Chapter 1

Landraces and Crop Genetic Improvement

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Additional information is available at the end of the chapter

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Abstract

Landraces are repository of gene pool that enrich biodiversity and maintain and stabilize ecosystem in a sustainable way to make it functional. Cultivation of traditional crops in different regions of the world, aside maintaining biodiversity in agriculture, also avails humanity of regulatory services such as nutrient cycling, carbon sequestration, control of soil erosion, reduction of greenhouse gas emission and control of hydrological processes. However, man through over-exploitation of some plant species with utter neglect to some other either deliberately or otherwise through modern agricultural systems that promote cultivation of a few high-input and high-yielding crop species caused disaffection to biodiversity with consequences of reduction in its regulatory services. In this chapter, different landraces of crops are examined, their usefulness in the maintenance of genetic diversity is explored, and implications of their depletion are discussed.

Keywords: genetic diversity, adaptation, conservation, heterogeneity, utilization

1. Introduction

Landraces are defined as dynamic populations of a cultivated plant with a historical origin, distinct identity, often genetically diverse and locally adapted, and associated with a set of farmers' practices of seed selection and field management as well as with a farmers' knowledge base [1] . Sangam et al. [2] referred to plant landraces as heterogeneous local adaptations of domesticated species providing genetic resources that meet current and new challenges for farming in stressful environments. These local ecotypes can show variable phenology and low to moderate edible yield but are often highly nutritious. The main contributions of landraces to plant breeding have been traits for more efficient nutrient uptake and utilization, as well as useful genes for adaptation to stressful environments such as water stress, salinity and high temperatures. A systematic landrace evaluation may define patterns of diversity, which will facilitate identifying alleles for enhancing yield and abiotic stress adaptation, thus raising the productivity and stability of staple crops in vulnerable environments. It can also be defined as a traditional variety with a high capacity to tolerate biotic and abiotic stresses, resulting in high-yield stability and an intermediate yield level under a low-input agricultural system [3]. A landrace differs from a variety that has been selectively improved by breeders for particular characteristics.

Landraces are important genotypes for crop breeding owing to their high potential to adapt to specific environmental conditions and the large source of genetic variability that they provide [4]. Landraces are generally less productive than commercial cultivars, although in recent years, they have become important as sources of genetic variability in the search for genes for tolerance or resistance to biotic and abiotic factors of interest in agriculture [5]. The genetic diversity observed across landraces is the most important part of maize biodiversity, and local races represent an important fraction of the genetic variability exhibited by this genus. However, few agronomic and genetic data exist for such collections, and this scarcity has limited the use, management and conservation of this germplasm. In addition, a few improved genotypes with narrower genetic variability are quickly replacing maize landraces [6].

Zeven opined that landraces have played a fundamental role in the history of crops worldwide, in crop improvement and agricultural production, and they have been in existence since the origins of agriculture itself. During this time they have been subject to genetic modification through abiotic, biotic and human interactions. For centuries, crop landraces were the principal focus for agricultural production [7]. Farmers sowing, harvesting and saving a proportion of seed for subsequent sowing over millennia have enriched the genetic pool of crops by promoting intraspecific diversity [8]. This cycle remained current until the dawn of formal plant breeding and the generation of generally higher-yielding cultivars that subsequently replaced many traditional landraces [7, 9, 10].

2. Historical background of landrace origin

The origin of landraces encompasses both the temporal and spatial components of where landraces were first developed. They (landraces) have a relatively long history, significantly more than the ephemeral lifespan of modern cultivars. Many authors suggest that landraces have been growing 'since time immemorial' [11], 'over long periods of time' [9], 'over hundreds even a thousand years' [12], 'for many years even centuries' [13], 'for generations' [14], 'for many centuries' and 'over a period of time' [15]. Nevertheless, few are explicit about the amount of time a landrace must be grown to be considered a landrace. However, Louette [16] indicated for maize that the period of time must be 'for at least one farmer generation (i.e. more than 30 years)', while Astley referred to vegetable landraces being grown for '50–70 or even 100 years'.

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Hawkes [17] opined that landraces are associated with one specific geographical location, in contrast to cultivars which are bred remotely, trialed in several locations and subsequently cultivated in diverse locations. Therefore, landraces are closely associated with 'specific locations' and often will take the name of the location [11]. Examples of this are Kent Wild White Clover from the UK county of Kent and Tuxpenõ maize from the Tuxpan region in Mexico. However, migrations (seed flow) of established landraces from their region of origin to new regions have also occurred as local informal variety introductions. Zeven [3] proposed two types of landraces: **autochthonous** (landraces cultivated for more than a century in a specific region) and **allochthonous** (a landrace that is autochthonous in one region introduced into another region and becoming locally adapted). In that case, the examples of Kent Wild White Clover and Tuxpenõ maize are cultivated in regions other than where they originated. Kent Wild White Clover is grown in some hilly areas of Scotland and Tuxpenõ maize in several regions of Southern Mexico. A third type known as a 'Creole' landrace may be derived from an originally bred variety [18, 19], which then becomes an effective landrace following numerous repeated cycles of planting and farmer seed selection in a specific location. For instance, Square Head Master Wheat, identified as a cultivar in the National List of the UK, has been grown continuously since 1930 by the family of Paul Watkin (a farmer from Suffolk, UK) saving seed each year.

Continuity and individual cultivation and discontinuity and collective cultivation are both significant. Individual farmers commonly lose and recover landraces as a result of their management of a dynamic portfolio of landraces [19] and seed replacement [20] and because of various stochastic events such as drought, floods, pests and diseases. Village or local community continuity may be maintained through farmer's seed exchange networks if cultivation is by more than one farmer. In fact, several papers have highlighted the relevance of seed exchange for the maintenance of landraces [20–22]. Such localized farmer exchange activities may help to define and ensure continuity of a landrace. However, the introduction of 'exotic' landraces to a locality is likely to adulterate the uniqueness and local adaptation of the local landraces. Therefore, many believe that the maintenance of an 'open' cultivation system, with routine local or more remote introductions of germplasm, is likely to be responsible for the maintenance of genetic diversity in landraces.

3. Lack of formal genetic improvement

Landrace production is associated with 'no human selection' [11] and 'it was naturally developed' [23]; thus, landraces have been developed as a result of time and natural selection alone. Other authors suggest that human selection has occurred but in the form of unconscious selection, and others suggest that a certain degree of consciousness is involved in the selection process, 'without or with only little mass selection' [23], 'subject to some deliberate selection' [24], 'artificial selection (probably largely of an unconscious nature)' [17] and 'breeding or selection … either deliberately or not' [14]. Where conscious human selection has been recognized as being significant in landrace development, it has nevertheless been distinguished that is applied to modern cultivars [7, 12] with qualifications such as 'more resistant to pests and diseases, have more yield stability' [25], 'grown in traditional farming systems' [7, 13], 'cultivated in low-input cultivation' [8], 'in a number of traits which together appear to form an adaptive complex' [3] and 'on a low selection pressure'.

It is generally accepted that farmers, gardeners and growers select and develop landraces [12–15, 17, 26], while formal plant breeders select and develop cultivars (**Figure 1**). However, even this division is not as clear as it first may appear if other considerations are included. Zeven [27] explained that 'continuous selection by some farmers for plants with desired characters is similar to the later proposed scientific selection within landraces to select by seekers for the best plants'. Examples of these are shown in vegetables that present special traits such as enormous size, developed by growers in the UK.

The situation concerning the involvement of landraces in participatory plant breeding is interesting, as Maxted [28] noted that care should be taken to ensure the security of the locally adapted genetic diversity or the former landrace could no longer be regarded as a landrace. Here, the decision over whether the former landrace may still be regarded as a landrace as described by Almekinders and Elings [29] depends on the degree of breeding and the quantity of external germplasm introgressed with the original landrace; the more of either the less the entity could be regarded as a landrace. Certainly, this would be the case for participatory varietal selection programs where external germplasm is introduced into an area and suitable material is selected by local farmers; even if the new germplasm is managed by the farmer in a manner usually associated with traditional farming and landrace maintenance, the use of the term landrace would be inappropriate. Yet, another consideration is understood by the term 'modern' crop improvement.

Simmonds [30] and Allard [31] further explained that modern professional crop improvement is based on the Darwinian theory of evolution through selection and the genetic mechanisms of evolution developed by Mendel, Johannsen, Nilsson-Ehle, East and others. Frankel and Bennett [9] used as a reference point the 19th century when conscious, individual plant selection commenced. Jarman and Leggett considered that 'modern' crop improvement started when formal breeding programs were initiated, in the UK, for example, in the 1920s. However, the fact that the history of crop improvement is different for each crop is also an important element to be considered [3]. Combining these considerations, formal crop improvement is understood as the application of genetic principles and practices to the development of cultivars by both classic breeding techniques (selection and hybridization) as well as more recent technologies (biotechnology, molecular biology, transgenics) within a crop improvement program. Virchow [32] when defining the characteristics of a landrace included the fact that landraces are not registered in official seed lists, but in the UK, several entities generally regarded as landraces, such as Kent Wild White Clover, are included on the National List and are regarded as landraces because they result from farmers' selection over millennia.

In fact, it is argued that inclusion of landraces on the UK National List is likely to promote their cultivation and thus conservation [33]. Landraces may therefore be more easily defined as being crop varieties which do not result in the first instance at least from formal crop

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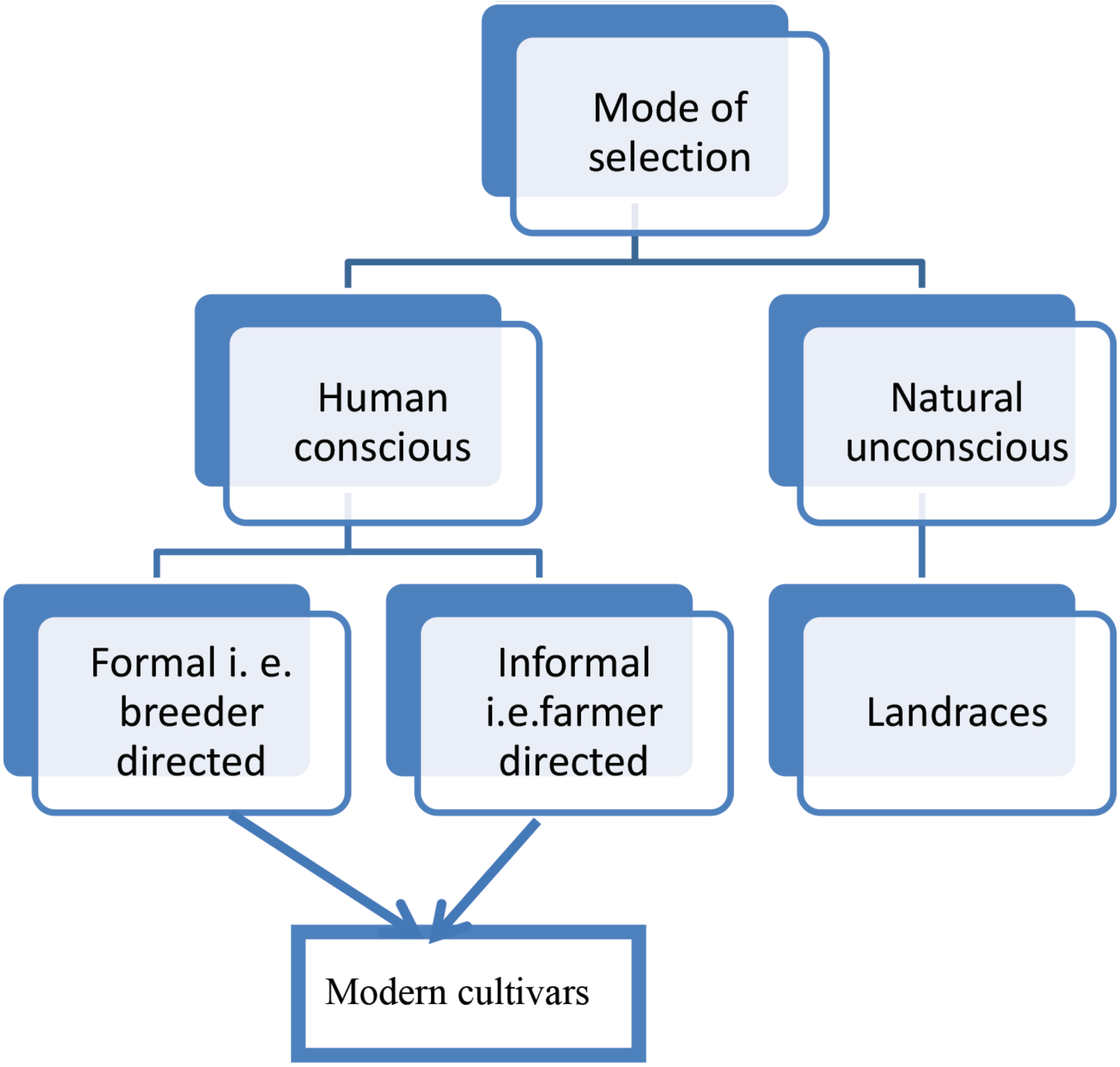

Figure 1. Different opinions about the types of landrace selection [36].

improvement programs, in contrast with modern cultivars which have resulted directly from these programs (**Figure 1**).

Despite this improved clarification, there remains confusion as regards the effect of crop evolution on landraces. Crop evolution is not a linear process, and there are different points of view of the position occupied by landraces in relation to their wild relatives, on the one hand, and cultivars, on the other. Some authors such as Marchenay [34] suggested that some landraces exist on the borders of cultivation, not having been fully domesticated and might be better considered as ecotypes. Other authors raised the issue that some landraces have crossed freely with their wild relatives over millennia [24, 35] and as a result possess rudimentary characters or 'wild relative traits' not found in cultivars because of their more ephemeral existence. While

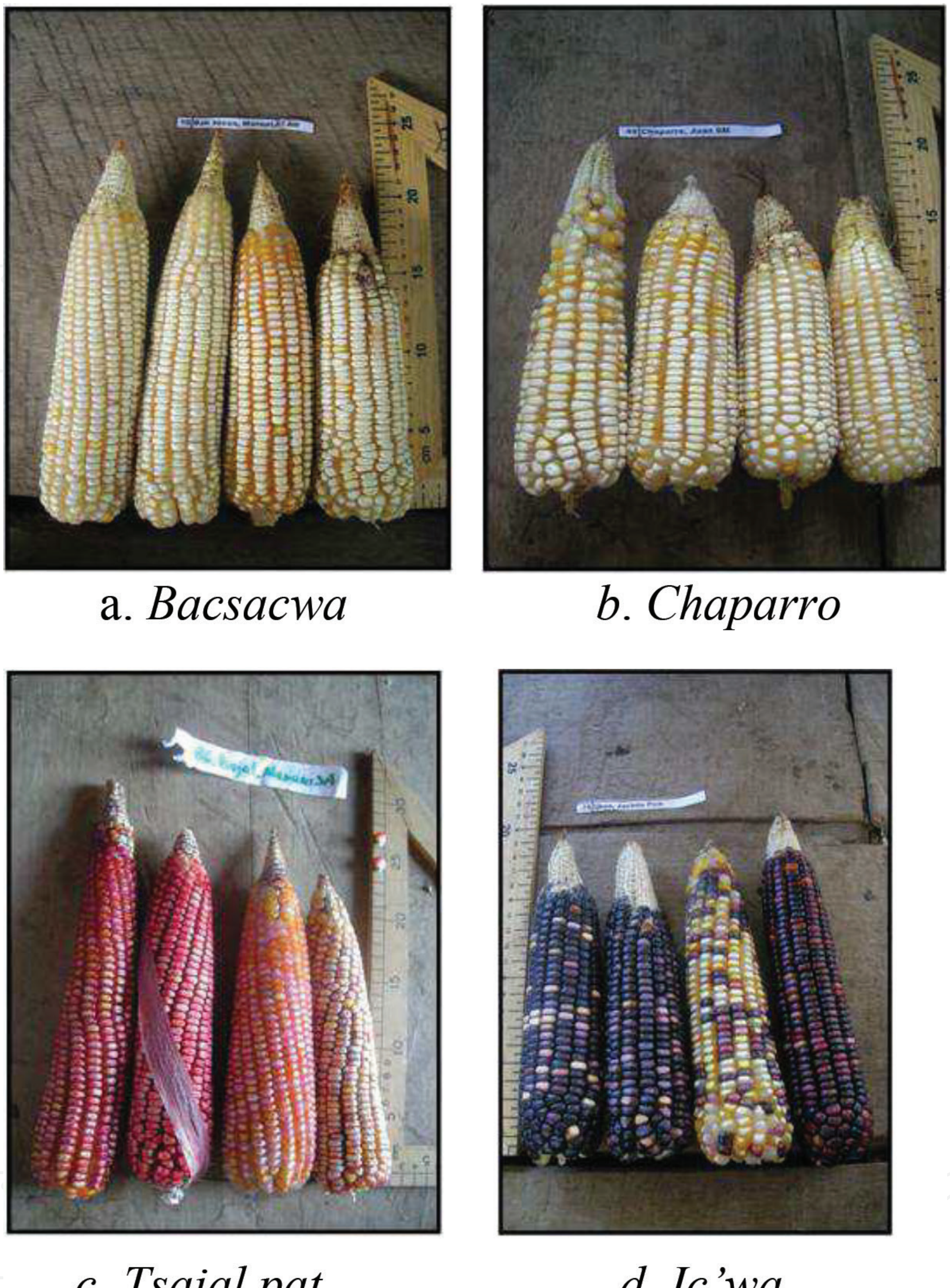

Figure 2. Types of landraces of maize [27].

others believe that landraces can even be selected from cultivars [18, 19], terms such as creolization or rustication are applied, and 'in the absence of traditional and formal maintenance breeding, any improved landrace (cultivar), including a hybrid variety, will regress with time into a landrace' [27]; 'a cultivar that has been growing under a low selection pressure for specific traits but not uniformity for a long time could be considered a landrace' (**Figure 2**).

4. Recognizable identity

Landrace must be intrinsically highly genetically diverse and recognized as a distinct entity via common-shared traits. These traits will allow the distinction of one landrace from another or from modern cultivars for the same crop. They will sometimes give rise to landrace names, but at other times, names may be determined by other factors such as use or origin. Therefore, landraces 'are each identifiable and usually have local names' [7], 'are recognized morphologically' [14], 'have a local name,' 'are a farmer selection based on local characteristics (specific use, local market, horticultural practices and locally adapted)' and 'are heterogeneous populations with a similar trait'.

However, this characteristic may be difficult to be applied universally as landraces identified on the basis of common names can be misleading because of non-associated synonyms and homonyms. Many disparate landraces may be named after their early flowering capability or seed color, for example. A landrace may be recognized by different names in different countries or communities [36], or conversely quite different landraces can be designated with the same name [14]. These factors contribute to one of the main problems associated with landraces, namely, their consistent identification and the determination of which traits can be consistently used to define the identity of a specific landrace.

5. High genetic diversity

The characteristics of landraces in relation to the magnitude of allelic and genetic diversity in contrast to cultivars are considered to be significantly more genetically diverse [37]. Thus, a landrace is a 'highly variable population in appearance' [7], 'highly diverse populations and mixtures of genotypes' [38], 'genetically heterogeneous' [13], 'not genetically uniform and containing high levels of diversity' [14], 'local diverse crop varieties' [26], 'heterogeneous crop populations' [39] and 'materials with variable levels of heterogeneity'. Frankel and Soule [40] indicated that the genetic diversity of landraces has two dimensions: between sites/populations and within sites/populations. The former is generated by heterogeneity in space and reproductive isolation, while the latter is generated by heterogeneity in time associated with both short-term variations between seasons and by longer-term climatic, biological and socio-economic changes.

Some authors have used the term 'meta-population' when referring to the diversity structure of a landrace. As such, a landrace constitutes a group of farmers' seed lots that are highly diverse both between and within themselves. In contrast however, Sanchez [41] when evaluating the genetic diversity of maize landraces of Mexico found that some landraces had very low levels of genetic diversity, and it was suggested that comparatively low diversity may be more associated with selfing crops. Bere barley, one of the oldest cereal varieties in Europe, is 'surprisingly homozygous', possibly because it has been maintained in isolation in marginal lands since the sixteenth century [42]. A similar picture is provided by Tibetan barley landraces which proved to be much less diverse than modern barley cultivars due possibly to their relative geographic isolation, their relatively recent introduction to Tibet and the fact that they have been subject to very little natural or man-made selection [43]. Therefore, the dynamics of genetic diversity and changes over time of the genetic structure of landraces are likely to be crop specific. It is also likely to be associated with the mode of fertilization (self- versus cross) and propagation (sexual or asexual), which has over time resulted in genetic bottlenecks, varying outcrossing rates, recombination and gene flow. Thus, as Almekinders and Louwaars [24] conclude, 'a landrace is usually a complex heterogeneous population, but not necessarily so'.

6. Local genetic adaptation

Landraces are generally adapted to local environment. With the continued cycles of local planting, harvesting and farmers' selection, over time landraces will be selected for local environmental and agroecosystem conditions and practices, just as ecotypes of wild species are adapted to the local environmental conditions. Landraces 'are adapted to their growing conditions' [11]; 'possess adaptive complexes associated with the special conditions of cultivation, pure-stand associations, harvesting and others factors' [44]; 'are not only adapted to their environment, both natural and man-made, but they are also adapted to each other' [7]; 'are adapted to the areas in which they grow' [12]; 'are specifically adapted to local conditions' [13]; and 'are adapted to local conditions' [26].

Bennett [44] made the assumption that landraces are more suited to cultivation in particular locations than highly bred cultivars that are bred for cultivation in the most common environmental conditions. Inevitably, cultivars will be less suited to grow in suboptimal conditions and therefore have less of a competitive advantage in marginal environments where the local landraces are likely to have an adaptive advantage. These local conditions may be defined as abiotic (e.g. salinity, drought, etc.), biotic (e.g. pests, diseases, weeds) and human (e.g. cultivation, management and use). Landraces are perceived to have the ability 'to sensitively respond to even minor environmental influences' [44]; 'to have some built-in insurance against hazards' possibly due to their inherent population structure [7]; 'to accumulate resistance genes to limiting factors in the physical and biological environment—drought, cold, diseases, pests' [24]; and 'to be capable of producing in any but disaster seasons at a level which safeguards the survival of the cultivator' and so provide yield stability [24].

Several studies have demonstrated the relationship between landraces and local adaptation, for example; Frankel [8] and Brown [39] discuss landrace adaptation to marginal conditions associated with climatic, soil and disease stress. The evolution of local adaptation over millennia in these stressed environments ensures yield stability even in extremely adverse years. In this sense, Zeven [27] considers yield stability to be a principal characteristic of landraces.

However, even though there are numerous references to a specific relation between a landrace and local environmental conditions, there are exceptions. Zeven [3] indicated that 'some landraces are able to adapt themselves to a wide range of environments, whereas others are able to adapt themselves only to a few environments'. Wood and Lenne [19] disagree with the assumption 'that all traditional varieties are locally adapted' and state that 'evidence against specific local adaptation in crop varieties is provided by the extensive interchange of traditional varieties of all crops'. Farmers employing an 'open' cultivation system where there is regular local or more exotic landrace introduction are less likely to have locally adapted landraces. Zeven [20] provided evidence of farmers' traditional practice of periodic seed replacement to combat so-called degradation, which indicates that in certain situations a 'closed' cultivation system that results in local adaptation of landraces may be deleterious. The farmer's criteria for seed selection also do not necessarily lead to selection for local adaptation; the varying environmental conditions under which traditional agriculture is carried out may in certain conditions not actually favor specific local adaptation. In this sense, some authors consider that local adaptation can comprise both wide adaptation in certain landrace characters and narrow adaptation in others.

7. Association with traditional farming systems

Traditional farming systems have often been considered beneficial reservoirs of landraces and intra-crop diversity [45]. Traditional farming systems involve traditional cultivation, storage and use practices, and integrated with these practical skills, traditional knowledge about landrace identification, cultivation, storage and uses is incorporated. In this sense, one important element of landraces conservation that has recently been the focus of researchers' attention is the way that landraces studies have focused on farmers' variety selection [46], farmers' seed exchange [22], farmers' seed networks [22], farmers' seed replacement [20], farmers' portfolios of varieties [19], farmers' landraces identification [47]and farmers' landrace uses [48]. Each has shown the role of farmers for the creation and maintenance of a landrace.

In fact, Zeven [27] suggested that landrace diversity can be explained by the combination of farmers' selection criteria on specific local landrace genotypes by means of farmers' seed saving and the introduction of variation by means of exchange with other farmers of other genotypes of the same crop. This indicates that landraces are more inherently dynamic than cultivars as they are maintained through repeated cycles of sowing, harvesting and replacing seed selection by farmers [49, 50] within complex informal systems. However, it is also important to consider that traditional farming systems are themselves also dynamic and that the frontier between them and other farming systems is not well defined. As such, traditional farming systems are subject to change, incorporating in some cases modern cultivars into their systems, growing them alongside landraces of the same species [51]. These have been managed and maintained by farmers.

8. Threat to landrace diversity

The current industrial agriculture system may be the single most important threat to biodiversity [2]. Also, Sarker and Erskine [52] opined that a serious consequence of biodiversity loss is the displacement of locally adapted landraces with adaptation traits to future climates by monocropping with genetically uniform hybrids and improved cultivars. Modern agriculture has contributed to decreasing agricultural biodiversity as most of humankind lives now on only crops, with wheat (*Triticum aestivum*) L.), rice (*Oryza sativa* L.), maize (*Zea mays* L.) and potato (*Solanum tuberosum* L.) accounting for 60% of diets [2]. For example, 74% of rice cultivars in Indonesia are derived from the same stock, while 50% of wheat, 75% of potato and 50% of soybeans in the USA. The genetic erosion was estimated at 72.4 and 72.8%, respectively [53]. Furthermore, the number of rice cultivars declined in India farms from about 400,000 before colonialism to 30,000 in the mid-nineteenth century with unknown thousands more being lost after the Green Revolution. Greece also lost 95% of its wheat landraces after being encouraged to replace them with modern cultivars.

9. The concept of local variety

The concepts of the local variety have already existed in the guidelines for the proper in situ, on-farm and ex situ conservation of plant varieties. A local variety is a variety or local crop that reproduces by seed or by vegetative process. It is a variable population, which is identifiable and usually has a local name. It lacks 'formal' genetic improvement and is characterized by specific adaptation to the environmental conditions of the area of cultivation (tolerant to the biotic and the abiotic stresses of that area) and is closely associated with the traditional use, knowledge, habits, dialects and celebrations of the people who developed and continue to grow it [54].

10. On-farm management of local seed diversity

In Nigeria, in spite of the event of the formal certified seed sector, many rural farmers continue to use traditional seeds or other planting materials to meet their seed need [55]. They have their own method of selection and conservation of seeds. This method varies slightly from one crop to another. Indeed, seeds are collected at maturity on apparent healthy plants and saved from season to season by individual farmers. As with selection, storage and conservation methods varied with crops. As such, seeds were stored either in packages and suspended at kitchen roofs (in the case of maize and cowpea, for example, in Yorubaland in Nigeria) or in grain and bottled (case of peppers, tomatoes, etc.). Yet, there can also be significant amounts of exchange between neighbors and relatives. They are also purchased when necessary. On-farm management of local seed diversity is predominant in the Nigeria seed sector since conversely to the cotton culture; no organized provision system exists for food crops.

11. Durum wheat

Durum wheat (*Triticum turgidum* var. L. *durum*) is grown on over 1 million ha. Forty-five percentage of which are sown in the arid and semiarid regions, 11% in high altitudes and 44% in more favorable areas [56]. The complexity of the population structure of wheat landraces may arise from a number of different homozygotes and the occurrence and frequency of heterozygotes in populations. The assessment of genetic diversity between and within wheat landraces is essential to utilize landraces as donors of traits in wheat breeding and to identify priority areas for on-farm conservation.

Landraces could act as donors of important characteristics, such as drought and cold tolerance and mainly grain quality. In general, they represent significantly broader genetic diversity than modern varieties, and, therefore, they could contribute to extend the genetic base of modern cultivars. The identification of quality parameters such as protein content, gluten strength, yellow pigment and their integration in the improved varieties is a priority in research on durum wheat [57]. Mineral content in modern wheat cultivars has significantly decreased, including copper, iron, magnesium, manganese, phosphorus, selenium and zinc. High levels of these nutrients can be found in landraces and old low-yielding varieties [56].

Landraces displayed a wide range of genetic diversities. This local germplasm forms an interesting source of favorable quality traits such as protein content, gluten strength and yellow pigment content useful to durum wheat breeders. The persistent cultivation of durum wheat landraces in some regions attests to their continued value to farmers and to their competitive agronomic or nutritional advantage relative to modern varieties. Adding value of these landrace is the main motivating factor for their on-farm conservation. Fungi seed treatment against seed-borne diseases and chemical weeding at the right time could improve the landrace productivity in a simple way.

Furthermore, composite landraces made up of promising lines selected from landraces could be another way for durum wheat landrace valorization. But, on-farm conservation of durum wheat genetic resources in Morocco could be more efficient provided that legislation changes are made that make it possible to market landraces as diversified genetic materials and encourage their consumption [56]. Durum wheat landraces have over many generations become adapted to the local environment and cultural conditions under which they are grown. Development of new varieties from landraces could be a viable strategy to improve yield and yield stability, especially under stress and future climate change conditions.

12. Rice

Rice is among the most important crops worldwide. While much of the world's rice harvest is based on modern high-yield varieties, traditional varieties of rice grown by indigenous groups have a great importance as a resource for future crop improvement. These local landraces represent an intermediate stage of domestication between a wild ancestor and modern varieties, and they serve as reservoirs of genetic variation. Such genetic variation is influenced both by natural processes such as selection and drift and by the agricultural practices of local farmers. How these processes interact to shape and change the population genetics of landrace rice is unknown [58]. Compared to new rice cultivars, rice landraces have more complex genetic backgrounds and more abundant genetic diversity and heterogeneity, as well as strong adaptability to the environment, excellent resistance to diseases and pests, high yields and good quality [59]. The Southwest China, Guizhou, Yunnan and Guangxi provinces, is one of the largest centers of rice genetic diversity and high-quality germplasm in the world [21, 60].

The genetic variability found within landraces affords the possibility of genetic flexibility; landraces have the potential to adapt to local field conditions, and they can adapt to changing environments, farming practices and specific uses such as animal vs. human consumption [61]. Moreover, the genetic diversity of traditional landrace varieties is the most immediately useful and economically valuable component of rice biodiversity [19]. To efficiently conserve, manage and use such germplasm resources, an understanding of structure, apportionment and dynamics of local landrace variation is required. Several studies have examined genetic variation and differentiation among rice landrace varieties [62, 63]. However, little to no information is available on how genetic diversity is structured within a given landrace.

Local adaptation plays an important role in maintaining yields in traditional agricultural systems. Selection for adaptation to each village environment by the farmer's seed selection enhances overall crop diversity and maintains evolutionary flexibility [64]. Almekinders [21] explained that farmers' selection in combination with natural selection results in landraces with high levels of adaptation to biotic and abiotic stresses and for agricultural traits. For example, the genetic diversity of *Phaseolus vulgaris* landraces in Italy has been shaped by local adaptation to microenvironments [65], and in wheat, selection by farmers has strongly influenced the evolution of neutral loci [66].

13. Advantages of landrace over modern cultivated agriculture

1. Landraces provide a medium to advertise information about the conservation and use of crop landraces.
2. Crop improvement often utilizes landrace diversity in the development of new cultivars [8, 24], particularly when developing cultivars for marginal environments. Although, breeders more routinely focus their efforts on a limited gene pool of advanced cultivars or breeders' lines which are more easily utilized without successive backcrossing to eradicate the undesirable traits introduced with the desirable [67, 68].
3. Landraces still present a unique source of specific traits for disease and pest resistance, nutritional quality and marginal environment tolerance [8].
4. Landrace tolerance to advert climatic condition.
5. They have become important as sources of genetic variability in the search for genes for tolerance or resistance to biotic and abiotic factors of interest in agriculture.
6. Knowledge of genetic distance among landraces will help the breeding of high-yielding, good quality cultivars that will increase crop production [14].
7. Landraces may provide new alleles for the improvement of commercially valuable traits.
8. Global climate change emphasizes the need to use better adapted cultivars of the main crops and landraces as potential donors of useful genes.

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9. There is an increasing consumer concern worldwide about food safety and nutrition. Landraces or old crop cultivars may prove solutions as sources of healthy and nutritious food.

14. Disadvantages

1. 1. Landraces are generally less productive than commercial cultivars.

15. Implication of replacement of landraces by commercial cultivars

1. It increases and causes genetic erosion by the replacement of diverse landraces with comparatively few, homozygous modern cultivars, which caused considerable concern among conservationists and breeders alike.
2. Landrace replacement by modern cultivars demonstrated a marked reduction in overall genetic diversity.
3. People's concerns over this rapid extinction or erosion of landrace diversity resulted in widespread action to promote their conservation.

16. Landrace conservation

Conservation of all gene pools is a high priority for sustaining food security and coping with current and future climate change effects. Not only must landraces be conserved, but so should local varieties that have been replaced by new and more productive ones. Older varieties, due to the emphasis on landraces and more exotic materials, must not be forgotten, and older varieties, as well as other breeding materials, need to be conserved as a source of genetic diversity. Despite the enormous efforts made by national and international programs to conserve landrace diversities, eventually the conservation of germplasm and characterization of key traits will provide specific information to breeders that will promote the use of genetic resources by the scientific community.

The discovery of abiotic stress at tolerant alleles in landraces of maize, rice and wheat clearly shows the importance of conserving and exploring landrace germplasm as a means to identify gnomonically beneficial alleles for enhancing adaptation and productivity in stress-prone environments [2].

16.1. Specifically, several challenges need attention:

i. Dealing with duplication where tracking is lost when moving germplasm from one place to other, particularly if a unique notation is not used

ii. Genetic diversity of collections widely determined by DNA markers available in gene bank facilities

iii. Diversity being well retained during collection through the use of molecular markers and visual observation and by using internationally accepted conservation and characterization standards in seed gene banks

iv. Increasing in situ conservation

v. Functional multiplication programs

vi. Organizing regular national or regional collection programs with functional surveys that gather high-quality information related to germplasm being collected

vii. Reliable 'passport' information being available with GPS coordinates

viii. Using internationally accepted database management programs in gene banks

ix. Providing a worldwide data system among gene banks

x. Spreading research results in a database system linked with gene banks

These activities, once established, will greatly improve the targeted use of genetic resources and will help scientists and breeders strategically extract and use allelic variation for important traits.

17. Conclusion and future perspective

Loss of genetic diversity has been recognized as a genetic bottleneck imposed on crop plants during domestication and through modern plant breeding practices. Allelic variation of genes originally found in the wild but gradually lost through domestication and breeding has been recovered only by going back to landraces. Landraces with increased biomass and total photosynthesis have potentially new allelic variation that should be exploited in plant breeding.

Landraces are heterogeneous with variable phenology, are low to moderate but stable edible yield and are often nutritionally superior. Traditional agricultural production systems in the past have played a vital role in the evolution and conservation of on-farm diversity, allowing farmers to circumvent crop failure by reducing vulnerability environmental stresses. A systematic evaluation of landraces for assessing the pattern of diversity is urgently needed to identify alleles for enhancing yield and adaptation to abiotic stress for raising the productivity of the staple food crops in stressful environments.

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Conflict of interest

Authors declare no conflict of interest.

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