Chapter 1
Introduction

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1.1 Origin and Evolution of Wheat

When humans are being turned to the agriculture-based society from the hunter-gatherer society, domesticating this cereal (wheat) became essential. Because of its easy harvest, high yield, and long-term storage, people unwittingly selected this crop and consequently its useful genes. Natural selection and hybridization between different species are also made and improved changes in wheat cultivars (Gustafson et al. 2009). Hybridization, drift, migration, and natural selection have impressed the generation of modern cultivars' genotype and as shown in their evolution by researches (Nevo et al. 2002).

Wheat species and the whole Triticeae tribe have been known to have n = 1x = 7 chromosome number since the 1900s. Einkorn, emmer, durum, rivet, Polish, Persian, spelt, bread, club, and Indian shot are some examples of cultivated wheats. Einkorn (*Triticum monococcum* ssp. *monococcum*) has diploid (2n = 2x = 14, AA) chromosomes; emmer (*Triticum dicoccum*) and durum (*Triticum durum*) have 2n = 4x = 28, BBAA; and spelt (*Triticum spelta*) and bread wheat (*Triticum aestivum* L.) have hexaploid (2n = 6x = 42, BBAADD) chromosomes. Chromosomes (1 to 7) in the diverse diploid genomes (B, A, and D) are suggested that they are related with wheat evolution (Gustafson et al. 2009).

One of the three genomes is A in wheat which is a part of the modern wheat evolution. It is known that *T. urartu Thumanjan ex Gandilyan* is the donor to A genome. Although there are some discussions about the donor of B genome, *Ae. speltoides Tausch* is strongly considered to be the origin. There is also a consensus about the donor of D which comes from *Ae. tauschii Coss*. Those with AA, BB, and

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N. Zencirci et al. (eds.), *Wheat Landraces*,
https://doi.org/10.1007/978-3-030-77388-5_1

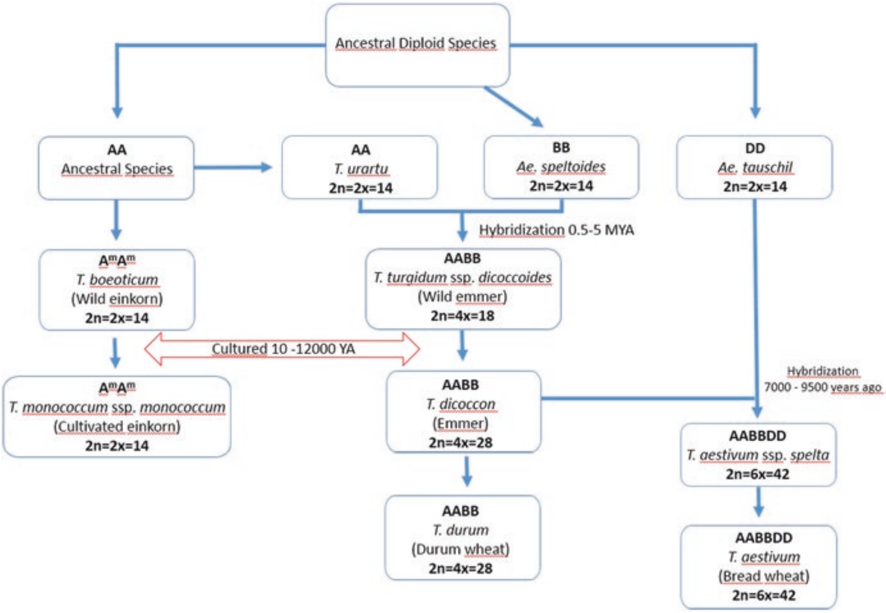

Fig. 1.1 Evolution of wheat. (Modified from Chantret et al. (2005))

DD chromosomes have 2n = 14, those with AABB chromosomes have 2n = 28, and those with AABBDD chromosomes have 2n = 42 chromosomes (Fig. 1.1).

There are two types of modern wheat cultivars: one of them is hexaploid bread wheat (*Triticum aestivum* L., 2n = 6x = 42) and the other is tetraploid hard or durum wheat (*T. turgidum* L. (Thell.)) (Gustafson et al. 2009). It is known that the modern cultivar of wild emmer came from the hybridization of *Ae. speltoides* (2n = 2x = 14) and *T. urartu* (2n = 2x = 14). In the process of evolution, first, the wild emmer (*T. dicoccoides Körn. ex Asch. & Graebn. Schweinf.*) transformed to emmer (*T. dicoccon*) and then to tetraploid wheats such as *T. turgidum* L., *T. polonicum* L., *T. carthlicum Nevski*, and *T. durum Desf*. Moreover, bread wheat emerged from the hybrid of *T. dicoccoides* and *Ae. Tauschii* (Özberk et al. 2016).

1.2 History of Wheat and Breeding Studies in Turkey

Southwest Asia is the place from where all wheat originated. First evidence of domestic wheats was in the Fertile Crescent, Central Asia, and southern China, around 10,000–12,000 years ago (Gustafson et al. 2009). Current evidence from genetics, botanical, and archaeology showed that the core of cereal agriculture was located in today's Southeastern Turkey and north Syria (Lev-Yadun et al. 2000). Einkorn and emmer, early domesticated wheat species, have been known to be cultivated around 10,000 BP (Harlan 1981). Site of Çatalhöyük in Turkey is a place that the first evidence had been found about the domesticated bread wheat around 7800 BP (Harlan 1975). Until 5000 BP, einkorn and emmer had been grown for about 3000 years, and according to the archeological findings, they suddenly almost vanished in Southeastern Turkey. Today, einkorn, emmer, and, of course, durum and bread wheat are popular again since they are important for diet as they are revalued in West Asia, North Africa, and Turkey as they were for the last 120,000 years (Braun 2011).

Because of its higher wheat production, Turkey is among the top ten wheat-producing countries in the world (Braun 1999). The total annual production of wheat in Turkey changes between 16 and 21 million tons (Özberk et al. 2005). The annual production of durum wheat reaches five million tons. Because of that, Turkey also became a leader of durum wheat production, especially among North African and West Asian countries (Özberk et al. 2005). Also, nearly one million ton of durum wheat grown in Turkey produced 750,000 tons of macaroni in 1998. Therefore, Turkey ranks fifth in wheat production (Özberk et al. 2005). The usage of wheat is varying from making bread to making pasta. That is why its consumption is very high worldwide, and the annual wheat consumption in Turkey per capita is 200 kg (Braun et al. 2001).

Talking about wheat landraces, one scientist deserves mentioning is Mirza Gökgöl. He is a leading plant scientist who collected various cultivated wheat samples all around Turkey between 1929 and 1955 and reported valuable information about Turkey's wheat landraces. In 1935, Gökgöl collected wheat samples and researched their genetic variations. At the end of his study, 18,000 types and 256 new varieties of wheat have been described (Karagöz and Özberk 2014; Zencirci et al. 2018). Wheats which were grown even in distinct areas of Turkey were reported in detail. According to him, Turkey does not need to introduce foreign wheat material, because it has very rich wheat varieties (Knüpffer et al. 2015).

Before the Turkish Republic was founded in 1923, researches about wheats were started in 1920. In 1925, the first Seed Improvement Station was founded in Eskişehir. The other stations followed Eskişehir were Adapazarı, Yeşilköy (Istanbul), Ankara, Samsun, Adana, and Antalya (Zencirci et al. 1996). Ak 702 wheat cultivar was released after the research in Eskişehir Research Station in 1931. Then, Sertak 52, Köse Melez 1713, and Kara Kılcık were released. Yayla 305 which was released in 1939 was selected by Emcet Yektay, another distinct Turkish wheat scientist. One advantage of Yayla 305 was its resistance to bunt; therefore, it was preferred to be cultivated by farmers. Besides these, Melez-13 was the first variety which was obtained from a crossbreeding program in 1944 (Braun et al. 2001). Köse 220–39 and Sivas 111–33 population selections were also cultivated in larger acreages for long years. At the same time, Manitoba cultivar from Canada to Central Anatolia, Mentana from Italy, and Florence from Australia were also introduced. Later, Kunduru 414/44 was improved by reselection, and Ankara 093/44 and Akova wheats were released after earlier crossing programs. Due to World War II, the wheat production and acreage sown decreased in Turkey. Because of this fall, people requested for an increase in wheat production. Despite the increase of wheat production after World War II, wheat production was still not enough for the increasing population in Turkey. Accelerating wheat breeding and exchanging of material were restarted in 1950. Local materials (with winter hardiness, good quality, and wide adaptation) were crossed with foreign materials (disease resistance and higher yield) to improve better adapted cultivars. Mexico established, with the support from Rockefeller Foundation, International Wheat and Maize Improvement Center (CIMMYT) in 1943. Then, some materials were sent to Turkey such as Sonora 64. These cultivars increased the wheat yield from 1.5 ton/hectare to 4 ton/hectare in Çukurova. Lerma Rojo 64, Penjamo 62, Sonora 63, Sonora 64, Mayo 64, and Super X were the other Mexican spring wheat cultivars which were introduced to Turkey. Also, Brevor, Scout, Gaines, Burt, Wanser, Gage, Warrior, Lancer, Duruchamp, and Nugaines cultivars were introduced from the USA and Bezostaja-1, Odeskaya-51, Harkovskaya, and Miranovskaya-808 from Russia in 1967 (Zencirci et al. 1996; Özberk et al. 2016).

The National Cool Season Cereals Research and Training Project was founded by the agreement between the Rockefeller Foundation and Turkish Government in 1967. The basic aims of this project were to develop techniques for the improvement of cultivars, enhance water-use efficiency in soil, decrease damages caused by insects and diseases, and educate people and seek new agricultural techniques and to search for economic wheat production. Moreover, some technical information, employees, germplasm, and education opportunities were provided by International Wheat and Maize Improvement Center (CIMMYT), Mexico, and Oregon State University, USA (Zencirci et al. 1996). With this project, the production of wheat nearly doubled by 1982. Therefore, the average yields have grown from 1.1 to 1.82 ton/ha (Özberk et al. 2005). Eskişehir Research Institute released Gerek-79 when the project was still alive. Some other cultivars of these early years of start were Çakmak-79, Gökgöl-79, Tunca-79, and Haymana-79. Gerek-79 was sown on more than 1.5 million hectares by 1996, and it stayed as the leading winter wheat cultivar for years (Braun et al. 2001).

International Winter Wheat Improvement Program (IWWIP) is a program which was initiated by the Government of Turkey, International Center for Agricultural Research in the Dry Areas (ICARDA), and CIMMYT in the mid-1980s. The main aim of this program is to develop winter and facultative wheat germplasm for Central and West Asia. IWWIP also encouraged the exchange of winter germplasm for the global breeding community. ICARDA was incorporated into a project in 1991 by integrating the facultative wheat breeding activities in Syria (iwwip.org). IWWIP developed winter and facultative wheats which were released in Argentina, Pakistan, Iran, Afghanistan, Turkey, and Tajikistan. Winter wheats (>157) are scattered around the world by IWWIP (Braun et al. 2001).

Recently, a total of 12 different local wheat varieties are relatively important and have been reportedly sown in Turkey mostly. These are Zerun, Ak, Kırmızı, Sarı, Karakılçık, Kirik, Siyez, Koca, Topbaş, Şahman, Üveyik, and Göderedi. The largest local wheat production has been in Southeastern Anatolia region. These populations can be considered to be used for different purposes. Some are especially preferred for bread making such as Zerun, Kırmızı Buğday, Kırik, etc. On the other hand, some are more important for bulgur making (Siyez, Şahman, Sarı Wheat etc.) (Kan et al. 2017).

1.3 Importance of Wheat Landraces

Wheat, one of the main foodstuffs in human nutrition, is among the most important food products in the world. Progressive increases in the population direct the development and call for production policies which aimed at ensuring food safety and security within the sustainability framework. Wheat is one of the most important sources of income in rural areas together with its nutrition and strategic importance (Karabak et al. 2012). Moreover, wheat has economic, social, cultural, historical, and even archeological value. Throughout the history, wheat has been deeply influenced and developed by many civilizations (Özberk et al. 2016).

In 2017, 771 million tons of wheat was produced worldwide. China, India, Russia, and the USA are among the leading wheat-producing countries in the world. Turkey is among the top ten wheat-producing countries worldwide. Although the amount of wheat produced increases regularly, its production area is gradually decreasing (FAO, Food and Agriculture Organization 2017; TUIK, Turkish Statistical Institute 2017). Local varieties are used as the basic genetic materials in wheat breeding programs across the world and in Turkey. "Particularly rapid increase in human population, technological changes, and infrastructure development" destroyed wheat production facilities rapidly (Frankel 1970). For this reason, the demand for basic wheat nutrients is increasing, including countries whose climates are not suitable for wheat growing. Similarly, climate change induced by global warming has started to affect, directly or indirectly, modern and traditional wheat production systems. Therefore, wheat production, which is expected still to be one of the main nutrients in the future, is expected to decrease. Then, it would become hard to meet the required amount of nutrients with the reduced production (Jaradat 2013).

With the green revolution, worldwide primitive landrace varieties have been replaced by bred cultural varieties, obviously resulting in a serious genetic erosion. Many of old wheat and barley varieties existed in Turkey, Iraq, Iran, and Pakistan have been replaced by these new cultivars. Genetic uniformity has increased with modern cultivars improved based on local wheat genetic resources. This genetic uniformity disrupted the heterogeneity of plant plasma in conventional agricultural systems and led to the emergence of epidemic diseases that attack these genetically uniform products. The reason why cultural crops are greatly damaged by diseases in the world is that there are very few limited resistance genes present in the available cultivars. On the other hand, the number of diseases increased and diversified. Starting from the 1950s, genetic natural wheat resources were rapidly destroyed (Altındal and Akgün 2015).

Wheat is a food source that is extensively produced in the world and consumed in different ways. In general, wheat used in bread making is also used to produce bulgur, pasta, biscuits, and flour (Özberk et al. 2016). Wheat is rich in micronutrients, including mineral substances, B vitamins, E vitamins, total phenol content, and antioxidant content, in the local varieties (Zhao et al. 2009; Cummins and Roberts-Thomson 2009). Together with these phytochemical and biological activities, wheat has also some medicinal effects on diseases (cardiovascular diseases, diabetes, and cancer). Some studies show a 21% lower risk of cardiovascular disease in the whole grain and bran fibers. In addition, 27% of daily cereal nutrition consumption decreased the risk of Type 2 diabetes. Due to its antioxidant activity, wheat prevents cancer diseases (Mozaffarian et al. 2003; Liu 2003; Şahin et al. 2017).

Turkey is a country so eligible for wheat farming in terms of both the farming culture and the environmental structures. When the statistical data by organizations of TUIK and FAO examination points out an annual production about 20 million tons of wheat in Turkey and it shows that Turkey has an income of approximately 5-7 billion dollars from wheat (FAOSTAT 2017; TUIK 2017). The improvement of new wheat species seen throughout the world is also observed in Turkey. This situation constitutes a threat to the existence of native landraces/species in Turkey. Moreover, highly efficient wheat production programs in Turkey have caused serious genetic erosion (Karagöz 2014a; b). This situation can be prevented by collecting local wheat varieties and preserving them in ex situ (outside their natural growing area) or in situ (in their natural growing area) regions while agricultural activities continue (Kan et al. 2017) (Fig. 1.2).

A local variety can be defined in many ways. Harlan (1995) describes the landraces as "well-matched populations – variable in equilibrium with both environment

Fig. 1.2 A view at Einkorn Wheat Field Day in Seben, Bolu, Turkey (2018)

and pathogens – and genetically dynamic." They are "local" when seed from that variety has been planted in the region for at least one farmer generation (Louette 2000). According to Biodiversity International, landrace is defined as follows: "A landrace of a seed-propagated crop is a variable population, which is identifiable and usually has a local name. It lacks 'formal' crop improvement, is characterized by non-specific adaptation to the environmental conditions of the area of the cultivation (tolerant to the biotic and abiotic stresses of that area) and is closely associated with the uses, knowledge, habits, dialects, and celebrations of people who developed and continued to grow it" (Karagöz 2014a; b).

Einkorn and emmer, ancient wheat species, are the first cultivated wheats. Einkorn wheat was found firstly in Karacadağ region, Turkey (Heun et al. 1997). Emmer wheat is the tetraploid ancestor of durum and bread wheat (Emebiri et al. 2008). Among crop types, diversity in Turkish wheat has always attracted greater interest since the beginning of the twentieth century. In the first quarter of the twentieth century, the leading Turkish scholar Mirza Gökgöl has collected local wheat varieties and evaluated them for basic features. As a result of this analysis, Gökgöl showed that almost all wheat varieties existed in Turkey, and the region provided an endless treasure for the breeders (Gökgöl 1935; Gökgöl 1955; Zencirci et al. 2018). Karagöz (1996) reported that farmed einkorn wheat was grown by farmers in fields with small amounts and no irrigation facilities in the north of Turkey such as Sinop, Kastamonu, Bursa, and Bolu provinces. These varieties, which are generally used as animal feed, are also used in bulgur, bread, and food. Although the varieties produced are lower yielding than modern varieties, they have higher nutritional values. Lower yield is due to the fact that the local wheat varieties are better adapted to the negative production conditions (biotic and abiotic) than modern varieties (Tan 2002). Russian scientist N. I. Vavilov identified eight rich centers for both wild relatives and old local varieties of crops around the world. Turkey is taking part in two of these centers (Vavilov 1951).

1.4 Advantages and Disadvantages

Wheat landraces are traditional crop varieties developed by farmers over the years by natural or artificial human selection and adapted to local growing conditions and management practices (Zeven 1999). Several factors such as physical, climatic, and socioeconomic conditions, market facilities, etc. play an important role in cultivation of landraces (Karagöz 2014a, b). Modern wheat species may not be enough to fill social, such as traditional food making, and economic conditions as wheat landraces do. Landraces can provide reliable sustenance and sustainable food source to local communities such as bulgur, macaroni, and fodder for their animals.

Landraces have higher level of nutrients such as copper, iron, magnesium, manganese, phosphorus, selenium, and zinc more than those in modern wheat cultivars (Jaradat 2013). Due to the high concentration of tocols, carotenoids, and lutein in these landrace varieties, they are more protective against chronic diseases such as cancer and diabetes. Because of these features, landraces have been considered as a healthy food; therefore, people consume those wheat varieties more (Azeez et al. 2018). With these kinds of intentions, people increase values of landraces. With all these reasons, wheat landraces like other crop landraces have become so important resources in breeding programs.

In traditional agricultural systems, farmers generate and conserve new varieties, most of which are landraces. Those farmers are only consumers of these landrace products selected, saved, and recycled by themselves. This individual knowledge process leads to a very dynamic genetic landrace structure (Özbek 2014). Reliable yield level, another important reason for retention of landraces, is because of resistance of landraces to marginal stress conditions.

Wheat landraces adapt better to changing climate conditions and stressed environments than modern cultivars (Jaradat 2013), and they provide useful genetic traits (Azeez et al. 2018). While landraces arisen through natural or human selection by years (Dotlağıl et al. 2010), most modern cultivars have been improved by professional breeders. Therefore, genetic base has become narrower in wheat or in other crops as well. In a wheat improvement program, scientist needs to take advantages of new genetic diversity resource (Dotlağıl et al. 2010). In that context, wheat landraces are important resources to improve the genetic base of modern wheat cultivars by providing valuable breeding characteristics by their more comprehensive genetic base.

Landraces also have tolerance to other abiotic stresses and the resulting good yield and developmental stability. Previous studies about einkorn and bread wheat under cold and drought stress applications shown that einkorn wheat landraces performed better than those stresses according to plant development parameters such as germination rate, germination power, and leaf length when compared to bread wheat (Aslan et al. 2016; Aktaş et al. 2017). The development of new varieties from landrace populations is an applicable strategy to increase landrace yield and yield stability and to endure expected future climate change conditions (Witcombe et al. 1996).

The genetic structure of wheat landraces is an evolutionary output to survival especially under arid and semiarid conditions. The effects of natural and human selections have led to structure of genotypes representing different combinations of traits, such as growth habit; cold, heat, or drought tolerance; early growth vigor time to heading and maturity; and quality traits. As a result, wheat landraces have become complex, variable, and diverse populations in equilibrium with both biotic and abiotic stresses in their environment.

On the other hand, wheat landraces have some disadvantages. Wheat landraces have been largely relegated by high-yielding cultivars in many developing countries and rarely cultivated in developed countries because of their low yield potential (Azeez et al. 2018). The other disadvantage of wheat landrace varieties is traditionally lower market price, though it has changed these days, and limited selling strategies (FAO 2015). Due to their good flavor, taste, and cultivation in local regions, they have higher prices and are sold at niche markets and luxury stores these days.

These two issues also decrease consumption of wheat landraces at a large scale by society.

Agriculture has been a great milestone at evolution of human society of lifestyle. Crops with useful features such as easy harvest, high yield, long-term storage, and easy transport have been important to humans. There are nine different crops that are cultivated in today's world, and wheat is one of these important crops for human consumption.

Evolution and diversity of wheat have been spread widely by not only natural selection but also conventional/modern breeding techniques which are made by human. Scientists usually focus on improvement of wheat cultivars on the purpose of increased resistance against biotic and abiotic stress conditions. To have wheat cultivars with important traits such as higher yield potential in rigid areas, resistant to biotic and abiotic stress, and healthy product content is important than even before because of the rapid increase in the human population. Wheat landraces have advantages according to their high amount of nutrient, protein, tocols, carotenoids, etc. contents when compared to modern wheat cultivars. Due to these valuable contents, wheat landraces are one of the important ingredients for healthy food.

Consumption of wheat landraces was limited at local areas because of increased use of modern wheat cultivars worldwide. Because of this reason, wheat landrace varieties conserve their natural traits, and some important ones have become more dominant because of the artificial selection by farmers, but mostly there has been continuation of their evolution according to their own natural environment. This was highly important for wheat landraces to conserve their genetic pool and their genetic diversity wider than modern wheat cultivars. The important genetic traits of wheat landraces can serve as a potential tool for wheat improvement programs including breeding, genetic engineering, and genetic transformation.

Health concerns, feeding the increasing human population, and development of new varieties will be some of the big problems scientists will face in the near future. Therefore, focusing on landrace cultivars, informing the people about important values of landrace for the future, and increasing experimental studies by scientists will bring big opportunities to overcome these problems.

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