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Review/Revue

Evolutions and stakes of genetic resources management

Evolutions et enjeux de la gestion des ressources génétiques

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A B S T R A C T

For hundreds of years, intuitively or deliberately, farmers and breeders have taken advantage of the slow and constant renewal of genetic diversity in their domesticated plants or animals. Their management efficiently combines selection to maintain existing varieties or breeds and selection to extract new biological items meeting incoming necessities and environmental changes. The traditional practice is now criticized for three main reasons. The fear that it might not follow the accelerated occurrence of new demands and changes is one. The second derives from advances in biology and technology that indeed offer the expected answers provided the existence of residual diversity in present stocks. At last, the management of genetic resources is no longer the concern of specialists. Interest in the issue has been taken up by public opinions when they realized that genetic diversity is a component of overall biodiversity and that its intimate knowledge and uses transforms the vision of our relation to the living world. What is at stake today in genetic resources management is combining three selection approaches. The two traditional are still thoroughly relevant. A third one offers a process aiming at constant and random enrichment of the existing variety of diversity in domesticated plants and animals, and giving a major and renewed place to men' imagination and innovation.

R É S U M É

Le renouvellement lent et permanent de la diversité génétique a amené les agriculteurs depuis des siècles et récemment les gestionnaires des ressources génétiques à conjuguer intuitivement ou délibérément deux pratiques de sélection : l'une pour entretenir les races animales et les variétés végétales existantes, l'autre pour en façonner de nouvelles qui répondent à des nécessités de production ou de circonstance. Trois facteurs incitent actuellement à une remise en cause de cette gestion : l'émergence inquiétante et à un rythme accéléré de nouvelles demandes de la société, le constat que, grâce au progrès des connaissances et des technologies, il est encore possible de trouver dans la diversité existante des réponses, et enfin la prise de conscience par l'opinion publique de l'intérêt économique et éthique de la diversité génétique. Celle-ci est perçue comme une composante intime de la biodiversité dont la compréhension transforme notre vision du vivant. L'enjeu de la future gestion des ressources génétiques est de conjuguer trois démarches de sélection : les deux premières qui conservent toute leur pertinence, et une troisième qui enrichisse en permanence et en aveugle le stock de diversité où les hommes puiseront dans le futur pour répondre à des besoins nouveaux et imprévisibles.

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1. Introduction

In the year 2004, André Cauderon drew biologists' attention to the growing discrepancy between the slow pace of evolving genetic resources and the high renewal of social demands. He thought the two processes could no longer be absolutely coupled, however genetic resources should still be managed as carefully as cattle move in a field. Indeed the goal is to escape from static conservation and disordered haste, and to meet today's expectations as well as the unpredictable ones of the future. Doing so when he had responsibilities, André Cauderon was successful and built for France an effective system of management. In this article we mean to show that his ideas and approaches have kept meaning and relevance.

In these days, when citizens ask for something and expect to get it immediately, managers may wonder about the risks we endorse now and the risks that are not ours but will be transferred to oncoming generations. Are we so eager to meet rapidly evolving demands without a thought for our children? But are we in a position to resist? Undoubtedly, the global economy, pressing necessities, constant advances in biology and technology forbid a conservative posture. Present management of genetic resources means making choices and taking decisions everyday, which should be decided carefully without haste to achieve them. Is there an intelligent way that would conjugate preservation and immediate uses? How to avoid intensive and reductive exploitations?

Genetic diversity is part of biodiversity as well as landscapes or species. It is, however, less visible for the public and less easy to manipulate by media or politicians. Consequently whether it fluctuates, expands or disappears is not an issue on the public stage. Unfortunately this absence of significant consideration weakens any management that would not be directly profitable...

Taking advantage of genetic resources assembles two concepts. Resource is the first one. It means collections of goods to be exploited, which is widely accepted since it is not specific of genetic diversity. By extension a resource is also information about those goods and its mastery is of primary importance as seen in the field of communication or finance. The nature of this information is no longer a simple oral or written exchange, it assembles quantities of data in organized and complex systems. Such constructions are only accessible through sophisticated processes and machines. Even if objects remain as the fundamental material, global information about them is now as valuable and essential for their understanding and management.

Genetic in its turn qualifies the specificity of living beings: they are all different, they live and die, but they do not disappear. They collectively maintain their presence and continuity through reproduction and successive renewals along generations. Technically speaking genetic qualifies a complex assembly where genes (DNA) are both molecular objects and information, where chromosomes are systematically organized structures made of DNA (genes in particular) whose expression may be constitutive or inducible, and where a genome is the personal and complete set of the genetic information carried by an individual. Indeed these properties are now accessible one by one. Their overall understanding is difficult and on constant renewal depending on advances in research and technology. Developing an intelligent management of genetic resources today implies recognizing and accepting that they are complex, evolving by nature and in their representations. Therefore explaining the choices and actions to the public is a real challenge, all the more so as at various steps the process may be frozen, biased or manipulated by ideological interferences. The Lyssenko's doctrine and its subsequent disaster remain one prominent example of such systematic deviations. And the dream of a return to traditional agriculture of the past may be another one.

The goal of modern genetic resources management is to conjugate concepts and data to offer societies the genetic elements they need now and to build up the stocks in which future generations will draw. Obviously the operation is not easy and results do not appear at once. Reflection and action are slow because of the difficult adjustment of the pace of genetic dynamics with that of the handling of goods for societies both in mind and in reality.

The sensible advice André Cauderon gave still keeps its original value. Even if the speed of modern social life increases, a careful approach is necessary to keep connected with biological processes. There is no reason to freeze all changes and decide for static conservation [1]. Time has come to take advantage of the slowness and gain some independence from invasive and transient demands. On the contrary unforeseen events should be welcome, evaluated and carefully dealt with [2]. Obviously it's easier when the system is prepared for such possibilities, when meeting in a hurry calls for profits is not the only objective, when pressures to freeze the inescapable evolution of life or to maintain privileges can be avoided whatever their political and communication supports. Such a goal is achievable, it does not require specific material tools, it needs time, capacity of anticipation and consideration for innovation. There is no reason not to generalize such management practices. Modern technologies are already available. For the future of genetic resources opportunities exist that go further static maintenance or return to the past. A first difficulty however may come from the lack of political will and pertinent institutions. Another is to tolerate and take advantage of various intellectual views about life, economy and society at large.

2. About times when processes were slow

Agriculture emerged some 10,000 years ago when men picked up berries and fruits so as to sow them and produce more instead of eating them right away. At that time breeding was already on its way, dogs were domesticated as early as 15,000 years BC. Today some scientists claim that men and wolves were commensal more than 700,000 years ago. Taming and domestication came later and very progressively [3]. This excessively schematic survey tells us that very long periods were needed to master a few plants and animals. Getting a complete control on individuals and populations could take thousands of years. The same is true for systematic production of food (wheat, rice, meat, milk...), of goods for services (transport) and for technical purposes (wool, leather, manure...).

The four major animal and domestic species (cattle, goat, sheep and pig) emerged from efforts of people of the Middle East by 8000 years BC. But domestication attempts were certainly many, as cattle appeared also in Egypt and pigs in China. Poultry was domesticated both in China and India (4000 years BC probably), turkey in North America (1000 years BC) and rabbit in Europe in the XVIth century. We do not know much about successful selections developed by breeders in the early days and even less about their failures. As far as cattle are concerned the first obvious criteria enforced were in the reduction in size of horns and overall morphology. This could have helped to gain some physical mastery of the individuals. Herd size was certainly a matter of concern too since breeders had to protect animals and insure a safe and regular access to the expected products (milk, meat...). For thousands of years the impact of men on genetic diversity has probably stayed at a low level. The situation changed drastically when breeds were systematically shaped and isolated. This happened rather recently, during the XIXth century for cattle, earlier for dogs (Antiquity). Selective pressures became very restrictive and specific, breeds being evaluated through their homogeneity and not their diversity. The European pink pig for example derives from wild black and hairy boars populations among which albinos animals were kept for reproduction in the XVIIIth century.

Similar chronologies and domestications paths are described for plants. Early farmers extracted domestic varieties from wild populations. Wheat emerged in the Middle East more than 10,000 years ago through hybridization of three close grass species. It became a major culture in France around 3000 years BC. Along the following centuries the more or less domesticated plants were cultured in close vicinity and near their wild parents. Interbreeding was frequent, genes were constantly exchanged and significant diversity maintained in populations in spite of selection and adaptation. This has been documented as well for all other cereals (rice, barley, maize...), for legumes and other vegetables (potatoes, tomatoes...). Today plant breeders still take advantage of these stocks of diversity and of gene flows to select for present demands such as resistance to pathogens, tolerance to various environments, controlled growth or gustative qualities. Present technologies are accurate enough to spot genes of interest that had been hidden for long periods of time.

Indeed farmers and breeders have long been aware of the potential wealth stocked in the genetic diversity of their crops and herds as well as in the wild parents. Consequently collections have been established, kept and made available. The access to these stocks and the mastery of crosses accelerated the pace of selections. But these advances in the science and technologies of genetics are so accurate that they may result in a loss of diversity in future breeds or varieties. In short, efficiency has a cost that will be paid by future generations. As long as the conservation process was empirical, intuitive and poorly focused, the usual biological processes maintained diversity. We have now to devise a specific policy to maintain and enrich the internal diversity of our breeds and varieties independently of selection efforts. A management of genetic resources with this specific goal has been carried on with some success in a few cases. The principles are still the old ones; the techniques are those of today.

Until the XVIIIth century museums assembled collections to present the span of biological diversity on Earth. True specific collections with an agricultural vocation appeared after the years 1800. The Vilmorin one for wheat is an example among many. A trend for systematic prospections and introductions has developed and has not ceased since. The Vavilov's collection established in Russia by 1920 is the archetype of these operations. In France the launching of such collections by public institutions (INRA, CIRAD, IRD) only started in 1950.

In recent studies [4] some 600 samples of wheat varieties established from 1849 to 2000 have been compared using chemical, biochemical and genetic markers. Although they all are wheat plants they appear largely different. Moreover their diversity is organized into three groups (Fig. 1). The oldest landraces and varieties obtained before 1970 constitute one group and are rather similar to their wild parents. They clearly derive from slow and continuous efforts of selection associated with biological processes (gene flows, mutations) that homogenize and maintain diversity. Two major and successive selection efforts have been made since 1930. They led to two distinct groups of varieties, a 1930–1970 set and a recent one 1980–2000. Obviously selection does not necessarily lead to a loss of diversity or to the potential of diversification. Even more recently when wheat breeders looked for a better quality of flour or a better environmental tolerance instead of being only focused on yield, they succeeded in extracting from the genetic background the elements to create new and adequate varieties.

In short, provided they are given enough time to operate, biological systems constantly maintain and renew diversity, and offer opportunities for innovations. The unpredictable needs of societies of the future may then eventually be satisfied. However, as the advances of science and technology shorten the time of genes

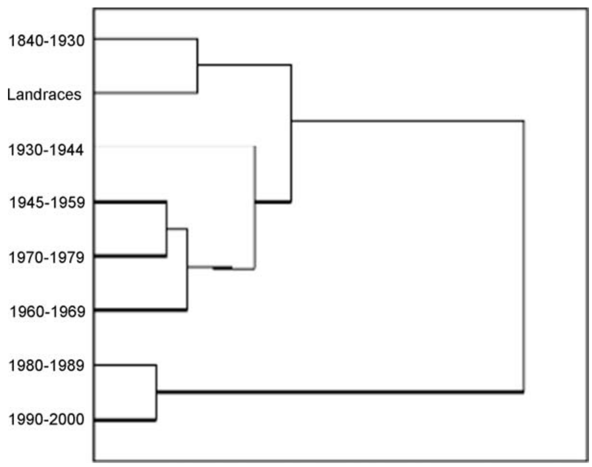

Fig. 1. Schematic representation of the phylogenetic relationships between wheat varieties according to their time of emergence [4].

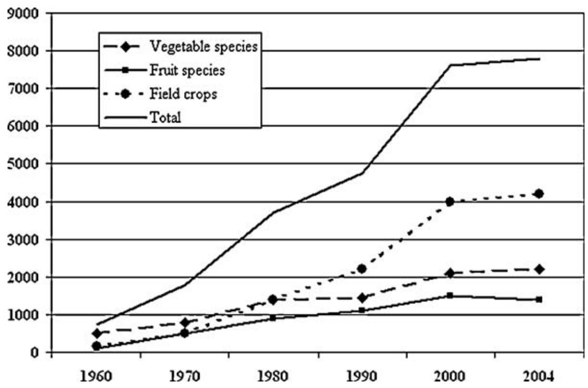

Fig. 2. Evolution of the number of varieties offered in the French catalog from 1960 to 2004.

extraction from a collection and make it very accurate, the acceleration may exceed the pace of renewal of genetic diversity and lead to threatening losses. In the future plant breeders will be obliged to distinguish systematically the operations of selection from the genetic resources management. A specific policy of preservation and enrichment is now necessary to transfer a rich stock of genes to our descendants.

The French ministry of agriculture and the GEVES (*Groupe d'étude et de contrôle des Varietiés et des Semences* in French) funded similar studies for maize and peas [5]. No significant loss of diversity was recorded in the two cases for the last fifty years. But a significant shift is observed: it illustrates the introduction of new selection criteria (longer ears, increased yields and longer growth periods for maize). Similar data are available for most domestic plants. The French catalog of grown species and varieties presents a large array of usable diversity (Fig. 2): some 155 species, more than 7800 varieties (about 4200 for the main crops, 2200 for vegetables, 1400 for fruit trees and vine).

Not only is diversity abundant in catalogs and public collections but it also increases in the fields. The place of the five major wheat varieties has decrease by 20% in favor of new accessions.

For domesticated animals the trend is similar but the processes followed different pathways. After a long phase of struggle to insure the homogeneity of breeds and resist unwelcome introductions or natural renewal of intra-population diversity, the very concept of breed is being reconsidered. Although a debate is still running about the genetic basis of standards and references, breeds are now considered as open and permanently selected patrimonies evolving under the concerted pressures of genes and social evolutions.

In contrast to coal or mineral mining, managing genetic resources is not mere exploitation. It involves a constant and reciprocal adjustment of unavoidable biological renewal and varying demands of societies. As long as the paces of the two processes are similar, men can maintain a comfortable compromise between respecting nature and promoting the benefits for their economies and communities. Recently increasing discrepancies between the two components have threatened the former dynamic equilibrium. In response some people hope to save our planet by freezing the movement and returning to past situations. In the long run their position is untenable. A prospective one or, even better, an inventive attitude would be to accept unavoidable changes and take advantage of their positive properties to protect nature and satisfy social needs at once. Of course, this involves a constant increase of men activities in natural processes and eventually leads to new domestications. Technically and biologically such goals may be reached provided specific efforts. The difficulty and pending questions deal with the proper sharing of property, knowledge and profits. Answers in return will have consequences on genetic resources management, as we see later and on nature in general.

3. Speeding paces

We are now aware that molecular events (mutation, repair, transposition...) constantly renew genome sequences at rather low frequencies so that reproduction seems roughly conservative, but significant enough to generate discrete changes generation after generation. If indeed varieties and breeds seem to breed true to type, this is due to slow rates of emergence of these events and to complementary mechanisms that correct the former events or compensate their consequences at functional levels. Actually a quite complex system of controls and retro-controls, positive and negative, is at work. The former hierarchical analysis–one cause, one consequence–is to be replaced by an approach of the complexity of multiple and inter-connected networks at various levels from genes to organisms. When properly deciphered those networks constitute an advantage to devise an intelligent management that would both satisfy the goals of conservation, enrichment and accessibility to selection of genetic diversity. To implement such a practice depends on local circumstances and requires institutions able to support it, as well as political will.

The key point of genetic resources management is to translate such principles into efficient tools, techniques and actions. In practice most molecular tools are already available as they are commonly used in genomic studies (PCR, sequencing, computerised analysis of data...). Owing to their accuracy it is no longer necessary for a geneticist to have a phenotype to identify the underlying genotype. Mutation, repairs, recombinations, repeats, or transpositions of DNA sequences (genes in particular) can be directly identified, traced and spotted. Their occurrence is purely at random and not oriented to any specific goal. When such an event is revealed by genomic techniques, its effects may be formally deduced by informatics and eventually confirmed by experiments. It is even possible to infer what living property or process would finally be affected and finally what social demand could be met via selection.

The second result of complexity analyses is almost as important. It appears that different genotypes and various expression processes may result in identical or very similar phenotypes. In short, random mutational events followed by selection do not yield THE only possible answer to breeder's expectation but ONE among others. This increases the scope for selection and has an important consequence on genetic resources management. Apart from maintaining living collections as they are, a second goal should be to produce more differences inside the stocks. An ultimate objective would be to look for the potential of diversification more than the diversity between the stocks. For sure the concepts of conservation and valorization are still the backbone of the management, but the operation as a whole is less static, more dynamic.

To succeed the ascension from molecular mutations to social functions the breeding and herding of new living forms has to be mastered. This does not require particular innovations; the techniques of quantitative and population genetics of today are fully adequate, well settled and recognized. This may even help to facilitate decisions of institutions as there is no need for more investments. Herd books, catalogs, certificates, patents are already available and adapted for new entries. No specific legal status has to be envisaged in advance. A more dynamic management of genetic resources is thus conceivable in the present social context.

How principles evolve and interfere with management is best illustrated by the question of domestic animal breeds. Among breeders and in society in general much consideration is devoted to the status and future of small population breeds, which can be endangered. Maintaining them is an obligation. They even benefit from the privilege status of potential victims and mobilize considerable technical and financial efforts. Is this acceptable? Is this not to the detriment of breeds with large populations that may be better placed to evolve and answer special demands? In the media the question of benefits/costs is never asked. In any case small population breeds will be taken care of; the challenge is then to devise methods to create diversity in large breeds at acceptable costs... The slogan might be: when possible create diversity first and second breed new living domestic forms among which society will select answers to its questions.

This revives the debate about the standardized criteria necessary to define animal breeds and the identification of any individual. In the view of dynamic modern management static references seem somewhat outdated. At present categories (species, breeds, varieties, lines or strains...) should serve only as transient frameworks to organize, understand and use diversity of individuals or gene combinations [6]. Frontiers between species, between domestic and wild animals and so forth are no longer permanent. This sort of genetic liberty has a major social cost.

Its future is not in biology but in the hands of men and societies. Social and political goals will prevail over natural processes. However to conceive and implement relevant decisions information must be accurate and the most sophisticated tools of biology and biotechnology must be mobilized.

Finally a modern management of genetic resources depends on how societies consider nature. This reverses the question of discrepancies in time and space. Could it be that the paces of science, technology and economy outpass the pace of philosophy or ideology? Advances in biology in the last thirty years (sequencing, cloning, transgenesis...) have been such that citizens are invited to revise their certainties. This creates considerable turbulences and contests. In the ongoing movement scientists find more knowledge, breeders new tools and farmers easier and more regular productions. However by lack of information or by ideology many are those who have not fully accepted the practical, intellectual and religious consequences of the changes. Of course this is not specific of genetic resources. Sanitary crises, technological rapid developments and political misunderstandings are also responsible for the general suspicion toward changes, progress or evolution. Difficulties and controversies are largely publicized in the media and the question of genetic resources is entangled into power struggles that deal with other stakes and have little to do with animal or plant domestications. It even seems that maintaining the debates between irreducible positions is an enterprise on its own! All partners pledge loyalty to public good and loudly ask for more ethical attitudes. Ethics in science is basically to consider and analyze facts; social knowledge that issues is a representation that depends on the vision of the world everyone has. Some lack of understanding obviates the dialog between farmers and geneticists on the one hand and citizens on the other. It may well be due to the bias introduced by media, politicians or NGOs when they form and inform citizens...

In such a context decisions about genetic resources are far from being consensual, all the more so that the GMO crisis is not solved and the Darwin theory still not accepted by a fraction of the population. Actually the management problem has not yet been drawn on the public stage. This is not easy to handle by the media and it only appears by bursts. The balance of risks versus profits is left to the responsibility of individuals who claim both for more facilities and for more insurance or precaution. Apparently the future lies more on cohabitations of various politics and decisions than on a monolithic exercise: Diversity is the final answer but it needs a perpetual search for consistency. This makes the implementation of a modern genetic resources management difficult and experience will tell the costs.

The analysis that follows tends to illustrate the problems and their context. In 2009 an OECD report on biotechnology in agriculture [7] presented the evolution of the number of patents asked by public and private companies on domestic plants and derived products. Data originated from the US Patent and Trade Office and from the European Patent organization. It appeared first that public institutions present many more patent demands than private enterprises in plants and their byproducts than in any other sector. The flow is about the same in Europe and in the US until 1999 when it began to drop (Fig. 3).

Whatever the explanation may be the change is significant... In second place the OECD report indicates that the public sector proposals deal mainly with plant resistance to pathogens or products quality when private companies concentrate on plant chemistry and resistance to herbicides. Obviously European governments, interested in biodiversity at large (France in particular), are not the driving force behind plant biotechnologies, and have a poor

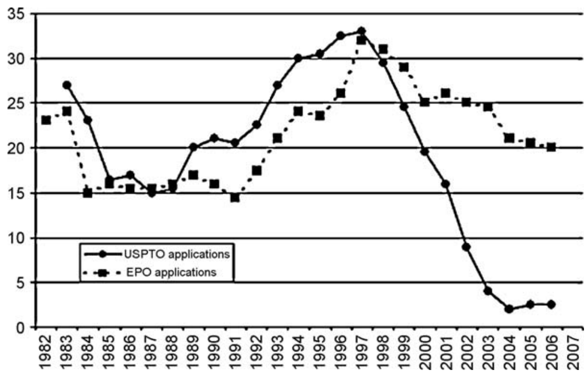

Fig. 3. Evolution of the public sector patents demands (%) in Europe (applications) and the US (grants and applications) from 1980.

evaluation of genetic resources role. In consequence private companies' orientations will be more and more decisive in choices and decisions. This shows up already since their number grew from some 50 in 1980 to more than 200 in 2000, and the five major companies obtained 42% of the patents in Europe and 80% in the US.

Two comments could serve as a temporary conclusion. First, the opportunity of a dynamic management of genetic resources does exist and may help to face present social demands and future unforeseen ones. Second, in Europe a tight frontier has been set up between biodiversity and biotechnology, largely in favor of biodiversity stakes. On doing so, governments get rid of present responsibilities and transfer them to future generations. The situation in France is a true caricature: until the end of the XXth century and under the impulse given by André Cauderon [8] a dynamic network of public and private actors in the fields of genetic resources was active (cooperation, coordination, investments, collections, research...), the elements of a national policy were laid down. From the 2000s successive political events and decisions have changed the course of things. The network has been dismantled and fused in the mist of general biodiversity concerns.

4. What about tomorrow?

The public today is interested in biodiversity and concerned by any threat to nature and environment. As to media, scientists and politicians genetic diversity is a component of overall diversity. For the sake of visibility, economy and political strategies, the management of genetic resources is included in the general biodiversity policy although the two fields only partially overlap. There is no reason to foresee any change in the near future. This means that the former efforts to conjugate biology of resources and demands from society through agriculture and technology are to be reoriented. Since some science is involved in present management and since science and technology are felt responsible for some risks and difficulties of everyday's life, the change may be the subject of controversies. The general context of suspicion will not ease the dialogs. Private companies no longer cooperate with public institutions, as it was in the past, to the management of collections, their conservation and uses. In the general tensions of liberal capitalistic economies financial investments needed by long term policies are difficult to find and some decisions may not be taken for the only sake of common good. Objectives of profit of private companies prevail over those of public institutions and over the random enrichment of collections. Public action is more and more reduced to insure decent capitalistic competitions and to separate management of resources from biodiversity concerns. In our view other opportunities could be given some consideration.

At last legal status and handling of genetic resources is presently bound to lag behind events. It's already entangled in a race to keep up with changes, shifting from one crisis to the other, from prices to property and to legal definitions. Genetic management is absorbed into social and economic complexities of higher orders. In such a situation the desirable fair sharing of resources may stay long a statement of mere intention.

Let us recall that in the field of resources the goal is to identify and enrich genetic diversity in present collections and stocks. Obviously conservation is needed as in the case of biodiversity. But the pace of dynamic enrichment has to be more rapid than that of natural evolution in order to keep up simultaneously with the rapid changes of social demands and structures. The goal is attainable owing to present biological knowledge and technology and they even open perspectives that have not been explored yet (new domestications). When the understanding of life spans from point mutation to genes, cells, individuals, populations and species the levels of human interventions are multiplied and give place to imagination. The responsibility of what is to be developed after increases but it remains in the hands of societies and on their representation of life, which is the framework of imagination.

Indeed bringing animals or plants under control and breeding them to produce food and material or as pets has been the goal of domestications for hundreds of years. The process efficiently supported the demographic expansion of humans, their migrations, the diverse emergences of religions, cultures and societies. Pathways of these evolutions have been many and successive along time. Domestications are not independent and linear stories, but have evolved through constant dialogs between farmers and their general social and biological environment. Moreover the processes have more implications than a mere duality man/animal or plant and examples of undesired and indirect domestications are many (especially in the case of parasites). This aspect was not clearly apparent as long as research concepts and methods were only centered on the individuals and their relationship. Recent sciencific advances in the fields of sociology, ecology, molecular physiology and genetics have revealed new dimensions in the domestication process. Interestingly our present understanding is in no way specific of any discipline, and on the contrary specificity springs from the very integrative goals of men in these matters.

In some cases the two partners' interaction has evolved toward total dependence of one on the other. *Bombyx mori*, the silk worm, is no longer able to live and reproduce by itself. Also *Saccharomyces cerevisiae*, the common wine and bread yeast, can hardly survive in the wild. Present situations span a full range of integration levels from mere adaptations to strictly organized and efficient associations. In most cases the irreversibility of the process concerns individuals, when the bulk of the species is still able to reproduce in the absence of human intervention.

Domestication depends on three critical factors, namely: time, complexity of the goal pursued, and individual diversity in and between species.

History tells that domestication is successful once man masters the reproductive cycle of his partner, has a farsighted goal and applies strict and demanding selections. Obviously, in the most advanced cases attempts have occurred early in time, as with dogs or yeasts. Less advanced interactions are observed with more recent attempts, but time is clearly involved both through its chronology and through the length of the reproductive cycle of domesticated species (from three hours for yeasts to years for cattle).

Complexity involved in the fulfillment of social needs: biology tells that internal functions and experimental efforts of very different orders are necessary to master the synthesis and export of proteins by yeasts, or the synthesis of a narcotic drug and its accumulation in a specific organ by the opium poppy. In the yeast case a sole one-cell function is required, in the opium case development, physiology and agricultural conducts of a complete poppy plant are involved. And, clearly, complexity increases with the neuronal and hormonal controls when the goal is lactation of cows or behavior of dogs...

Genetic diversity present in a species of interest is another factor. In other words: is the overall genetic potential distributed among all living individuals of this species varied enough to find the proper genes and combine them in a way that meets the goals of domestication? The present range of domesticated animals, plants and microorganisms shows that such situations existed and others may still exist even if they have not been experienced. Genetic diversity is thus a resource worth keeping and enriching.

Recent research and technology advances induce to reconsider the goals as well as their times and their limiting factors. Molecular genetics tells that each mutation, each mutation repair, each recombination, each gene repetition and each in-and-out movement of transposons, introns or viruses is a random and blind event, not expected and not intended. The genetic product of such an event is now perceived by genomics techniques. Only then can we know of what question chance has given an answer. Only then can one set up conditions to keep such diversity and make some social use. Obviously, it is necessary now to make considerable efforts to maintain and favor a constant renewal of this permanently incoming diversity.

Present and future aims of genetic resources management are no longer restricted to exploring and keeping objects but need to encompass and facilitate the molecular events at their origin. This change however meets social resistance since it questions the appropriation and the legal status of resources, techniques and products of domestications.

Complexity is also in the field of considerable scientific advances. Thorough knowledge of genes nature and products, of cells structures and expressions, of plant physiology and growth, of animal embryology, development, neuronal activities, allows direct approaches to functions and completely renews the potential of selection. Criteria of choice are no longer restricted to the overall individual or population. Indeed, for long, the role of hormones in the behavioral changes occurring in the domestication of animals has been recognized. The fine understanding of the underlying neuronal and hormonal processes opens the path to a new mastery of behavior and domestication attempts.

The third and possibly more important factor bears on the individual and collective appreciation we place on domestication and selection. Up to recent years the process was looked upon as a one-way partnership where man prevails on the animal or the plant. Now man's authority is occasionally questioned on several grounds. These relations between the men and animals (in a short term, maybe, the plants) must be revised in light of the diseases shared by different species (flu, encephalopathy, viral diarrhea, etc.), which open the door for genetic material exchanges.

Such situations are now many and they make our societies reconsider the advantages of selection versus the necessities of powers, institutions and individuals. The way our knowledge in genetics and complexity evolves even pushes our question one step further: can one be sure that the present products of past domestications are the best possible substrates to prepare the future of our societies? Obviously answers are many...

On the one hand a large majority stands for the development of projections of ongoing processes and uses of domestications, the goal being maximizing the benefits and minimizing the deleterious effects of unexpected random genetic changes. This policy requires protecting biodiversity at large and domesticated beings in particular. Its efficiency goes beyond doubts, but it needs the acceptance of new forms of domestications.

The disappearance of the species barriers allows to complete traditional methods restricted to each species by the exchanges of genes of any origin. Genes are now domesticated as such and can be used for their own capacity of fulfilling man's needs. The span of possibilities is as huge as imagination can produce. But such future depends on present political capacities to implement a management of genetic resources aiming at a systematic but random selection of diversity. Such a selection for absence of selection would maximize the probability to keep a stock of diversity ready to meet unexpected needs as well as intellectual and ideological evolutions.

5. Conclusion

For millennia the slow and constant renewal of genetic diversity enabled farmers and breeders to associate intuitively and late comprehensively two aspects of selection to domesticate animals, plants and microorganisms. The former is to reproduce breeds and varieties according to references and standards. The goal is to maintain organisms as they are because of their present use in agriculture. This is a true operation of conservation, a fight against renewal. The later practice aims at extracting from the stocks and multiplying individuals showing interesting characteristics to accommodate new agriculture challenges. This is an operation that profits from the mutations introduced by the renewal process. Both approaches are implemented through crosses and generations; they need time as the renewal process does. Consequently the pace of selection and domestication has long been slow and the techniques adapted to the necessities of agriculture. In fact social transformations depended on the emergence of new biological opportunities and biology was the limiting factor. The two selections were operated simultaneously and coordinated by the same actors: farmers. From the XIXth century the situation changed under the pressure of accelerating social demands and knowledge advances that offered answers. The complexity led to the transfer of the tasks and responsibilities to professionals; they specialized into conservation and selection, used the same tools as before but were not directly active in agriculture.

By the second half of the XXth century the situation and the profession have again been questioned. Demands became much more frequent and changing from the needs of searching for better yields to finding specific resistances to parasites, better nutrition properties and so on. Industry, media and politicians manipulate now these demands and require for the public immediate answers to these questions as well as traceability on the used processes, both in terms of scientific information and commercial practices. Some discrepancies between traditional approaches and public demands appear and proper solutions have to be found, in concertation.

Hopes of solutions lie in the potential diversity hidden in the old and present varieties and species. But to study and to take advantage of it more accurate tools are urgently needed. They have emerged from molecular biotechnology and combined with classical procedures they have recently been engaged in the selection of wheat lines requiring less fertilizers and pesticides without negatively impacting yield. For decades one did not so much care for such properties, the main goal being the yield, while the necessary supplies were not considered to be limiting factors. In this context, breeders recently succeeded in extracting the desired lines from the hidden diversity of cultivated varieties. This is an encouraging result. It shows more widely that a systematic and dynamic policy of enrichment in genetic diversity has a fair chance to meet as yet unforeseen demands provided that classical and molecular techniques are appropriately combined. This is a strong argument in favor of the definition of a new policy, of which concepts and tools are already available.

At last since the years 1970 it has been largely understood that genetic diversity is a component of biodiversity. The media initially documented this for humans. It was then, but more discretely, generalized to all living beings. It lies in the background of demands about quality, economy, traceability of agricultural products. To satisfy these, experts in genetics, ecology, nutrition, technology… are asked for information and advice. Following decisions will now depend on politicians and escape from the hands of farmers or scientists. Society leads the change and in return influences science and genetic resources management.

This change has also ethical and moral dimensions. Advances in biotechnology have created new interrogations about our representation of domestications and more generally about our relationship with life and the living world. Time has come for questions, debates and suspicions. In absence of complete agreements decisions are taken upon the issue of power struggles that have little to do with genetic resources per se. It may not be the best way to face our present and prepare the future common good, but time and democracy will tell.

Looking back to biological processes may be a way to transcend the present difficulties. As the fundamental phenomenon is the slow and constant renewal of diversity, it might be wise to promote a policy combining not two but three selections. The two usual practices (conservation and improvement of breeds and varieties) keep their place and role. But time has come to implement a new practice in between. It would enrich diversity at random inside collections and individuals; molecular techniques allow this. Selecting for randomness is indeed a way to constitute stocks where to find possible answers to unforeseen questions of the future. The approach is at its best when it is coupled with ongoing research for new biological functions and more accuracy in the wake of science and technology advances. However the development of this new type of selection may be hampered by the need for disinterested conception of public good and for long-term involvements and investments. Moreover as the goals of random selections are by essence imprecise, the operation is not acceptable by private companies and is left to public institutions where freedom, efforts and abnegation may be considered. In such institutions, as cattle in a field, genetic resources will evolve at the proper speed and for the benefit of all.

Conflict of interest statement

No conflict of interest.

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