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Review Article

Green Revolution: A Review

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Abstract

The Green Revolution refers to a series of research, development, and technology transfer initiatives, occurring between 1943 and the late 1970s in Mexico, which increased industrialized agriculture production in many developing nations. The initiatives involved the development of high-yielding cereal grains, expansion of irrigation infrastructure, and distribution of hybridized seeds, synthetic fertilizers, and pesticides to farmers. The term "Green Revolution" was first used in 1968 by former USAID director William Gaud. The goal of the Green revolution was to increase the efficiency of agricultural processes so that the productivity of the crops was increased and could help developing countries to face their growing population's needs.

Keywords: Green Revolution, technology transfer, agriculture.

1. Introduction

The Green Revolution began in 1944 when the Rockefeller Foundation founded an institute to improve the agricultural output of Mexican farms. This produced astounding results, so that Mexico went from having to import half its wheat to self-sufficiency by 1956, and by 1964, to exports of half a million tons of wheat. [1]

The growth of crop yields was such that agriculture was now able to outstrip population growth - per capita production increased every year following 1950.

The use of genetic engineering in agriculture to create genetically modified foods is viewed by some as the natural continuation of the Green revolution.[2]

1.1 What is the need for Green Revolution?

- More urban people
- Population increasing rapidly
- Food production not keeping pace[3]

2. Agricultural Techniques

The techniques refined and developed by the Green revolution are, roughly:

- Extensive use of chemical fertilizers - Every plant basically relies on several basic compounds in order to grow. Primary is nitrogen need. Only in the nitrate form can plants absorb the nitrogen they require.
- Irrigation: The Green revolution further developed irrigation methods to allow for more efficient irrigation.
- Use of heavy machinery - Mechanized harvesters and other machinery was not new to agriculture - the McCormick reaper was developed in the nineteenth century - but the Green revolution allowed a drastic reduction in the input of human labor to agriculture by extending the use of machinery to automate every possible agricultural process.
- Pesticides and herbicides - The development of chemical pesticides and herbicides (including organochlorine and organophosphate compounds) allowed further improvements in crop yields by allowing for efficient weed control (by use of herbicide early in the growing season) and eradication of insect pests. [4]

2.1 Techniques for plant transformation

Some transformation methods are based on utilizing Agrobacterium, a pathogen of dicotyledonous (broad-leafed) plants that transfer genes into the plant genome.

The major direct gene transfer method, particle bombardment (or biolistics), is the method of choice in many laboratories for the transformation of monocotyledonous plants, despite Agrobacterium-based protocols having subsequently been developed for the transformation of monocotyledonous plants.

2.1.1. Recombinant DNA:

Recombinant DNA techniques use biological vectors like plasmids and viruses to carry foreign genes into cells. Plasmids are small circular pieces of genetic material found in bacteria that have the ability to cross species boundaries. The circles can be broken and new genetic material added to them. Plasmids augmented with new genetic material can move across microbial cell boundaries and place the new genetic material next to the bacterium's own genes. Often the bacteria will take up the gene and begin to produce the protein for which the gene codes.

Viruses can also act as vectors in genetic engineering. The virus can carry the new gene into a recipient cell in the process of infecting that cell. [5]

2.1.2. Agrobacterium-mediated gene transfer:

Agrobacterium tumefaciens is a soil-borne, gram negative bacterium. A causative agent of crown gall disease, an economically important disease of many plants (particularly grapes, walnuts, apples and roses).the ability to cause disease i.e. crown galls (tumorous tissue growth) depends on the ability of Agrobacterium specie to transfer bacterial genes into the plant genome.

Example:

Agrobacterium-mediated transformation of Tobacco

Tobacco is a relatively easy plant to transform with Agrobacterium and provides a good introduction to the use of Agrobacterium in plant transformation.

Factors we need to keep in mind:

Several factors have to be considered in the design and implementation of any plant transformation study

1) Plant tissue to be transformed.
2) The vector used to deliver the transgene into the gienome of the plant.
3) The strain of Agrobacterium used.

Although this is a specific example, most Agrobacterim-mediated transformation protocols follow a similar pattern, which is summarized below:

- Identify a suitable explant.
- Co-cultivate with the Agrobacterium.
- Kill the Agrobacterium with a suitable antibiotic which does not harm the plant tissue.
- Select for transformed plant cell.
- Regenerate whole plants.

Dicotyledonous plants, the natural target for Agrobacterium transformation, are, in general, easily transformed using standard vectors and standard strains of Agrobacterium, such as LBA4404. Some crops, such as cereals (which are not naturally infected by Agrobacterium) are more difficult to transform and may require the use of modified vectors and/or so called super virulent strains of Agrbacterium (such as EHA101 or EHA105).

Antibiotics such as kanamycin are commonly used to select for transformed plant cells, but alternatives such as herbicides or more potent antibiotics are often required for cereal transformation.

2.2 Direct gene transfer methods

The term ‘direct gene transfer’ (or direct transfer) is used to discriminate between methods of plant transformation that rely on the use of Agrobacterium (indirect methods) and those that do not (direct methods). Direct gene transfer methods all rely on the delivery of large amounts of ‘naked’ DNA whilst the plant cell is transiently permeablised.

One of the major disadvantages of the direct gene transfer methods is that they tend to lead to higher frequency of transgene rearrangement. Other, less reproductive methods, such as laser mediated uptake of DNA, microinjection, ultrasound and inplanta exogenous application, have mainly been used for the analysis of transsient gene expression.

2.3.1. Particle bombardment:

Particle bombardment (biolistics) is the most important and most effective direct gene transfer method in regular use. In this technique, tungsten or gold particles are coated with the DNA that is to be used to transform the plant tissue. The particles are propelled at high speed into the target plant material, where the DNA is released within the cell and can integrate into the genome. The delivery of DNA using is technology has allowed transient gene expressions (which do not depend on integration of the transgene into the plant genome). In order to generate transgenic plants, the plant material, the tissue culture regime and the transformation conditions have to be optimized quite carefully.

Practical bombardment systems were first developed in 1987 and used an explosive charge to propell the DNA-coated tungsten particles. This technology was the key to cereal transformation. All the major cereals were able to be transformed, and the first commercial GM crops, such as maize containing the Bt-toxin gene, were produced by this method.

A balance has to be reached between the number and size of particle fired into the target cells, the damage they do and the amount of DNA they deliver. Too little DNA may lead to low transformation frequencies, but too much DNA may lead to a high copy number and re arrangements of the transgene constructs.

2.3.2. Biolistic plant transformation:

There are so-called projectile methods that use metal slivers to deliver the genetic material to the interior of the cell. The small slivers (much smaller than the diameter of the target cell) are coated with genetic material.

One projectile method, called bioballistics, propels the coated slivers into the cell using a shot gun. A perforated metal plate stops the shell cartridge, but allows the slivers to pass through and into the living cells on the other side. Once in the cell, the genetic material is transported to the nucleus where it is incorporated among the host genes.[7]

The biolistic process represents a completely new approach to the problem of how to deliver DNA into intact cells and tissues. In this method, high velocity micro projectiles are used to carry DNA or other substances past cell walls and membranes. Because DNA is being 'shot' into cells, it represents a type of biological ballistics, hence the term "biolistic"**.**

There are several fundamental advantages to the biolistic process over other plant transformation techniques.

- The biolistic process appears to be effective regardless of species or tissue type,
- It is a rapid and very simple procedure.
- It should facilitate the direct transformation of totipotent tissues such as pollen, embryos, meristems and morphogenic cell cultures.
- In addition, the biolistic process appears to be uniquely suitable for organelle transformation.

The disadvantages of the biolistic process are:

It requires special instrumentation, and is still in the early stages of its development. Consequently, delivery efficiencies are still not as high as can be achieved in highly optimized transformation systems such as electroporation or agro bacterial-infection of tobacco.

Furthermore, potential users should be prepared to spend some time adapting existing protocols to their specific species or tissue of interest.[8]

2.3.3. Electro- and Chemical Poration:

Other methods for direct gene transfer involve creating pores or holes in the cell membrane to allow entry of the new genes. This can be done by bathing cells in solutions of special chemicals—so-called chemical poration—or subjecting cells to a weak electric current—so-called electroporation.

In this method a jolt of electricity is applied to cells to create openings in the plasma membrane that surrounds a cell. A (typically antibiotic-resistant) marker gene is included in the package to verify degree of effectiveness in introducing the foreign DNA.

The whole process is illustrated below:

Steps in electroporation and other methods of gene transfer:

- The DNA sequence for the gene that will be altered is identified and obtained from a donor organism (bacterium). This can be done by referring to known information pertaining to the sequence of the gene which is to be selected, followed by the removal of the gene from the donor organism.
- The desired gene is removed from the donor organism through the use of site-specific enzymes known as restriction enzymes.
- The desired gene is then subject to polymerase chain reaction (PCR), a method to amplify DNA and produce a workable amount of the gene.
- Once acquired, there are several ways to transfer the donor gene into the cells of the target organism. In rice**,** for example, a process utilized is electroporation, wherein special wall-denaturing enzymes remove the plant cell wall. The cells become protoplasts, which are plant cells stripped of the cell wall but still encapsulated in the cellular membrane. In the next step of electroporation, a very high voltage electric charge is sent through the protoplast-containing solution. This charge causes the membrane to temporarily deteriorate, forming small pores. Through these temporary pores, the donor gene's DNA is injected. The DNA is injected in the form of transfer plasmids that migrate to the chromosome and become incorporated in the plant's DNA. Shortly after the charge and injection, the cell membrane reforms. The cell wall also reforms in a reverse process.
- The newly altered cells are then placed in a culture to reproduce the unique cell types that compose the organism.
- The resulting cells are then transferred to a regular growth environment where the newly incorporated gene will be expressed. [9]

2.3.4. Silicon carbide fibers:

This is a simple technique for which nospecialised equipment is required. Plant material (such as cells in suspension culture, embryos and embryo-derived calluses) is introduced into a buffer containing DNA and the silicon carbide fibers, which is then vortexes. The fibers, which are about 0.3-0.6 µm in diameter and 10-100 µm long, penetrate the cell wall and plasma membrane, allowing the DNA to gain access to the inside of the cell. The drawbacks of this method relate to the availability of suitable plant material land the inherent dangers of the fibers, which require careful handling.

Although the procedure has been utilized with friable callus from maize, this type of friable callus is limited only to a few genotypes pf maize and oats. Furthermore procedures are being developed to allow transformation of cereals such as rice, wheat, barley and maize without the need to initiate cell suspensions. [10]

2.3.5. Hybridization

It is a breeding method; where in two known parents are crossed with the objective of achieving hybrid vigour or heterosis. Parents may belong two varieties of same species or two species of same genus. [11]

Hybridization between cultivars or varieties is often used in agriculture to obtain greater vigor or growth. [12]

Hybridization also takes place in nature. This can bring out favorable traits from two different gene pools. Hybridization allows animals to adapt to changing environments, and if the hybrids thrive, a new species may emerge. [13] One of the first persons to study plant hybridization was Josef Kölrueter, who published the results of his experiments on tobacco in 1760. Kölrueter concluded that inter-specific hybridization in nature is rare unless humans disturb the habitat. Since that time, many instances of hybridization among various plant species have been documented. [14]

Types

2.3.5.1 Inter-specific Hybridization

Crossing of two species that are from within the same genus. The offspring from this cross could develop into adults but may not develop functional gametes. Sterility is often attributed to the different number of chromosomes the two species have.[15]

Interspecific hybridization in nature is rare unless humans disturb the habitat. Since that time, many instances of hybridization among various plant species have been documented.[16]

Example:

Narcissus x perezlarae Font Quer is a natural hybrid between two autumnal geophytes: *N. cavanillesii* A. Barra & G. López and *N. serotinus* L. It was first recorded in 1882.

2.3.5.2 General guidelines for plant hybrid management

Here we identify general outcomes of plant hybridization and propose guidelines that should be taken in consideration facilitating the management discussion process. The smaller the number of pure populations, the greater is the conservation value of the hybrid taxon. However, if one of the parental is threaten, recovering actions should be performed in order to rescue the remaining individuals and is this case the protection of the hybrids should not be considered. If none of the parental populations exist, the hybridized individuals may possess some value especially if they are a source of commerce. Intentional hybridization should not be considered as a conservation tool. But hybrid eradication may also be a threat to the parental species if their reproductive fitness is positively influenced by this interspecific gene flow.

2.3.5.4 Consequences of hybridization processes

Several outcomes may result from hybridization: introgression, extinction of species, and stabilization of the hybrid zone or hybrid speciation. Some effects are negative in terms of diversity, namely, the merging of the hybridizing forms and the genetic assimilation of geographically restricted species threaten their survival. Other outcomes may include the reinforcing of reproductive barriers through selection for assorted mating or the production of adaptive characters that allow them to colonize new habitats or increase their fitness, in their existence niche, more rapidly than through mutation. The major possible evolutionary contribution of hybridization is the formation of new hybrid species. [17]

3. Impacts of Green Revolution:

The projects within the Green Revolution spread technologies that had already existed, but had not been widely used outside industrialized nations. These technologies included pesticides, irrigation projects, synthetic nitrogen fertilizer and improved crop varieties developed through the conventional, science-based methods available at the time.

3.1 Food Security:

The world population has grown by about four billion since the beginning of the Green Revolution and many believe that, without the Revolution, there would have been greater famine and malnutrition. India saw annual wheat production rise from 10 million tons in the 1960s to 73 million in 2006. [18] The average person in the developing world consumes roughly 25% more calories per day now than before the Green Revolution. Between 1950 and 1984, as the Green Revolution transformed agriculture around the globe, world grain production increased by over 250%. [19]

The production increases fostered by the Green Revolution are often credited with having helped to avoid widespread famine, and for feeding billions of people. [20]

3.2 Problems:

There have been numerous attempts to introduce the successful concepts from the Mexican and Indian projects into Africa. These programs have generally been less successful, for a number of reasons. Reasons cited include widespread corruption, insecurity, a lack of infrastructure, and a general lack of will on the part of the governments. Yet environmental factors, such as the availability of water for irrigation, the high diversity in slope and soil types in one given area are also reasons why the Green Revolution is not so successful in Africa.[21]

3.2.1 Quality of diet:

Green Revolution agriculture produces monocultures of cereal grains, while traditional agriculture usually incorporates polycultures. These monoculture crops are often used for export, feed for animals, or conversion into biofuel. According to Emile Frison of Biodiversity International, the Green Revolution has also led to a change in dietary habits, as less people are affected by hunger and die from starvation, but many are affected by malnutrition such as iron or vitamin-A deficiencies. Frison further asserts that almost 60% of yearly deaths of children under age five in developing countries are related to malnutrition.[22]

3.2.2 Socio-economic impacts:

Smaller farmers often went into debt, which in many cases results in a loss of their farmland. The increased level of mechanization on larger farms made possible by the Green Revolution removed a large source of employment from the rural economy. Because wealthier farmers had better access to credit and land, the Green Revolution increased class disparities. The rich - poor gap widened due to that. Because some regions were able to adopt Green Revolution agriculture more readily than others (for political or geographical reasons), interregional economic disparities increased as well. Many small farmers are hurt by the dropping prices resulting from increased production overall.

3.2.3 Globalization:

In the most basic sense, the Green Revolution was a product of globalization as evidenced in the creation of international agricultural research centers that shared information, and with transnational funding from groups like the Rockefeller Foundation, Ford Foundation, and United States Agency for International Development (USAID). Additionally, the inputs required in Green Revolution agriculture created new markets for seed and chemical corporations, many of which were based in the United States. For example, Standard Oil of New Jersey established hundreds of distributors in the Philippines to sell agricultural packages composed of HYV seed, fertilizer, and pesticides.

3.3 Environmental impact

3.3.1 Pesticides:

Green Revolution agriculture relies on extensive use of pesticides, which are necessary to limit the high levels of pest damage that inevitably occur in monocroping - the practice of producing or growing one single crop over a wide area.

3.3.2 Water:

Industrialized agriculture with its high yield varieties are extremely water intensive. In the US, agriculture consumes 85% of all fresh water resources. For example, the Southwest uses 36% of the nation’s water while at the same time only receiving 6% of the country's rainfall. Only 60% of the water used for irrigation comes from surface water supplies.

Likewise, rivers are drying up at an alarming rate. In 1997, the lower parts of China’s Yellow River were dry for a record 226 days. Over the past ten years, it has gone dry an average of 70 days a year. Famous lifelines such as the Nile and Ganges along with countless other rivers are sharing in the same fate. The Aral Sea has lost half its area and two-thirds its volume due to river diversion for cotton production.

Also the water quality is being compromised. In the Aral Sea, water salinization has wiped out all native fish, leaving an economy even more dependent on the agricultural model that originated the problem.

Fish are disappearing through another form of agricultural runoff as well. When nitrogen-intensive fertilizers wash into waterways it results in an explosion of algae and other microorganisms that lead to oxygen depletion resulting in “dead zones”, killing off fish and other creatures.

3.3.3 Biodiversity:

The spread of Green Revolution agriculture affected both agricultural biodiversity and wild biodiversity [23].

There is little disagreement that the Green Revolution acted to reduce agricultural biodiversity, as it relied on just a few high-yield varieties of each crop.

There are varying opinions about the effect of the Green Revolution on wild biodiversity. One hypothesis speculates that by increasing production per unit of land area, agriculture will not need to expand into new, uncultivated areas to feed a growing human population. However, land degradation and soil nutrients depletion have forced farmers to clear up formerly forested areas in order to keep up with production. [24]

The development of wheat varieties tolerant to acid soil conditions with high aluminium content permitted the introduction of agriculture in the Amazonian Cerrado ecosystem in Brazil.[25]

3.4 Health impact:

The consumption of the chemicals and pesticides used to kill pests by humans in some cases may be increasing the likelihood of cancer in some of the rural villages using them. Poor farming practices including non-compliance to usage of masks and over-usage of the chemicals by un-educated farmers in poor countries face this situation.[26]

3.4.1 Pesticides and cancer:

Long term exposure to pesticides such as organochlorines, creosote, and sulfallate has been correlated with higher cancer rates and organochlorines DDT, chlordane, and lindane as tumor promoters in animals. Contradictory epidemiologic studies in humans have linked phenoxy acid herbicides or contaminants in them with soft tissue sarcoma (STS) and malignant lymphoma, organochlorine insecticides with STS, non-Hodgkin's lymphoma (NHL), leukemia, and, less consistently, with cancers of the lung and breast, organophosphorous compounds with NHL and leukemia, and triazine herbicides with ovarian cancer.[27]

4. Positive aspects of green revolution:

There are different positive effects of green revolution which are discussed below:

4.1 Increase in Production / yield:

Cereal production more than doubled in developing nations between the years 1961–1985.Yields of rice, maize, and wheat increased steadily during that period. While agricultural output increased as a result of the Green Revolution, the energy input to produce a crop has increased faster, [28] so that the ratio of crops produced to energy input has decreased over time. Green Revolution techniques also heavily rely on chemical fertilizers, pesticides and herbicides, some of which must be developed from fossil fuels, making agriculture increasingly reliant on petroleum products.[29] Proponents of the Peak Oil theory fear that a future decline in oil and gas production would lead to a decline in food production.[30]

4.2 Resistant varieties:

The successful incorporation and remixing of genetic diversity from wheat's wild relatives has created wheat containing more variation than has ever been available to farmers and breeders, possibly since hexaploid (the complex genetic structure of wheat that arose from the accidental crossing of wild relatives and grasses in the distant past) wheat first appeared 10 000 years ago. Today there is thousands of new wheat varieties created from crossing different wild relatives with modern wheat. These new wheat varieties are resistant to much rust and fungus diseases. Bt cotton is also an example of this. Bacillus thuringiensis (Bt) transgenic cotton is the unique Bt transgenic crop planted on a large scale in China. Insect resistance, based on Bacillus thuringiensis (Bt) endotoxins, is the second most widely used trait (after herbicide resistance) in commercial genetically modified (GM) crops. Other modifications for insect resistance, such as proteinase inhibitors and lectins, are also being used in many experimental crops. (Mowbray, 2008)

4.3 Impacts on environment:

Green Revolution has contributed to environmental preservation because it helps farmers to produce higher yields on less land. This is a very environmentally favorable benefit. For example, the world's grain output in 1950 was 692 million tons. Forty years or so later, the world's farmers used about the same amount of acreage but they harvested 1.9 billion tons a 170% increase.

If we had continued practicing conventional farming, we would have cut down millions of acres of forest, thereby destroying wildlife habitat, in order to increase cropland to produce enough food for an escalating population. And we would have to use more herbicides in more fields, which would damage the environment even more. Technology allows us to have less impact on soil erosion, biodiversity, wildlife, forests, and grasslands. [31]

Scientists are also developing a genetically modified strain of rice fortified with vitamin A that is intended to help ward off blindness in children, which will be especially useful in developing countries. While people have expressed concern about the environmental impact of genetically modified food plants, such plants are well established in the United States and some other countries and are likely to catch on in the developing world as well.

Important environmental gains have also arisen in the maize and canola sectors. In the maize sector, pesticide use decreased by 24 million kg and the environmental footprint decreased by 7.8%. In the canola sector, farmers reduced herbicide use by 5 million kg (a 10% reduction), and the environmental footprint has fallen by nearly 21%. [32]

4.4 Impact on green house gas emissions:

First, GM crops contribute to a reduction in fuel use due to less-frequent herbicide or insecticide applications and a reduction in the energy use in soil cultivation. In this analysis we used the conservative assumption that only GM crops reduced spray applications and ultimately GHG emissions. The fuel savings we used resulting from changes in tillage systems are drawn from Carbon Neutral. The adoption of no-tillage farming systems reduces cultivation fuel usage by 36.6 liters/ha compared with traditional conventional tillage and 16.7 liters/ha compared with chisel plough/disk tillage. In turn, this results in reductions of carbon dioxide emissions of 98.8 kg/ha and 45.0 kg/ha, respectively.

Secondly, the use of no-till and reduced till farming systems that utilize less plowing increase the amount of organic carbon in the form of crop residue that is stored or sequestered in the soil. This carbon sequestration reduces carbon dioxide emissions to the environment. [33]

5. Disadvantages of green revolution

- Poor farmers could not afford HYV seed
- Some borrowed and ended up with large debts

- HYV seeds need more water and fertilizer, which is expensive and unaffordable by the poor farmers.
- New machinery replaced manual labor leading to unemployment and rural-urban migration and made people to work at low wages.

Moreover, the fertility of the soil was lost due to the increased use of chemical fertilizers. The developed methods of modern irrigation drilled out the water table below the ground.

Organic Farming Disadvantages

- In 1998, increased risk of E. coli infection via consumption of organic food rather than non-organic food was publicized by Dennis Avery of the Hudson Institute.
- A 2008 survey and study conducted by the UN Environmental Program concluded that organic methods of farming result in small yields even in developing areas, compared to conventional farming techniques.
- The Father of the Modern Green Revolution, Norman Borlaug, argues that while organic farming practices are capable of catering to the demands of a very small consumer fraction, the expanding cropland is dramatically destroying world ecosystems.
- Research conducted by the Danish Environmental Protection Agency revealed that organic farms producing potatoes, seed grass and sugar beet are barely able to produce half of the total output churned out from conventional farming practices.
- Organic agriculture is hardly able to address or combat global climate change. Though regenerative organic farming practices are recognized as effective strategies for reducing CO_2 emissions to an extent, the impact is not dramatic.

These farming practices completely waive off external costs, incurred due to investment in chemical pesticides and nutrient runoff, and a number of health issues that result from agro-chemical residue.

Intensive farming alters the environment in many ways.

- Limits or destroys the natural habitat of most wild creatures, and leads to soil erosion.
- Use of fertilizers can alter the biology of rivers and lakes. Some environmentalists attribute the hypoxic zone in the Gulf of Mexico as being encouraged by nitrogen fertilization of the algae bloom.
- Pesticides generally kill useful insects as well as those that destroy crops.
- Is often not sustainable if not properly managed -- may result in desertification, or land that is so poisonous and eroded that nothing else will grow there.
- Requires large amounts of energy input to produce, transport, and apply chemical fertilizers/pesticides
- The chemicals used may leave the field as runoff eventually ending up in rivers and lakes or may drain into groundwater aquifers.
- Use of pesticides have numerous negative health effects in workers who apply them, people that live nearby the area of application or downstream/downwind from it, and consumers who eat the pesticides which remain on their food. [31]

6. Criticisms of Green revolution

The Green Revolution has been criticized on several ways, mostly by environmental and critics of globalization**.** These criticisms can be in three categories:

- Decline in agricultural quality
- Concerns about the social implications of the Green Revolution
- Broad concerns about the sustainability of Green Revolution and agricultural practices

6.1 Agricultural Quality

6.1.1 Loss of biodiversity:

The spread of Green Revolution hybrids and the associated techniques resulted in the cultivation of fewer varieties of crops. Some crops are upwards of a 90% reduction in crop varieties. Dependence on one or a few cultivators of a crop means a greater exposure to famine.

6.1.2 Health value and food quality

Many hybrid crops are claimed to be inferior in nutrition. Potentially leading to malnutrition .One reason is a Green Revolution crops due to the increased level of weed control wild plants which are occasionally eaten as a vegetable disappear. The replacement of various nutrition sources with a single Green Revolution alternative led to higher nutrition levels and increased caloric intake.

6.1.3 Globalization and Social Change

6.1.3.1 Social change:

The result of these techniques was the encouragement of large-scale industrial agriculture at the expense of small farmers who are unable to compete with the high-efficiency Green Revolution crops. The result is massive displacement and increasing urbanization and poverty among these farmers, and the loss of their land to large agricultural companies. The new economic difficulties of small holder farmers and landless farm workers led to increase the rural –urban migration.

6.1.3.2 Sustainability:

Fossil fuels- dependence -agricultural output increased as a result of the Green Revolution, the energy input into the process has also increased at greater rate, so the ratio of crops produced to energy input has decreased over time. Green Revolution techniques also heavily rely on chemical fertilizers, pesticides, and herbicides, some of which must be developed from fossil fuels, making agriculture increasingly reliant on petroleum products. This has raised concerns that a significant decrease in world oil and gas production, and the corresponding price increases, due to this billions of people facing poverty and hunger.

6.1.3.3 Pollution:

Pesticide and herbicide continue to be a significant source of pollution, and a major source of water pollution. Although the dangerous toxic material and causing cancer. Critics charge that the Green Revolution destroys soil quality over the long term. This is a result of a variety of factors, including increased soil salinity increasing salt in soil.

7. Steps to introduce second green revolution

If the gain of "First Green Revolution" is to be strengthened, then a Second Green Revolution can be initiated. The First Green Revolution made possible with the availability of miracle wheat variety, electricity at the farms and land reforms.

- Genetically modified (GM) seeds to double the per acreage production i.e. technology.
- Private sector to develop and market the usage of Genetically Modified foods i.e. efficient marketing of the ideas,
- Linking of rivers as much as economically possible to bring surplus water of one area to others i.e. linking of the rivers.

Consumer has to grow up. It is the salvations of the rapidly increasing population. Opposition to the GM food is wholly politically motivated. It has to be ended in favor of adopting new techniques to boost productivity.

8. How could Second green revolution help Pakistan?

A second green revolution will ensure food availability, particularly agricultural produce, which is in short supply, to avoid rise in food prices. "We have to involve the agricultural economy more pro-actively into the growth process, both as a centre of production and as a generator of demand for various products and services." A second green revolution will require new elements, because inorganic fertilizers that use oil as a feedstock are increasingly costly and water resources are becoming scarce or difficult to develop. Biotechnology or genetically modified crops are likely to play an important role, thus raising the need to share research and new technologies. It will also remove the fear of famine.

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