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Defining and identifying crop landraces

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Abstract

Awareness of the need for biodiversity conservation is now universally accepted, but most often recent conservation activities have focused on wild species. Crop species and the diversity between and within them has significant socioeconomic as well as heritage value. The bulk of genetic diversity in domesticated species is located in traditional varieties maintained by traditional farming systems. These traditional varieties, commonly referred to as landraces, are severely threatened by genetic extinction primarily due to their replacement by modern genetically uniform varieties. The conservation of landrace diversity has been hindered in part by the lack of an accepted definition to define the entity universally recognized as landraces. Without a definition it would be impossible to prepare an inventory and without an inventory changes in landrace constituency could not be recognized over time. Therefore, based on a literature review, workshop discussion and interviews with key informants, common characteristics of landraces were identified, such as: historical origin, high genetic diversity, local genetic adaptation, recognizable identity, lack of formal genetic improvement, and whether associated with traditional farming systems. However, although these characteristics are commonly present they are not always all present for any individual landrace; several crop-specific exceptions were noted relating to crop propagation method (sexual or asexual), breeding system (self-fertilized or cross-fertilized species), length of formal crop improvement, seed management (selection or random propagation) and use. This paper discusses the characteristics that generally constitute a landrace, reviews the exceptions to these characteristics and provides a working definition of a landrace. The working definition proposed is as follows: 'a landrace is a dynamic population(s) of a cultivated plant that has historical origin, distinct identity and lacks formal crop improvement, as well as often being genetically diverse, locally adapted and associated with traditional farming systems'.

Keywords: biodiversity; conservation; crop; definition; landraces; plant genetic resources

Introduction

Landraces have played a fundamental role in the history of crops[1] worldwide, in crop improvement and agricultural production, and they have been in existence since the origins of agriculture itself (Zeven, 1998). 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 (Harlan, 1975). Farmers sowing, harvesting and saving a proportion of seed for subsequent sowing over millennia have enriched the genetic pool of crops by promoting intra-specific diversity (Frankel *et al.*, 1998). This cycle remained current until the dawn of formal plant breeding and the generation of generally higher-yielding cultivars[2] that subsequently replaced many traditional

[1] The definition of a 'crop' used in this paper is broad and incorporates any plant that is cultivated or deliberately grown.

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[2] The definition of cultivar used in this paper is the product of formal crop improvement. It is also known as advanced variety or modern variety.

landraces (Frankel and Bennett, 1970; Frankel and Hawkes, 1975; Harlan, 1975).

Crop improvement often utilizes landrace diversity in the development of new cultivars (Frankel, 1977; Frankel *et al.*, 1998), 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 (Duvick, 1984; Peeters and Galwey, 1988), landraces still present a unique source of specific traits for disease and pest resistance, nutritional quality and marginal environment tolerance (Frankel *et al.*, 1998). Therefore, increasing genetic erosion caused by the replacement of diverse landraces with comparatively few, homozygous modern cultivars has caused considerable concern amongst conservationists and breeders alike. Specifically, Srinivasan *et al.* (2003), investigating wheat landrace replacement by modern cultivars in the UK, demonstrated a marked reduction in overall genetic diversity. Concerns over this rapid extinction or erosion of landrace diversity resulted in widespread action to promote their conservation.

Although in the 1960s it was assumed that landraces would inevitably disappear with time (Frankel and Bennett, 1970; Hawkes, 1983; Zeven, 1998), they still continue to play an important role in agricultural production, particularly in marginal environments where cultivars lose their competitive advantage. Landraces also fulfil a continuing commercial role, in specialist production for niche markets (Brush, 1992; Cleveland *et al.*, 1994), are associated with multipurpose use or the self-sufficiency movement (Almekinders and Louwaars, 1999). It is believed that farmers prefer landraces to modern cultivars in marginal areas because of their adaptation to local agro-environmental conditions and their ability to achieve yield stability (Harlan, 1992; Frankel *et al.*, 1998; Almekinders and Louwaars, 1999; Brown, 1999). Therefore, especially in traditional and subsistence farming systems (Altieri and Merrick, 1987; Louette *et al.*, 1997; Wood and Lenné, 1997), landraces continue to play a key role in food security (Brush, 1995). However, landraces are not limited to these farming systems; they are increasingly associated with alternative farming systems, such as organic agriculture (Negri *et al.*, 2000).

Several terms have been associated with the concept of a landrace; primitive cultivar, primitive variety, primitive form, farmers' variety, traditional variety, local variety and folk variety, all have been used as synonyms for the term landrace but with each term there are inconsistencies of application. The use of terms including 'variety' and 'cultivar' for landraces is confusing because they refer more accurately to formally improved material (Astley, personal communication; Jarman, personal communication). Also, there has been no consensus over use of these terms in the literature or in discussion between specialists. As an illustration of the nomenclatural confusion, Cleveland *et al.* (2000) indicated that farmers' varieties are composed of landraces, locally adapted modern varieties and progeny from crosses between landraces and modern varieties. Bellon and Brush (1994) consider that a landrace is constituted by several farmers' varieties. Exceptions to the application of these terms also abound. Other terms associated with landraces that were encountered during discussion with specialists while preparing this paper included: ecotypes, heirlooms, heritage varieties, selections and conservation varieties. While clearly there is no one term universally accepted, folk variety, local variety and traditional variety were more frequently used than others.

Since von Rünker in 1908 first used the term landrace (Zeven, 1998), various definitions have been developed which vary in their precision and applicability. Harlan's definition (1975) of a landrace was populations that had evolved in subsistence agricultural societies as a result of 'millennia long', 'artificial' human selection pressures, mediated through human migration, seed exchange as well as natural selection. Harlan (1975) believed that landraces have three basic characteristics: variability of genotypes, integrity and local adaptation; and this conception of a landrace is the one still most widely applied. Hawkes (1983) extended the term by adding the association with marginal environments and a lack of direct competition with highly bred cultivars. However, Zeven (1998) in a review of landrace definitions concluded that 'as a landrace has a complex and indefinable nature an all-embracing definition cannot be given'.

The fact that landraces remain a vital resource for contemporary plant breeding, and are still widely grown in marginal environments and for niche markets, considered alongside the threat they face from replacement by highly bred cultivars which has undoubtedly led to widespread landrace extinction and genetic erosion of the crop gene pool, has highlighted the need for urgent conservation action. The Conference of the Parties (COP) to the Convention on Biological Diversity (CBD) 2010 Biodiversity Target, as well as a number of other strategies and treaties, such as the Global Strategy for Plant Conservation, the International Treaty on Plant Genetic Resources for Food and Agriculture and the European Plant Conservation Strategy, outline the need for agro-biodiversity conservation. Specifically, they draw attention to the 'Genetic diversity of crops, livestock, and harvested species of trees, fish and wildlife and other valuable species conserved ... restore, maintain or reduce the decline of populations of species' (www.biodiv.org/2010-target). Clarity over what constitutes a landrace in the legal rather than scientific sense may have particular importance with a view to issues of intellectual property, farmers' rights and benefit sharing.

In the UK, obligations entered into as part of these conventions and treaties led the Department of the Environment, Food and Rural Affairs to commission an inventory and assessment of the UK's Genetic Resources for Food and Agriculture with the dual focus of producing a crop wild relative and landrace inventory (Scholten *et al.*, 2004). The justification being that it would be impossible to conserve effectively UK crop wild relative and landrace diversity without an inventory—how could a strategy be developed to conserve these resources without a baseline assessment?

However, when attempting to undertake the UK landrace inventory it became apparent that it would be impossible to achieve the goal without at least a working definition of what constitutes a landrace. The view of Zeven (1998) that landraces are indefinable proved untenable in the light of the pragmatic requirement for an inventory. It could also be argued that an entity that truly defies definition does not actually exist and all those interested in landrace conservation and use would agree landraces exist. Therefore, the aim of this paper is to review the concepts associated with definition of a landrace and propose a working definition that at least encompasses the characteristics associated with a landrace; a definition that can be applied to ensure that the COP 2010 Biodiversity Target for crop landraces is achievable.

Defining characteristics of crop landraces

To undertake the research a literature and media survey of landrace definitions was undertaken, along with a stakeholder workshop discussion or key informant interviews of those actively involved in landrace conservation and use. The key informants are listed in the acknowledgements and the standard questionnaire used during key informant interviews is shown in the Appendix.

The survey of landrace literature and key informant interviews indicated that there are several defining characteristics associated with landraces: historical origin, recognizable identity, lack of formal genetic improvement, high genetic diversity, local genetic adaptation and association with traditional farming systems.

Historical origin

The origin encompasses both the temporal and spatial components of where a landrace was first developed. Temporally landraces have a relatively long history, certainly significantly more than the ephemeral life-span of modern cultivars. Some authors suggest that landraces have been growing 'since time immemorial' (von Rünker, 1908), 'over long periods of time' (Frankel and Bennett, 1970), 'over hundreds even a thousand years' (Tudge, 1988), 'for many years even centuries' (National Plant Germplasm System (NPGS), 1991), 'for generations' (Food and Agriculture Organization (FAO), 1998; Munro, personal communication), 'for many centuries' (Chorlton, personal communication), 'over a period of time' (Almekinders and Louwaars, 1999). Nevertheless few are explicit about the amount of time a landrace must be grown to be considered a landrace. However, Louette *et al.* (1997) indicated for maize that the period of time must be 'for at least one farmer generation (i.e. more than 30 years)', while Astley (personal communication) referred to vegetable landraces being grown for '50 to 70 or even 100 years'.

Spatially, landraces are associated with one specific geographical location, in contrast to cultivars which are bred remotely, trialled in several locations and subsequently cultivated in diverse locations. Therefore, landraces are closely associated with 'specific locations' (Hawkes, 1983; Astley, personal communication; Chorlton, personal communication; Munro, personal communication) and often will take the name of the location (von Rünker, 1908). Examples of this are: Kent Wild White Clover from the UK county of Kent and Tuxpeño 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 (1998) proposed two types of landraces: autochthomous (landraces cultivated for more than a century in a specific region) and allochthomous (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 Tuxpeño maize are cultivated in regions other than where they originated. Kent Wild White Clover is grown in some hilly areas of Scotland (Holliwell, personal communication) and Tuxpeño maize in several regions of southern Mexico. A third type known as a 'Creole' landrace may be derived from an originally bred variety (Bellon and Brush, 1994; Wood and Lenné, 1997), 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 versus 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 (Wood and Lenné, 1997), seed replacement (Zeven, 1999) and because of various stochastic events such as drought, floods, pests and diseases (Ambrose, personal communication). 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 (Almekinders *et al.*, 1994; Louette and Smale, 1996; Zeven, 1999). 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 (Zeven, personal communication).

Recognizable identity

Although a landrace may be intrinsically highly genetically diverse it must be 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' (Harlan, 1975), 'are recognized morphologically' (FAO, 1998), 'have a local name' (Chorlton, personal communication), 'are a farmer selection based on local characteristics (specific use, local market, horticultural practices and locally adapted)' (Astley, personal communication), 'are heterogeneous populations with a similar trait' (Munro, personal communication). However, this characteristic may be difficult to apply 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 colour, for example. A landrace may be recognized by different names in different countries or communities (Fowler and Mooney, 1990) or conversely quite different landraces can be designated with the same name (FAO, 1998). These factors contribute to one of the main problems associated with landraces, namely their consistent identification (Chorlton, personal communication; Lamont, personal communication; Munro, personal communication) and the determination of which traits can be consistently used to define the identity of a specific landrace.

Lack of formal genetic improvement

Important for characterization of landraces are the different forms of selection that have given rise to them. It has been suggested by some authors that landrace production is associated with 'no human selection' (von Rünker, 1908), 'it [a landrace] was naturally developed' (Banga, 1944); thus landraces have developed as a result of time and natural selection alone. Other authors suggest human selection has occurred but in the form of unconscious selection (Chorlton, personal communication; Jarman, personal communication; Leggett, personal communication), and others suggest a certain degree of consciousness is involved in the selection process, 'without or with only little mass selection' (Banga, 1944), 'subject to some deliberate selection' (Frankel, 1977), 'artificial selection (probably largely of an unconscious nature)' (Hawkes, 1983), 'breeding or selection ..., either deliberately or not' (FAO, 1998). Where conscious human selection has been recognized as being significant in landrace development it has nevertheless been distinguished from that applied to modern cultivars[3] (Harlan, 1975; Tudge, 1988) with qualifications such as: 'more resistant to pests and diseases, have more yield stability' (Schindler, 1918), 'grown in traditional farming systems' (Harlan, 1975; NPGS, 1991; Astley, personal communication), 'cultivated in low-input cultivation' (Frankel *et al.*, 1998), 'in a number of traits which together appear to form an adaptive complex' (Zeven, 1998), 'on a low selection pressure' (Ambrose, personal communication).

Possibly more important than whether the selection was natural or human is the person who undertakes the selection. It is generally accepted that cultivators (farmers, gardeners and/or growers) select and develop landraces (Hawkes, 1983; Tudge, 1988; NPGS, 1991; FAO, 1998; Almekinders and Louwaars, 1999; Brush, 1999; Astley, personal communication; Munro, personal communication), while formal plant breeders select and develop cultivars. However, even this division is not as clear as it first may appear if other considerations are included. Zeven (2000) indicated 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 show vegetables that present special traits such as enormous size, developed by growers in the UK (Astley, personal communication).

[3] Taxa selected for a particular attribute or combination of attributes and that is clearly distinct, uniform and stable in its characteristics and that, when propagated by appropriate means, retains those characteristics (International Code for Nomenclature for Cultivated Plants, cited by Zeven, 1998).

Also, in which category is a formal breeder who grows and selects a landrace in an amateur capacity, and maintains it as a landrace (Astley, personal communication) or formal breeders and farmers who engage together in participatory plant breeding? It is in these situations that the purpose and pressure of the selection are important rather than the designation of the person involved.

The situation concerning the involvement of landraces in participatory plant breeding is interesting, as Maxted *et al.* (2002) noted 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 will, as described by Almekinders and Elings (2001), depend 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 programmes where external germplasm is introduced into an area and suitable material 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, use of the term landrace would be inappropriate.

Yet another consideration is what is understood by the term 'modern' crop improvement. Simmonds (1979) and Allard (1999) state 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 (1970) used as a reference point the 19th century when conscious, individual plant selection commenced. Jarman (personal communication) and Leggett (personal communication) considered that 'modern' crop improvement started when formal breeding programmes 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 (Zeven, 1998). 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 programme. Virchow (1999) 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 farmer's 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 (Scholten *et al.*, 2004). Landraces may therefore be more easily defined as being crop varieties which do *not* result in the first instance at least from formal crop improvement programmes, in contrast with modern cultivars which have resulted directly from these programmes (Fig. 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 (1987) suggest that some landraces exist on the borders of cultivation, not having been fully domesticated and might be better considered as ecotypes.[4] Other authors raise the issue that some landraces have crossed freely with their wild relatives over millennia (Frankel, 1977; Asfaw, 1999), and as a result possess rudimentary characters or 'wild relatives traits' (Munro, personal communication) not found in cultivars because of their more ephemeral existence. While others believe that landraces can even be selected from cultivars (Bellon and Brush, 1994; Wood and Lenné, 1997); 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' (Zeven, 2000); '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' (Ambrose, personal communication).

High genetic diversity

This characteristic relates to the magnitude of allelic and genetic diversity that constitute a landrace. Landraces in contrast to cultivars are considered to be significantly more genetically diverse (Hoyt, 1992). Thus, a landrace is a 'highly variable population in appearance' (Harlan, 1975), 'highly diverse populations and mixtures of genotypes' (Hawkes, 1983), 'genetically heterogeneous' (NPGS, 1991), 'not genetically uniform and containing high levels of diversity' (FAO, 1998), 'local diverse crop varieties' (Brush, 1999), 'heterogeneous crop populations' (Brown, 1999), 'materials . . . with variable levels of heterogeneity' (Ambrose, personal communication). Frankel and Soulé (1981) indicated that the genetic diversity of landraces has two dimensions: between sites/populations, and within sites/populations. The former is generated by

[4] Local or ecological race with genotypes adapted to a particular restricted habitat as a result of natural selection within the local environment (Zeven, 1996).

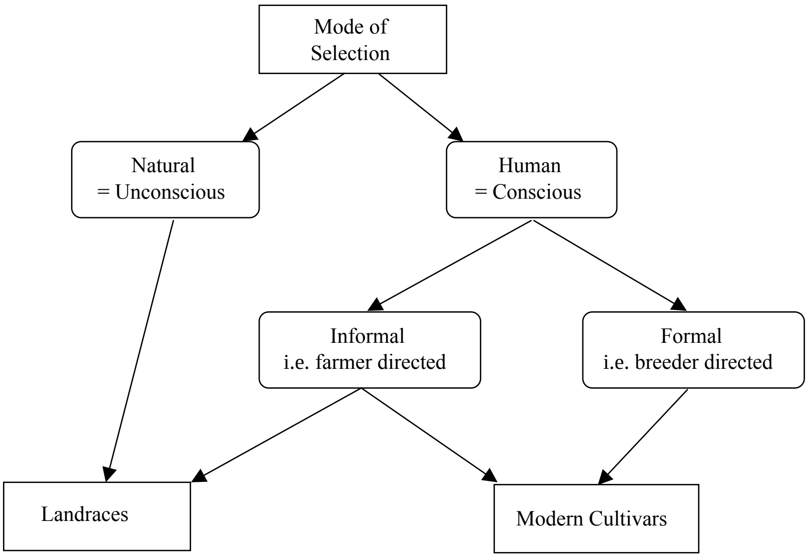

Fig. 1. Different opinions about the types of landrace selection (derived from Cleveland *et al.*, 2000).

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 (Louette and Smale, 1996; Zeven, personal communication). As such, a landrace constitutes a group of farmers' seed lots that are highly diverse both between and within themselves.

In contrast, however, Sanchez *et al.* (2000) evaluating the genetic diversity of maize landraces of Mexico found that some landraces have very low levels of genetic diversity and they suggest 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 16th century (Jarman, 1996). 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 (Choo, 2002). Therefore the dynamics of genetic diversity and changes over time of the genetic structure of landraces is 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 (1999) conclude, 'a landrace is usually a complex heterogeneous population, but not necessarily so'.

Local genetic adaptation

With the continued cycles of local planting, harvesting and farmer 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' (von Rünker, 1908), 'possess adaptive complexes associated with the special conditions of cultivation, pure-stand associations, harvesting and others factors' (Bennett, 1970), 'are not only adapted to their environment, both natural and man-made, but they are also adapted to each other' (Harlan, 1975), 'are adapted to the areas in which they grow' (Tudge, 1988), 'are specifically adapted to local conditions' (NPGS, 1991), 'are adapted to local conditions' (Brush, 1999).

The assumption is made 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 (Bennett, 1970). Inevitably cultivars will be less suited to growth 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' (Bennett, 1970), 'to have some built-in insurance against hazards' possibly due to their inherent population structure (Harlan, 1975), 'to accumulate resistance genes to limiting factors in the physical and biological environment—drought, cold, diseases, pests' (Frankel, 1977), '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 (Frankel, 1977). Several studies have demonstrated the relationship between landraces and local adaptation, for example, Frankel *et al.* (1998) and Brown (1999) 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 (personal communication) 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 (1998) 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 Lenné (1997) 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 (1999) 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 favour specific local adaptation. In this sense, Almekinders (personal communication) considers that local adaptation can comprise both wide adaptation in certain landrace characters and narrow adaptation in others.

Association with traditional farming systems[5]

A correlation between current cultivation of landraces and traditional farming systems has been made by numerous authors such as: Frankel and Bennett (1970), Harlan (1975), Altieri and Merrick (1987), NPGS (1991), Hoyt (1992), Brush (1995), Louette and Smale (1996), Maxted *et al.* (1997), Astley (personal communication) and Ambrose (personal communication). As such, traditional farming systems have often been considered beneficial reservoirs of landraces and intra-crop diversity (Altieri and Merrick, 1987). Traditional farming systems involve traditional cultivation, storage and use practices, and integrated with these practical skills is incorporated traditional knowledge about landrace identification, cultivation, storage and uses. In this sense, one important element of landrace conservation that has recently been the focus of researchers' attention is the way that landraces have been managed and maintained by farmers. Studies have focused on farmers' variety selection (Bellon, 1996), farmers' seed exchange (Louette and Smale, 1996), farmers' seed networks (Louette and Smale, 1996), farmers' seed replacement (Zeven, 1999), farmers' portfolios of varieties (Wood and Lenné, 1997), farmers' landraces identification (Boster, 1996) and farmers' landrace uses (Zimmermer, 1991); each has shown the role of farmers for the creation and maintenance of a landrace. In fact, Zeven (personal communication) 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 replacement seed selection by farmers (Maxted *et al.*, 1997; Qualset *et al.*, 1997) 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 (Brush, 1995).

In contrast, however, landraces may less commonly be associated with 'modern agricultural techniques', for example where organic production is on a relatively large scale or even associated with high-input farming where a particular niche market is being met. In central Italy, for example, Negri (2003) found that landrace consumption is strongly linked to regional cultural heritage (local rites, celebrations and local knowledge) and the local people who have grown up with this heritage make a link with their own identity. In this case the link is with the landrace itself, rather the means of producing the landrace, so the association with traditional farming systems may be absent.

Crop-specific landrace characteristics

When defining a landrace there are exceptions to the characteristics that are crop-specific and/or associated

[5] Traditional farming systems in contrast with modern farming systems depend more on hand labour, use less external inputs (fertilizers, pesticides), use more inter- and intraspecific diversity, learn by the test and error method, and there is no difference between physic and metaphysic events (Hernandez and Zarate, 1991).

with the propagation method (sexual or asexual), breeding system (self-fertilized or cross-fertilized species), time of formal crop improvement, crop management (selection, crop propagation, cultivation) and crop use.

Cereals

The definition of a landrace was first applied to cereals by von Rünker in 1908 (Zeven, 1998), and a range of different characteristics have been used to identify material as a landrace. For genetic diversity terms such as 'heterogeneity' (Ambrose, personal communication) or 'different genotypes as a segregating population' (Leggett, personal communication) have been used. For origin and crop improvement descriptions such as 'materials developed before 1920' (start of formal crop improvement programmes in the UK) (Jarman, personal communication) have been used. For other characteristics such as identity 'novel use' (Jarman, personal communication) or 'unique material' (Leggett, personal communication) have been applied. The explanation of this is due to the fact that formal crop improvement has developed standard criteria of selection (as defining ideotypic plants) and it is possible to identify landraces by specific unusual traits (such as horny wheats or six-rowed barleys), not present in cultivars (Ambrose, personal communication).

Fruits

Species where the fruit is eaten have been selected for specific purposes, commonly to provide large and sweet fruits; there have therefore been high levels of selection pressure, often associated with vegetative propagation, where a good phenotype is identified and from this the variety is propagated. In some cases, such as apples, production depends simply on selection of varieties rather than formal improvement (Lamont, personal communication). Also the term landrace would not apply to most fruits if heterogeneity were a defining characteristic as many fruit species are clonally propagated and so are genetically uniform (Lamont, personal communication). Nevertheless, it is possible to find references to landraces of apples, pears, plums, bananas, olives, grapes and apricots in their centres of origin or diversity. If other characteristics are applied such as historical origin, local adaptation and identity, landraces of fruits can be described but they will often be known as 'traditional varieties'. An important characteristic to identify a traditional variety is its ancient origin supported with historical records (Lamont, personal communication).

Forages

The crop evolutionary history of forages in terms of domestication and cultivation compared to other crop groups is more recent and underlies the reason why 'primitive variety' related with antiquity cannot be used as a synonym for landrace (Chorlton, personal communication). Forage landraces may have been subjected to varying levels of selection pressure and formal breeding, but it is often possible to observe crosses between the wild relatives, ecotypes,[6] landraces and cultivars from the same location. As such, the definition of a forage landrace should incorporate the fact that the landrace has been 'developed semi-naturally' with local adaptation and local identity (Chorlton, personal communication). The population concept for a landrace is that of a meta-population: a farmer's population may be an ecotype and a group of ecotypes cultivated in a specific area (such as a village), with a local name, will be a landrace (Chorlton, personal communication).

Vegetables

Formal improvement of vegetable crops has depended on the economic importance of each species. Different scales of production levels can range from commercial farmers and growers, to local farmers and gardeners, and this also is likely to impact on the application of the definition of landrace. For vegetables, common terms such as 'heirloom' and 'heritage varieties' are used and imply that the vegetable variety has been grown for a long time. So are heirlooms and heritage varieties synonymous with landraces? The answer is not straightforward, because each vegetable has it own characteristics; it is necessary to study each one individually. The most relevant characteristics are the identity in relation to use (Astley, personal communication) and the historical origin of the material by historical records (Munro, personal communication). It is also difficult to apply the genetic diversity characteristic because some species are clonally propagated and vegetables with high selection pressure will be highly uniform (Astley, personal communication; Munro, personal communication).

Discussion

The review of the defining characteristics of landraces clearly illustrates that certain characteristics are associated with landraces, and these are historical origin, high local genetic adaptation, recognizable identity, genetic diversity, lack of formal genetic improvement and association with traditional farming systems. These six characteristics are, however, not absolute and cannot all be applied consistently to define a landrace in all crop/agroecosystem situations. Application of these characteristics all together

[6] Chorlton (personal communication) used the term ecotype to refer to semi-natural vegetation that is undergoing the domestication process.

would cover many entities currently recognized as landraces, but in practice would be over-restrictive and many entities currently recognized as landraces by experts would then be excluded. For instance, material with a specific identity, which has a historical origin, is locally adapted and has undergone no formal improvement, but which is uniform, would not be considered a landrace.

It is interesting to note differences in perceptions of the key informants interviewed during the course of the research for this paper. We noted differences of opinion over what constituted the most important criteria for defining a landrace both between informants working on different crop groups but also between informants working on the same crop group. For instance, the most important criterion for identifying cereal landrace in the UK was associated with either heterogeneity for those curating collections or uniqueness of traits for plant breeders. This implied that among the six criteria the degree of emphasis placed on individual criteria is related to institutional goals, and these are likely to have consequences in the selection of landrace material for conservation by those institutes.

It must also be concluded that the application of any one of the six individual characteristics to define a landrace would exclude a large number of recognized landraces and there is no single most important characteristic for defining and identifying landraces. It is interesting to note that from the workshop discussion and key informant interviews undertaken no single characteristic was considered the most important for defining a landrace. As well as concluding that there is no absolute characteristic or set of characteristics for defining and identifying all landraces, it is also clear that there are clear crop-specific factors that affect the application of combinations of landrace characteristics for specific crop groups.

The absence of an unambiguous set of characteristics that define a landrace underlines their diversity and possibly led Zeven (1998) to believe in their 'indefinable nature'. However, in practice landraces are universally recognized by agriculturalists and conservationists alike on the basis of the six fundamental characteristics recognized above, and although there are exceptions to the application of each of these characteristics, various combinations of these six characteristics can be used to define the entities we recognize as landraces. Therefore, recognized landraces as dynamic entities resulting from crop-specific processes may practically be defined by the presence of the majority of the characteristics listed above in the absence of opposing characteristics, such as cultivation in intensive agroecosystems or being the product of formal breeding programmes. As such, any landrace need not fulfil all six characteristics to be considered a landrace and therefore we propose the following working definition that was adopted during the UK landrace inventory: 'A landrace is a dynamic population(s) of a cultivated plant that has historical origin, distinct identity and lacks formal crop improvement, as well as often being genetically diverse, locally adapted and associated with traditional farming systems'.

However, it should be emphasized that the weight placed on each characteristic within the definition will depend on the individual crop, its reproductive biology, domestication process, crop management and production purpose, and even the context and the purpose for which the definition is being applied. This definition can be widely applied to what would customarily be recognized by agriculturalists and conservationists as a 'landrace'. The definition has been shown to facilitate landrace conservation in the UK and will hopefully be just as useful elsewhere. It should allow landrace inventories to be widely established and changes in landrace populations over time to be assessed, so assisting in the achievement of the COP 2010 Biodiversity Targets.

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Appendix: Questionnaire used for key informants

Background Data

Interviewee name: . . . .

Institution: . . . .

Principal activity: . . . .

Crop groups: . . . .

Landrace Definition Concept Used

What is your working definition of landrace?

. . . .

. . . .

. . . .

. . . .

Which characteristics define a landrace for you?

. . . .

. . . .

. . . .

. . . .

Which of the following characteristics are present in landrace(s) you are familiar with?

Criteria	Yes/No	Why?
Heterogeneity:		. . . .
Local adaptation:		. . . .
Local identity:		. . . .
Informal breeding:		. . . .
Historical origin:		. . . .
Other:		. . . .

Please order these characteristics by level of importance from 1 (most important) to 5 (less important) for defining a landrace

Heterogeneity: . . . .

Local adaptation: . . . .

Local identity: . . . .

Informal breeding: . . . .

Historical origin: . . . .

Other: . . . .

Do you consider these terms as synonyms of land race?

Synonyms	Yes/No	Why?
Primitive variety:		. . . .
Local variety:		. . . .
Farmer variety:		. . . .
Folk variety:		. . . .
Traditional variety:		. . . .
Others:		. . . .

Are there crop-specific characteristics that must be applied to defining a landrace?

( )Yes ( )No

If yes, what are these characteristics?

. . . .

. . . .

. . . .

. . . .