What is the role of reductionism in agricultural technology transfers?

The Green Revolution and agricultural gene technology

By

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By Frøydis Kvaløy[1]

Abstract

This paper gives special attention to the questions of how and to what extent agricultural technology introductions particularly in the South have been informed by reductionist ways of thinking. The reductionist approach has dominated scientific investigation from as far back as the early seventeenth century. It has been incredibly successful when attempting to analyse and explain natural phenomena and processes. It may however be a different matter when reductionism constitutes the basis for technology applications in various contexts. Could the reductionist influence be the explanation when technology introductions bring about unexpected or problematic consequences in the field or in rural people's livelihood situation? The issue is discussed with reference to the Green Revolution and agricultural gene technology. In the case of the Green Revolution environmental and socio-economic consequences are addressed. In the case of gene technology the paper focuses specifically on introduction of Bt cotton and Golden rice.

Keywords: *Reductionism, agricultural technology transfers, the Green Revolution, gene technology, food security, poverty.*

1. INTRODUCTION

Most people have a vision of a world where nobody needs to be hungry and where the natural resources are managed sustainably. The efforts directed at achieving sustainable food security for all have changed over time. However, in the past century, these efforts have led to massive transformations of rural environments that have had far-reaching impacts upon social, economic and ecological systems. Linked to this issue, I will in this paper look at the impact of agricultural technology introductions in the South with examples from the Green Revolution and gene technology. The type of agricultural technology that has been promoted reflects the attitudes and contexts of that particular time, and should be seen in light of that. In this paper I am particularly interested in looking at the influence of reductionist thoughts when promoting agricultural technologies. Reductionism will thus be used as an analytical explanatory model when discussing the two examples.

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Reductionist approaches have dominated scientific investigation from as far back as the early seventeenth century. Reductionism in philosophy can be described as "a number of related, contentious theories that hold, very roughly, that the nature of complex things can always be reduced to (explained by) simpler or more fundamental things. This is said of objects, phenomena, explanations, theories, and meanings" (Wikipedia, electronic source, last updated Sep 2004). One example is to consider "a biological system to be composed of molecules with certain structures, or considering a molecule to be composed of atoms" (New England Complex Systems Institute 2004), e.g. fully described and explained by constituent parts. The alternative to reductionist ideas is often framed in terms of *holism* or *emergence*. *Holism* represents the idea that "things can have properties as a whole that are not explainable from the properties of their parts" (Wikipedia, Sep 2004). *Emergence* in evolutionary theories means the "rise of a system that cannot be predicted or explained from antecedent conditions. ….. - phenomena that are not predictable from their constituent parts" (Encyclopædia Britannica 2004).

Reductionism has been incredibly effective when attempting to analyse and explain natural phenomena and processes. It may however be a different matter when this type of analyses and explanations constitute the basis for technology application in various contexts. Technology applications have sometimes resulted in unexpected ecological, economic or social problems when tried out. To what extent and how can reductionist ideas influence technology applications? In this paper I will look at how and to what extent reductionist ideas have influenced the approaches used when promoting agricultural technologies. This means both that reductionism may influence the scientific presentation of reality as well as the identification of a problem and how it is to be solved.

In the following I will first say something about the ideas, attitudes and contexts when the technologies related to the Green Revolution and gene technology have been recommended for farmers in the South. I will then attempt to analyse how and to what extent the impacts of Green Revolution technology and gene technology may be seen as a result of influence by reductionist ideas.

2. HISTORICAL CONTEXTS OF THE GREEN REVOLUTION AND GENE TECHNOLOGY

According to Jules N. Pretty (1995), one of the driving forces behind the agricultural and rural transformations has often been the perceived need for increased food production to be able to feed quickly growing populations, particularly in the South. The Green Revolution seems to have been motivated by a combination of factors. It is a fact that the world faced problems of hunger and rapidly growing populations at that time. Increased food production was seen as the solution. Influence of Malthusian fear of population increases that soon would outstrip the world's capacity to increase food supplies was a widespread scientific and popular concern (Baum 1986). However, besides increased food production as a means to prevent hunger, it was also considered a means to avoid communist revolutions (Fowler and Mooney 1990, Borchgrevink 1998). The 1950s and 1960s were marked by the cold war and communist fear. The Vietnam War was escalating and there was a fear that countries in Latin America and Asia should fall "as domino pieces" for communism. At the time the British were fighting communists on the Malay Peninsula, there were troubles in the Philippines, the French were in the process of losing Indochina, the US-backed government in Korea was dealing with rural uprisings, and in Mexico the Cardenas government had expropriated Standard Oil and became distinctly hostile to large landholders. It was recognised that these problems stemmed from hunger and poverty, and it was believed these types of problems created favourable conditions for the growth of communism. USA therefore considered fighting these problems as an important foreign policy goal. The Green Revolution can thus be seen as a campaign where altruism and political strategy walked hand in hand.

The time period of the Green Revolution was also a time of optimism in relation to what could be achieved through technology progress. The early achievements of the Green Revolution where huge food production increase was achieved with relatively simple measures probably did not reduce this optimism. Both the label "Green Revolution" and the Nobel peace price given to Norman Borlaug in 1970 for the Green Revolution achievements, show how much the international community appreciated it at the time. As the time of the Green Revolution was marked by optimism linked to possible achievements through technology progress, it was also characterised by optimism or absolute confidence in the sovereignty in scientific rationality both in terms of guiding traditional farmers and in controlling nature. A typical scientific attitude of the time was that humans are able to control natural processes as opposed to the attitude that humans should work in accordance to natures' premises. An example here is that pesticides and chemical fertilisers were advised as the best measures to solve the problems of insects and decreasing soil fertility.

Genetics was established as a new science after Mendel's theories on inheritance were rediscovered in 1900. These theories contributed to make phenotypic selection more efficient. The situation from the 1990s has been that by the change from agricultural selection carried out on basis of a plant or animal's phenotype to selection directly based on the genotype, the precision of the selection has been improved and desired characteristics can be achieved in much less time. With modern gene technology it is also possible to introduce the genes that control the desirable traits into plant and animal strains with far greater precision and control than conventional methods (Persley and Doyle in Pinstrup-Andersen 2001). Examples of opportunities given by genetic engineering within agriculture, are crops and animals that are more efficient converters of nutrients, with better drought tolerance and pest and disease resistance. On the positive side, when comparing it to i.e. the Green Revolution technology, this could mean for instance limited use of pesticides and insecticides. It could also mean that marginal farmers with more marginal and less fertile lands could achieve benefits from the new plants. I will come back to this in section 4. Besides the new opportunities given by gene technology in comparison to conventional breeding methods, what can be said about common attitudes and the context with relevance to agricultural development of the last 10-15 years?

Today's ideas on what is the appropriate agricultural technology for farmers in the South are influenced by experiences with the Green Revolution and similar technology transfers, both on the positive and negative side. Researchers seem more humble when it comes to humans' ability to control and dominate nature. There is less faith in superiority of science, resulting in farmers' traditional knowledge to a greater extent being taken into consideration when searching for solutions. Biodiversity as a potential future resource and the threats towards it has been raised to the top of the international political agenda. There is increased recognition for more integrated approaches that to a larger extent aim at holistic, more environmentally sound contextual solutions. Examples on such approaches are Integrated Pest Management, and Integrated Plant Nutrient Management, - methods that aim at maintenance of the balance in nature instead of meeting problems with one-sided solutions such as eradication of damaging insects and weeds with pesticides and improved fertility with the application of chemical fertilisers.

When compared with the context at the Green Revolution period, both the present agricultural research and its products are to a greater extent put in a frame of increased market liberalisation and privatisation. Big multinational companies motivated by profit dominate developments in agricultural gene technology, and the access to information and innovations has become more restricted by patents. In contrast to the Green Revolution, developments within gene technology has not therefore been motivated primarily by the objective of increased food production in the South.

3. THE GREEN REVOLUTION

3.1. THE GREEN REVOLUTION – WHAT WAS IT?

The Green Revolution was the result of a strategic campaign whose objective was to increase agricultural production in the tropics and sub-tropics. It was based on an understanding of prosperous agriculture being essential. Because new arable land was believed to be limited, it was seen as important to increase the productivity of the existing land (Baum 1986).

The Green Revolution process began in Mexico with a less known 'wheat revolution' in the late 1950s. It was first with the agricultural developments with breakthrough in wheat and rice production in India, Pakistan and the Philippines during the 1960s and 1970s that the agricultural progress received world attention (Borlaug 30th anniversary speech at the Nobel Institute in Oslo, 2000). The basics of the Green Revolution is that plant breeders from the 1960s developed a process of large-scale plant breeding and testing that has produced new, higher-yielding varieties primarily of wheat, rice and maize.

The food crops that were to be applied in semi-tropic and tropic conditions had crop characteristics that up to then mostly had been confined to temperate crops: 'hybrid vigour' and dwarfing[2]. One of the advantages of the dwarf varieties, was that because of their reduced

[2] The dwarf character in wheat originated in Japan, and was incorporated into American wheats by O.A. Vogel. Norman Borlaug took Vogel's dwarf wheats to Mexico in 1954. The increase in wheat production was dramatic,

height these plants would use more of the nutrients to produce the cereal and less on the rest of the plant, - an increased grain to straw ratio. Another advantage of dwarf varieties was that they were less prone to lodging due to wind and rain as compared to the traditional varieties, which could only make use of a certain dosage of chemical fertilisers before they grew too high. The smaller plants could also be grown more densely and thus make use of the area in a better way (Robinson 1996). Besides the advantages of dwarfing and responsiveness to chemical fertilisers, the new cereal varieties did not require as long growing period as the traditional ones, making better use of limited rainfall. In many cases the farmers were able to cultivate an extra harvest per year; either increasing from one to two harvests of rice a year, or from two to three harvests. The Green Revolution varieties were not only responsive to chemical fertilisers, they were also responsive to water, leading to a more mechanised type of farming system with increased investments in irrigation systems. In sum, the production potential of the new plant varieties was much higher than that of the traditional ones, although this potential could only be successfully obtained with the supplement of chemical fertilisers and water. Because the success of the new plant varieties were dependent on these supplements, the Green Revolution led to an extensive change in factors of production, particularly in Asia. Norman Borlaug reports that over the past four decades in what he calls "developing Asia", the irrigated area has more than doubled – to 176 million hectares, chemical fertiliser consumption has increased more than 30-fold, and tractors in use has increased from 200,000 to 4.6 million (Borlaug 2000).

The Green Revolution was primarily driven forward by public research institutions. The Rockefeller and Ford Foundation copied Borlaug's work in the Philippines, except that they were working with rice with similar successful increasing yields as with wheat (Robinson 1996). The Rockefeller Foundation played an important role in bringing the Green Revolution process about, strengthening crop research at several research institutions in the South. The International Maize and Wheat Improvement Centre (CIMMYT) was established in Mexico. In Asia, the College of Agriculture at the University of the Philippines was rebuilt. The International Rice Research Institute (IRRI) was also established in the Philippines. Cornell University established a Southeast Asia programme to develop American experts and train students from Southeast Asia (Baum 1986, Fowler and Mooney 1990).

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and Mexico became self-supported in wheat within a few years. Seed were imported to India, Pakistan, China and various countries in the Middle East and North Africa with similar increases in production (Robinson 1996).

The new technology introduced by the Green Revolution was spread quickly, especially in its favoured areas. For instance in India, the Green Revolution wheat variety was cultivated in 40 percent of the wheat fields only five years after this variety was introduced, and in central parts of the Philippines more than 90 percent of the rice fields were cultivated with the Green Revolution rice variety (Borchgrevink 1998).

3.2. THE GREEN REVOLUTION AND ITS CONSEQUENCES

It is not easy to draw any clear conclusions regarding the consequences of the Green Revolution based on the literature. The effects have been hotly debated and researchers have come to highly diverging conclusions. This is not surprising, knowing that the Green Revolution was not only a matter of introduction of new seeds, but meant a broad set of changes that in the Green Revolution areas fundamentally altered most aspects of the local agricultural economy, including new technological components, altered land use patterns, and changes in the labour economy (Goldman and Smith 1995). Many scientists have made their contributions, attempting to grasp what the impacts have been, but what has been presented is very much dependent on who the presenter has been. The debaters have been of different scientific backgrounds, using different approaches, methodological techniques and terminologies when analysing the revolution and its consequences, and their conclusions have often been based on studies in different regions carried out in different time periods. In addition, as said, there is also the historical dimension to be taken into consideration, since both attitudes and contexts change over time.

Anyway, there seems to be no doubt that the Green Revolution in overall contributed to an increased agricultural production, - some would say as much as doubling or tripling of yields for the major food grains in the 1960s and 1970s. Some would also argue that the aggregate output of agricultural technology as a measure to reduce poverty is what is most important perceiving the main benefit of agricultural technology to be greater food availability and lower prices of food for people in general (Norton and Pardey 1995 in Janvry and Sadoulet 2002). However, there has been criticism concerning its socio-economic impacts arguing that the benefits of the Green Revolution primarily has benefited a small minority while the poor are in the same situation as earlier or even in a deteriorated situation. It has also been criticised that its intensive kind of agriculture has resulted in negative environmental effects. The main issue here, however is to what extent and how the Green Revolution was based on reductionist thinking, representing a type of scientific rationality that puts focus on isolated causal relations as opposed to a more holistic approach, and whether it has resulted in certain outcomes because of this.

Whatever motives were behind the Green Revolution, the main objective is clear: more food. In order to fulfil this objective some important strategic choices were made at the outset as to what priorities should rank highest. The efforts were for instance directed more at the problem of how to increase global food production than how the benefits should be distributed to different social layers and geographic regions of the South. Based on the strategic choices made, some of the consequences that could be seen after the Green Revolution process were probably expected, while others were unexpected.

One of the strategic choices made was to focus on particular areas where the potential of increased agricultural production was considered to be highest. The efforts of the Green Revolution were both directed at specific countries in the South and specific regions within these countries. These were areas with nutritious soils, access to water and with an infrastructure that could ensure access to the necessary inputs, agricultural supervision and marketing possibilities (Baum 1986). In the beginning the new technology was introduced to Mexico, India, Pakistan and the Philippines and has gradually become more important also in other countries in Asia and Latin America. Some researchers argue that the technology has not been evenly spread, but has up to the present been more successful in these ecologically favourable and central areas. Because of the Green Revolution's limitation to particular areas, the adoption of high yield varieties have apparently slowed after the 1970s, and large areas of poorer land in the South have not been planted with these varieties (Buttel, Kenney and Kloppenburg 1985).

On the other hand, there have been reported some very good results in the selected Green Revolution areas. The Green Revolution therefore cannot for example be blamed for not being successful in Rajasthan, an area that was not strategically chosen. Between 1964-65 and 1984-85, the wheat harvest in Punjab, one of the selected Green Revolution areas, increased more than fourfold, from 2.4 million metric tons to 10.2 million tons, resulting in Punjab being able to produce over 44 percent of India's total wheat harvest by 1984-85 (Goldman and Smith 1995). In addition, rice, which earlier had been of marginal importance in Punjab, was reported to have become the second most important food crop in the state (Goldman and Smith 1995).

However, the hopes that these favourable areas will also be the areas of future agricultural growth, has been undermined by emerging evidence of stagnating yields and increasing environmental costs due to intensive use of purchased inputs to maintain and extend the productivity gains (Pretty 1995, Robinson 1996, Morris and Byerlee in Eicher and Staatz 1998). Although Punjab has been one of Green Revolution's most celebrated successes, it has also been referred to as an area which is now facing these problems, - being left in a deteriorated situation because of negative impacts of the Green Revolution with diseased soils, pest infested crops, waterlogged deserts and indebted and discontented farmers (Shiva 1991).

Returning to the main topic of this paper, - can the Green Revolution be viewed as being influenced by reductionist ideas, and is it possible that the negative impacts seen today are caused by this influence? In my opinion, the answer is yes to both questions. In what way then has the Green Revolution been based on reductionist thinking?

In order to reach its main objective, the scope of the Green Revolution was reduced to one particular type of crop that responded best when considering yield in an artificial optimalised growing-environment. Farming was reduced to monoculture. The purpose of production was reduced to cereal grain yield. Other aspects such as i.e. cereal straws as animal fodder were not given priority or were forgotten. Stimulation of the productivity was reduced to simple factors that were possible to manipulate: water and plant nutrition – the latter a question of simple chemical elements of Nitrogen, Phosphorus and Potassium (NPK). Control with yield limiting factors was reduced to chemical control of certain insects and diseases. The causal relations based on these reductionist ideas implying that added chemical fertilisers and water would result in good yields turned out to be true regarding these specific cereal varieties. However, experience has shown that when the Green Revolution technology has been applied it has not always resulted in success. I will go further into some of these issues in the rest of this section.

Perhaps the most serious negative effect of the concentration on a few crops and planting in monocultures is the Green Revolution's contribution to accelerated loss of genetic diversity and breakdown of many intermixed agricultural systems based on a diversity of traditional varieties that have co-evolved with local environments. There are several factors that pose threats to the maintenance of agricultural biodiversity of which the replacement of local crop varieties due to the rise of industrial monocropping is one. I will just briefly also mention: global trade rules, patent laws, and concentration of agricultural research and development in technological solutions that are not sustainable, and introduction and promotion of genetically engineered organisms. The replacement of local varieties or landraces[3] by improved and/or exotic varieties and species is reported to be the major cause of genetic erosion around the world (FAO 1998). One example referred to by FAO is China where the number of wheat varieties supposedly was reduced from nearly 10,000 wheat varieties in 1949, to about 1,000 varieties by the 1970s (FAO 1998).

One of the reasons why loss of agricultural crop diversity is considered a serious problem, is that genetic diversity represents an important resource to be maintained in case today's most commonly used crop species and varieties are not sufficient to feed the human populations in the future, or are damaged by for instance diseases and/or pests, climate change etc. Relatives of the crop species that dominate the world's agriculture today may be more resistant to the potential threats. With the possibilities given by the new gene technology, the value of crop diversity and the importance of its maintenance are perceived as even more pressing than earlier. The importance of finding a balance between conservation of crop diversity in gene banks (*ex situ* conservation) and conservation of crop diversity in farmers' fields (*in situ* conservation) is increasingly being recognised. In contrast to *ex situ* conservation, the main advantage of *in situ* conservation is that it permits population of plant species to be maintained in their natural or agricultural habitat, thus allowing the evolutionary processes that shape the genetic diversity and adaptability of plant populations to continue to operate.

[3] **Landrace** is a cultivated plant population which is genetically diverse and genetically flexible. A landrace can respond to selection pressures during cultivation. The maize crops of tropical Africa, which were so vulnerable to the disease *tropical rust* for instance, were landraces, and they responded to the selection pressure for resistance. Prior to the discovery of Johansen's *pure lines* in 1905, most crop varieties in the industrial world were landraces, and most subsistence crops in the non-industrial world are still landraces (Robinson 1996).

An issue of concern from a socio-economic point of view in this regard is that the limited genetic base may make the farmers more vulnerable to widespread disease infestation with possible reductions in production (Peet and Watts 1996, Fowler and Mooney 1990, Robinson 1996). One of the reasons why cultivation in monocultures in general makes a farmer more vulnerable is that she/he does not have the flexibility of shifting to other crops when harvests fail. Another disadvantage of this concentration on a few crops is that a large number of other crops have become considered as minor as agro export crops and have received little or no attention within research. Also from a nutritional point of view, the wide spreading of a few crops at the expense of a more diverse production has been criticised.

The productivity of a farm is often considered to be the sum of many factors, and this is especially true for small-scale farmers in the South where the households often produce for own consumption as well as for the market. The Green Revolution technology was focused on improvement of the plant's ability to produce a high yield. Other aspects of a plant that may be of importance to farmers cover whether this is the variety which is best when considering production in diverse growing zones, harvest and storage, taste and cooking qualities, resistance to pests and diseases, suitability of crop residues as animal fodder etc. The new plant varieties' genetic limitation has increased the chance of parasites and pests developing resistance. The breeders’ primary aim when creating these varieties was increased yields and, by focusing selection on the genes that govern yield characteristics, the genes that confer protection were not retained. In general, traditional crops are considered to be less vulnerable to pests and diseases because they are genetically diverse and flexible (Robinson 1996, Pretty 1995).

In general, ecological and biological factors received little consideration in the early discussions of the pros and cons of the Green Revolution programme. One aspect of concern has been the intensive usage of pesticides. The idea that the problems caused by plant diseases and pests should be solved first and foremost by spraying of pesticides may be said to be an example of a scientific rationality that puts focus on isolated causal relations, as opposed to a more holistic understanding (Borchgrevink 1998). In developing the Green Revolution programme insects and diseases were considered an isolated problem, and the solution was therefore to eliminate the diseases and pests without consideration of its negative consequences like pollution and eradication of useful plants and animals and development of resistance. Massive uses of pesticides were recommended for everyone. The substitute of biological methods to fight pests and diseases with synthetic chemicals have also led to a drainage of the local knowledge on biological farming methods: using natural sources of nitrogen related to crop rotation, multiple cropping, incorporation of rich legumes, usage of agricultural plant remains, animal manure etc. (Pretty 1995, Fowler and Mooney 1990).

As said, the Green Revolution plants were created such as to have optimal response with application of chemical fertilisers. The idea was that soil fertility can be maintained by chemical fertilisers only, and that it was unnecessary to maintain the natural processes that contribute to the regeneration of nutrients in the soil. As said, some of the problems that have been experienced in the Green Revolution areas are stagnating yields and contamination of water by nitrates. Economically the dependence of chemical fertilisers has made farmers more vulnerable because they have to a larger extent become dependent on buying inputs from external markets.

The Green Revolution process has not however only resulted in negative impacts on the environment. If the intensification of agriculture caused by the Green Revolution had not happened, a larger area of non-agricultural land would probably have been required to produce the same amount of food. Borlaug said in his anniversary speech (2000) that had the global cereal yields of 1950 still prevailed in 1999 we would have needed nearly 1.8 billion hectares of additional land of the same quality instead of the 600 million hectares that was used to equal the current global harvest. According to him, agricultural productions without the Green Revolution would have meant that much more fragile land had been brought into agricultural production, resulting in negative impacts in the form of soil erosion, loss of forests and grasslands, and extinction of wildlife species.

Lack of equity regarding distribution of benefits from the Green Revolution is an issue that have been raised by many researchers. Since the main focus of this paper is reductionism and technology transfers, I will relate the issue of equity particularly to the discussion above. However, since it has been such a contested issue in the aftermath of the introduction of the Green Revolution technology, I think it is important to also briefly present some of the views not directly related to reductionism. As said, one of the major objections to the Green Revolution has been that its benefits has not been equally distributed, and that the ones who have benefited the most were those that were most resourceful in the outset.

As mentioned earlier, a strategic choice made in the Green Revolution process was to focus on particular suitable areas in terms of ecological and infrastructural conditions. There are therefore several bottlenecks that make it difficult for marginal farmers to take advantage of the technology. Among the ecological conditions required by the Green Revolution technology, water supply at a certain level can be mentioned as one. In addition, the new technology requires investments in inputs such as chemical fertilisers, pesticides and seeds, whereof transportation possibilities will be a hindrance for farmers in marginal areas. In addition there is often no credit system available in marginal areas in order for the farmers to make necessary investments in chemical fertilisers, irrigation, pesticides and seeds. Because of the prerequisites required by the Green Revolution technology to be successful, it has been unavoidable that some of the existing differences have been reinforced, both between countries and between regions in the same country.

In a review of more than 300 social science studies on the Green Revolution published during 1970-89 with conclusions on distributional effects of the technology, 80 percent of the studies reported that there had been an increased inequality, both interregional and even in the favoured zones among farmers (intraregional) (Freebairn 1995). The research findings referred to by this review contradict the view that the Green Revolution technology has had effects of evening out inequalities. Unequal benefits between farmers in the favoured areas from those living in the non-favoured areas of the Green Revolution is one thing. Differentiation between farmers also within the favoured areas is another. When looking at distribution of benefits however, it is important to be aware that farmers constitute a differentiated group of agriculturalists, such as landless labourers, smallholders, and large landowners.

Landless labourers and small-holders constitute a group that has too little land to make a living out of it and is therefore dependent on work in other farmers' fields or contracts where they have access to some land but are entitled to give a part of their harvest to the landowner. One important issue concerning this group's situation is demand of their labour power (Borchgrevink 1998). According to Borchgrevink (1998), changes resulting in benefits by agricultural technological innovations can roughly be divided in two: 1) changes that result in increased agricultural production in a given area, and 2) changes that contribute to a cost reduction. Regarding the Green Revolution, irrigation, high yielding plant varieties and usage of chemical fertilisers represents the first type of changes, resulting in increased demand for labour power. Mechanisation, usage of pesticides and some of the new agricultural techniques represents the second type of changes, not primarily contributing to an increased production, but a reduction of labour power demand and thus the total production costs.

The Green Revolution has not always resulted in increased mechanisation. However there seems to have been more mechanisation in areas dominated by large farmers, and in these areas one would expect that the demand of labour has decreased and so has the income levels (Borchgrevink 1998). Most research findings seem to support the argument that where there has not been any essential mechanisation of the agriculture, the Green Revolution has contributed to an increased demand for labour power, meaning an improvement of the situation of landless and small-holders (Borchgrevink 1998). One reason of this improvement is that the Green Revolution technology in many cases has resulted in a switch to double cropping. However, even though the situation of the hired labourers has been improved, there is the question whether the landowners have gained relatively more. For instance according to Prahladahar (Freebairn 1995), the employment effect of the new technology does reveal a positive influence leaving the absolute status of landless labourers in an improved situation, but the owners of the land and capital have gained relatively more due to the increased production of high yielding varieties. On the other hand indications by the Green Revolution literature showing that increased mechanisation automatically results in decreased demand for labour power are not that clear. The situation differs from region to region.

What have the impacts of the Green Revolution then been on the situation of landowners? As already said, marginal farmers have often not been in the situation to take full advantage of the Green Revolution technology because production increase several of the conditions required for a successful usage of the Green Revolution technology have not been there. Hazell and Ramasamy (1991) represents a common view among researchers, - that the adverse effects of the Green Revolution have been that it has mainly been the large farmers that have adopted the new technology, and smaller farmers have either been unaffected or adversely affected because the Green Revolution resulted in lower product prices and higher input prices. Several researchers have also reported that there are groups among the farmers that have been displaced because of the changes, i.e. small farmers by larger farmers and producers in marginal areas with producers in more suitable environments (Janvry and Sadoulet 2002, Hazell and Ramasamy 1991).

As already mentioned in the beginning of this section, one of the less controversial objections towards the Green Revolution impacts is that the technology requires a standardised type of agricultural system with focus on a limited number of plant varieties that make farmers vulnerable to harvest failures caused for instance by pests and diseases or unfavourable environmental conditions. This is a type of vulnerability that all types of landowners likely would be facing, although less wealthy farmers usually are left worse off. In addition to the environmental vulnerability caused by the Green Revolution technology, many landowners at all levels in the South have become more vulnerable economically because of their dependence on expensive chemicals and fluctuations in the external market. In this regard it has also been argued that landowners that lack access to or that could not afford to buy fertilisers, irrigation systems, herbicides and insecticides have been more prone to be left out of the development, or have become heavily indebted (Fowler and Mooney, Pretty 1995, Pete and Watts 1996).

4. AGRICULTURAL GENE TECHNOLOGY

Even though biotechnology also includes various techniques such as fermentation, enzyme technology and cell and tissue technology, I will focus only on gene technology in this paper.
One of the reasons why I have chosen to focus on gene technology is that it is mainly aspects related to gene technology that has been considered controversial and been a target of heated public debate in the North and the South. An other reason is that gene technology as it is applied today may bring up issues related to reductionism as the products are results of manipulation of genes directed at one particular characteristics. In addition there are also examples where gene technology is criticised for representing one-sided solutions to rather complex problems such as is the case with the so-called 'Golden rice'. I will return to the questions of to what extent and how gene technology can be seen as influenced by reductionist ideas and what consequences this might have after a short presentation of what is meant by biotechnology and gene technology specifically directed at improvements in agriculture.

4.1. AGRICULTURAL GENE TECHNOLOGY – WHAT IS IT?

Biotechnology may be defined as “Technology that utilises micro-organisms, plant and animal cells or their parts for the purpose of producing or modifying products, for medical purposes, to improve plants or animals and to develop micro-organisms for specific purposes” (National Programme for Biotechnology 1990-92). This definition covers both traditional uses of micro-organisms, like the production and use of yeast, and modern gene technology, but it does not include traditional methods of breeding in plant and animal husbandry.

The following gives a definition of gene technology (Norges Offentlige Utredninger 1990):

> Gene technology is a general term covering a number of techniques that are deliberately used to modify an organism’s DNA. The DNA can be altered by the removal of individual genes (deletion) or by introducing foreign genetic material. Many of these methods have been in use for a long time. The new recombinant DNA technology (gene splicing), developed about 25 years ago, has opened up completely new possibilities for altering an organism’s genes. This and the other more traditional methods make it possible to transfer genetic material across normal species barriers.

The industrialisation of a gene-based strategy to predict, understand and manipulate biological organisms for commercial agriculture and human health is sometimes being pointed out as the force that will drive the economic development in the 21st century. The gene technology products continue the tradition of selection and improvement of cultivated crops and animals developed over the centuries. The difference is that the new gene technology identifies desirable traits more quickly and accurately than conventional crop and animal breeding.
In practice, application of genetically modified organisms (GMOs) has up to now mainly been within crops of temperate regions: USA, Canada, Argentina, and China, accounting for 99 percent of the coverage (CropBiotech 2004). Globally, there are four genetically modified crops (GM crops) that dominate at the present: GM soybean occupying 41,4 million hectares (61% of the global GM area), GM maize planted on 15,5 million hectares (23% of the global GM area), transgenic cotton cultivated on 7,2 million hectares (11% of the global GM area) and canola rapeseed occupying 3,6 million hectares (5% of the global GM area) (CropBiotech 2004). During the period 1996-2003, herbicide tolerance has been the dominant trait followed by insect resistance. Herbicide tolerance deployed in soybean, maize, canola and cotton occupied 73 percent of the global GM area, with 18 percent planted to insect resistant crops (Bt crops) (CropBiotech 2004).

4.2 AGRICULTURAL GENE TECHNOLOGY AND ITS CONSEQUENCES

In line with the main focus of this paper as outlined in the introduction, I will attempt to discuss the following questions: How and to what extent can agricultural gene technology or the way it is applied be perceived as being influenced by reductionist ideas? What are the likely consequences? Is there a chance that a New Green Revolution where gene technology is integrated will have similar impacts as the previous Green Revolution?

Gene technology is used to solve a specific problem, e.g. crop damage by insect attack or vitamin deficiency in humans. What is the difference between a reductionist and holistic or contextual understanding of these problems, and how is the solution affected by the underlying understandings? Damage by an insect is an ecological phenomenon, - sometimes caused by imbalance between several factors in the ecosystem. However, when the problem is perceived to be the effect of one specific insect species without consideration of other related ecological factors, and the solution is chosen to be control of this specific insect, both the understanding of the problem and the solution to that problem could be seen as reductionist. In the same way one can say that vitamin deficiency is a consequence of unbalanced food intake caused by several contextual factors working together. However, in the case of 'Golden rice', the problem is presented to be deficiency of a specific vitamin (A vitamin) and the suggested solution is to add vitamin A to the main staple (rice). In this way the cases of *Bacillus thurengiensis* cotton and 'Golden rice', of which I will discuss further later in this section, may be seen as excellent examples to discuss the influence of reductionist ideas.

In practice gene technology often implies that one gene or a few genes carrying particular characteristics are isolated from one organism and integrated into another organism in order to obtain a desired trait to solve a problem. The result is that a particular characteristic is given priority resulting in other important traits being undermined. There are for instance examples where gene technology aimed at increased yields through control of yield reducing insects have in fact contributed to stagnating yields (Troyer 2004). According to Troyers' data on U.S. transgenic maize hybrids, the change from conventional technology to gene technology has meant that the steady increase in maize yields in USA has stagnated during the last eight years. Since the 1950s USA has never gone so long without an increase in maize yield. Troyer argues that this is probably because emphasis put on insect and herbicide resistance, has resulted in underemphasis on yield characteristics. Selection for yield as such has in this case only been an indirect purpose of the GM crop development, while experience as well as theory indicates that direct selection for yield is more efficient than indirect selection.

My assumption is that reductionist influence in agricultural gene technology application may result in some of the same types of problems as experienced with the Green Revolution. One example is the problem of development of resistance, as mentioned earlier. The problem of resistance is relevant to all pest-resistant GM crops wherever they are planted. The problem of the Green Revolution crop varieties that required pesticides was that over time, insect pests and weeds could become resistant to the chemicals. The same is likely to happen with application of GM crops: that eventually the GM crops will fail because insect pests will evolve tolerance to built-in insecticides and because weeds will evolve immunity to herbicides sprayed over fields of herbicide-tolerant GM crops. Said in botanist Wendel’s words: “Agriculture is an evolutionary arms race between plant protection and pests, and GM crops are just one more way that we’re trying to outsmart pest – temporarily” (Brown in Scientific American, April 2001).

With the aim of creating a world with improved food security and more equally shared benefits between the North and the South, researchers call for a so-called 'New Green Revolution', also by others called 'Second Green Revolution' or 'Doubly Green Revolution' (Conway 1997, UNDP 1998, CGIAR 1999). The proponents of a New Green Revolution emphasise the importance of using agricultural gene technology to meet the food requirement of the poor. Conway argues that this must be a revolution, which is even more productive than the first Green Revolution and even more 'green' in terms of conserving natural resources and the environment. While the first Green Revolution's primary goal was to find out how to produce new high-yielding food crops, and afterwards look for how the benefits could reach the poor, the aims of this new revolution is the opposite: to start with the socio-economic demands of the poor households and then seek to identify the appropriate research priorities.

Will a New Green Revolution, where gene technology is a part, assure equal distribution of benefits? Although the issue of distribution of benefits from gene technology is not seen as directly relevant to the issue of influence by reductionism, I think it is important to touch upon it briefly since it has been an issue that have been discussed a lot. The New Green Revolution proponents agree that the challenge of the New Green Revolution is to provide enough food for all over the next two-three decades without the same negative consequences brought about by the Green Revolution. This means not only that the poor must be benefited more directly, but also that the agricultural technologies must be applicable and be environmentally sustainable under highly diverse conditions. In contrast to this, the technologies of the Green Revolution were primarily developed in favour of particular farm areas with fertile soils, well-controlled water resources, and other climatic and environmental factors that made these areas suitable for high production. The Green Revolution's focus on particular suitable areas was a result of a strategic choice aiming at an overall agricultural production increase. The responsibility of an equal distribution of its benefits was probably perceived as to be outside the realm of the scientists and their technology, and it has been argued that it is exactly this premises that the adherents and the opponents towards the Green Revolution disagree on (Borchgrevink 1998). In order to obtain a new Green Revolution, it is thus argued as necessary to use an approach that also considers social and economic processes and application of science and technology in connection to each other, in addition to increasing the cooperation between scientists, farmers and politicians (Conway 1997). This kind of thinking is also very much in line with the new emerging approaches emphasising integration and more holistic perspectives referred to in section two.

Regarding the technical side of gene technology, it has become easy to predict the potential benefits of sequencing genes and identifying their functions. Gene technology represents important progress considering the possibilities of food crops' adjustments to different conditions. Many researchers are therefore of the opinion that the positive aspects of applying GM crops to improve livelihoods of people in the South exceed the negative. In theory the possibilities of creating crops that can be adjusted to difficult growing conditions seems almost without limits. However, it is still difficult to predict what the effects will be of gene technology application for farmers’ livelihoods in the South. Important questions in this relation are for instance: Who will have access to the technology, and who will decide priorities for using it? What are the long-term ecological consequences of released GMOs in nature? Is this technology more beneficial, appropriate and adjustable to diverse small-scale farming environments than other technologies or management tools?

When compared to the Green Revolution technology, one critical issue in retaining the aim of making gene technology adjusted to different categories of farmers in diverse environments is whether the interest and motivation to ensure poor people' and marginal farmers' access to the technology is there. The reason why this issue is raised is that research and innovation in the field of gene technology has up to the present been primarily dominated by private research institutions and large multinational companies depending on economic profits. The question regarding how to ensure that benefits of genetic engineering will reach the poor or marginal farmers is then very much a question of who will pay the expenses. Production of new GM varieties and agricultural inputs has been developed for private sector, requiring expensive research and products of which only better-off farmers can afford. Gene technology research and industries have therefore primarily been directed towards the markets of the North where the purchasing power is greater. The emphasis has been on a few commercial crops of temperate regions, and research in gene technology related to farming systems in the South has been very limited (Pinstrup-Andersen 2001). According to Calestous Juma (in Pinstrup-Andersen 2001), GM crops covered an estimated 44.2 million hectares in 2000, a 25-fold increase over the 1996 figure, and this rapid expansion occurred mainly in USA, Canada, Argentina, and China.

As mentioned earlier, GMO application has up to now been mainly focused on soybeans, maize, canola/rapeseed and cotton. Besides the high expenses of carrying out gene technology research, research aimed at feeding the poor has been perceived as less attractive for the private sector because this type of research often requires a long time before results are reached, for example in developing new plant types of minor staples. It has in addition been viewed as containing economic risks especially when focused on heterogeneous environments that are subject to climatic or other ecological variability. Crops that would have been more relevant for tropical farming in Africa would for instance be virus-resistant sweet potatoes, cassava, and maize; improved production of bananas, and other crops that can tolerate salt and desiccation (Thomson in Pinstrup-Andersen 2001).

An additional aspect hindering poor and marginal farmers of the South to benefit from agricultural gene technology, as opposed to the Green Revolution technology, is that highly restricted patents often protect the gene technology innovations. Restriction by patents have resulted in a slowing down of the process of innovation aimed at agriculture in the South as it creates a limited access to information both through international agricultural research institutions and national research institutions in the South (Conway 1999). I will now turn to the examples of genetically engineered '*Bacillus thurengiensis* cotton' and 'Golden rice', attempting to explain how they have been influenced by reductionism and what this entails.

4.2.1. The example of *Bacillus thurengiensis* cotton

The soil bacterium *Bacillus thurengiensis* (Bt for short) is a widely distributed species with many variants. It produces a mild toxin that acts on a small selection of insects that are harmful to a number of crops. The virtues of Bt have been known since 1913, and was first commercialised as a dust spray just after World War II (Jenkins, R. 1999). Bt has also been used in organic agriculture since it is produced naturally, biodegrades rapidly, and has no harmful side effects (Pinstrup-Andersen, P. and Schiøler, E. 2001).

With genetic engineering Bt can be applied to crops directly and automatically, by integrating the ability to produce the toxin into the plants themselves. International seed-producing companies have already successfully developed several such crops, including maize, cotton and tomatoes. Bt cotton was first approved in the middle of the 1990s. Positive and negative effects of Bt cotton have been experienced, as it has already been cultivated for some time. In the beginning this crop was primarily cultivated in the North, but results also from the South are increasingly being reported.

In the outset, this seems like a very good idea, at least seen from an environmental point of view. If crops have their own specific built-in resistance to insects, cultivators do not need pesticides. One example showing positive results is China where it has been reported that transition to Bt cotton has resulted in 80 percent reduction in pesticide use on fields that have been planted with this cotton variety (Pinstrup-Andersen and Schiøler 2001). In addition it has been reported that the improvement of conditions for all insect life are so much improved that the pests that attack cotton are more likely to be attacked by their natural enemies (Pinstrup-Andersen and Schiøler 2001).

There are however, environmental risks linked to this type of plant as to other GMOs. As said earlier, there is a chance that insects and pests over time develop resistance. Scientist are worried that in cases like Bt cotton, this will create a vicious circle forcing the farmers to change to other more toxic chemical controls (Pinstrup-Andersen and Schiøler 2001, Jenkins 1999, Brown 2001, deGrassi 2003).

Among other regions in the South where experience with this crop has been reported is Sub-Saharan Africa. Based on the argument that GM crops should not be applied simply because the technology exists, three GM crops introduced or near release (Bt cotton, Bt maize and

Virus resistant sweet potato) were evaluated according to six criteria: whether led by the demands of poor farmers, developed according to site-specificity, being cost-effective, and being environmentally and institutionally sustainable (deGrassi 2003). I will only present the research findings related to Bt cotton in this paper. However, similar shortcomings as found regarding Bt cotton were also found in relation to the other two GM crops.

According to deGrassi's study none of the above criteria were fulfilled in the case of Bt cotton. First of all, poverty in the area is not perceived as being caused by poor cotton technology, but rather socio-economic and political factors such as "…unequal land holdings and slow redistribution, authoritarian nature conservation, elitist tourism, declining off-farm wages, declining international commodity prices, HIV/AIDS, and undemocratic authorities" (deGrassi 2003:ii). The demand from African smallholders was insignificant since the private company Monsanto had already developed the technology. Bt cotton was originally developed for American farmers to reduce the problem of American bollworm. However, in South Africa the problem of pink bollworm prevails, and other new pests have appeared as well. When it comes to its cost-effectiveness, deGrassi argues that the number of pesticide sprayings has not been reduced at the rate foreseen, and the amount of labour saved is unclear. The environmental sustainability taking the issue of reduced pesticides spraying and other environmental risks such as resistance into consideration is seen as moderate. As a largely private marketing venue, there has been little institutional capacity building.

Based on the above example from South Africa, Bt cotton may be viewed as an example of a technology that has not fulfilled its expectations partly because the problem-definition has been influenced by reductionist ideas. Farmers' problems have in this case been reduced to attack by a particular insect species and the problem is to be solved by the introduction of one specific technology. However, after evaluating the situation of small-scale farmers of the area, deGrassi found that the constrains facing them turned out to be a result of a complex set of factors working together, primarily based on the problem of lack of political and economic power. The example also shows that a particular technology (here Bt cotton) is not always appropriate when transferred to a different area where flora, fauna and yield reducing problems are different.

4.2.2. The example of Golden rice

The example of Golden rice differs from the previous example since it has not yet been tried out in the field. It also differs by being aimed at improvement of poor people's nutritional intake while the above is aimed at controlling yield-reducing factors. I see the example of Golden rice as interesting both because it is a crop which is seen as particularly aimed at people in the South, and because it has given rise to a lot of debate that partly stems from the basic idea behind: that poverty and malnutrition can be solved simply by introducing one new variety.

‘Golden rice’ is the name of a type of genetically modified rice containing vitamin A or its precursor, beta-carotene[4]. The inventors of Golden rice, Dr. Ingo Potrykus of the Swiss Federal Institute of Technology and Dr. Peter Beyer of the University of Freiburg in Germany signed a deal with the companies AstraZeneca and Greenovation, agreeing that this technological innovation should be given free of charge to farmers for ‘humanitarian’ purposes. Among other things, Golden rice is presented as an example of how genetic engineering can directly benefit consumers, of which most GM crops developed so far have failed to do. It is claimed that it will provide a more sustainable, inexpensive and effective solution to vitamin A deficiency among poor, rice-eating people where drug-based supplementation and fortification have been ineffective (CGIAR 1999, AgBiotech Net 2000, Rockefeller Foundation, 2000).

On the positive side, this is an example of gene technology research that is directed at food crops that are important also in the South, and it is marketed as a license free crop. However, many critical questions have been raised. Some are related to the motivations behind promoting such a crop: - Is this ‘free technology’ promoted by the multinationals primarily to get acceptance and funding from the increasingly sceptical masses of consumers, scientific community and funding agencies? Others are questioning its usefulness: - Is this a relevant and efficient measure to solve problems of malnutrition? (BIOTHAI 2001, Primal Seeds 2000, Genetic Resources Action International 2000).

Before coming to the stage of Golden rice application there are some basic issues to be clarified. For instance it is still not clear whether the free license agreements cover release and

[4] The Golden rice was developed in 1999 by inserting two genes from daffodil and one gene from a bacterium, engineering a beta-carotene pathway into Taipei 309, a japonica rice variety.

commercialisation in addition to research. In this way the inventors have passed the problem of resolving intellectual property issues over to developing countries and public institutions to sort out themselves. In my opinion legal obscurities illustrated by this crop, requiring a lot of resources and efforts from the researchers' side to figure out, will often be the case with biotechnological innovations because they often have several patent owners involved. When trying to get an overview of the various Intellectual Property Rights and other patents that were used in order to develop the Golden rice, Ingo Potrykus was shocked by finding as many as 70 belonging to 32 different companies and universities (Potrykus 2001).

In line with what I would argue is a result of reductionist influence, scepticism has been raised regarding whether a simple measure such as Golden rice can solve problems that obviously are caused by a complex set of underlying factors. This means questioning the problem-identification. Has the problem-identification in this case been influenced by a reductionist way of seeing things? For instance critical voices argue that the problem is not only A vitamin deficiency, but often a lack of several minerals and vitamins at the same time (zinc, vitamin C and D, folate, riboflavin, selenium and calcium), and this problem is found in the context of poverty, environmental degradation, lack of public health and sanitation systems, lack of proper education and social disparity.

In the same manner it has also been argued that the problem of malnutrition is not linked to rice per se, but to the rice as it is produced in farming systems today with monocultures and high-yielding varieties, - a result from the Green Revolution's contribution to farmers' shift to one rice variety as their major crop. The increased rice production under the Green Revolution led to reduced prices and improved accessibility for the consumers, again leading to a one-sided diet. As opposed to solving the problem of A-vitamin deficiency by a GM rice variety, it has instead been suggested to meet the problem by increasing the nutritional security through increasing the diversity of crops. One contribution suggested is to promote more extensive use of kitchen gardening with crops such as green leafy vegetables. According to FAO, the contribution of such plants and systems in alleviating micronutrient deficiencies is greatly underappreciated (FAO 1996). Another suggestion is to a greater extent make use of the traditional integrated systems like for instance the rice-fish-duck-tree farming found in many Asian countries since they are seen as to provide superior energy-output (food, fuel wood and fodder) to the monoculture systems. In addition to ensuring a more nutritional diet and improved food security in general for individual households, such measures are believed to have positive impacts as to increase the use of local knowledge and practices and contribute to the strengthening of farmers' self-reliance.

5. CONCLUSIONS

The main topic of this paper has been to discuss some of the effects that introductions of agricultural technological solutions in the South may have. I have especially been interested in looking at how and to what extent particular agricultural technology introductions have been influenced by reductionist ideas, and whether this may be the explanation when technologies bring about unexpected problems. I have looked at the effects of technology transfers related to agriculture with specific consideration of the Green Revolution and gene technology. These two examples represent two different types of technologies, and they also reflect that they historically have been developed at different times influenced by attitudes and contexts of their particular time. There are however also some similarities.

Reductionism as an explanatory model is a fruitful approach when trying to understand the implications of the two types of technologies. Experience has shown that in general reductionism might be appropriate as a point of departure when trying to understand and explain some natural phenomena and processes. Agricultural technology introductions in the South, however, require analytical tools of a different character since they imply that one is facing contexts of complex ecological, socio-economic, political and cultural relations. Technologies influenced by reductionism may result in ignorance of the wider context when the phenomenon or causal relation given priority constitutes only a part, leading to unexpected and destructive impacts on nature and society (Pretty 1995, Peet and Watts 1996, Fowler 1994). In the cases referred to in this paper, influence of reductionism can sometimes be seen in the scientific representations of reality, and sometimes in the approaches aimed at solving a particular problem.

The overall goal of the Green Revolution has not been contested, - it was to increase cereal grain production in the South. There is no doubt that this goal was achieved when considering the strategically chosen Green Revolution areas. The Green Revolution also in a certain respect may be viewed as a contribution to conservation of the environment. The explanation is that without the intensification of agriculture and increase of production that the Green

Revolution brought about, much more uncultivated land would have been under cultivation today.

However, also negative effects of the Green Revolution have been observed. In what way may aspects of the Green Revolution be viewed as influenced by reductionism, and may some of these effects be a result of this influence? My opinion is that some of the effects can be directly or indirectly linked to the reductionist influence. One aspect of reductionism in the Green Revolution is that farming as a whole was reduced to monoculture. Another is that the purpose of production was reduced to cereal yield, neglecting other aspects such as i.e. cereal straws as animal fodder. Productivity was reduced to simple factors that were possible to manipulate: water and plant nutrition. Soil fertility was reduced to application of Phosphorus, Potassium and Nitrogen. Control with yield reducing factors was reduced to chemical control of certain insects and diseases.

Because the success of the Green Revolution technology has been based on inputs such as chemical fertilisers, pesticides and supplement of water there have been reported increased environmental problems related to pollution, salinisation etc. Probably the most serious environmental effect resulting from the spread of a farming system which has promoted a few crops in monocultures, is genetic erosion, with replacement of a diversity of local crop varieties and landraces with a few improved and/or exotic varieties and species. In addition to making individual farmers vulnerable in case of crop failures, loss of agricultural crop diversity is considered a serious problem for the world's future food security. Genetic diversity is regarded as a potential resource in case today's most commonly cultivated crops are insufficient or are damaged by diseases and/or pests, climate change etc.

In this paper I also ask whether gene technology application can be viewed as influenced by reductionist ideas, how gene technology is seen when compared to the Green Revolution, and whether similar and other impacts than experienced after the Green Revolution can be expected. Comparing aspects of the Green Revolution and gene technology is interesting since some researchers have a vision of a so-called 'New Green Revolution' where the negative effects of the Green Revolution are overcome and where gene technology is successfully integrated.

Some of the negative environmental effects experienced with the Green Revolution crops planted in monocultures are expected to be similar when GM crops are released. One issue is that GM crops planted so far also have been planted as monocrops with the risk of contributing to vulnerability of farmers in case of crop failures, resistance of pests because of evolution etc. However, from an environmental point of view, the type of GM crops that are created to resist insect attacks by integration of toxins that exist in nature are perceived as more environmentally friendly than the Green Revolution crops because they contribute to a reduction in pesticides application.

Even though the aims for the New Green Revolution are more in line with approaches that focus on integration, holism and diversity there seems to be a long way to go from the present usage of agricultural gene technology towards its contribution in fulfilling the objectives of a New Green Revolution. I argue in this paper that this may be because gene technology, as the Green Revolution, in several ways may be viewed as being informed by reductionist thinking. One aspect where the influence of reductionism can be seen is the way application of gene technology requires that one trait is given priority, thereby undermining other traits that may also be of importance to people. One example here is American farmers' shift to a GM maize variety developed primarily to reduce insect attacks. This shift has resulted in stagnation of maize yields for the first time in eight years. The explanation is that through the priority given to the plant's insect control characteristic, the yield characteristic has been underemphasised (Troyer 2004).

Problem-identification behind decisions on whether to apply GM crops or not, may also in some cases be viewed as influenced by reductionism. Examples presented in this paper are cases where problems caused by poverty are suggested solved by the introduction of one particular GM crop: improvement of South African cotton farmers' situation by introduction of Bt cotton, and limiting the problem of vitamin deficiency by promotion of a particular crop variety that contains vitamin A (Golden rice). Experience from South Africa shows that introduction of Bt cotton for smallholders in South Africa has neither been demand-driven, site specific, poverty-focused or environmental and institutionally sustainable (deGrassi 2003). Golden rice has not yet been applied, but many researchers are sceptic as to whether the limited objective of reducing A-vitamin deficiency will solve problems of general malnutrition seen in the context of a complex set of underlying factors such as monocropping, access to diverse food crops, environmental degradation, lack of public health and sanitation systems, lack of proper education etc.

Bt cotton and Golden rice as such thus represent cases where the solution has not been selected based on the problem, but rather the opposite: the solution has already been there before an area of application has been identified. In order to ensure that a specific crop and technology represents the most appropriate solution to improve small farmers' situation in a given context, it seems more fruitful to base the decisions on a more holistic livelihood situation analysis when identifying needs of technology introductions.

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