AATCC Review

13 August 2024: Received
15 September 2024: Revised
22 October 2024: Accepted
23 November 2024: Available Online

https://aatcc.peerjournals.net/

Original Research Article **Open Access**

Assessment of genotype response to drought stress under vegetative and reproductive stages in finger millet

Anupreethi R[1], V. Vengadessan*[1], S. Thirumeni[1], Santosh Kumar Meena[2], V. Krishnan[1], G. Abhilasha Priyadarshini[1], M. Narayanababu[1], B. Umasankari[1]

[1]Department of Pant Breeding and Genetics, PAJANCOA & RI, Karaikal 609603, Puducherry, India
[2]Department of Agronomy, PAJANCOA & RI, Karaikal 609603, Puducherry, India

ABSTRACT

This study aimed to assess the response of finger millet genotypes to drought stress under vegetative and reproductive stages. Thirteen finger millet varieties were evaluated at the Pandit Jawaharlal Nehru College of Agriculture and Research Institute in Karaikal during the Kharif season of 2023 (April-July). The study focused on three different treatments with each treatment being replicated three times. Various morphological, physiological, and root-related traits were recorded and subjected to statistical analysis. Except for the four traits namely CT, DFF, RLT, and RSR, all other trait exhibited a significant reduction in mean performance under vegetative and reproductive drought stress compared to the optimal condition. The DSI values ranged from -0.64 to 3.38 under vegetative drought stress and from -1.94 to 2.46 under reproductive drought stress. The mean yield reduction was 14.16% under vegetative drought compared to optimal conditions, and 19.44% under reproductive drought compared to optimal conditions in finger millet. Notably, it was observed that finger millet genotypes demonstrated superior drought tolerance especially under the vegetative stage compared to the reproductive stage. Based on the Smith selection index score, finger millet genotypes G9, G7, and G4 were identified as top performers under both vegetative and reproductive drought stress conditions. These preliminary findings emphasize the potential of these finger millet genotypes for breeding and genetic enhancement to improve drought tolerance in finger millet. The challenges of this study included the necessity to carefully manage the timing and intensity of drought stress to mimic natural conditions and ensure reliable results. The study's findings contribute to the ongoing efforts to develop drought-tolerant crops and enhance food security in regions prone to drought.

Keywords: *Finger millet, drought, vegetative stage, reproductive stage, genetic variability, PCA, selection index*

Introduction

Abiotic stresses and unpredictable severe weather conditions are the primary causes of annual yield losses. Li *et al.* (2016) [1] projected that the yield reduction for major crops due to drought will surpass 50% by 2050 and is expected to reach nearly 90% by 2100. Finger millet are small millet crops that are underutilized and demonstrate significant resilience to stress conditions, such as high temperatures, low moisture, and poor soils [2]. The lower productivity of finger millet can be attributed to various factors, such as marginal and poor soils or inadequate moisture and poor management practices. Despite the tolerance of finger millet to water stress, its growth is adversely affected by both intermittent and terminal droughts. Terminal drought occurring from flowering to maturity resulted in a yield loss of approximately 80.5% in finger millet [3]. In order to enhance crop productivity in regions susceptible to drought, it is imperative to comprehend the mechanism of drought tolerance, with the ultimate objective of ameliorating crop performance. However, the endeavor to measure drought tolerance using a solitary parameter is of restricted significance, as numerous factors and interactions contribute to the mechanism of drought tolerance. Crop plants have developed various mechanisms at the morphological, physiological, and molecular levels to evade or endure drought stress. To enhance crop productivity under water stress conditions, it is important to prioritize the incorporation of traits responsible for a well-developed root system, high stomatal resistance, high water use efficiency (drought avoidance), and traits responsible for increasing and stabilizing yield during water stress (drought tolerance). Consequently, the analysis of morpho-physiological and root-related traits holds great importance for comprehending the mechanism of drought tolerance.

Hence, the current investigation was conducted to evaluate the response of finger millet genotypes to drought stress under vegetative and reproductive stages based on morpho-physiological and root-related traits with the aim of identifying finger millet genotypes with enhanced drought tolerance, which can be employed in future breeding programs to develop improved drought-tolerant cultivars.

Materials and Methods

Thirteen finger millet genotypes including eleven advanced breeding lines and two varieties (GPU 28, GPU 67) received from various millet institutes were utilized as the experimental materials for this study (Table 1). Three distinct experiments were conducted which included drought stress at the vegetative stage, drought stress at the reproductive stage, and optimal condition (a well-watered environment). These experiments were accomplished using a randomized block design (RBD)

Corresponding Author: **V. Vengadessan*

DOI: https://doi.org/10.21276/AATCCReview.2024.12.04.306

with three replications. Each genotype was planted in two rows, with a spacing of 22.5 cm within the genotype and 30 cm between rows. Various morphological, physiological, and root-related traits were recorded. The morphological traits included days to 50 percent flowering (DFF), plant height (PHT), number of productive tillers (NPT), finger length (FLT), ear head weight (EWT), test weight (TWT) and single plant yield (SPY) were recorded. Physiological traits encompassed relative water content (RWC), Normalized Differential Vegetation Index (NDVI), Canopy Temperature (CT) and photosystem II (PS II). The root-related traits consisting of root length (RLT), Root shoot ratio (RSR), root fresh weight (RFW) and root dry weight (RDW) were assessed as well. Statistical methods such as analysis of variance, genetic variability analysis, correlation analysis, principal component analysis, and drought susceptibility index, were performed using R software [4] and the selection index was computed using PB tools [5] to analyze the data of observed traits under the three experiments.

Result and Discussion

Mean performance

The mean performance of fifteen traits in finger millet under the three treatments revealed that eleven traits, namely NDVI, PS II, RWC, PHT, NPT, SPY, TWT, FLT, EHW, RFW, and RDW, exhibited a significant reduction in both vegetative and reproductive drought stress compared to the optimal condition. The other four traits, CT, DFF, RLT, and RSR, showed an increase in their mean values after the imposition of drought stress at the vegetative and reproductive stages. Moreover, the single plant yield (SPY) and the yield contributing traits such as NPT, TWT, and EHW exhibited a decrease in their mean values under drought stress at a reproductive stage when compared to the vegetative stage. These findings are in agreement with the results reported by Ashok *et al.* (2018) [6] for the traits NPT, EHW, and TWT. Additionally, Aparna and Bhargavi (2017) [7] demonstrated a significant reduction in RWC due to water stress, which consequently affected the yield of finger millet. The decrease in the number of tillers observed in response to water stress can be considered as an adaptive mechanism employed by the plants to mitigate the effects of water stress [7]. This reduction in tiller number leads to a decrease in the transpiration area, thereby aiding the plant in coping with water stress. Furthermore, the reduction in test weight under drought conditions forces the plant to complete its grain formation in a relatively shorter period when compared to tolerant genotypes [8]. The mean performance across the three treatments for morphological traits are represented in boxplots (Figure 1). These visual representations provided a comprehensive overview of the variations in mean performance among the different treatments

Genetic variability, heritability, and genetic advance

Genetic variability is a crucial aspect in understanding the variation present in quantitative characters and its transmission to future generations, as well as the potential for improvement in subsequent generations. Notably, certain traits, including NPT, SPY, FLT, EHW, RFW, and RDW, exhibited high PCV and GCV values under all treatments. The findings of this study are consistent with previous research conducted by Lad *et al.* (2018) [9] and John (2006) [10] for EHW, Bhavsar *et al.* (2020) [11], and Bezaweletaw (2006) [12] for SPY, and Ganapathy *et al.* (2011) [11] for FLT, SPY, and NPT. On the other hand, traits like DFF, RLT, and RSR demonstrated moderate PCV and GCV values, whereas NDVI, PS II, RWC, PHT, and TWT exhibited the lowest PCV and GCV values under optimal conditions. The trait CT displayed low PCV and moderate GCV values in optimal conditions. Under vegetative stage drought conditions, the PCV and GCV values were nearly equivalent to the corresponding traits observed under reproductive drought stress such as NPT, PLT, PWT, PHT, DFF, and RDW. Traits such as DFF, NPT, SPY, PWT, PLT, RSR, RFW, and RDW exhibit higher values for heritability and genetic advancement under all three conditions. Comparatively, under reproductive conditions, the heritability and genetic advance scores for traits such as DFF, NPT, RLT, RSR, RFW, and RDW are similar to those observed under optimal conditions. Based on these observations, it can be inferred that traits exhibiting high heritability and genetic advance in finger millet under drought stress may be influenced by additive gene action and have a strong potential to respond well to selection.

Correlation analysis

Heatmap depicting the correlation coefficient among the various traits under three treatments were represented in Figure 2. The genotypic correlation revealed that the traits NPT, FLT, EHW, RFW, and RDW exhibited a significant positive genotypic correlation, while NDVI exhibited a significant negative association with SPY under optimal conditions. This finding aligns with the results of Bhavsar *et al.* (2020) [11] for NPT and FLT, Jyothsna *et al.* (2016) [14], and Sharathbabu *et al.* (2016) [15] for EHW, and Ayana (2001) [16] for EHW and FLT. Under both drought conditions (vegetative and reproductive stage), traits like NPT, EHW, FLT, RLT, RSR, RFW and RDW exhibited significant positive correlations to single plant yield. Conversely, traits such as DFF, PHT, and RWC showed negative associations with single-plant yield. Assefa *et al.* (2013) [17] and Worku *et al.* (2005) [18] reported a negative correlation between DFF and grain yield per plant, while Wolie and Dessalegn (2011) [19] observed negative correlations between SPY and DFF as well as PHT.

Principal component analysis

Principal component analysis revealed that the six principal components accounted for a substantial proportion of the variation in drought stress at the vegetative stage and optimal conditions, with percentages amounting to 80.5% and 79.7%, respectively. Under reproductive drought stress, the 75.7% of the total variation was recorded by the first five components that exceed the value more than 1. Notably, PC1 contributed to 33.26% of the variation under vegetative drought stress, 29.63% of the variation under reproductive drought stress, and 26.5% of the variation under optimal conditions. Furthermore, PC2, PC3, PC4, and PC5 contributed 12.72%, 11.48%, 8.67%, and 7.43% of the variation, respectively, under the vegetative drought stress. Similarly, PC2 to PC5, accounted for 26.63%, 14.57%, 12.29%, 10.26%, and 8.95% of the variation, respectively under reproductive drought stress. Under optimal conditions, PC2 to PC5 contributed 26.5%, 14.97%, 12.29%, and 10.99% of the variation, respectively. Percentages of variation contributed by each principal component under three treatments were depicted in Figure 3. Traits such as SPY, RLT, RSR, RFW, and RDW were the primary contributors to the variation observed in the first principal component under vegetative drought conditions. These results are in line with the findings of Suman *et al.* (2019) [20] who also noted the significant contribution of SPY in the first component. Similarly, under reproductive stage drought conditions, the variation in the first principal component was attributed to NPT, SPY, FLT, RSR, and RFW.

While under optimal conditions, the contribution was nearly identical to the traits observed in the reproductive drought stress, except for RSR, instead the trait RDW played a role in contributing to the observed variation. These findings are consistent with the results reported by Lule *et al.* (2012) [21] for NPT and Suman *et al.* (2019) [20] for FLT.

Drought susceptibility index and relative reduction in yield

The mean value of single plant yield in finger millet under optimal condition was recorded as 5.60 g and it ranged from 3.45 g to 8.53 g (Table 3). While under the vegetative and reproductive stage drought condition, single plant yield was observed as 4.79 g and 4.43 g respectively, and it ranged from 2.60 g to 7.47 g and 2.68 g to 6.82 g, respectively. Among thirteen finger millet genotypes, six showed low DSI values ranging from -0.64 to 3.38 under vegetative drought compared to normal conditions. When the reproductive drought stress compared to optimal conditions, five genotypes recorded low DSI values ranging from -1.94 to 2.46. The overall mean for the percentage reduction in yield of the thirteen genotypes was recorded as 14.16 percent and 19.44 percent in vegetative and reproductive drought stress over the optimal condition, respectively. These results are consistent with a previous study conducted by Ashok *et al.* (2016) [22].

Selection index

The Smith-Hazel index [23] revolves around the determination of an individual's genetic value by means of a linear function that takes into account the genetic values of multiple traits, each of which is assigned a specific relative economic value. The principal advantage of employing this index lies in its ability to amalgamate information about heritability, trait correlations, and, if available, economic importance [24]. Out of the 13 genotypes examined, the top three genotypes were selected based on the trait exhibiting maximum correlation with single plant yield, whereby the traits were assigned weight based on the correlated values that the maximum value of 1 was given to single plant yield and the least value of 0.2 was given to root length. Selection index scores for top three genotype under three different treatments were represented in Table 4 respectively. Based on the Smith index score, G9 performed better and secured the topmost position under reproductive drought stress and optimal conditions, and secured second position under vegetative drought stress. While G7 also performed better and held topmost position under vegetative drought stress and secured a second position under the remaining two treatments. The genotype G4 was recorded as a moderate performer and held third rank under all the treatments. the genotypes G9, G7, and G4 hold immense potential for drought tolerance breeding in finger millet.

Conclusion

This study provided an outline of the genotype response exhibited by finger millet to drought conditions at vegetative and reproductive growth stages. The mean yield reduction was 14.16% and 19.44% under vegetative and reproductive drought compared to optimal conditions respectively in finger millet. Notably, it was observed that finger millet genotypes demonstrated superior drought tolerance especially under vegetative drought stress when compared to reproductive drought. The reproductive stage, known for its critical importance in crop development, required additional supervision due to the potential direct impact that any stress during this phase could have on the final yield and overall productivity of the crops. Genotypes G9, G7, and G4 of finger millet were recognized as promising performers under both vegetative and reproductive drought stress conditions. Specifically, G9 demonstrated remarkable performance in reproductive drought conditions, yielding 6.82 g per plant, owing to its remarkably low drought susceptibility index (DSI) of less than 1. G7 exhibited the highest performance in vegetative drought conditions, yielding 7.47 g per plant, and similarly showcased a low DSI value of 0.22. These genotypes hold immense potential for future breeding programs and genetic enhancement initiatives aimed at improving the drought tolerance of crops across various growth stages.

Future scope of the study

Understanding the knowledge of drought stress exhibited at various crop stages holds immense potential for future breeding programs and genetic enhancement to improve drought tolerance in finger millet.

Conflict of interest

The authors have declared that no conflict of interest exists

Acknowledgment

The authors are grateful to the Dean and Head of the Department of Plant Breeding and Genetics, PAJANCOA & RI, Karaikal for providing the necessary facilities for the work and experimental needs.

Table 1. Advanced breeding lines and varieties of finger millet used for this experiment

G. No	Entry	Centre Name	Pedigree
G1	WN 572	Waghai	GE 120 x GE 5331-1-2
G2	VR 1149	Vizianagaram	Uduru mallige x GPU 48
G3	KMR 710	Mandya	L 6 x Indaf 9
G4	KMR 711	Mandya	Malavi 22 x Indaf 5
G5	KOPN 1055	Maharashtra	Selection from local germplasm
G6	KOPN 1056	Maharashtra	Selection from local germplasm
G7	IIMR FM-7066	Hyderabad	Pureline selection from IC 41810
G8	DHFM-13-6	Dharwad	GE 1219 x Indaf 8
G9	DHFM-78-33	Dharwad	GE 1219 x GPU 28
G10	BR 14-28	Jagadlpur	GPU 28 x KM 252
G11	VL 376	Almora	GE 4172 x VL ragi 149
G12	GPU 28	Bangalore	Indaf 5 x (Indaf 9 x IE 1012)
G13	GPU 67	Bangalore	Selection from GE 533

Table 2. Genetic Variability parameters (GVP) for fifteen traits in finger millet under vegetative drought (T1), reproductive drought (T2) and optimal condition (T3)

GVP	Trt.No	NDVI	CTD	PS II	RWC	PHT	DFF	NPT	SPY	TWT	PLT	PWT	RLT	RSR	RFW	RDW
PCV	**T1**	11.75	7.94	9.65	16.37	9.09	12.93	24.44	34.35	9.55	25.98	46.90	15.75	18.30	49.74	54.67
	T2	9.50	10.30	17.68	12.79	9.71	12.97	26.60	31.10	10.09	25.13	46.04	14.19	16.89	45.60	54.98
	T3	6.22	14.18	7.19	8.81	8.75	13.45	23.80	30.09	9.46	23.41	42.36	14.71	16.00	45.61	47.87
GCV	**T1**	9.96	4.07	1.89	16.20	6.37	12.58	23.41	29.70	5.07	20.10	46.09	15.61	16.53	49.45	54.22
	T2	8.74	4.75	5.54	12.59	7.68	12.66	25.63	28.99	5.79	21.86	45.53	14.07	15.68	45.36	54.54
	T3	5.39	9.34	2.72	8.54	7.93	12.91	22.88	25.21	2.88	22.70	41.73	14.54	15.22	45.46	47.58
h^2	**T1**	71.88	26.29	3.85	97.88	49.04	94.71	91.74	74.76	28.15	59.90	96.57	98.24	81.61	98.87	98.36
	T2	84.62	21.29	9.80	97.02	62.55	95.25	92.80	86.86	32.85	75.65	97.77	98.37	86.21	98.93	98.39
	T3	75.00	43.43	14.29	93.97	82.04	92.22	92.47	70.17	9.30	94.03	97.07	97.70	90.48	99.34	98.78
GA	**T1**	17.40	4.30	0.76	33.02	9.18	25.23	46.19	52.91	5.54	32.05	93.30	31.87	30.76	101.30	110.78
	T2	16.57	4.52	3.57	25.55	12.52	25.45	50.85	55.65	6.83	39.16	92.73	28.75	29.98	92.93	111.44
	T3	9.62	12.68	2.12	17.06	14.79	25.55	45.33	43.50	1.81	45.33	84.70	29.60	29.83	93.34	97.42

Table 3. Drought susceptibility index (DSI) and relative reduction (RR) in finger millet

G. No.	Single Plant Yield			DSI		RR (%)	
	Vegetative (T1)	Reproductive (T2)	Normal (T3)	T1 vs T3	T2 vs T3	T1 vs T3	T2 vs T3
G1	5.09	4.91	5.95	1.00	0.83	14.45	17.48
G2	2.60	3.74	5.06	3.38	1.25	48.62	26.09
G3	5.06	4.08	5.93	1.02	1.49	14.67	31.20
G4	6.55	5.72	7.02	0.47	0.88	6.70	18.52
G5	3.77	4.85	3.45	-0.64	-1.94	-9.28	-40.58
G6	3.87	3.10	4.35	0.77	1.37	11.03	28.74
G7	7.47	6.09	7.72	0.22	1.01	3.24	21.11
G8	5.60	3.98	5.38	-0.28	1.24	-4.09	26.02
G9	6.91	6.82	8.53	1.32	0.96	18.99	20.05
G10	3.17	3.34	3.81	1.17	0.59	16.80	12.34
G11	3.59	2.85	4.15	0.94	1.50	13.49	31.33
G12	3.91	2.68	5.52	2.03	2.46	29.17	51.45
G13	4.73	5.40	5.93	1.41	0.43	20.24	8.94
Mean	4.79	4.43	5.60	**0.98**	**0.93**	**14.16**	**19.44**
Min	2.60	2.68	3.45	-0.64	-1.94	-9.28	-40.58
Max	7.47	6.82	8.53	3.38	2.46	48.62	51.45

Table 4. Selection of top three genotypes in finger millet based on selection index scores under three different treatments

G.No.	Trt. No	NPT (No.)	EHW (g)	FLT (cm)	RLT (cm)	RSR (ratio)	RFW (g)	RDW (g)	SPY (g)	Selection index	Ranking
G9	T1	24.67	10.60	9.67	50.00	0.58	83.33	27.57	6.91	1.82	**2**
	T2	24.33	10.85	10.67	48.00	0.51	84.50	30.67	6.82	3.20	**1**
	T3	25.33	12.14	10.97	44.00	0.40	95.27	36.27	8.53	3.46	**1**
G7	T1	22.67	10.37	11.83	62.00	0.75	86.17	24.53	7.47	3.13	**1**
	T2	22.00	9.49	11.03	58.50	0.63	76.20	20.60	6.09	3.09	**2**
	T3	24.33	9.25	11.73	55.63	0.56	94.70	23.63	7.72	3.24	**2**
G4	T1	24.33	10.89	8.67	42.00	0.48	35.57	6.50	6.55	0.71	**3**
	T2	21.33	6.92	9.83	44.00	0.43	29.50	10.60	5.72	1.15	**3**
	T3	25.33	12.59	10.70	40.50	0.39	33.67	13.67	7.02	1.70	**3**
MSI	T1	21.83	11.85	9.71	47.76	0.57	57.64	17.31	6.63	NA	NA
	T2	19.83	7.94	10.21	46.62	0.50	60.13	25.47	5.87	NA	NA
	T3	23.00	10.58	10.56	45.16	0.44	78.81	24.12	7.30	NA	NA
MAI	T1	17.21	7.96	7.80	44.16	0.51	44.80	12.47	4.79	NA	NA
	T2	15.79	6.65	7.89	42.85	0.45	47.23	16.97	4.43	NA	NA
	T3	18.26	8.73	8.37	41.09	0.41	59.30	19.47	5.60	NA	NA
SDi	T1	4.63	3.89	1.91	3.60	0.06	12.84	4.84	1.84	NA	NA
	T2	4.04	1.30	2.32	3.77	0.05	12.91	8.50	1.44	NA	NA
	T3	4.74	1.85	2.19	4.07	0.03	19.51	4.64	1.70	NA	NA
EGG	T1	4.06	1.57	1.68	8.37	0.11	29.72	6.67	1.65	NA	NA
	T2	3.73	2.19	1.66	3.80	0.05	28.47	7.71	1.22	NA	NA
	T3	3.59	1.86	1.89	3.14	0.03	34.05	10.54	1.47	NA	NA

Figure 1. Boxplot showing mean performance of morphological traits across three treatments in finger millet

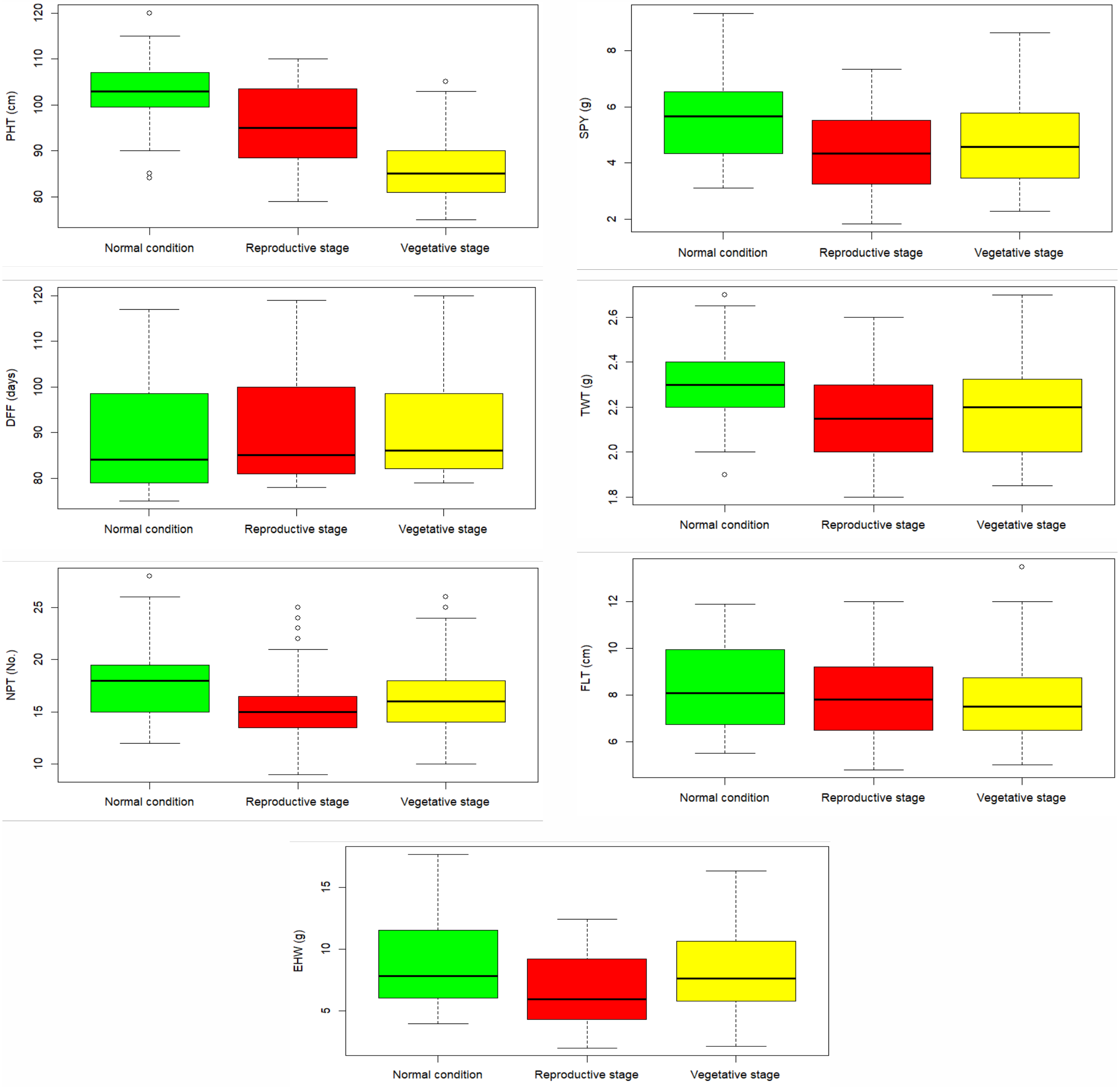
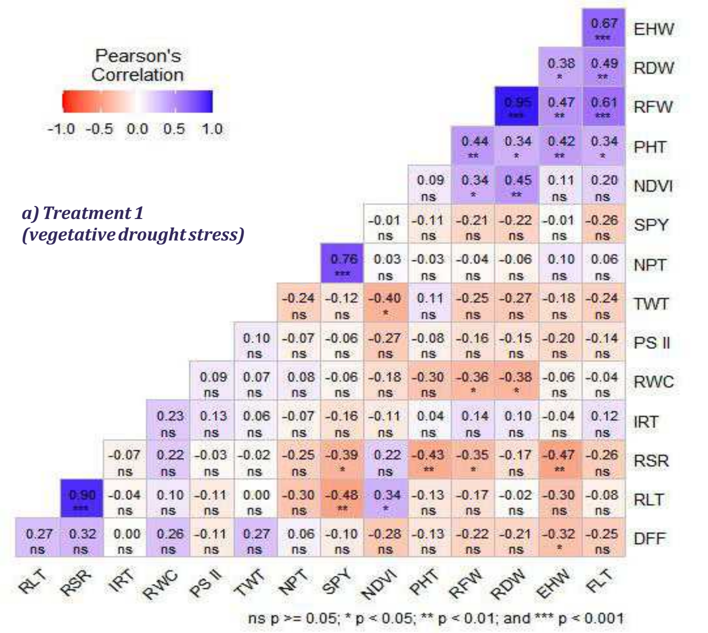
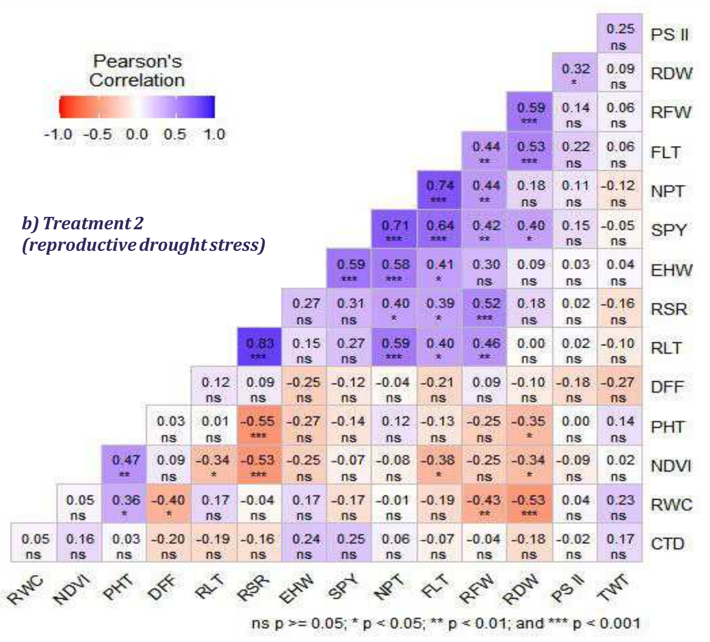


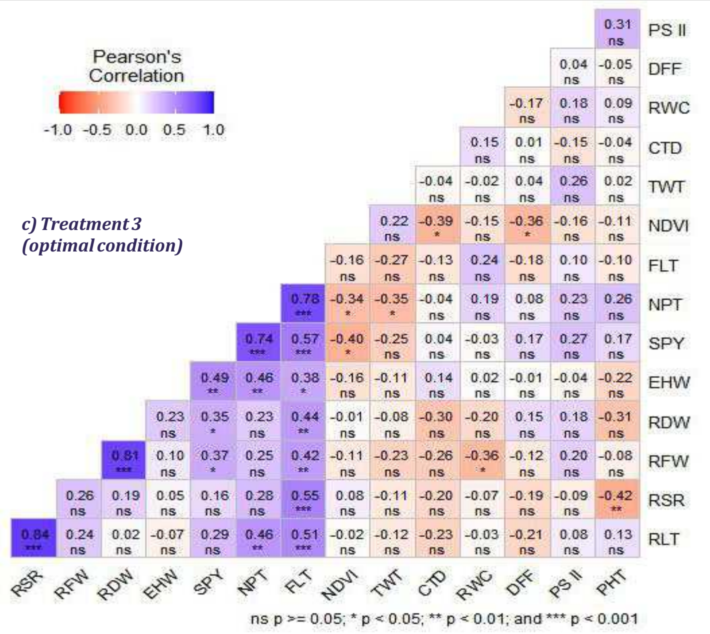
Figure 2. Heatmap for the correlation coefficient among fifteen traits in finger millet



a) Treatment 1 (vegetative drought stress)

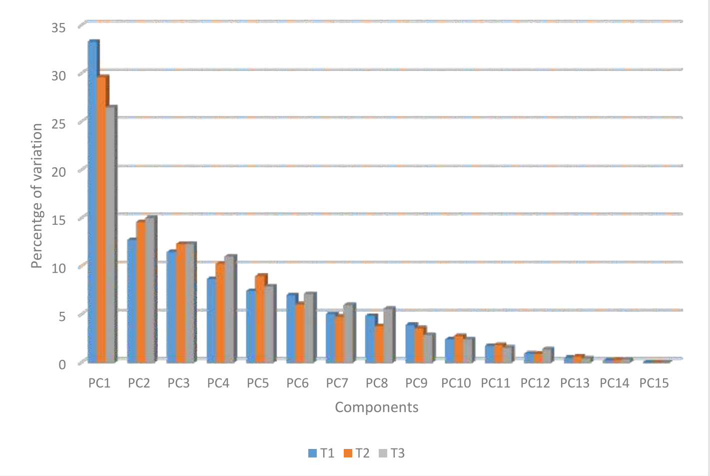


b) Treatment 2 (reproductive drought stress)



c) Treatment 3 (optimal condition)

Figure 3. Scree plot showing percentage of variation contributed by each component under vegetative drought (T1), reproductive drought (T2) and optimal condition (T3)



References

1. Li G, Woroch AD, Donaher NA, Cockshutt AM, Campbell DA (2016) A hard day's night: diatoms continue recycling photosystem II in the dark. Frontiers in Marine Science 3: 218.

2. Saleem S, Mushtaq NU, Shah WH, Rasool A, Hakeem KR, Rehman RU (2021) Morpho-physiological, biochemical and molecular adaptation of millets to abiotic stresses: a review. Phyton 90 (5):1363.

3. Matsuura A, Tsuji W, An P, Inanaga S, Murata K (2012) Effect of pre-and post-heading water deficit on growth and grain yield of four millets. Plant Production Science 15 (4): 323-331.

4. R v.4.2.1 and packages "agricolae", "corrplot" and "ggplot2". R Core Team (2022) R: A language and environment for statistical computing. R foundation for statistical computing, Vienna, Austria.

5. PB TOOLS, version 1.3 (2014) Biometrics and Breeding Informatics, PBGB Division, International Rice Research Institute, Los Banos, Laguna. Plant Science, 4: 442.

6. Ashok S, Senthil A, Srithara N, Punitha S, Divya K, Ravikesavan R (2018) Yield potential of small millets under drought condition. Madras Agric. J. 105 (2): 370- 372.

7. Aparna K, Bhargavi H (2017) Identification of drought tolerant and high yielding genotypes in ragi under rainfed conditions. Agric. 12: 2142-2145

8. Maqsood M, Ali SA (2007) Effects of drought on growth, development, radiation use efficiency and yield of finger millet (*Eleucine coracana*). Pakistan Journal of Botany 39 (1).

9. Lad DB, Borle UM, Dhumal NU (2018) Studies on genetic variability, association of characters and path analysis in maize (*Zea mays* L.) inbreds. International Journal of Pure and Applied Bioscience 6 (4):241-245.

10. John K (2006) Variability and Correlation Studies in Quantitative traits of Finger Millet [*Eleusine coracana* Gaertn]. Agril. Sci. 26: 166-169.

11. Bhavsar VV, Sapkal SR, Girase, Barhate KK (2020) Assessment of genetic variability among finger millet local germplasm collected from diverse climate. International Journal of Researches in Biosciences, Agriculture and Technology 15: 64-73.

12. Bezaweletaw K, Sripichitt P, Wongyai W, Hongtrakul V (2006) Genetic variation, heritability and path-analysis in Ethiopian finger millet [*Eleusine coracana* (L.) Gaertn] landraces. Agriculture and Natural Resources 40 (2): 322-334.

13. Ganapathy S, Nirmalakumari A, Muthiah AR (2011) Genetic variability and inter relationship analysis for economic traits in finger millet germplasm. World J. Agric. Sci. 7 (2): 185-188.

14. Jyothsna S, Patro TS, Ashok S, Rani YS, Neeraja B (2016) Studies on genetic parameters, character association and path analysis of yield and its components in finger millet (*Eluesine coracana* L. Gaertn). International Journal of Theoretical and Applied Sciences 8 (1): 25.

15. Sharathbabu, Sonnad K, Shanthakumar G, Salimath PM (2008) Genetic variability and character association studies in White Ragi (*Eleusine coracana* Gaertn). Karnataka J. Agric. Sci., 21: 572-575.

16. Ayana A (2001) Genetic diversity in sorghum [*Sorghum bicolor* (L.) Moench] germplasm from Ethiopia and Eritrea. (Ph.D thesis, Addis Ababa University).

17. Assefa A, Fetene M, Tesfaye K (2013) Agro-morphological, physiological and yield related performances of finger millet [*Eleusine coracana* (l.) Gaertn.] accessions evaluated for drought resistance under field condition. Asian Journal of Agriculture and Rural Development, 3 (10): 709-720.

18. Worku N, Zemede A, Yibra H (2005) Variation and association analysis on morphological characters of Linseed (*Linum usitatissimum* (L.) in Ethiopia. SINET: Ethiop. J. Sci., 28: 129-140.

19. Wolie A, Dessalegn T (2011) Correlation and path coefficient analyses of some yield related traits in finger millet (*Eleusine coracana* (L.) Gaertn.) germplasms in northwest Ethiopia. African Journal of Agricultural Research 6: 5099-5105.

20. Suman A, Surin, Ahmad E (2019) Finger millet germplasm characterization and evaluation using principal component analysis. Intl. J. Chem. Stud. 7:1002-1005.

21. Lule D, Tesfaye K, Fetene M, Villiers SD (2012) Inheritance and association of quantitative traits in finger millet (*Eleusine coracana)* landraces collected from eastern and south eastern Africa. International Journal of Genetics 2 (2): 12-21.

22. Ashok S, Patro SK, Jyothsna S, Divya M (2016) Character association, path and germplasm evaluation using principal component analysis in finger millet (*Eluesine coracana* L. Gaertn.). An International Journal Society for Scientific Development 11(3): 340-344

23. Bharathi A (2011) Phenotypic and genotypic diversity of global finger millet *(Eleusine coracana* L. Gaertn.*)* composite collection (Doctoral dissertation, Tamil Nadu Agricultural University).

24. Naveed M, Nadeem M, Islam N (2000) AMMI analysis of some upland cotton genotypes for yield stability in different milieus. World J. Agril. Sci. 3: 39-44.