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Crop Diversity: An Unexploited Treasure Trove for Food Security

Festo Massawe,[1,2,*] Sean Mayes,[1,2] and Acga Cheng[1]

The prediction is that food supply must double by 2050 to cope with the impact of climate change and population pressure on global food systems. The diversification of staple crops and the systems in which they grow is essential to make future agriculture sustainable, resilient, and suitable for local environments and soils.

So Many Crops, yet so Few to Feed the World

The contents of a typical food basket anywhere in the world today are limited to a small number of crops, with merely 20 plant species comprising 90% of the world's calories. A comprehensive study of global food trends [1] reported that human diets worldwide have grown 36% more similar in composition over the past five decades. In Africa and Asia, where most population growth is expected, populations have increased their consumption of the major staple crops, contributing towards the trend for a more uniform diet globally [1]. Today, the crops that provide a dominant proportion of the global diet are the 'big three' cereals; maize (*Zea mays*), wheat (*Triticum aestivum*), and rice (*Oryza sativa*), along with a suite of recently adopted energy-dense oil crops, including soybean (*Glycine max*), oil palm (*Elaeis guineensis*), and sunflower (*Helianthus annuus*). As a consequence of the focus on the big three, other crops of considerable local and/or regional importance, such as finger millet (*Eleusine coracana*) and rye (*Secale cereale*), have lost ground, both commercially and agriculturally [1,2].

The increasing trend for homogeneity in global food supplies will be a problem, given that current major staple crops have been bred largely for intensive agriculture with management practices designed to maximise outputs via high inputs. Recent breeding work in major crops is beginning to focus towards sustainability, particularly trying to bring in traits for efficiency and resilience that may have been lost in high-input agricultural systems. However, these crops may not intrinsically be the best-suited species for marginal and low-input environments. They may also not be able to cope with the extreme weather events predicted and now being increasingly seen due to climate change, one of the defining issues of our generation [3].

How Did We Get Here and Are We Headed in the Right Direction?

The shrinking list of crops that feed the world is largely driven by successful scientific advancement with demand shaped by social and economic forces [1,2]. In most developing countries, the trend towards reduced crop diversity began during the 1960s with the spread of the **Green Revolution** [4]: a series of new advances in agricultural research and crop genetics that boosted agricultural production worldwide (Box 1). However, the Green Revolution has not been successful everywhere and remains applied predominantly to the big three cereals (maize, wheat, and rice) and a handful of other crops. As a result, a greater uniformity of crops is grown over larger areas, making agriculture more vulnerable to major threats, such as pests and diseases, and, now, climate change [5].

In socioeconomic terms, strong income growth leading to the emergence of a new middle class and rising populations overall in developing countries have increased demand for high-value food products, such as meat and dairy products, while rapid urbanization and multinational food industries have encouraged greater consumption of processed, imported, and fast food [6]. These changes in food consumption will likely accelerate the global rise in noncommunicable diseases associated with excessive calorie intakes and poor nutrition, such as diabetes, strokes, heart attack, and certain types of cancer [6,7]. With two billion more mouths to feed by 2050, even brief failures in the current food production and supply systems could easily lead to severe famine and even civil unrest, especially in developing countries [8]. These global problems could be partially alleviated through increased crop diversification. Crop diversification is not only a strategy to protect global food supplies, but also a tool to combat hunger, malnutrition, and overnutrition [6].

Crop Diversification: Not An Option, but a Necessity to Safeguard Our Food Supplies

There are at least 50 000 species of plants that are suitable for human consumption, yet fewer than 300 species make their way into the market [4]. A recent analysis conjures up a worrying picture of global food consumption patterns and urges people to consume a broader range of food sources to combat malnutrition and global food insecurity, which is expected to grow [1]. That implies people should eat more of the world's underutilised crops, also known as 'orphan' or 'minor' crops (Figure 1). Most of these underutilised crops have resilience traits, with the ability to withstand drought, flooding, temperature extremes, and pests and diseases to a greater extent than current major staples [9]. As such, diversifying global food systems with these crops is one component to addressing extreme weather patterns or the effects of long-term climate change while tackling the problem of dietary imbalances facing the world today [9,10].

Box 1. Green Revolution: A Blessing or a Double-Edged Sword?

The Green Revolution has been credited for preventing starvation in famine-prone countries through a step-change in agricultural practices. The technology of the Green Revolution involved high-yielding varieties of cereal seeds, often termed 'miracle seeds', developed specifically to respond to heavy doses of fertilisers and irrigation to increase crop yields [5]. The impact of the Green Revolution was greatest in Asia, notably in India and China. Twenty years after the inception of the Green Revolution, global yields of the 'big three' cereals (maize, wheat, and rice) had skyrocketed to at least double average yields, successfully avoiding the threat of famine in several countries. However, this revolution did have some negative consequences. Single crop species are grown in a stand, with genetic uniformity of the crop within the stand and with intensive management of the environment. This model has become dominant in many parts of the world, leading to several drawbacks caused by the genetic uniformity of the crop and agricultural system, including crop vulnerability to pests and diseases, which must be countered by additional chemical inputs. Despite its influence, the distribution and implementation of Green Revolution strategies have been unevenly spread across various socioeconomic classes and geographical terrains. The cost of fertilisers, irrigation systems, and mechanical equipment may have prevented uptake by small-scale farmers, and many countries in Africa have not been able to benefit much from the revolution, due to socioeconomic, infrastructure, and political deficiencies. This, in effect, drew a division between classes of farmer who were able to afford or access these technologies, and the ones who could not. Consequently, the gap between the lower-income and the upper-income households has widened, which ultimately may lead to civil unrest among those left behind [3,5]. Regardless of these criticisms, it is an undisputed fact that the Green Revolution will forever be in the good books of modern agriculture. However, the next agricultural revolution will have to be more complex, more sustainable, and more suited to the local agricultural and environmental context. This will prove more challenging.

In fact, a small number of underutilised crops have recently graduated off the 'neglected list' and are attracting attention. Some underutilised crops have become popular in the developed countries due to their nutritional properties. One of these is quinoa (*Chenopodium quinoa*), a pseudo-cereal native to the Andean Mountains. Deemed the 'Queen of Superfoods', this ancient grain has been trending in many western countries as an ideal food source, being gluten-free but protein rich and containing all nine amino acids essential for the human diet [11]. Quinoa can be grown under a range of climatic conditions, making it a highly sustainable crop. The United Nations (UN) General Assembly declared 2013 as the International Year of Quinoa (http://www.fao.org/quinoa-2013/en/).

Other known nutritional gluten-free grains, such as amaranth (*Amaranthus caudatus*) and teff (*Eragrostis tef*), share the same kind of versatility and health benefits as quinoa. Just as quinoa was sacred to the Incas, so was amaranth to the Aztecs and teff is to the Ethiopians [10,11]. Cultural status may be one of the important reasons why some underutilised crops are still grown, coupled with their unique crop traits that make them invaluable to local farmers [2].

For low-input agriculture, legumes are an important component, providing high levels of protein in the seed. One crop that has recently received more attention is the bambara groundnut (*Vigna subterranea*), an indigenous African legume that thrives in hot climates and is well suited to poor, infertile soils where other crops fail to produce a reasonable yield. It can also contribute to companion crop yields through nitrogen fixation in intercropping or rotation systems [12]. In addition to its hardiness, the bambara groundnut seed is comparatively rich in essential amino acids (especially methionine), carbohydrate, and soluble fibres. Once called the 'poor man's crop', it is now considered a valuable weapon in the battle against hunger across Africa, and possibly beyond [12].

The Future of Food Security Lies in an Atypical Food Basket

About 75% of crop diversity has been lost from farmer's field over the past century, and the prediction is that more than 20% of the wild relatives of some important food crops will disappear from fields by 2055, due to climate change [13]. Underutilised crops around the world have not received the attention they deserve, partly because they are not championed by global corporations that control seed production and sale systems, usually for their own commercial gain. Nevertheless, on a positive note, there has been an increase in awareness regarding the importance of protecting and utilising the genetic diversity of food crops, including that of underutilised crops. Table 1 presents some examples of underutilised crop species, from 20 genera, held in different gene banks around the world [13]. The past decade has seen gene banks worldwide increase in both size and number, with many holding a large number of accessions for important underutilised crops that could become the foundation for future agriculture, alongside current major staples [13,14].

In addition, evidence suggests that agricultural research organisations, nongovernmental organisations, and, to some extent, funding agencies are increasingly changing their attitude in favour of crop diversification within agriculture [14,15]. The most recent and notable example was the declaration of 2016 as the 'International Year of Pulses' by the 68th UN General Assembly (http://www.fao.org/pulses-2016/en/). Research and development in underutilised plant species over the past decade has, in fact, gained momentum due to extensive efforts by several national, regional, and international organisations and institutions, such as Biodiversity International, the Food and Agriculture Organization of the United Nations (FAO), and Crops For the Future (CFF) [2,13–15]. The current wave of change must be maintained or accelerated through more collective global effort and the enabling of policies that not only protect and promote small-scale farmers in developing countries, but also recognise context-dependent sustainable farming as the only viable option to feed the hungry world.

Concluding Remarks and Future Perspectives

The increased likelihood of extreme weather events also signifies increased disruption to the production of major crops. There is now a dire need for a more