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Full Research Article

Physio-biochemical Changes in Sorghum Cultivars under Different Moisture Regimes

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Abstract

An experiment was conducted to evaluate the effects of water deficit on physio-biochemical and yield parameters on sorghum during *rabi* season (September 2009 to February 2010) in Maharashtra. The treatment combinations consisted of four moisture regimes viz., M_1, M_2, M_3 and M_4 upto harvest and six genotypes viz., Phule Yashoda, RSV-1006, Phule Chitra, Phule Vasuda, Phule Anuradha, Phule Maulee. The study revealed that, Phule Yashoda and Phule Revati genotypes had maximum mean growth parameters and hence had maximum yield and yield contributing characters at lower moisture regime M_1 than non-stress condition M_4. RSV-1006 and Phule Chitra genotypes had maximum total soluble sugar content. The proline content increased with a decrease in the soil moisture content in all the genotypes with predominance in Phule Maulee, Phule Chitra and Phule Anuradha which also reported positive correlation of proline accumulation with grain yield. The degree of reduction in protein content as a function of water stress was less in Phlule Maulee, Phule Chitra and Phule Anuradha respectively. The genotypes Phlule Maulee, Phule Chitra and Phule Anuradha had lowest nitrate reductase activity under moisture regime M_1. Among the six genotypes, Phule Yashoda and Phule Revati showed higher grain yield and yield contributing parameters. The present study revealed that genotypes Phule Chitra and Phule Maulee are more suited under limited soil moisture condition. Irrespective of moisture regime Phule Yashoda and RSV-1006 found better than rest of genotypes. Therefore, these genotypes are well suited for medium soil under stress as well as non-stress conditions.

1. Introduction

Sorghum is grown mostly in drought prone areas, which fall under semiarid (basaltic) agro-climatic zone and characterized by scanty, erratic and ill distributed rainfall, varying from 500 to 700 mm. The variation in the duration and amount of rainfall creates a broad range of environment for the crop production. The rabi sorghum is the predominant crop of drought prone areas grown on the receding soil moisture. However, the sorghum production is very low and unstable due to water stress under prevailing rainfall situation. Moisture stress is the most important limiting factor in dry land agriculture for crop growth and ultimately reflects in low production. The growth period from 9 to 13 weeks is crucial in the life period of rabi sorghum, which is sensitive to availability of soil moisture. During this period if this crop suffers due to sever moisture stress, it will affect the level of grain production (Belum et al., 2010).

The main characteristic of the sorghum is drought resistance because of the ability to minimize tissue water loss (Rao and Sinha, 1990). Grain sorghum leaf tissue has high desiccation tolerance. Sorghum being a C_4 plant has the capacity to use increasing light intensities prevailing during rabi season. Under stress, plants offer some adaptive mechanisms including accumulation of biochemical components acting as osmoregulators. These include the accumulation of proline, reducing sugars, free amino acids and proteins. Under these situations some enzymes are very active to counteract these stress environments (Maiti et al., 2000; Zala et al., 2014). During the onset of stress, within the plants all major processes such as protein synthesis, energy metabolism, lipid metabolism and the reductive metabolism are altered significantly (Flores and Galston, 1984). Several enzymes have been shown to be affected by water stress in different plants (Mali and Mehta, 1977) and the degree of stress tolerance has been positively correlated with the level of certain organic solutes like proline and glycine. Solutes like proline and glycine betaine in a number of crop plants (Barnett and Naylor, 1966). Accumulation of proline, is considered to be an important character responsible for drought tolerance (Blum and Ebercon, 1976). An increase of amino pool size induced by water stress has also been reported in various crop plants, probably suggesting modification in protein turn over.

For rabi sorghum, water stress is one of the major factors limiting the crop growth and ultimately the production under rainfed farming. Certain species of sorghum have a versatile characteristic of withstanding the drought condition and thus having a genetic potential to defend the stress condition. In the present investigation, some of the existing and recently released cultivars of sorghum are taken to test their water stress tolerance. These cultivars are presently used extensively in the commercial production in Indian farmers.

2. Materials and Methods

The present investigation was conducted from (September 2009 to February 2010) at Sorghum Improvement project, Mahatma Phule Krishi Vidyapeeth (MPKV) Rahuri, District Ahmednagar, Maharashtra, India. The seeds were obtained from Sorghum Improvement Project, MPKV, Rahuri. The Soil of experiment field was medium black type with bulk density of 1.3. The moisture content at field capacity and permanent wilting point were 34.40 and 21.66%, respectively. The field experiment was laid out in a Factorial Randomized Blok Design (FRBD) with three replications in field condition. A field trials consisting of M_1 (25% of field capacity), M_2 (50% of field capacity), M_3 (75% of field capacity) and M_4 (>90% of field capacity) moisture regimes along with six genotypes V_1: Phule Yashoda, V_2: RSV-1006, V_3: Phule Chitra, V_4: Phule Vasuda, V_5: Phule Anuradha,V_6: Phule Maulee was under taken.

2.1. Physiological characterization

Plant height (cm) of five randomly selected plants from each plot was recorded by measuring from the base of fully expanded leaf. After emergence of ear head, the height was measured up to the tip of ear head. Length (cm) of fully expanded leaf of each selected tagged plants was measured from the tip of the leaves up to the leaf sheath. The total leaf area plant^{-1} (dm^2) is measured by leaf area meter. Flag leaf area of each observational plant was measured in dm^2 at the interval of 30 days starting from flag leaf initiation up to harvesting. The observational plants were cut close to the ground and flag leaf was separated from the stem. By taking the maximum length and width at the broadest point of all the flag leaves and multiplying by the factor 0.747 flag leaf area was calculated. Leaf area index (LAI) was calculated from the data of leaf area plant^{-1} (dm^2) according to the formula given by Watson (1947). Leaf area duration (LAD) was calculated by the formula given by Watson, (1947). The plants used for the estimation of leaf area were used for dry matter studies. Different components i.e. stem, leaves and ear head were separated and dried in the hot air oven initially at 90 °C for one hour and subsequently at 60 °C till constant dry weight was obtained. Then dry weight was recorded repeatedly for each plant part. From this total dry matter plant^{-1} was computed. All the above observations were recorded at harvest stage.

2.2. Biochemical characterization

Various biochemical parameters were measured at 30 DAS, 60 DAS, 90 DAS and 120 DAS. The free proline level was determined at 520 nm (Bates et al., 1973), the total soluble carbohydrate level at 490 nm (Dubois et al., 1956), the soluble proteins at 750 nm (Lowery et al., 1951) and in vivo Nitrate reductase assay at 540 nm (Hageman and Hucklesby (1971); (Munjal et al., 1998).

2.3. Post harvest studies (at harvest)

In post harvest studies (at harvest) the length of the ear head, dry weight of ear head (g), 1000 grain weight (g), Grain yield (kg) net^{-1} plot, Grain yield (q ha^{-1}), biological yield (q ha^{-1}, adding fodder yield and ear head weight) and harvest index (%) were studied.

Fisher's method was used for data analysis and interpretation as suggested by Panse and Sukatme (1967). The level of significance used in 'F' and 't' test was p=0.05. Critical difference (CD) values were calculated at 5% probability level, wherever 'F' test was significant.

3. Results and Discussion

3.1. Physiological characterization

At harvest, the genotype V_1 (Phule Yashoda) showed significantly highest mean plant height (256.73 cm) while significantly lowest plant height (208.00 cm) was observed in V_5 (Phule Anuradha). The genotypes V_1 (Phule Yashoda) and V_2 (RSV-1006) showed better growth under moisture regime M_1 (at 25% of F.C.) seems to be drought tolerant (Table 1). This may be because of increased translocation of stored photosynthesis from the stem reserves when the current photosynthesis ceases due to water stress particularly during grain filling and grain development period (Kumar, 2009). In general, reduced plant height is an advantage under limited water condition by virtue of its reduction in leaf area and thus reducing the water being transpired. These results are in conformity with Chaudhari and Mahajan (1978), Hiremath and Parvatikar (1985); Gaosgelwe and Kirshan (1990); (Patil et al., 2003); Chand and Singh (2003).

The genotype V_1 (Phule Yashoda) was recorded significantly highest mean number of leaves plant^{-1} (3.95) and mean leaf area plant^{-1} (14.82), while significantly lowest was observed in V_5 (Phule Anuradha). These results are in agreement

Table 1: Physiological and yield parameters as influenced by genotypes, moisture regimes and their interactions at harvest in sorghum

Moisture regimes	Mean plant height (cm)	Number of leaves	Leaf area (dm^2)	LAI	LAD (days)	Total dry matter plant^{-1} (g)	Length of ear head (cm)	Girth of ear head (cm^2)	Dry weight of ear head (g)	1000 grain weight (g)	Grain yield plot^{-1} (kg)	Fodder yield ha^{-1}	Biological yield (q ha^{-1})	Grain yield ha^{-1}	Harvest index
M_1	223.63	2.59	10.96	1.62	65.46	169.40	19.49	6.12	72.53	37.00	1.90	65.86	90.96	24.98	27.38
M_2	231.21	3.14	12.04	1.78	74.10	184.33	20.65	6.66	77.29	38.15	2.45	84.98	117.35	32.37	27.42
M_3	236.13	3.58	12.59	1.86	83.22	199.79	21.84	6.90	84.13	40.46	2.66	90.19	125.30	35.11	27.92
M_4	245.52	3.96	13.39	1.98	87.17	221.55	23.11	7.07	89.53	41.44	2.81	95.58	132.72	37.14	27.91
SEm±	0.135	0.135	0.201	0.029	0.657	0.378	0.124	0.235	0.151	0.176	0.010	0.250	0.333	0.140	0.102
CD (p=0.05)	0.374	0.374	0.559	0.082	1.822	1.050	0.345	0.656	0.418	0.488	0.029	0.694	0.923	0.390	0.283
Genotypes															
V_1	256.73	3.95	14.82	2.20	94.24	216.81	22.84	7.04	95.03	40.60	2.78	94.01	130.6	36.65	28.04
V_2	256.63	3.66	13.11	1.94	83.90	216.36	22.51	7.40	83.62	40.94	2.77	92.69	129.4	36.61	28.25
V_3	226.29	3.24	11.74	1.74	74.09	191.43	21.11	6.78	80.39	39.34	2.51	84.97	118.2	33.16	28.01
V_4	237.97	3.45	12.37	1.83	77.73	199.47	22.72	7.15	88.56	40.66	2.75	92.66	129.0	36.28	28.09
V_5	208.00	2.65	9.86	1.46	63.38	151.41	18.27	5.66	63.42	35.39	1.77	68.65	91.97	23.32	25.42
V_6	219.48	2.95	11.56	1.71	71.59	187.13	20.19	6.09	74.18	38.64	2.15	71.94	100.4	28.41	28.14
SEm±	0.165	0.165	0.247	0.036	0.805	0.464	0.152	0.288	0.184	0.215	0.013	0.306	0.408	0.172	0.125
CD (p=0.05)	0.459	0.459	0.684	0.101	2.231	1.286	0.423	0.797	0.512	0.598	0.036	0.850	1.131	0.478	0.397
Interaction															
SEm±	0.331	0.331	0.494	0.073	1.610	0.928	0.305	NS	0.369	0.431	0.026	0.613	0.816	0.345	0.250
CD (p=0.05)	0.918	N.S.	N.S.	N.S.	4.463	2.572	0.847	NS	1.025	1.196	0.072	1.701	2.262	0.957	0.694

with the finding of (Zhang et al., 2004), Abdalla and El-Khoshiban, (2007). Effects of water stress on growth/morphological parameters such as leaf area, number of leaves and girth (diameter) have been documented by (Zhang et al., 2004); Abdalla and El-Khoshiban, (2007). These results are in conformity to the reduction in leaf area would limit the development of plant transpiration surface and keeps sink demand well balanced with plant assimilatory capacity (Bayoumi et al., 2008). Similarly, genotype V_1 (Phule Yashoda) recorded significantly highest mean leaf area index (2.20). Earlier studies also indicated similar observations with particular reference to sorghum grown under water stress condition (Kulkarni et al., 1981); Narkhede et al. (1998); Sonawane et al. (2008). Similarly, genotype V_1 (Phule Yashoda) noticed significantly highest mean leaf area duration plant^{-1} (94.24). In general water stress occurring during post flowering (i.e. early grain development) reduces final dry matter production Khannan et al. (1994). So, the production of maximum biomass under water deficit condition indicated that the dry matter production can be used as selection criterion for drought tolerance in sorghum than dry matter production under adequate water supply.

3.2. Biochemical characterization

The total sugar content, proline content, protein content and NR activity as influenced by different genotypes and moisture regimes and their interactions at critical growth stages of field condition are presented in Table 2. At 30 DAS, genotype V_2 (RSV-1006) showed significantly highest total sugar (22.21 mg g^{-1} FW), protein (4.09 μ mole g^{-1} FW), NR activity (3.11μ moles of NO_2^- formed g^{-1} f. wt. h^{-1}) while lowest proline content (0.40 μ mole g^{-1} FW). The genotype V_5 (Phule Anuradha) showed significantly lowest total sugar (17.68 mg g^{-1} FW). The genotype V_6 (Phule Maulee) recorded significantly highest proline content (0.75 μ mole g^{-1} FW) and lowest protein content (3.31 μ mole g^{-1} FW). Similar trend was noticed at 60, 90 and at harvest as that of 30 DAS.

At 30 DAS, moisture regime M_4 recorded significantly highest

Table 2: Biochemical parameters influenced by genotypes, moisture regimes and their interactions at various stages in sorghum

Moisture regimes	Total sugar content (mg g^{-1} FW)	Proline content of leaves (µ mole g^{-1} FW)	PCL (µ mole g^{-1} FW)	NRAL (µ moles of NO_2^- form g^{-1} f. wt. h^{-1})
At 30 DAS				
M_1	18.41	0.63	3.41	2.38
M_2	19.69	0.60	3.71	2.50
M_3	20.74	0.58	4.17	2.61
M_4	22.36	0.55	4.32	2.67
SEm±	0.084	0.005	0.005	0.059
CD (*p*=0.05)	0.233	0.015	0.015	0.163
Genotypes				
V_1	20.64	0.44	4.03	3.08
V_2	22.21	0.40	4.09	3.11
V_3	21.71	0.72	3.89	2.68
V_4	19.41	0.59	4	3.03
V_5	17.68	0.66	3.99	1.59
V_6	20.17	0.75	3.31	1.78
SEm±	0.103	0.007	0.007	0.072
CD (*p*=0.05)	0.286	0.019	0.019	0.200
Interaction				
SEm±	0.206	0.014	0.014	0.144
CD (*p*=0.05)	0.572	N.S.	0.038	N.S.
Moisture regimes at 60 DAS				
M_1	20.00	0.78	3.43	2.35
M_2	21.52	0.77	3.52	2.44
M_3	23.57	0.75	3.73	2.56
M_4	24.04	0.69	3.81	2.61
SEm±	0.049	0.005	0.006	0.050
CD (*p*=0.05)	0.138	0.015	0.016	0.139
Genotypes				
V_1	22.94	0.59	3.34	2.9
V_2	23.99	0.46	4.04	3.04
V_3	23.31	0.94	3.44	2.6
V_4	22.30	0.62	3.92	2.82
SEm±	0.061	0.007	0.008	0.061
CD (*p*=0.05)	0.169	0.019	0.020	0.170
Interaction				
SEm±	0.122	0.014	0.014	0.123
CD (*p*=0.05)	0.339	0.038	0.039	N.S.
Moisture regimes at 90 DAS				
M_1	21.99	1.33	2.99	2.21
M_2	23.15	1.27	3.26	2.36
M_3	23.91	1.20	3.50	2.46
M_4	25.27	1.15	3.72	2.57
SEm±	0.030	0.005	0.005	0.050
CD (*p*=0.05)	0.085	0.015	0.015	0.139
Genotypes				
V_1	23.99	1.14	3.09	2.69
V_2	26.01	0.86	3.91	2.89
V_3	25.13	1.43	3.43	2.49
V_4	22.48	1.16	3.79	2.88
V_5	20.9	1.21	3.3	1.85
V_6	22.97	1.61	2.68	1.6
SEm±	0.037	0.007	0.007	0.061
CD (*p*=0.05)	0.104	0.019	0.019	0.170
Interaction				
SEm±	0.075	0.014	0.014	0.123
CD (*p*=0.05)	0.208	0.038	0.038	0.341
Moisture regimes at 120 DAS				
M_1	20.09	1.49	2.37	1.91
M_2	21.40	1.47	2.45	2.23
M_3	22.03	1.43	2.52	2.32
M_4	23.23	1.43	2.63	2.45
SEm±	0.057	0.005	0.006	0.050
CD (*p*=0.05)	0.160	0.015	0.016	0.139
Genotypes				
V_1	22.05	1.21	2.86	2.68
V_2	24.00	1.21	2.48	2.81
V_3	23.35	1.67	2.12	2.4
V_4	20.47	1.37	2.38	2.39
V_5	19.06	1.46	2.51	1.59
V_6	21.19	1.81	2.59	1.51
SEm±	0.070	0.007	0.007	0.061
CD (*p*=0.05)	0.196	0.019	0.019	0.170
Interaction				
SEm±	0.141	0.014	0.014	0.123
CD (*p*=0.05)	0.393	0.038	0.039	0.341

PCL: Protein content of leaves; NRAL: Nitrate reductase activity of leaves total sugar (22.36 mg g^{-1} FW), protein content (4.32 μ mole g^{-1} FW), NR activity (2.67 μ moles of NO_2^- formed g^{-1} f. wt. h^{-1}) while moisture regime M_1 showed significantly lowest total sugar (18.41 mg g^{-1} FW), protein content (3.41 μ mole g^{-1} FW) and NR activity (2.38 μ moles of NO_2^- formed g^{-1} f. wt. h^{-1}). Thereafter, similar trend was noticed at 60, 90 and at harvest. However, the moisture regime M_1 showed significantly highest proline content (0.63 μ mole g^{-1} FW) followed by M_2 while M_4 showed lowest proline content (0.55 μ mole g^{-1} FW). Similar trend for proline content was found at 60 DAS, 90 DAS and at harvest. The present study was aimed to understand the effect of moisture stress on biochemical and yield attributes in sorghum cultivars in terms of total sugar, proline, protein content and NR activity and yield parameters. A comparative analysis of different sorghum cultivars under water stress revealed that the higher proline content was noticed in genotype V_6 (Phule Maulee) under lowest moisture stress condition M_1 (25% of F.C) as well as the genotype V_2 (RSV-1006) recorded higher total sugar content, protein content and of nitrate reductase activity under higher moisture regime M_4. The genotype V_1 (Phule Yashoda) and V_2 (RSV-1006) recorded higher grain and fodder yield at stress as well as non-stress situation than rest of genotypes.

In the present study it has been observed that the proline content increased with a decrease in the soil moisture content. These are in conformity with the findings of Mulla et al. (2006) and Satbhai et al. (1997). The genotypes V_6 (Phule Maulee), V_3 (Phule Chitra) and V_5 (Phule Anuradha) recorded significantly highest proline content under moisture stress condition (M_1) than non moisture stress (M_4). The present study indicated that the proline content also had significant negative correlation with grain yield and positive correlation with NR activity at all critical growth stages. This clearly indicates that proline accumulation increased as the soil moisture content decreased. These results are in conformity with the findings of Bhaskaran et al. (1985), who stated that the proline accumulation increased in response to water stress. Similarly (Morgan et al., 1984) also reported positive correlation of proline accumulation with grain yield in water limited environment. Proline accumulation was seen in wheat genotypes due to the imposition of osmotic stress PEG6000 (Mujtaba et al., 2007). High levels of proline enable a plant to maintain low water potentials, allowing additional water to be taken up from the environment, thus buffering the immediate effect of water shortages within the organism (Kumar et al., 2003). This helps plants supply energy for growth and survival, thereby helping the plant to tolerate stress (Sankar et al., 2007).

The significantly lowest protein content in the genotype V_6 (Phule Maulee), V_3 (Phule Chitra) and V_5 (Phule Anuradha) was recorded at moisture stress condition M_1. However, protein content significantly reduced in genotype V_6 (Phule Maulee) and V_3 (Phule Chitra) under limited moisture stress condition M_1. The degree of reduction in protein content as a function of water stress was less in V_6, V_3 and V_5 respectively. Protein content had decreasing trend with increase in water stress (Ranieri et al., 1989). In general, the content of protein in different sorghum cultivars progressively decreased with linear increase in water stress. The results obtained in the present investigation are supported by (Sharma et al., 1990) who reported similar trend in groundnut under water stress. Sarkar et al. (1989) reported that decrease in protein content in pea seedlings under PEG induced water stress. A decrease in protein content response to drought is an important criterion in understanding the growth and metabolism under water stress. The decline in protein content due to water stress may attributes to enhanced protein hydrolysis and impaired protein synthesis as well as reduction in total amino acid pool (Ranieri et al., 1989). Water stress increases the level of some amino acids like proline and glycine betaine due to protein breakdown, which probably provide some compatible osmoticum in the cytoplast there by maintaining low osmotic potential for retention of water within plant cell (Prakash et al., 1988). Decreased protein content under water stress could be attributed to reduced availability of amino acids (Davidson and Chanvalier, 1992). The total sugar content increased from 30 DAS to harvest in all the genotypes. The genotype V_2 (RSV-1006) has maximum total soluble sugar content. The decrease in soil moisture content and RLWC increased total sugar content in leaves at 60, 90 DAS and harvest. It may be because of increased activity of the amylase. The genotype which had high content of total sugars at 60 and 90 days and at harvest also performed better with respect to yield and yield components and other growth characters which could probably due to the maintenance of leaf water status through osmoregulation This could be another reason for higher yield in these genotypes. These results supported findings which stated that as water stress increase proportionate decrease in total sugar occurs (Deshmukh et al., 2001).

The significant interaction was found between plant genotypes and moisture regimes at all critical growth stages with respect of total sugar content. At 30 DAS, genotype V_2 (RSV-1006) with M_4 recorded significantly highest total sugar (24.48 mg g^{-1} FW) while V_5 (Phule Anuradha) with M_1 (15.43 mg g^{-1} FW) recorded lowest. On same interval V_3 (Phule Chitra) with M_4 showed significantly highest protein content (4.93 μ mole g^{-1} FW) and V_6 (Phule Maulee) with M_1 recorded lowest protein content (3.20 μ mole g^{-1} FW). Similar trend was found at 60, 90 DAS, and at harvest as that of 30 DAS. At 60 DAS the genotype V_6 (Phule Maulee) showed significantly highest proline content (1.37 μ mole g^{-1} FW) with lowest moisture regime M_1. While significantly lowest proline content (0.40 μ mole g^{-1} FW) was noticed in genotype V_2 (RSV-1006) under M_4. Similar trend was found at 90 DAS, and at harvest as that of 60 DAS. The significant interaction between plant genotypes and moisture regimes were recorded at all growth stages with protein content. The significant interaction between plant genotypes and moisture regimes were found at 90 DAS and at harvest. But it was found statistically non significant at 30 and 60 DAS. At 90 DAS, the genotype V_2 (RSV-1006) with moisture regime M_4 showed significantly maximum NR activity (3.05 μ moles of NO_2^- formed g^{-1} f. wt. h^{-1}) than rest of genotypes. While the significantly minimum NR activity (1.45 μ moles of NO_2^- formed g^{-1} f. wt. h^{-1}) was noticed in genotype V_6 (Phule Maulee) under minimum moisture regime M_1. Similar trend was observed at harvest at that of 90 DAS. The loss of nitrate reductase activity in response to water stress has been well established (Anikiev and Kuramagonedov, 1975). A most widely accepted explanation for the reduction in NR activity during water stress could be seen to be the inactivation of the enzyme, reduction in the availability of nitrate, inhibition of protein synthesis, consequent upon the reduction in the availability of NADH through the effect on photosynthesis, respiration and also changes in redox potential NR activity during water deficit is an important determinant of growth. In the present study the data on NR activity indicated that it decreased from 30 to 90 DAS in all the genotypes. The decrease in NR activity from 30 DAS onwards could be due to decrease in soil moisture content and RLWC. The genotypes V_6 (Phlule Maulee), V_3 (Phule Chitra) and V_5 (Phule Anuradha) had the lowest NR activity under moisture regime M_1. However the genotype V_2 (RSV-1006) and V_1 (Phule Yashoda) had the higher NR activity. The present findings are in agreement with earlier reported reviews which showed a decline in water potential caused decline in NR activity in sorghum and pea (Chandra et al., 1983; Sivaramkrishnan et al., 1988). In the present study there was positive correlation of NR activity with total dry matter accumulation at all growth stages. These results were conformity with findings of Chandrashekhar (1980).

3.3. Post harvest studies (at harvest)

Earlier it has been reported that positive association of leaf area with grain yield could be considered as selection criterion under drought stress situations (Patil et al., 2003). The positive correlation between number of leaves and grain yield of sorghum was observed by Chaudhari and Mahajan (1978). Correlation study also indicated that LAI had significant positive association with grain yield (Lin and Yeh, 1990; Pawar and Jadhav, 1996).

The grain yield and yield attribute, viz., length and girth of ear head, dry weight of ear head, 1000 grain weight, grain yield $plot^{-1}$ and hectare, harvesting index and biological yield are pooled over *rabi* season. The relevant data are presented in Table 1 and 2. Except girth of ear head all other parameters were statistically significant over pooled data. The genotype V_1 (Phule Yashoda) registered significantly highest length of ear head (22.84 cm), dry weight of ear head (95.03 g), fodder yield ha^{-1} (94.01 q ha^{-1}), grain yield $plot^{-1}$ (2.78 kg $plot^{-1}$), biological yield (130.62 q ha^{-1}). The genotype V_5 (Phule Anuradha) recorded minimum girth of ear head (5.66 cm^2), dry weight of ear head (63.42 g), panicle length (18.27 cm), 1000 grain weight (35.39 g), fodder yield ha^{-1} (68.65 q ha^{-1}), grain yield $plant^{-1}$ (1.77 kg $plot^{-1}$), grain yield ha^{-1} (23.32 q ha^{-1}), biological yield ha^{-1} (91.97 q ha^{-1}) and harvest index (25.42%). The genotype V_2 (RSV–1006) showed highest girth of ear head (7.40 cm^2), 1000 grain weight (40.94 g) and harvest index (28.25%).

The significantly maximum length of ear head (23.11 cm) was recorded in moisture regime M_4 followed by M_3 while minimum length (19.49 cm) was found in M_1. The moisture regime M_4 recorded highest while M_1 recorded lowest girth of ear head (7.07 cm^2, 6.12 cm^2), dry weight of ear head (89.53 g, 72.53 g), 1000 grain weight (41.44, 37.00), fodder yield ha^{-1} (95.58 q ha^{-1}, 65.86 q ha^{-1}), grain yield $plot^{-1}$ (2.81, 1.90), grain yield he^{-1} (37.14, 24.98), biological yield (132.72 q ha^{-1}, 90.96 q ha^{-1}) and harvest index (27.92, 27.38).

The significant interaction between plant genotypes and moisture regimes were found with respect to grain yield and yield attributes. The genotype V_2 (RSV–1006) with moisture regimes M_4 showed significantly highest length of panicle (24.81 cm), 1000 grain weight (44.23 g), fodder yield ha^{-1} (112.82 q ha^{-1}), grain yield $plot^{-1}$ (3.40 kg $plot^{-1}$), grain yield (44.92 ha^{-1}) and biological yield (157.73 q ha^{-1}). The genotype V_5 (Phule Anuradha) with M_1 recorded significantly lowest length of panicle (16.10 cm), dry weight of ear head (54.23 g), 1000 grain weight (33.18 g), fodder yield ha^{-1} (49.18 q ha^{-1}), grain yield $plot^{-1}$ (1.39 kg $plot^{-1}$), grain yield (18.17 ha^{-1}) and biological yield (67.55 q ha^{-1}). The genotype V_1 (Phule Yashoda) with moisture regime M_4 registered significantly highest dry weight of ear head (101.98 g). The genotype V_6 (Phule Maulee) with moisture regime M_3 showed highest harvest index (29.62%). The genotype V_5 (Phule Anuradha) under moisture regime M_3 noted significantly lowest harvest index (24.39). In present study the highest mean grain yield $plant^{-1}$ obtained by the genotype V_1 (Phule Yashoda) and genotype V_2 (RSV-1006) under lowest regime M_1 (25% of F.C) as well as non stress condition M_4 (>90% of F.C) appeared due to its higher mean length and girth of ear head, dry weight of ear head, 1000 grain weight, dry matter accumulation at maturity which played important role to increase grain yield. The higher grain yield with higher values of all growth parameters are in conformity with Channappagouda et al. (2008). Seed yield is primarily limited by relatively short duration of soil moisture during the later phases of reproductive development (Sinaki et al., 2007). Moreover, these authors have indicated that at early stage of flowering water stress increased death of floret and loss of seed size which resulted in reduction of harvest index of seed plant^{-1} (Seghatoleslami et al., 2008).

Perhaps the decline in the thousand seed weight might be because of floret death resulting from water stress during post flowering (Prasad et al., 2008). Besides low grain yield panicle^{-1} in genotype V_5 (Phule Anuradha) and V_6 (Phule Maulee) was reflected in parallel decline in translocation of assimilation rate. This is due to the fact that spikelet fertility is related to assimilation rate during anthesis and its susceptibility to water stress in most crop plants (Praba et al., 2009).

The genotype V_3 (Phule Chitra) and V_4 (Phule Vasudha) had moderate length, girth and dry weight of ear head and 1000 grain weight but lower yield plant^{-1} because of lower ear head length and girth and dry weight of ear head. The number of research workers viz., (Narkhede et al.,1998; Shinde et al. 2003; Naik ,1990; Ravikumar et al. 2003; Nirmal et al., 2008; Patil et al., 2008; Channapagoudar et al., 2008; Reddy et al., 2012) obtained significant positive correlation of various yield contributing characters with mean grain yield plant^{-1}. These existed positive and significant association of total chlorophyll content in leaf, at 50% flowering and drought stages with grain and fodder yield. These results were coincided with (Surywanshi et al., 2010). Those high yielding genotypes possess higher morphological parameters such plant height, number of leaves plant^{-1}, LA, LAI and LAD and accumulation of more biomass productivity, harvest index, 5-10% ear head emergence, 5% bolder seed. These traits lead to development of new varieties suitable for medium soil situations. Apart from high panicle dry matter (50% of total dry matter), these varieties should also have efficiency in conversion of photosynthesis to the grain, these findings was supported by (Reddy et al., 2012). Grain yield is positively correlated with function of the dry matter production, it's partitioning and harvest index generally leads to higher yield. It could be seen that the higher yield resulted from the higher mean biomass production (g plant^{-1}) coupled with higher harvest index. The genotypes V_1 (Phule Yadhoda) and V_2 (RSV-1006) obtained comparatively higher grain yield than others. In present investigation, harvest index showed significant positive correlation with grain yield plant^{-1}. (Narkhede et al., 1998) also reported similar result.

4. Conclusion

Genotype Phule Chitra and Phule Maulee are more suited under limited soil moisture condition. While genotype RSV-1006 found well suited for medium soil for stress as well as non-stress condition. Irrespective of moisture regimes, Phule Yashoda and RSV-1006 found better than rest of genotypes based on physiological, biochemical and yield parameters. However, Phule Chitra and Phule Maulee had some biochemical and physiological parameters which suited under low moisture regimes (M_1) i.e., under water stress condition.

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6. Conflict of Interests

The author declares there is no conflict of interests regarding the publications of this paper.

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