

## Multivariate Characterization of Common and Durum Wheat Collections Grown in Korea using Agro-Morphological Traits

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**ABSTRACT** Developing improved wheat varieties is vital for global food security to meet the rising demand for food. Therefore, assessing the genetic diversity across wheat genotypes is crucial. This study examined the diversity of 168 durum wheat and 47 common wheat collections from 54 different countries using twelve agro-morphological parameters. Geumgang, a prominent Korean common wheat variety, was used as a control. Both qualitative and quantitative agronomical characteristics showed wide variations. Most durum wheats were shown to possess dense spikes (90%), while common wheats showed dense (40%) or loose (38%) spikes, with yellowish-white being the dominant spike color. The majority of the accessions were awned regardless of wheat type, yellowish-white being the main awn color. White or red kernels were produced, with white kernels dominating in both common (74%) and durum (79%) wheats. Days to heading (DH) and days to maturity (DM) were in the ranges of 166–215 and 208–250 days, respectively, while the culm length (CL), spike length (SL), and awn length (AL) were in the ranges of 53.67–163, 5.33–18.67, and 0.50–19.00 cm, respectively. Durum wheats possessed the shortest average DH, DM, and SL, while common wheat had the longest CL and AL ( $p < 0.05$ ). Common wheats also exhibited the highest average one-thousand-kernel weight. Hierarchical cluster analysis, aided by principal component analysis, grouped the population into seven clusters with significant differences in their quantitative variables ( $p < 0.05$ ). In conclusion, this research revealed diversity among common and durum wheat genotypes. Notably, 26 durum wheat and 17 common wheat accessions outperformed the control, offering the potential for developing early-maturing, high-yielding, and lodging-resistant wheat varieties.

**Keywords :** diversity, phenotype data, *Triticum aestivum*, *Triticum durum*, wheat cultivation

**Wheat** is one of the most widely grown and traded crops in the world, providing a significant source of income for millions of farmers and a foundation for the economies of many nations. It is cultivated on approximately 220 million hectares of land worldwide, with an annual yield of more than 750 million metric tons. Currently, China, India, Russia, the United States, France, and Canada are the top wheat producers in that order (Bordes *et al.*, 2008; Sanchez-Bragado *et al.*, 2023; FAO, 2021). Because wheat contains high levels of carbohydrates, fibers, nutrients,

and polyphenols, it is a staple dietary crop in both developed and developing countries. This makes it an important part of a well-balanced diet that benefits human health (Gupta *et al.*, 2021; Royo *et al.*, 2022; Yang *et al.*, 2022). Furthermore, wheat accounts for a substantial amount of the world's daily caloric intake, making it critical for food security and nutrition (Khan *et al.*, 2023). It also has many industrial applications, including in the food and beverage sectors, where it is used as a crucial raw material to produce a variety of products such as bread, pasta,

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pastries, and beer, thus reinforcing its economic relevance (Faltermaier *et al.*, 2014; Gupta *et al.*, 2021).

Common wheat (*Triticum aestivum* subsp. *aestivum* (L.)) and durum wheat (*T. turgidum* subsp. *durum* (Desf.)) are two prominent wheat species widely cultivated in different parts of the world. Both species have a similar genetic origin. However, common wheat is a hexaploid species, while durum wheat is a tetraploid species (Yang *et al.*, 2022; Pignone *et al.*, 2015). The other major differences between common wheat and durum wheat rely on their end-use and gluten properties. Common wheat is mostly used to make bread and baked food products owing to its high gluten concentration which gives bread its distinctive flexibility and rise. Durum wheat, also known as hard wheat, on the other hand, is ideal for making pasta due to its high protein content and gluten quality, which provides the desired texture and hardness (Yang *et al.*, 2022). Despite differences in gluten characteristics and end-use, both common and durum wheat are important species in the human diet and help to ensure global food security. Therefore, they are a research focus, mainly in developing improved wheat varieties (Pignone *et al.*, 2015; Yang *et al.*, 2022).

Developments in molecular biology, genomics, and breeding techniques have significantly advanced wheat breeding in recent years. Modern breeding operations are geared toward developing wheat varieties that are not only high-yielding but also resistant to biotic and abiotic pressures such as pests, diseases, and climate change-related problems (Dodig *et al.*, 2012; Choi *et al.*, 2018; Yang *et al.*, 2022; Lee *et al.*, 2021a). Furthermore, the development of wheat cultivars with improved nutritional profiles has gained prominence (Sun *et al.*, 2023). Overall, wheat breeding is evolving to suit the increasing demands of a worldwide population, to ensure food security, environmental sustainability, and improved wheat product quality. Genetic resources from both common wheat and durum wheat are essential for advancing wheat breeding initiatives. These resources contain a diverse pool of genetic characteristics and attributes that can be exploited to develop enhanced wheat varieties (Ormoli *et al.*, 2015; Royo *et al.*, 2010; Yang *et al.*, 2022). Therefore, documentation and characterization of agromorphological features of wheat genetic resources are critical for classifying and distinguishing distinct wheat varieties, as well as deciding on suitable crossings to achieve certain breeding goals. By utilizing the genetic diversity of both

common and durum wheats, breeders can develop new varieties with desired features such as higher yields, increased disease resistance, and superior end-use attributes, among others (Cao *et al.*, 2015; Dagnaw *et al.*, 2022; Khan *et al.*, 2023). Moreover, such investigations provide essential information to breeders, allowing them to make informed selections and decisions during the breeding process (Tajibayev *et al.*, 2023; Jung *et al.*, 2021; Kumar *et al.*, 2020; Rahimi *et al.*, 2019). These all help to ensure the long-term viability, productivity, and resilience of wheat production around the world (Larkin *et al.*, 2019). Previously, several studies have evaluated the genetic diversity of common and durum wheat varieties grown in Korea and elsewhere (Ambati *et al.*, 2020; Dodig *et al.*, 2012; Cao *et al.*, 2015; Jung *et al.*, 2021; Ormoli *et al.*, 2015; Son *et al.*, 2015; Tajibayev *et al.*, 2023). In most of these studies, however, either common wheat or durum wheat genotypes were exclusively considered. Furthermore, studies investigating the relative characteristics of common and durum wheat genotypes grown under similar environmental conditions are very limited. This study aimed to characterize common wheat ( $n=47$ ) and durum wheat ( $n=168$ ) germplasms collected from 54 different countries and recently cultivated in Korea using a total of twelve agro-morphological traits. Geumgang, a popular Korean common wheat variety, was used as a control (check) to evaluate the performance of each wheat accession. The results of this preliminary study may provide useful information on the differences in agro-morphological traits between common and durum wheat genotypes and may initiate further research in the future.

## MATERIALS AND METHOD

### Plant materials collection and classification

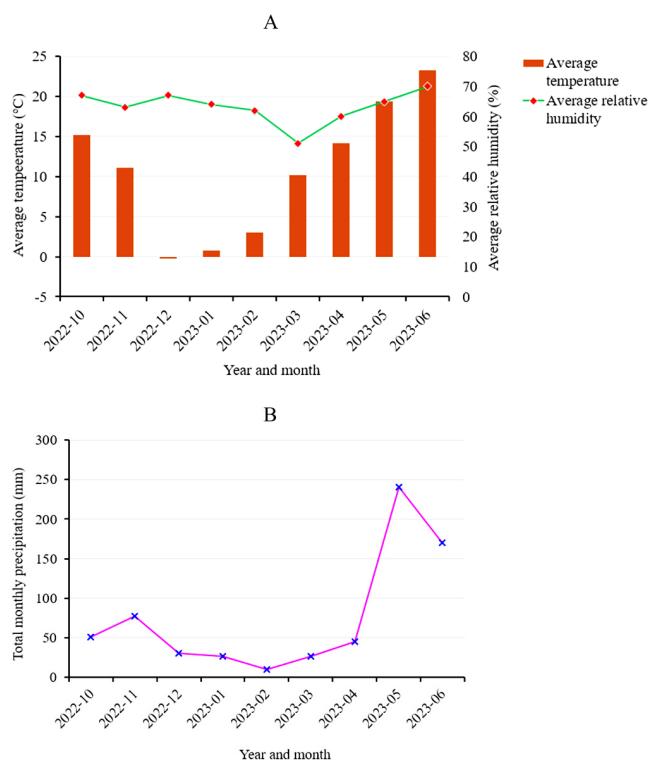
The wheat collection used in this study consists of 168 durum wheat and 47 common wheat genotypes obtained from the National Agrobiodiversity Center, Rural Development Administration (RDA, Jeonju, Korea). The germplasms were initially collected from 54 different countries including Afghanistan (AFG), Angola (AGO), Argentina (ARG), Australia (AUS), Azerbaijan (AZE), Bolivia (BOL), Bosnia and Herzegovina (BIH), Brazil (BRA), Bulgaria (BGR), Canada (CAN), Chile (CHL), China (CHN), Croatia (HRV), Cyprus (CYP), Czechoslovakia (CSK), Ecuador (ECU), Egypt (EGY), Eritrea (ERI), Ethiopia (ETH), France (FRA), Georgia (GEO), Germany (DEU), Greece

(GRC), Hungary (HUN), India (IND), Iraq (IRQ), Israel (ISR), Italy (ITA), Japan (JPN), Jordan (JOR), Kazakhstan (KAZ), Kyrgyzstan (KGZ), Lebanon (LBN), Macedonia (MKD), Malta (MLT), Mexico (MEX), Morocco (MAR), Nepal (NPL), Pakistan (PAK), Peru (PER), Poland (POL), Portugal (PRT), Russia (RUS), Saudi Arabia (SAU), Serbia (SRB), Spain (ESP), Sweden (SWE), Syria (SYR), Tunisia (TUN), Turkey (TUR), Ukraine (UKR), United States of America (USA), United Kingdom (GBR), and Uzbekistan (UZB). Among the total population, the origin of twenty-three genotypes, including 13 common and 10 durum wheat genotypes, was not confirmed. Geumgang, a common wheat cultivar cultivated in over 70% of wheat area in Korea (Jung *et al.*, 2022), was used as a check. Table S1 (Supplementary material) presents the general information and frequency of the wheat germplasms related to their type, variety, and origin.

#### Field cultivation and data recording

Cultivation of all the wheat genotypes was conducted during the 2022–2023 winter season in an experimental farm located at the National Agrobiodiversity Center, Jeonju, Republic of Korea (latitude/longitude: 35°49'38.37''N/127°09'07.78''E). Twenty-five seeds of each genotype were sown in a row with 5 cm spacing between seeds and 30 cm gap between genotypes on October 21, 2022. The control (check) was similarly cultivated with replication at every 20 genotypes. Fertilizer was applied in recommended doses and methods (RDA, 2020). Specifically, N:P:K at 3.6:7.4:3.9 kg/10ha was applied during sowing. An additional dose of N at 5.5 kg/10ha was applied at tillering stage. The accessions were grown under uniform weather and treatment conditions, and the growth period lasted until June of 2023. The average monthly temperature, humidity, and precipitation in the cultivation are summarized in Fig. 1.

A total of twelve agro-morphological traits were recorded following the manual presented by the Rural Development Administration (RDA, 2006). Among these, five were qualitative characters (spike density, spike color, awn presence (awnedness), awn color, and kernel color), while the remaining seven were quantitative traits (days to heading (DH), days to maturity (DM), days from heading to maturity (DHM), culm (stem) length (CL), awn length (AL), spike length (SL), and one-thousand kernel weight (TKW)). Spike color and awn color were visually measured on a 1–5 scale: 1 (yellowish white), 2 (yellow), 3



**Fig. 1.** Monthly temperature and humidity (A) and precipitation (B) during the cultivation period.

(brown), 4 (red to purple), and 5 (black). Kernel color was also visually determined and categorized as white or red. Awnedness (awn presence) was recorded as awnless, awnletted (short awn), and awned (conspicuous awn). Spike density was visually measured on a 1–9 scale: 1 (very loose), 3 (loose), 5 (intermediate), 7 (dense), and 9 (very dense). DH was counted as the number of days from sowing to 40% of plants with the first spikes emerged. DM was determined as the number of days from sowing to the time when the first node became yellow. AL was the length of the longest awn in a spike. CL was measured from the ground to the bottom of the spike at maturity, while SL was measured excluding awns. Similarly, TKW was measured in grams of 1,000 kernels after hand-cleaning and drying.

#### Data analysis

Data were recorded from the field as well as laboratory inspections. All the quantitative agronomical traits for individual accessions, except for AL, were reported as means from triplicate measurements. Differences between means were statistically evaluated by analysis of variance (ANOVA) followed by Fisher's least significant difference test at  $p < 0.05$  level ( $LSD_{0.05}$ ) using

**Table 1.** Frequency (*f*) of qualitative agronomical traits in common and durum wheat germplasms cultivated in Korea.

Trait	Category	Common wheat		Durum wheat		Total population		Geumgang (Control)
		Frequency ( <i>n</i> )	Rel. frequency (%)	Frequency ( <i>n</i> )	Rel. frequency (%)	Frequency ( <i>n</i> )	Rel. frequency (%)	
Spike density	Loose	18	38	4	2	22	10	✓
	Dense	19	40	152	90	171	80	
	Medium	10	21	12	7	22	10	
Awn presence	Awned	37	79	166	99	203	94	✓
	Awnleted	10	21	2	1	12	6	
Awn color	Yellow	3	6	20	12	23	11	✓
	Yellowish white	25	53	58	35	83	39	
	Brown	16	34	20	12	36	17	
	Black	3	6	70	42	73	34	
Spike color	Yellowish white	28	60	93	55	121	56	
	Brown	15	32	47	28	62	29	
	Yellow	2	4	17	10	19	9	✓
	Black	1	2	11	7	12	6	
Kernel color	Redish purple	1	2	0	0	1	0	
	White	35	74	133	79	168	78	✓
	Red	12	26	35	21	47	22	

xlstat software (Addinsfot, NY, USA). Principal component (PCA), Pearson's correlation matrix analyses, and boxplots were computed using R-software version 4.0 ([www.r-project.org](http://www.r-project.org)). Hierarchical cluster analysis (HCA) was also generated using JMP-software (SAS, Inc., Cary, North Carolina, USA).

## RESULTS AND DISCUSSION

### Variations of qualitative agronomic characteristics

Qualitative agronomical traits include categorical characteristics and are among the criteria that provide first-hand information on genetic variability (Sheoran *et al.*, 2019). As highlighted before, differences in genotype, cultivation condition, and years of cultivation affect the morphology and physical appearance of wheat genetic materials (Kumar *et al.*, 2020; Royo *et al.*, 2022, 2010). Therefore, previous studies on different wheat varieties showed ranges of variations in agronomical traits (Ma *et al.*, 2023; Mengistu *et al.*, 2015; Pignone *et al.*, 2015). In this study, five key qualitative agronomical traits including spike density, spike color, awn presence, awn color, and kernel color were recorded for each of the wheat accessions. The characteristic

features of individual accessions are provided in Table S2 (Supplementary material). Table 1 summarizes the frequency and relative frequency of each trait across durum wheat accessions, common wheat accessions, and the total population. While 90% of durum wheat accessions had a dense spike, the majority of the common wheat accessions had either dense (40%) or loose (38%) spike density. Geumgang, the control wheat variety, also had loose spikes, and only 10% of the total population had a similar spike density (Table 2). Spike density is an important trait in wheat and it is related to yield. Moreover, it has a significant effect on spike length, spikelet number per spike, and kernel length (Liu *et al.*, 2020; You *et al.*, 2021). Overall, the majority of the durum wheat accessions could be considered as high-yield genotypes compared to the common wheats. Regarding spike color, yellowish-white was dominant in both common (60%) and durum (55%) wheat accessions followed by brown color. Concerning awn presence, only 10 common wheat accessions and 2 durum wheat accessions were awnleted, the remaining all, including the control variety, being awned. Awn color was another trait that showed wide variation between common and durum wheats. In durum wheat, black

**Table 2.** Statistics of quantitative agronomical characteristics in common and durum wheat germplasms cultivated in Korea.

Trait	Wheat type	Min.	Max.	Mean <sup>v</sup>	SD <sup>u</sup>	CV <sup>t</sup>	Geumgang (Control)	Skew.	Kurt.
DH <sup>w</sup> (Days)	Durum	184.00	215.00	198.20 <sup>a</sup>	5.76	2.91	171	0.49	0.26
	Common	166.00	214.00	193.81 <sup>b</sup>	9.66	4.98		-0.47	0.65
	Total	166.00	215.00	197.24	7.05	3.57		-0.46	2.13
DM <sup>x</sup> (Days)	Durum	224.00	250.00	238.10 <sup>a</sup>	5.61	2.36	219	-0.17	-0.40
	Common	208.00	250.00	233.72 <sup>b</sup>	8.80	3.76		-0.58	0.64
	Total	208.00	250.00	237.014	6.69	2.82		-0.73	1.50
DHM <sup>y</sup> (Days)	Durum	27.00	52.00	39.90 <sup>a</sup>	4.04	10.12	48	-0.12	0.03
	Common	32.00	46.00	39.91 <sup>a</sup>	3.05	7.65		-0.53	0.65
	Total	27.00	52.00	39.90	3.8	9.763		-0.16	0.18
Culm length (cm)	Durum	53.67	163.00	118.92 <sup>a</sup>	22.38	18.82	65.00	-0.62	0.10
	Common	62.17	155.33	103.43 <sup>b</sup>	23.35	22.57		0.16	-1.18
	Total	53.67	163.00	115.53	23.48	20.33		-0.44	-0.48
Spike length (cm)	Durum	5.33	13.00	8.18 <sup>b</sup>	1.36	16.68	10.00	0.36	0.16
	Common	5.83	18.67	9.81 <sup>a</sup>	2.60	26.48		1.13	1.70
	Total	5.33	18.67	8.54	1.84	21.53		1.52	4.87
Awn length (cm)	Durum	5.00	19.00	11.18 <sup>a</sup>	2.32	20.76	5.00	0.28	0.50
	Common	0.50	15.00	6.19 <sup>b</sup>	3.65	58.98		0.57	-0.18
	Total	0.50	19.00	10.09	3.37	33.43		-0.62	0.53
TKW <sup>z</sup> (g)	Durum	20.33	78.00	44.73 <sup>a</sup>	8.10	18.11	46.00	0.32	1.20
	Common	25.00	56.67	38.74 <sup>b</sup>	6.83	17.64		0.22	-0.16
	Total	20.33	78.00	43.42	8.22	18.94		0.33	0.89

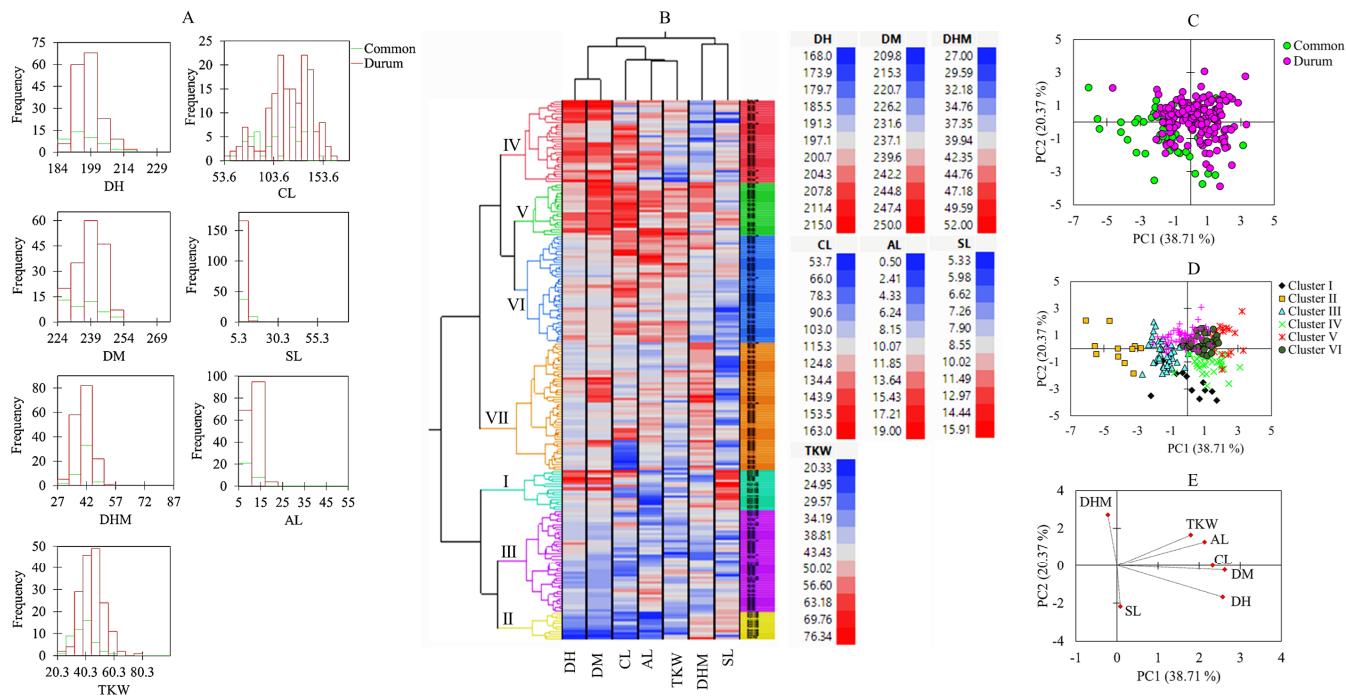
<sup>w</sup>Thousand kernel weight, <sup>y</sup>Days from heading to maturity, <sup>x</sup>Days to maturity, <sup>w</sup>Days to heading, <sup>u</sup>Standard deviation, <sup>t</sup>Coefficient of variation. <sup>v</sup>Different superscript letters in a column within a category represent means that are significantly different ( $p < 0.05$ ).

awn color dominated (70%) followed by yellowish white (58%), while yellowish- white (53%) was dominant in common wheat followed by brown color (34%). A recent review by Sanchez-Bragado *et al.* (2023) revealed how the presence and/or absence of awn in wheat affects spike photosynthesis, yield, and grain weight. Awns also provide protection against predators and aid grain dispersal. Moreover, the presence of awns could influence postharvest handling and processing (Huang *et al.*, 2020; Ntakirutimana & Xie, 2020). Kernel color is another important trait that is controlled by a variety of trait loci and affects the concentrations health-promoting metabolites in wheats (Li *et al.*, 2023; Ma *et al.*, 2019; Matus-Cádiz *et al.*, 2003). In this study, two dominant kernel colors, including white and red, were recorded. Similar to the control, most of the common and durum wheat accessions developed white kernels

with relative frequencies of 74 and 79%, respectively. Red kernel accounted for 26% in common wheats and 21% in durum wheat accessions. In general, the observation of different qualitative traits among the wheat accessions could provide a wide spectrum of options for the selection of genotypes with desirable characteristics (Sun *et al.*, 2023). Moreover, such wide variance could be an important input to induce molecular-level analysis in future studies (Ma *et al.*, 2023).

#### Variations of quantitative agronomic characteristics

Quantitative agronomical traits also play a significant role in the characterization of plant genetic materials and the selection of genotypes with desirable properties (Mondal *et al.*, 2016; Sheoran *et al.*, 2019). A total of seven quantitative traits were recorded in this study, and wide variations were observed among



**Fig. 2.** Histograms of quantitative agronomical characters (A), hierarchical cluster analysis (B), score plot of accessions based on variety (C) and cluster (D), and loading plot of variables (E) from the principal component analysis. AL: Awn length (cm), CL: Culm length (cm), DH: Days to heading (days), DHM: Days from heading to maturity (days), DM: Days to maturity (days), SL: Spike length (cm), TKW: One-thousand kernel weight (g).

the wheat accessions. Table S3 (Supplementary material) depicts the characteristic features of individual accessions, while their distribution patterns across each quantitative trait are illustrated in Fig. 2A. The statistical values for each of the traits are summarized in Table 2. All the traits, except for SL and TKW, were negatively skewed in the total population. On the other hand, kurtosis was between the highest negative value for CL and the highest positive value for SL. These observations signify that not all of the quantitative traits had normal distributions (Gayacharan *et al.*, 2020). The coefficient of variation was the highest for AL (33.43%) followed by SL (21.53%), and the lowest for DM (2.82%) in the total population. DH ranged from 166 days in accession Rufom-7 (a common wheat of unknown origin) to 215 days in ECH605 (a durum wheat from Great Britain). Likewise, DM was in the range of 208 - 258 days. Once again, Rufom-7 was the earliest to mature, while three durum wheat accessions including Timor (from Brazil), 4 (from Nepal), and HN-ROD25137700 (from Portugal), and one common wheat accession, PI277126 (from Great Britain), equally took the longest days to mature. Overall, the observed DH and DM ranges are comparable to many previous studies. In two

independent studies conducted in Korea, DH in the ranges of 156-210 and 168-218 days and DM in the ranges of 209-262 and 209-258 days were reported (Jung *et al.*, 2021; Lee *et al.*, 2021b). These ranges are in agreement with those observed in our study. Compared to our study, much narrower ranges of DH (61.8-78.0 days) and DM (134.0-145.2 days) were found in Ethiopian durum wheats (Dagnaw *et al.*, 2022). Other studies also reported wide-ranging DH and DM values for both common and durum wheat varieties (Baboev *et al.*, 2021; Rahimi *et al.*, 2019; Mohammadi *et al.*, 2019; Khan *et al.*, 2023). Such variations could arise due to differences in growing conditions, number of accessions examined, and year of cultivation, among others (Dodig *et al.*, 2012; Ren *et al.*, 2013). Statistical analysis was also conducted to view the variations in DH and DM between the common wheat and durum wheat accessions as well as in comparison to the control variety. The average DH and DM were both shorter in common wheats (193.8 and 233.72 days, respectively) than in durum wheat accessions (198.04 and 237.99 days, respectively) ( $p < 0.05$ ). DH and DM for the control variety were 171 and 219 days, respectively. Accordingly, three common wheat accessions including Kwangye W372 from

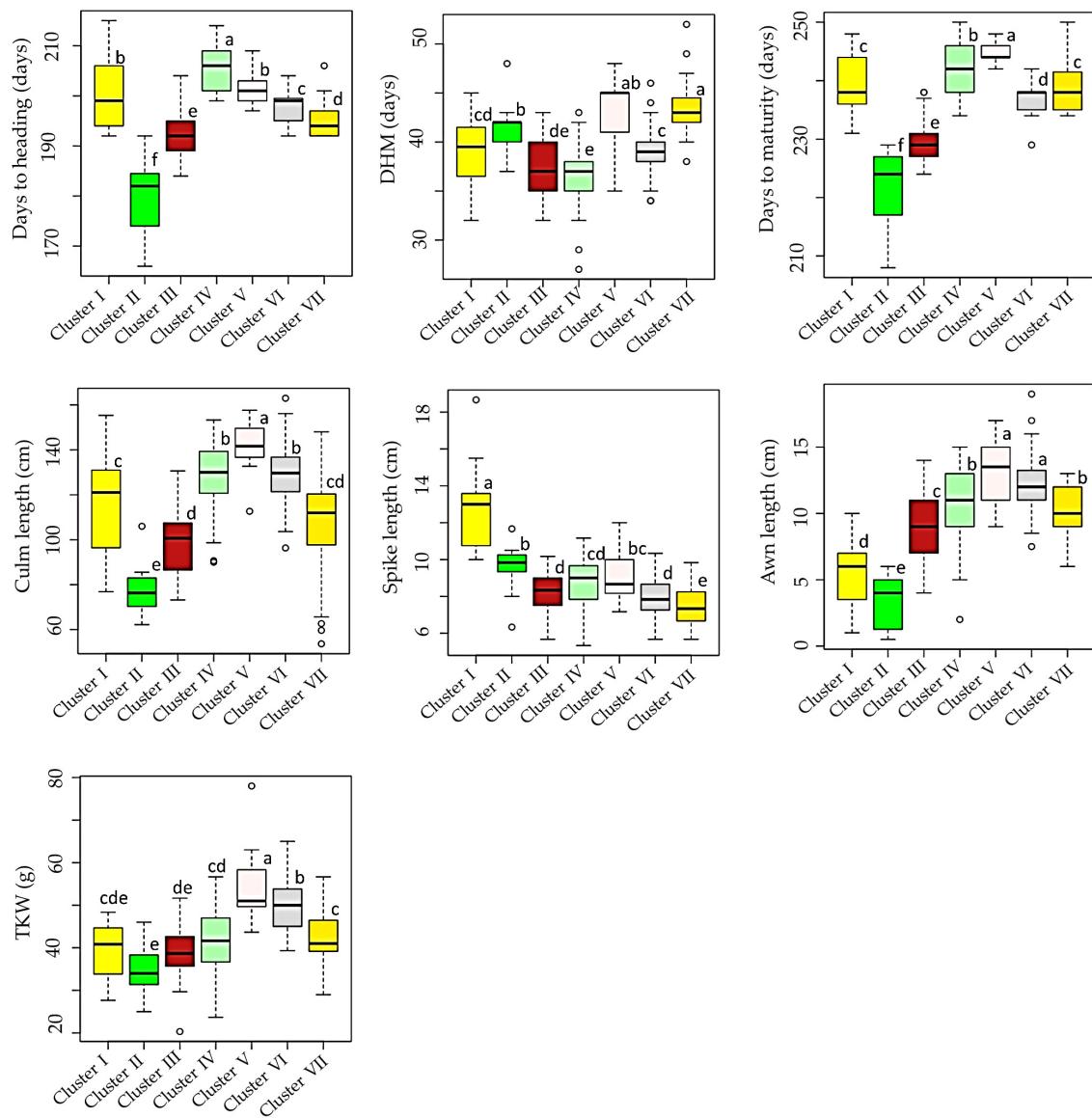
Japan, Ruform-7 and Dongbuk Sabigye 2403-10 of unknown origin were found to be early maturing than the control variety having DM of < 219 days. In contrast, no early maturing durum wheat genotype compared to the control was found. The development of early maturing wheat varieties is one of the main goals of breeding programs (Mondal *et al.*, 2016). These germplasms could therefore be important materials in the development of early maturing wheat varieties.

Apart from these growth-related traits, yield-related traits including CL, SL, AL, and TKW were also recorded and showed significant variations. CL ranged from 53.67 cm in accession U13864 (a durum wheat from Italy) to 163.00 cm in Pulawska fwarda (another durum wheat from Poland). Likewise, SL ranged from 5.33 cm in Akserez, a durum wheat from Turkey, to 18.67 cm in PI340745, a common wheat from Italy. On the other hand, two common wheats of unknown origin (Dongbuk Sabigye2403-7 and Dongbuk Sabigye2403-9) equally displayed the shortest AL (0.50 cm), while PI184641, a durum wheat from Portugal, displayed the longest AL (19.00 cm). TKW was the lowest (20.33 g) in Doubbi, a durum wheat from Australia, and the highest (78.00 g) in accession PI210948, another durum wheat from Cyprus. Previously, several studies have evaluated the variations of yield-related traits in different wheat genotypes and comparable results were reported. For instance, CL ranging from 40.00 cm to 122.70 cm, SL ranging from 3.30 cm to 14.30 cm, and AL ranging from 0.00 cm to 9.80 cm were reported across 287 wheat lines grown in different environments in Korea (Jung *et al.*, 2021). In other studies, SL ranged from 6.25 cm to 14.33 cm and from 7.4 to 17.8 cm (Kang *et al.*, 2019; Lee *et al.*, 2021b), while CL and AL ranged from 60.6 to 107.4 cm and 0.0 to 19.50 cm, respectively across different wheat varieties (Kang *et al.*, 2019; Sheoran *et al.*, 2019). On the other hand, Rahimi *et al.* (2019) reported TKW ranging from 14.9 to 74.50 g which is comparable to the TKW range observed in our study. In other studies, Jung *et al.* (2021) and Baboev *et al.* (2021) independently reported TKW in the ranges of 24.00 – 54.00 and 42.0 – 47.8 g, respectively, both ranges being narrower compared to our findings. Such discrepancies could arise due to differences in the number of genotypes analyzed as well as due to the variations in growing conditions, cultivation years, and post-harvest handling as highlighted before (Dodig *et al.*, 2012; Khan *et al.*, 2023; Ren *et al.*, 2013). The variations in yield-related traits between common wheat and durum wheat accessions were also statistically

investigated. On average, durum wheat accessions had longer CL (118.92 cm) as well as AL (11.18 cm) than common wheat germplasms (103.43 and 6.19 cm, respectively), the variation of each being significant ( $p < 0.05$ ) (Table 2). The average TKW was also higher in durum wheat accessions (44.73 g) than in common wheat accessions (38.74 g). In contrast, common wheat accessions had the longest average SL (9.81 cm) than durum wheat accessions (8.18 cm) and the variation was also significant ( $p < 0.05$ ). A relative comparison to the control variety was also conducted. In the control, CL, SL, and AL were 65.00, 10.00, and 5.00 cm, respectively, while TKW was 46.00 g. Compared to the control, 36.29% of the wheat accessions had higher TKW, the majority of them being durum wheat accessions. In contrast, 7.91% ( $n = 17$ ) of the accessions had lower AL than the control, all being common wheat varieties. On the other hand, only one common wheat (KwangyeW372 from Japan) and three durum wheat (U13864 from Italy, Sofare from France, and U13923 of Unknown origin) accessions had lower CL than the control. In terms of SL, a total of 32 accessions including 18 common and 14 durum accessions had higher SL than the control. As highlighted before, CL, SL, AL, and TKW are yield-related agronomical traits, and several studies have identified associated genes that control their variations in wheat germplasms (Bordes *et al.*, 2008; Ma *et al.*, 2019; Niu *et al.*, 2020; Tajibayev *et al.*, 2023; Irfan Ullah *et al.*, 2021). Moreover, some of these traits also demonstrate other important properties. For instance, wheat varieties with short CL are thought to be resistant to lodging. Likewise, wheat varieties with long CL of wide diameter are thought to have reduced lodging rates (Matsuyama, 2022; Shah *et al.*, 2019). Overall, those accessions with desirable properties and superior performances could be utilized to maximize yield and reduce lodging (Sun *et al.*, 2023).

### PCA, HCA, and correlation analyses

Multivariate statistical tools such as HCA, PCA, and Pearson's correlation analysis are used to categorize large populations of plant genetic resources and view their association with their characteristic features (De Flaviis *et al.*, 2022; Ormoli *et al.*, 2015). In this study, the HCA and PCA were computed using the whole quantitative data set in the entire population. Accordingly, the HCA clustered the wheat germplasms in two seven groups (Fig. 2B). Cluster I contained 16 accessions, all except two being common wheats. As shown in Fig. 3, this



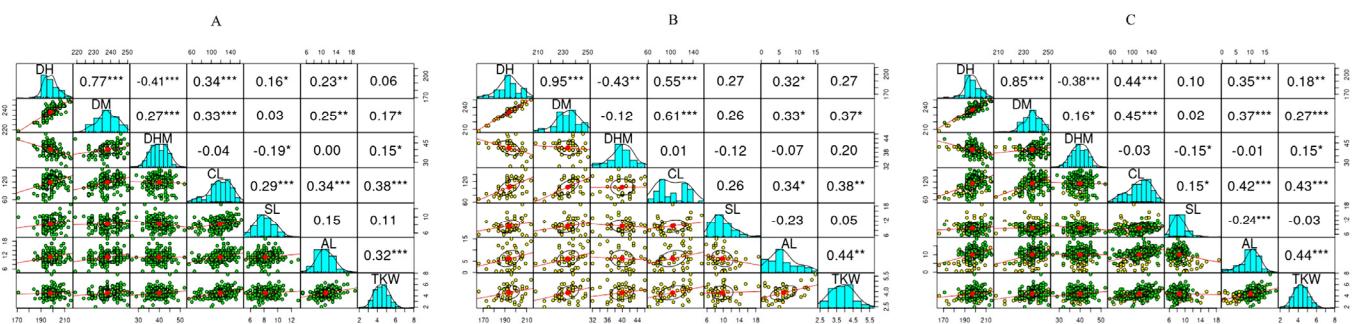
**Fig. 3.** Boxplots showing quantitative variations in agronomical traits between clusters. DHM: Days from heading to maturity, TKW: One-thousand kernels weight. Different letters on boxplots in a category indicate significantly different means ( $p < 0.05$ ).

cluster displayed the highest average SL compared to the other clusters ( $p < 0.05$ ). Cluster II contained II accessions, all being common wheats. These groups were characterized by having the lowest average DM and DH ( $p < 0.05$ ). Interestingly, those early maturing accessions and the control variety were all grouped in cluster II. Accessions in cluster II also displayed the lowest average CL, AL, and TKW. In contrast, durum wheat accessions dominated clusters V ( $n = 21$ ), VI ( $n = 43$ ), and VII ( $n = 51$ ), the former containing only one common wheat while the latter two each containing two common wheat accessions. Clusters III and

IV each contained 28 durum wheat accessions while having 13 and 5 common wheat accessions, respectively. Contrary to cluster II, cluster V had the highest average CL, AL, and TKW ( $p < 0.05$ ), while cluster VII had the lowest average spike length ( $p < 0.05$ ). Overall, the HCA categorized the wheat accessions according to their characteristic features. PCA was also conducted to further view the distribution of the wheat accessions and their relation to the agronomical traits. The PCA yielded three components (PC) with eigenvalues of greater than 1. The first two principal components, PC1 and PC2, displayed 59.09% of

**Table 3.** Eigenvalues and variability of the first three principal components and contribution of quantitative traits in the PCA.

Principal components	Eigenvalue	Variability (%)	Cumulative variance (%)	Values	Quantitative traits						
					DH <sup>x</sup>	DM <sup>w</sup>	DHM <sup>v</sup>	CL <sup>u</sup>	SL <sup>t</sup>	AL <sup>s</sup>	TKW <sup>r</sup>
PC1	2.71	38.71	38.71	FL	0.82	0.83	-0.07	0.74	0.03	0.68	0.57
				%	24.82	25.72	0.19	20.26	0.02	16.92	12.07
PC2	1.43	20.37	59.09	FL	-0.45	-0.06	0.74	0.00	-0.59	0.35	0.45
				%	14.45	0.27	38.41	0.00	24.45	8.49	13.93
PC3	1.02	14.6	73.68	FL <sup>y</sup>	-0.21	0.03	0.44	0.28	0.74	-0.29	0.26
				% <sup>z</sup>	4.26	0.09	19.29	7.69	53.51	8.46	6.71

<sup>x</sup>Contribution to variance, <sup>y</sup>Factor loading, <sup>x</sup>Days to heading, <sup>w</sup>Days to maturity, <sup>v</sup>Days from heading to maturity, <sup>u</sup>Culm length,<sup>t</sup>Spike length, <sup>s</sup>Awn length, <sup>r</sup>One thousand kernel weight.**Fig. 4.** Pearson correlation matrix of quantitative variables in durum wheat (A), common wheat (B), and the whole population (C). AL: Awn length, CL: Culm length, DH: Days to heading, DHM: Days from heading to maturity, DM: Days to maturity, SL: Spike length, TKW: One-thousand kernel weight. \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

the total variance. The score plots along these two components separated the wheat accessions based on their type (Fig. 2C) as well as according to their cluster (Fig. 2D). As shown in the loading plot (Fig. 2E) and Table 3, DH, DM, AL and TKW were the major contributors along PC1 having positive factor loading (FL) above 0.5. No variable had a negative FL above 0.5 along PC1. Along PC2, DHM was the only variable with a positive FL above 0.5, while SL had a negative FL above 0.5 both being the major contributors (Table 3). In general, the PCA supported the HCA observation and signified that quantitative agronomical traits could be used to distinguish between large populations of common wheat and durum wheat genotypes (Sheoran *et al.*, 2019). Correlation analysis was also computed to view the relationship between the quantitative traits (Fig. 4). The variable showed wide-ranging correlations in durum wheat, common wheat, and the whole population with different levels of significance. DH and DM showed a strong correlation regardless of wheat type ( $r > 0.77$ ,  $p < 0.001$ ). In agreement with our observation, previous studies also found positive and significant

correlation between DH and DM (Jung *et al.*, 2021; Lee *et al.*, 2021b; Sheoran *et al.*, 2019). On the other hand, CL showed positive and stronger associations with SL, AL, and TKW in durum wheats than in common wheats. The correlation between AL and TKW was also positive and strong in durum wheats ( $r = 0.32$ ), common wheats ( $r = 0.44$ ), and total population ( $r = 0.44$ ), each being significant ( $p < 0.001$ ). In contrast, SL showed a positive correlation with AL in durum wheats ( $r = 0.15$ ) and a negative correlation in common wheats ( $r = -0.23$ ), but both correlations were insignificant. Such variable correlations between AL and SL were also noticed in previous studies (Jung *et al.*, 2021; Sheoran *et al.*, 2019). Overall, the observed correlations are in agreement with many previous studies and could provide insight into how growth-related and yield-related traits are correlated in common wheat and durum wheat genotypes (Cao *et al.*, 2015; Jung *et al.*, 2021; Lee *et al.*, 2021b; Son *et al.*, 2015).

To conclude, this study investigated the diversity of global durum and common wheat accessions recently cultivated in Korea. Wide variations in both qualitative and quantitative

**Table 4.** Selected wheat accessions with superior and unique performances compared to the control variety.

IT. Number	Name	Origin	Type	Value
Early maturing accessions (< 219 days)				
187182	Rufom-7	Unknown	Common	208
177065	Dongbuk Sabigye2403-10	Unknown	Common	215
177069	Kwanggye W372	Japan	Common	215
Control	Geumgang	Korea	Common	219
Accessions with short (< 65.0 cm) and long (> 150.0 cm) culm length				
205805	U13864	Italy	Durum	53.7
198273	Sofare	France	Durum	59.7
177069	Kwanggye W372	Japan	Common	62.2
205840	U13923	Unknown	Durum	62.7
Control	Geumgang	Korea	Common	65.0
205499	Pulawska fwarda	Poland	Durum	163.0
306377	Tounse	France	Durum	157.7
307395	Kara Kiltschik	Uzbekistan	Durum	157.7
205529	HORDEIFORM 5695	Russia	Durum	156.2
307449	Dioszegi	Hungary	Common	155.3
330597	PI 345338	Macedonia	Durum	153.7
198930	Mutikovalensia C-31	Russia	Durum	153.3
205532	KUSTAIKAJA 14	Kazakhstan	Durum	152.5
205490	DONSKI 309	Russia	Durum	152.0
306455	Brkulja	Bosnia and Herzegovina	Durum	150.0
Accessions with long spike length (> 10.0 cm)				
330595	PI 340745	Italy	Common	18.7
305884	Shasti	Afghanistan	Common	15.5
307449	Dioszegi	Hungary	Common	14.3
160564	PI345219	Serbia	Common	14.0
16616	SWM6458-4y	Mexico	Common	13.2
198449	Me	Russia	Common	13.2
330574	PI 264959	Croatia	Common	13.2
307550	ECH 605	United Kingdom	Durum	13.0
310862	ELS 6404-151-2	Ethiopia	Common	13.0
330597	PI 345338	Macedonia	Durum	12.0
Control	Geumgang	Korea	Common	10.0
Accessions with short (< 5.0 cm) and long (> 15.0 cm) awn length				
177064	Dongbuk Sabigye 2403-9	Unknown	Common	0.5
177062	Dongbuk Sabigye 2403-7	Unknown	Common	0.5
177061	Dongbuk Sabigye 2403-6	Unknown	Common	1.0
205833	HUDEIBA 154	Unknown	Common	1.0
205907	U14009	Tunisia	Common	1.0
177065	Dongbuk Sabigye 2403-10	Unknown	Common	1.5

**Table 4.** Selected wheat accessions with superior and unique performances compared to the control variety (Continued).

IT. Number	Name	Origin	Type	Value
205917	U14031	Tunisia	Common	2.0
310862	ELS 6404-151-2	Ethiopia	Common	2.0
160564	PI345219	Serbia	Common	3.0
187182	Rufom-7	Unknown	Common	4.0
Control	Geumgang	Korea	Common	5.00
310992	PI 184641	Portugal	Durum	19.0
307371	Rosello	Chile	Durum	17.0
310944	PI 134943	Portugal	Durum	17.0
330550	PI 210948	Cyprus	Durum	17.0
307425	Timilia	Italy	Durum	16.0
307493	Malta 4	Malta	Durum	16.0
198927	WIR59877	Russia	Durum	15.0
205499	Pulawska fwarda	Poland	Durum	15.0
Accessions with high one-thousand kernel weight (> 55 g)				
330550	PI 210948	Cyprus	Durum	78.00
310964	Peygamber	Turkey	Durum	65.00
306455	Brkulja	Bosnia and Herzegovina	Durum	63.00
307371	Rosello	Chile	Durum	60.33
307493	Malta 4	Malta	Durum	59.67
198949	Shpilka	Azerbaijan	Durum	59.33
307431	PI 265011	Bosnia and Herzegovina	Durum	58.67
330555	PI 220704	Afghanistan	Durum	58.33
307480	Greece 14	Greece	Durum	57.67
330549	PI 210912	Pakistan	Durum	56.67
Control	Geumgang	Korea	Common	46.00

agronomical traits were observed among the wheat germplasms. While the common wheat accessions were characterized by early heading and maturity, and longer spike length, durum wheat accessions were characterized by longer culm and awn lengths and a higher one-thousand kernel weight. Moreover, the performance of individual accessions also varied compared to the control variety, and top-performing varieties were identified (Table 4). A total of three early maturing accessions were identified, all being common wheats. Moreover, three durum wheat accessions and one common wheat accession with a lower culm length were also identified. The top 10 accessions with higher culm length, except one, were durum wheats. Similarly, those with higher one-thousand kernels weight and awn length were all durum wheat accessions. In contrast, accessions with

lower awn length were all common wheats. Accessions with high spike length are also all common wheats except for two accessions. Among these, three durum wheat accessions including Malta 4, Rosello, and PI210948 simultaneously displayed high one-thousand kernels weight and long awn length. Likewise, common wheat accessions including PI345219 and ELS6404-151-12 simultaneously displayed shorter awn length and long spike length, while Rufom-7 and Donbuk Sabigye2403-10 simultaneously displayed shorter maturity days and short awn length. Doszegi, a common wheat, and PI345338, a durum wheat, simultaneously displayed long spike length and culm lengths. In general, the accessions with distinct characteristics and superior performances to the control cultivar could be utilized in wheat breeding programs. The variations observed

between common wheat and durum wheat accessions could also be a great input for future genomic investigations.

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### CONFLICT OF INTEREST

The authors declare no conflict of interest.

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**Supplementary Table S1.** Origin and status of durum wheat and common wheat germplasms used in this study.

Origin	Durum wheat			Common wheat			Total			Grand total
	Landrace	Advanced cultivar	Unknown	Landrace	Advanced cultivar	Unknown	Landrace	Advanced cultivar	Unknown	
AFG	1			2			3			3
AGO			1						1	1
ARG			3						3	3
AUS		1						1		1
AZE			1						1	1
BGR		9		1			1	9		10
BIH	2						2			2
BOL						1			1	1
BRA			1						1	1
CAN		2	4			1		2	5	7
CHL			3						3	3
CHN	1		1				1		1	2
CSK						1			1	1
CYP	1		1				1		1	2
DEU		6						6		6
ECU			1						1	1
EGY	2		1				2		1	3
ERI	2			1			3			3
ESP	2		1				2		1	3
ETH	14			2			16			16
FRA		1	2					1	2	3
GBR			2						2	2
GEO	1	1	1				1	1	1	3
GRC	3						3			3
HRV	1			1			2			2
HUN			1			1			2	2
IND	2					1	2		1	3
IRQ		3						3		3
ISR		1						1		1
ITA		2	4	1		1	1	2	5	8
JOR		2	2					2	2	4
JPN						1			1	1
KAZ			1						1	1
KGZ	1						1			1
LBN	2		1				2		1	3
MAR	1			1		1	2		1	3
MEX		3				3		3	3	6
MKD	1						1			1

**Supplementary Table S1.** Origin and status of durum wheat and common wheat germplasms used in this study (Continued).

Origin	Durum wheat			Common wheat			Total			Grand total
	Landrace	Advanced cultivar	Unknown	Landrace	Advanced cultivar	Unknown	Landrace	Advanced cultivar	Unknown	
MLT	2						2			2
NPL	1		1				1		1	2
PAK	1		2				1		2	3
PER	1				1		1		1	2
POL		1	2					1	2	3
PRT	3		3				3		3	6
RUS			13			3			16	16
SAU	2		1				2		1	3
SRB	2		1	1			3		1	4
SWE			1						1	1
SYR	1		1	1			2		1	3
TUN	2		2	1		5	3		7	10
TUR	6		1	1			7		1	8
UKR			3			1			4	4
USA		1	3					1	3	4
UZB	1						1			1
UNK			10			13			23	23
<b>Total</b>	<b>59</b>	<b>33</b>	<b>76</b>	<b>13</b>		<b>34</b>	<b>72</b>	<b>33</b>	<b>110</b>	<b>215</b>

**Supplementary Table S2.** General information and diversity of qualitative agronomic traits across 215 global wheat accessions grown in Korea.

IT Number	General information				Qualitative agronomic traits				
	Name	Origin	Species type	Genotype	Spike density	Awn presence	Awn color	Spike color	Kernel color
16616	SWM6458-4y	MEX	Common	Unknown	Loose	Awned	Yellow	YW	White
160564	PI345219	SRB	Common	Landrace	Loose	Awnleted	YW	YW	Red
177061	Dongbuk Sabigye 2403-6	Unknown	Common	Unknown	Dense	Awnleted	Brown	Brown	Red
177062	Dongbuk Sabigye 2403-7	Unknown	Common	Unknown	Dense	Awnleted	Brown	Brown	White
177064	Dongbuk Sabigye 2403-9	Unknown	Common	Unknown	Dense	Awnleted	Brown	Brown	Red
177065	Dongbuk Sabigye 2403-10	Unknown	Common	Unknown	Medium	Awnleted	Brown	Brown	White
177069	Kwangye W372	JPN	Common	Unknown	Medium	Awned	Brown	Brown	Red
187149	Haurani	Unknown	Durum	Unknown	Dense	Awned	YW	YW	White
187153	Loukos 3	SYR	Durum	Unknown	Dense	Awned	YW	YW	White
187155	Daki	MEX	Common	Unknown	Dense	Awned	YW	YW	White
187163	Om rabi 3	Unknown	Common	Unknown	Dense	Awned	Brown	Brown	Red
187173	Stojocri-1	Unknown	Common	Unknown	Dense	Awned	Brown	Brown	White
187180	341-730	Unknown	Durum	Unknown	Dense	Awned	Black	YW	White
187182	Rufom-7	Unknown	Common	Unknown	Medium	Awned	YW	YW	White
187185	Rufom-7	Unknown	Common	Unknown	Dense	Awned	Brown	Brown	Red
187195	341-747	Unknown	Durum	Unknown	Dense	Awned	Black	YW	White
189908	Tbilisyri 9	GEO	Durum	AC	Dense	Awned	Yellow	Yellow	Red
198270	U0001090	RUS	Durum	Unknown	Dense	Awned	YW	YW	White
198271	Hmahekas	RUS	Durum	Unknown	Dense	Awned	Black	YW	White
198272	U0001092	RUS	Durum	Unknown	Dense	Awned	Brown	YW	White
198273	Sofare	FRA	Durum	Unknown	Dense	Awned	Brown	YW	White
198274	U0001099	USA	Durum	Unknown	Dense	Awned	YW	YW	White
198449	Me	RUS	Common	Unknown	Medium	Awned	YW	YW	White
198451	3615/61 minn13	Unknown	Durum	Unknown	Dense	Awned	Black	Brown	White
198453	667/59	DEU	Durum	Unknown	Dense	Awned	YW	YW	Red
198475	C <sub>2</sub> 1660 c 253	IND	Common	Unknown	Loose	Awned	YW	YW	White
198927	WIR59877	RUS	Durum	Unknown	Dense	Awned	YW	Brown	White
198930	Mutikovalensia C-31	RUS	Durum	Unknown	Dense	Awnleted	YW	YW	White
198931	Arnautka	UKR	Durum	Unknown	Dense	Awned	Black	Black	White
198933	Atlant	RUS	Durum	Unknown	Dense	Awned	YW	YW	White
198947	Tbilisuri 9	GEO	Durum	Unknown	Dense	Awned	YW	YW	White
198949	Shpilka	AZE	Durum	Unknown	Dense	Awned	Black	Brown	White
202567	Local	MEX	Common	Unknown	Dense	Awned	YW	YW	White
205490	DONSKI 309	RUS	Durum	Unknown	Dense	Awned	YW	YW	Red
205493	SAMMARTINARA Si	Unknown	Common	Unknown	Loose	Awned	YW	YW	Red
205494	Czernokolososko	RUS	Durum	Unknown	Dense	Awned	Black	YW	Red
205499	Pulawska fwarda	POL	Durum	Unknown	Dense	Awned	YW	YW	White
205505	2037/61	Unknown	Durum	Unknown	Dense	Awned	Black	YW	White
205506	727/59	TUR	Durum	Unknown	Dense	Awned	Black	YW	White
205508	PRETO ALGARVIO	DEU	Durum	Unknown	Dense	Awned	Black	Black	White

**Supplementary Table S2.** General information and diversity of qualitative agronomic traits across 215 global wheat accessions grown in Korea (Continued).

IT Number	General information				Qualitative agronomic traits				
	Name	Origin	Species type	Genotype	Spike density	Awn presence	Awn color	Spike color	Kernel color
205510	3043/58	DEU	Durum	Unknown	Dense	Awned	Black	YW	Red
205515	WEISSER Tiirkischer	DEU	Durum	Unknown	Dense	Awned	YW	YW	White
205517	TRIGO CANDEAL	DEU	Durum	Unknown	Dense	Awned	Black	YW	White
205528	MELANOPUS 37	UKR	Common	Unknown	Medium	Awned	YW	YW	White
205529	HORDEIFORM 5695	RUS	Durum	Unknown	Dense	Awned	YW	YW	White
205530	BLACK HEAD	CHN	Durum	Unknown	Dense	Awned	Black	Black	White
205532	KUSTAISKAJA 14	KAZ	Durum	Unknown	Dense	Awned	YW	YW	White
205533	NARODNAJA	UKR	Durum	Unknown	Dense	Awned	YW	YW	White
205536	MELANOPUS 1932	RUS	Common	Unknown	Loose	Awned	YW	YW	White
205541	HARIKOVSKAJA 46	UKR	Durum	Unknown	Dense	Awned	Brown	Brown	White
205591	47/484	CSK	Common	Unknown	Dense	Awned	Black	YW	White
205593	MARROCOS 88	PRT	Durum	Unknown	Dense	Awned	Black	YW	White
205596	VERNUM	USA	Durum	Unknown	Dense	Awned	Yellow	Brown	White
205598	MK804	RUS	Common	Unknown	Medium	Awned	Brown	Brown	White
205621	WELLS	USA	Durum	Unknown	Dense	Awned	YW	YW	White
205804	U13863	ITA	Durum	Unknown	Dense	Awned	Black	YW	White
205805	U13864	ITA	Durum	Unknown	Dense	Awned	Brown	YW	White
205814	AMERICAN 378	Unknown	Common	Unknown	Medium	Awned	YW	YW	White
205815	GIZA 145	Unknown	Common	Unknown	Loose	Awned	Yellow	Yellow	White
205817	BIADH	Unknown	Common	Unknown	Dense	Awned	Brown	Brown	White
205829	SCHIMPERI PERIER	Unknown	Durum	Unknown	Medium	Awned	Brown	Brown	Red
205833	HUDEIBA 154	Unknown	Common	Unknown	Medium	Awnleted	YW	YW	White
205839	U13922	Unknown	Durum	Unknown	Dense	Awned	Black	Brown	White
205840	U13923	Unknown	Durum	Unknown	Dense	Awned	Black	Brown	White
205856	U13940	Unknown	Durum	Unknown	Dense	Awned	Black	Brown	White
205859	U13943	Unknown	Durum	Unknown	Dense	Awned	Black	YW	White
205893	TEHUACAN 60	LBN	Durum	Unknown	Dense	Awned	Black	Brown	White
205907	U14009	TUN	Common	Unknown	Loose	Awnleted	YW	YW	White
205917	U14031	TUN	Common	Unknown	Medium	Awnleted	Brown	Brown	Red
205929	U14050	TUN	Durum	Unknown	Dense	Awned	Black	YW	White
205932	U14053	TUN	Common	Unknown	Dense	Awned	YW	YW	White
205934	U14055	TUN	Common	Unknown	Dense	Awned	YW	YW	White
205940	U14078	TUN	Durum	Unknown	Dense	Awned	Black	YW	White
205944	MELANGE	TUN	Common	Unknown	Loose	Awned	YW	YW	White
209246	WIR52778	RUS	Durum	Unknown	Dense	Awned	YW	YW	White
209250	WIR36517	RUS	Durum	Unknown	Dense	Awned	Black	YW	White
209251	WIR35336	RUS	Durum	Unknown	Dense	Awned	Black	Brown	White
229647	Medora	CAN	Durum	Unknown	Dense	Awned	YW	YW	White
230261	APULIKUM 233	BGR	Durum	AC	Dense	Awned	Black	Brown	White
230262	ELA	BGR	Durum	AC	Dense	Awned	YW	YW	White

**Supplementary Table S2.** General information and diversity of qualitative agronomic traits across 215 global wheat accessions grown in Korea (Continued).

IT Number	General information				Qualitative agronomic traits				
	Name	Origin	Species type	Genotype	Spike density	Awn presence	Awn color	Spike color	Kernel color
230264	LOZEN76	BGR	Durum	AC	Dense	Awned	Black	Brown	White
230265	PROGRES	BGR	Durum	AC	Dense	Awned	Brown	Brown	White
230266	SREDEC	BGR	Durum	AC	Dense	Awned	Black	Brown	White
230267	TCHIRPAN 22-70	BGR	Durum	AC	Dense	Awned	Yellow	Yellow	White
230268	AD50	TUR	Common	Landrace	Loose	Awned	Brown	Brown	White
230948	Lloyd	USA	Durum	AC	Dense	Awned	YW	YW	White
236297	AC Morse	CAN	Durum	Unknown	Dense	Awned	Yellow	Yellow	White
237031	ZAGORKA	BGR	Durum	AC	Dense	Awned	Brown	Brown	White
247857	AC Melita	CAN	Durum	Unknown	Dense	Awned	YW	YW	White
267337	U13851	ITA	Common	Unknown	Loose	Awned	Brown	Brown	White
269497	1522	BGR	Durum	AC	Dense	Awned	YW	YW	White
269498	786	BGR	Durum	AC	Dense	Awned	Yellow	Brown	White
269504	K 1112I073	ETH	Durum	Landrace	Dense	Awned	YW	YW	Red
269517	K 1112I065	ETH	Durum	Landrace	Dense	Awned	Black	Black	Red
284260	8871-AN-I	CAN	Durum	Unknown	Dense	Awned	YW	YW	White
284261	8974-HA4-I	CAN	Common	Unknown	Medium	Awned	YW	YW	White
286089	K 1213I233	ETH	Durum	Landrace	Loose	Awned	YW	YW	Red
289452	K 1011I271	ERI	Common	Landrace	Dense	Awned	YW	YW	Red
290092	K 1213I240	ETH	Durum	Landrace	Dense	Awned	YW	YW	Red
290094	K 1213I271	ETH	Durum	Landrace	Dense	Awned	YW	YW	Red
290099	K 1213I276	ETH	Durum	Landrace	Dense	Awned	Black	YW	Red
302910	8871-AN-S	CAN	Durum	AC	Dense	Awned	Yellow	Yellow	White
305704	Dalmatia 3	HRV	Durum	Landrace	Dense	Awned	Yellow	Brown	White
305712	Nursith	ISR	Durum	AC	Medium	Awned	YW	YW	White
305831	ELS 6404-127	ERI	Durum	Landrace	Dense	Awned	Black	Brown	White
305847	ELS 6404-139-5	ETH	Durum	Landrace	Medium	Awned	Yellow	Yellow	White
305852	ELS 6404-140-2	ETH	Durum	Landrace	Loose	Awned	YW	YW	White
305855	ELS 6404-145-2	ETH	Common	Landrace	Loose	Awned	YW	Black	White
305863	ELS 6404-154	ETH	Durum	Landrace	Dense	Awned	Black	Black	White
305884	Shasti	AFG	Common	Landrace	Loose	Awned	Yellow	Yellow	White
305893	Royal de Almena	ARG	Durum	Unknown	Dense	Awned	Black	YW	Red
305946	CItr 15505	TUN	Durum	Landrace	Dense	Awned	Black	Brown	White
305960	Qualset BYDV 31	ERI	Durum	Landrace	Dense	Awned	Black	YW	White
305961	CI 17718	ARG	Durum	Unknown	Dense	Awned	Yellow	Yellow	White
305962	CI 17719	ARG	Durum	Unknown	Dense	Awned	Black	Brown	White
306030	Taganrog AC 1	TUN	Durum	Landrace	Dense	Awned	Black	Black	White
306048	FHB4501	CHN	Durum	Landrace	Dense	Awned	Brown	Brown	White
306086	ICARDA-IG-83562	ETH	Durum	Landrace	Dense	Awned	YW	YW	Red
306111	PI 113396	EGY	Durum	Landrace	Dense	Awned	Brown	Yellow	White
306123	Kaligawaran	IND	Durum	Landrace	Medium	Awned	Yellow	Yellow	Red

**Supplementary Table S2.** General information and diversity of qualitative agronomic traits across 215 global wheat accessions grown in Korea (Continued).

IT Number	General information				Qualitative agronomic traits				
	Name	Origin	Species type	Genotype	Spike density	Awn presence	Awn color	Spike color	Kernel color
306126	PI 115812	MAR	Durum	Landrace	Dense	Awned	YW	YW	Red
306137	Beladi 164	EGY	Durum	Unknown	Dense	Awned	Black	Brown	White
306161	Tripolino	ITA	Durum	Unknown	Dense	Awned	Yellow	Yellow	White
306178	PI 163274	ECU	Durum	Unknown	Dense	Awned	Brown	Brown	White
306219	PI 166454	TUR	Durum	Landrace	Dense	Awned	Black	Brown	White
306226	PI 166473	TUR	Durum	Landrace	Medium	Awned	Black	Brown	White
306232	Kkarabilcik	TUR	Durum	Landrace	Dense	Awned	YW	YW	White
306237	Akserez	TUR	Durum	Landrace	Dense	Awned	Black	Black	White
306255	PI 166543	TUR	Durum	Landrace	Dense	Awned	YW	YW	White
306377	Tounse	FRA	Durum	Unknown	Medium	Awned	Black	Brown	White
306380	PI 176228	NPL	Durum	Landrace	Dense	Awned	Black	Brown	White
306381	PI 176286	IND	Durum	Landrace	Dense	Awned	YW	YW	White
306412	Agyba 1	IRQ	Durum	Landrace	Dense	Awned	Black	Black	White
306427	S-45	PAK	Durum	Unknown	Dense	Awned	Black	YW	White
306433	Hourah	LBN	Durum	Landrace	Medium	Awned	YW	YW	White
306438	C-2	SYR	Common	Landrace	Dense	Awned	YW	YW	White
306454	Legami	SAU	Durum	Landrace	Dense	Awned	YW	YW	White
306455	Brkulja	BIH	Durum	Landrace	Dense	Awned	Brown	Brown	Red
306476	Carina	GBR	Durum	Unknown	Dense	Awned	Black	Yellow	White
306508	Mettes Rauhwizen	DEU	Durum	AC	Dense	Awned	Brown	Brown	Red
306527	Claro Fino de Balazote	ESP	Durum	Landrace	Dense	Awned	YW	YW	White
306560	Trigo de Albandeia	ESP	Durum	Landrace	Dense	Awned	Brown	Brown	White
306579	Duro del Pais	MAR	Common	Landrace	Dense	Awned	Black	YW	White
306623	Timor	BRA	Durum	Unknown	Dense	Awned	YW	YW	Red
306655	HN ROD 25 13770	PRT	Durum	Unknown	Dense	Awned	Brown	Brown	Red
307028	C F B	AGO	Durum	Unknown	Dense	Awned	Yellow	Brown	White
307138	Azizeah	ITA	Durum	Unknown	Dense	Awned	YW	YW	Red
307179	Ostpreuss	SWE	Durum	Unknown	Dense	Awned	Yellow	Yellow	Red
307205	Minos No. 251	BOL	Common	Unknown	Dense	Awned	YW	YW	White
307328	Sin El-Jamil	IRQ	Durum	Landrace	Dense	Awned	Black	YW	White
307337	AUS 9728	PAK	Durum	Landrace	Dense	Awned	Black	YW	White
307353	Kafel Rahman	JOR	Durum	AC	Dense	Awned	Black	Brown	White
307367	Perigo Candeal 24	CHL	Durum	Unknown	Dense	Awned	Black	Yellow	White
307371	Rosello	CHL	Durum	Unknown	Dense	Awned	YW	YW	White
307378	Durz Karaki	JOR	Durum	Unknown	Dense	Awned	YW	YW	White
307395	Kara Kiltschik	UZB	Durum	Landrace	Dense	Awned	Black	Brown	White
307407	K918	IRQ	Durum	Landrace	Dense	Awned	Black	YW	White
307417	PI 262670	RUS	Durum	Unknown	Dense	Awned	YW	YW	White
307418	Kubanka Karakolskaya	KGZ	Durum	Landrace	Dense	Awned	Brown	Brown	White
307419	Shaupkha	GEO	Durum	Landrace	Dense	Awned	Black	Black	White

**Supplementary Table S2.** General information and diversity of qualitative agronomic traits across 215 global wheat accessions grown in Korea (Continued).

IT Number	General information				Qualitative agronomic traits				
	Name	Origin	Species type	Genotype	Spike density	Awn presence	Awn color	Spike color	Kernel color
307421	PI 264934	GRC	Durum	Landrace	Dense	Awned	YW	YW	Red
307431	PI 265011	BIH	Durum	Landrace	Dense	Awned	YW	Brown	White
307446	Veneny	HUN	Durum	Unknown	Dense	Awnleted	Yellow	Yellow	Red
307449	Dioszegi	HUN	Common	Unknown	Loose	Awnleted	YW	YW	Red
307480	Greece 14	GRC	Durum	Landrace	Dense	Awned	YW	YW	White
307485	Crete 1	GRC	Durum	Landrace	Dense	Awned	Yellow	Yellow	White
307492	Malta 3	MLT	Durum	Landrace	Dense	Awned	Black	YW	Red
307493	Malta 4	MLT	Durum	Landrace	Dense	Awned	Black	YW	Red
307534	Valencia	ESP	Durum	Unknown	Dense	Awned	Yellow	Yellow	White
307536	Tripolitco	CYP	Durum	Unknown	Dense	Awned	Black	YW	White
307550	ECH 605	GBR	Durum	Unknown	Loose	Awned	YW	YW	White
307591	Bagudo 9032	POL	Durum	AC	Dense	Awned	YW	Brown	Red
310838	Belgrade 9	SRB	Durum	Landrace	Dense	Awned	Yellow	Brown	White
310859	ELS 6404-144-1	ETH	Durum	Landrace	Medium	Awned	Brown	Brown	White
310862	ELS 6404-151-2	ETH	Common	Landrace	Loose	Awnleted	YW	YW	White
310863	ELS 6404-160-5	ETH	Durum	Landrace	Dense	Awned	Black	Black	White
310870	Biadh	SAU	Durum	Unknown	Medium	Awned	Brown	Brown	White
310872	CItr 15273	JOR	Durum	Unknown	Dense	Awned	YW	YW	White
310875	CItr 15303	AFG	Common	Landrace	Dense	Awned	Brown	Brown	White
310910	PI 113397	EGY	Durum	Landrace	Dense	Awned	YW	YW	White
310944	PI 134943	PRT	Durum	Landrace	Dense	Awned	Black	YW	Red
310964	Peygamber	TUR	Durum	Landrace	Dense	Awned	Brown	Brown	White
310976	PI 182668	LBN	Durum	Landrace	Dense	Awned	Black	YW	White
310981	Gharbi	SYR	Durum	Landrace	Dense	Awned	Black	YW	White
310989	Marrocos 110	MAR	Common	Unknown	Dense	Awned	Black	YW	White
310992	PI 184641	PRT	Durum	Landrace	Dense	Awned	Black	Brown	White
311045	HN ROD 47 14870	PRT	Durum	Unknown	Dense	Awned	Black	Brown	Red
311162	PI 192849	PRT	Durum	Landrace	Dense	Awned	Black	YW	Red
311223	PI 221408	SRB	Durum	Unknown	Dense	Awned	Black	YW	White
330427	Wakooma	CAN	Durum	AC	Dense	Awned	Black	YW	White
330443	CItr 15436	TUN	Common	Landrace	Loose	Awned	YW	YW	White
330451	CItr 8164	PER	Durum	Landrace	Medium	Awned	YW	YW	Red
330535	PI 202796	PER	Common	Unknown	Dense	Awned	Brown	Brown	White
330549	PI 210912	PAK	Durum	Unknown	Dense	Awned	Black	YW	White
330550	PI 210948	CYP	Durum	Landrace	Dense	Awned	Black	YW	White
330555	PI 220704	AFG	Durum	Landrace	Dense	Awned	YW	YW	White
330562	PI 231311	CHL	Durum	Unknown	Dense	Awned	YW	YW	Red
330568	PI 261823	SAU	Durum	Landrace	Dense	Awned	YW	YW	White
330574	PI 264959	HRV	Common	Landrace	Loose	Awned	YW	YW	Red
330579	PI 273999	ETH	Durum	Landrace	Medium	Awned	Yellow	Yellow	Red

**Supplementary Table S2.** General information and diversity of qualitative agronomic traits across 215 global wheat accessions grown in Korea (Continued).

IT Number	General information				Qualitative agronomic traits				
	Name	Origin	Species type	Genotype	Spike density	Awn presence	Awn color	Spike color	Kernel color
330581	PI 274673	POL	Durum	Unknown	Loose	Awned	Yellow	Brown	White
330584	PI 277126	BGR	Common	Unknown	Loose	Awned	Brown	Redish purple	White
330595	PI 340745	ITA	Common	Landrace	Loose	Awned	YW	YW	Red
330596	PI 345107	SRB	Durum	Landrace	Dense	Awned	Brown	Brown	White
330597	PI 345338	MKD	Durum	Landrace	Medium	Awned	Black	Brown	White
333393	4	NPL	Durum	Unknown	Dense	Awned	YW	YW	White
333394	Mexicali C75	MEX	Durum	AC	Dense	Awned	Brown	YW	White
333401	CDSS04B00716T-0TOPY-42Y-0M-1Y-0M-4Y-0B	MEX	Durum	AC	Dense	Awned	Black	YW	White
333402	CDSS04B00717T-0TOPY-41Y-0M-3Y-0M-1Y-0B	MEX	Durum	AC	Dense	Awned	Black	YW	White
333406	K 1112I062	ETH	Durum	AC	Dense	Awned	YW	YW	Red
306153	Aziziah	ITA	Durum	AC	Dense	Awned	YW	YW	White
307355	Karaki Red	JOR	Durum	AC	Dense	Awned	Yellow	Yellow	White
307425	Timilia	ITA	Durum	AC	Dense	Awned	YW	YW	Red
310967	Beloturka	FRA	Durum	AC	Dense	Awned	YW	YW	White
330560	Doubbi	AUS	Durum	AC	Dense	Awned	Black	Black	White
Control/ Check	Geumgang	KOR	Common	AC	Loose	Awned	Yellow	Yellow	White

AC: Advanced cultivar; YW: Yellowish white.

**Supplementary Table S3.** Variations of quantitative agronomical traits across 215 global wheat accessions grown in Korea.

Name	DH (days)	DM (days)	DHM (Days)	CL (cm)	SL (cm)	AL (cm)	TKW (g)
SWM6458-4y	192	234	42	77.5	13.2	5.0	42.67
PI345219	199	235	36	76.8	14.0	3.0	27.67
Dongbuk Sabigye 2403-6	192	229	37	71.3	10.3	1.0	34.00
Dongbuk Sabigye 2403-7	182	224	42	85.5	10.5	0.5	33.33
Dongbuk Sabigye 2403-9	187	227	40	80.3	9.7	0.5	31.33
Dongbuk Sabigye 2403-10	173	215	42	84.3	11.7	1.5	30.67
Kwangye W372	175	215	40	62.2	8.0	5.0	25.00
Haurani	192	229	37	107.5	6.5	9.5	40.33
Loukos 3	184	227	43	80.2	7.2	10.0	51.67
Daki	185	227	42	71.3	9.7	4.0	43.33
Om rabi 3	189	229	40	86.5	7.0	6.5	42.33
Stojocri-1	189	229	40	83.3	7.5	7.0	38.67
341-730	192	228	36	116.7	8.3	14.0	43.33
Rufom-7	166	208	42	69.2	6.3	4.0	40.00
Rufom-7	189	229	40	83.3	6.3	6.0	47.00
341-747	187	227	40	73.2	5.7	11.5	47.33
Tbilisyri 9	202	242	40	109.8	7.5	9.0	35.00
U0001090	192	231	39	118.0	7.2	10.0	38.00
Hmahekas	201	236	35	129.7	9.0	12.0	54.00
U0001092	207	236	29	142.3	10.0	11.0	38.67
Sofare	192	236	44	59.7	7.2	13.0	29.00
U0001099	192	229	37	100.0	10.0	12.0	39.33
Me	205	242	37	132.3	13.2	6.0	30.33
3615/61 minn13	201	238	37	120.3	5.7	13.0	39.33
667/59	200	235	35	108.7	7.0	14.0	52.33
C <sub>2</sub> 1660 c 253	194	235	41	121.7	11.2	4.0	39.67
WIR59877	197	242	45	144.0	10.2	15.0	43.67
Mutikovalensia C-31	201	238	37	153.3	7.7	5.0	45.67
Arnautka	195	235	40	148.0	9.7	12.0	40.67
Atlant	195	235	40	132.8	7.5	7.5	45.33
Tbilisuri 9	201	244	43	124.0	7.8	9.0	27.67
Shpilka	202	238	36	129.0	7.2	13.0	59.33
Local	196	235	39	77.0	8.5	4.5	38.67
DONSKI 309	200	238	38	152.0	10.7	13.0	33.67
SAMMARTINARA Si	184	224	40	81.7	9.0	6.0	36.00
Czernokolososko	199	237	38	139.3	9.0	13.0	36.33
Pulawska fwarda	195	235	40	163.0	9.3	15.0	53.33
2037/61	196	238	42	137.7	8.0	14.0	50.67
727/59	199	238	39	138.8	8.5	9.5	49.00

Supplementary Table S3. Variations of quantitative agronomical traits across 215 global wheat accessions grown in Korea (Continued).

Name	DH (days)	DM (days)	DHM (Days)	CL (cm)	SL (cm)	AL (cm)	TKW (g)
PRETO ALGARVIO	199	238	39	103.7	7.2	8.5	47.67
3043/58	192	231	39	108.3	7.5	8.0	35.67
WEISSER Tilrkischer	196	231	35	129.0	7.8	13.0	40.67
TRIGO CANDEAL	196	238	42	124.5	6.7	9.0	49.67
MELANOPUS 37	192	231	39	130.7	8.7	4.5	32.00
HORDEIFORM 5695	199	239	40	156.2	8.7	13.0	49.00
BLACK HEAD	201	238	37	141.3	7.5	11.0	41.67
KUSTAISKAJA 14	199	238	39	152.5	7.8	11.0	42.00
NARODNAJA	194	234	40	142.2	7.0	11.0	43.67
MELANOPUS 1932	206	246	40	84.5	11.7	7.0	33.67
HARIKOVSKAJA 46	199	238	39	132.0	7.5	11.0	43.00
47/484	210	244	34	90.0	5.8	12.5	44.00
MARROCOS 88	204	238	34	113.7	7.3	13.0	48.67
VERNUM	199	242	43	136.7	9.0	13.5	50.00
MK804	184	227	43	106.0	10.2	4.5	36.67
WELLS	192	235	43	134.0	9.0	10.0	40.00
U13863	192	235	43	69.3	8.0	9.0	44.67
U13864	194	237	43	53.7	7.2	8.0	34.67
AMERICAN 378	199	238	39	97.3	8.2	4.0	42.67
GIZA 145	194	234	40	86.0	8.8	6.0	39.67
BIADH	192	238	46	112.0	7.3	6.0	41.00
SCHIMPERI PERIER	199	234	35	89.0	9.3	9.0	35.67
HUDEIBA 154	197	238	41	106.0	10.0	1.0	48.33
U13922	197	238	41	65.7	8.2	10.0	37.67
U13923	197	238	41	62.7	8.0	10.0	36.00
U13940	194	235	41	75.7	7.7	10.0	39.33
U13943	192	235	43	104.7	8.7	7.0	46.67
TEHUACAN 60	195	241	46	122.0	6.3	9.0	56.67
U14009	194	237	43	122.7	10.3	1.0	45.33
U14031	203	242	39	121.7	8.0	2.0	26.67
U14050	201	238	37	136.7	7.7	14.0	56.33
U14053	195	227	32	82.3	7.5	4.0	30.67
U14055	184	227	43	99.7	7.7	12.0	36.33
U14078	194	235	41	113.7	5.7	7.0	35.00
MELANGE	193	238	45	128.3	10.3	7.0	42.00
WIR52778	192	235	43	143.3	8.7	11.0	44.00
WIR36517	201	246	45	140.3	8.2	14.0	50.33
WIR35336	206	246	40	132.3	7.8	12.0	33.67
Medora	201	244	43	119.0	9.3	9.0	42.00

**Supplementary Table S3.** Variations of quantitative agronomical traits across 215 global wheat accessions grown in Korea (Continued).

Name	DH (days)	DM (days)	DHM (Days)	CL (cm)	SL (cm)	AL (cm)	TKW (g)
APULIKUM 233	203	239	36	118.7	5.7	11.0	41.00
ELA	194	240	46	100.8	7.7	9.0	42.00
LOZEN76	201	244	43	110.0	6.7	11.0	44.67
PROGRES	199	242	43	98.3	8.7	11.0	47.33
SREDEC	194	246	52	112.7	6.7	11.0	54.00
TCHIRPAN 22-70	195	244	49	117.3	7.5	8.5	31.67
AD50	195	236	41	107.0	8.5	8.5	36.33
Lloyd	194	238	44	72.2	7.7	10.0	39.33
AC Morse	192	234	42	113.3	10.0	11.0	50.00
ZAGORKA	201	244	43	85.3	6.7	11.0	39.67
AC Melita	192	238	46	132.7	9.8	12.0	50.67
U13851	180	222	42	76.3	9.8	5.0	31.33
1522	199	237	38	139.7	7.0	11.0	53.00
786	194	238	44	134.0	8.7	12.0	56.00
K 1112I073	189	224	35	99.3	10.2	10.5	35.33
K 1112I065	204	238	34	99.7	7.3	8.0	38.00
8871-AN-I	192	238	46	74.3	8.8	12.0	37.33
8974-HA4-I	195	238	43	89.2	11.2	6.0	34.00
K 1213I233	195	229	34	93.7	9.0	10.0	34.67
K 1011I271	188	227	39	96.5	7.7	11.0	34.67
K 1213I240	185	227	42	107.3	9.8	13.0	35.00
K 1213I271	192	229	37	104.0	8.8	7.0	38.67
K 1213I276	199	235	36	103.2	8.3	8.0	39.33
8871-AN-S	199	246	47	74.3	7.0	12.0	35.67
Dalmatia 3	199	244	45	149.7	8.0	15.0	49.67
Nursith	192	234	42	113.0	8.7	11.0	39.33
ELS 6404-127	192	229	37	105.7	6.0	8.0	37.33
ELS 6404-139-5	192	229	37	103.0	9.5	13.0	42.67
ELS 6404-140-2	187	227	40	101.7	9.0	11.0	43.33
ELS 6404-145-2	192	229	37	125.7	10.0	9.0	37.33
ELS 6404-154	192	227	35	111.3	8.5	10.0	46.33
Shasti	192	231	39	136.0	15.5	6.0	47.33
Royal de Almena	197	235	38	139.7	8.2	10.0	50.00
CItr 15505	199	238	39	96.3	6.7	9.0	44.33
Qualset BYDV 31	197	238	41	137.0	6.8	11.0	54.00
CI 17718	201	239	38	129.7	9.5	14.0	39.33
CI 17719	199	241	42	127.2	7.3	9.0	50.67
Taganrog AC 1	201	236	35	149.7	9.3	10.0	38.67
FHB4501	194	238	44	141.0	9.8	12.0	40.33

**Supplementary Table S3.** Variations of quantitative agronomical traits across 215 global wheat accessions grown in Korea (Continued).

Name	DH (days)	DM (days)	DHM (Days)	CL (cm)	SL (cm)	AL (cm)	TKW (g)
ICARDA-IG-83562	192	229	37	109.0	9.3	11.0	36.00
PI 113396	192	235	43	125.3	6.7	13.0	35.67
Kaligawaran	187	227	40	109.3	8.3	10.0	45.33
PI 115812	199	238	39	111.7	6.7	10.0	40.67
Beladi 164	199	244	45	132.7	8.2	14.0	56.33
Tripolino	195	238	43	108.7	6.3	8.0	43.67
PI 163274	199	242	43	77.0	6.2	10.0	33.67
PI 166454	199	238	39	139.0	7.3	13.0	45.00
PI 166473	202	244	42	138.3	10.8	10.0	51.00
Kkarabilcik	192	234	42	135.3	8.8	13.0	40.33
Akserez	211	238	27	98.7	5.3	10.0	45.00
PI 166543	195	234	39	125.8	9.5	15.0	54.00
Tounse	203	244	41	157.7	10.7	11.0	48.67
PI 176228	210	244	34	110.8	10.0	9.0	35.33
PI 176286	192	235	43	97.0	6.3	12.0	39.67
Agyba 1	195	235	40	123.3	8.0	11.0	50.00
S-45	195	234	39	125.0	10.3	10.0	54.67
Hourah	192	238	46	101.3	6.8	10.0	47.00
C-2	192	235	43	120.3	8.2	13.0	42.33
Legami	192	234	42	113.0	6.0	8.5	50.00
Brkulja	201	246	45	150.0	8.8	11.0	63.00
Carina	209	246	37	121.0	8.8	9.0	50.00
Mettes Rauhwizen	214	248	34	133.3	11.2	11.0	42.00
Claro Fino de Balazote	210	244	34	136.3	8.3	15.0	36.67
Trigo de Albandeia	206	244	38	130.0	8.8	8.0	40.67
Duro del Pais	200	246	46	134.0	10.0	11.0	51.00
Timor	206	250	44	107.7	8.0	11.0	41.67
HN ROD 25 13770	213	250	37	103.3	7.3	11.0	23.67
C F B	200	248	48	141.7	8.3	10.0	49.00
Azizeah	199	244	45	104.0	5.7	12.0	40.00
Ostpreuss	201	238	37	140.8	9.3	11.0	45.00
Minos No. 251	199	238	39	123.0	8.2	12.0	43.67
Sin El-Jamil	195	234	39	113.3	9.8	11.0	53.67
AUS 9728	192	234	42	123.3	8.3	12.0	46.33
Kafel Rahman	196	238	42	112.3	7.2	12.5	41.33
Perigo Candeal 24	201	246	45	138.0	8.3	14.0	51.33
Rosello	209	244	35	135.3	8.7	17.0	60.33
Durz Karaki	194	238	44	118.3	8.3	10.0	42.67
Kara Kiltschik	199	244	45	157.7	8.3	14.0	54.00

**Supplementary Table S3.** Variations of quantitative agronomical traits across 215 global wheat accessions grown in Korea (Continued).

Name	DH (days)	DM (days)	DHM (Days)	CL (cm)	SL (cm)	AL (cm)	TKW (g)
K918	199	244	45	113.0	6.7	13.0	48.33
PI 262670	201	242	41	133.0	7.5	13.0	44.33
Kubanka Karakolskaya	206	242	36	145.3	10.3	14.0	41.67
Shaupkha	206	242	36	145.3	9.0	13.0	45.33
PI 264934	207	244	37	117.7	6.0	11.0	49.00
PI 265011	206	244	38	144.7	9.7	12.0	58.67
Veneny	195	238	43	124.0	8.0	11.0	48.33
Dioszegi	209	248	39	155.3	14.3	4.0	37.67
Greece 14	199	241	42	135.0	9.0	13.0	57.67
Crete 1	199	244	45	149.0	7.8	12.0	49.67
Malta 3	209	246	37	120.7	7.8	13.0	50.33
Malta 4	207	248	41	112.7	7.2	16.0	59.67
Valencia	195	227	32	112.7	8.2	5.0	44.00
Tripolitco	200	246	46	110.7	8.2	12.0	51.00
ECH 605	215	248	33	120.3	13.0	10.0	31.67
Bagudo 9032	206	246	40	139.3	9.2	12.5	42.67
Belgrade 9	201	244	43	141.7	7.2	15.0	49.67
ELS 6404-144-1	195	238	43	107.3	8.0	7.0	47.00
ELS 6404-151-2	199	240	41	129.7	13.0	2.0	44.33
ELS 6404-160-5	206	242	36	132.7	9.7	13.0	48.00
Biadh	194	237	43	104.2	7.7	6.5	34.00
Cltr 15273	194	237	43	119.3	6.2	9.0	40.80
Cltr 15303	206	248	42	121.7	6.3	7.5	35.33
PI 113397	194	237	43	111.0	6.0	10.0	40.67
PI 134943	199	238	39	126.0	9.7	17.0	46.67
Peygamber	199	238	39	122.3	10.2	14.0	65.00
PI 182668	195	238	43	129.7	7.2	13.0	50.00
Gharbi	199	238	39	130.0	7.7	12.0	53.33
Marrocos 110	196	238	42	135.7	8.3	15.0	56.67
PI 184641	201	238	37	124.0	8.2	19.0	48.67
HN ROD 47 14870	203	235	32	136.7	7.0	10.0	40.00
PI 192849	203	237	34	119.3	8.0	13.5	54.33
PI 221408	200	238	38	135.7	7.7	12.0	52.00
Wakooma	199	234	35	135.3	10.3	10.0	48.33
Cltr 15436	199	235	36	105.0	8.7	6.0	29.67
Cltr 8164	199	235	36	83.3	9.7	10.5	33.33
PI 202796	201	238	37	132.3	8.7	9.0	40.33
PI 210912	192	229	37	118.7	10.3	13.0	56.67
PI 210948	199	244	45	134.7	8.7	17.0	78.00

**Supplementary Table S3.** Variations of quantitative agronomical traits across 215 global wheat accessions grown in Korea (Continued).

Name	DH (days)	DM (days)	DHM (Days)	CL (cm)	SL (cm)	AL (cm)	TKW (g)
PI 220704	206	246	40	142.0	10.8	10.0	58.33
PI 231311	209	244	35	113.7	9.7	14.0	37.00
PI 261823	196	235	39	125.7	7.7	11.0	46.00
PI 264959	206	238	32	135.7	13.2	9.0	42.67
PI 273999	195	229	34	97.3	9.3	11.0	36.00
PI 274673	206	242	36	116.0	10.0	9.0	56.67
PI 277126	214	250	36	122.7	10.3	14.0	51.33
PI 340745	206	244	38	103.7	18.7	7.0	45.00
PI 345107	201	244	43	149.7	9.0	10.0	46.00
PI 345338	206	244	38	153.7	12.0	9.0	50.00
4	213	250	37	90.7	9.0	12.0	47.00
Mexicali C75	192	227	35	76.0	8.0	9.0	51.67
CDSS04B00716T-0TOPY-42Y-0M-1Y-0M-4Y-0B	199	237	38	67.3	6.3	9.0	34.67
CDSS04B00717T-0TOPY-41Y-0M-3Y-0M-1Y-0B	192	229	37	78.3	8.0	9.0	45.33
K 1112I062	197	238	41	115.3	8.5	12.0	33.67
Aziziah	192	234	42	102.3	6.3	8.0	39.00
Karaki Red	194	239	45	120.5	7.3	11.5	47.33
Timilia	194	234	40	126.7	8.0	16.0	45.00
Beloturka	197	244	47	136.7	6.7	10.0	41.67
Doubbi	199	231	32	100.7	6.7	10.0	20.33
Geumgang (Control)	171	219	48	65.00	10.00	5.00	46.00
Min	166	208	27	53.67	5.33	0.50	20.33
Max	215	250	52	163.00	18.67	19.00	78.00
Total mean	197.12	237.06	39.94	115.30	8.55	10.07	43.43
SD	7.25	6.79	3.87	23.68	1.84	3.38	8.21
CV (%)	3.68	2.86	9.70	20.54	21.50	33.61	18.90
LSD (0.05)	-	-	-	12.93	1.71	-	0.25