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Selection of Drought Tolerance Pearl Millet Hybrids for Arid and Semi-Arid region using the Stress Indices

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Abstract

The present Findings were conducted to help identify F1 hybrids suitable for arid and semi-arid areas in pearl millet based on stress indices. Seventy-seven F1 hybrids along with three standard checks were laid down in randomized block design with three replications in three different environments. The nine stress indices viz., stress tolerance (TOL), stress susceptibility index (SSI), stress tolerance index (STI), mean productivity (MP), geometric mean productivity (GMP), yield index (YI), yield susceptibility index (YSI), harmonic mean (HM), and sensitivity drought index (SDI) were calculated using grain yield per plant in stressed and non-stressed conditions to screen the hybrids for moisture stress tolerance based on grain per plant. Pooled ANOVA showed that genotype, environment, and genotype x environment interaction effects were highly significant for both characters. Mean grain yield and dry stover yield per plant of hybrids decreased under stress environment. On the basis of different moisture stress tolerance indices, the crosses viz., ICMA 98222 x BIB 481-500, ICMA 97444 x BIB 571-580, ICMA 88004 x BIB 501-510, ICMA 30201 x BIB 511-520, ICMA 10444 x BIB 511-520, ICMA 93333 x BIB 531-540 and ICMA 30201 x BIB 561-570 were identified as most tolerant for moisture stress conditions. Therefore, these crosses can be adapted for higher yield in drought-affected areas and can be used as a parent for a hybridization program for moisture-stress tolerance breeding as well as developing moisture stress tolerant populations.

Keywords: *Pearl millet, Drought tolerance, Biological yield, Grain yield, Stover yield, hybrids, stress. calcium, iron, non-enzymatic browning*

Introduction

Pearl millet [*Pennisetumglaucum*(L.) R. Br.] is a major warm-season cereal grown on 26 million ha in the arid and semi-arid tropical (SAT) regions of Asia (more than 10 million ha) and Africa (15-16 million ha). Pearl millet is a staple food for the majority of poor farmers and also an important fodder crop for the livestock population in arid and semi-arid regions of India and gives out staple food for the millions of people flourishing under hunger. The crop is able to boom under adverse conditions and also set up an important fodder crop for livestock populations in arid and semi-arid regions. Pearl millet is a C_4 plant species like sorghum, corn, sugarcane, and switchgrass. This crop has high photosynthetic efficiency and the capacity to produce more dry matter production. The area under natural grasslands common property resources are on the decline, in some of the regions, especially under arid ecosystems are of considerable importance for livestock rearers. Excessive stocking pressure and degeneration of the original pasture grasses have led to a decline in biomass productivity from these resources.

The primary objective of the pearl millet improvement programme is to increase the yield potential(grain yield and biological yield) of the crop in improved

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management as well as adverse conditions. Moisture stress is a major limiting factor in the productivity of many crop species. Crop inevitably suffers from moisture stress during the reproductive period of growth after the depletion of stored water. Majority of the pearl millet cultivation is still dependent on rainfall and conserves moisture. Pearl millet is essential to increase production as well as productivity and naturally suffers from drought stress during the reproductive period of growth after the depletion of stored water (Kumar, 2001). Hence the development of drought-tolerant varieties of pearl millet is essential to raise the production. In the absence of an understanding of the special mechanisms of tolerance, the quantification of moisture stress tolerance should be based on the yield in both stress and non-stress conditions which can lead to the selection of tolerant genotypes under stress conditions (Koktene*t al.,* 2010). With this perspective, the present investigation was carried out to evaluate 77 single cross hybrids along with three standard checks, under moisture stress conditions, for grain yield and dry stover yield. Nine moisture stress indices *viz*., TOL, SSI, MP, GMP, YI, YSI, HM, STI, and SDI were calculated using grain yield per plant and dry stover yield per plant in stressed and non-stressed conditions.

Materials and Methods

Experimental material: The experimental material for the present study is based on 77 F_1 hybrids and three standard check hybrids (HHB 67 Improved, RHB-177 and BHB-1602). The 77 F_1 hybrids were generated using line x tester mating design at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad during Summer, 2019. The hybrids were generated by employing eleven male sterile lines (ICMA-04999, ICMA -88004, ICMA-93333, ICMA-97111, ICMA-97444, ICMA-98222, ICMA-10444, ICMA-30199, ICMA-30200, ICMA-30201 and ICMA-30209 from ICRISAT, Patancheru, Hyderabad) and 7 testers (BIB 481-500, BIB 501-510, BIB 511-520, BIB 531-540, BIB 551-560, BIB 561-570 and BIB 571-580 from AICRP on Pearl Millet, Bikaner, Rajasthan).

Experiment and Environmental details: The three environments created by differentiating number of irrigations namely E_1, (non-stress or normal environment, irrigations provided at the time of tillering, flowering, and grain filling) E_2 (irrigations provided at the time of flowering and grain filling) and E_3 (stress environment, only lifesaving irrigation) were provided three, two and one irrigations, respectively) at Agricultural Research Station, Bikaner during *Kharif,* 2019. Each plot consisted of two rows each of 4-meter length with row spacing of 60 cm and plant-to-plant spacing of 15 cm. According to meteorological data, recorded at Agricultural Research Station, Bikaner during *Kharif,* 2019 no rainfall is received during this crop period. In both situations, pre-sowing irrigation was given to facilitate seed germination.

Location: The research farm is situated between 27°1' N latitude and 71°54' E longitude at an altitude of 228.50 meters above mean sea level. This region falls under agro-climatic zone 1C of Rajasthan. The climate of the region is typically hyper-arid characterized by extreme temperatures during both summer and winter and the salinity of the rhizosphere. The average rainfall is about 260 mm, which is mostly received during July-September. All recommended cultural practices were followed to raise good crops except irrigation.

Observations: The observations were recorded on grain yield per plant and dry stover yield per plant in both environments and used to calculate different stress indices. The ear-heads of the ten tagged plants were threshed together, weighed, and averaged to obtain grain yield per plant as well as dry Stover yield per plant. Since the observations recorded on the above traits in environments described earlier were sufficient for the calculation of stress indices, the experiment was terminated after only one season.

Stress indices and statistical analysis: The following nine moisture stress tolerance indices were calculated using the following formulae:

Stress Tolerance (TOL)

Rosielle and Hamblin (1981) defined stress tolerance (TOL) as the differences in yield between the stress (Y_s) and non-stress (Y_p) environments.

$$TOL=Y_p - Y_s$$

Stress Susceptibility Index (SSI)

It was calculated for yield over stress environment and normal (non-stress) environment as per formula given by Fischer and Maurer (1978).

$$SSI= [1 (Y_s / Y_p)] /S$$

S= Stressintensity

Where, $S = 1 - \frac{\text{Mean } Y_s \text{ of all genotypes}}{\text{Mean } Y_p \text{ of all genotypes}}$

Stress Tolerance Index (STI)

Fernandez (1992) defined a new advanced index (STI), which can be used to identify genotypes that produce high yields under both stress and non-stress conditions. It was calculated by following formula:

$STI = [YP \times YS/Y^{-2}_{P}]$

$\bar{y}$ = Mean yield of all genotypes under normal condition(E_1)

Mean Productivity (MP)

Rosielle and Hamblin (1981) defined mean productivity (MP)for the genotypes with high value of this index will be more desirable. It was calculated by followingformula:

$MP = Y_S + Y_P/2$

Geometric Mean Productivity (GMP)

Fernandez (1992) defined the genotypes with high GMP value will be more desirable. It was calculated by following formula:

$GMP = \sqrt{Y_P} \times \sqrt{Y_S}$

Yield Index (YI)

Gavuzzi et al., (1997) defined (YI) the genotypes with high value of this index will be suitable for drought stress condition. It was calculated by following formula:

$YI = \frac{Y_S}{\bar{Y}_S}$

Yield Stability Index (YSI)

Bouslama and Schapaugh, (1984) the genotypes with high YSI values can be regarded as stable genotypes under stress and non-stress conditions. It was calculated by followingformula:

$YSI = \frac{Ys}{Yp}$

viii) Harmonic Mean (HM)

Jafari*et al.* (2009) define (HM) the genotypes with high value of this index will be more desirable. It was calculated by following formula:

$HM = \frac{2(Y_S)(Y_P)}{(Ys+Y_P)}$

ix) Sensitivity Drought Index (SDI)

Farshadfar and Javadinia (2011) defined the genotypes with low value of this index will be more desirable. It was calculated by following formula.

$SDI = \frac{Y_P - Ys}{Y_P}$

Where,
Y_s = Yield of genotype under stress condition(E_3)
Y_p = Yield of genotype under normal condition(E_1)

The mean data for grain yield and biological yield was subjected for analysis of variance following Panse and Sukhatme (1985). Ranks were assigned to each hybrid for each index. Based on the indices formula, the hybrid with the highest value for Ys, Yp, STI, MP, YI, YSI, and HM and the lowest value for TOL, SSI, and SDI received a rank 1st.

Result and Discussion

Pooled Analysis - The pooled analysis of variance in table 1 showed that the mean sum of the square for the environment, Genotype, and Genotype x environment is highly significant for both character.

Table1: Pooled Analysis of variance over the environment in pearl millet.

Source of Variance	df	Grain yield per plant	Dry Stover yield per plant
		Mean sum of square	Mean sum of square
Environment	2	63677.74**	1334271.7**
Genotype	79	1175.69**	33932.88**
G x E.	158	321.73**	7603.87**
Error	480	41.58	633.54

*,** indicates significant at 5% and 1% , respectively
Mean performance of grain yield per plant

The mean grain yield per plant in the normal environment or non-stress condition (Y_p) ranged

from 16.67 g (ICMA 30200 x BIB 511-520 and ICMA 88004 x BIB 531-540) to 95g (ICMA 98222 x BIB 481-500) while in stress condition (Y_s) it was ranged from 11.33 g (ICMA 30200 x BIB 511-520, ICMA 88004 x BIB 531-540, ICMA 04999 x BIB 531-540, ICMA 98222 x BIB 531-540, ICMA 10444 x BIB 531-540 and ICMA 97111 x BIB 571-580) to 61.67 g (ICMA 98222 x BIB 481-500). The hybrids ICMA 98222 x BIB 481-500, ICMA 9333 x BIB 551-560 and ICMA 04999 x BIB 561-570 showed the highest grain yield in non-stress conditions and hybrids ICMA 98222 x BIB 481-500, ICMA 97444 x BIB 571-580 and ICMA 30201 x BIB 561-570 were show highest grain yield in stress condition. Thus the data show that stress can reduce the grain yield per plant (Table 2).

Mean performance of dry stover yield per plant

The mean dry Stover yield per plant in non-stress condition (Y_p) ranged from 76.67 g (ICMA 30200 x BIB 511-520) to 510 g (ICMA 30199 x BIB 511-520) and in stress condition (Y_s) it ranged from 13.33 g (ICMA 04999 x BIB 551-560) to 333.33 g (ICMA 30201 x BIB 481-500). The hybrids ICMA 30199 x BIB 511-520, ICMA 93333x BIB 551-560 and ICMA 93333 x BIB 531-540 show highest dry Stover yield per plant in non-stress conditions, and hybrids ICMA 30201 x BIB 481-500, ICMA 98222 x BIB 481-500 And ICMA 30201 x BIB 561-570 show highest dry Stover yield per plant in stress condition. Thus the data show that dry stover yield per plant also decreases in the adverse environment (Table 3).

Identification of moisture stress tolerance hybrids
Screening of hybrids on the bases of grain yield

The cross ICMA 30201 x BIB 561-570 showed the lowest value of TOL (-9.00),SSI (-0.45), SDI (-0.27) and ranked first followed by ICMA 97444 x BIB-551-560 (value of TOL 0.33, SSI 0.03, SDI 0.02), ICMA 04999 x BIB 551-560 (value of TOL 2.00, SSI 0.14, SDI 0.09), ICMA 30209 x BIB-481-500 (value of TOL 2.67, SDI 0.14) and ICMA 10444 x BIB-481-500 (value of TOL 4.33, SSI 0.27, SDI 0.16) with respect to high moisture stress tolerance ability. The cross ICMA 30199 x BIB-561-570 showed the highest TOL value (65.33), cross ICMA 97111 x BIB-571-580 showed the highest SSI value (1.40), and cross ICMA 97111 x BIB-571-580 showed highest SDI value (0.84) which indicated that all were highly susceptible to moisture stress. The cross ICMA 98222 x BIB-481-500 had the highest value of STI (2.02), MP (78.33), GMP (76.54), YI (2.65), HM (74.79) and secured first rank also which indicated its high tolerance to moisture stress. The cross ICMA 30210 x BIB-561-570 had the highest value of YSI (1.27) which indicated its stable genotypes under stress and non-stress conditions. Based on the present study, it was recorded that STI, MP, GMP, YI, YSI, and MP values were handy attributes in selecting high-yielding genotypes under both stress and non-stress conditions, while the relative decrease in yield, TOL, SSI, and SDI values were better indices to establish tolerance levels(Table 2).

Screening of hybrids on the bases of Dry Stover yield per plant

The cross ICMA 98222 x BIB-481-500 showed the value of TOL (-56.67),SSI (-0.38), SDI (-0.23) and ranked first followed by ICMA 30201 x BIB-481-500 (value of TOL -33.33, SSI -.19, SDI -.11), and ICMA 30199 x BIB-501-510 (value of TOL -26.67, SSI -.18, SDI -.11) were highest moisture tolerance hybrids and had first rank in stress tolerance level. Thus they are less affected by stress conditions. The hybrid ICMA 30199 x BIB-501-510 had the lowest rank for TOL, and the hybrid ICMA 04999 x BIB-531-540 had the lowest rank for SSI and SDI. Thus indicated all were highly susceptible to moisture stress. The hybrid ICMA 30201 x 481-500 secured first rank and highest value for STI (34.47), MP (316.67), GMP (316.23), YI (14.34), and HM (315.79) so that it was highly tolerance to stress condition and less affected to stress. The hybrid ICMA 98222 x 481-500 had the highest value for YSI (1.23) and first rank which indicated its stable genotypes under stress and non-stress conditions (Table 3).

Bases of Selection criteria of hybrids for moisture stress

To evaluate moisture stress tolerance of various crosses, nine stress indices viz., TOL, STI, SSI, SDI, MP, GMP, YI, YSI, and HM were calculated using grain yield per plant and dry stover per plant in stress (Y_s) and non-stress (Y_p) condition (Table 2, 3).To determine the most tolerant cross, rank should be given to the induces individually as well as the sum of the rank of all indices including the rank of yield (Y_s and Y_p) were used to calculate the overall rank of crosses and based on this criteria the most desirable and tolerant crosses were identified (Table 2, 3). A cross with the least rank total was considered to be the best cross. According to this criteron for grain yield per plant crosses ICMA 98222 x BIB 481-500,

Table 2: Mean grain yield of normal environment, Stress environment, Stress indices, rank and over all rank of hybrids.

hybrids	Grain yield in E1		Grain yield in E3		STI		MP		GMP		YI		YSI		HM		Rank total	Over all rank	TOL		SSI		SDI		Rank total	Over all rank
	YP	R	YS	R	V	R	V	R	V	R	V	R	V	R	v	R	RT	OR	v	R	v	R	v	R	TR	OVR
ICMA 04999 × 481-500	66.67	16	21.33	36	0.49	31	44.00	23	37.71	31	0.92	36	0.32	59	32.32	36	268	34	45.33	66	1.13	59	0.68	59	184	60
ICMA 88004 × 481-500	50.00	44	28.67	20	0.49	30	39.33	35	37.86	30	1.23	20	0.57	22	36.44	26	227	27	21.33	20	0.71	22	0.43	22	64	20
ICMA 93333 × 481-500	36.67	69	29.67	18	0.37	42	33.17	57	32.98	42	1.28	18	0.81	7	32.80	33	286	36	7.00	8	0.32	7	0.19	7	22	6
ICMA 97111 × 481-500	43.33	61	21.33	36	0.32	50	32.33	59	30.40	50	0.92	36	0.49	29	28.59	45	366	46	22.00	23	0.85	29	0.51	29	81	25
ICMA 97444 × 481-500	60.00	26	17.33	58	0.36	43	38.67	40	32.25	43	0.75	58	0.29	63	26.90	52	383	48	42.67	62	1.19	63	0.71	63	188	63
ICMA 98222 × 481-500	95.00	1	61.67	1	2.02	1	78.33	1	76.54	1	2.65	1	0.65	15	74.79	1	22	1	33.33	45	0.58	15	0.35	15	75	24
ICMA 10444 × 481-500	26.67	72	22.33	33	0.21	67	24.50	72	24.40	67	0.96	33	0.84	5	24.31	58	407	52	4.33	5	0.27	5	0.16	5	15	5
ICMA 30199 × 481-500	73.33	11	34.67	8	0.88	6	54.00	7	50.42	6	1.49	8	0.47	33	47.08	6	85	6	38.67	51	0.88	33	0.53	33	117	37
ICMA 30200 × 481-500	53.33	39	24.67	28	0.45	34	39.00	36	36.27	34	1.06	28	0.46	34	33.73	29	262	32	28.67	35	0.90	34	0.54	34	103	33
ICMA 30201 × 481-500	50.00	44	31.67	13	0.55	23	40.83	28	39.79	23	1.36	13	0.63	16	38.78	18	178	18	18.33	15	0.61	16	0.37	16	47	15
ICMA 30209 × 481-500	19.33	78	16.67	60	0.11	77	18.00	77	17.95	77	0.72	60	0.86	4	17.90	75	508	71	2.67	4	0.23	4	0.14	4	12	4
ICMA 04999 × 501-510	23.33	74	14.67	65	0.12	76	19.00	76	18.50	76	0.63	65	0.63	18	18.01	74	524	72	8.67	12	0.62	18	0.37	18	48	16
ICMA 88004 × 501-510	83.67	6	42.33	3	1.22	2	63.00	2	59.51	2	1.82	3	0.51	26	56.22	2	46	2	41.33	57	0.82	26	0.49	26	109	35
ICMA 93333 × 501-510	50.00	44	11.33	68	0.20	68	30.67	64	23.80	68	0.49	68	0.23	74	18.48	70	524	72	38.67	51	1.29	74	0.77	74	199	70
ICMA 97111 × 501-510	56.67	34	14.67	65	0.29	57	35.67	48	28.83	57	0.63	65	0.26	67	23.30	60	453	63	42.00	58	1.24	67	0.74	67	192	68
ICMA 97444 × 501-510	41.67	66	10.67	79	0.15	75	26.17	70	21.08	75	0.46	79	0.26	68	16.99	77	589	80	31.00	40	1.24	68	0.74	68	176	56

continued

ICMA 98222 × 501-510	63.33	22	10.67	79	0.23	63	37.00	44	25.99	63	0.46	79	0.17	79	18.26	71	500	68	52.67	74	1.39	79	0.83	79	232	79
ICMA 10444 × 501-510	26.67	72	18.67	52	0.17	71	22.67	73	22.31	71	0.80	52	0.70	9	21.96	63	463	64	8.00	10	0.50	9	0.30	9	28	8
ICMA 30199 × 501-510	43.33	61	34.00	10	0.51	28	38.67	39	38.38	28	1.46	10	0.78	8	38.10	21	205	24	9.33	13	0.36	8	0.22	8	29	9
ICMA 30200 × 501-510	40.00	67	11.33	68	0.16	74	25.67	71	21.29	74	0.49	68	0.28	65	17.66	76	563	79	28.67	34	1.19	65	0.72	65	164	53
ICMA 30201 × 501-510	46.67	56	11.33	68	0.18	69	29.00	66	23.00	69	0.49	68	0.24	72	18.24	72	540	74	35.33	46	1.26	72	0.76	72	190	65
ICMA 30209 × 501-510	60.00	26	15.33	64	0.32	52	37.67	42	30.33	52	0.66	64	0.26	69	24.42	57	426	56	44.67	63	1.24	69	0.74	69	201	71
ICMA 04999 × 511-520	50.00	44	31.33	14	0.54	24	40.67	30	39.58	24	1.35	14	0.63	19	38.52	19	188	20	18.67	17	0.62	19	0.37	19	55	18
ICMA 88004 × 511-520	43.33	61	16.33	62	0.24	60	29.83	65	26.60	60	0.70	62	0.38	46	23.72	59	475	65	27.00	30	1.04	46	0.62	46	122	41
ICMA 93333 × 511-520	43.33	61	21.33	36	0.32	50	32.33	59	30.40	50	0.92	36	0.49	29	28.59	45	366	46	22.00	23	0.85	29	0.51	29	81	25
ICMA 97111 × 511-520	50.00	44	17.33	58	0.30	56	33.67	56	29.44	56	0.75	58	0.35	54	25.74	55	437	59	32.67	44	1.09	54	0.65	54	152	49
ICMA 97444 × 511-520	60.00	26	34.67	8	0.72	14	47.33	19	45.61	14	1.49	8	0.58	21	43.94	9	119	10	25.33	28	0.70	21	0.42	21	70	23
ICMA 98222 × 511-520	60.00	26	11.33	68	0.23	62	35.67	48	26.08	62	0.49	68	0.19	77	19.07	67	478	66	48.67	68	1.35	77	0.81	77	222	77
ICMA 10444 × 511-520	60.00	26	41.67	5	0.86	7	50.83	16	50.00	7	1.79	5	0.69	11	49.18	5	82	5	18.33	16	0.51	11	0.31	11	38	12
ICMA 30199 × 511-520	55.00	38	18.67	52	0.35	46	36.83	46	32.04	46	0.80	52	0.34	55	27.87	49	384	49	36.33	49	1.10	55	0.66	55	159	52
ICMA 30200 × 511-520	16.67	79	11.33	68	0.07	79	14.00	79	13.74	79	0.49	68	0.68	12	13.49	79	543	77	5.33	6	0.53	12	0.32	12	30	10
ICMA 30201 × 511-520	63.33	22	41.33	6	0.90	5	52.33	11	51.16	5	1.78	6	0.65	14	50.02	4	73	4	22.00	22	0.58	14	0.35	14	50	17
ICMA 30209 × 511-520	63.33	22	18.00	56	0.39	41	40.67	29	33.76	41	0.77	56	0.28	64	28.03	47	356	43	45.33	65	1.19	64	0.72	64	193	69
ICMA 04999 × 531-540	66.67	16	11.33	68	0.26	59	39.00	36	27.49	59	0.49	68	0.17	78	19.37	66	450	62	55.33	75	1.38	78	0.83	78	231	78

continued

ICMA 88004 × 531-540	16.67	79	11.33	68	0.07	79	14.00	79	13.74	79	0.49	68	0.68	12	13.49	79	543	77	5.33	6	0.53	12	0.32	12	30	10
ICMA 93333 × 531-540	48.33	55	40.00	7	0.67	17	44.17	22	43.97	17	1.72	7	0.83	6	43.77	11	142	13	8.33	11	0.29	6	0.17	6	23	7
ICMA 97111 × 531-540	53.33	39	11.33	68	0.21	65	32.33	59	24.59	65	0.49	68	0.21	75	18.69	68	507	69	42.00	58	1.31	75	0.79	75	208	72
ICMA 97444 × 531-540	60.00	26	24.67	28	0.51	27	42.33	27	38.47	27	1.06	28	0.41	42	34.96	27	232	28	35.33	46	0.98	42	0.59	42	130	43
ICMA 98222 × 531-540	46.67	56	11.33	68	0.18	69	29.00	66	23.00	69	0.49	68	0.24	72	18.24	72	540	74	35.33	46	1.26	72	0.76	72	190	65
ICMA 10444 × 531-540	53.33	39	11.33	68	0.21	65	32.33	59	24.59	65	0.49	68	0.21	75	18.69	68	507	69	42.00	58	1.31	75	0.79	75	208	72
ICMA 30199 × 531-540	46.67	56	21.33	36	0.34	47	34.00	54	31.55	47	0.92	36	0.46	37	29.28	42	355	42	25.33	27	0.90	37	0.54	37	101	32
ICMA 30200 × 531-540	40.00	67	16.33	62	0.23	64	28.17	68	25.56	64	0.70	62	0.41	43	23.20	61	491	67	23.67	26	0.99	43	0.59	43	112	36
ICMA 30201 × 531-540	60.00	26	21.33	36	0.44	36	40.67	30	35.78	36	0.92	36	0.36	51	31.48	39	290	37	38.67	53	1.07	51	0.64	51	155	50
ICMA 30209 × 531-540	70.00	13	21.33	36	0.51	26	45.67	20	38.64	26	0.92	36	0.30	61	32.70	34	252	30	48.67	69	1.16	61	0.70	61	191	67
ICMA 04999 × 551-560	23.33	74	21.33	36	0.17	72	22.33	74	22.31	72	0.92	36	0.91	3	22.29	62	429	57	2.00	3	0.14	3	0.09	3	9	3
ICMA 88004 × 551-560	80.00	7	29.00	19	0.80	8	54.50	6	48.17	8	1.25	19	0.36	49	42.57	13	129	12	51.00	71	1.06	49	0.64	49	169	55
ICMA 93333 × 551-560	94.33	2	31.33	14	1.02	3	62.83	3	54.37	3	1.35	14	0.33	56	47.04	7	102	7	63.00	77	1.11	56	0.67	56	189	64
ICMA 97111 × 551-560	20.67	77	13.00	67	0.09	78	16.83	78	16.39	78	0.56	67	0.63	17	15.96	78	540	74	7.67	9	0.62	17	0.37	17	43	14
ICMA 97444 × 551-560	21.67	76	21.33	36	0.16	73	21.50	75	21.50	73	0.92	36	0.98	2	21.50	64	435	58	0.33	2	0.03	2	0.02	2	6	2
ICMA 98222 × 551-560	56.67	34	28.67	20	0.56	21	42.67	25	40.30	21	1.23	20	0.51	27	38.07	23	191	22	28.00	32	0.82	27	0.49	27	86	27
ICMA 10444 × 551-560	50.00	44	20.67	47	0.36	44	35.33	51	32.15	44	0.89	47	0.41	40	29.25	43	360	44	29.33	37	0.98	40	0.59	40	117	37
ICMA 30199 × 551-560	76.67	9	28.00	23	0.74	13	52.33	11	46.33	13	1.20	23	0.37	48	41.02	15	155	15	48.67	69	1.06	48	0.63	48	165	54

continued

ICMA 30200 × 551-560	43.33	61	20.67	47	0.31	54	32.00	63	29.93	54	0.89	47	0.48	32	27.99	48	406	51	22.67	25	0.87	32	0.52	32	89	30
ICMA 30201 × 551-560	50.00	44	24.00	32	0.41	38	37.00	44	34.64	38	1.03	32	0.48	31	32.43	35	294	39	26.00	29	0.87	31	0.52	31	91	31
ICMA 30209 × 551-560	66.67	16	28.00	23	0.64	18	47.33	18	43.20	18	1.20	23	0.42	39	39.44	17	172	17	38.67	53	0.97	39	0.58	39	131	44
ICMA 04999 × 561-570	90.00	3	25.33	26	0.79	10	57.67	4	47.75	10	1.09	26	0.28	66	39.54	16	161	16	64.67	79	1.20	66	0.72	66	211	74
ICMA 88004 × 561-570	66.67	16	21.33	36	0.49	31	44.00	23	37.71	31	0.92	36	0.32	59	32.32	36	268	34	45.33	66	1.13	59	0.68	59	184	60
ICMA 93333 × 561-570	36.67	69	18.67	52	0.24	61	27.67	69	26.16	61	0.80	52	0.51	25	24.74	56	445	61	18.00	14	0.82	25	0.49	25	64	20
ICMA 97111 × 561-570	46.67	56	19.00	51	0.31	55	32.83	58	29.78	55	0.82	51	0.41	44	27.01	51	421	55	27.67	31	0.99	44	0.59	44	119	40
ICMA 97444 × 561-570	56.67	34	16.67	60	0.33	48	36.67	47	30.73	48	0.72	60	0.29	62	25.76	54	413	53	40.00	56	1.18	62	0.71	62	180	58
ICMA 98222 × 561-570	85.00	5	20.67	47	0.61	20	52.83	10	41.91	20	0.89	47	0.24	71	33.25	31	251	29	64.33	78	1.26	71	0.76	71	220	75
ICMA 10444 × 561-570	53.33	39	21.67	35	0.40	39	37.50	43	33.99	39	0.93	35	0.41	45	30.81	41	316	41	31.67	42	0.99	45	0.59	45	132	45
ICMA 30199 × 561-570	86.67	4	21.33	36	0.64	19	54.00	7	43.00	19	0.92	36	0.25	70	34.24	28	219	26	65.33	80	1.26	70	0.75	70	220	75
ICMA 30200 × 561-570	73.33	11	31.33	14	0.79	9	52.33	13	47.94	9	1.35	14	0.43	38	43.91	10	118	9	42.00	58	0.95	38	0.57	38	134	46
ICMA 30201 × 561-570	33.33	71	42.33	3	0.49	33	37.83	41	37.56	33	1.82	3	1.27	1	37.30	25	210	25	-9.00	1	-0.45	1	-0.27	1	3	1
ICMA 30209 × 561-570	60.00	26	21.33	36	0.44	36	40.67	30	35.78	36	0.92	36	0.36	51	31.48	39	290	37	38.67	53	1.07	51	0.64	51	155	50
ICMA 04999 × 571-580	70.00	13	32.33	12	0.78	11	51.17	14	47.57	11	1.39	12	0.46	36	44.23	8	117	8	37.67	50	0.90	36	0.54	36	122	41
ICMA 88004 × 571-580	76.67	9	25.33	26	0.67	16	51.00	15	44.07	16	1.09	26	0.33	57	38.08	22	187	19	51.33	72	1.12	57	0.67	57	186	62
ICMA 93333 × 571-580	50.00	44	31.33	14	0.54	24	40.67	30	39.58	24	1.35	14	0.63	19	38.52	19	188	20	18.67	17	0.62	19	0.37	19	55	18
ICMA 97111 × 571-580	70.00	13	11.33	68	0.27	58	40.67	30	28.17	58	0.49	68	0.16	80	19.51	65	440	60	58.67	76	1.40	80	0.84	80	236	80

continued

ICMA 97444 × 571-580	65.00	21	45.33	2	1.02	4	55.17	5	54.28	4	1.95	2	0.70	10	53.41	3	51	3	19.67	19	0.50	10	0.30	10	39	13
ICMA 98222 × 571-580	46.67	56	24.67	28	0.40	40	35.67	48	33.93	40	1.06	28	0.53	23	32.27	38	301	40	22.00	21	0.79	23	0.47	23	67	22
ICMA 10444 × 571-580	50.00	44	18.67	52	0.32	49	34.33	53	30.55	49	0.80	52	0.37	47	27.18	50	396	50	31.33	41	1.04	47	0.63	47	135	47
ICMA 30199 × 571-580	63.33	22	32.67	11	0.71	15	48.00	17	45.49	15	1.41	11	0.52	24	43.10	12	127	11	30.67	39	0.81	24	0.48	24	87	29
ICMA 30200 × 571-580	56.67	34	28.67	20	0.56	21	42.67	25	40.30	21	1.23	20	0.51	27	38.07	23	191	22	28.00	32	0.82	27	0.49	27	86	27
ICMA 30201 × 571-580	50.00	44	20.67	47	0.36	44	35.33	51	32.15	44	0.89	47	0.41	40	29.25	43	360	44	29.33	37	0.98	40	0.59	40	117	37
ICMA 30209 × 571-580	80.00	7	28.00	23	0.77	12	54.00	7	47.33	12	1.20	23	0.35	53	41.48	14	151	14	52.00	73	1.08	53	0.65	53	179	57
RHB - 177 (Check-1)	50.00	44	18.00	56	0.31	53	34.00	54	30.00	53	0.77	56	0.36	50	26.47	53	419	54	32.00	43	1.07	50	0.64	50	143	48
MPMH - 17 (Check-2)	66.67	16	22.00	34	0.51	29	44.33	21	38.30	29	0.95	34	0.33	58	33.08	32	253	31	44.67	64	1.12	58	0.67	58	180	58
BHB - 1602 (Check-3)	53.33	39	24.67	28	0.45	34	39.00	36	36.27	34	1.06	28	0.46	34	33.73	29	262	32	28.67	35	0.90	34	0.54	34	103	33

V= Value, R= Rank

Table 3: Mean Dry Stover yield of normal environment, Stress environment, Stress indices, rank and over all rank of hybrids.

hybrids	Stover yield in E1		Stover yield in E3		STI		MP		GMP		YI		YSI		HM		Rank total	Over all rank	TOL		SSI		SDI		Rank total	Over all rank
	YP	R	YS	R	V	R	V	R	V	R	V	R	V	R	v	R	RT	OR	v	R	v	R	v	R	TR	OVR
ICMA 04999 × 481-500	246.67	36	96.67	36	8.22	36	171.67	40	154.42	36	4.16	36	0.39	38	138.90	35	293	37	150.00	46	1.01	38	0.61	38	122	39
ICMA 88004 × 481-500	213.33	58	130	23	9.56	32	171.67	41	166.53	32	5.59	23	0.61	19	161.55	30	258	32	83.33	24	0.65	19	0.39	19	62	19
ICMA 93333 × 481-500	226.67	47	166.67	11	13.02	19	196.67	24	194.37	19	7.17	11	0.74	10	192.09	14	155	16	60.00	13	0.44	10	0.26	10	33	8
ICMA 97111 × 481-500	166.67	69	103.33	34	5.94	51	135.00	63	131.23	51	4.45	34	0.62	17	127.57	41	360	46	63.34	18	0.63	17	0.38	17	52	15
ICMA 97444 × 481-500	263.33	29	38.33	64	3.48	63	150.83	54	100.47	63	1.65	64	0.15	70	66.92	64	471	64	225.00	68	1.42	70	0.85	70	208	71

continued

ICMA 98222 × 481-500	250	34	306.67	2	26.43	3	278.34	4	276.89	3	13.20	2	1.23	1	275.45	3	52	3	-56.67	1	-0.38	1	-0.23	1	3	1
ICMA 10444 × 481-500	80	76	16.67	71	0.46	77	48.34	78	36.52	77	0.72	71	0.21	62	27.59	77	589	77	63.33	15	1.32	62	0.79	62	139	48
ICMA 30199 × 481-500	326.67	8	133.33	21	15.01	14	230.00	12	208.70	14	5.74	21	0.41	36	189.37	15	141	12	193.34	64	0.99	36	0.59	36	136	46
ICMA 30200 × 481-500	270	27	166.67	11	15.51	11	218.34	14	212.13	11	7.17	11	0.62	18	206.11	10	113	9	103.33	30	0.64	18	0.38	18	66	20
ICMA 30201 × 481-500	300	15	333.33	1	34.47	1	316.67	1	316.23	1	14.34	1	1.11	2	315.79	1	23	1	-33.33	2	-0.19	2	-0.11	2	6	2
ICMA 30209 × 481-500	76.67	79	36.67	65	0.97	73	56.67	75	53.02	73	1.58	65	0.48	26	49.61	66	522	69	40.00	6	0.87	26	0.52	26	58	18
ICMA 04999 × 501-510	86.67	74	36.67	65	1.10	71	61.67	74	56.38	71	1.58	65	0.42	34	51.54	65	519	68	50.00	8	0.96	34	0.58	34	76	23
ICMA 88004 × 501-510	266.67	28	220	5	20.22	5	243.34	10	242.21	5	9.47	5	0.82	6	241.10	5	69	5	46.67	7	0.29	6	0.18	6	19	6
ICMA 93333 × 501-510	253.33	31	80	46	6.99	41	166.67	43	142.36	41	3.44	46	0.32	51	121.60	45	344	41	173.33	57	1.14	51	0.68	51	159	58
ICMA 97111 × 501-510	226.67	47	60	55	4.69	55	143.34	60	116.62	55	2.58	55	0.26	56	94.88	56	439	57	166.67	54	1.23	56	0.74	56	166	59
ICMA 97444 × 501-510	320	9	40	62	4.41	57	180.00	35	113.14	57	1.72	62	0.13	72	71.11	62	416	55	280.00	75	1.46	72	0.88	72	219	75
ICMA 98222 × 501-510	160	72	63.33	53	3.49	62	111.67	69	100.66	62	2.73	53	0.40	37	90.74	57	465	62	96.67	29	1.01	37	0.60	37	103	34
ICMA 10444 × 501-510	181.67	65	123.33	26	7.72	37	152.50	51	149.68	37	5.31	26	0.68	11	146.92	33	286	34	58.34	12	0.54	11	0.32	11	34	11
ICMA 30199 × 501-510	250	34	276.67	4	23.84	4	263.34	6	263.00	4	11.90	4	1.11	3	262.66	4	63	4	-26.67	3	-0.18	3	-0.11	3	9	3
ICMA 30200 × 501-510	176.67	68	16.67	71	1.02	72	96.67	71	54.27	72	0.72	71	0.09	76	30.47	75	576	75	160.00	51	1.51	76	0.91	76	203	69
ICMA 30201 × 501-510	253.33	31	16.67	71	1.46	68	135.00	63	64.98	68	0.72	71	0.07	78	31.28	73	523	70	236.66	69	1.56	78	0.93	78	225	78
ICMA 30209 × 501-510	273.33	26	16.67	71	1.57	67	145.00	57	67.50	67	0.72	71	0.06	79	31.42	72	510	67	256.66	73	1.57	79	0.94	79	231	79
ICMA 04999 × 511-520	220	53	163.33	13	12.39	24	191.67	27	189.56	24	7.03	13	0.74	8	187.48	16	178	22	56.67	10	0.43	8	0.26	8	26	7

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ICMA 88004 × 511-520	180	66	50	58	3.10	64	115.00	68	94.87	64	2.15	58	0.28	54	78.26	60	492	66	130.00	35	1.20	54	0.72	54	143	52
ICMA 93333 × 511-520	226.67	47	83.33	44	6.51	43	155.00	48	137.44	43	3.59	44	0.37	43	121.86	44	356	45	143.34	43	1.05	43	0.63	43	129	44
ICMA 97111 × 511-520	163.33	70	16.67	71	0.94	74	90.00	72	52.18	74	0.72	71	0.10	73	30.25	76	581	76	146.66	44	1.50	73	0.90	73	190	64
ICMA 97444 × 511-520	226.67	47	130	23	10.16	30	178.34	38	171.66	30	5.59	23	0.57	21	165.23	29	241	30	96.67	27	0.71	21	0.43	21	69	22
ICMA 98222 × 511-520	196.67	64	20	69	1.36	69	108.34	70	62.72	69	0.86	69	0.10	74	36.31	68	552	71	176.67	58	1.50	74	0.90	74	206	70
ICMA 10444 × 511-520	333.33	7	173.33	9	19.92	8	253.33	9	240.37	8	7.46	9	0.52	22	228.07	7	79	7	160.00	50	0.80	22	0.48	22	94	26
ICMA 30199 × 511-520	510	1	106.67	33	18.75	9	308.34	2	233.24	9	4.59	33	0.21	61	176.44	24	172	18	403.33	80	1.32	61	0.79	61	202	68
ICMA 30200 × 511-520	76.67	79	16.67	71	0.44	79	46.67	80	35.75	79	0.72	71	0.22	59	27.39	79	597	79	60.00	13	1.30	59	0.78	59	131	45
ICMA 30201 × 511-520	313.33	11	120	27	12.96	21	216.67	15	193.91	21	5.16	27	0.38	40	173.54	25	187	23	193.33	62	1.03	40	0.62	40	142	50
ICMA 30209 × 511-520	230	44	76.67	48	6.08	50	153.34	50	132.79	50	3.30	48	0.33	47	115.00	49	386	51	153.33	48	1.11	47	0.67	47	142	50
ICMA 04999 × 531-540	373.33	4	16.67	71	2.15	66	195.00	25	78.89	66	0.72	71	0.04	80	31.91	71	454	60	356.66	79	1.59	80	0.96	80	239	80
ICMA 88004 × 531-540	80	76	23.33	68	0.64	76	51.67	76	43.20	76	1.00	68	0.29	53	36.13	69	562	73	56.67	11	1.18	53	0.71	53	117	37
ICMA 93333 × 531-540	416.67	3	103.33	34	14.84	15	260.00	7	207.50	15	4.45	34	0.25	57	165.59	28	193	24	313.34	78	1.25	57	0.75	57	192	65
ICMA 97111 × 531-540	276.67	23	26.67	67	2.54	65	151.67	52	85.90	65	1.15	67	0.10	75	48.65	67	481	65	250.00	71	1.51	75	0.90	75	221	77
ICMA 97444 × 531-540	220	53	96.67	36	7.33	38	158.34	46	145.83	38	4.16	36	0.44	32	134.32	37	316	38	123.33	34	0.93	32	0.56	32	98	29
ICMA 98222 × 531-540	180	66	68.33	51	4.24	58	124.17	66	110.90	58	2.94	51	0.38	41	99.06	55	446	59	111.67	32	1.03	41	0.62	41	114	36
ICMA 10444 × 531-540	200	62	66.67	52	4.60	56	133.34	65	115.47	56	2.87	52	0.33	46	100.00	54	443	58	133.33	36	1.11	46	0.67	46	128	43
ICMA 30199 × 531-540	276.67	23	90	40	8.58	35	183.34	33	157.80	35	3.87	40	0.33	49	135.82	36	291	36	186.67	60	1.12	49	0.67	49	158	55

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ICMA 30200 × 531-540	280	21	140	19	13.51	16	210.00	17	197.99	16	6.02	19	0.50	23	186.67	17	148	13	140.00	41	0.83	23	0.50	23	87	24
ICMA 30201 × 531-540	243.33	39	180	7	15.10	13	211.67	16	209.28	13	7.75	7	0.74	9	206.93	9	113	9	63.33	17	0.43	9	0.26	9	35	12
ICMA 30209 × 531-540	340	6	170	10	19.93	7	255.00	8	240.42	7	7.31	10	0.50	23	226.67	8	79	7	170.00	55	0.83	23	0.50	23	101	33
ICMA 04999 × 551-560	86.67	74	13.33	80	0.40	80	50.00	77	33.99	80	0.57	80	0.15	69	23.11	80	620	80	73.34	20	1.41	69	0.85	69	158	55
ICMA 88004 × 551-560	306.67	12	60	55	6.34	46	183.34	33	135.65	46	2.58	55	0.20	64	100.36	53	364	47	246.67	70	1.34	64	0.80	64	198	67
ICMA 93333 × 551-560	423.33	2	116.67	29	17.03	10	270.00	5	222.24	10	5.02	29	0.28	55	182.93	19	159	17	306.66	77	1.21	55	0.72	55	187	63
ICMA 97111 × 551-560	106.67	73	20	69	0.74	75	63.34	73	46.19	75	0.86	69	0.19	66	33.68	70	570	74	86.67	26	1.35	66	0.81	66	158	55
ICMA 97444 × 551-560	80	76	16.67	71	0.46	77	48.34	78	36.52	77	0.72	71	0.21	62	27.59	77	589	77	63.33	15	1.32	62	0.79	62	139	48
ICMA 98222 × 551-560	246.67	36	150	15	12.76	23	198.34	23	192.36	23	6.45	15	0.61	20	186.56	18	173	19	96.67	27	0.65	20	0.39	20	67	21
ICMA 10444 × 551-560	226.67	47	150	15	11.72	26	188.34	30	184.39	26	6.45	15	0.66	13	180.53	21	193	24	76.67	21	0.56	13	0.34	13	47	13
ICMA 30199 × 551-560	290	17	130	23	13.00	20	210.00	17	194.16	20	5.59	23	0.45	31	179.52	23	174	21	160.00	51	0.92	31	0.55	31	113	35
ICMA 30200 × 551-560	216.67	57	16.67	71	1.25	70	116.67	67	60.10	70	0.72	71	0.08	77	30.96	74	557	72	200.00	66	1.54	77	0.92	77	220	76
ICMA 30201 × 551-560	220	53	140	19	10.62	28	180.00	35	175.50	28	6.02	19	0.64	16	171.11	26	224	28	80.00	23	0.61	16	0.36	16	55	17
ICMA 30209 × 551-560	230	44	80	46	6.34	47	155.00	48	135.65	47	3.44	46	0.35	45	118.71	47	370	48	150.00	46	1.09	45	0.65	45	136	46
ICMA 04999 × 561-570	246.67	36	113.33	31	9.64	31	180.00	35	167.20	31	4.88	31	0.46	30	155.31	32	257	31	133.34	37	0.90	30	0.54	30	97	28
ICMA 88004 × 561-570	210	60	180	7	13.03	18	195.00	25	194.42	18	7.75	7	0.86	5	193.85	12	152	15	30.00	5	0.24	5	0.14	5	15	5
ICMA 93333 × 561-570	253.33	31	116.67	29	10.19	29	185.00	32	171.92	29	5.02	29	0.46	29	159.76	31	239	29	136.66	38	0.90	29	0.54	29	96	27
ICMA 97111 × 561-570	163.33	70	110	32	6.19	49	136.67	62	134.04	49	4.73	32	0.67	12	131.46	39	345	42	53.33	9	0.54	12	0.33	12	33	8

continued

ICMA 97444 × 561-570	343.33	5	60	55	7.10	40	201.67	22	143.53	40	2.58	55	0.17	67	102.15	51	335	40	283.33	76	1.38	67	0.83	67	210	73
ICMA 98222 × 561-570	276.67	23	210	6	20.03	6	243.34	10	241.04	6	9.04	6	0.76	7	238.77	6	70	6	66.67	19	0.40	7	0.24	7	33	8
ICMA 10444 × 561-570	303.33	13	40	62	4.18	59	171.67	42	110.15	59	1.72	62	0.13	71	70.68	63	431	56	263.33	74	1.45	71	0.87	71	216	74
ICMA 30199 × 561-570	290	17	120	27	12.00	25	205.00	20	186.55	25	5.16	27	0.41	35	169.76	27	203	27	170.00	55	0.98	35	0.59	35	125	41
ICMA 30200 × 561-570	233.33	43	90	40	7.24	39	161.67	44	144.91	39	3.87	40	0.39	39	129.90	40	324	39	143.33	42	1.02	39	0.61	39	120	38
ICMA 30201 × 561-570	316.67	10	290	3	31.66	2	303.34	3	303.04	2	12.48	3	0.92	4	302.75	2	29	2	26.67	4	0.14	4	0.08	4	12	4
ICMA 30209 × 561-570	240	41	46.67	61	3.86	61	143.34	59	105.83	61	2.01	61	0.19	65	78.14	61	470	63	193.33	62	1.34	65	0.81	65	192	65
ICMA 04999 × 571-580	286.67	20	95	38	9.39	33	190.84	28	165.03	33	4.09	38	0.33	48	142.71	34	272	33	191.67	61	1.11	48	0.67	48	157	54
ICMA 88004 × 571-580	290	17	86.67	43	8.66	34	188.34	29	158.54	34	3.73	43	0.30	52	133.46	38	290	35	203.33	67	1.17	52	0.70	52	171	60
ICMA 93333 × 571-580	243.33	39	160	14	13.42	17	201.67	21	197.31	17	6.88	14	0.66	15	193.06	13	150	14	83.33	24	0.57	15	0.34	15	54	16
ICMA 97111 × 571-580	210	60	90	40	6.52	42	150.00	55	137.48	42	3.87	40	0.43	33	126.00	43	355	44	120.00	33	0.95	33	0.57	33	99	30
ICMA 97444 × 571-580	300	15	146.67	18	15.17	12	223.34	13	209.76	12	6.31	18	0.49	25	197.02	11	124	11	153.33	49	0.85	25	0.51	25	99	30
ICMA 98222 × 571-580	200	62	93.33	39	6.43	44	146.67	56	136.62	44	4.02	39	0.47	28	127.27	42	354	43	106.67	31	0.89	28	0.53	28	87	24
ICMA 10444 × 571-580	256.67	30	63.33	53	5.60	53	160.00	45	127.49	53	2.73	53	0.25	58	101.59	52	397	52	193.34	65	1.26	58	0.75	58	181	62
ICMA 30199 × 571-580	280	21	133.33	21	12.87	22	206.67	19	193.22	22	5.74	21	0.48	27	180.64	20	173	19	146.67	45	0.87	27	0.52	27	99	30
ICMA 30200 × 571-580	226.67	47	150	15	11.72	26	188.34	30	184.39	26	6.45	15	0.66	13	180.53	21	193	24	76.67	21	0.56	13	0.34	13	47	13
ICMA 30201 × 571-580	220	53	83.33	44	6.32	48	151.67	53	135.40	48	3.59	44	0.38	42	120.88	46	378	50	136.67	40	1.04	42	0.62	42	124	40
ICMA 30209 × 571-580	303.33	13	50	58	5.23	54	176.67	39	123.15	54	2.15	58	0.16	68	85.85	58	402	53	253.33	72	1.39	68	0.84	68	208	71

continued

RHB - 177 (Check-1)	213.33	58	76.67	48	5.64	52	145.00	57	127.89	52	3.30	48	0.36	44	112.80	50	409	54	136.66	38	1.07	44	0.64	44	126	42
MPMH - 17 (Check-2)	240	41	76.67	48	6.34	45	158.34	46	135.65	45	3.30	48	0.32	50	116.21	48	371	49	163.33	53	1.13	50	0.68	50	153	53
BHB - 1602 (Check-3)	230	44	50	58	3.96	60	140.00	61	107.24	60	2.15	58	0.22	60	82.14	59	460	61	180.00	59	1.30	60	0.78	60	179	61

ICMA 88004 x BIB 501-510, ICMA 97444 x BIB 571-580, ICMA 30201 x BIB 511-520, and ICMA 10444 x BIB 511-520 for STI, MP, GMP, YI, YSI, HM, and crosses ICMA 97444 x BIB 571-580, ICMA 10444 x BIB 511-520, ICMA 93333 x BIB 531-540, ICMA 30201 x BIB 561-570 and ICMA 30201 x BIB 511-520 for TOL, SSI and SDI were identified as the most tolerant under moisture stress condition. For dry stover yield per plant crosses ICMA 30201 x 481-500, ICMA 30201 x 561-570, ICMA 98222 x 481-500, ICMA 30199 x 501-510 and ICMA 88004 x 501-510 for STI, MP, GMP, YI, YSI, HM and crosses ICMA 98222 x 481-500, ICMA x 30201 x 481-500, ICMA 30199 x 501-510, ICMA 30201 x 561-570 and ICMA 88004 x 561-570 for TOL, SSI and SDI were identified as the most tolerant under moisture stress condition. Various researchers like Kiani (2013) Abraha*et al.* (2015) and Arisandy*et al.* (2017) found that various indices like TOL, STI, SSI, SDI, MP, GMP, YI, YSI, and HM exhibited good correlation with grain yield and fodder yield under stress and non-stress conditions which may be used as selection criteria for moisture stress tolerant genotypes in different crops. Thus, these indices are used as selection criteria for moisture-stress tolerant crosses in the present study. Such strategies of using different tolerance indices and ranking patterns for screening tolerant genotypes were used by several other workers such as Kharrazi and Rad (2011), Kumawat*et al.* (2017), and El-Sabagh*et al.* (2018) in different crops.

Conclusion

On the of nine stress indices viz., TOL, STI SSI, SDI, MP, GMP, YI, YSI, and HM were calculated using grain yield per plant and dry stover per plant in stress (Y_s) and non-stress (Y_p) condition the crosses or hybrids ICMA 98222 x 481-500 and ICMA 30201 x 481-500 were best moisture stress tolerant for grain yield as well as fodder yield. These hybrids can be used for dual purpose (grain yield and biological yield) in arid, semi-arid, and drought-affected areas. At least the top ten ranked hybrids in all the nine stress induces can be used as a parents for a hybridization program for moisture stress tolerance as well as the development of drought tolerance population in pearl millet.

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