

How can local varieties contribute to agricultural intensification?

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1. Background

Plant breeding has existed since crop domestication. For more than 10,000 years farmers have selected plants for higher yields and health; uniformity in germination and ripening became important traits to allow better harvesting. Plants were exposed and adapted to various environments. Gradually, a rich, man-made diversity of agricultural crops developed. Thousands of plant species were utilised and each crop exhibited major diversity. In India, for instance, until a few decades ago up to 30,000 rice cultivars were grown (Pretty 1995).

During the past 150 years agricultural development has reversed this trend; biological diversity in agriculture is dwindling. Today only some 150 species are cultivated and no more than three of them (rice, maize and wheat) supply almost 60% of global food. But not only are fewer and fewer plant species used for food and agriculture. Plant breeding and commercial seed production have contributed to the reduction of genetic diversity within individual species. The number of varieties of a crop is constantly decreasing and varieties are becoming increasingly uniform (Vellvé 1992, Finckh 2007, Teklu and Hammer 2006).

Plant genes represent potential traits. Their loss – also called genetic erosion – is receiving increasing attention as it coincides with two global challenges: to ensure global food security and to adapt to climate-induced environmental changes. It is becoming increasingly clear that plant genetic resources are crucial for both. Reconciling agricultural intensification with the conservation of agro-genetic resources is becoming a key concern. Plant breeding and seed production are key to that endeavour. Seed production, in particular, needs a new paradigm. The following article explores the issues.

2. Intensification in agriculture – achievements so far

In the 50 years from 1950 to 2000, global grain production almost tripled (Dyson 1999). This increase was mainly made possible through progress in plant breeding, the use of synthetic nitrogen and effective herbicides for weed control. In plant breeding, for self-fertilising crops (e.g. wheat and rice) only the best plants were selected over many generations (pedigree-line breeding), while for cross-pollinating crops systematic inbreeding to obtain hybrid varieties became the dominant standard in the 20th century (Phillips and Wolfe 2005). In addition, breeders often used the same “elite material” for breeding. As a result, while different varieties do exist, genetic diversity within each crop species has become low.

This productivity increase, however, was mainly achieved on fertile land, under optimal growing conditions, and only a small percentage of farmers have benefited. According to Pimbert (2008), there are approximately 1.3 billion farmers worldwide, of which the majority of 96% are peasants who farm on small areas of land, mostly with little or no external inputs. In the 1980s Francis (1986) estimated that 60% of all agricultural land could be classed as “resource poor areas” with traditional agriculture. Today, this figure will be smaller, but the sector con-

tributes substantially to world food production and is fundamental to food security – not only in rural areas.

According to Tilman et al. (2002), the world population is expected to grow by 50% to approximately 9 billion people by 2050, and global grain demand for food only is expected to double (due to the greater number of people to be fed, and the increasing proportion that changes its diet towards greater consumption of meat). As the potential to expand agricultural land is very limited, further intensification is required. How this intensification can be achieved is largely unclear and the subject of controversial debate. Basic determinants are clear. Intensification has to become sustainable. This means agriculture has to increase its efficiency of nutrient and energy use, must sustain ecosystems and their functions, needs to conserve biodiversity and has to be climate-friendly.

Harmonising intensification and sustainability can most easily be achieved in the “resource poor areas” that have been neglected by past intensification strategies. The factors of neglect are manifold and their relationships complex. Markets are lacking. Agricultural input supply and other service providers are largely absent. And there is a lack of appropriate technology, plant breeding being a crucial part. “Appropriate intensification” must proceed in a setting in which the initial yield level is not 8 t/ha of grain, but often 1 t/ha or even less. Yield increases to two, three or even four tons per hectare could boost food production greatly. Secondly, inclusion of a wider range of “minor” crops would be an important step towards the improvement of food security.

Why are varieties inappropriate for the intensification of such areas? For the past century breeding has been increasingly conducted for optimal agricultural environments including abundant supply of nutrients and water. As a consequence “High Yielding Varieties” (HYV) depend in most cases on inputs such as chemical fertilisers, synthetic pesticides and irrigation if they are to be successful. But for the majority of farmers worldwide who are fighting with low soil fertility, seasonal droughts or other environmental constraints, such varieties are not suitable. Under such conditions, the yield increases of modern varieties dependent upon other external inputs are often too low and, therefore, not economical. Surging input costs are aggravating the problem. This is a challenge that plant breeding has to address. Therefore, two innovations in plant breeding – evolutionary methods and participatory organisation – merit particular attention.

3. Local varieties – a source for intensification

The search for alternatives started 50 years ago (Suneson 1956) and led to the method of evolutionary plant breeding (Murphy et al. 2005). This method can be described as follows. In order to generate new varieties, breeders systematically utilise genetically diverse and ecologically adapted local varieties (Phillips and Wolfe 2005). Landraces of different evolutionary origin are assembled and recombined by cross-pollination; such mixtures are named Composite Cross Populations. Over several generations the progenies are propagated as bulk, and the bulk is subjected to natural and artificial selection under various ecological conditions, which ultimately results in a “modern local variety”. Mainly with barley (Suneson 1956) and also with wheat, Composite Cross Varieties (Qualset 1968, Thomas et al. 1991) can become superior in comparison to “leading” HYV varieties, because they perform well under various ecological conditions. Obviously, yield stability and a high yield over a range of environments require genetic diversity (Soliman and Allard 1991). Secondly, Murphy et al. (2005) conclude that natural selection favours high yielding genotypes in environments with fluctuating selec-

tion pressures (e.g. variation in temperature, or rainfall) – a condition to which most agro-ecosystems are subject.

Better disease resistance of Composite Cross Populations is another important result. Not only can disease-induced yield reductions be limited by increasing genetic diversity (Wolfe 1985, Garrett and Mundt 1999, Zhu et al. 2000), but genetically diverse populations also adapt well to changing disease patterns (Allard 1990). The co-evolution of plants and diseases in genetically diverse populations is a well functioning, self-regulating mechanism that maintains the plant’s disease resistance, a characteristic which generally is not found in genetically homogeneous crops (Murphy et al. 2005).

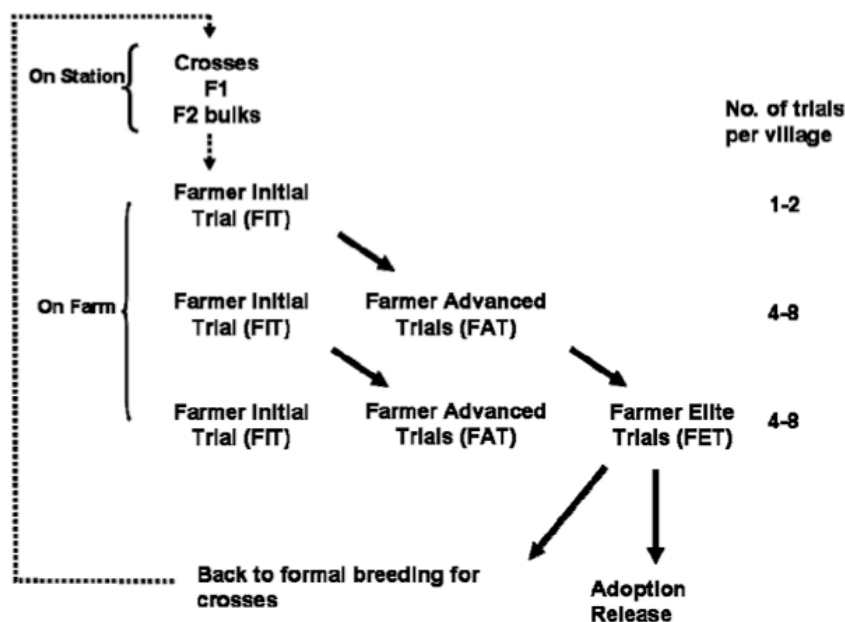
In summary, evolutionary breeding with Composite Cross Populations is a very promising method for the intensification of land-use systems and for future adaptation of crops to environmental change. This applies in particular to marginal environmental conditions and may become increasingly relevant to farming in general.

4. Breeding with farmers – sometimes faster and more efficient

Another innovation is called participatory plant breeding (PPB). In contrast to classical approaches, breeding is not done by breeders alone and hardly takes place on experimental fields or – as practised nowadays – in laboratories. Throughout the whole process of breeding – during the generation of variability, selection and testing of cultivars’ phases – farmers are fully included in decision making.

Secondly, most of the process takes place on farmer’s fields, not in research stations. In doing so, the bias of genotype – environmental interactions from research stations – can be avoided. Whereas research stations have better soils, possibly irrigation facilities, etc., farmers’ fields represent the full range of environmental (and management) conditions for cropping.

Diagrams: Example of participatory barley breeding in Syria (Ceccarelli 2006)



An example is given by Ceccarelli (2006) who breeds barley in Syria. Crosses from bulk collections and the following two generations (F₁ and F₂) are undertaken on-station and by breeders. Then testing is carried out on farmers' fields over a period of three years in "initial", "advanced" and "elite" trials. Once this stage has been completed, either the whole process is repeated, or the material is released as variety.

Participatory plant breeding emerged within the past 10 years, mainly promoted by the International Agrarian Research Centres (CGIAR) and by a number of NGOs. The process is now practised worldwide in developing countries, with outstanding results in three regions: barley in the Middle East (Ceccarelli), rice in South Asia (Witcombe et al. 1996, Joshi et al. 2007) and sorghum in West Africa (Weltzien et al. 2006). In all three programmes, the improvement of drought-tolerant cereals in low rainfall environments has been a main objective. Now the method extends to other crops such as vegetables and maize (Sunvar et al. 2006, Visser et al. 2006 and Song et al. 2006).

Considering the impact of the method, there are at least three strong arguments in favour of it:

- The effectiveness of breeding can be improved as farmers' experience, agronomic knowledge and preferences are included in the entire breeding process. All this gives varieties bred by this method high acceptance and accelerated adoption rates, lending a demand-driven approach to breeding (Ceccarelli and Grando 2007).
- Research efficiency can be improved. For instance Ceccarelli et al. (2000) found that farmers' selections are as high yielding as breeders' selections.
- Time for breeding can be reduced. Normally it takes about 15 years to release a variety. As under PPB site-testing on-farm is included in the breeding process, the release of superior bulks requires only half the time, and if pure lines are necessary 3-4 years can still be saved (Ceccarelli 2006). This is an important aspect in times of rapidly changing climate and the need for fast adaptation.

5. Synergies of both innovations

The method of evolutionary breeding and the organisational approach of participatory breeding interlock. Together they can provide an important complement to classical plant breeding. They have several advantages. They are more farmer (or client) oriented. They are successful due to the fact that environmental situations tend to be much more diverse than anticipated by common plant breeding. Also, farmers have the opportunity to select those materials that are most appropriate for their requirements, and they can play a key role in breeding.

Evolutionary, participatory plant breeding is still in the early stages and accordingly small, but its impact is manifold and very effective.

- Scientifically, it has broadened the understanding of appropriate breeding technologies. Complementing formal breeding, the new approach offers a methodology that focuses on crop-environment interaction and makes use of it. Secondly, it has stimulated discussion on genotype x environment interaction and new methods have been developed that allow breeding under local conditions with various environments. Last but not least, breeders have become increasingly aware that breeding primarily for

yield does not guarantee broad adoption by farmers. Therefore, more and more breeders are integrating farmer participation into their formal programmes.

- Socially it helps to empower farmers to regain control of their seed systems, to safeguard their interests after decades of marginalisation due to trade liberalisation. Secondly, small scale farmers in marginal areas are now receiving benefits from agricultural research and development, as well as recognition that greater efforts must be made to develop technologies that are better suited to improving their livelihood (Almekinders and Hardon 2006).
- Economically it provides an answer as to how the potential of marginal areas and the large range of minor crops can be exploited and made more productive. This is one key aspect of increasing global food production.
- Ecologically the new approaches provide an answer to sustaining the diversity of agro-genetic resources and further developing it in accordance with environmental change within a shorter period of time. The challenge of global warming is to adapt to difficult environments as fast as possible.

The two approaches in combination represent a great potential to contribute to future agriculture.

6. Scaling up – constraints to overcome

Meanwhile the innovations described – evolutionary and participatory breeding approaches – form a well established niche in plant breeding. However, the niche is still small. For scaling up and making it an institutionalised part of seed production, serious bottlenecks have to be overcome.

First of all, this requires a change of attitude among scientists, professionals and political decision makers, an attitude that realises the value of and need for the new approach. Only then can research policies be changed, national agricultural research centres moved to take up this approach and public funding raised.

Secondly, national seed laws need to be amended. Today, only registered varieties can be distributed and traded in almost all countries, and the registration criteria and procedures exclude local varieties as they demand a high standard of “distinctiveness”, “uniformity” and “stability” (DUS criteria). Therefore legal amendments have to be made that exempt local varieties and populations and allow registration at a much lower level and at less cost. Such a change is, however, firmly opposed by the formal seed sector.

Scaling up will only be possible with the systematic involvement of seed companies – at a local or regional level. Seed supply is an entrepreneurial task for the private sector and maintenance breeding could possibly be done 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 done 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, market opportunities, 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 advisory services 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 has the potential to contribute significantly to future agriculture.

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