Biodiversity conservation for agriculture, nutrition and health in an era of climate change

At a time when it seemed that continued availability of biodiversity in general, and agro-biodiversity in particular was taken for granted, one of us (MSS) as early as January 1983 in his Presidential address at the 15th International Congress of Genetics[1], held in New Delhi drew attention of the delegates to the importance of conservation of biodiversity of all organisms from 'microbes to man'. More than fifty years ago, it had occurred only to a few geneticists that there would be no plant breeding at all, whether molecular or Mendelian, should all the wild progenitors and related species of the cultivated crops become extinct. Since then, with his persuasion at the international level and also direct involvement, efforts to prevent the extinction of biodiversity by methods such as cryogenic preservation and *in situ* on-farm conservation have been intensified. The 'Svalbard Global Seed Vault' (https://www.croptrust.org/our-work/svalbard-global-seed-vault/) set up by the Norwegian Ministry of Agriculture, the Global Crop Diversity Trust and the Nordic Genetic Resource Centre is in evidence of the success of persistent endeavours over the past several decades. In recognition of his role, the Norwegian Government invited one of us (MSS) in February 2009 to deliver a lecture on the occasion of a Seminar on 'Frozen Seeds in a Frozen Mountain' at Longyearbyen on Svalbard Island situated at 78° north in Arctic circle; so, he delivered a lecture under the title 'Freezing Seeds: A Humanitarian Issue'. The Svalbard Seed Vault was created by chiseling an ice mountain to provide adequate space to store sample seeds and vegetative propagules of about 4.5 million plant species and varieties. The vaults have a natural temperature of –4°C round the year, which is further lowered to –18°C, the optimal temperature for long-term seed viability. In sequel, he wrote an editorial 'Gene banks for a warming planet' in *Science*[2]. It is noteworthy that the Defence Research and Development Organisation (DRDO), Government of India also established a permafrost seed vault at Chang La in Ladakh.

Preservation of seeds at freezing temperatures to prolong their viability does not lead to mutational changes in the seeds and further diversification of the gene pools. So, *in situ* on-farm conservation is essential. Hence, Swaminathan[3] designed a sequence of banks with a difference, i.e. these deal not with money, but with genes, seeds, grains, fodder and water. It is represented below:

Gene bank → Seed bank → Grain bank → Fodder bank → Water bank.

The gene bank represents the *in situ* on-farm conservation by the rural and tribal families. *In situ* on-farm conservation allows continued occurrence spontaneously of new mutations on which the natural selection could operate. New variability in response to abiotic stresses increasingly caused by rising temperature, drought, salinity and submergence is necessary for future food security. The 'seed banks' involve conservation of representative samples of landraces and traditional varieties in proper seed stores that will ensure availability and supply of seeds when natural extreme events (i.e. earthquake, cyclones, tsunami, floods, drought, etc.) cause significant destruction/loss of seed material for sowing in the ensuing season. 'Grain banks' provide grains for food on loan with a stipulation that the borrowed quantity would be returned after harvest with reasonably additional quantity as interest. Since farming requires freshwater for irrigation, community-centric rainwater harvesting and equitable sharing will ensure sustainability.

Yet another strategy to revitalize the conservation traditions of farming women in India is the 'Protection of Plant Varieties and Farmers' Right Act 2001' enacted by the Parliament of India. A unique attribute of this Act is that it recognizes farmers as 'conservers' of biodiversity, and 'breeders' of new landraces, indigenous varieties in addition to their primary role as 'producers of agricultural crops'.

While all the above said are the various ways to conserve agrobiodiversity, the most simple and striking strategy, however, is what is called the 4Cs[4]. The 4Cs form a continuum of Cultivation, Conservation, Consumption and Commercialization. The M.S. Swaminathan Research Foundation (MSSRF) has established the strategy of 4Cs in Kolli Hills, Tamil Nadu for nutritious millets (once referred to as 'coarse millets') and in Koraput, Odisha for a traditional landrace of rice (*kalajeera*) which after genetic purification is called *Kalinga Kalajeera* that fetches premium price in the market.

Any means of 'preservation' and 'conservation' is a step towards enhancement of resilience with regard to food and nutrition security in an era of climate change. However, some of the newer strategies to ensure food and nutrition security, notwithstanding sea level rise, salinization of land and aquifers especially in the coastal regions are discussed below:

(i) Halophyte garden: Halophytes (i.e. a plant adapted to growing in saline conditions) are the gifts of nature, a consequence of mutations and natural selection favouring survival in seawater. Many halophytes are used as food and feed (Figure 1).

(ii) 'Below sea-level farming' in Kuttanad, Kerala: The 'below sea level rice cultivation' in rotation with fish culture in Kuttanad and the 'halophyte garden' provide wide employment opportunities to youth because of their potential intellectual challenges and also commercial attractiveness.

(iii) Biodiversity for natural biofortification of crops and health: Writing an editorial in *Science*[5], Swaminathan added the nutritional dimension to the 'Zero Hunger' goal of the United Nations, launched in 2012. There are at least three major types of hunger: (1) caloric hunger – insufficient intake of cereal grains for energy; (2) protein hunger – insufficient intake of proteins necessary for growth; (3) hidden hunger – insufficient intake of micronutrients such as iron, iodine, zinc and vitamin A, vitamin B, vitamin D, etc.

Today the world in general and India in particular, have enough cereal grains to quench the caloric hunger of the entire global population. There is, of course, the need to have purchasing power and this lack of access to food is the cause of nearly one billion people of the world

Figure 1. Halophyte garden with *Salicornia* species.

Figure 2. Section of the biofortified garden with plants rich in Vitamin C.

going to bed unfed or underfed. Through a system of formation of 'Pulse Villages', the MSSRF has shown the way to enhance availability of protein in the country. As far as the micronutrients and vitamins are concerned, the prudence is to use the naturally bio-fortified crops[6]. Earlier, Swaminathan[7] developed the strategy of 'Farming System for Nutrition' (FSN). Its basic approach is to provide agro-horticultural remedies to nutritional maladies. If, for instance, there is an increased incidence of morbidity due to vitamin C deficiency, then plants naturally biofortified with more vitamin C (e.g. citrus species) would be grown in the farming system to provide more vitamin C in the diet. When such farms belong to resource-poor small and marginal farmers, they would also get the benefit through increased sales of farm produce and income. Fortunately, there are a large number of agro-horticultural plants rich in iron, iodine, zinc, vitamin A, vitamin C, vitamin D, etc.

The success of FSN will depend on the exposure of farmers to a wide variety of these naturally biofortified plants. Such an exposure can be done through establishment of 'biofortified plants garden' (Figure 2).

Inclusiveness in access to technologies: With an increasing interest in patenting commercially important technologies, there is every possibility that small and marginal farmers will not have access to emerging technologies. This is where the procedure adopted in Switzerland with reference to golden rice could be suitably adapted to other discoveries. The approach is in organizing a Humanitarian Trust which will purchase patents relating to new and eco-friendly technologies and make the technology available to developing countries at no or low cost. Probably, FAO could establish such a global Humanitarian Trust with a primary aim of technological empowerment of women farmers as well as small, marginal farmers.

The need for overcoming widespread malnutrition is widely accepted. What is lacking is a methodology for achieving this goal. This is where innovations like genetic gardens of biofortified plants and halophytes will be useful. Climate change is already adding to the problems of farmers. This is why approaches like the cultivation of naturally biofortified plants will be helpful in overcoming hidden hunger. Training is essential and suitable training material will have to be prepared and provided to Krishi Vigyan Kendras for use in their training programmes. Economically affordable technologies are now available and all that we have to do is to ensure that these technologies reach the unreached.

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