RESEARCH ARTICLE

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ASSESSMENT OF LATE SOWN WHEAT (*Triticum aestivum* L.) GENOTYPES UNDER HIGH TEMPERATURE STRESS CONDITIONS

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ABSTRACT

In recent years, climate change has led to an increase in extreme weather conditions, including high-temperature stress. High-temperature stress is the term for an increase in temperature (> 30°C) following anthesis during grain development. Wheat is particularly vulnerable to high temperature stress, and its productivity is severely affected. With the objective of identifying wheat genotypes tolerant to heat stress in terms of grain yield, a total of fifty wheat genotypes were evaluated under heat stress conditions at Directorate of Agricultural Research, Lumbini Province, Khajura, Banke in 2021/22. There was highly significant difference (<0.001) among genotypes for yield. The association between the grain yield (GY) and the biomass yield (BM), thousand grain weight (TGW), and spike number per meter square (SPMS), was highly significant and positive. The highest harvest index value of 0.59 and the highest grain yield were achieved from 20HTWYT#36 (4133 kg/ha), followed by Bandganga (3992 kg/ha), 20HTWYT#23 (3978 kg/ha), 20HTWYT#11 (3943 kg/ha), and 20HTWYT#05 (3758 kg/ha) exhibiting higher tolerance to high temperature stress and indicating the potential for this genotypes to be used as domain specific varieties suitable for heat stress conditions of Banke district and for breeding climate resilient varieties in the future.

1. INTRODUCTION

Wheat is the 3rd most important cereal crop of Nepal, in terms of area and production. At national level, wheat is grown in 711,067 hectares of land to produce 2,127,276 metric tonnes of grain (MoALD, 2022). The country's wheat production has increased significantly in recent years, especially after technological advancements and their application at the farm level. Wheat area and production have greatly risen since 1960, increasing by more than 7 and 17 times, respectively (Basnet, R, 2023).

Wheat is one of the most important staple crops in the world, providing a vital source of food for billions of people. Meanwhile, the production and quality of wheat are often threatened by various abiotic stresses, including high temperature stress. High temperature stress is a condition in which wheat crops are exposed to high temperature (>30oC), specially during the reproductive stage, mainly from heading to maturity stage (Nesar *et al*., 2022). High temperature stress can negatively affect various aspects of wheat growth and development, such as photosynthesis, respiration, and nutrient uptake, ultimately leading to reduced yield and poor grain quality (Prasad *et al*., 2011).

The primary agricultural system in Nepal is the rice-wheat pattern, in which the timing of wheat planting is governed by the timing of rice harvest. In lowland Terai area, farmers choose to cultivate medium to late ripening rice types, which is harvested from late November to early December. Wheat has a brief window of opportunity for growth and maturation following its planting in November and December (Sah, 2022). Hot air movement during the maturation period results in early maturation without physiological maturity, which severely reduces wheat production (NARC, 2020). Agricultural productivity itself is largely influenced by a range of abiotic stresses, including high temperature stress. Wheat, one of the most important staple crops in the world, is particularly vulnerable to high temperature stress, which can have a significant impact on grain yield and yield components. Late sown wheat, in particular, is at greater risk of exposure to high temperature stress (>30°C).

The reserach is conducted considering identifications of wheat genotypes with greater tolerance to heat stress for further breeding as specific objective to increase productivity of late sown wheat with high yielding, terminal heat stress tolerant parameters for western terai.

1.1. Theoretical framework

With present trend of population growth rate and food demand, it anticipated that by 2050, demand for wheat will have increased by 50% from current levels (CIMMYT, 2023). However, the crop is as high risk of new biotic and abiotic stresses. Of these stresses, high temperature is one of the major abiotic stresses that affect crop growth and yield, especially in the arid and semi-arid regions. Although having the biggest total harvested area of all the cereals, including rice and maize, wheat nonetheless has the lowest overall production. Abiotic stresses including drought, salt, and high temperatures account for the majority of production losses in wheat (Abhinandan, *et al*., 2018). Thus, for wheat development initiatives of Nepal that have mostly relied on the genetic variants contained in the wheat genome through traditional breeding, knowing the consequences of these stresses becomes essential.

In the case of wheat, high temperature stress during the reproductive stage can reduce the grain yield and yield components such as spike length, number of grains per spike, and thousand grain weight (Farooq *et al*. 2011). Late sowing of wheat is also a common practice in lowlands, which exposes the crop to high temperature stress during the critical growth stages. Therefore, it is essential to understand the effect of high temperature stress on grain yield and yield components of late sown wheat. Several studies have reported the negative impact of high temperature stress on wheat yield and yield components (Prasad *et al*. 2008; Dhakal *et al*. 2019). A study by Pandey *et al*. (2020) revealed that exposure to high temperature stress during the reproductive stage led to a decrease in grain yield and a decline in yield components of wheat.

Despite the increasing number of studies on the effect of high temperature stress on wheat yield, there is a paucity of research on the effect of high temperature stress on late sown wheat. There is limited information on the effect of high temperature stress induced by hot and dry air wave in late March and early April that coincides with the reproductive stage of the late sown wheat. Global temperatures continue to rise due to climate change; it is becoming increasingly important to develop wheat cultivars with improved tolerance to high temperature stress. This can be achieved through the identification of genotypes that exhibit greater resilience to high temperature stress, as well as a deeper understanding of the underlying physiological and molecular mechanisms involved in heat stress tolerance. Overall, this study has the potential to provide valuable insights into the development of more resilient wheat cultivars that can withstand the challenges of high temperature stress, and ultimately contribute to local, as well as provincial food security.

2. MATERIALS AND METHODS

2.1 Experimental site:

An open field experiment was conducted in the year 2021/22 at Directorate of Agricultural Research (DoAR), Lumbini Province, Khajura, Banke. The geographical location of the experimental site is 81° 37” East longitudes and 28° 06” North latitude, 181 meter above mean sea level. The site has sub-tropical climate and receives an average annual rainfall of 1000-1500mm. It has sandy to silty loam soil and pH ranges from 7.2 to 7.5 (DoAR Khajura, 2022).

2.2 Planting materials:

Forty-nine early maturing wheat genotypes were obtained from CIMMYT, Mexico via National Plant Breeding and Genetic Research Centre (NPBGRC), Khumaltar, Lalitpur, Nepal and Bandganga as a standard check variety were kept for testing (Table 1).

3.3 Experimental design:

The experimental was set up in Alpha Lattice with two replications, five blocks with ten plots in each block. The plot size was maintained 4.5 m2 (6 rows of 3m length) and the planting geometry was maintained as 25cm row to row spacing and continuous sowing. The plot-to-plot distance was maintained at 50 cm likewise a gap of 50cm was given between the blocks and 75 cm between the replications.

2.4 Irrigation and fertilizer:

A pre-sowing irrigation was applied prior tillage. First irrigation was given at CRI Stage (21 DAS) and second irrigation at booting stages.

The fertilizer was applied at the rate of 68:40:40 kg N: P2O5:K2O per hectare through Urea, Di-ammonium phosphate (DAP), and Murate of Potash (MOP). Full dose of N, P2O5, and K2O was applied as a basal dose at the time of final land preparation, before sowing. Remaining half dose of nitrogen was applied in two splits; one after a week of the first irrigation (28 DAS) and other after a week of second irrigation at late booting stage.

2.5 Land preparation and sowing:

One disc harrowing and two crisscross ploughing using rotavator (rotary tiller) was done to bring soil in good sowing condition. Sowing was done on 23rd December, 2021 which is about a month late than the normal recommended date. Late sowing was done to synchronize the reproductive stage of the crop with the weather of late march to early April. Banke district receives hot air waves at the end of March to mid-April, that causes heat stress to the crops, thus helps in screening resilient genotypes.

Pendimethalin 30% EC was applied @2ml/l water as pre-emergence herbicide, 48 hours after sowing to control weed competition at the early crop stage.

2.6 Agro-meteorological information:

Day to day agro-meteorological data on maximum-minimum temperature, rainfall and relative humidity was retrieved from the weather station installed at DoAR, Khajura. Relative humidity (RH%) was calculated by using formula followed by Huang *et al*. in 2013.

$$RH\% = \frac{e - A * P * \Delta t}{E}$$

Where, Δt = The difference between the dry-bulb temperature(Td) and the wet-bulb temperature (Tw)

Ew = The saturation vapour pressure in the wet-bulb thermometer, calculated by using Buck formula as:

Ew=6.112*e^{(17.502*Tw)/(240.97+Tw)}

Ed= The saturation vapour pressure in the dry-bulb temperature, calculated as:

Ed=6.112*e^{(17.502*Td)/(240.97+Td)}

A = The measuring humidity coefficient, calculated as:

A=0.00066*(1+0.00115*Tw)

P = The mean atmospheric pressure (assumed to be 1013.25024 mb)

2.7 Data collection and analysis:

Phenological data were monitored and meticulously gathered, including days to heading (DH), days to maturity (DM), plant height (PH), spike length (SL), spikes/m2 (SPMS), biomass yield (BM), and grain yield (GY). DH was noted when ear heads began to emerge from flag leaf sheaths in 50% of the plant population. Similar to this, DM was identified when more than 80% of spikes started to turn yellow. When the plants become brittle due to drying after maturity, middle four rows were harvested and threshed to measure grain yield per plot which was later converted to kg/ha after adjusting moisture to 13% by using following formula:

$$\text{Grain yield} \left(\frac{Kg}{ha}\right) \text{ at 13\% moisture level} = \frac{(100\text{-M\%})\text{*Plot yield (kg)*}10000m^2}{(100\text{-}13)\text{*Net Plot Area in } m^2}$$

Likewise, Harvest index (HI) was computed for each genotype by using following formula:

$$HI = \frac{\text{Economic yield or Grain yield}}{\text{Total Biomass Yield above ground i.e straw+grain yield}}$$

Where, M% = moisture percentage of sample grain.

Microsoft Excel 2013 was used to carry out simple mathematical calculations, tabulation, and graphical representation of the result. ADEL-R developed by CIMMYT was used to perform analysis of variance and IBM SPSS Statistics 20 was used to do correlation and cluster analysis.

3. RESULTS AND DISCUSSION

3.1 Agro-meteorological information:

The weather condition of the experimental site during the crop period is depicted in the Figure 1. This information on agro-meteorological condition was obtained from the weather station of DoAR, Khajura. The graph shows a gradual downfall of the maximum and minimum temperature until February and there was a gradual increment of both temperatures till April. Relative humidity (RH%) also decreased steadily after February. As crops reached the ripening stages in April, maximum (> 30^{o}C) and minimum temperature (~ 20^{o}C) were at the highest of the entire crop duration with lowest RH%. The ideal temperature for wheat throughout the ripening process is between 21^{o}C and 25^{o}C (Farooq *et al*., 2011). From this, we can ensure that the crops were at high temperature stress during grain filling stage.

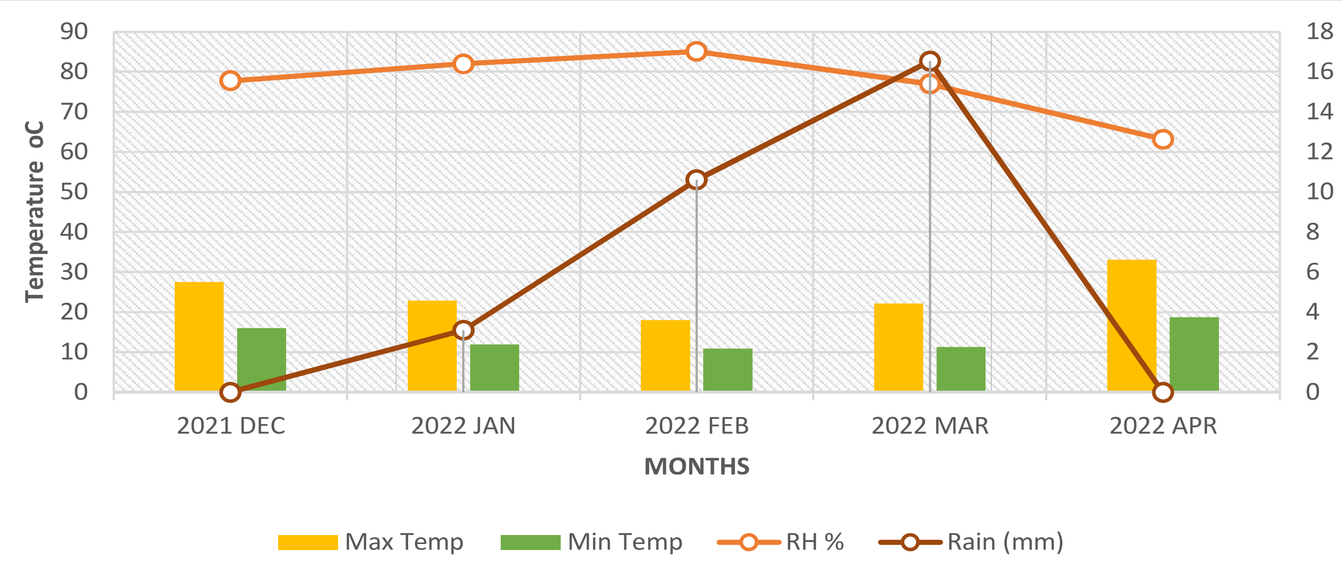

Figure 1. Distribution of maximum-minimum temperature, rainfall and relative humidity in the experimental site during crop period.

3.2 Days to heading and days to maturity:

Highly significant difference (P<0.001) were observed among the tested wheat genotypes for days to maturity and days to heading (Table 2), which is in agreement with the findings of Upadhyaya & Bhandari (2022). Genotypes 20HTWYT#42 and 20HTWYT#47 showed earlies heading (70 days) while 20HTWYT#06 showed earliest physiological maturity of 104 days followed by 20HTWYT#42, 20HTWYT#47, 20HTWYT#02, 20HTWYT#03, 20HTWYT#38 and 20HTWYT#07 with 105 days to maturity (Table 3).

3.3 Plant height and spike length:

Tested genotypes showed significant different (p<0.05) for the plant height. Similar result was obtained by Bohara *et al* (2023) while testing late sown wheat genotypes in drought stress environments. Final height was maximum for 20HTWYT#17 (98 cm), followed by 20HTWYT#47 and 20HTWYT#48 with 96cm height, whereas, shortest plant height was observed in 20HTWYT#25 (84 cm), followed by 20HTWYT#34 (86 cm), as presented in Table 3.

3.4 Grains per spike and 1000 grain weight:

Highly significant (p<0.001) and significant (P<0.05) differences were found for 1000 grain weight and no of grains per spike respectively among the tested genotypes. Number of grains per spike was obtained maximum for check variety: Bandganga (332), followed by 20HTWYT#30 (299), 20HTWYT#23 (281), 20HTWYT#03 (278), and 20HTWYT#05 (277). Likewise, genotypes 20HTWYT#18 (41.3 gm), 20HTWYT#31(41.0 gm), 20HTWYT#14 (40.7 gm), 20HTWYT#04 (40.4 gm), and 20HTWYT#47 (40.4 gm) had higher thousand grain weight correspondingly. With late sown wheat, it is common to find sunken and shrivelled seeds, which have low germination rates thus unfit for seed production (Tahir *et al*., 2009). Due to the inferior quality of the grains, late-sown wheat sells for cheap prices (Aalam *et al*., 2018).

3.5 Grain yield and harvest index:

Grain yield was recorded maximum from 20HTWYT#36 (4133 kg/ha) with highest harvest index value of 0.59, followed by Bandganga (3992 kg/ha), 20HTWYT#23 (3978 kg/ha) 20HTWYT#11 (3943 kg/ha), and 20HTWYT#05 (3758 kg/ha). There were highly significant differences (<0.001) for yield among the tested genotypes, which is similar with the finding of Ahmad *et al*., (2006), Khamssi and Najaphy (2012) and Poudel *et al*., (2021). Lowest yield was found in 20HTWYT#13 (2063 kg) with minimum harvest index (0.31). Harvest Index was supreme in 20HTWYT#36, followed by 20HTWYT#05 (0.44), 20HTWYT#04, 20HTWYT#11, 20HTWYT#23, and 20HTWYT#34 with 0.43 HI.

3.6 Correlation analysis:

To establish the selection criteria for various features during varietal selection programs, correlation analyses of wheat grain yield and its related component are essential. Grain yield (GY) showed positive association with days to maturity while, negative association with heading days, which coincide with the finding of Upadhyaya *et al*. (2022). Grain yield had highly significant and positive correlation with spike number per meter square (SPMS), thousand grain weight (TGW), and biomass yield (BM). Similarly, harvest index (HI) had highly significant and positive correlation with GY (Table 4).

3.7 Cluster analysis:

Fifty wheat genotypes were clustered into five clusters based on mean values of DH, DM, PH, SL, GY, TGW, SPMS, BM and HI (Figure 2). Cluster 1 is the largest cluster with twenty-seven members including Bandganga (Table 5), indicating close relationship among each other based on the phenological traits and yield components. Similarly, cluster 2, cluster 3, cluster 4 and cluster 5 had fourteen, four, three and two genotypes respectively.

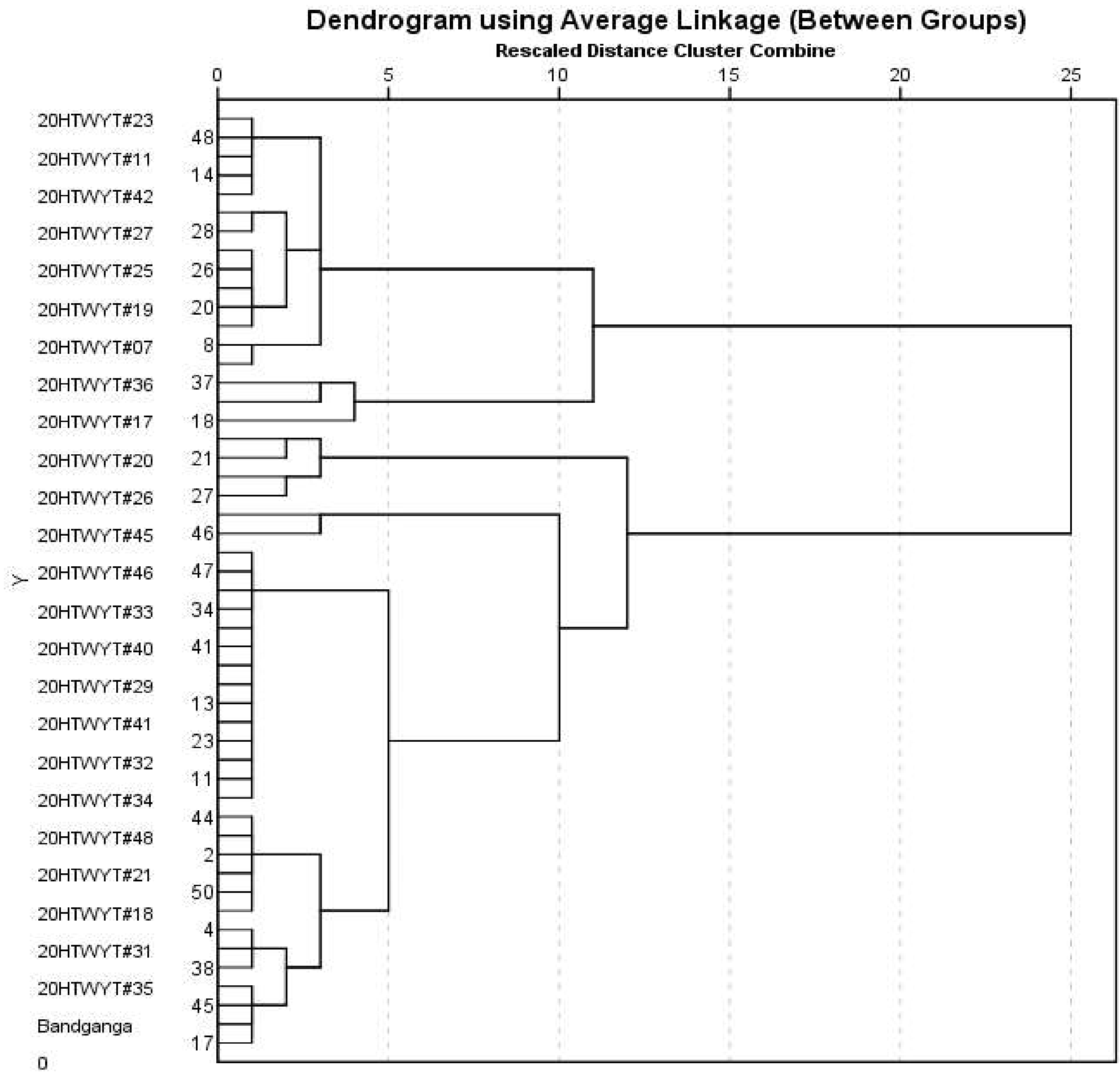

Figure 2. Clustering of wheat genotypes based on yield and yield components

4. CONCLUSION

Based on the study, it is concluded that the tested genotypes differed significantly at heat stress conditions for most of the important yield components. Some genotypes gave higher grain yield and thousand grain weight exhibiting higher tolerance to high temperature stress. Highest grain yield of 4133 kg/ha with highest HI value was obtained from 20HTWYT#36, followed by Bandganga (3992 kg/ha), 20HTWYT#23 (3978 kg/ha) 20HTWYT#11 (3943 kg/ha), and 20HTWYT#05 (3758 kg/ha) indicating the potential for this genotype to be used in breeding programs to develop heat-tolerant wheat varieties. Under high temperature stress conditions, grain yield of wheat was significantly dependent upon thousand grain weight, number of effective tillers per unit area, and biomass yield. As this research had focused on grain yield and only a few phenological parameters, it has a restricted ability to describe overall genotypic performance. Thus, further studies are needed to explore response against economically important disease and find the molecular basis of heat tolerance for more efficient screening of wheat with high tolerance to heat stress.

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ANNEX

Table 1. List of genotypes used in the experiment with their pedigree and origin.

SN	Genotype	Pedigree	Origin
1	Bandganga	n.d.	NWRP, Bhairahawa
2	20HTWYT#01	NADI #1	CIMMYT, Mexico
3	20HTWYT#02	WADER #1	CIMMYT, Mexico
4	20HTWYT#03	BORL14*2//BECARD/QUAIU #1	CIMMYT, Mexico
5	20HTWYT#04	ND643/2*WBLL1//VILLA JUAREZ F2009/3/KACHU//KIRITATI/...	CIMMYT, Mexico
6	20HTWYT#05	KAKURU/BORL14	CIMMYT, Mexico
7	20HTWYT#06	KAKURU//SUP152/BAJ #1	CIMMYT, Mexico
8	20HTWYT#07	KACHU*2/SUP152/3/WBLL1*2/BRAMBLING*2//BAVIS	CIMMYT, Mexico
9	20HTWYT#08	FRANCOLIN #1/NELOKI/3/PRL/2* PASTOR//KACHU	CIMMYT, Mexico
10	20HTWYT#09	KACHU/4/WHEAR/SHAMA/3/C80.1/3*BATAVIA//2*WBLL1/5/...	CIMMYT, Mexico
11	20HTWYT#10	TOH #1//KFA/2*KACHU	CIMMYT, Mexico
12	20HTWYT#11	HARTOG SUMAI3 (LINE B)/2* NAVJ07/4/MUTUS//KIRITATI/...	CIMMYT, Mexico
13	20HTWYT#12	BECARD/FRNCLN//BAJ #1/TECUE #1	CIMMYT, Mexico
14	20HTWYT#13	BORL14*2/3/WBLL1*2/BRAMBLING*2//BAVIS	CIMMYT, Mexico
15	20HTWYT#14	KACHU/DANPHE*2//MUTUS*2/HARIL #1	CIMMYT, Mexico
16	20HTWYT#15	BAJ #1/3/KIRITATI//HUW234+LR34/PRINIA/4/KIRITATI//...	CIMMYT, Mexico
17	20HTWYT#16	BAJ #1/3/KIRITATI//HUW234+LR34/PRINIA/4/KIRITATI//...	CIMMYT, Mexico
18	20HTWYT#17	BAJ #1/3/KIRITATI//HUW234+LR34/PRINIA/4/KIRITATI//...	CIMMYT, Mexico
19	20HTWYT#18	BAJ #1/3/KIRITATI//HUW234+LR34/PRINIA/4/KIRITATI//...	CIMMYT, Mexico
20	20HTWYT#19	WBLL1*2/BRAMBLING*2//BAVIS*2/3/SUP152/BAJ #1	CIMMYT, Mexico
21	20HTWYT#20	PFAU/MILAN/3/BABAX/LR42//BABAX/11/CROC_1/...	CIMMYT, Mexico
22	20HTWYT#21	WHEAR/KUKUNA/3/C80.1/3*BATAVIA//2*WBLL1*2/4/NIINI #1/5/…	CIMMYT, Mexico
23	20HTWYT#22	PFAU/WEAVER*2//TRANSFER#12,P88.272.2/3/WHEAR//2*PRL/...	CIMMYT, Mexico
24	20HTWYT#23	SUP152/BAJ #1//KIDEA	CIMMYT, Mexico
25	20HTWYT#24	SUP152/KENYA SUNBIRD/3/KACHU//KIRITATI/2*TRCH	CIMMYT, Mexico
26	20HTWYT#25	SOKOLL/3/PASTOR//HXL7573/2*BAU/4/SOKOLL/WBLL1/5/MUCUY	CIMMYT, Mexico
27	20HTWYT#26	KISKADEE #1/5/KAUZ*2/MNV//KAUZ/3/MILAN/4/BAV92/6/WHEAR/ MX12	CIMMYT, Mexico
28	20HTWYT#27	DANPHE/3/ROLF07/YANAC//TACUPETO F2001/BRAMBLING/4/...	CIMMYT, Mexico
29	20HTWYT#28	TOH #1//MUTUS*2/TECUE #1	CIMMYT, Mexico
30	20HTWYT#29	PFAU/MILAN/3/BABAX/LR42//BABAX*2/4/NIINI #1/7/W15.92/4/...	CIMMYT, Mexico
31	20HTWYT#30	HD 2967/3/SWSR22T.B./2*BLOUK #1//WBLL1*2/KURUKU	CIMMYT, Mexico
32	20HTWYT#31	KACHU/BECARD//WBLL1*2/BRAMBLING*2/3/ABLEU	CIMMYT, Mexico
33	20HTWYT#32	WBLL1*2/KIRITATI//FRNCLN/3/BECARD/4/2*KACHU/DANPHE	CIMMYT, Mexico
34	20HTWYT#33	WWBLL1*2/KIRITATI//FRNCLN/3/BECARD/4/2*KACHU/DANPHE	CIMMYT, Mexico
35	20HTWYT#34	WBLL1*2/KIRITATI//FRNCLN/3/BECARD/4/2*KACHU/DANPHE	CIMMYT, Mexico
36	20HTWYT#35	TAM200/PASTOR//TOBA97/3/HEILO/4/PAURAQ/5/BRBT1*2/...	CIMMYT, Mexico
37	20HTWYT#36	BAJ #1/KISKADEE #1/3/WBLL1*2/BRAMBLING*2//BAVIS/4/...	CIMMYT, Mexico
38	20HTWYT#37	BAJ #1/KISKADEE #1/3/WBLL1*2/BRAMBLING*2//BAVIS/4/...	CIMMYT, Mexico
39	20HTWYT#38	PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI/5/...	CIMMYT, Mexico
40	20HTWYT#39	SHORTENED SR26 TRANSLOCATION//2*WBLL1*2/KKTS/3/BECARD/... MX12	CIMMYT, Mexico
41	20HTWYT#40	SHORTENED SR26 TRANSLOCATION//2*WBLL1*2/KKTS/3/BECARD/... MX120	CIMMYT, Mexico
42	20HTWYT#41	MUTUS//KIRITATI/2*TRCH/3/WHEAR/KRONSTAD F2004/4/...	CIMMYT, Mexico
43	20HTWYT#42	MUNAL*2/CHONTE*2/3/SWSR22T.B./2*BLOUK #1//WBLL1*2/...	CIMMYT, Mexico
44	20HTWYT#43	MUNAL #1*2/4/HUW234+LR34/PRINIA//PBW343*2/KUKUNA/3/... SS14B01663T-099TOPY-099M-099NJ-099NJ-5Y-0WGY	CIMMYT, Mexico
45	20HTWYT#44	WBLL1*2/4/YACO/PBW65/3/KAUZ*2/TRAP//KAUZ/5/KACHU #1*2/.. MX120-2	CIMMYT, Mexico
46	20HTWYT#45	ORION/5/2*FRNCLN/4/WHEAR/KUKUNA/3/C80.1/3* BATAVIA//...	CIMMYT, Mexico
47	20HTWYT#46	ESTOC/7/2*KISKADEE #1/5/KAUZ*2/MNV//KAUZ/3/MILAN/4/...	CIMMYT, Mexico
48	20HTWYT#47	CROC_1/AE.SQUARROSA (205)//BORL95/3/PRL/SARA//TSI/...	CIMMYT, Mexico
49	20HTWYT#48	ADI#2/MUCUY	CIMMYT, Mexico
50	20HTWYT#49	MUNAL #1/SUJATA//CHIPAK	CIMMYT, Mexico

Table 2. Analysis of variance of phenological parameters, grain yield and yield attributing traits

	DH	DM	PH (cm)	SL(cm)	SPMS	GY (kg/ha)	1000 grain wt. (gm)	BM (kg/ha)	Grains/ spike (GPS)	HI
Mean	74.73	108.51	90.71	10.28	257.93	3132.85	32.692	8157.05	43.9	0.387
CV (%)	1.065	1.453	3.926	10.164	19.715	11.764	6.607	16.035	13.793	12.672
Std MSE	0.796	1.576	3.561	1.045	50.851	368.543	2.16	1308.023	6.055	0.049
LSD0.05	1.608	3.184	7.191	2.11	102.695	744.287	4.362	2641.606	12.228	0.099
P-value	<0.001	<0.001	0.005	0.371	0.605	<0.001	<0.001	0.331	0.038	0.015

Table 3. Means of different phenological traits, grain yield, yield attributing traits and harvest index of the wheat genotypes.

S.N	Genotypes	Days to 50% heading	Days to 80% maturity	Plant height (cm)	Spike length (cm)	No. of spike per m2	Grain yield (kg/ha)	1000 grain wt. (gm)	Biomass yield (kg/ha)	Grains/ spike	Harvest Index
1	Bandganga	72	110	89	12	332	3992	39.1	10400	43	0.38
2	20HTWYT#01	75	109	91	10	266	3439	36.6	8683	40	0.4
3	20HTWYT#02	72	105	93	9	272	3094	26.5	7994	56	0.39
4	20HTWYT#03	73	105	88	10	278	2446	26.9	6911	43	0.35
5	20HTWYT#04	73	107	92	10	258	3749	40.4	8806	37	0.43
6	20HTWYT#05	74	107	95	10	277	3758	32.1	8756	56	0.44
7	20HTWYT#06	72	104	85	9	246	2878	25.4	7961	49	0.36
8	20HTWYT#07	74	105	88	11	244	2615	27.6	7421	47	0.35
9	20HTWYT#08	76	109	89	10	230	2477	30.8	6133	42	0.4
10	20HTWYT#09	76	108	93	12	276	3420	31.6	9439	53	0.36
11	20HTWYT#10	76	110	90	11	242	3865	39	9822	42	0.39
12	20HTWYT#11	75	107	91	10	440	3943	38.7	9311	48	0.43
13	20HTWYT#12	76	107	89	11	272	2880	30.9	7778	45	0.37
14	20HTWYT#13	76	108	85	11	210	2063	33.1	6717	46	0.31
15	20HTWYT#14	76	111	95	11	238	3741	40.7	8978	40	0.42
16	20HTWYT#15	72	107	95	11	247	3101	31.4	8917	43	0.35
17	20HTWYT#16	74	107	92	10	253	2670	37.1	7461	38	0.36
18	20HTWYT#17	73	109	98	11	220	3023	33.5	8539	46	0.35
19	20HTWYT#18	73	108	92	10	250	3390	41.3	10611	40	0.33
20	20HTWYT#19	75	109	87	10	203	2776	29.4	6544	42	0.42
21	20HTWYT#20	81	115	90	10	251	3118	30.6	8561	47	0.37

S.N	Genotypes	Days to 50% heading	Days to 80% maturity	Plant height (cm)	Spike length (cm)	No. of spike per m2	Grain yield (kg/ha)	1000 grain wt. (gm)	Biomass yield (kg/ha)	Grains/ spike	Harvest Index
22	20HTWYT#21	75	110	94	9	262	3561	28.8	9094	52	0.39
23	20HTWYT#22	73	107	95	11	234	2725	33.4	7383	44	0.37
24	20HTWYT#23	76	109	93	11	281	3978	32.8	9244	49	0.43
25	20HTWYT#24	74	110	88	10	238	3330	36.9	7872	43	0.42
26	20HTWYT#25	79	111	77	12	257	2645	30.1	8017	36	0.33
27	20HTWYT#26	77	109	84	9	235	2814	26.3	7517	35	0.37
28	20HTWYT#27	78	109	94	11	243	2609	30.2	7856	38	0.33
29	20HTWYT#28	74	109	94	11	233	2784	32.1	7472	44	0.38
30	20HTWYT#29	77	109	89	11	263	2930	33	7339	37	0.41
31	20HTWYT#30	80	111	93	12	299	3610	24.8	7300	49	0.56
32	20HTWYT#31	72	106	93	10	268	3122	41	9206	40	0.34
33	20HTWYT#32	76	113	92	10	259	3407	28.7	8700	45	0.39
34	20HTWYT#33	76	113	92	10	279	3351	34	8356	44	0.4
35	20HTWYT#34	76	111	86	11	247	3514	33.4	8267	51	0.43
36	20HTWYT#35	75	108	90	10	270	3146	32.4	8317	40	0.38
37	20HTWYT#36	76	109	87	10	260	4133	36.8	6944	37	0.59
38	20HTWYT#37	76	110	89	11	214	2638	28	7406	46	0.36
39	20HTWYT#38	73	105	88	8	276	2514	27.3	7167	33	0.35
40	20HTWYT#39	77	109	87	10	268	2723	33	7644	38	0.36
41	20HTWYT#40	72	107	93	11	261	2884	30.5	7561	34	0.38
42	20HTWYT#41	76	109	94	10	269	2663	33.1	7422	45	0.36
43	20HTWYT#42	70	105	87	10	248	3318	32.5	8150	49	0.41
44	20HTWYT#43	76	112	95	11	265	2403	33	7389	51	0.33
45	20HTWYT#44	76	110	95	10	244	2653	31.4	7333	47	0.36
46	20HTWYT#45	76	109	88	10	260	2801	30.8	7200	46	0.39
47	20HTWYT#46	72	106	90	9	239	3513	33.4	9317	50	0.38
48	20HTWYT#47	70	105	96	10	274	3657	40.2	9400	40	0.39
49	20HTWYT#48	75	109	96	11	228	3638	34.5	9317	48	0.39
50	20HTWYT#49	76	109	91	10	221	3136	29.6	7922	47	0.4
	Grand Mean	74.73	108.51	90.71	10.28	257.93	3132.85	32.692	8157.05	43.9	0.387

Table 4. Pearson's correlation coefficients(r) of grain yield and associated components.

	DH	DM	PH	SL	SPMS	GY	TGW	BM	GPS	HI
DH	1	.739**	-.228	.299*	-.030	-.113	-.263	-.261	-.024	.172
DM		1	.018	.328*	-.088	.122	.036	.036	.026	.155
PH			1	.079	.063	.246	.259	.320*	.271	.024
SL				1	.014	.070	.138	.113	.055	.028
SPMS					1	.412**	.206	.332*	.093	.229
GY						1	.493**	.713**	.185	.632**
TGW							1	.557**	-.254	.069
BM								1	.170	-.068
GPS									1	.082
HI										1

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 5. Cluster Membership

SN	Cluster	1	2	3	4	5
1	Genotypes	Bandganga	20HTWYT#02	20HTWYT#04	20HTWYT#17	20HTWYT#28
2		20HTWYT#01	20HTWYT#07	20HTWYT#20	20HTWYT#36	20HTWYT#45
3		20HTWYT#03	20HTWYT#08	20HTWYT#24	20HTWYT#39	
4		20HTWYT#05	20HTWYT#09	20HTWYT#26		
5		20HTWYT#06	20HTWYT#11			
6		20HTWYT#10	20HTWYT#13			
7		20HTWYT#12	20HTWYT#15			
8		20HTWYT#14	20HTWYT#19			
9		20HTWYT#16	20HTWYT#23			
10		20HTWYT#18	20HTWYT#25			
11		20HTWYT#21	20HTWYT#27			
12		20HTWYT#22	20HTWYT#38			
13		20HTWYT#29	20HTWYT#42			
14		20HTWYT#30	20HTWYT#47			
15		20HTWYT#31				
16		20HTWYT#32				
17		20HTWYT#33				
18		20HTWYT#34				
19		20HTWYT#35				
20		20HTWYT#37				
21		20HTWYT#40				
22		20HTWYT#41				
23		20HTWYT#43				
24		20HTWYT#44				
25		20HTWYT#46				
26		20HTWYT#48				
27		20HTWYT#49				