Chapter 9
Climate Resilience Technologies for Wheat Production

Zahoor Ahmad, Ejaz Ahmad Waraich, Celaleddin Barutçular, Aiman Hina, Asim Abbasi, Muhammad Mohiuddin, Inzamam Ul Haq, Muhammad Ashar Ayub, and Sundas Sana

Abstract Climate change has greatly influenced overall agricultural production. Pakistan is an agricultural economy, and agriculture is the source of income for the majority of the population. Unfortunately, agriculture is most sensitive to climatic irregularities because drought, salinity, and heat stress are major causes of yield decline in both major and minor crops. This chapter provides useful insights regarding strategically utilization of the most recent research findings to speed up the development of wheat genotypes having resistance against climatic irregularities. The recommended strategies discussed in this chapter develop a link between translational research and breeding strategies. This chapter also addresses research gaps which together are anticipated to enhance wheat yield particularly under heat and

Z. Ahmad (✉)
Department of Botany, Constituent Punjab College, University of Central Punjab, Bahawalpur, Pakistan

E. A. Waraich
Department of Agronomy, University of Agriculture Faisalabad, Faisalabad, Pakistan

C. Barutçular
Department of Field Crops, Faculty of Agriculture, Cukurova University, Adana, Turkey

A. Hina
Ministry of Agriculture (MOA), National Centre for Soybean Improvement, State Key Laboratory for Crop Genetics and Germplasm Enhancement, Nanjing Agricultural University, Nanjing, China

A. Abbasi · M. Mohiuddin
Department of Environmental Sciences, Kohsar University Murree, Murree, Pakistan

I. U. Haq
College of Plant Protection, Gansu Agricultural University, Lanzhou, China

M. A. Ayub
Institute of Agro-Industry and Environment, The Islamia University of Bahawalpur, Bahawalpur, Punjab, Pakistan

S. Sana
Department of Botany, Sub Campus Rahim Yar Khan, The Islamia University of Bahawalpur, Bahawalpur, Pakistan

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drought stress. In addition to meet the demand of local growers, breeders must ensure the release of improved varieties having wider adaptation to support the efficacy of selection program. The genotype × environment interactions (GEI) are directly or indirectly linked to the existing biotic and abiotic stresses, soil nourishment status, agronomic practices as well as genetic composition of any crop. In order to enhance the efficiency of different breeding strategies, understanding the basis of GEI is prerequisite. Furthermore, modeling techniques that take into account environmental and genomic data could be used to locate genetic locus underlying stability across multiple locations and abiotic stress response. In addition, the technique of crop simulations will help to understand the fundamentals of GEIs and could be useful in predicting morphological characterization and growth trend in wheat genotypes when projected to various stressed of varying intensity. It is also possible to transfer genes between artificially hybridized and bread wheat by the backcrossing breeding method. By backcrossing with high-yielding wheat cultivars, the breeder could obtain an upraise of 10–40% in yield of synthetic wheat even in drought and stress conditions. By using recombinant inbred lines (RILS) and near-isogenic lines (NILS), 1RS translocation lines of rye have demonstrated high levels of tolerance and greater biomass production under heat and stress conditions. Similar to gene editing, gene cloning is also not very common in developing improved genotypes with better adaptation options against stress. Additionally, the use and regulation of genome edit technologies such as CRISPR/Cas9 system are still in ambiguity which has made it difficult to integrate such technologies into breeding program with an international focus.

Keywords Climate resilience · Wheat · Genomic technologies · Drought · Heat

1 Introduction

Climate change poses a significant threat to wheat production, as it leads to unpredictable weather patterns and increased incidence of extreme weather events such as droughts and floods. Different climate variables have varying impacts on different crops and regions. Recent years have seen an expansion of grain-sown area and increase in grain production due to increased heat caused by climate change (Pickson et al. 2020; Yang et al. 2015). However, high temperatures can negate the positive effects of increased rainfall and CO_2 concentrations on crop production in certain areas (Malhi et al. 2021; Dai et al. 2018). Climate change also negatively impacts grain production by increasing the occurrence of pests and diseases, shortening crop growth cycles, and increasing the frequency of extreme weather events (Wang et al. 2021; Chen et al. 2018).

To mitigate these impacts and ensure the continued productivity of wheat crops, farmers are turning to a range of climate resilience technologies for ensuring food security and sustainable agricultural practices in the face of increasing climate variability and extreme weather events. These technologies include a range of genetic, agronomic, and management practices that can help farmers adapt to changing conditions and protect their crops from the effects of drought, heat, and extreme weather (Bei et al. 2022; Belton et al. 2021; Jiang et al. 2020).

One technology that can help to increase the resilience of wheat crops to drought is the use of drought-tolerant wheat varieties. These varieties have been bred to have deeper roots, better water-use efficiency, and improved tolerance to high temperatures (Bapela et al. 2022). Crop rotation is another farming practice that can help to increase the resilience of wheat crops to the impacts of climate change. By rotating crops, farmers can improve soil health, reduce pest and disease pressures, and increase overall crop yields (Jalli et al. 2021). Climate-smart farming practices such as conservation agriculture, agroforestry, and the use of weather and climate information in crop management can also help to increase the resilience of wheat production to climate change. By adopting these practices, farmers can ensure that their crops are better able to withstand the impacts of extreme weather events and continue to produce high-quality wheat. Technologies such as precision irrigation and precision fertilization can help farmers use water and fertilizer more efficiently, which can be especially important in regions that are becoming drier or more water-stressed due to climate change. For example, a study found that precision irrigation led to higher wheat yields and reduced water use in a region that was experiencing drought (Djanaguiraman et al. 2020).

Climate-resilient wheat breeding using precision breeding, genome editing, and gene editing can also help to breed more resilient wheat varieties that can adapt to the changing climate. This chapter highlights these technologies and discusses their role to ensure that wheat crops are better able to withstand the impacts of extreme weather events and continue to produce high-quality wheat (Gul et al. 2022; Abbas 2022; Zhang et al. 2022). These practices are essential for ensuring food security and sustainable agricultural practices in the face of increasing climate variability and extreme weather events.

2 Climate Change Trends and Their Impact on Agricultural Productivity

Climate consists of complex structures with spatiotemporal dynamics. Naturally, the earth's sphere constantly remains in a variable and unstable state, experiencing various configurational dimensions which cause irregularities in climatic conditions. It is stated that the existing climate is different compared to the Mesozoic era and is continuously undergoing changes (Mac et al. 1998). Intergovernmental panel on climate change (IPCC) endorsed the side effects of climate change, namely, temperature fluctuations, increased water flow from ice caps, and glaciers causing them to melt faster and unexpected rise in sea levels around the globe (IPCC 2007). This whole scenario has become a burning issue of every debate; therefore, several think tanks and people from different schools of thought are sitting together to find applicable and universal preventive measures which can be adopted globally (IPCC 2007).

Studies showed that climatic changes may be caused due to natural or man-made factors, e.g., severe rainfall, deforestation, and extinction of natural flora and fauna due to urbanization. Sadly, all these factors are slowly damaging the natural ecosystem, destroying the natural habitat of animals, adding poisonous gases to human breath, and leading to an unhygienic place for living (Singh 2007; IPCC 2007). According to the facts stated by several studies, excessive emission of toxic gases from fuel consumption has damaged and reduced the greenhouse effect which is not only risking human lives but also impacting the national economy and food security.

Pakistan is an agricultural economy, and agriculture is the source of income for the majority of the population. Unfortunately, agriculture is most sensitive to climatic irregularities because drought, salinity, and heat stress are major causes of yield decline in both major and minor crops (Deschenes and Greenstone 2007; Timmins 2006; Schlenker and Roberts 2006; Ashenfelter and Storchmann 2006). Therefore, underdeveloped nations are more vulnerable to the losses and damages caused by climatic aberrations, 8–11% more compared to developed nations. Furthermore, this devastating situation has also increased the cases of depression, theft, and anxiety among such nations (Alteiri and Nicholls 2017; Lesk et al. 2016).

Climate change brings lots of inevitable disasters, among them food insecurity is top-ranked. Among the 17 Sustainable Development Goals (SDG), the first and second goals focus on no poverty and zero hunger, respectively. Considering these two goals, it is predicted to achieve zero hunger by the end of 2030 which seems impossible to attain under the current circumstances of climate change as to statistics around 815 million population are suffering from malnutrition (Richardson et al. 2018).

The agricultural sector always endures heavy production losses, with each degree rise in temperate. Data have shown an instant decline in the yield of both commercial and staple crops after a strong heat wave, flooding, or prolonged drought (Ito et al. 2018). The overall crop production is estimated to decline at a much faster rate than before because the temperature jumps from 2.6 °C to reached 4 °C (Rogelj et al. 2016). Moreover, the existing cropping pattern followed by the farming community is not enough strong to cope with the seventies of climate (Reckling et al. 2018).

Currently, the changes in rainfall patterns, temperature extremes, and increased insect pest infestation are paving the way for maximum crop production loss which will result in scarcity of basic food items (Dhanker and Foyer 2018; Campbell et al. 2016; Kang et al. 2009). These fluctuations in temperature and expected decline in crop yield are leading toward the onset of World War IV which will be on the issue of food security. Therefore, improving and securing food grain should be the fundamental objective of future studies. This chapter discusses and highlights the damages caused by climate change and tried to suggest mitigation strategies to cope with the calamities caused by climate irregularities.

2.1 Temperature

Temperature elevations are one of the best methods to explain climate change because temperature fluctuations or extremes affect almost aspect of human lives as well as the national economy of every country (Rasul et al. 2011). For example, during the plant growth cycle, temperature balance is very critical as it influences the majority of the important growing and reproductive metabolisms. In the case of wheat, rice, sorghum, barley, and oats crops, the flowering stage is very critical. Under stress conditions, slight temperature changes can cause delayed flowerings or permanent sterility (Barnabás et al. 2008; Winkel et al. 1997; Saini and Aspenal 1982). Similar studies reported about a 35–75% decrease in grain setting because of water scarcity (Sheoran and Saini 1996; Saini and Aspenal 1981). If the temperature rises to more than 35 °C, it causes hindrance in the process of photosynthesis (Griffin et al. 2004). In maize, heat stress is reported to impact antioxidant activity (Gong et al. 1997). According to a report, in Mexico, where *Zea mays* is the leading crop, it is predicted that in near future, overall crop production will decline by up to 25.7%, among them maize would face more yield losses (Hellin et al. 2014). Moreover, when both drought and heat stress are combined in cereal crops, it causes more yield loss and destruction (Wang and Huang 2004).

2.2 Drought

The quality of the grain may alter significantly as a result of the water availability; the changes vary depending on whether there is too much or not enough water. Drought-affected plants have a lower photosynthetic activity which has an impact on grain production (Jiang et al. 2009; Ahmad et al. 2022; Bukhari et al. 2022). Proteins must build up in the grain to produce high-quality grain; however, the availability of water, a suitable plant-growing environment, and nutrient conditions have a significant impact on this process (Rodrigues and Teixeira 2010; Ahmad et al. 2021). According to Kobayashi et al. (2018), over a 115-day cycle, wheat used an average of 347.2 mm of water or around 3.02 mm daily. The consumption was 0.70 mm day^{-1} during the establishment phase, 0.93 mm per day during the tillering phase, 2.21 mm day^{-1} during the booting phase, 3.74 mm per day during the blooming phase, and 2.12 mm day^{-1} during the grain maturation phase. Moreover, the critical times for water stress are the end of the tillering phase, the commencement of stem elongation, throughout head development, and the commencement of the blooming period (Sharma and Singh 2022; Yimere and Assefa 2022). Moreover, indeed, some tillers will not produce spikes if they experience water stress during the stem elongation period. Water scarcity during the milking stage of kernel growth also affects the yield of the wheat plant. Conversely, the vegetative development, which is often most impacted by the interruption of irrigation in the early heading stage, productivity was more vulnerable to stress during the emergence of the head

(Moreira and Cardoso 2009). In their study of water stress in four stages of development (tillering, booting, grain filling, and physiological maturity), Zulkiffal et al. (2021) found that water stress decreased grain yield by 22.7% during the tillering stage, 41.6% during booting stage, and 9.1% during grain filling stage. As a result, the impacts of low water availability vary depending on the plant's phenological stage, the length of the water stress, and its severity.

2.3 Rainfall

Current climatic changes such as droughts, floods, cold and heat waves, and abrupt rainfall patterns significantly affect the output of field crops particularly those grown in areas (Olayide et al. 2016; Rasul et al. 2002). Among these climatic variations, rainfall is vital ecological factors that significantly affect crop yield, growth, and normal development. Mostly, smallholder farmers are the ones which are greatly affected by the uncertain rainfall patterns (Mar et al. 2018; Ndamani and Watanabe 2015). Rainfall causes soil erosion which depletes soil nutrients and ultimately hinders crop growth and yield (Zike 2019). Preceding crop patterns and future rainfall sequences significantly diminish wheat leaf area index, plant height, crop growth, and root colonizing arbuscular mycorrhizal fungi (AMF) (Tataw et al. 2016). The decline in seasonal rainfall is usually associated with decreased soil humidity which exerts pressure on soil moisture resulting in decreased plant growth and yield. Moreover, population and damage potential of certain crop pathogens are also affected with soil and air moisture contents. An upsurge in soil and air moisture is usually correlated with increased rainfalls which provide a conducive environment for growth of certain disease-causing pathogens (Coakley et al. 1999).

3 Climate-Resilient Technologies for Enhancing Wheat Growth under Stresses

The recommended strategies discussed in this chapter develop a link between translational research and breeding strategies. This chapter will also address the existing research gaps which together are anticipated to enhance wheat yield particularly under different stresses, e.g., drought and heat (Reynolds et al. 2021).

3.1 Crop Design Targets by Using De Novo Genome Assembly

Breeders must ensure that their varieties offer enough wider adaptation to support the investment and scope of their selection program while also ensuring that they fulfill the local needs of growers. Hence, plant breeders must find ways to maintain a balance between crop yield and its adaption stability for a particular set of given ecological conditions, while ensuring that new crop cultivars should have the ability to withstand against multi environments. Hence, the process of crop improvement is very delicate and requires a lot of expertise, along with few difficulties. On top, selecting a suitable parent is a very crucial step in all breeding programs especially under multiple environments where environment interactions (GEIs) are an important factor to consider as well. The genotype × environment interactions (GEI) are directly or indirectly linked to the existing biotic and abiotic stresses, soil nourishment status, agronomic practices as well as genetic composition of any crop. In order to enhance the efficiency of different breeding strategies, understanding the basis of GEI is prerequisite (Reynolds et al. 2021).

3.2 Screening of Stress-Resistant Germplasm to Refine Breeding Targets

Although major portion of wheat cultivated area is under severe threat of drought and heat, various wheat breeding programs still lack efficient screening protocols of wheat cultivars and usually utilize quite general drought and heat stress criteria (Braun et al. 2010). Moreover, various breeding programs are vulnerable to global climatic changing patterns. During breeding schemes, some important factors cannot be ignored such as soil nutritional shortages or toxic effects, and biotic stressors, because if not correctly detected, it may compromise the genetic gain and understanding of molecular and biochemical mechanism of stress adaption (Mathews et al. 2011; Bagci et al. 2007).

As a result, elucidating the various stress profiles to which wheat must respond such as acquiring morphological and adaptive features and improved yield of a specific area. Screening of significant genotypes depicting resistance against drought and heat under severely stress affected areas along with diverse range of ecological conditions (Opare et al. 2018; Ramírez-Villegas et al. 2011). A few characteristics with maximum response toward GEIs could be used to draw information about the combined effect of phenological and physiological dataset as well as weather forecasts, soil type, and required agronomic practices could also be predicted (Reynolds et al. 2004). This method allows the identification of molecular markers that are related to tolerance to certain stress profiles, as well as the primary consequences of high temperatures and/or drought (Messmer et al. 2009). Selective trialing may go further in terms of exact phenotypic expression, critical physiological features, and accurate environmental characterization; however, it is only possible to do so at a limited range of locations based on the resources available. However, the results of this research may be utilized to improve the methods for data acquisition, which will allow the fundamental issues of GEI to be solved on a much broader scale.

3.3 Prediction of Phenological Wheat Growth under Drought and Heat Conditions

Genotype × environment interactions have strong impact on plant development and number of grains produced (Reynolds et al. 2020). The technique of crop simulations will help to understand the fundamentals of GEIs and could be useful in predicting morphological characterization and growth trend in wheat genotypes when projected to various stressed of varying intensity (Wallach et al. 2021). In crops, extreme temperature always influences the heading stage, grain filling duration whereas unavailability of water causes decline in nutrient intake of crop and eventually affects crop growth which is detrimental to crop production. Therefore, use of global girded crop models (GGCM) combining the crop and climate simulation models is suggested to lessen the crop production losses. The consortium was developed between three members, namely, University of Florida (UF), International Food Policy Research Institute (IFPRI), and CIMMYT. This consortium established the three global gridded crop models (GGCM) in wheat (NWheat, CROPSIMCERES, and CROPSIM) with the idea to increase the spatial modeling capability of wheat to assess any climatic irregularities (Pequeno et al. 2021; Hernandez-Ochoa et al. 2019; Gbegbelegbe et al. 2017). Similarly, another crop simulation technique, namely, the mink system is also reported to use in agriculture (Robertson 2017). Recently, CIMMYT's high-performance computer clusters have also been using this technology to execute analyses of time period between 1980 and 2010 to calculate the net worth of these 30 years and at the same time to predict future climatic conditions during 2040–2070 (Pequeno et al. 2021; Lopes et al. 2018; Asseng et al. 2002). It is hoped that the use of these simulation models would help in better defining of future breeding targets by considering the environmental factors, crop development, and growth directions and important introgression of important traits that contribute adaptation and stability.

3.4 Introgression of Climate-Resilient Genetic Materials from Landraces

The hexaploid wheat developed by hybridizing *Triticum durum* (AABB) × *Aegilops tauschii* (DD) has demonstrated the ability to survive under the extreme environmental condition which was contributed from the wild diploid ancestor *A. tauschii* (Zhang et al. 2018; Elbashir et al. 2017; Sohail et al. 2011; Trethowan and Mujeeb-Kazi 2008; Chevre et al. 1989; Kihara and Lilienfeld 1949). Therefore, without interfering with naturally occurring meiotic division, it is also possible to transfer genes between artificially hybridized and bread wheat by the backcrossing breeding method. By backcrossing with high-yielding wheat cultivars, the breeder can obtain a raise of 10–40% in yield of synthetic wheat even in drought and stress conditions (Cossani and Reynolds 2015; Lopes and Reynolds 2011; Narasimhamoorthy et al.

2006; del Blanco et al. 2001). To date, almost 85 synthetically developed wheat have been approved for general cultivation and are growing on more than 6% of field area in India (Aberkane et al. 2020). Wild relatives of bread wheat are blessed with the indispensable rich source of elite genetic materials conferring resistance against biotic and abiotic stresses and for improved yield. For instance, the transfer of the *Thinopyrum 7E* gene increases the 13% wheat yield (Reynolds et al. 2001).

Similarly, the introgression of *A. ventricosa* and 1RS translocation Rye is the most successful examples of working collections in CIMMYT during the early 1980s (Juliana et al. 2019; Sharma et al. 2009; Braun et al. 1998; Singh et al. 1998). By using recombinant inbred lines (RILS) and near-isogenic lines (NILS), 1RS translocation lines demonstrated high levels of tolerance and greater biomass production under heat and stress conditions (Sharma et al. 2018; Pinto and Reynolds 2015; Hoffmann 2008; Zarco-Hernandez et al. 2005; Ehdaie et al. 2003; Villareal et al. 1995; Schlegel and Meinel 1994; Ludlow and Muchow 1990). Conversely, 1RS was reported to decrease grain production under water deficit conditions which show the influence of genotype × environment interactions (Tahmasebi et al. 2015; Peake et al. 2011). Several translocation lines have been created overall, but because of their history and agronomically undesirable traits, they have not been used in wheat breeding (Hao et al. 2020; Kishii 2019; Friebe et al. 1996).

Almost 10% of the wild relatives that have been captured are likely to have been employed in interspecific crossing also, few of them are examined to assess genetic variation linked to a trait that may increase yield or climate resistance (Hao et al. 2020; Kishii 2019; Friebe et al. 1996). Any *Aegilops* species can be used to create new amphidiploids, which are diploid hybrids to discover novel sources of resistance in addition to creating synthetic hexaploid kinds of wheat. Additionally, cytogenetics that is currently being expedited by the marker is a very efficient and uncontroversial method for transferring genes between related species to create superior lines technology (King et al. 2017).

3.5 Application of Phenomics for Selection of Elite Parents

The foundation of plant breeding is phenotyping, and the effectiveness of using genomic technologies is based on how well and how pertinently phenotyping is done. Rigid phenotyping must support genetic and physiological understanding to speed genetic gain, particularly using new genetic material into new crossing schemes (Reynolds et al. 2020; Molero et al. 2019; Rebetzke et al. 2018). Current breeding stock is the most readily available and rich source of genetically diverse germplasm for multiple stress-tolerant/resistant/adaptive characteristics. It is interesting to note that choosing parents among advanced breeding lines does not yet typically involve comprehensive physiological or genetic dissection (Rai et al. 2018; Varshney et al. 2018; Crain et al. 2018). Hence, advances in field phenotyping have made it possible to choose adaptable features at a breeding level and have eliminated inherent biases associated with dependence on spatial evaluations.

Although these qualities can contribute to breeding for certain conditions, they are also prone to genotype × environment interactions (GEI), namely, crop yield (Reynolds and Langridge 2016; Richards 2006). It is obvious from the significant efforts of corporate and public sector breeders of adapting high-throughput phenotyping (HTP), for effective and accurate selection (Roitsch et al. 2019; Gaffney et al. 2015).

Use of distant remote sensing technologies may help to morphologically characterize crops at reproductive stages in an eco-friendly manner which could help to increase the effectiveness of HTP (Araus and Kefauver 2018; Araus and Cairns 2014). Moreover, high throughput is also considering for precise and accurate phenotyping of few traits which are difficult to estimate via HTP (Reynolds et al. 2020; Molero et al. 2019; Reynolds and Langridge 2016; Richards et al. 2010). Field phenotyping technologies have proliferated recently and yet only a few numbers have been demonstrated to be effective before and during breeding procedures (Araus and Kefauver 2018; Araus and Cairns 2014). Using various spectral reflectance indices, remote sensing may be used to quantify the expression of attributes conferring stress adaptability, namely, earliness, vigor, biomass production, pigmentation, and water intake capacity of plants.

In addition to performing geographically and temporal growth analyses, few new methods, namely, low altitude RGB (red, green, and blue) images have been employed to calculate vegetation cover and phenological assessment. Hence, more precise phenotyping protocols must be established to discriminate between pertinent traits during different phases of breeding schemes and translational research. These protocols must take into account considering other factors as well such as day time, crop development stage weather, and environmental conditions while collecting data along with mode of cultivation (Reynolds et al. 2020). Root vigor and depth play a pivotal role in dealing with heat and drought, making them essential traits. Substantial progress has been made in high-throughput phenotyping technologies that rely on imaging principles. However, it's worth noting that these technologies often demonstrate their effectiveness primarily in controlled environments. Excavating roots for visual inspection or measuring plant DNA extracted from soil samples remain the only effective screening method under field conditions, although they have a low processing capacity (Pinto and Reynolds 2015).

3.6 Prediction of Root Features by Developing Selection Index

Currently, in breeding populations, root capacity cannot be taken into serious consideration due to the lack of compatible screening technique with field. However, there is reason to believe that root capacity could be predicted by remote sensing methods thanks to a few examples (Pinto and Reynolds 2015; Lopes and Reynolds 2010). A strong association has been observed between canopy temperature (CT) with root mass under drought and heat stress conditions (Pinto and Reynolds 2015) which suggests the possibility to establish a screening protocol of root on the basis of remotely sensed characters, which could generate root index. This advancement could enhance the selection procedure for root characters and could be used in traditional wheat breeding schemes. In addition to CT, other features such as water index (WI), carbon isotope discrimination (CID), and oxygen isotope enrichment could be useful for extracting further necessary information (Gutierrez et al. 2010; Cabrera-Bosquet et al. 2009). Furthermore, shoot biomass and WI represent strong correlation which could facilitate effective assessment of root capacity (Babar et al. 2006).

Under different stress conditions, root capacity can also be measured by calculating WI, CT water scarcity conditions, and then simulating all these factors together with oxygen isotope enrichment and CID. This data modeling will give total root biomass, estimates of root index, and root capacity; these findings could have significant advantages for root research in general as well as other crops.

3.7 Association of Rhizosphere with Genotype to Determine Abiotic Stress

The diversification of soil microbiome is strongly influenced by the plant genotype as well as the environment (Latz et al. 2021). The genetic composition and population size of the rhizospheric microbiota are also directly influenced by genetic characteristics, e.g., root structure and composition, which vary greatly from one to another species (Sasse et al. 2018; Schweitzer et al. 2008). There is a lot of interest in determining the effect of rhizosphere microbiota in enhancing overall crop development and growth such as nutrient transport in wheat (Azarbad et al. 2018; Ahkami et al. 2017; Donn et al. 2015; Yang et al. 2009). For instance, new research indicates that plants under drought stress alter the genetics constitution of root exudates for enhanced activity of microbes. As a reward, this can produce favorable post-drought circumstances brought on by plants, such as increased nutrient availability, for plant regeneration. Therefore, it may be assumed that specific genotypes with modified exudation patterns following drought events produce a microbiota to develop better resistance to drought conditions (de Vries et al. 2019). It raises few more questions such as when used in a breeding scheme, whether rhizospheric microbiota could be influenced by the association with specific genotype under stress conditions. One study in wheat answered to such question by showing significant association between host plant and phyllosphere (Bradáová et al. 2019; Hafez et al. 2019; Sapkota et al. 2015).

3.8 Understanding of Genetic Mechanisms of Climate Resilience in Crops

For genetics studies, morphological characters such as plant height in wheat and soybean could be an under drought and heat stress conditions and provide useful dataset. These genetic mapping studies include nested association mapping (NAM) and genome-wide association studies (GWAS). Quantitative trait loci (QTL) mapping can be used to describe and compile information on both well-known and unknown genetic areas associated to heat and drought adaptation. To achieve this, genomic areas from various mapping studies are matched to pan-genomes or reference genomes of wheat that are readily available, enabling comparisons between research at the level of physical position. By reviewing these comparisons, one can then detect hotspot segments or clusters that contain markers associated with stress, indicating that these markers have a crucial and consistent role in a range of genetic backgrounds and contexts. The results of meta-analysis studies could be used to compute global P-value using summary statistics across several GWAS data (Soriano and Alvaro 2019; Acuna-Galindo et al. 2015; Griffiths et al. 2009). In single meta-analysis studies, the estimates of single nucleotide polymorphism (SNP) depicted false-positive effects by using larger sample size (Joukhadar et al. 2021; Montenegro et al. 2017; Evangelou and Ioannidis 2013). CIMMYT has already released high-quality 08 wheat lines, highly adaptable to stress, in addition to that, next-generation sequencing profiles of hundreds of important breeding lines developed by CIMMYT are now accessible for further exploration. The aforementioned cross-cutting genetic and agronomic resources will be essential ancillaries for manipulating genetic materials, enabling a novel method of identification of alleles and the search for highly valuable useful variations. The promise of epigenetics is not explored in this chapter because it will require more knowledge than is now accessible to translate (Varotto et al. 2020). Similar to gene editing, gene cloning is also not very common in developing improved genotypes with better adaptation options against stress. Additionally, the use and regulation of genome edit technologies such as CRISPR/Cas9 system are still in ambiguity which has made it difficult to integrate such technologies into breeding program with an international focus.

4 Conclusion

Climate change is bringing inevitable calamities to the earth's sphere. These changes are increasing threats to food security and national economy. In Pakistan, wheat is consumed as staple crop; therefore, it is very important not only to improve yield but also to develop climate-resilient wheat varieties. Although conventional breeding approaches have played significant role in the development of drought- and heat-resistant cultivars, still there is a dire need to take advantage of new technologies such as introgression of genes from wild species, identification of genomic spots harboring stable and elite QTLs, identification of candidate genes underlying these QTLs, and genetic manipulation of germplasm by using genome edit technologies to develop climate-smart wheat.

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