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Review on strategies to improved nutrient use efficiency, doubling farmer's income and sustainable agriculture in Indian context

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Abstract
Since the Green Revolution era, the farming sector exploited the soils for food, fiber, fodder, etc., with high input responsive varieties that excavated vast amounts of chemical fertilizers. The burgeoning population of the country calls for a commensurate increase in food production to satisfy the demands of its inhabitants. Further, due to innovative mechanization in agriculture, specialization, and government policy programs, the productivity of food has soared. Subsequently, it ensued greater productions and minimized food prizes. Regrettably, intensive agricultural operations degraded the soil quality and now reached such a stage where without external inputs, growers unable to achieve their targeted yields. India has lost 68% innate productive capacity of agricultural soils. This plunder of land's quality continues unabated, further resulting in low nutrient use efficiency and insufficient yields of agro-ecosystems. The present review paper highlights the impacts of non-judicious nutrient management on soil productivity, nutrient use efficiency, and novel technologies required to promote sustainable agriculture and achieve the target of doubling farmer's income in India.

Key Words: food security, sustainability, nutrient use efficiency, technologies

Introduction
The agriculture sector is the primary source of livelihood for over 58% of the Indian population and a key contributor to the health of the country's economy as it contributes approximately 17.1% to India's gross value added (GVA). It generates an employment opportunity for 44% of its workforce. Agriculture in India, continues to make impressive progress, while food grain production at record 296.7 million tons (Mt) and total oilseeds production at record 33.4 Mt., during 2019-2020. Such increments were also observed in other major crops. Current production estimates show that food grains, pulses, oilseeds, fruits, vegetables, and flower and aromatics are about 284.83, 25.23, 31.31, 97.35, 184.39, and 3.65 Mt., respectively. The production rates of different agricultural produce in India for the period from 2012 to 2013 to 2017–2018. Despite this remarkable growth in production in India, about 14.8% of the population and 38.4% of children remain malnourished. As per evaluation of the Global Food Security Index (GFSI), India ranked 76th out of 113 countries.
The persistent decline in nutrient use efficiency, soil fertility status, and environmental quality are the key constraints coming in the way of achieving sustainability in Indian agriculture. Specifically, in the Indian soils, nutrient use efficiency (NUE) is very low. It varies from 30 to 50% for nitrogen (N), 15 to 20% for phosphorus (P), 60 to 70% for potassium (K), 8 to 10% for sulphur (S), and 1 to 2% for micronutrients (Sarkar *et al*., 2021) [8]. The unutilized N is lost through several mechanisms such as leaching, denitrification, volatilization, etc., pollute the groundwater and atmosphere. Considerable amounts of P and K are also lost through soil erosion.

Technological options suitable for Indian agriculture
1. Enhancement of soil organic carbon
Improving SOC in agricultural soils is now a global challenge for environmental safety as it is the most realistic approach to regulate soil degradation and improve soil productivity to achieve higher crop yields. Mahmood *et al.*, 2017 [4] revealed in his experiment that incorporation of OC into the soil system through sheep manure (SM), farmyard manure (FYM), and poultry manure (PM) alone or amalgamation with chemical fertilizers significantly improved the soil organic carbon status as well as the available total nitrogen (TN), total phosphorus (TP) and total potassium (TK) over the control and complete inorganic treatment. Improvement in soil fertility always has a direct benefit on crop yields as the availability of all essential soil nutrients increases through the addition of C input. There was an increase in crop yields (kg/ ha) for every Mg /ha increase in SOC stock in the root zone. A field experiment conducted to evaluate the effect of C input under various crop production systems showed that an improvement in crop yields (kg/ ha) such as 170 for pearl millet, 145 for soybean, 150 for castor, 160 for upland rice, 18 for lentil, 90 for winter sorghum, 33 for groundnut, 124 for finger millet, 101 finger millet, 13 for groundnut, 145 for soybean, and 59 for safflower.

2. Organic manures and green manures

Manures are the decomposed heterogeneous organic mixture that are made up of farm wastages like crop residues, cow dung, and household wastages. Manure releases the plant nutrients very slowly, thus the initial requirements of the crop met by supplying fertilizer nutrients for optimum growth and development. Farmyard manure (FYM) contains almost all the essential plant nutrients that are needed for crop growth. Farmers in India could easily manage the FYM preparation and its application in the field as the cost of inorganic fertilizers are high which is unable to afford by small and marginal farmers. However, the availability and efficiency of manure are highly dependent on the method and amount of its application, time to incorporate, and decomposition rate by soil microorganisms.

3. Integrated nutrient management

Integrated nutrient management (INM) is a technique of combined usage of chemical fertilizers, organic amendments, and bio-fertilizers in farming which is an economically feasible and environmentally benign way of managing plant-available nutrients. This concept originated at the beginning of the 1990s because of the widespread emergence of multi-nutrient deficiencies and soil degradation. Thus, INM comprises major objectives such as soil fertility maintenance, sustenance of crop productivity, and improvement of the farmers' profitability. The amalgamation of inorganic fertilizers with organic amendments aids in the provision of improving soil productivity by improving soil C storage (Srinivasarao *et al*., 2019) [9]. The INM-induced SOM build-up aids in the provision of improved soil structure and water holding capacity that directly enhances crop yields.

4. Conservation agriculture

Traditional agriculture, based tillage, and other management operations lead to soil erosion problems, surface and groundwater pollution. Conservation agriculture (CA) technology involving three basic principles such as minimum soil disturbance, efficient and diversified crop rotations, and surface crop residue retention aids in the provision of enhancing/improving soil organic carbon storage. Tillage and residue management greatly influence the soil's physicochemical and biological properties (Jat *et al*., 2019) [2]. Zero tillage (ZT) for crop production has been identified as an important practice to increase soil aggregation and C sequestration as compared with traditional systems i.e., conventional tillage (CT).

5. Fertigation and foliar spraying

Fertigation is a technique of supplying plant nutrients along with irrigation which helps in increasing crop yields or N fertilizer efficiency in many conditions with different crops. Supplement of N and P fertilizer through fertigation technique significantly enhanced the wheat grain yield by 16% as compared to top-dressed N. The fertigation process allows the soil to absorb up to 90% of supplied nutrients, while it is only about 10 to 40% under dry fertilizer or granular application. It ensures saving in fertilizer quantity of about 40–60%, because of better fertilizer use efficiency and reduced leaching losses (Kumar and Singh, 2002) [5].

6. Water-soluble fertilizers

Water-soluble fertilizers are 100% soluble in water which is suitable for foliar application due to their low salt index to reduce the potential for the burning of plant tissue. It is also used in fertigation, sprinkler, or drip irrigation systems to increase yield and to improve the quality of fruits and vegetable crops. These fertilizers should meet certain criteria such as 100% solubility, high purity, low salt index, (EC = 0.9–1.2), pH acidic (5.5 to 6.5), and no inert matter, free from sodium and chloride, driven by R&D, suitable for fertigation and foliar application, higher nutrient use efficiency, etc. These fertilizers are mostly the combination of N, P, K, Ca, Mg, S, and micronutrients with different ratios developed to suit the type of crop, quality of water, soil fertility, and climatic conditions (Malhotra, 2016) [5].

7. Biofertilizers

Biofertilizers are the source of microbial inoculants prepared in a controlled laboratory condition that acts as a substituent for chemical fertilizer and helps to achieve sustainable agriculture boosting farm productivity. Several studies indicated the use of biofertilizers in agriculture enhanced crop yields at greater levels. Usage of biofertilizers such as *Azotobacter*, *Azospirillum*, *Rhizobium* for N, and phosphate solubilizing bacteria (PSB) for P, vesicular-arbuscular micorhizae (VAM) for other nutrients availability in crop cultivation helps in improving crop yields and quality. Soil inoculation with *Azotobacter*, *Azospirillum*, and PSB produced maximum crop yields by 5–10% over farmers' practice (Rao, 2018) [7].

8. Nano fertilizers

Regular synthetic fertilizers are highly vulnerable to the losses such as leaching, volatilization, percolation, etc. which ultimately results in low NUE which is below 30%. "Nano fertilizers" are prepared by extracting the nutrients from different parts of the plant through chemical, physical, mechanical, or biological methods using nanotechnology. Nanotechnology has a long-term impact on agriculture and food production as the usage of these fertilizers in farming improves crop growth, yield, and quality parameters while increasing the nutrient use efficiency (NUE), and reducing the wastage and cost of cultivation. A significant higher selenium uptake was

observed in the plots where nano-sized particles were applied. Nano-fertilizers in agriculture enhanced nutrient uptake and crop productivity (Iqbal, 2019) [1].

9. Customized fertilizers

Customized fertilizers (CF) are multi-nutrient (macro-N, P, K, secondary-Ca, Mg, S, and micro nutrient-Zn, Cu, B, Fe, Mn, etc.) produced from both inorganic and organic sources, manufactured through a systematic process of granulation designed to facilitate the availability of a complete range of nutrients to the plant growth during its growth stages (Rakshit *et al*., 2012) [6]. It has various advantages besides soil health enhancement and maximum crop yields.

Programs and policies executed by GOI for sustainable agriculture

The convergence of various policy programs has been initiated by the GOI to ensure the effective utilization of existing resources are briefly discussed here. The National Mission of Sustainable Agriculture (NMSA) under the National Action Plan on Climate Change (NAPCC) was launched in 2010 in order to encourage the judicious management of existing resources. The Paramparagat Krishi Vikas Yojana (PKVY) mission was executed in conjunction with the Indian Council of Agricultural Research (ICAR) and state governments of India to extensively leverage adaptation of climate-smart practices and technologies. In 2015, GOI has launched the Soil Health Card (SHC) scheme to protect the soil health for future agriculture with the main objective of analyzing soil samples of farmers' fields and recommending fertilizers accordingly.

Additionally, Neem-Coated Urea (NCU) was introduced to the farmers of India for a slow supplement of nitrogen (N0 by reducing the N losses and excess addition of urea fertilizers. Programs such as the National Project on Organic Farming (NPOF) and National Agroforestry Policy (NAP) was introduced in 2004 and 2014 respectively to encourage the farmers with more profit and ecosystem service through supplements of plant nutrients in the form of organic amendments, improvement of soil carbon storage, and soil protection from erosion loss. States like Andhra Pradesh, Himachal Pradesh, Sikkim, etc. have already adopted and promoted organic farming practices on a wider scale. "Sikkim" state recognized as an "*Organic State*" of India. A "4 per 1000/4 per mille" initiative launched by France in 2015 as a part of the Global Climate Action Plan (GCAA) adopted by the United Nations Framework Convention on Climate Change (UNFCCC) at a conference of the parties (COP) 22 also recognized the importance of SOC in achieving sustainability in agriculture system. It considered the technologies such as agroforestry, conservation agriculture system intensification (CASI), and landscape management to improve SOC.

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