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Screening and characterization of drought tolerance pearl millet hybrids for arid and semi-arid conditions

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Abstract
Drought is one of the major environmental stresses resulting in a huge reduction in crop growth and biomass production. Pearl millet (*Pennisetum glaucum* L.) has excellent drought tolerance, and it could be used as a model plant to study drought resistance. Efforts has been made for identification of suitable hybrids for drought tolerance in pearl millet using different stress induces *viz.*:, Yield reduction, Mean productivity index, Relative efficiency index, Mean relative performance, Drought resistance index, Golden mean, and Drought tolerance efficiency. hybrids ICMA 98222 × 481-500, ICMA 88004 × 501-510, ICMA 93333 × 551-560, ICMA 30199 × 481-500, ICMA 30200 × 561-570, ICMA 88004 × 551-560, ICMA 97444 × 571-580, ICMA 30209 × 571-580, ICMA 04999 × 571-580 and ICMA 30199 × 551-560 were identified as the most drought tolerant hybrids.

Keywords: Screening, characterization, tolerance, tolerance, semi-arid

Introduction
Plant growth is affected by various factors. Stress is an important challenge which triggers various physiological, molecular and cellular responses in plants. Environmental stresses are the main factors limiting the world's plant production. Increasing the tolerance to abiotic stresses such as drought is, therefore, essential for future global food security. Plants have to deal with various complex types of interactions involving numerous environmental factors such as temperature, light intensity, water availability and soil composition. When the environmental factors extend beyond an optimal range which is characteristic for a particular species, the plant will be subjected to a varying level of stress. Stable yield performance of genotypes under both favorable and drought stress conditions is vital for plant breeders to identify drought tolerant genotypes (Pirayvatlou 2001). Pearl millet (*Pennisetum glaucum* (L.) R. Br.), is the sixth most important economical cereal crops after rice, wheat, maize, barley and sorghum. It is cultivated on ~ 27 million hectares worldwide. It is used as a staple food crop in arid and semi-arid regions of sub-Saharan Africa, India and South Asia, where grain yields average is 900 kg/ha. This crop feeds more than 90 million farmers that live in poverty and is highly nutritious (8–19% protein), high in fiber (1.2 g/100 g), low in starch, and has higher concentrations of micronutrients (iron and zinc) than wheat, rice, sorghum and maize. Its planting on the dry land often results in the excellent drought resistance while simultaneously, it is tolerant to heat, salinity and deficiencies in soil nutrient. It is also beneficial as a source of genetic improvement to raise drought tolerance of other crops. In addition, there is a main challenge in developing drought tolerance hybrids in different crops because the yield reduction in rice is suffered a drastic yield reduction ranging from 18-60% and even more than 70% in some places due to water deficiency while it caused a 10-50%reduction in wheat. Moreover, the biomass of maize decreased by 1-76% and barley by 73-87% upon drought stress. The leguminous crops like chickpea, pigeon pea and chawla planted on arid lands had faced severe reduction in their yield because of drought conditions. These reports indicate that drought stress can lead to an economic impact which will depress the living quality of humans. More significantly, many researchers predicted that arid land would expand globally by the end of this century estimating 5.8 × 106 km^2 (or approximately 10%) larger than that between 1961 and 1990 because of increased concentrations of greenhouse gases in the atmosphere. The major expansion of arid regions will occur over south-west North America, southern Africa, the northern fringe of Africa, and Australia, while major expansions of semiarid regions will occur across southern Africa, North and South America and the north side of the Mediterranean.

Therefore, it is crucial to enhance the drought stress tolerance in corps. Studying of drought resistance in pearl millet and mining the stress induces related to drought tolerance are very important for pearl millet to acclimatize in severe water deficit environment in the future, which can decrease economic losses, particularly for those areas where pearl millet is used as a main staple food.

Methods and Material

The present study 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 seven testers (BIB 481-500, BIB 501-510, BIB 511-520, BIB 531-540, BIB 551-560, BIB 561-570 and BIB 571-580 from ICAR-AICRP on Pearl Millet, Bikaner, Rajasthan).

The experiment was conducted in three environments namely E1, (non-stress or normal environment), E2 (irrigations provided at the time of flowering and grain filling) and E3 (stress environment, only lifesaving irrigation) were provided 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 was received during sowing of the experiment in the month of July. In such situations, pre-sowing irrigation was given to facilitate seed germination. 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 temperature during both summer and winter and salinity of rhizosphere. The average rainfall is about 260 mm, which is mostly received during July-September. All recommended cultural practices were followed to raise good crop except irrigation.

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

1. Yield Reduction: Choukan *et al*., (2006) [4] explain ratio of yield of stress environment and yield of normal environment in to unity.

$$\text{Yield Reduction} = \left(1 - \frac{Ys}{Yns}\right)$$

2. Mean productivity index: Rosielle and Hamblin 1981 [17], define yield of non-stress minus yield of stress environment divided by two.

$$\text{Mean Productivity Index} = (Yns - Ys)/2$$

3. Relative Efficiency Index: Ramirez and Kelly 1918, explain multiplication, yield of stress and non-stress divided by mean of stress and non-stress.

$$\text{Relative Efficiency Index} = (Yns \times Ys)/(Xs \times Xns)$$

4. Mean relative performance: Ramirez and Kelly 1918, define yield of stress environment divided by mean of stress environment plus yield of non-stress environment divided by mean of non-stress environment.

$$\text{Mean relative performance} = (\text{Ys}/\text{Xs}) + (\text{Yns}/Xns)$$

5. Drought resistance index: Fischer and Maurer 1978, define yield of stress environment divided by yield of non-stress environment and divided by mean of stress environment by mean of non-stress environment.

$$\text{Drought resistance index} = (\text{Ys}/Yns)/(\text{Xs}/Xns)$$

6. Golden Mean: Moradi *et al.*, 2012 [15], explain addition of yield of stress environment and yield of non-stress environment divided by subtraction of yield of stress environment and yield of non-stress environment.

$$\text{Golden Mean} = (Yns + \text{Ys})/(Yns - Ys)$$

7. Drought tolerance efficiency: Fischer and Wood 1981, define yield of non-stress environment divided by yield of stress environment in to hundred.

$$\text{Drought tolerance efficiency} = (\text{Ys}/Yns) \times 100$$

Results and Discussion

Drought tolerance on the other hand is the ability of plants to utilize limited amount of water, leading to low tissue water potential, with higher efficiency regarding growth, biomass accumulation and reproduction (Ingram & Bartels, 1996) [13]. Moreover, high-yielding genotypes under optimum conditions may not be drought tolerant (Blum 1996, Mardeh *et al*. 2006) [1, 4]; therefore, many studies preferred the selection under stress and non-stress conditions (Clarke *et al*. 1992, Fernandez 1992, Byrne *et al*. 1995, Rajaram and Van Ginkle 2001) [5, 9]. In the same pattern, the selection in the current study was conducted under stress and non-stress conditions. Many studies have used drought indices to select stable genotypes according to their performance under favorable and stress conditions (Moosavi *et al*. 2008, Farshadfar *et al*. 2013, Mursalova *et al*. 2015) [14]. Examples of such indices are stress susceptibility index (SSI) (Fischer and Maurer 1978), tolerance (TOL) (Rosielle and Hamblin 1981) [17], mean productivity (MP) (Rosielle and Hamblin, 1981) [17], geometric mean productivity (GMP) (Fernandez 1992) [9], stress tolerance index (STI) (Fernandez, 1992) [9], yield index (YI) (Gavuzzi *et al.*, 1997) [12], yield stability index (YSI) (Bousalama and Schapaugh 1984) [3], yield reduction (YR) (Choukan *et al.*, 2006) [4] harmonic mean (HM) (Schneider *et al*., 1997) [18], sensitivity drought index (SDI) (Farshadfar and Javadinia 2011) [8], Mean productivity index (MPI) (Rosielle and Hamblin 1981) [17], Relative efficiency index (REI) (Ramirez and Kelly 1918), Mean relative performance(MRP) (Ramirez and Kelly 1918), Drought resistance index (DRI) (Fischer and Maurer 1978), Golden mean (GM) (Moradi *et al.*, 2012) [15], Drought tolerance efficiency (DTE) (Fischer and Wood 1981) [11], drought response index (DSI) (Bidinger *et al*. 1978) [2], drought resistance index (DI) (Lan 1998) [7], relative drought index (RDI) (Fischer and Maurer 1978) [10], stress susceptibility percentage index (SSPI) (Moosavi *et al*. 2008) [14], and modified stress tolerance index (MSTI) (Farshadfar and Sutka 2002) [6]. According to yield reduction hybrids ICMA 97111 × 571-580, ICMA 98222 × 501-510 and ICMA 04999 × 531-540, for mean productivity index hybrids ICMA 30199 × 561-570, ICMA 04999 × 561-570, ICMA 98222 × 561-570, for relative efficiency index hybrids ICMA 98222 × 481-500, ICMA 88004 × 501-510, ICMA 93333 × 551-560, for mean relative performance hybrids ICMA 98222 × 481-500, ICMA 88004 × 501-510, ICMA 97444 × 571-580, for drought resistance index hybrids ICMA 30201 × 561-570, ICMA 97444 × 551-560, ICMA 04999 × 551-560, for golden mean hybrids ICMA 97444 × 551-560, ICMA 04999 × 551-560, ICMA 30209 × 481-500, for drought tolerance efficiency hybrids ICMA 30201 × 561-570, ICMA 97444 × 551-560, ICMA 04999 × 551-560 were found highly stress tolerance hybrid for all the nine induces in both stress and non-stress conditions (Table-1).

Correlation Analysis: The correlation coefficients between Y_S, Y_{NS} and other quantitative indices of drought tolerance were calculated (Table-2). Mean yield of non-stress environment was significantly and positively correlated with mean yield of stress environment, YR, MPI, REI, MRP. Mean productivity index was significantly and positively correlated with yield reduction. Relative efficiency index was significantly and positively correlated with mean yield of non-stress environment and MPI. Mean relative performance was significantly and positively correlated with Y_{NS}, MPI and REI. Golden mean was DRI. Drought tolerance efficiency was significantly and positively correlated with DRI and GM.

Selection of suitable drought tolerant hybrids: To determine the most desirable drought tolerant hybrids according to the all indices mean rank and standard deviation of ranks of all criteria were calculated and based on these two criteria the most desirable drought tolerant hybrids were identified.

Only the basis of rank, selection of drought tolerance hybrid may be controversial so that high means rank and low standard deviation of ranks is most correct method. Perusal of Table 2 indicated that hybrids ICMA 98222 × 481-500, ICMA 88004 × 501-510, ICMA 93333 × 551-560, ICMA 30199 × 481-500, ICMA 30200 × 561-570, ICMA 88004 × 551-560, ICMA 97444 × 571-580, ICMA 30209 × 571-580, ICMA 04999 × 571-580 and ICMA 30199 × 551-560 were identified as the most drought tolerant hybrids. While hybrids ICMA 97444 × 501-510, ICMA 30200 × 501-510, ICMA 04999 × 531-540, ICMA 98222 × 511-520 and ICMA 04999 × 501-510 were identified as the most sensitive.

Table 1: Mean grain yield of normal environment, Stress environment, Stress indices, Rank and over all rank and standard deviation of hybrids.

S. No.	hybrids	Y_{NS}	R	Y_S	R	YR	R	MPI	R	REI	R	MRP	R	DRI	R	GM	R	DTE	R	OR	SDR
1.	ICMA 04999 × 481-500	66.67	16	21.33	36	0.68	21	22.67	14	2687.64	31	2.14	32	0.75	48	1.94	58	32.00	59	35.00	16.95
2.	ICMA 88004 × 481-500	50.00	44	28.67	20	0.43	59	10.67	61	2698.75	30	2.15	31	1.34	50	3.69	21	57.33	22	37.56	16.32
3.	ICMA 93333 × 481-500	36.67	69	29.67	18	0.19	74	3.50	73	2353.20	42	1.95	39	1.90	42	9.48	6	80.91	7	41.11	26.96
4.	ICMA 97111 × 481-500	43.33	61	21.33	36	0.51	51	11.00	57	2189.86	50	1.71	52	1.15	28	2.94	28	49.23	29	43.56	13.26
5.	ICMA 97444 × 481-500	60.00	26	17.33	58	0.71	18	21.33	19	2305.42	43	1.85	43	0.68	38	1.81	62	28.89	63	41.11	17.57
6.	ICMA 98222 × 481-500	95.00	1	61.67	1	0.35	66	16.67	36	7123.75	1	4.40	1	1.52	80	4.70	14	64.91	15	23.89	30.29
7.	ICMA 10444 × 481-500	26.67	72	22.33	33	0.16	76	2.17	76	1860.97	67	1.45	66	1.96	15	11.31	4	83.75	5	46.00	31.41
8.	ICMA 30199 × 481-500	73.33	11	34.67	8	0.53	48	19.33	29	3807.64	6	2.84	7	1.11	74	2.79	32	47.27	33	27.56	22.83
9.	ICMA 30200 × 481-500	53.33	39	24.67	28	0.54	46	14.33	45	2580.97	34	2.04	34	1.08	46	2.72	33	46.25	34	37.67	6.61
10.	ICMA 30201 × 481-500	50.00	44	31.67	13	0.37	65	9.17	66	2848.75	23	2.28	22	1.48	59	4.45	15	63.33	16	35.89	22.55
11.	ICMA 30209 × 481-500	19.33	78	16.67	60	0.14	77	1.33	77	1587.64	77	1.07	76	2.02	5	13.50	3	86.21	4	50.78	35.52
12.	ICMA 04999 × 501-510	23.33	74	14.67	65	0.37	63	4.33	69	1607.64	76	1.06	77	1.47	4	4.38	17	62.86	18	51.44	29.47
13.	ICMA 88004 × 501-510	83.67	6	42.33	3	0.49	55	20.67	24	4807.31	2	3.36	2	1.19	79	3.05	25	50.60	26	24.67	26.74
14.	ICMA 93333 × 501-510	50.00	44	11.33	68	0.77	7	19.33	29	1832.08	68	1.41	68	0.53	13	1.59	73	22.67	74	49.33	26.85
15.	ICMA 97111 × 501-510	56.67	34	14.67	65	0.74	14	21.00	20	2096.53	57	1.67	58	0.61	23	1.70	66	25.88	67	44.89	21.88
16.	ICMA 97444 × 501-510	41.67	66	10.67	79	0.74	13	15.50	41	1709.86	75	1.22	74	0.60	7	1.69	67	25.60	68	54.44	27.46
17.	ICMA 98222 × 501-510	63.33	22	10.67	79	0.83	2	26.33	7	1940.97	63	1.62	60	0.39	21	1.41	78	16.84	79	45.67	32.30
18.	ICMA 10444 × 501-510	26.67	72	18.67	52	0.30	72	4.00	71	1763.20	71	1.29	73	1.64	8	5.67	8	70.00	9	48.44	30.76
19.	ICMA 30199 × 501-510	43.33	61	34.00	10	0.22	73	4.67	68	2738.75	28	2.26	27	1.84	54	8.29	7	78.46	8	37.33	26.86
20.	ICMA 30200 × 501-510	40.00	67	11.33	68	0.72	16	14.33	47	1718.75	74	1.22	75	0.66	6	1.79	64	28.33	65	53.56	25.55
21.	ICMA 30201 × 501-510	46.67	56	11.33	68	0.76	8	17.67	33	1794.31	69	1.34	70	0.57	10	1.64	71	24.29	72	50.78	26.68
22.	ICMA 30209 × 501-510	60.00	26	15.33	64	0.74	12	22.33	18	2185.42	52	1.76	49	0.60	32	1.69	68	25.56	69	43.33	21.95
23.	ICMA 04999 × 511-520	50.00	44	31.33	14	0.37	61	9.33	63	2832.08	24	2.27	25	1.47	55	4.36	18	62.67	19	35.89	19.81
24.	ICMA 88004 × 511-520	43.33	61	16.33	62	0.62	35	13.50	51	1973.20	60	1.50	62	0.88	19	2.21	45	37.69	46	49.00	14.70
25.	ICMA 93333 × 511-520	43.33	61	21.33	36	0.51	51	11.00	57	2189.86	50	1.71	52	1.15	28	2.94	28	49.23	29	43.56	13.26
26.	ICMA 97111 × 511-520	50.00	44	17.33	58	0.65	27	16.33	37	2132.08	56	1.66	59	0.81	22	2.06	53	34.67	54	45.56	13.90
27.	ICMA 97444 × 511-520	60.00	26	34.67	8	0.42	60	12.67	53	3345.42	14	2.59	15	1.35	66	3.74	20	57.78	21	31.44	21.99
28.	ICMA 98222 × 511-520	60.00	26	11.33	68	0.81	4	24.33	13	1945.42	62	1.59	61	0.44	20	1.47	76	18.89	77	45.22	29.05
29.	ICMA 10444 × 511-520	60.00	26	41.67	5	0.31	70	9.17	65	3765.42	7	2.89	6	1.63	75	5.55	10	69.44	11	30.56	30.32
30.	ICMA 30199 × 511-520	55.00	38	18.67	52	0.66	26	18.17	32	2292.08	46	1.81	44	0.80	37	2.03	54	33.94	55	42.67	10.16
31.	ICMA 30200 × 511-520	16.67	79	11.33	68	0.32	68	2.67	74	1454.31	79	0.79	79	1.59	1	5.25	11	68.00	12	52.33	33.66
32.	ICMA 30201 × 511-520	63.33	22	41.33	6	0.35	67	11.00	59	3883.20	5	2.94	5	1.53	76	4.76	13	65.26	14	29.67	29.07
33.	ICMA 30209 × 511-520	63.33	22	18.00	56	0.72	17	22.67	16	2405.42	41	1.94	40	0.67	41	1.79	63	28.42	64	40.00	18.68
34.	ICMA 04999 × 531-540	66.67	16	11.33	68	0.83	3	27.67	6	2020.97	59	1.71	54	0.40	27	1.41	77	17.00	78	43.11	30.28
35.	ICMA 88004 × 531-540	16.67	79	11.33	68	0.32	68	2.67	74	1454.31	79	0.79	79	1.59	1	5.25	11	68.00	12	52.33	33.66
36.	ICMA 93333 × 531-540	48.33	55	40.00	7	0.17	75	4.17	70	3198.75	17	2.61	14	1.94	67	10.60	5	82.76	6	35.11	30.70

37.	ICMA 97111 × 531-540	53.33	39	11.33	68	0.79	5	21.00	20	1869.86	65	1.47	64	0.50	16	1.54	74	21.25	75	47.33	27.58
38.	ICMA 97444 × 531-540	60.00	26	24.67	28	0.59	39	17.67	33	2745.42	27	2.16	30	0.96	51	2.40	41	41.11	42	35.22	8.51
39.	ICMA 98222 × 531-540	46.67	56	11.33	68	0.76	8	17.67	33	1794.31	69	1.34	70	0.57	10	1.64	71	24.29	72	50.78	26.68
40.	ICMA 10444 × 531-540	53.33	39	11.33	68	0.79	5	21.00	20	1869.86	65	1.47	64	0.50	16	1.54	74	21.25	75	47.33	27.58
41.	ICMA 30199 × 531-540	46.67	56	21.33	36	0.54	44	12.67	54	2260.97	47	1.78	47	1.07	34	2.68	36	45.71	37	43.44	8.19
42.	ICMA 30200 × 531-540	40.00	67	16.33	62	0.59	38	11.83	55	1918.75	64	1.44	67	0.96	14	2.38	42	40.83	43	50.22	17.66
43.	ICMA 30201 × 531-540	60.00	26	21.33	36	0.64	29	19.33	26	2545.42	36	2.02	36	0.83	44	2.10	50	35.56	51	37.11	9.51
44.	ICMA 30209 × 531-540	70.00	13	21.33	36	0.70	20	24.33	11	2758.75	26	2.20	28	0.71	53	1.88	60	30.48	61	34.22	19.48
45.	ICMA 04999 × 551-560	23.33	74	21.33	36	0.09	78	1.00	78	1763.20	72	1.35	69	2.14	12	22.33	2	91.43	3	47.11	33.67
46.	ICMA 88004 × 551-560	80.00	7	29.00	19	0.64	32	25.50	10	3585.42	8	2.72	9	0.85	72	2.14	48	36.25	49	28.22	23.45
47.	ICMA 93333 × 551-560	94.33	2	31.33	14	0.67	25	31.50	4	4221.20	3	3.08	4	0.78	77	1.99	55	33.22	56	26.67	28.63
48.	ICMA 97111 × 551-560	20.67	77	13.00	67	0.37	64	3.83	72	1534.08	78	0.94	78	1.47	3	4.39	16	62.90	17	52.44	30.96
49.	ICMA 97444 × 551-560	21.67	76	21.33	36	0.02	79	0.17	79	1727.64	73	1.32	72	2.31	9	129	1	98.46	2	47.44	35.17
50.	ICMA 98222 × 551-560	56.67	34	28.67	20	0.49	53	14.00	48	2889.86	21	2.27	23	1.19	57	3.05	26	50.59	27	34.33	14.51
51.	ICMA 10444 × 551-560	50.00	44	20.67	47	0.59	40	14.67	43	2298.75	44	1.81	45	0.97	35	2.41	39	41.33	40	41.89	3.69
52.	ICMA 30199 × 551-560	76.67	9	28.00	23	0.63	33	24.33	11	3412.08	13	2.61	13	0.86	68	2.15	47	36.52	48	29.44	20.89
53.	ICMA 30200 × 551-560	43.33	61	20.67	47	0.52	49	11.33	56	2160.97	54	1.69	56	1.12	25	2.82	31	47.69	32	45.67	13.04
54.	ICMA 30201 × 551-560	50.00	44	24.00	32	0.52	50	13.00	52	2465.42	38	1.95	38	1.12	43	2.85	30	48.00	31	39.78	8.07
55.	ICMA 30209 × 551-560	66.67	16	28.00	23	0.58	42	19.33	26	3132.08	18	2.43	21	0.98	60	2.45	38	42.00	39	31.44	14.39
56.	ICMA 04999 × 561-570	90.00	3	25.33	26	0.72	15	32.33	2	3545.42	10	2.74	8	0.66	73	1.78	65	28.15	66	29.78	29.60
57.	ICMA 88004 × 561-570	66.67	16	21.33	36	0.68	21	22.67	14	2687.64	31	2.14	32	0.75	48	1.94	58	32.00	59	35.00	16.95
58.	ICMA 93333 × 561-570	36.67	69	18.67	52	0.49	56	9.00	67	1949.86	61	1.48	63	1.19	18	3.07	24	50.91	25	48.33	20.25
59.	ICMA 97111 × 561-570	46.67	56	19.00	51	0.59	37	13.83	50	2152.08	55	1.67	57	0.95	24	2.37	43	40.71	44	46.33	10.72
60.	ICMA 97444 × 561-570	56.67	34	16.67	60	0.71	19	20.00	25	2209.86	48	1.76	50	0.69	31	1.83	61	29.41	62	43.33	16.48
61.	ICMA 98222 × 561-570	85.00	5	20.67	47	0.76	10	32.17	3	3022.08	20	2.45	19	0.57	62	1.64	70	24.31	71	34.11	28.32
62.	ICMA 10444 × 561-570	53.33	39	21.67	35	0.59	36	15.83	39	2420.97	39	1.91	42	0.95	39	2.37	44	40.63	45	39.78	3.35
63.	ICMA 30199 × 561-570	86.67	4	21.33	36	0.75	11	32.67	1	3114.31	19	2.51	17	0.58	64	1.65	69	24.62	70	32.33	28.35
64.	ICMA 30200 × 561-570	73.33	11	31.33	14	0.57	43	21.00	20	3563.20	9	2.70	10	1.00	71	2.49	37	42.73	38	28.11	20.88
65.	ICMA 30201 × 561-570	33.33	71	42.33	3	-0.27	80	-4.50	80	2676.53	33	2.43	20	2.98	61	-8.41	80	127	1	47.67	33.56
66.	ICMA 30209 × 561-570	60.00	26	21.33	36	0.64	29	19.33	26	2545.42	36	2.02	36	0.83	44	2.10	50	35.56	51	37.11	9.51
67.	ICMA 04999 × 571-580	70.00	13	32.33	12	0.54	45	18.83	31	3528.75	11	2.68	11	1.08	70	2.72	35	46.19	36	29.33	20.06
68.	ICMA 88004 × 571-580	76.67	9	25.33	26	0.67	24	25.67	9	3207.64	16	2.50	18	0.77	63	1.99	56	33.04	57	30.89	21.68
69.	ICMA 93333 × 571-580	50.00	44	31.33	14	0.37	61	9.33	63	2832.08	24	2.27	25	1.47	55	4.36	18	62.67	19	35.89	19.81
70.	ICMA 97111 × 571-580	70.00	13	11.33	68	0.84	1	29.33	5	2058.75	58	1.77	48	0.38	33	1.39	79	16.19	80	42.78	31.12
71.	ICMA 97444 × 571-580	65.00	21	45.33	2	0.30	71	9.83	62	4212.08	4	3.14	3	1.63	78	5.61	9	69.74	10	28.89	31.84
72.	ICMA 98222 × 571-580	46.67	56	24.67	28	0.47	58	11.00	60	2416.53	40	1.92	41	1.24	40	3.24	22	52.86	23	40.89	14.71
73.	ICMA 10444 × 571-580	50.00	44	18.67	52	0.63	34	15.67	40	2198.75	49	1.72	51	0.87	30	2.19	46	37.33	47	43.67	7.60
74.	ICMA 30199 × 571-580	63.33	22	32.67	11	0.48	57	15.33	42	3334.31	15	2.57	16	1.21	65	3.13	23	51.58	24	30.56	19.45
75.	ICMA 30200 × 571-580	56.67	34	28.67	20	0.49	53	14.00	48	2889.86	21	2.27	23	1.19	57	3.05	26	50.59	27	34.33	14.51
76.	ICMA 30201 × 571-580	50.00	44	20.67	47	0.59	40	14.67	43	2298.75	44	1.81	45	0.97	35	2.41	39	41.33	40	41.89	3.69
77.	ICMA 30209 × 571-580	80.00	7	28.00	23	0.65	28	26.00	8	3505.42	12	2.67	12	0.82	69	2.08	52	35.00	53	29.33	23.03
78.	RHB - 177 (Check-1)	50.00	44	18.00	56	0.64	31	16.00	38	2165.42	53	1.69	55	0.84	26	2.13	49	36.00	50	44.67	10.79
79.	MPMH - 17 (Check-2)	66.67	16	22.00	34	0.67	23	22.33	17	2732.08	29	2.17	29	0.77	52	1.99	57	33.00	58	35.00	16.60
80.	BHB - 1602 (Check-3)	53.33	39	24.67	28	0.54	46	14.33	45	2580.97	34	2.04	34	1.08	46	2.72	33	46.25	34	37.67	6.61
	Mean	54.45	16	23.24	36		21		14		31		32		48		58		59	35.00	16.95

Y_{NS} =Yield of non-stress environment, Y_S = Yield of stress environment, YR= Yield reduction, MPI= Mean productivity index, REI= Relative efficiency index, MRP= Mean relative performance, DRI= Drought resistance index, Gm= Golden mean, DTE= Drought tolerance efficiency

Table 2: Correlation coefficients between mean grain yield of normal environment, stress environment andstress indices

	E1	E3	YR	MPI	REI	MRP	DRI	GM	DTE
E1	1								
E3	0.40**	1							
YR	0.52**	-0.51**	1						
MPI	0.84**	-0.16**	0.86**	1					
REI	0.74**	0.87**	-0.09	0.29**	1				
MRP	0.79**	0.79**	-0.06	0.34**	0.97**	1			
DRI	-0.52**	-0.52**	-1.00**	-0.86**	0.09	0.06	1		
GM	-0.29**	-0.29**	-0.38**	-0.31**	-0.12*	-0.15**	0.38**	1	
DTE	-0.52**	-0.52**	-1.00**	-0.86**	0.09	0.06	1.00**	0.38**	1

*,** indicated significant at 5 and 1%, respectively

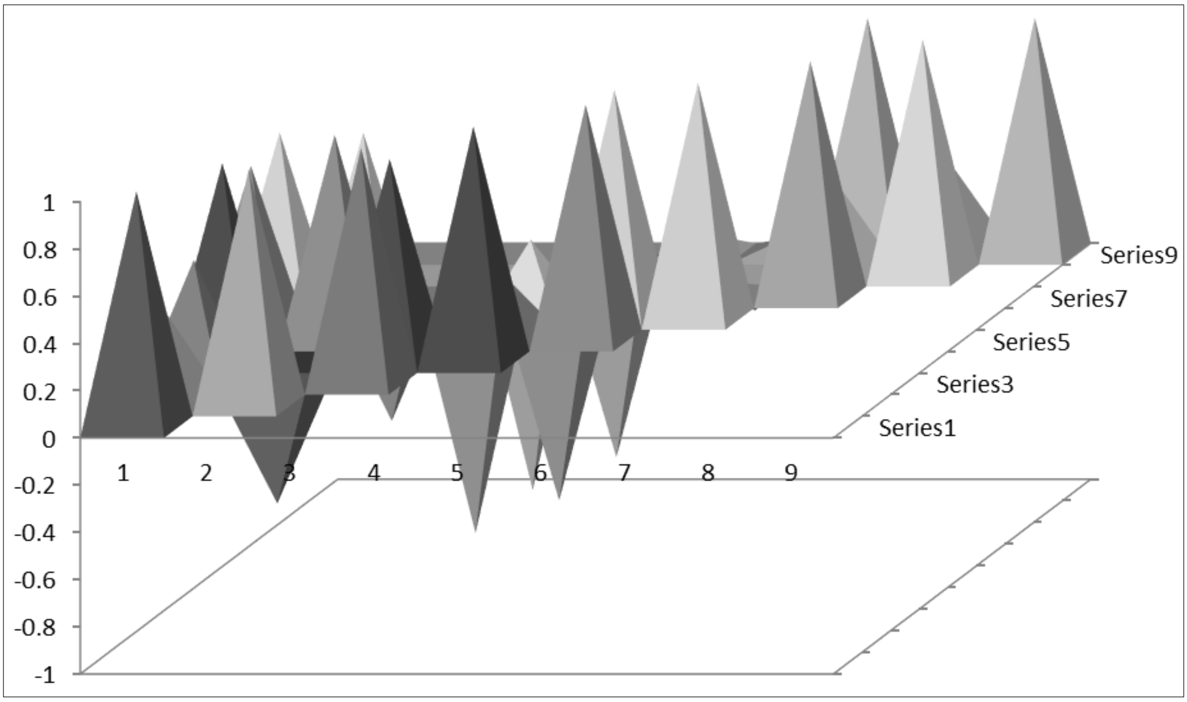

Fig 1: Graphical representation of Stress Induces

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