Genetics, Plant Breeding and Seed Science

pISSN: 3102-0089 eISSN: 3102-0151

Journal homepage: https://plantbreeding.org.np/page/journal.html

Research article

Evaluation of Elite Spring Wheat Lines for Agro-Morphological Traits and Grain Yield under Late-Sown Condition

Dinesh Khanal

Department of Genetics and Plant Breeding, College of Natural Resource Management, Marin, Sindhuli, Agriculture and Forestry University

Email: dineshkhanal0011@gmail.com | **ORCID**: 0000-0002-1901-1485

ARTICLE INFO

Keywords:

Biological yield, effective tillers, late sown, plant height, phenological trait, spike

Article history:

Received 9 Jun 2025
Revised 19 Jun 2025
Accepted 22 Jun 2025

ABSTRACT

Testing of wheat genotypes for the late sown condition is limited and little knowledge is available, so this research was carried out to provide insights on the performance of different genotypes in late sown condition. A total of 49 different wheat genotypes acquired from the 15th High-Temperature Wheat Yield Trial and local check Gautam were studied for agro-morphological characters, yield, and yield attributing traits at the farmer's field in Jamuniya, Nawalparasi, Nepal. The research was carried out from December 2016 to April 2017 in the alpha lattice design with two replications. Analysis of variance revealed that days to booting, days to heading, and thousand-grain weight were significantly different. Similarly, the studied genotypes showed significant differences in the number of effective tillers and harvest index. Non-significant differences between the genotypes were observed for emergence count, physiological maturity, plant height, spike length, number of grains per spike, biological yield, and grain yield. Based on correlation analysis of selected traits, all traits showed significant correlations with grain yield. Biological yield (0.950**), plant height (0.901**), and spike length (0.716**) were positively and highly correlated with grain yield. Similarly, the number of tillers (0.548**), thousand-grain weight (0.510**), and number of grains per spike (0.509**) had a positive correlation with grain yield. The study has indicated that biological yield, plant height, spike length, and the number of effective tillers per square meter could be valuable traits for the higher yield in late-sown conditions.

Introduction

Wheat (*Triticum aestivum* L.) is an important cereal crop that belongs to the Poaceae family. With a production of 799 million tons and a productivity of 3.62 t/ha, it is grown on nearly 220 million hectares in the world (FAOSTAT 2023). In terms of area and production, it is the third most important cereal crop after rice and maize in Nepal (MoALD 2023). In Nepal, It is cultivated on 0.71 million hectares of land, producing 2.1 million tons with a productivity of 2.99 t/ha (MoALD 2023). In Nepal, the Terai region occupies most of the wheat-producing area. Terai, hill, and mountain share 66.2%, 28.5%, and 5.3% respectively out of the total wheat production area of the country (Nayava et al. 2009). When the wheat crop is sown late, it experiences high temperatures during the grain filling duration. Due to its wider adaptability, wheat can be grown under a wide range of environmental conditions. In the central terai of Nepal, the optimum time for sowing wheat is from the second week to the third week of November (Sah et al. 2022). Higher yield is produced in early sowing than in late sowing due to longer duration, and late planting also affects wheat growth, yield, and quality (Sattar et al. 2010). In late sown conditions, the temperature of soil could reach below 10 °C and ultimately affects the seed germination and stand establishment. According to (Shewry 2009) optimum range of temperature 15 to 20 °C is suitable for wheat anthesis and grain filling. Due to climate change, cereal production across the world is severely affected (Quin et al. 2002) which may alter the wheat sowing calendar worldwide.

Depending upon the genotypes, high temperatures exceeding 30 °C during floret development can result in complete sterility in wheat (Kaur and Behl 2010). When the crop experiences temperatures above 24 °C during the reproductive phase drastically reduces grain yield and the increment in the duration of exposure to high temperatures continuously decreases grain yield (Prasad and Djanaguiraman 2014). During the critical growth stages, late sown wheat crop suffers from heat stress for grain yield production; flowering, and grain filling duration, and hence caused yield loss (Farooq et al. 2011). Grain yield reduction of up to 40% can occur if it is sown late (Sharma and Duveiller 2004). Delayed sowing of wheat also decreases growth, grain yield, grain per spike, spike length, biological yield, and harvest index (Muhsin et al. 2021). When wheat is sown from November 17 to December 7, it is considered the main season wheat in Nepal. When it is sown between November 1 and November 16, it is regarded as early season, and when it is planted between December 8 and December 30, it is late season wheat. In Nepal, wheat improvement through selection is still in its early stages. The evaluation of elite varieties remains limited due to a lack of modern technologies and tools. This research aims to assess the field and yield performances of elite spring wheat in Jamuniya, Nawalparasi, Nepal under late-sown conditions.

Materials and Methods

Fifty wheat genotypes obtained from the Agriculture Botany Division, Nepal Agricultural Research Council (NARC), Khumaltar, Nepal were included in this study. The research materials assessed were 49 elite wheat genotypes and Gautam as a local check. The experiment was carried out at the farmer's field in Jamuniya, Nawalparasi, Nepal, during the year 2016/17 following the alpha lattice design. The latitude and longitude of the experiment site were 27°28′N and 83°47′E, respectively, with an altitude of 115 meters above sea level. Sowing was done on December 12, 2016. Fertilizer was applied at the rate of 120:60:40 kg/ha nitrogen, phosphorus and potash, respectively, and the whole of phosphorus and potash, and half of the nitrogen were applied at the time of sowing. The remaining half dose of nitrogen is applied after the irrigation in the crown root initiation stage and late tillering stage. The soil of the research experiment was sandy loam with a pH value of 6.0. The individual plot size was 3×1 m² having four rows. The number of emergences was counted on the marked 50 cm length from the middle two rows for 4 days until the number was constant and converted to the average value. Phenological data were recorded for days to booting; when 50% of plants on the plot were booted,

Table 1. List of wheat genotypes used in the study

S.N.	Name	Genotype	S.N.	Name	Genotype
1	Gautam	Gautam (used as a check)	26	15HTWYT-25	MXI15-16 M37ES24SA15H 118
2	15HTWYT-1	MXI15-16 MULTTESTIGOS 6	27	15HTWYT-26	MXI15-16 M37ES24SA15H 128
3	15HTWYT-2	MXI15-16 MULTTESTIGOS 10	28	15HTWYT-27	MXI15-16 M37ES24SA15H 135
4	15HTWYT-3	MXI15-16 MULTTESTIGOS 11	29	15HTWYT-28	MXI15-16 M37ES24SA15H 139
5	15HTWYT-4	MXI15-16 MULTTESTIGOS 13	30	15HTWYT-29	MXI15-16 M37ES24SA15H 140
6	15HTWYT-5	MXI15-16 M37ES24SA15H 5	31	15HTWYT-30	MXI15-16 M37ES24SA15H 144
7	15HTWYT-6	MXI15-16 M37ES24SA15H 10	32	15HTWYT-31	MXI15-16 M37ES24SA15H 153
8	15HTWYT-7	MXI15-16 M37ES24SA15H 18	33	15HTWYT-32	MXI15-16 M37ES24SA15H 160
9	15HTWYT-8	MXI15-16 M37ES24SA15H 20	34	15HTWYT-33	MXI15-16 M37ES24SA15H 162
10	15HTWYT-9	MXI15-16 M37ES24SA15H 25	35	15HTWYT-34	MXI15-16 M37ES24SA15H 182
11	15HTWYT-10	MXI15-16 M37ES24SA15H 33	36	15HTWYT-35	MXI15-16 M37ES24SA15H 196
12	15HTWYT-11	MXI15-16 M37ES24SA15H 35	37	15HTWYT-36	MXI15-16 M37ES24SA15H 208
13	15HTWYT-12	MXI15-16 M37ES24SA15H 47	38	15HTWYT-37	MXI15-16 M37ES24SA15H 213
14	15HTWYT-13	MXI15-16 M37ES24SA15H 50	39	15HTWYT-38	MXI15-16 M37ES24SA15H 215
15	15HTWYT-14	MXI15-16 M37ES24SA15H 52	40	15HTWYT-39	MXI15-16 M37ES24SA15H 218
16	15HTWYT-15	MXI15-16 M37ES24SA15H 55	41	15HTWYT-40	MXI15-16 M37ES24SA15H 224
17	15HTWYT-16	MXI15-16 M37ES24SA15H 56	42	15HTWYT-41	MXI15-16 M37ES24SA15H 226
18	15HTWYT-17	MXI15-16 M37ES24SA15H 66	43	15HTWYT-42	MXI15-16 M37ES24SA15H 230
19	15HTWYT-18	MXI15-16 M37ES24SA15H 67	44	15HTWYT-43	MXI15-16 M37ES24SA15H 233
20	15HTWYT-19	MXI15-16 M37ES24SA15H 77	45	15HTWYT-44	MXI15-16 M37ES24SA15H 235
21	15HTWYT-20	MXI15-16 M37ES24SA15H 78	46	15HTWYT-45	MXI15-16 M37ES24SA15H 236
22	15HTWYT-21	MXI15-16 M37ES24SA15H 82	47	15HTWYT-46	MXI15-16 M37ES24SA15H 245
23	15HTWYT-22	MXI15-16 M37ES24SA15H 96	48	15HTWYT-47	MXI15-16 M37ES24SA15H 248
24	15HTWYT-23	MXI15-16 M37ES24SA15H 113	49	15HTWYT-48	MXI15-16 M37ES24SA15H 272
25	15HTWYT-24	MXI15-16 M37ES24SA15H 116	50	15HTWYT-49	MXI15-16 M37ES24SA15H 275

heading; when 50% of plants in each plot were headed, and physiological maturity; when glumes had lost chlorophyll and turned yellow in 75% spike in each plot. Ten sample plants from the middle two rows were randomly selected for the measurement of plant height and spike length. Plant height was measured from the soil surface to the tip of the spike excluding the awn and spike length was measured from the base to the tip of the spike excluding the awn. From the middle two rows in each plot number of tillers was counted at the time of physiological maturity, and calculated the number of tillers per square meter. The number of grains per spike was counted manually threshing of five randomly selected spikes out of those selected for spike length measurement. After harvesting and sun drying, a random sample of 100-gram grains from each genotype was weighed to estimate thousand-grain weight as per the method described by the International Seed Testing Association (ISTA) Rules 2023 (ISTA 2023). Harvesting from the middle two rows was done separately for each genotype and sun-dried for 2-3 days, and biological yield was measured. Grain yield was adjusted according to the standard moisture content (12%) and harvest index was computed by taking the ratio between grain yield and biological yield. The moisture content of the grain was measured by a Wile 200 moisture meter. Obtained data were analyzed for mean performance and correlation coefficient with the help of R-Software version 4.3.1.

Results

Phenological traits

Highly significant differences were observed from the analysis of variance for days to booting and days to heading while emergence count, plant height, and physiological maturity showed non-significant differences (Table 2). The emergence count was found highest in 15HTWYT-41 and the lowest in 15HTWYT-17 with an average value of 7.14±3.61. The 15HTWYT-35 booted earlier and the 15HTWYT-1 booted late with the average days to booting being 69.37±0.60, while the check variety Gautam booted in 65.12 days. The average days to heading was 72.71±1.21 with the earliest headed in Gautam and 15HTWYT-3 and late in 15HTWYT-1, 15HTWYT-26, 15HTWYT-45, and 15HTWYT-49. 15HTWYT-8, 15HTWYT-24, and 15HTWYT-25 matured earlier and 15HTWYT-10 matured late with the mean days to physiological maturity being 108.49±1.09.

Yield attributing traits

Thousand-grain weight showed highly significant differences, similarly, the number of effective tillers and harvest index showed significant differences for the studied genotypes(Table 2). Grain yield, biological yield, spike length, and number of grains per spike revealed non-significant differences between the genotypes (Table 2). 15HTWYT-7 had the highest plant height with the lowest in 15HTWYT-33, and 59.15±4.75cm of average plant height was found. 15HTWYT-7 had the longest spike length and 15HTWYT-49 had the shortest spike length with an average length of 7.01±0.63cm. Effective tillers per meter square were found to be highest in 15HTWYT-15 and lowest in 15HTWYT-27 with a mean number of 234.10±25.85. The number of grains per spike had an average value of 26.44±2.42 with the lowest value in 15HTWYT-18 and the highest value in 15HTWYT-8. The heaviest thousand-grain weight was in 15HTWYT-35 and lightest in 15HTWYT-21 with a mean weight of 36.09±2.24 gm. The average value of the harvest index was found to be 0.41±0.021 with the highest value in 15HTWYT-37 and the lowest value in 15HTWYT-26. 15HTWYT-41 had the highest biological yield while 15HTWYT-1 had the lightest with a mean value of 2.79±0.71 t/ha. Grain yield was found higher in 15HTWYT-35 and lowest in 15HTWYT-1 with an average grain yield of 1.22±0.30t/ha (Table 2).

Correlation analysis

Analysis revealed that most of the studied traits showed significant correlations with grain yield. Biological yield (0.950**), plant height (0.901**), and spike length (0.716**) had positive and highly significant correlations with grain yield (Table 3). Similarly, grain yield had a positive and significant correlation with the number of tillers (0.548*), thousand-grain weight (0.510*), and number of grains per spike (0.509*). Likewise, physiological maturity (0.495), harvest index (0.338), and emergence count (0.216) had a positive correlation with grain yield. While, negative correlations were observed for days to booting (-0.327), and days to heading (-0.271) with grain yield (Table 3). The highest positive correlation was found between grain yield and biological yield (0.950**), followed by between days to heading and booting (0.907**), grain yield and plant height (0.901**), plant height and biological yield (0.882**), spike length and plant height (0.794**), biological yield and spike length (0.687**), number of tillers and biological yield (0.594**) (Table 3).

Table 2. Phenological characters, yield attributing traits, and grain yield of elite spring wheat genotypes in Nawalparasi (2016/2017)

Genotype	EM	DB	DH	PM	PH	SL	NOT	NGPS	TGW	HI	BY	GY
Gautam	12.90	65.12^{hi}	68.0^{f}	106.5	58.5	6.2	237^{abcdef}	20.5	43.33^{abc}	0.415^{bcdef}	2.41	1.06
15HTWYT-1	8.40	70.62^{a}	77.0^{a}	108.5	51.6	5.9	169^{def}	23.0	30.07^{hijk}	0.385^{cdef}	1.32	0.52
15HTWYT-2	14.56	66.02^{fghi}	70.0^{def}	107.0	59.3	7.7	257^{abcdef}	26.0	37.31^{bcdefghij}	0.455^{bcdef}	2.55	1.16
15HTWYT-3	4.56	65.02^{hi}	68.0^{f}	107.0	59.7	7.1	201^{cdef}	31.0	37.49^{bcdefghij}	0.475^{bcd}	2.53	1.21
15HTWYT-4	3.40	67.12^{defgh}	72.5^{abcdef}	108.5	61.6	8.3	195^{cdef}	29.0	39.02^{bcdefghi}	0.435^{bcdef}	3.40	1.49
15HTWYT-5	6.06	66.52^{efghi}	72.5^{abcdef}	109.5	56.2	7.4	185^{cdef}	27.0	29.12^{jk}	0.440^{bcdef}	2.22	0.98
15HTWYT-6	7.56	65.52^{efghi}	70.0^{def}	106.0	54.6	6.8	221^{bcdef}	30.0	33.69^{defghijk}	0.460^{bcde}	2.38	1.07
15HTWYT-7	9.06	67.02^{defgh}	71.0^{cdef}	106.5	75.7	9.6	265^{abcdef}	28.5	36.90^{bcdefghij}	0.460^{bcde}	3.60	1.67
15HTWYT-8	4.90	64.62^{i}	68.5^{f}	105.5	66.7	8.0	215^{bcdef}	33.5	36.07^{cdefghij}	0.485^{bc}	3.09	1.50
15HTWYT-9	14.40	68.62^{abcde}	76.0^{ab}	111.0	68.6	7.7	222^{bcdef}	27.0	37.35^{bcdefghij}	0.465^{bcde}	3.31	1.55
15HTWYT-10	2.56	69.02^{abcd}	75.0^{abc}	112.0	72.5	8.1	232^{abcdef}	29.5	37.69^{bcdefghij}	0.410^{bcdef}	4.32	1.75
15HTWYT-11	2.90	69.12^{abcd}	76.0^{ab}	110.0	62.3	6.7	270^{abcde}	25.5	38.25^{bcdefghij}	0.370^{def}	3.21	1.26
15HTWYT-12	3.56	66.02^{fghi}	70.0^{def}	107.5	57.9	6.6	328^{ab}	27.5	29.93^{ijk}	0.430^{bcdef}	3.13	1.34
15HTWYT-13	7.90	67.62^{cdefg}	75.0^{abc}	110.0	73.1	7.3	296^{abc}	25.0	38.03^{bcdefghij}	0.460^{bcde}	3.83	1.75
15HTWYT-14	8.06	68.02^{bcdef}	75.0^{abc}	110.5	60.5	6.8	203^{cdef}	26.5	38.06^{bcdefghij}	0.430^{bcdef}	2.73	1.21
15HTWYT-15	3.40	67.12^{defgh}	72.5^{abcdef}	109.0	64.2	7.5	345^{a}	27.5	37.75^{bcdefghij}	0.425^{bcdef}	4.29	1.86
15HTWYT-16	4.90	66.62^{efghi}	72.5^{abcdef}	107.5	58.4	6.7	291^{abc}	23.5	32.55^{efghijk}	0.425^{bcdef}	2.84	1.21
15HTWYT-17	0.56	70.02^{ab}	76.0^{ab}	109.0	53.9	5.8	249^{abcdef}	26.5	33.64^{defghijk}	0.400^{bcdef}	2.14	0.87
15HTWYT-18	10.06	69.52^{abc}	76.0^{ab}	110.5	64.2	7.6	231^{bcdef}	19.5	36.24^{cdefghij}	0.430^{bcdef}	3.41	1.49
15HTWYT-19	2.90	68.12^{bcdef}	73.5^{abcde}	107.5	47.6	6.1	198^{cdef}	21.0	34.33^{cdefghijk}	0.435^{bcdef}	1.41	0.62
15HTWYT-20	10.40	66.12^{fghi}	70.0^{def}	106.5	61.8	7.3	249^{abcdef}	23.0	40.83^{abcde}	0.410^{bcdef}	2.91	1.17
15HTWYT-21	3.06	67.02^{defgh}	72.5^{abcdef}	108.0	51.4	6.9	214^{bcdef}	29.0	26.39^{k}	0.405^{bcdef}	1.81	0.72
15HTWYT-22	9.56	66.02^{fghi}	70.0^{def}	107.0	60.1	6.9	260^{abcdef}	31.0	35.20^{cdefghijk}	0.460^{bcde}	3.43	1.56
15HTWYT-23	13.06	69.02^{abcd}	76.0^{ab}	108.5	53.7	7.6	267^{abcdef}	30.5	32.79^{efghijk}	0.415^{bcdef}	2.77	1.16
15HTWYT-24	11.90	65.12^{hi}	70.0^{def}	105.5	51.3	5.8	283^{abcd}	26.0	34.26^{cdefghijk}	0.425^{bcdef}	2.11	0.90
15HTWYT-25	10.10	65.87^{fghi}	69.0^{ef}	105.5	53.0	5.9	226^{bcdef}	24.0	36.44^{bcdefghij}	0.450^{bcdef}	2.35	1.04
15HTWYT-26	4.10	69.87^{ab}	77.0^{a}	107.5	54.3	6.3	175^{def}	24.0	33.61^{defghijk}	0.350^{f}	1.71	0.60
15HTWYT-27	5.44	67.47^{cdefg}	72.5^{abcdef}	107.0	52.9	5.9	154^{f}	24.5	39.28^{bcdefgh}	0.415^{bcdef}	1.60	0.66
15HTWYT-28	5.44	66.97^{defgh}	71.5^{bcdef}	108.0	60.5	7.5	256^{abcdef}	25.5	30.91^{ghijk}	0.430^{bcdef}	2.92	1.25
15HTWYT-29	10.94	67.97^{bcdef}	72.5^{abcdef}	108.5	47.9	5.6	203^{cdef}	22.0	35.67^{cdefghij}	0.385^{cdef}	1.62	0.64
15HTWYT-30	7.60	66.87^{defgh}	74.0^{abcd}	108.0	61.3	6.3	240^{abcdef}	27.0	33.86^{defghijk}	0.485^{bc}	2.70	1.33
15HTWYT-31	6.60	66.87^{defgh}	72.5^{abcdef}	109.0	59.9	6.8	200^{cdef}	20.5	40.25^{abcdef}	0.430^{bcdef}	2.64	1.13
15HTWYT-32	6.94	66.97^{defgh}	72.5^{abcdef}	108.0	54.7	6.9	223^{bcdef}	25.0	33.28^{defghijk}	0.435^{bcdef}	1.79	0.77
15HTWYT-33	1.44	69.47^{abc}	76.0^{ab}	109.5	47.3	6.8	160^{ef}	25.0	29.68^{jk}	0.395^{bcdef}	1.33	0.56
15HTWYT-34	2.94	66.97^{defgh}	72.5^{abcdef}	111.0	63.1	7.3	255^{abcdef}	26.5	42.43^{abcd}	0.430^{bcdef}	3.38	1.44
15HTWYT-35	4.10	64.37^{i}	69.0^{ef}	108.5	65.7	7.2	253^{abcdef}	27.5	48.14^{a}	0.490^{bc}	4.02	1.98
15HTWYT-36	8.94	68.97^{abcd}	75.0^{abc}	110.5	57.6	6.5	274^{abcde}	28.0	32.69^{efghijk}	0.455^{bcdef}	2.84	1.34
15HTWYT-37	2.60	68.37^{abcde}	75.0^{abc}	111.0	67.0	8.1	183^{cdef}	32.5	36.87^{bcdefghij}	0.590^{a}	3.22	1.67
15HTWYT-38	18.10	65.37^{ghi}	69.0^{ef}	109.5	58.3	6.8	208^{cdef}	30.0	39.44^{abcdefg}	0.490^{bc}	2.85	1.40
15HTWYT-39	9.44	64.97^{hi}	69.0^{ef}	110.0	64.4	7.6	226^{bcdef}	27.5	36.64^{bcdefghij}	0.435^{bcdef}	3.73	1.62
15HTWYT-40	6.44	64.97^{hi}	70.0^{def}	110.5	63.2	7.5	227^{bcdef}	28.5	45.62^{ab}	0.485^{bc}	3.84	1.86
15HTWYT-41	19.10	66.87^{defgh}	72.5^{abcdef}	108.0	63.2	6.8	290^{abc}	31.5	36.31^{cdefghij}	0.360^{ef}	5.08	1.66
15HTWYT-42	6.10	66.87^{defgh}	72.5^{abcdef}	109.0	64.4	7.6	264^{abcdef}	33.0	37.67^{bcdefghij}	0.455^{bcdef}	3.91	1.77
15HTWYT-43	4.10	67.37^{cdefg}	72.5^{abcdef}	108.5	65.3	8.3	218^{bcdef}	25.0	42.16^{abcd}	0.470^{bcd}	3.01	1.41
15HTWYT-44	6.94	65.97^{fghi}	72.5^{abcdef}	107.0	63.3	7.5	256^{abcdef}	21.0	34.14^{cdefghijk}	0.410^{bcdef}	3.28	1.36
15HTWYT-45	4.44	69.47^{abc}	77.0^{a}	108.5	50.6	6.5	205^{cdef}	25.5	31.94^{efghijk}	0.400^{bcdef}	1.73	0.72
15HTWYT-46	6.60	66.37^{efghi}	72.5^{abcdef}	109.5	54.2	7.3	155^{f}	28.5	40.68^{abcdef}	0.495^{b}	1.97	0.98

Genotype	EM	DB	DH	PM	PH	SL	NOT	NGPS	TGW	HI	BY	GY
15HTWYT-47	2.94	67.47^{cdefg}	72.5^{abcdef}	109.5	58.8	7.2	224^{bcdef}	24.0	37.08^{bcdefghij}	0.390^{bcdef}	3.02	1.16
15HTWYT-48	4.94	69.97^{ab}	76.0^{ab}	109.0	53.8	6.8	297^{abc}	23.5	31.41^{fghijk}	0.430^{bcdef}	2.55	1.10
15HTWYT-49	10.10	69.37^{abc}	77.0^{a}	108.5	47.7	5.5	250^{abcdef}	25.0	32.04^{efghijk}	0.390^{bcdef}	1.61	0.64
Mean	7.14	67.26	72.71	108.49	59.15	7.01	234.10	26.44	36.09	0.43	2.79	1.22
SEM±	3.61	0.60	1.21	1.09	4.75	0.63	25.85	2.42	2.24	0.021	0.71	0.30
CV%	90.4	1.38	2.59	1.78	13.78	15.33	19.64	15.59	10.35	10.13	42.52	42.93
F-Statics	NS	***	***	NS	NS	NS	*	NS	***	*	NS	NS
LSD5%	12.97	1.91	3.74	3.88	16.40	2.16	92.52	8.29	7.51	0.088	2.39	1.05

EM= emergence count, DB= days to booting, DH= days to heading, PM= days to physiological maturity, PH= plant height, SL= spike length, NOT= number of effective tillers per meter square, NGPS= number of grains per spike, TGW= thousand grain weight, HI= harvest index, BY= biological yield, GY= grain yield, SEM=Standard effort of the mean, CV= coefficient of variation and LSD= least significant difference.

Negative correlations of emergence count were observed with days to booting, and days to heading, while, a positive correlations were observed with an effective number of tillers, grain yield, plant height, and biological yield (Table 3). Days to physiological maturity and days to heading were positively correlated with days to booting, while, days to booting were negatively correlated with the remaining traits (Table 3). Days to heading were negatively correlated with all the traits except days to booting and physiological maturity. Days to physiological maturity had a positive correlation with most of the traits. All the studied traits were positively correlated with plant height and spike length except with days to booting and days to heading (Table 3).

Table 3. The correlation coefficient among parameters measured during the field study of elite spring wheat genotypes in Nawalparasi, Nepal (2016/2017). In table, emergence count (EM), days to booting (DB), days to heading (DH), days to physiological maturity (PM), plant height(PH), spike length (SL), NOT= number of effective tillers per meter square (NOT), number of grains per spike (NGPS), thousand-grain weight (TGW), harvest index (HI), biological yield (BY), and grain yield (GY).

	EM	DB	DH	PM	PH	SL	NOT	NGPS	TGW	HI	BY
DB	-0.241										
DH	-0.242	0.907**									
PM	-0.085	0.360	0.379								
PH	0.225	-0.25	-0.202	0.459							
SL	0.139	-0.21	-0.211	0.393	0.794**						
NOT	0.326	-0.184	-0.188	0.097	0.437	0.237					
NGPS	0.174	-0.273	-0.218	0.196	0.440	0.420	0.180				
TGW	0.049	-0.311	-0.291	0.269	0.482	0.278	0.093	0.159			
HI	-0.063	-0.251	-0.202	0.123	0.259	0.297	-0.031	0.229	0.233		
BY	0.292	-0.289	-0.248	0.459	0.882**	0.687*	0.594*	0.503*	0.461	0.092	
GY	0.216	-0.327	-0.271	0.495	0.901**	0.716**	0.548*	0.509*	0.510*	0.338	0.950**

Discussion

The present study successfully differentiated wheat genotypes based on phenotypic and agronomic traits under late-sown conditions in Nawalparasi, Nepal. Significant variation was observed among genotypes for days to booting and days to heading, consistent with the findings from the late sown wheat experiment of Khanal et al. (2019). Similarly, the number of tillers per square meter and the harvest index also differed significantly among genotypes, corroborating the results reported by Khanal et al. (2019) from their experiment in late-sown spring wheat. Our findings of thousand-grain weight were in agreement with previous works (Khanal et al. 2019, Nawaz et al. 2013, Rahman et al. 2009) on wheat crops where highly significant differences among the studied genotypes for thousand-grain were reported. The differences between the genotypes for thousand-grain weight and the number of tillers per meter square were also reported by Sattar et al. (2010). Wheat grain yield observed under late sown conditions showed non-significant differences between genotypes, Rahman et al. (2009) supported this finding from their experiment in late sown wheat in Bangladesh. There was a non-significant difference between the genotypes for biological yield, a similar finding was reported by Sattar et al. (2010) by doing the experiment both in normal and late sown conditions.

Due to low-temperature exposure of wheat crops up to the booting stage coupled with the hotter reproductive phase might have a direct impact on the lower grain yield (Khanal et al. 2019, Singh et al. 2011). Ambient temperature variation during the growing season had attributed to lower biological yield and grain yield, Tyagi et al. (2003) reported a similar finding.

Biomass yield, thousand-grain weight, number of grains per spike, and plant height had positive significant correlations with grain yield; a similar result was obtained by Younus et al. (2024), Muhsin et al. (2021), Khanal et al. (2020), and Malik et al. (2018) from their experiment in late sown condition. Significant and positive correlations of grain yield with harvest index, biological yield, and number of grains per spike were also found in their late-sown wheat (Muhsin et al. 2021, Khanal et al. 2020, Nagarajan and Rane 2002). Days to physiological maturity, effective tillers per square meter and spike length had significant and positive correlations with grain yield, Malik et al. (2018) and Younus et al. (2024) reported a similar finding. From their experiment, Khairnar et al. (2018) also reported positive and significant correlations of grain yield with days to physiological maturity, number of effective tillers per square meter, and biomass yield. Days to booting and days to heading had a negative and significant correlation with grain yield, a similar result was reported by Khanal et al. (2020). Biomass yield and days to physiological maturity had a positive and significant correlation with grain yield, Rahman et al. (2009) also reported a similar finding.

Among all the traits, the highest and most positive correlation was observed between grain yield and biomass yield, a similar finding was reported by Khairnar et al. (2018) in similar late-sown conditions. This indicates higher biological yield was linked with higher yield and biological yield was a good trait for higher productivity (Tyagi et al. 2003). A low harvest index was observed in our study, which implied reduction in grain yield was higher as compared to biological yield due to planting of wheat in late sown condition, Tyagi et al. (2003) reported a similar finding.

Conclusion

This study demonstrated significant genotypic variation in spring wheat under late-sown conditions in Nawalparasi, Nepal, particularly for days to booting, days to heading, number of tillers per unit area, thousand-grain weight, and harvest index. These findings underscore the potential for selecting and promoting specific genotypes, for instance, 15HTWYT-35, 15HTWYT-40, and 15HTWYT-15 showed better adaptation to late sowing. The observed variability can be exploited in wheat breeding programs aimed at improving performance under suboptimal planting windows. Future research should focus on multi-location and multi-year evaluations to validate these results and identify stable, high-performing genotypes for wider recommendation.

Acknowledgment

The authors thank the Agriculture Botany Division, Khumaltar, Lalitpur for providing planting materials.

Data availability statement

The dataset includes raw measurements of phenological traits, plant growth traits, yield attributes, and farmer preference scores. Researchers are welcome to contact the corresponding author for any additional information or clarifications.

Declaration on the use of generative AI tools

Generative AI tools (such as ChatGPT by OpenAI) were used solely to improve the grammar and formatting of the manuscript. The content was critically reviewed and edited by the authors to ensure academic accuracy and integrity.

References

FAOSTAT database. 2023. Food and Agriculture Organization of the United Nations.

Farooq M, H Bramley, JA Palta and KHM Siddique. 2011. Heat stress in wheat during reproductive and grain-filling phases. Critical Reviews in Plant Sciences. 30(6):491–507. **DOI**: https://doi.org/10.1080/07352689.2011.615687

ISTA. 2023. Chapter 10: Thousand-seed weight (TSW) determination. In: International Rules for Seed Testing. The International Seed Testing Association (ISTA), Bassersdorf: pp.247–248. **DOI**: https://doi.org/10.15258/istarules.2023.F

Kaur V and RK Behl. 2010. Grain yield in wheat is affected by short periods of high temperature, drought and their interaction during pre- and post-anthesis stages. Cereal Research Communications. 38(4):514–520. **DOI**: https://doi.org/10.1556/CRC.38.2010.4.8

Khairnar SS, JH Bagwan, KJ Yashavantha Kumar, VS Baviskar, BK Honrao, VD Surve, VM Khade, AM Chavan and BN Bankar. 2018. Studies on genetic variability parameters and character association in bread wheat (Triticum aestivum L.) under timely and late sown environments of irrigated conditions. Electronic Journal of Plant Breeding. 9(1):190–198. **DOI**: https://doi.org/10.5958/0975-928X.2018.00023.6

Khanal D, BP Kandel and MP Pandey. 2019. Variability of root and agro-morphological traits, and grain yield of elite spring wheat lines developed for high temperature tolerance. Agricultura. 3(4):185–197.

Khanal D, DB Thapa, KH Dhakal, MP Pandey and BP Kandel. 2020. Correlation and Path Coefficient Analysis of Elite Spring Wheat Lines Developed for High-Temperature Tolerance. Environment & Ecosystem Science. 4(2):73–76. **DOI**: https://doi.org/10.26480/ees.02.2020.73.76

Malik A, P Chand, S Kerkhi, S Singh, P Kumar and M Yadav. 2018. Correlation and path coefficient analysis for grain yield and its component traits in wheat (Triticum aestivum L.) under timely and late sown conditions. Journal of Pharmacognosy and Phytochemistry. 7(4):2875–2880.

MoALD. 2023. Ministry of Agriculture and Livestock Development. Statistical Information on Nepalese Agriculture.

Muhsin M, M Nawaz, I Khan, MB Chattha, S Khan, MT Aslam, MM Iqbal, MZ Amin, MA Ayub, U Anwar, MU Hassan and MU Chattha. 2021. Efficacy of Seed Size to Improve Field Performance of Wheat under Late Sowing Conditions. Pakistan Journal of Agricultural Research. 34(1):247–253. **DOI**: https://doi.org/10.17582/journal.pjar/2021/34.1.247.253

Nagarajan S and J Rane. 2002. Physiological traits associated with yield performance of spring wheat (Triticum aestivum) under late-sown conditions. Indian Journal of Agricultural Sciences. 72(3):135–140.

Nawaz A, M Farooq, SA Cheema and A Wahid. 2013. Differential response of wheat cultivars to terminal heat stress. International Journal of Agriculture and Biology. 15(6):1354–1358.

Nayava JL, R Singh and MR Bhatta. 2009. Impact of Climate, Climate Change and Modern Technology on Wheat Production in Nepal: A Case Study at Bhairahawa. Journal of Hydrology and Meteorology. 6(1):1–14. **DOI**: https://doi.org/10.3126/jhm.v6i1.5479

Prasad PVV and M Djanaguiraman. 2014. Response of floret fertility and individual grain weight of wheat to high-temperature stress: Sensitive stages and thresholds for temperature and duration. Functional Plant Biology. 41(12):1261–1269. **DOI**: https://doi.org/10.1071/FP14061

Rahman M., A Hossain, M. Hakim, M. Kabir and MM. Shah. 2009. Performance of wheat genotypes under optimum and late sowing conditions. International Journal of Sustainable Crop Production. 4(6):34–39.

Sah MK, A Shrestha, P Shah, RP Yadav, BP Yadav and A Mishra. 2022. Impact of Sowing Dates on Wheat Varieties in Central Terai Region of Nepal. Agronomy Journal of Nepal. 6(1):162–169. **DOI**: https://doi.org/10.3126/ajn.v6i1.47966

Sattar A, MA Cheema, M Farooq, MA Wahid, A Wahid and BH Babar. 2010. Evaluating the performance of wheat cultivars under late sown conditions. International Journal of Agriculture and Biology. 12(4):561–565.

Sharma RC and E Duveiller. 2004. Effect of helminthosporium leaf blight on the performance of timely and late-seeded wheat under optimal and stressed levels of soil fertility and moisture. Field Crops Research. 89(2–3):205–218. **DOI**: https://doi.org/10.1016/j.fcr.2004.02.002

Shewry PR. 2009. Wheat. Journal of Experimental Botany. 60(6):1537–1553. **DOI**: https://doi.org/10.1093/jxb/erp058

Singh A, D Singh, JS Kang and N Aggarwal. 2011. Management practices to mitigate the impact of high temperature on wheat: A Review. IIOAB Journal. 2(7):11–22.

Tyagi PK, RK Pannu, KD Sharma, BD Chaudhary and DP Singh. 2003. Effect of sowing time on the performance of wheat genotypes. Annals of Biology. 19(2):119–122.

Younus S, MU Saeed and M Sajid. 2024. Assessment of Phenological and Physiological Traits in Wheat under Normal and Delayed Sowing Conditions. Journal of Biological and Agricultural Advancements. 2(1):1–10.