Evaluation of Root Traits for Water Stress Tolerance in Rabi Sorghum Genotypes

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Abstract— *The experiment was conducted for evaluation of nineteen sorghum genotypes for their varying degree of drought tolerance by studying their root system architecture. The genotypes were grown in 'Phule Root Box' structure one of which maintained with drought stress and other received regular irrigation considered as control. Root system architecture changes were recorded at post anthesis stage by studying the root profile. The responses under drought stress found increase in root length, root shoot ratio, decreased in root length density, root volume, root diameter, fresh root weight and root number. The genotypes RSV 2408, RSV 2371 and Phule Anuradha showed better performance in root traits such as increased root length, root shoot ratio, better root length density, fresh root weight and decreased root diameter. Considering the overall performance of root traits, the genotype RSV 2408, RSV2371 and Phule Anuradha could be selected as drought tolerant genotypes for their further utilization in crop improvement program.*

***Keywords*— *Sorghum, Rabi sorghum, Drought tolerance, Water stress, Root traits, Root length, Root-shoot ratio, Root volume, Root diameter, Root biomass, Crop improvement, Stress adaptation*.**

I. INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the most important multipurpose cereal crops cultivated in tropical and subtropical regions of the world. Being a C_4 crop plant, it plays an essential role in feed, food, and fodder security in dry land agriculture (Chapke and Tonapi, 2019). India is the fifth largest producer of sorghum in the world with total production of 4.7 MT from its 4.8 million hectares of area (USDA, 2020). However the average yields of 1050 kg ha^{-1} is very low among the major sorghum producing countries. Among the sorghum producing state, Maharashtra is the leading state in sorghum production with the production of 2.15 MT from the area of 2.28 million hectares and the productivity of 941kg ha^{-1} during 2021-22 (ESM, 2022-23). Drought stress causes major losses in agricultural productivity every year (Ahluwalia *et al.,* 2021). The early vegetative stage and reproductive stage (pre and post flowering) of sorghum are vulnerable to the effects of water deficit (Wani *et al.,* 2013). In response to drought stress, plants undergo several physiological and morphological modifications like reduced transpiration and photosynthesis rate, osmotic adjustments, repressed root and shoot growth, overproduction of reactive oxygen species (ROS), modified stress signaling pathways, and senescence. These modifications can cause permanent injury to the plants (Ahluwalia et al., 2021). In order to acclimate to water shortage, plants adjust their growth and development to promote water absorption and reduce water loss (Zheng *et al*. 2016; Kim *et al*. 2020). Root response is of prime importance to crop productivity under drought stress. This is because the root size, architecture and distribution determine the ability of plants to access and uptake the water for proper physiological functioning of shoots (Taiwo *et al.,* 2020; Henry 2013; Comas *et al.*, 2013). Drought stress adapted plants are often characterized by deep and vigorous root systems. Water uptake capacity of roots can be estimated by root parameters including root biomass, root volume, primary root length, lateral root number, root depth, and root length distribution (Meng, 2018). Generally, under drought conditions, plants trigger several phenomena to generate more developed root systems and a higher root to shoot ratio. This is evidenced by a more pronounced restriction of shoot production than root production in plants under water deficit (Zheng *et al*. 2016; Du *et al*. 2020). Sorghum grown in arid and semiarid parts of the tropics and subtropics are frequently prone to drought accompanied with water stress and high temperature stress in plants affecting various growth stages (Reddy et al., 2012). Therefore, the better water stress tolerant genotypes are desired in such a region to reduce the crop failure due to water deficit problem. The most drought tolerant and susceptible genotypes could be used in hybridization programmes to increase genetic variability and the selection criteria used under water stress for drought tolerance in sorghum could be higher root length, shoot length with lower leaf water potential, osmotic potential, and turgor pressure (Bibi *et al*., 2012). Keeping in consideration the above facts, an attempt has been made on different sorghum genotypes for water stress tolerance by studying and investigating the root architecture system of the sorghum genotypes.

II. MATERIAL AND METHODS

Plant material and growth condition

The seeds of nineteen *rabi* sorghum genotypes were obtained from the All India Coordinated Sorghum Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri. A field experiment was carried out at All India Coordinated Sorghum Improvement project, MPKV, Rahuri during *rabi* season 2021-22 to study physiological root traits in "Phule Root Box" structure under limiting water condition. Two replications of the experiment were carried out using a randomized block design. Nineteen genotypes of rabi sorghum were planted with a 45 x 15 cm spacing and optimal soil moisture levels. Every recommended cultural and agronomic practice was followed. One plot was treated as an unstressed control and was irrigated 17, 27, 49, and 63 days after seeding, whereas another plot that did not give irrigation was treated as a stressed plot. In order to maintain the water stress condition during unseasonal rain the root boxes were protected under rainout shelter. At post flowering stage, five plants were randomly selected from each genotypes and physiological study of roots were conducted for measurements of root length, root volume, root length density, fresh root weight, number of roots, root shoot ratio, and root diameter.

III. RESULTS AND DISCUSSION

The sorghum genotypes grown under water stress condition resulted in the considerable variation in overall growth as compared to that of unstressed condition (Table 1).

TABLE 1
ANALYSIS OF VARIANCE OF NINETEEN SORGHUM GENOTYPES FOR SEVEN ROOT PARAMETERS UNDER DROUGHT AND NORMAL CONDITION

Genotypes	Root Length (cm)		Root volume (ml)		Root Length Density (cm cm^{-1})		Root Diameter (mm)		Fresh Root Weight (g)		Root Count		Root Shoot Ratio	
	Control	stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress
RSV 2408	53.33	72.33	96	73.33	0.164	0.121	3.12	2.63	128.33	86.67	46.33	37.67	0.26	0.31
RSV 1850	53.67	71	161	88.33	0.174	0.11	3.68	3.5	147.67	101.33	52.33	37.33	0.28	0.33
RSV 1876	56.67	62	138.33	76	0.159	0.11	3.79	2.99	125.67	78.67	52.33	35.67	0.25	0.29
RSV1945	60.33	71.33	165	63.33	0.171	0.104	3.6	2.69	178.33	76.67	51.33	32.67	0.29	0.31
RSV 2371	56.67	63.33	113.33	80.33	0.153	0.121	3.3	2.35	133.33	97.67	46.67	39.33	0.2	0.3
CRS 89	67	73.33	126	71	0.184	0.116	2.66	2.61	140.67	68.67	51.67	35.33	0.27	0.37
CRS 93	59.33	65	103.33	64.33	0.181	0.123	2.42	2.2	143.33	76.33	54.67	34.67	0.23	0.31
CRS 95	48	55.33	98.33	63.33	0.153	0.119	2.8	2.38	135.67	103.67	49	41.67	0.21	0.23
CRS 98	55.33	66	141	68.33	0.169	0.111	3.54	2.75	165.67	89	47.67	36.33	0.26	0.29
CRS 99	55.67	68.33	136	53.33	0.162	0.097	3.25	2.48	143.33	97	45.67	33.33	0.27	0.29
VJP 2704	62.67	68.67	123.33	53.33	0.145	0.11	3.22	2.36	119	90.67	41.33	33.67	0.24	0.3
VJP 2705	56.67	63.33	113.33	73.33	0.133	0.104	3.6	3.14	166.67	91.33	39.67	31.67	0.23	0.28
RNTN 13-39	56	64	138.33	68.33	0.163	0.132	3.38	2.5	158.33	96.67	48.67	41.67	0.25	0.29
RNTN 141	48.67	53.33	125.67	52.33	0.171	0.099	3.11	2.38	145.67	69.33	52.33	33.67	0.22	0.26
RNTN 142	49.67	55	110.67	58.33	0.167	0.107	2.84	2.45	103.33	76.33	52.33	35.67	0.2	0.25
RNTN 143	56.33	67.67	93.33	65.67	0.173	0.125	2.33	2.25	98.33	79	50.33	39	0.26	0.3
M-35-1 (C)	44.33	53.67	108.33	61.67	0.152	0.098	3.18	2.42	113.33	85.67	47	37.67	0.22	0.25
Phule Suchitra (C)	46.67	53.33	116	78.33	0.161	0.103	3.2	3.04	128.33	84.33	50.67	34.67	0.21	0.28
Phule Anuradha(C)	50.67	71.67	83.33	58.33	0.144	0.102	3.07	2.32	108.33	88.33	42.67	35.67	0.23	0.31
Mean	54.61	64.14	120.56	66.91	0.162	0.111	3.16	2.6	133.33	85.93	48.56	36.18	0.24	0.29
SEm (±)	1.34	1.42	3.39	1.71	0.005	0.005	0.03	0.11	2.54	3.13	0.98	1.17	0.002	0.006
CD at 5%	3.83	4.06	9.74	4.89	0.015	0.015	0.08	0.31	7.27	8.58	2.82	3.34	0.007	0.018

It was observed that the root architecture were significantly altered which is the important attributes for drought avoidance mechanism in plants. The sorghum genotypes Phule Anuradha and RSV 2408 recorded maximum increase in root length by 41.44 percent and 35.63 percent respectively under water stress over control. The genotypes RSV 2408 (72.33 cm) and CRS 89 (73.33 cm) recorded higher root length than the standard check Phule Anuradha (71.67 cm). The similar result was reported in sorghum with higher root length in CRS 67(56 cm) over the standard check M 35-1 (40.67 cm) under water stress condition (Kiran *et al*. 2022). Shinde *et al*. (2017) observed the positive correlation between root length and grain yield of sorghum genotypes under moisture stress. The genotypes RSV 1850 recorded the highest volume of 88.33 ml plant^{-1} under water stress condition. However, the genotypes RSV 2408 showed the lowest percent decline in root volume by 23.6 percent followed by RSV 2371, RNTN 143 and Phule Anuradha. The results were in accordance with the findings by Vinodhana and Ganeshmurthy (2010). Gadakh *et al*. (2021) observed the positive correlation between root volume and dry fodder yield concluding that fresh root mass and root volume at maturity plays an important role for higher dry fodder yield in *rabi* sorghum genotypes under rainfed condition. The genotypes RNTN 1339 and RSV 2371 found the minimum percent decline in root length density with 19.02 and 20.92 percent respectively. The genotypes RNTN 141 recorded the highest 42.11 percent decline in root length density. The better root length density in the active root zone area up to 30 cm depth improved the uptake of water as well as nutrients which ultimately resulted in higher yield in chickpea grown under water deficit condition (Varshney *et al*., 2011). The mean root diameter for control and stressed condition was 3.16 mm and 2.60 mm respectively which indicate that there was mean reduction of 17.22 percent in water stress condition. The highest decline of 28.79 percent in root diameter was observed in RSV 2371 followed by VJP 2704 and RNTN 1339. The reduction in root diameter has been previously recorded as a trait for increasing plants acquisition for water and productivity under drought stress (Wasson *et al*., 2012). Dorbnitch *et al*. (2021) observed the association of greater root pressure with greater proportional investment in fine root length. The genotypes Phule Anuradha, RNTN 143 showed lowest decline in fresh root weight under drought stress by 18.46 percent and 19.66 per cent respectively. The genotypes RSV 1945, RNTN 141 and CRS 89 showed the significant decline in root weight by 57.01 per cent, 52.41 per cent, and 51.18 per cent respectively. Silva *et al*. (2016) observed the positive correlation of 0.457 between fresh root matters with grain yield. Goche et *al*. (2020). There was 24.77 percent reduction in mean root count in stress condition. The root number was significantly decreased by 36.58 percent and 36.53 percent in CRS 93 and RSV 1945 respectively. However, RNTN 1339 and CRS 95 showed the lowest decline of 14.38 percent and 14.96 percent respectively under water stress condition. Similar result was recorded by Gano *et al*. (2021) with reduction in number of root from mean 44.03 in well watered condition to 26.83 in drought stress condition in ten elite sorghum varieties. Shinde *et al*. 2017 observed a positive correlation between mean number of roots and grain yield in *rabi* sorghum genotypes under receding soil moisture condition. The genotype RSV 2371 showed the highest increase in root shoot ratio by 50 percent followed by CRS 95 and CRS 98. Fadoul *et al*. (2018) recorded shorter root and shoot length of drought sensitive sorghum cultivar than the drought tolerant cultivars. Ali *et al*. (2009) found that root to shoot ratio based on length was ranged from 0.119 to 0.375 at post anthesis stage in sorghum.

IV. CONCLUSION

The sorghum genotypes grown under water stress condition resulted in the considerable variation in overall root architecture under water stress which is the important attributes for drought avoidance mechanism in plants. Most of the sorghum genotypes under water stress modified their root system in order to combat the negative impact of drought stress. Longer the roots deeper it goes for more water extraction. The strongly hold water by soil particles can be better absorbed by this finer roots with smaller diameter would show the better drought tolerance. Considering the overall performance of root traits, the genotype

RSV 2408, RSV2371 and Phule Anuradha could be selected as drought tolerant one for their further utilization in crop improvement program.

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