International Journal of Environment and Climate Change

Volume 13, Issue 8, Page 2312-2316, 2023; Article no.IJECC.102663
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Characterization of Finger Millet Genotypes for Terminal Moisture Stress Tolerance Using Reported Indices

V. T. Manjunatha [a], L. N. Yogeesh [b++*] and T. M. Ningaraju [c#]

[a] *College of Agriculture Raichur, University of Agricultural Sciences, Raichur, India.*
[b] *Department of Genetics and Plant Breeding, College of Agriculture, Shimoga, Karnataka, India.*
[c] *Department of Plant Biotechnology, College of Agriculture, GKVK, UAS, Bangalore, Karnataka, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2023/v13i92276

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/102663

Original Research Article

Received: 01/05/2023
Accepted: 23/06/2023
Published: 24/06/2023

ABSTRACT

The present investigation is carried out to identify drought-tolerant genotypes among 108 finger millet accessions using drought-tolerant indices during *Rabi*, 2019. Drought tolerance indices like mean productivity (MP), drought susceptible index (DSI), drought tolerance efficiency (DTE) and stress tolerance index (STI) were employed in the screening of the genotypes. The variation in MP values ranged between 11.33-32.24, DSI between 0.03-1.53, DTE between 44.04%-98.90% and STI between 0.26-2.23. The genotypes with high MP, DTE, STI and low DSI were identified as drought-tolerant genotypes. The present study indicates that selection based on stress tolerance indices like MP, DSI, DTE and STI will result in the identification of drought-tolerant genotypes

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[++] *Assistant Professor (GPB);*
[#] *Assistant Professor;*
**Corresponding author: E-mail: yogeeshhari@gmail.com, yogeeshhagari@gmail.com;*

under terminal moisture stress that could reflect finger millet as a "Certain" crop for an "Uncertain" future and a solution to food insecurity and hidden hunger under environments prone to drought stress.

Keywords: Mean Productivity (MP); Drought Susceptible Index (DSI); Drought Tolerance Efficiency (DTE); Stress Tolerance Index (STI).

1. INTRODUCTION

"Finger millet (*Eleusine coracana* L.) is a crop of antiquity and known for its suitability to dry lands and tribal agriculture of sustainable nature. The resilience exhibited by this crop is helpful in their adjustment to different ecological situations making it an ideal crop for climate change and contingency planning. Although ragi is relatively a drought-resilient crop compared to rice, wheat and maize, it is most sensitive to drought stress at the time of the flowering period" [1]. The monsoon is India's life-giver, its rebirth and its lifeblood. The agonizing and often exhausting wait for the monsoon has long inspired Indians. But it's the country's farmers who know all too well the impact a delayed or indeed a failed monsoon can have on millions. About 42% of India's land area is facing drought, with 6% exceptionally dry-four times the spatial extent of the drought last year (Drought Early Warning System). Since 2015, Indian agriculture has been experiencing widespread drought conditions and millions of farmers hit by drought and crop failure are struggling to stay alive. Rampant changes in the rainfall patterns driven by climate change make agriculture the most difficult pursuit. In such perplexity finger millet might be an alternative climate-smart crop, as their adaptations to challenging environments are better than the current major crops of the world. Explicitly occurring terminal drought lowers the seed yield after flowering, which is really misleading from the farmer's point of view. So, the impacts of drought should be substantially mitigated and reduced by different strategies. Among all the mitigation strategies, one such noble method is the screening of drought-tolerant genotypes using drought indices.

"To evaluate the response of plant genotypes to drought stress, some selection indices have been proposed based on a mathematical relation between stress and optimum conditions" [2-4]. "Drought indices provide a measure of drought based on yield loss under drought conditions in comparison to normal conditions and have been used for screening drought-tolerant genotypes" [5]. "These indices are either based on drought resistance or susceptibility of genotypes" [4].

The present study was undertaken during *Rabi* 2019 at Agricultural Research Station, Hagari, Ballari, Karnataka to screen one hundred eight finger millet genotypes for terminal moisture stress tolerance using reported indices.

2. MATERIALS AND METHODS

The experimental material consisted of one hundred eight Ragi genotypes, along with three checks *viz*: ML365, GPU67 and GPU28. Two experiments were undertaken in the augmented design where the Finger millet genotypes were raised in Moisture Stress-Free (MSF) & Terminal Moisture-Stress (TMS) environmental conditions. Each genotype was grown in a 2 m-long single-row plot. Observations for yield and yield-contributing traits were recorded plant on five competitive plants selected at random for each genotype.

Several drought tolerance indices have been suggested on the basis of a mathematical relationship between yield under moisture stress free (MSF) and terminal moisture stress (TMS) conditions. Based on mean grain yield across trials under stress and non-stress, drought tolerance indices including mean productivity (MP), drought susceptible index (DSI), drought tolerance efficiency (DTE) and stress tolerance index (STI) were calculated.

Rosielle and Hamblin [2] defined "mean productivity (MP) as the average yield of Ys and Yp". Fischer and Maurer [6] proposed "a drought susceptibility index (DSI), which assesses the reduction in yield caused by unfavorable (stress) compared to favorable irrigated environments. DSI is expressed as DSI = [1- ((Yi)S / (Yi) NS] / SI. The stress intensity is estimated as SI = 1-(YS/YNS)". "YS and YNS denote the mean yield of all genotypes evaluated under stress and non-stress environments, respectively. Lower DSI values indicate a lower difference in yield across stress levels, in other words, more tolerance to drought. DSI has often been used for identifying genotypes with yield stability in moisture-limited environments" [7,8]. Drought tolerance efficiency (DTE) is estimated by the equation of Fischer and Wood (1981). According to this equation: DTE (%) = (Yield under stress /Yield under non-stress) * 100. The higher value of DTE indicates higher drought tolerance ability of genotypes. Fernandez [4] defined "a stress tolerance index (STI) as STI = [(Yi)NS*(Yi)S] /(YNS)2, which can be used to identify genotype that produces high yield under both stress and non-stress conditions. A high value of STI implies higher tolerance to drought stress".

3. RESULTS AND DISCUSSION

The drought-tolerant indices in the selected finger millet genotypes with respect to grain yield are represented in Table 1. A significant grain yield difference was observed between the mean grain yield of control and stress condition for all entries which implies that the performance under moisture stress free (MSF) and terminal moisture-stress (TMS) conditions was considerably different. Genotypes *viz*; WN591 (0.24), HR6(0.30), VR1125(0.40), VR1110 (0.81), OEB604 (0.83), HR25 (1.03), GPU101 (1.52), PPR1082 (1.53), VL399 (1.59), RAUF17 (1.61) and IIMRFM8011 (1.72) recorded the lowest values of yield difference and these genotypes were recognized as moisture stress tolerant genotypes. The characters like lower plant height, early maturity, deeper roots, increased root volume and proline accumulation might be the possible reasons for drought tolerance in those genotypes. But genotypes such as HR36 (12.13), HR57 (11.96), HR19 (11.96), HR18 (11.89), HR21 (11.59), HR24 (11.24), HR33 (11.23), HR11 (11.17), HR58 (10.9), HR16 (10.6) and HR54 (10.27) were reported for highest values of yield difference which clearly indicated drought susceptibility. Thus, lesser the yield difference indicates greater tolerance.

For mean productivity (MP) genotypes such GPU98 (11.33), VR117 (12.10), KMR703 (13.18), TNEC1311 (13.49), KMR704 (13.57), VL394 (13.65), HR16 (13.90), KMR652 (14.45), HR11 (14.82), GPU45 (14.87) and HR29 (15.24) had the lowest values of mean productivity and these genotypes were recognized as moisture stress susceptible genotypes. Whereas, the genotypes such as GPU28 (32.24), HR52 (31.62), HR50 (31.17), HR47 (30.86), HR19 (30.84), HR56 (30.71), HR46 (30.10), PR202 (30.00), HR44 (29.83), HR43 (29.80) and PRSW43 (29.45) were recorded for the highest values, clearly indicated them to be terminal drought tolerant genotypes. Thus, mean productivity plays a vital role in the characterization of finger millet genotypes under drought stress conditions that could be considered in breeding programs to improve drought tolerance. Comparable results were declared by Bennani et al. [9].

The Drought susceptibility index (DSI) assesses the reduction in yield caused by unfavourable environment compared to a favourable environment. Lower DSI values indicate the lower differences in yield between non-stress and stress conditions, in other words more tolerance to drought and DSI is a measure of yield stability. Genotypes such as WN591 (0.03), HR6 (0.04), VR1125 (0.06), VR1110 (0.09), OEB604 (0.10), HR25 (0.14), VL399 (0.15), RAUF17 (0.17), IIMRFM8011 (0.18), PPR1082(0.18) and GPU101 (0.18) were recorded to have the lowest values and these genotypes were recognized as drought tolerant genotypes. While the genotypes HR18 (1.53), HR16 (1.51), HR11 (1.49), HR36 (1.48), HR33 (1.18), HR13 (1.16), HR17 (1.16), HR54 (1.15), HR57 (1.15), HR21 (1.11) and HR58 (1.11) were recorded highest values that indicate these genotypes as drought susceptible genotypes. Therefore, DSI is helpful in identifying finger millet genotypes with low yield and tolerant to drought because under stress yield decreased with increasing DSI.

Drought tolerance efficiency (DTE) is a measure of drought tolerance mechanisms and determines the consistency of genotypes in response to drought stress having of different severity, timing and duration and thus may be helpful in identifying genotypes that possess drought resistance capability under terminal moisture stress (TMS) conditions. Genotypes such as HR18 (44.04), HR16 (44.79), HR11 (45.24), HR36 (45.82), HR17 (56.60), HR33 (57.41), HR13 (57.60), HR57 (57.76), HR54 (58.82), HR58 (59.29) and HR21 (59.48) were recorded the lowest values of drought tolerance efficiency and hence those were moisture stress susceptible varieties. Whereas the genotypes WN591 (98.90), HR6 (98.64), VR1125 (97.95), VR1110 (96.55), OEB604 (96.41), HR25 (94.88), VL399 (94.41), RAUF17 (93.86), GPU101 (93.45), VL400 (93.35) and PPR1082 (93.34) were recorded highest values and were terminal drought tolerant genotypes. Identical results were proclaimed by Patel et al. [10]. Thus, higher values of DTE imply higher tolerance of genotypes to stress.

Table 1. Drought tolerant indices in selected finger millet genotypes with respect to seed yield (g/plant)

Genotype	Diff	Genotype	MP	Genotype	DSI	Genotype	DTE	Genotype	STI
				Lowest values					
WN591	0.24	GPU98	11.33	WN591	0.03	HR18	44.04	GPU98	0.26
HR6	0.30	VR117	12.10	HR6	0.04	HR16	44.79	VR117	0.30
VR1125	0.40	KMR703	13.18	VR1125	0.06	HR11	45.24	HR16	0.36
VR1110	0.81	TNEC1311	13.49	VR1110	0.09	HR36	45.82	KMR703	0.36
OEB604	0.83	KMR704	13.57	OEB604	0.10	HR17	56.60	TNEC1311	0.38
HR25	1.03	VL394	13.65	HR25	0.14	HR33	57.41	VL394	0.39
GPU101	1.52	HR16	13.90	VL399	0.15	HR13	57.60	KMR704	0.39
PPR1082	1.53	KMR652	14.45	RAUF17	0.17	HR57	57.76	HR11	0.41
VL399	1.59	HR11	14.82	IIMRFM8011	0.18	HR54	58.82	HR18	0.43
RAUF17	1.61	GPU45	14.87	PPR1082	0.18	HR58	59.29	KMR652	0.45
IIMRFM8011	1.72	HR29	15.24	GPU101	0.18	HR21	59.48	GPU45	0.47
				Highest values					
HR36	12.13	GPU28	32.24	HR18	1.53	WN591	98.90	GPU28	2.23
HR57	11.96	HR52	31.62	HR16	1.51	HR6	98.64	HR52	2.15
HR19	11.96	HR50	31.17	HR11	1.49	VR1125	97.95	HR50	2.09
HR18	11.89	HR47	30.86	HR36	1.48	VR1110	96.55	HR47	2.06
HR21	11.59	HR19	30.84	HR33	1.18	OEB604	96.41	HR56	2.03
HR24	11.24	HR56	30.71	HR13	1.16	HR25	94.88	HR19	1.99
HR33	11.23	HR46	30.10	HR17	1.16	VL399	94.41	PR202	1.95
HR11	11.17	PR202	30.00	HR54	1.15	RAUF17	93.86	HR46	1.92
HR58	10.90	HR44	29.83	HR57	1.15	GPU101	93.45	HR43	1.91
HR16	10.60	HR43	29.80	HR21	1.11	VL400	93.35	HR44	1.89
HR54	10.27	PRSW43	29.45	HR58	1.11	PPR1082	93.34	PRSW43	1.88

Where, Diff=Difference between control and terminal drought with respect to seed yield, MP= Mean Productivity (g), DSI= Drought Susceptible Index, DTE= Drought Tolerance Efficiency (%), STI= Stress Tolerance Index

Stress tolerance index (STI) was used to identify genotypes that produce high yields under both moisture stress-free (MSF) and terminal moisture stress (TMS) conditions. The high value of STI implies higher tolerance to stress. Genotypes *viz*; GPU98 (0.26), VR117 (0.30), HR16 (0.36), KMR703 (0.36), TNEC1311 (0.38), VL394 (0.39), KMR704 (0.39), HR11 (0.41), HR18 (0.43), KMR652 (0.45) and GPU45 (0.47) recorded lowest values of tolerance and are moisture stress susceptible genotypes. Whereas, the highest values of tolerance were recorded by GPU28 (2.23), HR52 (2.15), HR50 (2.09), HR47 (2.06), HR56 (2.03), HR19 (1.99), PR202 (1.95), HR46 (1.92), HR43 (1.91), HR44 (1.89) and PRSW43 (1.88) which indicated them to be terminal drought tolerant varieties. Equivalent findings were reported by Bennani et al. [9] and Mohammed and Kadhem [11].

Thus finger millet genotypes such as GPU28, HR52, HR50, HR47, HR19, HR56, HR46, PR202, HR44, HR43, PRSW43, IIMRFM8011, WN591, HR6, VR1125, VR1110, OEB604, HR25, VL399, RAUF17, GPU101, VL400, PPR1082 and HR44 were identified as drought tolerant based on drought parameters such as seed yield difference, mean productivity, drought susceptible index, drought tolerance efficiency and stress tolerance index. Among these indices, drought tolerance efficiency (DTE) and stress tolerance index (STI) were found to be the best indices to identify drought-tolerant genotypes because DTE measures determine the consistency of genotypes in response to drought-stress, while STI detects the genotypes that have low water requirements and/or suffer less yield reduction by water shortage during their growth period.

4. CONCLUSION

Drought tolerance indices have been widely used in the screening and selection of drought tolerant genotypes among the 108 finger millet accessions. Drought tolerance indices like mean productivity (MP), drought susceptible index (DSI), drought tolerance efficiency (DTE) and stress tolerance index (STI) were employed in screening of the genotypes. The results of present study clearly indicate that these drought tolerance indices are very effective in identifying the drought tolerance finger millet genotypes which will contribute to increase the yield in drought prone areas of the world.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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