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Correlation and path analysis in relation to drought tolerance in *rabi* sorghum (*Sorghum bicolor* L. Moench)

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Abstract
Character association among various traits related to drought tolerance and direct and indirect effects of these traits on yield was carried out using 37 drought tolerant sorghum genotypes received from IIMR, Hyderabad along with three checks namely, M-35-1, CSV 22R and Phule Suchitra. A randomized block design was used with three replications and these treatments were evaluated and data pertaining to eight traits was recorded with the objective to determine character association among various traits related to drought tolerance in *rabi* sorghum. In present investigation there is existence of higher genotypic correlation when compared to phenotypic correlation this indicates the presence of inherent association among the characters. Studying association among the traits with each other and with yield component plays a major role in crop improvement program as yield is the dependent and complex trait which depends on various component traits. Significant and positive association was observed between grain yield per plant and other traits related to drought tolerance like third leaf area, flag leaf area, leaf area index, SPAD chlorophyll meter reading (SCMR) at 50 percent flowering, SPAD chlorophyll meter reading at physiological maturity at both genotypic and phenotypic levels, this association indicates increase in one or more of these traits results in increase in grain yield. Selection for a trait is effective when both the values of correlation and direct effect are higher and positive as this indicates its true association. In this investigation path analysis revealed at both genotypic and phenotypic level flag leaf area, SCMR at both 50 percent flowering and physiological maturity exhibited positive direct effect on grain yield there by it revealed their maximum contribution to the grain yield. Among the forty genotypes studied VJV 107, VJV 106, PEC 30, RSV 1921, RSV 1945 and RSV 1984 recorded better performance and these are considered as the superior genotypes.

Keywords: Correlation, path analysis, drought, SCMR, stay green

Introduction
With the frequent changes in climate, water availability to the crop is becoming very essential to meet the production needs. Sorghum (*Sorghum bicolor* L. Moench) is one of C4 cereal which is highly suited for the drought environment mainly due to its morphological and anatomical characteristics such as thick leaf wax, deep root system and physiological responses such as osmotic adjustment, stay green, quiescence [1]. C4 photosynthetic pathway in sorghum allows it to grow in high temperature, high light intensity and low water availability and it is highly efficient in fixing carbon dioxide [2]. It is one of the important cereal crop in the world occupying fifth position after maize, rice, wheat and barley [3]. Sorghum is the staple food in the human diet especially for poor and most food insecure people living in semi-arid tropics [4]. It is used as whole grain or processed into flour, it is gluten free and have essential nutrients (proteins, vitamins and minerals) and nutraceuticals (phenolics, antioxidants and cholesterol lowering waxes) [5]. Rabi sorghum occupies large area mainly in the states of Maharashtra, Karnataka and Andhra Pradesh with an average productivity of 819 kg/ha (Low). It's area is consistent over many years and it is an important component of dry land economy irrespective of its low productivity. The reasons for low productivity include biotic and abiotic stresses [6]. The major abiotic stress limiting crop growth is Drought. Sorghum as a staple food in the world, improving the crop is a key to ensure food security to the increasing population [7]. Even though sorghum is considered as drought tolerant crop, growth and yield reduction occurs due to water stress. Identification of the traits (especially morphological and physiological) related to drought stress given higher importance in drought related studies [8]. At both pre and post flowering stages sorghum is effected by water stress. Due to post flowering drought *rabi* sorghum is highly effected and it shows highly variable and low productivity. Even though it is one of the highly valued crop due to its good grain quality [9]. For reducing the risk due to post flowering drought superior genotypes are required.

This in turn requires the identification of traits (cost effective and easily measurable) related to terminal drought tolerance [10]. Among the various sorghum genotypes, variation to drought tolerance is identified and some of the better adopted genotypes are also identified [8]. For stabilizing the production of the crop growing under drought stress during post monsoon especially rabi sorghum, identification of the superior traits is essential. For successful planning and executing of the breeding programme, knowledge regarding the genetic variability is very essential. In order to increase the yield and drought tolerance among the genotypes identification of the essential traits, hybridization among these divergent sources and finally selection from the segregating generations is to be done [11]. The present study was undertaken with objective to determine character association among various traits related to drought tolerance in rabi sorghum.

Materials and Methods

Experimental material for the proposed work consists of 37 drought tolerant sorghum genotypes received from IIMR, Hyderabad along with three checks namely, M-35-1, CSV 22R and Phule Suchitra. These genotypes were evaluated using randomized block design with three replications during *rabi* 2019. The data pertaining to leaf area (cm2/plant), leaf area index (%), flag leaf area (cm^2), relative water content (%) at boot stage, SPAD chlorophyll meter reading at 50% flowering and at physiological maturity, stay green score (1- 9 scale) at 50% flowering and physiological maturity were recorded and used for studying character associations and indirect and direct effects on yield [12].

Results and Discussion

Current investigation was carried out to study correlation coefficient in order to determine the inter relationship between yield and traits related to drought tolerance at genotypic and phenotypic levels. The tables 1 and 2 represent the genotypic and phenotypic correlation coefficients for eight characters respectively.

Correlation coefficient

Degree of association among various traits can be studied by using one of the important statistical measures called correlation. In present investigation there is existence of higher genotypic correlation when compared to phenotypic correlation this indicates the presence of inherent association among the characters. Studying association among the traits with each other and with yield component plays a major role in crop improvement program as yield is the dependent and complex trait which depends on various component traits.

Significant and positive association was observed between grain yield per plant and other traits related to drought tolerance like third leaf area, flag leaf area, leaf area index, SPAD chlorophyll meter reading at 50 percent flowering, SPAD chlorophyll meter reading at physiological maturity at both genotypic and phenotypic levels, this association indicates increase in one or more of these traits results in increase in grain yield.

Similar results observed by Kadam *et al*. (2002) [7] recorded significant and positive association for leaf area index, Awari *et al.* (2003) [14] for leaf area index, Ghorade *et al*. (2013) [15] for SCMR, Dhutmal *et al*. (2014) [16] for SCMR, Khandelwal *et al*. (2015) [17] for leaf area, Chavan *et al*. (2017) [18] revealed existence of positive correlation between leaf area index, leaf area with grain yield,

The characters like relative water content at boot stage, stay green score at physiological maturity recorded positive and non- significant association with grain yield per plant at both phenotypic and genotypic level. These results are in agreement with Nirmal *et al.* (2013) [19] who recorded positive and non- significant association for relative water content and slay green at maturity, Dhutmal *et al.* (2015b) [20] for relative water content.

Generally, the traits which are showing positive and significant correlation with grain yield are given preference as valuable traits for yield improvement. Current study revealed several traits with that type of association; these traits are used in *rabi* sorghum for its improvement of yield.

Path analysis

Path coefficient analysis was carried out in order to find out the direct and indirect effects of various traits on the grain yield as outlined by the Dewey and Lu (1959) [12].

This analysis creates a decision for grain yield improvement i.e., to carry out the indirect selection for the trait which shows direct effect on the grain yield. Selection for a trait is effective when both the values of correlation and direct effect are higher and positive as this indicates its true association. Simultaneous consideration is made for indirect caused factors for selection if the direct effect is negative or negligible and correlation coefficient is positive. In order to reduce undesirable indirect effect, direct selection for the traits is followed if the direct effect is positive or high and correlation coefficient is negative.

Residual effect plays a major role in deciding how much amount of variability in grain yield i.e., dependent factor is due to causal factors. Moderate or higher residual value indicates besides the trait under study there are several other factors which account for the change in the yield.

The tables 3 and 4 represent the Direct and indirect effects at genotypic and phenotypic level for eight characters respectively.

Present study revealed presence of positive direct effect on grain yield for traits like flag leaf area, SCMR at both 50 percent flowering and physiological maturity, stay green score at flowering and physiological maturity. Results of the current investigation are in agreement with Dhutmal *et al*. (2015b) [20] who reported positive direct effect of chlorophyll content on grain yield and Narkhede *et al*. (2017) [21] for visual stay green score at flowering (1-9 scale), visual stay green score at maturity.

Positive direct effect on grain yield only at genotypic level reported for traits like leaf area index, relative water content. Among all the traits maximum positive direct effect on grain yield recorded for trait leaf area index (0.4214) followed by SCMR at 50 percent flowering (0.3299) while minimum positive direct effect recorded for stay green score at 50% flowering (0.0085) at genotypic level. At phenotypic level maximum positive direct effect on grain yield recorded for trait third leaf area (0.2037) while minimum positive direct effect recorded for stay green score at physiological maturity (0.0208).

Among all the traits negative direct effect on grain yield recorded for only trait third leaf area (-0.2224) at genotypic level. At phenotypic level maximum negative direct effect on grain yield recorded for trait leaf area index (-0.259) while minimum negative direct effect recorded for relative water content at boot stage (-0.0526).

Maximum positive indirect effect on grain yield recorded for the trait third leaf area (0.4304) and maximum negative indirect effect on grain yield recorded for the trait stay green score at 50 percent flowering (-0.4515) at genotypic level. At phenotypic level maximum positive indirect effect on grain yield recorded for the trait SCMR at 50% flowering (0.1648) and maximum negative indirect effect on grain yield recorded for the trait stay green score at 50% flowering (-0.1501).

At genotypic level residual effect value is moderate i.e., 0.183 and at phenotypic level also the residual effect value is moderate i.e., 0.152, this indicates almost the grain yield is due to the factors studied.

Table 1: Genotypic correlation coefficient for eight characters studied in rabi sorghum

Characters	Third leaf area (cm2/ plant)	Flag leaf area (cm2)	Leaf area index (%)	SCMR at 50% flowering	SCMR at Physiological maturity	Relative water content (%) at boot stage	Stay green score at 50 percent flowering	Stay green score at physiological maturity
Third leaf area (cm2/ plant)	1	0.643**	0.645**	0.812**	0.617**	0.079	-0.79	-0.284
Flag leaf area (cm2)		1	0.124	0.41	0.191	0.168	-0.325	0.029
Leaf area index (%)			1	0.346	0.407	0.175	0.171	0.343
SCMR at 50% flowering				1	0.825**	0.627**	-0.969**	-0.409
SCMR at Physiological maturity					1	0.589**	-0.5739**	-0.427
Relative water content (%) at boot stage						1	0.1002	-0.424
Stay green score at 50 percent flowering							1	0.401
Stay green score at physiological maturity								1

*Significant at 5 percent level, **Significant at 1 percent level.

Table 2: Phenotypic correlation coefficient for eight characters studied in *rabi* sorghum

Characters	Third leaf area (cm2/ plant)	Flag leaf area (cm2)	Leaf area index (%)	SCMR at 50% flowering	SCMR at Physiological maturity	Relative water content (%) at boot stage	Stay green score at 50 percent flowering	Stay green score at physiological maturity
Third leaf area (cm2/ plant)	1	0.643**	0.635**	0.72**	0.585**	0.076	-0.444*	-0.275
Flag leaf area (cm2)		1	0.622**	0.369	0.181	0.457*	-0.182	-0.444*
Leaf area index (%)			1	0.435	0.566**	0.653**	-0.579**	0.076
SCMR at 50% flowering				1	0.674**	0.468*	-0.443	0.585**
SCMR at Physiological maturity					1	0.481*	-0.34	0.72**
Relative water content (%) at boot stage						1	0.017	0.635**
Stay green score at 50 percent flowering							1	0.643**
Stay green score at physiological maturity								1

*Significant at 5 percent level, **Significant at 1 percent level.

Table 3: Direct and indirect effects (genotypic level) of drought components on grain yield

Characters	Third leaf area (cm2/plant)	Flag leaf area (cm2)	Leaf area index (%)	SCMR at 50% flowering	SCMR at Physiological maturity	Relative water content (%) at boot stage	Stay green score at 50 percent flowering	Stay green score at physiological maturity
Third leaf area (cm2/ plant)	-0.2224	-0.0987	-0.1435	-0.1808	-0.1374	-0.0176	0.1758	0.0633
Flag leaf area (cm2)	-0.0186	0.042	-0.0052	-0.0173	-0.008	0.0071	0.0137	-0.0013
Leaf area index (%)	0.2719	0.0524	0.4214	0.3145	0.2558	0.074	-0.4515	-0.1449
SCMR at 50% flowering	0.2682	0.1356	0.2463	0.3299	0.2724	0.0749	-0.32	-0.1349
SCMR at Physiological maturity	0.1034	0.032	0.1016	0.1382	0.1674	0.0385	-0.0961	-0.0715
Relative water content (%) at boot stage	0.0031	-0.0067	0.007	0.009	0.0091	0.0397	0.004	-0.0168
Stay green score at 50 percent flowering	-0.0067	-0.0028	-0.0091	-0.0082	-0.0049	0.0009	0.0085	0.0034
Stay green score at physiological maturity	-0.0148	0.0016	-0.0179	-0.0213	-0.0223	-0.0221	0.0209	0.0521

Residual effect 0.183.

Table 4: Direct and indirect effects (phenotypic level) of yield components on grain yield

Characters	Third leaf area (cm2/plant)	Flag leaf area (cm2)	Leaf area index (%)	SCMR at 50% flowering	SCMR at Physiological maturity	Relative water content (%) at boot stage	Stay green score at 50 percent flowering	Stay green score at physiological maturity
Third leaf area (cm2/ plant)	0.2037	0.0902	0.1294	0.1458	0.1192	0.0155	-0.0906	-0.0561
Flag leaf area (cm2)	0.0374	0.0845	0.0103	0.0312	0.0153	-0.0133	-0.0154	0.0022
Leaf area index (%)	0.1647	0.0317	-0.2592	0.1648	0.1459	0.0398	-0.1501	-0.0852
SCMR at 50% flowering	0.1144	0.0587	0.1009	0.1588	0.1071	0.0286	-0.0705	-0.053
SCMR at Physiological maturity	0.0563	0.0174	0.0545	0.1588	0.0961	0.0202	-0.0327	-0.0384
Relative water content (%) at boot stage	0.004	-0.0083	0.0081	0.0095	0.0111	-0.0526	-0.0009	-0.0199
Stay green score at 50 percent flowering	-0.0399	-0.0163	-0.0519	-0.0398	-0.0305	-0.0015	0.0896	0.021
Stay green score at physiological maturity	-0.0057	0.0006	-0.0068	-0.0069	-0.0083	-0.0079	0.0049	0.0208

Residual effect 0.152

Conclusion

This research project revealed presence of large amount of scope for a breeder in selecting superior genotypes for drought tolerance and yield improvement in *rabi* sorghum as this study recorded significant and positive association of various traits with yield and drought related aspects like days to physiological maturity, flag leaf area, SCMR, biological yield per plant and harvest index.

Generally, the traits which exhibit higher values for genotypic coefficient of variation, phenotypic coefficient of variation, high heritability coupled with high amount of genetic advance and significant and positive correlation with aspects related to yield and drought tolerance are used for identification of superior genotypes for drought tolerance.

Among all the genotypes and checks VJV 107, VJV 106, PEC 30, RSV 1921, RSV 1945 and RSV 1984 recorded better performance when compared to all the checks and genotypes hence among the forty genotypes these are considered as the superior genotypes for traits related to yield as well as drought tolerance aspects. Thereby these genotypes can be used for drought tolerance aspects and play a major role in breeding for abiotic stress tolerance i.e. for drought and these genotypes can be advanced to next generation.

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