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Identification of suitable Pearl Millet Hybrid for Arid and Semi-arid condition using Infrared Gas Analysis(IRGA)

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ABSTRACT: Maintenance of growth, development, and physiological processes in general is a key requirement for the survival of multicellular organisms such as plants and animals. Abiotic stresses are one of the major constraints to crop production and food security worldwide. The situation has aggravated due to the drastic and rapid changes in global climate. Drought is undoubtedly the most important stresses having huge impact on growth and productivity of the crops. It is very important to understand the physiological, biochemical, and ecological interventions related to these stresses for better management. Crop growth and yields are negatively affected by sub-optimal water supply and abnormal temperatures due to physical damages, physiological disruptions, and biochemical changes. This stresses have multi-lateral impacts and therefore, complex in mechanistic action. A better understanding of plant responses to these stresses has pragmatic implication for remedies and management. A comprehensive account of modern approaches (IRGA) deal with drought stresses responses of pearl millet. The hybrids ICMA 97111 × 561-570, ICMA 30200 × 511-520, ICMA 98222 × 551-560, ICMA 30209 × 511-520, ICMA 10444 × 551-560, ICMA 97444 × 561-570, ICMA 10444 × 481-500, ICMA 98222 × 561-570, ICMA 04999 × 571-580, ICMA 10444 × 511-520 showed high differentiate photosynthesis rate in both environment.

Keywords: Photosynthesis, Stress, Drought, IRGA, Temperatures.

INTRODUCTION

Abiotic stresses such as extreme temperatures, low water availability (Drought), flooding, high level of CO_2 and high salt levels are the major limiting factors for plant growth and productivity. The recent trends in global climate change and increasing erratic weather patterns are likely to aggravate these further. Climate change is defined as a significant difference between two mean climatic states, with substantial impact on the ecosystem (Agbola *et al.* 2007). Extreme climatic events, such higher temperatures, more intense precipitation, increased drought risk and duration as well as cyclones and flooding in coastal areas, are expected to increase in both frequency and intensity (Reynolds *et al.*, 2010, da Silva *et al.*, 2011). Rate of plant growth and development is dependent upon the temperature surrounding the plant and each species has a specific temperature range represented by a minimum, maximum, and optimum. These values were summarized by (Hatfield *et al.*, 2008, Hatfield *et al.*, 2011) for a number of different species typical of grain and fruit production. The temperature response of different species has been evaluated by Prasad *et al.*, 2001, Prasad *et al.*, 2002, Prasad *et al.*, 2003, Prasad *et al.*, 2006a, Prasad *et al.*, 2008. A recent IPCC report indicated, with medium confidence, that crop yields will experience 'severe and widespread impacts' if global warming exceeds 1.5 °C above pre-industrial levels, but that these impacts can be managed below this warming threshold (IPCC, 2018). Atmospheric concentrations of carbon dioxide have been steadily rising, from approximately 315 ppm (parts per million) in 1959 to a current atmospheric average of approximately 385 ppm (Keeling *et al.*, 2009). Current projections are for concentrations to continue to rise to as much as 500–1000 ppm by the year 2100 (IPCC 2007). While a great deal of media and public attention has focused on the effects that such higher concentrations of CO_2 are likely to have on global climate, rising CO_2 concentrations are also likely to have profound direct effects on the growth, physiology, and chemistry of plants, independent of any effects on climate (Ziska 2008). Drought is one of the most important abiotic stresses limiting global crop production. In order to combat its adverse effects, it is essential to develop water-deficit stress tolerant genotypes. Reduction in soil moisture leads to changes in the physical environment, which subsequently affect physiological and biochemical processes in plants (Sarker *et al.*, 2005, Sircelj *et al.*, 2005, da Silva *et al.*, 2005). Drought can cause nutrient deficiencies, even in fertilised soils, due the reduced mobility and absorbance of individual nutrients, leading to a lower rate of mineral diffusion from the soil matrix to the roots (da Silva *et al.*, 2011). Water is required for processes such as germination, cell division and elongation for the promotion of plant growth in height and width and metabolic activities, such as the synthesis of organic compounds, photosynthesis, respiration and a number of other physiological and biochemical processes (Taiz *et al.*, 2006). To achieve that, a better understanding of the stress induced responses and the interrelationships of physiological traits in drought tolerant crop such as pearl millet can prove to be very useful. Pearl millet [*Pennisetum glaucum* (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 livestock population in arid and semi-arid regions of India. It is an important boorish grain crop belonging to the family *Poaceae (gramineae)* and give out as staple food for the millions of people flourishing under hunger. The crop is able to booming under adverse conditions and also set up an important fodder crop for livestock population in arid and semi-arid regions of India.

MATERIAL AND METHODS

The experimental material for present study consisted of 11 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 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. The 77 crosses were generated using line x tester mating design at International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad during *Summer*, 2019. These hybrids were grown in randomized block design with three replications in three environments at Agricultural Research Station, Bikaner during *Kharif*, 2019. The observations were recorded on Infrared Gas Analyzer. Observations recorded different parameters in normal environment as well as stress environment. All the parameters were recorded by Infrared gas analysis (IRGA) model number CI-340. The CI-340 Ultra-Light Portable Photosynthesis System is an improved version of the first light weight, hand-held photosynthesis system in the world. Featuring a new design concept and compact solid-state structure, the entire system display, keypad, computer, data memory, CO_2/H_2O gas analyzer, flow control system and battery is contained in a single, hand-held case. Principle of Infrared Gas Analysis is measures heteroatomic trace gases based on the absorption wavelength of infrared (IR) light as it passes through an air sample. Parameters can be recorded by Infrared gas analysis (IRGA) model number CI-340 show in Table 1.

RESULTS AND DISCUSSION

The present study is conducted to understand the physiological reaction of 77 pearl millet hybrids and three checks at normal growing condition and stress condition. Here we discuss pearl millet hybrids on the bases of net photosynthesis, Transpiration rate, Photosynthesis Active Radiation, leaf temperature, air temperature, inlet $CO_{2,}$ fluorescence, vapor pressure deficit, outlet CO_2 inlet relative humidity, Outlet relative humidity, Outlet water pressure and inlet relative humidity.

Photosynthetic rate in normal environment: Photosynthesis is the formation of carbohydrates from CO_2 and a source of hydrogen (as water) in the chlorophyll containing tissues of plants exposed to light. The rate at which photosynthesis occurs is determined by measuring the rate at which a known leaf area assimilates the CO_2 concentration in a given time. Temperature, carbon dioxide concentration and light intensity can affect the rate of photosynthesis. The hybrids *viz.,* ICMA 04999 × 481-500, ICMA 97444 × 531-540, ICMA 93333 × 571-580, ICMA 88004 × 561-570, ICMA 10444 × 571-580, ICMA 93333 × 551-560, ICMA 30209 × 571-580, ICMA 88004 × 501-510, RHB - 177 (Check-1) and ICMA 98222 × 571-580 showed high photosynthesis rate at normal environment (Table 2, Fig. 1).

Table 1: List of Physiological data recorded by Infrared gas analysis (IRGA) model number CI-340.

Sr. No.	Denoted by	Abbreviation	Unit
1.	Internal T	Internal temperature for the instrument	deg C
2.	Pressure	Atmospheric pressure	kPa
3.	Tair	Air temp.	deg C
4.	CO_2 in	Inlet CO_2	ppm
5.	H_2O in	Inlet water pressure	kPa
6.	W	Mass flow rate	mol/m^{-2}/s
7.	E	Transpiration rate	mmol/m^{-2}/s
8.	RH in	inlet relative humidity	%
9.	int CO_2	Internal CO_2 concentration	ppm
10.	Flow	Flow rate	l/min
11.	PAR	Photosynthesis Active Radiation	umol/ m^{-2}/s
12.	Tleaf	Leaf temp.	
13.	CO_2out	Outlet CO_2	ppm
14.	H_2Oout	Outlet water pressure	kPa
15.	Pn	Net photosynthesis rate	umol/ m^{-2}/s
16.	C	Stomatal conductance rate	mmol/ m^{-2}/s
17.	RHout	Outlet relative humidity	kPa
19.	fluorescence	fluorescence	
20.	VPD	Vapour-pressure deficit	kPa
21.	Month	Current month	
22.	H, min and s	Time experiments conducted	
23.	Year	Current year	
24.	Date	Current date	

Photosynthetic rate in stress environment: According to (Table 3, fig. 2) the hybrids *viz.*, ICMA 97111 × 561-570, ICMA 30200 × 511-520, ICMA 98222 × 551-560, ICMA 30209 × 511-520, ICMA 10444 × 551-560, ICMA 97444 × 561-570, ICMA 10444 × 481-500, ICMA 98222 × 561-570, ICMA 04999 × 571-580, ICMA 10444 × 511-520 showed high photosynthesis rate at stress environment.

Difference of photosynthesis rate between normal environment and stress environment: One of the key physiological phenomena affected by the drought in plants is photosynthesis (Farooq *et al.,* 2009b). It is mainly affected due to reduced leaf expansion, improper functioning of the photosynthetic machinery and leaf senescence (Wahid *et al.,* 2007). Stomatal closure under drought reduces the CO_2 availability which makes plant more susceptible to photo damage (Lawlor and Cornic, 2002). The reduced moisture availability induces negative changes in photosynthetic pigments, damages the photosynthetic machinery (Fu and Huang, 2001) and impairs the performance of important enzymes (Monakhova and Chernyadev, 2002) causing considerable loses in plant growth and yield. Similarly, the heat stress also impairs the process of photosynthesis by disturbing the photosynthetic pigments (Camejo *et al.,* 2006), reducing activity of photosystem II (Camejo *et al.,* 2005) and impairing the regeneration capacity of RuBP (Wise *et al.,* 2004). Pearl millet is a C_4 plant, C4 photosynthesis reduces photorespiration by concentrating CO_2 around RuBisCO. To ensure that RuBisCO works in an environment where there is a lot of carbon dioxide and very little oxygen, pearl millet leaves generally differentiate two partially isolated compartments called mesophyll cells and bundle-sheath cells. CO_2 is initially fixed in the mesophyll cells by the enzyme PEP carboxylase which reacts the three carbon phosphoenolpyruvate (PEP) with CO_2 to form the four carbon oxaloacetic acid (OAA). OAA can be chemically reduced to malate or transaminated to aspartate. These diffuse to the bundle sheath cells, where they are decarboxylated, creating a CO_2-rich environment around RuBisCO and thereby suppressing photorespiration. The resulting pyruvate (PYR) together with about half of the phosphoglycerate (PGA) produced by Rubisco diffuse back to the mesophyll. PGA is then chemically reduced and diffuses back to the bundle sheath to complete the reductive pentose phosphate cycle (RPP). This exchange of metabolites is essential for pearl millet photosynthesis to work. On the one hand, these additional steps require more energy in the form of ATP used to regenerate PEP. On the other hand, concentrating CO_2 allows high rates of photosynthesis at higher temperatures. Higher concentration overcomes the reduction of gas solubility with temperatures (Henry's law). The CO_2 concentrating mechanism also maintains high gradients of CO_2 concentration across the stomatal pores. This means that pearl millet plants have generally lower stomatal conductance, reduced water losses and have generally higher water use efficiency.

Table 2: Physiological parameters of pearl millet at normal environment.

S. No.	Hybrids	Tair	Tleaf	CO_2 in	CO_2 out	H_2O in	H_2O out	RH in	RH out	VPD	E	PAR	Fluro	Pn	R	Yn
1.	ICMA 04999 × 481-500	26.8	25.6	1202.9	862	2.3	2.63	65	74.2	0.67	1.08	134.3	217	109.08	1	66.67
2.	ICMA 88004 × 481-500	27.3	26	1074.6	929.6	2.43	2.67	67	73.5	0.71	0.78	132.3	188	46.68	37	50.00
3.	ICMA 93333 × 481-500	27.5	26.2	965.9	895.8	2.48	2.53	67.4	68.5	0.88	0.14	88	122	22.41	70	36.67
4.	ICMA 97111 × 481-500	27.6	25.7	1031.3	884.7	2.5	2.4	67.3	64.7	0.92	0.5	51.1	161	47.12	34	43.33
5.	ICMA 97444 × 481-500	28.1	26.9	932.2	813.1	2.52	2.78	66	72.9	0.77	0.87	142.9	152	37.96	55	60.00
6.	ICMA 98222 × 481-500	28.5	27.8	920.9	773.6	2.57	2.84	65.9	72.8	0.91	0.89	146.3	158	46.81	35	95.00
7.	ICMA 10444 × 481-500	28.5	26.8	917.9	829.2	2.55	2.6	65.1	66.4	0.93	0.17	119.8	219	28.33	69	26.67
8.	ICMA 30199 × 481-500	29	27.8	929.4	779.8	2.54	2.8	63	69.5	0.96	0.86	121.2	205	47.75	33	73.33
9.	ICMA 30200 × 481-500	29.3	27.7	924.9	829.4	2.56	2.57	62.6	62.8	1.15	0.03	110.6	135	30.36	66	53.33
10.	ICMA 30201 × 481-500	29.4	27.4	948.7	813.8	2.54	2.84	61.9	69.1	0.82	0.97	85	174	42.72	44	50.00
11.	ICMA 30209 × 481-500	29.2	27.2	907.2	817.6	2.53	2.65	62.1	65	0.98	0.4	92.2	230	28.61	68	19.33
12.	ICMA 04999 × 501-510	29.5	28.1	1006.6	891.4	2.51	2.87	60.6	69.3	0.94	1.19	142.6	212	36.7	59	23.33
13.	ICMA 88004 × 501-510	29.8	28.4	1027.5	820.5	2.54	3.04	60.5	72.2	0.85	1.62	146.1	142	65.55	8	83.67
14.	ICMA 93333 × 501-510	30.1	28.4	948.7	776.6	2.61	3.25	60.8	75.8	0.63	2.11	180.1	182	54.44	17	50.00
15.	ICMA 97111 × 501-510	30.6	29.3	965.5	804.4	2.61	3.06	59.2	69.6	1.03	1.49	171.1	271	50.86	28	56.67
16.	ICMA 97444 × 501-510	30.5	29	907	852.6	2.61	3.18	59.3	72.5	0.83	1.9	206	136	17.18	73	41.67
17.	ICMA 98222 × 501-510	30.7	29.7	955.8	950.4	2.61	3.06	58.7	68.8	1.14	1.46	194.7	137	1.72	78	63.33
18.	ICMA 10444 × 501-510	31.1	30.4	973.5	921	2.65	3.15	58.4	69.3	1.21	1.62	176.7	178	16.57	75	26.67
19.	ICMA 30199 × 501-510	31.1	30	945.3	776.2	2.69	3.26	59.1	71.7	1	1.88	149.8	175	53.44	21	43.33
20.	ICMA 30200 × 501-510	31.2	30	925.4	871.3	2.71	3.17	59.4	69.5	1.09	1.52	135.5	167	17.15	74	40.00
21.	ICMA 30201 × 501-510	31.5	30.4	1010.7	821.8	2.75	3.2	59.2	69	1.16	1.49	201.7	128	59.74	11	46.67
22.	ICMA 30209 × 501-510	31.6	30.5	927.6	755.6	2.74	3.56	58.6	76	0.83	2.66	229.3	148	53.87	18	60.00
23.	ICMA 04999 × 511-520	31.5	30.5	935.7	797.8	2.76	3.35	59.5	72.2	1.04	1.94	180.9	185	43.53	42	50.00
24.	ICMA 88004 × 511-520	31.4	30.7	953.6	788.5	2.72	3.39	59	73.6	1.04	2.21	254.6	195	51.86	25	43.33
25.	ICMA 93333 × 511-520	31.4	30.7	929.8	803	2.69	3.51	58.2	76.1	0.91	2.71	233.3	418	39.95	49	43.33
26.	ICMA 97111 × 511-520	31.4	30.7	932.7	744.5	2.68	3.47	58.1	75.2	0.95	2.58	216	153	59.26	12	50.00
27.	ICMA 97444 × 511-520	31.2	30.3	949.9	831	2.7	3.32	59.1	72.6	1.03	2.03	150.6	98	37.5	57	60.00
28.	ICMA 98222 × 511-520	31.3	30.3	919.1	800.3	2.67	3.43	58.2	74.7	0.92	2.48	173.4	156	37.51	56	60.00
29.	ICMA 10444 × 511-520	31.1	-57.3	976	918.1	2.69	2.6	59.4	57.3	-2.6	1.23	140	273	18.31	72	60.00
30.	ICMA 30199 × 511-520	31.4	29.7	984.2	838.1	2.66	3.37	57.5	72.9	0.82	2.32	110	174	45.88	39	55.00
31.	ICMA 30200 × 511-520	31.6	30	958.3	803.1	2.76	3.31	59.2	71.1	0.96	1.82	103.4	139	48.9	32	16.67
32.	ICMA 30201 × 511-520	31.8	30.1	950.2	831.6	2.82	3.36	59.9	71.4	0.93	1.77	159.7	144	37.4	58	63.33
33.	ICMA 30209 × 511-520	32.1	30.6	938	821.9	2.86	3.42	59.7	71.5	0.98	1.84	170.4	166	36.53	60	63.33

34.	ICMA 04999 × 531-540	32.4	30.7	943.5	779.5	2.88	3.63	58.9	74.3	0.8	2.46	260.6	155	51.59	26	66.67
35.	ICMA 88004 × 531-540	32.5	31.2	964.4	837.3	2.85	3.65	58.1	74.3	0.93	2.6	206.2	183	39.82	50	16.67
36.	ICMA 93333 × 531-540	32.7	32	1045.6	898.8	2.89	3.4	58.4	68.5	1.38	1.65	230	197	46.1	38	48.33
37.	ICMA 97111 × 531-540	32.9	31.9	977.8	821.8	2.95	3.78	58.7	75.4	0.96	2.75	146.8	170	49.06	31	53.33
38.	ICMA 97444 × 531-540	33.4	32.8	1139.6	791.9	3	3.83	58.1	74.2	1.16	2.72	329.9	153	108.65	2	60.00
39.	ICMA 98222 × 531-540	33.4	32.2	955.2	885.6	2.94	3.58	56.8	69.1	1.24	2.09	197.7	148	21.92	71	46.67
40.	ICMA 10444 × 531-540	33.5	31.9	1002.5	860.6	3.01	3.2	58	61.6	1.54	0.62	178.6	140	44.66	41	53.33
41.	ICMA 30199 × 531-540	33.5	32.4	940.6	829.5	2.97	3.43	57	65.9	1.47	1.52	248.3	177	34.81	61	46.67
42.	ICMA 30200 × 531-540	33.5	32.2	982.4	859.1	2.76	3.48	53.1	66.9	1.36	2.35	209.2	175	38.64	53	40.00
43.	ICMA 30201 × 531-540	33.5	32.3	916.4	749	2.66	3.62	51.1	69.5	1.23	3.13	295.7	160	52.3	23	60.00
44.	ICMA 30209 × 531-540	33.6	32.1	906.8	808.5	2.48	3.45	47.3	65.8	1.37	3.15	204.8	137	30.74	64	70.00
45.	ICMA 04999 × 551-560	33.8	33	1028.8	902.2	2.53	3.35	47.8	63.2	1.72	2.65	303.5	231	39.53	51	23.33
46.	ICMA 88004 × 551-560	33.8	33.3	970.2	872.5	2.52	3.3	47.6	62.4	1.83	2.55	263.3	171	30.59	65	80.00
47.	ICMA 93333 × 551-560	34.1	33.8	1059	843.2	2.57	3.42	47.9	63.7	1.87	2.76	251.9	205	67.57	6	94.33
48.	ICMA 97111 × 551-560	33.9	33.2	959.1	833.2	2.52	3.26	47.4	61.2	1.84	2.4	183.8	126	39.52	52	20.67
49.	ICMA 97444 × 551-560	33.9	33.4	959.6	782.5	2.47	3.44	46.3	64.6	1.73	3.19	239.8	182	55.68	16	21.67
50.	ICMA 98222 × 551-560	34.1	33.6	1000.8	838.5	2.55	3.56	47.5	66.2	1.67	3.29	302.7	235	50.86	28	56.67
51.	ICMA 10444 × 551-560	34.3	33.3	966.7	835.4	2.53	3.09	46.7	57	2.05	1.81	304.9	257	40.98	47	50.00
52.	ICMA 30199 × 551-560	34.2	33	926.2	819.4	2.56	3.44	47.4	63.7	1.61	2.85	192.4	208	33.42	62	76.67
53.	ICMA 30200 × 551-560	33.9	32.5	1018.6	847.8	2.58	3.48	48.4	65.4	1.44	2.94	121.6	200	53.55	19	43.33
54.	ICMA 30201 × 551-560	34.3	34.1	998.5	830	2.49	3.47	45.8	63.9	1.89	3.19	253.8	210	52.54	22	50.00
55.	ICMA 30209 × 551-560	34.1	32.6	931.2	837	2.5	3.22	46.3	59.9	1.72	2.36	204.9	237	29.4	67	66.67
56.	ICMA 04999 × 561-570	34.2	33.7	917.2	780.6	2.4	3.44	44.5	63.7	1.81	3.37	318.7	320	42.68	45	90.00
57.	ICMA 88004 × 561-570	34	34.3	1129.1	870.6	2.41	3.16	45.3	59.4	2.26	2.44	302.2	192	81.02	4	66.67
58.	ICMA 93333 × 561-570	34.1	33.5	945.8	900.5	2.48	3.15	46.2	58.7	2.06	2.18	154.2	333	14.22	76	36.67
59.	ICMA 97111 × 561-570	34	33.5	999.8	838.5	2.49	3.3	46.5	61.6	1.91	2.64	229	453	50.55	30	46.67
60.	ICMA 97444 × 561-570	34.3	34.2	956.4	834.3	2.52	3.14	46.2	57.7	2.25	2.04	282	186	38.26	54	56.67
61.	ICMA 98222 × 561-570	34.5	42.6	938.4	837.5	2.52	3.35	46	61	5.15	2.68	150	161	31.6	63	85.00
62.	ICMA 10444 × 561-570	34.7	33.9	996	812.6	2.49	3.56	44.9	64.1	1.75	3.46	283.3	207	57.27	15	53.33
63.	ICMA 30199 × 561-570	34.7	33.8	1005.3	834.6	2.62	3.06	47.2	55.1	2.22	1.42	192.7	204	53.48	20	86.67
64.	ICMA 30200 × 561-570	34.8	34.1	957.6	768.3	2.52	3.44	45	61.6	1.93	3.02	238.1	160	59.14	13	73.33
65.	ICMA 30201 × 561-570	35.1	34.9	934	899.4	2.52	3.51	44.4	62	2.1	3.24	199.1	160	10.76	77	33.33
66.	ICMA 30209 × 561-570	35.2	34.6	915.8	765.9	2.56	3.69	44.8	64.5	1.84	3.68	272	183	46.77	36	60.00
67.	ICMA 04999 × 571-580	35.6	35.2	913.4	776.1	2.41	3.61	41.3	61.8	2.11	3.9	155.2	165	42.8	43	70.00
68.	ICMA 88004 × 571-580	35.6	34.3	928.7	793.5	2.48	4.11	42.5	70.3	1.32	5.3	196.9	209	42.08	46	76.67
69.	ICMA 93333 × 571-580	35.6	34.3	1027.4	743	2.51	3.93	43	67.2	1.52	4.6	216.9	181	88.5	3	50.00
70.	ICMA 97111 × 571-580	36.2	37.1	955.8	976.2	2.53	3.05	41.9	50.4	3.3	1.66	378.5	141	-6.34	79	70.00

71.	ICMA 97444 × 571-580	36	35.2	997.7	830.2	2.61	3.77	43.6	63	1.96	3.76	233.8	190	52.15	24	65.00
72.	ICMA 98222 × 571-580	36.3	36	1010.8	801.9	2.5	3.59	41.3	59.2	2.37	3.52	256.9	154	64.94	10	46.67
73.	ICMA 10444 × 571-580	36.1	35.1	978.5	739.4	2.54	4.07	42.3	67.7	1.61	4.95	356.2	147	74.08	5	50.00
74.	ICMA 30199 × 571-580	35.9	34.7	921.8	1042.8	2.44	3.66	41	61.4	1.91	3.94	333.6	124	-37.6	80	63.33
75.	ICMA 30200 × 571-580	35.4	31.6	1029.1	863.4	2.5	3.2	43.3	55.4	1.48	2.26	305.3	174	51.55	27	56.67
76.	ICMA 30201 × 571-580	35.8	35.5	977.7	788.8	2.44	3.86	41.4	65.5	1.95	4.61	268	175	58.75	14	50.00
77.	ICMA 30209 × 571-580	35.8	35	973.3	758.9	2.51	3.25	42.6	55	2.42	2.39	204.2	149	66.98	7	80.00
78.	RHB - 177 (Check-1)	34.4	36.1	980	750	2.14	3.12	40.2	54	2.45	72	320	147	65.12	9	50.00
79.	MPMH - 17 (Check-2)	33.8	35.6	964	760	2.19	3.48	40.6	56	2.46	40	310	156	45.36	40	66.67
80.	BHB - 1602 (Check-3)	32.9	32	840	780	2.66	3.49	40.7	60	2.79	32	330	148	40.9	48	53.33

R = Rank, Yn = Mean Yield of normal environment.

Table 3: Physiological parameters of pearl millet at stress environment.

Sr. No.	Hybrids	Tair	T leaf	CO_2 in	CO_2 out	H_2O in	H_2O out	RH in	RH out	VPD	E	PAR	Fluro	Pn	R	Ys
1.	ICMA 04999 × 481-500	29.8	28.7	994.8	812.6	2.19	2.81	51.8	66.6	1.15	2.06	177.6	198	58.18	39	21.33
2.	ICMA 88004 × 481-500	30.3	29	933.4	829.3	2.3	2.52	53.1	58.1	1.5	0.71	273	180	33.24	59	28.67
3.	ICMA 93333 × 481-500	30.4	29.2	1096.8	896.4	2.34	2.53	53.6	58	1.54	0.62	103.5	145	64.12	35	29.67
4.	ICMA 97111 × 481-500	31.2	31.1	968.9	892.2	2.37	2.46	51.9	53.9	2.08	0.3	295.7	182	24.38	63	21.33
5.	ICMA 97444 × 481-500	31.9	31.4	1456.2	1469.3	2.41	2.5	50.6	52.6	2.12	0.3	248.1	142	4.12	78	17.33
6.	ICMA 98222 × 481-500	32.3	32	1112.6	952.5	2.37	2.44	48.8	50.1	2.35	0.2	301.4	115	50.6	50	61.67
7.	ICMA 10444 × 481-500	32.7	32.4	1584	980	2.37	3.41	47.9	68.8	1.46	3.39	184.6	163	189.38	7	22.33
8.	ICMA 30199 × 481-500	33	33.6	1175.8	888.1	2.38	3.4	47.2	67.3	1.82	3.31	243	181	90.53	23	34.67
9.	ICMA 30200 × 481-500	33.2	32.7	1086.1	1085.9	2.35	3.65	45.9	71.3	1.32	4.28	327.3	189	0.06	80	24.67
10.	ICMA 30201 × 481-500	33.6	33.1	1018.7	841.7	2.34	3.38	44.9	64.8	1.71	3.4	206.9	167	55.69	44	31.67
11.	ICMA 30209 × 481-500	33.6	32	1000.8	1077.1	2.34	2.96	44.9	56.9	1.8	2.02	298.3	212	23.9	66	16.67
12.	ICMA 04999 × 501-510	33.5	32.2	1251.9	803.3	2.3	3.39	44.3	65.3	1.43	3.57	239.5	198	141.42	14	14.67
13.	ICMA 88004 × 501-510	33.7	32.9	1031.8	858.1	2.36	3.72	45	70.8	1.3	4.43	263	186	54.5	45	42.33
14.	ICMA 93333 × 501-510	34	33.2	1161.5	924.6	2.38	3.54	44.5	66.2	1.57	3.78	287.5	177	74.31	31	11.33
15.	ICMA 97111 × 501-510	33.9	29.7	985.4	949.5	2.35	2.52	44.3	47.5	1.68	0.55	216.1	11	11.23	76	14.67
16.	ICMA 97444 × 501-510	34	32.4	1077.3	1118.4	2.45	2.92	45.8	54.6	1.96	1.52	214.1	156	12.38	75	10.67
17.	ICMA 98222 × 501-510	34.1	34.9	1230.5	1095.9	2.39	2.59	44.4	48.2	3.04	0.65	233.1	153	42.2	53	10.67
18.	ICMA 10444 × 501-510	33.8	33	1035	803.2	2.33	3.59	44.1	68.1	1.45	4.14	382.2	205	72.83	33	18.67
19.	ICMA 30199 × 501-510	33.9	33.2	1056.2	784.7	2.29	3.7	43.2	69.7	1.42	4.63	231.1	155	85.7	28	34.00

20.	ICMA 30200 × 501-510	34.3	34.3	954.6	817.9	2.4	3.75	44.2	69	1.67	4.41	285	267	42.93	52	11.33
21.	ICMA 30201 × 501-510	34.5	34	936.4	703.3	2.44	3.93	44.4	71.4	1.41	4.87	291.7	169	73.02	32	11.33
22.	ICMA 30209 × 501-510	34.7	34	1099.9	782.7	2.35	3.39	42.3	61	1.94	3.39	274	194	99.39	21	15.33
23.	ICMA 04999 × 511-520	34.8	34.5	1033.1	1134.8	2.32	2.87	41.6	51.3	2.62	1.77	358.2	150	31.78	60	31.33
24.	ICMA 88004 × 511-520	35	34.4	951.1	1082	2.29	2.47	40.4	43.6	3	0.59	348.9	94	41.06	54	16.33
25.	ICMA 93333 × 511-520	35	34.5	1047.5	930.6	2.31	2.45	40.9	43.4	3.05	0.45	272.7	35	36.58	57	21.33
26.	ICMA 97111 × 511-520	34.8	32.8	952.2	866.6	2.28	2.82	40.9	50.5	2.18	1.72	197.2	104	26.74	62	17.33
27.	ICMA 97444 × 511-520	34.9	-51.2	1454.5	1408.2	2.36	3	42	53.4	-3	2.08	234.3	53	14.49	72	34.67
28.	ICMA 98222 × 511-520	35.4	35.5	1463.5	1113	2.37	3.25	41.1	56.5	2.55	2.86	279.5	283	109.22	18	11.33
29.	ICMA 10444 × 511-520	35.1	34.9	1411.6	878.3	2.35	3.32	41.3	58.5	2.3	3.18	315.7	169	167.03	10	41.67
30.	ICMA 30199 × 511-520	35	34.9	1357.1	1113.9	2.32	3.06	41.2	54.3	2.57	2.4	241.4	210	76.31	30	18.67
31.	ICMA 30200 × 511-520	35.1	35.1	2181.2	937.4	2.38	3.26	41.9	57.5	2.41	2.88	273	224	389.33	2	11.33
32.	ICMA 30201 × 511-520	35.4	34.6	1232.4	944.5	2.5	3.7	43.3	63.9	1.82	3.89	258.6	123	89.89	24	41.33
33.	ICMA 30209 × 511-520	35.6	43.8	1593.1	806.4	2.55	3.49	43.5	59.6	5.54	3.06	292.7	143	245.68	4	18.00
34.	ICMA 04999 × 531-540	35.5	34.9	976.7	791.9	2.54	3.63	43.6	62.4	1.99	3.55	212.6	242	57.64	40	11.33
35.	ICMA 88004 × 531-540	35.6	34.1	1058	1053.7	2.68	2.97	45.8	50.8	2.41	0.95	214	219	1.33	79	11.33
36.	ICMA 93333 × 531-540	37.6	15.7	1249.7	1198.9	2.73	3.02	41.9	46.3	-1.23	0.93	208.3	148	15.68	71	40.00
37.	ICMA 97111 × 531-540	38.5	18.4	962.8	839.5	2.71	3.26	39.6	47.6	-1.14	1.75	262.4	153	38.18	56	11.33
38.	ICMA 97444 × 531-540	36.6	35.1	1215.6	815	2.78	3.94	45	63.7	1.73	3.74	309.8	191	124.27	15	24.67
39.	ICMA 98222 × 531-540	36.6	36.4	977.1	852	2.76	3.89	44.7	63.1	2.2	3.65	268.1	219	38.69	55	11.33
40.	ICMA 10444 × 531-540	36.3	35.7	945.5	765.2	2.58	4.34	42.5	71.4	1.53	5.71	340.8	221	55.89	43	11.33
41.	ICMA 30199 × 531-540	36.6	36.3	1108.7	1160.8	2.53	4.11	41	66.7	1.94	5.14	296.5	187	16.17	70	21.33
42.	ICMA 30200 × 531-540	36.9	37	1316.4	930.2	2.64	3.72	42.1	59.5	2.59	3.51	303.6	183	120.01	16	16.33
43.	ICMA 30201 × 531-540	36.9	36.4	975.1	786	2.58	4.33	41.2	69.2	1.77	5.69	403.6	155	58.53	38	21.33
44.	ICMA 30209 × 531-540	37	45	941	863.3	2.5	4.23	39.7	67.3	5.4	5.65	314.6	213	24.2	64	21.33
45.	ICMA 04999 × 551-560	36.8	-49.7	943.4	879.4	2.5	3.75	40.1	60	-3.74	4.06	199.1	159	19.99	67	21.33
46.	ICMA 88004 × 551-560	36.1	35.2	983.6	866.4	2.55	3.42	42.5	56.9	2.28	2.8	94.9	221	36.44	58	29.00
47.	ICMA 93333 × 551-560	35.4	33.9	1058	1116.4	2.52	3.3	43.7	57.2	2.02	2.51	77.5	163	18.19	69	31.33
48.	ICMA 97111 × 551-560	34.1	33.5	943	1227	2.44	3.34	45.4	62.2	1.86	2.93	290	215	88.48	27	13.00
49.	ICMA 97444 × 551-560	34.6	34.3	981	920	2.64	3.75	47.8	67.8	1.69	3.61	248	172	19.1	68	21.33
50.	ICMA 98222 × 551-560	35.6	36	978.9	2112.5	2.55	3.71	43.8	63.5	2.25	3.73	249.8	247	351.2	3	28.67
51.	ICMA 10444 × 551-560	36.1	36.4	1789.4	1042.1	2.6	3.86	43.4	64.5	2.24	4.08	356.8	264	231.95	5	20.67

52.	ICMA 30199 × 551-560	36.5	35.7	1004.5	1500.6	2.5	3.57	40.7	58	2.3	3.45	215.9	122	154.6	12	28.00
53.	ICMA 30200 × 551-560	37.1	36.1	1642.7	1939.9	2.71	4.73	42.8	74.7	1.28	6.59	348.4	155	92.08	22	20.67
54.	ICMA 30201 × 551-560	37	36.5	1127.9	1138.5	3.02	4.07	47.9	64.5	2.06	3.39	351.4	154	30.28	61	24.00
55.	ICMA 30209 × 551-560	36.8	-10.3	953	790	2.88	4.28	46	68.6	-4	4.58	297.6	270	50.61	49	28.00
56.	ICMA 04999 × 561-570	37	37.6	1112.6	825.3	2.79	3.9	44.2	61.8	2.6	3.61	300.3	250	89.45	26	25.33
57.	ICMA 88004 × 561-570	37.4	37	964.4	1314	2.71	4.41	42	68.3	1.9	5.54	326.9	157	108.7	19	21.33
58.	ICMA 93333 × 561-570	37.5	37.2	1006.7	854.8	2.72	4.49	42.1	69.3	1.88	5.74	252.8	148	47.09	51	18.67
59.	ICMA 97111 × 561-570	37.8	37.5	2185.4	883.5	2.89	4.47	44	68	2.01	5.13	365.9	159	403.39	1	19.00
60.	ICMA 97444 × 561-570	38.3	38.1	1907.1	1168.1	2.83	4.53	41.8	67	2.15	5.54	351.2	137	228.9	6	16.67
61.	ICMA 98222 × 561-570	38.2	37.2	1328.2	729.3	2.73	4.72	40.6	70.2	1.67	6.5	382.4	169	185.77	8	20.67
62.	ICMA 10444 × 561-570	38.2	37.3	979.7	1057.7	2.59	4.86	38.5	72.1	1.54	7.41	355.1	160	24.18	65	21.67
63.	ICMA 30199 × 561-570	38.4	38.5	1122	927.9	2.69	4.04	39.5	59.4	2.81	4.41	317.7	149	60.42	36	21.33
64.	ICMA 30200 × 561-570	38.3	37.2	1039.7	766	2.73	4.69	40.4	69.3	1.69	6.38	216.3	180	84.58	29	31.33
65.	ICMA 30201 × 561-570	38.6	38.1	1237.7	744.3	2.63	4.95	38.3	72	1.73	7.55	369.5	127	152.33	13	42.33
66.	ICMA 30209 × 561-570	38.7	38.2	990.7	757	2.7	4.77	39.1	69.2	1.95	6.73	341.1	163	71.97	34	21.33
67.	ICMA 04999 × 571-580	38.8	38.7	1489.3	930.8	2.69	4.39	38.8	63.3	2.54	5.51	326.4	135	172.47	9	32.33
68.	ICMA 88004 × 571-580	38.4	39.9	972.8	930.8	2.56	3.42	37.5	50.3	3.94	2.79	261.6	112	12.98	73	25.33
69.	ICMA 93333 × 571-580	38.1	38.3	1299.3	975.6	2.42	3.94	36.3	59	2.83	4.89	213.1	211	100.09	20	31.33
70.	ICMA 97111 × 571-580	37.8	38.5	1011.4	1043.1	2.43	3.91	37	59.5	2.92	4.77	285.8	293	9.8	77	11.33
71.	ICMA 97444 × 571-580	37.8	37.3	936.4	751.6	2.51	4.46	38	67.7	1.95	6.34	317.6	182	56.93	42	45.33
72.	ICMA 98222 × 571-580	37.5	37.3	959.1	786.3	2.49	4.05	38.4	62.5	2.37	5.03	311.7	209	53.37	46	24.67
73.	ICMA 10444 × 571-580	37.4	37.5	1184.6	999.5	2.48	4.33	38.5	67.3	2.13	6.04	302	126	57.44	41	18.67
74.	ICMA 30199 × 571-580	37.6	37	1116.9	826.4	2.43	4.53	37.4	69.6	1.78	6.82	407.8	200	89.81	25	32.67
75.	ICMA 30200 × 571-580	37.5	37.1	1203.8	821.4	2.48	4.24	38.3	65.4	2.09	5.71	336.1	168	118.49	17	28.67
76.	ICMA 30201 × 571-580	37.9	37.7	952.6	993.9	2.52	4.23	38.2	64.1	2.31	5.57	250.6	137	12.83	74	20.67
77.	ICMA 30209 × 571-580	37.8	37.9	1018.9	828.7	2.62	4.08	39.8	61.8	2.56	4.69	361.8	180	58.64	37	28.00
78.	RHB - 177 (Check-1)	37.9	38.2	932.2	761.2	2.54	4.34	38.3	65.5	2.4	5.87	383	211	52.99	48	18.00
79.	MPMH - 17 (Check-2)	38.3	38	1285	774.8	2.64	4.6	39.1	68.1	2.07	6.4	342.6	169	158.21	11	22.00
80.	BHB - 1602 (Check-3)	38.5	39.6	1011.8	839.6	2.78	3.98	40.5	58.1	3.29	3.89	363.5	146	53.24	47	24.67

R= Rank, Ys= Mean Yield of stress environment.

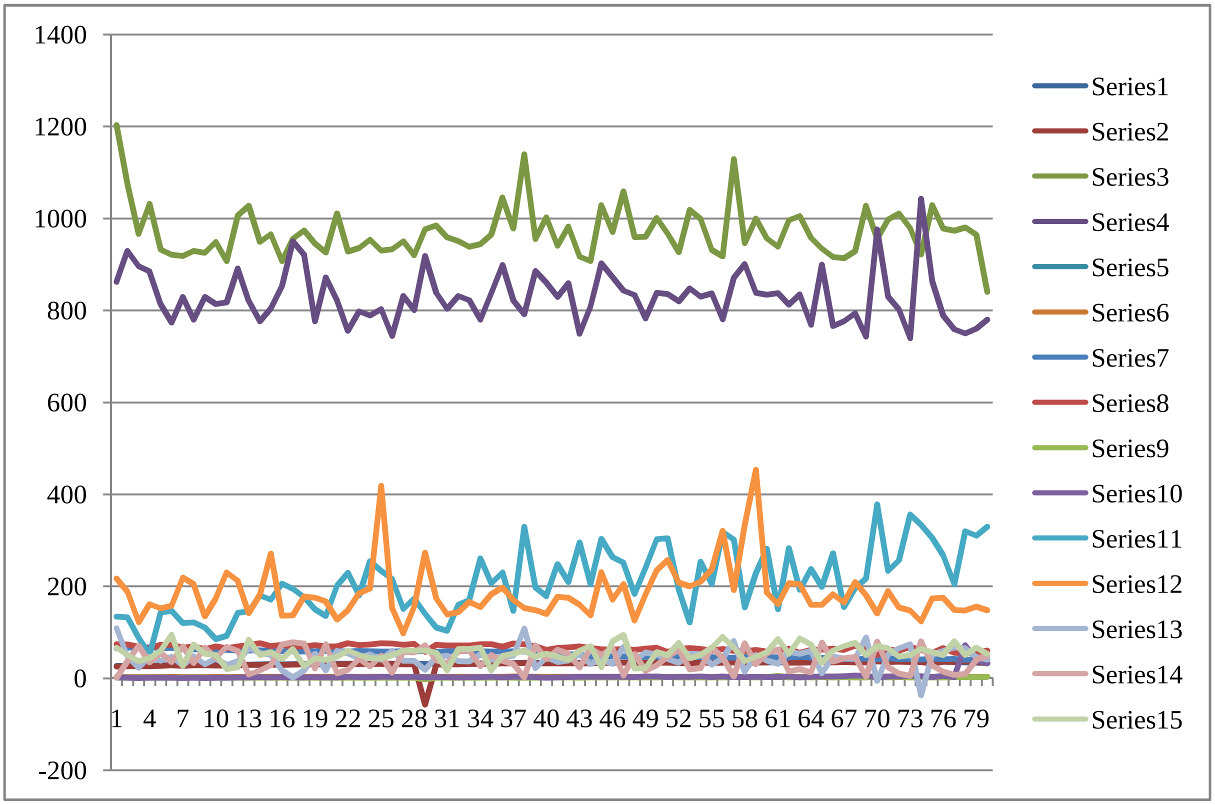

Fig. 1. Graphical Representation of different Physiological Parameters in normal environment.

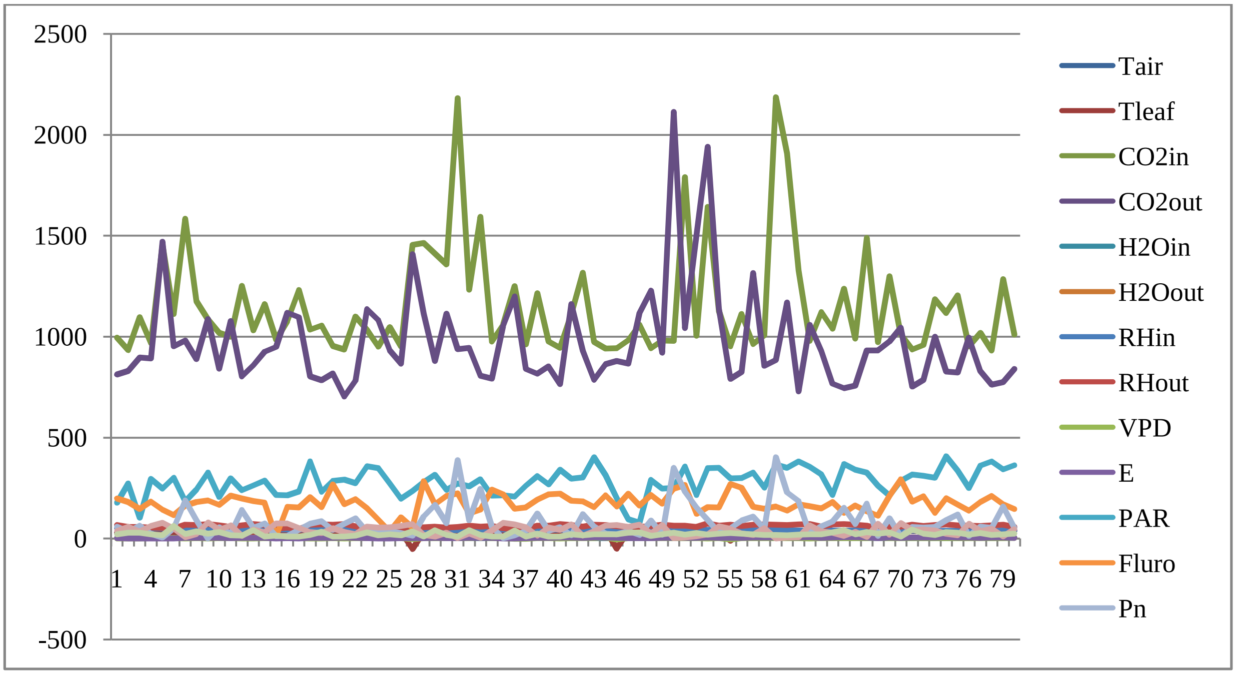

Fig. 2. Graphical representation of different physiological parameters in stress environment.

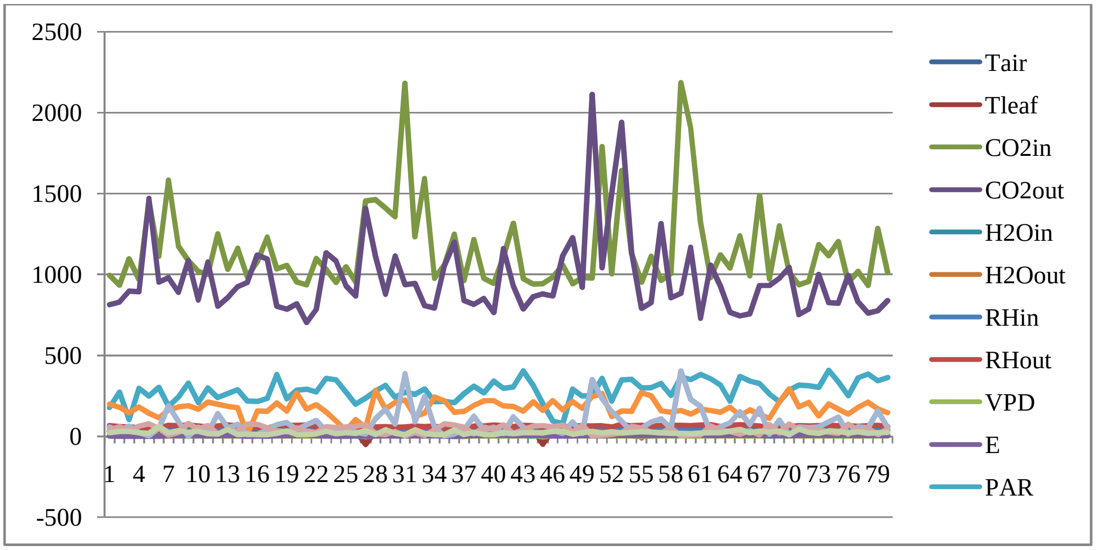

Fig. 3. Graphical represent of difference between photosynthetic rate at normal environment and stress environment.

Fig. 3 is clearly indicates that the rate of photosynthesis in stress environment is more than rate of normal environment. Majority of hybrids showed good photosynthesis rate in stress environment.

Conciliation: The environmental factors which can affect the rate of photosynthesis are carbon dioxide, light, temperature, water, oxygen, minerals, pollutants and inhibitors. The most suitable hybrid for stress as well as non-stress environment were ICMA 97111 × 561-570, ICMA 30200 × 511-520, ICMA 98222 × 551-560, ICMA 30209 × 511-520, ICMA 10444 × 551-560, ICMA 97444 × 561-570, ICMA 10444 × 481-500, ICMA 98222 × 561-570, ICMA 04999 × 571-580, ICMA 10444 × 511-520 so that they can be used for future study of stress factors.

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