ORIGINAL RESEARCH

Impact of late sowing on morphological and yield traits in 40s bread wheat

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ABSTRACT
The unpredictability and large fluctuations of climatic conditions in rainfed regions influence spring wheat yield and grain quality. These variations offer opportunities for the production of better quality wheat. The effect of late sowing on wheat morphology and grain yield was studied in 40 bread wheat genotypes at the research farm of PBG, The University of Agriculture, Peshawar, Pakistan during 2013–14. Forty wheat genotypes were tested under normal and late sowing in a 5 × 8 alpha lattice design with three replicates. Combined analysis of variance exhibited significant genotype × environment interactions for days to heading, flag leaf area, days to maturity, plant height, spikes m^{-2}, grains $spike^{-1}$, 1000-grain weight, biomass yield, grain yield, and harvest index. Days to emergence, heading, and maturity ranged from 9 to 12, 111 to 121, and 155 to 164 days under normal planting, while under late planting they ranged from 25 to 29, 95 to 107, and 137 to 143 days, respectively. Mean data under normal planting ranged between 77 to 125 cm, 25 to 41 cm^2, 99 to 199, 10 to 13 cm, 32 to 49, 52 to 88 g, 8533 to 13,667 kg, 1869 to 4681 kg, and 21 to 35% for plant height, flag leaf area, spikes m^{-2}, spike length, grains $spike^{-1}$, 1000-grain weight, biomass yield, grain yield, and harvest index, respectively. Under late planting, the ranges were 63 to 91 cm, 18 to 37 cm^2, 57 to 137, 8 to 12 cm, 22 to 52, 36 to 75 g, 2400 to 7933 kg, 540 to 2739 kg, and 20 to 42% for the same traits, respectively. Wheat genotypes planted under late conditions took the maximum number of days to emerge, while fewer days were required for wheat genotypes planted under normal sowing dates to mature. Late planting negatively affected all yield-contributing traits, such as spikes m^{-2} (29%), grains $spike^{-1}$ (18%), 1000-grain weight (29%), biomass (55%), and grain yield (50%). On the basis of the current study, genotype SRN 19111 was identified as superior for 1000-grain weight, biomass yield, and grain yield under normal planting, while genotype PR-107 exhibited higher grain yield under late planting. Therefore, these genotypes are recommended for further extensive testing..

KEYWORDS: Alpha lattice design, genotypes, sowing time, wheat yield and yield components

1. Introduction

Wheat (*Triticum aestivum* L.) is one of the major cereal crops in the world, valued for its high nutritional content (Adnan et al., 2017; Dutta et al., 2019). Together, wheat, rice, and maize account for nearly half of the world's human caloric intake (Rosenthal and Ort, 2012). Wheat is regarded as a staple food crop in most countries, including Pakistan.

Global wheat production during 2009–2010 decreased by 0.32% compared to the 2008–2009 season, while an additional 5.4% decline was estimated for 2010–2011. This reduction in production can be attributed to several factors, including improper agronomic practices, poor management, and unfavorable weather conditions such as high temperature, drought, and salinity (Ali et al., 2019).

The assessment and characterization of plant germplasm are vital for the effective utilization of genetic resources (Ali et al., 2019; Vigna et al., 2011). Wheat genotypes developed through modern breeding technologies have shown improved yield potential and harvest index. However, there remains a significant gap in the development of new genotypes that can withstand harsh environmental conditions while maintaining high yields (Riazuddin et al., 2010).

In Pakistan, it has been observed that nearly 80% of the wheat crop is sown late, while only 20% is planted at the optimal sowing time. Timely sowing could potentially add about two million tons of wheat to the national production. Delays in sowing often result from the presence of preceding crops in the field and the unavailability of timely agricultural inputs. Consequently, wheat frequently experiences terminal high temperatures during the grain-filling stage, leading to severe yield losses. Traits such as tiller production, kernel size, 1000-grain weight, spike length, biomass yield, grain yield, and harvest index are all reduced under late sowing, with variations depending on genotype. High temperatures further impair biochemical and physiological functions of the wheat plant (Hamam and Khaled, 2009; Kattenberg et al., 1995; Reynolds et al., 2001).

It has been reported that sowing after 10th November may result in a yield loss of about 42 kg ha^{-1} per day of delay (Khan, 2003). Late-sown wheat is also more susceptible to pest and disease attacks, drought, and heat stress. In contrast, timely planting produces superior yields. Both molecular and conventional breeding approaches can play a crucial role in developing wheat genotypes that combine high yield potential with resilience to diverse environmental stresses.

Planting time strongly influences production-related traits such as vegetative growth, grain yield, and grain quality. Research on sowing dates has consistently demonstrated that late sowing increases the risk of yield loss (Ehdaie et al., 2001). Morphological and yield traits are directly associated with sowing time: mid-November sowing typically produces the highest tiller density, spike number, 1000-grain weight, and grain yield (Nasser, 2009). In contrast, both early and late sowing increase the likelihood of yield reduction (Ehdaie et al., 2001). Similarly, Aftab et al. (2004) reported that early November sowing enhanced biomass accumulation, grain yield, spike number, and 1000-grain weight compared with late December sowing.

Therefore, the present study was conducted to investigate the impacts of late sowing on morphological and yield traits in newly developed wheat genotypes

2. Materials and methods

2.1 Experimental location and weather detail

The field experiment was conducted during 2013–2014 at the Research Farm of the Department of Plant Breeding and Genetics (PBG), The University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan. The experimental site is located at 34.01° N latitude and 71.35° E longitude, at an altitude of 350 m above sea level in the Peshawar Valley. It lies approximately 1600 km north of the Indian Ocean and is characterized by a continental type of climate. Irrigation was provided through the Warsak Canal, sourced from the Kabul River. The soil at the experimental site is clay loam in texture, low in organic matter (0.87%), phosphorus (6.57 mg kg^{-1}), and potassium (121 mg kg^{-1}). It is alkaline in reaction (pH 8.2) and calcareous in nature (Khan et al., 2009; So et al., 2012). Meteorological data on minimum and maximum temperatures as well as average rainfall were recorded from the meteorological station and are presented in Figure 1a and 1b.

2.2 Experimental design and agronomic practices

The experimental material consisted of 40 wheat genotypes (39 advanced lines and 1 local check). These genotypes were evaluated under normal and late sowing conditions to study the effects of planting time on their performance. The experimental material was obtained from the National Agricultural Research Center (NARC), Islamabad, as part of the National Uniform Yield Trial (NUYT) 2013–14. The experiment was arranged in a 5 × 8 alpha-lattice design with three replications. Each genotype was sown in a six-row plot with a row-to-row spacing of 0.25 m and a plot length of 5 m. Normal planting was carried out on November 20, 2013, while late planting was performed on December 21, 2013.

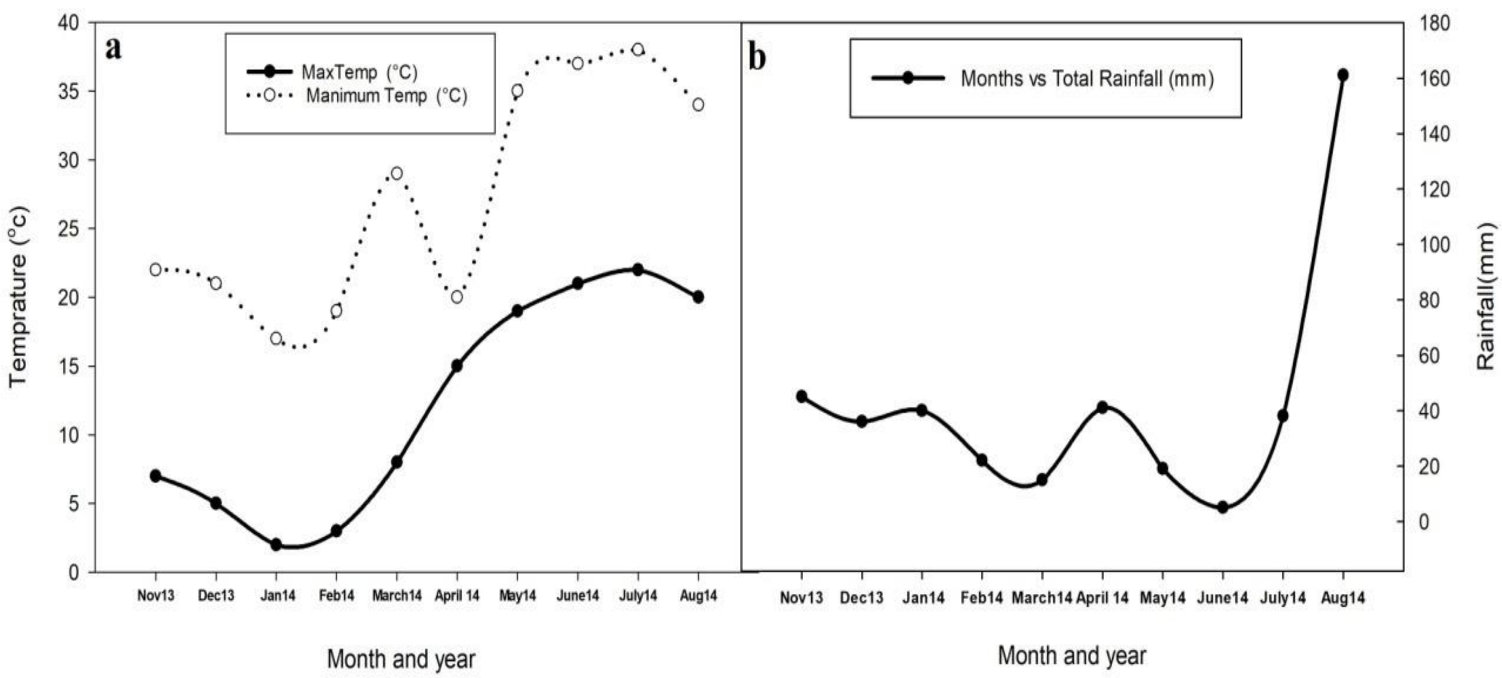

Figure 1. Mean monthly precipitation and air temperature during Nov 2013 to August 2014.

Table. 1. List of genotypes used in the experiment

Genotype	Code	Breeding center
1	109384	RARI- Bahawalpur
2	99172	RARI – Bahawalpur
3	99346	RARI – Bahawalpur
4	99114	RARI – Bahawalpur
5	DN-93	ARI- DI Khan
6	CT 09137	NIFA-Peshawar
7	SRN 09111	NIFA – Peshawar
8	V-09082	WRI – Faisalabad
9	V-09087	WRI – Faisalabad
10	V-10104	WRI – Faisalabad
11	V-10110	WRI – Faisalabad
12	V-11160	WRI – Faisalabad
13	SKD-11	WRI-Sakrand
14	NN-Gandum-I	NIBGE Fsd
15	NN-Gandum-II	NIBGE Fsd
16	TW96010	AZRI Bhakkar
17	TW96018	AZRI Bhakkar
18	SD-998	NIA Tandojam
19	NIA-MN-08	NIA Tandojam
20	CIM-04-10	NIA Tandojam
21	ESW-9525	NIA Tandojam
22	PR-103	CCRI-Pirsabak
23	PR-106	CCRI-Pirsabak
24	PR-107	CCRI-Pirsabak
25	RCA-1	RCA Seeds
26	V-11005	WRS-Tandojam
27	NR-413	NARC-Islamabad
28	NR-421	NARC-Islamabad
29	NR-409	NARC- Wheat
30	NR-419	NARC-Islamabad
31	UAF-9452	Univ. of Agri. Fiasalabad
32	Guard-C	Hybrid – Guard
33	SAWSN-02-102	AZRC-DI Khan
34	Janbazz	UOA Peshawar
35	TD-1	WRI-Sakrand
36	Pirsabak-13	CCRI-Pirsabak
37	Sehar-06	WRI-Faisalabad
38	V07096	WRI-Faisalabad
39	Aas-11	RARI- Bahawalpur
40	NARC-11	Wheat-NARC

Note: The Code column indicates the official genotype code or breeding line number assigned by the respective breeding center.

All recommended agronomic practices were applied uniformly across both planting dates. A total of three to four irrigations were provided during the wheat growing season.

2.3 Data collection and measurements

Days to emergence of wheat were observed in all plots by counting the number of days from sowing until the date when more than 70% of plants emerged. Days to heading were recorded by counting days in number from sowing until the date when more than 75% of tiller formed anthers. Data on plant height was recorded by taking the height of 5 tillers at random in each plot and the height from the base to the tip of each tiller was measured using a meter rod including awns and was then averaged. Flag leaf area was recorded at the panicle initiation stage. Days to physiological maturity of wheat were observed in all plots by counting the number of days from sowing until the date when more than 75% of tillers had become mature in all plots. Spikes m^{-2} was recorded by counting spikes in three middle rows and were then converted to m^{-2} using the same formula as spikes m^{-2}. Spike length was recorded at physiological maturity by using simple geometric ruler. Data on leaf chlorophyll content was recorded as a SPAD value using the Spad meter by putting the flag leaf on the scanner of the meter and hold for a while (Islam et al. 2014). Grains $spike^{-1}$ was noted by counting number of grains per spike in five randomly selected spikes in each plot and was averaged. Data on thousand grain weight was obtained by counting 1000 grains at random from the grain lot of each plot and were measured using an electronic balance. Biological yield was noted by harvesting three rows in the middle of each plot and were dried in an open field for one week and were then weighed and converted to kg ha^{-1} using equation 1. The grain yield was determined by threshing the harvested sample and the grain obtained was weighed and converted to kg ha^{-1}. Harvest index expressed in percentage is the ratio of seed yield to biological yield. It was determined by dividing seed yield by biological yield multiplied by 100.

BY(kg ha^{-1})= BY(kg) in four central rows× 10000/rows-row distance × number of number of rows × row length-------------(1)

2.3 Statistical Analysis

Analyses were carried and the significant means for various traits were separated with the application of LSD test. Sigma plot X7 was used for figure and data analysis was done through IBM-SPSS20 and Microsoft excel.

3. 3. Results

3.1 Phenology

Data on days to emergence, days to heading and days to maturity was considerably altered by wheat genotypes, normal and late planting. Days to emergence for wheat genotypes was recorded from 9 to 12 days under normal planting sowing and 25 to 29 days under late planting sowing condition (Table 2). Whereas among genotypes 109384, DN-93, V-10104, V-10110, V-11160 and NN-Gandum-I took minimum (9) days to emergence while genotype SD-998 took maximum (12) days to emergence.

In contrast, genotypes DN-93 and UAF-9452 took minimum (25) days to emergence while genotype ESW-9525 took maximum (29) days to emergence under late planting condition. Average over normal and late planting days to emergence ranged from 18 days for genotype NR-419 to 26 days for genotype PR-107. Mean values for 40 wheat genotypes for days to emergence were 10 and 26 days under normal and late planting sowing conditions, respectively (Figure 2A).

Data on days to heading showed minimum (111) days to heading were observed for genotype PR-419 and maximum (121) days to heading were observed for genotypes CT 09137, SD-998 and NIA-MN08 under normal planting while at late planting minimum (95) days for genotypes TW96018 and PR-419 and maximum (107) days to heading were observed for genotypes DN-93 and ESW-9525 (Table 2). Genotype PR-419 took minimum days to heading under both normal and late planting conditions. The significant G×E interaction implies that the genotypes were observed to have different relative days to heading across planting dates. Mean genotypic performance across normal and late plantings for days to heading were 118 days in normal planting while 103 days in late planting(Figure 2B). Thus in late sowing conditions the head in emergence 15 days were reduced as compared to normal sowing.

Data on day's physiological maturity under normal planting ranged from 155 to 164 days, while under late planting condition it ranged from 137 to 143 days (Table 2). Genotype UAF-9452 took minimum (155) days to physiological maturity while maximum (164) days to maturity were recorded for genotype NR-413 under normal planting. Under late planting condition minimum (137) days to maturity were recorded for genotype UAF-9452 while maximum (143) days to maturity were recorded for genotype NR-413. Interestingly the genotype UAF-9452 took minimum days while genotype NR-413 took maximum days to maturity under both normal and late planting. Mean days to maturity across two production environments ranged from 147 for genotype 99346 to 153 for genotype V-09082. Average days to maturity were 159 and 140 days under normal and late planting conditions, respectively (Figure 2C). From the net difference in days to maturity it was notice that the wheat genotypes planted at late planting condition get mature 19 days earlier than wheat genotypes sown at their normal sowing condition.

3.2 Growth traits

Data on wheat plant height varied significantly among genotypes and planting dates (Table 2). Generally, shorter plants were observed under late sowing compared with normal sowing. Under normal planting conditions, the minimum plant height (77 cm) was recorded for genotype TD-1, while the maximum height (125 cm) was observed for genotype SAWN-02-102. In late planting, genotype TD-1 again showed the minimum height (63 cm), whereas SAWN-02-102 recorded the maximum (91 cm). Across both environments, plant height ranged from 63 cm for genotype TD-1 to 125 cm for genotype SAWN-02-102.

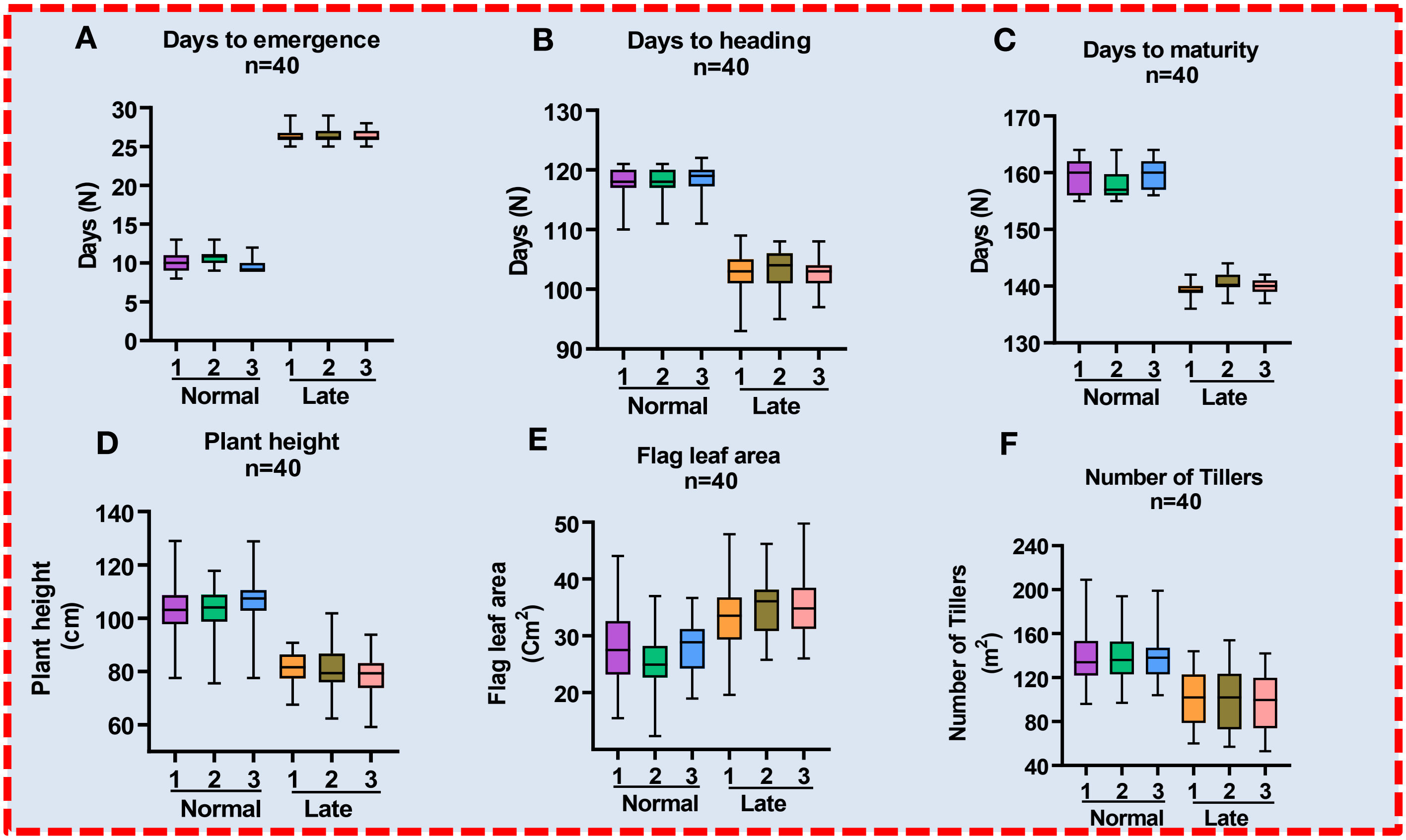

Figure 2. Impact of normal and late planting on days to emergence (A), days to heading (B), days to maturity (C), plant height (D), flag leaf area (E), and number of tillers (F) of 40 bread wheat genotypes. Different letters above the columns indicate statistical significance at $p < 0.05$.

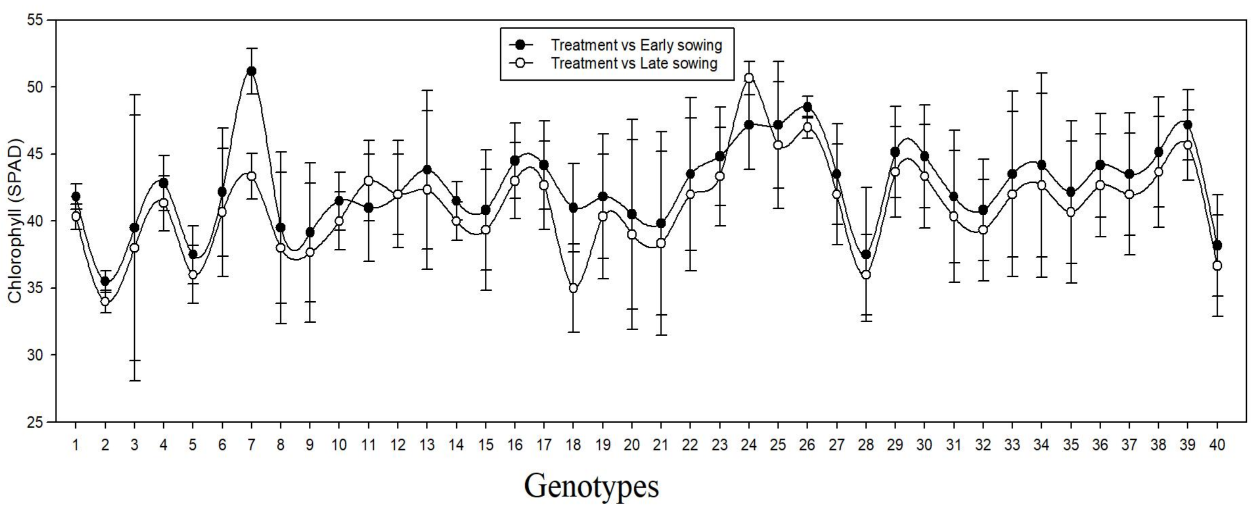

Figure 3. Chlorophyll content as influenced in different wheat genotypes and by sowing dates. Note: the serial numbers from 1 to 40 indicates the genotypes, for detail see table 1.

Mean values across planting dates indicated that genotype TD-1 averaged 70 cm, while genotype SAWN-02-102 averaged 108 cm. The overall mean plant height was 105 cm under normal planting and 80 cm under late planting (Figure 2D). Spike length also varied across planting environments. Under normal planting, spike length ranged from 10 to 13 cm, while under late planting it ranged from 8 to 12 cm (Table 2). Genotype Guard-C showed the minimum spike length (10 cm) and genotype 109384 the maximum (13 cm) under normal planting. In contrast, genotype CT 09137 showed the minimum spike length (8 cm) and genotype Aas-11 the maximum (12 cm) under late planting. Overall, the interaction mean for spike length ranged from 8 cm for genotype CT 09137 to 13 cm for genotype 109384. Across both environments, genotype Aas-11 produced the longest spikes (13 cm), while CT 09137 produced the shortest (9 cm). The mean spike length for the 40 genotypes was 12 cm under normal planting and 10 cm under late planting .

The number of spikes per square meter (spikes m^{-2}) was also significantly influenced by planting time. The maximum number of spikes (199 m^{-2}) was recorded under normal planting, while the minimum (57 m^{-2}) occurred under late planting. Among genotypes, Guard-C produced the highest number of spikes (199 m^{-2}), whereas SAWN-02-102 had the lowest (99 m^{-2}) under normal planting. Under late planting, genotype CIM-04-10 showed the minimum (57 spikes m^{-2}), while PR-107 produced the maximum (145 spikes m^{-2}). The interaction means across environments ranged from 166 spikes m^{-2} for Guard-C to 81 spikes m^{-2} for CIM-04-10 (Table 2). Mean values for the 40 genotypes across normal and late planting were 140 and 100 spikes m^{-2}, respectively.

Mean values for 40 genotypes for spikes m^{-2} over normal and late planting were 140 and 100 respectively

3.3 Physiological traits

The data recorded for flag leaf area under late planting ranged from 18 cm^2 to 37 cm^2, whereas under normal planting conditions it ranged from 25 cm^2 to 41 cm^2 (Table 2). Under late planting, genotype DN-93 showed the minimum flag leaf area (18 cm^2), while genotype V-11005 exhibited the maximum (37 cm^2). In contrast, under normal planting, the minimum flag leaf area (25 cm^2) was observed for genotype NR-419, while the maximum (41 cm^2) was recorded for genotypes PR-107 and RCA-1. The significant G × E interaction was evident from the mean values, as the genotypes with the maximum flag leaf area under normal sowing did not exhibit the maximum values under late sowing, indicating a change in genotype ranking across environments. Based on the overall mean performance, the minimum flag leaf area (25 cm^2) was recorded for genotype V-11160, while the maximum (38 cm^2) was observed for genotypes PR-107 and RCA-1. On average, across the 40 genotypes, flag leaf area was 34 cm^2 under normal planting and 27 cm^2 under late planting.

Data on chlorophyll content also revealed significant differences between genotypes and sowing dates. Early sowing consistently resulted in higher chlorophyll content across genotypes (Figure 3). Among the genotypes, SRN 09111 (genotype no. 7 in Table 2) exhibited the highest chlorophyll content (51.1) under early sowing, while genotype PR-107 (no. 24) recorded the highest (50.6) under late sowing. This variation may be attributed to the genetic characteristics of the genotypes, as reported by Kochak-Zadeh et al. (2013).

3.4 .Yield components and yield traits

Data on 1000-grain weight also showed significant variation between genotypes and sowing dates. Under normal planting, the lightest grains (52 g) were recorded for genotypes SD-998 and NIA-MN-08, while the heaviest grains (88 g) were observed for genotype SRN 09111. In late planting, the minimum 1000-grain weight (36 g) was recorded for genotype NIA-MN-08, and the maximum (75 g) for genotype V-07096 (Table 2). Interestingly, genotype NIA-MN-08 consistently showed the lowest 1000-grain weight under both sowing dates.

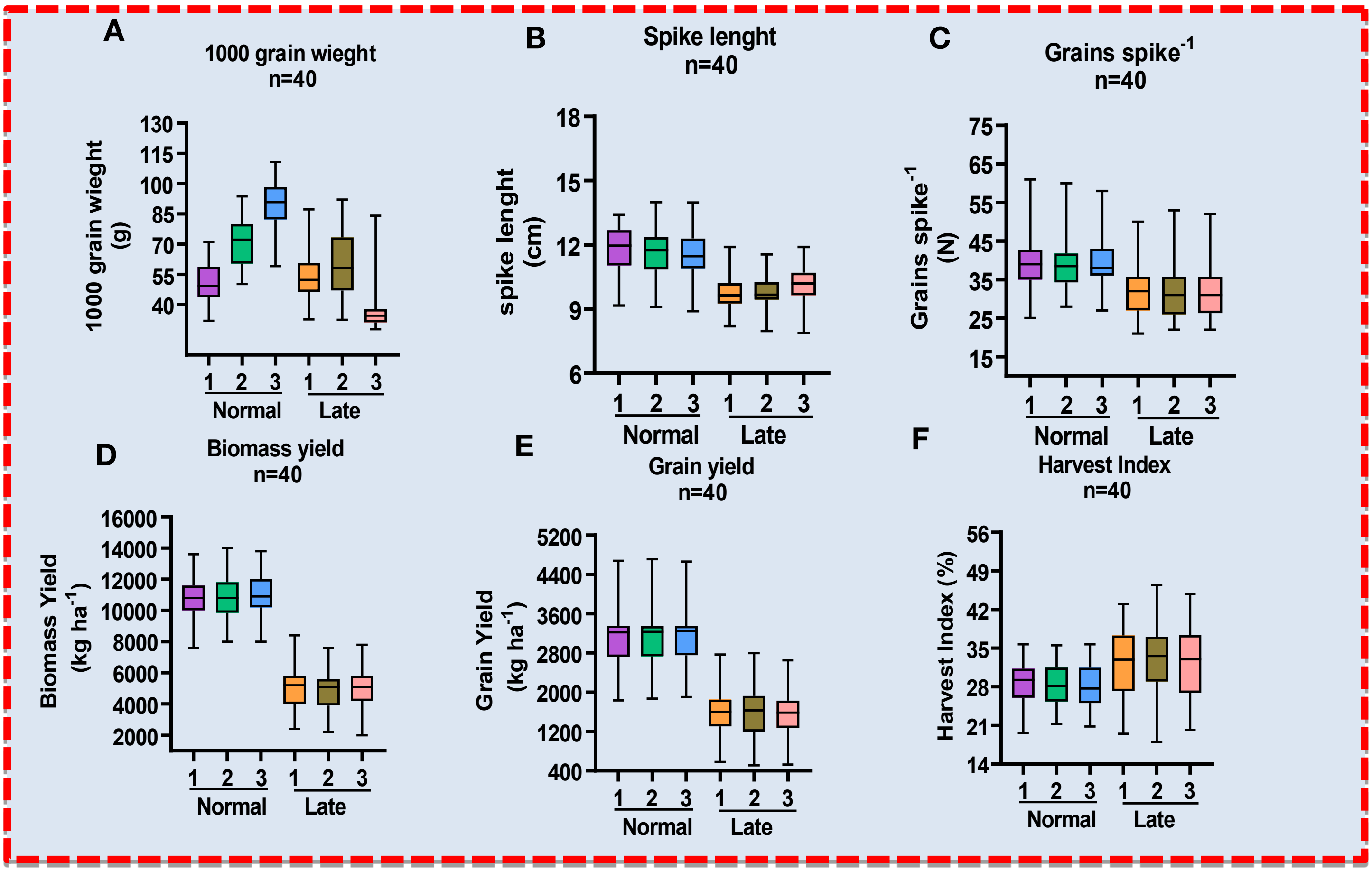

Figure 4. Impact of normal and late planting on 1000-grain weight (A), spike length (B), grains per spike (C), biomass yield (D), grain yield (E), and harvest index (F) of 40 bread wheat genotypes. Different litters above the column indicate statistical significance at $p < 0.05$.

Table 2: Mean performance of wheat genotypes for spikes m^{-2}, spike length, grain $spike^{-1}$, 1000 grain weight, bio-mass yield kg ha^{-1}, grain yield kg ha^{-1} and harvest index for wheat genotypes under Normal and late plantings 2013-14.

	Normal				Late			
Traits	Ranges	Means	Best Genotype	LSD (0.05)	Ranges	Means	Best Genotype	LSD (0.05)
Days to emergence (no)	9-12	10	109384	0.8	25-29	26	UAF-9452	1
Days to heading (no)	95-121	118	NR-409	0.8	95-107	103	NR-409	1.4
Plant Height (cm)	76.93-125.2	104.41	V-09082	1.2	63.26-90.66	80.38	Janbaz	3.4
Flag leaf Area (cm^2)	25.26-40.86	34.40	PR-107	1.6	17.69-36.73	27.28	V-11005	2.1
Days maturity (no)	155-164	159	UAF-9452	4.6	137-143	140	UAF-9452	1
Spike m^{-2} (no)	99-199	140	Guard-C	7	56-145	100	CIM-04-10	7
Spike length (cm)	9.7-13.2	11.63	109384	0.7	8.31-11.56	9.92	Aas-11	0.6
Grains $spike^{-1}$	27-59	39	CM-04-10	2	22-53	32	Janbaz	2
1000- grain weight (g)	51.74-87.59	70	SRN 09111	1.9	36.27-75.46	50.24	V07096	2
Bio-mass yield (kg ha^{-1})	8533-13667	11089	SRN 09111	403	2400-7933.3	4895	NR-421	390
Grain yield (kg ha^{-1})	1869-5336	3127	SRN 09111	51	540-27389	1548.21	PR-107	68
Harvest index	21-35	28	RCA-1	1.4	20.4-41.6	32.4	V-9082	2.7

Across the two planting conditions, 1000-grain weight ranged from 36 g (NIA-MN-08) to 88 g (SRN 09111). Mean values indicated that NIA-MN-08 had the lowest 1000-grain weight (44 g), while genotype V-07096 had the highest (75 g). On average, the 40 wheat genotypes produced 70 g under normal sowing and 50 g under late sowing (Figure 4A). Thus, kernel weight was markedly reduced under late planting, highlighting the superiority of normal sowing. Overall, 1000-grain weight under normal planting was 20 g higher than under late planting, representing a 29% reduction due to delayed sowing.

Data on the number of grains per spike showed significant differences among genotypes and planting dates (Figure 4C). On average, across the 40 wheat genotypes, the minimum number of grains per spike (32) was observed under late sowing, while normal sowing produced the maximum (39 grains per spike) (Figure 3). Under late planting, genotype CT 09137 recorded the minimum (22 grains per spike), whereas genotype Janbaz produced the maximum (52). In contrast, under normal planting, genotype CIM-04-10 exhibited the maximum (59 grains per spike), while genotype Guard-C produced the minimum (27) (Table 2). Planting dates thus had a significant effect on grain number per spike in wheat genotypes. Overall interaction values ranged from 22 (CT 09137) to 59 (CIM-04-10). Due to late planting, an 18% reduction in grains per spike was recorded.. The significant G × E interaction was evident, as genotypes with the highest grain number under normal sowing did not maintain the same ranking under late sowing, indicating differential responses across environments.

Biomass yield also varied significantly across genotypes and planting dates. Under normal planting, the minimum biomass (8533 kg ha^{-1}) was recorded for genotype TD-1, while the maximum (13,667 kg ha^{-1}) was observed for genotype SRN 09111 (Figure 4D). In late planting, biomass ranged from 2400 kg ha^{-1} (SD-998) to 7933 kg ha^{-1} (NR-421). Overall, maximum biomass was recorded under normal sowing and minimum under late sowing, highlighting the strong influence of planting time on genotypic performance. The significant genotype × planting date interaction further confirmed that genotypes responded differently under normal and late planting conditions. Averaged across both planting dates, the minimum biomass (5767 kg ha^{-1}) was observed for genotype TD-1, while the maximum (9700 kg ha^{-1}) was recorded for genotype NR-421. Notably, late planting resulted in a 55% reduction in biomass yield compared with normal sowing. On average, the 40 wheat genotypes produced 10,885 kg ha^{-1} under normal planting, whereas the same genotypes sown late produced only 5990 kg ha^{-1} (Figure. 4D). These results clearly demonstrate that wheat genotypes sown at the optimum planting time produced 4895 kg ha^{-1} more biomass than those sown under late planting conditions.

Grain yield also varied significantly among genotypes and planting dates. Yields ranged from 540 kg ha^{-1} (NIA-MN-08) to 5336 kg ha^{-1} (SRN 09111) across environments (Table 2). Under normal planting, genotype NIA-MN-08 produced the lowest grain yield (1869 kg ha^{-1}), while genotype SRN 09111 recorded the highest. In late planting, NIA-MN-08 again produced the lowest yield (540 kg ha^{-1}), whereas genotype PR-107 gave the highest (2739 kg ha^{-1}). Averaged across planting conditions, genotype NIA-MN-08 produced the lowest grain yield (1205 kg ha^{-1}), while genotype V-11005 gave the highest (3329 kg ha^{-1}). Overall, normal planting produced considerably higher grain yield compared with late planting (Figure 4E).

Harvest index also showed notable variation across genotypes and sowing times. Under normal planting, it ranged from 21% (SD-998) to 35% (RCA-1). In contrast, under late planting, the harvest index ranged from 20% to 42%, with genotype SD-998 recording the minimum (20%) and genotype Guard-C the maximum (42%) (Table 2, Figure 4E).

4. Discussion

Planting time is one of the major factors responsible for low yield in wheat. Ideally, wheat sowing in Pakistan should be completed during November. However, in some cases, when wheat follows cotton, rice, sugarcane, or fodder crops in rotation, sowing is delayed until December. Such delays have a negative impact on grain yield. Therefore, research on the role of planting time and the identification of wheat genotypes with better performance under delayed planting is highly desirable.

Among the tested genotypes, 109384, DN-93, V-10104, V-10110, V-11160, and NN-Gandum-I required a minimum of 9 days to emerge, while genotype SD-998 took the maximum of 12 days under normal planting. In contrast, under late planting, genotypes DN-93 and UAF-9452 emerged in the minimum 25 days, while genotype ESW-9525 took the maximum of 29 days. Across both planting dates, days to emergence ranged from 18 days for genotype NR-419 to 26 days for genotype PR-107. Mean values for 40 wheat genotypes were 10 days under normal planting and 26 days under late planting conditions.

For days to heading, genotype PR-419 recorded the minimum of 111 days, whereas CT 09137, SD-998, and NIA-MN-08 recorded the maximum of 121 days under normal planting. Under late planting, genotypes TW96018 and PR-419 took the minimum of 95 days, while DN-93 and ESW-9525 required the maximum of 107 days. Genotype PR-419 consistently headed earlier under both planting conditions.

Data on days to physiological maturity showed that, under normal planting, maturity ranged from 155 to 164 days, while under late planting it ranged from 137 to 143 days. Genotype UAF-9452 took the minimum of 155 days and NR-413 the maximum of 164 days under normal planting. Under late planting, UAF-9452 matured in the minimum 137 days, while NR-413 matured in the maximum 143 days. Average maturity was 159 days under normal planting and 140 days under late planting. Overall, wheat genotypes under late planting conditions matured 19 days earlier than those under normal planting. This reduction may be due to low temperatures at late planting, which delayed emergence and shortened the growth cycle. Similar findings were reported by Benjamin (1990) and Gul et al. (2012), who observed that low temperatures during emergence and seedling growth negatively affect crop establishment and productivity. Early heading is a desirable trait in wheat breeding because it allows maximum time for grain filling, whereas late heading reduces grain size and grain weight (Irfaq et al., 2005). Significant genotype × environment interactions for days to heading have also been reported by Razzaq et al. (1986), Subhan et al. (1991), Inamullah et al. (2007), and Ilyas et al. (2013). Muhammad et al. (2007) also observed significant effects for days to heading across environments. Nahar et al.

(2010) reported up to a 15% reduction in maturity due to heat stress, while Ilyas et al. (2013) and Muhammad et al. (2007) also reported significant differences among wheat genotypes for days to maturity.

Plant height, spike length, and number of spikes m^{-2} were significantly influenced by both genotypes and planting dates. Generally, shorter plants were observed under late sowing. Under normal planting, genotype TD-1 produced the shortest plants (77 cm), while SAWN-02-102 produced the tallest (125 cm). Under late planting, TD-1 remained the shortest (63 cm), while SAWN-02-102 remained the tallest (91 cm). Spike length under normal planting ranged from 10 to 13 cm, compared with 8 to 12 cm under late planting. Guard-C had the shortest spikes (10 cm) and 109384 the longest (13 cm) under normal planting, while CT 09137 had the shortest (8 cm) and Aas-11 the longest (12 cm) under late planting. The number of spikes m^{-2} ranged from 57 to 199. Under normal planting, Guard-C produced the highest number of spikes (199 m^{-2}), while SAWN-02-102 produced the lowest (99 m^{-2}). The variation in plant height and spike traits may be due to genetic differences among genotypes, as also reported by Wahid et al. (2017), Ahmad et al. (1997), Laghari et al. (2012), Rashid et al. (2004), and Irfaq et al. (2005). Reductions of 25 cm in plant height due to late sowing were also noted in previous studies.

Flag leaf area under late planting ranged from 18 to 37 cm^2, while under normal planting it ranged from 25 to 41 cm^2. On average, flag leaf area was 27 cm^2 under late planting and 34 cm^2 under normal planting. Under late planting, DN-93 recorded the minimum flag leaf area (18 cm^2), while V-11005 recorded the maximum (37 cm^2). Under normal planting, NR-419 recorded the minimum (25 cm^2), while PR-107 and RCA-1 recorded the maximum (41 cm^2). For chlorophyll content, genotype SRN-09111 recorded the highest (51.1) under normal sowing, while PR-107 recorded the highest (50.6) under late sowing. These variations may be attributed to the genetic characteristics of the genotypes (Kochak-Zadeh et al., 2013). Rane et al. (2007) also reported that cooler climates favor both vegetative and reproductive phases of wheat growth.

Grains per spike, biomass, thousand-grain weight, and grain yield were all significantly affected by genotype and planting date. Under late planting, genotype CT 09137 produced the minimum of 22 grains per spike, while Janbaz produced the maximum of 52. For biomass, TD-1 recorded the lowest and SRN-09111 the highest under normal planting, while SD-998 had the lowest and NR-421 the highest under late planting. On average, the 40 wheat genotypes produced 10,885 kg ha^{-1} under normal planting and 5,990 kg ha^{-1} under late planting. Thousand-grain weight was lowest in SD-998 and NIA-MN-08, and highest in SRN-09111 under normal planting. Under late planting, the lowest thousand-grain weight was recorded for NIA-MN-08 and the highest for V-07096. Grain yield was also affected: under normal planting, NIA-MN-08 produced the lowest and SRN-09111 the highest yield, while under late planting, NIA-MN-08 again produced the lowest and PR-107 the highest.

Across both planting dates, NIA-MN-08 consistently produced the lowest yield, while V-11005 produced the highest. These differences in biomass and yield attributes may be due to genetic variability, as reported by Kakar et al. (2003), Akram et al. (2008), Abdullah et al. (2007), and Ansari et al. (1989). Several researchers, including Laghari et al. (2012) and Irfaq et al. (2005), also reported reductions in yield components due to late sowing. Similarly, Cotes et al. (2006), Amin et al. (2005), Khalil et al. (2005), and Garcya et al. (2003) observed changes in the ranking of wheat genotypes when sown under different environmental conditions. "Overall, the study demonstrates that delayed planting significantly reduces wheat growth and yield due to temperature stress, but genotypic variability indicates the potential for selecting and breeding heat-tolerant wheat varieties suitable for late sowing conditions.

5. Conclusion

From this study it is concluded that late sowing of wheat negatively affect both morphological traits and grain yield and may results in 50 % of wheat yield loss. Hence timely sowing of wheat genotypes is highly suggested. The conducted research identified genotype SRN 19111 superior for 1000-grain weight, bio-mass yield and grain yield under normal planting, while genotype PR-107 exhibited higher grain yield under late planting. Therefore, these genotypes are recommended for further extensive testing and utilization in different wheat breeding programs.

Authors Contributions:

M.A and F.M conceived the main idea of research, M.A wrote the manuscript. A.K, F.A and Q.H revised the manuscript and provided suggestions. In addition M.A and AK assessed and analyzed the data, and performed data collection. All authors have read and agreed to the published version of the manuscript.

Data Availability statements: The data presented in this study are available on request from the corresponding author.

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