Abstract: Three species provide currently 60% of human energy intake: wheat, rice and maize. From its domestication wheat has been the basic staple food of the major civilizations of Europe, West Asia and North Africa. Today wheat is grown in more than 215 million hectares and provides around 20% of global calories for human consumption. Many changes have occurred from the low productive plants cultivated in prehistoric times to the modern varieties grown nowadays, characterized by their high productivity and quality standards. Adaptation processes occurred during wheat migration from the Fertile Crescent to the Iberian Peninsula that was reached about 7,000 years BP. With the Greek settlers and after with the Romans, wheat production reached unprecedented levels in Spain due to the agricultural improvement introduced by the Romans at the beginning of the 2nd century. Under the Arab rule, between the 8th and 15th centuries, farming techniques and new wheat types led to a considerable expansion of agriculture in the Iberian Peninsula. A brief history of wheat migration from Europe into America will be presented. The effects of the Green Revolution in the late 1960s constituted the world conversion to modern agriculture characterized by extreme homogeneity in cultural practices and cultivar structures. Wild relatives and landraces were replaced and many of them lost during this process.
1. Introduction

Wheat is currently the most widespread crop. It is grown on about 219 million hectares all over the world and is the basic staple food of mankind, providing humans with 18% of their daily intake of calories and 20% of their protein (http://faostat.fao.org/).

There are several species of the wheat genus (Triticum). The most wide spread is common or bread wheat (T. aestivum L.), which occupies 94% of the total area cultivated with wheat and is mainly used for manufacturing bread and biscuits. Durum wheat (T. turgidum L. var. durum) is grown on about 13 million hectares, about 60% of them located in the Mediterranean basin, where it is considered a typical crop. Durum wheat is mostly used for pasta making, but it is also the raw material for producing other traditional goods of Mediterranean countries such as flat breads, couscous and bulgur. The genetic differences between the two species lie in the number of chromosomes, as durum wheat is a tetraploid species (with 28 chromosomes in four sets), while bread wheat is a hexaploid species (with 42 chromosomes in six sets).

2. The origin of wheat and its initial spreading

Wheat was one of the first domesticated food crops and its history is that of humanity. The domestication of wheat and the beginning of agriculture go hand in hand. Kislev (1984) classified the data of wheat husbandry into three major phases: i) the agro-technical revolution, which occurred within a still hunting-gathering society during the Natufian period (Epipalaeolithic, 13,000-10,300 BP), ii) the domestication revolution (Pre-Pottery Neolithic 10,300-7,500 BP), and iii) the expansion of agriculture, mostly during the Ceramic or Pottery Neolithic (7,500-6,200 BP).

The crucial separation of individuals of the Triticeae tribe that resulted in the different cereal species (wheat, barley, rye, etc.) is believed to have occurred during the Pleistocene, a glacial epoch. The major climate changes that started on the eastern Mediterranean coast about 15,000 BP replaced the original cold and arid conditions with warmer and moister ones, thus allowing the expansion of grasses (Feldman, 2001; MacKey, 2005). Palaeobotanical investigations and other indications show that from about 11,500 BP the climate of the eastern Mediterranean region (Levant) became dry and cold (Hillman, 1996; Bar-Yosef, 1998), and the large variations in rainfall and temperature between years and seasons forced vegetation to make important changes in order to adapt to the new environmental conditions. It is believed that at that time self-fertilization (autogamy) increased as a mechanism of reproductive assurance (Takebayashi and Morrell, 2001). The growth habit of vegetation became annual, and seed dormancy augmented, allowing seeds to overcome periods of harsh environmental conditions by remaining in the soil until conditions were suitable for germination (MacKey, 2005). It was probably during this time that, somewhere along the Fertile Crescent, the hunter-gatherers who were accustomed to collecting grains of wild cereals, fruits and roots of other plants started to cultivate grasses (Harlan, 1981; Hillman and Davis, 1990). It has been suggested that the Natufian tribe, who lived around Mount Carmel in present-day Israel and showed advanced preadaptive traits, or the dwellers in the Karadağ Mountains in southeast Turkey may have been the first (Kislev, 1984; Zohary, 1989; Heun et al., 1997). This assumption is supported by genetic studies demonstrating that in this area wild einkorn grass (a diploid ancestor species of wheat) contains an identical genetic fingerprint to modern domesticated wheat. As women had the primary responsibilities for plant gathering in hunter-gatherer societies, it is believed that they probably planted the first seeds. Einkorn (diploid), emmer (tetraploid) and spelt (hexaploid) are among the earliest cultivated wheats and are commonly referred to as ‘ancient’ wheats (Abdel-Aal et al., 1998).
The first signs of cultivation of the so-called ‘emmer’ (an awned wild wheat) correspond to the Pre-Pottery Neolithic A period (10,300-9,500 BP), at the end of which all basic agricultural practices had already been established (MacKey, 2005). The transformation of some wild cultivated forms into domesticated wheats proceeded very rapidly from this stage. From the Karacadag Mountains, emmer spread first northward and then southward. There is a general agreement that domestication occurred at the beginning of the Pre-Pottery Neolithic B (9,500-7,500 BP) (Kisley, 1992; Hillman, 1996; Harris, 1998; Bar-Yosef, 1998), when the spontaneous crosses between grasses that led to the appearance of bread wheat probably took place. Plant domestication was driven by humans’ need to secure the greatest possible amount of food with the least possible labour.

Wheat domestication involved major morphological, physiological and adaptive changes in plants, most of them induced by humans. One of the clearest examples of the contribution of humans to domestication was the transformation of the spike axis from brittle to tough. In wheat ancestors the spike became brittle at maturity, falling apart into small pieces (spikelets) containing the seeds, which were spread by wind and animals as an essential mechanism of propagation and survival. However, a small number of plants (those carrying a recessive allele conferring axis-robustness) tended to develop robust spike axes, and this caused the seeds to remain together in the spike at ripeness without falling down. This feature was very beneficial for humans, as it allowed them to harvest complete spikes at ripening instead of unripe spikes. It is likely that seed collectors gradually increased the proportion of tough-axis spikes gathered, thus unconsciously favouring the tough-axis genes in the harvested grains, which led to a suppression of the brittle axis in domesticated wheats (Helbaek, 1959). Thus, due to the loss of the seed-dispersal mechanism, wheat started to depend on humans for survival. Other important changes that occurred during domestication were the reduction of grain self-protection (due to the loss of the leaf-like glumes that covered each seed), which made the grains free-threshing, and the loss of seed dormancy, which favoured a uniform and rapid seed germination.

The establishment of agriculture in the Levant and the neighbouring regions was a very gradual evolutionary process that took place over a period of several hundred years (Kisley, 1992; Hillman, 1996; Harris, 1998; Bar-Yosef, 1998). Studies conducted today to imitate different harvest techniques of wild wheats grown in a dense stand suggest that at that time it was possible to obtain about 0.5 to 1 kg of pure grain per hour or 300 to 700 kg of grain per hectare, or even more (Harlan, 1967, 1990; Zohary, 1969; Hillman and Davies, 1990). This significant improvement led to a substantial population growth.

In the Ceramic or Pottery Neolithic the wheat culture spread from the western flank of the Fertile Crescent to south-eastern Europe through Transcaucasia, reaching the Balkan Peninsula and Greece in about 8,000 years BP. From there, wheat followed the rivers Danube (7,000 BP) and Rhine, reaching England and Scandinavia by 5,000 BP. The original cultivated wheat species underwent an adaptation to the increasingly harsher climates as farming cultures moved northwards (Helbaek, 1959). Primitive wheat was also transported by ships along the coast of the Mediterranean Sea to Italy and Spain (7,000 BP) (Feldman, 2001; Zohary and Hopf, 2000), and south of Gibraltar. Two possible ways have been proposed for the introduction of durum wheat into the Iberian Peninsula: North Africa and south-eastern Europe (Moragues et al., 2006, 2007). Wheat also reached central Asia through northern Iran and Egypt through Israel and Jordan (Feldman, 2001).

After arriving in a given territory, wheat underwent a progressive adaptation to the varying conditions of the new area and gradually established new strategies for yield formation, which likely conferred adaptive advantages under the new environmental conditions (Royo et al.,
2015). During the dispersal of wheat the farmers took their habits wherever they went: not just sowing, reaping and threshing but also other well established technologies such as baking and fermenting. This process of migration and natural and human selection resulted in the establishment of a wide diversity of local landraces specifically adapted to different agro-ecological zones. These dynamic populations with distinct identities are considered to be genetically more diverse than currently cultivated varieties, they show local adaptation and are associated with traditional farming systems (Camacho Villa et al., 2005).

3. The first few centuries of the Christian era

The word ‘spelt’ appears first in the Edict of Diocletian, in 301 BC. Initially, the Romans consumed emmer grain as porridge, but by the end of the Republic they were eating bread wheat. Hulled wheats were progressively replaced by hull-less wheats, which were easier to plant, harvest, store, transport and process. As new lands were conquered by Romans, they needed more provisions, so the trade of wheat and other raw materials began to grow from the fourth century BC (Álvarez-Sanchís, 2005). Grain imports from North Africa, particularly Egypt, had already become very substantial by the 1st century BC (Harlan, 1981). The cereal production in the Iberian Peninsula reached unprecedented levels during the Greek and Roman periods, particularly as a consequence of the gradual agricultural improvements introduced by the Romans from the beginning of the 2nd century BC (Álvarez-Sanchís, 2005). Wheat imports to the Iberian Peninsula from Italy were frequent in several periods (De Herrera, 1645), and during the seven centuries of Roman rule a number of wheat landraces were probably introduced to Spain from overseas Roman colonies (Royo and Briceño-Félix, 2011). The importance of wheat in the development of Mediterranean populations in the last two millennia has been well documented by Vallega (1974).

Farming techniques introduced under the Arab rule in the Iberian Peninsula (between the 8th and the 15th centuries) resulted in a substantial expansion of agriculture and probably in the introduction of a number of wheat landraces by Arabs (Royo and Briceño-Félix, 2011).

4. The spread of wheat to America

Wheat reached the New World as part of the famous ‘Colombian Exchange’. The Spaniards took it to Mexico in 1529 when the Catholic Church and the Spanish government ordered that it should be cultivated to produce the communion wafers needed for Mass (Feldman, 1976). A black slave of Hernan Cortés was probably the first person to introduce wheat to Mexico when he planted three grains found under a rice shipment from Spain to nourish the Spanish army (Collantes and Alfaro, 1855). Wheat was produced by indigenous people in Mexico as a tribute crop grown for export to Spain, where it was a staple (Reeves and Cassaday, 2002).

After the discovery of America, Spanish wheat landraces spread to the new continent with the help of Spanish conquerors and colonists during successive expeditions and migrations (Royo and Briceño-Félix, 2011). Landraces of bread wheat and durum wheat were reported to be grown in Santo Domingo in 1519, in Mexico in 1522 and in Argentina in 1527 (Skovmand et al., 1997). The first historical reference of wheat cultivation in Ecuador was given by the German historian Alexander von Humboldt (1769-1859) in his Tableaux de la Nature (Collantes and Alfaro, 1855) where he wrote: “In the Franciscan monastery of Quito the clay cup that contained the first wheat is conserved as a relic. Fray Jodoco Rixi de Gante, a Flemish Franciscan monk, brought the seed to this city. Initially it was grown in front of the Monastery, in a place called Plazuela de San Francisco, after the destruction of the forest that spread from there to the end of the Pichincha Valley”. The glass cup bore the inscription: “He who pours me should not forget God”.
The first wheat sowing in Chile, where it was introduced by Pedro de Valdivia, is dated in the spring of 1541. In 1556 wheat was taken by Spanish soldiers from Chile to Argentina (Capparelli et al., 2005), where it was taken up by local indigenous people during the period of the encomenderos and used to carry out a pachamancan ceremony at El Shincal during a Diaguita rebellion (Capparelli et al., 2005). It is documented that bread from wheat was still unknown in Cuzco (Peru) in 1547, but there is a reference to a wheat exportation from Chile to Peru in 1575 (Ross, 1894). The Jesuits had already introduced wheat to the Pacific coast of Mexico and to Baja California by 1773 (Skovmand et al., 1997).

5. Recent times

The technological change of wheat cultivation in Europe in the 20th century has been well documented by Pujol-Andreu (2011). In this paper we focus on the main changes that occurred from a breeding perspective.

The traditional varieties

During the first few decades of the 20th century the wheat varieties grown were the so-called ‘traditional varieties’ or ‘landraces’. Landraces resulted jointly from the evolution of wheat during its dispersal to new territories and from the role of humans in selecting large spikes for planting the next generation after the advent of agriculture. Landraces are heterogeneous in their shape and genetically very diverse because they are populations formed by sets of plants with different genetic constitutions. As wheat plants are self-pollinated crops, the genetic background of each plant passes to the next generation unless out-crossing, mutation or migration occur.

The earliest approaches to breeding

The pioneer breeders or entrepreneurial agriculturalists started selecting from within landrace populations (sometimes from foreign countries) the plants with the most favourable characteristics in terms of vigour, phenological adaptation, spike length and yield in order to produce superior lines. This pure-line selection did not entail the development of new genotypes as the improvement was only achieved by identifying and isolating the best lines already existing within the original landrace. This methodology was used by Nazareno Strampelli in Italy to release the durum wheat cultivar ‘Senatore Capelli’ in 1915 from the Algerian population ‘Jean Retifah’ (Di Fonzo et al., 2005), and by Enrique Sánchez-Monge Parellada in Spain to release the barley variety ‘Albacete’ from a selection within a local population, and the bread wheat ‘Aragón 03’ from a selection within the local variety ‘Catalán de Monte’.

The first organized wheat programme in France was implemented by the Vilmorin family in the 18th century (Bonjean et al., 2001). Until Mendel’s laws were rediscovered at the beginning of the twentieth century and plant breeding was established as a science, made crosses between varieties or breeding lines selected in the previous phase of breeding. The Italian breeder Nazareno Strampelli, considered the local promotor of the Mendelian findings, started to make crosses around 1900 (Borghi, 2001). In parallel, breeders started to interchange germplasm and to use foreign varieties or lines developed by their colleagues in other countries, for crossing with their best types. Farmer-breeding was also encouraged by the collection and distribution of wheat seed from all over the world. In the USA an official effort was made in the early 1860s to collect wheats worldwide and make them available to anyone who might be interested in crossing them with local wheats (Witt, 1985). At that time the harvest index (the partitioning of photosynthates between the grain and the vegetative plant) of most wheats was about 0.3 or less (Sinclair, 1998).
The Green Revolution

From around 1940, breeding programmes based on scientific findings were created in a number of countries. One of the most famous was the Rockefeller-Mexico programme, led by Dr. Norman Borlaug, which started in 1945. The wheat varieties grown in Mexico at that time had not changed too much since the 16th century (Khan, 1985), but Borlaug used germplasm from different origins in his crosses.

After a cross has been made in a breeding programme, wheat needs no less than ten generations of self-pollination before it reaches the desirable level of phenotypic uniformity (homozygosity). In addition, in most world regions no less than 9 to 10 months are needed to complete the whole wheat cycle, from sowing to harvesting. The particularities of Mexico allowed Borlaug’s programme to grow a wheat cycle from November to April in Sonora, northern Mexico, at sea level, and a second one from May to October in central Mexico, about 2000 m above sea level. This halved the time needed to obtain a new variety as two generations rather than only one could be grown every year.

Another major result of the ‘shuttle breeding’ between northern and southern Mexico was the reduction of the photoperiod sensitivity of wheats. Wheat is a long-day crop that needs to develop part of its cycle in days with 14 hours or more of light in order to flower. The original wheats grown in Mexico were all of spring growth habit, with very few or no cold requirements to flower, but they needed a certain pattern of light during the growth cycle to develop flowers. When wheat was grown in northern Mexico, with an increasing photoperiod from sowing to flowering, and subsequently during summer in the south, under a decreasing photoperiod, the best performing plants in both environments were those that did not require a special pattern of light to flower, that is, that had low or no photoperiod sensitivity. The incorporation of photoperiod insensitivity in the wheats developed in Mexico allowed them to be adapted to a wide range of environments all around the world, showing good adaptation to a number of environmental conditions.

One of the first aims of Borlaug was to reduce the incidence of rusts, three species of fungal diseases that at that time reduced wheat yield throughout the world. Gene pools from Kenya were used to incorporate stem rust resistance (Rajaram 2001). Another breeding objective was to reduce lodging, one of the greatest weaknesses of unimproved varieties, as they tended to lodge under intensive agronomic practices such as irrigation, high sowing densities or increased fertilization. As a source of dwarfing genes, Borlaug used the Japanese cultivar Norin 10, which was developed partly from Daruma (a wheat of Japanese or Korean origin), and was sent to the US after the Second World War. Using Norin 10 and the cross Norin/Brevor as a parental, Borlaug obtained ‘semi-dwarf wheats’ that yielded far better than the taller wheats grown in most parts of the world at that time. The dwarfing genes incorporated, designated as Rht-B1b (formerly Rht1) and Rht-D1b (formerly Rht2), belong to a class of genes known as gibberellic acid (GA) insensitive, and they had other important secondary effects on plants such as the increase in spike fertility. With the use of these genes, breeding resulted in an increased earliness, a reduction in plant height and lodging without significant decreases in total plant dry weight, and a larger allocation of resources in grains, thus improving the harvest index (Sinclair, 1998; Royo et al., 2007; Sanchez-Garcia et al., 2013, 2015b). By 1963 semi-dwarf varieties accounted for 95% of Mexico’s wheat and the country’s wheat harvest had multiplied by six in comparison with before Borlaug’s breeding programme.
Expansion of improved varieties

The semi-dwarf varieties developed in Mexico were rapidly disseminated to many countries, some of the best known being India and Pakistan (Reeves and Cassaday, 2002). The cultivation of landraces was abandoned at most sites, mainly because of their plant height, general lateness (Blum et al., 1989), lower productivity in high-yield environments and lower value for specific grain quality traits than modern ones (Nazco et al., 2012; Sanchez-Garcia et al., 2015a). The adoption of improved semi-dwarf varieties was accompanied by the intensification of management practices to allow the semi-dwarf wheats to express their potentiality. Sowing densities, application of fertilizers (particularly nitrogen), irrigation and the use of pesticides to control weeds and diseases increased. As a result, yield rose in many countries of the world. CIMMYT (International Maize and Wheat Improvement Center) was formally launched in 1966 and Norman Borlaug was honoured with the Nobel Peace prize in 1970 for his contribution to the Green Revolution.

The progress achieved for grain yield was the result of combining improved varieties with appropriate crop management strategies. A number of studies have tried to ascertain the contribution of the variety and agronomic practices to the yield increases achieved in the world during the past century. Changes in management practices leading to crop intensification have had positive effects on yield but also, although to a lesser extent, they have had some negative effects. On a global balance among the factors that have affected wheat yield gains, the positive effect of improved varieties has been estimated to contribute 60% (Mackay et al., 2011). Other issues that have positively influenced yields are increased fertilization, the use of appropriate sowing densities, weed control, field mechanization and phenology fitting, whose effects have been estimated at around 47%, 25%, 22%, 12% and 8%, respectively. However, the intensification of agriculture all over the world has had a serious impact on soil degradation (Araus et al., 2003). The reduction of manure application has been estimated to decrease yields by 15%, the declining level of organic matter in soils by ca. 12%, soil erosion by 9%, increases in the number of pests by 9%, the reduction of crop rotation by 7%, and other minor factors by 22%.

The role played by the variety is generally ascertained by growing historical series of cultivars in a common environment. Advances in yield during the 20th century due to variety improvement have been widely reported in the literature for bread wheat (Austin et al., 1980; Cox et al 1988), and durum wheat (Royo et al., 2007; Álvaro et al., 2008a and references therein). Moreover, since 1982 most of the improvement in yield has been attributed to genetic improvement with little evidence that changes in agronomy have improved yields (Mackay et al., 2011). In most wheat-growing areas of the world, yield increases attributable to the variety were achieved by altering the partitioning of photosynthates within the plant. Semi-dwarf varieties have the capacity to redistribute the plant weight so as to allocate a higher percentage of it to the grain than in unimproved varieties. As a result, plant height decreased but harvest index increased. In Spain, changes of harvest index during the 20th century have been estimated to be from 0.25 to 0.40 in bread wheat (Sanchez-Garcia et al., 2015b), and from 0.36 to 0.44 in durum wheat (Royo et al., 2007, Álvaro et al., 2008b). However, the GA insensitivity conferred by the dwarfing genes Rht-B1b and Rht-D1b resulted in grains of similar weight. Although most modern cultivars have less grain protein content than traditional varieties, breeding activities during the 20th century resulted in an improvement of global grain quality in both bread and durum wheat (Subira et al., 2014; Sanchez-Garcia et al., 2015b).
The problem of extreme homogeneity

Although the Green Revolution was critical for raising wheat production enough to mitigate the effect of rapid demographic growth, it affected the natural habitat of wheat. Landraces and pure-line cultivars obtained through mass selection from them during the first decades of the 20th Century were widely grown until the late 1960s, but due to the massive introduction of the homogeneous and more productive semi-dwarf cultivars released since the Green Revolution, they practically disappeared from farmer’s fields. Particularly, in the domestication area of wheat (West Asia) and the Mediterranean regions, which are the reservoir of the greatest genetic variability of the species, wild relatives and landraces were displaced by improved varieties. In consequence, the variability present on farmer field’s due to the cultivation of old unimproved varieties (landraces) gave way to the genetic uniformity of the most productive modern cultivars. The decrease in cultivar diversity and the loss of the natural variation present in landraces increased the genetic vulnerability of wheat crops (Skovmand et al., 2005) and led to a loss of the diversity exploitable by plant breeders, the so-called ‘genetic erosion’. Among the factors that have been reported to contribute to the narrow genetic background underlying successful modern wheat varieties, the reduced number of ancestors and the relatively small number of varieties cultivated at present are among the most significant (Autriqué et al., 1996; Soleimani et al., 2002; Maccaferri et al., 2005).

Another important change derived from the advent of modern cereal culture was the requirement of field uniformity, which led to the planting of large extensions of a single variety or a small number of varieties, managed under similar cultural practices. This homogeneity is very convenient from the industrial and commercial viewpoints as it allows sets of tons of wheat grains with similar quality characteristics to be obtained. However, it most likely increases the vulnerability to diseases as the pressure exerted by large extensions of uniform varieties pushes the races of fungal species to mutate, and to very rapidly overcome the genetic resistance of cultivars (Hovmøller and Justesen, 2007).

The role of genetic resources in modern breeding programmes

The breeding paradigm has changed in recent years. While past yield improvements relied on the development of improved varieties that needed the intensification of agricultural practices to maximize yields, the new released varieties have to be able to produce with the minimum environmental impact: that is, they must fit into the concept of ‘sustainable agricultural ecosystems’. This entails their genetic adaptation to environmental conditions, making it unnecessary to modify the environment through the use of non-sustainable practices to cover the variety requirements, as was the case in the past. This is a huge challenge for breeders, as wheat breeding today largely depends on the incorporation in improved varieties of adaptive traits for specific environments.

Given that most traits useful for improving the adaptation of modern cultivars to abiotic or biotic constraints cannot be found in modern cultivars, in many cases the enlargement of the genetic variability has to be sought in local landraces and close-related species. The high genetic diversity of landraces buffers them against spatial and temporal variability and upgrades the resilience to abiotic and biotic stresses in comparison with modern varieties (Lin 2011; Newton et al., 2010).

Aware of the loss of diversity that could occur during the second half of the 20th century, and the importance of preserving the natural diversity of genes present in wheat species, governments of several countries intensified the gathering of local landraces, which are now mostly conserved ex situ in Germplasm Banks. In Spain, most local landraces were collected in the first half of the 20th century and are maintained in the national collection at the INIA-CRF.
(Centro de Recursos Fitogenéticos) Centre. The essential role of landraces as likely sources of highly beneficial untapped diversity has led them to be considered essential for food security because they are as potential providers of new favourable genes to be incorporated into modern cultivars. However, as the genetic variation contained in them is usually unknown (Dreisigacker et al., 2005), the effective use of landraces in breeding programmes will make necessary to evaluate the existing diversity in the gene pool, and to characterize the available accessions. Detecting the presence of variants of potential interest for breeding purposes in landraces may be particularly useful in situations of breeding for suboptimal environments. International strategies have been deployed in order to coordinate the identification, characterization, description and accessibility to genetic resources (Newton et al., 2010).

Among the set of wheat landraces, the ones coming from the Mediterranean basin are considered to hold the largest genetic variability within the species. Large variability has been found in Portuguese (Carvalho et al., 2009) and Spanish (Moragues et al., 2006) wheats. Mediterranean wheat landraces are considered as a potential genetic resource of drought resistance, frost tolerance, and biotic and abiotic stresses in general. In addition, an increase in the available genetic variation through the use of landraces in breeding programmes seems possible in terms of yield component enhancement and end-product quality. The value gained by genetic resources in the last few decades has led to the widespread introduction of MTA (Material Transfer Agreements) for the interchange of germplasm between organizations.

The challenge of feeding an increasing world population

In 10,000 years, the earth’s population has multiplied by 700, from less than 10 million to more than 7 billion today, and it will rise to between 8.0 and 10.4 billion in 2050 (http://esa.un.org/unpp; Jaggard et al., 2010). To feed this population world food production will have to increase by about 70% over current levels. On a global scale, the world will require 1.1 billion metric tons of wheat in 2050 as compared with the current production of 716 metric tons (http://faostat.fao.org/), which in productivity means that, if the area devoted to wheat remains stable, the current global average wheat yield of 3.3 t/ha must rise to roughly 4.6 t/ha in 2020 and close to 5 t/ha in 2050. Achieving this will be a big challenge for humanity because land use for food production cannot increase greatly: there is only a little room for expansion in Sub-Saharan Africa and South America. Nevertheless, the enormously expanding potential of recently developed technologies offers opportunities for improvement of plant traits and agricultural management that were inconceivable few decades ago. Biotechnology, statistics, precision agriculture, and information technologies such as GIS, remote sensing and the exploitation of big data among other new tools will hopefully help to meet the challenges of breeders and agronomists in the next few decades.

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