Chapter 9
Climate Change and Global Warming Effect(s) on Wheat Landraces: A General Approach

Hakan Ulukan

9.1 Introduction

The world's human population is predicted to reach over 12 billion by the year 2050 (Anonymous 2018a) according to UN, and population projection and shifts in diets toward animal products, oils, and other resource-intensive foodstuffs are placing even more pressure on agricultural systems to increase production (Kastner et al. 2012). Changes in temperatures and precipitation are known as climate change (CC). Nevertheless, global warming (GW) is a different phenomenon. Shortly, their impacts depend on their size and frequency/frequencies (Semenov et al. 2014). As known, CC affects many sectors, particularly the agricultural sector (Mengü et al. 2008), with its amount and time (Valizadeh et al. 2014). The main factor, due to the human activity, is an increase in the greenhouse gas concentration (CO_2, CH_4, N_2O, and types of halocarbons (CFC)), and the gases that regulate the climate system and absorb the sun's light rays (Tubiello et al. 2000).

While *climate* is important for agricultural production due to its parameters such as temperature, precipitation, humidity, etc., global warming threatens the agricultural production because of GHG accumulation in the atmosphere. Due to GHG accumulation, sunlight is not reflected back to space, thereby increasing the Earth's temperature (IPCC 2007, 2014). Researcher Fuhrer (2003) reported that global warming would lead to an increase in world temperature by 2100 (1.4–5.8) °C, leading to significant agricultural losses. The amount of losses is related to the increase in CO_2 and CH_4 and other greenhouse gas concentrations in the atmosphere (Zavarzin 2001). The CO_2 gas content was 270 ppm before the Industrial Revolution, reaching up to 355 ppm in the modern age. It is expected to reach 600 ppm in the twenty-first century (Rogers et al. 1994) (Fig. 9.1).

H. Ulukan (✉)
Ankara University, Agricultural Faculty, Field Crops Department, Ankara, Turkey
e-mail: ulukan@ankara.edu.tr

N. Zencirci et al. (eds.), *Wheat Landraces*,
https://doi.org/10.1007/978-3-030-77388-5_9

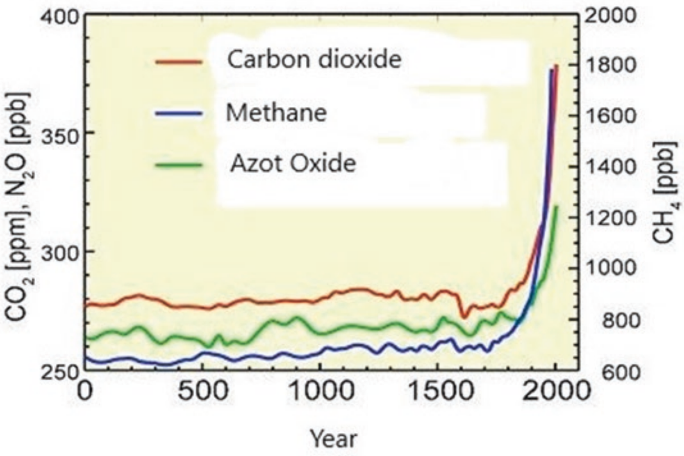

Fig. 9.1 Some greenhouse gas concentrations and global temperature change over the last 2000 years (Di Norcia 2008)

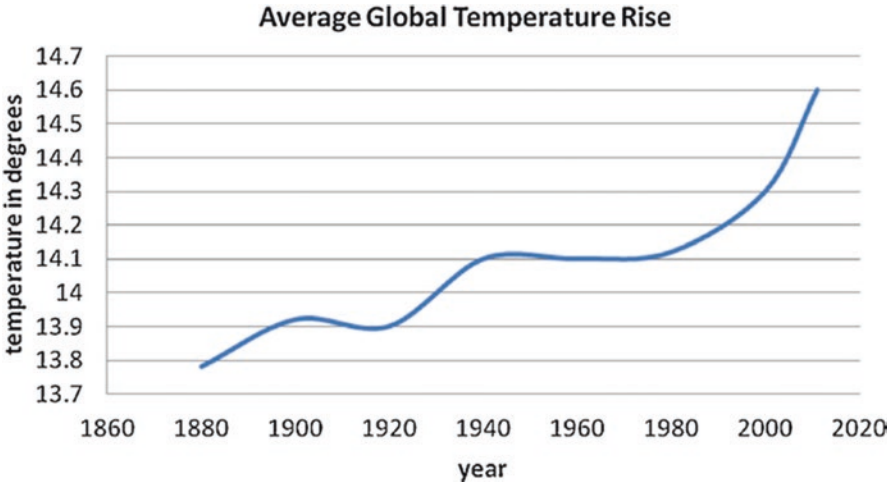

Fig. 9.2 The graph of mean global temperature rise in the measured period (Nema et al. 2012)

The most recent value of CO_2 gas is 411.97 ppm according to the records in March 2019 (https://www.co2.earth/). Greenhouse gases CH_4 and N_2O have annual growth rates of 1% and 0.3%, respectively. All GHG gases protect the Earth by acting as a shield against harmful rays of the sun and negatively affect O_3 gas in the troposphere (Krupa 1997); they are (GHGs) spreading from the refineries, rice paddies, and various elements such as the atmosphere (Mei et al. 2007) (Fig. 9.2).

The effect(s) of CC and GW can be illustrated as follows (Fig. 9.3):

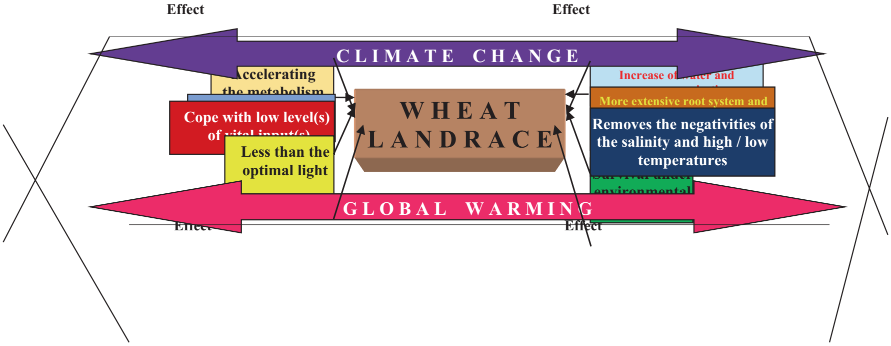

Fig. 9.3 Schematic showing CC and GW effects on wheat landraces (original)

Future climate change scenarios suggest that abiotic stress may occur at unexpected stages of plant development, thus decreasing yield consistency, and various global warming scenarios could reduce wheat productivity in zones where optimal temperature already exists, potentially increasing food insecurity and poverty (Elissavet et al. 2014), and consequently all the landrace's genotypes, including the wheat, have a very important/crucial/vital place in plant breeding for the elimination of many agricultural deficiencies against abiotic and biotic stresses. However, in predominantly self-pollinated species like wheat, no long-term investments are attractive when farmers use their own seeds (Stamp and Visser 2012). There is an inverse relationship between the ability to compete with yield and adverse conditions in the wheat lands, and they are valuable gene pools due to many other superior properties (such as high protein content) (Lopes et al. 2015) (Fig. 9.4).

On the other hand, CC and GW have some both positive and negative effects. All of them can be illustrated as follows (Fig. 9.5):

Climate change refers to changes in climate measures over a long period of time, say approximately 100 years, but global warming is a natural phenomenon that affects all living and nonliving things arising from greenhouse gases. The information obtained in all these processes is very important for the sustainability of the agricultural sector. In fact, the agricultural sector is extremely vital to various inputs (such as biodiversity, soil, water, etc.). However, in any case, CC and its natural consequence, the GW, are the factors that threaten our planet, and the effect is getting felt more and more every day. In another study, it was found that wheat yield decreases by 4.1% to 6.4% in each crop due to global climate change. Consumption is estimated to be more than 30% in 40 years of production (Tricker et al. 2018). As known, all culture plants are classified as C3, C4, and Crassulacean acid metabolism (CAM) according to the number of carbons they bind to the nutrients they form by photosynthesis. C3 plants are trees, edible legumes, rice (*Oryza* spp.), wheat (*Triticum* spp.), barley (*Hordeum* spp.), soybean (*Glycine max*), potato (*Solanum tuberosum*), vegetables, citrus (*Citrus* spp.), grape (*Vitis vinifera*), coffee (*Coffea arabica*), tea (*Camellia sinensis*), peanut (*Arachis hypogea*), lemon (*Citrus limon*), peach (*Prunus persica*), mango (*Mangifera indica*), carrot (*Daucus carota*), etc.

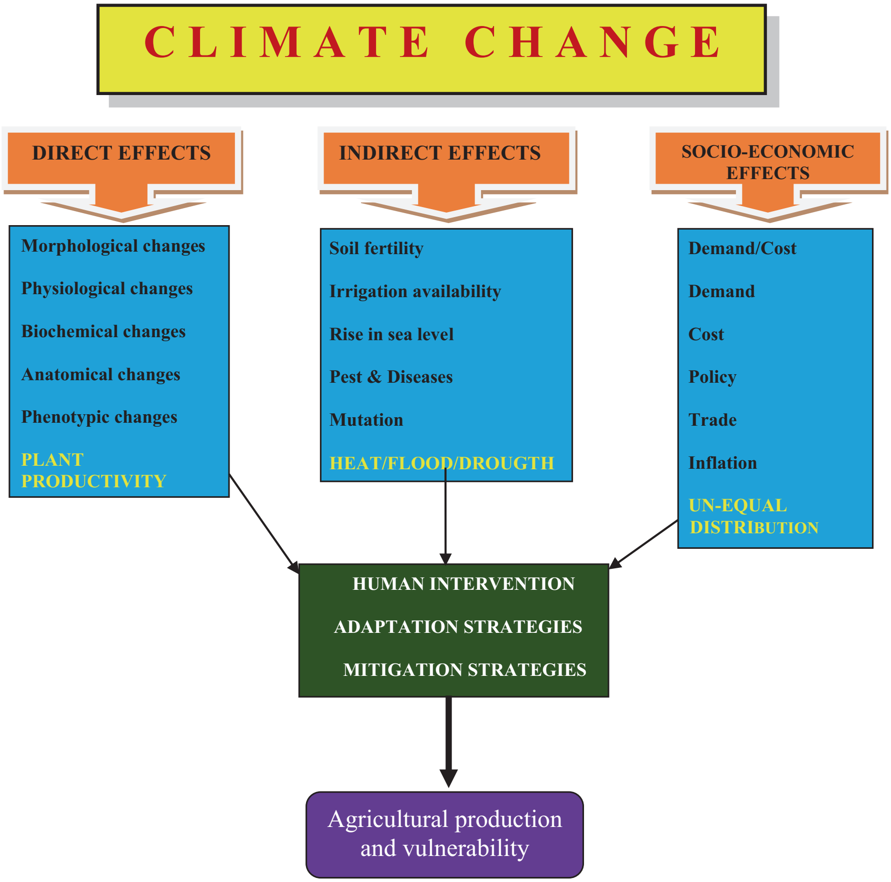

Fig. 9.4 Direct, indirect, and socioeconomic effects of climate change on agricultural production (Rosenzweigh and Hillel 1995; Raza et al. 2019)

with a sowing area of 200 million hectares and constitute approximately 21% of the total nutritional requirements in the world (Anonymous 2018a). Such plants are less affected by CC limitations (as compared to C4) due to CO_2 fertilization, but their yields increase as much as 36% (Uzmen 2007; Mercer and Perales 2010), but afterward, they immediately reduce. The situation may even reduce the photosynthetic activity in other C3 plants outside the grain (Zhai and Zhuang 2009). It is concluded that temperature extremes are complementary to the important physiological parameters in wheat landraces. Frost and heat events cause infertility in bread wheat landraces and cut the grain formation, and the excess heat decreases the number of grains and narrows the formation process. CC's photosynthetic activity with increased photosynthesis rate but increased CO_2 concentration and decreased the WUE values (Dhakhwa and Campbell 1998) was expressed. All the C3 plants,

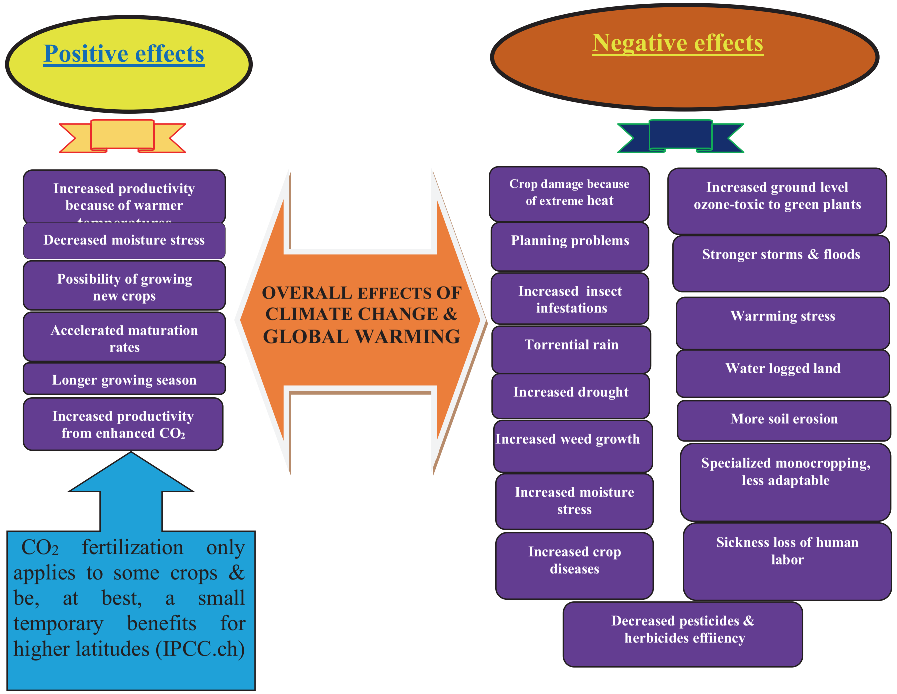

Fig. 9.5 Overall positive and negative effects of climate change and global warming on crops and humans (Raza et al. 2019)

especially local wheat landraces, have different responses to increased CO_2 gas concentration and other climate factors.

Obtained findings showed that elevated CO_2 increases. Findings show that dramatically affect the growth and development of plants against CC and its consequent of GW (Romanova 2005); elevated CO_2 also increases WUE, and is particularly distinct in C3 plants (Cutforth et al. 2007); especially high temperature increasing during the flowering and growing stages decrease grain filling rate, nutrient balance, and all of these adversely affects the fruit and grain formation, especially the critical temperatures at (35–40) °C prevent the development of pollen development with the meiosis division (Fuhrer 2009) (Table 9.1).

The anatomical effects of CC on plants, including wheat landraces, generally result in the increase of the CO_2 concentration and the increase in temperature and their interaction(s). Changes happen in the thickness and viability of leaves as a result of these factors and interaction, decrease in plant height, in growth and development; at the stomata, decrease in the water uptake of the increased amount of chloroplasts in the cell (Romanova 2005; Mei et al. 2007; Ulukan 2008, 2009) (Table 9.2). They rarely fail in the most extremely stressed environments (Ceccarelli 1994) (Figs. 9.6 and 9.7).

9.1.1 Landrace Formation

A landrace of a self-pollinated crop can be defined as a variable population which is identifiable and usually has a local name (Jaradat 2012), and its formation has been carried out for quite a long time with a selection process that is not entirely done by human. During this period, they have survived to the present day by maintaining their resilience to stress factors in their natural conditions, but their yield levels were not as high as modern varieties, but their nutritional values were found to be quite high (Nasserlehaq et al. 2011). On the other hand, they have played a fundamental role in the history of crops worldwide, in crop improvement and agricultural production, and they have been in existence since the origins of agriculture itself (Villa et al. 2006). There are approximately 50,000–60,000 species of crop wild relatives (CWR), of which 10,000 may be considered of high potential value to food security, with 1000 of these being very closely related to the most important food crops (Maxted and Kell 2009; Dempewolf et al. 2014). They have higher biological yields than the cultivated varieties, root dry weights are not very high, but can be increased depending on the situation, transpiration efficiency is higher, soluble carbohydrate concentration is higher than early (early dry matter transfer), early ripening or maturity, grain yields lower (due to earliness) and escape from drought, alternative growing nature, low harvest index, taller and united to low nitrogenous conditions with micronutrients (such as Cu, Fe, Mg, Mn, P, Se, and Zn), especially wheat landraces in the Southeastern Anatolia, the response to fertilizer low, which are not suitable for machine agriculture, sensitive to leaf diseases, adaptation ability is high, grain

Table 9.1 Some agronomic and botanic responses to CC and GW of the wheat landraces' traits. (Modified from Krupa (1997), Dhakhawa and Campbell (1998), Tubiello and Ewert (2002))

Some botanic and agronomic traits	Some CC and GW components			Response
	(Elevated CO_2)	(Elevated UV-A, B)	(Elevated O_3)	
Roots	+	?	?	Root/stem
Photosynthesis	+ in C_3, – in C_4	– in many [C_3 vs C_4]	– in many [C_3 vs C_4]	Yield and respiration
Leaf conductance and leaf development	– in [C_3, C_4]	Majority	– in susceptibles	Leaf area
Water use efficiency (WUE)	+ in [C_3, C_4]	+ in [C_3, C_4]	– in susceptibles	Stomatal conductivity and apertures
Leaf area	More in C_3	– in [C_3, C_4]	– in susceptibles	PAR point
Leaf thickness	+	– in minority	– in susceptibles	?
Maturity and thresh	+	Non-affected	?	Vegetative stage, yield
Flowering (anthesis)	Happens early	Prevents and stimulates	– Flower number and flowering day number	Vegetative stage, yield
Number of days from planting to maturity	?			
Dry matter production	Doubles in C_3, Unknown in C_4	Wide variation	Wide variation	Yield
Susceptibility of species and genus	Varied	Varied	Varied	Yield
Drought resistance	Varied from susceptible to resistance	Varied from susceptible to resistance	Varied from susceptible to resistance	Wiltness, dwarfness, death
Mineral matter	Less response	Some are lots, some are less susceptible	Susceptible to O_3	Dwarfness, death
Vernalization	+	?	?	Vegetative stage
(CO_2/O_2)	?	?	?	Photosynthesis
Respiration rate	?	?	?	Biomass
Seed formation period	?	?	?	Yield
Biomass production	+	?	?	Yield
Internode number	?	?	?	Green part, P. height
Weed distribution	?	?	?	+
Seed germination	+	?	?	Distribution
Rhizomes	+	?	?	Distribution
Seed longevity	+	?	?	?

(continued)

Table 9.1 (continued)

Some botanic and agronomic traits	Some CC and GW components (Elevated CO_2)	 (Elevated UV-A, B)	 (Elevated O_3)	Response
DNA and sterility	+	?	?	Mutation, death
Ecological factors	+	+	+	Stress

CO_2 carbon dioxide, *O_2* oxygen, *UV-A, B* ultraviolet A, B, *O_3* ozone, + increasing, − decreasing, ? unknown, *WUE* water use efficiency, *PAR* photosynthetic activity radiation

Table 9.2 Some agronomic traits which are based physiologically on wheat landraces (Fischer 2001)

Trait	Related with yield	Heredity	Reflection to genotype
Growth and dry matter distribution			
Growth ratio	No in material	Unknown	Very high
Harvest index	Middle-high	Low-middle	High
Spike index at flowering	Middle	Unknown	Very high
Grain weight at the unit spike	Middle	Unknown	Very high
Leaf effectiveness			
Stoma conductance	Middle	Middle	High
Leaf resistance to air flow	Middle	Middle	Middle
Depression of canopy temp.	Low-middle	Unknown	Low-middle
Distribution of oxygen-18	Middle	Unknown	High
Photosynthetic activity	Low-middle	Low	High
Fluorescence of chlorophyll	Low-middle	Middle	High
Distribution of carbon-13	Low-middle	Middle	High
Leaf greenness	Low	Unknown	Low
Leaf density	Low	Low-middle	Low
Yield components			
Spike number at m^2	No	Middle-high	Low
Spike number	No-low	Low-middle	Middle
Spikelet number in spike	No	Middle-high	Low
Grain number in spike	No-low	Middle	Low-middle
Grain number in spikelet	No-low	Unknown	Low
Grain formation index	No-low	Unknown	Low-middle
Grain weight	No	High	Low
Grain number at m^2	High	Low-middle	High
Morphology			
Mature plant height	Low in 70–100 cm	Very high	Low
Leaf erectness	Unknown-low	Middle-low	Low-middle
Leaf thickness	Unknown	Middle	Low
Awnless	Unknown	Very high	Very low
Yield potential (Yp)			
Yield potential (Yp)	Very high	Low	High

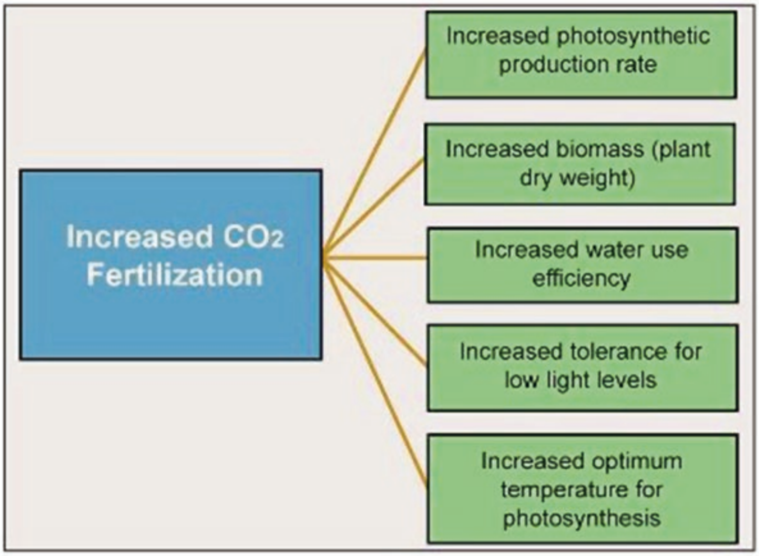

Fig. 9.6 Effect of CO_2 fertilization on wheat landraces' some physiologic components (Lenart et al. 2006)

III. WHAT ABOUT CO_2 BENEFITS?
CO_2 IS PLANT FOOD

Here is What Happens With More CO_2

385 ppm 535 ppm 685 ppm 835 ppm

Source: William Happer, 2014.

There is a reason greenhouses pump in CO_2.

20

Fig. 9.7 General impacts of elevated CO_2 on plants (Anonymous 2018b) quality is good, generally coarse grains, stalks and straws are consumed by animals and liked by animals (Jaradat 2012; Özberk et al. 2016).

Essentially, there are two types of landraces according to Jaradat (2013):

(a) Primary: Developed its unique characteristics through repeated in situ grower selection and never been subjected to formal plant breeding as autochthonous and allochthonous
(b) Secondary: Developed in the formal plant breeding sector but is now maintained through repeated in situ grower selection and seed saving

Generally, the formation of the landraces can be schematized as follows (Fig. 9.8):

They represent heterogeneous, local adaptations of domesticated species, and thereby provide genetic resources that meet current and new challenges for farming in stressful environments, especially landraces, provide a valuable gene resources for enhancing the crop adaptation to abiotic stresses (Dwivedi et al. 2016), and, landraces have been defined as dynamic populations of a cultivated plant with a historical origin, distinct identity, often genetically diverse and locally adapted and associated with a set of farmers' practices of seed selection and field management as well as with a knowledge base (Bellon and Etten 2014). These carry beneficial genes that were not introduced into elite durum cultivars (Kabbaj et al. 2017). Northern landraces evolved a higher tillering capacity, fewer grains per spike and less fertile tillering than those from the south. Our results support the hypothesis that during the Neolithic dispersal of durum wheat from the Fertile Crescent to southern Europe, significant and gradual changes in yield component structure of populations occurred (Akçura 2009). The main threat to the landraces (including wheat landraces) is current minor or major industrial developments such as construction of huge shopping malls, housing, apartments and blocks, and golf fields,

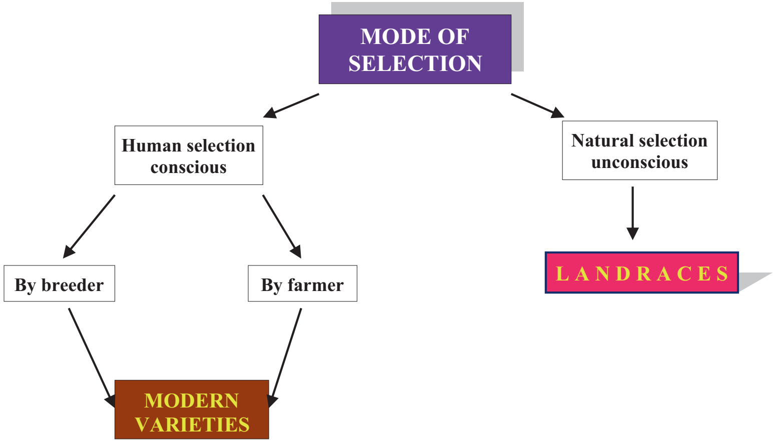

Fig. 9.8 Schematized landrace and modern variety general formation. (Modified Cleveland et al. 1994)

leading to reduction in biodiversity. The landrace gene pool harbors a wide genetic diversity that could be used to enrich the modern wheat genetic repository (Blum et al. 1989; Dotlačil et al. 2010; Ben-David et al. 2014). Wheat landraces generally tolerant to biotic and abiotic stress have been grown under low-input or sustainable farming conditions where they produce reasonable yield (Akçura 2009).

CC and GW effects on wheat landraces, like other cultivated plants, can be itemized as follows (Gray and Brady 2016; Anonymous 2019):

1. Air enriched with CO_2 stimulates growth and development of wheat landraces, thus resulting in the development of more fibrous and voluminous root systems.
2. Leaf size increases and cells expand.
3. More CO_2 (which means elevated CO_2) means less water stress.
4. Helps cope with low levels of essential resources such as light, water, nutrients, etc.
5. In less than optimal conditions, higher CO_2 means more plant growth.
6. Atmospheric CO_2 enrichment increases plant water acquisition.
7. Rising CO_2 enhances plant resource acquisition, such as root system, nitrogen-fixing bacteria, symbiotic soil bacteria, carbon starvation, etc.
8. Promotes the growth of important soil fungi such as *rhizosphere*, *mycorrhizae*, etc.
9. At current CO_2 concentrations (February 2019, which is 411,75 ppm (https://www.co2.earth/), plants are close to starvation.
10. Elevated CO_2 level helps plants to survive environmental stresses such as salinity, pollution, elevated temperatures, etc.
11. Elevated CO_2 level helps in reducing the negative impacts of soil salinity on plant growth.
12. Elevated CO_2 level helps in reducing the negative impacts of high temperatures on plant growth.
13. Elevated CO_2 level helps wheat landraces to survive biological stresses such as weeds, diseases, insects, herbivory, etc.
14. Rising CO_2 does not disappear with time (but it has been observed that in some plant species, foliar N concentrations may decrease; however, in others, it will not).
15. Rising CO_2 enhances carbon sequestration (particularly, this issue is very crucial in terms of the sustainability of agroecosystems, grasslands, and forests).

All the effect(s) of the CC and GW's components were summarized on wheat landraces' traits which were presented generally in Tables 9.1 and 9.2.

Increasing the temperature rises evapotranspiration and drops the soil moisture availability and increases the growth and development of plants, including wheat landraces, due to higher CO_2 concentrations. Wheat landraces, based on their nutritional value, when locally produced can contribute to lower greenhouse gas emissions (0.1 g CO_2 per calorie) as compared to rice (0.43 g CO_2 per calorie) or vegetables (0.57 g CO_2 per calorie) (Jaradat 2013). In addition to this information, Schlenker and Roberts (2009), the yield of low CO_2 concentration, the wheat landrace (36%- (-40))% and (63–70)% depending on the statistical program used.

Hatfield and Prueger (2011) calculated it as 3.8–5.0%, and Fuhrer (2009) stated that the increase of 1 °C in the temperature caused a decrease of 7.0–124.0% in the yield level. At the same time, it has been reported that wheat yield losses in developing countries (producing 66% of the total wheat production) are likely to be around 20–30% due to the increases in temperature caused by climate change (Easterling et al. 2007; Lobell et al. 2008). Under normal conditions and during the development period, the mean temperature increase of 1 °C, causes 6 kg/ha yield losses in *durum* and 12 kg/ha common wheats, and it is expected that the number of wheat yield losses will be between 20 and 30% with a temperature increase of 2–3 °C in developing countries until 2050 (Anonymous 2011; Sayılğan 2016). High temperature (air and soil temperature) and water deficit (drought) are the most important environmental factors that limit plant growth in many huge/mega wheat fields of the world and occur simultaneously (Shah and Paulsen 2003). But its mechanism is still unknown.

The main threat caused by CC and GW is not only increased or elevated CO_2 concentration and temperature but also reduction of the effectiveness of RuBisCo during the production of glucose via PSII stage in photosynthesis. In parallel, the WUE value diminishes. This development leads less water for a less dry matter (that means low yield level), the role of the RuBisCo and indirectly WUE value which is very important. But their mechanisms, etc. are still not fully and clearly known today. In any case, the main aim should be an increase in the WUE values of wheat landraces, especially those grown in arid and semiarid regions.

The enzyme RuBisCo has played a crucial and vital role in photosynthesis and one of the most abundant proteins in leaves of plants. Accelerated development and premature senescence were the primary factors affecting its activity in response to the CO_2 enrichment. This role is very clear during photosynthesis and this enzyme is in close relationship with the WUE of the plant, especially during CC and the GW (Table 9.3).

According to Marin and Nassif (2013), the increase of atmospheric CO_2 concentration increases the gradient that drives the diffusion of CO_2 from the atmosphere to the chloroplasts. And this effect stimulates photosynthesis and reduces stomatal conductance, and a reduction in the transpiration rate happens (Taiz and Zaiger 2013). In Tables 9.1 and 9.2, CC and GW act on C3 plants effects have been with their components. Especially their effects on "vernalization, CO_2/O_2 rate, respiratory rate, seed maturation, sub- and topsoil biomass production, number of internodes, weed distribution, germination of seeds, root/stem or rhizome, seed longevity, DNA molecule and sterility, ecological parameters, etc. " have not yet been fully known. Their effect on the plants is mostly and generally on the biomass, specifically on the leaf and leaf factors. At the selections to be made by taking advantage of the relevant features, which are mentioned or not mentioned in Table 9.2, wheat landraces can be used to complete a gene resource and the missing characters(s) for a valuable genitor or donor.

Water sources and/or soil moisture, which are diminishing due to the decreases in wheat sowing areas and climatic reasons,, have been emphasized that the wheat landraces are an insurance for future agricultural production. Wheat landraces have

Table 9.3 Main agronomic traits of strategically important 18 major field crops (Rötter and Geijn 1999)

	World[a]				
Crops	Production (Mt)	Yield (Hg/Ha)	Origin	Type	WUE
Barley	141,277	30,108	W. Asia	C_3	1.25–2.50
Bean, dry	26,833	9129	S. and Cent. Amer.	C_3	1.40–3.30
Cassava	277,103	118,006	S. and Cent. Amer.	CAM	1.30–3.30
Coconut	59,011	48,493	Africa, Asia	C_3	1.40–3.30
Cotton (seed.)	46,988[a]		S. Amer.	C_3	1.40–3.30
Grape	77,439	109,119	Asia	C_3	1.25–3.30
Maize	1,060,107	56,401	Cent. Amer.	C_4	2.90–6.70
Oats	22,992	24,373	W. Europe	C_3	1.25–2.50
Peanut	–		S. Amer.	C_3	1.40–3.30
Pea, dry	14,363	18,835	W. and N. Asia	C_3	Unknown
Potato	376,827	195,790	S. Amer.	C_3	1.25–2.50
Rice	740,962	46,366	Asia, Africa	C_3	1.40–3.30
Rye	12,944	29,398	W. Asia	C_3	1.25–2.50
Sorghum	63,931	14,279	Africa	C_4	2.90–6.70
Soybean	334,894	27,556	E. Asia?	C_3	1.40–3.30
Sugarcane	1,890,662	706,148	NW Asia, Aust.	C_4	1.25–6.66
Sweet potato	105,191	121,975	S. and Centr. Amer.	C_3	1.40–3.30
Wheat	***794,460***	***34,050***	***Fertile Crescent***	$\boldsymbol{C_3}$	***1.25–2.50***

W. West, *S.* South, *Cent.* Central, *Amer.* America, *N.* North, *E.* East, *NW* North West, *Aust.* Australia, *WUE* water use efficiency, *CAM* Crassulacean acid metabolism

[a] Anonymous 2018b

agriculturally more undesirable traits such as hulledness in grain, tallness, and low yield level(s) than modern commercial (wheat) varieties. However, cultivation of landraces has been successful for many years without any human intervention under stress conditions. The main contributions of wheat landraces to plant breeding programs have been their desirable traits such as having efficient nutrient uptake and utilization and having useful genes adapted to stressful environments such as water stress, salinity, and higher temperatures (Dwivedi et al. 2016).

In the light of the information that was given, our recommendations are (generally) as follows:

- To make national or international agreements that enable effective use of both CO_2 and water resources.
- To minimize the release of CH_4 from ruminants and nitrous oxide by efficient fertilization (Prasad 2009).
- To avoiding excessive and artificial nitrogenous fertilization.
- To take crop rotation and animal feeding of tuberous plants and legumes (Ulukan 2009).
- To use alternative or clean energy sources.
- To apply minimum soil tillage techniques (Çakır et al. 2009).

- To use organic or environmentally friendly agricultural practices.
- To not burn waste materials at the end of the production.
- Especially in continents, coasts, and oceans, to take the necessary measures without forgetting that the polar regions will warm faster than the equator.
- All activities that cause greenhouse gas emissions should be terminated or minimized.
- Without losing the principle of sustainability, to prevent the destruction of soil, water, and biodiversity.
- When they are used as parent(s) directly in the hybridizations, expands high yielded modern wheat cultivars' and provides the resistance to biotic and abiotic stress factors; in addition, the use of bridge hybridization (Şehirali and Özgen 1987), the production of seeds on a periodically, scientifically and characterization is of great importance (Özberk et al. 2016).
- To develop new (wheat) varieties which are also suitable for the purpose of producing wheat landrace, especially from the elements of genetic variation (Heslop-Harrison 2012). It should be used as rootstock or genitor in breeding studies by utilizing physiological characteristics.
- The development of new varieties using wheat landraces that are more adapted to local biotic and abiotic stresses presents a viable strategy to improve and sustain yields, especially under stresses and future changes in climate (according to Calanca (2017).
- However, landraces with high genetic diversity should be selected and crossed with locally adapted landraces and varieties to achieve breakthroughs in wheat genetic improvement (according to Calanca (2017) and in order to increase tolerance which therefore results in increased yield potential and to respond to climate change (Semenov et al. 2014).

It should be remembered that in all cereals, except wheat landraces, there is an agronomically negative relationship between yield and stress conditions, although higher yield is obtained by cultivation in suitable ecologies with appropriate varieties and cultivation techniques in modern plant breeding programs. However, some agricultural properties that are superior to the various stress conditions can only be achieved by using them as genitors. These genotypes are very important in terms of providing efficiency to the producer and generating income, where stress conditions are common (especially extreme temperature, limited water, etc.) and inadequate. As seen from Table 9.4, *durum*-type local wheat landraces (more than 113 local wheat landraces) are more cultivated than the *aestivum* types. And nearly all the genotypes that are being cultivated are called with their morphological traits such as grain or spike color. Even that, the same local cultivars have different name place to place among the farmers.

Crops of these genotypes are being mostly consumed as regional and healthy dishes (e.g., bulghur, erişte, etc.) due to not only their weak gluten strength but also their nutrition profile (esp. Fe, P, and protein percentage) and poor agronomic traits such as yield level (100–150 kg/da), lateness, short plant height, etc. Wheat landraces are commonly and mainly grown at Black Sea and Central Anatolian regions in

Table 9.4 Turkey's climate regions and total vegetation period length of the wheat cultivars and landraces (Anonymous 2017)

Climate	Vegetation period (days)	Climate	Vegetation period (days)
Overrained Mediterranean	200 (for *common*)	*Erzurum-Kars Pr. Pl.*	322 (for *common*) 115 (for *durum*)
Mediterranean	205 (for *common*)	*Van Pr.*	315 (for *common*) 120 (for *durum*)
P. Mediterranean-1	200 (for *common*)	*Hakkâri Pr.*	310 (for *common*) 110 (for *durum*)
Marmara	252 (for *common*) 130 (for *durum*)	*Southeastern Anatolia-1*	211 (for *common*)
Marmara T.	270 (for *common*)	*Southeastern Anatolia-2*	226 (for *common*)
Cool Black Sea-1	–	*Southeastern Anatolia and T.*	268 (for *common*) 130 (for *durum*)
Cool Black Sea-2	270 (for *common*) 130 (for *durum*)	*Upper Fırat and Murat*	286 (for *common*) 125 (for *durum*)
The warm Black Sea	251 (for *common*) 130 (for *durum*)	*Mediterranean-Southeastern Anatolia T.*	229 (for *common*)
East Black Sea-1	–	*Mountainside and East*	273 (for *common*) 128 (for *durum*)
East Black Sea-2	270 (for *common*) 130 (for *durum*)	*Inner Anatolia and Inner Transition and Cool Black Sea*	270 (for *common*)
Yusufeli Rg.	–	*Mountainside*	270 (for *common*)
East-1	300 (for *common*) 120 (for *durum*)	*Post Mediterrenean-2*	265 (for *common*)
East-2	315 (for *common*) 127 (for *durum*)	*T. Zone*	267 (for *common*)
Iğdır Pr. Microclimate	270 (for *common*) 105 (for *durum*)	*Inner Anatolia*	225 (for *common*)

T. transition, *P.* post, *Pl.* plateau, *Pr.* province, *Rg.* region, minimum days, 105; *Iğdır Pr. microclimate rained climate* (for *durum*); maximum days, 130; (*Marmara and Cool Black Sea-2*) *climates* (for *durum*); minimum days, 200; *P. Mediterranean-1 climate* (for *common*); maximum days, 322; *Erzurum-Kars Pr. Pl. climate* (for *common*)

Turkey. And these regions are mostly marginal and have suffered from stress factors. Particularly, elevated CO_2 is a very critical and crucial factor for them since their water consumption for grain formation is getting reduced during this process. In addition, consuming water for 1 g dry matter is getting lower for C3 plants including wheat landraces. Generally, the CC and GW's effect(s) on wheat landraces are (particularly) at vernalization stage, cellular CO_2/O_2 changeability, respiration ratio, maturity, topsoil and subsoil biomass/root volume(s), internode number, weed distribution, germination, rhizome activity, seed longevity, DNA molecule breaking, sterility and ecological factors where their mechanism, etc. have not been fully known and clear today.

Generally, in the cultivation areas, water is a major determining and limiting factor for agricultural yield. On the other hand, the amount of precipitation and its distribution of the water landrace's vegetation period are ultimately important. Particularly, it is important for the availability of water (directly), nutrient availability, soil fertility, ph value, etc. Water availability has long been known as one of the most important abiotic factors governing crop yield (Boyer 1982; Gray and Brady 2016), and it has played a significant role in plant growth and development processes such as photosynthesis and transpiration. At this point, WUE arises as an important physiological factor which also determines yield. During climate change and global warming, wheat landrace's WUE value is affected and reduced when the CO_2 is elevated and directly linked with the yield. It can be defined as

$$WUE\left(\mathrm{kg\,da^{-1}\,mm^{-1}}\right) = \mathrm{Y} / \mathrm{ET_a}$$

where Y is the yield (kg da^{-1}) and ET_a is the actual water consumption (the sum of water consumption for each stage) during the wheat landrace's growth period (mm) as mentioned above.

CC and GW physiologically affect first WUE, which has an important role in the Calvin cycle in the *PSII* stage of photosynthesis. When WUE affects, directly reduces the effectiveness of RuBisCO (ribulose-1,5-bisphosphate carboxylase/oxygenase) enzyme, which links CO_2 and partly O_2 entrance to the chloroplasts, in other words, results in dry matter production and yield reduction. But, this situation (yield reducing) does not happen in C4 grouped plants and increasing yield aggregating CO_2 in C3 grouped plants (incl. wheat landraces): CO_2 fertilization (Uzmen 2007). In a breeding strategy, selection for elevated water use efficiency causes reduced or earlier flowering that results in lower water usage along with lower yield capacity (Blum 2005). Hence, it is vital to produce genotypes having higher WUE as well as higher yields compared to the present varieties (Farooq et al. 2009). But, this point is clear that despite the significant increase in the yield potential of wheat breeding based on yield worldwide, the future success will be determined by the cooperation of plant breeders and plant physiologists and by the support of physiological criteria (Jackson et al. 1996; Sayılğan 2016) (Fig. 9.9).

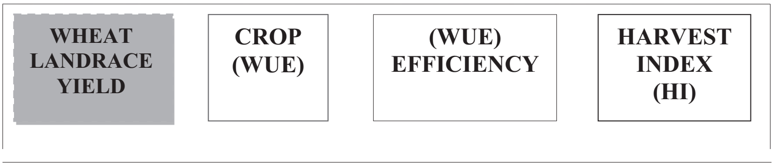

Fig. 9.9 Some major yield components of wheat landraces. (Modified from Richards et al. 2015)

9.2 Status in Turkey

When evaluated in terms of topography and climate, Turkey has a very wide genetic diversity and geographical structure. The most important plant is wheat and wheat landraces are still grown in Turkey. Derived end products such as bread, yufka, noodles, lavash, and bulghur are made from wheat. According to the TUİK-2018 and FAO-2017 statistics, Turkey's wheat sowing area is (7.6–7.7) million ha, its production level is approximately 20 million tons, and its mean yield is (4–4.5) t/ha for common and (2.5–3.0) t/ha durum wheats (Anonymous 2018a, 2019). Wheat landraces in Turkey are usually kept as populations rather than selected as homogenous cultivars. Thus, those populations are characterized by great genetic and phenotypic variations. Landraces even within a single village may show traits such as white, black, or red grain, the presence and absence of awns, tightly or loosely packed spikes, and different abilities to tolerate abiotic conditions (According to Brush 2004 and Karagöz 2014). Wheat landraces are generally grown in small fields and marginal places, in the west and northern transition zones of Central Plateau, and in forest openings of North, Eastern, and Southeastern Anatolia (Akçura 2009), and a full taxonomic list of wheat landraces, which are grown in Turkey, was presented in Table 9.4.

In Turkey, wheat landraces are mostly grown in arid and semiarid regions which are dominated by stress factors such as salinity, drought, and cold (Zencirci et al. 2019). Precipitation, especially in the period of growth of these wheat landraces in arid regions, and high temperatures cause significant decreases in yield level. As mentioned above, their mean yield level is rather lower (100–150 kg/da) compared to modern wheat cultivars' mean yield level (400–450 kg/da). For determining WUE values of wheat cultivars in Turkey, many types of research were carried out in meteorological stations, i.e., more than 259 (Anonymous 2017) at different 28 climate regions. These climate regions and the total vegetation period length of the wheat cultivars and landraces which are grown in Turkey are presented in Table 9.4.

In Turkey, mostly vegetation period length depends on water availability, temperature, and distribution of the precipitation. According to measurements in the meteorological stations (in total 259), a variation of the WUE value in Turkey can be mentioned like this (Anonymous 2017) (Table 9.5):

On the other hand, these findings can be evaluated like the following as well:

As seen from Table 9.6, durum and common wheat WUE values are higher than those in wheat landraces in Turkey. It means that except wheat landraces, wheat

Table 9.5 Min. and max. WUE (kg da^{-1} mm^{-1}) mean values of the Turkish wheat cultivars and wheat landraces in 2019 (Original)

	(A) Durum wheats [250 – 300 (kg/da) / 320]	(B) Common wheats [400 - 450 (kg/da) / 320]	(C) Wheat landraces [100-150 (kg/da) / 488.19]
	(0.78-0.94)	**(1.25-1.41)**	**(0.20-0.31)**
Climate: Type	(*Mediterranean*)	(*P. Mediterranean*)	*(All)*

uses more water and produces more dry matter, resulting in higher yield level. WUE values of landraces are lower than those of durum and common wheat (at least three to four times), and these values should be increased by aggregating the yield. For this purpose, various breeding methods should be used (e.g., mutation breeding) by benefiting from landraces as against stress factors as parents. It was demonstrated that temperature was found to have a positive effect on potential yield as well as earliness within Turkish local wheats, whereas lower drought and heat stress caused varieties from Ethiopia and Syria to have longer spike (Alhajj et al. 2017). But in terms of CC and GW, Turkey is not on dangerous position, but all necessary precautions without delay should be taken into consideration for the sustainability of animal and plant production.

Table 9.6 List of some grown Turkish wheat landraces in 2019 (original)

	Local name	
Region *Province*/district	*T. monoccum* (AA)-*T. durum* (AABB)	*T. aestivum* (AABBDD)
Manisa/Akhisar	Üveyik, Sarıbaşak, Zerun, Akbuğday, Agbuğday, Kırmızı buğday, Sarı buğday, Karakılçık	
Erzurum, *Van*, *Iğdır*/Tuzluca	Kırik	
Kastamonu/İhsangazi Seydiler/Merkez/Devrekani	Siyez	
Kütahya/Çavdarhisar	Kocabuğday	
Eskişehir, *Balıkesir*/Sındırgı	Topbaş, Kırmızı Topbaş, Şahman, Devedişi, Ak 702, Sertak 52, Melez 13, Gernik, Sivas 111/33, Havrani, Köse 220/39, Polatlı/Kobak, Yayla 305, Sürak 1593/51	
Kayseri/Develi	Gacer	
Kütüphane/Çavdarhisar	Koca buğday	
Gümüşhane/Torul	Rus buğdayı	
Karabük/Eflani	Köy buğdayı	
Malatya/Akçadağ	Aşurelik buğday	

(continued)

Table 9.6 (continued)

	Local name	
Region *Province*/district	*T. monoccum* (AA)-*T. durum* (AABB)	*T. aestivum* (AABBDD)
Malatya/Akçadağ, *Elazığ*/Merkez	Kırmızı Kunduru	
Elazığ/Baskıl	Menceki	
Ağrı/Patnos	Kıraç 70	
Adıyaman/Gölbaşı	Malatya Sarı Bursası	
Tokat/Yeşilyurt	Ormece	
Aksaray/Güzelyurt	Kırmızı Kamçı	
Yozgat/Kadışehri	Çalıbasan	
Van	Tir, Kırmızı, Sarı, Koca, Göderedi	
North East Anatolia	Göle buğdayı, Kelkit buğdayı	
Middle North Anatolia *Ankara, Çankırı, Çorum, Uşak Kırşehir, Yozgat, Bolu, Bilecik, Eskişehir, Kütahya,*	Sarı Buğday Siverek, Çirpuz, Karakılçık, Kunduru, Şahman, Sarı Bursa, Aşurelik Buğday, Ak Başak, Üveyik, Ağ buğdayı	Akbuğday, Sünter, Bindane, Kadiroğlu, Çalıbasan, Köse
Middle East Anatolia *Amasya, Elazığ, Malatya, Sivas, Tokat, Tunceli*	Üveyik, Menceki, Kunduru	Aşure, Akbuğday, Zerun, Gürük, Zerin, Dimenit, Yazlık, Kırik, Köse, Kırmızı, Tercan
Middle South Anatolia *Afyon, Kayseri, Konya, Nevşehir, Niğde*	Bolvadin, Sarı Buğday, Karakılçık	Akbuğday, Akbarnaz, Çomak, Köse, Sivas Buğdayı, Germir, Akevli, Kamçı Wheat, Kızıl Topbaş
North East Anatolia *Ağrı, Artvin, Erzincan, Erzurum, Kars*	Karakılçık, Hazerik,	Kırmızı Buğday, Kırik, Topbaş, Sarıbaş, Kızıl, Köse, Akbuğday
Southeast Anatolia *Bingöl, Bitlis, Hakkâri, Van Mardin, Muş, Siirt, Şanlıurfa,*	Bağacak, Sorgül, Beyaziye, Menceki, İskenderi, Mısri, Havrani, Karakılçık, Sorik Akbaş, Akbaşak, Hamrik	Aşure
Mediterrenean *Antalya, Gaziantep, Hatay, Mersin, Maraş, Adana*	Akbuğday, Karakılçık, Tığrak Buğdayı, Sarı Buğday, Kıbrıs Buğdayı	Yerli Macar, Kırmızı Buğday, Akbuğday, Devedişi, Çavdarlı
Agean *İzmit, Aydın, Muğla, Denizli, Burdur, Isparta, Çanakkale, Manisa, Balıkesir*	Fata, Gökala, Sarı Başak, Kunduru, Menemen, Karakılçık, Sarı Çam, Akbaşak, Akpüsen, Çam Buğdayı, Sarı Buğday, Deve Dişi, Kırmızı Buğday	Kızılca, Akgernaz, Akça Rodos
Marmara *Bursa*, *Kocaeli*, *Sakarya*, *İstanbul*, *Edirne*, *Tekirdağ*, *Kırklareli*	Akbaşak, Karakılçık, Tunus Buğdayı, Sarı Başak, Köse Buğday, Arnavut Buğdayı, Kunduz, Kocabuğday, Kokana	Sünter, Kızılca, Akova, İngiliz Buğdayı, Çapraz Köse Buğday, Çalıbasan,
Black Sea *Rize*, *Trabzon*, *Giresun*, *Ordu*, *Samsun*, *Sinop*, *Gümüşhane, Kastamonu*, *Zonguldak*	Rumeli/Yunan buğdayı, İlik, Sarı Buğday, Akbuğday, Sarıbaş, Karakılçık, Üveyik, Rumeli, Sarı Hamza, Koçarı, Diş Buğdayı	Mengen, Topbaş, Dimenit, Kırmızı Sünter, Akça

References

Akçura M (2009) Genetic variability and interrelationship among grain yield and some quality traits in Turkish winter durum wheat landraces. Turk J Agric For 33:547–556

Alhajj AS, Tedone L, De Mastro G (2017) Climate variability impact on wheat production in Europe: adaptation and mitigation strategies. In: Ahmed M, Stockle CO (eds) Quantification of climate variability adaptation and migration for agricultural sustainability. Springer, Cham, pp 252–299. https://doi.org/10.1007/978-3-319-32059-5

Anonymous (2011) WHEAT-Global alliance for improving food security and the livelihoods of the resources-poor in the developing world'. Proposal submitted by CIMMYT and ICARDA to the CGIAR consortium board, in collaboration with Bioversity, ICRISAT, IFPRI, ILRI, IRRI, IW MI, 86 NARS Institute, 13 Regional and International Organizations, 71 Universities and Advance Research Institutes, 15 Private Sector Organizations, 14 NGOs and Farmers Cooperatives and 20 Host Countries, p 197

Anonymous (2017) Türkiye'de sulanan bitkilerin bitki su tüketimleri. T.C. Gıda, Tarım ve Hayvancılık Bakanlığı Yayınları, Tarımsal Araştırmalar ve Politikalar Genel Müdürlüğü (TAGEM)-Devlet Su işleri Genel Müdürlüğü (DSİ), Sf. 586, Altındağ, Ankara, Turkey ISBN 978-605-9175-93-7

Anonymous (2018a) FAO statistical database. http://www.fao.org/faostat/en/#data/QC. Access date May 14, 2018

Anonymous (2018b) Plant response to rising carbon dioxide. http://articles.extension.org/pages/58381/plant-response-to-rising-carbon-dioxide. Access date May 20, 2018

Anonymous (2019) Plants need CO_2, carbon dioxide is green. https://plantsneedco2.org/default.aspx/MenuItemID/103/MenuSubID/52/MenuGroup/Home.htme. Access date April 05, 2019

Bellon M, Etten van J (2014) Climate change and on-farm conservation of crop landraces in centers of diversity, In Jackson M, Ford-Lloyd B, Parry M (eds). Plant genetic resources and climate change, pp 1–30.

Ben-David R, Amram A, Nashef K (2014) Genetic improvement of durum wheat establishment under fluctuating environmental conditions. In: Porceddu E, Qualset CO, Damania AB (eds) Proceedings of the International Symposium on Genetics and Breeding of Durum Wheat, vol 110. CIHEAM, Bari, pp 147–149

Blum A (2005) Drought resistance, water-use efficiency, and yield potential: are they compatible, dissonant, or mutually exclusive? Aust J Agr Res 56:1159–1168

Blum A, Golan G, Mayer J, Sinmena B, Shpiler L, Burra J (1989) The drought response of landraces of wheat from the northern Negev desert in Israel. Euphytica 43:87–96

Boyer JS (1982) Plant productivity and the environment. Science, New series 218(4571):443–448

Çakır E, Aykas E, Yalçın H, Dereli İ (2009) The benefit of conservation tillage and its applications in the World and Turkey, 1st Int. Congress on Global Climate Change and Agriculture May 28–30 Tekirdağ, Türkiye, pp 124–134.

Calanca PP (2017) Effects of abiotic stress in crop production. In: Ahmed M, Stockle CO (eds) Quantification of climate variability adaptation and migration for agricultural sustainability. Springer, Cham, pp 166–176. https://doi.org/10.1007/978-3-319-32059-5

Ceccarelli S (1994) Specific adaptation and breeding for marginal conditions. Euphytica 77:205–219

Cleveland DA, Soleri D, Smith SE (1994) Folk crop varieties: do they have a role in sustainable agriculture? BioScience 44:740–751

Cutforth HW, McGinn SM, McPhee E, Miller PR (2007) Adaptation of pulse crops to the changing climate of the Northern Great Plains. Agron J 99:1684–1699

Dempewolf H, Eastwood JR, Guarino L, Khoury KC, Müller VJ, Toll J (2014) Adapting agriculture to climate change: a global initiative to collect, conserve, and use crop wild relatives. Agroecol Sustain Food Syst 38(4):369–377. https://doi.org/10.1080/21683565.2013.870629

Dhakhawa GB, Campbell CL (1998) Potential effects of differential day-night warming in global climate change on crop production. Clim Change 40:647–667

Di Norcia V (2008) Global warming is man-made: key points in the international panel on climate change 2007 Report, Hard like water-ethics in business. Oxford University Press, Oxford, pp 1–4

Dotlačil L, Hermuth J, Stehno Z, Dvořáček V, Bradová J, Leišová L (2010) How can wheat landraces contribute to present breeding? Czech J Genet Plant Breed 46:S70(1)–S74(5)

Dwivedi LS, Ceccarelli S, Blair WM, Upadhyaya DH, Are KA, Ortiz R (2016) Landrace germplasm for improving yield and abiotic stress adaptation. Trends Plant Sci 21(1):31–42

Easterling DR, Horton B, Jones PD, Peterson TC, Karl TR, Parker DE, Salinger MJ, Pazuvayev V, Plummer N, Jamason P, Folland CK (2007) Maximum and minimum temperature trends for the globe. Science 277:364–367

Elissavet GN, Ioannis GM, Athanasios T, Parthenopi R, Christos D, Tokatlidis IS (2014) Wheat landraces are better qualified as potential gene pools at ultra spaced rather than densely grown conditions, Hindawi Publishing Corporation. Scientific World Journal 2014:1–5. https://doi.org/10.1155/2014/957472

Farooq M, Wahid A, Kobayashi N, Fujita D, Basra SMA (2009) Plant drought stress: effects, mechanisms and management. Agron Sustain Dev 29:185–212

Fischer RA (2001) Selection traits for improving yield potential, Chapter 13. In: Reynolds MP, Ortiz-Monasterio JI, McNab A (eds) Application of physiology in wheat breeding. CIMMYT, Mexico, D.F., pp 148–159. p 219

Fuhrer J (2003) Agroecosystem responses to the combination of elevated CO_2, ozone, and global climate change. Agric Ecosyst Environ 97:20

Fuhrer J (2009) Climate change-risks and opportunities for agriculture, 1st Int. Congress on Global Climate Change and Agriculture May 28–30 Tekirdağ, Türkiye, pp 81–87

Gray BS, Brady MS (2016) Plant developmental responses to climate change. Dev Biol 419:64–77

Hatfield JL, Prueger JH (2011) In: Yadav SS, Redden RJ, Hatfield JL, Lotze-Campen H, Hall AE (eds) Agroecology: implications for plant response to climate change. Wiley-Blackwell, West Sussex, pp 27–43

Heslop-Harrison J (2012) Genetics and genomics of crop domestication. University of Leicester, Leicester. 10.10.16/B978-0-12-381466.0001-8

IPCC (2007) New assessment methods and the characterization of future conditions. In: Climate change 2007: impacts, adaptation and vulnerability. The Contribution of Working Group II to the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, p 976

IPCC (2014) Climate change 2014: synthesis report. The Contribution of Working Groups I, II and III to the 5th Assessment Report of the Intergovernmental Panel on Climate Change Core Writing Team, R.K. Pachauri and L.A. Meyer (Eds.). IPCC, Geneva, pg. 151.

Jackson P, Robertson M, Cooper M, Hammer G (1996) The role of physiological understanding in plant breeding, from a breeding perspective. Field Crop Res 49(1):11–37

Jaradat AA (2012) Wheat landraces: genetic Resources for sustenance and sustainability, USDA-ARS, 803 Iowa, Morris, MN 56267 USA, pp 1–20

Jaradat AA (2013) Wheat landraces: a mini review. Emirates J Food Agric 25(1):20–29

Kabbaj H, Sall AT, Al-Abdallat A, Geleta M, Amri A, Filali-Maltouf A, Belkadi B, Ortiz R, Bassi FM (2017) Genetic diversity within a global panel of durum wheat (*Triticum durum*) landraces and modern germplasm reveals the history of alleles exchange. Front Plant Sci 8(1277):1–13

Karagöz A (2014) Wheat landraces of Turkey. Emirates J Food Agric 26(2):149–156. https://doi.org/10.9755/ejfa.v26i2.16397

Kastner T, Rivas MJI, Koch W, Nonhebel S (2012) Global changes in diets and the consequences for land requirements for food. Proc Natl Acad Sci 109:6868–6872

Krupa SV (1997) Global climate change: processes and products-an overview. Environ Monit Assess 46:73–88

Lenart M, Jones C, Kimball B (2006) Rising carbon dioxide levels and forest management, climate change and variability in the southwest ecosystem series, The University of Arizona, College of Agriculture and Life Sciences Arizona Cooperative Extension, AZ1395, p 4

Lobell DB, Burke MB, Tebaldi C, Mastranddrea MD, Falcon WP, Naylor RL (2008) Supporting online materials for prioritizing climate change adaptation needs for food security in 2030. Science 319:607–610

Lopes MS, El-Basyoni I, Baenziger P, Singh S, Royo C, Ozbek K, Aktas H, Ozer E, Özdemir F, Manickavelu A, Ban T, Vikram P (2015) Exploiting genetic diversity from landraces in wheat breeding for adaptation to climate change. J Exp Bot 66(12):3477–3486. https://doi.org/10.1093/jxb/erv122

Marin F, Nassif DSP (2013) Mudanças climáticas e a cana-de-açúcar no Brasil: fisiologia, conjuntura e cenário futuro. Revista Brasileira Engenharia Agrícola Ambiental 17(2):232–239

Maxted N, Kell S (2009) Establishment of a global network for the *in situ* conservation of crop wild relatives: status and needs, FAO Commission on Genetic Resources for Food and Agriculture, Background Study Paper No 39, pp 1–112, Rome, Italy

Mei H, Chengjun JI, Wenyun Z, Jinsheng HE (2007) Interactive effects of elevated CO_2 and temperature on the anatomical characteristics of leaves in eleven species. Acta Ecol Sin 26:326–333

Mengü GP, Şensoy S, Akkuzu E (2008) Effects of global climate change in agriculture and water resources, Balwois-Ohrid, Republic of Macedonia 27–31 May 2008, p 10

Mercer KL, Perales HR (2010) Evolutionary response of landraces to climate change in centers of crop diversity. Evol Appl 3:481–493

Nasserlehaq N, Amamou A, Taghouti M, Annicchiarico P (2011) Adaptation of Moroccan durum wheat varieties from different breeding eras. J Plant Breed Crop Sci 3(2):34–40

Nema P, Nema S, Roy P (2012) An overview of global climate change in the current scenario and mitigation action. Renew Sustain Energy Rev 16:2329–2336. https://doi.org/10.1016/j.rser.2012.01.044

Özberk F, Karagöz A, Özberk İ, Ayhan AT (2016) Buğday genetik kaynaklarından yerel ve kültür çeşitlerine; Türkiye'de buğday ve ekmek. Tarla Bitkileri Merkez Araştırma Enstitüsü Dergisi 25(2):218–233. [In Turkish]

Prasad PK (2009) Effects of agriculture on climate change: a cross-country study of factors affecting carbon emissions. J Agric Environ 10:72–88

Raza A, Razzaq A, Mehmood SS, Zou X, Zhang X, Lv Y, Xu J (2019) Impact of climate change on crops adaptation and strategies to tackle its outcome: a review. Plants 8(34):1–29

Richards RA, Condon AG, Rebetzke GJ (2015) Chapter 88–100. In: Reynolds MP, Ortiz-Monasterio JI, McNab A (eds) Application of physiology in wheat breeding. CIMMYT, Mexico, D.F, p 219

Rogers HH, Runion GB, Krupa SV (1994) Plant responses to atmospheric CO2 enrichment with emphasis on roots and the rhizosphere. Environ Pollut 83:155–189

Romanova AK (2005) Physiological and biochemical aspects and molecular mechanisms of plant adaptation to the elevated concentration of atmospheric CO_2. Russian Journal of Plant Physiology 52:112–126

Rosenzweigh C, Hillel D (1995) The potential impact of climate change in agriculture and food supply. Consequences 1:24–32

Rötter R, Van de Geijn SC (1999) Climate change effects on plant growth, crop yield and livestock. Clim Change 43:651–681

Sayılğan Ç (2016) Küresel sıcaklık artışının buğdayda beklenen etkileri ve yüksek sıcaklığa toleranslılığın fizyolojik göstergeleri, YYUniv. J Agric Sci 26(3):439–447. [In Turkish]

Schlenker W, Roberts MJ (2009) Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change. Proc Natl Acad Sci 106:15594–15598

Şehirali S, Özgen M (1987) Bitki genetik kaynakları. Ankara Üniv. Zir. Fak. Yay. No: 1020/, p 294, Ankara [In Turkish]

Semenov MA, Stratonovitch P, Alghabari F, Gooding MJ (2014) Adapting wheat in Europe for climate change. J Cereal Sci 59:245–256

Shah NH, Paulsen GM (2003) Interaction of drought and high temperature on photosynthesis and grain filling of wheat. Plant and Soil 257:219–226

Stamp P, Visser R (2012) The twenty-first century, the century of plant breeding. Euphytica 186:585–591

Taiz L, Zeiger E (2013) Fisiologia vegetal, 5th edn. Porto Alegre, Artmed, p 918

Tricker PJ, Elhabti A, Schmidt J, Fluery D (2018) The physiological and genetic basis of combined drought and heat tolerance in wheat. J Exp Bot 69(13):3195–3210

Tubiello FN, Ewert F (2002) Simulating the effects of elevated CO_2 on crops: approaches and applications for climate change. Eur J Agron 18:57–74

Tubiello FJ, Donatelli M, Rosenzweig C, Stockle CO (2000) Effects of climate change and elevated CO_2 on cropping systems: model predictions at two Italian locations. Eur J Agron 13:179–189

Ulukan H (2008) Agronomic adaptation of some field crops: a general approach. J Agron Crop Sci 194:169–179

Ulukan H (2009) The evolution of cultivated plant species: classical plant breeding versus genetic engineering. Plant Syst Evol 280:133–142

Uzmen R (2007) Global warming and climate changing, is it a catastrophe for humanity ?, Knowledge and Culture Publ., No 221, Ankara, Turkey, p 176. [in Turkish]

Valizadeh J, Ziaei SM, Mazloumzadeh SM (2014) Assessing climate change impacts on wheat production (a case study). J Saudi Soc Agric Sci 13:107–115

Villa CCT, Maxted N, Scholten M, Ford-Lloyd B (2006) Defining and identifying crop landraces. Plant Genet Res 3(3):373–384

Zavarzin AG (2001) The role of biota in global climate change. Russ J Plant Physiol 48(2):265–272

Zencirci N, Ulukan H, Ordu B, Aslan D, Mutlu TH, Örgeç M (2019) Salt, cold, and drought stress on einkorn and bread wheat during germination. Int J SecondMetab 6(2):113–128

Zhai F, Zhuang J (2009) Agricultural impact of climate change: a general equilibrium analysis with special reference to Southeast Asia. ADBI working paper 131. Tokyo, Asian Development Bank Institute, p 21