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Diversity analysis for yield and yield contributing traits for drought tolerance in *rabi* sorghum (*Sorghum bicolor* L. Moench)

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Abstract
In this study thirty seven genotypes of *rabi* sorghum with three checks namely M 35-1, Phule Suchitra and CSV-22-R were evaluated for drought tolerance at Sorghum Research Station, V.N.M.K.V., Parbhani during *rabi* 2019. This study was carried out based on various yield contributing traits *viz*., days to 50% flowering, plant height (cm), panicle length(cm), panicle width(cm), days to physiological maturity, 100-seed weight (g), fodder yield per plant (g), grain yield per plant (g), total biomass (g/plant) and harvest index (%). In this study analysis was subjected to mean performance, genetic variability and character association. Further these forty genotypes are subjected to diversity analysis using D2 statistics and further inter cluster distances and cluster means also studied. This analysis grouped the thirty seven genotypes and three checks into 11 clusters. These clusters represented presence of considerable amount of genetic diversity. Further, principle component analysis (PCA) revealed five components namely plant height, fodder yield per plant, days to physiological maturity, days to 50% flowering and harvest index contributed each by 64.87%, 22.18%, 5.90%, 3.46% and 3.33% respectively when compared to total variation based on various yield contributing traits. Among the forty genotypes studied VJV 107, VJV 106, PEC 30, RSV 1921, RSV 1945 and RSV 1984 under the clusters I, II and III considered as superior genotypes with high mean performance for all the ten traits studied. These genotypes can be advanced to next generation for crop improvement studies in relation to drought tolerance.

Keywords: Sorghum, diversity analysis, drought tolerance, yield

Introduction
Sorghum is the staple food in the human diet especially for poor and most food insecure people living in semi-arid tropic [1]. It is one of the important cereal crop in the world occupying fifth position after maize, rice, wheat and barley [2]. It contains essential nutrients (proteins, vitamins and minerals) and nutraceuticals (antioxidants, phenolics and cholesterol lowering waxes) and is gluten free. It is used as whole grain or processed into flour [3]. Among all the states rabi sorghum occupies large area mainly in Maharashtra, Karnataka and Andhra Pradesh states. 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 includes biotic and abiotic stresses [4]. Drought is one of the major abiotic stress limiting crop growth. As the climate is changing frequently, water availability to the crop is becoming very essential to meet the production needs. It is one of C4 cereal which is highly suited for the drought environment mainly due to its morphological and anatomical characteristics such as deep root system, thick leaf wax and physiological responses such as osmotic adjustment, stay green, quiescence [5]. Sorghum as a staple food in the world, its improvement is a key to ensure food security to the increasing population [6]. 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 [7]. 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. Though it is one of the highly valued crop due to its high grain quality [8]. 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 [9]. Among the various sorghum genotypes, variation to drought tolerance is identified and some of the better adopted genotypes are also identified [7].

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 [10].

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 seedling vigour (1-5 scale), days to 50% flowering, plant height (cm), panicle length(cm), panicle width(cm), days to physiological maturity, 100-seed weight (g), fodder yield per plant (g), grain yield per plant (g), total biomass (g/plant) and harvest index (%) were recorded. Then D2 statistics was calculated according to Mahalnobis (1936) and Rao (1952) and here tree diagram was constructed based on the clustering by TOCHER method [11, 12].

Table 1: List of treatment materials used for the study

Sr. No.	Genotype
1	RSV 1837
2	RSV1921
3	RSV1945
4	RSV1984
5	RSV1988
6	RSV2124
7	RSV2197
8	RSV2209
9	RSV2234
10	RSV 2252
11	VJV 106
12	VJV 107
13	VJV 108
14	VJV 109
15	VJV 110
16	VJV 111
17	VJV 112
18	VJV 113
19	VJV 114
20	VJV 115
21	CRS 69
22	CRS 70
23	CRS 71
24	CRS 72
25	CRS 73
26	CRS 74
27	EP 85
28	EP 89
29	EP 94
30	EP 98
31	PEC 15
32	PEC 23
33	PEC 30
34	PVRL 16-2
35	PVR 16-3
36	PVR 947
37	PVR 950
38	M 35-1 (C)
39	CSV 22R (C)
40	Phule Suchitra (C)

Results and Discussion

Current investigation shown presence of significant variation for various yield contributing traits (Table 2) for drought tolerance in rabi sorghum based on the estimates of analysis of variance and mean performance.

Table 2: Mean, range, standard error difference (SE), and critical difference (CD) at 5% for yield contributing traits in *rabi* sorghum

Yield contributing traits	Mean	Range	SE	CD at 5%
Days to 50% flowering	74.54	65.54-78	0.3	0.84
Days to physiological maturity	117.7	106.7-119	0.46	1.22
Plant height (cm)	177	136.2-205	0.37	1.05
Panicle length(cm)	15.07	11.17-18.06	0.65	1.83
Panicle width(cm)	4.66	3.8-5.73	0.11	0.32
Fodder yield per plant (g)	60.07	37.93-74.15	0.58	1.62
Total biomass (g/plant)	87.49	57.82-116.3	2.44	6.86
Harvest index (%)	29.65	23.83-39.61	0.71	1.99
100-seed weight (g)	2.98	2.21-3.56	0.13	0.37
Grain yield per plant (g)	26.41	17.25-41.8	1.4	3.94

Further analysis based on the D2 statistics and Tochers method, the forty genotypes were grouped into 11 clusters (Table 3). Among all the clusters observed maximum number of genotypes recorded in cluster I which is with 14 genotypes followed by cluster V with 7 genotypes, cluster II with 6 genotypes, cluster III with 4 genotypes, cluster VII with 3 genotypes and remaining six clusters with single genotype each. The presence of these clusters with individual genotype may be the result of intensive natural or human selection or gene flow for diverse adaptive complexes and their by they remained diverged from the others.[13] This grouping of accessions into various clusters will be useful for identifying and selecting the drought tolerant genotypes by a breeder there by these genotypes can be used as donors in future breeding programme especially related to drought tolerance aspect. Cluster III included the check CSV 22-R and cluster V included checks M-35-1 and Phule Suchitra. Among all the clusters superior genotypes with drought tolerance was observed in cluster I, II and III which are with maximum genotypes indicating their stability without compromising the yield.

Table 3: Clustering composition of forty sorghum genotypes

No. of clusters	Name of the genotypes
I	VJV 110, EP 89, VJV 108, VJV 112, EP 94, PEC 15, VJV 109, RSV 1921, RSV 1984, RSV 2124, PVR 950, CRS 69, PVR 947, VJV 113
II	CRS 71, PEC 30, VJV 114, RSV 2234, CRS 74, VJV 115
III	VJV 106, VJV 107, CSV 22-R, RSV 1945
IV	PVRL 16-2
V	RSV 2209, M-35-1, RSV 2197, Phule Suchitra, EP 85, RSV 1837, RSV 1988
VI	RSV 2252
VII	VJV 111, CRS 73, PVR 16-3
VIII	CRS 70
IX	EP 98
X	CRS 72
XI	EC 15

Genotypes which recorded higher plant height, were found in cluster III along with check CSV 22-R and this is considered as the major trait contributed to the yield under drought tolerance as indicated by the PCA.

Among all the clusters superior genotypes with higher values for fodder yield and lower number of days to physiological maturity and 50% flowering observed in cluster III followed by cluster I indicating their higher stability when compared to all the eleven clusters formed. Genotypes with the moderate and lower level of mean performance had clustered separately, which indicates their importance as a source for drought tolerance is less when compared to other genotypes.

By comparing the cluster distances (Table 4) maximum inter cluster distance was found between the cluster VII and cluster III (88.97) followed by cluster IX and cluster III (70.71), cluster II and cluster III (64.05), cluster X and cluster III (60.44) and cluster VIII and cluster III (59.76) while minimum inter cluster distance observed between cluster I and cluster II (10.18).

Table 4: Cluster distances of forty sorghum genotypes

	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	GROUP 6	GROUP 7	GROUP 8	GROUP 9	GROUP 10	GROUP 11
GROUP 1	13.32	27.72	41.71	19.62	20.50	17.52	51.45	23.61	34.97	27.64	25.48
GROUP 2	27.72	10.18	64.05	26.98	37.19	25.75	28.02	19.93	25.35	20.43	39.10
GROUP 3	41.71	64.05	16.73	42.35	33.26	49.40	88.97	59.76	70.71	60.44	50.16
GROUP 4	19.62	26.98	42.35	0.00	20.83	28.73	52.20	33.34	44.02	33.41	40.90
GROUP 5	20.50	37.19	33.26	20.83	19.55	27.81	61.26	35.31	46.44	35.77	34.55
GROUP 6	17.52	25.75	49.40	28.73	27.81	0.00	45.93	11.98	22.30	18.17	17.36
GROUP 7	51.45	28.02	88.97	52.20	61.26	45.93	15.08	35.55	31.25	34.54	56.44
GROUP 8	23.61	19.93	59.76	33.34	35.31	11.98	35.55	0.00	12.74	13.81	22.38
GROUP 9	34.97	25.35	70.71	44.02	46.44	22.30	31.25	12.74	0.00	17.10	29.80
GROUP 10	27.64	20.43	60.44	33.41	35.77	18.17	34.54	13.81	17.10	0.00	30.67
GROUP 11	25.48	39.10	50.16	40.90	34.55	17.36	56.44	22.38	29.80	30.67	0.00

By the data related to cluster means (Table 5), it was observed that there is existence of considerable differences for all the ten traits studied among all the eleven clusters. Higher cluster mean values recorded for cluster III in relation to plant height and harvest index and higher values in relation to fodder yield recorded for cluster IV. The lower cluster mean values recorded for cluster III in relation to traits days to physiological maturity and days to 50% flowering. It was also observed existence of variation in relation to the inter cluster distances among the genotypes. Thus the superior genotypes VJV 107, VJV 106, PEC 30, RSV 1921, RSV 1945 and RSV 1984 can be used in the future breeding programme for the crop yield improvement majorly with respect to drought tolerance.

Table 5: Cluster means of forty sorghum genotypes

	Days to 50% flowering	Days to physiological maturity	Plant height	Panicle length	Panicle width	Fodder yield per plant	Total biomass	Harvest index	100-seed weight	Grain yield per plant
GROUP 1	74.71	117.29	179.63	15.03	4.59	60.58	88.79	28.17	2.86	25.25
GROUP 2	75.11	117.89	163.86	14.68	4.61	59.79	86.21	27.64	2.98	24.54
GROUP 3	72.25	110.50	201.13	16.78	5.48	71.49	105.18	35.02	3.42	36.17
GROUP 4	73.33	116.33	175.67	16.67	5.43	74.15	104.65	29.23	3.44	30.50
GROUP 5	74.76	112.81	184.01	15.80	4.81	66.40	94.62	32.51	3.22	29.79
GROUP 6	73.33	118.33	177.23	14.37	4.47	48.47	74.90	33.67	3.32	26.80
GROUP 7	76.33	117.89	149.94	13.69	3.79	50.66	70.97	25.42	2.47	20.32
GROUP 8	74.67	118.33	171.10	12.90	3.97	46.40	66.90	30.73	2.85	20.50
GROUP 9	74.00	118.33	166.67	12.93	4.51	37.93	58.96	29.97	2.54	21.15
GROUP 10	73.67	110.67	169.33	13.87	4.80	45.80	80.53	33.57	2.82	25.42
GROUP 11	76.00	118.00	184.20	15.20	3.80	40.57	57.82	28.17	2.84	17.25

Based on the mean performance and diversity analysis, it is better to cross genotypes of cluster III with genotypes of cluster II, VII, VIII, IX and X in order to combine the desirable traits as the inter cluster distance between these clusters is high, thereby it is possible to produce transgressive segregants. Presence of this diversity helps in providing greater opportunities for releasing of hidden variability present in the genotypes by breaking the close linkage i.e., by inter-crossing.[14] Among all the clusters, genotypes present in the cluster III can be regarded as drought tolerant and there by drought tolerant lines can be developed by combining with these genotypes.

Among all the traits contributing to the genetic divergence for yield under drought stress, five component traits namely plant height, fodder yield per plant, days to physiological maturity, days to 50% flowering and harvest index contributed largely to the total divergence each by 64.87%, 22.18%, 5.90%, 3.46% and 3.33% respectively and can be regarded as stress tolerance indicators. The genotypes present in the cluster III recorded higher values for plant height, fodder yield per plant and harvest index and lower values for days to physiological maturity, days to 50% flowering and these helps in effective selection thereby these can be used as parents for future crop improvement programmes.

Conclusion

This research project revealed presence of large amount of scope for a breeder in selecting superior genotypes for yield improvement in *rabi* sorghum. This study recorded presence of large amount of diversity among the forty genotypes studied and these are categorized into eleven clusters. Among all the genotypes and checks VJV 107, VJV 106, PEC 30, RSV 1921, RSV 1945 and RSV 1984 recorded better performance among the forty genotypes as it is evident from higher mean values especially in relation to the stress indicator components and these are considered as the superior genotypes for traits related to yield as well as drought tolerance aspects. There by these genotypes can be used as parental source 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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