Original Research Article

Characterization of finger millet genotypes for terminal moisture stress tolerance using reported indices

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 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 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 stressful environments.

Keywords: Mean productivity (MP), drought susceptible index (DSI), drought tolerance efficiency (DTE) and stress tolerance index (STI).

Introduction

Finger millet (*Eleusine coracana* L.) is a crop of antiquity and known for their 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 flowering period (Ojulong *et al.*, 2017) [7]. The monsoon is India’s life-giver, its rebirth and its life blood. 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 makes the 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 of terminal drought lowers the seed yield after flowering, which is really misleading from the farmers 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 screening of drought-tolerant genotypes using drought indices.

To evaluate response of plant genotypes to drought stress, some selection indices has been proposed based on a mathematical relation between stress and optimum conditions (Rosielle and Hamblin, 1981; Clarke *et al*, 1992; Fernandez *et al*, 1992) [11, 2, 3]. Drought indices provides a measure of drought based on yield loss under drought conditions in comparison to normal conditions have been used for screening drought tolerant genotypes (Mitra, 2001) [5]. These indices are either based on drought resistance or susceptibility of genotypes (Fernandez *et al*, 1992) [3].

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.

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 under taken 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 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 (1981) [11] defined mean productivity (MP) as the average yield of Y_s and Y_p. Fischer and Maurer (1978) [4] proposed 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 level, in other words, more tolerance to drought. DSI has often been used for identifying genotypes with yield stability in moisture limited environment (Puri *et al*., 2010; Raman *et al*., 2012) [9, 10]. 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 (1992) [3] 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.

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) & 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), IIMRFM8011 (1.72) recorded 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) were recorded 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 play 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*., (2017) [1].

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 condition, 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 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 indicates 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.*, (2017) [8]. Thus, higher values of DTE implies higher tolerance of genotypes to stress.

Stress tolerance index (STI) was used to identify genotypes that produce high yield under both moisture stress free (MSF) and terminal moisture stress (TMS) conditions. 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*., (2017) [1] and Mohammed and Kadhem (2017) [6].

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 determines 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.

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	11.5	HR19	30.8	HR33	1.1	OEB60	96.4	HR56	2.0

	9		4		8	4	1		3
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

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