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Glories of Indian Agriculture and the Challenges-A perspective Analysis

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Indian agricultural innovations made a landmark in the global scenario in just over 60 years compared to the previous 10,000 years of agricultural development. Before the historic independence the primitive agricultural practices were a serious threat to support the livelihoods of man and livestock from the healthy soils. Sir, Albert Howard 1900-1947 considered as the father of modern organic agriculture-a British agronomist developed organic composting process through mycorrhizal fungi at Pusa in Samastipur in North India in 1905. He published the document "An Agricutural Testament" in 1940 that suggests the methods to restore and maintain soil fertility. Mention of organic farming is made in Ramayana, Mahabharata, Kautilya Arthashastra, Brihad-samhita, Rigveda and the holy Quran. The agricultural productivity was low and the output growth was less than half of the population during the period 1901 to 1946. As a result the per capita income of the rural population was awfully low. The Famine Inquiry Commission in 1945 estimated that about 30% of the people were hungry. The country was always vulnerable to famines due to dependence on rains with uncertain harvests of food grains to feed the vast populations. Frequent famines were the recurrent fortunes until the severe Bengal famine in 1943 when an estimated 4 million people died of hunger in Eastern India. There were 22 famines in 130 years between 1770 and 1900. There were 10 million deaths in 1770 . The food grain production was stagnant for more than half a century before independence from 1891 to 1947.

The planned five year development initiative in 1950 launched from 1951-52 was the beginning for the development of agriculture to raise the standard of living and overcome the chronic food deficits and deaths of people and livestock. India faced food shortages until 1970s. In 1950s the country imported about 2-3 million tons of food grains to feed the population of 359 million people. The food shortage worsened following severe drought for 2 years in 1965-66 and 1966-67. The domestic production of food grains that includes cereals and pulses was 72 Mt in 1966. This was insufficient. The famous public law act still remembered as PL 480 reminds the plight of the nation. Food grains were imported to the extent of 10 Mt in 1966 and nearly12 Mt in 1967 under this enactment from the United States. The organized research efforts and application of science and technology soon turned the fortunes of the nation. The yield per unit of farm land increased from 1947 to 1979 by more than30%. Success in wheat and rice paved the way for innovation in other crops-sorghum, pearl millet and maize.

Major concerns

Green Revolution system of farming is heading towards collapse- is the echo of farmers from Punjab who enjoyed prosperity and now yelling to save them from the present crisis.When they switched from growing a variety of traditional crops to high-yield wheat and rice, they also had to make other changes. There was not enough rainwater to grow the thirsty improved seeds. So farmers had to start irrigating with groundwater. They hired drilling companies to dig wells, and they started pumping groundwater onto the fields. The problems are now wide spread throughout the country.

The new varieties and hybrids of crops rescued the fast growing population from hunger. They have a high water requirement and are responsive to good management and inputs. They are highly sensitive to moisture stress. They are vulnerable to an array of insects and diseases. The

economic yield plateaus are emerging in several crops. There is no scope to increase the land for cultivation. The resources are shrinking while population is increasing unabated. It is commonly agreed that the over exploitation of agriculture since green revolution resulted in silent ill effects on the resources. New generation problems intensified that need to be addressed.

Soil fertility

The excess and inappropriate application of fertilizers and pesticides to improve food production leads to an uncontrolled release of undesired substances-nutrients and toxins in the soil, atmosphere, ground and surface waters. This is not safe for health. The soils are sick and continuously degraded. The massive application of fertilizers and insufficient animal or green manures made the soils dusty and susceptible to erosion washing away the nutrients. The efforts to increase the food grain production by the application of high dose of fertilizers with imbalanced nutrient proportions to the new high yielding varieties disrupted the equilibrium of the native nutrient fertility. Symptoms of nutrient deficiencies erupted from time to time. Multi nutrient deficiencies are now wide spread. The soils are universally deficient in nitrogen. An estimated 63% of the soil samples were estimated to be low in available status of N, 42% in phosphorus and 13% in potassium in the beginning of the millennium . The factor productivity of 35 kg food grains for 1 kg of fertilizers at the time of green revolution drastically fell to 12 kilograms. As a result more fertilizer is needed for the same response as in the past. The soils fatigued in intensively cultivated irrigated rice fields led to the use of 40% more nitrogenous fertilizer to produce the same quantity of rice as 10 years ago. Contrary to the general perception, estimated that there has been not much depletion of soil fertility in terms of available NPK of agricultural soils in the country due to the effects of green revolution. This is witnessed by the analysis of samples from different states for 1967, 1977 and 1997. The N fertility index for the country increased from 1.59 to 1.79, P fertility index changed from 1.50 to 1.46 and the potassium fertility index changed from 2.00 in 1967 to 2.17 in 1997. Yet, there were little changes in the status of these 3 nutrients in the soils–increase and decrease or static in different states over the 4 decades. The status of soil organic carbon remained static for the last 25 years based on the results of long term fertility experiments on rice-wheat cropping systems in northwest India. An increase in soil organic carbon stock in the last 25 years between 1980 and 2005 in the Indo-Gangetic plains and the black soil regions in the semi-arid tropics. The recent nutrient budgeting studies also ascertained that there are no major negative balances of nutrients. There was a positive balance of 1.4 Mt N and 1.0 Mt P but a negative balance of 3.3 Mt K. Estimated net positive balance of 1.9 to 14.4 Mt N. Positive balance of N and P but negative balance of K in the long term fertility experiments of rice-rice cropping system. These evidences establish that there has been no depletion of soil fertility in terms of N and P nutrients since the period of green revolution in the country as a whole. The trends in declining yield of crops in different regions are largely attributed to the gradual decline in the supply of nutrients causing imbalances in their availability due to inappropriate proportion of their application. Soil salinity is becoming an increasing problem in heavily fertilized areas. Nitrate accumulation is recorded in the ground water in intensive rice-wheat cultivation systems. The eutrophication of water bodies due to accumulation of excess salts by the application of heavy dose of fertilizers made the soils less productive for cultivation.

Mechanization

The continuous use of heavy machinery and implements in the fields created new problems. They compact the soil. This reduces the ability of the soil to absorb sufficient water in the root zone and reduce the crop yield. The water runs off the compact soil and contributes to erosion. The excessive tilth eroded the soils resulting in loss of nutrients. The organic carbon reduced due to evolution of CO2 in such soils. The stable aggregates are destroyed and the void proportions are disrupted. These changes reduce the growth and development of roots. Mechanization has little access in hill agriculture that covers about 20% of the cultivated area. The average farm size in India is <2 hectares compared to 14 ha in the European Union and 170 ha in USA. Therefore it is difficult for a large section of the farmers to own machinery. This requires the designing and development of machines to suit such small holdings for quick adaptation by the farmers. Therefore farm

mechanization of 40-45% in India is still less than many countries: USA-95%, Western Europe-95%, Russia-80%, Brazil-75% and China 57%.

Irrigation

Water is the life line of agriculture. The decade 2005-15 commemorated as water for life and the annual world water day held on 22 March every year is significant to create awareness that water is finite, scarce, costly and precious. It should be managed very effectively. .Agriculture is the largest consumer of 70% fresh water diverted from rivers and ground water in the world. About 85% of the available fresh water is used for irrigation in India. It is not used efficiently. The water use efficiency through the traditional system of flood irrigation is only 30-40% which is lowest in the world. This is largely due to seepage, evaporation, distribution and conveyance losses etc. Therefore there is a need to conserve water and adopt micro irrigation practices. It is estimated that 2-4 times more water is used to produce one unit of major food crops than that used in China, Brazil and USA. If water use efficiency is improved to the level of these countries India is likely to save at least half of the water presently used. This can cover still larger areas without incurring heavy expenditure on creating new irrigation sources. The faulty irrigation practices led to the development of barren lands by accumulating salts to toxic level and creating water logged conditions. This reduces the crop yield. The saline and alkaline soils are losing carbon and micro nutrients.

Drip and sprinkler systems maximize water use efficiency in upland crops. They deliver water to plants where and when they need it. Drip system has a network usually of plastic porous or perforated piping that delivers water on or below the soil surface directly to crop roots. Sprinkler system requires higher pressure and delivers water by spray to plant leaves instead of roots. In both systems water is applied frequently and in low levels to maintain optimal moisture conditions for the crops and minimize the potential for salinity. The water use efficiency through micro irrigation system is70-95%. Unlike the flood method of irrigation, drip can be efficiently operated in all types of grounds-undulating terrains, rolling lands, hilly areas, shallow soils and areas which have saline soils. In recent years 70% of the irrigated area is dependent on ground water. The exploitation of ground water is increasing at an alarming rate in different parts of the country. A shift from traditional flood irrigation to drip system is a fair option.

A portion of the water evaporated from the US weather service class-A- evaporation pan is replaced by the drip irrigation. Sensors for soil moisture monitoring have been used in various natural resource management practices such as research on crop yield; water shed management, environmental monitoring, precision agriculture and irrigation scheduling. Several investigators recorded up to 70% reduction in water use by adopting this technology in different upland crops. The use of soil moisture sensors and irrigation controllers increase the precision of irrigation management resulting in maximum water use efficiency. These technologies allow efficient control of water flows to various zones, help in injection of water conditioners, fertilizers and agricultural chemicals. They allow remote check of system performance, control filter back flushing and provide extensive records of water use. They enable irrigation to be scheduled based on evapo- transpiration calculations from nearby weather stations.

Pest management

Pests are a great challenge to crops and stored food. Both insects and diseases intensified with the crop improvement programs. Every year they eat away on an average 15-25% of the food produced by the farmers in the country. Pesticides control the pest damage and reduce the yield losses. But the common practice to apply these agro chemicals indiscriminate is another serious challenge for health and safety of not only man and livestock but also of other life on the earth, in the rhizosphere, water bodies and environment. A plethora of information exists on this issue in literature. Overuse of chemical fertilizers and pesticides have similar effects on soil organisms to human overuse of antibiotics. Indiscriminate use of chemicals might work for a few years, but after a while there are not enough beneficial soil organisms to hold onto the nutrients. The densely populated Ganges river basin is heavily polluted by fertilizers, pesticides, and industrial and domestic effluents. The contamination of water sources with herbicides like Ronstar and Roundup are acutely toxic to fish. Some herbicides produce sub lethal effects on fish and reduce their chances for survival and thereby threaten the population as a whole.

Glyphosate or glyphosate-containing products create sub lethal effects like erratic swimming and labored breathing in fish. The contamination of the water with the insecticide chlorpyriphos is also toxic to fish. Exposure of eggs to 2, 4-D reduced successful hatching of chicken eggs and caused feminization or sterility in pheasant chicks. The herbicide oxadiazon is toxic to bees, which are pollinators.

The balance between harmful insects and predators has disrupted due to the continuous application of pesticides. The pests continued to evolve and through the process of natural selection build up resistance to the chemicals. As a result yesterday's pests have become super pests to withstand large doses of pesticides. Sometimes they have become cross resistant to five or more pesticides and are less likely to be troubled by the predators. Insects like *Helicoverpa armigera* on cotton and red gram and stem borer in rice etc. attained devastating dimensions. They became resistant to the insecticides and were not controlled satisfactorily as they developed resurgence. Weeds like *Phalaris minor* in wheat developed tolerance to the herbicide Isoproturon and wrinkle grass in rice to butachlor. Repeated use of any single herbicide in any crop generates a shift in the composition of weed flora leading to dominance of secondary weeds. Rodent control in the fields by the regular use of Zinc phosphide @ 2% in cereal baits has become ineffective in Punjab and Haryana. These are some of the classical examples to injure and kill the non-target organisms too. Chemical residues in food increased the incidence of many types of cancer particularly among the farmers. Over forty thousand Third world farm workers are killed each year and up to one million made ill or permanently injured due to overexposure or mishandling of the agrochemicals.

The cultivation of Bt. Cotton since 2002 was overwhelming to the farmers. The larvae of *Helicoverpa* were effectively controlled until 90 days after sowing the crop without insecticide sprays. This technology saved the farmers from committing suicides. But, in 2007-08, the pest became virulent early at 60 days in Andhra Pradesh. This threat appears to be due to the silencing effects on the genes. A hitherto major pest of custard apple, mango and red gram- the mealy bug infestation emerged as a new and serious pest on Bt. or non Bt. cotton. The application of confidor lost its toxic effect on the sucking pests. There are several such examples that the modern technology is challenged and demand a revision of human intelligence to search alternative options.

Organic farming

The international Federation of Organic Agricultural Movement (IFOAM) set up on 5 November, 1972 in France with 130 countries including India and 600 organizational members is creating worldwide awareness to revert to the use of natural resources in crop management for safe food and environment.

Transgenics

The transfer of an unrelated desired gene from one organism to another or non-crossable species is called transgenic. The plants or animals so derived are called genetically modified organisms. Such varieties of crop plants are now emerging as strong tools for yield security because of their promise to resist the damage due to pests and diseases, tolerance to the herbicides, high level of salinity, alkalinity and aridity etc. It is also possible to improve the appearance and color of fruits, flowers and vegetables, increase their shelf life, nutrient content of plants and foods etc. The release of a caffeine free coffee crop in Hawaii is a classic example. It produces only 3% of the normal amount of caffeine. The transplant was a tobacco developed in 1983. There are >50 other genetically modified crops which occupied about 120 M ha in the world by 2007. Initially transgenic improvement was restricted to dicots and now it is also employed in monocots. The transgenic Bt. cotton varieties were introduced in India during 2002 to overcome the severe damage of the polyphagous boll worm *Helicoverpa armigera.* This was the pest that had developed a high level of resistance to several pesticides and up to 30 sprays in a season. Therefore the conventional varieties soon made a way for this novel introduction. The farmers were comfortable. The larvae of *Helicoverpa* were not traced until 90 days after sowing of this cotton. Surprisingly, they emerged heavily by 60 days in 2007. This was due to the silencing of genes.

Cisgenesis is now considered to open new options for second green revolution in India. It can be used directly for the improvement of existing varieties which already proved to be safe for use in the market. The native genes, isolated from the

crop plant itself or from other cross compatible species are currently referred as cisgenes. No genes are introduced from cross incompatible species. Thus manipulation is done using DNA entirely from the same species as the host plant or a species that is closely related enough to be sexually compatible. In simple words cisgenesis is the genetic modification of a recipient plant with a natural gene from a crossable sexually compatible plant. In contrast transgenesis is the genetic modification of a recipient plant with one or more genes from any non-plant organism or from a donor plant that is sexually incompatible with the recipient plant. Cisgenic or intragenic plants are considered safer than the conventionally bred plants as they lack linkage drag. Only the desired genes are introduced unlike in the traditionally bred plants. Plant modification for pest or disease resistance through cisgenesis substantially reduce the application of pesticides, reduce the input costs and left overs of the pesticides on the plants and their products thereby lessening the pollution.

Crop substitution

It is possible in the near future that the traditional food crops can be substituted with factory produced foods such as starch, proteins and fats grown in fermentation tanks by the use of modern techniques of cell and tissue culture. This will replace some of the agricultural crops such as vanilla, sugar or oilseeds to be grown at current production levels. Some food and nutrition products containing nano scale additives are already commercially available.

Nanotechnology

Nanotechnology is a frontier area of science and technology in the new millennium. It has developed fast in recent years and has wide prospects of its application in materials, life, information, environment, energy, and national security. It improves the existing cultural practices by enhancing the management and conservation of inputs in crops, animal production, and fisheries . It utilizes structures of 0.1 to 100 nm in size. This could be visualized from the human hair which is 100,000 nm in diameter and a virus is roughly 100 nm in size. Nanotechnology is the manipulation or self-assembly of individual items, molecule or molecular clusters into structures to create materials and devices with new or vastly different properties. The prefix 'nano' is the Greek word meaning dwarf. Technical meaning is it is 10-9 or one millionth of a millimeter or billionth of a meter. It describes a scale 1000 times smaller than that of present elements of the micrometer-sphere. Nanomaterial means a natural, incidental, or manufactured material containing particles in an unbound state or as an aggregate or agglomerate and where for 50% or more of the particles in the number size distribution, one or more external dimension is in the range 1–100 nm.

The application of nano technology to agriculture and food industries was first addressed by a United States Department of Agriculture road map in September 2003. India also made great progress in this technology and is taking the leading position among developing countries. It enables plants to use water, pesticides, and fertilizers more efficiently. Nano sensors are used to sense a wide variety of fertilizers, herbicides, insecticides, pathogens, moisture and soil pH. This helps in precise farming practices with controlled use of these inputs to suit the requirements. Dispersed in the field they detect the presence of plant viruses, pathogens and the level of soil nutrients. Nano smart dust or the tiny wireless sensors and transponders and gas sensors quickly detect the level of pollution in the atmosphere. Nano bar codes and nano-processing are used to monitor the quality of agricultural produce . Nano scale sensors identify plant health conditions before the symptoms are visible to the farmer and reduce or prevent the viruses and pathogens . If not, they alert the farmer to the problem. These smart devices thus act both as preventive and an early warning system. Low cost sensors are developed to detect and remove the pathogens and undesirable compounds in foods and beverages within minutes of exposure and ensure safety for consumption

Nanoparticles are used to prepare new formulations of pesticides, insecticides and insect repellants. The particle size of the existing emulsions is reduced to nano scale. The active ingredients are also encapsulated and designed to split open in response to sunlight, heat or alkaline conditions etc. in an insect's stomach. The formulations contain nanoparticles within 100-250 nm size that dissolve in water more effectively than the existing ones thereby increasing their activity . The nano emulsions are water or oil based uniform suspensions of pesticide or herbicide nano particles of 200-400 nm. They can be easily incorporated in

various media like gels, creams and liquids. They have multiple applications for preventive measures, treatment or preservation of the harvested product. Nano formulations reduce the current application dose of agrochemicals and improve their efficiency. They enable effective penetration of pesticides/ herbicides through cuticles and tissues. They allow slow and constant release of the active substances and thereby achieve greater effects with low dose. Specific nano formulations kill only the targeted insects. They are absorbed on the surface of the plants and released slowly for a long time unlike the traditional pesticides that are washed away in the rain. The nano pesticides are 3 times more efficient to control insects and diseases with half the cost of production than the ordinary pesticides and increase the crop productio. Pesticide residues are pressing issues. They affect the environment and safety of agricultural products. The control release formulations do not leave behind the toxic residues. This was demonstrated by the nano formulations of carbofuran and imidacloprid to potato. A range of smart agricultural inputs and products are developed such as nano seed varieties with inbuilt pesticides that are released under certain environmental conditions.

Nanotechnology is also potentially used in aquaculture and seafood, water treatment, fishpond sterilization, nano feed for feeding the fish and controlling of aquatic diseases. The aquaculture industry suffers tremendous losses due to diseases caused by bacteria. Traditional disinfection and sterilization methods are used to control aquatic diseases. Different chemical disinfectants, antibiotics and sulfa drugs are also frequently used in large quantities. The cost of these chemical drugs is quite high, stimulation is strong, efficiency is low and there are numerous side effects; thus, various related problems cannot be fundamentally solved leading in turn to many adverse effects.

Nanotechnologies reduce greenhouse gas emissions and make the air clean. They are also used in sewage treatment, including surface water and ground water. Sewage usually contains toxic and harmful substances, suspended matter, sediment, rust, odor pollutants, bacteria and viruses. Sewage treatment is a process to remove toxic and harmful substances from water. Nanotechnologies extract and purify precious metals such as gold, ruthenium, palladium, platinum and other metals from sewage and transform the harmful substances to useful ones.

Farming systems

The holistic development of a farm by integrating livestock, poultry and other small scale enterprises helps to uplift the farmers' economic condition. Sericulture, ericulture, mushroom cultivation, duckery, apiary, post-harvest technologies, food processing, floriculture, horticulture and custom hiring of small implements etc. are the possible options. This will reduce the distribution of risk in events of crop failures especially due to drought. Every input in the farm should be recycled. No waste is wasted. Even wastelands are fully utilized to spin money. The animal droppings are excellent source of soil conditioners, water conservers and fertility restorers.

The seasonal fodder crops are harvested only once at the beginning of flowering for green fodder. This is not available fresh every day to feed the animals. The only choice is to preserve it as hay or silage. Perennial grasses and legumes can be harvested/cut at frequent intervals of about 45-60 days for long time extending up to about 5 years or more. Even this 1 ½ - 2 months period is not sufficient to feed the herbage fresh and green. But selection of proper perennial crops, sowing and harvesting plan for the estimated number of animals overcomes this difficulty. Similar to the concept of **ATM**-any time money, **ATF**-any time fodder in fresh and green form can be harvested and fed to the animals.

Greenhouse gases and global warming

Emissions of greenhouse gases (GHGs) such as carbon di oxide, methane nitrous oxide and other gases from agriculture, forestry and other land uses contribute significantly to the threat of global warming. Crop and livestock production produce half of the methane (CH4) and two-thirds of the nitrous oxide (N2O) emitted into the atmosphere by human activity. The gases are also emitted from fertilizers, crop residues, puddle rice fields, landfills, termites, riverbeds and lakes, cultivated organic soils and burning of crop residues etc. . The livestock and poultry produce CO2 during respiration. They produce CH4 in the digestive tract during fermentation. Manure releases CO2, CH4 and N2O through the microbial activity during handling, storage and application to the field. Poultry produce less CH4 due to less enteric fermentation in the small digestive system than livestock . Emissions of CH4 occur under anaerobic conditions, while

N2O emissions occur when alternating aerobic and anaerobic conditions exist. The exposed poultry manure emits nitrogen in the form of ammonia (NH3), dinitrogen (N2), nitrous oxide (N2O) and nitrate (NO3).These emissions increased by an average of 1.6% per annum since 1990. The total emissions from agriculture were estimated at 5-6 G t CO2 per year (FAO Statistical year book, 2013). The atmospheric concentration of these gases influences the climate of the earth and cause global warming. Methane has global warming effect 25 times greater than carbon di oxide (IPCC, 2007) while N2O is 296 times more toxic. More than 60% of the global methane release is due to human activities.

The greenhouse gases cause extreme events in rainfall, temperature, wind velocity and other weather elements. These effects are localized. The high intensity of droughts and floods is the result of more frequent climatic extremes in the environment. Abrupt changes in the rainfall pattern make dry years drier and wet years more wet.

Livestock are adversely affected by the detrimental effects of extreme weather. But the risk is relatively less than the dry land agriculture. Extreme seasonal fluctuations will affect the quantity and quality of herbage. This affects the intake of diet by the livestock resulting in less production and low reproduction efficiency. Sudden changes in climate sometimes result in death of animals.Fluctuations in temperature and uneven rainfall introduce vector-borne diseases and attack of parasites and transmission of new diseases . Sudden rise in temperature reduce the rate of conception by 20-70% in dairy cows during summer. The expression of oestrus is low in heat stressed animals. Reproductive inefficiency due to heat stress is exhibited by changes in ovarian function and embryonic development because of reduction in the competence of oocyte to be fertilized and the resulting embryo . The environmental stress reduces milk yield and quality. Cattle, goat, horses, and sheep are also vulnerable to an extensive range of nematode worm infections.

Livestock and poultry perform best in the temperature range of 10-30oC. Their feed intake reduces by 3-5% for each degree rise in temperature. The flocks of poultry are readily vulnerable to climate change. Their production and reproduction are both affected. They tolerate only a narrow range of temperatures. The annual report of ICAR (2010) shows that as the ambient temperature increased to e”34oC the mortality rate of the meat type of chicken increased by 8.4% due to heat. The consumption of feed reduced from 108.3 grams at 31.6oC to 68.9 g/bird/day at 37.9oC and the eggs reduced by 6.4% as compared to their standard production. The climate change alters the global disease distribution, encourage outbreak of diseases that will reduce the intake of feed, production of eggs and meat while increasing the cost of production. The temperature, relative humidity, light, sunshine, housing system and ventilation influence the performance of birds. High rainfall and relative humidity provides a favorable environment for breeding of parasites that causes outbreak of diseases which invariably reduces egg production. They further reported that temperature reduces the feed intake of poultry birds because more energy is needed to conserve the heat caused by high temperature.

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