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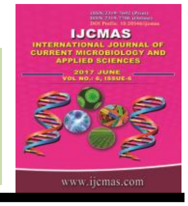

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Physiological Evaluation of Genotypes for Drought Tolerance on Receding Soil Moisture

U.D. Chavan*, S.V. Nirmal, S.R. Gadakh, M.S. Shinde, V.R. Patil, V.R. Awari and U.S. Dalvi

All India Coordinated Sorghum Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, India
**Corresponding author*

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Thirteen new *Rabi* sorghum genotypes and three checks were evaluated for their physiological characterization under medium and shallow soils during Rabi season viz., 2014-15, 2015-16 and 2016-17 in randomized block design with three replications. The grain yield was positively correlated with leaf area, leaf area index, biomass at harvest, HI %, 1000 grain weight, RLWC %, stay green at physiological maturity, while per day production of grain and fodder yield negatively correlated with leaf temperature differences. While considering all physiological parameters on medium soil genotype RSSV 1640 was found significantly superior over the checks. On shallow soil, none of the new genotype was found significantly superior over the check Phule Anuradha.

Introduction

Sorghum (*Sorghum bicolor* L. Moench) is the king of cereals and is one of the important food crops in dry lands of tropical Africa, India and China (Shobha *et al.,* 2008). India ranks second in the world for sorghum production and first with respect to many regionally important crops like millets and pseudo-cereals. Sorghum is the principal staple food of Maharashtra, and is also an important food of Karnataka, Madhya Pradesh, Tamil Nadu and Andhra Pradesh. Sorghum can be milled to produce starch or grits (semolina) from which many ethnic and traditional dishes can be made. The most common products are leavened and unleavened breads, porridges, boiled grains and steam cooked products such as couscous. Sorghum flour also makes an excellent fry coating for fish, chicken and beef. Sorghum is also used in the preparation of several snacks and for popping, chewing, and malting (Rao and Murty, 1981). There is a considerable variation in sorghum for levels of proteins, lysine, lipids, carbohydrates, fiber, calcium, phosphorus, iron, thiamine, and niacin (Chavan *et al.,* 2009). Sorghum has chemical composition similar to or better than rice and wheat in some respects. The grains contain high fiber and non-starchy polysaccharides and starch with some unique characteristics. Protein quality and essential amino acid profile of sorghum is better than many of the cereals. Sorghum in general is rich source of B-complex vitamins (Chavan *et al.,* 1988; 2010; 2015).

Sorghum *roti* is very popular in villages and small towns as an accompaniment to gravy meat and vegetable curries and is one of the traditional recipes of India. It is round, flat; unleavened bread often used in the cuisine of western and central India, especially in the states of Gujarat, Sorghum *roti* is known by various names in the different languages of India: *chapati* (Hindi), *bhakri* (Marathi), *rotla* (Gujarati), *rotte* (Telugu), etc. (Subramanian and Jambunathan, 1981). Because sorghum flour is gluten-free flour, it is very tough to spread the dough without breaking the shape and one really needs hands-on experience and many failed attempts to get the skill. No leavening agents, oil/ghee are added. Just fresh sorghum flour, warm water and touch of fire - pure grain power in its glory. Arabinoxylans have been isolated from different cereals and responsible to play important role in maintaining water balance and rheological properties of dough (Michniewicz *et al.,* 1991; Vietor *et al.,* 1992; Nandini *et al.,* 2001).

Typically *bhakri* is accompanied by various curries, chutney (*thecha* – a thick paste of really hot green or red chilies) and raw onion (Murty and Subramanian, 1981). *Bhakri* has its own advantages from dietary point of view. Being made from cereals, it is high in dietary fiber but at the same time very easy to digest (Chavan *et al.,* 1989, Chavan and Patil, 2010 and Chavan and Salunkhe, 1984**.** However it was necessary to study the effect different locations on the nutritional and roti quality therefore, present study was under taken to identify superior genotype for future development.

Materials and Methods

Thirteen new Rabi sorghum genotypes and three checks were evaluated for their physiological characterization under medium and shallow soils at Sorghum Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri during Rabi season viz., 2014-15, 2015-16 and 2016-17 in randomized block design with three replications. The gross and net plot size was 4.50 x 2.70 m and 4.10 x 1.80 m, respectively and the sowing was done by keeping 45 x 15 cm spacing. All agronomic practices were followed as a when required. Goth and physiological parameters were recorded at 50% flowering and grain yield data was recorded after the harvest of the crop.

Plant height (cm)

Plant height of five randomly selected plants from each plot was recorded in cm by measuring from the base of the plant near the ground up to the tip of the panicle.

Leaf area (dm^2)

The leaf area of the plant was calculated by taking maximum length and width at the broadest point of the green leaves and multiplying by the factor 0.747 (Stickler *et al.,* 1961).

Leaf area index (LAI)

From the data of leaf area per plant the leaf index was calculated according to the following formula by Watson (1947).

$$LAI = \frac{\text{Leaf area per plant } (dm^2)}{\text{Land area } (dm^2)} = \frac{LA}{P}$$

Relative leaf water content (RLWC, %)

The relative leaf water content was determined according to the procedure given by Barrs and Weatherly (1962) at flowing stage and it was expressed in percent (%).

$$RLWC\ (\%) = \frac{\text{Fresh weight (Wf) – Dry weight (Wd)}}{\text{Turgid weight (Wt) – Dry weight (Wd)}} \times 100$$

Dry matter (%)

The dry matter at 50% flowering, of leaf, stem and panicle were recorded using standard methods.

Heat unit

The total heat units required from sowing to panicle ignition, panicle flowing, flowering to physiological maturity worked by the total submission of the degree days above the base temperature with the help of formula suggested by Iwata (1984) Base temperature taken as 10 ^{0}C (Klages, 1958).

$$\text{Heat unit} = \sum_{i=1}^{n} \frac{\text{Max tem. + Min. tem.}}{2} - \text{Base } ^0\text{C temperature}$$

Heat unit efficiency (HUF)

The heat unit efficiency calculated for grain and dry matter per plant at maturity by the formula given by Rajput (1980).

$$\text{Heat unit efficiency (grain yield)} = \frac{\text{Grain yield (g)}}{\text{Total heat unit (sowing to maturity)}}$$

$$\text{Heat unit efficiency (Dry matter yield)} = \frac{\text{Dry matter (g)}}{\text{Total heat unit (sowing to maturity)}}$$

Thousand grain weight (g)

Thousand grains of each genotype were counted and weight (g) was recorded by electronic balance.

Harvest index (%)

The harvest index (HI) expressed in (%) was calculated by using the formula given by Donald (1962).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (g/plant)}}{\text{Biological yield (g/plant)}} \times 100$$

Other parameters

The standard methods given in the AOAC (1990) were used to record the observations and yield of the crop.

Statistical analysis

The statistical analysis of the data was carried out by Analysis of variance method suggested by Panse and Sukhatme (1985).

Results and Discussion

Sorghum crop is included in the C-4 plants which have high capacity of photosynthesis. The photosynthesis is mostly depends on the leaf area of that plant. The leaf area and leaf area index showed positive correlation to yield parameters (Table 1a). The genotype RSV 1640 gave highest leaf area and leaf area index which governs the final yield of the crop for medium soil type. But for shallow soil type Phule Anuradha showed higher level of yield. LAI helps in intercepting more solar radiation and thereby enhancing photosynthetic rate and resulting in higher total dry matter production and grain yield.

Leaf area index is an important parameter which governs dry matter production and thus yields (Kulkarni *et al.,* 1981).

Similar findings were also reported by Haremath and Parvatikar (1985).

The genotype RSV 1640 recorded higher RLWC (90.00%) as compared with all checks in medium soil (Table 1a).

But for shallow soil the check genotype Phule Anuradha showed lowest RLWC than other genotypes studied (Table 2a). Nirmal *et al.*, (2013) reported that the RLWC % under rainfed condition and irrigated conditions ranged from 49-76% and 48-76% respectively.

The SPAD value of RSV 1640 was medium but their leaf temperature difference was highest (-7.1) as compared to other all genotypes studied in medium soil type.

This indicated that more energy is used for the development of yield component during their growth development. In shallow soil Phule Anuradha showed highest SPAD value than other genotypes studied (Table 2a). Similar results are also reported by several researchers.

The heat unit and heat unit efficiency also play important role in the directly utilization energy for growth and yield components. The new genotype RSV 1640 showed 89% energy efficiency in medium soil (Table 1a).

In shallow soil also Phule Anuradha check genotype showed 74% efficiency in the utilization of heat energy in to yield production in *Rabi* sorghum (Table 2a). Similar results also reported by Nirmal *et al.*, (2013).

Shinde and Narkhede (1998) studied the heat unit required of parental lines during *kharif*, *rabi* and summer season. The results revealed that heat units were lower in *rabi* season and higher in summer flowed by *kharif*.

For yield contributing characters it was indicated that highest biomass at flowering was produced by the genotype BRJ 341 (6395 kg/ha) and at harvest 9280 (kg/ha) on medium soil and the BRJ 235 produced highest biomass at flowering (287 (kg/ha) and at harvest 4776 (kg/ha) on shallow soil (Table 2 a, b).

As regards per day production (kg/ha/day) the genotype RSV 1640 produced higher grain 28.35 (kg/ha/day) and fodder 42.47 (kg/ha/day) on medium soil and genotype Phule Anuradha produced higher grains (8.20 (kg/ha/day) and fodder 22.70 (kg/ha/day) on shallow soil (Table 1b and 2b). Kusalkar *et al.*, (2003) also reported similar results.

The dry matter yield at harvest is mostly based on the harvest index. For medium soil type genotype RSV 1640 showed highest harvest index (40) than other new genotypes, while for shallow soil type the genotype Phule Anuradha showed highest harvest index 27 (Table 2a).

The genotype Phule Suchitra produced higher 1000-seed weight (40/1000 grains) on medium soil and BRJ 341 and Phule Suchitra gave highest 100-seed weight (34/1000 grains) on shallow soil. These genotypes also showed 5-6 range for the stay green at physiological maturity stage on both medium and shallow soil (Table 1b and 2b). Narkhede *et al.*, (1998) and Nirmal and Patil (2008) also reported similar results.

Table.1a Physiological traits associated with grain and fodder yield (Medium soil)

Entry	Leaf area (dm^2)	LAI	RLWC (%)	SPAD at flow.	Leaf temp. Diff. (^0C)	Heat Unit	Heat Unit Efficiency	EE (%)	Biological Yield kg/ha	HI	Yield (kg ha-1)	
											Grain	Fodder
RSV1544	33.8	5.02	86	54.9	-6.7	1395	2.209	85	8731	35	3082	5649
RSV1572	25.7	3.81	90	58.2	-6.2	1395	1.928	69	6804	40	2690	4114
RSV1620	29.9	4.43	86	63.6	-6.2	1435	2.291	77	9518	35	3287	6231
RSV1640	34.6	5.11	90	56.9	-7.1	1413	2.388	89	8428	40	3374	5054
RSSV167	30.6	4.54	88	53.7	-5.2	1484	2.123	81	10467	30	3150	7317
CRS 49	24.0	3.57	86	54.2	-6.1	1413	1.778	83	8396	30	2513	5883
CRS 50	29.9	4.43	85	55.4	-6.6	1484	1.811	72	9645	28	2687	6958
PVR 930	29.9	4.43	83	52.9	-6.0	1421	2.082	77	7732	38	2958	4774
BRJ 229	33.8	5.02	87	53.0	-6.4	1484	1.953	79	8807	33	2898	5909
BRJ 343	34.6	5.11	86	53.6	-5.5	1472	2.163	83	9508	33	3184	6324
BRJ 235	25.4	3.76	86	54.7	-7.1	1489	2.074	74	8915	35	3088	5827
BRJ 376	28.8	4.24	75	52.5	-6.5	1472	1.708	82	9141	28	2514	6627
BRJ 341	26.4	3.92	86	54.7	-6.3	1460	1.993	79	9280	31	2910	6370
M-35-1 (C)	26.7	3.96	81	51.8	-6.3	1441	1.986	85	7205	40	2862	4343
P. Suchitra (C)	29.8	4.42	83	53.7	-6.2	1472	2.213	76	8980	36	3258	5722
P. Anuradha (C)	22.6	3.36	76	56.8	-6.2	1403	1.964	81	6134	45	2755	3379
SE ±											126.8	271.3
CD at 5 %											366.1	783.4
CV %											7.44	8.31
Correlation	+0.38	+0.26	+0.32	+0.48	-0.67	+0.38	+0.45	+0.18	+0.45	+0.53	-	+0.43

Table.1b Physiological traits associated with grain and fodder yield (Medium soil)

Entry	Plant height (cm)	Biomass at 50 % flow. (kg/ha)	1000 grain weight (g)	Days to		Per days production kg/ha/day		Dry matter at 50% flow. (g/m^2)			Stay green at phy. maturity (1-9 scale)
				50 % flow.	Phy. maturity	Grain	Fodder	Leaves	Stem	Panicle	
RSV1544	232	4888	33	75	115	26.80	49.12	79	253	64	5-6
RSV1572	208	5419	32	75	115	23.39	35.77	78	300	61	5-6
RSV1620	232	4864	32	80	123	26.72	50.66	78	256	60	5-6
RSV1640	230	4321	32	77	119	28.35	42.47	80	209	61	5-6
RSSV167	227	4851	36	85	126	25.00	58.07	79	261	52	5-6
CRS 49	206	3975	37	77	115	21.85	51.16	77	189	56	5-6
CRS 50	214	5370	38	85	126	21.33	55.22	97	272	65	7-8
PVR 930	201	4160	33	77	118	25.07	40.46	81	189	68	5-6
BRJ 229	226	5000	35	85	124	23.37	47.65	95	247	64	7-8
BRJ 343	230	5543	33	84	124	25.68	51.00	99	283	67	7-8
BRJ 235	209	5172	31	86	125	24.70	46.62	97	255	67	5-6
BRJ 376	216	4185	32	84	124	20.27	53.44	92	185	62	7-8
BRJ 341	224	6395	39	83	119	24.45	53.53	86	367	65	5-6
M-35-1 (C)	217	5555	35	81	120	23.85	36.19	81	319	49	7-8
P. Suchitra (C)	221	5666	40	84	125	26.06	45.78	94	298	67	5-6
P. Anuradha (C)	198	4358	35	76	108	24.17	29.64	73	222	58	5-6
Correlation	+0.648	+0.531	+0.367	+0.289	+0.063	+0.319	+0.068	+0.238	+0.489	+0.639	-

Table.2a Physiological traits associated with grain and fodder yield (Shallow soil)

Entry	Leaf area (dm^2)	LAI	RLWC (%)	SPAD at flow.	Leaf temp. Diff. (^0C)	Heat Unit	Heat Unit Efficiency	EE (%)	Biological Yield kg/ha	HI	Yield (kg ha-1)	
											Grain	Fodder
RSV1544	20.2	2.99	84	39.9	-3.9	1385	0.675	75	4775	20	905	3840
RSV1572	20.2	2.99	89	44.2	-3.9	1395	0.518	70	4756	15	723	4033
RSV1620	17.1	2.54	81	33.4	-3.4	1413	0.585	52	4773	17	827	3946
RSV1640	17.8	2.57	89	40.1	-3.4	1395	0.524	65	3101	24	731	2370
RSSV167	20.5	3.03	81	40.6	-3.5	1429	0.624	51	3732	24	891	2841
CRS 49	14.3	2.13	79	40.8	-3.8	1385	0.624	63	4456	19	864	3592
CRS 50	14.0	2.07	83	39.2	-3.2	1435	0.594	55	3525	24	853	2672
PVR 930	15.3	2.27	77	34.6	-2.8	1395	0.652	55	2928	31	909	2019
BRJ 229	18.7	2.78	82	38.9	-2.7	1435	0.620	47	3179	28	889	2290
BRJ 343	17.6	2.60	81	44.1	-3.9	1435	0.576	64	3453	24	827	2626
BRJ 235	13.2	1.96	84	41.5	-3.3	1421	0.643	61	4776	19	914	3862
BRJ 376	15.4	2.27	77	39.0	-3.4	1441	0.609	50	3559	25	878	2681
BRJ 341	15.6	2.31	81	35.2	-2.8	1429	0.304	50	2812	15	434	2378
M-35-1 (C)	17.1	2.53	81	42.2	-3.4	1429	0.452	62	3774	17	646	3128
P. Suchitra (C)	18.5	2.74	72	37.1	-3.3	1435	0.484	59	3982	17	694	3288
P. Anuradha (C)	18.9	2.78	68	44.4	-4.0	1385	0.675	74	3523	27	935	2588
SE ±											61.60	96.00
CD at 5 %											177.9	277.3
CV %											13.18	5.52
Correlation	+0.89	+0.36	+0.37	+0.67	-0.29	+0.349	+0.272	+0.72	+0.09	+0.27	-	+0.25

Table.2b Physiological traits associated with grain and fodder yield (Shallow soil)

Entry	Plant height (cm)	Biomass at 50 % flow. (kg/ha)	1000 grain weight (g)	Days to		Per days production kg/ha/day		Dry matter at 50% flow. (g/m^2)			Stay green at phy. maturity (1-9 scale)
				50 % flowering	Phy. Maturity	Grain	Fodder	Leaves	Stem	Panicle	
RSV1544	142	199	28	74	114	8.01	33.68	50	111	38	7-8
RSV1572	152	207	27	75	115	6.29	35.07	49	120	38	5-6
RSV1620	163	201	27	77	117	7.07	33.73	62	104	35	5-6
RSV1640	161	244	27	75	115	6.36	20.61	50	164	30	5-6
RSSV167	137	225	30	79	119	7.49	23.87	64	124	37	5-6
CRS 49	135	225	32	74	114	7.58	31.51	44	146	35	5-6
CRS 50	132	236	33	80	120	7.11	22.27	63	132	41	7-8
PVR 930	135	190	28	75	115	7.90	17.56	52	102	36	7-8
BRJ 229	141	197	31	80	120	7.41	19.08	53	112	33	7-8
BRJ 343	164	200	28	80	120	6.89	21.88	61	101	38	5-6
BRJ 235	138	287	25	78	118	7.75	32.73	63	184	41	5-6
BRJ 376	103	276	26	81	121	7.26	22.16	68	168	40	7-8
BRJ 341	139	228	34	79	119	3.65	19.98	63	119	46	5-6
M 35-1(C)	152	184	29	79	119	5.43	26.29	51	102	31	7-8
P. Suchitra (C)	151	241	34	80	120	5.78	27.40	75	122	45	5-6
P. Anuradha (C)	120	197	29	74	108	8.20	22.70	46	113	38	5-6
Correlation	+0.48	+0.29	+0.69	+0.09	+0.33	+0.67	+0.582	+0.36	+0.639	+0.24	-

For the final yield genotype RSV 1640 gave 3374 kg/ha grain yield and 5054 kg/ha fodder yield on medium soil. While Phule Anuradha gave highest grain yield 935 kg/ha and 2588 kg/ha fodder yield on shallow soil. Chavan *et al.*, (2012) studied the seven *rab*i genotypes and reported that the grain yield ranged from 17.3 to 26.8 q/ha on medium soil. Similar results are reported by Shinde and Narkhede (1998).

The grain yield was positively correlated with biomass at harvest, HI %, 1000 grain weight, RLWC %, stay green at physiological maturity, while per day production of grain and fodder yield negatively correlated with leaf temperature differences. On medium soil genotype RSSV 1640 was found significantly superior over the checks. On shallow soil, none of the genotype was found significantly superior over the check Phule Anuradha.

For medium soil new *Rabi* sorghum genotype RSV 1640 is the best one while for shallow soil Phule Anuradha is the best *Rabi* sorghum genotype which gives higher grain and fodder yield on the basis of the physiological parameters.

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