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Effect of individual and combined drought and high temperature stress condition on chlorophyll contents and growth of wheat (*Triticum aestivum* L.) seedling

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Abstract
Most of the wheat growing areas of the world experience environmental stresses including drought (moisture stress) and high temperature (heat stress) that adversely affect crop growth, development and yield. Water-deficit often combined with high temperature stress is the main abiotic factor limiting crop growth and development. Present investigation was performed to see the growth response of different wheat genotypes under individual and combined stress conditions. Growth parameters like dry mass accumulation, fresh weight, root length & shoot length per plant and physiological traits (chlorophyll contents measured in terms of SPAD units), were recorded in 10 days old wheat seedling. Results showed genotypic difference exist among wheat genotypes in response to combined stress, genotype KO-307 was severely affected however C-306 was least affected by combined stress. Under combined drought + high temperature stress condition decrease in chlorophyll (12.72%), plant dry mass (26.09%), fresh weight (21.93%), root length (10.91%) and shoot length (14.41%) were observed compared with the optimum condition and when averaged across genotypes. Overall, combined effect of drought + high temperature stress was more detrimental than the individual stress, however, the interaction effect was hypo-additive in nature, which might be due to cross adaptation effect.

Keywords: wheat, moisture stress, SPAD, high temperature, dry matter

Introduction
Changes in concentrations of carbon dioxide and other greenhouse gases have caused global surface air temperatures to rise by about 0.8°C over the last century (IPCC, 2007) [5]. It has been suggested that variability in temperature extremes and water deficit events will be more critical in future climates. Therefore, stress combinations instead of individual stresses have been recognized as realistic threats faced by plants (Rizhsky, 2002) [8], (Mittler, 2006) [7], (Suzuki *et al*., 2014) [13], (Mahalingam, 2015) [6], (Ramegowda and Senthil Kumar, 2015) [9]. Most of the wheat growing areas of the world experience environmental stresses including drought (water stress) and high temperature (heat stress) that adversely affect crop growth, development and yield (Semenov and Shewry, 2011) [12]. Water-deficit often combined with high temperature stress is the main abiotic factor limiting crop-plants productivity and food-security worldwide (Boyer *et al*., 1982) [2]. Drought and high temperature stress often occur simultaneously especially in rainfed grown wheat crop causing severe yield loss in most of the wheat growing areas of the world (Pradhan *et al*., 2012) [11]. The simultaneous effects of these two stresses on crop performance in terms of growth, development, biomass accumulation, and yield may be quite different than the individual stress, but there are limited studies on this topic (Rizhsky, 2002) [8], (Mittler, 2006) [7]. There exists a strong relationship between the plant water status and temperature, thus making it very hard to separate the contributions of heat and drought stress under field conditions. Growth, physiological, and metabolic responses of plants to a combination of drought and heat stress are unique and cannot be directly extrapolated from the response of plants to each of these different stresses applied individually (Mittler, 2006) [7]. The purposes of this study was to compare the effect of individual and combined drought and high temperature stress on growth parameters and pigments contents of wheat seedlings of different genotypes.

Materials and Methods
The present study was performed in the Department of Botany & Plant Physiology, Faculty of Basic Sciences and Humanities, Dr. Rajendra Prasad Central Agricultural University. Seeds of twenty wheat genotypes (KO-307, CSW-16, RAJ-4120, HW-2045, CBW-38, DPW-621,

BRW-3708, HD-2985, DBW-14, WR-544, HD-2888, C-306, DBW-16, BRW-934, DBW-39, BAAZ, HD-2967, HP-1953, HD-2824, BRW-3711) for present experiments were received from Department of Agronomy, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur (Bihar); Regional station, Indian Agricultural Research Institute, Pusa (Bihar) & Borlaug Institute for South Asia, Samastipur (Bihar). Twenty genotypes were subjected to screening for combined drought and heat stress. Healthy wheat (*Triticumaestivum*L.) seeds of equal size were selected and surface sterilized using 1 % sodium hypochlorite solution for 10 minutes and followed by washing five times with distilled water. The seeds were sown in petri plates lined with three layers of filter paper that had been moistened with distilled water for germination and allowed to grow in incubator for ten days under control and stress condition. Drought stress imposed for 72 hours by use of twenty percent PEG 6000, high temperature (37±2°C) exposed for 6 hours in incubator and combined drought and high temperature by drought stressed plant (72 hours) was exposed to elevated temperature (37±2°C) in incubator for 6 hours. Control seeds were germinated in sterilized petriplate and kept at 25±2 °C in incubator and normal water without exposure to high temperature served as control. The sample size per treatment was 30 seeds in four replication and all parameters were measured in ten days old seedling. Root length, shoot length, fresh weight and dry weight and leaf chlorophyll contents (in term of SPAD value with help of chlorophyll meter) were measured. Experiments were conducted in completely randomized design. Statistical analysis of the data was done following the methods of analysis of variance (ANOVA) using SAS software. The critical difference was calculated at 5% and 1% probability level.

Results

Chlorophyll contents (in terms of SPAD value)

Drought, high temperature and combined stress of drought + high temperature significantly decreased chlorophyll content by 11.41, 8.73 and 12.72%, respectively, compared with the optimum condition and when averaged across genotypes. The genotypes behaved differentially to these stresses (Table 1). Under the optimum condition, chlorophyll content ranged from 28.75 SPAD units for C 306 to 20.9 SPAD units for KO 307. Drought stress significantly decreased chlorophyll content in all genotypes, however, among genotypes maximum decrease in chlorophyll occurs in KO-307 (29.55%) and minimum decrease occurs in C-306 (4.35%). Among genotypes the adverse effect of high temperature on chlorophyll content was the highest in KO-307 (25.12 % decline over control) and the lowest in C-306 (2.6 % decline over control). Combined stress of drought + high temperature significantly decreased chlorophyll contents, and it was more detrimental, however result was hypo-additive in nature. Among genotypes the decline due to combined stress (drought + high temperature) was highest in KO 307 (30.02% over control) and lowest decline was reported in C 306 (4.66% over control).

Dry weight

Drought, high temperature and combined stress of drought + high temperature significantly decreased dry mass content by 22.93, 20.48 and 26.09%, respectively, compared with the optimum condition and when averaged across genotypes. The genotypes behaved differentially to these stresses (Table 2). Under the optimum condition, plant dry mass ranged from 34.8 mg plant^{-1} dry mass for C 306 to 22.2 mg pant^{-1} dry mass for KO 307. Drought stress significantly decreased dry mass content in all genotypes, however, among genotypes maximum decrease in dry mass occurs in KO-307 (43.69%) and minimum decrease occurs in C-306 (4.6%). Among genotypes the effect of high temperature on dry mass content was the highest in KO-307 (40.32 % decline over control) and the lowest in C-306 (3.74% decline over control). Combined stress of drought + high temperature significantly decreased total dry mass, and it was more detrimental, however result was hypo-additive in nature. Among genotypes the decline in dry mass due to combined stress (drought + high temperature) was highest in KO 307 (48.2% over control) and lowest decline was reported in C 306 (5.61% over control).

Fresh weight

Drought, high temperature and combined stress of drought + high temperature significantly decreased fresh weight content by 19.53, 14.86 and 21.93%, respectively, compared with the optimum condition and when averaged across genotypes. The genotypes behaved differentially to these stresses (Table 3). Under the optimum condition, fresh weight content ranged from 450 mg plant^{-1} for C 306 to 336 mg plant^{-1} for KO 307. Drought stress significantly decreased fresh weight content in all genotypes, however, among genotypes maximum decrease in fresh weight occurs in KO-307 (38.01%) and minimum decrease occurs in C-306 (5.22%). Among genotypes the effect of high temperature on fresh weight content was the highest in KO-307 (25.69 % decline in fresh weight over control) and the lowest in C-306 (3.33% decline in fresh weight over control). Combined stress of drought + high temperature significantly decreased fresh weight contents, and it was more detrimental, however result was hypo-additive in nature. Among genotypes the decline in fresh weight due to combined stress (drought + high temperature) was highest in KO 307 (47.84% over control) and lowest decline was reported in C- 306 (7.02% over control).

Root length

Drought, high temperature and combined stress of drought + high temperature significantly retarded root growth by 8.75, 7.6 and 10.91%, respectively, compared with the optimum condition and when averaged across genotypes. The genotypes behaved differentially to these stresses (Table 4). Under the optimum condition, root length ranged from 17.5 cm for C- 306 to 9.79 cm for KO-307. Drought stress significantly retarded root growth in all genotypes, however, among genotypes maximum reduction in root growth occurs in KO-307 (25.07%) and minimum reduction occurs in C-306 (2.43%). Among genotypes the effect of high temperature on root length was the highest in KO-307 (24.19 % decline over control) and the lowest in C-306 (1.68% decline over control). Combined stress of drought + high temperature significantly retarded root growth, and it was more detrimental, however result was hypo-additive in nature. Among genotypes the decline in root length due to combined stress (drought + high temperature) was highest in KO-307 (38.02% over control) and lowest decline was reported in C 306 (2.86% over control).

Shoot length

Drought, high temperature and combined stress of drought + high temperature significantly retarded shoot growth by 12.68, 10.1 and 14.41%, respectively, compared with the optimum condition and when averaged across genotypes. The

genotypes behaved differentially to these stresses (Table 5). Under the optimum condition, shoot length ranged from 18.75 cm for C-306 to 10.9 cm for KO-307. Drought stress significantly retarded shoot growth in all genotypes, however, among genotypes maximum reduction in shoot growth occurs in KO-307 (40.05%) and minimum reduction occurs in C-306 (4.27%). Among genotypes the effect of high temperature on shoot growth was the highest in KO-307 (25.23 % decline over control) and the lowest in C-306 (4.16% decline over control). Combined stress of drought + high temperature significantly retarded shoot growth, and it was more detrimental, however result was hypo-additive in nature. Among genotypes the decline in shoot growth due to combined stress (drought + high temperature) was highest in KO 307 (44.13% over control) and lowest was reported in C 306 (6.53% over control).

Discussion

All parameters were measured in 10 days old wheat seedlings under control and stress condition. Drought, high temperature and combined stress of drought + high temperature significantly decreased chlorophyll content (measured in terms of SPAD units) compared with the optimum condition. The genotypes behaved differentially to these stresses (Table 1). Combined stress of drought + high temperature significantly decreased chlorophyll contents, and it was more detrimental, compared to individual stress. Among twenty genotypes the decline due to combined stress (drought + high temperature) was highest in KO 307 and lowest decline was reported in C 306. This study showed that C-306 has potential to retain higher amount of leaf chlorophyll under drought, high temperature and the combined stress of drought + high temperature. Tolerant cultivars able to maintain significantly higher chlorophyll content compared to susceptible one. Pradhan *et al*. (2012) [11] also reported combined stresses decreased leaf chlorophyll by greater magnitude than by the drought or high temperature stress alone in all wheat genotypes. Wang *et al*. (2010) [14] recently reported similar effects of these stresses in transgenic and wild-type wheat seedlings. Our observations are also in agreement with the earlier ones reporting reduction in pigment contents due to heat stress in wheat (Krishna, 2011) [15] and mungbean (Chand, 2015) [4]. Drought stress activates the rapid relocation of metabolites from leaves resulting in a quick loss of chlorophyll and senescence (Yang *et al*., 2001) [16]. High temperature stress, in contrast, decreases chlorophyll content as a result of damaged thylakoid membranes (Ristic *et al*. 2007) [10] or lipid peroxidation of chloroplast membranes (Djanaguiraman *et al*. 2010) [3].

Drought, high temperature and combined stress of drought + high temperature significantly retarded the pigment contents, seedling dry mass, fresh weight, root length and shoot length compared with the control condition. The genotypes behaved differentially to these stresses (presented in Table 2, Table 3, Table 4 and Table5). Combined stress of drought + high temperature severely retarded/ affected the growth of seedling (measured in terms of decrease in dry mass, fresh mass, root and shoot length) and proved more detrimental compared to individual stress. Among genotypes adverse effect of combined stress (drought + high temperature) was more in KO 307 and lowest reported in C 306. This study showed that C-306 have more potential to maintain growth of seedling under drought, high temperature and the combined stress of drought + high temperature. This ability of C-306 may be due to significant enhancement of compatible solutes and antioxidant machinery. Agarwal *et al.* (2005) [1] also reported similar effects of moisture stresses in wheat (C-306) seedlings.

Table 1: Effect of drought, high temperature and combined stress on chlorophyll content (SPAD units) of 10 days old wheat seedling

SPAD units								
Genotypes	**Control**	**Drought**	**% Change (±)**	**High Temperature**	**% Change (±)**	**Drought+High Temperature**	**% Change (±)**	**Mean**
KO-307	20.90	14.73	-29.55	15.65	-25.12	14.63	-30.02	16.45
CSW-16	24.68	22.58	-8.51	23.25	-5.78	22.08	-10.54	23.14
RAJ4120	21.05	19.43	-7.72	19.78	-6.06	18.85	-10.45	19.78
HW2045	21.58	19.95	-7.53	19.88	-7.88	19.83	-8.11	20.31
CBW-38	26.98	21.75	-19.37	25.15	-6.77	20.75	-23.08	23.41
DPW621-50	24.20	22.70	-6.20	23.00	-4.96	21.50	-11.16	22.85
BRW-3708	22.88	19.98	-12.68	21.50	-6.01	19.98	-12.68	21.08
HD2985	21.73	19.93	-8.29	20.40	-6.10	18.35	-15.54	20.10
DBW-14	25.40	24.00	-5.51	24.10	-5.12	22.75	-10.43	24.06
WR-544	25.90	24.73	-4.54	24.93	-3.76	24.63	-4.92	25.03
HD-2888	21.65	19.08	-11.89	19.28	-10.97	18.70	-13.63	19.68
C-306	28.75	27.50	-4.35	28.00	-2.61	27.41	-4.66	27.94
DBW-16	26.95	24.55	-8.91	24.63	-8.63	24.43	-9.37	25.06
BRW-934	22.78	20.88	-8.34	21.20	-6.92	20.83	-8.56	21.42
BAAZ	24.45	22.50	-7.98	22.90	-6.34	22.38	-8.49	23.06
HP-1953	25.53	22.95	-10.09	23.25	-8.91	22.35	-12.44	23.52
HD-2967	21.25	18.33	-13.76	19.15	-9.88	15.55	-26.82	18.57
HP-1939	24.13	22.28	-7.67	23.08	-4.35	21.38	-11.40	22.71
HD-2824	23.53	18.75	-20.30	18.63	-20.83	18.00	-23.49	19.73
BRW-3711	26.18	22.00	-15.95	22.43	-14.33	21.83	-16.62	23.11
MEAN	24.02	21.28	-11.41	21.93	-8.73	20.97	-12.72	22.05
FACTORS	L.S.D (P=0.05)		L.S.D (P=0.01)	SEm±	Sign .F			
TRATMENT	0.70		0.88	0.24	**			
GENOTYPES	1.50		1.96	0.54	**			

Table 2: Effect of drought, high temperature and combined stress on dry weight of 10 days old wheat seedlings

Dry Weight (mg plant^{-1})								
Genotypes	**Control**	**Drought**	**% Change (±)**	**High Temperature**	**% Change (±)**	**Drought+High Temperature**	**% Change (±)**	**Mean**
KO-307	22.20	12.50	-43.69	13.25	-40.32	11.50	-48.20	14.86
CSW-16	34.85	27.65	-20.66	28.30	-18.79	28.30	-18.79	29.78
RAJ4120	24.70	20.60	-16.60	21.85	-11.54	19.23	-22.17	21.59
HW2045	24.15	18.90	-21.74	18.95	-21.53	18.85	-21.95	20.21
CBW-38	25.30	20.35	-19.57	21.50	-15.02	19.15	-24.31	21.58
DPW621-50	25.05	20.73	-17.27	20.75	-17.17	19.65	-21.56	21.55
BRW-3708	25.65	18.65	-27.29	21.65	-15.59	17.80	-30.60	20.94
HD2985	24.30	18.43	-24.18	18.50	-23.87	17.55	-27.78	19.70
DBW-14	34.85	30.35	-12.91	30.70	-11.91	30.43	-12.70	31.58
WR-544	24.50	19.80	-19.18	20.08	-18.06	20.40	-16.73	21.20
HD-2888	24.30	20.25	-16.67	16.25	-33.13	15.70	-35.39	19.13
C-306	34.75	33.15	-4.60	33.45	-3.74	32.80	-5.61	33.54
DBW-16	24.75	19.55	-21.01	21.58	-12.83	18.95	-23.43	21.21
BRW-934	24.40	16.30	-33.20	16.88	-30.84	15.80	-35.25	18.35
BAAZ	26.10	15.20	-41.76	17.55	-32.76	13.85	-46.93	18.18
HP-1953	24.60	18.40	-25.22	18.45	-25.00	18.10	-26.42	19.89
HD-2967	27.55	23.00	-16.52	25.40	-7.80	21.70	-21.23	24.41
HP-1939	24.15	17.65	-26.92	17.75	-26.50	17.10	-29.19	19.16
HD-2824	24.60	19.15	-22.15	19.65	-20.12	17.15	-30.28	20.14
BRW-3711	26.25	18.80	-28.38	19.50	-25.71	17.10	-34.86	20.41
MEAN	25.85	19.92	-22.93	20.56	-20.48	19.11	-26.09	21.36
Factors	L.S.D. (0.05)		L.S.D. (0.01)	S.E.M.	Sign .F			
Tratment	1.31		1.72	0.47	**			
Genotypes	2.92		3.85	1.05	**			

Table 3: Effect of drought, high temperature and combined stress on fresh weight of 10 days old wheat seedlings

Fresh Weight (mg plant^{-1})								
Genotypes	**Control**	**Drought**	**% Change (±)**	**High Temperature**	**% Change (±)**	**Drought+High Temperature**	**% Change (±)**	**Mean**
KO-307	336.45	208.55	-38.01	250.00	-25.69	175.50	-47.84	242.63
CSW-16	375.00	280.00	-25.33	292.05	-22.12	260.75	-30.47	301.95
RAJ4120	227.40	197.95	-12.95	218.80	-3.78	180.45	-20.65	206.15
HW2045	175.30	156.75	-10.58	165.55	-5.56	144.75	-17.43	160.59
CBW-38	214.10	161.15	-24.73	186.20	-13.03	154.60	-27.79	179.01
DPW621-50	209.30	181.40	-13.33	198.80	-5.02	179.15	-14.41	192.16
BRW-3708	175.80	145.25	-17.38	161.93	-7.89	141.60	-19.45	156.14
HD2985	174.60	147.65	-15.44	158.55	-9.19	134.60	-22.91	153.85
DBW-14	244.50	180.45	-26.20	194.60	-20.41	176.05	-28.00	198.90
WR-544	188.30	150.50	-20.07	153.55	-18.45	149.95	-20.37	160.58
HD-2888	168.45	143.80	-14.63	156.05	-7.36	121.35	-27.96	147.41
C-306	450.00	426.50	-5.22	435.00	-3.33	418.40	-7.02	432.48
DBW-16	203.30	175.60	-13.63	179.25	-11.83	179.75	-11.58	184.48
BRW-934	142.20	114.25	-19.66	116.40	-18.14	107.40	-24.47	120.06
BAAZ	224.25	169.55	-24.39	191.78	-14.48	165.75	-26.09	187.83
HP-1953	170.95	123.65	-27.67	133.53	-21.89	118.90	-30.45	136.76
HD-2967	178.40	141.45	-20.71	146.80	-17.71	136.85	-23.29	150.88
HP-1939	235.30	181.30	-22.95	192.50	-18.19	159.65	-32.15	192.19
HD-2824	121.40	92.50	-23.81	98.80	-18.62	85.35	-29.70	99.51
BRW-3711	198.30	137.75	-30.53	160.75	-18.94	134.00	-32.43	157.70
Mean	230.67	185.61	-19.53	196.38	-14.86	180.09	-21.93	198.19
Factors	L.S.D. (0.05)		L.S.D. (0.01)	S.E.M.	Sign .F			
Tratment	16.57		21.84	5.95	**			
Genotypes	37.05		48.83	13.30	**			

Table 4: Effect of drought, high temperature and combined stress on root length of 10 days old wheat seedlings

	Root Length (cm plant^{-1})							
Genotypes	**Control**	**Drought**	**% Change (±)**	**High Temperature**	**% Change (±)**	**Drought+High Temperature**	**% Change (±)**	**Mean**
KO-307	9.79	7.34	-25.07	7.43	-24.19	6.07	-38.02	7.66
CSW-16	15.10	13.58	-10.10	13.96	-7.57	13.33	-11.76	13.99
RAJ4120	13.39	12.75	-4.81	12.88	-3.83	12.68	-5.32	12.93
HW2045	15.55	14.67	-5.69	14.71	-5.43	14.22	-8.56	14.79
CBW-38	15.33	13.88	-9.46	13.90	-9.30	13.39	-12.60	14.12
DPW621-50	15.32	13.81	-9.83	14.03	-8.40	13.10	-14.48	14.07
BRW-3708	16.11	15.16	-5.90	15.44	-4.15	14.99	-6.98	15.43
HD2985	14.08	13.34	-5.26	13.40	-4.84	12.69	-9.85	13.38

DBW-14	13.43	12.68	-5.63	12.92	-3.83	12.03	-10.47	12.76
WR-544	13.72	12.59	-8.26	12.76	-6.97	12.21	-10.98	12.82
HD-2888	16.41	14.42	-12.15	15.50	-5.56	13.82	-15.80	15.04
C-306	17.50	17.08	-2.43	17.21	-1.68	17.00	-2.86	17.20
DBW-16	14.65	13.20	-9.90	13.55	-7.54	13.00	-11.24	13.60
BRW-934	11.63	10.73	-7.74	11.03	-5.16	10.71	-7.90	11.03
BAAZ	12.66	11.51	-9.13	11.45	-9.58	10.78	-14.91	11.60
HP-1953	15.49	14.31	-7.58	14.59	-5.78	13.41	-13.39	14.45
HD-2967	9.81	9.19	-6.31	9.23	-5.92	9.12	-7.07	9.34
HP-1939	14.40	13.23	-8.12	13.82	-4.04	12.48	-13.37	13.48
HD-2824	10.23	9.70	-5.13	9.80	-4.16	8.93	-12.71	9.66
BRW-3711	12.17	10.00	-17.82	10.26	-15.67	9.91	-18.54	10.59
Mean	13.84	12.63	-8.75	12.79	-7.60	12.33	-10.91	12.90
Factors	L.S.D(P=0.05)		L.S.D(P=0.01)	SEM	Sign .F			
Tratment	0.34		0.12	0.45	**			
Genotypes	0.77		0.28	1.01	**			

Table 5: Effect of drought, high temperature and combined stress on shoot length of 10 days old wheat seedlings

Shoot Length (cm plant^{-1})								
Genotypes	**Control**	**Drought**	**% Change (±)**	**High Temperature**	**% Change (±)**	**Drought+ High Temperature**	**% Change (±)**	**Mean**
KO-307	10.90	6.54	-40.05	8.15	-25.23	6.09	-44.13	7.92
CSW-16	15.38	13.00	-15.51	13.25	-13.85	12.61	-18.01	13.56
RAJ4120	15.17	13.93	-8.14	14.08	-7.19	13.38	-11.80	14.14
HW2045	15.20	12.89	-15.20	14.05	-7.57	12.30	-19.08	13.61
CBW-38	14.89	12.37	-16.92	12.50	-16.08	12.06	-19.01	12.95
DPW621-50	14.45	12.53	-13.32	12.60	-12.80	12.32	-14.78	12.97
BRW-3708	16.27	14.79	-9.07	14.91	-8.33	14.40	-11.47	15.09
HD2985	14.75	13.68	-7.29	13.70	-7.12	13.24	-10.24	13.84
DBW-14	14.45	13.43	-7.06	13.50	-6.61	12.89	-10.83	13.57
WR-544	15.88	14.64	-7.81	14.90	-6.14	14.50	-8.66	14.98
HD-2888	15.54	12.85	-17.31	14.65	-5.73	12.25	-21.17	13.82
C-306	18.75	17.95	-4.27	17.97	-4.16	17.53	-6.53	18.32
DBW-16	14.56	13.00	-10.72	13.33	-8.42	12.85	-11.71	13.43
BRW-934	12.70	11.56	-9.02	11.69	-7.99	11.53	-9.25	11.87
BAAZ	12.98	11.53	-11.18	11.65	-10.21	10.68	-17.73	11.71
HP-1953	12.88	10.33	-19.81	12.03	-6.60	10.15	-21.17	11.34
HD-2967	14.05	12.93	-8.01	13.05	-7.12	12.85	-8.54	13.22
HP-1939	10.65	8.50	-20.19	10.05	-5.63	7.40	-30.52	9.15
HD-2824	12.02	11.19	-6.95	11.25	-6.41	10.48	-12.85	11.23
BRW-3711	12.13	9.90	-18.35	10.13	-16.49	9.80	-19.22	10.49
Mean	14.18	12.38	-12.68	12.75	-10.10	12.14	-14.41	12.86
Factors	L.S.D (P=0.05)		L.S.D (P=0.01)	SEM	Sign .F			
Treatment	0.32		0.43	0.12	**			
Genotypes	0.72		0.95	0.26	**			

Conclusions

The genotypes behaved differentially to these stresses. Drought, high temperature and combined stress of drought + high temperature significantly retarded the chlorophyll contents, seedling dry mass, fresh weight, root length and shoot length as compared with the control condition. Combined stress of drought + high temperature proved more detrimental compared to individual stress, however, results was hypo-additive in nature which might be due to cross adaptation effect. Genotype C-306 showed least reduction in growth parameters and thus was more tolerant to the imposed stresses, while KO-307 showed highest susceptibility among the studied genotypes.

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