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Association of important morpho-physiological and biochemical traits associated with grain yield for moisture stress tolerance in *rabi* sorghum under late sown condition

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Abstract
Ten different genotypes and three checks of *rabi* sorghum (*Sorghum bicolor* var. Moench) were evaluated for their morpho-physiological, growth, biochemical parameters with yield parameters under moisture stress late sown condition at research farm of sorghum research, Akola. The experiment was laid out in a Randomized Block Design, replicated thrice. The morpho-physiological and phenological parameters *viz.*, plant height, leaf area plant^{-1}, total dry matter plant^{-1}, relative leaf water content, chlorophyll content index, adaxial stomatal frequency and abaxial stomatal frequency showed positive and significant correlation with grain yield. The correlation between growth and biochemical parameters indicated that the growth parameters *viz.,* relative growth rate, crop growth rate, absolute growth rate, leaf area index, specific leaf weight and number of green leaves plant^{-1}, biochemical parameters *viz.,* leaf proline content, chlorophyll stability index, nitrogen content in leaves, nitrogen content in seed and protein content in seed showed positive and significant correlation with grain yield. While, the phenological parameters *viz.*, Days to 50 percent flowering, days to physiological maturity showed negative and significant correlation with grain yield. Therefore, these all parameters should be considered for the developing genotypes for stress tolerance under late sown rainfed condition.

Keywords: *Sorghum bicolor* L., water stress, morpho- physiological traits, growth traits, biochemical traits, correlation with yield

Introduction
Sorghum [*Sorghum bicolor* (L.) Moench] is the important cereal crop as it is a source of food for rural masses, food for cattle population and the raw material for the industries. Also with the present situation sorghum cultivation is the heart of the dry land agriculture. Being C_4 plant sorghum can utilize sunlight and water efficiently. In Maharashtra, about 4.92 lakh ha. area is under *Kharif* sorghum while 20.21 lakh ha area is under *Rabi* sorghum. *Rabi* sorghum is normally grown under stored and receding soil moisture conditions (Anonymous, 2017) [2].
Sorghum is one the most important cereal grain crop in the world, popularly known as “King of Millets” or “Great Millet” as an account of its large grain size among millets. Sorghum has been in India since prehistoric times and there is a record of sorghum being growing in Assynia as early as 700 BC. Evidence indicates that centre of origin of sorghum is East Africa in Ethiopia (Southern border west word to Chand) and then it spread to India, China, Middle East and Europe. Sorghum ranks fifth, among the world cereal food crops after rice, wheat, maize and barley (Anonymous, 2012) [1].
Rabi sorghum is the most important post rainy season cereal crop in peninsular India, grown predominantly under rainfed conditions. There is decline in the productivity of *rabi* sorghum under rainfed areas. Limited and erratic rainfall in the rainfed area creates moisture stress conditions during the various critical growth stages of crop life, resulting in severe yield reduction (Massacci *et al*., 1996) [18]. They limit the photosynthesis and consequently, limited availability of photosynthetic assimilates and energy to the plant. Apparently, under drought stress conditions, an urgent need for plants would be to increase the uptake of water, which is usually more available deep down in the soil (Xiong *et al*., 2006) [27]. The limited availability of water causes moisture stress which affects various metabolic processes of the plant. The limited availability of water causes moisture stress which affects various metabolic processes of the plant. The major limitations for Sorghum productivity are the occurrence of various biotic (shoot fly, stem borer, charcoal rot etc.) and abiotic (drought, salinity and temperature, etc.) stresses at different crop growth stages.

Sowing date can affect development and maturity of sorghum in semi-arid region, where high temperature and drought stress are common during development and maturity.

Materials and Methods

Thirteen genotypes of sorghum (*Sorghum bicolor* L.) including three checks *viz.*, M 35-1 (c), Phule Anuradha (c), Ringni (c), CSV-22R, CSV-26R, CSV-29R, Parbhani Moti, PKV-Kranti, Phule Maulee, Elongvan-19, Elongvan-42, Elongvan-227, Elongvan-277 were chosen on the basis of their morphological and agronomic diversity. The experiment was conducted during *rabi* 2015-16 and 2016-17 on sorghum research unite, Dr. PDKV, Akola (M.S). The experiment was laid out in randomized Block Design with spacing of 45x15 cm. in three replications under moisture stress condition. Five competitive plants were selected from each entry in each replication for recording the observations on grain yield per plant and other morpho-physiological, growth and biochemical parameters associated with grain yield for moisture stress tolerance. Correlation will be calculated as per Karl Pearson's correlation coefficient (Burton, 1951) [5].

$$r = \frac{\Sigma XY - \frac{(\Sigma X)(\Sigma Y)}{n}}{\sqrt{\left[\Sigma X^2 - \frac{(\Sigma X)^2}{n}\right]\left[\Sigma Y^2 - \frac{(\Sigma Y)^2}{n}\right]}}$$

Where, r = Coefficient of correlation
X = Variable one (Independents)
Y = Variable two (dependent)

Results and Discussion

Water stress due to drought is one of the most significant abiotic factors that limit the seed germination, plants growth, various physiological process and yield (Hartmann *et al.*, 2005, Van den Berg and Zeng, 2006) [13, 26]. Several methods have been developed to screen stress tolerant genotypes in plant species.

The correlation coefficient for important morpho physiological, growth, phenological and biochemical parameters with grain yield were studied for late sown in moisture stress under rainfed condition at 0.01% and 0.05% level of significance. Correlation was performed for various parameters and presented in Table 1 and 2.

Data presented in Table 1. It is revealed that the morpho-physiological and phenological parameters *viz.*, plant height (r=0.341), leaf area plant^{-1} (r= 0.896**), total dry matter plant^{-1} (r=0.910**), relative leaf water content (r= 0.869**) chlorophyll content index (r=0.866**), adaxial stomatal frequency (r= 0.969**), abaxial stomatal frequency (r=0.978**) showed positive and significant correlation with grain yield. While, the phenological parameters *viz.*, Days to 50 percent flowering (r= -0.792**), days to physiological maturity (r=-0.607*) showed negative and significant correlation with grain yield. Therefore these parameters should be considered for the developing genotypes for stress tolerance under late sown rainfed condition.

The correlation between growth and biochemical parameters with grain yield are presented in table 2 indicated that the growth parameters *viz.*, relative growth rate (r=0.629*), crop growth rate (r=0.866**), absolute growth rate (r=0.866**), leaf area index (r=0.895**), specific leaf weight (r=0.861**) and number of green leaves plant^{-1} (r=0.719**), biochemical parameters *viz.*, leaf proline content (r=0.886**), chlorophyll stability index (r=0.853**), nitrogen content in leaves (r=0.962**), nitrogen content in seed (r=0.882**) and protein content in seed (r=0.883**) showed positive and significant correlation with grain yield. Hence these parameters should be considered for the developing genotypes for stress tolerance under late sown rainfed condition.

Correlation analysis revealed that plant height had a positive and significant correlation with most of the parameters while it showed positive relationship with grain yield. Blum *et al.* (1989) [3], Kalhapure *et al.* (2013) [16] and Getnet *et al.* (2015) [11] found a positive correlation between plant height, dry matter production and grain yield. This may be because of increased translocation of stored photosynthates from the stem reserves when the current photosynthesis ceases due to environmental stress factors, particularly during grain filling and grain development period (Erick and Musick, 1979) [10].

Leaf area was found to have positive and significant correlation with morpho-physiological, growth, biochemical traits and yield and these results are consistent with previous reports Ghorade *et al.* (2013) [12], Getnet *et al.* (2015) [11] and Hulihalli *et al.* (2016) [14] in sorghum.

Table 1: Correlation coefficient among morpho-physiological and phonological parameters with yield in moisture stress under late sown rainfed condition in *rabi* sorghum genotypes

Particulars (parameters)	Plant height	Leaf area plant^{-1}	Total dry matter plant^{-1}	RWC %	CCI SPAD	Adaxial SF	Abaxial SF	Days to 50% flowering	Days to physiological maturity	Yield plant^{-1} (g)
Plant height	1	0.058	0.303	0.190	0.280	0.307	0.330	-0.425	-0.455	0.341
Leaf area plant^{-1}		1	0.905**	0.934**	0.920**	0.951**	0.910**	-0.703**	-0.453	0.896**
Total dry matter plant^{-1}			1	0.904**	0.920**	0.917**	0.956**	-0.698**	-0.470	0.910**
RWC				1	0.917**	0.914**	0.890**	-0.742**	-0.524	0.869**
SPAD					1	0.922**	0.919**	-0.809**	-0.526	0.866**
Adaxial SF						1	0.963**	-0.821**	-0.599*	0.969**
Abaxial SF							1	-0.803**	-0.599*	0.978**
Days to 50% flowering								1	0.838**	-0.792**
Days to physiological maturity									1	-0.607*
Yield plant^{-1}										1

* and ** indicates significant of value at P= 0.05 and 0.01, respectively

Table 2: Correlation coefficient among growth and biochemical parameters with yield in moisture stress under late sown rainfed condition in *rabi* sorghum genotypes

Particulars (parameters)	RGR	CGR	AGR	LAI	SLW	No. of leaf plant^{-1}	Leaf proline content	CSI	Nitrogen content in leaves	Nitrogen content in seed	Protein content in seed	Yield plant^{-1} (g)
RGR	1	0.514	0.514	0.679**	0.524	0.381	0.554	0.525	0.628*	0.591*	0.588*	0.629*
CGR		1	1.00**	0.868**	0.965**	0.661*	0.908**	0.800**	0.925**	0.899**	0.895**	0.866**
AGR			1	0.868**	0.966**	0.661*	0.908**	0.800**	0.925**	0.898**	0.895**	0.866**
LAI				1	0.875**	0.608*	0.865**	0.808**	0.925**	0.961**	0.959**	0.895**
SLW					1	0.774**	0.943**	0.886**	0.946**	0.890**	0.887**	0.861**
No. of leaf plant^{-1}						1	0.682*	0.959**	0.755**	0.545	0.540	0.719**
Leaf proline content							1	0.814**	0.949**	0.899**	0.898**	0.886**
CSI								1	0.890**	0.747**	0.743**	0.853**
Nitrogen content in leaves									1	0.925**	0.924**	0.962**
Nitrogen content in seed										1	1.000**	0.882**
Protein content in seed											1	0.883**
Yield plant^{-1}												1

* and ** indicates significant of value at P= 0.05 and 0.01, respectively

The data on SPAD reading revealed significant differences among the genotypes both at 30 and 60 DAS and the maximum SPAD readings was recorded at 30 DAS by all the genotypes compared to 60 and 90 DAS. Significant differences were also observed between the genotypes, during late sown and water stress conditions. The SPAD readings decreased in all the genotypes due to the moisture stress imposed during post flowering period. The SPAD chlorophyll meter readings had significant and positive correlation with grain yield per plant (r = 0.866). So, CCI can be used to evaluate the performance of Sorghum genotypes under moisture stress condition. In general, higher CCI means greater nitrogen and chlorophyll and thus these values can be taken as an index for evaluation of Sorghum genotypes for drought tolerance. The results observed in the present study are in conformity with the results of Talwar *et al.* (2011) [25], Sudhakar *et al.* (2006) [24], Ghorade *et al.* (2013) [12] and Devkumar *et al.* (2014) [7] in sorghum. Reddy *et al.* (2012) [23] reported that chlorophyll stability index is associated with desiccation tolerance under terminal water deficit condition and can be used as one of the reliable selection criteria in rapid screening for post rainy adapted genotypes for drought tolerance.

It can be said that increase in leaf area index results positively in building up these important traits. Reddy *et al.* (2012) [23] reported that leaf area index of a genotype which produced high dry matter could be considered as an indicator of grain yield. This results also confirmed by Ghorade *et al.* (2013) [12] and Hulhalli *et al.* (2016) [14] in sorghum.

Specific leaf weight showed positive and significant phenotypic correlation with grain yield per plant. Increase in specific leaf weight increased the assimilation of the photosynthates definitely which ultimately and indirectly boosted up the economics of sorghum. Similar results were obtained by Rao (2003) [22] and Pawar and Chetti (1998) [20] who observed similar positive correlations between specific leaf weight and grain yield per plant under water stress condition. They also reported positive and significant correlations of specific leaf weight with net assimilation rate, leaf area ratio and crop growth rate under water stress condition and these results are consistent with report by Ghorade *et al.* (2013) [12]. Crop growth rate is nothing but relative growth rate expressed on unit ground area basis. In crop community parameters, net assimilation rate is insufficient to describe growth of crop considering correlations, crop growth rate at 60-90 days after sowing recorded positive and significant correlation with relative growth rate at 60-90 days after sowing, absolute growth rate at 60-90 days after sowing and grain yield per plant. It indicated that increase in crop growth rate ultimately increased these parameters. Dhoran (1987) [9] observed similar correlations between crop growth rate and grain yield per plant. Ghorade *et al.* (2015) found crop growth rate was positively and significantly correlated with grain yield per plant and relative growth rate.

Relative growth rate is comparable compound interest growth representing rate of simple addition and compound addition of total dry matter per plant. Relative growth rate at 60-90 days after sowing showed positive and significant correlation with grain yield per plant. Relative growth rate enhanced the leaf area and in turn productivity as plants favouring assimilates of more carbohydrates which ultimately results in good economic yield and in turn stress tolerance capacity of plants. Lamani *et al.* (1997) [17] recorded similar observations and reported positive significant association between RGR and grain yield per plant. Ghorade *et al.* (2015) noted that positive and significant correlation between grain yield per plant and RGR found at 60-75 DAS under water stress condition.

Leaf proline content showed the positive significant correlation with grain yield per plant at 90 DAS. Singh *et al.* (1974) recorded similar observations and reported positive correlation of proline content and yield. It also indicates that the genotypes with a higher proline accumulation under a water limited environment had a better SG trait by preventing the water in the plant from loss. Proline accumulation increased in response to water stress is a common phenomenon (Husen, 2010) [15]. In addition, Pawar (2007) [21] also reported correlation of proline accumulation with grain yield in water limited environment.

Nitrogen content in leaves at 90 DAS showed positive and significant correlation with grain yield per plant. It can be said that nitrogen content in leaves was also found for higher yield response. It also had a positive correlation with chlorophyll contents. This was expected because nitrogen is one of the components of chlorophyll molecule. The higher nitrogen content in the leaves naturally increases chlorophyll content, which in turn increases the photosynthetic rate (Borrell and Hammer, 2000) [4]. The above results are in agreement with the results reported by many researchers, Ghorade *et al.* (2013) [12], Nirmal *et al.* (2013) [19], Getnet *et al.* (2015) [11], Hulihalli *et al.* (2016) [14] and Chavan *et al.* (2017) [6] in sorghum.

Conclusion

The present research work was conducted that all-important morpho-physiological, biochemical and growth parameters under study have shown desirable and significant correlation with grain yield per plant in moisture stress under late sown condition and hence, need to be considered as important parameters for increasing grain yield under stress condition.

Moreover, distinct genetic differences were found among the genotypes with respect to morpho-physiological, biochemical and growth parameters and yield subjected to moisture stress condition.

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