Biodiversity and agricultural intensification – how farmers' varieties can contribute

Plant breeding has existed since crop domestication. For more than 10,000 years farmers have been selecting plants to develop varieties that produce higher yields, are less susceptible to diseases, and that show a certain degree of uniformity in germination and ripening, which makes harvesting easier. Through this selection of crop plants and by cultivating them under various, in some cases harsh environmental conditions, over the millennia a rich diversity of agricultural crop species has developed. In India, for instance, until a few decades ago up to 30,000 rice cultivars were grown.

During the past 150 years this trend has reversed. The biological diversity of crop plants has since been dwindling. Fewer and fewer species are being used for agriculture, and no more than three of them (rice, maize and wheat) supply 60% of the world's food. Not only are fewer and fewer plant species used for agriculture, but genetic diversity within species is also declining. Plant breeding and commercial seed production have contributed substantially to the reduction of genetic diversity within individual species. The number of varieties of any given crop is constantly decreasing and the varieties are becoming increasingly uniform, while certain characteristics are being lost during the process. In view of the necessity of adapting to climate change and of ensuring global food security, this 'genetic erosion' threatens the existence of the global population. In order to meet these and future challenges, some of which are still unknown, humanity needs whatever genetic diversity still exists. At the same time, conservation of biological diversity must be reconciled with agricultural intensification. Plant breeding plays a key role in this endeavour.

Intensification in agriculture – achievements so far

In the 50 years from 1950 to 2000, global grain production almost tripled. This increase was mainly made possible through progress in plant breeding, intensive nitrogen fertilisation and effective herbicides for weed control. This productivity increase, however, was mainly achieved on fertile soils, under optimal growing conditions, and only a small percentage of farmers benefited. According to more recent estimates, 95% of all farms are still peasant smallholdings.

On-farm breeding of local rice varieties in the Philippines: many farms are going back to producing and using their own seed.
Photo: Masipag

Only small areas of land are cultivated, and these mostly involve no external inputs such as fertiliser and pesticides, because the classic intensification strategies are not suitable for such farms. In the 1980s, around 60% of all agricultural land was still being farmed in this manner. Even though this figure is probably smaller today, traditional agriculture still contributes substantially to world food production and is fundamental to food security.

In order to feed the increasing world population, further agricultural intensification is required. The world population is expected to grow to approximately 9 billion people by 2050. The potential to expand agricultural land to feed this population, however, is very limited. In order for intensification to be sustainable, agriculture must start using nutrients and energy more efficiently, it must sustain ecosystems and their functions while conserving biodiversity, and it has to be climate-friendly.

Harmonising intensification and sustainability can most easily be achieved in the resource poor areas farmed by peasants that have been neglected by past intensification strategies. One possibility for increasing the yield potential of traditionally farmed lands is plant breeding, another is increasing on-farm species diversity. These are key steps to improving food security. But crops and their varieties that are expected to produce higher yields on poorer sites must have traits differ-

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ent to the high yielding varieties used on agriculturally favourable sites. This is a challenge that plant breeders must address.

Local farmers' varieties – a source for intensification

The search for alternatives started 50 years ago and led to today's method of evolutionary plant breeding. In order to generate new varieties, breeders systematically utilise farmers' local varieties that are genetically diverse and have adapted ecologically. This involves bringing together seed from different origins and recombining them through crossbreeding. The resulting mixtures, also known as 'composite cross populations', can also be crossed with high yielding varieties. From these crosses, the best progenies are selected and again propagated as bulk. In this manner, the populations are subjected to natural and artificial selection processes, ultimately resulting in a modern local variety with good performance characteristics. For example, it has been shown that composite cross populations of barley in Syria are superior to the leading high yielding varieties, because they adapt very well to various ecological conditions. Furthermore, scientists conclude that natural selection favours genotypes that also produce high yields under fluctuating environmental conditions.

Definitions

DUS criteria	*distinctiveness, uniformity, stability*
Maintenance breeding	selection of individual plants for maintaining the purity of a variety, which are then propagated as bulk.
Genotype	the entirety of genes of an organism located in the nucleus (on the chromosomes)
Uniformity	a variety is uniform if it is sufficiently homogeneous in the expression of the traits responsible for distinctiveness.
Coevolution	the process of mutual adaptation of two closely interacting species that exert strong selection pressure on each other (e.g., a plant with a parasitic fungus).
Population	the reproducing community of individuals of a species that are different in terms of their genetic constitution

Another important characteristic of crossbred populations, if they are suitably assembled, is their better disease resistance. With genetically diverse populations, disease-induced yield losses can be limited. These populations adapt well to mutating pathogens. The coevolution of plants and diseases in genetically diverse populations is an effective, self-regulating mechanism that maintains the disease resistance of the plant. As a general rule, this characteristic is not found in genetically uniform crop plants.

Evolutionary breeding with composite crossbred populations is a very promising method for agricultural intensification, particularly under ecologically disadvantageous conditions, and for adapting crops to climate change-induced environmental changes.

Breeding with farmers – faster and more efficient

Another innovation is called participatory plant breeding (see the '*Farmers as Breeders*' issue paper). In contrast to classical approaches, breeding is not done by breeders alone, nor does it take place only in experimental fields or in laboratories. Farmers are involved throughout the entire breeding process and most of the breeding takes place in their fields. This challenges the ecological adaptability of the populations, as in the farmers' fields the crops are exposed to a wide range of different environmental conditions and individual production methods. In contrast, research stations of commercial breeders are usually located on better soils and the environmental and growing conditions are more uniform than those on farms.

An example is the participatory barley breeding programme in Syria (see box right above). Breeders and farmers make crosses and selections over several generations, according to the evolutionary breeding method. The populations thus obtained are then tested over a period of three years in field experiments. Once this stage has been completed, either the material is released as a variety or the whole process is repeated.

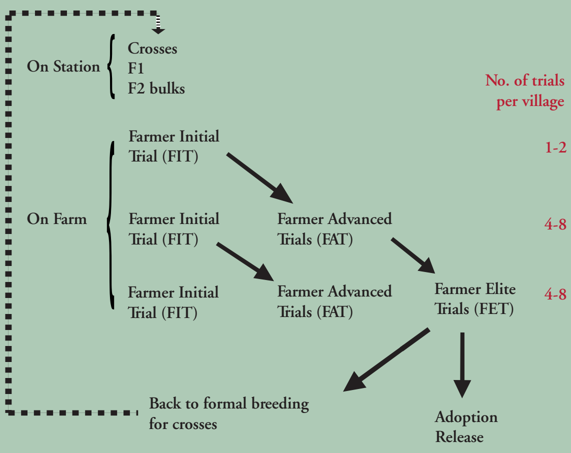
Participatory evolutionary plant breeding has emerged over the past 10 years. It is mainly supported and promoted by international agricultural research centres (e.g. ICARDA and ICRISAT) and by a number of NGOs (e.g. Misereor and Oxfam). The process is now being practised in many countries with outstanding results. Using this method to breed varieties with higher drought tolerance and better adaptation to low rainfall environments has been particularly successful.

Outstanding successes include barley in the Middle East, rice in South Asia and sorghum in West Africa. The method has been extended to other crops such as vegetables and maize.

There are three strong arguments in favour of the participatory approach:

Breeding barley in Syria: farmers and scientists working together to produce high-yield and robust native varieties.
Photo: ICARDA

Example: Participatory barley breeding in Syria



<u>Source of the diagramme</u>: Ceccarelli 2006

- The effectiveness of breeding can be improved as the farmers' experiences, as well as their agricultural knowledge and skills, are fed into the entire breeding process.
- Varieties bred by this method have high acceptance and accelerated adoption rates because the farmers, as users of the new seed, are able to input their own needs and preferences.
- The breeding time can be reduced by several years because, in contrast to classical breeding methods, a lower DUS (distinctiveness, uniformity and stability) level is sought and variety screening trials can also be omitted. This saving of time is an important aspect during our period of rapid climate change, with the resultant need for fast adaptation of agriculture.

Synergies of both innovations

Evolutionary and participatory breeding are intertwined. Together they represent an important complement to classical plant breeding. The innovations have already accomplished much in various areas:

Scientifically, this method has broadened the understanding of appropriate breeding technologies. It has enriched the discussion about the interaction between plants and the environment, and it has shown that breeding primarily for yield is no guarantee that farmers will accept and adopt a variety. So far, however, very few breeding companies are making use of this finding.

In socioeconomic terms, this method empowers farmers to regain control of their seed systems, and to safeguard their interests after decades of marginalisation due to global trade liberalisation.

From an ecological standpoint, it will become easier to exploit unfavourable sites and to tap the potential benefits of plants that have been little used in the past. The new method thus contributes substantially to improving global food production. Furthermore, it will enable us to sustain the diversity of agro-genetic resources and to develop it further for a more rapid adaptation to environmental change.

Scaling up – constraints to overcome

In terms of adoption ('scaling up'), evolutionary and participatory plant breeding is still in the early stages. For this new approach to become an institutionalised part of seed production, some bottlenecks still need to be overcome. Scientists, professionals and political decision makers must realise its value, as well as the need for the new approach. Only then will national agricultural research centres be moved to take it up, and public funding be raised.

National seed laws need to be amended. Today, in almost all countries, only registered varieties can be distributed and traded. The registration criteria and procedures exclude local farmers' varieties, as they do not meet the high DUS standard and novelty requirements. Therefore legal amendments have to be made that exempt local varieties and populations and allow registration at a much lower DUS level and at less cost. Such a change, however, is firmly opposed by the commercial seed sector.

Scaling up will only be possible with the systematic involvement of seed companies at local or regional level. Seed supply is an entrepreneurial task for the private sector, and maintenance breeding could possibly be undertaken in cooperation with the national agricultural research sector. Can seed production, seed provision in rural areas and maintenance breeding of publicly owned local varieties be undertaken in the context of such partnerships? Joint ventures between private and public sectors need to be explored, and new business models need to be developed. The potential is there, as the farmers' need for good quality seed is enormous.

Plant breeding and seed production cannot be considered in isolation. Both are components of rural development. They will only have a significant impact on food security and biodiversity conservation if agricultural smallholders gain access to resources (land, water, other agricultural inputs) and markets, and if they can rely on improved transport infrastructure and reasonable commodity prices. In this context the key requirements for plant breeding and seed production are:

- The topic of seed supply breeding, production and marketing must be put back on the agenda of rural development.
- The amendment of seed laws must be given priority in the advisory services provided to governments.
- The importance of plant genetic resources in adapting agriculture to climate change needs to be understood and incorporated in national development plans, programmes and projects. The same goes for agricultural research and rural development.
- The private and public sectors must collaborate in the provision of suitable seed.

The ongoing paradigm change in agriculture towards sustainable intensification must embrace the role of agro-biodiversity in general, and the need for innovation in plant breeding in particular. Evolutionary, participatory plant breeding could make a significant contribution to agriculture in the future.

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Further information:

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