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Achieving second green revolution through nanotechnology in India

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Abstract
Initial spurt in agricultural growth rate as a result of the "First Green Revolution" has experienced distinct slowdown in recent years. There is urgent need to enhance productivity through technological as Nanotechnology, intervention. It is one of the emerging technologies with enormous agricultural application, which can be effectively applied in the development and design of methods and instrumentation for enhancing quantity and quality of food products and managing environment in better way. The paper discusses feasibility of achieving Second Green Revolution in India through nanotechnological application in agriculture in India.

Keywords: Agricultural growth, nanotechnology, market forces, subsistence agriculture

1. Introduction
The 'First Green Revolution' witnessed during early 70's culminated in tremendous yield increase through four basic elements of production system viz. semi-dwarf high yielding varieties of rice and wheat, extensive use of irrigation, fertilizers and agro-chemicals. However, after tremendous growth, there has been a distinct slowdown in the agricultural growth rate since the mid-1990s. The agricultural production is experiencing a plateau, which has adversely affected the livelihood base of the farming community at large. As the availability of arable land for agriculture would reduce in future due to urbanisation, the only way out could be expected through productivity route. In fact, the country needs a 'Second Green Revolution'. In this background, this paper tries to investigate whether nanotechnology can be used as a catalyst to initiate 'Second Green Revolution' in India?
Nanotechnologyl is the latest buzzword in the engineering, and technological field and if believed the experts, it is going to make drastic changes in almost every aspect of economic life of 21st century. In general parlance, nanotechnology2 is a science of miniature. Contrary of bulk material, nano-materials are 5,000 to 50,000 times smaller than the diameter of a human hair. These light but strong, transparent materials are very active and aggressive in any chemical reaction. Nano-materials can be mixed with any other materials to make them thousand times stronger and more efficient. The paper discusses feasibility of achieving 'Second Green Revolution' through nanotechnology in India. Second section of the paper discusses myriad agricultural application of Nanotechnology which can be effectively applied in the development of new functional material, product development, and design of methods and instrumentation for enhancing productivity, food safety and bio-security. Third section discusses present state of Indian agriculture. Challenges associated with Nanotechnological application in agriculture in India and India's preparedness to face them have been discussed in fourth section. Last section concludes the discussion.

2. Application of Nanotechnology in Agriculture
The recent UN Millenium Project Report, task force on Science, Technology and Innovation, puts forward the idea that nanotechnology will be important to the developing world because it harbours the potential to transform minimal work, land and maintenance inputs into highly productive and cheap outputs; and it requires only modest quantities of material and energy to do so. It has wide range of agricultural application also. Some of them have been discussed as follows.

2.1 Agrinfortronics
Agriculture is seasonal in nature and depends on many variables such as soil, crops, weather etc.

Sensing, acquisition, manipulation, storage and transfer of reliable and accurate data about the plant/animal and productionhandling environment is therefore crucial in managing this variability to optimise both inputs and outputs and reduce impacts on the environment to meet the demand for high and good quality products. This requires successful fusion of ICT and mechatronics for agricultural applications. Based on advances in nanotechnology research, it was recently reported that the development of a new scanningprobe-based data-storage concept called “millipede” that combines ultrahigh density, terabit capacity, small form factor, and high data rate. Other developments include nanosensors to monitor the health of crops and farm animals and magnetic nonoparticles to remove soil contaminants. Dispersed throughout fields, a network of nano-sensors would relay detailed data about crops and soils. The sensors will be able to monitor plant conditions, such as the presence of plant viruses or the level of soil nutrient. Nanoparticles or nanocapsules could provide a more efficient means to distribute pesticide and fertilizers, reducing the quantitites of chemicals released into the environment. Livestock may be identified and tracked using implanted nanochips.

2.2 Integration of Agricultural Biotechnology, Bioengineering and Nanobiology

Agriculture is an integral part of the wider biological industry. Given that the world of biology is at the scale of microns and below region where the sphere of nanotechnology resides, the convergence of biotechnology, bioengineering and nanobiology to solve practical problems facing agricultural is logical. Just like advances in modern agricultural biotechnology have separately created staggering possibilities in crop and animal production through genetic manipulation of species, development in nanobiology are bound to impact on future agricultural technologies. For instance, it was reported that the successful arrangement of control proteins on DNA within a cell. These advances open up tremendous scope for nanofabrication in modern molecular biology or agricultural biotechnology of plants and animals. Nanoscience is leading to the development of a range of inexpensive nanotech applications to increase fertility and crop production. Furthermore, nanofabricated devices offer the scope for their injection into plants and animals to detect tissue parts affected by rare phenomena such as diseases, nutrient deficiency and developmental abnormalities.

2.3 Agricultural Diagnostics and Drug Delivery with Nanotubes

Progress in nano material sciences and technology has resulted in the development of several devices which have potential applications in agricultural and related biological industries. For instance, nanotube devices can be integrated with other chemical, mechanical, or biological system, and can be excellent candidates for electrical sensing of individual bio molecules. Nanotube electronic devices have been shown to function very well under certain extreme biological conditions such as saline (salty) water and have dimension comparable to typical biomolecules (e.g. DNA, whose width is approx. 2 nm). Despite the practical difficulties in achieving reliable, rapid and reproducible nanofabrication of complex arrays of nanotubes, such devices have the potential to revolutionise site-specific and process exact diagnosis, drug delivery and in livestock disease and health management as well as in the identification and sitespecific control of plant pests and diseases. Nanotech materials are being developed for slow release and efficient dosages of fertilizers for plant and nutrients and medicines for livestock.

2.4 Particle farming

It is an example of harvesting nanoparticles for industrial use, by growing plants in specially prepared soils. For example, research has shown that alfalfa plants grown in gold rich soil absorb gold nanoparticles through their tissues. The gold particles can be mechanically separated from the plant tissue

2.5 Nanobots

Nanobots (miniature/micro robots the size of human blood cells or even smaller) which can be deployed by billion, could explore every capillary and even by guiding in for close-up inspections of neutral details in animals during breeding and special on-farm diagnostic. Using highspeed wireless connections, the nanobots would communicate with one another and with other computers that are compiling the scan database.

2.6 Nanostructures

Nanostructures (such as smart nano-cards that collect and store data about products and process history) which can be implanted into plants and animals during growth and development to collect and transmit vital realtime data such as growth rates and physiological activities that provide clues on performance, productivity and exposure to environmental, chemical and physical hazards. Such smart nano-cards will further facilitate integrated supply chain traceability and management.

2.7 Nanotechnology and Food Processing

The application of Nanotechnology in the food industry has become more apparent with the initiation of consortia for better and safe food along with increased coverage in the media. Nanotechnology food application includes: smart packaging, on-demand preservation, and interactive foods which allows consumers to modify food, depending on their own nutritional needs and tastes. The concept is that thousands of nano-capsules containing flavour or colour enhancers or added nutritional elements (such as vitamins), would remain dormant in the food and will only be released when triggered by the consumer Nanoparticles may also deliver growth hormone or vaccine to livestock, or DNA for genetic engineering of plants. A nanocomposite coating process could improve food packing by placing anti microbial agents directly on the surface of the coated film. Nanocomposites could increase or decrease gas permeability of different fillers as is needed for different products. They can also improve the mechanical and heat-resistance properties and lower the oxygen transmission rate. Research is being performed to apply nanotechnology to the detection of chemical and biological substances for sensing biochemical changes in foods (Dept. of Electronics, 2007/08).

2.8 Electricity

In India, there has not been much effort to link the technology's potential with development in agriculture and addressing the needs of people in rural areas, which form the backbone of India's economy, according to Anil Rajvanshi, Director of the Nambkar Agricultural Research Institute, Maharashtra. For example, nanomaterials could help improve solar cells and biogas reactors, said Rajvanshi (http://www.scidev.net/en/news/india-mustregulate-nanotechnology-urgently.html). Which can be used for mechanization and electrification of agricultural processes. It is a challenge before Indian researchers and scientists to innovate and adapt Nanotechnological application for Indian agriculture.

3. Present State of Indian Agriculture

Indian agriculture may be discussed form two point of view i.e. supply side and demand side. From supply side, even though, there is high levels of aggregate growth over the last two decades, the Indian economy still remains predominantly an agrarian economy in terms of livelihood activities of people. The share of employment in agriculture (UPSS) in 2004-05 was as high as 52.1% but its share in GDP was 15.7 in 2008-09. The growth of agriculture in terms of both gross product and output has visibly decelerated during the post-reform period compared to the 1980s. For example, the growth rate of agricultural GDP decelerated from 3.08 per cent during 1980-1 to 1990-1 to 2.57 per cent during 1992-3 to 2005-6. The growth rate for all crop taken together decelerated to 1.96 per cent during 1990-1 to 2000-1, compared with a growth rate of 3.19 per cent during 1980-1 to 1990-1. The cause for concern is not merely the decline in the rate of growth of agricultural production, but also the decline in the growth rate of foodgrains, which fell from 2.85 per cent in the 1980s to 1.16 per cent in the 1990s, lower than the rate of growth of population of 1.9 per cent during the latter period. The 1990s were thus the first decade since the 1970s in which the rate of growth of food production fell below the population growth rate. This was essentially due to the gradual decline in the growth of yield levels, especially of some food crops. While the annual yield growth rate for all crops taken together declined from 2.56 per cent during the 1980s to 1.09 per cent during the later period, for rice it decelerated from 3.47 per cent to 0.92 per cent, and for wheat from 3.10 per cent to 2.21 per cent. There is increasing evidence that there can not be rural development, even in relatively prosperous regions like A.P. and Punjab without high agricultural growth. Some of the significant features of the deceleration in Indian agricultural growth have been discussed below:

3.1 Resource Stress in Indian Agriculture

Unequal availability of irrigation across the country, and increasing stress on available irrigation resources are one of the major reason for deceleration in agricultural growth. The recent trends in irrigation show the distortion in the development and utilization of water resources for agricultural purposes. It is well known that one of the major areas of public investment in post-Independence India has been the investment on major and medium irrigation projects, which contributed to a substantial expansion of areas irrigated. In the post-reform period, however, there has been a net decline in the area irrigated under canals. The Plan era also showed neglect of minor surface irrigation sources such as tanks, leading to decay and disuse of these water bodies. The only source that has been continuously on the increase, which by 2003-4 accounted for almost two-thirds of the net irrigated area in the country, is groundwater exploitation through wells and borewells, though the rate of growth of even this resource is slowing down because of increasing risks and limits to the potential in certain regions. The extension of Green Revolution technology to rain fed and dry regions, the neglect of small surface water harvesting system such as tanks, and decline in public investment in irrigation in the 1990s have together contributed to the growing reliance on ground water resources. Dependence on groundwater has emerged as the single largest source of irrigation, with all its accompanying problems of serious risks to farmers' investment and degradation of environment. There has been over exploitation in the dry regions, leading to serious and unstoppable depletion in these regions. The existing irrigated areas have been displaying serious water stress as both reservoir and groundwater resource are depleting in many parts of the country (Reddy and Mishra, 2009) [6]. Fertilizer and pesticide which was one of the key factor for productivity improvement during first green revolution has also losing its shine. Effectiveness of pesticide is declining. One of the important reasons may be pest resistance.

Another crucial input for agricultural growth is electricity which is not available in sufficient amount as well as quality of electricity is also not good. As a support, farmers prefer to have diesel run generators which ultimately increases cost of cultivation.

3.2 Environmental Stress

A serious source of environmental footprint of agriculture is increasing pollution of river and canal water. Many of the rivers and lakes are getting contaminated from industrial effluents and agricultural run-off, with toxic chemicals and heavy metals, which are hard to remove from drinking water with standard purification facilities. Irrigation undertaken by polluted water can also seriously contaminate crops such as vegetables and fruits with toxic elements. Soil erosion is the most serious cause of land degradation in India. Estimation shows that around 130 million hectares of land (45 per cent of total geographical area) is affected by serious soil erosion through ravine and gully, cultivation of wastelands, water logging, shifting cultivation, etc. It is also estimated that India loses about 5310 million tonnes of soil annually. According to estimates of the National Remote Sensing Agency (NRSA), the degraded land increased in the 980s by 7 million hectares from 11.31 per cent to 18 per cent of cultivable area (Chand 2006) [6]. These accumulation of salts and alkaline affects the productivity of agricultural lands in arid and semi-arid regions that are under irrigation. The magnitude of waterlogging in irrigated command is estimated at 2.46 million hectares. Besides, 3.4 million hectares suffers from surface water stagnation. Injudicious use of canal water causes water logging and a rise in the watertable, which, if left uncorrected, eventually leads to salination. Although irrigation and drainage should go hand in hand, the drainage aspect has not been given due attention in major and medium irrigation projects in the country. There has been water logging associated with many of the large reservoirs since their inception (Government of India, Ninth Five Year Plan). Another area of concern, which is adding to land degradation, is over and unbalanced use of chemicals and fertilisers, which are important inputs for increasing agricultural production. Their use has increased significantly from the mid-1960s due to the Green Revolution technology. Over and unbalanced use of these chemicals is fraught with danger. Serious problems have arisen in the Indo-Gangetic Plain (IGP) because of the distorted ratio of application of nitrogen, phosphorus and potassium (NPK). There has been excessive use of nitrogen with adverse effects on soil fertility. This partly is the result of price differentials and partly due to lack of knowledge among farmers about the need for balanced fertilizer use. The consequence is soil nutrient depletion that is a major cause of the stagnation of rice yields. This is especially true is areas that make concentrated use of fertilizers and pesticides (Reddy and Mishra, 2009) [6].

Climate change is also intensifying the strain on crops such as rice, corn and wheat. Poor long-term growing conditions such as drought, saline soils and heat, cold or extreme weather phenomenon cause billions of rupees of damage to agriculture every year.

3.3 Human Stress

There are two type of human stress on Indian agriculture. As it has already been that almost half of the working population is dependent on agriculture and most of them are illiterate. After liberalisation and globalisation, they have been exposed to the global market without having proper information about them. Second type of human stress is about large agricultural dependant population is landless and resource starved.

3.4 Demand Side Perspective of Agriculture

India ranked 65 out of 84 countries in the Global Hunger Index of 2004, in the 'alarming' category, below countries including North Korea, Sudan and Zimbabwe. China was 60 places higher than India, in 5th place. Only 57 per cent of Indian men and 52 per cent of women are at a healthy weight for their height. 43.5 per cent of Indian children under the age of five are underweight for their age, compared to 7 per cent in China (Williams, 2005-06). The situation is quite alarming and if food security has to be realised, the agricultural output must has to increase, not only in terms of quantity but it needs to have more nutritional value4 also. Along with the existing problems of food insecurity, growing prosperity and threshold market has changed the eating habits. Global agriculture in the 21st century has undergone a remarkable paradigm shift to emphasis on quality and traceability. Consumers are increasingly demanding for steady supply of consistent quality extending from organoleptic attributes to meeting their specific health and nutritional needs. Measuring and predicting quality reliability is therefore an important challenge in postharvest engineering of agri-foods. There is increasing demand of non vegetarian food "meat" which means more and better food is not only required for human being but for animals also. Then, there is increasing demand of non-food agricultural products also which creates a lot of stress on the available natural resources.

4. Challenges associated with Nanotechnological Application in Agriculture in India and India's Preparedness to Face Them

As U. N. Millennium Project Report, task force on Science, Technology and Innovation discussed the benefits of nanotechnology to make millennium goal into more achievable goal, several developing countries have launched nanotechnology initiatives. Countries like Argentina, Brazil, Chile, China, Mexico, Philippines, South Africa and Thailand are all involved in this frontier science. More precisely, there are 44 countries working on Nanotechnology in the food and agriculture field. But most of the activities are in the early stage (http:// www.nanoindia.com/printphp?news id=766). The Indian Government has also taken plunge to develop human resource and their capability in the emerging technology 5. Impetus for developing a plan stems from fears that India has fallen behind China, Japan, the United States and the United Kingdom, which all have launched Nanotechnology programme over the past several years and are investing heavily in R&D. Though Nanotechnology as a branch of study is not very old, Indian universities and R&D centres have taken Nanotechnological research very aggressively6. Along with the government other stake holders are also taking interest in the development of the area. SabirBhatita, co-founder of Hotmail, plans to build a multibillion dollar "Nano city" in Chandigarh, Northern India, envisioned as the "Silicon Valley" of India. In the United states, IndianAmerican have already begun to show their support for a National Nanotechnology initiative in India though a programme dubbed the "Indus Nanotechnology Association" which hopes to provide a common platform for researchers, entrepreneurs, technologists and investors of Indian origin seeking to leverage the emerging nanotechnology industry.

The Indian government is looking towards nanotechnology as a means of boosting agricultural productivity in the country. A report released in April'08, Planning Commission of India has recommended that Nanotechnology research and development (R&D) should become one of the six areas of investment. The report says that Nanotechnology such as nano-sensors and nanobased smart delivery systems could help to ensure natural resources like water, nutrients and chemicals are used efficiently in agriculture. Nano-barcodes and nanoprocessing could also help monitor the quality of agricultural produce. The report proposes a national consortium on nanotechnology R&D, to include the proposed national institute and Indian institutions that are already actively researching nanotechnology. The report suggests ways to harness nanotechnology, biotechnology and bioinformatics to transform Indian agriculture, including creating a National Institute of Nanotechnology in Agriculture (Sreelata M, 2008) [7].

The road map for development of Nanotechnological application in agriculture is very logical. The government took initiative which was the first level. At second level, R&D work was carried out aggressively at the universities and R&D centres. The second stage is at present going on. At third level, successful R&D need to be commercially produced7. Despite explosion in nanotechnology R&D, realisation of those R&D still lies ahead in the near future.

Most of the R&D is being carried out in government research institutions (e.g. universities, research institutions) and private sector companies. This means that much of the knowledge arising from these laboratories will be tied up to intellectual property rights of the funding organisations and this implies that it would take much longer time than anticipated to see agriculture nano-machine in farms and food handling/processing centres. Not only that, as they are tied with IPR, it is difficult to get full access to research materials 8. Another aspect is commercial feasibility of successful R&D. At the development stage, researchers hardly takes care of the economic aspect. India has the example of successful model of Information, and communication technology 9 which can be replicated for Nanotechnology also. However, in case of Nanotechnology, while there is still not coherent international approach to determining if and what risks are posed by what kind of nanotechnology materials (Maynard, 2006) [8]. A lack of standard.definition10 makes these early investigations hard to compare and sometimes they even contradict each other, a situation that is especially confusing in risk assessments of carbon nanotubes. It has been discusses by many that nanoparticles are more toxic than their bulk counterparts which may enter in our body through membrane (Anbrecht et al., 2006) [9] and ultimately, it could be critical to biodiversity and ecosystem health 11. Nematodes are pretty much at the bottom of the food chain and if they are capable of absorbing nanoparticles then another point of great interest and concern is the possible transfer and accumulation of nanoparticles through the food chain (Berger, 2009) [4].

The broad implication of Nanotechnology for society can be grouped into two categories, namely environmental, health and safety implications and societal & economic dimensions. Responsible development of Nanotechnology entails along with aggressive R&D towards agricultural application of Nanotechnology, research must be carried out towards understanding the public health and safety of all those who are producing and will consume them. Another important issue associated with Nanotechnological application in agriculture is the prospect for improving environmental quality. It is predictable that widespread adoption of Nanoagriculture in the future may be induced by environmental regulation to promote sustainable agriculture. Research is warranted to determine the application of nanotechnology in environmental management. Channels of communication should be established with relevant stakeholders, in terms of providing information and seeking input. Second is the cost and benefit aspect, especially in context of socio economic milieu of the majority of the Indian farmer and size of the majority of the land holding 12. Adoption of Nanotechnological application in agriculture depends on its ability to create employment and increase wage ratel3. However, even now, there are more than 700 nano products which are already in the market. Some of them are used in agriculture also as pesticides (Syngenta), Food additive (nano-carorenoids, BASF) etc. Under such circumstances, there is high probabilities that the benefit of nanotechnology will only be experienced by rich people but its side effect will be experienced by all as nanoparticle present in pesticide may go into water body. It will create further gap between rich and poor.

Technological advances have always been a two edged sword; offering a two-edged sword; offering both upsides and downsides. Sometimes, even when technology has been used for good, it has had unexpected negative results. But the history of human progress is the story of our ability to exploit the benefits (http:// knowledge.cta.int/ en/layout/set/print/Dossiers/S-T Issues-in-Perspective/ Nanotechnology). So, onus is on the government, scientific community and social activists to discuss at different platform and inform the farming community about the pros and cons of nanotechnological application in agriculture. It will create a well inform farming community to be able to judge about its adoption

5. Conclusion

India is basically an agrarian economy and has experience production boost during First Green Revolution. But the agricultural growth rate is experiencing a plateau and there is immediate need for enhancing agricultural productivity for maintaining self sufficiency in agriculture. Nanotechnology is the latest buzz word in the field of engineering and technology which can play as a catalyst for enhancing agricultural growth rate. Nanotechnology has myriad agricultural application across the spectrum which includes both on-farm as Nanosensors which may detect plant disease and off-farm which include nano packaging or nano coating which increases self life of the food products. At least, forty four countries of the world including India are pursuing R&D for Nanotechnological application in agriculture for alleviating malnutrition and to achieve Second Green Revolution. So far, it has been done mainly for developed countries only and now it is up to the Indian researchers and scientists to innovate and adapt them to suit the socio-economic milieu. Successful R&D should be commercially produced which means taking care of financial and regulation aspects. The broad implication of Nanotechnology for society can be grouped into two categories, namely environmental, health and safety implication and societal dimensions. Responsible development of Nanotechnology entails along with aggressive R&D towards agricultural application of Nanotechnology, research must be carried out towards understanding the public health and safety of all those who are producing and will consume them. Research is warranted to determine the its effect on environmental management. Even if India does not adopt nanotechnological initiative in agriculture, there are chances that they will come in the Indian market due to liberalization and opening up of the economy. In those circumstances, farmers need a lot of counselling and guidance regarding pros cons of adoption. Channels of communication need to be established with relevant stake holders, in terms of providing information and seeking input from them.

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