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Biodiversity and crop adaptation to environmental changes

We are in the midst of an Agricultural Revolution, the second after the Neolithic Revolution, when crop plants were domesticated. Under pressure for the climate change occurred at the end of the last big glaciation, humans exploited their empirical knowledge for choosing some species among those available to their attention and for setting up cultivation technologies that allowed them to have reliable food close to their settlements, instead of collecting it from the wild. Through a gradual process, cultivated plants became increasingly distant from their wild relatives. By carrying these plant materials during their migrations, humans introduced cultigens throughout different parts of the world exposing them to different environments, where recombination and selection redistributed genes that are important for crop defence and nutrition, creating landraces. For millennia these plant materials represented the crucial bases for the rising of human civilisations and cultures. Also they formed the genetic resources on which the second agriculture revolution, still in progress, started in Europe some 100-150 years ago, under the pressure of population explosion, and 50-60 years ago spread across different parts of the planet in response to massive famine and low staple crop yield. Breeders identified a few key traits that in an improved growth environment could burst yield, and recombined them breeding high yielding varieties Such activities allowed to gain food security in many parts of the world. Norman Borlaugh, to whom this meeting is dedicated, was a master in this tremendous international effort.

Unfortunately not all crops received the same attention, nor all developing countries benefitted equally from the Green Revolution, sub-Saharan Africa and

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South Asia being two of the vast areas that were left behind in this process. Attention was initially devoted to three major crops, rice, wheat and maize, followed later by a few others, such as some millets, major pulses, tuber and root crops. Other crops most widely consumed by inhabitants of the poor countries, crops with nutritional qualities for the poor and safety crops that can tolerate climate fluctuations were poorly considered and tended to decline. Today 99% of crop harvest relies on 24 plant species and three of them – rice, wheat and corn – account for about two thirds of the world food. An additional side effect of these plant breeding advances was the erosion of the genetic variation on which the new materials were built.

We are now at the beginning of a third phase, in which the complex of technologies made available by scientific advances in genetics and genomics, mutation, bioinformatics, gene transfer, tissue culture, etc., known as biotechnology, promise to exploit further the wealth of genetic variation present in crop land races and their wild relatives.

Farmers during millennia and breeders during the last 100-150 years relied on visible traits, such as plant height, grain quality, disease and/or pest resistance for selecting and breeding new materials. Using the new tools, scientists are acquiring detailed information on chromosome location of genes, how many of them are involved in the control of a specific character, how they function and how their expression is orchestrated in plants. Genetic resources, both landraces and crop wild relatives, allow an insight into the evolution of genomes, the amount and organisation of diversity, the genetic architecture of complex traits, including response to environmental stimuli that control plants' life, production, interaction with other useful organisms and resistance/tolerance to biotic and abiotic stress factors. Different species and their populations, wild and cultivated, annual and perennial, may have different strategies to cope with those aspects and this makes genetic resources an irreplaceable research material. By allowing the classification of genetic components as being either variable or conserved, they permit the analysis of the phenotypic variation and to relate it to genetic adaptability or to functional stability. Genetic resources are fostering new links between molecular biology, ecology and evolution; these are among the fundamental disciplines at the base of modern plant breeding, which ultimately depends on the genetic model underlying variation. Breeders will thus become increasingly able to upgrade the process of field based selection with a thorough system of genetic knowledge.

Breeding strategies and activities will change considerably and, in order to take full advantage of the potentialities of the new technologies, scientists in many countries must be trained and endowed with adequate laboratory space and appropriate tools. Moreover success in the laboratory or experimental plots still needs to be integrated in order to benefit rural communities. A technological continuum exists from germplasm improvement to development in GM technology, marker assisted breeding, genetics and bioinformatics laboratories.

Global climate models agree on two main issues: all regions will become warmer and soil moisture will decline, due to higher evapo-transpiration, leading to sustained drought conditions, irrespective of the precipitation, whose projections are less certain.

But this is also the time wherein global climate is changing. Plant species and humans will be affected by this change. Climate change, both directly and indirectly, may exacerbate famine, malnutrition and food security problems. Scientists will be confronted with this additional challenge.

Models indicate that future growing season temperatures will exceed even the most extreme season temperatures recorded during the last 100 years for most of the tropical and sub-tropical areas, where more than three billion people dwell and depend primarily on agriculture for their livelihoods. High temperatures and prolonged droughts were experimented from late 1960s to early 1990s in the Sahel, where agriculture contributes 40% of the GDP and employs 60% of the active population, a situation that contributed to hunger-related deaths and high rate of migration. Despite rain returned to some locations during the past 15 years, the growing season has been reduced, yields remained far below varietal potential or continue to stagnate. Hundred thousands of children still die each year from hunger-related causes and malnutrition contributes to long term mental and physical disabilities.

Global climate change presents widespread risks also in the middle latitudes. Despite the general perception that agriculture in temperate latitudes will benefit from increased seasonal heat, crops will likely suffer very high temperatures in the absence of adaptation. Warmest summers of the last 100 years will represent the norm in the future, challenging global population's ability to produce adequate food, unless major adaptation is made. Severe heat in summer of 2003 affected crop production in Europe. High temperatures over most of the summer growth season reduced leaf development and grain filling of crops such as maize, wheat, fruit trees and vineyards; accelerated crop ripening and maturity by 10 to 20 days and resulted in reduced soil moisture and increased water consumption. Italy experimented a record drop in maize yield of 36% from the year earlier, fruit harvests declined by 25%. A shortfall that hurt heavily the economy of the region's farmers.

Agricultural systems will have to adapt to these dramatic climate changes, this will require substantial breeding efforts and the availability of diverse crop genetic material.

High temperatures and drought will be the most significant stresses, consequently yield improvement in such environments will be a major goal of future plant breeding. Unfortunately thermo-tolerance and water use efficiency are complex characters and progress in their improvement may be difficult and slow, since relationships between such traits and their simple Mendelian components, which can be assigned to QTLs (Quantitative Traits Loci) or single genes, are neither clear nor unambiguous. In fact plants may exhibit different strategies for survival and growth under different conditions. They may avoid the effects of severe drought by developing early and shortening the growing season, by conserving available water through reducing leaf size and regulating stomata closure, or by extracting water more efficiently with an improved root system. Plants may also tolerate water deficit, becoming water stressed and still able to maintain productivity. Genetic resources with contrasting traits can be used in crop simulation models to quantify the effects of variation in different groups of traits on crop performance under stress conditions at contrasting environments. Present crop simulation models integrate the current understanding of crops derived from physiological studies, but very few, if any, incorporate knowledge drawn from genetic studies. Crop models may include landrace or cultivar parameters that have been inferred from phenotypic characteristics measured in different environments, and associate those parameters with measurable traits and dissected QTLs. Once this link has been established then the genetic research can focus on the search for genes and QTLs for component traits having the best potential. The next step would be the development of a theoretical framework able to allow reliable predictions of phenotypic consequences when making alterations of the genetic make up of a plant. As result progress in designing of molecular breeding strategies for complex characters would be greatly speeded up. The characterisation of genetic resources could then be based on the search of the best required combination of genes.

The situation of conservation and characterisation of crop resources is quite uneven. Whereas 95% of the genetic diversity of the three major crops has been collected, although poorly characterised, only 35% of the genetic diversity of manioc has been collected; those of minor crops, such as millets, pulses, yams have even smaller collections, those of leafy vegetables have no significant genetic collection. To stimulate the characterisation of these resources the Government of Italy has endorsed a proposal by the Academy of Sciences to establish an International Doctoral Programme in Agrobiodiversity, devoted to students from developing countries.

Special attention deserve wild species, since most of them are expected to leave considerable part of their area; all species will likely move to higher elevations and some will shift in latitude, whereas a number are expected to go extinct. If wild relatives are threatened, the same must be said, though more so, of the remaining uncollected landraces, still found in the fields of small and subsistence farmers. More than one billion rural households are thought to be self provisioning in terms of seed supply. The loss of these varieties will not only deprive the world and future generations of an immense source of diversity, it will doubtless result in extreme hardship to some of the poorest of the poor as their varieties steadily loose their productivity and resilience.

We seriously doubt that collection and *ex situ* conservation of this material can be achieved in short term, rather we feel that *in situ*/on farm conservation would be more feasible. In addition to conservation, these landraces will continue their co-evolution in response to natural and human selection, leading to crop populations with better adaptive potential for climate change and related pest and diseases. In addition, on farm conservation, as designed more than 15 years ago by MS. Swaminathan, can enrich indigenous knowledge and cultural traditions associated with genetic diversity, leading to self esteem, visibility and empowerment of local communities. For this reason we heartily endorsed the MSS idea of establishing local genetic resources conservation communities and did our best in seeking to secure support for the initiative he dedicated to G.T. Scarascia Mugnozza (Scarascia Mugnozza Genetic Resources Centre), as we are happy today that all these initiatives will evolve in a larger context in view of the on going genetic and cultural erosion and climate scenarios which call for urgent measures. The experience accumulated by the MSS Foundation staff and other participants to the initiative, which has been spreading in different parts of India, will be extremely useful in carrying the *in situ*/on farm projects we have prepared in cooperation with scientists and governmental authorities in some African countries.