Innovative Technologies and Sustainable Agricultural Development

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ABSTRACT

Monotonous practices in agriculture over the years have resulted in declining crop yield, loss of soil fertility, and have also contributed to environmental problems. This acts as a hindrance in addressing bigger issues like climate change, and food and nutritional security for an ever growing population. In order to address climate change, increase crop yields, and ensure food and nutritional security to all, it is suggested that we follow and promote a mix of innovative technologies, like biotechnology, bio-fertilizers and bio-pesticides, nanotechnology, magnetic agriculture, etc. Adoption of these technologies will also help in achieving long run sustainability in agriculture.

Keywords: *Sustainable agriculture; Innovative technologies; Climate change; Food and nutritional security;*

The concept of sustainable development therefore, helps us understand our limitations in the world we live in. It helps us understand that we cannot establish our authority on the earth and its resources. Also, we cannot exploit or overuse them in a way that they affect the need of generations to come, a hundred or thousand years later. The problems that we are facing in today's world are complex and serious and we need to address them. The issue of sustainability is raised in agricultural practices also. Whatever advances we have made in agriculture, we should think that we have exploited our soils, and other natural and manmade resources available as input in agricultural production to such an extent, that the quality of, and profitability from such resources is on a decline worldwide. Nations have started addressing the issue of sustainability in Agriculture, but a lot more is needed in India. A mix of technologies that leads to environmental, economic and social sustainability is required for overall sustainable agricultural development, so that we continue to address the issues of climate change, and food and nutritional security.This paper highlights certain innovative technologies which have emerged sustainable in the long run.

Innovative Technologies to enhance crop yields and achieve agricultural sustainability:

Biotechnology:

Plant Tissue Culture (PTC): Plant tissue culture is a technique with which plant cells, tissues or organs are grown on artificial nutrient medium, either static or liquid, under aseptic and controlled conditions. *Singh and Shetty (2011)* acknowledged that only tissue culture can help in catering to the needs of quality planting material of banana and Jatropha, and can bridge the gap between demand and supply by increasing the yield. "The demand within the country for quality Jatropha plants is about 5 billion (50,000 lakhs). This huge quantum of quality planting material supply is possible either through the adoption of tissue culture technique or by providing hybrid seeds", said *Singh and Shetty (2011). Hanumantharaya et al (2009)* analyzed the comparative economics of Tissue culture banana (TCB) and Sucker Propagated Banana (SPB) production in Karnataka and found that the average yield of tissue culture banana was 50.04 quintal per hectare (q/ha) while that of sucker propagated banana was just 40.05 q/ha. *Alagumani (2005)* did a similar study in Tamil

Nadu. The study revealed, "The gross income was higher by 35.35 per cent in TCB than SPB, which worked out to Rs 2,53,302 and Rs 1,87,149 per hectare, respectively. The net income was also higher by 42.37 per cent in TCB than in SPB. This indicated the economic advantage of TCB over SPB. The cost of production per bunch was Rs 52.31 and Rs 43.78 in TCB and SPB, respectively". *Singh and Shetty (2011)* highlighted that capital; labour and energy are the most important input in tissue culture technology. The author duo emphasized on a major constraint in the way of developing nations and that is the well equipped laboratories, and trained personnel to carry the experiments. Today, we need more of biotech experts specialized in Tissue Culture techniques.

Genetic Engineering and transgenic crops: Genetic engineering (GE) differs significantly from traditional biotechnological techniques in that DNA from different species can be combined to create completely new organisms called as Genetically Modified Organisms – GMOs (*Burkhard Mausberg and Maureen Press-Merkur, 1995*). *Parikh (2012)* mentioned "with increased awareness of agro ecosystem functioning and best management practices, biotechnology and agricultural practices have evolved together to solve a range of problems and promote agricultural sustainability. Today, farming practices which reduce erosion (e.g., no till, perennial grains) are being combined with the use of hardy and pest resistant crops (e.g., selective cross breeding, genetic engineering) to enhance long-term food and biofuel production." *Thomson (2007)* suggested GE as one of the ways to improve agricultural production in Sub Saharan Africa to prevent a shortfall of nearly 90 Mt of cereals by the year 2025, if current agricultural practices were maintained.

According to the Indian GMO Research Information System (IGMORIS) is currently working on the development of various GE crops, mainly for pest resistance, herbicide tolerance, fungal resistance, abiotic stress tolerance, and yield enhancement. The crops being developed by public sector institutions include banana, cabbage, cassava, cauliflower, chickpea, cotton, eggplant, rapeseed/mustard, papaya, pigeon pea, potato, rice, tomato, watermelon and wheat. The private seed companies are focusing on cabbage, cauliflower, corn, rapeseed/mustard, okra, pigeon pea, rice and tomato, and next generation technologies for cotton.

Bio Fertilizers: A 'biofertiliser' could be defined as the formulated product containing one or more living / quiescent microorganisms that enhance the nutrient status, the growth and yield of the plants by either replacing soil nutrients and / or by mobilizing nutrients more available to plants and their by increasing plant access to nutrients leading to best productivity. A few widely used bio-fertilizers are: Rhizobium, Azotobacter, Azospirillum, Azolla, Anabaena, etc (*Vyas et al, 2008*). Through the use of biofertilizers, healthy plants can be grown while enhancing the sustainability and the health of soil. There are two types of technologies for biofertlizer production. One is conventional carrier based, and the other one is liquid based (Table 1):

Table 1. Types of technologies for biofertlizer production

Carrier Based (or powder based)	Liquid Based
Low cost	High cost
Less investment for production unit	Higher investment for production unit
Low cell count	High cell count
Temperature sensitive	Temperature tolerant
Contamination prone	Contamination free
Short shelf life (1/2 year)	Longer shelf life (>1year)
Less effective	More effective
High dosage	Dosage is 10 times less than carrier based

N. Sambasiva Rao and Umesh Mishra (2013) at KRIBHCO (Krishak Bharti Cooperative) in their paper on "Strategic marketing of biofertilizers", presented a success story of a banana farmer based in Gujarat. This farmer had used Liquid BioFertilizer @ 2 Ltrs/Acre along with other chemical fertilizers i.e. .DAP, Urea, Potash, ZnSo4, 20-20-0 and obtained an increase in yield by 9.92 % (Table 2)

Though Biofertlizer technology is a low cost, eco-friendly technology, but the understanding of this technology and its handling by skilled personals, is very important. Use of improper, less efficient strains for production, will not yield desirable results.

Precision Farming: Precision farming is about the application of technologies and agronomic principles to manage temporal and spatial variability associated with all aspects of agricultural production for the purpose of improving crop performance and environmental quality. Simply put, precision farming is - management of farming practices that use computers, satellite positioning

Table 2. Success story of a banana farmer based in Gujarat (Source: *Rao and Mishra, 2013*)

Particulars	Unit	With Liquid Bio Fertilizer		Without Liquid Bio fertilizer		Additional Income
Chemical Fertilizers		Qty	Value	Qty	Value	Rs. (+/-)
DAP	Kg	100	1900	125	2375	475
MOP	Kg	125	1325	125	1325	-
UREA	Kg	200	1164	250	1459	295
ZINC SULPHATE	Kg	25	600	25	600	
NPK [20:20:0]				50	700	700
COMPOST	Kg	1000	4000	1000	4000	-
Liquid bio-fertilizer	Liter	2	200	-	-	-200
Fertilizer cost / sub total	Rs	Total	9189	-	10459	1270
Cultivation expenses	Rs	-	13000	-	13000	
Irrigation expenses	Rs	-	9600	-	9600	
Weedicides spraying	Rs	-	1500	-	1500	
Labour expenses	Rs	-	8800	-	8800	
Seed	Rs	-	19600	-	19600	
Sub total	Rs		52500		52500	
Total	Rs -		61689	-	62959	1270
Yield	Qtls	-	288		262	26
Rate per qtl	Rs	-	750	-	750	
Earnings from yield	Rs	-	216000	-	196500	19500
Net profit/ additional income	Rs	-	154311	-	133541	20770
Increase in income %						15.55%
Increase in yield %						9.92%

systems, and remote sensing devices to provide information on which enhanced decisions can be made. Sensors can determine whether crops are growing at maximum efficiency, identify highly specific local environmental conditions, and point out the exact nature and location of problems (*HGCA, 2012*). Information collected can be used to produce maps, showing variation in factors such as crop yield or soil nutrient status, and provides a basis for decisions on, for example, seed rates and application of fertilizers and agrochemicals, as well for the automatic guidance of equipment. Overall, precision farming is a way towards sustainable agricultural practices.

In India, precision farming is not as advanced as in the West owing to the high cost of technology and the high level of fragmentation of farm holdings. However, by adhering to the basic principles of precision farming, farmers in Tamil Nadu, Maharashtra, Kerala and Andhra Pradesh, among others, have increased yields by more than two times. Initially the costs of setting up technology is high, but the returns are higher enough than traditional farming practices, for per Hectare area of cultivation.

(Source: TNAU, and NAU- Precision Farming Project)

Nanotechnology: It deals with the physical, chemical and biological properties of matter considered at nanoscale (1–100 nm) and their implications for the welfare of human beings (*Holdren, 2011*). According to the US EPA (US Environmental Protection Agency), nanomaterial is an ingredient containing particles with at least one dimension that approximately measures 1–100 nm. It has the ability to control and/or manufacture matter at this scale which results in the development of innovative and novel properties that can be utilized to address numerous technical and societal issues (*Ditta, 2012*). Nanotechnology has the potential to revolutionize the agricultural systems, biomedicine, environmental engineering, safety and security, water resources, energy conversion, and numerous other areas (*Naderi and Shahraki, 2013*). *Chen and Yada (2012)* in their paper on "Nanotechnologies in agriculture: New tools for sustainable development," highlighted several industrial examples where nanotechnology applications have been developed. A few of them are:

- Nanotechnology enabled delivery of agriculture chemicals (fertilizers, pesticides, herbicides, plant growth regulators, etc.)- nanoscale carrier enabled transfer of fertilizers and pesticides at a targeted point, that prevents spoilage and reduces environmental problems that arise due to runoff of these chemicals when used under current agricultural practices.

- Field sensing systems to monitor the environmental stresses and crop condition-Networks of wireless nanosensors positioned across cultivated fields provide essential data leading to best agronomic intelligence processes with the aim to minimize resource inputs and maximizing output and yield (*Scott & Chen, 2003*). Such information and signals include the optimal times for planting and harvesting crops and the time and level of water, fertilizers, pesticides, herbicides, and other treatments that need to be administered given specific plant physiology, pathology, and environmental conditions.

Magnetic Technology in Agriculture[1]*:* Magnetic technology has the immense potential to increase the agricultural productivity multifold. Experiments have shown that the pre sowing magnetic treatment of seeds results in improvement of seeds' quality and their germination properties (*Iqbal et al, 2012*). This technology not only allows spending 30-50% less on the sowing material but also results in significant reduction of vegetative period, an increase of harvest by 12-36%, and in some cases up to 100% and more. Magnetic treatment of seeds has also been found to speed up protein formation, providing for the growth of roots and activating growth processes in weak seeds.

Magnetic water is able to dissolve salts effectively and therefore can effectively wash the soils rich in chloride-sulphonitrate, making it more suitable for the plants. Harder water available from tube wells in rabi season leads to hardness and deposition of salts on soil surface, ultimately leaching down. As a result, soil available for kharif crop is richer in salts and may adversely affect kharif plant growth and productivity. This can easily be overcome by using magnetized water as magnetic water absorbs and dissolves hard salts in the soil. It has been found that magnetization reduces water utilization by 30 percent. A study conducted by Magnetic Technologies LLC, a company in Dubai reveals that sorghum crop/harvest increased by 45%, and corn by 30%, compared to a control area that was irrigated by normal (non- salty) and non-magnetized water

Benefits of implementing magnetic technology include yield increase by 25-60 percent, reduction in fertilizer use by 30-70 percent, reduction in water and seed consumption upto 30 percent, no scale formation in drip pipes. The technology is also considered beneficial in early maturity of crops ensuring better quality, nutrients level and foliage. (*Agriculture Today, Jan 2014*)

Not many of the research studies are available in India to support the benefits of Magnetic Technology. It is suggested to conduct such researches on different crops (especially of economic significance). Favorable results may help small farmers come out of the complexities of vicious crop cycles.

Vertical Farming[2]*:* According to the Food and Agricultural Organization (FAO), at present, throughout the world, over 80% of the land that is suitable for raising crops is already in use. This is an issue that we Indians should think of more seriously. Dickson Despommier – an ecologist at Columbia University in New York City – first suggested in 1999, that food should be grown year-round in high-rise urban buildings, reducing the need for the carbon-emitting transport of fruit and vegetables. This is what he has termed as, "Vertical farming". Vertical farms aim to avoid the problems inherent in growing food crops in drought-and-disease-prone fields many hundreds of kilometres from the population centres in which they will be consumed. Proponents of vertical farming feel that it is much better and sustainable way of securing food supplies in future, with minimum wastage, reduced cost, and less inputs.

The vertical farms can be set on smaller area. Growing one crop over land spread in acres or hectares, you can rather grow different crops vertically on stacks over one another. *Paul Marks (2014)* in his article in the New Scientist Tech says, "The plant racks in a vertical farm can be fed nutrients by water-conserving, soil-free hydroponics systems and lit by LEDs that mimic

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[1] Studies related to the use of magnetic techn. in Agriculture are available here: Reports on Magnetic Technology

[2] On September 26, 2012 the University of Maryland, USA conducted a workshop on challenges in Vertical Farming. The presentations and lectures are available online and can be accessed at: http://challengesinverticalfarming.org/

sunlight (if there is no sunlight). And they need not be difficult to manage: control software can choreograph rotating racks of plants so each gets the same amount of light, and direct water pumps to ensure nutrients are evenly distributed." However, you need energy to keep your LEDs working, when required. Furthermore, as these farms thrive on water than soil, you have more opportunity to control the attack of pests and diseases.

The crops that are likely to be grown on vertical farms are high-value nutritious crops – like tomatoes, lettuces, green crops (high valued plants). Vertical Farming is not limited to produce; preliminary plans include chickens, ducks, geese, fish, crustaceans, and molluscs to be raised within the same building, creating one large integrated system of food production. Vertical farming drastically reduces fossil fuel use, and there is no weather related crop loss. Besides, the food is grown organically on vertical farms (Natural Blaze).

Banerjee, C. and Adenaeuer, L.(2014) constructed a vertical farm in Germany to study the economic feasibility of these farms. A farm, 32 floors high on a 0.25 hectare area, was designed and simulated in Berlin, to estimate the cost of production and market potential of vertical farming technology. The research revealed due to closed environment and closed lightening; the land productivity of vertical farms was twice as high as traditional agriculture. Just 0.25 ha area grown vertically yielded about 3,500 tons of fruits and vegetables, almost 516 times more than traditional agriculture (Table 3). The investment costs add up to € 200 million, and it requires 80 million litres of water and 3.5 GWh of power per year. The produced food costs between € 3.50 and € 4.00 per kilogram. The research, however, suggested that in order to tap the economic, environmental and social benefits of this technology, extensive research is required to optimize the production process. In 2012, the world's first commercial vertical farm was opened in Singapore, developed by Sky Greens Farms, and is three stories high. They currently have over 100 towers that stand at nine meters tall. The concept has gathered attention of locals and governments alike all over the world.

Table 3. Estimated yield of a vertical farm compared to traditional agriculture

Crops	Yield in VF due to tech (t/ha)	Field yield (t/ha)	Factor increase due to tech	Factor increase due to tech and stacking
Carrots	58	30	1.9	347
Radish	23	15	1.5	829
Potatoes	150	28	5.4	552
Tomatoes	155	45	3.4	548
Pepper	133	30	4.4	704
Strawberry	69	30	2.3	368
Peas	9	6	1.5	283
Cabbage	67	50	1.3	215
Lettuce	37	25	1.5	709
Spinach	22	12	1.8	820
Total (av.)	71	28	2.5	516

Source: Banerjee, C. and Adenaeuer, L.(2014).

CONCLUSION

Technological innovations as discussed, could offer potential solution for the developing countries to improve and innovate their production systems, thereby achieving sustainability in the long run. Most of these technologies have the prospective to enhance farm productivity and reduce environmental stress that is associated with agricultural production, and has emerged as a key constraint. These technologies also have the potential to address the issues that arise as a result of climate change by protecting environmental quality. However, before their adoption, it is important to consider their social, environmental and economic implications. At the same time, developing countries should invest in capacity building so that the benefits of these technologies can be extended to world farming community, appropriately.

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