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Study of Photosynthetic Efficiency of Some Guar (*Cyamopsis tetragonoloba* L. Taub) Genotypes Grown under Different Water Regimes

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Abstract: The experiment was conducted in four cemented tanks of four guar genotypes i.e. S-807, Esser, Brooks and S-1183, under different water regimes (control, pre-post flowering stress, and terminal stress). The treatments were imposed at different stages of growth. Photosynthetic efficiency was determined by measuring leaf area, chlorophyll content and seed/yield. The findings show that water deficit reduced seed yield leaf area and chlorophyll content in all four guar genotypes. However, the genotypes S-807 and Esser had comparatively better performance than the other genotypes tested i.e. Brooks and S-1183.

Key words: Chlorophyll content, leaf area, seed/yield and water stress

Introduction

Guar is one of the most important summer annual legume that was introduced into the United State from India in 1993. In Pakistan, it is grown an area of about 127.3 x 10^3 hectares with seed production of 121.4x10^3 tons/year and with an average yield of 953 kg/ha (Anonymous, 1999-2000). It is multipurpose crop and is used as a vegetable for human consumption and forage for cattle and is also used as a green manure crop (Hymowitz and Matlock, 1964) and it improves the soil fertility through adding nitrogen in soil as its roots have nitrogen fixing bacteria. Its seeds are also a rich source of agro-based industry to obtain galactomanin gum, which is used in food processing paper manufacturing, textile printing and in pharmaceutical industries (Alexander *et al.,* 1998).

Drought is a major abiotic stress, causing not only significant yield reduction, but also yield variations from year to year with crop cultivating zone of the world. Globally, about 35% of the arable land can be classified as arid or semi-arid. In Pakistan, field crop are mainly irrigated by canal, however, about 1/3 rd of the total cultivable land is rainfed, which is variable and unpredictable (Anonymous, 1999-2000). In addition, the crop near the tail end of the canal, generally face water shortage in their life cycle. Water stress ix one of the most important environmental factors inhibiting photosynthesis (e.g. Bradford and Hsiao, 1982). Drought is considered to be a main limiting factor for crop yields (Schulze, 1986). However, for long term drought, it has been shown that stomatal control of photosynthetic rate becomes progressively less effective as soil water deficit intensifies (Tezara and Lawlor, 1995). Drought is the main environmental factor limiting plant photosynthesis, growth and yield, even in plants well adopted to arid conditions, such as grapevine (*V. Vinifera* L.) (Charas, 1991; Cornic and Massacci, 1996). The grain filling period is relatively more affected than the period from sowing to anthesis and occasionally the crop is prematurely ripened. Besides many other factors, productivity of crop depends on the photosynthetic efficiency, which is regulated by gaseous exchange capacity, leaf area, and their chlorophyll content (Ashraf *et al.*, 1994).

This study therefore, investigated on the effect of water stress on leaf area and chlorophyll content of four guar genotypes.

Materials and Methods

The experiment was conducted in four cemented tanks, each tank measuring 9m^2 (3 x 3m) and 1 m in depth. Individual tank was separated by a 15 cm thick cemented wall which acted a buffer zone on each side to prevent seepage. Prior to sowing the soil of the tanks were carefully leveled to ensure the even distribution of water. Soil samples from individual tanks were collected from 0-15, 16-30 and 31-60 cm depths before sowing the seeds and then analyzed for various physio-chemical properties (Table 1). A basic dose of urea (70 kg N/ha) and diammonium phosphate (35 kg P_2O_5 ha^{-1}) were broadcast and mixed with the surface layer (0-15 cm) immediately prior to sowing.

Four guar genotypes were selected to this study (S-807, Esser, Brooks and S-1183). The experiments were laid out in a complete randomized block design (RCBD) with irrigation regimes in the main plots and genotypes in the

Table 1: Soil characteristics of experimental site

	Soil Profile		
	0-15 cm	16-30 cm	31-60 cm
Characteristics	Depth		
A. Physical (%)			
Sand	45.96	46.00	46.00
Clay	29.50	28.86	28.06
Silt	24.54	25.14	25.94
Texture	**Stand clay loam**	**Stand clay loam**	**Stand clay loam**
Bulk Density (g cm^{-3})	1.40	1.40	1.40
Water Holding Capacity (%)	39.20	39.00	39.00
Field Capacity (-0.03 Mpa)	28.20	28.00	28.00
Wilting Point	14.00	13.94	13.69
B. Chemical			
Nitrogen (%)	0.05	0.05	0.05
Available P (ppm)	6.50	5.00	4.00
Exchangeable K (ppm)	160.00	155.00	155.00
Organic Matter (%)	0.74	0.71	0.54
Ece (mS cm^{-1})	0.20	0.21	0.20
PH	7.20	7.20	7.20
HCO_3 (meq^{-1})	2.21	2.25	2.15
CI (meq^{-1})	6.20	6.34	6.86
SO4 (meq^{-1})	12.46	11.76	11.68
Ca+Mg (meq^{-1})	12.40	11.26	11.36
Na (meq^{-1})	10.42	10.42	10.45

sub-plots with three replications.The pre-sowing irrigation (75 mm) was applied. Seed were hand drilled after the soil come into field capacity conditions, each genotypes was allotted three rows of 0.8 m length and having row to row distance of 0.30 m. The plants were grown up to maturity and when needs (75 mm) irrigation water was applied. The following stress treatments were imposed to simulate the type of drought generally encountered in the region.

Control	=	Normal irrigation as recommended for guar.
Pre-flowering	=	No irrigation up to flowering initiation.
Post-flowering	=	No irrigation after flowering.
Terminal drought	=	No irrigation (during entire growth period).

All the cementered tanks were protected from any possible rain by manually operated shelter equipped with moveable sheet of white flexible transparent plastic. The tanks were hand weeded and hoed whenever necessary. Before maturity, but at the grand growth period (normally 45 days of sowing), these observations such as : leaf area (LI-3100 Area meter, LI-COR, inc., USA), chlorophyll content (a, b and total) (Arnon, 1949) were determined and seed yield (100 seeds weight) were recorded. Analysis of variance was applied to determine the significance of different among the treatment and/or genotypes. Differences were compared by Duncan's multiple range test (DMRT) at 5% probability (Steel and Torrie, 1980).

Results

Leaf area: Leaf area was significantly influenced by water stress in all the genotypes (Table 2). Under control condition, the maximum leaf area was observed in S-807 (17.90 cm^2) followed by the Esser (16.27 cm^2). S-1183 (16.06 cm^2) and Brooks (14.56 cm^2). The difference between pre and post-flowering water stress was non-significant with genotypes except S-807. The maximum reduction in leaf area was recorded under terminal drought with genotypes. The highest leaf areas was noted in Esser (8.94 cm^2), followed by S-807 (8.27), Brooks (7.94) and S-1183 (cm^2). The value of the treatments for leaf area showed non-significant differences between pre and post-flowering treatments. The genotypic means showed non-significant differences between S-807 and Esser and similar trend was observed for Brooks and S-1183.

Table 2: Leaf area (cm^2) of four guar genotypes grown under different water regimes

	Treatments				
Varieties	Control	Pre-flowering stress	Post-flowering stress	Terminal stress	Mean
S-807	17.90 Aa	12.76 Ba	10.94 Ca	8.27 Dab	12.47 a
ESSER	16.27 Ab	11.33 Bb	10.92 Ba	8.94 Ca	11.86 ab
Brooks	14.56 Aa	10.20Bb	10.18 Ba	7.94 Cab	10.72 ab
S-1183	16.06 Ab	11.09 Bb	11.09 Ba	7.39 Cab	11.41 ab
Mean	16.20A	11.34B	10.78C	8.14C	

Means in the same column and same row sharing the same letters did not differ significantly according to Duncan's New Multiple Range Test at 5% level

Table 3: Effect of water stress on chlorophyll (A) content (mg g^{-1} fresh wt.) of different guar genotypes

	Treatments				
Varieties	Control	Pre-flowering stress	Post-flowering stress	Terminal stress	Mean
S-807	0.979Aa	0.891Ba	0.777Ca	0.683Da	0.832a
ESSER	0.984Aa	0.847Bab	0.768Ba	0.677Ca	0.827ab
Brooks	0.970 Aa	0.788Bab	0.712Cab	0.541Db	0.753ab
S-1183	1.009Aa	0.836Bab	0.748Cab	0.587Db	0.795ab
Mean	0.986A	0.841A	0.759B	0.622C	

Table 4: Effect of water stress on chlorophyll (B) content (mg g^{-1} fresh wt.) of different guar genotypes

	Treatments				
Varieties	Control	Pre-flowering stress	Post-flowering stress	Terminal stress	Mean
S-807	0.600Aa	0.565Ba	0.493Ca	0.404Da	0.516a
ESSER	0.605Aa	0.541Bb	0.534Ca	0.407Da	0.522a
Brooks	0.600Aa	0.514Bc	0.510Bb	0.342Cc	0.492
S-1183	0.590Aa	0.516Bc	0.520Ba	0.382Cb	0.502b
Mean	0.599A	0.534B	0.514C	0.348D	

Means in the same column and same row sharing the same letters did not differ significantly according to Duncan's N multiple range test at 5% level

Table 5: Effect of water stress on total chlorophyll content (mg g^{-1} fresh wt.) of different guar genotypes

	Treatments				
Varieties	Control	Preflowering stress	Post-flowering stress	Terminal stress	Mean
S-8.7	1.579Aa	1.456Ba	1.270Cab	1.087Da	1.348a
Esser	1.590Aa	1.388Bab	1.332Ba	1.084Ca	1.348a
Brooks	1.570Aa	1.302Bbc	1.222Cab	1.883Db	1.244ab
S-1183	1.599Aa	1.352Bbc	1.268Cab	0.969Db	1.297ab
Mean	1.584A	1.374B	1.373C	1.005D	

Chlorophyll content: Chlorophyll contents were determined chlorophyll a, b and total chlorophyll are presented in Table (3, 4 and 5) which were affected negatively by the induction of water stress.

Chlorophyll a: Chlorophyll (Chla) significantly decreased due to application of water stress in the genotypes (Table 3). Under controlled condition, the genotypes Rad similar value under pre flowering stress maximum chlorophyll a, was recorded in S-807 (0.891 mg^{-1}F. wt) S-1183 (0.836 mg g^{-1} F.wt) and Brooks (0.788 mg g^{-1} F. wt). under post-flowering, the trend was similar to pre-flowering except in Easer, where the maximum chla content was observed. Under terminal drought, genotypes clearly split in to

Table 6: Effect of water stress on 100 seed weight (g) of different guar genotypes

	Treatments				
Varieties	Control	Preflowering stress	Postflowering stress	Terminal stress	Mean
S-8.7	3.78Ab	3.56Bb	3.48Bb	2.75Ca	3.39b
Esser	3.96Aa	3.79Ba	3.62Ca	2.79Da	3.54a
Brooks	3.79Ab	3.50Bb	3.39Cc	2.15Dc	2.88d
S-1183	3.75Ab	3.44Bc	3.36Bc	2.25Cb	3.25c
Mean	3.56A	3.40B	3.36B	2.42C	

Means in the same column and row sharing the same letters did differ significantly according to Duncan's multiple range test at 5% level

two groups, S-807 and Esser with higher chlorophyll content, while books and S- 1183 with the lower. The treatments means showed that differences between control and pre flowering were non-significant. On the other hand, significant differences were recorded between post-flowering and terminal drought. The genotypic means indicated, the highest chla as S-807 (0.832 mg g^{-1} F. wt) followed by Esser (0.827 mg g^{-1}F.wt), S-1183 (0.795 mg g^{-1} F. wt and Brooks (0.753 mg g^{-1} F. wt).

Chlorophyll b (Chlb): Chlorophyll (chlb) was significantly affected by the induction of water stress (Table 4). Maximum reduction in chlb was recorded at terminal drought in the genotypes. Under control condition, the genotypes had similar value. Under pre-flowering stress maximum chlb was observed in S-807 followed by Esser, S-1183 and Brooks. Under post-flowering stress, maximum value was recorded in Esser, which differed non-significant with S-1183 and the minimum in S-807. The differences between S-807 and S-1183 were significant. Under terminal drought, S-807 and Esser had maximum value. On the other hand, Brooks had minimum value for chlb, the differences between Brooks and S-1183 were significant. Treatments means also showed significant differences. The genotypic mean formed two groups. S-807 and Esser with higher chlorophyll b and Brooks and S-1183 with lower value.

Total chlorophyll (chlt): The total chlorophyll was also influenced by different water regimes and non substantial difference were recorded in the genotypes (Table 5). Under pre flowering stress, maximum amount of chlorophyll was recorded in S-807 followed by others. The differences between Esser and S-1183 was non-significant and some was true in the case of S-1183 and Brooks. Under post-flowering stress, the maximum value for total chlorophyll was noted in Esser and the differences among S-807, S-1183 and Brooks were non-significant. Under terminal drought, the genotypes Brooks and S-1183 formed a group with lower total chlorophyll and Esser and S-807 with the higher total chlorophyll. Genotypic mean also different in similar way. The treatment means showed highly significant differences.

Seed yield: Seed yield was recorded in terms of 100 seed weight. Hundred seed weight progressively decreased due to increasing water stress in the genotypes (Table 6). Under control condition, the genotypes had similar value except Esser had the highest value for 100 seeds weight. Under post-flowering stress, again Esser had the highest value. Under terminal drought, S-807 and Esser had non-significant differences in 100 seeds weight under all treatments. The treatment mean indicated non-significant differences between pre and post-flowering stress. The highest seed weight was recorded under control condition and the lowest under terminal stress. In genotypic means, the highest value for 100 seeds weights were recorded in Esser following by S-1183 and Brooks.

Discussion

The result shows reduction in chlorophyll contents (Table 3, 4, 5) and leaf area (Table 2) of guar plant in terminal stress. The role of chlorophyll and leaf area in photosynthesis in beyond to doubt leaf is a major organ of plant where all photosynthetic activities take place and photosynthesis is the process by which radiant energy from the sun is converted into chemical energy necessary for vital functions of living organisms. This physiological process is vital for the maintenance of life on the earth. The reduction of leaf area chlorophyll content in plants may effect the photosynthetic activity of plant.

The end product of photosynthesis is utilized by human kind as grain/seed yield of which is reduced due to increase of water stress. The reduction in chlorophyll may be due to many reasons, it may be due to enhanced chlorophyll activity (Garcia *et al.*, 1987) due to increased water stress. But, according to others (Ashraf and Khan, 1994; Ashraf *et al.*, 1994; Huff, 1982; Johanson and Mclanchlan, 1990; Kato and Shimizu, 1985; Kuroda *et al.*, 1990; Mujmda *et al.*, 1991) the reduction in chlorophyll contents may be due to higher peroxidase activity and accumulation of some phenolic compounds, which might occur in drought conditions. As a result of reduced leaf area, the crop intercepted less photosynthetically active radiant energy, resulting in a reduction if grain/seed yield (Fischer, 1973). In the present study with guar genotypes, the weight of 100 seeds was considerably influenced by water stress applied at different stages of growth. The degree of shrivelness depended on the characteristic of genotypes. Genotypes S-807 and Esser had higher 100 seed weight compared to other genotypes used in this study, which suggests that 100 seed weight do positively play a significant role in increasing yield under drought.

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