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Research Article

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Progress in Yield and Yield Attributes of Bread Wheat from 1968 to 2011 in Thrace Region

Abstract
In the study, 30 genotypes, including 24 varieties of bread wheat (registered or produced between 1968 and 2011 in the Thrace Region) and 6 local pure lines, were used. Grain yield and some yield attributes such as plant height, spike length, number of spikelets per spike, number of grain per spike, grain weight per spike and harvest index were evaluated in the study. Regarding the data obtained, significant progress has been made in wheat breeding between the years 1960-2011. While plant height, spike length and the number of spikelets per spike decreased, plant grain yield, grain number per spike, thousand grain weight, harvest index and grain yield increased continuously. When the obtained data were evaluated, grain yield was the most important selection criterion in all breeding periods, while the harvest index and the number of grains per spike were determined as important selection characteristics. In recent years, thousand grain weight and spike length are important characters in terms of selection.

INTRODUCTION

Wheat is accepted as the most significant strategic crop because of its importance in human nutrition and world trade. In particular, there has been an increase in wheat production, which has no alternative in the nutrition of the world population, in parallel with the population increase; while it was 222 million tons in the 1960s, it reached 586 million tons in the 2000s and 650 million tons in 2010 (Anonymous, 2011). World wheat production is 775 million tons on an area of approximately 220 million hectares (USDA, 2021). Turkey, located between 36°42'N and 26°44'E, is a centre of origin and diversity for many crop plants, primarily wheat. The country is a key contributor to the global wheat market, producing more than 20.5 million tons in an area of nearly 7.1 million ha annually (TUIK, 2020). When we evaluate the developments in wheat from the past to the present in our country, wheat production, which was 2.5 million tons in the 1930s, increased to 10 million tons in 1967 and 20.6 million tons in 2009. The increase rate of wheat production was 724% in this period. Wheat cultivation areas, which were 2.8 million hectares in 1930, reached 8 million hectares in 1967, that is, their 2010 level. While the yield per unit area was 920 kg ha^{-1} in 1930, it increased by 35.9% in 1967 to 1250 kg ha^{-1}. Despite the 1.0% increase in cultivation areas from 1967 to 2010, the increase in yield was 104.8% (Anonymous, 2011). Wheat production has great economic importance especially in the Thrace Region, which covers a 23.485 km^2 and consists of Tekirdağ, Edirne and Kırklareli and some districts of Istanbul and Çanakkale provinces. bread wheat is cultivated on about 537.000 ha in the region. Total production was 2495 t (0.3% of global wheat production) and yield per hectare was 4.68 t in 2011 (TUIK, 2011). These figures mean that 6.71% of Turkey's wheat cultivation areas are in the Thrace Region and constitute 11.88% of the total national production. While the average wheat yield in Turkey was 2.59 t ha^{-1} between 2000 and 2010, the fact that it was 4.75 t ha^{-1} in the Thrace Region shows that the average wheat yield in the Thrace Region is about twice the national yield average (Anonymous, 2011). It has been observed that wheat cultivation areas have been reduced in recent years. The area planted to wheat in Turkey has declined from 9.5 million hectares (Mha) at the beginning of the 1990s to 7.0 Mha in 2011-2019, but grain yield increased from 2 t ha^{-1} to 2.7 t ha^{-1} during the same period. The breeding progress of common wheat (*Triticum aestivum* L.) has received great attention lately. The trend of increasing wheat yield at farm level, which has been going on for at least half a century (Calderini and Slafer, 1998), has stagnated in many major producing countries, especially in our country (Şener et al., 2009), and in France, the United Kingdom and Germany (Lin and Huybers, 2012). An analysis of the breeding progress of the past can help to get back on track for a much-needed increase in wheat yields. The benefits and costs of genetic improvement require periodic evaluation of its benefits. This assessment is useful both to demonstrate the importance of plant breeding and as a way to identify traits or target environments that may require further effort by breeders (Cox et al., 1988). Furthermore, genetic gain assessment is vital for assessing selection efficiency and identifying associated traits as criteria for future selection. Genetic gain estimates can also be used to identify reasons for increased yields and thus to design selection strategies (Morrison et al., 2000). Although there have been limited studies on genetic improvement in wheat in Turkey so far (Avçın et al., 1997; Kuşcu, 2006; Şener et al., 2009; Gummadov et al., 2015; Akın et al., 2017, Keser et al., 2017), there are hardly any documented studies on cultivar changes that contribute to wheat yield gains for the Thrace Region, which is one of the important wheat production regions of Turkey. This study aimed to document the

genetic gains in the grain yield and yield components of winter wheat of domestic and foreign origin registered and put into production in the Thrace region to help develop future breeding strategies on a regional, national and global scale.

MATERIAL and METHODS

The genetic material, environment characteristics, field trial procedure and set up of the experiments, fully described by Bilgin et al. (2016). Thirty bread wheat genotypes, including 24 varieties that were registered and produced in the Thrace Region from 1968 to 2011 and six landrace pure lines were used genetic material in the study. Each trial was sown in a randomized complete block design (RCBD) with three replicates. Sowing was done using an experimental drill into plots of 6 m^2 (6 rows, 5 m long, spaced 20 cm apart) using a seeding rate of 500 seeds per m^2. Sowing time was in mid-October, and a total of 160 kg ha^{-1} N was applied at sowing, tillering, and pre-anthesis stages. Additionally, 50 kg ha^{-1} P_2O_5 was applied at the sowing stage. Weeds were controlled by chemical to avoid a confounding effect. Grain yield and some yield components such as plant height, spike length, number of spikelets per spike, number of grain per spike, grain weight per spike and harvest index were evaluated in the study.

Statistical analysis

In the study conducted with bread wheat varieties improved in different years in 4 different locations for two years, the change of characters by years and regression charts were analyzed using the GE-AR (Genotype x Environment Analysis with R for Windows, Version 4.0) statistical package program.

RESULTS and DISCUSSION

In the study conducted in four different locations for 2 years, bread wheat varieties that were improved between 1968-2011 were used as a material. According to the evaluation made in the data obtained, significant increases in a positive direction were obtained in the most of the analysed characters (Figure 1). The grain yield value, which was around 2.7-4.4 tons in the 1960s, increased to around 4.7-6.3 tons in the 2000s. As can be seen in the data obtained, although it varies according to the locations, an increase in yield of approximately 2 tons/ha has been achieved during this period. While this increase was more remarkable in Edirne and Lüleburgaz locations, it was slightly lower in Tekirdağ and Kırklareli locations. This may be due to the changes in the soil and climate structure in the region, and the lower response of the cultivated varieties to cultural practices compared to the regions. One of the most important breeding goals is to increase the harvest index. The harvest index value, which was around 32% in 1968, increased significantly in Lüleburgaz location reached around 44%. Edirne location with 42% harvest index and Tekirdağ location with 41% harvest index followed this location. The lowest harvest index value was in Kırklareli with an increase of 8-9%. One of the important selection criteria in breeding studies is to obtain genotypes with high harvest index (50% harvest index). The results obtained show that the desired targets have not been reached yet in plant breeding studies.

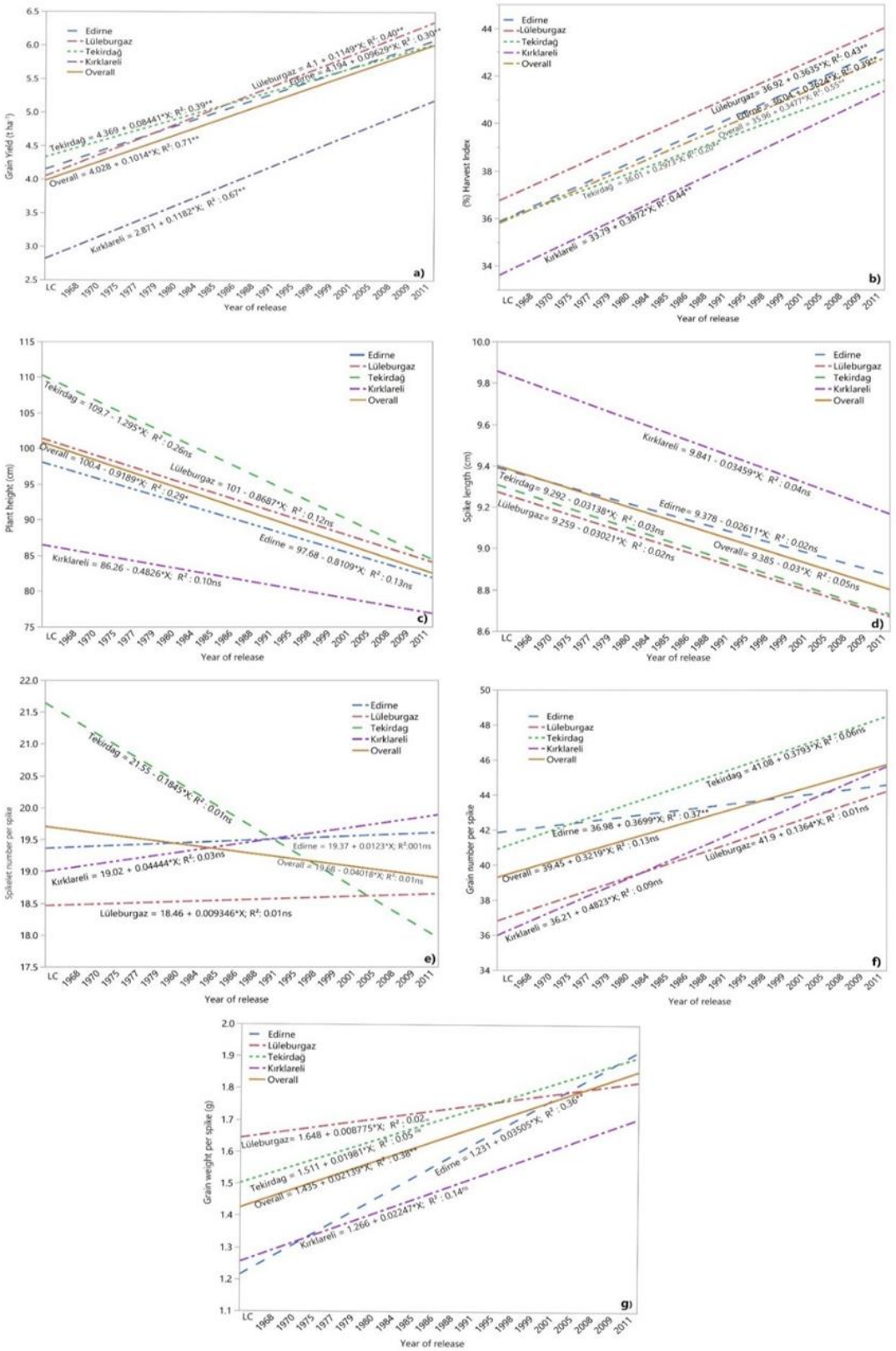
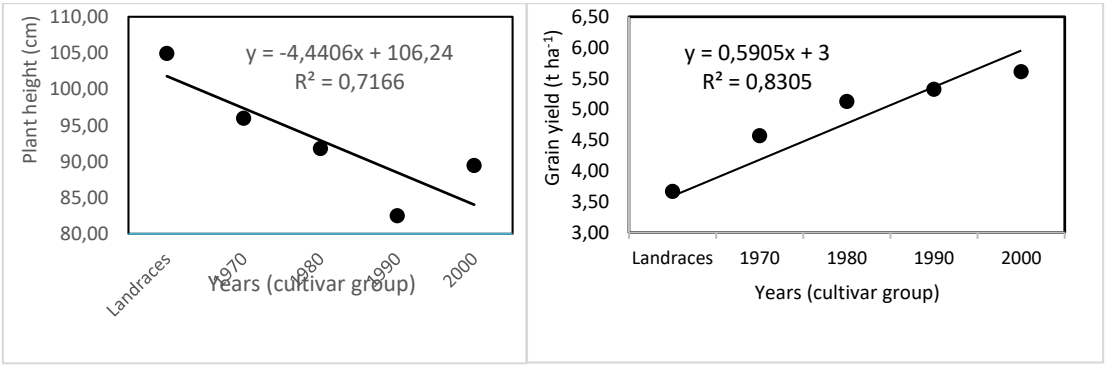


Figure 1. Changes in the analysed characters over the years

According to the data obtained in the study conducted between 1968-2011 years, significant decreases occurred in terms of plant height. The main purpose of plant breeding is to increase the economic yield in biological yield. Therefore, one of the main goals in the breeding studies has been to shorten the plant height. Among the locations, the highest decrease was in Tekirdağ location with the highest average yield, followed by Lüleburgaz and Edirne locations. The lowest decrease was seen in Kırklareli location. According to the data results, Plant height values were found to be 100 cm in Tekirdağ location in 1985-86, 96-97 cm in Lüleburgaz location, 92-93 cm in Edirne location and 82-83 cm in Kırklareli location, while plant height was 87-88 cm in Tekirdağ and Lüleburgaz locations in 2000-2010. Around 85 cm in Edirne location, 77 cm in Kırklareli location. As a result of 52 years of studies, the plant height decreased between 23-24 cm in Tekirdağ location, 15-16 cm in Lüleburgaz location, 13-14 cm in Edirne location and 9-10 cm in Kırklareli location. Between the years 1968-2011, there was a decrease in the spike length values in the improved bread wheat varieties. The plant height and accordingly the spike length in local varieties were also high, due to the high number of plants per unit area, there is lodging in the plant stems. Although the decreases in terms of spike length are in all four locations, these decreases are not statistically significant. The very low stability coefficients obtained for the locations explain that the decrease in the spike length is low. While the spike length was between 9.3-9.9 cm in 1968, these values were around 8.7 and 9.3 cm in 2011. While the maximum decrease in spike length was in Kırklareli location, it was followed by Tekirdağ and Lüleburgaz, and the least decrease was in Edirne location. In the study, different values were obtained based on locations in the evaluation of the number of spikelets in spike over years and locations. While there is a small increase in the number of spikelets in the spike in Kırklareli location, this increase is very low in Lüleburgaz location. On the other hand, while there was no significant change in the number of spikelets in the Edirne location, it decreased remarkably in the Tekirdağ location. While there is a decrease in the number of spikelets in the spike on average, this is due to the shorter plant height and the aim of the variety breeding is the spikelets that are more sparsely arrayed on the spikes.



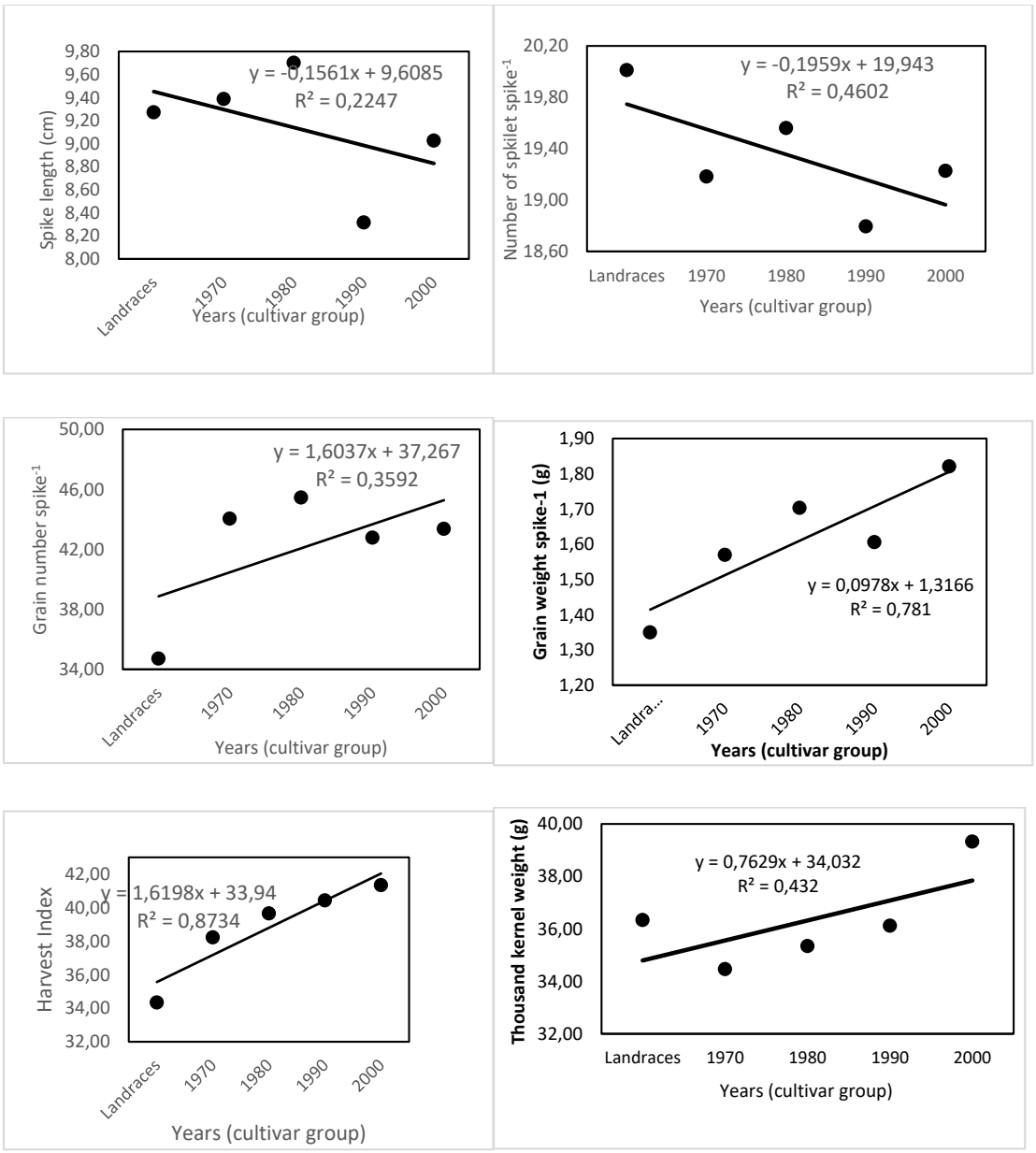


Figure 2. Regression graphs for each character according to breeding periods

The number of grains per spike has generally increased in four different locations for 2 years. Among the locations, the highest increase was in Kırklareli location, followed by Tekirdağ and Edirne locations. The lowest increase was obtained in the Lüleburgaz location. As a result of the breeding studies carried out for fifty-three years, significant increases have been achieved in the number of grains per spike of the varieties. In the evaluation made according to years and locations, a remarkable increase was observed in grain weight per spike, which is one of the important yield criteria. The highest grain yield increase per spike was in Edirne location, which increased from 1.2 g to 1.9 g, followed by Lüleburgaz location with an increase of 1.6 g from 1.27 g and 1.55 g from 1.25 g. Kırklareli locations followed. The least increase was achieved in Tekirdağ location, which increased from 1.5 g to 1.8 g. The grain weight of the spike, which was around 1.2-1.65 g in 1968, reached the range of 1.60-1.95 g in 52-53 years. This shows that there is an average grain weight

increase of 0.40-0.75 g for each spike, and an increase of 160-300 kg per decare is achieved when there are 400 thousand plants in one decare area. The regression graphs for each character were evaluated separately and different graph formations were seen according to the characters (Figure 2). The grain yields of bread wheat varieties between 1968-2011 are examined by years (Figure 2), it is seen that there is a linear increase in yield. While the grain yield of the varieties was around 300 kg/decare in 1968, it was 450 kg da^{-1} in 1970, 500 kg da^{-1} in 1980, and the rate of increase decreased slightly in 1990 was around 530 kg/da. In the 1970s and 80s, the first production of the varieties developed with combination breeding in our country resulted in a significant increase in yield. In 2000 years, there was a slight decrease in the rate of increase in yield. It is observed that there is a linear decrease in plant height values of bread wheat cultivars over a period of approximately 50 years. While the plant height values of the varieties were around 105 cm in 1960, this value decreased to 96-97 cm in the 1970s and 92-93 cm in 1980. Especially in the 1990s, the decrease in plant height reached the highest level and the plant height decreased to around 81-82 cm. Due to the increase in the value of the wheat stalk by the producers, the selection criteria for a certain plant height in wheat breeding studies have been created, and the plant height values have increased slightly in 2000 compared to 1990 and reached around 90 cm. The spike lengths of bread wheat varieties have followed a fluctuating course in the form of increases and decreases over the years. While the spike length of the varieties was 9.20 cm in 1960, this value was 9.40 cm in 1970 and 9.70 cm in 1980. Especially in the 1990s, there has been a decrease in spike height due to the spread of short-planted varieties. In the breeding studies carried out in 2000, the increase in plant height caused an increase in spike length, and a spike length of 9.0-9.1 cm was reached. The data obtained show that the spike length varies according to the characteristics targeted in the breeding studies, and the maximum spike length should be targeted according to the characteristics such as plant height and the number of grains per spike. In the breeding studies carried out in the 2000s, a slight increase in the plant height caused an increase in the spike length and the spike length was 9.0-9.1 cm. It is understood that there are changes in the number of spikelets per spike in different years of the cultivars according to the breeding period (Figure 2). While the number of spikelets of the cultivars in the 1960s was 20 unit on average, this value was 19 unit in 1970 and 19.6 unit in the 1980s. In the 1990s, the lowest value was 18.8 spikelets per spike. The reason for this is the decrease in the number of spikelets per spike due to the decrease in plant height and spike length characteristics, and the number of spikelets per spike increased in the 2000s and reached 19.20 units. It is seen that the varieties have a linear increase in the number of grains per spike by years (Figure 2). While the grain number of varieties was as low as 34 unit in 1960, it increased to a very high value such as 43-44 unit in 1970. The reason for this is that the varieties obtained by crossbreeding are put into production in our country. While the number of grains per spike increased and reached around 45 in the 1980s, the number of grains per spike decreased to around 41 due to the decrease in plant height, spike length and spikelet number of cultivars cultivated in 1990 and 2000. There was a linear increase in grain yield of bread wheat cultivars bred in different periods (Figure 2). While the grain yield of the cultivars was 1.35 g in 1960, this value increased to 1.55 g in 1970 and 1.65-1.75 g in 1980. In 1990, the ear grain weight decreased to around 1.55 g, and in 2000 it increased to 1.8 g. The data obtained reveal that the number of grains per spike has increased in general. The obtained data reveal that the number of grains per spike generally increases during breeding periods. It is seen that there is a linear increase in the harvest index, the harvest

index of varieties was 32% in 1960, 38% in the 1970s, 39-40% in the 1980s and 40% in the 1990s. In 2000, the harvest index showed the highest increase and reached 41%. It is seen that the thousand grain weight values of the varieties taken into the experiment changed to the breeding periods (Figure 2). While the grain weight of the cultivars was 36-37 g in the 1960s, this value decreased by 34 g in the 1970s. The grain weight of a thousand reached 35 g in the 1980s and 36 g in the 1990s. In 2000, thousand grain weight increased significantly and reached 39 g. The correlation values between the data obtained for the examined characteristics of bread wheat varieties grown in 5 different periods between 1968 and 2011 are given in Table 1.

Table 1. Correlation coefficients between the characters examined

	GY (t ha^{-1})	PH	SL	SNS	GNS	GWS	HI	TGW
Landraces	3.66	-0.73**	0.22	-0.14	0.44*	0.39*	0.75**	0.51**
1970	4.57	-0.77**	-0.07	0.20	0.41*	0.35*	0.83**	0.12
1980	5.12	0.08	-0.28	-0.61**	-0.40*	0.68**	0.65**	0.34*
1990	5.32	0.58**	0.33*	-0.54**	-0.87**	0.73**	-0.12	0.82**
2000	5.61	-0.47*	0.13	0.73**	0.31*	0.32	-0.34*	-0.22

In the 1960s (in local genotypes), there were important and positive relationships between grain yield per decare and grain number per spike, grain weight per spike, harvest index and thousand grain weight, while a positive and insignificant relationship was found between the number of spikelets per spike and yield. A negative and significant relationship was found between grain yield per decare and plant height, whereas a low level of negative correlation was found between grain yield and spike length. In the 1970s, a positive and significant relationship was found between grain yield and the number of grains per spike, the harvest index (0.01), and between the grain weight per spike and the number of spikelets per spike (0.05). There was a statistically significant and negative relationship between grain yield and plant height at 0.01 level, while there was a negative and insignificant relationship between spike length. In 1980, positive and significant correlations were found between grain yield and harvest index at the level of 0.01 and between grain yield and thousand grain weight at the level of 0.05. Grain yield showed statistically significant and negative relationships with the number of spikelets per spike and the number of grains per spike. There was found a statistically insignificant and negative relationship between grain yield and spike length. In 1990 years, grain yield showed a significant and positive relationship with grain weight per spike, thousand grain weight, plant height, spike length and the number of grain per spike at 0.01 level, while thousand grain weight was positively and significantly related at 0.05 level. Grain yield was found statistically significant and negatively correlated with the number of spikelets per spike and the number of grains per spike. In 2000 years, grain yield showed positive and significant relationships with the number of spikelets per spike, the number of grains per spike, the grain weight per spike and spike length while there were showed negative relationships with plant height, harvest index and thousand kernel weight.

CONCLUSION

According to data from studies carried out, significant progress has been made in wheat breeding between the years 1960-2011. While plant height, spike length and the number of spikelets per spike were

decreased, plant grain yield, grain number per spike, thousand grain weight, harvest index and grain yield per decare increased continuously. These results showed that grain yield was the most important selection criterion in breeding periods, while the harvest index and the number of grains per spike were determined as the other important selection characteristics.

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