

Background to plant breeding

Farmer historical roles

Plant selection is at the base of agriculture itself, when humans began identifying and domesticating selected plants for food. With conscious human selection over time, plants adapted genetically to cultivation and away from survival in the 'wild' (Almekinders and Louwaars, 1999). Domestication involved selecting crop plants for traits of uniformity, predictability and higher productivity. Contributing traits include: height, growth habit, ripening, seed dormancy, seed shattering, fruit/seed size, ease of dispersal, threshing, reproduction, germination, hair/spines and toxins (Brown, 2010).

Intrinsic farmer activities in relation to conservation include keeping seeds, preparing the soil, fertilising, planting, watering, weeding and harvesting. Farmers bring deep knowledge, such as how to identify varieties, ideal planting locations, care requirements, and harvest and post-harvest practices. These are linked to use of and adding value to resources (Meldrum, 2013:98). Across cultures, women play a central role in maintenance, conservation and enhancement of crops and varieties. Agricultural systems globally have a gendered division of labour. Women and men have different tasks in and around the homestead and farm, and distinct roles and responsibilities with respect to resource management. Women and men develop separate, shared and complementary sets of knowledge about the natural world (Elias, 2013). Women play a critical role in identifying and bringing wild plants into food systems, and women hold extensive and detailed knowledge about food, fodder and medicine. Worldwide, women smallholder farmers are active in breeding, selection, management, processing, storage and conservation of plant resources. Globally, women are the primary actors involved in smallholder seed selection and storage and in farmer-to-farmer seed distribution networks (Elias, 2013).

Rise of breeding as a specialised activity

Crop husbandry and stewardship by cultivators themselves has, thus, been the bedrock of agriculture for thousands of years. It is only relatively recently, at the dawn of the scientific revolution in the 1700s, that scientists began entering into this space, with contributions to a better understanding of plant anatomy and reproduction. Experiments at hybridisation started in the early eighteenth century. In the early 1900s, the United States Department of Agriculture (USDA) was collecting and disseminating germplasm to growers (Catotti, 2010). Plant breeding as a scientific discipline can be traced to Gregor Mendel's experiments in the early 1900s, on the inheritance of genetic traits (Shelton and Tracy, 2016). This led to the rise of plant breeding as a specialised activity, which, combined with commercialisation in agriculture, led to the separation of breeding from farming practices.

From the 1920s, the Rockefeller Foundation in the US began supporting hybridising efforts in maize to produce an improved crop for industrial agriculture. This led to yield expansion in the US, and the activities were taken to other countries: Mexico, Brazil and Argentina in the 1940s and Kenya in the 1950s. Parallel efforts were made in the 1960s to introduce similar programmes, mainly in wheat and rice, in India, Pakistan, the Philippines and Indonesia.

Scientific breeding for yield was the cornerstone of what has come to be termed the Green Revolution. These activities led to the establishment of what later came to be known as the International Maize and Wheat Improvement Centre (CIMMYT), based in Mexico, and the International Rice Research Institute (IRRI), based in the Philippines (Kaur, 2010). Undoubtedly, these efforts did lead to sharply increasing yields, but there were significant negative social and ecological impacts (Carson, 1962; George, 1976). The trade-offs were considered to be worth it by the ruling powers, and in 1971 the Rockefeller and

BOX 1: Plant breeding in Africa

Agriculture was and remains one of the core economic activities across Africa. In the immediate post-independence era of the 1960s, the public sector was tasked with agricultural research and development (R&D). Formal variety development in sub-Saharan Africa (SSA) began in the 1970s with testing through international varietal trials and a search for broadly adapted varieties. This was successful for wheat in Asia but was found to be “highly inefficient for maize under African conditions” (Lynam, 2011:37), given the wide range of agro-ecologies under limited input use and rain-fed production. These pose an inherent difficulty in developing commercial seed systems, even for dominant staples in Africa. There was a small amount of private sector investment in R&D and plant breeding in narrow channels of profitability.

Hybrid development is mainly limited to maize, mostly for use in East and Southern Africa, in particular South Africa, Kenya and Zimbabwe. The private sector has also invested selectively in ‘closed’ value chains such as cotton, coffee and tobacco, where companies organise the whole chain, including inputs, production methods and outputs. Otherwise, formal plant breeding research was, and essentially remains, a public sector activity in Africa (Lynam, 2011).

Following global economic crisis and the related debt crisis in Africa in the 1980s, structural adjustment programmes and the rise of neoliberal approaches led to stagnation and decline in agricultural R&D spending in the 1980s and 1990s. There was a shift to regional approaches, especially through the CGIAR regional centres and the creation of sub-regional agricultural research organisations, for example, Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) and the West and Central African Council for Agricultural Research and Development (WECARD).⁴

Political unrest in numerous countries accompanied structural adjustment and market liberalisation. Donor priorities shifted to governance and economic enterprises, and agricultural research was not considered a ‘quick win’ for results. National agricultural research systems (NARS) continued to rely on donor funding, with the World Bank and European governments amongst the main donors in national systems. In Malawi, donor funding to agricultural research almost stopped, with a shift to productivity increases through the farm input subsidy programme. This has produced a stratification of research capacity across countries, with stronger systems in South Africa, Kenya and Ghana, where there is more commercial agriculture, and an expectation that the private sector would fill the space vacated by the public sector, even in countries with limited commercial agriculture (Lynam, 2011:38).

Investment in agricultural R&D started to pick up again from around 2000, but under private sector authority (Beintema and Stads, 2011). This expansion was in response to the commodities boom and the search for profitable avenues for the use of excess capital being generated in the capitalist core at that time. Although this growth in investment in agricultural R&D in Africa has continued to 2011 (at least), it was mainly driven by a few countries – Nigeria, Ethiopia and Kenya in particular, with many other smaller countries falling behind (Beintema and Stads, 2014). Part of liberalisation and privatisation was decentralisation of agricultural research to semi-autonomous institutes, which faced issues around economies of scale for plant breeding and coordination of varietal testing (Lynam, 2011:39). It is also apparent that while public sector breeders could produce potentially useful varieties for a range of agro-ecological contexts, they did not always have the capacity to multiply and get these out to farmers. To this day, potentially useful varieties sit on the shelf without being used.

4. Conference de responsables de recherché agronomique africains (CORAF)

In 2006, the Bill and Melinda Gates Foundation created the Global Development Programme. Its principle focus was on agriculture, with a significant component supporting agricultural research. Together with the Rockefeller Foundation, the Global Development Programme established the Alliance for a Green Revolution in Africa (AGRA). AGRA's Programme for Africa's Seed Systems is dedicated to crop breeding and seed system development, including individual breeding programmes and start-up activities for seed companies (Lynam, 2011:39; ACB 2012). Currently, there is a mosaic of donor support for agricultural research in SSA. The World Bank has shifted from funding research projects to providing indirect agricultural loans, and promotes public-private partnerships. There is a disparity across national systems and a focus on regional approaches and strategic areas, where some capacity already exists to build on. Plant breeding may be a part of this (Lynam, 2011:39).

In 2007, ASARECA shifted to competitive grants. This is not conducive to the needs of ongoing breeding programmes. Plant breeding has its own organisational architecture, which relies heavily on predictable, recurring financial support, continuity and long investment horizons (Lynam, 2011:43). The shift to competitive grants broke the connection between the CGIAR centres and national ARI breeding programmes (Lynam, 2011:40). Regional breeding networks deteriorated significantly in the 2000s, with some regional breeding programmes closing, due to lack of funding (Lynam, 2011:43). Plant breeding capacity is a bellwether for the expansion and contraction of agricultural research. It is a long-term investment requiring commitment. However, it does not have a lot of policy visibility or short-term impact compared to interventions like input subsidies, and is often considered of lesser importance in funding decisions (Lynam, 2011:45-46).

The plant breeding challenge for sub-Saharan Africa is to optimise existing genetic diversity to match agro-ecological, cropping system and consumption system heterogeneity that characterise food and agriculture on the continent (Lynam, 2011:43).

Ford Foundations, working with the World Bank and the United Nations (UN) Food and Agriculture Organisation (FAO), established the Consultative Group on International Agricultural Research (CGIAR) to expand the Green Revolution into more countries and more crops. Today, the CGIAR coordinates agricultural research in developing countries worldwide (Kaur, 2010:15). Its research agenda has evolved and now includes such issues as sustainable agriculture and adaptation to climate change. However, recent times have witnessed a decline in public sector spending on agricultural research, and a shift in research from public to private.

Formal breeding has historically focused attention on increasing yields (productivity). Many other major breeding objectives are indirectly related to this, for example, pest or disease resistance, and adaptation to abiotic stresses (drought, low soil fertility), as they aim to increase or stabilise yields in specific socio-ecological conditions (Weltzien and Christinck, 2009:76). Undoubtedly, yield and productivity are central concerns for farmers.

Formal breeding responded to longstanding concerns for crop producers, including predictability, higher productivity, and for some farmers and some traits, uniformity. However there are also trade-offs in adopting formal breeding.

Trade-offs and limitations of formal breeding

Formal breeding tends to focus on relatively few crops and to direct activities towards favoured, high-potential areas, with little, if any, work on diverse demand in more marginal areas (Danial et al., 2007). Although farmer breeding practices have resulted in thousands of different and genetically unique varieties cultivated in farming systems, today only 150 plant species are widely cultivated, and just 12 provide three-quarters of the world's plant-based food. These 'mega-crops' include rice, wheat and maize along with sorghum, millet, potatoes and sweet potatoes. The result is genetic erosion and increasing dependence on a relatively few plant varieties, with species loss and

reduction of diversity, as well as a gradual breakdown of processes that maintain the evolution of diversity (Fowler and Mooney, 1990; Vernooy, 2003:2–3).

The formal breeding system is not very responsive to issues beyond yield, with unintended consequences that ripple out into seed systems. Other traits and qualities, including appearance, conservation, processability and culinary value are marginalised or even traded off for yield. These are influenced by local factors, making farmer preferences difficult to assess and integrate into large-scale formal breeding programmes aiming for uniform outputs (Trouche et al., 2012:70). There is mounting evidence that the global availability of staple food alone is not sufficient for reducing hunger and malnutrition (Weltzien and Christinck, 2009:76). Participatory appraisals with farmers and users indicate a preference for a combination of multiple traits, with some willingness to trade off some yield advantages to retain these combinations – this is shown in the case studies later.

Materials developed in CGIAR institutes are often developed for wide use but are poorly adapted to diverse local conditions (Rios Labrada, 2005), and will need local adaptation and testing to be integrated into local farming systems. Often this will require crossing with local materials. Most conventional breeding activities use gene bank materials, rather than materials currently maintained in farmers' production systems, despite the continuing availability of considerable and unique local crop diversity (Gyawali et al., 2010).

Varieties that may perform well at research stations ('on-station'), under ideal conditions, with fertiliser, irrigation and so on are not necessarily good in relation to specific and unique socio-ecological contexts, especially marginal areas (Vernooy, 2003). Conditions 'on-farm' may differ considerably from those on-stations, with GxE interactions resulting in cultivars selected on-station being poorly adapted to conditions on-farm (Manu Aduening et al., 2006). Selection in an environment different from the target environment results in a decrease in selection efficiency (Wakjira et al., 2008:188).



Today there is widespread recognition that the conventional package of new varieties and external inputs, while successful in the more favourable production areas, has often failed to benefit small-scale farmers in marginal areas ... traditional farming and low-input systems are a very heterogeneous population of target environments and not easily served by centralised, conventional plant breeding" (Ceccarelli et al., 2009:vii–viii).

While technicians consider homogeneous lines a sign of genetic uniformity, this may not be what performs best in a highly heterogeneous, risky environment. Having more genetic variability in the field can be a way of avoiding the very real risk of total crop failure, and may be gained by mixing cultivars in the field (McElhinny et al., 2007).

Challenges to farmer historical role in biodiversity conservation and adaptation

Formal breeding is built on the separation of farmers from the breeding process. This has posed a major threat to agricultural biodiversity, as indicated in the limits to formal plant breeding methods and approaches. These limitations on formal breeding are also located in a broader context of pressure on farmer seed practices. In the process of pushing a commercialisation and modernisation project onto African agriculture in the form of the Green Revolution, for example, formal plant breeding has fallen under the sway of private interests. These interests are pushing for IP protection and standardised



quality controls shaped by their needs. This involves promoting certified seed as the only legitimate seed for farmers to use, and the simultaneous denigration of farmer seed as diseased, low quality and illegal.

There is limited recognition amongst government authorities that most seed is produced and reproduced in farmer systems (Hardon et al., 2005). This has produced a marginalisation of indigenous and farmer varieties and knowledge, despite the existing agricultural biodiversity maintained by smallholder farmers. Farmer knowledge and skills in selecting and breeding quality seed are being lost through breakdown of intergenerational knowledge sharing. Smallholder farmers are the natural custodians of biodiversity, in contrast with large-scale commercial farmers, who are locked into mono-cropping, which is not conducive to the maintenance and enhancement of agricultural biodiversity. Mono-cropping, whether on a large or small scale, leads to segregated zones of production with very low biodiversity. Men also tend to dominate these spaces, since mono-cropping is, more often than not, for cash crop production.

In places with large-scale commercial farming, farmers have completely lost their historical role in maintaining and expanding agricultural biodiversity. “The combination

of industrialisation of agriculture and formal training for plant breeders created a gap between breeders and farmers, a gap that was exported to developing countries in the post-war era” (Ceccarelli et al., 2009:vii). Formal plant breeding deskills farmers by removing plant breeding from their range of activities and placing these skills with a separate, laboratory-based layer of specialised technical experts. This has created centralisation of decision-making and concentration of resources. Biotechnologies prompt even greater centralisation and concentration; for example, molecular breeding using markers; advanced molecular characterisation of germplasm; integrated information systems linking genetic, genotype and phenotype information; and the exclusive use of this information for private profit and integrated transgenic platforms linking biotechnology, seed and agrochemicals.

Experience in Asia indicates that the known benefits of agricultural biodiversity are constrained, due to the limited number of plant breeders who can respond to the needs of poor farmers. Reasons for this include: a small proportion of accessions are used by plant breeders; public sector investment in plant breeding is declining; there is an over-emphasis on biotechnological tools for plant breeding; young scientists are showing declining interest in conventional plant



breeding; and there is a lack of innovative and simple plant breeding methods for use by local institutions (Sthapit and Ramanatha Rao, 2007).

Farmers in sub-Saharan Africa also face other pressures. Poor soil fertility, low rainfall and frequent drought limit agricultural production across the region. Farmers who survive develop complex, adapted farming systems and strategies to respond to these realities (Weltzien and Christinck, 2009:76). However, these diverse farming systems themselves are presently undergoing rapid change, including declining size of landholdings, reduction in fallowing periods, and low productivity. Traditional crops and varieties ideally adapted to certain farming practices and site-specific conditions tend to disappear because of technological or climate change, economic pressure, changed

food habits, and loss of traditional knowledge (Weltzien and Christinck, 2017:260). Climate change is manifested in rising temperatures, altered rainfall patterns, drought, and increasing incidence of pests and diseases. This has uneven impacts on farmer varieties/materials. Some varieties in some places perform better than certified seed but others perform less well.

Urbanisation and changing lifestyles and diets may require new varieties. Bulk commodity markets such as maize and soya may displace local crops and facilitate monocultures. The need for uniformity on the market means diverse forms of the same product will not be valued as highly as uniform products that can be used at large scales for processing and industrial value addition (Sthapit and Ramanatha Rao, 2007).