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Determination of pre-harvest sprouting tolerance and quality traits of the bread wheat landraces

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Yerel ekmeklik buğday çeşitlerinin hasat öncesi çimlenme toleransı ve kalite özelliklerinin belirlenmesi

Abstract: In this study, pre-harvest sprouting tolerance and some quality characteristics of some wheat landraces and modern varieties in Turkey were determined. In Eskişehir, Karaman and Samsun locations of Turkey, 126 genotypes were tested in the 2014-2015 growing seasons, and 48 genotypes were tested in the 2015-2016 and 2016-2017 growing seasons in two-replication experiments. Data regarding germination index, protein content, sedimentation volume and falling number of genotypes were observed. Physical properties of grain, the number of days to spike, and plant height were also investigated. The difference between genotypes was found to be statistically significant for all traits. We found the germination index of the genotypes varied between 0.19 and 0.70 for the 2015-2016 and 2016-2017 growing seasons, respectively. The average germination index value of red kernel genotypes is lower than white kernel genotypes. The landraces from Turkiye included in the research were taller and harvested lately. In comparison, modern genotypes are in the first place regarding sedimentation volume. The landraces had higher protein content but lower protein qualities than modern cultivars. The grain hardness of landraces was lower than that of modern cultivars in the three years. We found positive relationships between the germination index, grain filling time, thousand-grain weight, and grain color. Protein content, sedimentation volume, falling number, and grain hardness are negatively and significantly related to the germination index. The results showed that white kernel Clark's Cream and red kernel Karakılçık (1) genotypes could be used as gene sources for pre-harvest sprouting tolerance breeding in bread wheat.

Key words: Pre-harvest sprouting, bread wheat, landrace, quality characteristics

Özet: Bu çalışmada, Türkiye'deki bazı buğday yerel çeşitler ve modern çeşitlerin hasat öncesi filizlenme toleransı ve bazı kalite özellikleri belirlenmiştir. Türkiye'nin Eskişehir, Karaman ve Samsun lokasyonlarında 2014-2015 yetiştirme sezonlarında 126 genotip, 2015-2016 ve 2016-2017 yetiştirme sezonlarında ise 48 genotip iki tekerrürlü denemelerde test edilmiştir. Genotiplerin çimlenme indeksi, protein içeriği, sedimantasyon hacmi ve düşme sayısına ilişkin verileri alınmıştır. Tanenin fiziksel özellikleri, başaklanma gün sayısı ve bitki boyu da araştırılmıştır. Genotipler arasındaki farkın tüm özellikler açısından istatistiksel olarak önemli olduğu belirlenmiştir. Genotiplerin çimlenme indeksinin 2015-2016 ve 2016-2017 yetiştirme sezonları için sırasıyla 0,19 ile 0,70 arasında değiştiği tespit edilmiştir. Kırmızı taneli genotiplerin ortalama çimlenme indeksi değeri beyaz taneli genotiplere göre daha düşük bulunmuştur. Araştırmaya dahil edilen Türkiye'deki yerel çeşitlerin daha uzun boylu ve hasada kadar geçen sürenin daha uzun olduğu belirlenmiştir. Tüm genotipler karşılaştırıldığında modern çeşitler sedimantasyon hacmi açısından ilk sıralarda yer almışlardır. Yerel çeşitler modern çeşitlere göre daha yüksek protein içeriğine ancak daha düşük protein kalitesine sahiptir. Üç yılda yerel çeşitlerin tane sertliği modern çeşitlerden daha düşük olmuştur. Çimlenme indeksi, tane doldurma süresi, bin tane ağırlığı ve tane rengi arasında pozitif ilişki olduğu belirlenmiştir. Protein içeriği, sedimantasyon hacmi, düşme sayısı ve tane sertliği çimlenme indeksi ile negatif ve önemli ölçüde ilişkilidir. Sonuçlar, beyaz taneli Clark's Cream ve kırmızı taneli Karakılçık (1) genotiplerinin ekmeklik buğdaylarda hasat öncesi çimlenme toleransı ıslahında gen kaynağı olarak kullanılabileceğini göstermiştir.

Anahtar Kelimeler: Hasat öncesi çimlenme, ekmeklik buğday, yerel çeşit, kalite özellikleri

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1. Introduction

The increase in the world population and global climate changes have increased the importance of wheat in the food supply. Wheat, which has a wide range of use as a food source and ease of storage, has wide adaptability and biodiversity (Shewry and Hey, 2015). In recent years, tolerance studies against stress factors that cause yield and quality decrease in wheat have gained importance. In this context, landraces and wild species are of great significance as genetic resources.

Local gene resources are essential in ensuring genetic improvement in wheat breeding programs (Xu et al., 2019).

Local gene sources are used intensively for grain yield, adaptation, and quality characteristics in breeding programs, also used in breeding for abiotic and biotic stress factors. Especially the climate changes experienced in recent years and the anticipated stress factors (Marcińska et al., 2013; Aghanejad et al., 2015) necessitate new genetic resources. Climate changes may cause drought and heavy rainfall in some locations. Changes in the precipitation regime will make tolerance to pre-harvest sprouting crucial for many regions.

Especially in our regions that receive precipitation during the maturity period of wheat, sprouting reduces the quality and price of the product. In addition to our areas with high annual rainfall during the summer months, the number of heavy rains and floods in the world has increased in recent years (Nonogaki et al., 2018). It has been reported that the economic losses that may occur due to the climatic conditions of the pre-harvest sprouting cannot be readily estimated. The severity of these losses depends on the physiological maturity period, precipitation, and the number of cloudy days after rain (Aghanejad et al., 2015).

Seed color is one of the breeder's essential phenotypic traits regarding tolerance to pre-harvest sprouting. Tolerance to pre-harvest sprouting generally depends on the post-harvest dormancy characteristic of the genotype, the climatic conditions after flowering, the morphological characteristics of the spike, and stress factors (Barrero et al., 2015; Wang et al., 2019). Due to the pleiotropic effect between the seed color and post-harvest dormancy, white kernel wheat is generally more susceptible to sprouting than red kernel wheat (Mares et al., 2005; Zhu et al., 2019). Some studies have shown that seed color and post-harvest dormancy are also genetically controlled by independent QTLs (Zhu et al., 2019; Tai et al., 2021). There are also studies in which the relationship between dormancy and red kernel color is not partially observed (Zhou et al., 2017; Gautam et al., 2021). Some researchers found that dormancy genes were independent of grain color in their research on hybrids of red x white kernel genotypes (Lin et al., 2016; Yang et al., 2019). Liu et al. (2008) determined a significant QTL carried by the winter bread wheat variety Rio Blanco, which is used effectively for dormancy. Another study published in 2018 determined that a white Danby cultivar had one major and three minor QTLs for resistance to germination in the spike (Shao et al., 2018).

The pre-harvest sprouting is a genetically complex trait. The trait with low heritability is also significantly affected by the environment. Therefore, breeding studies on this subject are also challenging. Except for the 1D chromosome in bread wheat, the other chromosomes carry the quantitative trait region or genes for resistance to the pre-harvest sprouting. However, chromosomes 3A, 3B, 3D, and 4A had more important for dormancy. In a study, a major QTL related to dormancy was detected on chromosome 3A (*QPhs.ccsu3A.1*) (Kulwal et al., 2005; Wang et al., 2018). The pre-harvest sprouting has also been the subject of many molecular studies (Cabral et al., 2014; Lin et al., 2015; Abe et al., 2019; Miao et al., 2019).

In a study from Canada, the spring wheat genotypes were tested for pre-harvest sprouting and reported that breeders could use both white and red material for pre-harvest sprouting resistance (Rasul et al., 2012). Ogbonnaya et al. (2008) determined two significant QTLs for resistance to germination in the white kernel CN10955 gene source and stated that this source is helpful for marker-assisted selection. Studies also advocate that red kernel wheat should be used as a genetic source for resistance to the pre-harvest sprouting in white kernel wheat (Lawson et al., 1997).

Breeders need effective and reliable methods to measure pre-harvest sprouting.The tests to measure the resistance to pre-harvest sprouting are the germination tests on the grain or the spike and the determination of the falling number. Germination tests can be done in the laboratory for artificial climate conditions and in the field under the rain (Bassoi et al., 2006; Zeeshan et al., 2018). Gavazza et al. (2012) used a rain simulator in the greenhouse to test the resistance of the pre-harvest sprouting in wheat. Researchers reported that this artificial precipitation method is suitable for determining pre-harvest sprouting resistance.

The pre-harvest sprouting can adversely affect the agronomic characteristics of wheat and the milling and final product quality of the harvested grain. Since the quality of germinated wheat is not at an acceptable level, its price is generally low (Shu et al., 2015). Kruger and Tipples (1982) reported that only a tiny amount of germinated grain in a batch of wheat could adversely affect the quality of the flour. The parameters used by the flour industrialist to determine the germination degree of the spike are generally the falling number and α-amylase activity (Stoy, 2019). Germinated grains will have a lower falling number (Ral et al., 2016; Newberry et al., 2018). When the falling number value of wheat is less than 220 – 250 sec., it is not suitable for bread making, and millers do not use wheat with this characteristic as raw material (Olaerts and Courtin, 2018).

Within the scope of the research, the landraces bread wheat varieties collected from Turkey and advanced lines developed from landrace populations, and modern bread wheat varieties were used as plant materials. We determined falling number, grain hardness, and tolerance to pre-harvest sprouting. In addition, we collected data for plant height, heading date, thousand-grain weight, sedimentation value, size analysis, and protein content.

2. Materials and Method

2.1. Trial locations

Trials were conducted in Karaman (37°01′23″N- 33°05′39″E), Eskişehir (39°39′31″N-31°2′13″E), and Samsun (41°17′25″N- 36°20′1″E) locations in Turkey. In Eskişehir and Samsun, the trials were carried out at Agricultural Research Institutes and KaramanoğluMehmetbey University in Karaman. We paid attention to the fact that the locations had different climatic characteristics during the grain filling period. Thus, it has been tried to ensure the genotype x environment interaction. As a result of the study, we tested the genotypes in nine environments, three years x three locations.

Samsun is a location with high relative humidity, likely to receive precipitation in the summer months and naturally pre-harvest sprouting. However, there was no rain during research period in the Samsun location, which received rainfall during the harvest period for many years. The Eskişehir location represents Turkey's western gateway and is geographically central to most research materials. The Karaman location allowed the testing of genotypes in terms of low α-amylase activity due to its common relative humidity. As expected, the amount of precipitation falling during the growing season was most observed at the Samsun location. In terms of total annual rainfall, the Karaman location received 221 mm of rain in the 2015-2016 growing season and experienced one of the driest winters and springs in its history.

Regarding average temperature and relative humidity, the highest average belongs to the Samsun location. Karaman province is the location with the lowest relative humidity averages. Eskişehir location experienced its wettest season in the 2014-2015 growing season in the experiments conducted.

2.2. Plant material

Bread wheat varieties registered in Turkey and abroad and landrace were used as plant material in the research. Trials included 126 materials in the first year of the study. Forty-eight of the genotypes with the lowest average germination index and falling number values obtained in the first year of the study were selected. These materials were used in the trials in the second and third years of the project (Table 1). As control cultivars, Clark's Cream (dormant), Halbert (semi-dormant), HD2329 (non-dormant), Altındane (non-dormant), Demir2000 (red kernel control), Sönmez2001 (red kernel control), Tosunbey2000 and Tahirova2000 (white kernel control) cultivars were used. Clark's Cream variety originates from the USA, and Halbert is resistant to sprouting, originating from Australia. HD2329 is a genotype used as a sensitive parent in mapping populations where sprouting is investigated. In addition, control cultivars selected according to the first year's results and sensitive to pre-harvest sprouting were also included (Kırik (2) and Kocabuğday).

2.3. Trials

In the first year of the study, 126 genotypes included in the trials carried out in three different locations were sown manually in 2 meter-long rows without repetitions and in a single row. In the project's first year, the trials were planted in an augmented trial design and four blocks. The experiments included control varieties in each block. Forty-eight genotypes selected according to the first year's results were planted by hand in two replications in two rows and 1.5 meters long rows according to a randomized block design (Munkvold et al., 2009).

We used herbicides to control weeds. The fertilizer program has been optimized not to lie down the tall landraces. Six kg da pure phosphorus and 8 kg da nitrogen fertilization in Karaman and Eskişehir locations and 10 kg da nitrogen fertilization in Samsun have been applied. We gave half of the nitrogen fertilizer at planting and the other half during the stem elongation period. Since the land belonging to the research institute where the experiments were carried out in the Samsun location is rich in phosphorus, phosphorus fertilization was not done in this location. In all areas, pesticides were applied against fungal diseases and spreading. In the winter and spring of 2016, we irrigated the experiments three times due to the intense drought in Karaman. While irrigation was done twice in Karaman in 2017, irrigation was done once in 2015. Irrigation was done once in 2017 at the Eskişehir location, and there was no irrigation at the Samsun location.

Table 1. Wheat genotypes used in the research

No	Genotype	Modern/Land race	Collected location	No	Genotype	Modern/ Landrace	Collected location
1	Sukezmez	Landrace (L)		25	Kırik (3)	L	Erzurum/Toprakkale
2	Göderedi (1)	L	Konya	26	Kocabuğday	L	Burdur
3	Kobak (1)	L	Kütahya	27	Göderedi (2)	L	Karaman
4	Yektay406	L		28	Şahman	L	Aksaray
5	Mv18	Modern (M)		29	Demir2000	M	
6	Kırik (1)	L	Erzurum/Güzelsu	30	Sarı misli	L	
7	Tosunbey	M		31	Gülümbür	L	Kütahya
8	Çalıbasan (1)	L	Kütahya	32	4-11	L	
9	Sarı Buğday (1)	L		33	Ak702	L	
10	Clark's Cream	M		34	Sönmez2001	M	
11	Kırik (2)	L	Erzurum/Güllüce	35	Çalıbasan (2)	L	Yozgat
12	Akbuğday (1)	L	Aksaray	36	Kobak (2)	L	Kütahya
13	Kırmızı Buğday (1)	L	Aksaray	37	Buğday	L	Konya
14	Kabak Buğday	L	Balıkesir	38	Atay85	M	
15	Halbert	M		39	Urumeli	L	
16	Akbuğday (2)	L	Afyon	40	Zincirli	M	
17	Nevzatbey	M		41	Müfitbey	M	
18	Karakılçık (1)	L	Konya	42	Bogruala	L	
19	Esperia	M		43	Bezostaja	M	
20	Kırmızı Buğday (2)	L	Isparta	44	Arıbuğday	L	Uşak
21	No name	L	Aksaray	45	Karakılçık (2)	L	Çanakkale
22	Topbaş	L	Erzurum	46	Tir Line	L	
23	Altındane	M		47	Sarı Buğday (2)	M	Yozgat
24	HD2329	M		48	Altay2000	M	

2.4. Examined agricultural and quality characteristics

To determine the plant height, we measured the distance from the soil surface to the tip of the last spikelet. Grades are given between 1 and 9 according to the lying ratio of the plants in the rows. From January 1 until approximately 50% of the plants in the plot are heading was determined and expressed as the heading days (Tavella, 1978; Bohn et al., 1998). We counted the days from the heading date to physiological maturing to determine the grain filling time. One hundred seeds from each genotype were counted twice with an automatic seed counting machine (Chopin - Numigral-I), and we calculated the average of 1000 seeds by multiplying by 10 (g). Grain color was measured using the HunterlabColorflex Color measuring device. L (brightness), a (redness), and b (yellowness) values were used to determine color changes (Coşkuner et al., 2002). Amylolytic (α-amylase) activities of flours obtained from wheat were determined using a falling number tester (Falling Number 1500, Perten Instruments, Sweden) (AACC Method 56-81B) (AACC, 2000). The moisture content of wheat was determined using Dickey-John-GAC Plus (AACC Method 55-10) and expressed as a percentage. 100 g of grain was sieved for 5 minutes in a shaking system (Pfeuffer – Sortimat) with 2.8, 2.5, and 2.2 mm sieves. The proportional size distribution was obtained by separately weighing the remaining part on each sieve and in the collecting bowl. Uniformity was determined by considering the remaining material on two successive sieves (2.2+2.5 mm or 2.5+2.8 mm) (Köksel et al., 2000; Elgün et al., 2002).

We used the TA-TXPlus Texture analyzer for grain hardness analysis. Ten grains of approximately equal size from each genotype were crushed to calculate average resistance values. The protein content of wheat flour was determined using the flour module of the Perten Inframatic 9500 device (Perten Instruments, Sweden) and expressed as a percentage in dry matter. Sodium dodecyl sulfate (SDS) sedimentation volumes, which are indicators of wheat flour quality, were measured using the modified AACC method (AACC Methods 56-70) (Maghirang et al., 2006; Sayaslan et al., 2006).

2.5. Germination tests

We performed germination tests to determine the dormancy levels of the genotypes. The grains threshed from the ears were used in the germination test. As a morphological indicator of physiological maturity, the green color in glumes turns yellow (Hanft and Wych, 1982). Harvested ears were dried at room temperature (20-23 °C) for five days. We used an air conditioner in the room. The threshed grains were not immediately tested for germination and stored at -20 °C to prevent them from losing their dormancy properties. There were 50 seeds in each petri dish. We established the germination tests with one replication in the first year. Two replications in the second and third years were carried out in a plant growth cabinet kept at an ambient temperature of 20 °C and 90% relative humidity. The germination test was carried out in sterile Petri dishes with filter papers (Whatman No 2). Before the seeds were taken for the germination test, they were sterilized with 1% sodium hypochlorite and then washed with sterile water. 8-10 ml of pure water was added to the Petri dishes at the rate to wet the seeds, and the seeds were kept constantly moist. We took the seeds to the germination test in the dark. The germination test took seven days. The germinated seeds were counted every day at the start of the germination time and taken from the Petri dishes. The germination index was calculated according to the formula below (Walker-Simmons and Sesing, 1990):

General Germination Index= 7 x n_1 + 6 x n_2 + 5 x n_3 + 4 x n_4 + 3 x n_5 + 2 x n_6 + 1 x n_7 / Total test days x total grain count

n_1, n_2, ...,n_7 represents the number of grains germinated on the first, second……. and seventh days of the germination test. The maximum germination index is 1.0, indicating that the genotype is not dormant. The minimum value is 0.0, which indicates that the genotype is dormant.

2.6. Evaluation of data

The data obtained from the experiments were analyzed in the Jump statistical program using the Augmented design in the first year and the randomized blocks experimental design in the second and third years using the Jump 12.0.1 program (Patterson and Hunter, 1983; Munkvold et al., 2009). Since there was a recurrence in the first year of the experiment, the values could not be transformed, and the coefficient of variation was calculated by applying the square root transformation only for the values where the locations were combined. In calculating the LSD value, the data obtained from analyzing the values without transformation were used. The student's t-test was used to compare the data. Since the dimensional analysis values have 1 in the under-sieve values, the coefficient of variation was calculated using the square root transform values.

3. Results

In the 2014-2015 growing season, the first year of the research, 126 genotypes were grown in three locations, and the obtained seeds were tested for germination. Forty-eight genotypes with low germination index values were selected for trials in three areas in the 2015-2016 and 2016-2017 growing seasons.

3.1. Germination index

According to the data obtained in the 2014-2015 growing season, the average germination index values in Eskişehir, Karaman, and Samsun locations were 0.40, 0.40, and 0.42, respectively. All of the genotypes in the first place regarding high germination index values are white-grained genotypes. The germination index values of the genotypes in the experiment for the 2015-2016 and 2016-2017 growing seasons are given in Table 2 and the variance analysis values are shown in Table 3. According to the results of the 2015-2016 and 2016-2017 growing seasons, we found the statistical differences between the average germination index of the genotypes, the interaction of genotype x location, and genotype x years (Table 3).Karakılçık (1), Bezostaja, Clark's Cream, Kobak, Demir2000, Göredeli (1), Sukezmez, MV18, and Sönmez2001 genotypes had the lowest average germination index values, respectively (Fig. 1). Clark's Cream is the only genotype with white kernel color among these cultivars. While the germination index average of the white-grained genotypes is 0.53, the average of the red-grained genotypes is 0.40 (Fig. 2). These results show that this cultivar originating from the USA can be used for resistance to the pre-harvest sprouting in Turkey.The genotypes with the highest average germination index are

Table 2. Average data of the genotypes included in the study for the 2015-2016 and 2016-2017 growing seasons

Analyzed Agricultural Characteristics		2015-2016			2016-2017			Average
		Eskişehir	Karaman	Samsun	Eskişehir	Karaman	Samsun	
Germinating index	Average	0.23	0.34	0.42	0.51	0.59	0.70	0.46
	Range	0.08-0.66	0.06-0.85	0.06-0.82	0.15-0.71	0.19-0.86	0.35-0.81	0.19-0.70
	LSD	0.11	0.21	0.19	0.12	0.12	0.09	0.09
	CV	%10.3	%15.9	%11.4	%6.11	%4.95	%3.27	%14.1
Heading date	Average	138	139	132	157	148	137	142
	Range	130-145	123-147	121-140	152-161	142-154	126-143	133-147
	LSD	1.31	2.87	1.21	1.74	5.45	1.21	1.69
	CV	%0.47	%1.02	%0.45	%0.55	%1.83	%0.43	%1.48
Grain filling date	Average	38	36	44	35	40	52	41
	Range	33-48	31-41	36-54	31-41	35-46	48-58	37-47
	LSD	1.63	1.99	3.41	1.52	4.09	1.95	1.40
	CV	%2.11	%2.75	%3.83	%2.19	%5.04	%1.87	%4.27
Failing number	Average	381	310	327	373	385	291	344
	Range	332-400	245-352	215-397	351-400	356-400	112-372	296-385
	LSD	31	34	54	22	23	38	23
	CV	%4.0	%5.4	%8.2	%3.0	%3.0	%6.5	%8.2
Grain color value	Average	403	356	353	-	-	-	371
	Range	272-514	277-438	283-450	-	-	-	303-441
	LSD	29	92	31	-	-	-	33
	CV	%3.6	%12.8	%4.4	-	-	-	%7.8
Plant height	Average	117.5	63.2	122.6	122.4	105.4	122.4	108.9
	Range	85-132	33-82	65-150	81-146	70-135	78-144	68-127
	LSD	4.44	15.9	16.7	4.36	12.5	6.97	7.40
	CV	%1.87	%12.5	%6.80	%1.77	%5.90	%2.82	%6.09
Sedimentation volume	Average	19	23	12	14	16	17	17
	Range	6-35	8-36	5-37	6-32	5-30	5-33	5-32
	LSD	7.0	3.8	4.4	2.4	2.9	2.2	2.1
	CV	%18.4	%8.4	%18.5	%8.7	%9.1	%6.7	%15.6
1000 grain weight	Average	39	29	29	37	39	44	36
	Range	28-45	16-38	18-42	27-45	26-49	35-52	28-41
	LSD	3.2	7.8	5.6	4.8	4.2	4.5	2.7
	CV	%4.11	%13.8	%9.5	%6.6	%5.4	%5.0	%9.5
Grain hardness	Average	16.5	25.4	17.8	16.9	15.2	19.2	18.5
	Range	13.01-24.7	17.4-34.4	12.7-23.5	12-23.9	10-21.4	14.1-25.5	13.9-23.9
	LSD	3.2	9.8	4.6	2.3	1.9	2.9	2.1
	CV	%9.8	%19.3	%12.9	%6.8	%6.1	%7.5	%14.4
Average sieve analysis	Average	4	-	17	7	6	5	8
	Range	1-18	-	5-47	1-41	3-28	1-14	3-25
	LSD	5.7	-	13.3	8.7	10.3	3.3	5.9
	CV	%31.6	-	%16.1	%33.8	%36.3	%16.4	%26.0
Grain moisture content	Average	11.2	-	11.8	10.8	10.5	11.5	11.1
	Range	9.3-12.2	-	9.4-13	10.5-11.2	10.3-10.8	10.4-12.1	10.2-11.7
	LSD	1.0	-	1.2	0.3	0.5	0.5	0.4
	CV	%4.6	-	%5.2	%1.2	%2.2	%2.0	%3.5
Protein content	16.9	21.6	15.7	14.4	15.1	17.6	16.9	16.9
	14.4-20	18.3-23.9	14.3-19.5	12.6-16	12.8-16.8	15.1-22.1	15.4-19.8	14.4-20
	1.98	2.54	1.78	1.80	1.04	1.49	0.84	1.98
	CV	%5.8	%5.8	%5.6	%6.2	%3.4	%4.2	%6.2

Kırik (2), Tir line, Kocabuğday, Kırik (1), Altay2000, Yektay406, SarıBuğday (2), Kırik (3) and HD2329 genotypes, respectively. Among these genotypes, the only red-grained genotype is the Tir line. HD2329 genotype also has a high germination index value, 0.58.

The genotype numbers according to the germination index averages in the locations are given in Fig. 1. While the number of genotypes between 0-0.30 is highest in Eskişehir and Samsun locations, the number of genotypes between 0.31-0.50 is higher in Karaman location. However, the number of genotypes in the ranges of 0.51-0.70 and 0.71< is higher in Samsun location compared to Eskişehir and Karaman locations.Wang et al.

3.2. Plant height

The average plant height of the genotypes, including the local material selected from different regions of Turkey and passed through certain selection stages, varied between 64-115 cm for three locations in the 2014-2015 growing season. Esperia, Zincirli, HD2329, Altındane, Adana99, and Mv18 genotypes are the shortest plants according to the mean values, respectively. The genotypes with the longest plant height are Clark's Cream, KaşıkçıBuğday, SarıBuğday, Çomak, Karakılçık and Göderedi, respectively.

According to the results of the trials carried out in the 2015-2016 and 2016-2017 growing seasons, it was determined that the difference between genotypes and plant height was significant for the genotype x location interaction, while the genotype x year interaction was not significant (Table 3). The plant height was 108.9 cm according to the average of the six circles, and the average plant height values changed between 63.2 cm and 122.6 cm according to the average of the locations (Table 2). We obtained the shortest plant height average of 63.2 cm in the Karaman location in 2016 (Table 2). Karaman experienced one of its history's driest winter and spring seasons in the relevant year. At the same time, considering the general average, the location with the shortest plant height is the Karaman location.

3.3. Heading date

For the 2014-2015 breeding season, the average heading date of genotypes is 145 in all locations. According to the results in the 2015-2016 and 2016-2017 growing seasons, we statistically found the differences between heading dates for genotypes. The interaction of genotype x year and genotype x location are also crucial for the number of days to heading (Table 3). The average heading day of the trials in six environments harvested in 2016 and 2017 was 142 days (Table 2). The earliest heading date was obtained in Samsun in the 2016-2017 growing season with 132 days. We received the latest heading date in Eskişehir in the 2016-2017 growing season with 157 days (Table 2). Heading time varies between 133 and 147 days. According to the mean values, the earliest heading genotypes were HD2329, Esperia, Topbaş, Mv18, Çalıbasan (1), Sönmez2001, Halbert, and Nevzatbey, respectively. In contrast, the latest heading genotypes were Kabak, Zincirli, Sukezmez, Kobak (2), Kocabuğday, Atay85, Bogruala, and Göderedi (1, 2). The landraces often headed late.

3.4. Grain filling time

In the experiment conducted in three different locations in the 2014-2015 growing season, the average grain filling time of the genetic material was 35.3 days, and the average grain filling time in Eskişehir, Karaman, and Samsun locations was 39.9, 33.2, and 33.3 days, respectively. Grain filling time varied between 32 and 40 days according to the locations' average. The genotypes with the shortest grain filling period according to the average of the three locations are Sönmez2001, Kabak, Topbaş, Gülümbür, Akbuğday, Domaniç, and KırmızıAkbuğday. The genotypes with the longest grain filling periods in the experiments are Tir line, Şahman, Akbuğday, Kıraç66, Kobak, Çalıbasan, and Müfitbey, respectively.

We found the differences between the grain filling times of the genotypes in these years, the interaction of genotype x years, and genotype x location to be significant at 1% (Table 3). According to the locations' average, the grain filling time is 41 days. Grain filling time varied between 31-48 days in Eskişehir, 31-41 days in Karaman, and 36-54 days in Samsun in 2016 and 2017 (Table 2). While the shortest grain filling time was experienced at the Eskişehir location with an average of 35 days in 2017, the longest grain filling time was shared at the Samsun location with 52 days (Table 2). According to the results and average values obtained from the 2015-2016 and 2016-2017 growing seasons, the genotypes with the shortest grain filling time are Kabak Buğday, Akbuğday (2), Göderedi (1), Kobak (1), Akbuğday (1), Kocabuğday, Şahman, Clark's Cream, and Kirik (2, 3) are listed. The order of the genotypes with the longest grain filling time is HD2329, Tosunbey, Çalıbasan (1), Halbert, Yektay406, Mv18, Esperia, Topbaş, Altay2000 and Nevzatbey.

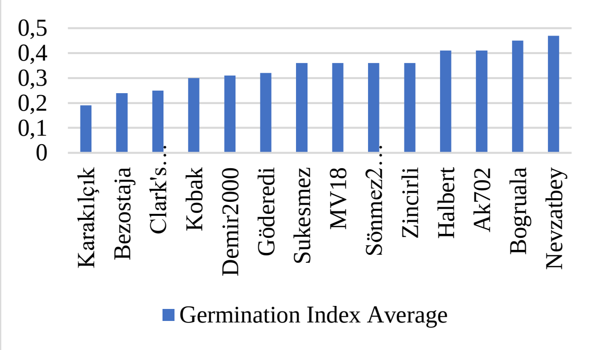

Fig.1. Germination index average of some genotypes

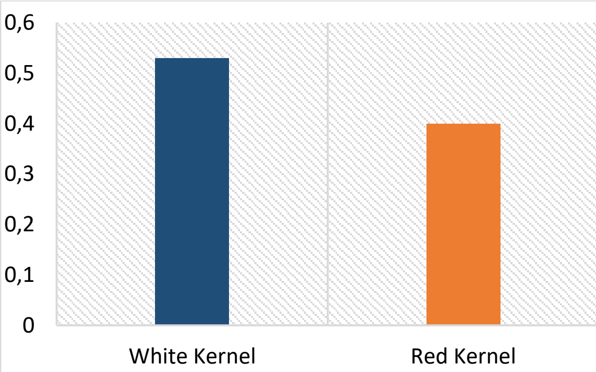

Fig.2. Germination index averages of red and white grain genotypes in six environments

3.5. Protein content

In the trials in the 2014-2015 growing season, the average protein content was determined as 12.2%, 15.1% and 13.9% in Eskişehir, Karaman and Samsun locations, respectively. The protein content varied between 11.6% and 17.9% according to the average of the locations.The genotypes with the highest protein content were listed as MV18, Altındane, KırmızıBuğday, Elbistan, SarıBuğday, Kırik, Sarı Misli and Gülümbür, respectively. The genotypes with the lowest protein content are Tosun21, Atay85, Altay2000, KaşıkçıBuğday, Akbuğday, KırmızıBuğday, ES86-7 and Topbaş, respectively.

In the trials conducted during the 2015-2016 and 2016-2017 growing seasons, we found the differences between the protein content of the genotypes, the interaction of genotype x year, and genotype x location to be statistically significant (Table 3). The lowest average protein content was obtained at the Eskişehir location, with a rate of 14.4% in 2017. The highest average was obtained from the Karaman location, with a rate of 21.6% in 2016 (Table 2). As a result of a dry winter and spring in the Karaman location in 2016, plants and seeds remained very small. The

Table 3. Variance analysis table for agricultural and quality characteristics of 2015-2016 and 2016-2017 growing seasons

		Year	Location	Rep.	Genotype	Year x Location	Genotype x Year	Genotype x Location	Error
Source of variation					**SD**				
		1	**2**	**1**	**7**	**2**	**47**	**94**	**381**
Germination index	MS	6.520	0.989	0.004	0.101	0.019	0.020	0.016	0.008
	F	759.3**	115.2**	0.492	11.73**	2.22	2.43**	1.96**	
Heading date	MS	17362.2	9192.4	1.479	134.7	2271.5	11.0	14.0	4.41
	F	3933.8**	2082.8**	0.335	30.5**	514.7**	2.50**	3.17**	
Grain filling date	MS	1068.5	7361.5	2.57	67.9	1571	6.64	11.7	3.05
	F	350**	2411**	0.84	22.3**	514**	2.17**	3.82**	
Failing number (sn)	MS	14560.4	220576.5	47.8	104393.5	62099.5	306.3	2167.3	797.7
	F	18.3**	276.5**	0.06	5.56**	03.2**	1.63**	2.72**	
Grain color value (Chroma)	MS	-	75965.3	118.8	7815.4	-	-	2769.6	835.1
	F	-	90.9**	0.14	9.4**	-	-	3.3**	
Plant Height	MS	35344.0	87348.3	756.3	2719.1	25587.0	50.8	169.9	44.0
	F	804**	1987**	17.2**	61.9**	882**	1.16	3.86**	
Sedimentation volume	MS	910.0	1171.2	14.7	432.5	1824.5	11.4	6.9	6.66
	F	136.6**	175.8**	2.2	64.9**	273.9**	1.71**	2.5**	
1000 grain weight(g)	MS	8513.1	950.2	0.478	147.2	3891.9	25.8	19.9	11.6
	F	735**	82**	0.04	12.7**	336**	2.22**	1.72**	
Grain hardness (kg)	MS	1111.4	622.5	107.4	91.0	2015.6	8.04	8.18	7.08
	F	157.0**	87.9**	15.2**	12.9**	284.7**	1.14	1.16	
Average sieve analysis (%)	MS	2311.3	2819.1	245.9	170.8	-	62.9	54.0	19.9
	F	116.4**	141.9**	12.4**	8.60**	-	17**	2.72**	
Grain moisture content (%)	MS	31.7	20.2	1.8	18.6	-	0.70	0.33	0.15
	F	210.0**	133.4**	11.8**	5.3**	-	4.7**	2.2**	
Protein Content (%)	MS	800.4	367.5	18.4	8.65	823.2	2.30	2.02	1.09
	F	737.2**	338.4**	17.0**	7.97**	758.1**	2.1**	1.9**	

protein ratio was relatively high in small grains. The protein content was 16.9%, according to the average of the six locations (Table 2). The genotypes with the highest average protein content are MV18, Kırik (1, 3), Kocabuğday, Zincirli, Gülümsür, Çalıbasan (2), Akbuğday (2), No name, Urumeli, Arıbuğday, Şahman, Sarımisli and Nevzatbey. The genotypes with the lowest protein content are Atay85, Sönmez2001, Sukezmez, Kırik (2), Yektay402, Altay2000, Tosunbey, Halbert and KırmızıBuğday (1, 2).

3.6. Sedimentation volume

The average sedimentation volume of the genotypes is 23 ml in the 2014-2015 growing season. According to the locations' average, the sedimentation volume ranged from 5 ml to 44 ml. The highest mean sedimentation volume was obtained from Altındane, MV18, Esperia, Kamçı, Göderedi, Şahman, Adana99, Bezostaja, Tosunbey, and Kırik genotypes, respectively. The genotypes in question are the genotypes known to have superior quality characteristics.

In the trials conducted in the 2015-2016 and 2016-2017 growing seasons, the differences between the sedimentation volume values of the genetic material, the interaction of genotype x year, and genotype x location were found to be significant at the level of 1% (Table 3). According to the average of the trials conducted in Eskişehir, Karaman, and Samsun locations in 2016 and 2017, the average sedimentation volume of the genotypes varied between 5 ml and 32 ml (Table 2). The lowest average sedimentation volume was obtained at the Samsun location in 2016 with 12 ml; the highest average sedimentation volume was received at the Karaman location in 2016 with 23 ml (Table 2). The genotypes with the highest sedimentation volume are MV18, Esperia, Altındane, Nevzatbey, Bezostaja, Tosunbey, Clark's Cream, Müfitbey, Sukezmez, and Kırik (3) genotypes, respectively. Modern varieties, known to be superior in terms of quality characteristics, took the first place in terms of sedimentation volume. Göderedi (1), Kırik (2), Kabak Buğday, Kobak (1,2), Ak702, Yektay406, Urumeli, Gülümbür, 4-11, Çalıbasan (2) and KırmızıBuğday (2) were in the last place in terms of low sedimentation volume. The landraces such as Ak702 and Yektay406 were preferred in biscuit production in the past. Sedimentation volume values are arithmetically relatively low for some genotypes. The fact that the grinding process was carried out by breaking the seeds with a cyclone mill may have been effective in this result.

3.7. Falling number

The average falling number of the genotypes for the 2014-2015 growing season varied between 309 seconds and 400 seconds. The device gives 400+ results for values above 400 in falling number readings. For this reason, we took this value as 400 for statistical analysis.

In the years when the experiments were carried out with two replications, the differences between the falling number values of the genotypes and the interactions of genotype x year and genotype x location were found to be significant at the level of 1% (Table 3). The falling number relative to the average of six locations is 344 sec. We obtained the lowest falling number with 291 sec. from the Samsun location in 2017 and the highest with 385 sec. from the Karaman location in 2017, on average. The falling number of the genotypes varied between 296 sec and 400 sec for all environments (Table 2).

The genotypes with the lowest falling number for the 2016 and 2017 harvesting years are Sönmez2001, Şahman, 4-11, Kocabuğday, Tir line, Topbaş, Çalıbasan (1), Göderedi (1) and Akbuğday (2), respectively. Clark's Cream, Zincirli, Müfitbey, MV18, Esperia, Bezostaja, Demir2000, Beyaz Buğday (1), SarıBuğday (2, 1), and Kobak (2) genotypes have the highest falling number (Tables 2 and 3). The falling number relative to the average of six locations is 344 sec. Since there was no rain during the harvest period in the years when the experiments were carried out, germination activity did not start under field conditions. The average falling number is high. However, lower averages were obtained from the Samsun location, where the relative humidity is high. Genotypes with a high falling number mean are generally dormant or red-grained genotypes.

The correlation analysis between the falling number and the germination index values in the 2016 and 2017 harvest year data showed a negative and significant relationship between the two features, with -0.19**. Another importance of the falling number in wheat quality is that additives should be added to the flours obtained from wheat with a very high falling number to increase enzyme activity.

3.8. 1000-Thousand-grain weight

The average thousand-grain weight of the three locations was 39 g in the 2014-2015 growing season, and the thousand-grain weights of the genotypes ranged from 29 g to 56 g. The landraces from Anatolia had extreme values for thousand-grain weight.

In the 2015-2016 and 2016-2017 growing seasons of the study, the differences between the thousand-grain weights of the genotypes and the interactions of genotype x year and genotype x location were found to be statistically significant (Table 3). According to the average of the trials in the mentioned years, the thousand-grain weight is 36 grams. While the highest thousand-grain weight was obtained at the Samsun location in 2017, the Karaman and Eskişehir locations had the lowest thousand-grain weight averages in 2016 (Table 2). The drought in the Karaman location in 2016 effectively kept the grains small.

As given in Table 2, the thousand-grain weight values varied between 28 g and 43 g, according to the locations' average. Genotypes with the lowest averages of thousand-grain weight are MV18, Zincirli, Halbert, 4-11, Topbaş, Ak702, Kobak (1), Kabak wheat, Nevzatbey, and No name, respectively. Urumeli, KırmızıBuğday (2), Çalıbasan (2), Bezostaja, Karakılçık (2), SarıBuğday (2,1) Gülümbür, Buğday, Sukezmez and Göderedi (1,2) genotypes had the highest values of thousand grain weight. Although genotypic sources related to thousand-grain weight have been determined in recent studies, thousand-grain weight is significantly affected by agriculture and climatic factors (Shahwani et al., 2014).

3.9. Grain hardness

In many countries, grain hardness is an essential quality criterion and a standard in wheat classification. The average grain hardness in the 2014-2015 growing season was 16.8 kg. The genotypes' grain hardness ranged from 12.2 kg to 25.4 kg. Ak702, İri Çalıbasan, Ağsunteri, Sukezmez, Akbuğday, Arıbuğday, Kobak, Kabak wheat, Yektay406, Çalıbasan and ES26 are the soft-grained genotypes with the lowest values of grain hardness. Genotypes with high grain hardness are HD2329, Tahirova2000, Demir2000, Atay85, Alpu2000, Bezostaja, Tosunbey, Altındane, Adana99, and Tir lines, respectively.

The average of six trials showed that the grain hardness was 18.5 kg (Table 2). Grain hardness was an average of 16.5 kg in 2016 and 16.9 kg in 2017 in the Eskişehir location. These values were 25.4 kg in 2016 and 15.2 kg in 2017 for Karaman, 17.8 kg in 2016, and 19.2 kg in 2017 for Samsun.

The grain hardness varied between 13.9 kg and 24.8 kg for all environment averages. While the landraces were in the first place for low grain hardness in the three years, modern cultivars took the first place in terms of high grain hardness. The varieties Ak702 and Yektay406 were preferred for biscuit production in the years when produced in the past. Atay85 variety has high grain hardness, and millers did not prefer this variety in the past due to its hardness.

3.10. Seed size analysis

Size distribution and homogeneity analysis give information about the size distribution of grains of a genotype. This trait is vital for milling wheat and the products' standards. In the experiment carried out in the 2014-2015 breeding season, the under-sieve analysis values of the genotypes varied between 1% and 5%. While the genotypes with the highest average sieve average were Zincirli, No Name, Ağsunteri, Şahman, Albostan, Sarı Misli, and 4-11, the lowest sieve values were obtained from Kobak, Clark's Cream, Çalıbasan, Akbuğday, Domaniç, and Göderedi genotypes, respectively.

In the last two years of the study, the difference between the average sub-sieve values of the genotypes was found to be statistically significant. In addition, the interactions of genotype x year and genotype x location (year) are also significant (Table 3). In the 2016 and 2017 harvest years, the lowest sieve analysis values were obtained in the Eskişehir location in 2016 with 4%, and the highest value was obtained from the Samsun location with 17% in 2016. In 2017, the average under-sieve values in Samsun, Karaman, and Eskişehir locations were 5%, 6%, and 7%, respectively (Table 2). Bezostaja, SarıBuğday (2), Sukezmez, SarıBuğday (1), Kırik (2), Sönmez2001 and Çalıbasan (2) genotypes had the lowest sieve average, respectively, while the highest values were 4-11, Zincirli, Kabak Buğday, Şahman, Ak702, Esperia, KırmızıBuğday (1) and Kirik (3), respectively. Although the sieve values increase with the shrinkage of the grains in disease epidemics, drought or lodging conditions, they also vary depending on the small grain and low thousand-grain weight in some genotypes.

3.11. Grain moisture content

The grain moisture content of genotypes varied between 10.2 and 11.9% in the 2014-2015 growing season. The moisture content of the products obtained from the Samsun location, which has the highest rainfall and relative humidity, is higher than the averages of other locations.

Genotype x year and genotype x location (year) interactions are also important for grain content (Table 3). The difference between the average grain moisture content of the genotypes in the study in the 2015-2016 and 2016-2017 growing seasons was statistically significant. The average grain moisture content is 11.2% in Eskişehir and 11.8% in Samsun in the 2016 harvest year. The 2017 harvest year was 10.8%, 10.5%, and 11.5% for Eskişehir, Karaman, and Samsun locations, respectively (Table 2).The general average of the locations was 11.1%, and the grain moisture content varied between 10.2% and 11.7%.

The genotypes with the lowest grain moisture content according to the six environmental averages are Zincirli, Bogruala, Demir2000, Arıbuğday, Kocabuğday, and Göderedi (2), respectively.The highest grain moisture content was obtained from Yektay406, Sukezmez, Kabak Buğday, HD2329, Tosunbey, Çalıbasan (1) and SarıBuğday (1) genotypes.

3.12. Grain color

The average Chroma color values in the 2014-2015 growing season at Eskişehir, Karaman, and Samsun locations were 168, 165, and 152, respectively. The color values of the genotypes varied between 109 and 194. The genotypes with the lowest values in terms of chroma color values are Demir2000, Sönmez2001, Bezostaja, Esperia, KırmızıBuğday,SarıBuğday, Sarımisli, No Name and Urumeli, respectively.The visible grain color of these genotypes is red. Genotypes with the highest values in terms of chroma color value are Akbuğday, P8-6, Ak702, KırmızıBuğday,Beyaz Buğday and Hatip Buğday, respectively. The visible grain colors of these genotypes are white.

The difference between the average Chroma color values of the genotypes in the study in the 2015-2016 and 2016-2017 growing seasons was found to be statistically significant. Genotype x location interaction is also important for color values (Table 3). Chroma color values varied between 303 and 441 according to the location averages of the genotypes in the 2016 harvest year (Table 2). Genotypes with the lowest mean values in terms of chroma color value are Demir2000, Sönmez2001, Esperia, Bezostaja, Çalıbasan (2), and SarıBuğday (1) genotypes, respectively. The visible grain color of these genotypes is red. Genotypes with the highest average values in terms of chroma color values are Altay2000, Karakılçık (2), Arıbuğdayı, Kırik (1), Çalıbasan (1), No Name and Topbaş genotypes, and the visible grain colors of these genotypes are white.

3.13. Correlation analysis between properties

The data relating to the correlation analysis obtained using the replication data of the genotypes in the research in the 2015-2016 and 2016-2017 growing seasons are given in Table 4. The table did not include values related to plant height, considering that the relationship between plant height and the investigated characteristics would not be significant.

We found a positive relationship between germination index and grain filling time, thousand-grain weight, and grain color (Table 4). These results suggest that the germination index of genotypes with a more extended grain filling period may be higher.However, since the genetic source of the post-harvest dormancy trait of the genotypes in this study is not known, it is difficult to comment on the effect of grain filling time.However, the fact that the genotypes with high Chroma color values are white-grained and the germination index of the white-grained varieties is generally high makes the relationship between these two features significant. Another property that has a positive relationship with the germination index is the thousand-grain weight. It is known that the genotypes with a high thousand-grain weight have high germination power. This positive relationship was obtained due to the germination index values of the coarse-grained genotypes that are not tolerant to pre-harvest sprouting.

Properties that are negatively and significantly related to the germination index are protein content, sedimentation volume, falling number, and grain hardness (Table 4). The relationship between the germination index and the falling number is explainable. Because of the low alpha-amylase activity of genotypes tolerant to germination in the pre-harvest sprouting, the falling numbers are generally low. The relationship between protein content, sedimentation volume, and grain hardness is challenging to explain.

Table 4. Data from the 2015-2016 and 2016-2017 growing seasons

Agronomic Properties	Germination index	Heading date	Grain filling date	Protein Content	Sedimentation volume	Failing number	1000 grain weight	Grain hardness	Grain color value	2.8+2.5 mm sieve	2.5+2.2 mm sieve
Germination index Heading date	0.10*										
Grain filling date	0.43**	-0.58**									
Protein content	-0.22**	-0.34**	-0.01								
Sedimentation volume	-0.15**	-0.21**	0.04	0.42**							
Failing number	-0.19**	0.38**	-0.38**	-0.40**	0.01						
1000 grain weight	0.30**	0.14**	0.28**	-0.26**	-0.12**	0.04					
Grain hardness	-0.09*	-0.27**	0.02	0.45**	0.38**	-0.29**	-0.20**				
Grain color value	0.12*	0.09	-0.01	-0.13*	0.03	0.21**	0.27**	0.22**			
2.8+2.5 mm sieve	0.11*	0.10*	0.06	0.05	0.19**	0.04	0.81**	0.04	0.31**		
2.5+2.2 mm sieve	-0.26**	0.13**	-0.40**	-0.28**	0.01	0.30**	-0.68**	-0.18**	-0.13	-0.60**	
Sieve	-0.05	-0.18**	0.09*	0.04	-0.19**	-0.14**	-0.69**	0.03	-0.28**	-0.91**	0.30**

Heading date has a statistically significant correlation coefficient with many examined features (Table 4). For example, the longer grain filling times of the early genotypes make the negative relationship between these two characteristics significant. However, relationships with other traits are difficult to explain. There is an important positive relationship between grain filling time and thousand-grain weight. The grain weight of the genotypes increases when the grain filling time is prolonged. Grain filling time also has a negative and significant correlation coefficient with the falling number. This value shows that genotypes with longer grain filling times generally have lower falling numbers.

While it had a positive and significant correlation coefficient with protein content, sedimentation volume, and grain hardness, it showed a negative and significant correlation coefficient with the falling number and thousand-grain weight (Table 4). The negative relationship between thousand-grain weight and protein content may be due to small grains' relative increase in protein content. High protein content can increase grain hardness. Sedimentation volume and grain hardness are scientifically related to protein content.

4. Discussions

Grain color is an influential factor in seed dormancy due to the pleiotropic effect. Many genotypes with white kernel and post-harvest dormancy have been reported (Shao et al., 2018). In this study, a pleiotropic effect was also observed for these properties. When the genotypes in the experiment are grouped according to grain color, the average germination index of the white-grained genotypes is 0.53, while the average germination index of the red kernel genotypes is 0.40. Similarly, in the studies conducted by Rasul et al. (2012), it was found that the germination index of the red kernel genotypes was lower. In this study, Clark's Cream, Zincirli, Ak702, Halbert, Bogruala, Nevzatbey, and 4-11 varieties with white grains were found to have a germination index below 0.50. Among the red kernel genotypes, Tir line, Beyaz Buğday (2), KırmızıBuğday (1), and Kabak buğdayı have relatively high germination index values. However, researchers have determined that dormancy genes also act independently of grain color in their research on red × white kernel hybrids (DePauw and McCaig, 1983). We could not find a dormant white-grained landrace in the material we used in this research.

While the red kernel Karakılçık (1) genotype had the lowest germination index, the white kernel Karakılçık (2) genotype collected with the same name reached a germination index value of 0.55. This result shows that lines with different phenotypic and genotypic characteristics can be developed within the local populations with the same name in Turkey.Genetic variation within local populations is desired by wheat breeders and is an essential resource for wheat breeding programs. Karakılçık (1) and American-origin Clark's Cream genotypes had germination indexes of 0.35 and 0.49, respectively, in the Samsun location in 2017, when the germination index was the highest. These two sources can be used in breeding programs as a source of tolerance for pre-harvest sprouting, especially in coastal areas with high relative humidity.

Genotypes with an average germination index value of less than 0.50 and white kernel color can be expected to tolerate pre-harvest sprouting under conditions where the amount of rain is not high and the number of days off after rainfall is low. In field conditions, the amount of precipitation falling during the harvest period, the number of rainy days, and the number of cloudy days after rain are also crucial for tolerance to pre-harvest sprouting (Nyachiro et al., 2002). While many genotypes can germinate if the precipitation amount per square meter is high and the number of cloudy days after precipitation is high, genotypes tolerant to pre-harvest sprouting have an essential advantage in case of low precipitation amount and duration.

As a result, it is a significant advantage to prefer genotypes with red kernels and post-harvest seed dormancy in regions with high relative humidity as in the world. However, if some white-grained genotypes find a large cultivation area in risky areas, developing new varieties using white-grain dormant varieties becomes inevitable.

The genotypes with the shortest plant height according to the location averages are Zincirli, Esperia, HD2329, Altındane, Mv18, Nevzatbey, Halbert and Tosunbey, respectively, while the tallest plant heights are Sukezmez, Karakılçık (1), Şahman, Urumeli, Kırik (2), Gülümbür, Çalıbasan (2), 4.11, Arıbuğday, SarıBuğday (2) and Clark's Cream are genotypes. Although plant height is genetically controlled by dwarfing genes, it is influenced by many climate and environmental factors (Thomas, 2017; Okada et al., 2019). All genotypes with tall plant heights are Anatolian landraces except Clark's Cream. It is an expected result that local Anatolian landraces have high plant height.

Although genotypic factors affect the grain filling period, the effect of the climatic conditions experienced in this period is much more critical. In the years when heat and drought stress are encountered during the grain filling period, the grain filling times of the early and late genotypes may have relative values. The grain filling time affects the dormancy characteristics of the genotypes (Mares and Mrva, 2014). The correlation analysis between the grain filling time and germination index shows a positive and important relationship (0.43**). The study determined that Clark's Cream variety, which is resistant to germination, showed a tolerant response to germination tests before harvest in the Samsun location, where the germination index and grain filling time were the longest.

The effect of environmental variance on protein ratio is higher than its effect on protein quality (Taghouti et al., 2010; Tekdal et al., 2017). Genotypes with extraordinarily high and low values in terms of protein content are usually the landraces. However, there are genotypes with genetically high protein content independent of the environment, such as the Atlas66 variety.Therefore, evaluating the material included in the project as a genetic resource is essential.The presence of genotypes with higher protein content than varieties such as Bezostaja, Esperia, Altındane and Tosunbey, which are crucial in Turkey in terms of quality characteristics, shows the potential of using the material used in the project as a gene source in wheat breeding programs.

A remarkable result in sedimentation volume is that the genotypes, already known as high quality in the wheat industry, are modern varieties and rank first in terms of quality characteristics. This result may be due to modern breeding studies and the high heritability of the sedimentation volume. Another exciting development is that local genotypes with similar names have different sedimentation volumes. Because village populations are genotypically different alleles, it is natural to find genotypes carrying different HMW-GS unit combinations in the same population, especially regarding quality characteristics. This result is expected for the landraces populations.

Although quality has a broad meaning in wheat, it varies greatly depending on the product used as raw material. The landrace genotypes included in the study have low values in terms of protein quality, which has a potential for biscuit wheat research. Karakılçık genotype has the lowest germination index value and has an average sedimentation volume of 14 ml. The fact that Clark's Cream and MV18 genotypes, which have a low germination index value, are in the top ranks in terms of sedimentation volume will increase the potential of using these genotypes as genitors for bread wheat breeding programs.

Most of the landrace bread wheat in Turkey are white grained. There is a close relationship between germination and grain color in pre-harvest sprouting (Zhu et al., 2019; Tai et al., 2021). Due to the pleiotropic effect between dormancy genes and grain color, red kernel genotypes are generally more resistant to germination in the harvest period spike. However, recent studies have shown that white kernel genotypes also have effective QTLs in harvest dormancy. It is of great importance that white kernel genotypes have dormancy characteristics, especially in countries such as Australia, where white kernel wheat breeding is essential.

5. Conclusions

Within the scope of the research, we screened the genotypes, including the landraces, for tolerance to pre-harvest sprouting. During the 2014-2015, 2015-2016, and 2016-2017 growing seasons, some agronomic and quality characteristics of the genotypes were determined in the trials carried out in Eskişehir, Karaman, and Samsun locations.In addition, genotypes that were tolerant or sensitive to germination in the pre-harvest spike, which originated from abroad or in Turkey, were also included in the trial set.

Genotypes that are tolerant to the pre-harvest sprouting and have the lowest average germination index are Karakılçık (1), Bezostaja, Clark's Cream, Kobak, Demir2000, Göderedi (1), Sukezmez, MV18, and Sönmez2001 genotypes, respectively. These genotypes had very low germination index values except for the Samsun location in 2017. Karakılçık (1) and Clark's Cream genotypes had germination indexes of 0.35 and 0.49, respectively, in the Samsun location in 2017. These genotypes can be used in pre-harvest sprouting tolerance studies. The mapping population can be developed to determine the genetic source of the pre-harvest sprouting tolerance of the Karakılçık (1) genotype. Genotypes with white kernel color and average germination index below 0.50; Clark's Cream, Zincirli, Ak702, Halbert, Bogruala, Nevzatbey, and 4.11. These genotypes can tolerate germination in the spike in years when the rainfall is not high during the harvest period. The germination index of white kernel genotypes increases more than red kernel genotypes. This study observed a pleiotropic effect between grain color and seed dormancy.

However, tolerance responses to germination were also experienced in the pre-harvest sprouting, regardless of grain color. For this reason, we recommend growing primarily red-grained varieties in coastal areas with a risk of pre-harvest sprouting. Examples of these genotypes are Clark's Cream and Tir line.

Turkey, which is the gene center of wheat, is very rich in landrace resources, and these resources have been used as a gene source in many country breeding programs. We determined the quality characteristics of the materials in the study. The landraces are generally softer and coarser than the modern varieties; the protein content is higher, but the protein quality is lower, and the grain size is relatively large in some landrace materials. Grain characteristics of some landrace genotypes, especially Sarı Buğday, can add genetic richness to breeding programs.It has the potential to be used in drought tolerance studies due to the earliness of the Tir genotype and the possibility of the possible long coleoptile.Including these genotypes in breeding programs to develop new varieties will contribute significantly to wheat breeding programs.

Conflict of interest

The authors have no relevant financial or non-financial interests to disclose.

Authors' contribution

All authors contributed to the study conception and design. All authors read and approved the final manuscript.

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