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RESEARCH ARTICLE :

Physiology of drought tolerance in selected *Rabi* sorghum [*Sorghum bicolor* (L.) Moench] genotypes

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SUMMARY : A field experiment entitled "Physiological studies in some selected *Rabi* germplasm of sorghum [*Sorghum bicolor* (L.) Moench]" was conducted to study the germplasm lines for morpho-physiological traits for drought tolerance and to identify germplasm lines with drought adaptations traits at the Sorghum Research Station, Marathwada Agricultural University, Parbhani during *Rabi* season 2006-07. Genotype GP 1 recorded the highest AGR, (1.090 g/day/plant)and RGR (0.011 g/g/day) at in between 90 DAS-harvest stage. Further this genotype also recorded the highest LAI (2.13) and the highest LAD (51.30 day). Whereas, genotype IS 5589 recorded the highest NAR (0.062 g/dm^2/day) at 90 DAS-harvest and genotype IS 6368 at 45-60 and -75 days after sowing stage. 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. High grain (2837 kg/ha^{-1}) and fodder yield (71.01 q/ha) was observed in GP 1 as compared with check M 35-1 (1620 kg/ha). The increase in harvest index was found more in GP 1 (28.54%) because of effective translocation of dry matter from vegetative parts to economic parts.

KEY WORDS :
Physiology, Drought tolerance, *Rabi*, Sorghum

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BACKGROUND AND OBJECTIVES

Sorghum [*Sorghum bicolor* (L.) Moench] is the fourth most important cereal following rice, wheat and maize. It is a staple food in the semi-arid parts of the world and well recognized for its drought resistance and is the most suitable for dry region. It is one of the most efficient C_4 plant terms of photosynthesis. With a shift in an approach from subsistence agriculture to quantum jump in production, it has become pertinent to stabilize yields of sorghum, through the utilization of high yielding hybrids and varieties.

Understanding the physiological mechanisms involved in imparting drought tolerance is most crucial for development of stress tolerant genotypes. 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 to study the germplasm lines for morpho-physiological traits for drought tolerance and to identify germplasm lines with drought adaptations traits.

RESOURCES AND METHODS

A field experiment entitled "Physiological studies 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. Twelve genotypes *viz*., V_1- GP 15, V_2 - SPV 1411, V_3 - Yashoda x SPV 655, V_4 - GP 1, V_5 - IS 21971, V_6 - IS 6368, V_7 - GP 31, V_8 - IS 47579, V_9 - S 35, V_{10} - PVR 453, V_{11} - IS 5589 and V_{12} - M 35-1 (check) were selected for the experiment. These were grown in a Randomized Block Design with three replications. Various observations were recorded at an interval of 15 days interval starting from 30 days after sowing. The statistical analysis of data were carried out by analysis of variance method suggested by Panse and Sukhatme (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

In attempting to improve crop productivity of *Rabi* sorghum under limited moisture environment, fundamental questions are faced concerning plant responses and alternative strategies to be adopted for coping with water stress. Research efforts can be used for exploiting genetic variability and screening genotypes for desirable traits and for evolving ideal plant types. The results obtained from present investigation are discussed hereunder.

Growth functions :

AGR is a plain and simple measure of rate of increase in dry weight. The data regarding AGR revealed that genotype differed at all growth stages. It could be seen that the mean absolute growth rate was increased upto between 60-75 DAS period declined thereafter in all genotypes.Genotype GP 1 recorded the highest AGR, (1.090 g/day/plant). These results were also supported by Maiti *et al.* (1994).RGR expresses the dry weight increase in a unit time interval in relation to initial dry weight. The mean RGR was found to be increased

Table 1 : Differences of sorghum genotypes for mean absolute growth rate, mean relative growth rate and mean net assimilation rate

Genotype	Mean absolute growth rate (days)					Mean relative growth rate (g/g/day)					Mean net assimilation rate (g/dm²/day)				
	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90 DAS-At harvest	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90 DAS-At harvest	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90 DAS-At harvest
V_1-GP 15	0.274	1.006	2.380	1.946	1.022	0.082	0.085	0.066	0.027	0.010	0.037	0.062	0.080	0.054	0.053
V_2-SPV 1411	0.234	1.006	2.070	1.549	0.700	0.076	0.091	0.061	0.024	0.008	0.032	0.063	0.075	0.046	0.043
V_3-Yashoda x SPV 655	0.247	1.046	1.829	1.794	0.476	0.086	0.093	0.056	0.012	0.0059	0.032	0.078	0.078	0.054	0.031
V_4-GP 1	0.275	1.169	2.412	2.08	1.090	0.081	0.091	0.062	0.028	0.011	0.035	0.070	0.080	0.058	0.054
V_5-IS 21971	0.135	1.115	1.858	1.737	0.569	0.104	0.134	0.059	0.012	0.007	0.020	0.075	0.080	0.067	0.040
V_6 -IS 6368	0.120	0.920	1.940	1.46	0.300	0.122	0.132	0.068	0.012	0.001	0.025	0.097	0.102	0.062	0.25
V_7 -IS 5589	0.184	1.000	2.023	1.832	0.439	0.072	0.126	0.066	0.029	0.009	0.030	0.090	0.090	0.063	0.062
V_8-GP 31	0.256	1.084	1.893	1.760	0.665	0.097	0.096	0.054	0.028	0.008	0.034	0.067	0.069	0.058	0.049
V_9-IS 47589	0.186	1.004	2.034	1.588	0.666	0.095	0.115	0.059	0.25	0.009	0.026	0.065	0.072	0.051	0.045
V_{10}-S 35	0.120	1.172	2.135	1.964	0.458	0.111	0.151	0.058	0.029	0.005	0.017	0.075	0.077	0.067	0.037
V_{11}-PVR 453	0.160	1.160	2.130	1.990	0.900	0.077	0.119	0.061	0.029	0.009	0.030	0.079	0.079	0.063	0.056
V_{12}-M 35-1	0.185	1.043	2.113	1.643	0.570	0.105	0.113	0.065	0.011	0.007	0.032	0.094	0.099	0.065	0.044
Mean	0.202	1.080	2.002	1.789	0.630	0.090	0.109	0.061	0.023	0.0075	0.029	0.075	0.079	0.058	0.043
S.E. ±	0.023	0.090	0.181	0.048	0.048	0.0026	0.0033	0.0044	0.0023	0.00021	0.0034	0.0027	0.0031	0.0031	0.0030
C.D. (P=0.05)	0.068	NS	NS	0.143	0.142	0.0078	0.0098	NS	0.0069	0.00063	0.0100	0.0081	0.0093	0.0093	0.0089

NS=Non-significant

between 45-60 DAS and decreased thereafter. The genotypes GP 1 recorded the highest RGR (0.011 g/g/ day) at in between 90 DAS-harvest stage.

The data regarding NAR (Table 1)revealed that the varietal differences were found significantly at all the growth stages. NAR value increased upto period between 60-75 DAS and decreased thereafter. Similar results were indicated by Santamaria *et al.*(1990).Genotype IS 5589 recorded the highest NAR (0.062 g/dm^2/day) at 90 DAS-harvest and genotypes IS 6368 at 45-60 and -75 days after sowing stage.

The data regarding CGR (Table 2) showed significant varietal differences at all the growth stages. It also indicates that the CGR was higher between the period of 60-75 and decreased thereafter. Similar results were indicated by Santamaria *et al.* (1990).The physiological causes of variation in crop yield Watson (1947) reacted to the conclusion that variation in leaf area and leaf area duration was the main cause of differences in yield and variation in net assimilation rate was of minor importance. In other words, the area of leaf surface that intercepts solar radiation is the most important factor. As a result, the importance of leaf area index (LAI) as a determinant of dry matter production and hence the yield has been widely recognized.

A close look at the data in Table 2 indicate the effect of variation in leaf area index and leaf duration on the difference in dry matter production and grain yield of sorghum genotype. The LAI was higher upto 75 days which afterwards declined. High LAI of genotypes during 30-75 DAS might have intercepted more light, enhancing their photosynthetic rate which ultimately resulted in higher dry matter production and hence the 1000 grain weight. The high LAD in the genotypes indicated the importance of not only the higher leaf area but also its persistence for longer time during the most critical growth stages like panicle emergence and grain filling period. The above observation strongly indicated the dependence of grain yield on leaf area and leaf area duration.The genotype GP 1 recorded the highest LAI (2.13) and the highest LAD (51.30 day). These findings derive support from Dhoble and Kale (1988) and Kulkarni *et al.*(1981).

The data regarding LAR (Table 2) showed significant varietal differences at all growth stages. It was also indicated that the LAR was highest at 30 DAS and decreased thereafter. These results are supported by Dhoble and Kale (1988). The genotype GP 1 recorded

Table 2 : Differences of sorghum genotypes for mean crop growth rate, mean leaf area index, mean leaf area duration (days) and mean leaf area ratio

Genotype	Mean crop growth rate (g/m^2/day)					Mean leaf area index						Mean leaf area duration (days)					Mean leaf area ratio					
	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90 DAS-at harvest	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At harvest	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90 DAS-at harvest	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At harvest
V_1-GP 15	0.043	0.150	0.362	0.286	0.165	0.60	1.73	3.13	5.93	4.70	1.56	17.47	36.45	67.95	79.65	46.95	241.76	200.51	101.0	70.74	36.96	10.47
V_2-SPV 1411	0.038	0.143	0.316	0.226	0.116	0.53	1.74	2.83	5.61	4.24	1.16	18.07	34.02	63.30	73.80	40.50	223.30	228.57	94.32	73.78	38.39	9.20
V_3-Yashoda x SPV 655	0.039	0.153	0.287	0.265	0.083	0.60	1.87	2.07	5.37	4.46	0.92	18.52	29.55	55.80	73.65	40.35	295.68	247.45	67.16	75.12	40.07	7.55
V_4-GP 1	0.044	0.175	0.362	0.309	0.184	0.64	1.87	3.13	5.93	4.72	2.13	18.82	37.50	67.95	79.80	51.30	246.59	212.79	89.34	67.15	35.05	13.40
V_5-IS 21971	0.022	0.164	0.279	0.254	0.130	0.46	1.80	2.59	4.40	3.32	1.20	16.95	32.85	52.35	57.00	48.90	587.03	474.31	90.56	62.95	30.59	9.90
V_6-IS 6368	0.018	0.140	0.310	0.231	0.050	0.45	1.01	1.98	4.31	3.18	0.82	10.95	22.25	47.10	56.10	30.07	885.71	312.72	83.33	64.35	31.98	7.82
V_7-IS 5589	0.028	0.148	0.319	0.273	0.136	0.56	1.31	2.00	5.10	3.59	0.83	14.02	24.75	53.25	65.10	33.00	426.66	332.33	76.44	71.69	32.19	6.42
V_8-GP 31	0.040	0.164	0.290	0.263	0.113	0.57	1.84	3.09	5.34	3.75	0.90	18.07	36.90	63.15	68.10	34.80	337.06	249.60	100.7	74.70	33.81	7.25
V_9-IS 47589	0.029	0.150	0.311	0.235	0.106	0.58	1.67	2.97	5.68	3.57	1.17	16.87	34.80	64.80	69.30	35.55	457.47	309.01	52.39	76.29	47.94	9.47
V_{10}-S 35	0.019	0.174	0.327	0.297	0.076	0.48	1.80	2.85	5.65	3.24	0.88	17.10	34.80	63.75	66.60	30.90	771.42	286.55	50.48	72.13	26.56	6.72
V_{11}-PVR 453	0.025	0.174	0.327	0.297	0.144	0.54	1.67	2.75	5.56	3.89	1.28	16.57	33.15	62.25	70.80	38.70	340.36	323.71	49.45	70.99	31.76	8.98
V_{12}-M 35-1	0.028	0.157	0.325	0.243	0.091	0.57	1.18	2.06	4.32	3.19	0.98	13.12	24.30	47.85	56.25	31.20	543.06	227.42	75.58	57.34	28.51	7.94
Mean	0.031	0.170	0.316	0.264	0.109	0.56	1.63	2.50	5.22	3.82	0.15	16.35	32.08	59.11	68.02	38.61	446.30	290.97	77.30	69.78	34.18	8.56
S.E. ±	0.0019	0.045	0.025	0.025	0.011	0.013	0.057	0.15	0.23	0.25	0.033	0.47	0.93	0.61	1.33	3.51	3.95	2.59	4.16	3.44	2.12	0.84
C.D. (P=0.05)	0.0056	NS	NS	NS	0.034	0.039	0.16	0.44	0.67	0.73	0.099	1.39	2.73	1.81	3.90	10.29	11.57	7.60	12.20	10.09	6.22	2.47

NS=Non-significant

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

Genotype	At 0-30 cm depth				At 30-60 cm depth (%)				Grain yield per plant (g)	Fodder yield (qha^{-1})	Harvest index (%)
	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	23.26	58.42	25.97
V_2-SPV 1411	21.36	18.22	10.30	9.34	23.28	19.16	13.34	10.43	19.10	51.30	25.50
V_3-Yashoda x SPV 655	21.19	19.16	10.20	10.37	22.20	20.20	11.26	10.72	19.23	47.67	26.02
V_4-GP 1	21.54	16.29	7.25	7.15	23.40	18.37	8.49	8.55	25.13	71.01	28.54
V_5-IS 21971	20.75	16.35	7.30	6.61	23.53	18.28	8.37	7.51	20.13	41.86	26.02
V_6 -IS 6368	23.20	16.42	9.50	6.53	24.59	19.78	13.34	6.36	18.45	40.11	23.30
V_7 -IS 5589	23.55	17.51	9.91	7.45	24.50	19.46	14.35	8.56	18.85	42.86	23.61
V_8-GP 31	22.76	16.52	7.67	6.56	23.51	17.21	10.64	7.17	20.56	47.13	26.26
V_9-IS 47589	21.53	19.69	12.35	11.62	23.49	21.43	14.62	13.45	19.19	46.70	26.30
V_{10}-S 35	22.59	19.46	9.49	7.65	23.35	20.43	11.32	9.31	21.36	44.66	28.03
V_{11}-PVR 453	21.43	19.15	10.58	8.41	24.33	19.27	12.27	9.43	19.89	61.32	23.40
V_{12}-M 35-1	23.16	18.49	11.52	8.37	24.52	20.39	12.38	9.42	20.75	48.00	25.23
Mean	22.10	17.96	9.96	8.21	23.74	19.46	12.00	9.28	20.49	48.92	25.68
S.E. ±	2.19	1.34	1.38	0.85	2.48	1.41	1.14	0.77	0.77	2.94	0.237
C.D. (P=0.05)	NS	NS	NS	2.51	NS	NS	3.34	2.25	2.26	8.62	0.694

NS=Non-significant

significantly the highest LAR (13.40) at harvest.

Soil moisture studies :

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 from Table 3 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 per cent 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 areaslo supported by Matthew *et al.* (1994).

Grain yield is the manifestation of morphological, physiological and growth parameters. The critical study of yield and yield contributing components revealed significant differences due to genotypes for these traits. 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.The number of research workers *viz*., Bulm (1966); Dabholkar *et al.*(1970); Oleksenka (1972); Parvatikar and Prasad (1973); Hiremath and Parvatikar (1985) and Naik (1990) observed yield contributing characters.

High grain yield was observed in 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 (Table 3). 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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