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Muhammad Sajid Aqeel Ahmad
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Crop Production for Agricultural Improvement

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Editors
Muhammad Ashraf
Department of Botany
University of Agriculture
Jail Road
Faisalabad
Pakistan

Münir Öztürk
Center for Environmental Studies
Ege University
Science Faculty Building A-Block
Bornova, Izmir
Turkey

Muhammad Sajid Aqeel Ahmad
Department of Botany
University of Agriculture
Jail Road
Faisalabad
Pakistan

Ahmet Aksoy
Department of Biology
Erciyes University
Rektörlüğü
Melikgazi, Kayseri
Turkey

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Chapter 1
Crop Improvement Through Different Means: Challenges and Prospects

Muhammad Ashraf, Muhammad Sajid Aqeel Ahmad, Münir Öztürk, and Ahmad Aksoy

Contents

Abstract In the recent years, the looming food scarcity problem has transformed plant sciences as an emerging discipline committed to devise new strategies for enhanced crop productivity. The major factors causing food scarcity are biotic and abiotic stresses such as plant pathogens, salinity, drought, flooding, temperature extremes, nutrient deficiency or excess, etc. which substantially limit crop productivity world-wide. In this scenario, such strategies should be adopted which may be

M. Ashraf (✉) • M.S.A. Ahmad
Department of Botany, University of Agriculture, Faisalabad, Pakistan
e-mail: ashrafbot@yahoo.com; sajidakeel@yahoo.com

M. Öztürk
Centre for Environmental studies, Faculty of Science, Building A Block, Ege University, 35100, Bornova, Izmir, Turkey
e-mail: munirozturk@gmail.com

A. Aksoy
Faculty of Art and Sciences, Department of Biology, Erciyes University, 38039, Kayseri, Turkey
e-mail: aksoy@erciyes.edu.tr

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employed to achieve maximum productivity and economic crop returns under such adversaries. Major strategies include pathogen/pest management practices, breeding of new crop varieties, screening and selection of existing crop gene pool, production of genetically modified (GM) crops, exogenous use of osmoprotectants and plant hormones, agronomic and soil reclamation practices, sustainable use of available water supplies, etc. In this book, we have mainly focused on physiological, biochemical, molecular and genetic tools for crop improvement under environmental adversaries. In addition, the adverse effects of different biotic (diseases, pathogens, etc.) and abiotic (salinity, drought, high and low temperatures, metals, etc.) stresses on crop development and the potential strategies to enhance crop productivity under such stressful environments have been critically discussed. Moreover, the role of nutrient, water and soil management in improving crop efficiency is also a part of this book.

Keywords Crop production • Food security • Crop improvement • Stress tolerance • Disease resistance

1 Introduction

The rapidly increasing human population is causing a number of challenges to sustain life on earth. For example, we are losing biodiversity, degrading environment, facing food scarcity, over-exploiting natural resources and performing activities that lead to increased levels of abiotic stresses in our environment. Among these, food scarcity is surely the largest issue that directly or indirectly relates to environmental issues. In this situation, it is imperative to keep updated ourselves with advances in plant production science to meet these scientific challenges and thus overcome the increasing food scarcity and sustain life on earth. For this purpose, we are in need to develop new high yielding and stress tolerant varieties, through modern biotechnological, molecular and genetic tools. We should have enhanced knowledge of stress tolerance mechanisms and should develop methodologies to overcome the stresses. We need to understand our environment and ecosystems in the changing environment and develop methodologies to conserve it. For this purpose, we invited a number of scientists worldwide to review the current scenario of the problems, current development and future prospects of the challenges and their solutions. Their contributions are compiled in this book that is a valuable contribution towards our struggle for improved crop production to meet the demands of the growing human population.

2 Human Population Growth

With the announcement of the United Nations on October 31, 2011 that the World's population has crossed 7 billion, the hard question raised in our minds is "will the current population growth rate be supported by carrying capacity of the earth?" It is a fact that currently, approximately 2.5 babies are being added to the world population per second (US Census Bureau 2010). The current growth rate of world's population is 1.8%.

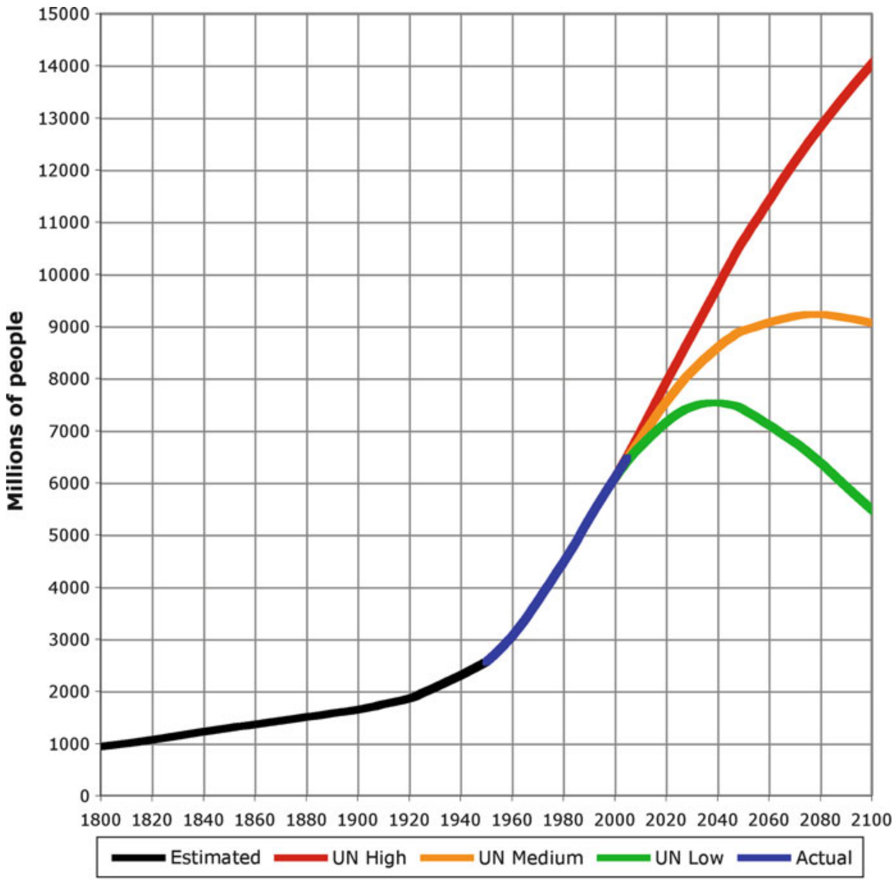

Fig. 1.1 The estimates of world population from years 1800 to 2100. The estimates are based on UN-2004 projections (*red*, *orange*, *green*) and US Census Bureau historical estimates (*black*). If the current growth rate continues, the world population will cross 14 billion at the end of twenty-second century that is almost double the current world population (7 billion) (Sources: UN 2004; U.S. Census Bureau 2010)

It is estimated that more than 120 million people will be added to the planet during the year 2011 while the deaths will be only about 70 million. So, there will be the addition of 50 million people to the planet this year (Population Institute 2011). The UN estimated that at the end of 2025 the human population will cross 8 billion while at the end of 2050 it could be over 10 billion. At the end of twenty-second century, the human population is projected to cross 14 billion (Bongaarts 1997; United Nations 2004). Where the most rapid growth would be? It is estimated to be in Asia and Africa, which will be the most crowded continents on earth. It is estimated that by the year 2025, out of 8 billion world's population, 6 billion will be living only in Asia and Africa. In comparison, the developed countries will be experiencing near zero population growth. Thus, at the end of year 2025, approximately 80% of world population will be living in under-developed countries of Asia and Africa (Fig. 1.1).

3 Global Demands for Food Supply

It is claimed that the food production on the globe is enough to support the world's current population. However, the fact is that a large proportion of the population is still starved. Since the start of twenty-first century, the proportion of malnourished people has been reported to be almost halved in the past 40 years. Nevertheless, recent estimates indicate that the proportion of malnourished/starved people is once again steadily increasing. For example, 843 million people under- or mal-nourished in 1990–1992 increased to 923 million in 2007 (FAO, 2010). In 2009, this figure further increased to 1023, while a little decrease in this figure was reported in 2010 as 925 million under- or mal-nourished people in the world. This shows that the share of malnourished/starved people in the world has steadily increased during the past two decades. If the current trend continues, one can easily estimate the situation of food supply in near future particularly in the developing countries (Figs. 1.2 and 1.3).

Although the statistics presented by FAO indicates that the proportion of hungry people has decreased significantly at the global scale, it is a fact that every day, almost 16,000 children (one child every 5 s) die from nutrition-related causes. According to another estimate, nearly 9 million children died before they reached their fifth birthday only in the year 2008. One third of these deaths were due directly or indirectly to hunger and malnutrition. Most of these deaths occurred in Asia Pacific and African countries including Chad, Congo, Ethopia, Niger and India (Fig. 1.4).

4 Global Food Production

Although, there are 250,000–300,000 known plant species on planet earth, only 150–200 of these are used by humans for dietary purposes. About 75% of the world's food is generated from only 12 plants and 5 animal species (FAO 1999a). Among these, only three crops (rice, maize and wheat) contribute ~60% of calories and proteins obtained by humans from plants, while animals provide about 30% of human requirements for food and agriculture (FAO 1999b). The food production is steadily increasing with the demand. For example, during the year 2011 a record production of cereal grains (2,325 million tonnes) has been estimated by FAO that is 3.7% more than that in the year 2010. Thus, about 507 million tonnes cereal crops have been estimated to be in stock in 2011 by FAO. Overall, there is an increase of 6.0% in wheat, 2.6% growth in the coarse grains and a 3.4% rise for rice production has been estimated by FAO during the year 2011 (FAO 2011a). Nevertheless, a question arises as to whether the people are still hungry worldwide? This is due to the reason that most of the food production is in developed countries, while developing countries experience less increase in food production, resulting in food scarcity and hunger related issues in these regions. Secondly, the World Bank estimates that the increase in global food prices in 2008, accompanied by a global economic

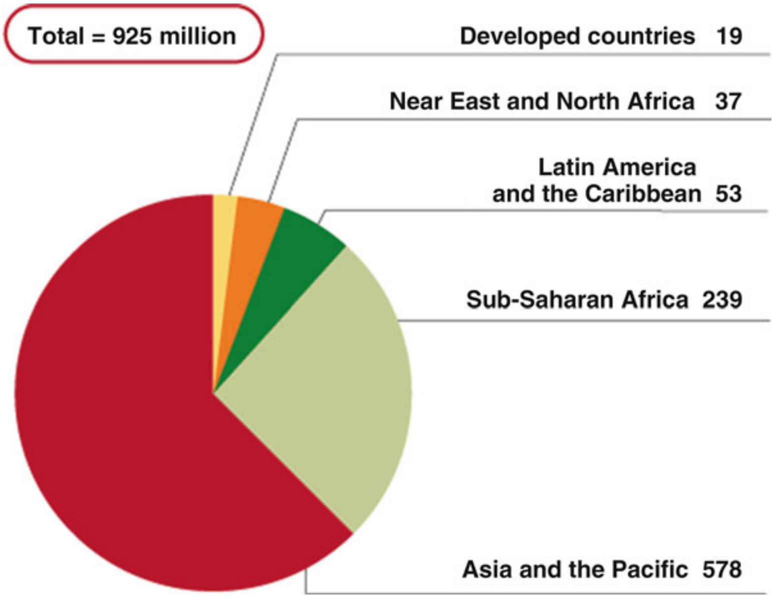

Fig. 1.2 The distribution of hungry people-world wide during 2001. Note that out of 925 million people worldwide, the largest proportion of malnourished people is in the Asia and the Pacific (578 million) followed by Sub-Saharan Africa. Here, the cause of hunger in Asia and the Pacific is population explosion while in the Sub-Saharan Africa is environmental extremes. The least proportion is in developed countries (19 million) that experience almost zero-population growth (Source: World Hunger Education Service 2011; FAO 2010)

depression in 2009 and 2010 has pushed an additional 100–150 million people into poverty worldwide leading to increase in global hunger (Mitchell 2008; Bread for the World 2011) (Fig. 1.5).

5 Is the Population Explosion a Real Problem?

The rapid growth in human population raises a serious question about environmental health and food security issues. The biggest question in our minds is that will the earth be able to support 14 billion people in the year 2100, the population double to the present day (7 billion), with the same limited resources of the present day? Will our requirements of food, health and education and residence be met? Shall we be able to sustain our renewable and non-renewable resources? What would be the situation of biodiversity and croplands? Will our future generations be supplied with clean water and air? Indeed, the policy-makers, economists and ecologists are worried by this situation as these things seem hard to sustain in future, particularly in the developing countries of Asia and Africa.

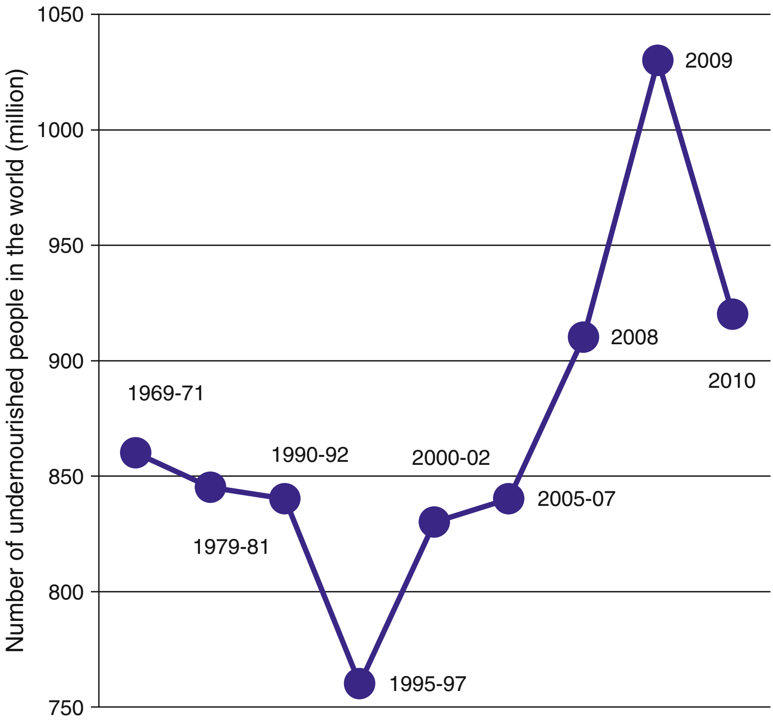

Fig. 1.3 The extent of hungry people from 1969 to 2010. There was a slight decrease in global hunger from 1969 to 1997. However, afterwards, a rapid increase is reported, although there is again a decline in global hunger in 2010 (Sources: World Hunger Education Service 2011; FAO 2010)

The fact is that currently, approximately 434 million people live in areas of either extreme water stress or scarcity. It is estimated that depending on future trends of human population growth, in the year 2025 approximately 2.6–3.1 billion people will be living in areas of water-scarcity (Valerio 2008; US Department of State 2006). Similarly, approximately 600–986 million people will be living in regions where cultivated land will become critically scarce in 2025. Despite the improvement in crop production after Green Revolution aided by technological advances, agricultural experts are worried. The debate is how long crop production will be enough to feed increasing human population. In future, the crops will be produced mostly from today's cropland. Therefore, our current croplands must remain fertile to sustain food production. The minimum amount of land needed to provide the vegetarian diet for one person without the input of any artificial chemical fertilizer and loss of soil nutrients is 0.07 ha. Currently, 415 million people already live in countries having land less than required for a person for this purpose (Population Action International 2011).

Our forested lands are also becoming critically scarce. It is estimated that currently, more than 1.8 billion people live in 36 countries where the forested land is less than

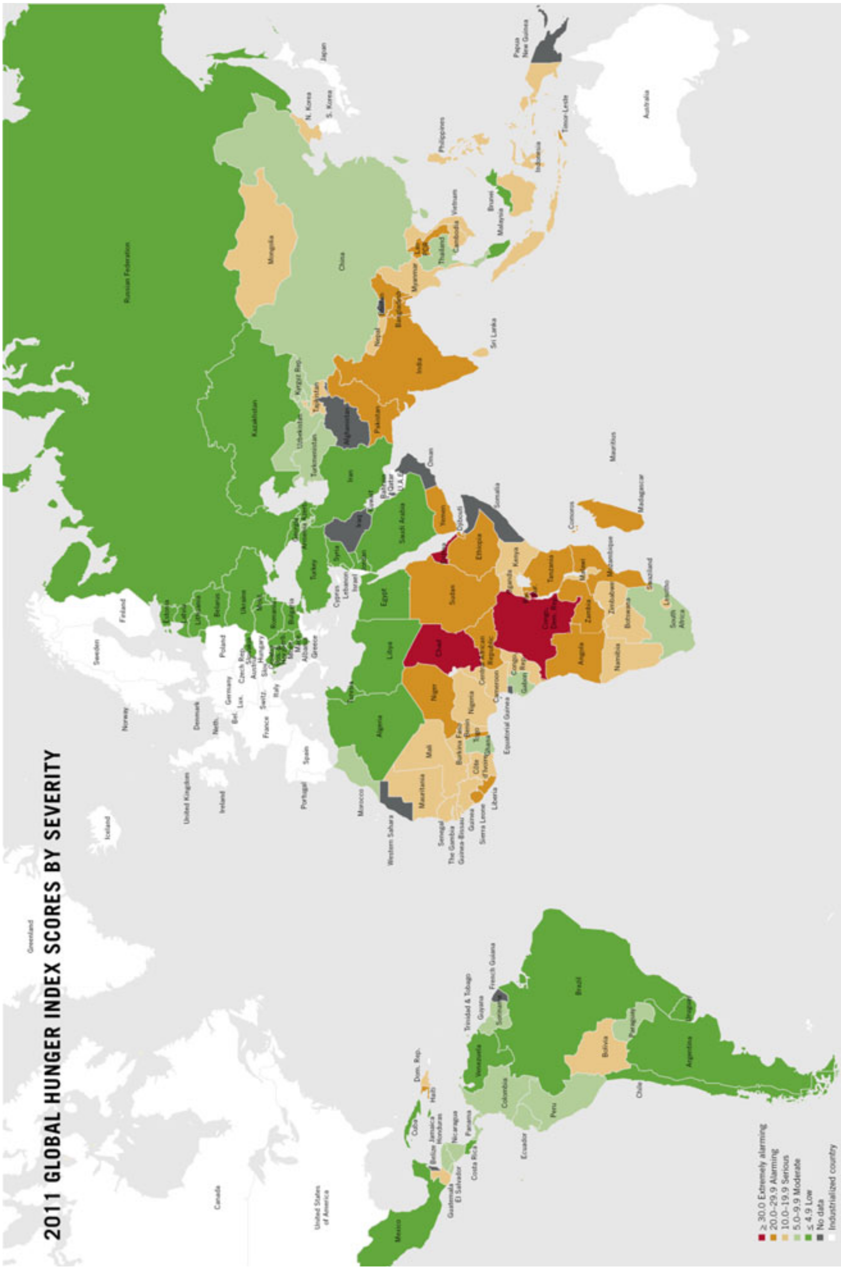

Fig. 1.4 The distribution of global hunger by country (Source: International Food Policy Research Institute 2010; http://www.ifpri.org/ifprimaps/index.php/ghi/v2010)

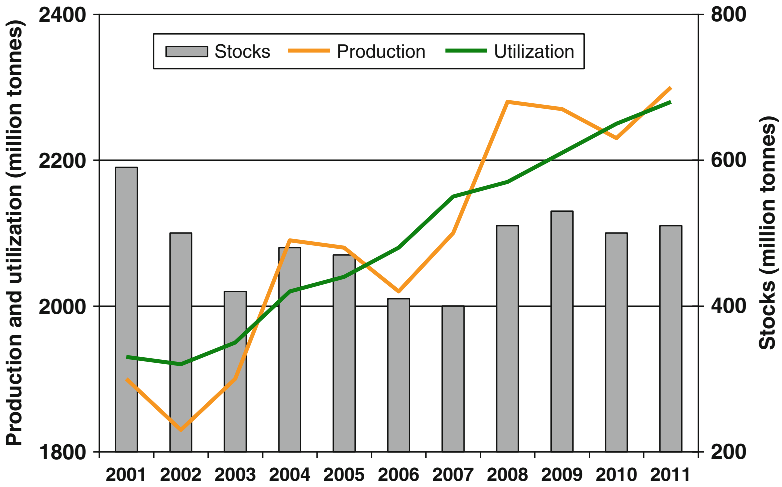

Fig. 1.5 World cereal production and utilization during 2001–2011 (Source: FAO 2011a; http://www.fao.org/worldfoodsituation/wfs-home/csdb/en/)

0.1 ha per capita. This indicates a critically low level of forest cover in these regions. Based on the current deforestation trends and medium population projection, approximately 3 billion people (double to present day) will be living in countries having critically scarce forest land in 2025. At present, more than 1.1 billion people live in biodiversity hot-spots. These regions comprise about 12% of the earth dry-land wherein about 20% of human population is currently living. The alarming fact is that in comparison to the annual growth rate of world's population (1.3%), the growth rate in these biodiversity hotspots is 1.8%, pushing the regions under pressure. Thus, these regions are under severe threat by human activities (Population Action International 2011).

Despite an increase in global crop production is claimed by the FAO, the prices of food commodities have reached to a historical high limit in the year 2011. The average Food Price Index (FPI), a measure in the inflation of food prices, was approximately 100 during 2002–2004. With a consistent increase in the later years, it is now estimated to be more than 200 in the year 2011 indicating that the global food prices have bloomed almost double within only 6 years (FAO 2011b). This has no doubt pushed more people in poverty and made the nutrition related issues more severe (Fig. 1.6).

6 Challenges for Sustainable Crop Production

Currently, the crop production world-wide is facing a number of challenges. These, include, environmental constraints, diseases and pathogens, loss of genetic diversity, and global climate change. Among the abiotic stresses, drought is the most important and most common limitating factor of crop production in arid and semi-arid regions

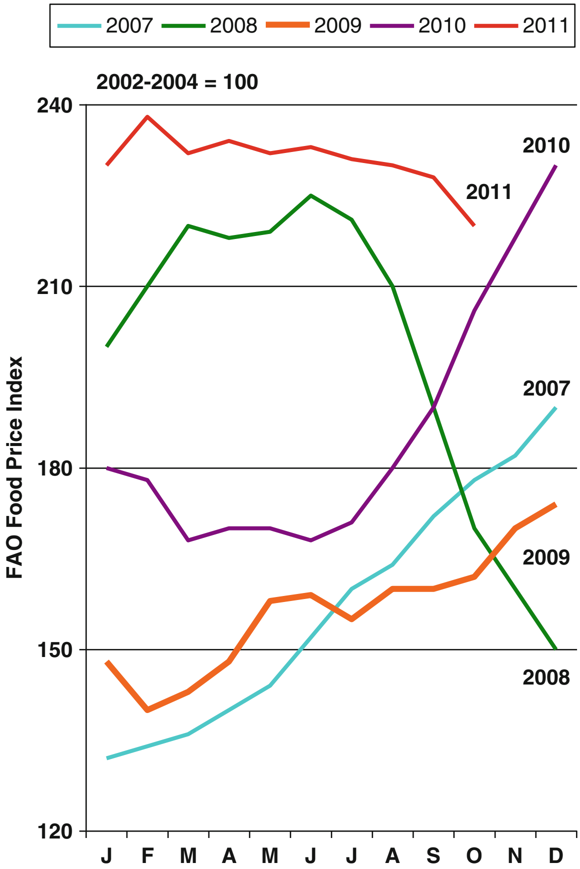

Fig. 1.6 FAO Food Price Index (FPI) from 2002 to 2011. The highest FPI can be seen for the year 2011 (Source: FAO 2011b)

of the world (Saranga et al. 2001). It is estimated that more than 1/4 of total land area is dry and about 1/3 of the world's cultivable land is under water shortage conditions (Kirigwi et al. 2004). The crop quality and production is also seriously influenced by global climatic changes which enhance the frequency and intensity of water shortage thereby making the situation more serious (Hongbo et al. 2005).

Salt stress is the second most prevalent abiotic stress in the world that adversely impacts plant growth (Pessarakli 1991). It is estimated that over 800 million hectares are salt affected in the world either by salinity (397 Mha) or sodicity (434 Mha) which is over 6% of the total land area in the world (FAO 2005). Most of the salinity and all of the sodicity is natural; however, a significant proportion of recently cultivated land has become saline because of land clearing and irrigation. The United Nations Environment Programme (UNEP) and Food and Agriculture Organization (FAO) have estimated that approximately 45 Mha out of 230 Mha of irrigated land in the world are salt affected (FAO 2005). Approximately, 10 Mha of the irrigated land is forced out of cultivation every year due to high salinity (Szabolcs 1989) and one third to half of the irrigated land may be heading towards this fate (Nelson et al. 1998).

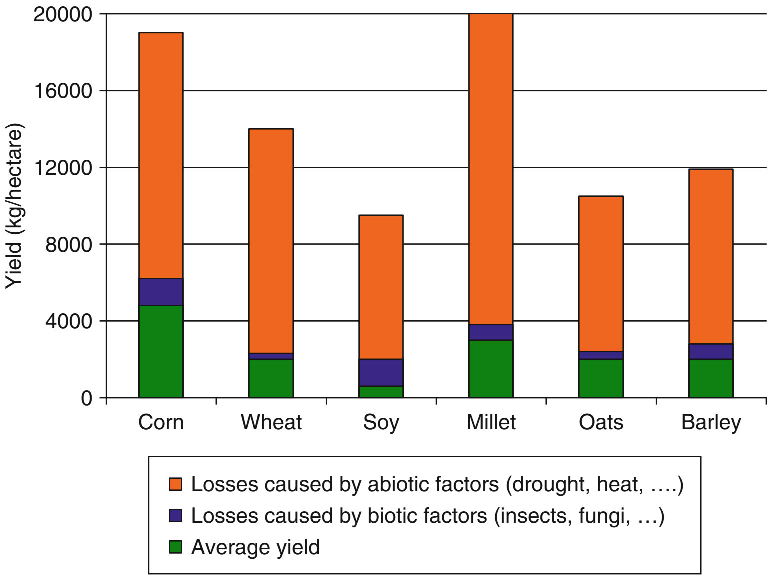

Fig. 1.7 Estimated crop losses due to biotic and abiotic stresses (Bayer Crop Science 2008, http://www.seedquest.com/News/releases/2008/october/23973.htm)

High temperature stress is another major factor that significantly affects plant productivity particularly in arid zones (Bray et al. 2000). Heat stress or heat shock, caused by rise in ambient temperature beyond a threshold level, is a major threat to crop production worldwide (Hall 2001). In general, heat stress is considered when temperature elevates 10–15°C above ambient temperature. However, the probability of its occurrence depends on period of high temperatures occurring during the day and/or the night. Elevated temperatures may lead to alteration in geographical distribution as well as also result in altered growing season of agricultural crops, allowing crop maturity to reach earlier by causing threshold temperature for the start of the season (Porter 2005). Intergovernmental Panel on Climatic Change (IPCC) has estimated that global mean temperature will rise 0.3°C per decade (Jones et al. 1999) and this will reach to 1°C and 3°C by years 2025 and 2100, respectively. The situation becomes worse when heat stress usually combines with drought and salinity stresses, further impeding crop production worldwide.

Other problems of relatively less intensity that hinder crop production include, environmental pollutants such as heavy metals, pesticides, fertilizers, petroleum products, and other organic and inorganic chemicals. Soil mismanagement and loss of soil fertility due to excessive cultivation of crop is also threatening the crop production worldwide. In addition to all these abiotic stresses, biotic stresses such as diseases, pests and pathogens also contribute significantly towards crop losses worldwide, though their contribution is significantly less than that of abiotic stresses (Fig. 1.7).

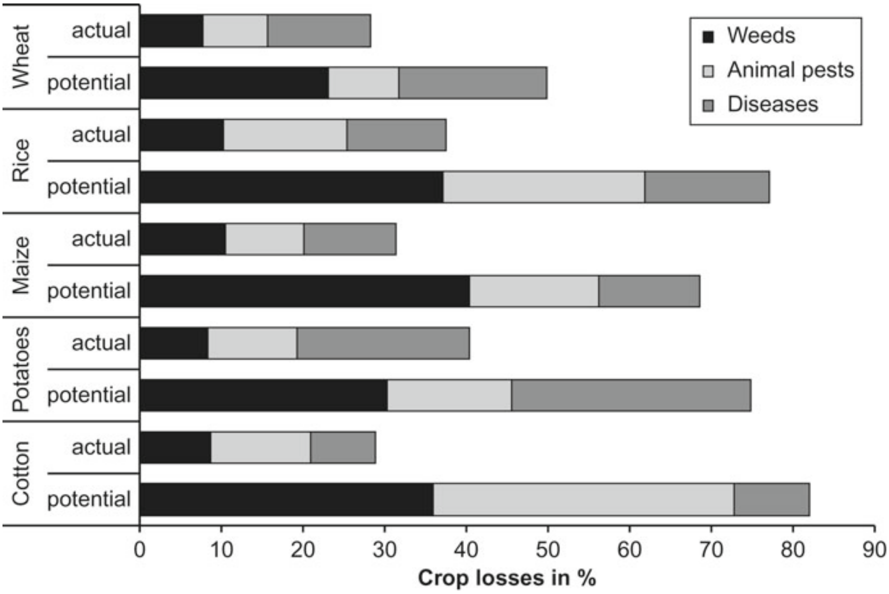

Fig. 1.8 Estimated global crop losses in major crops due to pests and pathogens (Qaim 2011)

7 Crop Losses Due to Biotic and Abiotic Factors

It is estimated that abiotic and biotic stresses collectively contribute more than 50% crop losses worldwide. A survey conducted by Bayer in 2008 indicated that crop losses caused by stresses were significantly greater than the average yield of economically important crops (corn, wheat, soy, millet, oats and barley). They also showed that the abiotic stresses caused significantly higher crop losses than did the biotic ones. For example, the highest crop losses were shown for millet, a crop of the arid regions, where average yield was 2,000 kg/ha and crop losses were 3,800 and 20,000 kg/ha due to biotic and abiotic stresses, respectively. Similarly, the average yield of corn in 2008 was 4,500 kg/ha while the crop losses due to biotic and abiotic stresses were 6,000 and 19,000 kg/ha, respectively. The third highest crop losses were recorded for wheat, another economically crucial crop of third world countries. The average yield of wheat was approximately 1,500 kg/ha, while crop losses were 2,000 kg/ha due to biotic stresses and 14,500 kg/ha due to abiotic stresses. Almost a similar extent of crop losses due to abiotic and biotic factors was reported for barley, oats and soya crops. All these data indicate that crop losses due to abiotic stresses were more severe than those by the biotic ones (Fig. 1.7).

In another report, Qaim (2011) compared the crop losses due to various biotic agents such as disease, weeds and animal pests in five economically important crops, i.e. wheat, rice, maize, potatoes and cotton (Fig. 1.8). He showed that these biotic agents collectively caused approximately 28–40% harvest loss in these economically important crops. Here, the highest crop losses were shown in potatoes (40%) followed by rice (38%) and maize (30%). The harvest losses in wheat and cotton were 28%. Among the biological agents, the highest contribution towards crop losses was by diseases, followed by animal pests and the least was due to weed competition (Fig. 1.8).

8 Strategies for Crop Improvement

In view of the situation prevailing for food security worldwide, it is amply clear that we need to devise concrete methodologies to increase average crop yield. At the first instance, we need to control haphazardly increasing human population so that pressure on our croplands for crop production could be reduced. Secondly, we need to combat environmental adversaries, a major reason of crop losses worldwide, by developing conventional and advanced methodologies. This can be achieved by water management, soil manipulation, nutrient management, screening and selection of the existing gene pool, conventional and molecular breeding, tissue culture, genetic transformations and molecular enhancements. Additionally, we have to manage crop losses arising from biotic agents through disease and pest management.

As discussed earlier, the impact of abiotic stresses on yield losses is more severe than that by the biotic ones. Therefore, we have to combat abiotic stresses in the first instance so as to fulfil our desire to increase crop productivity worldwide. Normally, it is achieved through conventional breeding and selection strategies to select tolerant varieties/lines. Although, such efforts have enduring impact, their development is usually slow and requires a considerable time to succeed (Witcombe et al. 2008). In the recent past, use of various molecular enhancements has shown a promising means to induce short-term resistance to abiotic stresses and have been summarized in various reviews (Ashraf and Foolad 2007; Alcázar et al. 2010; Ashraf 2009; Ashraf et al. 2011). More recently, genetic transformations have also been shown to be another effective and long lasting means to improve crop productivity under stress conditions (Cushman and Bohner 2000; Zhang et al. 2000; Vinocur and Altman 2005; Mittler and Blumwald 2010; Roy et al. 2011). All these reports indicate that there is still a potential to improve crop production under stress conditions in future to overcome the problem of food security of growing human population.

It is a fact that biotic stresses, although have comparatively less damaging impact on harvest losses, most of the genetic modifications to enhance crop productivity have been performed to confer resistance against biotic stresses. For example, Huang et al. (2002) compared the genetic modifications in crop plants against various stresses. They concluded that majority of genetic transformations have been performed for insect resistance (37%), herbicide resistance (29%), stalked traits

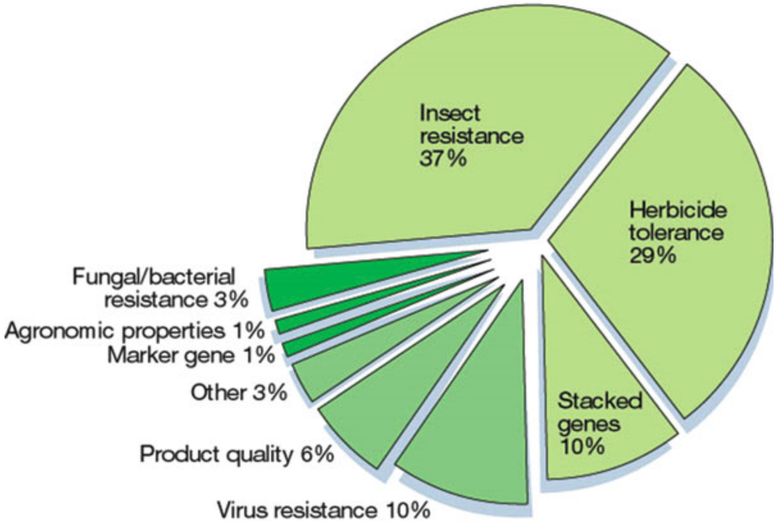

Fig. 1.9 Genetically modified crop traits tested in developed countries from 1987 to 2000 (After Huang et al. 2002)

(10%) and virus resistance (10%). In comparison, a little attention has been paid to agronomic properties (1%), marker genes (1%) and resistance against abiotic stresses that constitutes only 3% of all GM crops tested under field conditions (Fig. 1.9). This shows that we need to focus our efforts to develop GM crops that can perform better under field conditions against abiotic stresses, a major problem for crop production worldwide.

9 Conclusion

It is amply clear from the above discussion that we will be facing food security issues in near future particularly in the developing countries where most of human population will be living. Additionally, the increasing crop losses due to environmental adversaries will amplify food security issues. Majority of crops losses are due to abiotic stresses that cause more than 50% harvest loss. Although, scientists are working hard to increase the average yield of various economically important crop plants, a limited success is achieved due to the increasing extent of abiotic and biotic stresses. Therefore, there is a dire need to devise methodologies to enhance crop production particularly in the stressed-regions of the world.

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Part I
Breeding for Crop Improvement

Chapter 2
Bridging Genomic and Classical Breeding Approaches for Improving Crop Productivity

Mehboob-ur-Rahman, Tayyaba Shaheen, Muhammad Ashraf, and Yusuf Zafar

Contents

M. Rahman (✉) • Y. Zafar
National Institute for Biotechnology and Genetic Engineering (NIBGE),
Jhang Road, P.O. Box 577, Faisalabad, Pakistan
e-mail: mehboob_pbd@yahoo.com; mehboob@nibge.org;
y_zafar@yahoo.com

T. Shaheen
Department of Bioinformatics and Biotechnology, GC University, Faisalabad, Pakistan
e-mail: tayaba_pgmb@yahoo.com

M. Ashraf
Department of Botany, University of Agriculture, Faisalabad, Pakistan

Department of Botany and Microbiology, King-Saud University, Riaydh, Saudi Arabia
e-mail: ashrafbot@yahoo.com

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Abstract Numerous genomic tools have been used vigorously for studying the inherent genetic polymorphisms which were instrumental in resolving the phylogenies of many crop species, developing genetic maps, initiating marker assisted selection and incorporating genes from distantly related taxa-introduction of Bt genes in cotton, corn etc., these together set a stage for developing crop varieties with improved genetic potential to multiple stresses. Wider adaptation of genomic based breeding in crop improvement programs is impeded due to the narrow genetic base resulting from selection pressures applied during the domestication of many plant taxa, which also can confer genetic vulnerability to crop gene pools. Genomic based breeding may contribute to increasing crop genetic diversity by introgressing novel alleles from feral and or alien species. Association mapping approaches coupled with identifying single nucleotide polymorphisms the most elemental form of polymorphism in the genomes, may facilitate breeding by design. In this article, efforts to advance genomic-based breeding for improving crop species, providing food, feed, fuel and fiber to the world community, will be discussed.

Keywords RFLP • SSRs • SNPs • QTLs • Marker-assisted selection • GM cotton • GM rice • GM wheat • GM soybean • GM maize • GM sorghum

1 Introduction

Molecular markers have been proved vital tools for bridging the genomic tools with the classical breeding procedures for improving the genetic potential of multiple crop species (Rahman et al. 2009). In conventional breeding schemes, various traits of interest are combined in one genotype by hybridizing two genotypes (Beckmann and Soller 1986). Various studies elucidate that pyramiding of complex traits conferred by numerous genes which contribute directly or indirectly to the development of same trait, is really a mammoth task to achieve by deploying classical breeding methods (Beckmann and Soller 1986). Marker-assisted selection (MAS) is an approach which utilizes the tightly linked DNA markers for diagnosing plants having that particular trait of interest (Ribaut and Hoisington 1998). MAS can expedite the process of improved breeding by reducing time for selection of true to type genotype, increasing efficiency in selection procedure and efficient utility of the available resources. In other words MAS is a procedure to merge genomic and conventional resources in a better way (Moose and Mumm 2008). Second strategy for merging the conventional and genomic resources is bringing the deployment of transgenic technology for developing genetically modified (GM) crops. Transgenic crops overcome the limitations of utilizing genetic resources among different species (Qaim and Subramanian 2010). To meet the demands of new era breeding with desired characteristics is unavoidable which is only possible with GM technology (Qaim and Subramanian 2010). In this review economically important crops will be discussed in the context of utilizing the aforementioned technologies to improve their genetic potential of crop plants.

2 Wheat

Among the biotic factors, substantially depressing wheat production, are the rust diseases like leaf rust (Singh et al. 1998), stripe rust (Helguera et al. 2003), and stem rust (Mago et al. 2009). A fungus *Puccinia recondite* causes leaf rust. Two genes *Lr34* and *Lr46* which causes slow rusting have been found effective to combat many disease causing fungi (Singh et al. 1998). All combinations of other Lr genes and *Lr34* genes (Kloppers and Pretorius 1997) have explained the hypersensitive resistance responses. DNA markers have been identified which are linked with the other leaf rust genes (Huang and Gill 2001) and *Lr34* (Suenaga et al. 2003) which have further utility for probing the F_2 wheat plants, and also in succeeding generations, containing the gene(s) which can potentially cause resistance to the disease. In another study resistant genes for leaf rust *Lr47, Lr24*, *Lr1*, *Lr9*, were introgressed into bread wheat gentypes (Nocente et al. 2007) using MAS. Similarly, translocation lines 6VS/6AL derived from a cross *Triticum aestivum/Haynaldia villosa which* harbors a gene *Yr26* located on chromosome 1B show resistance to the majority of races of *Puccinia striiformis* f. sp. *tritici* (Pst) causing yellow or stripe rust. DNA markers *Xwe173* and *Xbarc181* were utilized for monitoring the introgression in cultivated wheat varieties (Wang et al. 2008). Another gene *Yr15*, imparts resistance to stripe rust, tagged with two SSR markers *Xgwm413 and Xbarc8*, further these markers served the purpose of diagnosis in all genetic backgrounds except in one (Murphy et al. 2009). Commercialization of the first wheat variety “Patwin” was done by the University of California at Davis (http://www.plantsciences.ucdavis.edu; Helguera et al. 2003) is a master piece example that was developed with the help of diagnostic DNA markers which assisted in introgression of *Yr17* and *Lr37* genes for resistance against stripe rust and leaf rust respectively into one genotype.

T. timopheevii ssp. *Armeniacum,* confers resistance against a recently appeared strain of stem rust (Ug99). The resistant gene *Sr40* was tagged with a closely linked marker *Xwmc344* (0.7 cM), and later two flanking markers *Xgwm374 and Xwmc474* (~2.5 cM) were identified, together can be used in marker-assisted incorporation and pyramiding of *Sr40* to develop superior lines (Wu et al. 2009b). Another gene *Sr39* was introgressed along with *Lr35* gene for resistance against leaf rust into wheat from *Aegilops speltoides.* Mago and Co-workers (2009) induced homoeologous recombinations between the *Ae. Speltoides and* wheat chromosome and developed a set of recombinant lines with reduced *A. speltoides* parts. For the resultant resistant and susceptible genotypes, DNA markers were utilized for conveniently pyramiding of other stem rust resistant genes with enhanced sources of Sr39 which effectively combat the Pgt pathotype TTKSK and its other strains in wheat. Two genes from *Thinopyrum ponticum* (*Sr25* and *Sr26*) were introduced into wheat and proved to be useful against new strains of TTKSK (syn. Ug99) and its types. Co-dominant markers for *Sr25* and *Sr26* were identified which can be potentially used in MAS (Liu et al. 2010).

Powdery mildew is another threat to wheat production. SSR markers linked with genes *Pm4a* and *Pm5e* have been detected (Huang et al. 2003; Ma et al. 2004).

Markers linked with another gene *Pm4b* (STS_241, *Xgwm382,* Me8/Em7_220) were identified which can improve resistance to the powdery mildew disease in wheat (Yi et al. 2008).

A locus Glu-1 has some impact on the wheat's quality of bread making. Coding and promoter regions of this locus were scrutinized for polymorphisms (Radovanovic and Cloutier 2003; Ma et al. 2003). Two specific PCR based markers were confirmed and utilized for alleles identification at *Glu-B1x* locus for its further utility in introgression of cultivated wheat varieties (Xu et al. 2008).

A linkage map of all 14 chromosomes was developed containing 280 SSRs, and also for detection of tan spot resistance associated QTLs. A tetraploid wheat doubled haploid (DH) population was derived by crossing a *T. turgidum* var Lebsock and *T. turgidum* subsp. *carthlicum* (accession PI 94749). A total of five QTLs for tan spot resistance were identified on chromosome arms, 3BL, 7BL, 5AL and 3AS. The out come of this study can facilitate genetic dissection of agronomic traits and marker identification for MAS (Chu et al. 2010).

2.1 GM Wheat

Transgenic studies in wheat have been focused mainly on improvement of grain quality characteristics and effect of expression of endogenous genes on dough quality (Francki 2009). It has been experimentally proven that expression of endogenous gene have positive or negative impact on grain quality and dough characteristics. Impact of genes 1Ax1, 1Dx5, LMW-GS, HMW-GS and pinA have been experimentally determined (Alvarez et al. 2000; Blechl et al. 2007; He et al. 2005; Tosi et al. 2004, 2005; Masci et al. 2002; Martin et al. 2006).

Fusarium graminearum, causes Fusarium head blight which is a challenging disease of wheat globally. Wheat has low resistance against this disease due to narrow genetic diversity in the existing pool. GM wheat containing barley class II chitinase gene was found effective against *F. graminearum* when experimentally tested (Shin et al. 2008).

RNA interference is a sequence specific gene silencing mechanism which can be utilized in determining gene functions. The application of RNAi in wheat has confirmed the function of VRN1, VRN2, SBE11a, SBE11b, EIN2, PDS, GPC and 1Dx5 (Francki 2009).

It has been studied recently that ferulic acid esterase which is derived from *Aspergillus niger* or endo-xylanase (from *Bacillus subtilis*) when expressed under the control of endosperm-specific *1DX5* glutenin promoter have an impact on wheat baking quality (Harholt et al. 2010).

National Institute for Biotechnology and Genetic Engineering has evaluated Arabidopsis AVP1 gene by introducing into tobacco for assessing its role for developing resistance against salinity and drought which are major limiting factors for crop productivity. Arabidopsis AVP1 gene encodes a vacuolar pyrophosphatases that function as proton pump and generates an electrochemical gradient in vacuole activating vacuolar membrane-antiporters including Na^+/H^+ antiporter, which helps in sequestration of Na+ into vacuole as well as overexpression of AVP1 gene promotes vegetative growth by enhancing root development under the influence of auxins. Results of this study elucidate the significance of this gene in salinity and drought tolerance. This gene can further be utilized in economically important crops like wheat (Ibrahim et al. 2009).

3 Rice

All over the world yield of rice is being depressed by a fungal disease called Bacterial Blight (BB). Three genes *xa*5, *xa13* and *Xa21* causing resistance to BB were incorporated in susceptible rice cultivars and were tracked using STS markers flanking these genes (Chunwongse et al. 1993; Huang et al. 1997; Singh et al. 2001). Basmati rice is also highly vulnerable to BB. In another study, pyramiding of two genes *Xa7* and *Xa21* was carried out using MAS for improved resistance for BB in hybrid rice (Zhang et al. 2006). Foreground selection was integrated with background analysis using mapped SSR markers to detect the genes *xa13* and *Xa21* which show resistance against BB and superior quality features while these genes were non-Basmati resource derived. In India an improved Pusa Basmati 1 line, developed through MAS, has been commercialized (Gopalakrishnan et al. 2008). SSR markers were utilized to introgress three major genes for resistance *xa5, xa13 and Xa21* in a superior indica rice variety (Sundaram et al. 2008).

Magnaporthae grisea (fungus) causes a disease blast which is another destructive disease of rice. Three vital genes (*Pi*1, *Piz*-5 and *Pi*ta) control this disease. Utilization of tightly linked RFLP markers has facilitated the pyramiding of these genes and also mapping of these genes on respective chromosomes 11, 6 and 12 (Hittalmani et al. 2000). There are many concerns about a race-specific resistance in many crop plants which can be overcome by non-race-specific resistance that was effectively used in breeding against fungal diseases. Some strains of *Japonica* rice contain a resistant *pi21* allele, is able to improve resistance to the blast disease in rice (Fukuoka et al. 2009).

Tightly linked SSR and RFLP markers with a Waxy gene allele were employed to improve the grain quality of a rice cultivar Zhenshan-97A (Zhou et al. 2003).

Among abiotic stresses, limited water condition is the most detrimental factor for causing substantial reduction in yield. Root traits remained a major focus for tackling this menace. Root length was increased by 12–27% in IR64 by introgressing four QTLs for penetrating roots from Azucena (*japonica* variety) (Shen et al. 2001). Another QTL involved in osmotic adjustment (OA) under drought condition was mapped on chr-8 (Robin et al. 2003) would be helpful in future rice improvement program. Synteny between rice and maize was found for a QTL for OA mapped on chr-3 of rice and chr-1 of maize. This QTL accounts for numerous agronomic and physiological traits contributing tolerance to drought (Zhang et al. 2001). Conservativeness among these regions can pave the way for translating information