Genetic Erosion of Wheat (Triticum spp.): Concept, Research Results and Challenges

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Abstract
Wheat is an important food crop in the world. It is also one of the top three global food crops produced after rice and maize that constitutes an enormously significant role with respect to global food security. Due to finite land resources that can be dedicated to agriculture global wheat production has been consistently dependent on genetic improvement of wheat germplasm across the world. Traditional plant breeding has been an important tool in increasing global food production by producing disease and stress resistant, high yielding and early maturing wheat varieties. Genetic erosion within and between crop species is a worldwide problem and it is mainly related to modern agriculture, whereby uniform and high yielding varieties are grown on large scale and replaced the landraces. In addition, climate change and drought, fire, war, etc. are some other causes of genetic erosion. Reduced soil fertility, reduced land size and expansion of improved common wheat varieties are the major causes. The current study looks in detail at the concept of genetic erosion and how the concept of genetic erosion relates to the general diversity trends in variety of wheat and how to suggest the way forward. Genetic erosion may occur at three levels of integration: crop, variety and allele. Genetic erosion as reflected in a reduction of allelic evenness and richness appears to be the most useful definition, but has to be viewed in conjunction with events at variety level.
Keywords: genetic erosion; wheat; modern bottle neck

1. Introduction

In high-tech era, modernization of agriculture production practices, urbanizations and industrialization policies of governments have been challenging biodiversity. Unwanted human actions are the primary factors of diminishing earth's eco-system (Cardinale *et al.,* 2012). Exploration is of immense importance along with conservation for sustainable agriculture system and food production. Limited efforts, however, are being made for conservation and enhancement of biodiversity especially for major crop species.

Cardinale *et al.* (2012) reviewed results of research experiments of last two decades and revealed impact of loss of biodiversity on functional ecosystems and goods and services supply. Long term research on grassland revealed diverse plant communities tolerate more and recover fully from major biotic and abiotic stresses (Zavaleta *et al.,* 2010). Dismantling of eco-systems cause loss of biodiversity and this is a primary concern around the globe. Loss of biodiversity is mainly due to habitat fragmentation and destruction, overexploitation, climate change, deterioration and extinction cascades, invasion by alien species and many other factors (Brook *et al.*2008; Dunn *et al.,* 2009).

Wheat is one of most cereal produced in the world followed by rice and maize. It is a primary source of calories for 1.2 billion people around the globe and thus constitutes a main platform for the global food security. Traditional plant breeding has been an important tool in increasing global food production by producing high yielding, disease resistant cultivars with better agronomic practices. However, genotypic variation is one of prerequisites to improve any trait including grain yield. Therefore, scientific community often rely on land races or wild progenitors when the genetic diversity/variation is not present in the immediate gene pool. Unfortunately many existing genotypes and land races are now being threatened with threat of extinction due to several natural and anthropogenic factors

Wheat (*Triticum spp.*) is a self-pollinating annual plant, belonging to the family Poaceae (grasses), tribe Triticeae, genus *Triticum*. According to different classifications, number of species in the genus varies from 5 to 27 (Merezhko, 1998). The two main groups of commercial wheats are the durums (*Triticum durum* L.) and bread wheats (*Triticum aestivum* L.) with 28 and 42 chromosomes respectively.Wheats (*Triticum*) and ryes (*Secale*) together with Aegilops, Agropyron, Eremopyron and Haynalidia form the subtribe Triticinae (Simmonds ,1976).

In the highly developed agricultural systems of North America and North-Western Europe, the replacement of traditional landraces of major field crops with cultivars had practically been completed when, in the 1970s, the Green Revolution in the developing world started. Genetic erosion within and between crop species is a worldwide problem and it is mainly related to modern agriculture, whereby uniform and high yielding varieties are grown on large scale and replaced the landraces. In addition, climate change and drought, fire, war, etc. are some other causes of genetic erosion. In the present investigation drought, fire, and war are not factors for genetic erosion. Reduced soil fertility, reduced land size and expansion of improved common wheat varieties are the major causes. However, other researchers (Teklu and Hammer, 2006; Tsegaye and Berg, 2007a) reported drought as one factor of genetic erosion in tetraploid wheat landraces especially in eastern part of Ethiopia.

In the late 1920s Vavilov explored Ethiopia and he was amazed by the high genetic diversity in wheat landraces particularly in durum wheat. The conditions conducive to a rapid uptake of modern cultivars as present in the late 19th and early 20th centuries in North America and Western Europe do apparently not exist to a similar extent in other parts of the world. When modern plant breeding methods were developed, several countries in Western Europe already had a, for that time, highly developed agriculture, characterized by a labour and land intensive production system (van Zanden, 1991), in which a specialized seed industry played an important role. This set the conditions for a rapid uptake of modern cultivars in these areas.

Genetic erosion may also be caused by the effects of urbanization and modern agricultural practices. Use of fertilizers, mechanization, irrigation, abandonment of marginal lands and crop specialization are all factors, which could lead to a loss of landraces because the habitat to which the landrace is adapted is no longer used or does no longer exist. Climate change and environmental degradation can also result in changed cropping patterns and disappearance of traditional varieties. Changes in food preferences of a growing urban population and a decreasing demand for local products may also add to the loss of diversity. Furthermore, natural disasters or human conflicts, which result in a large-scale displacement of farmers, can lead to the loss of the agricultural diversity that was used by the farmers involved (Richards and Ruivenkamp, 1997). Although some are convinced that 'plant breeding is a strong force in the reduction of genetic diversity' (Gepts, 2006), and view the introduction of modern cultivars as evidence of genetic erosion (Bennett, 1973). The current study looks in detail at the concept of genetic erosion and relates to the general diversity trends in variety of wheat and how to suggest the way forward.

2. Literature review

2.1 Wheat Biodiversity: Challenges

Major grain crops such as wheat, rice, maize, soybean, canola etc. have been losing diversity due to long term monoculture of a few high yielding cultivars. High level of selection pressure for favourable traits is the primary reason for narrow genetic bases for numerous other characters. Single assemblage limits the multi-functionality in a crop eco-system. Uniformity in genetic make-up of varieties in same genetic pool causes reduction of overall performance and stability, at the same time bring in risk of vulnerability to biotic and abiotic stresses (Pecetti *et al.,* 1992).

2.1.1 Loss of Wheat Biodiversity

Biodiversity of *Triticum* species for physiological performance, quickly adapting to biotic and abiotic stresses such as evolutionary adaptation is reduced in elite germplasm compared to landraces and wild relatives. It could be seriously threatened in the crop improvement by future epidemic, global warming and high level of regional droughts. Sustainable performance such as durable diseases and pest resistance, drought and salinity tolerance is highly responsible traits on wider biodiversity. Uniqueness of individuals within population for physiological, biochemical, metabolomic processes govern high biodiversity within species. Biodiversity of crop plants could be directly impacted by the existence of genetic diversity. It has been known that wheat was domesticated about 10,000 year ago, since then considerate selection and breeding efforts has been significantly eroded genetic diversity (Chatzav *et al.,* 2010).

2.1.2 Genetic Erosion/Gene Pollution

Genetic erosion term referred as the loss of variability of crop production in the areas of domestication and secondary diversification i.e. centre of origin (Tsegaye and Berg 2007). Genetic variability of a crop population is altered in ways that make negative genetic gain over a period. Genetic erosion is one of the most important factors contributing to global wheat biodiversity. de Carvalho *et al.,* (2013) defined genetic erosion as the "Steady reduction of combination of alleles over time in a defined areas or lasting reduction in richness of common alleles". Variability is coined to heterogeneity of alleles and genotypes that reflect morphotypes and phenotypes composition. The numbers of crops grown are declining steadily and crop with commercial importance enhancing production areas with highly similar genetic constitution. As a result wild and weedy relatives lose their own genetic make-up over long period of time. The primary cause of genetic erosion is wide distribution of modern cultivars from crop breeding programs (Brush ,1995).

Initially domesticated landraces were replaced by the cultivars selected based on conventional breeding programs and recently those cultivars were replaced by modern high-quality homogenous new varieties or hybrid selected by molecular marker assisted selection. Concentrated focus on breeding for crop yield and related traits is highly responsible factors for genetic erosion of major crop species. In genetic diversity analysis, about 20 % genetic erosion of local gene pool of Russian origin ancestors observed in 78 spring durum wheat genotypes introduced in Russia between 1929–2004 (Martynov *et al*., 2005). Gradually reduction in genetic diversity reported in spring bread wheat from early domestication to traditional landrace cultivars to modern breeding varieties and collected germplasm for long term breeding program through 90 SSR markers distributed across the wheat genome (Reif *et al.,* 2005). Similarly, decay in genetic diversity reported in 242 accession of common wheat released in China since 1940s. The study revealed lower genetic diversity found in cultivars released in 1990s compared to 1940s (Tian *et al.,* 2005). In addition to that other gene pools also found similar pattern of decayed in the genetic diversity of wheat cultivars over times (Huang *et al.* 2007; Tsegaye and Berg 2007). A study reported a survey based on in situ conservation of local varieties and landraces protected by farmers in Ethiopia, results suggested that localized landraces of species Triticum polonicum and T. turgidum have great genetic erosion. The primary causes of the genetic erosion of landraces of several species of genus Triticum in Ethiopia is displacement of landraces by other high yield modern wheat cultivars (Teklu and Hammer 2006).

2.2 Factors Contributing to the Loss of Wheat Biodiversity

Plant breeding continuously selects the favourable allelic combinations in gene pool to improve per se performance of elite lines that eventually to be used as parents of new variety development.

2.2.1 Changing Genetic Architect of Wheat Populations in Genetic Pools

Long term breeding operations change original genetic architect of plants as a result genetic shift observed in improved gene pools in wheat, barley and maize (Fu 2006; Koebner *et al.,* 2003). Improved gene pools could have desirable allelic composition for traits like yield, quality and agronomy but that may not have durable resistance capacity to diseases and pest, long term sustainability to changing climate and high performance stability.

2.2.2 Narrowing Genetic Base for Biotic and Abiotic Stresses

Robust and rapid maker assisted selection system for selection of foreground and background genome of elite lines causes elimination of large genomic variations resulting genetic bases of elite germplasm would be narrow for quantitative control of biotic and abiotic stresses in the newly developed cultivars. Most recent concern of this genetic bottleneck has been taken into consideration and breeder perform wide inter-specific or inter-generic crosses to enhance genetic variation within gene pool for sustainable durable resistance to biotic and abiotic stresses in wheat.

2.2.3 Vanishing Original Genetic Composition of Wild and Weedy Relatives

In the current agriculture system, farmers prefer to grow genetically uniform crop varieties and majority farmers select high yield varieties of same crop because of high revenue. Cultivation of large area with highly genetically uniform varieties creates pressure on original genetic composition of wild and weedy relatives which exist in the surrounding areas. Selection pressure over many generations in wild populations due to pollen drift from cultivated areas causes loss in the genetic diversity in wild and weedy relatives.

2.2.4 Insufficient Resources for Germplasm Conservation and Utilization

In addition to above mention factors, inadequate resources for germplasm conservation and long term maintenance highly impact on the biodiversity of important crop like wheat. Collection, conservation, research and utilization of wheat germplasm resources play an important role in wheat breeding program to improve production and productivity in the world. More resources need to be allocated for the preservation of germplasm that can be used in current and future breeding program to maintain biodiversity and overall performance of wheat crop. Current collections in the gene banks have limited or no contribution to the modern cultivar development programs for most essential agricultural traits. Crop improvement, is still focused on poor genetic base for all the major crop species including wheat (Tanksley and McCouch 1997).

2.3 Wheat Biodiversity Conservation: Current Status

Wheat is one of the most important cereal crops in term of its production and consumption in the world. Various sub species of genus Triticum are cultivated in different regions of the world; therefore genetic diversity is one of the most crucial factors for wheat crop improvement. It has been widely debated that the genetic diversity of major self-pollinating crops such as wheat has suffered with reduction over time due to pure line breeding and selection (Donini *et al.,* 2000; Hoisington *et al.,* 1999).

Genetic diversity evaluated for the 150 accessions of durum wheat collected from worldwide using Single Nucleotide polymorphism (SNP) molecular markers. The SNP diversity analysis study indicated significant loss of gene diversity in terms of landraces as well as older and later released cultivars during initial stages of green revolution, however genetic diversity increased during post green revolution (Ren *et al.,* 2013). In comparative analysis of genetic diversity in geographical regions Middle East showed moderate compared to the North and South Americas and the European regions (Ren *et al.,* 2013).

Several studies reported about the current status of genetic diversity of wheat in different geographical regions of the world based on the molecular marker analysis on old landraces and modern cultivars. Studies based on various molecular marker systems suggested existence of genetic diversity at certain degree. There is no evidence however reported for the existence or loss of physiological, agronomical and overall fitness diversity status since plants undergo numerous biochemical and physiological and metabolomic mechanisms during growth and development.

2.4 Global Wheat Germplasm Collections

Key global collections of wheat were identified from existing public databases including those held by FAO, Bioversity International, and European Cooperative Programme for Plant Genetic Resources (ECPGR) as well as the regional and crop specific surveys conducted as part of regional conservation strategies. The Wheat Strategy Advisory Group recognizes nearly 40 collections (Table 1), consisting of more than 560,000 accessions, as major global wheat collections.

Table 1. Major Global Wheat Collections

Country	Institute	No. of accessions	IT-PGRA ratified
Global	CIMMYT, El Batan, Mexico	111,681	Yes
Global	ICARDA, Aleppo, Syria	37,830	Yes
Albania	Agricultural Research Institute, Lushjne	6,000	No
Albania	Albanian Genebank, National Seed and Seedling Institute, Tirane	2,015	No
Argentina	Banco Base Nacional de Germoplasma, Instituto de Recursos Biologicos, INTA	648	No
Australia	Australian Winter Cereals Collection, NSW Department of Primary Industries	23,917	Yes
Austria	Agrobiology Seed Collection, Linz	876	Yes
Bulgaria	Institute for Plant Genetic Resources “K. Malkov”, Sadovo	9,747	Yes
Brazil	Recursos Geneticos e Biotecnologia, (EMBRAPA/ CENARGEN), Brasilia	5,169	Yes
Brazil	Centro Nacional de Pesquisa de Trigo (CNPT;EMBRAPA), Passo Fundo	13,594	Yes
Canada	Plant Gene Resources of Canada, Saskatoon	5,052	Yes
China	Institute of Crop Germplasm Resources (CAAS), Beijing	9,633	No
Cyprus	National Genebank (CYPARI), Agricultural Research Institute, Nicosia	7,696	Yes
Czech .R	Genebank Department, Research Institute for Crop Production, Prague	11,018	Yes
Egypt	Field Crops Institute, Agricultural Research Centre, Giza	2,867	Yes
Ethiopia	Plant Genetic Resources Centre, Institute of Biodiversity Conservation and Research, Addis Ababa	10,745	Yes
France	Station d'Amelioration des Plantes, INRA, ClermontFerrand	14,200	Yes
Germany	Genebank, Institute for Plant Genetics and Crop Plant Research (IPK),	9,633	Yes
Hungary	Institute of Agrobotany, Tapioszele	7,531	Yes
India	National Bureau of Plant Genetic Resources (NBPGR), New Delhi	32,880	Yes
Iran	National Genebank of Iran, Genetic Resources Division, Karaj	12,169	Yes
Israel	Lieberman Germplasm Bank, Institute of Cereal Crop Development, Tel-Aviv	5,500	No
Israel	Institute of Evolution, Haifa University, Haifa	1,000	No
Italy	Instituto del Germoplama, Bari	32,751	Yes
Japan	Genebank, National Institute of Agrobiological Sciences, Tsukuba	7,148	No
Japan	Plant Germplasm Institute, Graduate School of Agriculture, Kyoto	4,378	No
Netherland	Centre for Genetic Resources (CGN, CPRO-DLO), Wageningen	5,529	Yes
Pakistan	Plant Genetic Resources Institute, National Agricultural Research Centre	2,572	Yes
Poland	Plant Breeding and Acclimatisation Institute (IHAR), Radzikow	12,974	Yes
Portugal	Banco de Germoplasma-Genetica, Estacao Agronomica Nacional, Oeiras	831	Yes
Portugal	Departmento de Genetica e Biotecnologia, Universidade Tras-os-Montes	1,466	Yes
Romania	Suceava Genebank, Suceava	1,543	Yes
Russia	N.I. Vavilov Research Institute of Plant Industry (VIR), St. Petersburg	39,880	No
Serbia	Institute of Field and Vegetable Crops, Novi Sad	2,431	No
South .A	Agricultural Research Council, Small Grains Institute, Bethlehem	2,527	No
Spain	Centro de Recursos Fitogeneticos, Madrid	3,183	Yes
Sweden	Nordic Gene Bank, Alnarp	1,843	Yes
Switzerland	Station Federale de Recherches en Production Vegetale de Changins, Nyon	6,996	Yes
Turkey	Plant Genetic Resources Department, Aegean Agricultural Research Institute	6,381	Yes
Ukraine	Yurjev Institute of Plant Production, National Centre for Plant Genetic Resources of Ukraine, Kharkov	20,626	No
United .K	Crop Genetics Department, John Innes Centre, Norwich	9,584	Yes
USA	Wheat Genetic Resource Centre, Kansas State University, Manhattan, Kansas	5,000	No
USA	USDA/ARS, Wheat Genetic Stocks Collection, University of Missouri, Columbia, Missouri	3,000	No
USA	USDA/ARS, National Small Grains Research Facility, Aberdeen, Idaho	56,218	No
Total	**44 institutes**	**562,831**	

Sources: Bioversity, 2006; FAO, 2007

2.5 Conserving Global Wheat Biodiversity: From a Multi-disciplinary Perspective

Plant germplasms including modern cultivated varieties, landraces, closely and distance wild and weedy relative can be conserved by ex situ and in situ methods. These methods facilitate management, maintenance and data bank that can be available for future use in the breeding programs for crop improvement (Benz, 2012).

2.5.1 Ex Situ Conservation

The ex situ germplasm conservation method is most traditional approach that has been utilized for many crop species especially for the maintenance of landraces and wild relatives. Ex situ conservation is continuous requirement to preserve neglected landraces, disappearing wild and weedy relative or distinct relative and cultivated wheat species. Such germplasm collected in ex situ can be indispensable resources to restore cropping system after major disease epidemic or other disasters. Ex situ conservation has played important role in distribution of productive crop varieties and breeding lines to those countries or regions where crop has challenges for producing enough to sustain agriculture production (Benz, 2012).

Nowadays, ex situ conservation faces numerous challenges in term of maintenance of large number of accession in various biotic abiotic stresses and changes in different agro-climatic conditions such as global warming. In addition to that, there is a vast collection of valuable data regarding global genetic resources maintained globally in different Gene bank. Unfortunately, significant portion of such useful information is not easily accessible to researchers due to lack of infrastructural facilities and lapses in the existing data exchange programs. Particular information about accession such as traits, pedigree, growth and physiological habits are also lack in the Gene bank which make collected and landraces unusable in several existing breeding programs conducted all over the world in wheat growing belts.

Table 2.Crop collections studied and held at the RICP Prague (by species and status of accession, October 2001) wheat (including wild relatives)

		Status of genetic resources						
Crop	**Number of acc. in crop collection**	**not known**	**wild relative**	**Landrac e**	**Cultivar**	**Breeding material**	**Special stock**	**Number of accessions**
Winter wheat	6520	1	90	362	4007	1962	98	
Triticum aestivum L.		1		268	3888	1890	98	6145
Triticum durum L.				4	70	48		122
Triticum spelta L.				26	27	9		62
Other *Triticum* sp. of winter habit		37	64	22	15		138	
Spring wheat	4366	13	80	332	2588	1258	95	
Triticum dicoccum Schrank			6	65	11	9		91
Triticum monococcum			6	16		6		28
Triticum turgidum L.		1	1	17	4	6		29
Triticum durum Dest L.		1	2	92	516	174		785
Triticum polonicum L.			3	11		5		19
Triticum araraticum Jakub.			41					41
Triticum spelta L.			4	3	2	9		18
Triticum compactum Host			1		16	16		29
Triticum aestivum L.		10	1	102	2039	1013	95	3260
Other Triticum spp. of spring habit	1	15	26	4	20		66	
Tritical	604	27		1	229	347		
Triticale (winter)		8		1	100	290		399
Triticale (spring)		19			129	57		205

2.5.2 In Situ Conservation

In situ conservation offers an alternative conservation approach to ex situ, in which conservation has high priority than development. Biotechnology represents several techniques for enhancing genetic diversity in crop through the introduction of novel genes. Introduction of genes through traditional breeding approaches has many challenges that hindrance expansion of biodiversity which can be overcome through biotechnological approaches. Several biotechnological tools have been employed for wheat biodiversity conservation (Belokurova 2010).

2.5.3 Cryopreservation of Wheat Species

Long term conservation of non-used landraces or wild relative of wheat can be preserved using biotechnological approaches, and those accessions can be used in the future based on requirements. Cryopreservation of wheat suspension culture and subsequent callus regeneration after long time preservation reported for variable retention of important genotypes of different species of wheat (Chen *et al.,* 1985).

2.5.4 Seed Germplasm Bank

Collection and storage of viable seeds is most common and feasible approach for germplasm conservation. Germplasm of cereal crops including wheat can be stored in two types of collections (i) working collections, and

(ii) preservation. Seeds can be storage at near freezing and low humidity through this way viability can be maintained for 10 years or longer (Sachs, 2009). Long term storage of wheat seed needs ambient temperature gradient between − 10 to − 20 °C. Seeds can also be stored by using cryogenic methods like application of liquid nitrogen (Walters *et al.,* 2005).

2.6 Genetic bottlenecks in wheat

Bottleneck as only a subset of the diversity in the progenitor found its way into the domesticated species. This domestication bottleneck is caused by a process in which a small founder population experienced intense selection for agronomically desirable characteristics (Tanksley and McCouch, 1997). Aegilops tauschii Cross shows considerable more genetic variation than what is found in the A. tauschii-derived D genome in hexaploid wheat (Lelley *et al.,* 2000), pointing to a severe bottleneck in the development of bread wheat. It is unknown whether recombination typically limits the effect of selection to a small genomic region or whether large genomic regions are 'dragged along' with selected genes (Doebley *et al.,* 2006).

2.7 Analysis of genetic erosion at different levels of integration

2.7.1 Genetic erosion: the loss of crop species

Genetic erosion is defined as the loss of variability from crop populations in diversity centers, that is, areas of domestication and secondary diversification (Brush, 1999). Hammer *et al.* (1996) defined it broadly as the loss of particular local landraces expressed as the ratio of the number of landraces currently available to their former number. The term "genetic erosion" is sometimes used in a narrow sense, that is, the loss of genes or alleles, as well as more broadly, referring to the loss of varieties (FAO, 1998). It is a process acting both on wild and domesticated species. It is also both natural and manmade process. Naturally, it occurs when there is inbreeding between members of small population that will reveal deleterious recessive alleles. It causes a population "bottleneck" by shrinking gene pool or narrowing the genetic diversity available. This natural process could be the causes for the losses of heterozygosity that reduces the adaptive potential of every population (Caro and Laurenson, 1999).

2.7.2 Varietal erosion

Genetic erosion as a loss of varieties (landraces and cultivars), sometimes described as varietal erosion (Sperling, 2001). The focus of most of these studies has been the transition stage in which landraces were replaced by modern cultivars. The addition of improved cultivars with a foreign origin to a group of closely related landraces could actually increase local diversity levels and also be a source of new, advantageous genes for these local landraces. However, some authors consider that genetic erosion has taken place as soon as new alleles are introduced through introgression from advanced cultivars into traditional landraces (Ishikawa *et al.,* 2006), as the original genotype will then have changed. However, this ignores the dynamic nature of the management of landraces by farmers. Even without introgression from advanced cultivars, a current landrace will not remain genetically identical to that same landrace a decade ago, due to constant farmer selection and incorporation of new alleles.

2.7.3 Allelic erosion

The development of molecular techniques in the last decades has made it possible to study genetic erosion at the level of alleles. The drawbacks of studying genetic erosion at the level of varieties or using pedigree information are overcome by looking into more detail at the genetic makeup of the genotypes. Allelic richness is important for the survival of a species as a significant loss of alleles can affect the evolutionary potential of even common species (Ellstrand and Elam, 1993), and allelic richness is important for breeders as a basis for the continuous improvement and adaptation of the crop. Diversity in both nuclear and cytoplasmic DNA is important (Levings, 1990; Kik *et al.,* 1997).

2.8 Genetic erosion reflected in pedigrees

Pedigree studies have been used in an attempt to overcome some of the problems in assessing diversity based on varieties. Using information on ancestors, these studies estimated the distinctness of cultivars and the extent to which old landraces are present in the pedigree of modern cultivars (Martynov *et al.,* 2005; Martynov *et al.,* 2006).A large proportion of the local landraces disappeared from the pedigree of the released cultivars, but these were replaced by foreign material resulting in maintenance of diversity levels. The loss of local landraces from the pedigrees is viewed by the authors as evidence of genetic erosion (Dobrotvorskaya *et al.,* 2004; Martynov *et al.,* 2005, 2006).

Pedigree studies suffer from some methodological flows as they ignore selection pressures and assume the parental contributions to be equal. In addition, pedigree studies assume the original ancestors to be unrelated, which lead to overestimation of the diversity (Soleimani *et al.,* 2002). Furthermore, pedigree studies depend on the availability and reliability of pedigree information, which for many crops are often rather limited. A further bias is introduced since the morerecent cultivars will have better pedigree information and therefore more ancestral parents in their pedigree. Pedigree studies do demonstrate that breeders are able to harness variation from a wide range of sources (Smale *et al.,* 2002), which suggests that the modernization bottleneck cannot be simply characterized as a population bottleneck, resulting from the use of a limited number of original ancestors as the basis of new cultivars.

2.9 The modernization bottleneck

2.9.1 Replacement of landraces with modern cultivars

The first stage in the modernization bottleneck possibly leading to genetic erosion is the replacement of land races by modern cultivars. The replacement of landraces with modern cultivars is a gradual process, and the length of the transition period will vary much between crops and regions. In developing countries, the replacement of landraces is currently in progress, while in North America and many European countries for many crops landraces have become absent and only modern cultivars are grown by farmers. A possible modernization bottleneck due to the replacement of landraces by cultivars would be reflected in a higher diversity of the landraces before the introduction of cultivars when compared to the diversity of the cultivars after the replacement with the landraces is completed. Studies that compare groups of landraces with sets of cultivars mostly show a reduction in both richness and evenness of alleles (Thomson *et al.,* 2007; Warburton *et al.,* 2006).

2.9.2 Diversity trends in modern breeding

The second stage in the modernization bottleneck is reflected in the diversity trends in cultivars after the replacement of traditional landraces by modern cultivars has been completed. Genetic erosion could then occur if the cultivars grown by farmers are increasingly similar to each other and/or the total number of different cultivars grown is reduced. The most common approach used to study diversity trends in modern breeding is the comparison of the genetic diversity of groups of cultivars with different release dates using a diverse array of molecular techniques. Results from studies using this approach vary considerably. Some studies showed a decrease in diversity over time (Reif *et al.,* 2005a; Malysheva-Otto *et al.,* 2007), while others observed diversity increases (Fu *et al.,* 2007; White *et al.,* 2008).

A significant reduction in genetic diversity in the 1960s was observed, but even here the observed reduction in diversity was only 5%, and indications are that after the 1960s and 1970s breeders have been able to again increase the genetic diversity as released in cultivars. The recovery of diversity after the 1960s might reflect the greater use of exotic germplasm and crop wild relatives in the breeding process. In addition, the breaking of a domestication bottleneck by using advanced breeding techniques such as synthetic hybrids in wheat (Warburton *et al.,* 2006) might have been partly instrumental in increasing the total diversity. If all cultivars that are made available to farmers by the seed producers in a period are included the resulting diversity can be higher than if only the new releases are included, as for example was found for wheat in Argentina (Manifesto *et al.,* 2001). Using weighted coefficients reflecting the area grown by farmers between 1973 and 1993, a reduction in Australian wheat genetic diversity was found, mostly due to the choice of variety by the farmers and not so much due to the diversity released by breeders and available to farmers (Brennan and Fox, 1998).

2.10 Genetic erosion at a regional and global scale

Although genetic erosion is often presented as a global issue, it is most often studied at a regional scale. In recognizing genetic erosion regionally, it is understood that what is happening with the diversity of a crop in a region will affect the global richness of the crop or might be extrapolated to global events. Ancient dispersal bottlenecks could have led to distinct diversity at different locations. By using germplasm from other regions, breeders can contribute strongly to the removal of a dispersal bottleneck. This could lead to a higher similarity of the germplasm in the various regionsand genetic erosion at the global scale.

One of the factors contributing to genetic erosion is the push for uniformity, a result of a development in which centralized breeding institutes of a limited number of breeding companies produce varieties that can be grown across different ecosystems and localities (Heal *et al.,* 2004). In regions and countries with strong breeding programmes, improved cultivars may have evolved gradually from local germplasm. In Italy close links have been demonstrated between old and new wheat cultivars, while in Spain old wheat cultivars have been replaced by foreign material, resulting in the loss of the link between old and new cultivars (Martos *et al.,* 2005).

3. Conclusions

Wheat represents an important food crop species that is closely related to global food security. It is therefore important to conserve all existing landraces, genotypes and germplasm of different types of wheat (including both wild and cultivated species) to protect the wide global genotypic diversity of this crop. Such genetic variability will be useful for future breeding programs and biotechnological improvements for developing high yielding, disease and stress resistant varieties locally suitable for different agro-climatic regions of the world. Rapid loss of genetic diversity of wheat has been reported from different corners of the world and hence it is important to initiate an efficient and effective integrated global wheat conservation program to conserve diverse species including landraces and germplasm of this valuable food crop. We have explored the current status of wheat biodiversity and identified several factors hampering such diversity, globally. In order to obtain estimates on the genetic erosion that might have taken place, it will also be necessary to obtain information on the genetic diversity that was available in the past. Reduced soil fertility, reduced land size and expansion of improved common wheat varieties are the major causes. The vulnerability of the crops due to uniformity is as much related to the choice of variety and species by the farmers, as it is by the number and nature of varieties offered by the breeders. Both play a key role in combating uniformity. Generally, in developing countries, the replacement of landraces is currently in progress, while in North America and many European countries for many crops landraces have become absent and only modern cultivars are grown by farmer.The following suggestions were importantly for the way forwarded

- Farmers should be encouraged to diversify and not all select the same cultivars and species, while breeders need to ensure that farmers can choose from a wide range of locally adapted cultivars with a diverse genetic base.
- Breeding efforts in minor crops and disease susceptible varieties should be encouraged, so that these crops will keep their place in farming systems and the food chain, while agriculture modernizes.
- Genetic erosion is the chief problem of reduction of variation while variation back bone of plant breeding program so it should be to conserve/maintain the land race in gene bank.
- We have also suggested potential measures for wheat conservation from a multi-disciplinary perspective with special emphasis on modern biotechnological approaches.

4. Reference

Belokurova ,VB .2010. Methods of biotechnology in the system of efforts for plant biodiversity preservation. Tsitol Genet 44:58–72
Bennett 1973.Wheats of the Mediterranean basin. In: Frankel OH (ed.) Survey of Crop Genetic Resources in Their Centre of Diversity. First Report: FAO – IBP, pp. 1–8.
Benz ,B .2012. The conservation of cultivated plants. Nat Edu Knowl 3:4
Bettencourt E, Konopka, J .1990. Directory of crop germplasm collections. 3. Cereals: Avena, 0, millets, Oryza, Secale, Sorghum, Triticum, Zea and pseudocereals. International Board for Plant Genetic Resources, Rome
Brennan JP and Fox PN, 1998. Impact of CIMMYT varieties on the genetic diversity of wheat in Australia, 1973–1993. Australian Journal of Agricultural Research 49: 175–178.
Brook BW, Sodhi NS, Bradshaw, CJ .2008. Synergies among extinction drivers under global change. Trends Ecol Evol 23:453–460
Brush ,SB .1995. In situ conservation of landraces in centers of crop diversity. Crop Sci 35:346– 354
Brush ,SB .1999. Genetic erosion of crop populations in centers of diversity: a revision. In: Proceedings of the technical meeting on the methodology of the FAO World Information and Early Warning Systems on plant genetic resources. Rome, Italy. pp. 34–44.
Cardinale BJ, Duffy JE, Gonzalez A, Hooper DU, Perrings C, Venail P, Narwani A, Mace GM, Tilman D, Wardle DA, Kinzig AP, Daily GC, Loreau M, Grace JB, Larigauderie A, Srivastava DS, Naeem ,S .2012. Biodiversity loss and its impact on humanity. Nature 486:59–67
Caro TM, Laurenson, MK . 1999. Ecological and Genetic Factors in Conservation: A Cautionary Tale. Science 263: 485-487.
Chatzav M, Peleg Z, Ozturk L, Yazici A, Fahima T, Cakmak I, Saranga ,Y .2010. Genetic diversity for grain nutrients in wild emmer wheat: potential for wheat improvement. Ann Bot 105:1211–1220
Chen TH, Kartha K, Gusta L (1985) Cryopreservation of wheat suspension culture and regenerable callus. Plant Cell Tissue Organ Cult 4:101–109
de Carvalho M, Bebeli PJ, Bettencourt E, Costa G, Dias S, Dos Santos TMM, Slaski, JJ .2013.Cereal landraces genetic resources in worldwide GeneBanks. A review. Agron Sustain Dev 33:177–203
Dobrotvorskaya TV, Martynov SP and Pukhalskyi VA (2004) Trends in genetic diversity change of spring bread wheat cultivars released in Russia in 1929–2003. Russian Journal of Genetics 40: 1245–1257.
Doebley JF, Gaut BS and Smith BD (2006) The molecular genetics of crop domestication. Cell 127: 1309–1321.
Donini P, Law JR, Koebner RMD, Reeves JC, Cooke ,RJ .2000. Temporal trends in the diversity of UK wheat. Theor Appl Genet 100:912–917
Dunn RR, Harris NC, Colwell RK, Koh LP, Sodhi ,NS .2009. The sixth mass coextinction: are most endangered species parasites and mutualists? Proc Biol Sci R Soc 276:3037–3045
Ellstrand NC and Elam, DR.1993. Population genetic consequences of small population size – implications for plant conservation. Annual Review of Ecology and Systematics 24: 217–242.
FAO .1998. The state of the world's plant genetic resources for food and agriculture, viale delle Terme di Caracalla. Italy. pp.33-70.
Fu ,YB .2006. Impact of plant breeding on genetic diversity of agricultural crops: searching for molecular evidence. Plant Genet Resour 4:71–78
Fu YB, Peterson GW and Morrison ,MJ .2007. Genetic diversity of Canadian soybean cultivars and exotic

germplasm revealed by simple sequence repeat markers. Crop Science 47: 1947–1954.
Gepts,P.2006. Plant genetic resources conservation and utilization: the accomplishments and future of a societal insurance policy. Crop Science 46: 2278–2292.
Hammer K, Kn puffer H, Xhuveli L, Perrino, P.1996. Estimating genetic erosion in FV's – two case studies. Genet. Resour. Crop Evol. 43: 329–336.
Heal G, Walker B, Levin S, Arrow K, Dasgupta P, Daily G, Ehrlich P, Maler KG, Kautsky N, Lubchenco J, Schneider S and Starrett,D.2004. Genetic diversity and interdependent crop choices in agriculture. Resource and Energy Economics 26: 175–184.
Hoisington D, Khairallah M, Reeves T, Ribaut JM, Skovmand B, Taba S, Warburton, M .1999. Plant genetic resources: what can they contribute toward increased crop productivity? Proc Natl Acad Sci U S A 96:5937–5943
Huang XQ, Wolf M, Ganal MW, Orford S, Koebner RMD and Roder, MS. 2007. Did modern plant breeding lead to genetic erosion in European winter wheat varieties? Crop Science 47: 343–349.
Ishikawa R, Yamanaka S, Fukuta Y, Chitrakon S, Bounphanousay C, Kanyavong K, Tang LH, Nakamura I, Sato T and Sato, YI .2006. Genetic erosion from modern varieties into traditional upland rice cultivars (Oryza sativa L.) in northern Thailand. Genetic Resources and Crop Evolution 53: 245–252.
Kik C, Samoylov AM, Verbeek WHJ, Van Raamsdonk LWD and Mitochondrial DNA .1997. variation and crossability of leek (Allium porrum) and its wild relatives from the Allium ampeloprasum complex. Theoretical and Applied Genetics 94: 465–471.
Koebner R, Donini P, Reeves J, Cooke R, Law ,J .2003.Temporal flux in the morphological and molecular diversity of UK barley. Theor Appl Genet 106:550–558
Lelley T, Stachel M, Grausgruber H and Vollmann, J .2000. Analysis of relationships between Aegilops tauschii and the D genome of wheat utilizing microsatellites. Genome 43: 661–668.
Levings, CS .1990. The Texas cytoplasm of maize: cytoplasmic male sterility and disease susceptibility. Science 250: 942–947.
Malysheva-Otto L, Ganal MW, Law JR, Reeves JC and Roder ,MS .2007. Temporal trends of genetic diversity in European barley cultivars (Hordeum vulgare L.). Molecular Breeding 20: 309–322.
Manifesto MM, Schlatter AR, Hopp HE, Suarez EY and Dubcovsky, J .2001. Quantitative evaluation of genetic diversity in wheat germplasm using molecular markers. Crop Science 41: 682–690.
Martos V, Royo C, Rharrabti Y and del Moral ,LFG.2005.Using AFLPs to determine phylogenetic relationships and genetic erosion in durum wheat cultivars released in Italy and Spain throughout the 20th century. Field Crops Research 91: 107–116.
Martynov SP, Dobrotvorskaya TV and Pukhalskiy ,VA .2005. Analysis of genetic diversity of spring durum wheat (Triticum durum Desf.) cultivars released in Russia in 1929–2004. Russian Journal of Genetics 41: 1113–1122.
Martynov SP, Dobrotvorskaya TV and Pukhalskiy ,VA .2006. Dynamics of genetic diversity in winter common wheat Triticum aestivum L. cultivars released in Russia from 1929 to 2005. Russian Journal of Genetics 42: 1137–1147.
Martynov SP, Dobrotvorskaya TV, Pukhalskiy ,VA.2005. Analysis of genetic diversity of spring durum wheat (Triticum durum Desf.) cultivars released in Russia in 1929–2004. Russ J Genet 41:1113–1122
Merezhko, A. F.: Impact of plant genetic resources on wheat breeding. Euphytica, 100, 1998, 295-303.
Pecetti L, Annicchiarico P, Damania ,AB.1992. Biodiversity in a germplasm collection of durumwheat. Euphytica 60:229–238
Reif JC, Hamrit S, Heckenberger M, Schipprack W, Maurer HP, Bohn M and Melchinger ,AE . 2005a. Trends in genetic diversity among European maize cultivars and their parental components during the past 50 years. Theoretical and Applied Genetics 111: 838–845.
Reif JC, Zhang P, Dreisigacker S, Warburton ML, van Ginkel M, Hoisington D, Bohn M, Melchinger ,AE .2005.Wheat genetic diversity trends during domestication and breeding. Theor Appl Genet 110:859–864
Ren J, Sun D, Chen L, You FM, Wang J, Peng Y, Nevo E, Sun D, Luo MC, Peng ,J .2013. Genetic diversity revealed by single nucleotide polymorphism markers in a worldwide germplasm collection of durum wheat. Int J Mol Sci 14:7061–7088
Richards R and Ruivenkamp, G .1997. Seeds and Survival: Crop Genetic Resources in War and Reconstruction in Africa. Rome: International Plant Genetic Resources Institute.
Sachs ,MM .2009. Cereal germplasm resources. Plant Physiol 149:148–151
Simmonds, N.W. 1976. Evolution of Crop Plants. Longman, London.
Smale M, Reynolds MP, Warburton M, Skovmand B, Trethowan R, Singh RP, Ortiz-Monasterio I and Crossa, J .2002. Dimensions of diversity in modern spring bread wheat in developing countries from 1965. Crop Science 42: 1766–1779.

Sperling, L .2001. The effect of the civil war on Rwanda's bean seed systems and unusual bean diversity. Biodiversity and Conservation 10: 989–1009.

Tanksley SD and McCouch ,SR .1997. Seed banks and molecular maps: unlocking genetic potential from the wild. Science 277: 1063–1066.

Tanksley SD, McCouch ,SR .1997. Seed banks and molecular maps: unlocking genetic potential from the wild. Science 277:1063–1066

Teklu Y, Hammer,K .2006. Farmers' perception and genetic erosion of tetraploid wheats landraces in Ethiopia. Genet Resour Crop Evol 53:1099–1113

Teklu, Y. and Hammer, K.2006. Farmers' perception and genetic erosion of tetraploid wheat landraces in Ethiopia. Genetic Resources and Crop Evolutionl, 43, 1099-1113.

Thomson MJ, Septiningsih EM, Suwardjo F, Santoso TJ, Silitonga TS and McCouch ,SR .2007. Genetic diversity analysis of traditional and improved Indonesian rice (Oryza sativa L.) germplasm using microsatellite markers. Theoretical and Applied Genetics 114: 559–568.

Tian QZ, Zhou RH, Jia ,JZ .2005. Genetic diversity trend of common wheat (Triticum aestivum L.) in China revealed with AFLP markers. Genet Resour Crop Evol 52:325–331

Tsegaye B, Berg ,T .2007.Genetic erosion of Ethiopian tetraploid wheat landraces in Eastern Shewa, Central Ethiopia. Genet Resour Crop Evol 54:715–726

Tsegaye, B. and Berg, T. 2007a. Genetic erosion of Ethiopian tetraploid wheat landraces in Eastern Shewa, Central Ethiopia. Genetic Resources and Crop Evolutionl, 54, 715-726.

van Zanden ,JL.1991. The first green revolution: the growth of production and productivity in European agriculture, 1870–1914. The Economic History Review 44: 215–239.

Walters C, Wheeler L, Grotenhuis, J .2005. Longevity of seeds stored in a genebank: species characteristics. Seed Sci Res 15:1–20

Warburton ML, Crossa J, Franco J, Kazi M, Trethowan R, Rajaram S, Pfeiffer W, Zhang P, Dreisigacker S and van Ginkel,M .2006. Bringing wild relatives back into the family: recovering genetic diversity in CIMMYT improved wheat germplasm. Euphytica 149: 289–301.

Warburton ML, Crossa J, Franco J, Kazi M, Trethowan R, Rajaram S, Pfeiffer W, Zhang P, Dreisigacker S and van Ginkel, M .2006. Bringing wild relatives back into the family: recovering genetic diversity in CIMMYT improved wheat germplasm. Euphytica 149: 289–301.

White J, Law JR, MacKay I, Chalmers KJ, Smith JSC, Kilian A and Powell ,W .2008.The genetic diversity of UK, US and Australian cultivars of Triticum aestivum measured by DArT markers and considered by genome. Theoretical and Applied Genetics 116: 439–453.

Zavaleta ES, Pasari JR, Hulvey KB, Tilman, GD .2010. Sustaining multiple ecosystem functions in grassland communities requires higher biodiversity. Proc Natl Acad Sci U S A 107:1443–1446