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RESEARCH PAPER

Biophysical parameters and their association with drought tolerance in *rabi* sorghum genotypes [(*Sorghum bicolor* (L.) Moench]

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Abstract: Field experiment was conducted with seven rabi sorghum genotypes consisting of three dates of sowing *viz.,* D_1-1st week of October, D_2-1st week of November, D_3- 1st week of December at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during rabi season to know the performance of rabi germplasm materials under receding soil moisture condition and to understand genetic variations for drought tolerance in different genotypes. The performance of the genotypes with respect to biophysical characters were superior during D_1 (1st week of October) were mainly due to the differences in the amount of receding soil moisture which was more during D_1. The relative water content (RWC) was maximum at 50 per cent anthesis and decreased with advancement in the crop growth. Among the genotypes, maximum RWC was observed in BJV 44 and CSV 29 R at all the stages. Higher photosynthetic rate at flowering gave higher grain yield in the receding soil moisture conditions. With regard to grain yield the genotypes BJV 44, CSV 29 R, Phule Anuradha performed well under receding soil moisture conditions.

Key words: Drought tolerance, Photosynthetic rate, Transpiration rate, Relative water content

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important world crop grown for food, feed and industrial uses. It is the major crop for millions of people in the semi-arid tropics, and is extensively grown in Africa, China, USA, Mexico and India, where water availability is a major constraint to crop production. In India, it is grown in an area of 5.82 million hectare with an annual production of 5.39 million tonnes and yield of 926 kg/ha. In Karnataka, grain sorghum is grown under an area of 1.18 m ha with production 0f 1.30 m tons and yield of 1105 kg/ha (Anon., 2014). Water shortage is one of the most important limiting factors in crop production at world level. Drought is a multidimensional stress affecting crop plants at various stages of their development and is generally acknowledged as the foremost abiotic stress. Drought imposes many adverse effects on plants, resulting in decreased growth and yield. The major limitations to sorghum productivity are the occurrence of various biotic (shootfly, stem borer, charcoal rot etc) and abiotic (drought, salinity and temperature, etc.) stresses at different crop growth stages. Early and mid season droughts are common in *kharif,* while, terminal drought occur during rabi season.

Material and methods

A field experiment was conducted during rabi season, 2015-16 in Main Agricultural Research Station, University of Agricultural Sciences, Dharwad with Seven rabi sorghum genotypes (SPV 2217, BJV 44, CSV 29 R, M 35-1, DSV 4, E 36-1, Phule Anuradha) and three different dates of sowing (D_1-1st week of October, D_2-1st week of November, D_3-1st week of December). The experiment was laid out in factorial randomized block design with three replications. The observations on biophysical and biochemical characters were recorded at 50 per cent anthesis, every 15 days interval from 50 per cent anthesis upto physiological maturity and at harvest in five tagged. The relative water content was estimated at flowering by adopting the formula of Barrs and Weatherly (1962). The photosynthetic rate, transpiration rate and stomatal resistance were recorded by using portable photosynthetic system (LICOR 6400 Lincoln Inc, USA). Fisher's method of analysis of variance was applied for the analysis and interpretation of the experimental data as suggested by Panse and Sukhatme (1967). The level of significance used in 'F' and 't' test was P=0.5. Critical difference (CD) values were calculated at 5 per cent level, wherever 'F' test was significant.

Results and discussion

Relative water content

The relative water content (RWC) was maximum at 50 per cent anthesis and decreased with advancement in the crop growth. Among the genotypes, maximum RWC was observed in BJV 44 and CSV 29 R at all the stages. The water status of the plant could conveniently be studied with the observation like moisture content in plant and relative water content (RWC) as developed by Barrs and Weatherly (1962). In present study, RWC differed significantly among the genotypes. In general, the RWC was maximum at 50percent anthesis and decreased thereafter. The genotypes BJV 44, CSV 29 R and E 36-1 had higher RWC when compared to other genotypes. The lower RWC was recorded in genotype DSV 4. However, maintenance of higher RWC at later stages by the genotype will play a role in its tolerance under receding soil moisture. (Nirmal *et al.,* 2015). Similarly, significant and positive correlation has been reported by Salunke *et al.,* 2003.

Photosynthetic rate

Significant differences were observed among the genotypes with respect to photosynthetic rate and transpiration rate. The genotypes BJV 44 and CSV 29 R had higher values for these parameters. Photosynthesis is a process which converts solar energy into chemical energy in the presence of water and CO_2 which occur in green chlorophyll of the cells. The net carbohydrate production from the plant is a balance between photosynthesis and respiration. Sorghum being a C_4 tropical crop had relatively higher net photosynthesis. This C_4 pathway has advantage in sorghum under high temperature and drought stress conditions. In the current study, rate of photosynthesis is higher in high yielding genotypes like BJV 44 and CSV 29 R.(Table 1). The present findings are in agreement with Devkumar *et al.* (2014), Zelalem Getnet *et al.* (2015).

Transpiration rate

It was observed in our study that the transpiration rate decreased from 15 DAA to 30 DAA in all the genotypes (Table 2). In general, the genotypes which had maximum transpiration rate had low stomatal diffusive resistance. At 50 per cent A, the minimum transpiration rate was observed in E 36-1 and CSV 29 R. Similarly at 15 and 30 DAA, the genotypes

Table 1. Genotypic differences in photosynthetic rate (μ mol of CO_2 m^{-2} s^{-1}) at different stages in *rabi* sorghum at different dates of sowing.

Treatments	At 50 per cent anthesis	At 15 DAA	At 30 DAA
Date of sowing			
D_1(9th October)	48.01^{a}	36.08^{a}	18.62^{a}
D^2(1st November)	42.67^{ab}	32.07^{ab}	16.55^{ab}
D_3(1st December)	35.56^{b}	26.73^{b}	13.79^{b}
S.Em ±	2.59	1.01	0.80
LSD @ 5 per cent	7.40	2.88	2.28
Genotypes			
SPV 2217(G_1)	34.24^{b}	32.54^{ab}	12.29^{c}
BJV 44(G_2)	45.33^{ab}	34.83^{a}	20.59^{a}
CSV 29 R(G_3)	46.16^{a}	32.86^{a}	16.37^{b}
M 35-1(G_4)	42.78^{ab}	32.34^{ab}	14.48^{bc}
DSV 4(G_5)	38.73^{ab}	26.15^{c}	14.75^{bc}
E 36-1(G_6)	44.07^{ab}	34.32^{a}	20.04^{a}
Phule anuradha(G_7)	43.24^{ab}	28.36^{bc}	15.74^{bc}
S.Em ±	1.22	0.47	0.38
LSD @ 5 percent	3.49	1.36	1.07
Interaction (DxG)			
D_1 G_1	50.28^{ab}	39.15^{ab}	22.86^{a}
D_1 G_2	51.72^{a}	37.13^{a-d}	14.02^{f-i}
D_1 G_3	52.67^{a}	39.74^{a}	18.68^{b-d}
D_1 G_4	48.81^{a-d}	36.90^{a-e}	23.49^{a}
D_1 G_5	44.19^{a-f}	29.84^{fg}	16.83^{c-g}
D_1 G_6	39.06^{b-g}	37.49^{a-c}	16.52^{d-g}
D_1 G_7	49.34^{a-c}	32.36^{ef}	17.96^{b-e}
D_2 G_1	34.72^{e-g}	33.32^{c-f}	12.46^{hi}
D_2 G_2	45.97^{a-e}	33.00^{c-f}	20.32^{a-c}
D_2 G_3	46.81^{a-e}	35.32^{a-e}	16.60^{d-g}
D_2 G_4	43.39^{a-f}	32.80^{d-f}	20.88^{ab}
D_2 G_5	39.28^{b-g}	26.52^{gh}	14.96^{d-h}
D_2 G_6	44.69^{a-f}	34.80^{b-e}	14.68^{e-h}
D_2 G_7	43.85^{a-f}	28.76^{fg}	15.96^{d-h}
D_3 G_1	28.93^{g}	27.77^{gh}	10.39^{i}
D_3 G_2	38.31^{b-g}	27.50^{gh}	16.93^{c-g}
D_3 G_3	39.01^{b-g}	29.43^{fg}	13.83^{f-i}
D_3 G_4	36.16^{e-g}	27.33^{gh}	17.40^{b-f}
D_3 G_5	32.73^{fg}	22.10^{i}	12.47^{hi}
D_3 G_6	37.24^{c-g}	29.00^{fg}	12.24^{hi}
D_3 G_7	36.54^{d-g}	23.97^{hi}	13.30^{g-i}
S.Em ±	3.66	1.42	1.13
LSD @ 5 per cent	10.47	4.07	3.22

Note: G- Genotypes DAA – Days after 50 per cent anthesis.
DMRT: Letter followed by same letter do not show significant difference

Table 2. Genotypic differences in transpiration rate (μ mol of H_2O m^{-2} s^{-1}) at different stages in *rabi* sorghum at different dates of sowing.

Treatments	At 50 per cent anthesis	At 15 DAA	At 30 DAA
Date of sowing			
D_1(9th October)	3.54^{b}	4.12^{b}	1.64^{b}
D^2(1st November)	4.22^{ab}	4.90^{ab}	1.95^{ab}
D_3(1st December)	4.69^{a}	5.44^{a}	2.17^{a}
S.Em ±	0.35	0.36	0.23
LSD @ 5 per cent	1.00	1.04	0.66
Genotypes			
SPV 2217(G_1)	4.81^{ab}	4.16^{d}	0.96^{b}
BJV 44(G_2)	4.22^{a-c}	5.24^{ab}	1.87^{ab}
CSV 29 R(G_3)	3.51^{bc}	4.37^{c}	2.15^{a}
M 35-1(G_4)	4.87^{ab}	5.57^{a}	2.64^{a}
DSV 4(G_5)	5.18^{a}	4.87^{b}	2.00^{a}
E 36-1(G_6)	3.01^{c}	4.63^{bc}	1.78^{ab}
Phule anuradha(G_7)	3.45^{bc}	4.91^{b}	2.01^{a}
S.Em ±	0.17	0.17	0.11
LSD @ 5 per cent	0.47	0.49	0.31
Interaction (DxG)			
D_1 G_1	4.11^{b-f}	3.57^{e}	0.83^{f}
D_1 G_2	3.60^{c-f}	4.47^{b-e}	1.58^{b-f}
D_1 G_3	2.98^{ef}	3.75^{de}	1.84^{b-f}
D_1 G_4	4.17^{b-f}	4.76^{a-e}	2.26^{a-c}
D_1 G_5	4.45^{a-e}	4.17^{b-e}	1.70^{b-f}
D_1 G_6	2.55^{f}	3.96^{c-e}	1.52^{c-f}
D_1 G_7	2.93^{ef}	4.19^{b-e}	1.72^{b-f}
D_2 G_1	4.89^{a-d}	4.22^{b-e}	0.98^{ef}
D_2 G_2	4.29^{a-e}	5.33^{a-d}	1.91^{a-f}
D_2 G_3	3.57^{d-f}	4.43^{b-e}	2.19^{a-d}
D_2 G_4	4.95^{a-d}	5.66^{a-c}	2.68^{ab}
D_2 G_5	5.26^{a-c}	4.95^{a-e}	2.04^{a-e}
D_2 G_6	3.07^{ef}	4.70^{a-e}	1.81^{b-f}
D_2 G_7	3.51^{d-f}	4.99^{a-e}	2.04^{a-e}
D_3 G_1	5.44^{ab}	4.69^{a-e}	1.09^{d-f}
D_3 G_2	4.77^{a-d}	5.92^{ab}	2.13^{a-d}
D_3 G_3	3.97^{b-f}	4.92^{a-e}	2.43^{a-c}
D_3 G_4	5.49^{ab}	6.29^{a}	2.98^{a}
D_3 G_5	5.85^{a}	5.50^{a-d}	2.26^{a-c}
D_3 G_6	3.41^{d-f}	5.22^{a-e}	2.01^{a-e}
D_3 G_7	3.90^{b-f}	5.54^{a-c}	2.26^{a-c}
S.Em ±	0.50	0.51	0.33
LSD @ 5 per cent	1.42	1.46	0.93

Note: G- Genotypes DAA – Days after 50 per cent anthesis.
DMRT: Letter followed by same letter do not show significant difference

SPV 2217 and E 36-1 also had low transpiration rate. This clearly indicates that it was because of this the genotypes were able to maintain low leaf temperature which is a desirable character. The maintenance of plant water balance in these genotypes is due to its higher RWC values and more extraction of soil moisture which could have helped to keep low leaf temperature.

Stomatal conductance

The genotype CSV 29 R had higher stomatal conductance at 50 DAA. In the present study, it is observed that the relation between transpiration rate and stomatal conductance was similar in all genotypes (Table 3)

Table 3. Genotypic differences in stomatal conductance (m mol m^{-2} s^{1}) at different stages in *rabi* sorghum at different dates of sowing

Treatments	At 50 per cent anthesis	At 15 DAA	At 30 DAA
Date of sowing			
D_1(9th October)	0.13^{b}	0.10^{b}	0.03^{ab}
D^2(1st November)	0.15^{a}	0.11^{ab}	0.04^{a}
D_3(1st December)	0.15^{a}	0.12^{a}	0.04^{a}
S.Em ±	0.008	0.006	0.004
LSD @ 5 per cent	0.023	0.018	0.011
Genotypes			
SPV 2217(G_1)	0.17^{a}	0.10^{ab}	0.03^{c}
BJV 44(G_2)	0.12^{c}	0.12^{a}	0.03^{c}
CSV 29 R(G_3)	0.13^{bc}	0.11^{ab}	0.04^{ab}
M 35-1(G_4)	0.16^{ab}	0.12^{a}	0.05^{a}
DSV 4(G_5)	0.13^{bc}	0.11^{ab}	0.04^{ab}
E 36-1(G_6)	0.15^{a-c}	0.09^{b}	0.03^{c}
Phule anuradha(G_7)	0.13^{bc}	0.11^{ab}	0.05^{a}
S.Em±	0.004	0.003	0.002
LSD @ 5 per cent	0.011	0.008	0.005
Interaction (DxG)			
D_1 G_1	0.16^{a-c}	0.09^{c}	0.02^{c}
D_1 G_2	0.11^{e}	0.11^{a-c}	0.02^{c}
D_1 G_3	0.12^{de}	0.10^{bc}	0.03^{bc}
D_1 G_4	0.15^{a-d}	0.11^{a-c}	0.04^{b}
D_1 G_5	0.12^{de}	0.10^{bc}	0.03^{bc}
D_1 G_6	0.14^{b-e}	0.09^{c}	0.03^{bc}
D_1 G_7	0.13^{c-e}	0.10^{bc}	0.04^{b}
D_2 G_1	0.17^{ab}	0.10^{bc}	0.03^{bc}
D_2 G_2	0.12^{de}	0.12^{ab}	0.03^{bc}
D_2 G_3	0.13^{c-e}	0.11^{a-c}	0.04^{b}
D_2 G_4	0.16^{a-c}	0.12^{ab}	0.05^{ab}
D_2 G_5	0.13^{c-e}	0.11^{a-c}	0.04^{b}
D_2 G_6	0.15^{a-d}	0.09^{c}	0.03^{bc}
D_2 G_7	0.14^{b-e}	0.11^{a-c}	0.05^{ab}
D_3 G_1	0.18^{a}	0.11^{a-c}	0.03^{bc}
D_3 G_2	0.13^{c-e}	0.13^{a}	0.04^{b}
D_3 G_3	0.14^{b-e}	0.12^{ab}	0.04^{b}
D_3 G_4	0.17^{ab}	0.13^{a}	0.06^{a}
D_3 G_5	0.13^{c-e}	0.13^{a}	0.05^{ab}
D_3 G_6	0.16^{a-c}	0.11^{a-c}	0.04^{b}
D_3 G_7	0.14^{b-e}	0.12^{ab}	0.05^{ab}
S.Em ±	0.011	0.009	0.005
LSD @ 5 per cent	0.032	0.025	0.015

Note: G- Genotypes DAA – Days after 50 per cent anthesis.

DMRT: Letter followed by same letter do not show significant difference

Yield and yield components

Yield stability is an important aspect under drought conditions and reduced grain yields due to water stress during *rabi* season is a common occurrence and has been well documented. The degree of yield reduction due to water deficit depends on the timing and severity of stress . Yield components that are influenced by water deficit depend largely on the timing of stress. In the present study the genotype BJV 44 recorded higher yield followed by CSV 29 R and lowest was recorded in E 36-1 followed by DSV 4 (Table 4)

It was concluded from the findings that plants have different adaptive mechanisms for coping with limited

Table 4. Genotypic differences in yield and yield components at different stages in *rabi* sorghum at different dates of sowing

Treatments	Grain yield (kg/ha)	Fodder yield (kg/ha)	Harvest index
Date of sowing			
D_1(9th October)	4615^{a}	7139^{a}	42^{a}
D^2(1st November)	4082^{b}	7496^{b}	38^{b}
D_3(1st December)	2321^{c}	5280^{c}	32^{c}
S.Em±	218	263	2
LSD @ 5%	622	752	7
Genotypes			
SPV 2217(G_1)	3839^{ab}	8832^{b}	30^{cd}
BJV 44(G_2)	4197^{a}	7499^{c}	35^{bc}
CSV 29 R(G_3)	4088^{a}	5659^{d}	41^{b}
M 35-1(G_4)	3293^{ab}	6616^{d}	33^{b-d}
DSV 4(G_5)	3479^{ab}	10600^{a}	24^{d}
E 36-1(G_6)	3042^{b}	2481^{f}	54^{a}
Phule anuradha(G_7)	3773^{ab}	4783^{e}	43^{b}
S.Em±	102	124	1
LSD @ 5%	293	356	3
Interaction (DxG)			
D_1 G_1	4551^{a-c}	9894^{b}	32^{f-i}
D_1 G_2	5135^{a}	8198^{c}	39^{d-h}
D_1 G_3	5060^{ab}	6051^{d}	46^{c-e}
D_1 G_4	4354^{a-d}	6942^{d}	39^{d-h}
D_1 G_5	4426^{a-d}	11623^{a}	28^{h-j}
D_1 G_6	3714^{c-e}	2581^{i}	59^{a}
D_1 G_7	5068^{ab}	4685^{ef}	52^{a-c}
D_2 G_1	4300^{a-d}	9929^{b}	30^{g-i}
D_2 G_2	4654^{a-c}	8479^{c}	35^{e-i}
D_2 G_3	4512^{a-c}	6432^{d}	41^{c-g}
D_2 G_4	3477^{d-f}	7650^{d}	31^{f-i}
D_2 G_5	4055^{b-d}	11753^{a}	26^{ij}
D_2 G_6	3493^{d-f}	2709^{i}	56^{ab}
D_2 G_7	4086^{b-d}	5521^{ef}	43^{c-f}
D_3 G_1	2667^{fg}	6674^{fg}	29^{h-j}
D_3 G_2	2802^{e-g}	5820^{g}	32^{f-i}
D_3 G_3	2691^{fg}	4494^{h}	37^{d-h}
D_3 G_4	2049^{g}	5255^{h}	28^{h-j}
D_3 G_5	1955^{g}	8424^{de}	19^{j}
D_3 G_6	1918^{g}	2154^{j}	47^{b-d}
D_3 G_7	2165^{g}	4142^{i}	34^{e-i}
S.Em±	308	372	3
LSD @ 5%	879	1063	10

Note:G- Genotypes DAA – Days after 50 per cent anthesis.

DMRT: Letter followed by same letter do not show significant difference moisture supply conditions, thus indicating that one or more mechanism exist for adaptation to limited moisture conditions. The genotypes differed widely in their response to change in soil moisture content. The information thus generated would be more useful in breeding for drought tolerance and higher grain yield for a particular trait or the combination of traits for yield stability in limited moisture supply conditions. Considering all the mechanisms and relative performance of the genotypes with respect to various characters, it could be inferred that the genotypes BJV 44, CSV 29 R, Phule Anuradha and M-35-1 are more suited under limited water situations.

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