Making environmental sustainability an integral part of agricultural research

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The agricultural sector plays a critical role in mitigating environmental sustainability challenges and climate change impacts. Agricultural research is essential for conserving genetic resources, developing nutritious and high-yielding varieties, and enhancing soil, animal, and human health without affecting the biodiversity-ecosystem. This paper gives an outlook on what means environmental sustainability integration possible in agricultural research through multidisciplinary partnerships. The state of agricultural research today looks at innovative approaches to support sustainable agriculture and discusses how we might use these approaches to make real strides towards environmental sustainability.

The timeless tryst between man and crops also shows that various strategies of crop improvement, like introduction, selection (marker-assisted and genomic), hybridization, mutation, etc. have been adopted since the advent of agriculture[1,2]. With the marvellous increase in human population, a corresponding increase in crop production has also been observed, including an increase in the biotic and abiotic stresses[3,4]. With much less focus on other strategies, plant breeding, hybridization and, in the last few decades, tissue culture, biotechnology and bioinformatics have been given immense importance in agricultural research and development[5]. The green revolution, because of investment in agricultural research, has helped countries feed their teeming billions and maintain peace around the world[6–8]. However, the phenomenon of climate change poses a challenge to the further evolution of crops and man together, i.e. the food security gains made through agricultural research and development. In addition, the growing emphasis on sustainable development requires a review of past strategies to promote sustainable development in the future. Integrating environmental sustainability through agricultural research requires input in the form of multidisciplinary knowledge, including agriculture, medicine, nutrition and social sciences. Historically, crop improvement focuses on yield attributes that ignored the local environmental sustainability by heavily investing in mono-cropping systems. For instance, India achieved a record in food grain production (~315 million tonnes in 2021–22; Economic Survey, 2022–23) but did not overcome the poverty and malnutrition prevalence in the country. Therefore, crop production should aim for improved crop nutrition, input use efficiency, and adaptation to biotic and abiotic (climate change) stresses to increase farm incomes locally and sustainably. Balancing food grain nutrition and staple productivity through new varieties would reward more inclusiveness of local, regional and global adaptation food production strategies.

Nutrition-related diseases, both malnutrition and overnutrition, affect billions of people across the globe[9]. The crop to be consumed by the affluent should be lower in calories and higher in fibre and nutrients. The crop consumed by the undernourished should have more deficiency-reducing factors in it. Crop improvement could be derived from the life sciences for the factors that determine human health and well-being. While non-food factors also play a critical role in health and well-being, food factors play a significant role. Since agriculture contributes to food, focusing on food factors and avoiding non-food factors in agricultural research is better and necessary. If the scientific community can determine how much nutritional loss can be tolerated for the gain in productivity. In the present scenario, nutrition will likely be given more importance than productivity. This line of research could be considered by working on a baseline of the existing dietary pattern of the locality, the nutritional factors in the food, and the bioavailability and bioequivalence of the nutrients in that locality. While all these are considered at the level of a single crop, the same should also be considered at the level of multiple crops and many crop interactions of the locality. Research could change the cropping pattern of an area and, therefore, the nutrient pattern. For example, a high-productivity crop should not create a nutritional imbalance in the intended locality. Another factor to consider is that increased productivity can lead to reduced fodder production, with consequent impacts on livestock, soil and human health. Broad guidelines should also be established for achieving an ideal population based on the global land-carrying capacity.

While there is no way to prevent farmers from using improved varieties, even in agrobiodiversity hotspots, the only option left to the scientific community is to invest in conservation activities. Various conservation activities are being conducted, but the question is: ‘Will not even one gene be lost from a given locality?’ Once lost, varieties and genes are lost forever. Considering the gravity of the situation, especially in the climate change scenario where biodiversity could be of immense help, an inventory of the existing diversity and conservation at all costs should be done. In addition, innovations in genome sequencing and bioinformatics have opened new vistas for harnessing conserved varieties, species and their genes. For instance, the Norin 10 and Dee-Gee-Woo-Gen dwarfing genes have immensely fed billions of people[10]. Bringing genome sequencing into use can bring immense contributions.

It is known from historical evidence that genetic uniformity and climate change would make a species vulnerable to new biotic challenges and cause severe damage to society. The devastating impact of plant diseases on human societies and food security under a changing environment is well explained by Rosenzweig *et al.*[4] and several other authors. Considering the co-evolution of pathogens and pests against host virulence, agricultural scientists need to focus more on the co-evolutionary interactions between host and parasite at the molecular level, which will lead to continuous natural selection for adaptation and counter-adaptation by ecologically interacting pest and pathogen species under changing environment.

In an era of immense climate change, and with targets to reduce emissions, emissions from agriculture must also be reduced. Most of these emissions come from the factories that run agriculture, including fertilizers and pesticides. Time-bound strategies should be developed to phase out polluting agriculture and achieve an agricultural system with a zero-carbon footprint. Further strategies should be developed to sequester carbon emitted by industry through agriculture. The breeding process should strategize on how to sustain farmers' livelihoods through agriculture in the long term. An example of sustainability in the breeding perspective is to have long roots and consider yield based on rainfall data over 100 years. This could be the basic framework for releasing varieties in the context of climate change. While research is at one end of establishing equity and sustainability, other technologies that could drive such change include marketing and economics. Producer companies could effectively determine the movement of the percentage of compensation farmers receive from the consumers' pie of payment.

The role of agricultural researchers must therefore shift from a single objective of increasing yields and incomes to a multi-objective strategy of health, nutrition, climate change, economics, consumers and marketing. This has multiplied the work of scientists and the investment in developing better crop varieties and technologies. Crop breeding gave us solutions to hunger in the early part of the century and has the potential to meet the many challenges we now face. Investment in agricultural research should help to address these multiple challenges. Agricultural research with sustainability objectives across sectors is the need of the hour.

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Nano impacts: from science to society

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Uses of nanotechnology-based products in daily life brings human health under the scrutiny of nanotoxicity and nanosafety domains. Standard guidelines set for nanotoxicity assessment and nanosafety measures are yet to generate public awareness. This gap needs to be bridged by educating society about the toxicity and safety issues of the daily use of nanomaterials. An effort is made here to conceptualize the basic framework for raising awareness about the nanotoxicity and nanosafety of public concerns.

Medical science and technology have made significant progress in the early detection and curing of human diseases. In recent times, many newly emerged biotic factors (BFs) and abiotic factors (AFs) have been detected that cause serious human health issues. Among the most significant BFs, new strains of clinical pathogens of natural mutation origin are worth mentioning. Clinical detection and treatment of human diseases caused by newly emerged pathogens are being made possible, and successes have been made to a great extent. However, the same trend line is not seen with many AFs. Lack of theoretical knowledge, limitations in research modalities and clinical trial guidelines have been found to be the basic possible causes that have delayed dealing with the human health issues originating from AFs. Among the vast arrays of newly emerged AFs, nano-sized (1–100 nm) materials have been found to be hazardous to human and environmental health[1]. It can be recalled that nanoscience and nanotechnology are two important scientific disciplines that have made significant societal contributions. Nanotechnology-based commodities for daily life uses have been manufactured at industrial and global scales, and overall demand is still growing. In this regard, the great contribution in the form of theoretical knowledge made by Richard Feynman is highly appreciated[2]. However, not more than three decades ago, the pros and cons of nanoproducts were included under the global regulation protocols for emerging contaminants, and extensive research has been carried out in the direction of nanotoxicity. The presence of nano-sized AFs, such as nanomaterials (NMs), in the human body and environment has raised serious public concerns. Laboratory investigations carried out *in vitro*, *in vivo* and clinical levels have shown the hazardous nature with sufficient evidence of the genotoxicity and mutation caused by NMs[3]. Significant research progress has been made in the part of nanotoxicity caused by NMs. However, due to the complex physicochemical properties and lack of standard analytical techniques, many aspects of the nanotoxicity that can be triggered by NMs are yet to be uncovered. From a societal point of view, it is pertinent to have general