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Research Article

Evaluation of Wheat Genotypes under Irrigated, Heat Stress and Drought Conditions

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Abstract

The field research was conducted at the Bhairahawa, Nepal in 2016/17 and 2017/18 in order to determine the physio-morphological and yield potential traits associated with heat and drought tolerance in wheat genotypes. The plant material consists of 20 genotypes out of which 17 are advanced lines and 3 are commercial varieties of Nepal. The research was carried out in alpha lattice design with two replications under three different environmental condition i.e. fully-irrigated, late sown and drought condition. In each replication there were 5 blocks consisting of 4 plots. Each plot was 4 m in length and 2.5 m in width. Each plot consists of 10 rows with a spacing of 25 cm between the rows and there was continuous sowing in a row. Seed sowing on Irrigated and Drought condition was done in 23rd November 2016 and 2017, similarly, seed sowing on Heat stress environment was done on 28th December 2016 and 2017. Data recoding were done for days to heading, days to maturity, plant height, grain yield, spikes/m^2, number of grains per spike, thousand grain weights. The mean values of all yield potential traits in Heat stress and drought condition were less than in irrigated condition. Genotypes were significantly different for all phonological traits in irrigated heat stress and drought treatments. The mean number of days to heading for irrigated, drought and heat stress condition was 78.22, 76.58 and 60.8 respectively. The mean number of days to maturity for irrigated, drought and heat stress condition was 115.3, 110.41 and 99.25 respectively with the mean of 108 days. Similarly, mean plant height for irrigated, drought and heat stress condition was 89.53, 68.21 and 79.9 cm respectively with the mean of 81 cm. The mean spike/m^2 for irrigated, drought and heat stress condition was 340.025, 226.11 and 262.73 respectively with the mean of 276.28. Similarly, the mean NGPS for irrigated, drought and heat stress condition was 43.32, 36.68 and 37 respectively with the mean of 39. The mean TKW for irrigated, drought and heat stress condition was 45.06,40.25 and 36.025 g respectively with the mean 40.445 g. It was observed significant difference in genotypes and environments for yield and yield potential traits. Genotype by environment interaction showed significant difference for grain yield. The mean grain yield for irrigated, drought and heat stress condition was 3.3, 1.4 and 1.79 ton/ha respectively with the mean of 2.18 ton/ha. Under normal irrigated condition, BL4708 highest mean yield with 3731.5 kg/ha and NL1328 yield lowest mean yield of 2.65 ton/ha. In heat stress condition BL4699 had maximum mean yield of 2.22 ton/ha and NL1307 had minimum mean yield of 1.18 ton/ha. Similarly, in drought condition NL1327 had maximum mean yield of 2.0 ton/ha and NL1325 had minimum yield of 1.04 ton/hay.

Keywords: Wheat • Heat stress • Drought • Irrigated traits

Introduction

Triticum aestivum, commonly known as wheat, is a cereal grass placed in family poaceae. Many species of wheat including Triticum aestivum and Triticum durum collectively make the genus Triticum. Wheat (Triticum aestivum) is the largest food crop to cover the earth's surface (218.54 million hectares in 2017) and the second largest crop after maize in terms of the production (771.71 million tons in 2017) in the world [1]. Roughly 30.0% of the global cereal region is represented by wheat [2]. In general, late sowing wheat varieties faces severe temperature stress, shortens the heading and maturity duration, ultimately affecting final yield and grain quality [3,4]. Worldwide, wheat production was about 729.5 million tons in 2014, exceeding the 717.2 million tons produced in 2013 [5]. Given the growing world population, wheat productivity is expected to reach 3.5 tons per hectare by 2033 [6]. However, the demand for wheat is also increasing, and is predicted to increase by 2.0% annually [7]. Developing nations are the biggest importers of wheat, which comprises about 34.0% of their imported food [8]. The European Union recorded the highest Grain production in 2014 at 156.1 million tons followed by China, India, the United States, the Russian Federation and Canada. Kazakhstan, Argentina, Ukraine, Australia and the Russian Federation are major wheat exporters. In 2014, the global wheat trade recorded 153.0 million tons, while wheat use was 711.7 million tonnes. Asia is the biggest import region, followed by Africa, South America, Central America and Europe [9]. According to Consultative Group for International Agricultural Research (CGIAR), 215 million hectare of the land is dedicated solely for the growth of wheat each year. Wheat is used as human food and fodder for livestock. It is consumed by over 2.5 billion people all over the world. Wheat has a high content of starch (60-70%) and 6-26% protein content. It is a good source of carbohydrates, fibres, minerals (2.1%), fat (2.10%), vitamins and sugars and meets half of the energy demand of human population [10]. Wheat is the most important cereal crop cultivated in Nepal after rice and maize and is ranked at 3rd position both in order of area and productivity. It occupies 21.7% of total cereal crop area and contributes 19.7% of the total cereal production in the country. The productivity of wheat in Nepal is almost constant ranging from 1.9 to 2.5 t/ha and very low compare to other developed nation like New Zealand and Ireland and comparable with other Asiatic country like Bangladesh and world since 2006. Presently, area under cultivation, production and productivity of wheat is 7,06,843 hectares, 1.95 million metric tons and 2.757 tons/ha respectively [8]. Until 2017, Nepal Agriculture Research Council (NARC) has released and recommends 43 wheat varieties for different agro ecological domains, i.e. 26 for Terai and 17 for hills. But, 13 wheat varieties have been denotified and only 30 varieties are under cultivation (NWRP, 2018). Wheat has been growing since time immemorial particularly in Far and Mid-Western hills of Nepal. Iqbal reported many landraces and 10 wild relatives of wheat in Nepal [11]. It is the third most important crop after rice and maize in Nepal. During mid-1960s the yield potential of dwarf high yielding varieties initiated a scope for raising wheat production in the country. Several exotic varieties were obtained through CIMMYT and USAID (NARC 1997). National Wheat Development Programme was established in 1972 to organize the research and development works on wheat as a commodity crop. Since then, there has been great achievement brought out by the consolidated efforts of wheat researchers, extension workers and farmers. So far there are 35 improved wheat cultivars and 90% of the wheat area is covered by modern wheat cultivars in Nepal. Currently wheat is mainly used for bread and biscuits and is becoming more important in Nepalese economy. Genetic diversity is necessary to derive different transgenic segregants suitable for different agro-ecology to meet the needs of farmers. Both the potential for long term genetic gain and the reduction of genetic vulnerability may depend on the genetic diversity present in the genetic base. The level of genetic variation present in gene pools of most important crops has been analyzed by studying the pedigree relationship between cultivars. Kinship coefficients estimation of cultivars of oat, soybean, winter wheat, rice and barley has shown that a restricted number of ancestral genotypes account for a large proportion of the variation present in released cultivars. However Nepalese wheat cultivars possess great diversity because of using many ancestral genotypes to develop them. Richness on wheat taking into account the ancestors of cultivars and landraces should be assessed for effective conservation and utilization of wheat gene pools. Therefore we have focused here on landraces and its distribution in Nepal and countries from where genes were introduced through improved lines in Nepal.

Thirty-five improved bread wheat varieties suitable to hills, plains and Western regions of Nepal are real efforts of researchers to be released during the period from 1960 to 2001. More numbers of crosses involving many parental lines in cultivars like Annapurna 2, Annapurna 4, Bhrikuti, LR64, RR21, NP884 and NP809 indicate the effort of scientists to collect value genes in single genotype.

A total of 89 ancestors originated in 22 different countries were used to develop 35 cultivars. Mexico, India and Nepal are the origin countries for 35 cultivars. In Nepal four cultivars had been originated and maximum number of cultivars was originated in Mexico. Ancestors of aestivum and durum species having winter, spring and intermediate growth habit indicated the collection of wide gene pool.

Apart from yield potential, quality traits possessed by wheat seeds should be high temperature tolerance, drought tolerance and rust resistance. About 50 years ago, wheat in Nepal was cultivated only as a traditional crop but in 1960s Wheat genotypes that were photo insensitive and input responsive were introduced in Nepal from India because of it wheat turned into a commercial crop also in Nepal. On the road of evolution, wheat has gained appreciable genetic diversity form Emmer to the bread and Durum wheat. The number of wheat varieties being added to the database is increasing every year but due to modern breeding, the spectrum of genetic diversity is relatively reduced. Modern high yielding commercial varieties of wheat are being propagated discouraging the primitive wheat varieties leading to narrowed genetic diversity of wheat. The foundation for genetic improvement is genetic diversity. With narrowed genetic diversity, yield of a specie decreases in the face of abiotic stresses, e.g. drought and heat stress. Some plant varieties are more susceptible to abiotic stress and are known as susceptible plants while others wholly escape the adverse effects of stress. Wheat is the largest deficit item in the developing country food basket. Between 1970 and 2010, more than half of the increment in wheat consumption was met by increased wheat imports, and several countries became totally dependent on imports for wheat [12]. The Cereal Import Dependency Ratio, an indicator of a country's dependency on the import of cereals calculated as the average of three years by FAO, of Nepal was 1.2 in 1990. It has risen to 1.7% in 2000, 3.9% in 2014 and 7.6% in 2016 [11,12]. Nepal imported 0.19 million metric ton of wheat worth NRs. 5.2 billion (approx. 48 million USD) in 2016/17 [13]. Demand of wheat is rising and it is expected that by 2050 the requirement of wheat would be 60% higher than the present year. Food security is the major challenge faced by human race in the 21st century [14]. The uncertainty in environmental condition will cause a reduction of 7% in the global crop yield. The limiting factors among abiotic stresses for wheat production worldwide are drought and heat [15,16].

The cultivation of wheat will be most affected because wheat is vulnerable to high temperature, drought and heat stress. Main limiting factor for wheat cultivation in Nepal is lack of water for wheat cultivation and genetic makeup [18]. Wheat is a mesophytic plant so for cultivation of wheat temperature range is relatively narrow and ranges from 10°C-15°C during sowing and 21°C-26°C during the ripening period though there are varieties of wheat that can even grow at 35°C. With every passing year, there is change in rainfall patterns, increase in Carbon dioxide and other greenhouse gases concentration along with decrease in annual precipitation [19]. The period 1980 to 2015 has been the warmest period of the 1400 year duration; global temperature has risen to about 0.85°C during this period. This climate change will have lethal effects on the natural systems. In many regions of the world there is alteration in the precipitation patterns and snow is melting. One of the consequences of climate change will be the reduced crop yield and it is believed to be the major risk in the realm of agriculture [13]. Among all the crops, wheat production will be highly reduced due to rise in temperature. If the global temperature rise just 1°C it would lead to fall in global wheat yield. Heat stress reduces the number of grains leading to lower harvest index in wheat [20]. However, the influence of heat stress on both the number and size of grains varies with the growth stages encountering heat stress. For instance, temperatures above 20°C between spike initiation and anthesis speed up the development of the spike but reduce the number of spikelets and grains per spike [21]. Theoptimum temperature for wheat anthesis and grain filling ranges from 12 to 22°C [10]. Plants exposed to temperatures above >24°C during reproductive stage significantly reduced grain yield and yield reduction continued with increasing duration of exposure to high temperature [22], Photosynthesis is the most sensitive physiological event leading to poor growth performance in wheat [23]. A major effect of heat stress is the reduction in photosynthesis resulting from decreased leaf area expansion, impaired photosynthetic machinery, premature leaf senescence, and associated reduction in wheat production [24,25]. In general, late sowing wheat varieties faces severe temperature stress, shortens the heading and maturity duration, ultimately affecting final yield and grain quality [3,4]. Along with heat stress climate change would come with other problems one of them is drought. Drought is a period of dry weather that can extend from months to years and area under drought does not receive normal amount of rain. Temperature rise of 1°C increases evapotranspiration to about 3%-5%. Water requirement of wheat crop is estimated to be 266.8-500 mm which is much higher as compared to water requirement of other crops including maize [26]. Wheat yield is strongly influenced by the availability of water. By 2050, there is utter need for increasing crop yield from 50% to meet the requirements of increasing population. Breeders are striving for development of wheat varieties that can withstand heat and water stress.

Materials and methodology

Description of experimental site

The field experiment was conducted at Bhairahawa, Rupandehi, Nepal. Geographic location of the research site is 27º30 N and 83º27 E and at the altitude of 79 m above the sea level. This site has a humid sub-tropical climate where summers are hot and winters are cold with total annual rainfall as 1725.3 mm.

Soil properties

Soil sample was taken from the field after land preparation. The soil was air dried, ground sieved through mortar and pestle. The soil characteristics (Table 1) were analysed in National Wheat Research Program (NWRP), Bhairahawa. The details of the soil analysis are given below.

Agro-metrological features

The agro-metrological information was collected from National Wheat Research Programme (NWRP), Bhairahawa, which is the nearest meteorological station from the research sites (Figure 1).

Plant materials

A set of 20 wheat genotypes were obtained from National Wheat Research Program (NWRP), Bhairahawa, Nepal. There were 4 Bhairahawa Lines (BL), 13 Nepal Lines (NL) and 3 commercial varieties. Bhrikuti, RR21 and Gautam were used as the standard check variety which was released as variety of Nepal. The complete sets of genotype with their entry names are presented in the Table 2.

Design of the experimental plot and treatment combination

The field experiment was conducted following Alpha Lattice design (Figure 2) with five blocks and the block size of 4 plots, replicated twice, Irrigated as normal condition, drought as water stress and heat stress condition as late season. In each replication there were 5 blocks consisting of 4 plots. Each genotype was planted in a plot size of 10 m^2 (4 m × 2.5 m). Each plot was provided with rows with spacing of 25 cm between rows and there was continuous sowing as in line sowing method. There was gap of 0.5 m in each plot and 1 m gap between two replications.

Field preparation, sowing and crop management

The field was prepared by using tractor for deep ploughing followed by two harrowing with disc and with one manual levelling. The line sowing was done on 24th November for irrigated and drought stress condition and 24th December for heat stress condition at the seed rate of 120 kg/ha.

Fertilizer dose

Irrigated and heat stress condition: Compost manure at the rate of 5 ton/ha and the individual plots was fertilized with recommended dose of 100:50:25 kg NPK/ha. All the phosphorus, potash and half dose of nitrogen were applied before sowing. The remaining dose of nitrogen was applied in two split dose: a quarter at 30 DAS and the last dose at 70 DAS. One manual weeding was done during heading stage of plants. Five irrigations (Table 3) were given to irrigated and heat stress trail which are shown below whereas no irrigation was provided to drought condition.

Drought condition: Compost manure at the rate of 5 ton/ha and the individual plots was fertilized with recommended dose of 50:50:20 kg NPK/ha. All dose of fertilizer were applied before sowing.

Table 1: Details of soil analysis.

Particulars	Physical properties	Organic matter (%)	Total Nitrogen (%)	Phosphorus (kg/ha)	Potash (kg/ha)	pH
Soils of the experimental site, Pakhlihawa	Clay loam	3.351	0.49(high)	187.53(high)	123.11	5.2 (acidic)

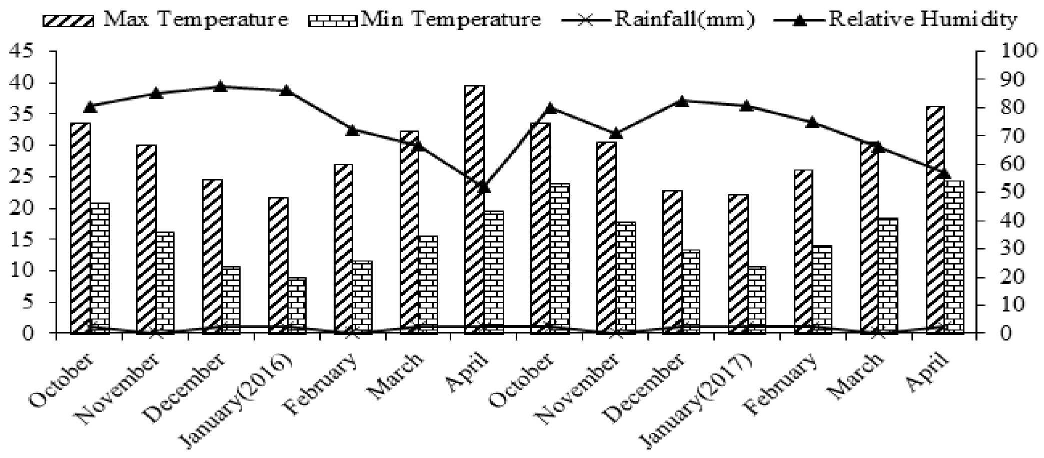

Figure 1: Agro-metrological data (2016-2018) of research site.

Table 2: List of genotypes used for the field experiment.

S.No	Genotypes	Source	Parentage	Released year
1	BL4335	Bhairahawa	n.d	n.d
2	NL1202	Mexico	n.d	n.d
3	NL1207	Mexico	n.d	n.d
4	NL1211	Mexico	n.d	n.d
5	NL1244	Mexico	n.d	n.d
6	NL1247	Mexico	n.d	n.d
7	NL1253	Mexico	n.d	n.d
8	NL1254	Mexico	n.d	n.d
9	BL4699	Bhairahawa	n.d	n.d
10	BL4707	Bhairahawa	n.d	n.d
11	BL4708	Bhairahawa	n.d	n.d
12	NL4307	Mexico	n.d	n.d
13	NL1260	Mexico	n.d	n.d
14	NL1325	Mexico	n.d	n.d
15	NL1326	Mexico	n.d	n.d
16	NL1327	Mexico	n.d	n.d
17	NL1328	Mexico	n.d	n.d
18	BHRIKUTI	Mexico	CMT/COC75/3/PLO//FURY/ANA75	1994
19	RR21	India	1154-388/AN/3/YT54/NIOB/RL64	1971
20	GAUTAM	Nepal	SIDDHARTH/NING8319/NL297	2004

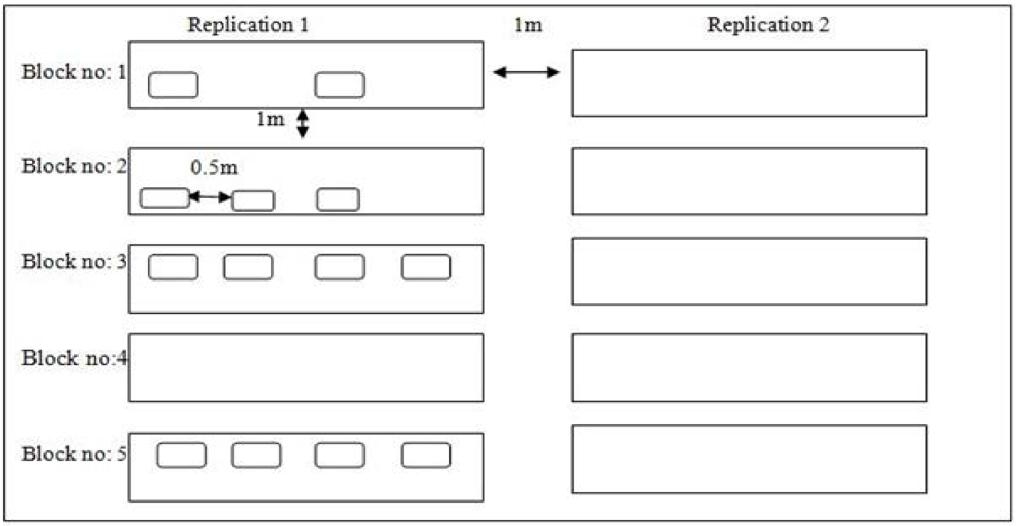

Figure 2: Experiment layout of the field in alpha lattice design.

Harvesting and threshing: Harvesting was done manually by using serrate edges sickles when the grains were dried enough, and awns colour had turned to straw colour. Harvesting of 1 m² of each plot were kept in different tagged plastic bags whereas total yield of plot was harvested ignoring first row from sides of the plot and also packed in another plastic bag. Harvested wheat was threshed on the floor by beating through sticks and hands.

Observations recorded

10 plants per genotype per replication were randomly selected except the boundary rows for data readings. The observations were taken for following parameters:-

Days to heading: The date of heading was recorded on all the plots when the 50% of the plants exposed their heads out from flag leaf sheath and it were converted to DAS.

Days to maturity: The maturity date was recorded when the 50% of the plants in the plot had their peduncle yellow and converted to days after sowing.

Plant height: It was measured from the soil surface in centimetre up to the height of the uppermost flag leaf angle spikelet at the time of harvesting.

Number of spikes/m^2: Number of spikes per meter square were counted at the time of harvest and recorded.

Table 3: Irrigation scheduling of wheat for irrigated and heat stress condition.

Irrigation	Stage of plant
1st	Crown Root Initiation(CRI)
2nd	Heading
3rd	Flowering
4th	Milking stage
5th	Soft dough stage

Number of grains per spike: The number of grains in the main spike were counted at the time of harvest and recorded.

Grain yield: Grain yield per meter square were expressed in gram per plot and this value was converted to ton per hectare.

Thousand kernel weight (Test Weight): After harvesting, 500 seeds rom each plot were randomly counted and weighted. The value was then converted to thousand grain weight

Statistical analysis

Data entry and processing was carried out using Microsoft Office Excel 2010. Analysis of variance of all the parameters and calculation of means was done by using R3.5.0 a software package for alpha lattice design by ADEL-R (CIMMYT Mexico).

Result

Grain yield

There was highly significant (P<0.001) difference in grain yield for the genotypes in irrigated, drought and heat stress environments and highly significant in combined environment (Table 8). The mean grain yield for irrigated, drought and heat stress condition was 3328.02, 1435.93 and 1793.65 kg/ha respectively with the mean of 2186 kg/ha. Under normal irrigated condition, BL4708 highest mean yield with 3731.5 kg/ha and NL1328 yield lowest mean yield of 2653.25 kg/ha. In heat stress condition BL4699 had maximum mean yield of 2226.25 kg/ha and NL1307 had minimum mean yield of 1185 kg/ha. Similarly, in drought condition NL1327 had maximum mean yield of 2005.75 kg/ha and NL1325 had minimum yield of 1042.5 kg/ha (Table 4, Figure 3).

Days of Maturity (DOM)

There was highly significant (p<0.001) difference in days to maturity

Table 4: Mean of Yield and yield attributing character of stress and non-stress condition.

S.No	Genotype	Grain Yield (GY)				Days of Maturity (DOM)			
		Heat stress	Irrigated	Drought	Overall	Heat stress	Irrigated	Drought	Overall
1	NL_1326	2173.25	3101.75	1458.25	2226.649	97	113.75	103.25	105.0334
2	NL_1244	1455.25	3034.75	1714	2108.318	99.75	115.5	112	108.9929
3	NL_1202	1277	3603.25	1548.75	2316.001	100.5	116.25	109.5	108.4399
4	BHRIKUTI	2152.5	3516	1611	2336.557	99.25	112.75	109	107.1692
5	RR_21	1720	3134.75	1179.5	2070.635	100.25	115	109.5	108.2044
6	NL_1327	1641.5	3519.75	2005.75	2311.661	100.5	115.25	110.5	108.6939
7	GAUTAM	1796.75	3150	1372.5	2138.256	99.5	116	112	109.0378
8	NL_1307	1185	3323.5	1385.75	2047.081	100.5	117.25	113.5	110.1694
9	BL_4708	2110.5	3731.5	1473.75	2345.246	97	115.75	110	107.6194
10	BL_4699	2226.25	3249.25	1591.75	2303.362	98.25	115.25	113	108.7519
11	NL_1207	1277	3296.25	1308.25	2037.261	100.5	116.5	116.25	110.741
12	NL_1211	1714.5	3596.75	1444.25	2231.743	100.25	116.25	111.5	109.251
13	NL_1325	1830.25	3714.25	1042.5	2196.88	99.25	115.75	112.5	109.1368
14	NL_1253	2038.75	3356.25	1459.5	2243.702	99.5	115.25	108	107.6914
15	NL_1260	1805.25	3423.5	1163.75	2149.451	97.5	114	107.75	106.6124
16	BL_4707	1813.5	3666	1293.75	2231.325	99.75	115	110.75	108.5002
17	NL_1247	1798.25	2912.75	1409.5	2089.171	99	115.25	112	108.7709
18	NL_1254	1274.75	3511.5	1377.5	2100.068	100.25	116.25	110.5	108.9676
19	NL_1328	1707.5	2653.25	1307.5	1999.858	100.5	116.25	111.5	109.2195
20	BL_4335	2147	3065.5	1541.25	2227.526	97	112.75	105.25	105.4136
Mean		1793.65	3328.025	1434.938		99.25	115.3	110.4125	
CV		12.05939	7.686496	13.77501		0.71245	0.576392	1.057183	
M Serror		46787.13	65438	39070.55		0.5	0.441667	1.3625	
LSD		305.9446	361.8218	279.5789		1.000149	0.939998	1.651003	

for the genotypes in irrigated, Drought and heat stress environments as well as in combined environment (Table 8). The mean number of days to maturity for irrigated, drought and heat stress condition was 115.3, 110.41 and 99.25 respectively with the mean of 108 days (Table 4). Under normal irrigated condition, BL4335 and Bhrikuti maturity was earliest with the mean of 112.75 days and NL1307 maturity was the last in 117.25 days. In Heat stress condition NL1326, BL4335 and BL4708 mature earliest with the mean of 97 days and NL1202, NL1327, NL1207 and NL1328 maturity was last in 100.5 days. Similarly in drought condition NL1326 matured earliest and it took 103.25 days while NL1207 took longest days of maturity i.e. 116.25 days (Figure 4).

Days of heading

There was highly significant (P<0.001) difference in days to eading for the genotypes in irrigated, Drought and heat stress environments as well as in combined environment (Table 8). The mean number of days to heading for irrigated, drought and heat stress condition was 78.22, 76.58 and 60.8 respectively with the mean of 71.87 days (Table 5). Under normal irrigated condition, BL4335 heading was earliest with the mean of 73.5 days and NL1207 heading was the last in 81.5 days. In heat, stress condition NL1326 headed earliest with the mean of 57 days and BL4707 heading was last in 63.75 days. Similarly, in drought condition NL1326 headed earliest and it took 69 days while NL1207 took longest days of heading i.e. 84 days (Figure 5).

Plant height

There was highly significant (P<0.001) difference in plant height for the genotypes in irrigated, drought and heat stress environments as well as in combined environment (Table 8). The mean plant height for irrigated, drought and heat stress condition was 89.53, 68.21 and 79.9 cm respectively with the mean of 81 cm (Table 5). Under normal irrigated condition, BL4699 highest mean plant height with 104.75 cm and Bhrikuti had lowest mean plant height of 77.25 cm. In Heat stress condition BL4699 had maximum mean plant height of 88.5 cm and NL1327 had minimum mean plant height of 73.75 cm. Similarly in Drought condition BL4335 had maximum mean plant height of 73.25 cm and NL1325 had minimum plant height of 62.5 cm (Figure 6).

Spikes/m^2

There was highly significant (P<0.001) difference in spike/m^2 for the genotypes in irrigated, drought and heat stress environments as well as in

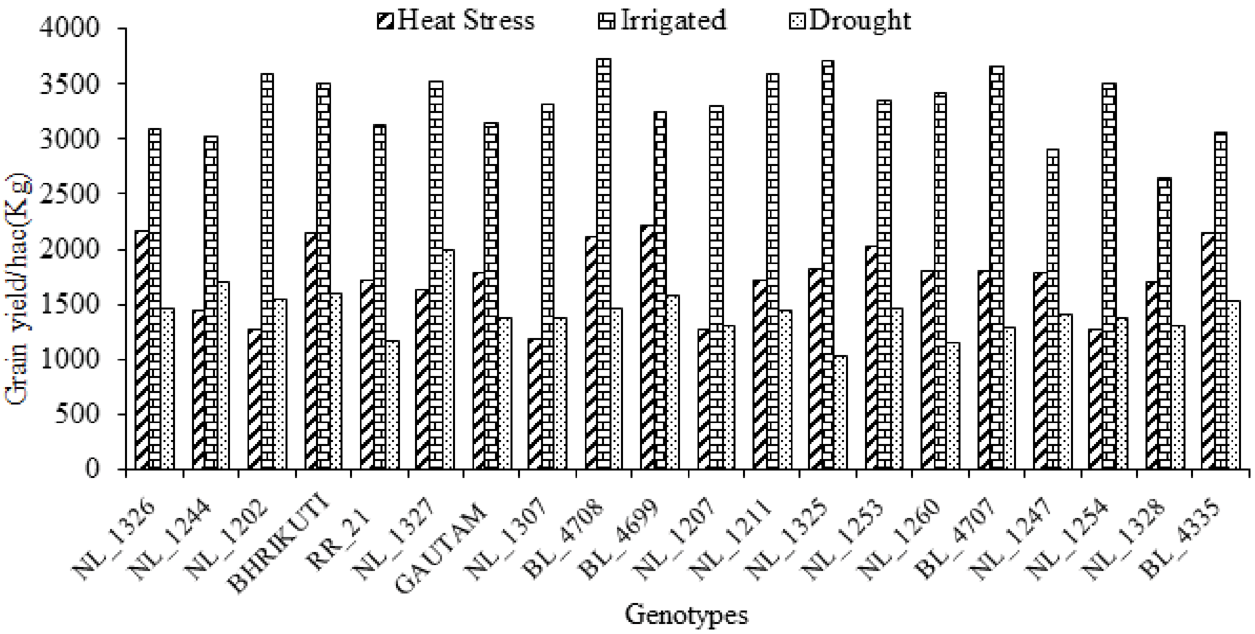

Figure 3: Mean of Grin yield of 20 genotypes at irrigated, heat stress and drought condition.

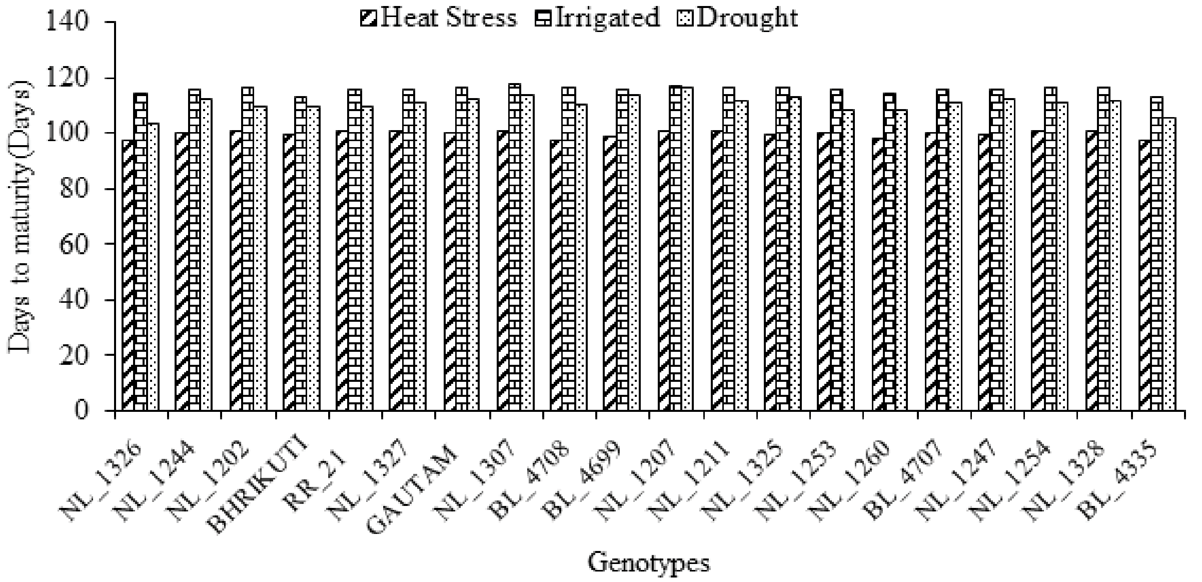

Figure 4: Mean of days of maturity of 20 genotypes at irrigated, heat stress and drought condition.

Table 5: Mean of days of heading and plant height of stress and non-stress condition.

S.No		Days of Heading (DOH)				Plant Height (PH)			
	Genotype	Heat stress	Irrigated	Drought	Overall	Heat stress	Irrigated	Drought	Overall
1	NL_1326	57	75	69	67.31139	77.75	92.5	70	82.05085
2	NL_1244	62	80.5	78.5	73.54815	80.75	94.5	67.75	83.26236
3	NL_1202	61	80	75.75	72.24431	76.75	83.5	69.5	78.7652
4	BHRIKUTI	60	75	74.75	70.04978	78.75	77.25	70.5	77.13306
5	RR_21	60	75.5	74.25	70.04081	84.25	91.75	69	83.82775
6	NL_1327	62.75	78.5	76.5	72.54184	73.75	88.5	64.75	78.13137
7	GAUTAM	60.75	78	76.75	71.8254	87.5	91.5	69.75	85.01616
8	NL_1307	61	79.75	80	73.45716	80.5	90	65	81.40575
9	BL_4708	57.5	78	76.75	70.82216	79.5	94.75	71.25	83.40132
10	BL_4699	60.25	79.25	78.75	72.6776	88.5	104.75	71.25	90.60529
11	NL_1207	63.25	81.5	84	75.96543	77.5	87.5	68.5	79.93563
12	NL_1211	63	80.25	78.25	73.71839	80.75	95.25	66.75	83.50217
13	NL_1325	59.75	75.75	77.25	70.97529	74.75	84.25	62.5	76.74342
14	NL_1253	60.5	76.25	72	69.73796	77.5	84	63.75	77.92917
15	NL_1260	59.5	76	74.25	70.03973	76.25	91.5	67.75	80.57459
16	BL_4707	63.75	79.5	78	73.63393	81.75	91.5	71	83.04383
17	NL_1247	61	81	78	73.25522	81.25	86.75	68	80.82499
18	NL_1254	62	80	74.75	72.22183	75.25	82.75	66	77.09012
19	NL_1328	63.25	81.25	79.25	74.39337	78.5	81.75	68	78.13997
20	BL_4335	58.5	73.5	74.75	69.12358	86.5	96.5	73.25	87.01699
Mean		60.8375	78.225	76.575		79.9	89.5375	68.2125	
CV		1.633417	1.125396	1.379986		4.216491	3.846654	5.699073	
M Serror		0.9875	0.775	1.116667		11.35	11.8625	15.1125	
LSD		1.405556	1.245175	1.494657		4.765161	4.871557	5.498545	

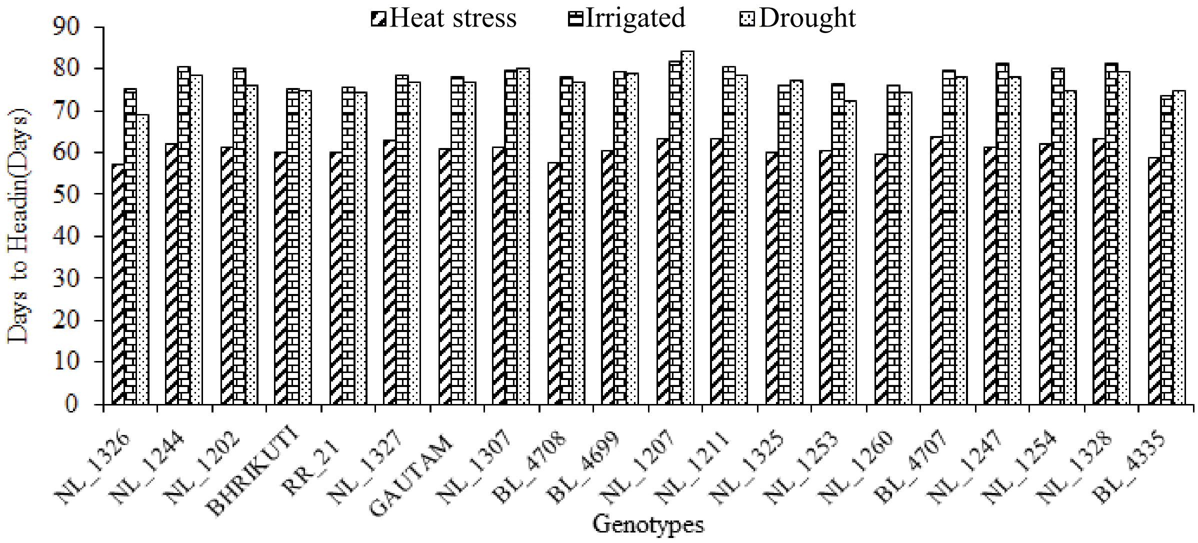

Figure 5: Mean of days of heading of 20 genotypes at irrigated, heat stress and drought condition.

combined environment (Table 8). The mean spike/m^2 for irrigated, drought and heat stress condition was 340.025, 226.11 and 262.73 respectively with the mean of 276.28. Under normal irrigated condition, NL1328 highest mean spike/m^2 with 405.25 and BL4334 had lowest mean Spike/m^2 of 29.75. In Heat stress condition BL4707 had maximum mean spike/m^2 of 306.75 and NL1307 had minimum mean spike/m^2 of 194.5. Similarly, in Rain fed condition NL1244 had maximum mean Spike/m^2 of 278 and BL4335 had minimum Spike/m^2 of 147 (Table 6 and Figure 7).

Number of grain/spike (NGPS)

There was highly significant ($p<0.001$) difference in NGPS for the genotypes in irrigated, Drought and heat stress environments as well as in combined environment (Table 8). The mean NGPS for irrigated, drought and heat stress condition was 43.32, 36.68 and 37 respectively with the mean of 39. Under normal irrigated condition, NL1327 highest mean NGPS with 53 and NL1328 had lowest mean NGPS of 35. In Heat stress condition NL1307 had maximum mean NGPS of 51.5 and NL1207 had minimum mean NGPS of

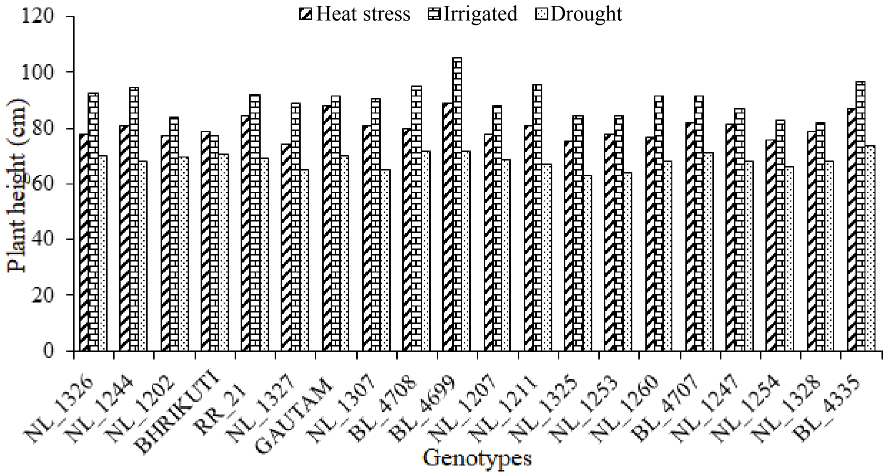

Figure 6: Mean of plant height of 20 genotypes at irrigated, heat stress and drought condition.

Table 6: Mean on number of grains per spike and spike per m² of stress and non-stress condition.

S.No	Genotype	Number of Grain Per Spike (NGPS)				Spike per m²			
		Heat stress	Irrigated	Drought	Overall	Heat stress	Irrigated	Drought	Overall
1	NL_1326	41.25	45.75	42.5	42.16573	293.75	371	263.25	299.9305
2	NL_1244	40.25	42	46	41.83939	294.5	345.75	278	297.6106
3	NL_1202	36.75	43.25	38.5	39.46497	232.75	312.5	251.75	268.5706
4	BHRIKUTI	40.75	43.75	39.25	40.74267	271.5	359	218.5	281.031
5	RR_21	30.25	38.25	34.25	35.37705	236.75	313	187.75	254.2961
6	NL_1327	36.5	53	40.25	42.19181	250.25	304.5	231.75	266.0531
7	GAUTAM	40.25	40.75	43.25	40.83569	241	360.25	257.25	283.3109
8	NL_1307	51.5	39.25	37.75	41.96035	194.5	321	222.75	254.4889
9	BL_4708	35	47	38.25	39.86756	233	357.25	260.25	281.3785
10	BL_4699	39	44.75	33.5	39.07514	302	313.5	269.75	289.7132
11	NL_1207	22	41.75	32.25	33.64593	272.5	332.25	203.75	271.3093
12	NL_1211	41	43	31.25	38.55701	247.5	302	223.25	262.7338
13	NL_1325	46	46.75	34.5	41.58869	275.5	357.5	222.5	282.5579
14	NL_1253	39.5	47.5	35.25	40.35797	279.75	330.25	233	279.5933
15	NL_1260	32	44.5	38	38.41576	242	345.5	224.5	272.1484
16	BL_4707	32.5	45.25	35	37.91916	306.75	368.5	174.75	281.2656
17	NL_1247	33.75	45.75	29.25	36.87483	296.75	358.75	213	285.702
18	NL_1254	39.75	42	35.75	39.1077	271.75	350	224.75	280.4182
19	NL_1328	31.75	35	35.25	35.14457	234.25	405.25	214.75	282.268
20	BL_4335	30.25	37.25	33.75	34.95136	258	292.75	147	244.7866
Mean		37	43.325	36.6875		261.7375	340.025	226.1125	
CV		10.40628	8.79417	8.731894		9.599415	6.136443	10.68074	
M Serror		14.825	14.51667	10.2625		631.2792	435.3667	583.2458	
LSD		5.445992	5.389061	4.531127		35.53779	29.51259	34.15903	

22. Similarly in drought condition NL1244 had maximum mean NGPS of 46 and NL1247 had minimum NGPS of 29.25(Table 6 and Figure 8).

Thousand Kernel Weight (TKW)

There was highly significant (p<0.001) difference in TKW for the genotypes in irrigated, Drought and heat stress environments as well as in combined environment (Table 8). The mean TKW for irrigated, drought and heat stress condition was 45.06, 40.25 and 36.025 g respectively with the mean 40.445 g. Under normal irrigated condition, BL4335 highest mean TKW with 52.25 g and NL1326 had lowest mean TKW of 38.75 g. In Heat stress condition BL4335 had maximum mean TKW of 47 gm and NL1244 had minimum mean TKW of 29.75 g. Similarly in Drought condition BL4335 had maximum mean TKW of 47.25 g and NL1244 had minimum TKW of 35 g (Table 7 and Figure 9).

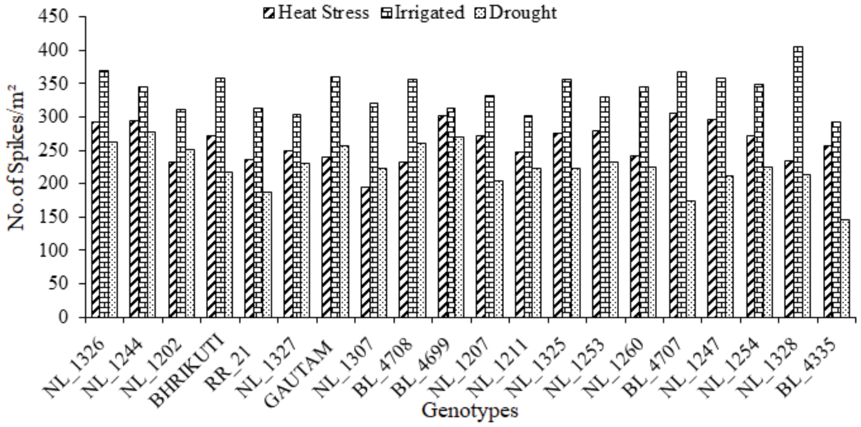

Figure 7: Mean of number of Spikes/m^2 of 20 genotypes at irrigated, heat stress and drought condition.

Table 7: Mean of test weight.

S.N	Genotype	Test Weight (TW)			
		Heat stress	Irrigated	Drought	Overall
1	NL_1326	33	38.75	36.75	36.33327
2	NL_1244	29.75	41	35	35.45229
3	NL_1202	41	47.25	40.5	42.82047
4	BHRIKUTI	33.75	40.25	38	37.45451
5	RR_21	35	45.25	43.5	41.21869
6	NL_1327	37.5	48.75	42	42.66029
7	GAUTAM	39.5	48.25	45	44.10189
8	NL_1307	30.75	46.5	37.75	38.41558
9	BL_4708	39.75	46.25	41.5	42.42003
10	BL_4699	38.75	48.75	43.25	43.46118
11	NL_1207	33	43	38	38.09522
12	NL_1211	37.75	51.5	43.25	44.0218
13	NL_1325	30.5	41.75	38.5	37.05407
14	NL_1253	37	46.5	41.5	41.61914
15	NL_1260	35	43	36.75	38.33549
16	BL_4707	36	44.5	43	41.1386
17	NL_1247	35	41	37.5	37.93505
18	NL_1254	35	46.5	38.5	40.01736
19	NL_1328	35.5	40.25	37.5	37.85496
20	BL_4335	47	52.25	47.25	48.50678
Mean		36.025	45.0625	40.25	
CV		2.645566	2.518015	2.913302	
M Serror		0.908333	1.2875	1.375	
LSD		1.348038	1.60492	1.658559	

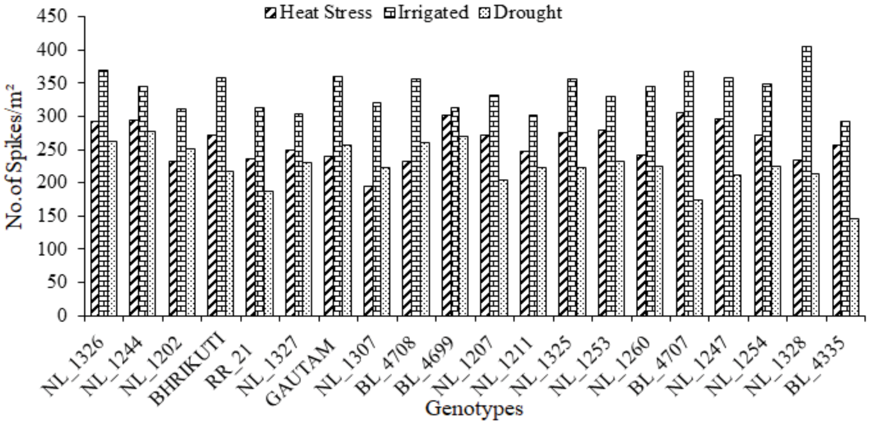

Figure 8: Mean of NGPS of 20 genotypes at irrigated, heat stress and drought condition.

Table.8: Combined analysis of ANOVA by environment and year.

Environment	Statistic	BLUP_DOH	BLUP_DOM	BLUP_PH	BLUP_Spike_m2	BLUP_NGPS	BLUP_TKW	BLUP_Yield
overall	Heritability	0.935465	0.895285	0.884571	0.718865	0.769388	0.961067	0.655449
overall	Genotype Variance	4.675694	2.238563	15.03176	281.7774	9.074181	11.32083	17970.08
overall	GenxLoc Variance	1.360223	1.246409	5.08645	321.5274	8.203266	2.007675	29707.01
overall	Residual Variance	1.150289	0.649135	9.442269	679.3246	16.23164	1.487939	53942.23
overall	Grand Mean	71.87917	108.3208	81.42	275.9583	39.00417	40.44583	2185.538
overall	LSD	1.09489	0.978424	2.819215	17.96603	2.936074	1.326456	161.1301
overall	CV	1.492109	0.743799	3.774045	9.444852	10.32928	3.015912	10.62689
overall	n Replicates	2	2	2	2	2	2	2
overall	n Environments	6	6	5	6	6	6	6
overall	Genotype significance	8.79E-21	4.42E-14	9.44E-12	5.35E-05	2.65E-06	6.96E-29	0.001312
overall	GenxEnv significance	1.20E-09	5.24E-14	0.000957	0.000714	0.000707	5.26E-11	0.000309

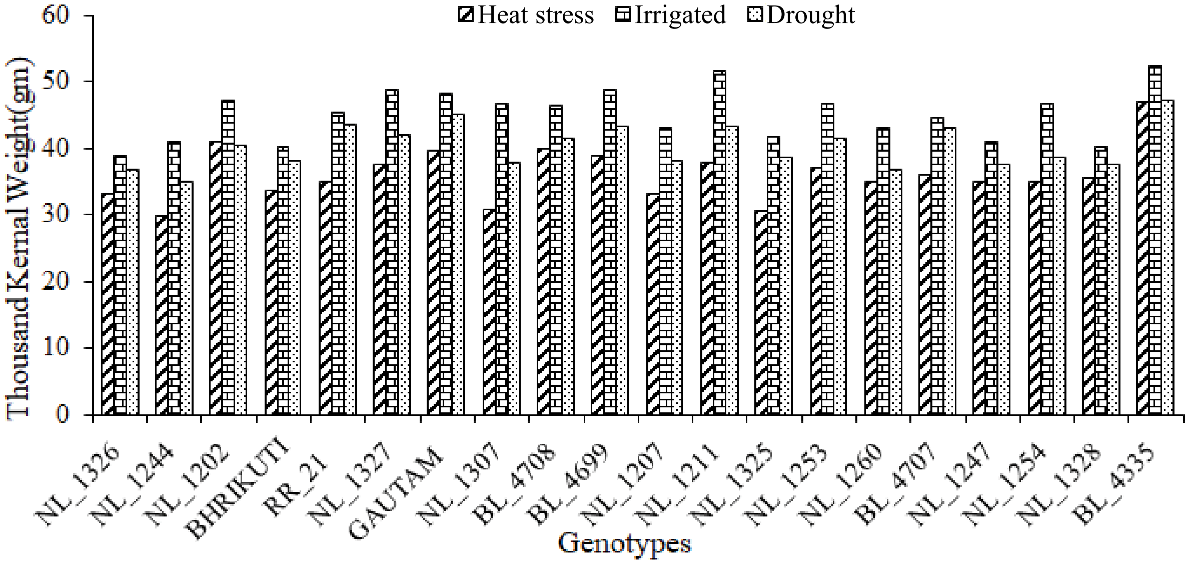

Figure 9: Mean of TKW of 20 genotypes at irrigated, heat stress and drought condition.

Discussion

Yield attributing character

Highly Significant genotypic differences were observed for all agro-morphological traits which were in agreement with the findings by Singh et al. [27].

Days of Heading (DOH)

Significant reduction of DOH is due to heat stress condition is in agreement with the findings by Din et al., [28,29]. It seems to be caused mainly due to the shortening of life cycle as a result of terminal heat stress associated with late planting.

The reduction of DOH also occurs at drought condition. Matching of the growth duration of plants to soil moisture availability is the critical to realize high seed yield [30]. Araus et al. reported that the drought escape occurs when phenological development is successfully matched with the periods of soil moisture availability and where crop growth season is shorter and terminal drought stress occurs [31]. High yields can be reached when the growth stages of booting and flowering, heading and milking are provided with sufficient quantities of water [32]. Selection of early maturing genotypes has been an effective strategy for minimizing the yield loss from terminal drought stress in which crop growth duration has been shortened.

Days to Maturity (DOM)

The highly significant (p<0.001) difference for days to maturity of genotypes in all environment suggested the genotypes were fall into different maturity group. Combined ANOVA revealed a significant effect of DOM. It had been confirmed with the findings of others. The interaction between genotype and environment was highly significant and it showed variability across environment. The reduction of days to maturity under heat stress condition is also reported by other scientist [33]. Heat stress ranging from 28°C to 30°C may alter the plant growth duration by reducing seed germination and maturity periods. Warm environment produces lower biomass compared to plants grown under optimum or low temperature. In wheat, grain-filling duration may be decreased by 8-12 days with the increase of 5°C temperature above 20°C [34]. The increase in night temperature is more responsive, shortens the grain-filling period, and reduces the grain yield than that of day temperature. Night temperatures of 20°C and 23°C reduced the grain-filling period by 3 to 7 days [35]. Recently, Song et al. observed a significant reduction in the rate of grain filling in wheat cultivars at day/night temperature of 32/22°C when compared with that of 25/15°C [36].

The decrease in maturity days under drought is controlled by the lower of nutrients in the plants which decreased chlorophyll in leaves due to the lack of nitrogen needed for the assimilation. The loss of the chloroplast integrity in the leaf causes the early senescence in drought that ultimately leads plant to mature early. It is generally known that the duration of maturity of wheat crop is reduced by delayed planting than the optimum time. Wheat grown under heat stress conditions is exposed to low temperature up to booting stage, but the later stages face higher temperature that inhibits grain development, resulting into poor grain yield [37]. In wheat, period from onset of spike ignition to flowering is very sensitive to temperature acceleration and it seems to be the main reason for reduction in sink size under high temperature conditions. Delayed planting affects the production of wheat by causing reduction in duration of grain filling phase, kernel size, biomass, tiller number, etc.

Plant height

Delayed planting significantly reduced plant height, days to heading and maturity. This is in agreement with the findings by Singh et al. [37]. It seems to be caused mainly due to the shortening of life cycle as a result of terminal heat stress associated with late planting. Decrease in plant height in late sown condition might be due to increased air temperature in vegetative stage of late sown wheat. Increased air temperature stops vegetative development and shortens the size of the organ developed [38]. The averages reduction of plant height at heat stress condition is 25.8% in wheat [39].

Highly significant ($p \leq 0.01$) differences among the genotypes for plant height showing variation in plant height were in agreement with the findings. The decrease in plant height of all genotypes in drought condition in comparison to irrigated condition may be due to decrease in relative turgidity and dehydration of protoplasm which is associated with a loss of and reduced expansion of cell and cell division. The reduction in plant height under water stress condition could be attributed to decline in cell enlargement and more leaf senescence [27]. These results are similar with findings of Bayoumi et al. [28] who had observed significant reduction in plant height under drought stress condition. Optimum plant height is require for better yield in wheat as tall plants are susceptible to lodging and excessively short plants are associated with a yield loss in a drought environment. Rebetzke et al. reported that the dwarfing genes Rht-D1b and Rht-B1b are sensitive to gibberellic acid have increase yield in irrigated condition through reduction in lodging and increased grain number [29]. Current research papers conclude drought has bearing on plant height. Well irrigated varieties are taller than plants under drought stress condition. Furthermore, tall genotypes resulted greater decrease in yield than dwarfish genotypes under drought conditions.

Number of grains per spike and number of spike/m^2

Highly significant ($p<0.001$) differences among genotypes for number of grains per spike and number of spike/m^2 indicated variation among genotypes confirmed with the findings of Ahmad et al. [41].

The number of spikes/m^2 decrease at heat stress condition. Delayed emergence of seedlings caused by low temperature and early maturity due to high temperature during reproductive stage particularly the grain filling process, leads to reduced number of effective spikes per m^2 [42]. Temperatures above 20°C between spike initiation and anthesis speed up the development of the spike but reduce the number of spikelets and grains per spike [21]. Heat stress adversely affects pollen cell and microspore resulting into male sterility [43]. Even high temperature of above 30°C during floret development may cause complete sterility in wheat depending on genotypes. In wheat, the anther produced under 3 days heat stress during anthesis was found to be structurally abnormal and non-functional florets [44].

In drought condition, stress causes sterile pollen, disruption of current photosynthesis and transfer of stored food material to the grains which may cause reduction in grain number in spike and finally leads to decrease in No. of spike/m^2. Similar result of 48% reduction in grain number per head was reported by Giuanta et al. Moisture stress before pollen (stage between stem elongation and pollen) reduced the number of grains per spike than in irrigated condition was reported by Fischer et al. [45]. In addition, there are some evidences that the amount of dry material and more important the amount of nitrogen on spike at the time of pollination is an important component for determining the grain number in spike.

Thousand Grain Weight (TGW)

Highly significant difference ($p<0.001$) in thousand grain weight for genotypes indicates the variability among genotypes revealed with findings of Nasier. Islam et al., [46,47]. Heat stress caused significantly reduction of TKW which was also reported by Kumar and Sharma. [48].

Decrease in thousand grain weight under drought stress condition was reported by 49. Lamaoui, M., et al. [49]. The decrease in thousand grain weight may be due distributed nutrient uptake efficiency and photosynthetic translocation within the plant that produced shriveled grains due to hastened maturity. This is possible due to the shortage of moisture which forces plant to complete its grain formation in relatively lesser time. Reduction in grain weight potential as indirect selection criteria for grain under drought condition had identified by Sharma et al. [50,51]. Grain weight is a function of grain length and width. Ji et al. reported the critical period of grain weight determination which starts shortly before anthesis and continues throughout the grain filling duration determines the final grain size in wheat [52]. Thus, drought stress during grain-filling period reduces grain weight significantly. Similarly, in heat stress condition, wheat sowing significantly reduced TKW which was also reported by Kumar and Sharma [48].

Grain yield

It is generally known that the duration of maturity of any crop is reduced by delayed planting than the optimum time. Wheat grown under heat stress conditions is exposed to low temperature up to booting stage, but the later stages face higher temperature that inhibits grain development, resulting into poor grain yield [27]. In wheat, period from onset of spike ignition to flowering is very sensitive to temperature acceleration and it seems to be the main reason for reduction in sink size under high temperature conditions. Heat stress affects the production of wheat by causing reduction in duration of grain filling phase, kernel size, biomass, tiller number, etc. Heat stress adversely affected days to appearance of first node, tiller per plant and spikelets per plant, thereby resulting in reduction of sink capacity and future sources capability of the plant [41]. Asif et al., Ahmad et al. reported highly significant ($p \leq 0.001$) differences in genotypes showing variation for grain yield which confirms with our findings [53,54]. Khamssi reported the similar findings [55]. Decrease in grain yield under drought condition was reported by many researches [56,57]. Grain yield was greater in irrigated condition than in drought and heat stress environment as a consequence of more spikes per square meter, heavier grains, and a longer plant cycle. Significant reduction in grain yield due to post anthesis water stress may result from a reduction of production of photo-assmilates (source limitation), power of the sink to absorb photo-assimilates and the grain filling duration. Kazmi et al. reported the severe reduction in grain yield with 40% reduction at three irrigation stage to 98% in the post anthesis indicates that the sensitivity of grain yield to drought stress depends upon the severity of the stress and the stage in which the drought condition was imposed [58]. Drought stress reduced the number of grains/spike and grain yield and the genotypes with more number of grains per ear produce more yields [59]. The improvement of cultivar yield under drought stress condition has resulted from a prolonged grain filling period, high chlorophyll content, a more sustained turgor or combination of them was reported by Paknejad et al. [60]. Neumann stated that rapid inhibition of shoot and limited root growth are the symptoms induced by drought which are further characterized by stomatal closure resulting in transpiration rate and CO2 uptake reduction during photosynthesis [61]. Banker et al. found that irrigation at crown root initiation, tillering, jointing, flowering and milking stage gave highest value of growth parameters [62-69]. Wang et al. observed that grain yields under irrigation treatments were significantly increased [70], but the content of grain protein, monomeric protein and flour wet gluten was reduced in wheat. The effect of deficit irrigation on wheat yield and consumptive water use was studied and it was observed that there was a good agreement between measured and predicted yield. It was indicated that under deducing 30% of full irrigation, wheat yield was reduced by less than 6%. Furthermore, studying the depletion of readily available water from root zone could help in saving up to 24% of the applied irrigation water with almost no water yield loss [71-76]. During the growing season ofwinter wheat in China, the precipitation is approximately 200 mm; however, water use by the wheat plant can be 400-500 mm to obtain grain yield of approximately 6 to7 t/ha as a result, supplemental irrigation has become an important measure to obtain a stable yield of winter wheat [77,78]. Jajarmi showed that effect of water shortage on plant growth indices in wheat varieties and concluded significant differences between varieties and moisture levels [79-83]. Significant decrease was observed with increase in moisture level in all traits. Singh et al. found that the yield and yield components of wheat plant were affected with decreased amount of irrigation water as well as the quality [84,85]. The varietal differences among wheat cultivars and their response to varying production environment have been studied for years by plant breeders and crop scientists. The topics have been more relevant in recent times, because of the increasing wheat demand for food and food-processing industry as a result of increasing world population [86-89], and production challenges due to changing climatic conditions [90-96]. Exposure of wheat crop to different biotic and abiotic stresses has been reported to adversely affect the growth and development of the crop, grain yield and quality [97,98]. In the warm humid wheat production areas of Indo-Gangatic Plains that also includes the major wheat growing areas of Nepal, heat stress combined with drought, especially in the case of delayed sown crop has been projected as a major wheat production constraint [99]. Therefore, wheat varieties with enhanced heat and drought tolerance will be instrumental for mitigating yield losses in these areas.

A set of twenty wheat microsatellite markers was used with fifty five elite wheat genotypes to estimate genetic diversity. It has been argued that genetic diversity in crop varieties has been declining in recent times due to plant breeding. This can have serious consequences for both the genetic vulnerability of crops and their plasticity when responding to changes in production environments. It is, therefore, vital for plant breeding programs to maintain sufficient diversity in the cultivars deployed for multi-period cultivation. To understand the temporal genetic diversity in wheat, improved wheat cultivars were analyzed and distinguished using the thirteen microsatellite markers on the basis of their molecular characterization indicating that recent breeding efforts have reduced allelic richness in recent cultivars [100]. Thus, deployment of exotic wheat lines in breeding programs could enhance genetic diversity in wheat cultivars. Genetic diversity analyses aids in classification of groups with possible utility for specific breeding goal [101-105]. Genetic improvement to develop varieties with high yield potential and resistance/tolerance to abiotic stresses is the most viable and environment-friendly option to sustainably increase wheat yield [106]. Another study was undertaken to dissect the diversity of genetic, agronomic characteristics of bread wheat cultivars grown in Turkey. A total of twenty four wheat cultivars and five wild progenitors of wheat were examined using twenty four SSR primers with a known physical locus on the A, B, and D genomes of hexaploid wheat. A total of seventy two bands produced nine hundred thirty ninealleles on the wheat cultivars and wild progenitors. Markers were efficient in discriminating the species and the highest genetic diversity information was obtained from the markers Xgwm312 and Xgwm372. Four agronomic characteristics including yield component traits and eight bread quality analyses were used for the diversity analyses. Molecular variance between old (released before the year 2000) and new cultivars accounted for one percent of the total variation and the sixteen variance was three percent between national and foreign cultivars. Results showed that the number of alleles was lower in national and new cultivars compared to foreign and old cultivars. Therefore, breeding sources do not appear to improve the genetic base of wheat cultivars in Turkey. Introducing new variation sources may be needed to broaden the narrowed gene pool of bread wheat. Thewealth of diverse genetic diversity should be exploited for improvement of wheat yield and for resistance to abiotic stresses, particularly terminal drought and heat stress [107]. Use of crop diversity is one of several approaches to improving agricultural productivity and is a key to achieving global food security. Knowledge of existing genetic diversity and its distribution in crop species is useful for germplasm conservation and selection of parents with diverse genetic background, thereby rendering crop improvement more efficient [108,109].

Conclusion

The field research was conducted at the Bhairahawa in 2016/17 and 2017/18 in order to determine the physio-morphological and yield potential traits associated with heat and drought tolerance in wheat genotypes. Cultivars, moisture, temperature condition, growth and development are the crucial factors for successful wheat production. The rising world population and predicted change in future climatic conditions prevails the identification and selection of wheat genotypes that are adapted to stress conditions over diverse range of environments. Drought and heat stress are the major problem in wheat production in many parts of the world including Nepal. Both stresses are most common environmental stresses which affect the plant production through the alteration in plant metabolism and gene expression. Abiotic stresses are major challenge to agriculture scientists and plant breeders despite in the present scenario for the wheat production despite of many decades of research. It is the major constraint to the wheat production in many developing countries of the world and occasional causes of loss of agricultural production in many developed ones. Drought stress may occur at any time during the wheat growing season i.e. early or late however severe yield reduction occurs after anthesis. The amount and distribution of rainfall during the wheat growing season influence the variability in yield from year to year and from location to location. It is necessary to improve productivity of wheat under rainfed and dry conditions in Nepal through breeding of drought tolerant cultivars with high yield in order to solve the problems of food security. Late sowing of wheat is major reason for low grain production. In Nepal, wheat is mostly sown after the harvesting of paddy which pushes back the appropriate sowing time of wheat resulting in higher temperature stress during the grain filling period as a result yield of wheat is very poor. Genetic diversity in cultivated crops is essential for successful breeding and creation of new cultivars. Estimating the genetic diversity of wheat germplasm can help in identifying diverse parental combinations and creating segregating progeny with high genetic variability for selection. An increase in yield could be achieved by expanding the genetic diversity of bread wheat. The present study consists of diversified wheat genotypes so there is need to test the quality parameters like starch and gluten which help to improve the nutritional content and quality of wheat and also this research should be repeated in other major wheat growing ecological zones to check the response of wheat genotypes. The genotypes having highest yield can be tested for superiority in large scale trial.

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References

1. FAO. "World food and agriculture statistical pocketbook.(2018). Food and Agriculture Organization of the United Nations". (2018).
2. Cossani, CM., & Reynolds, MP. "Physiological trait for improving heat tolerance in wheat". Plant Physiol. 160(2012):1710-1718.
3. Hossain, A., et al. "Phenology, growth and yield of three wheat (Triticum aestivum L.) varieties as affected by high temperature stress". Not Sci Biol. 4(2012):97-109.
4. Hakim, MA., et al. "Yield, protein and starch content of twenty wheat (Triticumaestivum L.) genotypes exposed to high temperature under late sowing conditions". J Sci Res. 4(2012):477-489.
5. FAO. "World food and agriculture statistical pocketbook. Food and Agriculture Organization of the United Nations". (2015).
6. Ortiz, R., et al. "Climate change: Can wheat beat the heat? ". Agric Ecosyst Environ. 126.1(2008):46-58.
7. Jaradat, AA. "Ecogeography, genetic diversity, and breeding value of wild emmer wheat (TriticumdicoccoidesKörn ex Asch.&Graebn.) Thell". Aust J Crop Sci. 5(2011):1072-1086.
8. Cimmy, T. "CIMMYT Business plan. (2006- 2010). Translating the vision of seeds of Innovation into a Vibrant Work Plan. International Maize and Wheat improvement Centre". (2005):31-37.
9. FAO. "World food and agriculture statistical pocketbook. Food and Agriculture Organization of the United Nations". (2015).
10. Shewry, PR. "Wheat. J Exp Bot. 60(2009):1537-1553.
11. Iqbal, M., et al. "Yield and yield components of durum wheat (Triticum durum Desf.) as influenced by water stress at various growth stages". Pak J Biol Sci. 2.4(1999):1438-1440.
12. FAO. "World food and agriculture statistical pocketbook. Food and Agriculture Organization of the United Nations". (2015).
13. MoAD. "Ministry of Agriculture and Development, Nepal. Statistical Information on Nepalese Agriculture. Singh Durbar, Kathmandu". (2018).
14. FAO. "FAO statistical year book. World food and agriculture Food and Agriculture Organization of the United Nations". (2013).
15. Liu, B., et al. "Similar estimates of temperature impacts onglobal wheat yield by three independent methods". Nat Clim Change. 6(2016):1130-1136.
16. Lesk, C., et al. "Influence of extreme weather disasters on global crop production". Nature. 529.7584(2016):84-87.
17. Poudel, M., et al. "Assessing genetic diversity for drought and heat stress tolerance of Nepalese wheat genotypes by SSR markers". "EurAsian J Biosci. 13.2 (2019): 941-941.
18. Flato, G., et al. "Evaluation of climate models". Cambridge University Press. (2013).
19. Sonia, SKN., et al. "Assessing the Impact of Climate Change on Wheat Productivity in Khyber Pakhtunkhwa, Pakistan". Sarhad J Agri. 35.1(2019):284-292.
20. Lukac, M., et al. "Asynchronous flowering and within-plant flowering diversity in wheat and the implications for crop resilience to heat". Ann Bot. 109(2011):843-850.
21. Semenov, MA". "Impacts of climate change on wheat in England and Wales. J R Soc Interface. 6(2009):343-350.
22. Prasad, PVV., & Djanaguiraman, M. "Response of floret fertility and individual grain weight of wheat to high temperature stress: sensitive stages and thresholds for temperature and duration". Funct Plant Biol. 41(2014):1261-1269.
23. Feng, B., et al. "Effect of heat stress on the photosynthetic characteristics in flag leaves at the grain filling stage of different heat-resistant winter wheat varieties". J Agron Crop Sci. 200(2014):143-155.
24. Ashraf, M., & Harris, PJC. "Photosynthesis under stressful environments: an overview". Photosynthetica. 51(2013):163-190.
25. Mathur, S., et al. "Photosynthesis: response to high temperature stress". J Photochem Photobiol B Biol. 137(2014):116-126.
26. Deo, K., et al. "Water requirement of wheat crop for optimum production using CROPWAT model". J Med Plant Res. 5.3(2017):338-342.
27. Singh, A., et al. "Management practices to mitigate the impact of high temperature on wheat: A Review". IIOAB Journal. 2.7(2011):11-22.

28. Din, K., & Singh, RM. “Grain filling duration: An important trait in wheat improvement”. SAIC Newsletter. 15.4(2005):4-5.

29. Mondini, L., et al. “Evaluation of European emmer wheat germplasm for agro-morphological, grain quality traits and molecular traits”. Genet Resour Crop Evol. 61.1(2014):69-87.

30. Siddique, KHM., et al. “Cool season grain legumes in dryland Mediterranean environments of Western Australia: significance of early flowering”. Management of agricultural drought: agronomic and genetic options. (2003):151-162.

31. Araus, JL., et al. “Plant Breeding and Drought in C3 Cereals : What Should We Breed For? Ann Bot. 89.7(2002):925-940.

32. Kirda, C., et al. “Yield response of cotton, maize, soybean, sugar beet, sunflower, and wheat to deficit irrigation. In Crop Yield Response to Deficit Irrigations”. (1999):21-38.

33. Yamamoto, Y., et al. “Quality control of photosystem II: impact of light and heat stresses.” Photosynth Res. 98(2008):589-608.

34. Yin, XY., et al. “A quantitative approach to characterize sink-source relationships during grain filling in contrasting wheat genotypes”. Field Crops Res. 114(2009):119-126.

35. Prasad, PVV., et al. “Impact of night time temperature on physiology and growth of spring wheat”. Crop Sci. 48(2008a):2372-2380.

36. Song, QJ., et al. “Development and mapping of microsatellite (SSR) markers in wheat”. Theor Appl Genet. 110.3(2005):550-560.

37. Singh, RB., et al. “Water production function of wheat irrigation with saline and alkali water using double line source sprinkler system”. Agric Water Manage. 96(2009):736-744.

38. Bagga, AK., & Rawson, HM. “Contrasting responses of morphologically similar wheat cultivars to temperatures appropriate to warm temperature climates with hot summers: a study in controlled environment”. Funct Plant Biol. 4.6(1977):877-887.

39. Hamam, KA. “Response of Bread Wheat Genotypes to Heat Stress”. Jordan J Agric Sci. 9.4(2013):486-506.

40. Jaleel, CA., et al. (2007). “Pseudomonas fluorescens enhances biomass yield and ajmalicine production in Catharanthusroseus under water deficit stress. Colloids and Surfaces B”. Biointerfaces. 60.1(2007):7-11.

41. Ahmad, M., et al. “Physio-morphic response of wheat genotypes under rainfed conditions”. Pak J Bot. 38.5(2006):1697-1702.

42. Tripathi, N. “Studies on physiological parameters in relation to heat tolerance in eight wheat genotypes. GB Pant University of Agriculture and technology”. (2003).

43. Anjum, F., et al. “Influence of foliar applied thiourea on flag leaf gas exchange and yield parameters of bread wheat (Triticumaestivum) cultivars under salinity and heat stresses”. Int J Agri Biol. 10(2008):619-626.

44. Hedhly, A., et al. “Global warming and sexual plant reproduction”. Trends Plant Sci. 14(2009):30-36.

45. Fischer, RA., & Maurer, R. “Drought resistance in spring wheat cultivars. I. Grain yield responses”. Crop Pasture Sci. 29.5(1978):897-912.

46. Islam, R., et al. “Screening of heat tolerant wheat genotypes in Bangladesh”. J Nat Prod. 6(2013):132-140.

47. Mohammadi, R., et al. “Pattern analysis of genotype-by-environment interaction for grain yield in durum wheat”. J Agric Sci. 147(2009):537-545.

48. Kumar, R., & Sharma, SN. “Effect of levels of nitrogen on wheat as influenced by date of sowing”. Ann Agric Sci. 24.1(2003).

49. Lamaoui, M., et al. “Heat and drought stresses in crops and approaches for their mitigation”. Front Chem. 6.26(2018).

50. Sharma, RK., & Tandon, JP. “Investigation on heat tolerance during vegetative and grain filling phase in wheat”. Crop Research Hisar. 14.2(1997):269-274.

51. Sharma,S., et al. Agric Biol J N Am. 6.4(2015):108-117.

52. Ji, X., et al. “Importance of pre-anthesis anther sink strength for maintenance of grain number during reproductive stage water stress in wheat”. Plant Cell Environ. 33(2010):926-942.

53. Ahmad, E., et al. “Molecular Diversity of Wheat (TriticumaestivumL.) Genotypes Resistance to Rice Weevil (Sitophilusoryzae L.) Revealed by SSR Markers.” Int J Curr Microbiol App Sci. 7.7(2018):761-772.

54. Ahmad, HM., et al. “Multivariative analysis of some metric traits in bread wheat (Triticum aestivum L.).” European j biotechnol Biosci. 1.4(2014):21-26.

55. Khamssi, NN., & Najaphy, A. “Agro-morphological and phenological attributes under irrigated and rain-fed conditions in bread wheat genotypes”. Afr J Agric Res. 7.1(2012):51-57.

56. Gooding, MJ., et al. (2003). “Effects of Restricted Water Availability and Increased Temperature on the Grain Filling, Drying and Quality of Winter Wheat”. J Cereal Sci. 37(2003):295-309.

57. Wardlaw, IANF. “Interaction between Drought and Chronic High Temperature During Kernel Filling in Wheat in a Controlled Environment.” Ann Bot. 90(2002):469-476.

58. Khan, A., et al. “Genotypic competition among elite wheat breeding lines under irrigated and drought conditions”. Sarhad J Agric. 28.01(2012):47-52.

59. Saleem, M. “Response of Durum and Bread wheat Genotypes to Drought Stress: Biomass and Yield Components”. Asian J Plant Sci. 2.3(2003):290-293.

60. Paknejad, F., et al. “Effects of drought stress on chlorophyll fluorescence parameters, chlorophyll content and grain yield in some wheat cultivars”. Online J Biol Sci. 7.6(2007):481-492.

61. Neumann, PM. “Coping mechanisms for crop plants in drought-prone environments”. Ann Bot. 101(2008):901-907.

62. Banker, KB., et al. “Effect of different irrigation treatment on growth and yield of wheat crop varieties”. Intl J Agric Sci. 4(2008):114-118.

63. Wang, X., et al. “Coupling effects of irrigation and nitrogen fertilization on grain protein and starch quality of strong-gluten winter wheat.” Front Agric. 2(2008):274-280

64. Ooudal, SAEF., et al. “Using yield-stress model in irrigation management for wheat grown in Egypt”. J App Bio Sci. 2(2008):57-65.

65. Quanqi, I., et al. “Water potential characteristics and yield of summer maize in different planting patterns”. Plant Soil Environ. 54, 2008:14-19.

66. Jajarmi, V. “Effect of water stress on germination indices in seven wheat cultivar”. World Acad Sci Eng Tech. 49(2009)105-106.

67. Shiferaw, B., et al. “Crops that feed the world 10. Past successes and future challenges to the role played by wheat in global food security”. Food Sec. 5.3(2013):291-317.

68. Hassanein, MK., et al. “Impacts of sowing date, cultivar, irrigation regimes and location on bread wheat production in Egypt under climate change conditions”. Nat Sci. 10.12(2012):141-150.

69. Prasad, M., et al. “The use of microsatellites for detecting DNA polymorphism, genotype identification and genetic diversity in wheat”. Theor Appl Genet. 100.3 (2000):584-592.

70. Prasad, PV., & Maduraimuthu, D. “Response of floret fertility and individual grain weight of wheat to high temperature stress: Sensitive stages and thresholds for temperature and duration”. Funct Plant Biol. 41.12(2014):1261-1269.

71. Henkrar, F., et al. “Genetic diversity reduction in improved durum wheat cultivars of Morocco as revealed by microsatellite markers”. Sci Agric. 73.2(2016):134-141.

72. Nezhadahmadi, A., et al. “Drought tolerance in wheat”. Sci World J. 2013.

73. Ashfaq, S., et al. “Estimation of Genetic Variability, Heritability and Correlation for Some Morphological Traits in Spring Wheat Journal of Biology”. Agri Health. 4.5(2014):10-16.

74. Erayman, M., et al. “Diversity analysis of genetic, agronomic, and quality characteristics of bread wheat (Triticum aestivum L.) cultivars grown in Turkey”. Turk J Agric Fore. 40(2016):83-94.

75. Mengistu, DK., et al. “Phenotypic diversity in Ethiopian durum wheat (Triticum turgidum var. durum) landraces”. Crop J. 3(2015):190-199.

76. Teklu, Y., et al. “Analysis of microsatellite diversity in Ethiopian durum wheat landraces”. Genet Resour Crop Evol. 53(2006):1115-1126.

77. Adhikari, S. "Drought Impact and Adaptation Strategies in the Mid-Hill Farming System of Western Nepal." Ministry Forest Env. (2018).

78. Akter, N., & Islam, MR. "Heat stress effects and management in wheat". A review Agron Sustain. 37.5(2017):37.

79. Al Khanjari, S., et al. "Molecular diversity of Omani wheat revealed by microsatellites: II. Hexaploid landraces". Genet Resour Crop Evol. 54.7(2007):1407-1417.

80. Asif, M., et al. "Analysis of Wheat Genotypes for Yield Stability in Rainfed Environments". Pak J Biol Sci. 6.17(2003):1509-1511.

81. Bayoumi, TY., et al. "Application of physiological and biochemical indices as a screening technique for drought tolerance in wheat genotypes". Afr J Biotechnol. 7.14(2008).

82. Farooq, M., et al. "Drought stress in wheat during flowering". J Sustain Agric. (2014):123-132.

83. Farooq, M., et al. "Plant drought stress: effects, mechanisms and management". J Sustain Agric. (2009):153-188.

84. Farshadfar, E., et al. "Screening agronomic, physiological and metabolite indicators of drought tolerance in bread wheat (Triticumaestivum Flato, G., Marotzke, J., Abiodun, B., Braconnot, P., Chou, S.C., &Collins, W. Evaluation of climate models". Cambridge University Press. (2013).

85. Fleury, D., et al. "Genetic and genomic tools toimprove drought tolerance in wheat". American J Sci Res. 38(2010):88-90.

86. Gibson, LR., & Paulsen, GM. "Yield components of wheat grown under high temperature stress during reproductive growth". Crop sci. 39(1999):1841-1846.

87. Goyal, M., et al. "Molecular Marker analysis Reveals Genetic Diversity among Wheat (Triticum aestivum L.) Genotypes varying for Thermo-Tolerance". Int J Plant Res. 28.4 (2015):54-61.

88. Hasan, K., & Tacettin, Y. "The Effect of Drought Stress on Grain Yield, Yield Components and some Quality Traits of Durum Wheat (Triticumturgidum ssp. durum) Cultivars, Not". Bot Hort Agrobot Cluj. 38.1(2010):164-170

89. Hassanulzzaman, M., et al. "Physiological, biochmeical, and molecular mechamisms of heat stress tolerance in plant". Int J Mol Sci. 14(2013):9643-9684.

90. Huang, B., et al. "Root carbon and protein metabolism associated". (2012).

91. Kamal, AHM., et al. "Abiotic stress responsive proteins of wheat grain determined using proteomics technique". Aust J Crop Sci. 4(2010):196-208.

92. Kazmi, RH., et al. "Effect of water stress on the performance of wheat grown under controlled conditions at Rawalakot, Azad Jammu and Kashmir". Sarhad J Agri. (2003).

93. Khakwani, AA., et al. "Growth and yield response of wheat varieties to water stress at booting and anthesis stages of development". Pak J Bot. 44.3(2012):879-886.

94. Kimurto, PK., et al. "Response of bread wheat genotypes to drought simulation under a mobile rain shelter in Kenya". Afr Crop Sci J. 11.3(2004):225-234.

95. Krishna, D., et al. "Water requirement of wheat crop for optimum production using CROPWAT model". JMPS. 5.3(2017):338-342.

96. Ma Dongyun., et al. "Physiological Responses and Yield of Wheat Plants in Zinc-Mediated Alleviation of Drought Stress." Front Plant Sci. 8(2017):860. doi:10.3389/fpls.2017.00860.

97. Mahalingam, G, et al. "Terminal drought and a d2 dwarfing gene affecting grain iron and zinc density in pearl millet". J Cereal Sci. 79(2018):247-252.

98. Marci, RB. "Wide adaptation of Green Revolution wheat: International roots and the Indian context of a new plant breeding ideal, 1960-1970, Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences". 50(2015):41-50.

99. Nasir, HM., et al. "Effect of time and frequency of irrigation on yield of wheat". Thai. J Agric Sci. 32(1999):205-209.

100. Nevo, E., & Chen, G. "Drought and salt tolerances in wild relatives for wheat and barley improvement". Plant Cell Environ. 33.4(2010):670-685.

101. Nilsen, ET., & Orcutt, DM. "Physiology of plants under stress. Abiotic factors. Physiology of plants under stress". Abiotic Factors. (1996).

102. Pourhossein, A., & Shalaei, M. "Determination of total iron in corn and wheat samples by electrothermal atomic absorption spectrometry after solid phase preconcentration". Anal Chem. 16.14(2016):104.

103. Raza, MAS., et al. "Evaluating the drought stress tolerance efficiency of wheat (TriticumAestivumL.) cultivars". Russ J Agric Soc. 12(2012):41-46.

104. Sadozai, KN., et al. "Assessing the Impact of Climate Change on Wheat Productivity in Khyber Pakhtunkhwa, Pakistan". Sarhad J. Agric. 35.1(2019).

105. Senapati, N., et al. "Drought tolerance during reproductive development is important for increasing wheat yield potential under climate change in Europe". J Exp Bot. 70.9(2019):2549–2560.

106. Tabatabai, SMR., et al. "Evaluation of some characteristics of corn under water stress and zinc foliar application". Gmp Rev. 16(2015):34-38.

107. Tiwari, R., et al. "Wheat improvement for drought and heat tolerance. In: Recent trends on production strategies of wheat in India. Directorate of Wheat Research: Karnal, Haryana, India". (2014).

108. Tricker, PJ., et al. "The physiological and genetic basis of combined drought and heat tolerance in wheat". J Exp Bot. 69(2018):3195-3210.

109. Huang, B., et al. "Root carbon and protein metabolism associated with heat tolerance." J Exp Bot 63(2012):3455-3465.