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RESEARCH ARTICLE :

Physiological studies in *Rabi* sorghum [*Sorghum bicolor* (L.) Moench]

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SUMMARY : A field experiment in some selected *Rabi* germplasm of sorghum [*Sorghum bicolor* (L.) Moench] was conducted at the Sorghum Research Station, Marathwada Agricultural University, Parbhani during *Rabi* season 2006-07. The experimental material comprised twelve genotypes. Among the genotypes GP 1 significantly recorded highest plant height than all other genotypes whereas IS 6368 recorded lowest plant height at all the growth stages than all other genotypes. The mean leaf area increased up to 75 days thereafter leaves started senescence and reduced leaf area. The maximum leaf area was recorded by GP 1 at all growth stages than all other genotypes. The mean leaf dry weight was more in the genotype GP 1 increased rapidly upto 90 days and declined thereafter slowly. At all stages of observations GP 1 showed maximum stem dry weight relative to other genotypes. The genotype GP 1 recorded maximum panicle dry matter continuously increased upto harvest. The genotype GP 1 showed maximum total dry matter per plant throughout the period of crop growth than all other genotypes. The genotype GP 1 was late maturing and genotype IS 6368 was early maturing genotype. The relative water content was highest in GP 1 whereas it was minimum in genotypes IS 6368 at panicle emergence and 50 per cent flowering. The genotype GP recorded the highest total chlorophyll content than all other genotypes. The mean chlorophyll stability index indicated significant differences among genotypes. The significantly lowest CSI was recorded by SPV 1411. Soil moisture content decreased gradually from sowing to harvesting. The genotype IS 5589 recorded significantly highest mean soil moisture at 0-30 cm depth and 30-60 cm depth at physiological maturity. The genotype IS 6368 recorded significantly lowest mean soil moisture content than all other genotypes at physiological maturity. The genotype GP 1 produced highest grain yield/plant among all other genotype. Several desirable yield determining factors an yield limiting factors in twelve sorghum genotypes have been identified. Such parameters may be helpful in further crop improvement programme. However, further intensive study is needed for increasing sorghum yields. The results are based on one year data hence the experiment may be repeated for one or two years to confirm the results.

KEY WORDS :
Rabi sorghum, Drought tolerance, Yield, RWC, CSI

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BACKGROUND AND OBJECTIVES

Sorghum [*Sorghum bicolor* (L.) Moench] is an important food crop of global significance and belongs to family graminae. It is cultivated in tropical and subtropical climates especially in the semi-arid tropics. A part from grains it provides valuable fodder which is one of the principle roughage feed in India. Sorghum is called as camel among the crops because of drought, water logging and saline-alkaline tolerance. It is one of the most efficient C_4 plant terms of photosynthesis.

The moisture stress is the chief limiting factor in sorghum production in our country. Understanding the physiological, biochemical and molecular mechanisms involved in imparting drought tolerance is most crucial for development of stress tolerant genotypes. Evolutions of drought tolerant genotypes and identifying drought tolerant genotypes amongst the existing ones which are better suited to the conditions prevailing in Maharashtra would be of great practical significance.

Moisture stress at any stage of the crop growth reduces yield considerably. There exist genotypic differences with regard to their response to moisture stress resulting in different levels of yield reduction. Hence, it is important to isolate genotypes which are affected to a lesser degree by moisture stress. Such genotypes could be directly recommended for cultivation under rainfed conditions or used in a breeding programme, to combine such characters which high yields, with this view the present investigation was undertaken with an object to studythe germplasm lines for morpho-physiological traits for drought tolerance and to identify germplasm lines with drought adaptations traits.

RESOURCES AND METHODS

A field experiment in some selected *Rabi* germplasm of sorghum [*Sorghum bicolor* (L.) Moench] was conducted at the Sorghum Research Station, Marathwada Agricultural University, Parbhani during *Rabi* season 2006-07. The experimental material comprised twelve genotypes *viz*., GP 15, SPV 1411, Yashoda x SPV 655, GP 1, IS 21971, IS 6368, GP 31, IS 47579, S 35, PVR 453, IS 5589, M 35-1 (check). These were grown in a Randomized Block Design with three replications with 45 x15 cm spacing between and within rows. Total 15 observations *viz*., days to 50 per cent flowering, days to physiological maturity, relative leaf water content at panicle initiation (%), relative water content at 50 per cent flowering, total chlorophyll content (mg/g), chlorophyll stability index, plant height (cm), leaf area (dm^{-2}), leaf dry matter (g/plant), stem dry matter (g/plant), total dry matter (g/plant), 1000 grain weight (g), grain yield per plant (g), fodder yield (qha^{-1}) and harvest index (%)were recorded. The statistical analysis of data were carried out by analysis of variance method suggested by (1967), standard error (SE) of the mean were worked out for each factor. Whenever, the results are significant critical difference (C.D.) at 5 per cent level of significance was worked out.

OBSERVATIONS AND ANALYSIS

Though plant height is basically a genetically controlled character, it is being influenced by environmental conditions and genotypes. The present study revealed significant differences in plant height (Table 1) among the genotypes at different growth stages and noticed that higher the plant height, higher the grain yield. The present study revealed significant differences in plant height among the genotypes at different growth stages.

The mean plant height increased rapidly from 30 DAS to 75 DAS and declined slowly later on. The genotype GP 1 (168.87 cm) recorded significantly the highest plant height. The data further indicated that the grain yield of GP 1 (28.37 q/ha) was the highest among the genotypes. These findings are supported by Kulkarni *et al.* (1991), Sutoro and Pirtoutom (1989) and reported positive correlation between yield and plant height.

Dry matter production is an important yield contributing character. By knowing the pattern in which it is produced and distributing in different plant parts would give a better understanding of the genotypes. The data presented in Table 1 give a quantitative picture of accumulation and partitioning of total dry matter among the plant parts throughout the growth of the crop.

The data on dry matter of leaves showed increasing trend upto 50 per cent flowering and decreased thereafter in all genotypes. At 50 per cent, flowering to at physiological maturity, there was decreased in the leaf dry matter in all the genotypes and it continued to show a lower distribution further due to senescence and leaf drying. These results are in agreement with the findings of Babu and Reddy (1971) who noticed that the dry matter in leaves decreased from milk to ripening stage in proportion of accumulation of dry matter in ear, indicating active translocation of assimilates during grain filling.The genotypes GP 1 recorded the highest (21.05 g/plant) dry matter of leaves.

The data on mean dry matter of stem per plant revealed that there was continuous increase upto 50 per cent flowering and decreased further. The genotypes GP 1 showed the highest stem dry matter per plant, whereas IS 6368 shoed the lowest stem dry matter among the genotypes at most of the growth stages. During early growth phase larger portion of total dry matter was shared by leaves than the stem. The accumulation of dry matter continued in stem. Rao and Sing (1978) also recorded similar results and they opined that the decline in stem weight and sugar was found to be due to remobilization of stem dry matter.The genotype GP 1 (44.52 g/plant) recorded stem dry matter.

The data on panicle dry matter in Table 1 revealed that there was continuous increase in a panicle dry matter upto harvest. The data on mean panicle dry weight per plant showed significant differences among the genotypes. At physiological maturity, the genotype GP 1 recorded the highest (41.83 g) and the genotypes IS 6368

Table 1 Differences of sorghum genotypes for different growth parameters

Genotype	Plant height (cm)						Leaf area (dm^{-2})						Leaf dry matter (g/plant)					
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At harvest	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At harvest	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At harvest
V_1-GP 15	19.00	31.83	69.16	113.83	155.83	161.73	4.11	11.67	21.12	40.05	31.72	10.59	1.15	3.43	6.40	17.30	22.46	17.63
V_2-SPV 1411	18.50	28.33	73.50	105.00	158.67	164.07	3.64	11.75	19.10	37.86	28.62	7.83	1.18	3.06	5.20	17.35	19.80	10.23
V_3-Yashoda x SPV 655	19.83	33.16	52.66	107.33	162.67	167.57	4.31	12.62	13.97	36.24	30.10	6.21	1.02	3.10	5.15	16.34	21.63	20.73
V_4-GP 1	20.50	45.83	77.50	121.17	163.17	168.87	4.34	12.64	21.13	40.07	31.90	11.40	1.19	3.44	6.44	18.45	23.52	21.05
V_5-IS 21971	13.16	26.33	56.50	73.66	140.17	152.20	3.17	12.19	17.48	29.70	22.41	8.10	0.37	1.58	5.16	15.18	18.13	11.30
V_6 -IS 6368	8.75	19.16	44.33	68.00	96.16	99.86	3.10	6.88	13.40	29.12	21.48	5.55	0.31	1.20	4.02	14.15	16.05	10.02
V_7 -IS 5589	20.33	24.83	52.33	84.66	142.67	148.67	3.84	8.84	13.50	34.42	24.23	5.61	0.62	2.44	5.14	14.61	16.86	19.13
V_8-GP 31	19.50	31.50	67.00	100.67	162.50	166.77	3.91	12.48	20.42	36.04	25.24	6.14	0.81	3.00	5.26	16.02	21.43	14.73
V_9-IS 47589	17.50	24.16	64.00	97.33	153.33	161.13	3.98	11.39	20.09	38.34	24.09	7.96	0.65	2.16	5.52	16.44	18.30	11.63
V_{10}-S 35	18.00	20.00	57.33	96.00	113.67	116.93	3.24	12.15	19.25	38.13	21.87	6.00	0.32	1.25	5.93	16.47	20.41	7.80
V_{11}-PVR 453	14.16	25.83	66.50	90.33	144.83	152.97	3.71	11.33	18.56	37.53	26.25	8.64	0.77	1.75	5.45	16.97	21.03	17.40
V_{12}-M 35-1	15.16	28.33	61.66	76.66	144.00	151.10	3.91	7.96	13.90	29.16	21.53	6.68	0.52	2.30	5.06	15.08	19.86	14.96
Mean	17.03	28.27	61.87	94.55	144.81	150.99	3.89	10.91	17.68	35.56	25.78	7.59	0.73	2.39	5.39	16.46	20.12	14.69
S.E. ±	1.05	2.15	3.74	4.77	4.99	3.18	0.21	0.44	0.63	0.94	0.77	0.31	0.11	0.12	0.33	0.87	1.19	0.87
C.D. (P=0.05)	3.36	6.31	10.95	13.98	14.63	9.31	0.62	1.28	1.85	2.78	2.25	0.91	0.34	0.36	0.97	2.55	3.49	2.55
CV							6.27	6.98	6.20	4.62	5.17	4.37						

Table 1 continued

Genotype	Stem dry matter (g/plant)						Total dry matter (g/plant)					
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At harvest	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At harvest
V_1-GP 15	0.55	2.40	16.50	40.31	42.50	44.42	1.70	5.82	20.91	56.61	85.80	101.13
V_2-SPV 1411	0.45	2.10	15.06	34.13	35.50	36.67	1.63	5.15	20.25	51.31	74.55	85.05
V_3-Yashoda x SPV 655	0.37	2.00	15.64	31.93	32.00	28.06	1.39	5.10	20.80	48.24	75.11	82.25
V_4-GP 1	0.57	2.50	17.04	41.22	43.50	44.52	1.76	5.94	23.48	59.67	90.01	107.40
V_5-IS 21971	0.17	1.01	14.16	33.02	35.16	35.38	0.54	2.57	19.30	47.18	73.24	81.78
V_6 -IS 6368	0.04	1.00	12.06	30.64	31.96	28.01	0.35	2.20	16.08	45.25	67.16	71.71
V_7 -IS 5589	0.27	1.22	12.50	33.84	35.50	30.31	0.90	2.66	17.66	48.01	75.26	87.12
V_8-GP 31	0.35	2.03	14.80	32.24	33.50	31.28	1.16	5.00	20.27	48.24	74.64	84.62
V_9-IS 47589	0.22	1.66	15.20	33.81	35.33	36.19	0.87	3.66	19.73	50.25	74.00	84.00
V_{10}-S 35	0.05	1.01	15.90	36.39	37.83	44.20	0.42	4.24	20.83	52.86	82.33	89.20
V_{11}-PVR 453	0.32	1.75	15.44	37.19	39.50	39.75	1.90	3.50	20.91	52.86	82.65	96.15
V_{12}-M 35-1	0.20	1.20	14.10	35.81	37.83	32.32	0.72	3.50	19.15	50.85	75.50	84.05
Mean	0.29	1.65	14.95	35.10	36.67	35.93	1.04	3.94	20.19	50.80	77.64	88.00
S.E. ±	0.032	0.088	0.48	0.87	1.54	0.86	0.15	0.22	0.73	1.29	0.66	1.42
C.D. (P=0.05)	0.094	0.25	1.41	2.56	4.53	2.53	0.44	0.67	2.16	3.80	1.95	4.18

recorded the lowest the (33.58g) panicle dry matter per plant, and this trend was noticed at most of the growth stages. Panicle dry matter showed significance with grain yield (at physiological maturity) due to higher number of grains and higher accumulation of food from source to sink. The similar results are reported by Choudhari and Mahajan (1978).

The data on total dry matter (Table 1) revealed that genotypes differed significantly at all growth stages. It could be seen that the total dry matter accumulation was increase upto harvest continuously. Increase in dry matter accumulation was rapid upto 90 DAS and it is more food accumulation in plant parts and transferred towards sink. These findings were in confirmative with those reported by Hiremath and Parvatikar (1985) and Kulkarni *et al.* (1983). They reported that higher yield in sorghum genotypes may be due to higher dry matter production especially at harvest and higher LAI and LAD particularly during post anthesis period. Santamaria *et al.* (1990) opined that the entries with high osmotic adjustments had greater root length, soil water extraction and dry matter production during post anthesis stress period.

The genotypes selected in the present study revealed significant differences in their phenology with GP 1 taking more days (132.67 days) for maturity, while IS 6368 having the lesser number of days (108.67 days) required for maturity. Both had much differences in yield observed *i.e.* 283 kh/ha, respectively.

This could be due to increased light utilization by the canopy and more time for active photosynthesis to produce more dry matter. However, IS-6368 and M 35-1 (check) had few day early maturity thereby escaping the terminal stress being increased to later stages. It can be inferred that early and midlategenotypes escapes that drought probably due to reduced root resistance and increased stomatal resistance. Verma and Eastin (1985) also was of the opinion that sorghum genotypes have different drought resistance mechanism under water stress conditions.

The data on relative leaf water content (Table 2) indicated that there were significant differences among genotypes. Relative leaf water content (RL WC) is an important parameter which indicated the ability of a plant to maintain high water in the leaves under moisture stress condition and can be used as index to determine drought tolerance of a genotypes. The genotypes GP 1 showed highest RL WC (83.00%), King and Nguyen (1991) made similar observation.

The data regarding chlorophyll content and chlorophyll stability index is given in Table 2. The data indicated that the varietal differences were significant.

Table 2 : Differences of sorghum genotypes for different morphological and physiological parameters

Genotype	Days to 50% flowering	Days to physiological maturity	Relative leaf water content at panicle initiation (%)	Relative leaf water content at 50% flowering	Total chlorophyll content (mg/g)	Chlorophyll stability index	1000 grain wt. (g)	Grain yield per plant (g)	Fodder yield (qha^{-1})	Harvest index (%)
V_1-GP 15	71.33	115.67	82.06	79.80	1.951	0.223	27.15	23.26	58.42	25.97
V_2-SPV 1411	84.66	129.33	86.16	81.09	1.715	0.020	32.88	19.10	51.30	25.50
V_3-Yashoda x SPV 655	71.00	111.00	81.12	78.21	1.956	0.324	34.16	19.23	47.67	26.02
V_4-GP 1	89.00	132.67	87.47	83.53	2.525	0.223	35.78	25.13	71.01	28.54
V_5-IS 21971	88.00	130.67	86.19	80.91	1.771	0.074	24.92	20.13	41.86	26.02
V_6 -IS 6368	69.00	108.67	77.06	73.80	1.551	0.109	18.60	18.45	40.11	23.30
V_7 -IS 5589	71.33	111.67	82.29	82.29	1.863	0.043	33.04	18.85	42.86	23.61
V_8-GP 31	74.66	114.67	81.29	78.64	1.984	0.051	26.48	20.56	47.13	26.26
V_9-IS 47589	73.66	129.00	79.80	76.54	2.142	0.194	25.94	19.19	46.70	26.30
V_{10}-S 35	71.33	114.67	80.20	74.12	2.492	0.433	27.92	21.36	44.66	28.03
V_{11}-PVR 453	75.66	117.00	82.33	78.85	2.372	0.112	29.66	19.89	61.32	23.40
V_{12}-M 35-1	69.33	110.67	81.53	80.34	2.320	0.231	33.96	20.75	48.00	25.23
Mean	75.75	118.81	82.29	79.01	2.053	0.170	29.21	20.49	48.92	25.68
S.E. ±	2.30	3.40	1.53	1.07	0.118	0.0022	1.56	0.77	2.94	0.237
C.D. (P=0.05)	6.80	9.97	4.49	3.13	0.345	0.0065	4.58	2.26	8.62	0.694

Table 3 : Differences of sorghum genotypes on mean soil moisture content (%)

Genotype	At 0-30 cm depth				At 30-60 cm depth (%)			
	At sowing	Panicle initiation	50% flowering	Physiological maturity	At sowing	Panicle initiation	50% flowering	Physiological maturity
V_1-GP 15	22.19	18.32	12.50	8.49	24.22	19.58	13.59	10.53
V_2-SPV 1411	21.36	18.22	10.30	9.34	23.28	19.16	13.34	10.43
V_3-Yashoda x SPV 655	21.19	19.16	10.20	10.37	22.20	20.20	11.26	10.72
V_4-GP 1	21.54	16.29	7.25	7.15	23.40	18.37	8.49	8.55
V_5-IS 21971	20.75	16.35	7.30	6.61	23.53	18.28	8.37	7.51
V_6 -IS 6368	23.20	16.42	9.50	6.53	24.59	19.78	13.34	6.36
V_7 -IS 5589	23.55	17.51	9.91	7.45	24.50	19.46	14.35	8.56
V_8-GP 31	22.76	16.52	7.67	6.56	23.51	17.21	10.64	7.17
V_9-IS 47589	21.53	19.69	12.35	11.62	23.49	21.43	14.62	13.45
V_{10}-S 35	22.59	19.46	9.49	7.65	23.35	20.43	11.32	9.31
V_{11}-PVR 453	21.43	19.15	10.58	8.41	24.33	19.27	12.27	9.43
V_{12}-M 35-1	23.16	18.49	11.52	8.37	24.52	20.39	12.38	9.42
Mean	22.10	17.96	9.96	8.21	23.74	19.46	12.00	9.28
S.E. ±	2.19	1.34	1.38	0.85	2.48	1.41	1.14	0.77
C.D. (P=0.05)	NS	NS	NS	2.51	NS	NS	3.34	2.25

NS=Non-significant

Genotype GP 1 recorded the highest total chlorophyll (2.525 mg/g). Genotype SPV1411 (0.020) recorded minimum chlorophyll stability index. Mean chlorophyll content and chlorophyll stability index was less as water stress adversely affected plant metabolic processes. Yadava *et al.*(1991) and Narkhede *et al.* (1988) noticed the similar observation.

The data on mean per cent soil moisture content (Table 3) revealed that genotypes differed for mean soil moisture content at all growth stages. Mean soil moisture content decreased gradually from sowing till harvest. Due to differential moisture extracting abilities of genotypes, the differences of genotypes, in soil moisture content at different soil depth at various growth stages are soon.

In the present investigation it can be observed that mean soil moisture was highest in 30-60 cm depth then 0-30 cm depth among the genotypes at various growth stages. The genotype GP 1 was superior in terms of grain yield indicating that importance of soil moisture at early growth period *i.e.* at sowing and panicle emergence. At 50% flowering and physiological maturity the high yielding genotypes GP1 had comparatively lower soil moisture content over low yielding genotypes.

Genotype GP1 at both depths indicating that high yielding genotypes extract more water from soil profile at later growth stages than low yielding genotypes. Theses result are also supported by Matthew *et al.* (1994).

The critical study of yield and yield contributing components revealed significant differences due to genotypes for these traits (Table 2). Thus the differences for grain yield among the genotypes were mainly because of variation in yield contributing characters. Since the yield of cereals is interplay of may yield contributing characters.

Bulm (1966); Dabholkar *et al.* (1970); Oleksenka (1972); Parvatikar and Prasad (1973); Hiremath and Parvatikar (1985) and Naik (1990) also observed yield contributing characters.

Genotypes GP1 recorded highest 1000 grain weight (35.78g), High grain yield in case of GP 1 (2837 kg/ha^{-1}) as compared with check M 35-1 (1620 kg/ha) and highest fodder yield *i.e.* 71.01 q/ha.

Grain yield is function of dry matter production and harvest index and higher harvest index invariably leads to higher grain yield. The increase in harvest index was more in GP 1 (28.54%) because of effective translocation of dry matter from vegetative parts to economic parts. The genotype GP 1 has given higher grain yield though, the partitioning was low, it may be due to higher total dry matter production and it higher harvest index. Secondly increased seed number might have increased the demand of food from the reproductive parts and thereby increased the harvest index. Singh and Stoskopf (1971) studied the harvest index in cereal.

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