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Physiological Characterization of Rabi Sorghum Genotypes For Drought Tolerance Under Irrigated and Rainfed Condition

KEYWORDS: Rabi sorghum, root characters, water stress, Physiological characters.

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ABSTRACT *Thirteen sorghum genotypes including four checks were evaluated for key physiological parameters that help to survive under drought conditions. This experiment was conducted in root box structure by maintaining medium type of soil. The root number, length, volume and fresh mass all these root parameters were significantly higher in irrigated condition than rainfed condition. Under irrigated condition highest root number (82.33), root length (97.67 cm), volume (136.00 ml) and fresh mass (164.00) was recorded by genotype CRS-19 while same genotype also recorded highest root parameters under rainfed condition. Moisture limitation under rainfed condition also decreased chlorophyll content, photosynthesis rate, grain and fodder yield. Genotype CRS- 19 was also found superior for root parameters , morpho- physiological , yield and yield contributing characters under rainfed and irrigated condition.*

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is used as staple food in human diet as well as used in animal feed. It is fifth leading cereal crop in the world after wheat, maize, rice and barley. Sorghum is the staple food of poor and the most food insecure people, living mainly in the semi-arid tropics. It performs better under adverse soil and weather conditions as compared to other crops. However sorghum grown in arid and semiarid regions is influenced by water stress at terminal growth stages like anthesis and post anthesis which renders the most adverse effect on yield in sorghum. Water stress is a problem in 45 % of the world's geographical area and is major limitation to the productivity of agricultural systems and food production worldwide. Water shortage is a worldwide challenge and it's adverse effects on water uptake by roots and uses by shoots results to low production and even death of food or forage crops. Water stress at different growth stages causes various morphophysiological changes in the plant to acclimatize under such conditions.

Roots are place where plants first encounter water stress, it is likely that roots may be able first to sense and response to the stress condition. It plays an important role in water stress tolerance by reduction in leaf expansion and promotion of root growth. Water uptake by root is a complex parameter that depends on root structure and root anatomy. The information about significant correlation among the traits is important for initiation of any breeding programme because it provides a chance for selection of desirable traits. The results of correlation analysis revealed some important associations among the root traits and morphological characters. There was positive correlation between seed yield and root development in sorghum. However Ali *et al* (2011) reported a positive relation between drought tolerance and root length in sorghum. This suggested that these characters could be selected simultaneously with their positive effects on drought tolerance in sorghum. Hence, the objective of the present investigation was to screen plant types for *rabi* under *rainfed* and irrigated conditions for different morphological, physiological and root characteristics which may contribute to drought tolerance in sorghum.

MATERIAL AND METHODS

A field study was carried out for three consecutive years at Sorghum Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri during the *rabi* season 2011-12 to 2013-14 .Thirteen sorghum genotypes including four checks *viz.* Phule Chitra, Phule Anuradha, CSV 22 R and M-35-1 were characterized for key morphophysiological and root parameters that help surviving under drought conditions. All these sorghum genotypes were planted in root box structure with maintaining by medium type of soil before post rainy season for soil moisture conservation. Crop was sown on receding soil moisture under rainfed condition and under protective irrigated condition. The seeds were sown manually with a spacing of 45x15 cm. The gross plot size was 1.70 x 0.45 m and net plot size was 1.50 x 0.45 m. A basal dose of 25 kg N through urea was applied for two times. All physiological observations were recorded at 50 % flowering. Leaf temperature was recorded using an infrared thermometer. The photosynthetic rate and transpiration were recorded at flowering by using portable infrared gas analyzer (IRGA). Plant water status was monitored by measuring relative water content by leaves (RLWC%) calculated by the formula RLWC % = (FW-DW) / (TW-DW) (Hernandez *et al*, 2014). Leaf area was measured by using formula L.W.F dm^2. The yield parameters were recorded at harvest. The average data of three years were subjected to basic statistics and correlation analysis using statistical software packages of SPSS Version 12.

RSSULTS AND DISCUSSION:

In the present study significant effect of genotypes and water stress were observed on some morphological parameters of root including root number, root length, root volume and fresh mass of root in sorghum. There were significant differences in the morphological parameters of root under irrigated and rainfed condition (Table 1a and 2a). Under irrigated condition root number ranged from 52.00 to 82.33, length varied from 69.00 to 97.67 cm while root volume ranged from 59.33 ml to 136.00 ml. Fresh mass ranged from 68.00 to 164.00 g/plant. Under *rainfed* condition root number ranged from 26.3 to 45.7, root length 50.0 to 80.0 cm, root volume 40.0 to 70.3ml and fresh mass 33.3 to 60.7 g/plant. Root number, root length, volume and fresh mass was reduced by water stress under rainfed condition while under irrigated condition all these root parameters were significantly higher than rainfed condition. Results are in conformity with Vinodana and Ganeshmurthy, (2010). Water stress reduced phenotypic expression starting from germination to other growth parameters like shoot length, leaf area , total dry matter and fresh weight of roots. All rapidly growing divisions in different plants are strictly effected by drought stress. Similar findings reported earlier by Saddam *et al* (2014) in sorghum. Under irrigated condition highest root number (82.33), root length (97.67 cm), volume (136.00 ml) and fresh mass (164.00 g/plant) was recorded by genotype CRS-19 while under rainfed condition same genotype recorded highest number of roots (45.7), root length (80.0 cm), root volume (70.3 ml) and fresh root mass(60.70 g/plant). Based on root characters CRS-19 showed highest root length, number, volume and root mass implying that they are more drought tolerant among genotypes. A present study showed that high root mass and length are associated with drought tolerance implying maximization of water absorption in drought tolerant genotypes. This is also in agreement with Mutisya *et al* 2010.

Differences in plant height as response to stress was found among genotypes studied (Table 1 b & 2b). Under irrigated condition plant height ranged from 214 cm to 249 cm and under rainfed condition plant height varied from 183 cm to 217 cms. Under both conditions genotype CRS- 19 recorded maximum plant height *i.e* 214 cm and 217 cm respectively. Significantly higher plant height was found in irrigated condition than rainfed. Cellular growth appears to be most sensitive response to drought stress. Several investigations have reported that drought stress imposed during vegetative phase lessens plant height referring to Menezes et al 2014. Biomass under irrigated condition ranged from 146.0 g/ plant to 223.7 g/plant while under rainfed condition it ranged from109.0 g/plant to 209.3 g/plant. LAI ranged from 4.21 to 5.64 cms and 3.70 to 5.19 under irrigated and rainfed conditions respectively. Considerable differences exist among the sorghum genotypes studied in their ability to endure drought stress. Table 1a and 2a shows that under rainfed condition showed lower LAI than irrigated condition. During stress during Growth and photosynthesis in young leaves frequently do not reach the original rates for several days and old leaves are often shed. Furthermore, cells are smaller and leaves develop less during water shortage stress, resulting in reduced leaf photosynthesis and LAI. (Sher *et al*, 2013). Under both condition CRS-19 recorded maximum LAI *i.e.* 5.19 and 5.64 under rainfed and irrigated condition respectively. Higher LAI of CRS-19 favors better light interception and maintains a supply of assimilates to the productive organs, hence maximize grain yield. Under rainfed condition RLWC (%) varied from 56.67 to 64.00 and under irrigated condition it varied from 60.00 to 68.67 % . The RLWC (%) were higher in irrigated than rainfed condition. Genotype CRS- 19 maintained highest RLWC (%) (64.00 and 68.67) under rainfed and irrigated condition respectively. (Table 1a and 2a) . Plants that can hold high amount of leaf water are presumed more drought tolerant. Less stay green score (5-6) in CRS-19 indicates that in stay green lines the stalk transporting system continued to function under severe drought stress. Low stay green score of CRS- 19 also shows good source –sink relationship and assimilate portioning thus resulting in improved grain yield. Similar results were also observed by Kharrazi and Rad (2011). Stay green trait is the ability of the plant to retain greenness during grain ripening under water limited conditions. This phenomenon enables the plant to exhibit drought tolerance . Sorghum genotypes have stay green characteristics that may influence variable chlorophyll index.

SPAD value under rainfed condition ranged from 36.03 to 53.13 while under irrigated condition SPAD ranged from 47.93 to 63.57.Under rainfed condition there is decrease in chlorophyll content due to changing green colour of the leaf into yellow. Decrease chlorophyll content due to changing green colour of the incident radiation increased Plants irrigated maintained increased SPAD values that can be linked to the addition of nitrogen in plants.. Results are in conformity with Hernandez *et al* 2014. Genotype CRS-19 recorded highest SPAD value under irrigated (63.57) and (53.13) under rainfed condition.

Photosynthesis rate ranged between 29.73 µ mol Co_2 m^{-1} S^{-1}. to 34.20 µ mol Co_2 m^{-1} S^{-1}. under irrigated and 25.20 µ mol Co_2 m^{-1} S^{-1}. to 30.73 µ mol Co_2 m^{-1} S^{-1}. under rainfed condition. Water stress significantly decreased leaf area in all genotypes , an important factor in drought induced decrease in photosynthesis rate. (Moseki and Dintwe 2011). CRS- 19 recorded highest photosynthesis rate 30.73 and 34.20 µ mol Co_2 m^{-1} S^{-1}under both rainfed and irrigated condition. Transpiration rate under rainfed condition was ranged from 1.37 to 1.54 m/mol H_2O m^{-1} $\mathbf{S^{-1}}$).while under irrigated condition it ranged from 1.48 to 1.68 m/mol H_2O m^{-1} $\mathbf{S^{-1}}$.CRS- 19 recorded lowest transpiration rate under both the condition *i.e* 1.37 and 1.48 m/mol H_2O m^{-1} $\mathbf{S^{-1}}$ respectively. Physiological changes in root system induced by water shortage, such as closure of water channel which affects photosynthesis rate and transpiration rate. Influence on photosynthesis and gas exchange characteristics by water stress was another important reason inducing root water uptake decline. The declining effect of drought stress on water dissipation by transpiration varied among genotypes. This is another confirmation of differences in drought tolerance among species by Li *et al* 2011. Grain and fodder yield were higher under irrigated condition than rainfed (Table 1b & 2b) . Under irrigated condition grain yield ranged from 72.0 g/plant to 121.5 g/plant and under rainfed condition it ranged from 37.5 g/plant to 70.5 g/plant. CRS- 19 gave higher grain yield *i.e* 102.0 and 65.0 g/plant under irrigated and rainfed condition than other genotypes and at par with resistant check CSV-22R.

From above investigation it can be concluded that genotype CRS-19 was superior for putative drought tolerant root traits like root length, number, volume and fresh root

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mass as well as physiological characters like RLWC, SPAD chlorophyll value when compared to other genotypes. Hence CRS-19 can be considered while identification of good potential genotypes to drought environment and can be used for future breeding programme, where the sorghum varietal improvement for drought conditions could be achieved.

Table 1a. Evaluating rabi sorghum genotypes for physiological characteristics in medium soil under irrigated condition. (Pooled mean of three years data2011-12, 2012-13, 2013-14)

SN	Entry	LAI	RLWC (%)	SPAD at flow.	Leaf temp. Diff. (⁰C)	Photosynthesis rate (µ mol/m² / sec.)	Stomatal cond. (mol/m² / sec.)	Transpi.. rate (m/ mol H_2O m^{-1} S^{-1})	Root				Stay green at phy. maturity (1-9 scale)
									Number	Length (cm)	Volume (ml)	Fresh Mass (g/ plant)	
1	RSV 1098	5.26	62.67	51.23	-5.47	32.70	25.93	1.51	71.67	79.33	113.33	127.67	5-6
2	MSV 71	4.94	63.00	53.30	-4.70	31.97	24.97	1.58	67.33	81.33	107.00	110.33	5-6
3	RSV 1410	4.25	63.33	59.70	-5.50	33.70	25.87	1.67	59.33	72.67	84.00	82.67	7-8
4	RSV 1429	4.66	63.67	54.47	-4.80	34.37	26.33	1.54	60.00	73.33	69.67	99.67	5-6
5	CRS 15	4.35	60.00	52.33	-4.67	30.37	24.10	1.68	65.00	72.67	85.00	91.33	7-8
6	CRS 19	5.64	68.67	63.57	-5.77	34.20	26.13	1.48	82.33	97.67	136.00	164.00	5-6
7	BJV – 83	4.99	63.33	54.37	-5.67	29.73	26.83	1.51	75.00	87.33	88.67	138.67	5-6
8	BJV – 103	4.89	62.00	47.93	-4.07	31.90	24.20	1.59	59.00	80.33	62.33	68.00	7-8
9	CSV 19SS	4.77	62.00	56.33	-4.57	32.00	25.50	1.53	66.67	69.00	59.33	106.33	5-6
10	P.Chitra (c)	4.89	66.33	56.43	-5.60	32.97	24.73	1.51	56.33	88.00	92.33	107.67	5-6
11	P.Anuradha(c)	4.21	60.00	52.80	-5.20	30.57	25.13	1.50	61.33	82.00	87.33	87.33	5-6
12	CSV 22R (C)	5.56	62.00	53.97	-5.60	33.87	25.57	1.55	70.00	79.33	101.67	137.00	5-6
13	P.Vasudha (c)	4.86	63.33	55.30	-4.70	31.73	25.03	1.55	52.00	78.00	80.67	104.33	5-6
	Correlation	0.38	0.37	0.38	-0.53	0.36	0.25	-0.41	0.51	0.50	0.53	0.59	-

Table 1b. Evaluating rabi sorghum genotypes for physiological characteristics in medium soil under irrigated condition .(Pooled mean of three years data2011-12, 2012-13, 2013-14)

Sr. No.	Entry	Plant height (cm)	Biomass (g/plant) at	Days to		Grain yield (g/ plant)	Fodder yield (g/ plant)	Dry matter at 50 % flow. (g/ plant)			1000 grain wt. (g)
			50 % flow.	50 % flow.	Phy. maturity			Leaves	Stem	Panicle	
1	RSV 1098	234	161.0	74	117	95.5	127	35.7	102.0	23.3	41.73
2	MSV 71	240	168.3	77	120	99.5	116	39.0	107.3	22.0	40.33
3	RSV 1410	235	155.0	62	110	92	125	36.7	93.3	25.0	38.33
4	RSV 1429	227	199.0	75	118	87.5	126	43.3	131.3	24.3	42.53
5	CRS 15	221	152.0	69	111	81.5	104	34.3	88.3	25.3	42.57
6	CRS 19	249	212.7	75	116	102	130	47.7	113.3	31.0	42.10
7	BJV – 83	235	179.3	74	116	82	107	40.0	144.3	28.3	41.23
8	BJV – 103	214	178.3	77	120	87	109	44.3	106.7	27.3	34.13
9	CSV 19SS	220	146.0	66	109	54.5	118	32.0	87.0	27.8	36.60
10	P.Chitra (c)	240	165.7	72	114	85	120	39.7	96.7	29.3	40.97
11	P.Anuradha(c)	230	151.7	65	107	72	104	43.0	81.7	27.0	40.00
12	CSV 22R (C)	244	223.7	76	118	121.5	116	46.3	148.0	33.0	38.23
13	M 35-1 ©	238	179.0	72	115	94	103	38.0	111.3	29.7	40.40
	SE ±					21.4	6.6				
	CD at 5 %					64.55	20.2				
	CV %					18.4	17.0				
	Correlation	0.27	0.33	0.42	0.30		0.44	0.13	0.39	0.15	0.43

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Table 2 a. Evaluating rabi sorghum genotypes for physiological characteristics in medium soil under rainfed condition . (Pooled mean of three years data data2011-12, 2012-13, 2013-14)

S N	Entry	LAI	RLWC (%)	SPAD at 50 %flow.	Leaf temp. Diff. (^{0}C)	Photosynthesis rate (µ mol Co_2 m^{-1} S^{-1}.)	Stomatal cond. (mol/m^2 / sec.)	Transpi. rate (m/mol H_2O m^{-1} S^{-1})	Root				Stay green at phy. maturity (1-9 scale)
									No.	Length (cm)	Volume (ml)	Fresh Mass (g/plant)	
1	RSV 1098	4.86	58.67	47.40	-4.9	30.77	22.67	1.52	36.0	76.7	58.0	51.0	5-6
2	MSV 71	4.67	60.33	42.03	-4.0	25.20	22.40	1.54	32.0	63.3	48.0	42.3	7-8
3	RSV 1410	3.84	60.33	44.77	-5.0	26.53	20.67	1.51	37.3	60.7	56.0	44.7	8-9
4	RSV 1429	4.07	56.67	45.37	-3.8	27.43	21.03	1.45	26.3	59.7	44.0	33.3	7-8
5	CRS 15	3.89	57.33	36.03	-4.6	26.70	22.17	1.51	36.7	62.7	47.3	48.7	8-9
6	CRS 19	5.19	64.00	53.13	-5.1	30.73	22.17	1.37	45.7	80.0	70.3	60.7	5-6
7	BJV – 83	4.43	62.00	47.57	-4.8	26.00	21.70	1.54	35.3	70.0	64.3	45.7	5-6
8	BJV – 103	4.87	64.00	48.20	-4.9	26.13	23.00	1.38	35.3	54.3	40.0	35.0	7-8
9	CSV 19SS	3.70	60.00	49.47	-3.5	27.03	21.50	1.42	39.0	50.0	53.0	41.7	8-9
10	P.Chitra (c)	5.16	63.00	52.47	-4.9	30.37	23.17	1.45	41.0	75.7	63.7	48.7	5-6
11	P.Anuradha (c)	3.96	57.33	51.13	-4.8	27.90	20.80	1.49	44.7	75.7	57.3	37.7	5-6
12	CSV 22R (C)	4.78	61.67	46.17	-5.1	25.83	22.50	1.54	45.0	64.7	50.3	50.7	7-8
13	P.Vasudha (c)	4.21	58.00	51.50	-4.8	29.40	22.37	1.44	43.0	63.7	69.3	54.0	7-8
	Correlation	0.25	0.41	0.47	-0.4	0.52	0.35	-0.02	0.6	0.5	0.5	0.4	-

Table 2 b. Evaluating rabi sorghum genotypes for physiological characteristics in medium soil under rainfed condition. (Pooled mean of three years data data2011-12, 2012-13, 2013-14)

Sr. No.	Entry	Plant height (cm)	Biomass at 50 % flow. (g/plant)	Days to		Yield (g/plant)		Dry matter at 50 % flow. (g/plant)			1000 grain weight (g)
				50 % flow.	Phy. maturity	Grain	Fodder	Leaves	Stem	Panicle	
1	RSV 1098	203	168.7	72	115	68.0	100.3	34.3	112	22.0	29.05
2	MSV 71	183	156.0	76	118	44.0	97.0	34.0	108	21.5	32.40
3	RSV 1410	214	109.0	64	108	59.5	83.0	25.7	66	19.5	30.45
4	RSV 1429	191	175.0	73	114	48.0	93.7	34.0	127	21.0	31.35
5	CRS 15	199	134.7	66	108	56.5	77.7	35.7	74	28.5	31.30
6	CRS 19	217	177.3	73	113	65.0	115.0	34.0	118	25.0	28.40
7	BJV – 83	195	197.0	72	114	51.0	108.3	41.0	135	22.0	29.05
8	BJV – 103	197	153.7	74	116	37.5	79.3	39.3	97	23.0	23.55
9	CSV 19SS	187	124.0	61	102	43.5	88.7	25.3	75	27.5	29.25
10	P.Chitra (c)	191	142.0	69	110	70.5	84.0	36.0	74	27.0	26.20
11	P.Anuradha(c)	188	141.3	62	104	46.0	71.7	30.0	85	30.0	31.65
12	CSV 22R (C)	204	209.3	71	113	59.5	98.7	42.7	145	29.3	31.75
13	M 35-1 ©	199	152.7	68	110	53.0	88.7	32.3	88	29.0	30.85
	SE ±					16.5	18.7				
	CD at 5 %					50.4	60.1				
	CV %					14.9	13.2				
	Correlation	0.107	0.191	0.230	0.701			0.069	0.317	0.030	0.045

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