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Biodiversity/Biodiversité

Biodiversity, evolution and adaptation of cultivated crops

Biodiversité, évolution et adaptation des plantes cultivées

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ABSTRACT

The human diet depends on very few crops. Current diversity in these crops is the result of a long interaction between farmers and cultivated plants, and their environment. Man largely shaped crop biodiversity from the domestication period 12,000 B.P. to the development of improved varieties during the last century. We illustrate this process through a detailed analysis of the domestication and early diffusion of maize. In smallholder agricultural systems, farmers still have a major impact on crop diversity today. We review several examples of the major impact of man on current diversity. Finally, biodiversity is considered to be an asset for adaptation to current environmental changes. We describe the evolution of pearl millet in West Africa, where average rainfall has decreased over the last forty years. Diversity in cultivated varieties has certainly helped this crop to adapt to climate variation.

Mots clés :
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RÉSUMÉ

L'humanité dépend de très peu de plantes pour se nourrir. La diversité observée au sein de ces quelques plantes est la résultante d'un long processus d'interaction entre les agriculteurs, les plantes qu'ils cultivent et leur environnement. Cette diversité a largement été modelée par l'homme depuis les débuts de l'agriculture il y a 12 000 ans jusqu'au développement des variétés commerciales lors du siècle dernier. Nous illustrons ce processus par une étude détaillée de la domestication du maïs et de la diffusion de sa culture. L'agriculture familiale domine encore largement le paysage agricole sur notre planète. Dans le cadre de cette agriculture, l'agriculteur a encore un impact très fort sur la diversité des plantes qu'il cultive. Nous détaillons quelques exemples de cette action de l'homme. Enfin, cette diversité est souvent considérée comme une assurance pour répondre aux variations environnementales. Dans cet article, nous détaillons le cas du mil en Afrique de l'Ouest où les agriculteurs font face à des baisses importantes de pluviométrie depuis une quarantaine d'année. La diversité présente au sein des variétés de mil a permis une adaptation des variétés locales.

1. Introduction

Crops are the direct product of human selection on wild plant diversity. This domestication process has produced plants (crops) with unique features that make them suitable for agriculture. Among cereals, some of the traits

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commonly linked to the domestication process are larger seeds, nonshattering seeds, more compact plant development, and absence of seed dormancy. Each of these traits represents useful agricultural innovations. For instance, nonshattering crops allow a single harvest when the seeds are ripe. The development of crops has had a major impact on the organization of human societies. The domestication process is closely related to the development of sedentary human society and advanced civilisations. The timing of agricultural development coincides with the end of the last ice age from 12,000 B.P. onwards. Agriculture probably developed independently in several areas around the world, including Mesoamerica, South America, Middle East, Sahelian Africa, China and South-East Asia [1–3]. In these areas, different plants were domesticated independently. Each of these areas is the presumed birthplace of certain crops. Among cereals, maize originated from Mexico [4], wheat (einkorn and emmer) from the Middle East [5], pearl millet from western Sahelian Africa [6], japonica rice from southern China, and indica rice from the region south of the Himalayas [7]. Some authors [8] distinguish between different subregions, for instance in Africa: western Sahelian Africa, West African savannah and woodlands, West African rainforest, East Sudanese Africa and East African uplands. The distinction is mainly driven by the occurrence of different societies linked to different crops. However, whether domestication arose independently in each of these subregions or not is still an open question.

Harlan [9] counted around 360 cultivated species. The term 'cultivated' is rather restricted in its meaning. Several thousand plants are also collected in their wild habitats for food, fibre or medicine. However, only around 20 crops play a prominent role in the human diet, in particular cereals such as wheat, maize, rice, barley, sorghum and millet. Cultivation of these six groups of species covered 683 million hectares harvested in 2008 (Table 1), representing about half the total area under crops worldwide. Another group of crops which make a significant contribution to our carbon diet are root and tuber crops like cassava, potatoes, yams and sweet potatoes. These different cereals, root and tuber crops are the main starch component of the human diet.

In this article, we illustrate how the diversity found in a cultivated crop has been continuously shaped by demographic as well as by selection processes. Understanding the diversity of cultivated plants today requires an understanding of the impact of the domestication process as well as that of ongoing human actions. We illustrate these points with the example of maize domestication up to the development of hybrid varieties in the 1930s. We then review some recent studies focusing on the impact of farmers on crop diversity today, which is most pronounced in smallholder agricultural systems. Finally, we show that selection continues today, using the example of the adaptive response of pearl millet to climate variation.

Table 1
Area of cultivated land under the main cereal crops.

Crop(s)	Cultivated land in millions of hectares
Wheat	224
Maize	161
Rice, paddy	159
Barley	57
Sorghum	45
Millet	37

Land used to grow the main cereal crops in 2008. The area is based on crops cultivated for their grain. Data from FAOstats (http://faostat.fao.org).

2. Maize history: from domestication to the development of hybrids

Maize is a good example of the history of the domestication process because of the spread of this cultivated plant at continental and worldwide scales. Phylogenetic analyses point to the Balsa River basin in Mexico as the area where the closest living relatives are found [4]. Genetic data suggest domestication occurred 9200 years B.P. with a wide confidence interval (5600–13,000 years B.P.). The oldest cob was found in Mexico and dates back 6250 years [10]. However, a recent archaeological study based on starch grains and phytoliths suggests maize was cultivated earlier, at around 8700 B.P., in the Balsa River basin [11]. Both archaeological and genetic analyses have provided evidence for the very early domestication of maize in Mexico around 9000 B.P. (Fig. 1). Moreover, these studies suggest that the domestication process took place in the Balsa River basin. The closest plant related to today's cultivated maize is *Zea mays* ssp *parviglumis*, a teosinte which grows at low elevations. Another teosinte (*Zea mays* ssp *mexicana*) prefers higher elevations and is also found as a weed in fields of maize [12]. A scenario for the origin and the spread of maize across America has been proposed based on several genetic studies [4,13]. Probably the initial cultivation of maize spread quickly at both high and low latitudes in Mexico and from there to lower altitudes in the tropics (i.e.

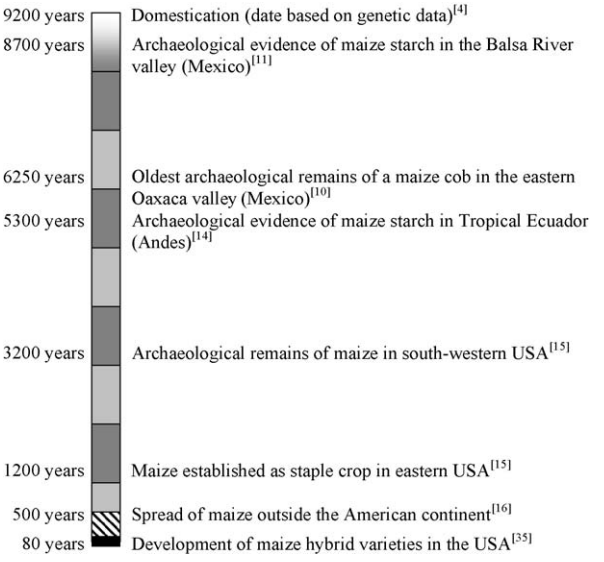

Fig. 1. Agricultural history of maize from domestication to the development of hybrids. Key events from domestication to the development of hybrid varieties.