation on the performance of sorghum progeny to drought stress.

REFRENCES

Abogadallah, G.M. (2011) Differential regulation of photorespiratory gene expression by moderate and severe salt and drought stress in relation to oxidative stress. *Plant Sci*. **180**:540–547.

Ahmed, F.E., Suliman, A.H. (2010) Effect of water stress applied at different stages of growth on seed yield and water-use efficiency of Cowpea . *Agri. Biol. J. N. Am*. **1**(4): 534-540.

Amzallag, G.N. (1994) Influence of parental NaCl treatment on salinity tolerance of offspring in *Sorghum bicolor* (L) Monech. *New Phytol*. **128**: 745-751.

Asghar, M. and Ibgram, B.F. (1993) Effect of defoliation on dryland wheat production in central Queensland. *Aust. J. Exp. Agri*. **33**:349-351.

Beadle, C.L. (1993) Growth analysis. In: Photosynthesis and production in a changing environment. A field and laboratory manual (eds: Hall, D.O., Scurlock, J.M.O., Bolhar-Nordenkampf, H.R., Leegood ,R.C. & Long, S.P.), Chapman and Hall, London, pp:36-46.

Beis, A. and Patakas, A. (2012) Relative contribution of photoprotection and anti-oxidative mechanisms to differential drought adaptation ability in grapevines. *Environ. Exp. Bot.* **78**: 173–183.

Blödner, C., Goebe, C., Feussner, I., Gatz, C. and Polle, A. (2007) Warm and cold parental reproductive environments affect seed properties, fitness, and cold responsiveness in Arabidopsis thaliana progenies. *Plant Cell Environ*. **30**(2):165-75.

Board, J.E. (2004) Soybean cultivar differences on light interception and leaf area index during Seed Filling. *Agron. J.* **96**:305–310

Caviness, C.E. and Thomas, J.D. (1980). Yield reduction from defoliation of irrigated and non irrigated soybeans. *J. Exp. Bot*. **44**: 1627-1629.

Craufurd, P. Q. and Peacock, J.M. (1993) Effect of heat and drought stress on sorghum (*Sorghum bicolor)*. II. Grain yield. *Exp. Agri.* **29**:77-86.

Deeba, F., Pandey, A.K., Ranjan, S., Mishra, A., Singh, R., Sharma, Y.K., Shirke, P.A. and Pandey, V. (2012) Physiological and proteomic responses of cotton (*Gossypium herbaceum* L.) to drought stress. *Plant Physiol. Biochem*. **53**: 6-18.

Doggett, H. (1988) Sorghum. Longman, London (UK).

Duffus, C.M. (1992) Control of starch biosynthesis in developing cereal grains. *Biochem. Soc. Tran*. **20**: 13-18.

Fernandez-Figares, I., Marinetto, J., Royo, C., Ramos, J. M. and Garcia del Mora, L.F. (2000) Amino-acid composition and protein and carbohydrate accumulation in the gain of triticale grown under terminal water stress simulated by a senescing agent. *J. Cereal Sci*. **32**: 249–258.

Fischer, R.A. and Murrer R. (1978) Drought resistance in spring wheat cultivars .I. Grain yield response. *Aust. J. Agri. Res*. **29**:897-912.

Fukoshima, M.T., Hinata, K. and Tsunoda, S. (1985) Effect of defoliation on the photosynthetic parameters and yield components under flooded and drought conditions in rice varieties. *Jpn. J. Breed*. **35**:292-300.

Gooding, M.J., Ellis, R.H., Shewry, P.R. and Schofield, J.D. (2003) Effects of restricted water availability and increased temperature on the grain filling, drying and quality of winter Wheat. *J. Cereal Sci.* **37**: 295-309.

He, J.F., Goyalb, R., Larocheb, A. , Zhaoa, M.L. and Lu, Z.X. (2012) Water stress during grain development affects starch synthesis, composition and physicochemical properties in triticale. *J. Cereal Sci*. in press.

Herman, J.J., Sultan, S.E., Horgan-Kobelski, T. and Riggs, C. (2012) Adaptive transgenerational plasticity in an annual plant: grandparental and parental drought stress enhance performance of seedlings in dry soil. *Integr. Comp. Biol.* **52**(1):77-88.

Jaleel, C.A., Manivannan, P., Wahid, A., Farooq, M., Somasundaram, R. and Panneerselvam, R. (2009) Drought stress in plants: a review on morphological characteristics and pigments composition. Int. *J. Agri. Biol.* **11**: 100–105.

Khanna-Chopra, R., Rao P.S.S., Maheswari, M. And Xiaobing L. (1994) Effect of water deficit on accumulation of dry matter, carbon and nitrogen in the kernel of wheat genotypes differing in yield stability. *Ann. Bot*. **74**:503-511.

McWilliam, J.R. (1989) The dimensions of drought. In: Drought resistance in cereals (ed. Baker, F.W.G.), CAB Int., UK, pp:1-11.

Montes, N., Gonzalez, V.A., Mendoza, L.E. and Livera M. (1993) Effect of defoliation on grain yield and yield components of sorghum submitted to drought. *Sorghum Newsletter* **34**:47.

Mutava, R.N. , Prasada, P.V.V., Tuinstrab, M.R., Kofoidc, K.D. and Yua, J. (2011) Characterization of sorghum genotypes for traits related to drought tolerance. *Field Crops Res*. **123**: 10–18.

Naguib, M.I. (1963) Colourimetric estimation of plant polysaccharides. *Zucher* **16**:15-18.

Pirie FG 1955. Proteins. In: Modern methods of plant analysis (eds. Peach, K. and Tracey, V.M.) **IV**: 23- 68, Spirnger-Verlage, Berlin.

Riazi, A., Matsuda, K. and Arslan, A. (1985) Water-stress induced changes in concentrations of proline and other solutes in growing regions of young barely leaves, *J. Exp. Bot.* **36**:1716-1725.

Rajewski, J.F. and Francis, C.A. (1991) Defoliation effects on grain fill, stalk rot and lodging of grain sorghum. *Crop Sci*. **31**:353-359.

Savin, R. and Nicolas, M.E. (1996) Effects of short periods of drought and high temperature on grain growth and starch accumulation of two malting barley cultivars. *Aust. J. Plant Physiol.* **23:** 201-210.

Wang, Q. C., Niu, Y.Z., and Zhang, X.O. (1996) Effect of altered source –sink ratio on canopy photosynthetic rate and yield of maize (*Zea maize* L.). *Photosynthetica* **32**:271-276.

Westgate, M.E. (1994) Water status and development of the maize endosperm and embryo during drought. *Crop Sci.* **26**:951-956.

White, J.W., Ochoa R., and Ibarra P. (1994) Inheritance of seed yield, maturity and seed weight of common bean (*Phaseolus vulgaris*) under semi-arid rainfed conditions. *J. Agri. Sci.* **122**: 265–273.

Xia, X.Z. (1994) Effects of soil drought during the generative development phase of faba bean (*Vicia faba*) on photosynthetic characters and biomass production. *J. Agri. Sci*. **122**:67-72.

Yang, Z., Midmore, D.J. (2004) Experimental assessment of the impact of defoliation on growth and production of water-stressed maize and cotton plants. *Exp. Agri*. **40**: 189-199.

Younis, M.E., El-Shahaby, O.A., Abohamed, S.A. and Ibrahim, A.H. (2000) Effects of water stress on growth, pigments and $^{14}CO_2$ assimilation in three sorghum cultivars. *J. Agron. Crop Sci.* **185**:73-82.