

Is the proliferation of genetically engineered crops a viable development policy in developing countries? An analysis of Bt cotton and its economic, social and environmental impact in India.

Genetik mühendisliđi yoluyla geliştirilen ürünlerin yaygınlaşması, gelişmekte olan ülkeler açısından yürütülebilir bir kalkınma politikası olabilir mi? Bt pamuk ve Hindistan'daki ekonomik, toplumsal ve çevresel etkisi üzerine bir çözümleme.

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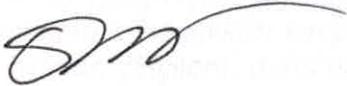
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ABSTRACT

Genetically engineered crops were commercialized in 1996 and have since spread across the largest agricultural producing countries in the world. They are heralded as the solution to economic underdevelopment, poverty, hunger and environmental degradation in developing countries; insect resistant and herbicide tolerant traits will allow farmers to grow more, at less risk and at less cost. This paper analyzes the effect of insect resistant Bt cotton in India and finds that the impacts on the economy, its farmers and their environment do not correlate with the promises made by the agricultural biotech companies that produce the seeds and the governments that approve them. This paper argues that whilst agricultural biotechnology works in a technical sense, there are many critical issues that need to be overcome to ensure that long-term social and environmental security are not sacrificed for short-sighted economic gain. Underdevelopment will not be solved by biotechnology alone; the right combination of national and international social, economic and political policies are at the heart of any viable development policy.

ÖZET

Genetik mühendisliği yoluyla geliştirilen ürünler, 1996'da ticarileştirilmiş olup, o günden bu yana, dünyanın en büyük tarım üreticisi ülkelerinde yaygınlaşmıştır. Söz konusu ürünler, gelişmekte olan ülkelerdeki ekonomik az gelişmişlik, yoksulluk, açlık ve çevre bozulmasına karşı bir çözüm olarak sunulmaktadır. Böceklere karşı dirençli ve ayırık otları için kullanılan ilaçlara karşı toleranslı ürünler, çiftçilere, daha az risk ve daha az maliyetle daha çok üretecekleri vaadinde bulunmaktadır. Bu çalışma, böceğe karşı dirençli Bt pamuğun Hindistan'daki sonuçlarını incelemekte ve ekonomi, çiftçiler ve çevreleri üzerindeki etkilerin, tohumları üreten tarımsal biyoteknoloji şirketleriyle bunları onaylayan hükümetler tarafından öne sürülen vaatlerle orantısız olduğunu tespit etmektedir. Çalışma, tarımsal biyoteknolojinin, teknik anlamda işleyen bir teknoloji olmakla birlikte, uzun vadeli toplumsal ve çevresel güvenliği kısa vadeli ekonomik kazançta feda etmemek bakımından aşılması gereken pek çok kritik sorun bulunduğunu savunmaktadır. Az gelişmişlik sorunu yalnızca biyoteknoloji marifetiyle çözülemez; yürütülebilir bir kalkınma politikasının odağında, ulusal ve uluslararası ölçekte, doğru bir toplumsal, ekonomik, ve siyasal politikalar bileşiminin yer alması gerekmektedir.

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TERMINOLOGY & ABBREVIATIONS

- Agri-biotech Agricultural biotechnology
- Bt Bacillus thuringiensis- soil bacterium
- CGIAR Consultative Group for International Agricultural Research
- CIMMYT Centro Internacional de Mejoramiento de Maiz y Trigo (International Maize and Wheat Improvement Center).
- FAO Food and Agriculture Organisation of the United Nations
- FDA Food and Drug Administration (USA)
- GE Genetically Engineered
- GEAC Genetic Engineering Approval Committee (India)
- GM Genetically Modified
- GMOs Genetically Modified Organisms
- HT Herbicide Tolerant
- IFPRI International Food Policy Research Institute (USA)
- IPRs International Property Rights
- IR Insecticide Resistant
- IRRI International Rice Research Center (Philippines)
- ODA Official Development Assistance
- RR RoundUp Ready
- TG Transgenic
- TRIPs Trade Related Aspects of International Property Rights
- UNDP United Nations Development Program
- USAID United States Agency for International Development
- USDA United States Department of Agriculture
- WTO World Trade Organisation

A: INTRODUCTION

Chapter 1. Introduction

a) A new solution to an old problem?

The overriding question of the 2008 World Development Report is what can agriculture do for development? In the light of 250 years of modern economic analysis it may seem like an unnecessary question given that it is generally recognized that no great leap of industrial development began without an agricultural revolution preceding it. It was true in England in the mid 18th Century, the USA and Japan in the 19th and in India and China, the rising powerhouse economies of the early 21st century. Agriculture nourishes growing populations, it provides employment and a livelihood for millions of rural households, it generates economic activity up and down the supply chain, creates value and wealth that feed into new industries, and generates foreign currency when traded. The fact that the question had to be asked at all demonstrates the nature of the policy neglect and underinvestment in agriculture in developing countries over the last thirty years. Whilst agriculture may only contribute 4% to world GDP this neglect is unacceptable given the fact that over 50% of the global population live in rural areas and 45% of the global labor force are employed in agriculture (World Development Report, 2008; FAO, 2009). In developing countries an average of two thirds of the rural population derive their livelihoods from agricultural activity, and it is among these people that the majority of the world's one billion hungry can be found. The neglect of rural populations because of urban bias has been the neglect of the root cause of underdevelopment.

In an attempt to redress this problem over the last few years, a new strategy has increasingly found support as the much needed rural focused answer to underdevelopment: agricultural biotechnology (agri-biotech). The genetic engineering of crops to resist certain pests, be tolerant to chemical herbicides, and grow in unsuitable arid or salty conditions have the technical ability to solve a plethora of rural and national challenges. This paper will analyze the performance of genetically engineered insect resistant cotton in India to try to determine how far agri-biotech can really be considered to be a viable development policy in developing countries. The pro-poor claims of the biotech companies will be compared to the Indian experience with genetically engineered Bt cotton, which it adopted in 2002, to

establish the true impact of the technology on the national economy, farmers, rural communities, and the environment. An analysis of India, which suffers from all the social and economic problems associated with underdevelopment, will help formulate a conclusion on whether genetically engineered crops really are a viable and sustainable method for tackling those problems.

The problem of underdevelopment

The three main dimensions of underdevelopment in rural communities are poverty, inequality and hunger. Economic growth alone is not enough to tackle these issues, a fact illustrated very clearly in China and India. These countries represent the second and fourth largest economies in the world and yet 36% and 75% of their respective populations live below \$2 a day; between them they account for over a third, nearly 400 million, of the world's hungry (Human Development Report 2009). The ongoing struggle, and arguable failure, to sufficiently redress these three issues through broad economic liberalization and the plethora of industrial development strategies that have been pursued in the past thirty years has led inexorably to a renewed focus on agriculture for development. Studies have shown that economic growth originating from agriculture, especially the small-holder sector, is at least twice as effective at benefiting the poor than growth from other sectors (FAO, 2009). This is because it helps the poorest in society not through trickle down improvements or services, but directly through reducing hunger and malnutrition, which have significant economic knock-on benefits on rural health and productivity. With the impetus created by the devastating effects of the global economic crisis of the past two years and corresponding dramatic spike in food prices in 2007-08, the World Bank and many developed economies have doubled the money they are putting into poor countries' farming and have encouraged developing economies to refocus their rural policies.

There are already one billion hungry people in the world and the prospect of a projected 3 billion extra mouths to feed by 2050 is daunting, particularly given that nearly all of that increase will come in the developing world where the worst poverty and inequality are already found. The Food and Agricultural Organization (FAO) (2009) estimates that to meet this demand, food production (net of food crops used for biofuels) will need to increase by 70%. However, this is set against a background of escalating environmental damage. Agriculture is by far the largest user of the dwindling supplies of global fresh water and also a major player in agro-chemical pollution, soil exhaustion, and climate change- contributing 30% of global Green House Gases. The world is now approaching its agricultural expansion

limits; millions of hectares of arable land are degraded, and untapped croplable lands are few and far between. To meet food requirements by mid-century 90% of total production increases will therefore need to come from increased yields and only 10% from land expansion (FAO, 2009). The only way to achieve this is through the development of higher yielding, more efficient and truly sustainable production practices. For development to be sustainable in the long-term agricultural production must increase, the question is how?

The solution?

In the last decade it is agricultural biotechnology (agri-biotech) that has increasingly been advocated as a new solution to both the problem of sustainable food production and the primary dimensions of rural underdevelopment. Proponents see genetically engineered (GE) and transgenic (TG) crops as the answer to both hunger and poverty but also to economic underdevelopment and agricultural degradation of the environment. Their line of reasoning is that new breeds of crops designed in a laboratory to grow in specific environments and to 'naturally' counter damaging diseases and pests will not only lead to greater yields, but will require less fertilizers, less pesticides and less irrigation, and thus will be environmentally sustainable as well as economically advantageous (Brookes & Barfoot, 2006, 2009; James, 2008). GE crops are supposed to be 'scale neutral' meaning that small farmers should benefit as much as large, tackling rural inequality. They should also provide a more sustainable source of food for the world's poor and allow them to exit the vicious cycle of poverty by engaging in non-agricultural activities to earn greater capital. Consequently, it is vehemently argued from many corners- political, economic and corporate- that the use of agricultural genetic engineering is the only way to feed the hungry and generate better incomes for poor farmers in developing countries. By tackling the three main tenets of underdevelopment, GE crops will provide the catalyst for national economic development. In short, genetic engineering is presented as *the* solution to global underdevelopment.

At the same time, there are equally virulent opponents to genetic engineering. These critics not only question the ethics of whether it is right to alter the genetic structure of the living kingdom, or through international property rights (IPR) claim ownership over the natural world, they also deny the ability of biotechnology to genuinely tackle malnutrition, poverty and inequality. Significant scientific evidence has been presented that suggests the process of genetic engineering is not only unreliable but also potentially harmful to human and animal consumers, as well as the environment (Ho, 2001; Rowell, 2003; Gala, 2005b). Unfortunately, the history of biotechnology in agriculture in the developing is not wholly

encouraging from either an ecological or economic point of view. Evidence from countries that embraced the high yielding varieties of the Green Revolution forty years ago have shown unsustainable practices contributing to *increasing* poverty and rural inequality in spite of food security.

Furthermore, the very nature of the agri-biotech industry, dominated by a handful of private corporate giants, and supported by the United States government and international trade system, has led many to question the true motives behind the promotion of technology that appears to put profits before development (Kumar, 2009; Robin, 2008). Ownership and control of the global food supply in too few hands and too few varieties of crops relied on worldwide are a threat to food security not a solution. Critics of agri-biotech maintain that as millions of people go to bed hungry each night in countries that are net-exporters of grains, it must be established whether, morality and safety aside, increased production alone is a viable policy for economic development (Sharma, 2003b, 2004b).

b) Methodology

The aim of this paper is to examine the actual performance of genetically engineered crops to determine whether they really are a viable tool for tackling underdevelopment. The wealth of literature, data, analysis and opinion on genetic engineering is so polarized that it is extremely difficult to establish an impartial opinion on the role agribiotech should play in the developing world. The majority of the literature is sponsored by one side or the other, each striving to prove scientifically, economically, politically and/ or environmentally that genetic engineering is either the ultimate solution to the developing world's most fundamental problems, or a Pandora's box of new and unpredictable consequences that will merely exacerbate those issues. The primary research focus will be on insect resistant Bt cotton in India, with some supporting evidence and analytical references from other crops and countries. In this paper I will examine the literature from both sides as well as use my own analysis of social and economic data to try to come to an impartial verdict on the long-term viability of genetic engineering in agriculture. This is a relevant and indeed critical study because of the size of the development challenges the world will face in the next fifty years, including demographic pressure, food insecurity and climate change. If, as is suggested agricultural biotechnology can be a panacea for the world's development problems then it must be pursued; alternatively, if it is merely a profit driven ruse by the agri-biotech

companies that will exacerbate those problems then it must be exposed as such and other solutions sought.

Focusing on one country has its limitations as there are significant differences in the situations and needs of developing countries around the world, and hence what they seek to gain from GE crops. In agriculture, the variance between and among developing economies is important; they not only cultivate and rely on different foods and cash crops but have widely differing social, economic and ecological environments, which all influence the viability GE crops. There are however strong reasons for choosing to focus on India: there are other developing countries that have a greater variety of genetically engineered (GE) crops, more important agricultural sectors, or a greater incidence of hunger, however few can offer such scope for analysis on such a wide variety of variables. India has so far only commercially approved one genetically engineered (GE) crop, therefore the direct impact of the technology on the economy, farmers and rural communities can be more easily isolated than in countries with multiple GE crops. Furthermore, India's 260 million agricultural workers make up nearly a quarter of the population and over half of the labor force, meaning nearly 60% of the country is dependent on agriculture. As a very rural country with one of the largest, poorest populations in the world, India is able to give a truly representative indication of how far agri-biotech can genuinely tackle the problems of the rural poor.

Furthermore, the potential of genetically engineered crops in India extends beyond the rural community. Whilst agriculture contributes over 17% to Indian GDP and constitutes 12% of the country's exports, it is the manufacturing sector, dominated by the cotton textiles industry that drives the economy (Ministry of Commerce, 2008; Indian Central Statistic Organization (CSO), 2009). The significance of cotton for manufacturing is another important reason for choosing to study the impact of GE crops in India as the impact of biotech cotton is felt above and beyond agricultural production.

There are also important social considerations for choosing India to study the impact of GE crops, not least its endemic poverty, with 171 million people living below the national poverty line of 356.3 Rupees per month (Indian National Institute of Rural Development, 2009).¹ This is the equivalent of only \$8 a month, well below the International Poverty line of \$1.25 a day, which the Millennium Development Goals estimates 42% of the population lives below (World Bank, 2009).² In spite of the dramatic economic growth India has experienced over the last few decades these problems are not receding; they are also

¹ National Poverty Line data from Development Statistics 2004-05, National Institute of Rural Development.

² Exchange rate in 2005: \$1 = 43.5861 INR from www.x-rates.com

complicated and exacerbated by the effects of severe ecological degradation that threatens the long-term sustainability of rural communities. The agri-biotech companies however seem to have promised that they can succeed where economic growth has not, and as one of largest, poorest, and hungriest nations in the world India potentially has a huge amount to gain from biotechnology in agriculture.

Nevertheless, I have chosen India not just because of the extent of the problems it faces but also because of its qualities. In the face of its problems India is also blessed with considerable natural resources, a vast number of diverse farmers with a history of utilizing the most modern technologies and well-established research institutions with respected and reliable agricultural ministries. India has prior experience of being at the forefront of agricultural biology during the Green Revolution, and is well aware of the dangers of unfettered technological adoption. If GE cannot succeed in a country, which in relation to other developing economies, has considerable infrastructural, political and economic backing as well as a beneficial social and ecological environment, how can it expected to be a success elsewhere?

Method

To come to an overall conclusion on whether GE can truly tackle fundamental rural development problems and contribute to sustainable economic growth I will analyze the contribution the technology has made to net economic and social growth at both a national and local level. There is no denying the ‘potential’ of genetic engineering, but all that can truthfully be done at this stage is to come to a conclusion based on the actual results and effects of GE crops on the ground. Without reducing what is a very complex argument to a black and white conclusion, I am aiming to try to remove some of the ‘ifs’ and ‘buts’ that abound in the literature and answer some relatively clear cut questions regarding the nature of GE’s impact on economic growth, poverty, inequality and the environment.

The data I focus is predominantly independent or officially provided to limit the bias inherent in much of the literature. It must however be noted that there are severe limitations to the statistics available, for example the lack of accurate estimates of the number of farmers that even grow GE crops. It is also important to highlight the fact that GE crops were only released for commercial cultivation in India in 2002, with certain data sets only complete up to a few years subsequent. This leaves a relatively short period of time to discern the economic and social impacts of the technology when realistically it may take decades rather than years to determine the full ramifications of GE crops. Consequently, alongside my

own analysis of the data I will also incorporate a review of the literature on each topic, which will enable me to examine the widest body of information available and thus come to a more accurate and impartial conclusion.

Biotechnology is an incredibly polarizing subject with virulent supporters both for and against. To get a true understanding of the nature of the debate it is important to understand something of the science involved, hence the first section of this paper will include an overview of the process of genetic engineering as well as a discussion of both the pro and con arguments. Subsequently I will give an overview of the Green Revolution in India, which is crucial to understanding the effect agricultural technology has already had in shaping the current social and economic conditions in rural India. The main section of the paper attempts to provide a concrete answer to the question of whether genetically engineered crops are a viable development policy for India. The argument is broken down into three thematic questions that will analyze the short-term economic effects of GE cotton, the medium-term socio-economic impact on adopting communities, and finally the long-term environmental consequences. Determining whether the impact of the commercialization of Bt cotton has been either predominantly positive or negative in each of these areas will enable me to come to a comprehensive conclusion on the overall potential of GE crops to drive economic development, tackle social problems and provide a sustainable agricultural future. To be a truly comprehensive analysis of the development potential of agricultural biotechnology, the conclusions of the primary analysis will be supplemented with a more qualitative assessment of the biotech industry as a whole. Hence the final section places crop biotechnology into the context of globalization and the power of multinational corporations to influence development within the current systems of international trade and regulations.

Chapter 2. What is agricultural biotechnology?

For centuries agriculture has progressed through the selective breeding of crops and animals. Increased productivity has been sought through traditional breeding methods to make plants and animals taller, stronger, faster growing, more nutritious and generally more efficient at meeting the needs of humans. Crop breeding entered a new phase in the mid twentieth century when modern scientific techniques allowed the development of novel, homogenous varieties of crops with very specific genetic qualities that enabled the production of significantly larger yields. The spread of these new technologies specifically in Mexico and South and East Asia in the 1960s and 1970s became known as the Green Revolution and has been attributed with bringing countries such as Mexico and India from the point of starvation to one of food security and self-sufficiency. Despite its notable success at the time, support for the Green Revolution has dwindled over the last twenty years as the boon of increased yields has been steadily undermined by ecological damage caused to soil, water supplies and ultimately crop yields by the intensive irrigation and overuse of chemical fertilizers and pesticides that the improved varieties required. Food security has since been juxtaposed with growing inequality and undiminished poverty. The world has come to experience a ‘paradox of plenty,’ in which the number of chronically impoverished and malnourished in the world is rising in spite of adequate aggregate food supplies and record harvests (Sharma, 2003b).

Nevertheless, the next phase of the Green Revolution, what has become known as the “Gene Revolution,” is attempting to tackle the same problems with what many see as essentially the same tools (Davies, 2003). Proponents of genetic modification and transgenic technology counter this assertion with the argument that genetically engineered crops that can grow in the most hostile environments, resist the most virulent pests and diseases, and consequently produce dramatically increased yields will feed the world’s starving poor and tackle its underlying rural problems in a way that the Green Revolution could not. The debate over genetic engineering (GE) is virulent to the point of violence: it divides scientists, politicians, economists and the public down the middle, with little room for establishing a middle ground. In the short history of the commercialization of GE crops (fourteen years), they have been invoked, accused and generally involved in venomous public smear campaigns, court cases, international trade disagreements, corporate monopoly and anti-trust liabilities, political and economic slanging matches and even used as political weaponry. A

sound knowledge of the actual science of genetic engineering is therefore essential to understanding the complex nature of the arguments for and against the use of the technology, and its implications on health, the environment and economic growth.

What are genetically engineered crops?

"Genetically modified" (GM), "genetically engineered" (GE), and "transgenic" (TG) are often used interchangeably although they do not actually mean exactly the same thing. A GM crop is one that has had its genetic material altered through any method, including conventional breeding. A GE crop is one that has been altered using techniques that permit the synthetic modification or transfer of genes to that organism. A transgenic crop is one that has been genetically engineered using a gene from an external source; one belonging to a different species or variety. Collectively GE and TG are called recombinant DNA technology (Natural Resources Canada, 2009). For the purpose of this paper I will use the terms GE and TG as opposed to GM as I believe that the terms 'engineering' and 'transgenic' more accurately represent the true nature of the scientific process involved in agri-biotech than does 'modification.'

Conventional breeding based on sexual reproduction only occurs between organisms of the same or closely related species, where entire sets of genes are paired together naturally. This method of breeding has been gradually improved over centuries to breed crops of better quality and improved yields. However, it is a lengthy and imprecise process, often taking many years and painstaking experimentation with hundreds of different varieties to get the right combination of genes to produce desired traits. Genetic engineering dramatically speeds up that process. By inserting, or splicing, a new gene into a plant or synthetically changing an organism's own genome to produce a desired characteristic, biotechnology essentially removes the need for plant 'breeding' for any kind of genetic evolution.

When a plant with the desired characteristic is identified, the specific gene that produces that trait is located and cut out of the plant's DNA. The gene is then attached to a carrier, or *vector*, which transports the foreign gene into the genome of the target organism—such as a cotton or soybean plant. The most common vectors are *plasmids*, small DNA molecules occurring in bacteria that can be exchanged between different cells under natural conditions. The foreign gene will not usually express itself (generate the desired characteristic) in its new environment without an artificial boost. This is supplied by fusing to the plasmids *promoters* from viruses or pathogenic bacteria, which 'switch-on' the new gene. (The Cauliflower Mosaic Virus is the most commonly used promoter in GE crops already

commercialized.) The gene package is then transferred into the plant being modified either by attaching it to tiny particles of gold or tungsten and firing it at high speed into the plant tissue; or by using natural soil bacterium as hosts through which the new genes can infiltrate when the bacteria infects the plant tissue. This modified plant tissue is then grown into whole plants that produce the seeds used to grow commercial GE crops. (Ho, 2001; UK Food Standards Agency, 2009; GMO-compass, 2009)

Genetic engineering does not necessarily involve the transfer of new genes; it can also involve changing how a gene works by 'switching it off' to stop a certain trait from expressing. For example, the gene for softening a fruit can be artificially switched off so that although the fruit ripens in the normal way, it will not soften too quickly. This has been used successfully in commercial GE tomatoes. Controlling the gene 'switch' can allow scientists to switch on genes only in certain parts of a plant, such as the leaves or roots. The genes that give a plant resistance to a pest, for example, might only be switched on in the bit of the plant that comes under attack such as the stem, and not in the part used for food.

Why genetically engineer crops?

The four primary biotech crops grown commercially are soybeans, corn (maize), cotton and canola (rapeseed), which account for 124.5 million hectares of the 125 million hectares total global biotech area (James, 2008). Of these, soybeans are the most prevalent, accounting for 53% of that area, followed by corn at 30%. The other important commercial GE crops include squash, papaya, alfalfa, tomatoes, sweet pepper, petunia, carnation and poplars. The two dominant traits of all these crops are herbicide tolerance (HT) and insect resistance (IR), with HT crops accounting for 63% of all global biotech planted hectares. Weeds, pests and disease are responsible for the loss of millions of tons of food crops every year, and the conventional inputs needed to try and stave off those losses (herbicides, pesticides, fertilizers) put huge pressure on farmers' resources and contribute to the degradation of their soils and water sources. The economic and environmental effects of these inputs combine to exacerbate the decline in rural livelihoods, food security, and economic development of the South. Consequently, genetically engineered crops that can mitigate these losses and reduce farmers' financial burden potentially offer a great opportunity for industrial and developing countries alike.

Excessive weed growth forces crops to compete for sunlight and nutrients, which not only hinders crop growth but also undermines the final quality of the yield. In modern agriculture weeds have been tackled by a combination of carefully selected herbicides, which

tackle individual weeds but do not harm crops. The main problem of this system is that a large variety and quantity of herbicides have to be used per crop, which damages the land and does not necessarily remove all the weeds. HT technology allows plants to be genetically engineered to enable them to degrade the active ingredient in herbicide hence rendering it harmless. This enables farmers to apply one powerful broad-spectrum herbicide, usually glyphosate based, which kills all weeds but is harmless to the crop. As a result weeds become easier to control, giving farmers more flexibility in when to spray their crops, less need for multiple applications, and can therefore significantly reduce input costs and energy use. HT technology also facilitates the practice of no-till techniques, which has proven to be just as efficient and more environmentally sustainable than conventional ploughing and sowing (GMO-compass, 2009; Brookes & Barfoot, 2006, 2009; FAO, 2009; Institute of Science in Society (I-SIS), 2003). Roundup Ready (RR), produced by Monsanto, is the most widely used HT technology and is common in soybeans, maize, canola and cotton.

Whereas developers of HT crops strive towards the use of broad-spectrum chemical inputs, insect resistant technology allows farmers to shift away from broad-spectrum pesticides that kill all insects, to more specified chemicals that only target the true pests. Insect attacks can devastate entire yields in both fields and storage silos, and every year destroys around 25% of food crops worldwide (GMO-Compass, 2009). This amounts to hundreds of millions of dollars of lost income across the globe, and is most devastating to the millions of poor farmers in developing countries who have no insurance and can least afford the loss. Whilst traditional pesticides can help mitigate the problem, they are costly and have chronic ecological effects. The majority of insects they affect are benign and even beneficial to crops, so destroying can have potentially serious economic knock-on effects. Bees, for example, play a direct or indirect role in pollinating 1 in 3 global food crops; their severe recent decline partly caused by pesticide use could have a serious impact on the foods we eat (van Englesdorp, 2008).

The GE solution to pesticide use is found in *Bacillus thuringiensis* (Bt), a soil bacterium that produces a protein toxic to certain types of insect. Through genetic engineering, Bt genes are inserted into plants such as cotton and corn so that they ‘naturally’ produce toxins that are poisonous to certain pests. A critical aspect of this process is the fact that Bt is naturally occurring and is therefore understood to be safe for humans; it is even used to control insects in organic agriculture. There are more than a hundred different variations of the Bt toxin with different insect specificity, making it a widely versatile trait that has the

potential to provide farmers with huge savings on chemical insecticides as well as being less damaging to the environment.

Agri-biotech is not restricted to just Herbicide Tolerant and Insect Resistant traits. Whilst these two have been the drivers of agri-biotech growth so far there are hundreds of different technologies, or events, being developed and in the testing and field-trial stage around the world. There are some commercially available virus resistance plants, such as Papayas and Squash, and fungus resistance varieties are the next likely to be commercialized. The scope of biotechnology is vast, with few limitations on what can be attempted in the lab: plants with “stacked traits” that will provide multiple advantageous properties in one seed; *Golden Rice*, rich in Beta-Carotene, promises to conquer malnutrition in Asia through improved vitamin-A consumption; trees that are able to remove toxic pollutants from the soil; maize that can survive droughts and tomatoes that can grow in saline water, all appear to present almost unbelievable opportunities to global farmers. The benefits theoretically on offer from GE crops are genuinely revolutionary. In a world with a steadily growing population, deteriorating soil and water resources and unpredictable climate change the prospects of what genetic engineering could bring to the developing world are obviously appealing.

Understanding the science of genetic engineering is vital to determining the viability of the technology for development. As opposed to most development strategies focusing on industrial policies or trade agreements, agricultural biotechnology is not just a policy, it is a process in which the reliability of the science itself is integral to its success. Like the debate over how to tackle climate change, competing scientific arguments are at the heart of the debate as to whether GE can drive development. There are extremists on both sides who either exaggerate the risks or who underestimate them (Victor and Runge, 2002). Agri-biotech, and how far it is reliable and indeed safe is far from established. It is not just politicians and economists, but well-respected scientists of the highest international caliber that still debate the very substance of what is being offered, and indeed what is already in commercial production. Unfortunately the science itself has been contaminated by the debate. The arguments for and against are so virulent, and what is at stake so important, that money and politics have corrupted the evidence. Both sides fund and promote research that backs their stance, and claim that the effects and impacts of GE ‘proved’ by the other side are false and manipulated. To come to a verdict on the viability of genetic engineering as a foundation for rural and national economic development we must first establish the true nature of the technology and its social, economic and environmental consequences.

An overview of the argument FOR genetically engineered crops

It goes without saying that within the pro camp there is little demonstrable doubt regarding the safety or reliability of transgenic biotechnology. Over 3,400 international scientists, including 25 Nobel Prize winners, have signed the “Declaration of Support of Agricultural Biotechnology” of the non-for-profit pro-biotech organization AgBioWorld, confirming their belief that “recombinant DNA techniques constitute powerful and safe means for the modification of organisms and can contribute substantially in enhancing quality of life by improving agriculture, health care, and the environment” (AgBioWorld, 2005:para 1). It is worth quoting directly in greater length as the declaration summarizes the pro-GE argument very succinctly:

Recombinant DNA techniques have already been used to develop 'environmentally-friendly' crop plants with traits that preserve yields and allow farmers to reduce their use of synthetic pesticides and herbicides. The next generation of products promises to provide even greater benefits to consumers, such as enhanced nutrition, healthier oils, enhanced vitamin content, longer shelf life and improved medicines... Through judicious deployment, biotechnology can also address environmental degradation, hunger, and poverty in the developing world by providing improved agricultural productivity and greater nutritional security. (AgBioWorld, 2005: para 4).

Brookes and Barfoot (2009) state that GE technology has had a “significant positive impact” on farm income amounting to over \$44 billion over the period 1996-2007. In 2007 alone the income benefit from biotech crops was \$10 billion, which is the equivalent of adding 4.4% to the value of production of the four major biotech crops. These benefits are gained from a combination of increased yields and improved crop quality, but predominantly from savings on the key production costs afforded by GE technologies: chemical inputs, fuel and labor costs, and crop protection. The rapid proliferation of agri-biotech in the last thirteen years is perhaps testament to its success, with 800 million hectares now planted by 13.3 million farmers in 25 countries, of which 15 are developing economies (James, 2008).

Supporters are keen to highlight the importance of biotech for development and subsequently stress the benefits to small farmers. James (2008) states that over 90% of producers using biotech crops are small and resource poor farmers in developing countries. After the United States the next three biggest producers of GE crops are all developing nations- Argentina, Brazil and India- in fact Canada is the only other industrial nation in the list of top ten biotech producers. Trigo and Cap (2003) suggest that the popularity of TGs in

Argentina, particularly soybeans, is down to the fact that they genuinely generate considerable cost savings and dramatic production gains due the synergy of biotech crops with no-till practices which allows farmers to double crop (plant wheat and soybeans on the same plot in one year). The expansion of soybean cultivation in Argentina is also seen as largely responsible for halting the long-term decline in agricultural employment. Using evidence from Latin America, South Africa and Asia, James cites augmented yields, decreased use of chemical inputs (and thus improved health and productivity) and increased profitability all resulting from the adoption of transgenic crops. Consequently, agri-biotech has improved quality of life and income for poor farming households and contributed to the alleviation of poverty. By increasing supply and decreasing the cost of production GE crops are also alleviating food insecurity by making produce more affordable.

Agri-biotech is positioned as the savior of not only the poor and hungry in developing nations but also of the environment. The diminution in pesticides and herbicides permitted by HT and IR varieties helps conserve soils and reduce carbon dioxide emissions, contributing to a significant decline in the global environmental impact of agriculture. Additionally, the prospect of drought-tolerant varieties is a potentially critical solution to escalating global water scarcity in a world where agriculture uses up 70% of fresh water supplies (James, 2008). If Genetic engineering can truly generate sustainable agricultural growth that benefits all farmers, fights poverty and hunger as well as being environmentally benign then it is not unreasonable to assume that it can be a fundamental driver of economic development.

An overview of the argument against genetically engineered crops

Within the GE debate there are not just a few sticking points on which there is disagreement, practically every single premise outlined above in support of agri-biotech is challenged by the other side. An open letter to all governments calling for “the immediate suspension of all environmental releases of GM crops and products, both commercially and in open field trials” has so far been signed by over 800 scientists from 84 countries, but has not yet gained much traction with biotech producing governments (I-SIS, 2000). Nonetheless, the stance of those scientists and economists against genetic engineering is as equally steadfast and scientifically based as their pro counterparts:

GM crops offer no benefits to farmers or consumers. Instead, many problems have been identified, including yield drag, increased herbicide use, erratic performance, and poor economic returns to farmers. GM crops also intensify corporate monopoly on food, which is driving family farmers to destitution, and preventing the essential shift to sustainable agriculture that can guarantee food security and health around the world... The hazards of GMOs to biodiversity and human and animal health are now acknowledged by sources within the UK and US Governments. (I-SIS, 2000: para 3).

Central to the anti GE stance is the issue of “substantial equivalence.” This is a legal concept invented by the biotech industry in the United States to claim that a genetically engineered crop is basically the same as a non-GE crop and therefore does not require any specific labeling or extraordinary testing to market it commercially. The acceptance of this fact has permitted the rapid dissemination of GE crops across the US and many developing countries, but has proved its sticking point in the EU where the assumption that producing food through recombinant DNA technology is completely safe is less acceptable (Lacey, 1999). Campaigners and scientists opposed to GE draw attention to the fact that the vast majority of research, testing and also approval of transgenic crops is done by the biotech companies themselves. It is generally acknowledged that there is insufficient evidence to support their safety given the dearth of peer-reviewed scientific studies that establish categorically the safety of GE food.

As outlined above, the basic tools of genetic engineering are bacteria, viruses and other genetic parasites that spread drug and anti-biotic resistance. Anti-GE geneticists argue that wedging foreign genetic material essentially at random into an organism’s genome necessarily causes some degree of disruption in what is a very delicate, complex and interdependent living system. Transgenics are a much more imprecise technology than biotech companies imply and we cannot predict the potential outcomes of the technology; introducing new genes into plants leads them to make proteins in different amounts and perhaps even new ways. There is no guarantee that the insertion of viruses (such as the cauliflower mosaic virus, which is very similar to the hepatitis B virus) could not potentially lead to a new genetic recombination in the plant itself, or in later processing or consumption (Anderson, Antonion & Cummins, 2006). This could create virulent new viruses that devastate crops, animals or humans.

The unreliability of the technology also presents a significant risk to the environment through potential contamination of non-GE and wild varieties. Two infamous cases have already highlighted this danger, as well as drawing attention to the ominous

stranglehold that the biotech corporations hold over the agriculture industry. The first was the case of Canadian farmer Percy Schmeister who was sued by Monsanto in 1998 after they discovered that his Canola crop, unbeknownst to the farmer, had been contaminated by their patented RR variety (Holdridge, 2004). Then, in 2001 Berkeley scientist Ignacio Chapela discovered that traditional corn varieties in remote areas of Mexico had been contaminated by genetically modified varieties (Quist & Chapela, 2001). These results were particularly disturbing given the almost sacred nature of corn in what is considered the origin of its domestication and site of enviable biodiversity. Chapela became a target of a venomous smear campaign to try and discredit him on both a scientific and personal front, which was later tracked back to Monsanto itself (Rowell, 2003). These two cases not only highlight the very real threat to biodiversity posed by genetic engineering, but more worryingly they demonstrate the power of the biotech corporations to determine the advance of the technology. There have even been accusations of corporate-government collusion to encourage WTO allow rules that enable corporations to engage in bio-piracy as well as force countries to accept GE imports through food aid even if it is against their will and national laws (Sharma, 2003a; Herrick, 2008).

The scientific, corporate and political costs of biotechnology are all finely balanced in determining whether, over all, genetic engineering could bring economic benefits and development to poor countries. There are strong questions about how far GE technology actually works: there is evidence of failed crops, limited yield gains at the expense of increased input costs and environmental costs (with broad-spectrum herbicides actually creating more problems than they solve), and consequently, suffering farmers. There is also a strong indication that the use of GE technology is compounding rural inequality not ameliorating it. The terms imposed on farmers who purchase GE seed locks them into contracts with biotech corporations, which put unbearable strains on their resources.

Underlying the whole debate surrounding genetically engineered crops and the fight against rural poverty and hunger is the argument that the availability of food is not the problem. Even in India, which in 2001 counted 320 million hungry people, there was a record 65 million tons of grain rotting in silos around the country; a picture repeated in Mexico and throughout South and East Asia (Sharma, 2004b). Amartya Sen (1976) brought attention to the difference between food supply and food access in the 1970s: hunger persists in the developing world in spite of adequate food supplies. It is therefore reasonable to doubt that increased production from GE crops will have any affect on global poverty and hunger.

The arguments for and against the adoption of agricultural biotech appear equally convincing, with both providing strong scientific and economic evidence for their stance. The situation of both industrialized and developing countries in both camps shows the power each side of the argument has to determine national policy. This polarization however, demonstrates how hard it is to come to any conclusive resolution on whether GE crops are essentially good or bad for development. The aim of this paper is to try and find the reality behind the rhetoric, promises and denials of the two sides. By focusing on the economic, social and environmental data rather than the literature to determine the true impact of Bt cotton in India, I will be able to formulate at the very least an impartial judgment on the viability of GE crops.

Chapter 3. The Green Revolution

In paragraph one of the conditions to be met by a recipient of the a Nobel Prize, it states that the prize shall be awarded to the person who, during the preceding year, “shall have conferred the greatest benefit on mankind.” Scientist Norman Borlaug was deemed to have fulfilled this criterion when he was awarded the peace prize in 1970 for his pioneering work in plant breeding technologies, which led to him being known as the father of the Green Revolution. In the presentation speech for his award the chairman of the Nobel committee explained their choice by saying that in providing the world with bread it was hoped that “bread would also give the world peace” (Lionaes, 1970). This sentiment is characteristic of the hope and expectation that surrounded the Green Revolution. The movement was seen as a means of providing starving nations with food security and staving off the genuinely held fear of an imminent Malthusian crisis. Furthermore, it was believed that food security would prove to be the first step in a total transformation of the economic situation of developing countries that would reduce poverty and inequality and fuel industrialization. Unfortunately, the fact that there is greater poverty and hunger in existence today clearly demonstrates that the Green Revolution did not fulfill its weighty expectations.

Background and politics

The Green Revolution is understood as the breakthrough in food production in Latin America and Asia (namely Mexico, India, Pakistan, China and the Philippines) resulting from the introduction of new high yielding varieties of rice and wheat, and the large-scale application of modern science and technology to agriculture in these developing nations. Since Borlaug’s award, debate has continued to rage around whether his achievements and what they helped create were ultimately a force for good. Borlaug and supporters of Green Revolution technologies believe that they saved the world from hunger, and without it, countries like India would never have been able to feed themselves and the natural world would have been worse off from over cultivation with inefficient traditional methods (Niazi, 2004). There is certainly no doubt that genuinely massive production gains were achieved through High Yielding Varieties (HYVs) and other Green Revolution technologies from the 1960s-80s. India and Mexico were the golden children of the movement as they experienced a shift from the brink of nationwide famine and mass grain import to grain self-sufficiency and even an export orientation in agriculture. Supporters highlight the improvements this brought to rural life; agricultural growth brought financial security along with food security as village

livelihoods and standards of living were transformed through better nutrition and the more material benefits of paved roads, electrification and water pumps (Baker & Jewitt, 2007).

Unfortunately the consequences were not all positive. Detractors criticize the methods used during this period as actually creating and compounding the very problems they sought to tackle. The Green Revolution is blamed for increased income inequality, maldistribution of assets, a worsening of absolute poverty, ecological degradation of soils and water sources and consequently can be seen as catalyst for social conflict (Shiva, 1991). Despite the hundreds of studies on the impacts of the Green Revolution, measuring its success is a complex undertaking as it can be simultaneously understood as both a scientific success and politico-economic failure.

The Green Revolution must be understood as an ideology as well as a technical program. Global politics are vital in understanding its rapid spread in certain countries of the South. After the Second World War there was a palpable fear in industrialized countries, especially the US, that the developing world was on the brink of a food crisis, which would give rise to political instability that would at worst push countries into communism (Wu & Butz, 2004). Accordingly, it was unquestioned among the developed nations at the time that greater food production was the key to political stability, prosperity and peace. Understandably, therefore the US was highly concerned with agriculture in and for the developing world, and American philanthropic organizations such as the Rockefeller and Ford foundations provided the backbone of early funding for Green Revolution technologies. These organizations offered substantial funds to dedicated scientists and researchers around the world for agricultural advances that could help feed the hungry. When the success of Borlaug in creating his high yielding and resilient wheat strains became public knowledge, there was a genuine belief that the race between food and population was over. Advocates at the time saw the new seeds as “engines of change” on the same scale as the steam engine during Western Europe’s industrial revolution (Brown, 1968:692). It was understood to be an “unparalleled opportunity to break the chains of rural poverty in important parts of the world” (Wharton, 1969:464).

There was still a strong belief at the time that food insecurity was principally a problem of inadequate production, therefore the US sponsored Green Revolution package was an easy sale in ideological terms. There were eager recipients among countries suffering severe food shortages due to a combination of rapid population growth and repeated harvest failures caused by inefficient production systems and droughts, and compounded by pest and disease epidemics. HYVs were seen as a simple remedy through which to solve the immediate

hunger problem and thence buy a few decades in which to tackle the root causes of underdevelopment (Niazi, 2004).

Brown (1968) acknowledged at the time that the political commitment of the top echelons in developing countries was essential to the spread of the Green Revolution. After its independence in 1947, India, for example, had seen substantial areas of agricultural production lost to the newly created states of Pakistan and Bangladesh; therefore its wholesale acceptance of the new technology is understandable. Dhanagare (1987) however, suggests that India's dire need led to an "over-enthusiastic" and "uncritical" acceptance of the new technology; it was an apparently easy way to deal with starving people immediately, without tackling the major sources of that hunger. He argues that with the promise of improved farm production came the belief that it would generate a new resource base and prove to be a launch pad for rural industrialization. Similarly, in Pakistan the economic growth promised and indeed achieved with HYVs in the early phase meant that the Green Revolution provided a politically painless answer to the problems of rural inequality without having to force land reforms that upset the *status quo* and alienated the political support of the rural elite (Niazi, 2004). The hope and expectation surrounding the new technologies in the 1960s notwithstanding, the environmental and health risks that are so prominent today were not such a concern at the time and NGOs not nearly as influential. The underlying arguments against the Green Revolution in the 1960s were perhaps understandably given considerably less political scrutiny than they would be given today (Wu & Butz, 2004).

What were the Green Revolution technologies?

For centuries farmers have been using conventional breeding techniques to create hybrids that best suit their needs and their environment, Borlaug's innovation made this process much more scientific and precise. He created a system of "shuttle breeding" during which he could grow two successive plantings in one year in different environments and thus speed up the breeding process. Consequently, he was able to halve the time in which he could grow and cross breed plants with desirably qualities. By spreading the plants over two separate environments he could also quickly establish which varieties performed best in both locations and could therefore create a wide adaptability to a range of variables. It was through this process that he developed the "high-yielding, daylight-insensitive varieties with a wide range of ecological adoption and a broad spectrum of disease resistance" that became synonymous with the Green Revolution (Borlaug in Hesser, 2006:54).

Farmers had traditionally been restricted to growing plants that were naturally adapted to their local soils and climatic conditions. What the Green Revolution managed to achieve was to create seeds that, with the right combination of inputs, could grow almost anywhere: in mountainous regions or low-lying, in wet climates or dry, in poor soil or rich, and in both winter and summer. Wheat developed in Mexico or rice bred in the Philippines could be exported to India or Pakistan and could effectively be grown more efficiently than conventional local breeds. The most important of these new characteristics, in both wheat and rice, was the reduction in height through the breeding of specific genes determining stature, what became known as dwarf varieties. These new varieties had a much greater grain to straw ratio, with 50% grain in contrast to 30% grain to 70% straw ratios of earlier cultivars (Davies, 2003). The significance of this was enormous for farmers in starving nations, whose yield potential per acre was almost doubled by virtue of the new seeds made available by their governments and agricultural research centers.

Other traits that helped to create the production revolution of the period included those in which genes were incorporated for ‘photoperiod insensitivity,’ most notably in rice seeds. This feature allowed planting at any time of year regardless of the amount of daylight. Together with the development of hybrids that reduced growth time, these new seeds permitted farmers to grow two or even three crops of rice per year on the same piece of land, dramatically increasing the yield from each plot. Other traits were subsequently tackled such as greater adaptability and yield stability in poorer growing conditions, as well as resistance to certain diseases or pests. The economic possibilities offered by the new varieties were seemingly endless as unprecedented yield increases not only improved nationwide rural nutrition but the entire domestic agricultural market place.

Achievements of the Green Revolution

With a big boost to the international agricultural research centers from the Rockefeller and Ford foundations, the new seeds quickly spread through Mexico and Asia. These public research institutions were at the heart of the Green Revolution. With their private foundation backers combined with government support the mood and motivation of the scientific progress was predominantly a humanitarian one. Organizations such as the International Maize and Wheat Improvement Center (CIMMYT) in Mexico, central to the success of Borlaug’s work, and the International Rice Research Institute (IRRI) in the Philippines, were not-for-profit entities which provided and promoted the seed multiplication infrastructures, distribution and extension systems that were crucial for the dissemination of

the new seeds (Davies, 2003). Peter Rosset and his colleagues (2000) suggest that by the 1970s the term “revolution” was well deserved; the new seeds (accompanied by the chemical inputs and irrigation systems necessary for their success), had replaced traditional farming practices for millions of farmers in developing countries. By the 1990s almost 75% of the rice sown in Asia were new hybrid varieties, and more than half the wheat in Latin America and South Asia. The success of the Green Revolution in terms of the ability of the science to generate increased yields was substantial (Table 3.1). World wheat production increased from 222.4 million Metric Tons (MT) in 1961 to 546.9 million in 1991. Rice production also more than doubled over the same period from 215.6 to 518.7 million MT, although what is most impressive is that during this time the area of rice harvested only increased by 17%, which means that the average rice yield increased by a staggering 71% (Davies, 2003).

Table 3.1

Yields of Green Revolution Crops in millions of Metric Tonnes (MT)

Year	Mexico			India			Pakistan			Philippines			World		
	Wheat	Rice	Maize	Wheat	Rice	Maize	Wheat	Rice	Maize	Wheat	Rice	Maize	Wheat	Rice	Maize
1961	1.4	-	6.2	10.9	53.5	4.3	3.8	1.7	35	-	3.9	1.3	222.4	215.6	205
1971	1.8	-	9.8	23.8	64.6	-	6.5	3.4	0.7	-	5.3	2	347.5	317.7	313.6
1981	3.2	0.7	14	36.3	79.8	6.9	11.5	5.1	0.9	-	7.9	3.3	449.6	410.1	446.8
1991	4.1	-	14.3	55.1	112	-	14.6	4.8	-	-	9.7	4.7	546.9	518.7	494.4
2001	3.3	-	20.1	69.7	139.9	-	19	5.8	-	-	13	4.5	589.7	597.5	615.5

Source: FAOSTAT

Thanks to the Green Revolution hundreds of millions of extra tons of staple food crops were harvested every year and throughout the latter half of the 20th century, food production generally managed to keep pace with rapid annual demographic growth throughout South and East Asia. A study by Kathleen Baker and Sarah Jewitt (2006) evaluating the impact of Green Revolution technologies over a 35 year period in Uttar Pradesh, part of India’s northern breadbasket, is one of numerous studies to have witnessed some of the subsequent positive effects on farming communities. The higher yields not only brought food security throughout the local population but consequently, financial security for many. Baker’s study of villages in 1970, repeated in 2005 found numerous changes that have contributed to improving the local socio-economic conditions, which most locals attribute to the increased wealth generated from higher yields. For example the heavy input requirements of the new seeds, particularly intensive irrigation, has led to the replacement of open wells with the more efficient and sanitary hand pumps. Other developments include the

electrification of villages and significant improvements in infrastructure such as paved roads to deal with new machinery and transport needs. Increased profits have made education more affordable, nutrition is better therefore general health has improved and even the poorest castes and landless have seen their situation improved. The larger towns have grown up with agricultural wealth providing jobs such as rickshaw pullers or sweepers in banks and hotels so even the poorest can afford to eat. Whilst it is certain that many factors have contributed to changing standards of living, it is also evident that to local people the majority of the changes were catalyzed by HYVs.

Niazi's (2004) study of Pakistan demonstrates the enduring power of Green Revolution ideology today as he outlines the impact the new technologies can have on national economic growth. As a predominantly agrarian economy, the dramatic increase in production in the farm sector boosted the manufacturing and services sector, contributing to very impressive national economic growth in the late 1970s and 80s. Pakistan was for a while the poster child of the Green Revolution: its agricultural growth drove rapid economic development becoming one of Asia's agricultural and economic leaders by the early 1980s.

The dark side of the Green Revolution

One of the major dangers of the Green Revolution legacy is that its productivity achievements are often still blindly presented as a solution to food insecurity and development problems today, even though further scrutiny of the long-term sustainability of the revolution actually provides a much less positive picture. There is no disputing the fact that HYVs helped millions of people in developing countries to avert starvation and contributed to national economic growth; these are not inconsiderable achievements. However, critics argue that in spite of this, the Green Revolution has actually exacerbated the very processes and problems it sought to tackle, and in the long term was both ecologically unsustainable and economically unviable (Rahul & Nellithanam, 1997). The huge steps in production have not ended hunger, rural unemployment or indeed poverty; there is considerable evidence to suggest that inequality of income and asset distribution in adopting countries has actually worsened since the 1960s. The benefits have not been evenly spread and it appears that both the technologies and the policies favored certain regions, crops and farmers over others. A large majority of modern commentators, including Borlaug, concur that the Green Revolution actually reached a peak in the mid 1980s in terms of production of food grains; since then it has leveled off or even declined as yields have become subject to increasing instability (Rahul & Nellithanam; Murgai, Ali & Yerlee 2001; Sharma 2000; Shiva 1991).

The new varieties are extremely costly in terms of inputs and require intensive irrigation and costly chemicals to reach their yield potential. The high cost of cereal technology in monetary terms called for substantial investments usually above the means of the majority of small and marginal farmers, meaning that the benefits of new varieties predominantly accrued to already wealthy farmers. The environmental costs of these inputs are even more substantial, particularly given that many of the ensuing problems were an anticipated consequence of HYVs, which have high water and nutrient demands. Consequently, instead of freeing the farmer from the constraints of nature, the new varieties generated a new ecological vulnerability by destabilizing soil and water supplies, reducing genetic diversity and hence providing a catalyst for underlying local and ethnic conflicts (Shiva 1991).

The first issue that must be understood to comprehend the scale and breadth of the social and environmental impacts of the Green Revolution is the degree of irrigation and chemical inputs required by the new varieties. Unlike modern transgenic crops, the HYV seeds themselves were relatively uncontroversial from a genetic point of view. The nature of the collateral that came with them however was ill understood by the majority of adopting governments and farmers at the time. Whilst HYVs could grow in much less hospitable soils and produce greatly increased yields, they needed the right inputs to do so. Green Revolution technology must therefore be understood not just as seeds, but as intensive irrigation (driven by electrical pumps), high doses of chemical fertilizers and pesticides and also the use of farm machinery such as threshing machines. Water is always the limiting factor when it comes to success in agriculture, and the proliferation of irrigation either through canals or tube-wells was central to the production achievements of HYVs (Rosset et al. 2000). It was irrigation that allowed for the production of rice in naturally dry areas traditionally inhospitable for its cultivation. Along with water, the new varieties were also particularly greedy for soil nutrients therefore required large doses of chemical fertilizers to supplement the micronutrients often in short supply on exhausted or marginal lands. Furthermore, the homogenous new breeds of crop were more vulnerable to devastating and increasingly widespread attacks from pests and disease, thus required further chemical inputs in the form of pesticides. The destructive consequences of Green Revolution HYVs and their inputs are still being felt today, not least the environmental damage but also the social issues that in the long-term have been exacerbated not reduced. The very problems that modern agricultural biotechnology is claiming to tackle today are the very ones created in that last great agricultural revolution.

Development impact

i) Inequality

The Green Revolution technologies were supposed to be scale neutral, meaning that with the same inputs small farmers should benefit as much as, or more than, large farmers. However, the sheer costs of these inputs meant that the development programme associated with HYVs was inherently biased towards richer farmers. The earliest adopters in the fertile lands of the Indian and Pakistani Punjab for example were the higher caste and highest social status groups, among which were the most influential farmers, with the largest landholdings and best access to resources (Baker & Jewitt 2007). Over time access to the technologies became broader but the cost of cultivation also rose; as farmers needed ever more fertilizers and pesticides to achieve the same results they received diminishing returns available for future investment (Ninan & Chandrashekar 1993). Irrigated water was more expensive for the poor than the rich on a per-acre basis because the former are generally more distant from canals and therefore dependent on tube-wells and the expensive electricity needed to draw ground water. (Whilst political necessities dictated that agrarian electricity be supplied free in India, original costs of installation, connection to the electricity board and maintenance of the electric pumps accrued to the farmers. If any problems of distribution arose the needs of the rich farmers were catered to on a priority basis [Rahul & Nellithanam 1997.]

Dhanagare (1987) and Niazi (2004) give strong evidence of how government policies in India and Pakistan perpetuated and worsened the inequality stemming from the Green Revolution. The agricultural bureaucracy tended to ignore the smaller farmers, believing that only the larger farms could contribute to increased production. Consequently, bigger subsidies and preferential credit were awarded to larger landholdings and richer farmers who could borrow more and hence invest, and accumulate more. Marginal farmers on the other hand became locked into perpetual and vicious cycles of debt as they had to constantly seek ever more expensive credit to finance the necessary equipment and chemicals. Shiva (1991) details the dramatic rise in suicides in rural areas which she attributes to the unsustainable debts incurred from buying fertilizers and pesticides required by HYVs. Parallel to the already extant orientation of the new technologies towards the rich, rapid population growth exacerbated rural inequalities. Severe land fragmentation particularly among small and marginal farmers, where family planning was limited, meant that smaller and smaller landholdings became increasingly worse off, with decreasing profits and escalating debts. Overall, whilst the poor may have been eating more, the gap between the

best and worse off in the rural economy widened dramatically after the 1960s as the Green Revolution compounded and exacerbated the socio-economic differences caused by uneven access to land and resources. The deterioration of the Gini coefficient of income inequality in Pakistan from 0.23 in 1979 to 0.41 in 1990 demonstrates this fact starkly (Niazi).

ii) Poverty

As Dhanagare (1987) outlines, the Green Revolution has actually had a contradictory impact on rural unemployment. Wages have risen as production has increased, and landless laborers can actually obtain more employment due to farmers' ability to grow two or three crops on their land in a year. However, the subsidies available to larger commercial producers mean that wealthy farmers have been encouraged and enabled to rely increasingly on labor-displacing mechanization and chemical inputs, which have replaced the traditional seasonal employment in labor intensive jobs such as leveling, sowing, planting, weeding and harvesting. Consequently, whilst the bottom line for the poorest rural laborers may have improved, the percentage of landless in each community has also risen substantially. The figures on population below the poverty line since the Green Revolution have remained worryingly high, with one in four small farmers (holding 2.5 - 5 acres) and one in five medium farmers (5 - 7.5 acres) living below the poverty line (Dhanagare). FAO figures show that despite the dramatic increases in production detailed above undernourishment is still rife: for the period 1990-2 the percentage of the total population classified as undernourished was 24% for India, 22% in Pakistan and 21% in the Philippines. In 2005 those figures were still 21%, 23% and 16% respectively. In South America, while food supplies per capita rose almost 8%, the number of hungry people increased by more than double that (Rosset et al. 2000). Among the largest of Green Revolution adopting countries only Mexico had fewer than 5% of its population undernourished by 1990.

Changing patterns of food crops and the health consequences of the Green Revolution have been both a cause and effect of increasing poverty. Whilst more food is being produced in India than ever before, the encouraged growth of cash crops for sale at market has adversely affected the nutritional levels of populations using the new technologies. Farmers have substituted growing a variety of food crops in traditional rotational practices intended for personal consumption with monocultures of HYVs destined for the market. Studies show that not only are HYVs inferior in nutritional terms, but rural populations are becoming less healthy because they are unable to afford the substitutes for the food crops they have

displaced (Rahul & Nellithanam 1997). Highly nutritious legumes, pulses and oilseeds are among the major casualties of the Green Revolution affecting both health and biodiversity.

In addition, dramatic increases in working injuries and deaths have also been attributed to the Green Revolution and the associated agrarian mechanization process across Asia. Machinery, particularly threshing machines, appeared with the start of the Green Revolution and helped make traditional systems obsolete. It also contributed to crippling unemployment not only by displacing labor, but also from the loss of limbs and thousands of deaths from excessive bleeding and tetanus acquired in using new machines. Chandan (1979) highlights the plight of tens of thousands of impoverished and uninsured workers who were pushed beyond their limits for overtime pay on large farms, working untrained on unlicensed machinery and often influenced by alcohol and drugs. Contrary to the positive impacts outline above, new seeds, new practices and substantial public support for the Green Revolution, not only failed to reduce rural poverty, but statistics strongly suggest that the entire package has merely succeeded in spreading “greater and greater immiseration and pauperization” (Dhanagare, 1987:142).

iii) Environment

Some of the most tangible and measurable impacts of the Green Revolution have been the environmental degradation it has caused, the most serious of which is the damage done to water systems and soils. The water needs of HYVs, particularly to irrigate rice grown in regions that are not naturally sufficiently wet, has led to the excessive withdrawal of ground water as deeper and deeper aquifers have been tapped. Electric pumps mean that water tables, which have built up over millions of years, have dropped off in the space of a few decades, often beyond the reach of deep tubes (Rahul & Nellithanam 1997). Sharma (2000) accuses the Green Revolution of “sucking the land dry” as even South Asia’s breadbasket of the Punjab and Pradesh regions have seen the natural fertility of their lands eroded due to increased soil salinity from the deterioration of tube-wells and water-logging in canal irrigated areas.

High doses of chemical fertilizers to meet the high nutrient demands of HYVs were another integral part of the Green Revolution, and unfortunately have had a similarly negative impact. When fertilizers are added the plants absorb extra nitrogen, phosphorus and potassium from the chemical compounds, but also absorb proportionately more than normal levels of other soil micro-nutrients, such as zinc, iron and manganese from the soil. These all have important roles to play not just in cultivation but also in the health and immune systems of the people that eat those crops (Shiva 1991). The extension of cultivation to marginal lands

and substitution of organic manures for chemical inputs has led to the 'mining' of micronutrients from the soil during the decades of increased HYV use, which has in turn led to farmers applying ever-increasing quantities of chemical fertilizers to obtain the same yields (Sharma 2000).

An underlying cause of the environmental damage precipitated by HYVs was the inefficient support system and education of farmers at the time. Poor farmers, for example, tend to use certain fertilizers whether they are right for their soils or not (Baker, 2006). Whereas large farmers tend to over fertilize, small farmers usually obtain their inputs from the larger farmers in exchange for work and implement them without guidelines and below the recommended levels, all of which is equally damaging to the soil. Exacerbating the damage done by fertilizers is that done by high levels of pesticides. Strong scientific evidence shows that more homogenous Green Revolution crops are much more susceptible to pests and diseases than traditional crops with broader genetic bases. To prevent devastating and widespread epidemics of disease and pest infestations the new varieties required an ever-increasing amount of chemical pesticides that degrade fragile soils. The combination of over irrigation and over use of chemical inputs means that intensively cultivated HYV areas such as the Punjab have seen their ground water contaminated due to the leeching of nitrates into the soil. The knock-on effects of which effect more than crop cultivation: nitrate contamination leads to algae that sucks oxygen from water killing fish and other aquatic life, and has been linked to human cancers, birth defects and methemoglobinemia, oxygen deprivation in babies.

The list of threats emanating from the publicized successes of the Green Revolution is extensive, and because those threats have often been indirect they have tended to be underestimated. The introduction of new varieties at the expense of local crops and traditional cultivation has led to the deterioration of genetic diversity, from which many fear increased ecological vulnerability (Brush, 1992). Shiva (1991) counts the cost of the Green Revolution in the Punjab to include the loss of 250,000 metric tons of pulse and oilseed production once central from Punjabi diets; 40 new insect pests and 12 new diseases in rice monocultures; 260,000 hectares of waterlogged fields; and over 3 million people affected by the flooding of the Bhakra dam built to service irrigation needs in the region. She also holds responsible the invisible ecological, political and cultural costs of the Green Revolution for the increasing social and ethnic conflict that grew up alongside the new crops. New scarcities have created fresh sources of conflict as ethnic and class structures were altered by the fight

for control over resources and access to profits, particularly evident in the mixed Hindu and Muslim regions of Pakistan and India.

iv) food security

The most widespread consequence of the destabilization of soil and water systems was the dramatic drop-off in production in the post Green Revolution period, from the mid-1980s onwards. Murgai and colleagues (2001) estimate that resource degradation in Pakistan lowered growth rates by 0.53% per year, and more than cancelled out the productivity enhancing contributions of technological change, education and infrastructure improvements. The study also suggests that government subsidies in both India and Pakistan were maintained well beyond the initial period when they might have been economically justifiable. Consequently, the promise of inexhaustible food supplies that can keep up with population growth has been proved to be a fantasy. Annual average growth rates for rice, wheat and maize during the period 1966-95 show that latterly, there has been a substantial drop off in productivity (Wu, 2004). At their peak, in the period 1976-85 rice was achieving growth rates of 5% per annum, wheat 7.5% and maize 5%. In the latter period however (1986-95), these rates dropped to 1.5%, 2% and 3.5% respectively. If the Green Revolution was unsustainable even from a production point of view, its major success, then its socio-economic as well as environmental viability were not just questionable, but possibly perilous in the long-term.

Lessons from the Green Revolution

Examining the case nearly forty years on, did Norman Borlaug benefit mankind? We cannot take away the significance of feeding millions of hungry people, but as time has gone on and initial production increases have diminished the doubts surrounding the cost effectiveness and sustainability of Green Revolution technology have begun to put the earlier yield increases and Borlaug's achievement into a less positive context. As Niazi (2004) argues, the Green Revolution can be seen as both a success and a failure at the same time. From a scientific point of view the cultivation of HYVs and dramatic increases in production they stimulated can be seen as a major success. The feeding of millions of starving people throughout Latin America and Asia is an achievement not to be derided. That achievement must however be mitigated by a broader social analysis. Unfortunately, the political and ecological impacts of the new technologies appear to outweigh the production gains. The main failure of the Green Revolution was that it failed to reach the developmental conclusion that increased production was meant to generate: Niazi sums the whole program up as a

“success of production and failure of distribution”. More food created neither more equality nor less poverty, it also proved to be environmentally unsustainable. The ongoing ecological damage created by Green Revolution processes is a clear demonstration that production increases cannot be sustained at the expense of the environment.

The challenge for the biotechnology revolution and new forms of agricultural technology is to heed the lessons of the Green Revolution. The technology itself might be scientifically strong, but the entire implementation package needs to equally sound. If similar technological policies are followed it is essential that the same political and economic mistakes be not repeated. Unfortunately, the rhetoric today is worryingly similar to that used forty years ago. Well meaning foundations and profit hungry agro-chemical companies both expound the potential benefits of production without detailing or examining all possible environmental and social consequences of uneven access and distribution. Genetic modification, just like HYVs, is not a policy in itself; it needs to be combined with other pertinent development strategies such as land reform, education and infrastructural improvements at the very least. Poverty and food insecurity after all, are not a problem of food availability, but of unequal access to food and food-producing resources.

If crops are to be developed with poor countries in mind, they must take into context the political and social environment as well as the natural one. The correct implementation of a wide-range of social and economic policies, combined with sustainable agricultural practices is required to make any agricultural development program a success. The Green Revolution essentially failed in Africa because it was not suited to its climatic, ecological or infrastructural circumstances (Wu & Butz 2004). Because of HYVs’ success elsewhere, adopters tried to push the technology in Africa regardless of the natural obstacles in the hope that nature would be defeated. The plight of Africa today demonstrates the failure of that policy. If the Gene Revolution is to succeed where its forerunner failed, the new technologies must be better tailored for local requirements and local success.

B: Bt COTTON IN INDIA

Chapter 4. Short term: impact on economic growth

The proponents of GE technology argue that after thirteen years of commercialization, biotech crops have provided substantial economic, environmental and welfare benefits to millions of small and resource-poor farmers around the world (Brookes & Barfoot, 2009; James, 2008). It has been estimated that the global net benefit of genetically engineered crops from their commercialization in 1996 until 2007 was over \$44 billion, \$10 billion of which were achieved in 2007 alone.³ Of this, \$6 billion was realized by developing countries. In a 2004 report the Council for Biotechnology Information (Runge & Ryan, 2004) proposed that if the spread of GE crops continued at its present rate then the GDP of adopting poor nations could increase by as much as two per cent by 2014. The well-publicized production accomplishments of biotech crops in developing countries have certainly lent weight to this suggestion. James (2008) states that genetically engineered Bt Cotton in India has increased yields by 31%, reduced insecticide applications by 39% and increased profitability by 88%, which in a country where cotton impacts the lives of over 50 million people, the potential economic benefits of biotechnology are substantial. Trigo and Cap (2003) state that the accumulated benefits from GE crops in Argentina in the first five years of commercialization was over \$5 billion from GE herbicide tolerant (HT) soybeans alone, wealth that would not have been created without biotechnology. The same authors concluded in 2006 that the release of HT soybeans may have contributed to the creation of almost one million jobs economy wide, reversing an almost century long decline in the number of agricultural workers. Furthermore, the assertion that agricultural biotechnology can drive economic development is seemingly supported by the World Bank's 2008 report, *Agriculture or Development*, which calls for a productivity revolution in small-holder farming; a call that has been interpreted by supporters of biotechnology as a vote of confidence for GE crops.

To test these assertions and establish how far agri-biotech can really contribute to national and state-level economic growth I will analyze the performance of genetically engineered pest resistant Bt cotton in India. Determining the extent to which one individual crop with a specific trait can really influence a trillion dollar economy that is dependent on a

³ Note for further discussion later in paper that between them, Monsanto and Syngenta, two of the world's largest agri-biotech companies and providers of GM seeds, saw a gross profit of nearly \$9bn in 2007. (\$4.58 for Syngenta, \$4.23 for Monsanto)

vast web of interacting and interdependent variables is a complex task at best. It is a task that is perhaps underestimated given the body of work that appears to testify rather straightforwardly to the economic benefits of GE crops. In this paper I will isolate three factors which I believe can provide a relatively accurate analysis of the impact of GE crops on the Indian economy: a) the extent to which Bt cotton has contributed to agricultural output and the sector's overall contribution to GDP; b) the evidence of positive knock-on effects of agricultural biotechnology on other domestic industries; c) the impact of GE crop cultivation on employment. Evidently, these are not the only indicators that could be used to assess the economic impact of modern crop technology, however they do provide a broad and accurate lens for analyzing the general health and growth of certain critical sectors. A thorough analysis of these issues should therefore lead to a reliable conclusion on whether the cultivation of GE crops can be considered to have positively contributed to India's overall economic performance.

a) Agricultural production, exports and GDP

India is the second largest producer and consumer of cotton in the world, second only to China having leapfrogged the USA in 2006/07. Over 2008/09 it produced 21% of the total global production of 23 million tonnes and consumed 17% (Karihaloo and Kumar, 2009). Despite having the largest number of cotton farmers in the world, estimated between 4 and 6 million depending on different sources, cotton was considered only a secondary crop in India until very recently. During the 19th century Indian cotton was one of the world's most valuable commodities but the decline of British rule and final withdrawal from India in 1947 was matched by the decline of the cotton industry. Only in 2004-05 did cotton again begin to be referred to as a 'principal crop' in agricultural data sets, demonstrating its revived significance in India agriculture. It has been suggested that the adoption of Bt cotton in 2002 was the catalyst for this revival, which has subsequently had a dramatic effect on the Indian economy.

It is clear from national statistics that the commercialization and production of Bt cotton has not had any revolutionary effect on the Indian economy. In 1990-91 agriculture accounted for 29% of Indian GDP, but has since steadily declined to contribute just over 17% in 2008-09 (at both current and constant prices); a decline not affected by the introduction of Bt cotton in 2002. (See Table 4.1). The share of agricultural exports to total national exports has witnessed a similar decline, falling from over 18% in 1990-91 to less than 11% in 2006-

07 (DGCI&S, 2008). Nevertheless, whilst agriculture's gross economic significance may be declining, the importance of cotton within agriculture has actually increased. After decreasing in the late 1990s the value of cotton production has increased every year since 2002. At constant (1999-00) prices the value of cotton as a share of total agricultural production value has increased to over 5%, its highest level since before 1970. (See Table 4.2).

Table 4.1

India gross agricultural revenue (millions Rupees) and as % of total GDP at Current prices

Year	Amount in Rupees (million)	contribution of Agriculture
1990-91	150,800.00	29.28%
1991-92	176,166.00	29.65%
1992-93	197,569.00	28.99%
1993-94	229,172.00	28.93%
1994-95	263,895.00	28.52%
1995-96	286,946.00	26.49%
1996-97	345,020.00	27.37%
1997-98	366,125.00	26.12%
1998-99	420,486.00	26.02%
1999-00	446,515.00	24.99%
2000-01	449,565.00	23.35%
2001-02	486,617.00	23.20%
2002-03	472,060.00	20.87%
2003-04	532,342.00	20.97%
2004-05	552,422.00	19.20%
2005-06	625,636.00	19.06%
2006-07	686,044.00	18.15%
2007-08	782,597.00	18.11%
2008-09	876,563.00	17.57%

Source: VMW Datacenter, 2010

Table 4.2

India gross value of cotton production (millions Rupees) and % share of agricultural output.

Year	At constant (1999-00) prices		At current prices	
	Value	% of agriculture	Value	% of agriculture
1970-71	5,062	2.72	742	4.01
1975-76	6,490	3.58	921	3.16
1980-81	6,817	2.99	1,768	3.58
1980-85	8,768	3.44	2,276	3.04
1990-91	9,851	3.28	5,019	3.68
1995-96	13,234	4.07	12,931	5.62
2000-01	9,184	2.46	9,626	2.58
2001-02	9,719	2.44	9,828	2.28
2002-03	8,572	2.40	9,288	2.40
2003-04	13,345	3.32	16,208	3.58
2004-05	16,532	4.15	16,799	3.67
2005-06	17,846	4.20	18,012	3.44
2006-07	21,959	4.97	23,782	4.14
2007-08	25,114	5.37	31,938	4.88

source: Centre for Monitoring Indian Economy (CMIE)

Whilst the performance and indeed contribution of cotton to total national export earnings has been distinctly variable over the past two decades, it is clear that since the introduction of Bt varieties in 2002 the share of cotton in agricultural exports has dramatically increased. In the late 1990s cotton was contributing less than 1% of agricultural exports, in 2003-04, the season after the commercialization of GE cotton, this contribution rose to 2.5%. In 2007-08 cotton exports accounted for over 10% of the total value of agricultural exports (Ministry of Agriculture, 2004, 2008). The value of cotton exports in 2007-08 was almost 8 billion rupees, the equivalent of adding US \$20 million to the national economy compared to the meager US \$126,000 contributed by cotton exports in 2002-03.⁴ By 2007-08 cotton alone accounted for over 1% of the total value of national exports for only the second time since 1990. (See Table 4.3; Figure 4.1). The value of this contribution could have been even greater were it not for the recent depression in world cotton prices. The downward pressure on world prices created by the increased proliferation of GE crops is a crucial factor to consider in the

⁴ Exchange rate in April 2008: US\$1 = 39.9668 INR (Retrieved from www.x-rates.com on 09/02/10)

assessment of the economic viability of their cultivation. This problem will be assessed in greater detail in the next chapter, but it is pertinent to keep in mind the possible negative effect on GDP of depreciating prices in a vital export commodity.

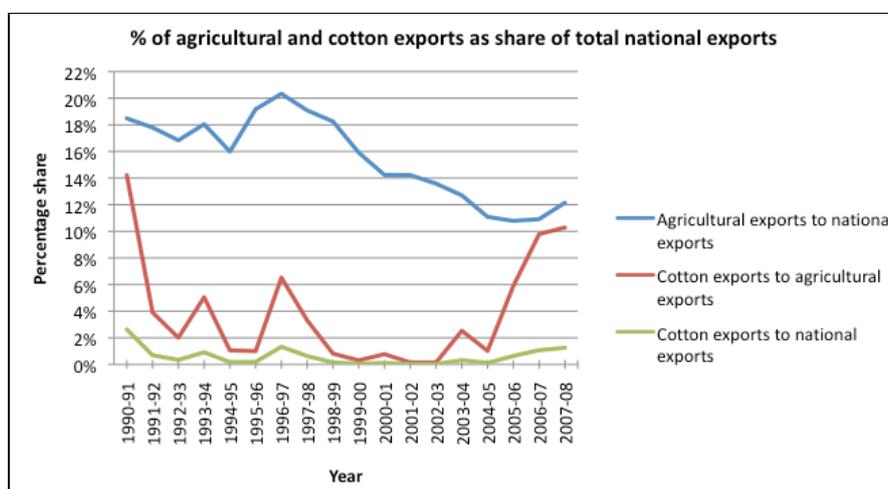
Table 4.3

India agricultural and cotton exports during 1990-91 to 2007-08 (millions Rupees)

Year	Total value cotton exports	Total value agricultural exports	Total value national exports
1990-91	85.47	601.28	3,252.73
1991-92	30.59	783.80	4,404.18
1992-93	18.18	904.03	5,368.83
1993-94	63.56	1,258.66	6,974.89
1994-95	13.98	1,322.28	8,267.34
1995-96	20.35	2,039.77	10,635.34
1996-97	157.45	2,416.13	11,881.73
1997-98	82.19	2,483.25	13,010.06
1998-99	20.69	2,551.06	13,975.18
1999-00	7.71	2,531.37	15,909.52
2000-01	22.11	2,865.74	20,135.65
2001-02	4.27	2,972.86	20,901.80
2002-03	5.03	3,465.39	25,513.73
2003-04	94.24	3,726.65	29,336.68
2004-05	42.26	4,160.27	37,533.95
2005-06	290.44	4,921.70	45,641.79
2006-07	610.78	6,241.14	57,177.93
2007-08	799.97	7,776.97	64,017.21

Source: Directorate of Economics & Statistics, Ministry of Agriculture. Statistics at a glance 2004, 2009.

Fig. 4.1



source: Directorate of Economics and Statistics, Ministry of Agriculture. 2004, 2009

The data clearly shows that since the introduction of the Bt gene the value of cotton for agricultural production and the national economy has increased. Furthermore, the rise of the commodity as a share of agricultural exports suggests that if cotton production had not increased in the last 8 years, then agriculture's relative decline may have been even

steeper, denoting a positive role for GE technology in the economy. This relationship must not be overstated though. The contribution of cotton to export earnings has actually varied significantly over the past two decades, with current exports still well below the 2.6% share they held of total national exports in 1990-91. Prodigious domestic consumption of cotton from the textiles industry, fluctuations in production due to weather, competition from other cotton-growing countries, and an unsteady export policy mean that the exportable surplus of cotton and ability to sell excess lint is widely variable and not dependent on production alone (Mahadevaiah, Ravi & Chengappa, 2005). Ergo, the small rise in the value of India's agricultural exports as a share of national exports over the past few years cannot simply be explained by the increase in cotton export value over the same period.

Bt cotton has had a positive impact on export earnings but the data cannot be taken in isolation and in no way provides a causal link between increased agricultural export earnings and the proliferation of Bt cotton. Agriculture is still a fundamental part of the economy without the cotton industry. Even though its contribution to GDP may be declining in percentage terms, in both current and constant prices the value of agriculture's contribution is rising appreciably year on year. Agriculture contributed over US \$200 billion to the economy in 2008-09, excluding the contribution of cotton export earnings, clearly demonstrating its ongoing critical role in the economy regardless of the introduction of genetically engineered cotton.

At the state level the same conclusions can be drawn. In India's nine principal cotton-growing states agriculture's contribution to Gross State Domestic Product (GSDP) has been declining along with, and in some cases faster than, the national rate.⁵ (see Appendix A for map of Indian cotton states). Only four states have experienced any increase in agriculture's contribution to GSDP, and only in Madhya Pradesh was this increase significant enough (5%) to suggest a possible causal link to the proliferation of biotech cotton. (See Table 4.4). Unfortunately for the biotech cause it must be acknowledged that even this result may be misleading as the seasons spanning 2002 and 2003 were affected by terrible droughts across India that all but devastated agricultural production in many regions (Tate, 2002; IFRC, 2002).

This is a crucial factor because 2002 was the year Bt cotton was introduced and therefore is used as the demarcation point in the data; the point to which results are measured before and after to analyze the effect of its introduction. Subsequently, because 2002 and 2003

⁵ India's 9 principal cotton states are Andhra Pradesh, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan and Tamil Nadu.

were drought years, production statistics that span those seasons must be treated with considerable caution. Low yields in 2002-2003 may mean that data sets ending then could show a greater decline in production up until the introduction of Bt cotton, than was really happening. Similarly, a sharper increase thereafter could also be misleading; results for 2004 seasons could in fact have been a return to normality rather than dramatically increased growth due to the proliferation of Bt cotton. To overcome the distorting effects of 2002-03 it is necessary to use a wider range of data to ascertain the true impact of Bt cotton on GDSP. Table 4.4 demonstrates that when data is analyzed over the whole period 1999-2008, all cotton growing states actually experienced an overall decline in the contribution of agriculture to GDP since the introduction of Bt cotton.

Table 4.4

India % Share of agriculture to Gross State Domestic Product at constant (1999-2000 prices)

State	1999-2000	2000-2001	2001-2002	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	Difference in agriculture contribution 1999-2000 to 2007-08#	Difference in agriculture contribution 1999-2000 to 2001-02*	Difference in agriculture contribution 2002-03* to 2007-08#
Andhra Pradesh	28.69%	30.08%	28.42%	25.39%	26.76%	26.32%	26.26%	24.56%	25.65%	-3.04%	-0.27%	0.26%
Gujarat	16.11%	14.99%	18.06%	15.56%	18.96%	16.19%	18.27%	15.97%	NA	-0.14%	1.95%	0.41%
Haryana	32.10%	31.05%	29.05%	27.31%	27.14%	25.83%	23.50%	21.42%	20.71%	-11.39%	-3.05%	-6.60%
Karnataka	27.36%	27.49%	23.69%	21.02%	17.64%	19.29%	11.76%	18.05%	17.81%	-9.55%	-3.68%	-3.21%
Madhya Pradesh	29.75%	23.57%	3.40%	23.03%	28.26%	26.21%	25.54%	28.12%	NA	-1.63%	-26.35%	5.09%
Maharashtra	15.70%	15.44%	15.94%	15.08%	14.91%	13.02%	12.71%	12.97%	NA	-2.73%	0.24%	-2.11%
Punjab	37.52%	36.61%	36.21%	34.79%	34.87%	33.50%	32.62%	31.21%	30.91%	-6.61%	-1.31%	-3.88%
Rajasthan	29.71%	28.46%	32.43%	23.94%	33.74%	29.83%	28.09%	25.40%	25.25%	-4.46%	2.72%	1.31%
Tamil Nadu	16.93%	16.83%	16.70%	13.23%	12.25%	12.80%	13.26%	13.99%	12.76%	-4.17%	-0.24%	-0.47%

Source : Central Statistical Organisation (CSO), New Delhi.

* 2002 and 2003 were severe drought years in India with wide-scale crop losses and low yields.

For states where 07-08 data is not available, the 06-07 data is used instead.

It would appear that the commercialization of Bt cotton has had a limited visible impact on state economies. Evidence from both the national and state level indicates that whilst cotton may be growing as an export commodity, its rise has not been so great as to stimulate any dramatic improvement in agriculture's contribution to GDP. Consequently, contrary to the rhetoric coming from supporters of agri-biotech, it is possible to say that the direct impact of GE crops on economic growth in India has been minimal. National economic development catalyzed by the proliferation of GE crops predicted by Runge and Ryan (2004) has not yet been realized in India.

b) Knock-on effects on other domestic industries

Textiles

The growth of cotton's contribution to agricultural exports shows that the value of the commodity within the farm sector has grown since 2002. Whilst not strong enough to stem agriculture's relative decline in relation to GDP at national or regional levels, there is evidence to suggest that cotton growth has had a positive effect on other sectors of the economy, notably India's critical textiles industry. Textiles is the second largest employer in India after agriculture; it employs over 35 million people (Ministry of Textiles, 2009) and provides a livelihood for between a further 16 million (Osakwe, 2009) to 30 million people (Kambhampati et al, 2005). Cotton accounts for almost 70% of the raw material mix of the industry, and hence textiles are heavily reliant on domestic agriculture (Agarwal, 2007; Kapasindia.com, 2010). At the other end of the supply chain there are many subsidiary industries who are in turn dependent on textiles: manufacturing machinery, accessories, dyes and chemicals, and retail stores among others. This means that including the estimated 4-6 million cotton farmers, the number of people in India whose livelihood is directly reliant on cotton is as many as 51.5 million.⁶ Consequently, if growth in the cotton textiles industry can be stimulated by GE cotton production has the potential to improve the livelihood of tens of millions of Indians. It also has the capability to dramatically impact the economy as a whole.

Textiles are at the heart of the Indian economy; the industry is the largest foreign exchange earner for India, generating 12% of export earnings. It currently accounts for over 14% of industrial production and 4% of GDP (Ministry of Textiles, 2009). In the six years before the introduction of Bt cotton mill consumption grew by less than 1% a year, but in the same time period after its introduction annual growth in consumption was almost 8%. (Table 4.5). A similar picture is visible in the individual cotton growing states, amongst which only Gujarat has witnessed a decline in cotton consumption since 2002. The others saw mill consumption growth of between 8% (Karnataka) and 56% (Andhra Pradesh) between 2002 and 2008 (Office of Textile Commissioner, 2010). (Table 4.6). The implication is that the introduction of Bt cotton has led to an increase in production that has directly stimulated mill consumption.

⁶ Maximum of 51.5 million is derived by calculating the total number of people dependent on textiles (35 million direct employees + 30 million further dependents= 65 million). If 70% of the textiles industry is cotton based then 70% of those 65 million people can be said to be reliant on cotton (c. 45.5 million people). Including up to 6 million cotton farmers it is possible that the upper limit of people reliant on cotton for their livelihood is 51.5 million. The lowest estimate is 39.7 million people, still a substantial number.

Table 4.5

Cotton Consumption by Indian cotton mills (million bales of 170kgs)

Year	consumption non SSI mills	consumption SSI mills	total consumption
1951-52	4.07		4.07
1961-62	5.69		5.69
1971-72	6.36		6.36
1980-81	7.66		7.66
1990-91	10.76		10.76
1995-96	13.83		13.83
1996-97	15.04	0.79	15.83
1997-98	14.32	0.65	14.98
1998-99	14.55	0.62	15.18
1999-00	15.06	0.84	15.90
2000-01	14.94	1.10	16.03
2001-02	14.70	1.17	15.87
2002-03	14.24	1.16	15.41
2003-04	15.04	1.30	16.34
2004-05	16.40	1.66	18.06
2005-06	18.01	2.00	20.01
2006-07	19.49	2.13	21.62
2007-08 (E)	20.30	2.30	22.60

Source: Cotton Advisory Board (20/01/10)

non SSI= Organized Sector Textile Mills

SSI= Small Scale Spinning Mills

E= estimate by Cotton Advisory Board

Table 4.6

State-wise Cotton consumption by textile Mills (million bales of 170 Kgs)

Year	Andhra Pradesh	Gujarat	Haryana	Karnataka	Madhya Pradesh	Maharashtra	Punjab	Rajasthan	Tamil Nadu	All India
2000-01	0.70	1.16	0.79	0.47	0.96	1.97	1.43	0.60	6.59	16.03
2001-02	0.66	1.34	0.89	0.47	0.80	1.85	1.37	0.53	6.73	15.87
2002-03	0.63	1.25	0.63	0.47	0.84	1.75	1.51	0.58	6.93	15.41
2003-04	0.73	1.17	0.55	0.41	0.86	1.60	1.56	0.56	6.83	16.34
2004-05	0.78	1.39	0.56	0.49	0.87	1.89	1.73	0.57	7.33	18.06
2005-06	0.84	1.44	0.81	0.51	0.93	1.78	2.06	0.74	8.27	20.01
2006-07	0.94	1.51	0.69	0.51	1.04	1.95	2.45	0.79	9.30	21.62
2007-08 (E)	0.99	1.20	0.74	0.51	1.08	1.99	2.76	0.85	9.76	22.60
total growth 02-03 to 07-08	56.37%	-3.96%	18.04%	8.48%	28.60%	13.86%	82.29%	46.53%	40.76%	46.71%

Source: Office of textile commissioner

Karihaloo and Kumar (2009) argue that this growth is evidence that the introduction of Bt Cotton has helped transform the industry by reducing problems of labor, machinery obsolescence and lack of raw materials. There is no doubt that there has been an unprecedented increase in cotton production since 2002. 29 million bales were produced in 2008-09 compared to just under 13 million in 2002-03, a dramatic increase compared to the average of only 9.7 million bales produced per year during the previous two decades (Cotton Corporation of India, 2010). (See Appendix B). Increased supply of cotton has certainly allowed mills to increase output, generating higher incomes from gins. Whether Bt cotton alone is responsible for the transformation of the textiles industry as a whole though is more debatable.

One of the paradoxes of the recent growth in cotton textiles is that whilst production has nearly tripled since 2002, exports have practically halved. The percentage

share of textiles exports to national exports was relatively steady at around 28% throughout the 1990s but in 2001-02 this share began to drop off rapidly, reaching a low of 13.5% in 2007-08. (Table 4.7) The primary cause of this appears to be the termination of the Multi-Fiber Arrangement (MFA), which had governed world trade in textiles and imposed quotas on the amount developing countries could export to industrial countries since 1974. In the ten years during which the arrangement was phased out the Indian government invested considerable sums in the industry and therefore had a relatively modernized textiles sector even before 2002 (Kambhampati et al., 2005). When the MFA regime finally ended at the end of 2004 India was supposed to be one of the principal beneficiaries of the throwing open of western markets. The reality though was the opposite, with textile exports entering a period of relative decline (Tewari, 2005). Fortunately this has not been too damaging for the economy as despite real declines, the relative dollar value of textile and apparel exports has increased. Furthermore, as the world's second largest cotton consumer it appears that the domestic market has subsequently become more important for the economy than the foreign.

The fact that the industry has still been able to expand to such an extent, and absorb this dramatically increased production is testament to the government's investment and modernization of the industry in the run up to the end of the MFA and since. \$25 billion was invested in textiles in the years 2004-07 alone (Kambhampati). The downside of this is that the shift in orientation of the industry means that it is hard to estimate exactly how far Bt cotton has contributed to the changes. There is no doubt that the industry has greatly benefitted from increased production, but it is also somewhat fortuitous that the phasing out of the MFA induced the government to invest heavily in the industry and hence put it in a position in which it was able to take advantage of this unpredicted windfall from genetically engineered cotton. Without this unplanned and unforeseen combination of events it is unlikely that the domestic market would have been able to absorb the excess production generated by Bt cotton. Crop biotechnology has therefore had a beneficial effect on the textiles industry in India, but this is as a result of a combination of coinciding factors and not just the consequence of the technical ability of the crop to produce larger yields.

Table 4.7

India's Textile Exports 1990-91 to 2007-08 (Millions Rupees)

Year	Total National Imports	Total National Exports	Textile Exports	% of Textile Exports to Total National Exports
1990-91	43,170.82	32,527.28	NA	NA
1991-92	47,850.84	44,041.81	12,470.80	28.32%
1992-93	63,374.52	53,688.26	15,483.60	28.84%
1993-94	73,101.01	69,748.85	18,816.70	26.98%
1994-95	89,970.70	82,673.40	23,701.30	28.67%
1995-96	122,678.14	106,353.35	28,520.40	26.82%
1996-97	138,919.88	118,817.32	33,920.20	28.55%
1997-98	154,176.29	130,100.64	36,412.10	27.99%
1998-99	178,331.69	139,751.77	40,171.57	28.74%
1999-00	215,528.53	159,095.20	45,536.11	28.62%
2000-01	228,306.64	201,356.45	54,797.84	27.21%
2001-02	245,199.72	209,017.97	51,337.34	24.56%
2002-03	297,205.87	255,137.28	60,071.70	23.54%
2003-04	359,107.66	293,366.75	62,017.31	21.14%
2004-05	501,064.54	375,339.53	63,024.18	16.79%
2005-06	660,408.90	456,417.86	77,567.47	16.99%
2006-07	840,506.31	571,779.28	86,702.65	15.16%
2007-08(P)	964,849.76	640,172.14	86,410.66	13.50%

Source : DGCIS, Ministry of Commerce, Kolkata.

P Provisional

Other industries

Beyond textiles, Kambhampati and his colleagues (2005) look at the impact of the introduction of Bt varieties up and downstream in the cotton supply chain, and sees both sides benefiting. From the seed and input suppliers on one side to the spinners and clothing companies on the other, there have been many opportunities to take advantage of Bt cotton. US agri-biotech behemoth Monsanto is essentially the 'owner' of the Bt gene and acquires the lion's share of the royalties from the significant cost of Bt seeds, although some domestic companies have also benefitted. The Indian Maharashtra Seed Company (Mahyco) for example, works in a 50/50 partnership with Monsanto in India and has profited considerably from the proliferation of GE cotton. James (2007) estimates that the Indian biotech and seed industry grew ten-fold between 2002 and 2007 to over US \$225 million. Since 2002, 35 seed companies have released over 600 Bt hybrids for commercial cultivation, and six new centers for plant molecular and genetic studies have been established by the Indian Department of Biotechnology.

India is lucky to have a large and vibrant network of both public and private agricultural research centers and universities, which have benefited from the race to develop GE crops (Karihaloo & Kumar, 2009). Nevertheless, despite some domestic growth in India the power of the multinational agri-biotech companies has tended limit the opportunities for gain among private seed companies in developing countries and has all but squeezed out public entrepreneurship. Whilst Mahyco is an example of a successful domestic seed

company it is also an illustration of how national seed producers and input suppliers often end up aligning themselves with the large multinationals such as Monsanto and Syngenta simply in order to survive (Kambhampati et al). Those that fail to grow with the changing face of crop cultivation, such as small-scale seed providers and badly funded research centers, are simply squeezed out when they fail to either keep up with or latch on to the multinationals. The biotech industry monopoly will be discussed in more detail in chapter 7.

It is clear that some companies and industries have been able to take advantage of the spread of Bt cotton, but it is equally true that others have not only failed to benefit, but have actually been ruined. Textiles is an obvious example of a winner, but even within that industry the incidence of ‘sickness’ and closure of units in the organized sector is a matter of concern as small units have lost ground to more efficient and cost-effective power looms in the decentralized sector (Ministry of Textiles, 2009). Many of the small mills and village spinners that sprung up in the 1990s have also been losing out as they fail to operate to capacity or cope with higher costs (Dave, 2008). Even in businesses that are well placed to directly benefit from increased cotton production, the spread of Bt cotton is no guarantee of survival, let alone success.

c) Employment

Textiles

One undeniably positive outcome of the expansion of Indian textiles is increased employment in the industry as mills have been built, expanded or reinvigorated with increased consumption. In the relatively small organized textiles sector in India, which accounts for only about 1/7th of the total number of people estimated to be directly employed in textiles, the employment rate has witnessed considerable growth since the introduction of Bt cotton. The annual growth rate of employment has been over 4.5% since 2002 compared to only 3.3% in the seven years previous. (Table 4.8). There are roughly 35 million people directly employed in the textiles industry, so if this same growth rate is replicated across the unorganized sector then Bt cotton could indeed be responsible for the creation of millions of jobs. In its latest five-year plan (2007-12) the Indian government estimates that the continued rise in cotton production, combined with simultaneous investments in textiles, will create a further 17 million jobs. If textiles continue to grow as expected then any increased production brought about by Bt cotton will be a boon for employment in that industry.

Table 4.8

India Employment in Organised Textiles sector

Year	Number of workers
1993-94	3,207,383
1994-95	3,320,123
1995-96	3,431,143
1996-97	3,539,610
1997-98	3,835,995
1998-99	3,997,785
1999-00	4,074,633
2000-01	4,153,875
2001-02	4,165,083
2002-03	4,231,843
2003-04	4,592,140
2004-05	4,757,830
2005-06	4,859,730
2006-07	4,975,770
2007-08	5,265,925
2008-09	5,513,380

Source: Office of Textiles Commissioner, 2010

Nonetheless, there is an important proviso that must be kept in mind in relation to employment: as the last two years have demonstrated, no increase in cotton production can overcome the impact of a severe economic downturn. The economic crisis of 2007-2008 has had a severe effect on the Indian economy; industrial production has dwindled and millions of people across the country have slipped into poverty as unemployment has increased and food prices spiked (Aziz, 2009). The textiles industry, like all others, does not act independently and has been badly affected by the downturn. Cotton fabric output has shrunk to its lowest rate in four years and apparel exports have contracted by 10%, all of which has resulted in the loss of tens of millions of dollars and hundreds of thousands of jobs across the industry (Kinetz, 2009; Tyagi, 2009). The current economic situation is a timely reminder that Bt cotton can boost employment in textiles when the industry is thriving, but GE crop yields can do little for the economy when industrial output is at the mercy of the world economic climate.

Agriculture

In agriculture itself it is slightly more difficult to determine the effect of Bt cotton on employment. Since the introduction of biotech the area under cotton has increased from 7.8 million to 9.4 million hectares, which would imply a significant increase in jobs available for cultivators and laborers. It is likely that increased yields and the promise of higher profits from Bt cotton have encouraged farmers to grow cotton over other crops. The argument that larger harvests with Bt cotton means greater employment is certainly advocated by GE proponents (Subramanian & Qaim, 2009). However, despite a real increase in the area under

cotton, cotton's share of gross cropped area in India has remained stagnant at roughly 4.5 %, the level it has been at since 1996-97 (Ministry of Agriculture, 2007).⁷ The expansion of cotton is therefore in line with that of other crops meaning that any increased employment in cotton is just as likely to be the result of overall increases in cultivation as it is the result of the arrival of Bt varieties. The fact that cotton was grown on over 9 million hectares twice before in the mid 1990s supports this argument. Furthermore, the variance in the estimated number of cotton workers, between 4 and 6 million depending on the source, makes it difficult to determine whether Bt cotton has had any sizeable impact on employment in cotton farming, let alone agricultural employment as a whole. In a country the size of India, with a rural population of over 740 million there are inherent difficulties in obtaining accurate employment statistics. Given that the last national census was in 2001 it is not possible to give a realistic estimate on Bt cotton's impact on gross agricultural employment.

Despite impressive growth in the Indian economy as a whole over the past decade and reduced demographic pressure as population growth has slowed, it is generally understood that agricultural employment has stagnated (Jha, 2006). The steady rise in the number of landless laborers in relation to cultivators is evidence of this as it reveals the intense pressure on land; the scope for employment in agriculture diminishes as cultivatable land approaches total saturation. (Table 4.9). Whilst there are more agricultural workers than ever before the capacity for absorption of labor is decreasing no matter how successful the crops themselves may be. Success in cotton growing, as with all crops, is reliant on optimal biological and environmental factors, such as the right soil and favorable climatic conditions. Due to these limitations there is obviously a natural limit to the expansion of any given crop regardless of the quality of the seeds. Genetic engineering is attempting to overcome some of these natural barriers through the creation of crops that can grow in salty or arid conditions and other less than optimal environments, however Bt cotton is engineered to resist pests, not to enable it to grow all over India. Therefore it is still limited by its environmental requirements as well as the demand from the textiles industry.

It is most likely that Bt cotton's greatest contribution to agricultural workers will be from the wealth it can generate among existing farmers rather than through a dramatic increase in the number of new cultivators. This appears likely given the suggestion that the adoption of Bt cotton actually reduces the number of laborers needed because reduced pesticide applications saves some of the labor involved in pest scouting and spraying

⁷ In 2005-06 cereals made up 52% of gross cropped area, pulses 12%, oil seeds 16%, fruits and vegetables 5%.

(Subramanian & Qaim). The most significant impact Bt cotton will have on employment will therefore be in facilitating the expansion of the textiles industry rather than in agriculture itself. That the greatest benefits of Bt cotton appear to be accruing to the industrial sector rather than the primary is arguably highly desirable from a development point of view. Developing countries are seeking to make their agricultural sectors more efficient, not gain more farmers, therefore if labor saved in cotton production can be reallocated to other non-agricultural activities rural families stand to earn more. It is generally accepted that greater economic growth will occur as farming becomes more efficient and less labor intensive, thus freeing up labor to enter into manufacturing and service industries, which generate more wealth and drive economic growth. If the introduction of Bt cotton facilitates this process by turning the rural labor force into textiles workers and not agricultural laborers, then biotechnology could indeed be said to be driving economic development.

Table 4.9.

Population and Agricultural Workers (Millions)

Year	Total Population	Average annual growth rate (%)	Rural Population	Non-Agricultural rural workers	Agricultural Workers		
					Cultivators	Agricultural Laborers	Total
1951	361.1	1.25	298.6	42.8	69.9 (71.9%)	27.3 (28.1%)	97.2 (100%)
1961	439.2	1.96	360.3	57.6	99.6 (76.0%)	31.5 (24.0%)	131.1 (100%)
1971	548.2	2.22	439.0	54.7	78.2 (62.2%)	47.5 (37.8%)	125.7 (100%)
1981	683.3	2.20	523.9	96.6	92.5 (62.5%)	55.5 (37.5%)	148.0 (100%)
1991	846.4	2.14	628.9	NA	110.7 (59.7%)	74.6 (40.3%)	185.3 (100%)
2001	1,028.7	1.95	742.6	NA	127.3 (54.4%)	106.8 (45.6%)	234.1 (100%)

Source: Registrar General of India, New Delhi, 2002.

Chapter 5. Medium term: socio-economic effects

The experience of Bt cotton in India demonstrates that the cultivation of genetically engineered crops can contribute to national economic growth in the short term if they are introduced with the right combination of policies and feed into critical areas of the economy. Bt cotton has contributed to economic growth in India through increased exports of raw cotton and as a critical input to the textiles industry. Nevertheless, increased production has not been enough to dramatically effect agriculture's gross economic contribution, enhance the relative value of agricultural production, or boost rural employment. It is therefore not immediately evident how far cotton farmers, their families and the communities in which cotton is grown actually benefit from the new technology.

Genuine economic development will not simply be a product of increased GDP. There must also be evidence that the millions of small-holder farmers that grow transgenic crops are also benefiting so that development can be driven from the bottom up and not rely on trickle down. GE crops must not only produce more than traditional hybrids, they also need to be more economical to grow and hence more profitable. At the end of the day, the household economic impact and social benefits provided by biotechnology are much more important for farmers and rural communities than export gains. Analyzing the socio-economic impact of Bt cotton on Indian farmers can thus give a strong indication of the medium to long-term viability of cultivating GE crops.

In 2008 there were an estimated 13.3 million cultivators growing biotech crops globally. Over 90% of these are small or resource poor farmers from developing countries, who themselves are overwhelmingly made up of Bt cotton farmers; 7 million in China and a further 5 million in India. GE advocates claim that the millions of cotton farmers in India are reaping economic, environmental and welfare rewards with higher incomes from increased yields and lower production costs. They also suggest that communities where the adoption of Bt cotton is high are healthier, have better infrastructure and social services, and greater access to markets, health resources and education (Morse, Bennet & Ismael, 2004, 2007; Sadashivappa & Qaim, 2009; Qaim, Subramanian, Naik & Zilberman, 2006; Monsanto, 2007; James, 2008). An abundance of studies present a wide range of evidence touting the advantages of planting Bt cotton over conventional varieties, claiming yield increases of up to 80%, pesticide reductions of up to 50% and net economic advantages of over 150% in monetary terms.

Nevertheless, there has also been considerable criticism of a large number of the studies purporting to have evidence of the overwhelming advantages of GE crops over traditional varieties. Dominic Glover (2009) highlights the methodological and presentational flaws in many of these studies, which have distorted the picture of both the performance of GE crops and their impacts on small-holder farming. Scientific analysis of GE crops carried out by the biotech companies and the development rhetoric that comes with it is not enough to justify the claim that Bt crops help poor farmers. It is arguable that if development were a technical problem, it would have been solved a long time ago. As the story of the Green Revolution clearly illustrates, increased production statistics do not tell the whole story; whilst some Indian farmers have no doubt benefited from the introduction of Bt cotton, others have not. This chapter will provide an independent analysis of the actual impact of Bt cotton on farmers across India, examining exactly how the crop has affected domestic producers. The analysis is divided into three sections that give a different insight into the development potential of Bt cotton: a) yield increases and sustainability, b) economy of production and profitability of growing Bt instead of conventional varieties, and c) community and social advantages gained from adopting Bt varieties. To say that farmers are genuinely benefitting from GE crops, indicators such as these must prove that their own private economic and social situations are improving, regardless of what is happening at a gross national economic level.

a) Yield increases and yield sustainability

India accounts for 25% of the global cotton area, cultivated by 5-6 million farmers, yet its average yield is among the world's lowest. In 2007-08 Indian cotton yields averaged 467 kilogram(kg)/hectare(ha), 300kg/ha lower than the world average, and barely a quarter of the yields averaged in Australia (International Cotton Advisory Committee [ICAC], 2008). Nearly 70% of cotton farmers in India are small or marginal, each planting less than 5 acres (2 hectares) under rain-fed (un-irrigated) conditions (Agarwal, 2007). For these farmers even seemingly small cost savings or profit gains can be the difference between living above or below the poverty line; if Bt cotton really does improve yields then the potential impact on these farmers is enormous.

The promise of Bt cotton

Cotton is renowned for being a remarkably unpredictable crop varying dramatically in its performance year to year as a result of weather, soils, pests and disease. It

requires high investment and constant attention, and whilst revenues can be high it is a much riskier investment than traditional, lower income food crops such as Jowar (Sorghum). It is reliant on just the right amount of water to produce healthy cotton bolls whether the crop is genetically engineered or conventional, yet only 35% of the national cotton area in India is irrigated. Consequently, the yearly rains play a critical role in the performance of the crop. The potential of Bt cotton is that through resistance to certain insect pests it promises to mitigate one of the elements of risk inherent in cotton cultivation.

No biotech crop is engineered to increase yields per se; in cotton the Bt (*Bacillus thuringiensis*) gene was introduced to provide the crop with a 'natural' ability to produce a particular protein that is toxic to certain insect pests. The most devastating cotton pests are the American and Pink bollworms, moth larvae that in India alone can cause upwards of \$300million worth of losses in a season despite up to 20 insecticide sprays (Manjunath, 2008). By providing some resistance to bollworms, fields planted with Bt cotton are much less likely to suffer from infestations of these pests, and therefore yields should be higher than in conventional plots where the risk of pest damage is greater. Inherent resistance to major pests not only means farmers harvest more healthy bolls, it also enables them to save on cultivation costs. Bollworm pesticides contribute a substantial proportion of input costs, not to mention health risks, and therefore their elimination can be a significant financial bonus to farmers.

Yield variability

The previous chapter highlighted the remarkable increase in cotton production since the introduction of Bt varieties in 2002; between 2003-04 and 2008-09 production of cotton in India increased by 69%. However it is likely that some of this increase is partially explainable by the enlargement of the cotton growing area, and is not just the result of the introduction of agri-biotech. To what extent yield increases can be judged to be the direct result of the introduction of Bt cotton is particularly complicated given that we do not know exactly what percentage of the cotton area is in fact Bt. Karihaloo & Kumar (2009) estimate that in 2008/09 the area under Bt cotton was 7.6 million hectares, 81% of the total cotton area, but these are imprecise estimates at best. (Table 5.1). The difficulties in performing a reliable rural census in India are significant, and any conclusions are complicated by the number of farmers whose decision to plant Bt seeds can change year on year depending on the previous year's performance. Consequently any conclusion on the yield effects of Bt cotton, determined from either national statistics or local studies, will always be undermined by the problems of defining precisely how far biotechnology has spread.

Table 5.1

India area of Bt cotton as share of total cotton

Year	Total area under cotton (millions hectares)	Area under Bt cotton (millions hectares)	% area of Bt	Total production (millions bales of 170kg)	Avg yield (Kg/Hectare)
2001-02	9.13	0.00	0.00%	9.52	190
2002-03	7.76	0.04	0.52%	8.62	191
2003-04	7.60	0.09	1.18%	13.73	307
2004-05	8.79	0.50	5.69%	16.43	318
2005-06	8.68	1.26	14.52%	18.50	362
2006-07	9.14	3.80	41.58%	22.63	421
2007-08	9.41	6.20	65.89%	25.88	467
2008-09	9.41	7.60	80.77%	23.16	419

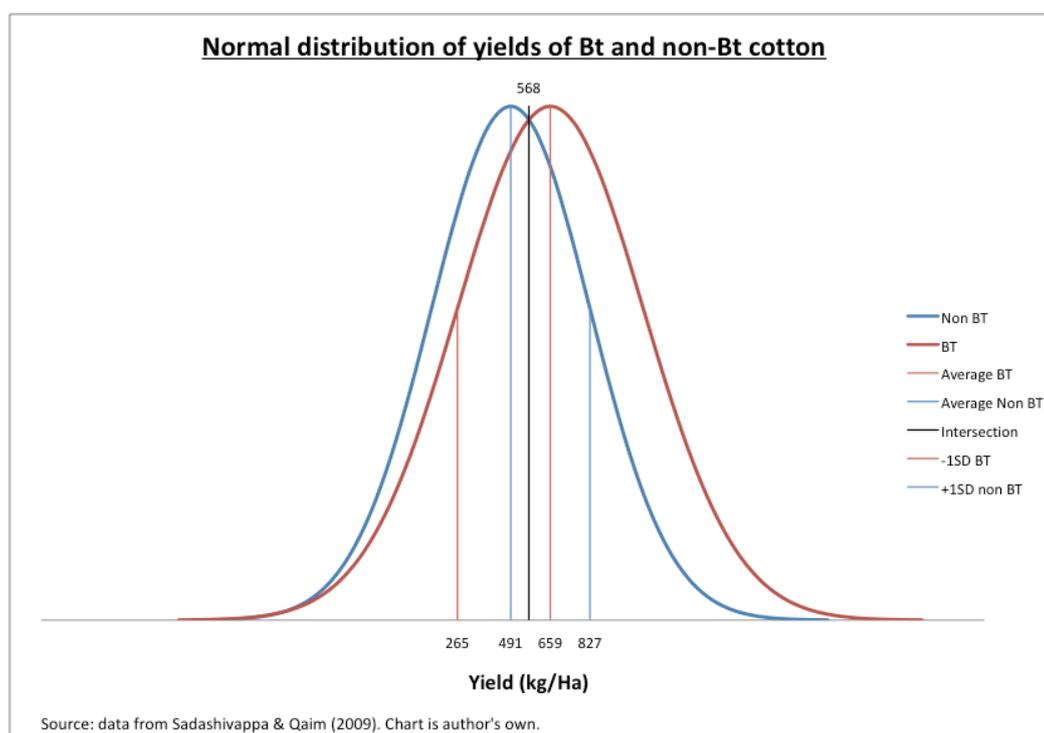
Source: Directorate of Economics and Statistics, Ministry of Agriculture, 2004, 2009; APCOAB, 2009

Early studies on the yield effects of Bt cotton placed yield advantages over conventional varieties at up to 80%; these have since been revised downwards but a study of farmers in four states in 2006-07 still found yield gains of 43% with Bt cotton (Qaim, 2003; Sadashivappa & Qaim, 2009). What is immediately apparent from the compilation of numerous studies on the impact of Bt cotton is the variability of results. (Appendix 3). Those which found significantly strong yield advantages and go on to advocate the cultivation of Bt cotton, show yield gains of between 7 and 80%, with an average of 49% across twelve studies. In contrast, five studies performed by Indian institutions found Bt cotton actually yielding the same or less than its conventional counterparts. A variety of studies in Andhra Pradesh between 2002 and 2005 for example found that non-Bt varieties either matched or outperformed their biotech counterparts. The average yield impact of Bt found in the five Indian studies was a loss of 29% in terms of kilograms per hectare. As a result of its terrible early experience the state of Andhra Pradesh actually revoked permission to grow three varieties of Bt cotton in 2005 after witnessing severe agricultural and financial losses as well as a high suicide rate among cotton farmers (Zaidi, 2006).

The overall picture provided by Appendix 3 is that there is a significant variability in the performance of cotton that has not been sufficiently acknowledged by the overwhelmingly positive proponents of GE varieties. Whilst claiming substantial yield gains with Bt cotton many of these authors fail to draw attention to the variability evident in their data. Sadashivappa and Qaim (2009) are one such example; they provide evidence that in 2002-03 Bt cotton produced an average yield advantage of 34% over conventional varieties, but the standard deviation is so wide that there is a high likelihood that non-Bt varieties may actually have outperformed Bt. One standard deviation above and below the average shows

the range of yields as 68%. Figure 5.1 shows the large overlap between the likely yield range of Bt and non-Bt in this study. If there was a small overlap with a large area of the Bt curve ahead of the non-Bt curve, there would be a distinct advantage of adopting Bt cotton. The large overlap of these bell curves however shows that the potential advantage to be gained from adopting Bt over non-Bt is limited; the statistical likelihood of yielding significantly more with Bt is relatively small. The large standard deviations of the data in this study and numerous others clearly demonstrates that the average benefits publicized by GE supporters disguise the fact that many farmers not only did not benefit from adopting Bt cotton, some actually had very negative experiences with complete crop failure and significant income losses.

Fig. 5.1.



Averaging of the data can hide important variations that show the unreliability of cotton in general. Qaim, Subramanian, Naik & Zilberman (2006) claim an average 34% yield advantage with Bt, however on closer examination of the data Bt cotton only outperformed non-Bt in three of the four states analyzed. In Andhra Pradesh yields, revenues and profits for conventional varieties were all higher than for the genetically engineered crop. This variability illustrates the problem of making assumptions about the potential impact of Bt cotton, which can alter from state to state and district to district. Productivity advantages coming from Bt

cotton need to be qualified with the observation that yield gains from Bt should only be expected in seasons where Bollworm pest pressure is high (Glover, 2009). In a crop as unreliable as cotton the essentially limited nature of the technology means that yields are more dependent on weather patterns, soil quality and individual farming practices than they are on the variety of cotton.

Part of the problem lies in the methodological and presentational flaws of the studies conducted, not forgetting their apparent bias towards GE crops. A major criticism of all the pro-GE studies in Appendix 3 is that the data used to formulate their conclusions is old. Apart from one study performed in 2006-07 by Sadashivappa & Qaim (2009) all others derive their conclusions from data that is often four years out of date or restricted to field trial results from the first two years of commercialization, when the spread of Bt was limited. Early researchers keen to prove Bt's effectiveness overlooked the variable results apparent in farm environments, and largely based their data on scientifically conducted field trials on fertile soils and with optimal inputs, which was not actually relevant to the majority of farmers. Later, less positive results should then have raised fundamentally important questions about how Bt cotton fitted into farming practices across a very diverse country with widely varying soil quality and rain dependability. Regrettably the results and the questions were ignored and Bt cotton was marketed across the country unrestrainedly touting the advantages of the technology to farmers who would subsequently suffer from the negative effects of this unpublicized variability and unreliability.

The clearest evidence that the yield benefits of Bt cotton have been exaggerated is that they are not reflected in the national statistics. If Bt was really providing yield gains of over 40% then as the area of Bt cotton increased year on year the average national yield should have grown a lot faster. Overall, there is no doubt that yields have increased since the introduction of Bt cotton in 2002, it is the extent and reliability of that growth that is questioned and how far the Bt gene itself is the cause. In the 6 years prior to the commercialization of Bt, cotton yields were decreasing in all nine cotton-growing states; since 2002, all states have seen their yields increase by between 5 and 31% annually. (Table 5.2). Unfortunately neither the national nor state data can be disaggregated by variety, so there is no data to show the difference in production or yield between Bt or non-Bt crops. Consequently it is impossible to accurately estimate how far the Bt gene alone is responsible for the overall increase in average yields. As with production levels analyzed in the last chapter, we must bear in mind the effect of the 2002-03 drought and be wary of data showing dramatic growth following the significant yield losses in those two years. In Rajasthan for

example the 300% jump in yields between 2002-03 and 2003-04 cannot reasonably be explained by the introduction of Bt cotton during that time because the yields for the preceding two years were obviously well below the state average.

Table 5.2.

India state-wise annual cotton yield (Kg/hectare)

Year	Andhra Pradesh	Gujarat	Haryana	Karnataka	Maharashtra	Madhya Pradesh	Punjab	Rajasthan	Tamil Nadu	All India
1996-97	315	304	393	237	173	139	441	354	222	265
1997-98	248	356	301	246	95	168	220	229	267	208
1998-99	202	400	255	261	139	147	180	230	316	223
1999-00	261	230	408	207	162	145	340	287	324	225
2000-01	277	122	424	263	100	84	430	268	317	189
2001-02	288	165	195	171	147	124	366	94	295	186
2002-03	230	175	341	143	158	119	410	111	188	191
2003-04	384	417	454	142	190	193	556	351	213	307
2004-05	316	421	568	224	176	185	697	297	256	318
2005-06	347	604	437	228	187	204	731	317	258	362
2006-07	630	625	581	273	253	505	747	364	374	421
2007-08*	687	786	563	338	330	567	619	451	714	465
2008-09*	670	633	523	392	336	467	554	572	708	526

Source: Directorate of Economics and Statistics, Ministry of Agriculture, 2004, 2009

* estimate

The state-wise figures again highlight the unpredictability of cotton performance and the difficulties in determining any consistent impact of the BT gene on yield growth. After five years of falling yields up until 2002, it is a relatively safe assumption that Bt cotton has contributed to the reversal of that trend in the years since its introduction. Nevertheless, the difference between each state's yield growth in the few years after adoption shows that the gene itself may not actually be the determining factor in raising yields. In 2004-05 the transgenic variety was grown on less than 6% of the national cotton area, and therefore cannot possibly explain the significant augmentation in yields witnessed across all the cotton states, some of which had almost no Bt penetration. Variability in the experiences of each state demonstrates the palpable dangers of making a broad generalization about the yield impact of switching to Bt.

Table 5.2 shows that Punjabi cotton farmers yielded the most in 2002-03, and as one of the richest farming states with the most fertile, well irrigated soils in India it would be expected to gain the most from the introduction of Bt. As it happens Punjab has actually experienced the lowest per annum growth in yields of all nine cotton states since 2002. The unpredictability of Bt cotton's impact is also visible in Gujarat and Maharashtra who between them account for 60% of the cotton area in India, but as neighboring states have had very different experiences. Both states were yielding similarly low amounts when biotech cotton was introduced. Since then Gujarat has experienced annual yield growth of 24%, and in 2007-

08 had the highest average yield in India of 786 Kg/Ha. In contrast, Maharashtra's growth has been only 13% per annum, and remains the lowest yielding state despite having the largest area of cotton in the country (3.2 million hectares) and hence the most to gain from Bt. (Table 5.3). From the evidence of yield growth alone it seems that farmers in Gujarat have benefitted most from the introduction of Bt cotton, and those in Punjab, despite being the most well off, have actually gained least from the new technology in terms of improved yields. It is clear from the extent of the variation demonstrated in all the yield data that whilst Bt cotton has no doubt contributed to an increase in yields overall, it has obviously not benefited all farmers equally.

Table 5.3

India state-wise average annual growth in yield (%)

State	1996-97 to 2001-02	2002-03 to 2008-09
Anhra Pradesh	-1.75	19.53
Gujarat	-10.46	23.88
Haryana	-13.09	7.41
Karnatak	-6.32	18.27
Maharashtra	-3.19	13.45
Madhya Pradesh	-2.27	25.67
Punjab	-3.66	5.14
Rajasthan	-23.37	31.38
Tamil Nadu	5.83	24.76
All India	-6.83	18.43

Source: Directorate of Economics and Statistics, Ministry of Agriculture, 2009;
Cotton Corporation of India, 2010

Yield determinants

Contrary to the assertions of the biotech companies and conclusions of pro-GE authors, Bt cotton is not an automatic ticket to higher yields. As with conventional varieties, the performance of Bt cotton is primarily the result of the agro-ecological and socio-economic conditions under which it is grown, not the seed variety. Cotton performance is intrinsically tied to the quality of the soil it is grown in and the reliability of irrigation. The low yields in 2002 and 2003 clearly show the effect drought can have on productivity, but many authors have failed to acknowledge the contrasting effect good rains have had on the yield growth of cotton over the past few years. Since 2005 above average yearly monsoon rains have provided the ideal growing conditions for cotton and are surely responsible for a good proportion of rising productivity during that time (Villar, 2008).

Any good yield also depends on a variety of farm technology as well as the requisite infrastructural, institutional and physical environment. Functioning markets, effective transport systems, dependable water supply and good soil quality can have all have a

decisive influence on the success of a yield above and beyond the technical qualities of the seed (Glover, 2010). Beyond that, fertilizers and pesticides, sufficient credit with which to buy them, and the necessary labor to harvest the crop are all crucial to a successful cotton harvest. Glover (2008) suggests that the problem with the endorsement of Bt cotton so far is that the marketing is misleading to farmers; as with all technology, it requires new knowledge and new skills to use, not just improved genetic makeup. Bt technology is a process not just a seed, but it is not presented as such. Many Indian farmers have therefore been unable to take advantage of the technology because they lack the necessary knowledge of how it works and reliable information on how to monitor its performance.

The problems of adopting Bt cotton are compounded further by the fact that the seed itself must be suitable for local conditions, and even then any yield increase is reliant on the quality of the germplasm. Bad quality germplasm can actually result in a negative aggregate yield effect in relation to non-Bt, particularly when pest pressure is low (Qaim et al, 2006). As more Bt hybrids become available the problems associated with badly adapted varieties are decreasing. Nonetheless there remains the parallel problem of the proliferation of fake and illegal seeds, which further complicates any data that might be used to analyze the performance of Bt technology.

It is said that in India there are four types of Bt cotton: legal, illegal, fake legal and fake illegal, all of which will perform differently depending on the expression of the Bt gene, if it is even present in the seed (The Science and Development Network, 2006). Unofficial varieties where the Bt gene is inserted without permission (F1) from either Monsanto or the government are prevalent across the country because they cost significantly less than genuine varieties. Second generation (F2) seeds, which farmers retain illegally are also prevalent to save on cultivation costs. Unbeknown to most farmers though, F1 and F2 seeds will confer significantly less or even no protection against Bollworm year on year (Bennet, Ismael & Morse, 2005). Whilst this is predominantly an infrastructural and regulatory problem (an issue that will be discussed in greater detail in a later chapter), it is indicative of the role farmer knowledge and skill must play in the successful cultivation of GE crops. Biotechnology can certainly lead to yield gains, but variable results confirm that success is dependent on more than just planting GE seeds. The right soil, husbandry and infrastructure are essential to begin with, and then without irrigation the ultimate success of Bt cotton is left to the vagaries of the rains.

Yield sustainability

There remains a further caveat that must be highlighted in respect to the yield potential of Bt cotton, and that is the sustainability of the technology itself. Even if all these other requirements are observed, and husbandry and agricultural infrastructure improve dramatically over the coming years, there remains a high probability that over the same period bollworms may become resistant to the Bt toxin, thus rendering the technology redundant. Karihaloo and Kumar (2009:25) suggest that extensive cultivation of Bt cotton can impose “a continuous and intense selection pressure on bollworms” which leads to the development of resistance. This hypothesis seems to be confirmed by a number of studies conducted in the United States, which found that over time the number of bollworm populations that were susceptible to the Bt toxin had decreased. More significant is a report from Mahyco-Monsanto scientists themselves who detected an unusual survival of bollworm to first-generation Bt cotton in four districts of Gujarat (Mahyco-Monsanto, 2010).

Resistance development is a severe threat to the future of Bt cotton, undermining the very reason for its adoption. Unfortunately it is very difficult to prevent. One of the conditions for the environmental release of Bt crops is that farmers must plant a belt of five rows of the same variety of non-Bt around their Bt crop, or 20% of the sown area, whichever is more, to provide a refuge for bollworm. This ensures that susceptible and resistant insects mate and therefore confer susceptibility to their offspring. Without this the seed companies admit that the build up of resistance could be rapid. Enforcing these requirements in India however is not only extremely difficult given the sheer number of cotton farmers, but economically unfeasible for the vast majority of farmers whose tiny plots prevent them from setting aside any land for refuges (Jayaraman, 2002; CSA, 2005). There is also a debilitating lack of knowledge amongst poor farming populations who may buy illegal and fake seed, or have no understanding of why the refuge is necessary in the first place, which makes it unlikely they will adhere to technical specifications. Even if farmers do understand the need to grow refuges it no doubt appears to be a very complex action to deal with one single problem, somewhat negating the supposed ease of management of Bt (Glover, 2009). Nevertheless, establishing how to ensure farmers implement refuges is not only critical for the future of Bt cotton, but also for other crops such as Bt Brinjal (eggplant) which may soon be released into an environment where its major pests may already be resistant to the toxin the biotech variety purports to express.

Unfortunately, planting refuges does not remove the threat to sustainability of Bt cotton. The very *success* of Bt cotton at controlling bollworm infestations can create the

contrasting problem of secondary pests: by eliminating one pest with Bt toxins an opportunity arises for new pests to fill the vacuum. Sucking pests, mealy bugs and leaf-reddening have traditionally been considered secondary problems for cotton growers, but in the absence of bollworms these pests, which are immune to the Bt toxin, have become increasingly destructive. Bt protects against only a handful of the 160 pests that attack cotton. The risk inherent in Bt technology is that in solving one problem, it may well have created another. In Andhra Pradesh and Maharashtra in 2005 there were reports of up to a 300% increase in non-target pests and attacks from leaf wilt (Centre for Sustainable Agriculture [CSA], 2005). Similarly in the Punjab, Bt cotton initially looked to be contributing to impressive yield gains, but by 2007 there were reports from four major cotton districts of unprecedented mealy bug attacks destroying thousands of acres of cotton (Goswami, 2007). The link between mealy bugs and Bt cotton has not been proved outright, but there is no doubting the decline in Punjabi cotton yields since 2007. (Table 5.2). The environmental impact of Bt cotton will be considered in more detail in the next chapter, but this issue is important to keep in mind when judging the long-term yield potential of the biotechnology.

Overall yield impact

On balance, the question of whether Bt cotton increases yields deserves a two-fold answer. From a technical point of view, yes Bt cotton is effective in reducing the damage caused by bollworms and can lead to greater yields if resistance is controlled. From a socio-economic point of view this technical advantage must be qualified by the fact that simply planting Bt cotton provides no guarantee of increased yields. If bollworm pressure is lower than normal Bt varieties will have no significant yield advantage over conventional varieties. Furthermore, Bt crops rely on good husbandry, good infrastructure and good weather just as much as conventional crops; if anything from fertilizers to rain or refuge provision are lacking they are just as likely to provide low yields.

Unfortunately for many farmers who were sold Bt cotton on false premises and suffered as a consequence, it appears that many pro-biotech authors have gone to excessive lengths to exaggerate the yield benefits of the technology. The success of the crop depends on a multitude of factors, a reality testified to most dramatically by slow yield improvement in Maharashtra, India's largest cotton-growing state, and devastating losses in the early years of Bt cultivation in Andhra Pradesh. In the short to medium-term, the viability of Bt cotton for providing sustainable yield gains is heavily dependent on the farmers themselves and their environmental and economic capabilities. In the long-term sustainability will depend on the

unpredictable environmental consequences of the introduction of the gene itself, which interrupts the balance between cotton and its natural pests. Seed companies will need to stay ahead of both expected and unforeseen impacts of GE technologies to help the farmers that do take the risk of adopting the newest technologies. Governments must also ensure that the necessary infrastructure, institutions and regulations are in place to make sure that farmers have access to the best quality seeds, and that sufficient markets are present in which to sell their output.

b) Income effect and profitability

Cotton is environmentally the ‘dirtiest’ crop in the world, accounting for 16% of global insecticide releases, more than any other single crop. In India cotton is responsible for an alarming 54% of all pesticides used annually despite covering less than 5% of the land under crops; in 2001 the cost of the 21,500 metric tonnes of active ingredient used against insects in India was \$340 million (Karihaloo & Kumar, 2009). Worldwide the cotton chemical pesticide industry is worth \$26 billion annually, of which up to 2/5th is considered hazardous by the World Health Organization (Environmental Justice Foundation, 2007). Consequently, the greatest environmental prospect of Bt cotton is not that it can produce higher yields, but that in providing a natural resistance to cotton’s most virulent pests, the technology can hopefully contribute to reducing the astronomical amount of toxic pesticides applied each year. The advantage of this to farmers is two fold. Firstly, Bt should reduce the cost of cultivation for farmers who are heavily burdened by the ever-increasing need for and cost of insecticides. Secondly, cultivators should benefit from pesticide reductions that help relieve heavily polluted soils and watercourses, the current rate of degradation of which is threatening the sustainability and long-term future of agriculture in certain regions.

The argument that Bt cotton reduces pesticide costs, like the claim that it leads to increased yields, needs to be treated with caution. The same authors who exaggerate the yield advantages of biotechnology are equally liberal with their embellishment of the net profit margins received by farmers of Bt cotton. Similarly, those studies that totally admonished the initial adoption of Bt in the face of drastic losses in Andhra Pradesh in the first drought-crippled year of adoption also need moderation. As Appendix 3 shows, the actual financial net gain provided by Bt cotton is widely variable both in real terms and as a percentage gain over non-Bt. Even when Bt performs as expected in controlling bollworm pests, the evidence that it leads to a reduction in pesticide use is contradictory. The potential cost savings and profit

margins that can be acquired with Bt are heavily dependent on a host of factors unrelated to the technology itself, from growing conditions and farmer decisions to the wider social and economic environment. Even more than with yield effects, the ability to make a profit is reliant on adequate infrastructure and market institutions that ensure farmers can get sufficient prices to cover the cost of inputs for any crop they cultivate. Because the assets invested and risks taken in any season will vary from farmer to farmer depending on his resources, security and market access, the potential financial impact of Bt cotton is highly context specific.

Cost savings

One of the leading assertions made by the seed companies is that Bt cotton's ability to control the bollworm population means farmers should experience a reduction in insecticide use and hence input costs. The most recent full country analysis of the cost of cotton cultivation in India seems to support this claim by showing an average annual 8% reduction in the cost of insecticides for farmers since 2002. (Table 5.4). At a state level however, the results are less convincing.

Table 5.4.

India State-wise % annual growth in critical costs of cultivation 2002-2006

Cost	Andhra Pradesh	Gujarat	Haryana	Karnataka	Madya Pradesh	Maharashtra	Punjab	Rajasthan	Tamil Nadu	All Cotton states
Seed	0.34%	61.12%	95.09%	1.38%	17.13%	21.51%	66.98%	20.47%	9.70%	29.83%
Fertilisers	-5.21%	29.60%	60.50%	27.05%	10.68%	-1.01%	25.89%	-21.78%	5.13%	9.34%
Insecticides	-13.15%	42.44%	25.74%	-23.05%	18.44%	-16.94%	-33.36%	11.63%	-9.82%	-8.34%
Irrigation	6.14%	27.96%	-10.39%	-8.22%	-10.23%	-23.68%	-8.48%	5.91%	-2.45%	-1.36%
Total Cost	-1.11%	26.65%	21.41%	-1.20%	19.16%	-0.11%	6.93%	5.91%	-2.47%	8.35%

Source: Directorate of Economics and Statistics, Ministry of Agriculture, 2008

Between the principal cotton-growing states the effect of Bt cotton on insecticide costs has actually been very variable, ranging from a 33% annual reduction in costs in the Punjab to a 42% increase in Gujarat. The results from the latter are particularly surprising as Gujarat was the state that gained most impressively in terms of yield after the introduction of Bt cotton, which should signal the efficacy of the Bt gene at preventing losses from Bollworm infestations. The significant rise in insecticide costs actually implies the opposite. Unfortunately the data does not specify the target pest for these insecticides, which makes it difficult to determine the reason for changing insecticide costs. If the Bt gene has not been controlling bollworm and insecticides are still needed as the first line of defense, then adopting the biotech crop instead of a conventional variety is worthless. If on the other hand,

the insecticides are intended for a secondary pest, then the value of Bt must also be questioned if in solving one problem another has been created. At an aggregate level, there does not seem to be any significant correlation between pesticide use and the rate of growth of cotton yields since 2002. The data thus conveys the impression that insecticide use may only be partly influenced by whether the crop is Bt or not.

The level of pest pressure in any given year is critical for Bt crops to provide a meaningful advantage over conventional varieties, but pressure varies from region to region and is therefore difficult to quantify. A significant bollworm infestation enables Bt cotton's natural strengths to be expressed, but high pressure from other pests will require increased insecticide applications regardless of the cotton variety. Glover (2009) therefore argues that to determine how far biotech cotton has contributed to reduce costs it is necessary to understand something about the farmer's decision-making process.

How many sprays a crop *needs* in any one season does not necessarily correlate with how many it actually receives. It is generally accepted that most farmers use pesticides relatively inefficiently, spraying far more than is required for adequate protection (Crost, Shankar, Bennet et al, 2007). Consequently, changes in pesticide use are more likely to be influenced by farmers' prior experience than current performance, and by existing assumptions about expected pest-resistance afforded by Bt cotton (Glover). Even pro-GE authors concede that the pesticide effect depends on farmers' correct understanding of the substitution effect between Bt and pesticide applications, and the ability to optimally adjust inputs to the new technology (Qaim et al, 2006). Furthermore, farmer choices regarding seeds, pest management strategies and cropping patterns are all embedded in a particular household's wider livelihood strategy, which in turn is influenced by longstanding social and institutional relationships and processes. Given the unpredictability of cotton as a crop, the risks and uncertainties faced by cotton farmers and the impact these will have on their decision making process must not be underestimated. For smallholder farmers in particular, the risks associated with missing one insecticide spray are of a life and death magnitude, therefore farmers are unlikely to be conservative with pesticide application even if they do plant Bt. This demonstrably complicated relationship between Bt cotton and insecticides helps account for the variability in pesticide costs across the cotton states since 2002.

That there is evidence at all of a reduction in pesticide application is a significant achievement in the face of what is commonly referred to as the "pesticide treadmill," on which farmers have to use more and more active ingredient to get the same level of protection. If Bt has contributed to the slowing down of this treadmill and easing of annual cost increases

for some farmers, then it can certainly be considered to be a success. That all farmers have not realized this dividend though is evident in the fact that in spite of some pesticide reductions the total annual cost of cultivation of cotton has actually increased since the introduction of Bt in 2002.

Trying to determine the exact relationship between Bt cotton and the rise in cost of cultivation though is very complicated. Four states have experienced a marginal decrease in production costs in this time, but of these only Tamil Nadu has seen an annual reduction over any more than 2%. (Table 5.4). In cotton states as a group, the cost of cultivation has increase by about 8% per year from an average of 21,023 Rupees per hectare (Rs./Ha) in 2001-02, to 28,460 Rs./Ha in 2005-06 (Table 5.5). Of the four states where the average cost of cultivation has decreased the common factor appears to be a significant drop in the expenses associated with pesticides, implying a positive impact of Bt cotton on costs. This assertion is negated though by the case of the Punjab where pesticide costs fell the most but overall costs actually increased. Of the five states where the cost of cultivation increased, the most likely source appears to be a rise in operational costs including labor, fertilizer, and seed expenses. Only the latter is a development directly attributable to the introduction of Bt seed, which is up to three times as expensive as conventional seed. It appears that even if Bt was successful in reducing insecticide costs, in states where the cost of production increased after 2002 this reduction was not enough to offset the increase in the price of Bt seeds, and hence cost of cultivation has increased in spite of Bt cotton.

Table 5.5

Overall Cost of Production in Cotton Growing States (Rs./Ha.)

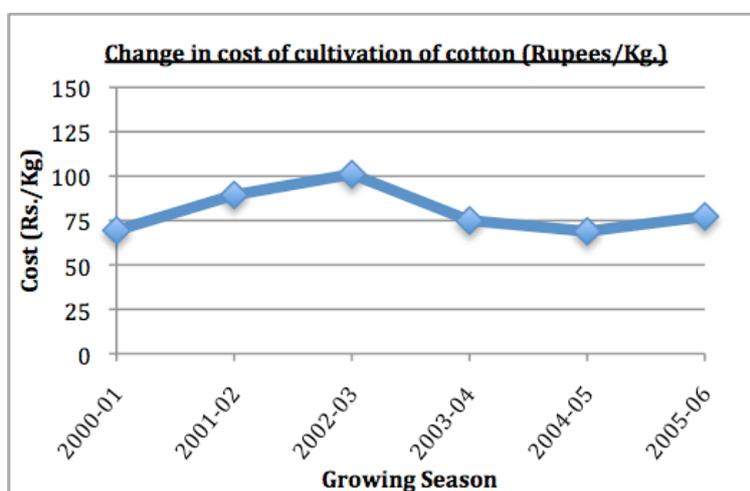
	2000-2001	2001-02	2002-03	2003-04	2004-05	2005-06
Andhra Pradesh	21,233	23,401	28,563	36,202	32,735	27,625
Gujarat	10,691	16,768	15,475	23,396	23,586	31,437
Haryana	19,248	14,760	18,878	24,169	27,289	33,781
Karnataka	11,320	11,006	11,915	9,520	11,631	NA
Madya Pradesh	NA	11,009	19,968	18,664	20,715	33,781
Maharashtra	14,234	17,234	20,860	20,990	21,180	20,794
Punjab	22,998	25,772	27,684	33,233	34,071	33,849
Rajastan	13,195	13,104	14,808	17,410	17,687	17,594
Tamil Nadu	28,149	31,845	31,062	34,386	27,560	28,815
All Cotton States	17,634	18,322	21,023	24,219	24,050	28,460

Source: Directorate of Economics and Statistics, Ministry of Agriculture, 2008

A further complication to the analysis of Bt's effect on cultivation costs is the difference between the real cost of cultivation of cotton per hectare, and the relative cost of the output in kilograms. In real terms the average cost of cultivation of cotton has increased by over 7000 Rs./Ha since 2002. However, in all states the annual percentage growth in cost

of cultivation is well below the growth in production and yield, which indicates that relative to output cost of cultivation has actually decreased since 2002. (Figure 5.2). This can be demonstrated by ascertaining the increase in cost of production per kilogram produced rather than by area of production. In all cotton states in 2002-03 the average yield was 208 Kg./Ha and average cost of production 21,023 Rs./Ha, which means each kilogram cost on average 101 Rupees to cultivate. In 2005-06 the cost of cultivation per kilogram had fallen to 77 Rupees, showing a relative decrease in the costs of producing a kilogram of cotton since 2002. It would be interesting to see if this conclusion holds for the period after 2006 during which time production and yield growth rates have slowed, but unfortunately the data is not available.

Fig. 5.2



Source: Directorate of Economics and Statistics, Ministry of Agriculture, 2008

As with all yield and production data we must bare in mind the fact that 2002 was a drought year, which may affect the reliability of data for that period. Nevertheless, the result still holds when examining the data from 2000-01; the cost of producing a kilogram of cotton has actually remained relatively stable at around 70 Rs./Ha in spite of the introduction of Bt cotton. Consequently, it would appear that the impact of Bt cotton on the cost of cultivation is essentially negligible. There is no overwhelming evidence to suggest that it has put any downward pressure on cultivation costs nor has it resulted in any significant increase in the relative cost of production in spite of increased seed prices. All the authors compiled in Appendix 3 concur that the cost of cultivation of Bt is greater than non-Bt, but even those studies oriented against biotech crops find that there is often little to differentiate between the outlay required for biotech and non-biotech production other than seed prices. Accordingly,

the argument that Bt cotton provides farmers with cost savings has limited supporting evidence; increased seed prices and rising operational costs would in fact suggest the contrary. A farmer switching to biotech cotton will find limited cost savings over conventional crops. The benefits of adopting Bt must therefore be realized in the net profits rather than the net savings to justify the claim that biotech cotton is economically advantageous to farmers.

Net Profits

If farmers have not been significantly affected by any changes in production costs as a result of the introduction of Bt cotton, an increase in profits from raised yields must be evident to conclude that farmers have gained economically from planting Bt over non-Bt seeds. If yields have grown at a rate greater than cost of production then theoretically net profits will have increased, on the condition that prices have at least remained the same. The studies in Appendix 3 which demonstrated increased yields with Bt cotton also find net economic advantages pertaining to the cultivation of the biotech crop. These advantages were variable to the tune of between 1060 and 8694 Rupees per acre, or more significantly a profit differential of between 28% and 426% over non-Bt varieties. However, as with the yield reports, those authors who found better yields among non-Bt cottons also found that net profits were greater with those varieties too, in some cases observing that Bt cotton had actually contributed to net losses (Qayum & Sakkhari, 2005; RFSTE, 2003). Whilst these studies were conducted in years and areas particularly badly affected by drought and must therefore be treated with caution, they nevertheless highlight once again that the impact of Bt cotton is extremely variable and dependent on a host of factors.

Planting Bt is not an automatic paycheck; badly adapted varieties and unsuitable growing conditions mean that in bad years Bt can perform even worse than traditional cotton (Gala, 2005b; CSA, 2005). Gene Campaign, an agricultural think-tank found that when there was a low yield 60% of Bt cotton farmers failed to recover their costs, whereas non-Bt farmers still made a profit of over 2,500 Rupees an acre (CSA). Even in high yielding areas the same authors found that non-Bt farmers made more of a profit than biotech varieties; the losses incurred in some adopting communities have been enough to stir up local violence. Qayum & Sakkhara (2005) recount a much-publicized story of angry villagers in the Warangal district of Andhra Pradesh who held hostage the Mahyco-Monsanto representative after the complete failure of genuine Bt cotton in hundreds of acres around their village. Protestors went to Warangal city and held a violent demonstration that included destroying

seed depots. This well documented event clearly shows the extent to which crop failures have abounded despite the promises of biotech seed providers. Whilst many studies may conclude that overall Bt has been a success, authors' selective use of data conceals significant experiences that demonstrate the variability and unpredictability of biotechnology's impact on cotton farmers.

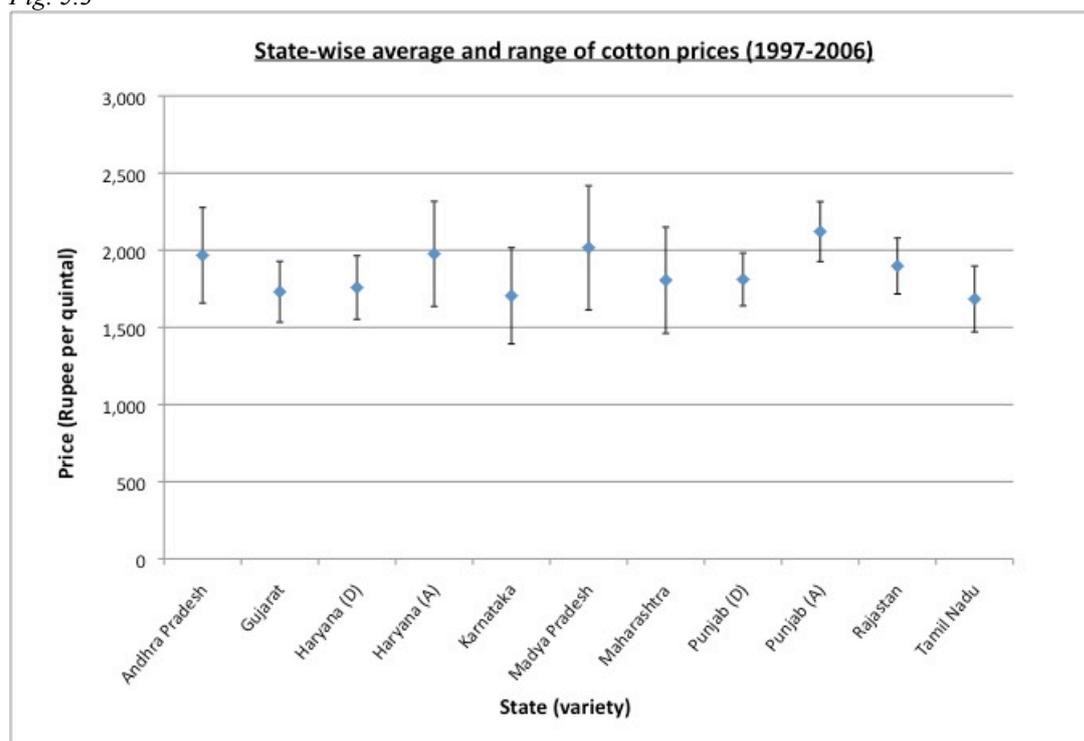
Market prices

Critical to farmers' profits every season regardless of how successful the yield, is the price that they receive for selling their cotton in the market. If Bt cotton earned higher revenues for the same level of production as conventional varieties it would be easy to say that the biotech crop holds an intrinsic economic advantage over its traditional counterparts. However, that does not appear to be the case. A study commissioned by the Andhra Pradesh Department of Agriculture recorded that 3664 out of 3700 responders (99%) said that the quality of Bt cotton produce was lower than non-Bt and 3343 responders (90%) observed that market value of Bt cotton was poor (CSA, 2005).

The value of a yield is heavily influenced by the length of cotton fiber that particular variety produces, known as the staple. The longer the staple the more valuable it is; extra-long staples can be worth more than double short staple varieties. Despite good information on the price of staples, finding an accurate average of farmer incomes is not easy because of the difficulty in estimating how much of each variety is grown from state to state, let alone from farm to farm. If Bt staples are longer than non-Bt then the value of production per hectare should be significantly more than non-Bt varieties: not only would the price per bale be higher but Bt plants supposedly yield more therefore farmers should be selling more crop at a higher price, thus generating greater profits. As it happens, when the gross income per acre is divided by yield per acre in the studies in Appendix 3 Bt crops returned roughly the same revenue per kilogram as non- Bt, around 20 Kg/acre. This indicates that any positive effect on net income from Bt cotton is from increased yields alone and not from better quality cotton or longer staples. Nevertheless, it is important to keep in mind that most of these studies are from the first few years of commercialization of Bt when there were only three biotech varieties available on the market. Now there are over 600 varieties available including Bt versions of Bunny & Brahma that have long staples, which would suggest Bt farmers are generating higher profits due to both higher yields and higher prices. Unfortunately the lack of data to corroborate this hypothesis highlights the problem of the dearth of studies available for research performed after 2005.

Stable prices are essential for cotton farmers; particularly smallholders whose margins are so narrow that any drop in prices can be devastating. Even if yields increase, if the cost of cultivation continues to rise, prices must at least remain stable to ensure farmers can cover their costs. The introduction of Bt cotton actually appears to have had little impact on the prices farmers receive for their cotton crop. Figure 5.3 shows that some states have more variable prices than others, but the average price of cotton is relatively uniform. Only Maharashtra has seen any noticeable increase in the average price of cotton since 2002, with prices rising from 1,464 Rupees per quintal (14.64 Rs/Kg) in 1997-98 to 2,152 Rs./Qn in 2004-05. Punjab, with both Desi and American varieties, is the only other state where prices per quintal were higher in 2006 than they were in 1997. With stagnant prices, the increased cost of Bt seeds means that farmers have to produce an above average yield year on year to ensure that their input expenses are redeemed.

Fig. 5.3



Source: Directorate of Economics and Statistics, Ministry of Agriculture, 2008

A= American Variety
D= Desi Variety

The failure of prices to rise demonstrates how the success of Bt cotton in raising production could actually come to be a potential threat to cotton farmers. Dramatically increased supply puts considerable pressure on prices, as whilst world consumption has been

growing it has been at a pace slower than production. Farmers have been able to sell more because they are producing more, but world prices have been effectively unmoved since the mid 1990s. Enhanced production seen particularly in India and China has saturated markets and made it hard for cotton sales to grow significantly in value. After a welcome rise in prices in 2007, 2008 was an *annus horribilis* for cotton producers as world cotton prices plummeted from \$1.98/Kg to \$1.15/Kg from March to December as a result of the world financial crisis during which rising production overwhelmed crashing demand (Cotlook, Dec 2009).⁸ Bt cotton may be very successful in driving increased supply of cotton, but it can have only a very limited effect on demand. As discussed in the previous chapter the domestic cotton textiles industry has been expanding rapidly to take advantage of increased production, but as the economic crisis proved, the supply of cotton cannot drive demand from the mills. The basic laws of supply and demand require that unless other political and economic factors combine to maintain consumption levels the production success of Bt cotton could end up being a disaster for farmers.

However, food crops demonstrate the more positive reverse side of this situation: the reduction in market prices for producers is actually a fillip for consumers. Lower prices for food crops could be extremely beneficial to the millions of hungry people in developing countries who have been devastated by the dramatic rise in food prices in recent years. Whilst this does not really pertain to cotton given that it is not a food crop (although lower prices would benefit the textiles industry) the double edge of this predicament is important to remember when biotech companies tout the poverty and hunger-tackling properties of GE crops.

Minimum Support Prices

Planting Bt cotton is not enough to enable farmers overcome the risks of price fluctuations, therefore to try and counteract this variability in prices the government offers Minimum Support Prices (MSPs) for different staple lengths set by the Textiles Commissioner. This ensures that if market prices fall farmers can still sell to the government through the Cotton Corporation of India. MSPs ensure that farmers are guaranteed a basic income regardless of the state of the local and global market, and are the same whether the produce is genetically engineered or not. As Table 4.6 shows MSPs remained relatively low

⁸ Prices are derived from the Cotlook 'A' Index, a global price index that averages the five cheapest prices of middling grade cotton sold in Far Eastern ports from 19 countries. It is a Far East index because this is where the majority of cotton is consumed.

over the turn of the century, and have failed to rise in step with increases in the cost of production. If a farmer was producing a medium stapled variety such as F414 in Rajasthan in 2005/06 and sold it at the MSP he would have received 1760 Rs./Quintal (17.6 Rs./Kg). In that year the average yield in Rajasthan was 317 Kg/Ha, which means the farmer would have a gross revenue of 5579 Rs./Ha. The average cost of production in Rajasthan in 2005/06 was over 17,500 Rs./Ha, with operational costs alone (labor, seed, pesticides, fertilizers etc.) costing over 11,000 Rs./Ha. Consequently, if that farmer was forced to sell his medium staple crop to the government he would not even have been able to cover the costs of cultivation. MSPs were given a significant boost in 2006-07, but they are still well below the level required for farmers to earn an adequate income if they are forced to sell to the government. In this respect, Bt farmers hold no advantage over their traditional counterparts.

Table 5.6

India Minimum Support Prices (Rupees/Quintal)

Variety	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07
Short Staple (<20mm)												
Assam Comilla	1000	1025	1100	1150	1250	1290	1330	1330	1370	1400	1400	2000
Bengal Desi	1000	1025	1025	1075	1175	1215	1250	1250	1285	1310	1310	2000
Medium Staple (20.5mm-24.5mm)												
GCOT-12	1135	1165	1200	1300	1400	1440	1485	1485	1530	1560	1560	2333
Jayadhar	1095	1125	1265	1370	1475	1515	1560	1560	1605	1640	1640	2250
AK/Y-1 (MAH/MP)	1145	1175	1320	1430	1525	1550	1595	1595	1640	1675	1675	2350
Medium Long Staple (25.0mm-27.0mm)												
F414/H-777/J-34(Raj)						1625	1675	1675	1725	1760	1760	2500
LRA-5166	1260	1290	1430	1545	1650	1700	1750	1750	1800	1835	1835	2600
F414/H-777/J-34 Hybrid (Hry)	-	-	-	-	-	-	-	1695	1750	1785	1800	2700
Long Staple (27.5mm-32.0mm)												
F414/H-777/J-34 Hybrid (Pjb)	-	-	-	-	-	-	-	1715	1780	1815	1835	2800
H-4/H-6/MECH/RCH-2	1350	1380	1530	1650	1775	1825	1875	1875	1925	1960	1980	2850
Sankar-6/10	1385	1415	1565	1670	1795	1840	1840	1860	1910	1960	1985	2850
Bunny/Brahma	-	-	-	-	-	-	1900	1925	1975	2010	2010	3000
Extra Long Staple (32.5mm>)												
MCU-5/Surabhi	1390	1420	1570	1690	1820	1875	1950	1950	2000	2035	2055	3400
DCH-32	1400	1430	1580	1700	1830	1900	1975	1975	2030	2065	2100	3400
Suvin	2060	2105	2330	2520	2750	2900	3000	3000	3080	3135	3135	4200

Source: Cotton Corporation of India; Cottonindia.com

Debt

Longer staples and MSPs can only go so far to help farmers. There have been increasing calls for greater political commitment to farmers' welfare regardless of the introduction of genetically engineered varieties. Particular emphasis has been put on the need to improve post harvest infrastructure, such as transport and storage facilities, so that farmers do not have to fight every season just to break even, or worse still, plunge into debt despite selling their harvest (Swaminathan, 2008). It is not just a question of covering costs; how far households can actually stretch their incomes is essential for their survival. Farmers need to make a clear profit so that they can afford basic living expenses such as food, health bills and

a rudimentary education for their children. Tremendous rises in food prices over the last twenty years have made life even harder for farmers and the rural poor in general whose meager incomes are no longer sufficient to feed their families. The global financial crisis of the last few years contributed to a further spike in basic food prices in 2007-08, which the FAO (2009) estimates has pushed the number of undernourished people in the world to over one billion, with another billion considered micronutrient deficient.

When cotton revenues are insufficient to cover the costs of production or basic living requirements farmers can get sucked into degenerating cycles of debt. Malnutrition and rural poverty are the most obvious manifestations of this, but suicides also appear to be rising in rural India, a development many GE opponents have linked to the proliferation of Bt cotton (Sharma, 2010b; Nagaraj, 2008). Farmer debt is a severe problem in India, where it is estimated that over 43 million farming households are indebted, 49% of all farmer households; in cotton states this percentage rises to 61%, a total of 24 million households. (Table 5.7). Unfortunately, apart from the data in Table 5.7 from 2005, the most recent full survey on household indebtedness was compiled in 2002-03, which makes it difficult to determine the true impact the introduction of biotech cotton has had on farmer debts. The evidence of rising cultivation costs and apparent the difficulties of turning a profit in cotton farming suggests that the vast majority of cotton households, Bt or not, struggle to cover their costs let alone live comfortably. If the trend in prices remains downward and cost of production upward then the incidence of indebtedness is only going to increase.

The majority of indebted farmers in India (61%) cultivate less than one hectare of land. However for plots over one hectare, as land size increases so does the likelihood of being in debt; 66% of farmers with ten hectares or more are indebted compared to only 45% of those with less than one hectare. (Table 5.8). One of the most interesting elements of the data on farmer debt relates to the average amount of outstanding loan among farmers of different size. Whilst this data is not specific to cotton, let us take it as an example to illustrate how difficult it is for farmers to escape the debt trap. If a cotton farmer with one hectare had 7,096 of debt in 2002-03 it would be the equivalent of an additional third of the average cost of production for that year (21,023 Rs./Ha). Just to repay that debt and cover his costs the next year (which would have increased) the farmer would have to earn a gross income of close to 30,000 Rupees. Even if he was growing an extra-long staple variety that he could sell at 4000 Rs./Quintal the farmer would still have to yield 750 Kg./Ha to earn that amount, which is far above what Bt varieties are capable of producing even in the best yielding cotton states today let alone in 2002-03.

Table 5.7

State-wise estimated no. of rural households and indebted farmers (May 2005)

States	Estimated no. of rural households	Estimated no. of farmer households	Estimated no. of indebted farmer households	% of farmer households indebted
Andhra Pradesh	14,251,200	6,033,900	4,949,300	82%
Gujarat	3,601,500	3,784,500	1,964,400	52%
Haryana	3,147,400	1,944,500	1,033,000	53%
Karnataka	6,990,800	4,041,300	2,489,700	62%
Madhya Pradesh	9,389,800	6,320,600	3,211,000	51%
Maharashtra	11,817,700	6,581,700	3,609,800	55%
Punjab	2,984,700	1,844,200	1,206,900	65%
Rajasthan	7,017,200	5,308,000	2,782,800	52%
Tamil Nadu	11,018,200	3,888,000	2,895,400	74%
Cotton States	70,218,500	39,746,700	24,142,300	61%
All India	147,898,800	89,350,400	43,424,200	49%
Cotton states as % of all India	47.48%	44.48%	55.60%	-

Source: Compiled from the statistics released by Lok Survey Unstarred Question No. 1217, 01.08.2005.

Table 5.8

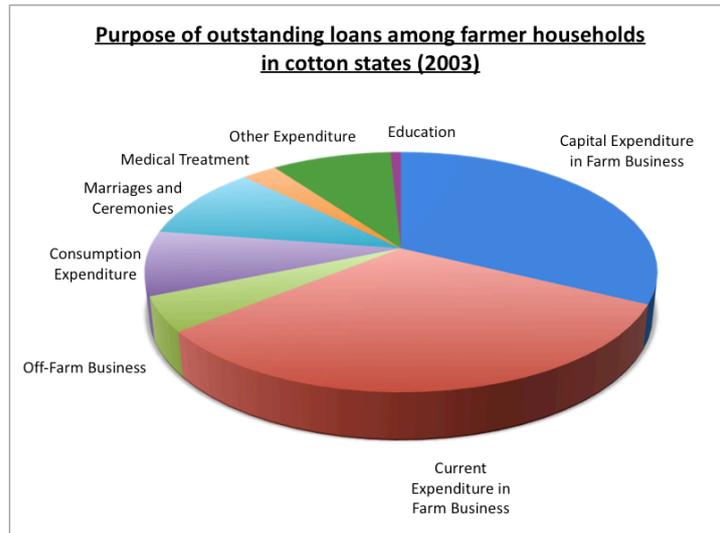
India estimated no. of indebted farmers by size of land possessed (2003)

Amount of land possessed (Ha.)	Estimated no. of farmer households	farmer households as % of total	Estimated no. of indebted farmer household	indebted farmer households as % of total farmer households	Prevalence rate of indebtedness (%)	Avg amount of outstanding loan (Rs.) per farmer household
<0.01	12,594	1.4	5,708	1.3	45.3	6,121
0.01-0.40	292,867	32.8	130,112	30.0	44.4	6,545
0.41-1.00	283,610	31.7	129,211	29.8	45.6	8,623
<1.00	589,071	65.9	265,031	61.1	45.0%	7,096
1.01-2.00	160,600	18.0	81,920	18.8	51	13,762
2.01-4.00	93,504	10.5	54,409	12.5	58.2	23,456
4.01-10.00	42,581	4.8	27,734	6.4	65.1	42,532
10.00+	7,748	0.8	5,148	1.2	66.4	73,232
All Sizes	893,504	100.0	434,242	100.0	48.6	12,585

Source : Report No. 498(59/33/1), Situation Assessment Survey of Farmers: Indebtedness of Farmer Households, National Sample Survey 59th Round (January-December 2003)

With rising costs of production and stagnating prices associated with Bt cotton, it is unsurprising that so many farmers engage in illicit trade and cultivation of Bt seeds from Pakistan or buy fake or saved seeds to try and find ways to cut costs. In the majority of cotton states 60-70% of loans to farming households are spent on capital and current expenditures on the farm itself. (Figure 5.4). This shows the true depth of debt among farming households; not only are cultivators not making enough profit to cover household expenses such as food, health and important socio-cultural expenses, for which loans are also used, they are unable to earn sufficient amounts to reinvest in cultivation for the next year. Underinvestment in the farm itself means an even greater likelihood that the next year's yield will be poor, thus perpetuating the cycle. Consequently farmers take out loans to cover losses, buy more seeds and cover family medical expenses in the hope that the next year's crop will allow them to repay it. When they are unable to do so, debts escalate to the point where committing suicide appears like a viable option for desperate farmers.

Fig. 5.4



Source: Situation Assessment Survey of Farmers: Indebtedness of Farmer Households, National Sample Survey 59th Round

Farm suicides

The main reasons suggested for such high suicide rates in India are the absence of adequate social infrastructure, lack of credit available to small farmers (only 4% of farmers turn to banks for aid), a relative absence of irrigation (which puts more reliance on unpredictable rainfall thus increasing the rate of crop failure), and a lack of political will to solve chronic debt problems by tackling prices (Bunsha, 2005). When crops fail, farmers have no safety net and with the added costs of growing Bt cotton the fall can be further. Poor farmers are left to turn to local moneylenders who charge exorbitant interest rates of up to 60%, or relatives as a last resort; the pressure to repay both is heavy and farmers are often harassed and threatened by lenders (Kumar, 1998). Over the season farmers see a battery of operators ranged against them from the moneylender to the pesticide dealer and the cotton merchant who all contribute to diminishing the amount of money a farmer can take home from his cotton crop. Debt relief is too small and existing assistance packages and investment schemes are not tackling the root of the problem.

Farm suicides are not a new phenomenon in India, but there is no doubt that they have increased significantly during the last decade, particularly in cotton-growing states. It is not possible to prove accurately the extent to which Bt cotton has contributed to the debt problems and rising suicides in the cotton community. However, if we can say relatively surely that Bt has pushed costs of cultivation up and prices down, it is pertinent to conclude that Bt varieties have indeed contributed to the rising incidence of indebtedness among cotton

farmers. There is nonetheless a danger of stretching the link too far between the technical problems of Bt cotton cultivation and the social elements involved in suicide. For example, a study of suicides in Maharashtra discovered that an unexpectedly large percentage of deaths were among lower castes who only took to farming recently through land reform measures and did not have the requisite skills or financial knowledge to manage the cotton or its necessary investments (Mohanty & Shroff, 2004). To blame Bt specifically is therefore unfair. The problems of identifying the population base and obtaining reliable information are a significant problem in establishing causality; nevertheless, due to very limited death records it is highly possible that suicides are actually underreported (Behere & Behere, 2008).

The greater part of farm suicides appear to be in cotton growing areas, where the majority are particularly poor, with very bad basic social infrastructure, such as drinking water, regular electricity, primary health care and all-weather roads. These conditions are especially prevalent in Maharashtra, notably the Vidarbha region, a poor, overpopulated area with high incidences of poverty and malnutrition, and where the rise in farmer suicides has become a national talking point. There are over 3 million cotton farmers in Vidarbha of whom it is estimated 95% struggle with massive debt. A psychological assessment of local farmers concluded that chronic indebtedness caused by rising costs and falling prices led to financial difficulties which in turn contributed to family disputes, depression and alcoholism, and not unusually ended in suicide (Behere & Behere, 2008). The feelings of hopelessness and helplessness combined with the knowledge that compensation following suicide can help families repay the debt, makes it seem like the only option for farmers. The easy access to dangerous pesticides (poisoning is the most common method of farmer suicide) just makes it more immediately viable when times are bad.

Farmer suicides were not unusual before the introduction of biotech cotton, in fact they had increased significantly over the course of the 1990s. There has nonetheless been increasing suggestions that the spread of Bt cotton has exacerbated the problem. The seed companies vehemently deny any link between the proliferation of Bt cotton and the increase in suicides, but unfortunately the data is somewhat damning. Table 5.9 shows that there have been on average 4000 suicides a year in Maharashtra, 24,402 in total, in the six years since the introduction of Bt cotton. In the six years previous the total was 43% less. Of the five states with the worst suicide rates, four of them are cotton producers, among whom only Karnataka has seen the number of suicides per year decline since the introduction of Bt cotton.

Table 5.9

Farm suicides in the 'big five' cotton states compared with the rest of India

Year	Maharashtra	Andhra Pradesh	Karnataka	Madhya Pradesh & Chhattisgarh*	Farm suicides in Big 5 States Yearly total	Farm suicides All-India yearly total	ALL suicides in India yearly total	Big 5 as % of all farm suicides	Big 5 as % of ALL suicides
1997	1917	1097	1832	2390	7236	13622	95829	53.1	7.6
1998	2409	1813	1883	2278	8383	16015	104713	52.3	8
1999	2423	1974	2379	2654	9430	16082	110587	58.6	8.5
2000	3022	1525	2630	2660	9837	16603	108593	59.2	9.1
2001	3536	1509	2505	2824	10374	16415	108506	63.2	9.6
2002	3695	1896	2340	2578	10509	17971	110417	58.5	9.5
TOTALS 1997-2002	17002	9814	13569	15384	55769	96708	638645	57.5	8.7
2003	3836	1800	2678	2511	10825	17164	110851	63.1	9.8
2004	4147	2666	1963	3033	11809	18241	113697	64.7	10.4
2005	3926	2490	1883	2660	10959	17131	113914	64	9.6
2006	4453	2607	1720	2858	11638	17060	118112	68.2	9.9
2007	4238	1797	2135	2856	11026	16632	122637	66.3	9
2008	3802	2105	1737	3152	10797	16196	125017	66.7	8.6
TOTALS 2003-2008	24402	13465	12116	17070	67054	102424	704228	65.5	9.6
TOTALs 1997-2008	41404	23279	25685	32454	122823	199132	1342873	61.5	9.1

Source: Data for 1997-2005 derived by Prof. K. Nagaraj from NCRB reports (Accidental Deaths & Suicides in India) for those years (The Hindu , Nov. 12-15, 2007) and extended thereafter with NCRB ADSI data from years 2006, 2007 and 2008.

* MP & Chhattisgarh now have separately recorded data for recent years (available on the NCRB website). As the data for earlier years cannot be disaggregated they are treated as a single entity in this table.

Behere & Behere (2007) draw attention to the failure of the government to support its farmers by contrasting India with the United States, where 18,600 cotton farmers receive \$4 billion in subsidies and government aid every year to grow their crops in conditions infinitely superior to Maharashtra's three million plus small holder farms. Indian cotton farmers do not get any kind of meaningful subsidy and their only form of debt relief is in the shape of loan waivers that do not even cover informal loans from local moneylenders and relatives to whom the vast majority are indebted. Suicide is a social as well as an economic manifestation and the technology itself can only be held accountable for rising suicides to a limited extent. The Indian government is just as culpable for failing to remove the underlying causes of chronic debt that have been extant for far longer than the Bt gene. The number of farmers committing suicide in India is double the total of the next 100 countries together, which clearly shows that something particular is occurring in India regardless of the introduction of biotechnology. Bt cotton is obviously not the whole answer, but the manner in which it has been promoted and then failed to produce has no doubt contributed to significant indebtedness and stress.

Overall profit impact

Overall, the evidence from Bt cotton in India does not reflect well on the potential of biotech crops to increase the incomes of poor farming households. There have certainly been farmers who have gained from introducing Bt cotton, but new hybrids are by no means a

guarantee of higher net profits. The evidence suggests that at best Bt varieties have helped stabilize the relative cost of producing a kilogram of cotton, but this is only because it has improved yields. The actual cost of production per hectare has increased since 2002, which means that farmers *have* to produce more simply to cover the rise in input expenses that come particularly from seed costs. Contrary to the promises of the biotech companies, planting Bt cotton has had little real effect on the use of insecticides, mainly because of the complex relationship between farmers and pesticides, which is primarily influenced by the risks associated with not applying them, rather than the actual need to use them. Any net gains farmers have realized since the introduction of biotech crops have come from increased yields, not cost savings nor higher prices for Bt cotton.

The development of more long staple Bt varieties will help farmers gradually raise the revenue they get from their crop, but a Bt long staple holds no advantage over a non-Bt long staple in terms of the prices offered at market or from the government. There is also evidence to suggest that the proliferation of Bt and the production boom it has inspired have actually put downward pressure on prices with local and global markets saturated as demand struggles to keep up with supply. Balancing production growth and demand is a serious challenge for biotech crops all over the world, as falling prices could turn out to negate any advantages generated by increased yields, thus rendering biotech crops worthless or even damaging to the farmers that grow them. There are indications that this scenario is already playing out in the impoverished cotton growing regions of India, with escalating problems of farmer debt and a spike in suicides that seem to be partly attributable to the cost/price dilemma of Bt cotton.

At this stage, only eight years since the commercialization of Bt cotton, the limitations of the data do not allow any comprehensive judgment on the economic benefits of biotech crops at the household level. There are farmers who have benefited and there are farmers who have been disadvantaged; both situations are the outcome of the complex interaction of factors in which Bt cotton plays only a small part. Most worrying is that any profits that are realized will only be short term if the government does not actively improve market and infrastructural conditions or welfare schemes for farmers so that further rises in the cost of production can be offset by adequate prices. Without this, Bt will not just fail to enrich farmers; it will make them worse off. Biotech crops are not a quick fix remedy for poor farmers; they do not increase revenues simply by the virtue of being genetically engineered. To improve the wealth of farmers, biotech crops need to be but one part of a comprehensive rural institutional, infrastructural, market and welfare strategy.

c) The local community and services

Two studies from 2007 released by the Associated Chambers of Commerce and Industry of India (ASSOCHAM) that strongly expound the virtues of Bt cotton are heavily publicized by Monsanto, and form the basis of the company's argument that growing biotech crops brings significant socio-economic benefits. The studies by Indicus Analytics and the Indian Market Research Bureau (IMRB), which are unavailable publicly, are detailed in a press release from Monsanto (2007) and claim to prove "that the average Indian cotton farmer who has adopted Bt cotton is leading a much better life over his non-Bt counterpart." It is alleged that villages with predominantly Bt farmers are "clearly" ahead when compared to non-Bt villages in socio-economic indicators.

This contrasts significantly with the evidence from the section above, which found cotton farmers increasingly struggling to make a living and communities struggling with debt and suicides, regardless of whether they have adopted Bt varieties. There is little other official evidence to support any of the claims made by the two studies and Monsanto's case is not helped by the fact that its own conclusions are based on a summary of these studies released by ASSOCHAM, not the data itself. If farmers cannot cover the costs of production, it is highly unlikely that they would be able to afford better health, education or social services. It is arguable that since 2002 the very opposite scenario has developed in certain areas. Sharma (2010b) is very vocal in his belief that the actions of the government and seed companies in promoting Bt cotton and its subsequent failures in many parts of country, has caused villages to descend into "cesspools of deprivation."

Healthcare

The Indicus Analytics (Monsanto, 2007) study supposedly illustrates the positive impact Bt cotton has on access to health services, and particularly on the wellbeing of women and children in biotech cultivating households. The study describes higher levels of maternal care and increased levels of immunization among children of Bt farmers. Those who had only recently taken up Bt cotton were found to be not as socially advantaged as early adopters, implying that the longer farmers cultivate Bt, the better off they become. Monsanto understandably highlights this study to promote the advantages of its biotech products, but there are some serious shortcomings in the use of this study primarily due to the fact that the original studies are not publicly available for analysis. There is absolutely no evidence in these studies of a causal relationship between the adoption of Bt cotton and improved socio-

economic standards of farmers. The situation of these farmers prior to the commercialization of Bt cotton is not known, and it is likely that early adopters were wealthier and healthier to start with, given that they were able to afford both the cost of Bt seeds and the risk of adopting a new technology (Morse, Bennet & Ismael. 2007a).

The general trend in rural health standards over the past few decades has been upward using a multitude of indicators, such as births attended health professionals, child and infant vaccinations, birth and death rates, life expectancy, and the number of rural people covered by health care infrastructure. It is expected that these issues will have continued to improve in the 2000s as they did in the 1990s, but unfortunately there is little data to confirm this. Determining the true impact of Bt cotton on the health of cotton households is actually very difficult due to the limited availability of recent and comprehensive statistics at either the state or national level. The last full census was in 2001 and the most recent national family health survey covered 2005-06, and neither can be disaggregated to a state or sector level to find a causal link to Bt cotton.

The National Rural Health Mission launched in 2005 has led to an improvement in performance of a multitude of programs, from the maternal mortality ratio, which is down to 254 deaths per 100,000 during 2004-06 from 381 in 2001-03, to the infant immunization ratio which had risen to 54% over 2007-08 from 46% during 2002-04 (Health Management Information System, 2009). The creation of the programs such as the Janani Suraksha Yojana maternal health scheme in 2003, which focuses directly on families below the poverty line, helps provide health benefits to rural households regardless of the success of crops or market conditions. The achievements of these programs compared to the variability of cotton performance implies that any increases in access to health care among poor cotton farmers are much more likely to be attributable to these schemes than the introduction of Bt cotton.

Brookes and Barfoot (2008) argue that additional income derived from biotech crops, especially insect resistant Bt cotton has enabled more farmers to consistently meet their food subsistence needs. National statistics on the other hand show that contrary to these authors' argument, intake of calories in India has actually been declining over the last forty years, with the number of malnourished reaching a new high in recent years (FAO, 2009). Data from the Ministry of Health and Family Welfare shows that the average number of calories consumed per day has decreased from 2,296 in 1975 to 1,955 in 2001, with protein intake falling from 63.6 grams per day to 50.7g over the same period. Unlike other GE crops, Bt cotton is not cultivated as a food staple and therefore any impact it has on nutrition must come from higher farm incomes, which have not necessarily been forthcoming. The effect of

Bt cotton on malnutrition will be discussed in greater detail in the next section, but it appears that there is little evidence to suggest that the cultivation of biotech has had any positive effect on rural consumption.

From a nutritional point of view, the majority of Bt cotton is not grown for food, and although some of it does end up as cotton-seed oil, farmers are not deriving any direct nutritional or health benefits from increased production of Bt cotton. There has been much written about the potential health threats of growing genetically engineered foods; the use of viruses to insert and switch-on foreign genes is deeply controversial and the infamous cases of L-tryptophen related deaths in the US and BSE in the UK have all been linked to dangerous genetic modifications. The potential risks of food crops such as wheat, corn and soy are at the heart of the EU's reluctance to approve their cultivation. The safety of Bt cotton and derived food products has however been established by a number of bodies, including the OECD (2007) and Genetic Engineering Approval Committee (GEAC) in India.

The lack of receptors that bind to Bt toxins and their instant degradation in the human digestive system means that the Bt gene is innocuous to humans (Karihaloo & Kumar, 2009). Nevertheless, health concerns have been raised following a growing number of incidences of animal deaths including nearly 2000 goats and smaller flocks of sheep in Andhra Pradesh who had been grazing in Bt cotton fields. The intestines of the goats had shriveled, and the food found inside them was undigested which suggests that the organisms and enzymes that digest the food had died from novel toxins (Bhatt, 2009). Animal Husbandry Department officials admitted for the first time that a group of dead sheep showed "complex, mixed symptoms, which cannot be attributed to any known diseases" and that an "as-yet unidentified toxin in Bt cotton could be the cause" of the deaths (Venkateshwarlu, 2007). The GEAC has vehemently denied these claims and has criticized the scientific evidence, accusing the NGOs that reported it of scaremongering. However, whilst a direct connection with the Bt gene has not been formally established it raises enough degree of uncertainty to query the safety current and proposed Bt crops. It is not possible to say categorically that Bt cotton is unhealthy, but neither is it possible to say categorically that it is not. Combined with the lack of any evidence that Bt cotton has improved the access to health services of adopting farmers, it is viable to conclude that the health impact of Bt cotton has been negligible at best.

One tangible health benefit Bt cotton can bring, although the evidence that it has done so is limited, is through the reduction of toxic chemicals that are sprayed in pesticides. Cotton is one of the most heavily treated crops in commercial production, and Indian cotton

farmers are considered to work in some of the most unsafe agricultural environments in the world (Environmental Justice Foundation, 2007). Women and children are directly exposed to pesticide application and are often the first victims of poisoning due to the lack of, or inefficient adoption of safe-handling and protective measures when spraying pesticides. Some of the pesticides used on cotton are among the most toxic chemicals used in global agriculture. Yet, contrary to the explicit instructions of chemical providers, millions of poor cotton farmers work bare-footed and bare-handed when spraying pesticides, often mixing active ingredient with their hands without any protective clothing. Farmers are not supposed to enter the field for 48 hours after spraying because of many of the chemical's impact on the human nervous and immune systems, and yet a study of poor farmers in Madhya Pradesh found farmers were frequently reusing pesticide containers to carry drinking water, let alone entering the fields.

In a 2005 study of cotton farmers in three villages of Andhra Pradesh over a five-month growing season, 97 cotton laborers involved in the study suffered 323 separate incidences of ill health, of which 84% showed symptoms of mild to severe pesticide poisoning, such as tremors, nausea, weakness and paralysis (Environmental Justice Foundation). Pesticide poisoning has also been linked to infant and foetal neural development problems, chronic fatigue syndrome and Parkinson's disease. The environmental impacts of many of these chemicals will be discussed in greater detail in the next chapter, but it is important to note here the huge impact Bt cotton could have on the health of cotton households if it does succeed in reducing the amount of toxic pesticides applied to cotton. There has been a steady decline in the amount of the most toxic technical grade pesticides in the last fifteen years, but this reduction began in the 1990s and has seen much variability year to year (Karihaloo & Kumar).⁹ Unfortunately, as detailed above there is limited evidence to suggest that the proliferation of Bt cotton over the last eight years has had any truly significant reduction in pesticide consumption, and thus the health problems associated with it are likely little changed.

Education

The impact of Bt cotton on education appears to be similarly slight despite the ASSOCHAM studies claiming higher school enrollments in Bt-growing communities. As

⁹ Technical Grade pesticides are those in which the chemical compound consists of over 85% of the active chemical constituent. The rest being made up of impurities produced during the chemical synthesis in production.

with health statistics, there is a dearth of comprehensive data for recent years, which makes it difficult to define any clear relationship between the proliferation of Bt cotton and education levels. In the data that exists there does not appear to be any conclusive evidence to suggest that the introduction of GE cotton has improved access to education or the percentage of children attending school in rural areas, at either a national or state level. Whilst there was a significant increase in the number of recognized primary schools nationwide over the course of 2002-2004, these growth levels have not been replicated in enrollment rates, particularly in cotton states. From 2000-01 to 2006-07 the number of children enrolled in primary education in all cotton states actually decreased by 200,000.

The link between the proliferation of Bt cotton and increased education is particularly tenuous given that 5 out of 9 cotton states have seen a reduction in enrollment since its introduction. (Table 5.10). This is especially apparent in Andhra Pradesh where the number of children enrolled in grades I to V decreased by 17% from 2000 to 2007, despite being one of the states to benefit the most from increased production levels since the commercialization of Bt cotton. The largest jump in the number of schools offering primary education was seen in Madhya Pradesh from 2003 to 2005, which also experienced a significant rise in enrollment, particularly among girls. This is directly explicable by the introduction of compulsory primary education in that state in 2004, and cannot be attributed to the spread of Bt varieties among its millions of poor cotton farmers. Rajasthan experienced the largest increase in the number of children enrolled in primary education since 2002, but this rise is accounted for entirely by a 50% increase in the number of girls attending school, an intriguing development that cannot reasonably be explained by the spread biotech cotton.

Table 5.10

State-wise number of children enrolled in primary education- Classes I-V (ages 6-11)

State	2000-01			2006-07			% Growth 2000-01 to 2006-07		
	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls	Total
Andhra Pradesh	4,553,047	4,352,906	8,905,953	3,736,789	3,626,448	7,363,237	-18%	-17%	-17%
Gujarat	3,815,558	2,955,246	6,770,804	3,706,139	2,854,784	6,560,923	-3%	-3%	-3%
Haryana	1,063,730	954,125	2,017,855	1,172,867	1,024,429	2,197,296	10%	7%	9%
Karnataka	3,462,982	3,195,021	6,658,003	2,955,183	2,769,823	5,725,006	-15%	-13%	-14%
Madhya Pradesh	6,141,829	4,971,349	11,113,178	6,219,123	5,593,845	11,812,968	1%	13%	6%
Maharashtra	6,128,312	5,592,379	11,720,691	6,167,188	5,481,262	11,648,450	1%	-2%	-1%
Punjab	1,120,484	991,740	2,112,224	1,021,123	901,430	1,922,553	-9%	-9%	-9%
Rajasthan	5,091,685	2,830,160	7,921,845	4,998,342	4,328,223	9,326,565	-2%	53%	18%
Tamil Nadu	2,918,410	2,791,035	5,709,445	3,162,388	2,983,583	6,145,971	8%	7%	8%
Cotton States	34,296,037	28,633,961	62,929,998	33,139,142	29,563,827	62,702,969	-3%	3%	0%
India	64,006,431	49,820,547	113,826,978	70,985,611	62,540,119	133,525,730	11%	26%	17%

Source : Ministry of Human Resource Development, Govt. of India.

There are serious problems in the Indian education system; including very high teacher pupil ratios, bad infrastructure, and poor quality teacher training which all have significant impacts in enrollment. Bad education leads parents to question the worth of sending children to school, which perpetuates the cycle of under-education in rural areas, a problem that will not be much remedied by the introduction of any biotech crop. It is only in the last two decades that primary education has become compulsory throughout India, with Rajasthan the last cotton state to implement it in 2009, and then only after a nationwide act was introduced for free and compulsory education for children across India (Right of Children Act, 2009). There remain significant shortcomings in the educational infrastructure, although government schemes are making some progress in rural areas. The District Primary Education Program for example, has opened 160,000 new schools since 1994 making primary education available to over 3.5 million children. Despite the limitations to these schemes, they are much better able to explain any increases in rural education than widely variable increases in farmer incomes from Bt cotton. It is not impossible that in areas where Bt cotton has in fact been successful, the reduction in labor requirements related to cotton pest control has enabled farmers to afford to send more of their children to school. However, at a nationwide and statewide level there is insufficient evidence to draw any kind of causal relationship between the introduction of Bt cotton and higher school enrollment.

Overall impact on local services

There have doubtless been incidences throughout India where villages and farming communities have benefitted from the adoption of Bt cotton, the positive yield and production developments across India necessitate that some farmers will have benefitted from these developments. Rising incomes do contribute to socio-economic advantages; for example, farmers gain the ability to allow some or all children to attend school instead of requiring them to work on the farm, or can afford for pregnant wives and daughters to be attended by medical professionals. It is very likely that a good number of farmers will now have experienced these benefits if they managed to realize higher earnings from Bt cotton than they did with non-Bt. Unfortunately, the scope of national and regional data does not provide sufficient evidence to state comprehensively that planting Bt cotton automatically brings socio-economic advantages; there are too many contributing factors in the success of a crop or realization of profit to isolate the Bt gene as the cause of community development. The two ASSOCHAM studies publicized by Monsanto to promote its Bt seeds demonstrate significant health and educational benefits for Bt farmers, but there is scant support provided

to back up these claims. Progress in primary education is shown to be a fabrication by the government data that proves declining enrollment in cotton growing states since the commercialization of Bt cotton. Similarly, the evidence from national statistics reveals that improved health services appear to be primarily the result of government initiatives not greater rural wealth.

Chapter 6. Medium-term: development impact

At the heart of the argument in favor of genetically engineered crops, extolled by scientists, economists, seed companies and NGOs alike, is that biotechnology in agriculture is not just a tool for economic development; it is a genuinely pro-poor technology that will reduce poverty and inequality in rural areas and increase food security (ISAAA, 2008; Monsanto, 2008; Bill & Melinda Gates Foundation, 2010). It is widely publicized that cost efficient, high yielding, genetically engineered crops will help raise the income levels of millions of impoverished farming households across developing countries; ‘scale-neutral’ technology will tackle inequality in farming with the benefits of GE crops realizable by farmers large and small alike; higher, more stable yields will contribute to greater food security and help bring down food prices, fighting malnutrition among the rural and urban hungry. This is a very idealistic vision, and as can be inferred from the analysis in preceding sections, whilst Bt cotton does work from a technical point of view it is not conspicuously pro-poor.

Deriving benefits from Bt is not just the outcome of purchasing a seed; it is the successful implementation of a process. A very complex process that depends just as much on farmers’ skills and resources as it does on favorable market conditions, geographic location and the weather. GE crops were not originally designed with poverty alleviation in mind, they were intended for large scale farming in the United States where farmers are supported by subsidies, insurance and market networks (Glover, 2010). The constraints of the small-holder farmer in the developing world were not necessarily considered in the initial development of GE crops, which helps explain the failure of Bt cotton across much of India in the first few years of adoption. This chapter will try and look beyond the promises and potential of GE crops to try and establish exactly how far Bt cotton really has helped fight poverty, inequality and malnutrition in India.

a) Poverty

The pro-poor argument of proponents of GE crops in India is epitomized by Subramanian and Qaim (2009:1) who state that “aggregate household incomes rise, including the poor and vulnerable farmers, highlighting that Bt cotton contributes to poverty reduction and rural development.” This argument has been roundly criticized by opponents of GE crops

who argue that the pro-poor label attached to agri-biotech is merely invoked by biotech companies as a moral platform on which to sell more crops to developing countries. The analysis in preceding chapters illustrates that there is considerable evidence to suggest that the pro-poor argument has been exaggerated in India; pro-GE authors can be reliably accused of insufficient analysis of the counter arguments or complex institutional barriers to social change. If development were a technical problem, it would have been solved a long time ago.

At an individual level the ways Bt cotton effects farmers are complex and highly context dependent. Some farmers have gained, but some undoubtedly have not. Certainly, on an aggregate level there has been no revolutionary impact on rural poverty in India as a result of the introduction of Bt cotton. Nevertheless, it is a mere eight years since Bt cotton was introduced to India, a very short time in the scope of national development. To declare comprehensively that Bt cotton has been either beneficial or detrimental to poverty reduction would be premature. The best that can be done is to analyze the evidence so far and form a realistic expectation on the technology's long-term impact on poverty at the national level.

Jansen and Gupta (2009) stress the importance of not misunderstanding the pro-poor biotech writings emanating from within the biotech community. These authors are not promising a future paradise in which transgenic crops end hunger, they are merely arguing that biotech can contribute to reducing poverty. Farmers, National governments and NGOs are all heavily influenced by their assumptions and fears about the poor, poverty and the 'onrushing future,' in which the key message is that we cannot afford to postpone action. They are therefore highly susceptible to the promises, however slender, of the development prospects of new technology. The fear of poverty is an important factor that must not be ignored when attempting to explain the continued spread of biotech crops despite minimal benefits accruing to farmers.

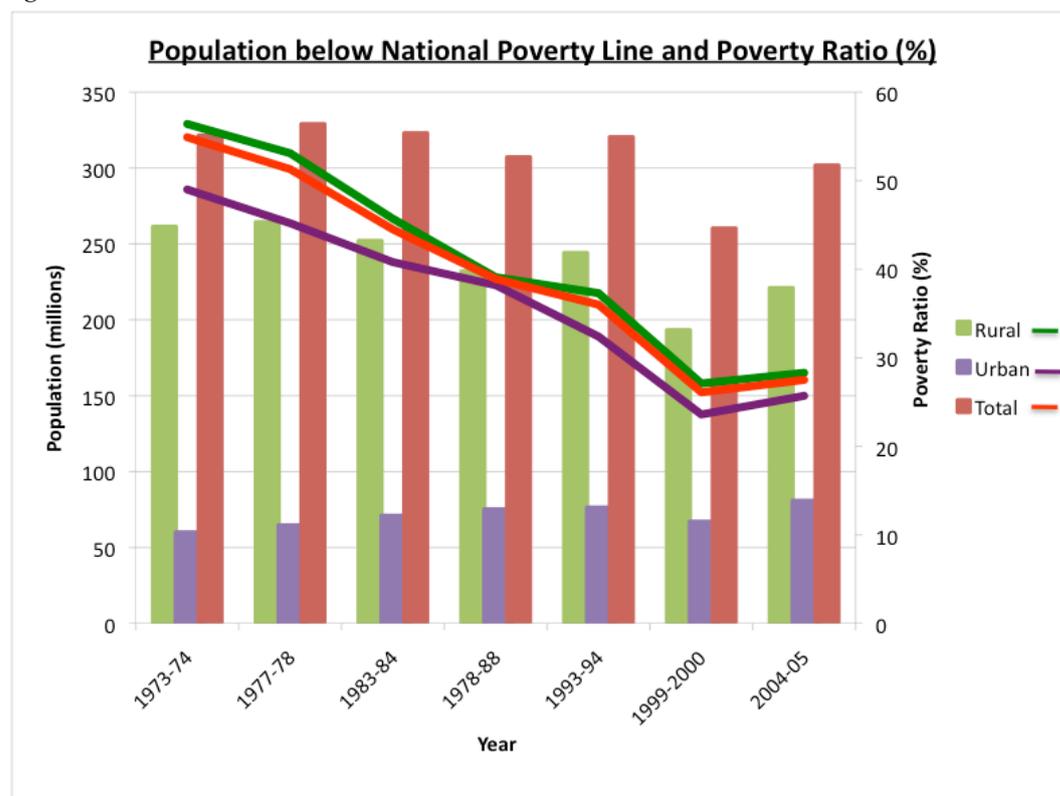
Rising poverty levels

What can be derived from national statistics is relatively limited given the complex relationship between technology and poverty. Whilst the poverty ratio in India experienced a steady decline between the 1970s and 2000, the actual number of people living below the national poverty line effectively remained stagnant until the late 1990s at around 320 million (National Institute of Rural Development, 2004).¹⁰ There was a significant drop in

¹⁰ Poverty Ratio is the percentage of people or households who live below the national poverty line as a share of the total population. The Poverty Line (or threshold) is the minimum level of income deemed necessary to achieve an adequate standard of living, determined by totaling the cost of all essential resources one adult will

the number of poor to a low of 260 million between 1994 and 2000, but the latest statistics compiled in 2005 show that the number below the poverty line has risen again to over 300 million. (Figure 6.1). After a steady three-decade long declining trend the poverty ratio also increased after 2000 rising to 27.5% of the population. Since 2000 the increase in urban poverty has been slightly more marked, increasing by over 20% in five years compared to 14% in rural areas. The incidence of poverty among the rural population has nevertheless been consistently slightly higher than in the urban centers, with those living in rural areas accounting for 73% all of poverty in India. The incidence of rural poverty has declined since the 1970s but it is arguable that this is primarily the product of massive migration to the cities and subsequent rise in the number of urban poor rather than the effect of a significant increase in rural wealth. This negative turn in poverty levels since the turn of the century is particularly troubling for Indian development given that it has happened during a period of unparalleled national economic growth and significantly reduced demographic pressure.

Fig. 6.1



Source: Rural Development Statistics 2002-03, National Institute of Rural Development & Annual Report 2003-04; and Press Information Bureau, Gov. of India.

consume in a year. The international poverty line as determined by the World Bank and United Nations is \$1 per day, or \$1.25 at 2005 Purchasing Power Parity (PPP). National poverty lines vary for country to country and can be significantly lower than \$1.25 per day in developing countries.

The state-wise figures show a similarly negative development in rural poverty since 2000, with an increase of nearly 10 million people living below the poverty line in cotton states, the majority of these in Maharashtra. (Table 6.1). Despite increases in the state poverty threshold in every state since 2000, cotton states have still witnessed increased poverty since the introduction of Bt cotton. Madhya Pradesh is the only cotton state to have experienced a decline in both the number of people living below the poverty line and the rural state poverty ratio. Unfortunately there is no more recent data than 2005, therefore the role which Bt cotton has played in this is hard to define. Given that 2004-05 was only two full cotton seasons after the commercialization of GE varieties and Bt farmers numbered under a million across all states, the new technology is not realistically the cause of such a significant rise in state poverty levels (Manjunath, 2008).

Table 6.1

State-wise number & percentage of rural population below rural poverty line (1999-00 to 2004-05)

State	1999-2000			2004-2005			Annual % growth in Poverty Line
	No. of Persons (millions)	% of Persons	Poverty Line (Rs per capita per month.)	No. of Persons (millions)	% age of Persons	Poverty Line (Rs per capita per month.)	
Andhra Pradesh	5.81	11.1	262.94	6.47	11.2	292.95	2.74%
Gujarat	3.98	13.2	318.94	6.35	19.1	353.93	2.64%
Haryana	1.19	8.3	362.81	2.15	13.6	414.76	3.40%
Karnataka	5.99	17.4	309.59	7.51	20.8	324.17	1.16%
Madhya Pradesh	21.73	37.1	311.34	17.57	36.9	327.78	1.29%
Maharashtra	12.51	23.7	318.63	17.11	29.6	362.25	3.26%
Punjab	1.02	6.4	362.68	1.51	9.1	410.38	3.14%
Rajasthan	5.51	13.7	344.03	8.74	18.7	374.57	2.15%
Tamil Nadu	8.05	20.6	307.64	7.65	22.8	351.86	3.41%
India	193.2	27.09	327.56	220.9	28.3	356.3	2.12%
Cotton States	65.80	9.2	322.07	75.05	9.6	356.96	2.61%

Source 1999/00 : Agricultural Statistics at a Glance 2003, Ministry of Agriculture & Rural, Development Statistics 2002-03

Source 2004/05: Compiled from the statistics released by Press Information Bureau, Govt. of India.

Note: Poverty Line based on Uniform Recall Period (URP) Consumption in which the consumer expenditure data for all the items are collected from 30-day recall period.

One possible explanation for rising poverty can be found in the misalignment of the national and state poverty lines with inflation in the price of commodities as measured by the Consumer Price Index (CPI). The annual growth in the average poverty line of cotton-growing states was 2.61% per year between 2000 and 2005, whereas inflation in India's CPI was on average 4% per year during the same period (www.global-rates.com, 2010).¹¹ This implies that even though the nominal poverty line has risen every year it has never been high enough to offset the increase in consumer prices. Consequently, more and more people have

¹¹ The Indian CPI shows the change in prices of a standard package of goods and services which Indian households purchase for consumption. In order to measure inflation, an assessment is made of how much the CPI has risen in percentage terms over a given period compared to the CPI in a preceding period.

slipped below the poverty threshold each year as they suffered from the effects of increased consumption expenditure but stagnant income levels, particularly among cotton farmers.

Interpretations of poverty

The complexity of trying to derive any significant relationship between Bt cotton and aggregate poverty levels is further complicated by variability within poverty data itself. The significance of which data is chosen and how it is interpreted is critical when determining the impact of Bt cotton; the polar differences in many of the judgments on its effect clearly show how data can be understood and represented for different ends. The traditional means of establishing poverty levels in India is through the use of Uniform Recall Period (as is used in Table 6.1) because of its continuity with historical data. However, there are other methods that give entirely contrasting results, and could easily be interpreted to denote causality between Bt cotton and poverty where none exists.

Use of the Mixed Recall Period (MRP) consumption method is one such example. This method supplements the traditional 'uniform' consumption thirty-day recall period with consumer expenditure data for five non-food items, namely clothing, footwear, durable goods, education, and institutional and medical expenses from a 365-day recall period. Table 6.2 shows the very contrasting changes in rural poverty levels that can be realized using different methods. The URP method shows poverty increasing between 2000 and 2005, whereas the MRP method shows the number of people below the poverty line declining over the same period. The MRP method may in fact be a more comprehensive way of measuring the poverty line, but it is not available for the 1999-2000 period and therefore gives no reliable indication of a change in poverty levels over that period. It therefore cannot be used to illustrate a relationship between the introduction of Bt cotton and poverty levels.

Overall prospects for poor cotton farmers

It is essential to remember that poverty is a relative term, particularly in the global context. Whatever the claims of the pro-Bt authors, Indians are still among the poorest in the world. In a population of over one billion, where over 300 million live below the poverty line the effect of one crop grown by a mere 5-6 million farmers can only have a limited effect on national poverty levels no matter how much yields increase. Even if Bt cotton does help to reduce poverty in national terms compared to industrial nations India's farmers will still be extremely poor. The national poverty line in India in 2004-05 was 356.3 Rupees monthly per capita; at 2004 exchange rates this was the equivalent of about US 30 cents per day. Even in

terms of Purchasing Power Parity (PPP), this is still well below the international poverty line of \$1.25 per day that 34% of Indians live below (Subramanian & Qaim, 2009; UNDP, 2005). Without accounting for PPP it is estimated that 44% of Indians live below \$1.25, and a staggering 80% live below \$2 per day, which is nearly seven times the national poverty line (World Bank, 2005; Chen & Ravallion, 2007).

The scope of poverty in India is such that Bt cotton, or any other single technology, can only do so much to reduce it. As a result, the bold pro-poor statements of GE authors and biotech seed companies need to be tempered in light of the context of Indian poverty. On a national level it is evident that the adoption of Bt cotton has had no significant effect on poverty reduction in India. Since its introduction poverty has in fact increased, although it is also unlikely that Bt cotton has played any demonstrable role in this either. It is essential to remember that poverty is a social and institutional manifestation as much as it is an economic or a technical one. Despite the positive yield and profit effects they may bring genetically engineered crops are not a solution to poverty. Even if implemented with a full compliment of supporting social policies GE crops can only ever be one of many approaches to tackling the problem.

Table 6.2

State-wise comparison of rural poverty data using different methods

State	1999-2000 (Uniform Recall Period)		2004-2005 (Uniform Recall Period)		2004-2005 (Mixed Recall Period)	
	No. of Persons (millions)	% of Persons	No. of Persons (millions)	% age of Persons	No. of Persons (millions)	% age of Persons
Andhra Pradesh	5.81	11.1	6.47	11.2	4.32	7.5
Gujarat	3.98	13.2	6.35	19.1	4.63	13.9
Haryana	1.19	8.3	2.15	13.6	1.46	9.2
Karnataka	5.99	17.4	7.51	20.8	4.33	12
Madhya Pradesh	21.73	37.1	17.57	36.9	14.20	29.8
Maharashtra	12.51	23.7	17.11	29.6	12.84	22.2
Punjab	1.02	6.4	1.51	9.1	0.98	5.9
Rajasthan	5.51	13.7	8.74	18.7	6.67	14.3
Tamil Nadu	8.05	20.6	7.65	22.8	5.65	16.9
India	193.2	27.09	220.9	28.3	170.30	21.8
Cotton States	65.80	9.2	75.05	9.6	55.08	7.1

Source 1999/00 : Agricultural Statistics at a Glance 2003, Ministry of Agriculture & Rural, Development Statistics 2002-03
Source 2004/05 : Compiled from the statistics released by Press Information Bureau, Govt. of India.

Note: - Uniform Recall Period (URP) poverty Line: Consumption in which the consumer expenditure data for all the items are collected from 30-day recall period.
- MRP Consumption (MRP) poverty Line: Mixed recall period consumption in which consumer expenditure data for five Non-Food items, namely, clothing, footwear, durable goods, education and institutional, medical expenses are collected from 365-day recall period and the consumption data for the remaining item are collected from 30 day recall period.

b) Inequality

Poverty and inequality are often mentioned in the same breath when discussing development, but whilst they are frequently the outcome of the same social and economic

processes, one does not necessitate the other. Countries with high levels of poverty can have relatively good income equality throughout its society, of which India is a commonly used example, whereas rich countries can have high income inequality, such as the United States. Bt cotton is often presented as a 'scale neutral' technology, which means that no group should be more advantaged in growing it than others; all should benefit, including small and resource poor farmers (Morse, Bennet & Ismael, 2007; Rao & Dev, 2009; Herring, 2009). Despite these bold claims, there is in fact a dearth of studies on Bt cotton's effect on inequality, and those that have been done fail to provide any grounds for inferring a causal relationship between growing Bt cotton and greater equality. Many inequality studies actually base their results on data from field trials or studies of early adopters who had more land, good access to irrigation and better resources than most cotton farmers. Consequently, any evidence that adopting Bt cotton reduces inequality is compromised by the fact that many studies were performed on a relatively wealthy, and equal group.

Measuring national inequality

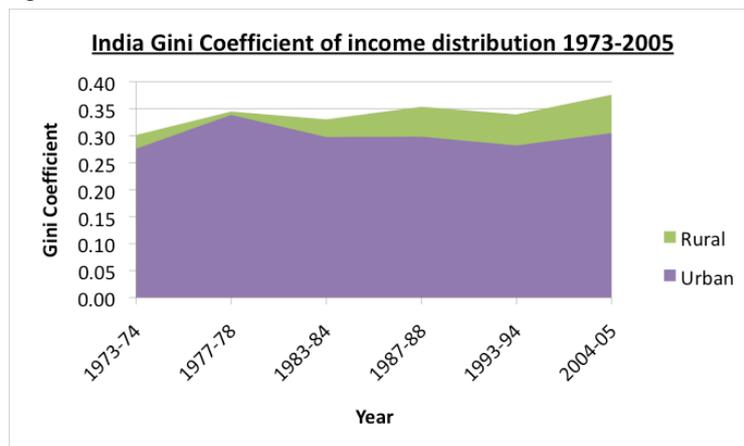
The easiest way to assess Bt cotton's overall effect on national equality is to look at the aggregate national data, in which there is little significant evidence of the technology's impact either way. The most commonly used indicator for measuring income inequality is the Gini-coefficient, in which the coefficient varies between 0, which reflects complete equality and 1, which indicates complete inequality, when one person has all the income or consumption and all others have none. India has an infamously low Gini-coefficient (0.368), which is only marginally greater than New Zealand and the United Kingdom, and significantly lower than other developing countries, notably China and Brazil who have larger economies (Human Development Report, 2009). India's Gini-coefficient has risen since the turn of the century, but has stayed relatively low primarily because of the breadth of poverty in India shared by hundreds of millions people compared to a limited number of the relatively wealth. Compared to other issues inequality is therefore one of the least of India's problems.

There is however evidence to suggest that India's Gini-coefficient is actually not truly indicative of the extent of inequality. The National Sample Survey Organisation (NSSO) that collects the statistics on which the Gini-coefficient is based, is not only under-representative of the rich but also refers to the distribution of consumption expenditure and not income distribution like most other countries (Bardhan, 2009). Consumption expenditure is not only usually less than income, but because the rich tend to save more than the poor it also reduces the gap between rich and poor much more than income distribution does. The

NCAER (National Council of Applied Economic Research) occasionally collects income data, and according to their last household survey in 2004-05 India's Gini-coefficient of income inequality was actually 0.535, which would put Indian inequality in the realms of Latin American countries, which are notoriously and dangerously unequal.

Other forms of inequality also suggest that India is less equal than is often suggested. For example, the Gini-coefficient for land distribution is extremely high in India (0.620) mainly due to the size of the landless population. Inequality of opportunity, which has not been much studied in India, is also understood to be considerable (Bardhan, 2009). Bt cotton is only really equal in that all farmers grow the same seed, but this is also true of conventional seeds. The opportunity afforded by Bt seeds is not just technical; it is something that depends on land distribution, education and also social identity. In a country like India where caste still plays a very influential role in life, education and land (or lack of it), social identity can severely handicap a farmer regardless of whether he plants a Bt or conventional seed. The role of land distribution and caste in inequality is illustrated by the differences between rural and urban Gini coefficients, through which rural inequality is consistently higher than urban. (Figure 6.2).

Fig. 6.2



Source: Ministry of Rural Development, Govt. of India.

Scale neutral technology & the farmer effect

Usual patterns would suggest that large farmers would benefit more from Bt cotton than small farmers due to costs reductions through economies of scale, better infrastructure, greater access to markets and labor, and higher credit levels. It is also arguable that wealthier farmers are more inclined to apply inputs correctly. Morse et al (2007a) however, suggest that there is no 'farmer effect' in the success of Bt cotton and hence it is a

'scale-neutral' technology; all farmers benefit from Bt regardless of plot size, access to credit, other farm and non-farm sources of income, irrigation or education. These authors propose that the Gini-coefficient among Bt cotton adopters was less (0.340) than among non-adopters (0.412). From this they conclude that there is greater equality among Bt households than among non-Bt households, consequently Bt cotton increases equality regardless of farm size or wealth. The implication is that wider adoption of Bt will reduce inequality among all farmers. There are however serious grounds for objection to this conclusion. The causal relationship inferred between adopting Bt cotton and reducing inequality is not validated with any significant evidence. To be able to substantiate this claim Gini-coefficients would need to be provided for these same groups before the adoption of Bt cotton, to prove that the Bt adopters were not already more equal before 2002. No such evidence is provided though and it is likely that equality among the Bt groups is related to something entirely different, such as plot size or access to irrigation.

The argument that Bt cotton is scale-neutral and not impacted by a 'farmer-effect' is further undermined by the experiences of Andhra Pradesh and Maharashtra where irrigation proved to have a significant effect on Bt yields. Furthermore, some studies by ostensibly pro-GE authors also imply similar conclusions regarding the importance of irrigation. Morse, Bennet & Ismael et al (2004, 2005, 2007a) undermine their pro-poor conclusions about Bt performance by admitting that their trials were conducted in irrigated areas with good growing conditions that allowed higher than average production, and are the domain of the wealthiest farmers. The implication is that poor farmers without irrigation (more than two thirds of cotton growers) may not be able to obtain such positive results.

Farmers with irrigation tend to be wealthier farmers in the most fertile regions, such as in Haryana and the Punjab, which are heavily irrigated and consistently had the highest yields among cotton-growing states even before the introduction of Bt varieties. These farmers were also more likely to be able to afford the cost of Bt seeds, which in the first few years of commercialization were up to three times more expensive than conventional varieties (Sadashivappa & Qaim, 2009). Pressure from farmers and regional governments has encouraged companies to reduce seed prices, but the serious problem of the proliferation of fake seeds particularly among small farmers, shows that basic wealth remains an important factor in the ability of many farmers to really take advantage of Bt.

More controversially, some authors touting the equality benefits of GE seeds have actually been found to contradict themselves from one paper to another (Glover, 2009). Morse, Bennet & Ismael (2007a) state in one paper that there is no farmer effect and all

farmers can benefit equally from Bt cotton, yet in another from the same year (2007b) they argue that there is in fact a significant difference between farmers of Bt and non-Bt, which can have a sizeable effect on performance. In the latter paper Morse suggests that Bt farmers tend to have a number of advantages over non-Bt farmers: they have greater access to credit; they are more likely to be involved in other income generating activities such as livestock rearing, hence a lower proportion of their income comes from cotton production; Bt adopters are also inclined to be better educated. Farmers of GE cotton are thus likely to be 'better' farmers in terms of education, ability and resources and are therefore better able to afford the risks involved in adopting a new technology. Consequently, and in direct contradiction to their earlier claims Morse et al imply that inequality is actually exacerbated by Bt cotton adoption; rich farmers in fertile areas who are able to take the risk with Bt cotton get richer, and the poor who don't have the necessary resources stay poor. Subramanian & Qaim (2009:2) support this conclusion by declaring that while small and large farms "can" benefit from Bt cotton adoption, income gains are bigger for the large farm category and the effects on landless households are relatively small. This is substantiated by the contrasting experiences of farmers in predominantly resource poor, rain-fed and infertile Andhra Pradesh and Maharashtra. In these states there were obvious differences between the experiences of small-scale farmers who faced crop losses and mounting debts, and medium farmers with better access to irrigation, who did benefit from the introduction of Bt cotton (Qayum & Sakkhari, 2005).

Overview of impact on inequality

It is therefore pertinent to deduce that Bt cotton has had no effect on rural inequality at either an aggregate or a local level. Bt seeds have been most beneficial to farmers who were already living in optimal growing conditions, with the best soils, largest irrigation networks and the greatest infrastructural penetration. As discussed earlier in this chapter, the role the farmer himself plays in obtaining maximum yields and maximum profits from cotton, such as in his use of pesticides, is often more important than the type of seed itself. In very poor states where irrigation is absent, soils are poor and farmers are handicapped by their own skills and the quality of the seeds they buy, Bt cotton has not performed as promised. Hence, instead of reducing the income and opportunity gap between small and large farmers, the introduction of Bt cotton means inequality has remained the same at best, and been exacerbated at worst. As with poverty, these conclusions do not preclude Bt cotton and other genetically engineered crops from generating positive social development in poor farming

communities in the future; it must however be acknowledged that the seeds themselves are not enough. There needs to be institutional and infrastructural improvements and the political will to provide the necessary reforms that ensure that farmers of all sizes and resources can take advantage of the technology and not be impeded by it.

c) Food security & hunger

Many of the sweeping statements commonly spouted about the benefits of genetically engineered crops claim that they can and will contribute to the alleviation of hunger and malnutrition around the world (James, 2007, 2008). In a world where the global population is due to hit 9 billion by 2050 and one billion of the existing 6 are already living in hunger the prospect of producing enough food to stave off a Malthusian crisis is daunting. The Malthusian argument, still implied by many of the proponents of genetic engineering, is that hunger persists because of a gap between food production and population density and growth rate. The implication is that if we don't act now we will face an economic and social catastrophe in the face of billions of starving people in a few decades. Biotech crops are consequently presented as the only solution to this impending disaster. Proponents focus on the benefits of the technology for small and resource-poor farmers who make up as much as 50% of the global poor and stand to gain the most from increased production. Higher yields and lower costs will allow farming households to eat more; increased production will also bring prices down for all poor people urban and rural alike.

FAD v. FED

James (2007) claims that biotech cotton and maize have already contributed to the improved livelihood and nutrition of 12 million poor farmers in India, China, the Philippines and South Africa. Similarly, Brookes & Barfoot (2008) claim that additional production from biotech crops between 1996-2006 has contributed enough extra calorific energy for 310 million people. As discussed previously there is considerable evidence that Bt cotton has led to significantly increased yields across India (and in some cases, incomes), a situation replicated by other GE crops from maize to soybeans throughout the world. The conclusion drawn from this is that poor people must therefore be able to eat more because they are not only growing more food crops but they have more money from cash crops with which to buy food. GE crops are therefore publicized as contributing to the alleviation of hunger among farming households and the rural poor.

Of all the claims made by proponents of transgenic crops it is this one that is perhaps the most derided by economic commentators, including many supporters of agri-biotech. This is because it goes against all contemporary understanding of the processes behind hunger. First of all, cotton is not a food crop; therefore increased nutrition can only be achieved through higher incomes, an outcome that is not guaranteed simply by growing Bt seeds. The majority of the world's GE crops are not actually grown for the consumption needs of poor people in developing countries; most are grown for animal feed, biofuels or as additives in highly processed foods in wealthy industrialized countries (FOE, 2009). Furthermore, it is universally recognized today that hunger is not due to poverty or lack of food production, it is a social and economic manifestation that is the consequence of inefficient distribution (FAO, 2009).

This is not a new theory; it has been propagated since Amartya Sen (1976) first differentiated between Food Availability Decline (FAD) and Food Entitlement Decline (FED) in the 1970s, and concluded that it was the latter that is the true cause of hunger. If hunger could be addressed by technology, the green revolution would have done it long ago. Instead there exists today a shameful “paradox of plenty” in which hunger now persists despite the existence of adequate food supplies (Sharma, 2003b, 2004b). India alone is home to over a third of the world's hungry and marginalized; a country where nearly 400 million people go to bed hungry every night whilst sixty million tonnes of food grains sit rotting out in the open and in silos around the country. In reality, more food is available per inhabitant than ever before, but more people than ever are going hungry. This situation is replicated throughout the developing world where too many people are too poor to buy the food that is available, or not able to access it when they can afford it (Altieri & Rosset, 1999). Consequently, the number of hungry people in the world is now over one billion.

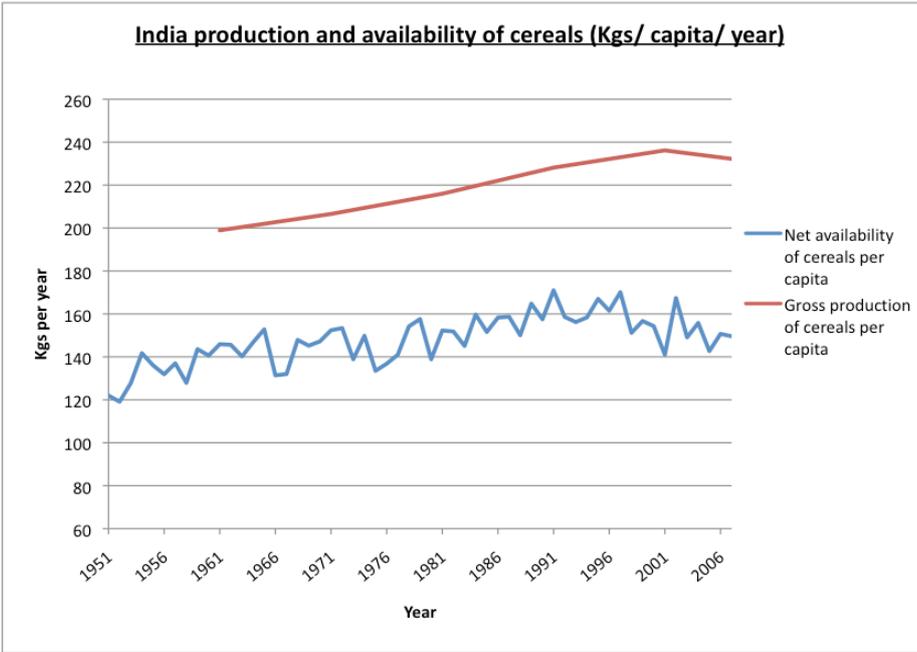
Figure 6.3 clearly illustrates the situation in India, where the net availability of cereals per person every year has effectively remained stagnant since the 1980s despite the fact that the amount of cereals produced per year has risen faster than population growth.¹² In 2007 the amount of cereal crops produced in India was 266.5 million tonnes, the equivalent of 232 kg per person. The average availability of those crops however was only 150 kg, which means that over 80 kg of cereals were lost per person somewhere between production and market. The situation for most poor Indians is actually worse than this figure suggests because availability does not even mean consumption. Due to economic and infrastructural issues

¹² Cereals include: rice, wheat, barley, maize, millet & Sorghum

much of the food available for consumption in India is not actually consumed either because it is too expensive, or because distributional inefficiencies mean that it does not get to those who need it.

There is no doubt that the need to increase global food production is paramount; the FAO (2009) estimates that food production, net of food crops used for biofuels, must increase by 70% to meet population increases in the next 40 years. The vast majority of the world’s cultivable land is already under production, and there remains very little scope for expansion under current methods of cultivation. 90% of these projected food requirements must therefore come from increased production. Nevertheless, whilst the prospect of even greater hunger in the coming decades is more than a pressing problem, it must be acknowledged that hunger itself will not be solved by increased production alone.

Fig. 6.3



Source: Selected Socio-Economic Statistics, 2006, Central Statistical Organisation, Ministry of Statistics and Programme Implementation, Govt. of India; Directorate of Economics and Statistics, Ministry of Agriculture, 2008.

Attitudes towards hunger

Sharma (2003a) accuses the governments of the industrial world of turning a blind eye to the real causes of hunger, and of exacerbating it with international trade laws that are unfair to producers in developing countries. The USA for example provides \$4 billion of subsidies for less than 20,000 cotton farmers, which allows them to produce, very inefficiently, huge amounts of cotton to sell on the international market at artificially low prices. American farmers would not be able to sell competitively if they did not have these

subsidies, but every year subsidies are raised and therefore so is supply, which saturates the market and naturally depresses global prices (Stiglitz, 2006). The people that suffer most are the tens of millions of resource poor cotton farmers around the world, including the six million in India, who eke out an existence on small plots of infertile, unirrigated soil without so much as a reliable credit line, let alone a subsidy, and yet are forced to sell at prices manipulated by the world's strongest economy. The role played by international trade on the agri-biotech industry will be discussed in greater detail in chapter 8.

Developing countries themselves are just as guilty of focusing on the wrong solutions for hunger. Dr. P. Chidambaram, former Indian Minister of Finance stressed the importance of applying biotechnology in agriculture and trying to replicate the 'success' of cotton in other crops so as to make India self-sufficient in rice, wheat, pulses and oil-seeds (James, 2007). It is arguable though, that self-sufficiency is not necessarily the answer to food-security (Runge & Senauer, 2000). Self-sufficiency is when a nation tries to produce all the crops that its population needs by itself, regardless of the cost or the country's natural resources. Food-security on the other hand can be achieved simply by improving access to the necessary foods at the lowest possible cost, which may involve importing them from comparatively advantaged exporting countries. This process is supported by the FAO (2009), which stresses the need for countries like India to rehabilitate their traditional and indigenous food crops particularly among small farmers, instead of focusing on the production of non-traditional cash crops in sub-optimal conditions. The governments of developing countries as well as bodies such as the UN Development Program are culpable of being seduced by the promises of technologies that are created in response to market pressures, not the needs of poor (Sharma, 2003b). Hunger and poverty in the agricultural community will only truly be solved with the requisite social and political commitment from developing and industrial countries alike, including the reassessment of everything from storage silos and domestic price supports to international trade laws.

Bio-fortified crops

Technology can only go so far in tackling social problems, and yet another way in which biotech companies claim to be able to tackle hunger and malnutrition is through the creation of nutritionally superior food crops. Malnutrition has significant long-term economic repercussions leading to an estimated per capita productivity loss equivalent to 10% of lifetime earnings (World Bank, 2008). Malnutrition in childhood stunts growth and learning, and compromises cognitive and physical development, which can have a significant impact on

earning potential. In adults, physical incapacity, illness and disease become more probable with undernourishment, which not only affects productivity but is also financially debilitating because of increased medical costs. Micronutrient deficiency affects over two billion people worldwide, and in countries such as India where up to 1/3 of the population is chronically undernourished, it can hold back the development of the entire economy (World Bank, 2008). In Asian countries with vast, poor populations such as India and China the overwhelming majority of people rely almost exclusively on a diet of rice, which is renowned for its micronutrient deficiencies, particularly Vitamin A, Iron and Zinc. Vitamin A deprivation causes vision problems and immune system deficiencies, and affects the health of twelve million people in India alone, the majority of whom are the extreme rural poor and marginalized. In food deficit areas where access to a well balanced diet is unattainable, 'bio-fortified' crops such as Golden Rice are presented as the solution to micronutrient deficiency (www.goldenrice.org, 2010; James, 2008).

Golden Rice has two novel genes inserted to generate the production and accumulation of Beta-Carotene, a pre-cursor of vitamin A that the human body can use to form the vitamin. The concentration of Beta-Carotene explains the golden color of the rice that remains after milling and polishing when the grain would normally be white. Whilst it is presented as another biotech solution to the severe effects of malnutrition, it is arguable that as with increased production, it is the answer to the wrong question. The millions of people who suffer from vitamin A deficiency in India are not malnourished because of the deficiencies of their food, they are hungry because they cannot afford to eat enough of it. If impoverished Indians cannot afford to buy conventional rice, they are certainly not going to be able to afford more costly genetically engineered rice (Sharma, 2004b). Vandana Shiva (2000) argues that the reason Indians suffer from micronutrient deficiencies in the first place is because of the elimination of traditional food crops and vegetables during and since the Green Revolution when farmers switched from producing a variety of crops for consumption to producing one single crop for cash, such as cotton. The proliferation of high-yielding and 'bio-fortified' GE crops threatens to exacerbate this situation, when the cheapest, most efficient and most environmentally sound solution to nutrient deficiency is to rehabilitate indigenous food crops, and import, cheaply, necessary staples (World Bank, 2008).

Overall impact on hunger

Hunger is both the cause and effect of poverty: poverty means you cannot buy food, and hunger increases the liability of illness which means you cannot go to school or

work effectively, so therefore become or remain poor. India is but one of a multitude of developing countries that suffers from severe and increasing malnutrition despite adequate food supplies. More food has not stopped the number of hungry people in the world from creeping above one billion. This is evidence enough that increased yields from GE crops, be they cotton or soy, will not reduce hunger. Most commentators acknowledge that at the heart of tackling food security is mobilizing political will, both domestically and in the international community. Trade laws that perpetuate the vicious cycle of poverty and hunger among millions of poor agricultural producers need to be comprehensively revised. The governments of developing economies also need to invest in the institutions and infrastructure that will enable poor farmers to generate the most income possible from their production. Effective social safety nets need to be in place, but also better policies to regulate the market so that poor people are better able to cope with the shocks that produce dramatic spikes in food prices as seen in the last three years. Creating better access to that food and ensuring that families, both rural and urban, earn enough to be able to afford it when it is available is the only thing that will bring hunger levels down.

Chapter 7. Long term: environmental effects

Cotton cultivation is one of the 'dirtiest' agricultural activities in terms of impact on the environment. It accounts for 16% of global insecticide use, and more than half of all pesticide applications in India despite covering less than 5% of the gross cultivated area. Cotton is also among the highest consumers per hectare of nitrogen and phosphate fertilizers in India (FAO, 2005). The damage done to the environment each year by these chemicals threatens not only the future of cotton cultivation due to rapidly degenerating soils and water supplies, but also a huge swathe of other plant, insect and animal life that live in polluted environments. Humans are also at risk from the plethora of chemicals that are applied each year to cotton plants, of which 2/5 are considered hazardous by the World Health Organization (WHO) and yet are widely administered without the necessary safety precautions. Most traditional cultivation methods have become trapped in what is known as the 'pesticide treadmill' where more and more active ingredient is required each year to achieve the same level of protection against increasingly resistant pests. Getting off this treadmill is essential for the future of the natural environment, and the long-term sustainability of agriculture in industrialized and developing countries alike.

It has been widely acknowledged for some time that traditional cropping methods are not sustainable at the present rate of consumption of fertilizers and pesticides, and recently genetically modified crops that can reduce chemical input levels have been put forward as a more sustainable alternative. Unsurprisingly, the role that could be played by agricultural biotech in tackling the problem is highly contentious among scientists, politicians and the public. Organic practices where chemical inputs are eliminated entirely from the production process are the most environmentally sound and sustainable solution to the plight of modern agriculture. Unfortunately, whilst there is strong evidence that organic methods can produce high yields they remain chronically underinvested and under-promoted in the developing world, and therefore organic cotton only accounts of 0.15% of world cotton production (Environmental Justice Foundation, 2007). Genetically engineered crops on the other hand are richly funded and heavily promoted as the only economically viable solution to the environmental problems of agriculture.

It is claimed that the introduction of herbicide tolerant (HT) and insecticide resistant (IR) crops will not just significantly reduce the need for chemical herbicides and pesticides, but that those and other GE traits will also counter the huge energy and water consumption of modern agriculture (Brookes & Barfoot, 2007, 2009; James, 2007, 2008). As

with all aspects of biotechnology, there is considerable debate surrounding the environmental claims of the biotech corporations when viewed in light of the variable experiences of farmers. Herring (2008a, 2008b) picks holes in all the arguments presented by the environmental lobby against the proliferation of biotech crops, but there are an equal number of doubts and inconsistencies in the literature of advocates. IR cotton may convey significant pesticide reductions but it also brings with it new problems. The development of resistance to the Bt toxin is a very real danger that threatens the future efficacy of the transgene against its target pests. The ‘unnatural’ expression of the Bt gene in IR crops such as cotton and corn has also raised the question of unexpected knock-on ecological effects on non-target pests and soil microbial communities. Biotech crops have been cited as threatening long-term environment stability by reducing biodiversity and undermining the very complex ecological interactions that sustain soil ecosystems and multi-trophic food chains (Conner, Glare & Nap, 2003).

As with all elements of genetic modification there are substantial arguments both for and against their cultivation. The environmental factors are some of the most complicated and also most important. Any one change in ecological conditions, from soil micro-nutrients to beneficial insects or watercourses, can have severe knock-on effects throughout the environment and affect the future of not just that crop, but the entire ecosystem and those that rely on it for food, shelter and income. Environmental sustainability is therefore the critical factor when determining the long-term viability of genetically engineered crops. Short-term economic and social gains will be redundant if agri-biotech undermines the ecological foundation of the world food supply. Nevertheless, it must also be remembered that at the present rate of chemical, water and energy use the current global system of intensive agricultural production is also entirely unsustainable in the long-term. Consequently, the question at the heart of the environmental debate is whether GE crops are better for the environment than current practices?

Bt cotton in India is an excellent subject for analyzing this question because of the extreme and detrimental nature of chemical use on cotton there. Having been at forefront of the Green Revolution, India also provides the added advantage of being a ready example and reminder of the long-term effects of unfettered environmental stress. This chapter will focus on three crucial elements of the ecological impact of BT cotton that together can help determine the long-term environmental viability of GE crops: a) the impact of Bt cotton on use of chemical inputs, b) the impact on energy and water use c) the extent of ecological threats posed by novel Bt transgenes to critical ecosystems, biodiversity and non-target organisms.

a) Chemical inputs

Pesticides

Modern intensive agricultural methods are synonymous with high levels of chemical inputs. They are deemed essential to ensure the high yields necessary to feed the global population, but they are also severely detrimental to the environment. Cotton is renowned for being one of the world's most environmentally 'dirty' crops. It uses more pesticides than any other crop in the world despite being grown on an area a fifth of the size cultivated by rice, and a seventh of wheat, the two most important global food crops. In India cotton is responsible for 54% of all pesticides used annually despite covering less than 5% of the land under cultivation; in 2001 the cost of the 21,500 metric tonnes of active ingredient used against insects in India was \$340 million (Karihaloo & Kumar, 2009).

Indian farmers lose an estimated 33% of their crops to pests and disease every year and thus pesticide application is critical, particularly in cotton where input costs are high and yields must be substantial to ensure that the cost of cultivation can be recuperated at market (Shetty, 2004). Pesticides are a fickle friend though. A large number of the chemicals used are extremely toxic, with 2/5 of those commonly applied considered hazardous by the WHO (Environmental Justice Foundation, 2007). Overuse to try and stem the effects of pests and disease is often self-defeating; it contributes to increased resistance among target pests and threatens non-target organisms including birds, fish and beneficial insects such as bees. Pesticide use is a vicious cycle that sees natural advantages being lost in the process of removing threats, which means that every year more and more chemicals are needed to kill those threats.

Resistance

The development of resistance is a considerable risk to the sustainability of genetically engineered cotton, as years of development and billions of dollars of scientific research can be nullified in a few seasons. Whether pesticides are sprayed or the crops are genetically engineered to produce the toxins, pests usually adapt sooner or later. History is constantly repeating itself on this front, and GE crops are unlikely to be an exception. The resurgence of the bollworms now being targeted by Bt cotton is the result of the resistance the pests developed to the broad-spectrum pesticides that proliferated in the 1970s and 1980s (Shetty, 2004). Insect resistant crops are no silver bullet for the problem of pest control; Bt cotton is only effective as long as target pests remain immune to the toxins they are

engineered to produce. Increased resistance has already been witnessed in some bollworm populations in India, which threatens to effectively nullify the progress Bt cotton has made in enabling the reduction of pesticide use. Contrarily, the success of the gene can also increase the need for pesticides on other pests: the reduction in bollworm pressure facilitated by the Bt gene creates a gap in which secondary pests can assert themselves. These new pests will need to be tackled by conventional chemicals unless, or until, the biotech companies create new varieties with stacked genes to tackle numerous pests. (Resistance is discussed in greater detail in chapter 5a).

Non-target effects

The principal threat of pesticides is the toxic nature of their active ingredients. Although usually diluted to a level of less than 1% active ingredient, pesticides are by nature highly toxic (International Fertilizer Association, 2010). They not only kill target pests but are indiscriminate on other non-target insects; they find their way into soils, watercourses and their application and consumption also affects animal and human health. A 2005 WHO survey of India found that ‘extremely hazardous’ and ‘highly hazardous’ pesticides were widely used. Methyl Parathion is one of the most toxic chemicals used in global agriculture and has faced numerous calls for an international ban on its use; it nonetheless happens to be one of the most widely used pesticides in India (Environmental Justice Foundation, 2007). The active ingredient targets nerve and brain function and is highly toxic to both humans and animals, with symptoms that can range from tremors and nausea to paralysis and death. It has also been linked to infant neural development problems and Parkinson’s disease.

Farm workers are not supposed to enter fields that have been sprayed for 48 hours even when chemicals are applied according to directions and with all safety precautions in place. However this is rare in developing countries where for millions of poor cotton farmers the only effective way to administer pesticides is with hand-held sprayers. Farmers work bare-footed and bare-handed without the rubber boots and gloves, coveralls or respirators suggested by producers, often mixing active ingredient with their hands. Given that family provides the bulk of farm labor in India, women and children are directly exposed to pesticide application and are often the first victims of poisoning due to the lack of, or inefficient adoption of safe-handling and protective measures when spraying pesticides.

It is not just humans that are at risk from pesticide use. Mammals such as dogs, rats and rabbits are also susceptible to Methyl Parathion, as are aquatic invertebrates. Endosulphan, an equally toxic and prevalent cotton pesticide is poisonous to fish, birds and

bees, all of which play an intricate role in the balancing of the agricultural environment. In the United States in 1995 Endosulphan was recorded as leaching into rivers during a rainstorm and killing 240,000 of fish in just a few days (Capkin, Altinok & Karahan, 2006). The threats to the environment of these chemicals are therefore significant. They upset the delicate balance in soil and water ecosystems in which small chemical changes can have intricate and widespread implications throughout the food web. The necessity of reducing pesticides in cotton is clearly essential for the future of agriculture and the health of the environment. Proponents of genetically engineered crops argue that biotech varieties with herbicide tolerant and insect resistance traits are the most effective way to slow or even stall the pesticide treadmill. Brookes & Barfoot (2007) claim that since 1996 the use of pesticides on areas that adopted GE varieties has declined by 359 million kilograms of active ingredient, a reduction of 8.8%. The greatest environmental gains on a per hectare basis were experienced by Bt cotton where farmers have supposedly used 147.6Kg less of insecticide on GE crops, a 23% reduction.

Reductions

In India there has no doubt been a steady decline in the amount of technical grade pesticides applied over the past fifteen years.¹³ Across all cotton-growing states the amount of pesticide used has fallen by almost half since 1989-90, and accounts for 89% of all pesticide reductions in India during that time. (Table 7.1). This data is not disaggregated for cotton and includes pesticide use on all crops, however it is realistic to assume that reductions in chemicals consumption are primarily on cotton given the extent of cotton cultivation in these states and the scale of pesticide use by that crop in comparison to others. All but two cotton-growing states have seen a significant decline in pesticide use, with only Punjab and Rajasthan experiencing relatively little change over the years. The biggest improvement has been in Andhra Pradesh, where applications of active ingredient have declined by over 11% per year, and the state has gone from being one of the highest consumers of pesticide in 1989-90 to the second lowest in 2007-08.

¹³ Technical Grade pesticides are those where the chemical compound consists of 85% or more of the active chemical constituent. The rest are impurities produced during chemical synthesis.

Table 7.1

State-wise consumption of pesticides in India 1989-2008 (Metric Tonnes, Technical Grade)

Year	Andhra Pradesh	Gujarat	Haryana	Karnataka	Madhya Pradesh	Maharashtra	Punjab	Rajasthan	Tamil Nadu	India	Cotton growing states
1989-90	11,580	5,500	4,690	4,380	3,036	4,470	6,000	3,230	10,000	71,894	52,886
1990-91	13,520	4,100	5,156	4,150	5,000	4,920	6,500	3,198	7,500	75,033	54,044
1991-92	13,442	5,400	5,265	4,295	4,000	5,660	6,500	2,981	3,500	72,133	51,043
1992-93	13,650	4,792	5,200	4,125	2,134	6,450	6,300	3,200	5,500	70,794	51,351
1993-94	10,805	4,531	5,200	4,164	2,432	3,021	7,400	3,266	5,177	63,651	45,996
1994-95	9,343	4,985	5,100	3,640	2,771	3,647	7,300	3,308	3,394	61,357	43,488
1995-96	10,957	4,560	5,100	3,924	1,748	5,097	7,200	3,210	2,080	61,260	43,876
1996-97	8,702	4,545	5,040	3,665	1,159	4,567	7,300	3,075	1,851	56,114	39,904
1997-98	7,298	4,642	5,045	2,962	1,641	3,649	7,150	3,211	1,809	52,239	37,407
1998-99	4,741	4,803	5,035	2,600	1,643	3,468	6,760	3,465	1,730	49,157	34,245
1999-00	4,054	3,646	5,025	2,484	1,528	3,614	6,972	2,547	1,685	46,195	31,555
2000-01	4,000	2,822	5,025	2,020	871	3,239	7,005	3,040	1,668	43,584	29,690
2001-02	3,850	4,100	5,020	2,500	714	3,135	7,200	4,628	1,576	47,020	32,723
2002-03	3,706	4,500	5,012	2,700	1,026	3,725	7,200	3,200	3,346	48,350	34,415
2003-04	2,034	4,000	4,730	1,692	62	3,385	6,780	2,303	1,434	41,020	26,420
2004-05	2,135	2,900	4,520	2,200	749	3,030	6,900	1,628	2,466	40,672	26,528
2005-06	1,997	2,700	4,560	1,638	787	3,198	5,610	1,008	2,211	39,773	23,709
2006-07	1,394	2,670	4,600	1,362	957	3,193	5,975	3,567	2,048	41,515	25,766
2007-08	1,541	2,660	4,391	1,588	696	3,050	6,080	3,804	3,940	43,630	27,750

Source : Agricultural Research, Data Book 2004 & Compendium of Environment Statistics, 2001, Central Statistica Organisation, Ministry of Statistics and Programme Implementation; Ministry of Chemicals and Fertilizers; Ministry of Agriculture

Whilst this table shows a positive development in pesticide use in India it does not suggest any causal relationship between the introduction of Bt cotton and the reduction in technical grade pesticides. It is clear that the trend in pesticide use was downward well before 2002, and it actually appears that since the introduction of insect resistant cotton in that year this long-term decline has stalled. Since 2005-06 there has been a marginal increase in the use of technical grade pesticides. To what extent BT cotton is responsible for any of these changes is still debatable.

Proponents of agricultural biotechnology have claimed that the introduction of Bt cotton has led to significant reductions in pesticide applications in India. Evidence discussed in detail in chapter 5b however suggests that these claims need some moderation. It is true that across all cotton states insecticide costs, as part of the total cost of cotton cultivation, have declined at an annual rate of over 8%. Having said that, the results are significantly variable from state to state; four states actually experienced considerable growth in pesticide costs after 2002. (Table 5.4). The variability in the data complicates the evidence of any causal relationship between Bt cotton and insecticide use. It is important not to overstate the case of one single technology in tackling the problem of pesticide use in India. The variability in insecticide costs is important because it underlines the significance of the environmental surroundings, changing pest pressure from year to year and region to region, and the role of a farmer's own decision-making process in choosing to apply pesticides. That Bt cotton is effective technically is not in doubt, but it is essential to remember that biotech crops are not

simply a technology, they are a process. The human role in reducing pesticide applications must not be ignored when determining the environmental viability and sustainability of GE crops.

Fertilizers

The over use of fertilizers is another considerable environmental threat among Indian cotton communities, where the amount of fertilizer consumed per hectare is on a par with sugarcane and wheat, the two most fertilized crops in India. Nitrogen, phosphorus and potassium based compounds and combinations are the most commonly used fertilizers, and are essential for healthy plant growth. These elements are all present naturally in soils, but modern intensive cultivation methods in which organic manures have been substituted for chemical inputs, and production has extended to marginal and mineral poor soils, means that micronutrients have been ‘mined’ from the soil quicker than they can be replenished (Sharma, 2000). Each year farmers must therefore apply an increasing amount of synthetic fertilizers to ensure seeds have the essential nutrients to grow large yields. A recent study found that large farmers in particular tend to over-fertilize and small farmers, who often obtain their inputs from larger cultivators in exchange for work, tend to apply chemicals without adhering to guidelines and regardless of whether or not they are appropriate for the soil (Baker & Jewitt, 2007). Cotton is particularly greedy for nutrients, however the utilization of fertilizers to facilitate strong plant growth actually exacerbates soil degradation rather than protects it from nutrient depletion. When fertilizers are added plants absorb extra nutrients from the chemical compounds but they also absorb proportionately more than normal levels of other soil micro-nutrients, such as zinc, iron and manganese, which further degrades the nutrient balance in the soil.

Over fertilization is not just a threat to crop growth, nitrogen compounds that get into watercourses also threaten human and animal health. Water-logging in fertile areas, such as the Punjab where over-irrigation is a problem, and monsoon floods in rain-fed regions contribute to water contamination due to the leeching of nitrates from fertilized soils. Nitrate contamination leads to algae that sucks oxygen from water, killing fish and other aquatic life, and has been linked to human cancers, birth defects and methemoglobinemia, a condition that causes oxygen deprivation in babies. The need to reduce synthetic fertilizers is therefore another pressing challenge that needs to be met by improved agricultural techniques.

GE crops have unsurprisingly been presented as a solution to the problems of over-fertilization, but so far there is little evidence of any success (James, 2008). Fertilizer

applications have increased across India over the last decade, a situation that appears to be have been exacerbated by the introduction of Bt cotton. (Table 7.2). Since 2002, increased fertilizer costs have contributed significantly to the rising cost of cultivation of cotton in India. The cotton-growing states have experienced annual growth of 9% in the cost of fertilizers, but with very variable changes across the individual states. Only three states have experienced a decline in the cost of fertilizers since the introduction of Bt cotton, and among those that have seen costs increase, it has been by up to 60% a year (Tables 5.4). Advocates of Bt cotton have tended to underplay the increase in fertilizer use because it detracts from the message that Bt cotton facilitates a reduction in the application of chemical inputs. Nevertheless, even though it is not discussed in the analysis the data in a number of studies clearly shows that fertilizer costs are consistently higher on Bt cotton than on conventional varieties (Bennet et al, 2005; Qaim et al, 2006; Morse et al, 2007a; Sadashivappa & Qaim, 2009).

Table 7.2

Consumption of fertilizer products in India (1997-2007)

Fertilizer type (1000 tonnes)	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	% annual growth in consumption
Total Straight Nitrogen (N) fertilizers	20729.5	21509.1	21338.4	20112	20711.7	19181.8	20524.2	21460.4	23099.7	25102.7	2.15%
Total Straight Phosphorus (P₂O₅) fertilizers	3819.6	3817.6	3601.1	2941.4	2685.7	2576.6	2618.6	2612	2816.4	2953.5	-2.82%
Total Straight Potassium (K₂O) Fertilizers	1744.2	1636.9	2066.4	1839	2010.8	1931.3	1863.1	2431.8	2759.2	2612.9	4.59%
Total Combined NP/NPK Fertilisers	9156.9	9649.3	11459.8	10664.7	11147.7	10288.8	10381.8	11764.3	13458	14177.6	4.98%
Total Product	35450.2	36612.9	38465.7	35557.1	36555.9	33978.5	35387.7	38268.5	42133.3	44846.7	2.65%

Source : Fertiliser Association of India.

Overall impact of Bt on chemical inputs

Proponents of genetically engineered crops have been selling their products to farmers and the public for the last fifteen years on the understanding that biotech crops reduce this environmental damage done by conventional crops and associated pest management processes. Bt cotton is a commonly cited example of the significant reductions in pesticide use afforded by the adoption of biotech varieties, which not only brings down the costs of cultivation for farmers but provides a substantial boon to the environment. It is apparent however, that these claims are neither as straight forward nor as incontrovertible as is usually suggested.

The use of synthetic fertilizers has increased not diminished on cotton plants since

the commercialization of Bt varieties, a fact that GE supporters go to pains to ignore. Pesticide use on the other hand has clearly declined since 2002 across cotton-growing states, and it appears likely that a principal reason for this is the introduction of Bt varieties. Nevertheless, there is considerable variability between states which indicates that the positive impact on pesticide use among cotton farmers is not universal. Bt cotton is not a silver bullet for pest control; there exists a very complicated relationship between farmers and pesticide use, in which the role of the farmer is consistently understated and importance of the seed exaggerated. Bt cotton has reduced pesticide use in India much to the benefit of the environment; however, natural adaptations among target and non-target pests, as well as unforeseen consequences within the local ecology compromise the sustainability of the technology. If resistance becomes prevalent or new primary pests emerge that are immune to Bt then the application of chemical insecticides will once again have to increase, and the proliferation of biotech varieties will have been in vain.

The evidence from India thus implies that whilst Bt cotton is currently a boon for the environment with regard to pesticide use, its sustainability is questionable. It is essential that farmers and biotech companies alike keep ahead of the development of pest resistance otherwise GE crops threaten merely to temporarily stall the pesticide treadmill rather than stop it altogether. For many, insect resistance and herbicide tolerance are short-cited solutions to a problem that requires a comprehensive solution unavailable in biotechnology (Friends of the Earth, 2009). It is arguable that the only alternative the biotech companies can provide to the pesticide treadmill is the trait treadmill, on which ever more traits are stacked into crops to try and combat a growing list of primary pests. The danger of this is that we will be facilitating ever more unnatural changes in the environment, the consequences of which we cannot know. Besides, it is not impossible that this development would be a desirable for the biotech companies, on whom farmers would become ever more dependent in their fight against pests.

b) Energy and water consumption

Modern agriculture is an incredibly inefficient consumer of both energy and water, which not only contributes to high costs of cultivation for farmers but is also severely damaging to the environment on which it depends. Cotton is an archetypal avaricious crop, consuming vast quantities of chemical inputs per hectare in insecticides and fertilizers and requiring high levels of water to be productive. 90% of all fresh water in India is used in irrigation, up to 35% of which is considered unsustainable (Water Business Council for

Sustainable Development [WBCSD], 2009). This is responsible for the degradation and deterioration of water supplies that threatens agricultural production as well as human health. The long-term viability of genetically engineered crops such as Bt cotton is therefore dependent on them being more efficient and less environmentally destructive than current methods of cultivation. The agri-biotech companies claim that through the development of more robust varieties, including drought tolerant traits, GE crops will moderate the high energy and water requirements of conventional agriculture (James, 2008). These claims do not tend to be explicitly extended to Bt cotton where water and fertilizer requirements are understated, although it is often highlighted that the reduction in pesticide use will bring down energy costs from spraying (Brookes & Barfoot, 2007).

Energy

Genetically engineered herbicide tolerant crops such as Roundup Ready Soy have been attributed with a considerable reduction in energy consumption during cultivation. Herbicide tolerance in crops enables farmers to spray a limited number of broad-spectrum herbicides in place of a large number of specified sprays. It also facilitates the proliferation of no or low-till practices that dramatically lessen fuel consumption from ploughing (Trigo & Cap, 2003; World Bank, 2008). It has been suggested that insect resistant crops such as Bt cotton have also enabled savings in energy associated with reduced spraying and machinery use, but the evidence is less compelling. Fuel efficiencies may have been experienced in the United States and Australia where cotton production is an extensive mechanized system of cultivation, but these savings do not extend to the millions of resource poor Indian cotton farmers whose small plots are tended by hand and pesticides applied with hand-held spray pumps. Similarly, the minimal use of machine labor in India means that the introduction of Bt cotton has not had any significant beneficial effect on farm fuel consumption. Table 7.3 (an expansion of table 5.4) demonstrates that the cost of machine labor in cotton production has actually increased annually in six of the nine principal cotton states since the commercialization of Bt in 2002. This suggests that although Bt cotton may have contributed to a reduction in pesticide applications it has had a negligible and possibly even a negative impact on energy consumption in cotton cultivation.

Table 7.3

India State-wise % annual growth in critical costs of cultivation per hectare of cotton 2002-2006

Cost Items	Andhra Pradesh	Gujarat	Haryana	Karnataka	Madhya Pradesh	Maharashtra	Punjab	Rajasthan	Tamil Nadu
Human Labor	14.74%	23.16%	1.36%	6.69%	11.79%	0.98%	11.89%	-0.40%	-3.04%
Bullock Labor	-7.10%	13.24%	28.96%	-14.03%	-8.42%	3.39%	-39.16%	-11.47%	-42.00%
Machine Labor	47.38%	13.41%	-22.82%	191.25%	171.72%	-14.98%	-3.91%	30.77%	21.24%
Seed	0.34%	61.12%	95.09%	1.38%	17.13%	21.51%	66.98%	20.47%	9.70%
Fertilisers	-5.21%	29.60%	60.50%	27.05%	10.68%	-1.01%	25.89%	-21.78%	5.13%
Manure	53.53%	11.68%	-	13.15%	96.83%	-4.18%	-16.77%	42.27%	4.63%
Insecticides	-13.15%	42.44%	25.74%	-23.05%	18.44%	-16.94%	-33.36%	11.63%	-9.82%
Irrigation Charges	6.14%	27.96%	-10.39%	-8.22%	-10.23%	-23.68%	-8.48%	5.91%	-2.45%
Total Operational Costs	4.64%	25.92%	16.85%	5.10%	10.78%	1.30%	0.40%	1.93%	-3.31%
Total Fixed Costs	-10.22%	28.59%	29.12%	-11.86%	36.83%	-3.81%	19.33%	-1.83%	-0.41%
Total Cost	-1.11%	26.65%	21.41%	-1.20%	19.16%	-0.11%	6.93%	5.91%	-2.47%

Source: Directorate of Economics and Statistics, Ministry of Agriculture, 2008

Whilst the reduction in pesticide use facilitated by the adoption of Bt cotton may not translate into a significant decline in energy consumption by farmers, the overall cuts in their application may be beneficial further up the production chain. The high levels of chemicals used on cotton not only adversely impact the environment into which they are released, but are also responsible for the affects of high energy consumption in their fabrication and distribution. Proponents of GE crops argue that by reducing pesticide applications, Bt cotton can help save raw materials and fuel used in the making of chemical inputs (Purcell & Perlak, 2004).

Almost all hydrocarbons used in pesticides are derived from petroleum, and liquid pesticides also use kerosene and petroleum distillate as a carrier. In fertilizers the resources needed to make them are relatively limited, particularly potassium and phosphorus, which have to be retrieved from mines or saline lakes. Therefore, not only are the natural resources needed for creating chemical inputs limited but the creation and distribution of both pesticides and fertilizers is very energy intensive. It is estimated that 5% of global natural gas consumption is used in the production of synthetic ammonia found in most nitrogen fertilizers (International Fertilizer Association, 2010). The high use of these inputs is therefore not only unsustainable for the soils into which they are released, the resources used to make them are both finite and energy intensive. If Bt cotton contributes to diminishing the overall energy consumption of the pesticide industry then this is certainly beneficial for the environment. However, the limitations of Bt's impact on pesticide use on small farms and its high fertilizer requirements demonstrate that the energy needs of GE varieties are not significantly more sustainable than their traditional counterparts.

Water

Agriculture consumes 70% of the world's fresh water resources, and in India a staggering 90% of available fresh water is used in agriculture (WBCSD, 2009). Increased irrigation has been critical for producing more food since the Green Revolution, but up to a third of India's water consumption is dangerously unsustainable. Electric pumps implemented in highly irrigated regions such as the Punjab and Haryana mean that water tables, which have built up over millions of years, have dropped off in the space of a few decades, often beyond the reach of deep tubes (Rahul & Nellithanam 1997). In west India excessive fresh water abstraction has allowed seawater to enter aquifers, making the water so saline it is unfit for human consumption (WBCSD, 2009). Heavy water extraction from ground sources also contributes to fluoride contamination of drinking water, which poses considerable health hazards, such as dental and skeletal fluorosis affecting millions of people in many parts of India (Raju, Dey & Das, 2009).

Cotton has a very high water requirement, on a par with wheat and fruits, and not dissimilar to rice in certain regions, and therefore is a net contributor to these problems. Genetically engineered drought tolerance has been advocated by the biotech companies as a solution to water consumption, enabling crops to grow in arid conditions without having to increase irrigation networks. Drought tolerance would not only help bring down water consumption in the greediest irrigated states, it would also be extremely beneficial in states like Maharashtra where millions of cotton farmers cultivate on predominantly unirrigated, thin red soils where the risk posed by unreliable rains is considerable. At this stage however, insect resistant cotton does not confer any such benefits, and the effect of Bt varieties on water requirements is largely debatable.

Table 7.3 shows that in six of the nine cotton states irrigation costs have been declining year on year since 2002, which would suggest that Bt cotton might actually require less water than traditional varieties. However, it is not possible to confer any causal relationship in this instance, not least because of the variability in the data, but also due to the fact that the data refers to costs and not actual consumption of water. More significantly, good rains since 2005 are much better able to explain declining irrigation costs over this period than the adoption of Bt cotton (Villar, 2008). Whilst droughts in 2002 and 2003 would have driven water prices upwards, benign monsoons in subsequent years mean that not only would the cost of water be lower, the need to apply it would also be diminished. Hence, the falling annual costs in irrigation charges over the period 2002-06 are much more likely to be attributable to the weather than the introduction of Bt cotton, which confers no drought

tolerance and whose genetic makeup should have little impact on water requirements.

The evidence from comparative studies is sufficiently contradictory to prevent assuming any causal relationship between Bt and water consumption. Bennet et al (2005) found lower irrigation costs on Bt compared to non-Bt, whereas Morse et al (2007a) show considerable variability from year to year with Bt irrigation costs 83% higher than non-Bt in 2002-03 but 33% lower in 2003-04. It has been argued that Bt varieties are less able to adapt to environmental stress than their conventional counterparts and are therefore more at risk from bad rains. Najma Sadeque (2008) for example, argued in a well-publicized newspaper article that Bt cotton actually required 20% more water than traditional hybrids. Whilst this argument has been comprehensively refuted by a number of pro-Bt authors, their line of reasoning is somewhat undermined by admitting that their own studies were conducted in irrigated areas with good growing conditions (Morse et al, 2004, 2005, 2007a; Herring, 2009). The implication is that the vast majority of cotton farmers who cultivate without irrigation will not experience these same gains, and thus contrary to the claims of biotech advocates Bt cotton actually does need more water than non-Bt to provide a comprehensive yield advantage.

This conclusion is supported by a study from a group of South African scientists who found that even moderate water deficit leads to a decreased concentration of Bt toxins in cotton leaves, flowers and bolls (Martins, Beyere, Hofs et al, 2008). The implication is that insufficient water consumption increases the vulnerability of the crop and reduces the efficacy of Bt varieties. This does not mean that Bt plants will fail any more than non-Bt plants in drought conditions, but it signifies that scarce water availability reduces the advantages GE varieties confer over conventional ones. Overall this intimates that instead of helping reduce the water consumption of cotton cultivation, the adoption of Bt varieties actually encourages the spread of irrigation and higher water consumption to ensure the benefits of the biotechnology are acquired.

Summary of energy and water effect

From the point of view of cultivation in developing countries, where farmers operate under unirrigated and unmechanized conditions, the effect of the commercialization of Bt cotton on water and energy consumption has been negligible. Machine use is limited among poor Indian farmers and therefore the reduction in pesticide application does not impact substantially on gross energy consumption. Diminishing pesticide use can certainly contribute to lessening the environmental impact of the chemical industry that produces them,

but these declines must be contextualized with the understanding that the sustainability of pesticides reductions attributable to the Bt gene is highly questionable. Furthermore, fertilizer production and consumption remains unabated with the adoption of genetically engineered varieties.

The effect on water consumption of Bt adoption has been similarly limited for farmers in developing countries among the majority of whom the rain does most of the irrigating. For the third of India cotton farmers who do have access to irrigation, the reduction in water costs they have experienced seems to be better explained by above average rainfall rather than any effect of Bt. Technically the Bt gene should have no effect on the need for water, therefore the evidence that a water deficit does reduce the efficacy of the Bt toxin is a blow to the claims of pro-GE authors. As opposed to decreasing the water requirements of cotton, the adoption of Bt varieties will put more pressure on existing irrigation networks and will likely lead to more being built. From this point of view, Bt cotton will not reduce the harmful environmental effects of modern cultivation and thus the long-term sustainability of agri-biotech is no greater than traditional crops.

c) Ecological threats and biodiversity

At the heart of much of the resistance to genetic engineering in agriculture is the belief that manipulating nature is a dangerous and unpredictable activity, in which the consequences are unforeseeable. The biotech companies and governments that allow the commercialization of genetically engineered products rely on the concept of ‘substantial equivalence.’ This legal definition implies that genetically engineered and transgenic crops are essentially the same as conventionally bred crops and therefore do not need any special treatment either in distribution, cultivation or marketing. The problem for skeptics is that whilst GE crops may be *substantially* the same as conventional hybrids, they are not *exactly* the same; one genetic change is a tiny difference and yet it causes the most concern when considering the long-term implications of growing transgenic crops.

Introducing new genes into plants leads them to make proteins in different amounts and perhaps even new ways that could upset the natural dynamics and very complex interdependent elements in the environment. Bt toxins can negatively affect non-target organisms from insects and beneficial pests to soil microorganisms that play an crucial role in the health of the environment (Gala, 2005b; Conner et al, 2003). On a more worrying level, there is no guarantee that the insertion of viruses to switch on new genes could not potentially

lead to a new genetic recombination in the plant itself or in later processing that could create virulent new viruses that devastate crops, animals or humans (Anderson, Antonion & Cummins, 2006). The unreliability of the technology also presents a significant risk to the environment through potential contamination of non-GE and wild varieties, which threatens biodiversity.

There is a large number of studies that concur that the direct threat to soil organisms and beneficial insects, and likelihood of dangerous plant mutations are negligible (Conner et al, 2003; Zipf & Rajasekaran, 2003; Brookes & Barfoot, 2008; APCOAB, 2009; James, 2008). It is argued that compared to traditional seeds and the terrible damage done to insects, soils and biodiversity by chemical pesticides and other processes in conventional agriculture, any minor negatives of Bt cotton pale in comparison (Naranjo, 2009). The environmental impact quotient (EIQ), which is used to measure the effect of farming practices on the environment, is said to have declined by 28% on biotech cotton areas since the introduction of Bt cotton (Brookes & Barfoot, 2009)¹⁴. Nevertheless, global agriculture is at risk if the fragile ecosystems on which it depends are changed or damaged. Just because Bt cotton can reduce pesticide applications, it does not mean that its other impacts should be assumed to be benign.

Secondary ecological impacts

The threat of secondary ecological impacts has been well-publicized since a 1999 study discovered high levels of the Bt toxin in non-target Monarch Butterflies who fed on the pollen of Bt maize plants (Losey, Rayor, Carter, 1999). Whilst the risks were found to be negligible the case raised considerable public debate surrounding the unforeseen knock on effects of the Bt gene. Bt toxins are seen as a threat to the environment through two process: the direct effect on non-target insects from toxicity due to exposure to genetically engineered plant material, and the non-target indirect effect on other organisms through multi-trophic food chains. Supporters of genetic engineering maintain that the Bt gene is relatively benign due to the specificity of its target pests. *Bacillus thuringiensis* is after all a naturally occurring soil bacterium and has been used for insect control in Bt sprays since the 1950s and is considered to be so environmentally benign it is even used in organic farming. When used in a spray the Bt toxins are inert until ingested by insect larvae where they are processed and the

¹⁴ EIQ measures effect of agricultural practices, particularly effect of chemical inputs on arthropod natural enemies; toxicity to dermal, chronic, systemicity, fish, birds, bees, beneficial arthropods; soil half-life; plant surface life; leaching possibility; and picker and farm worker exposure (James, 2006).

toxin is activated. The difference with Bt crops that are genetically engineered to express the same gene inside the plant is that the bacteria requires much less processing to generate the toxin and thus can cause harm to a host of other organisms that were previously unaffected (Greenpeace, 2004).

The Bt toxin does not just affect the target organisms that live or feed on cotton plants, but can also affect organisms higher up the food chain that eat or rely on those pests, including non-target insects, birds, fish and mammals (Gala, 2005b). Natural predators and parasitoids (natural enemies to pests) are important regulators of pest populations and play a vital role in biological control (Sanvido, Stark, Romeis, Bigler, 2006). If these insects are affected in any way by exposure to the Bt toxin it can have serious repercussions for the cotton farmer that may result in the need to apply even more pesticides to tackle those pests that are no longer naturally controlled. More worrying still is the threat to pollinators such as for which there is no chemical or technical substitute. One in every three foods eaten in the world is directly or indirectly pollinated by bees; if they are negatively affected by Bt toxins the loss threatens not just the cotton community but could have severe repercussions on the entire global food network (Van Engelsdorp, 2008).

The effects of the Bt toxin are thus clearly not limited to the lepidopteron pests it targets, their impact reaches both above and below ground as toxins are secreted into the earth by roots and through decay after ploughing. Negative effects of Bt on soil invertebrates and microorganisms can upset the complex nutrient balances in the soil which are essential to keep soils, the foundation of the all ecosystems, healthy. The tiny change conferred in the genetic make-up of Bt cotton is therefore non insignificant and should not be assumed to be benign just because it is ‘substantially equivalent’.

The danger of minor effects

Despite the high profile of arguments against the ecological safety of Bt cotton there is in fact limited scientific evidence to support them. The primary advantage of the Bt gene is that even after being inserted into crops the toxin retains high specificity towards certain insect species, primarily lepidopteron pests. Several studies have demonstrated that aphids, who feed extensively on cotton, do not take up Bt toxins and therefore neither aphids nor the predators that feed on them are likely to be exposed to any threat. The direct toxicity to non-target organisms is understood to be extremely rare (Conner et al, 2003; Zipf & Rajasekaran, 2003; Sandivo et al, 2006). The majority of field studies have revealed only “minor, transient or inconsistent” effects of Bt crops when compared to non-Bt control and

thus even among detractors it is generally accepted that the effect of Bt on non-target organisms is negligible (Sandivo et al, 2006:25; Karihaloo & Kumar, 2009).

Nonetheless, this is not to say that negative impacts are impossible or even unlikely, and they should certainly not be ignored. In honeybees for example, one of cotton's primary pollinators, direct toxicity is rare but not unheard of. Protease inhibitors from Bt have been found in the guts of bees that could reduce longevity of life, a danger that risks the very future of cotton pollination. There is also some evidence that the Bt gene can inhibit learning and foraging behavior of bees, although it is very difficult to gauge how far this reaction is the consequence of Bt toxins alone (Conner et al, 2003). Likewise there are possible undesired consequences in soil microbial communities as toxins find their way into the soil via root exudates, plant material remaining the ground after harvest and from dead or damaged plant and root cells. The amount of toxin in the soil and how long it takes to decay is highly dependent on the type of soil and local climate (Conner et al). This process is important though, as nematodes and earthworms have been found to take up the Bt toxin, and whilst no significant differences were determined between worm populations in Bt and non-Bt soils, it must be acknowledged that a change in their constitution does take place (Sandivo et al).

Soils are very complex and variable ecosystems; whilst Bt cotton has been seen to produce fleeting increases in soil bacteria and fungi compared to non-Bt, the high natural variability in soils makes it extremely difficult to establish any direct or measurable relationship between Bt cotton cultivation and potential threat to soil communities. It is similarly difficult to gauge accurately any indirect effects on non-target insects through the food chain, as insect population dynamics are very complex and extremely variable from year to year and region to region. For example, it is possible that the drop in natural insect predators on Bt cotton is the result of the absence of food because Bt cotton has eliminated their prey, not because the toxins themselves are dangerous for predators. Proponents of Bt cotton are subsequently keen to point out that compared to broad spectrum pesticides which have no discrimination against pests and are hugely damaging to soils, Bt toxins and biotechnology are a considerably more environmentally preferable form of pest management (Naranjo, 2009; Zipf & Rajasekaran, 2003; Conner et al; Sandivo et al).

It is arguable however that these authors use the argument of soil variability to hide any negative impacts found with Bt crops. It is likely that Bt toxins are largely benign but it is also possible that soil and pest variability is actually masking, or being used to mask, considerable changes caused by novel Bt toxins. Naranjo (2009) for example, in trying to prove the safety of Bt crops, uses the very flimsy argument that hazards identified in the

laboratory may not always manifest themselves in the field. But if this is true, then the opposite must also be true; there are potentially many dangerous affects of Bt that are not developing in the lab, but could become rife in the natural environment. It is considerations such as this that must be acknowledged when judging the safety of Bt cotton and other GE crops in the face of heavily publicized benefits and understated risks.

This is particularly true when assessing the safety of Bt cotton on human and animal health. As is discussed in Chapter 5c, the safety of Bt toxins has been established by a number of regulatory and scientific bodies in India and abroad. The lack of receptors that bind to Bt toxins and their instant degradation in the human digestive system means that the Bt gene is innocuous to humans (Karihaloo & Kumar, 2009). Nevertheless, health concerns have been raised following a spate of goat and sheep deaths after the animals had been grazing in Bt cotton fields. Evidence suggests that the organisms and enzymes within these animals' digestive tracts had died from novel toxins and that an "as-yet unidentified toxin in Bt cotton could be the cause" of the deaths (Venkateshwarlu, 2007; Bhatt, 2009). India's governing body for biotechnology, the GEAC, has vehemently denied these claims, and as yet no direct connection with the Bt gene has been formally established. Nevertheless, whilst any undesirable effects of the Bt toxin on humans or mammals has either been found to be negligible or is as yet unproved, the threats are not non-existent. We do not know what we may be doing to our bodies in the future by ingesting small amounts of genetically engineered material in our food today. Some detractors have linked it to smoking tobacco: smoking for even five to ten years may not show any noticeable impact and long-term health could be unaffected, but if you smoke for fifty years you're lungs and heart will show the effects. It is arguable that the same could be true of GE crops. Minimal risks now may prove to be considerable in the future particularly if new GE crops are rolled out without the requisite understanding or acceptance of the risks they pose.

There remains a significant degree of uncertainty regarding the long-term safety of Bt toxins, as whilst it is not possible to say categorically that Bt cotton is unsafe for humans or the environment, neither is it possible to say categorically that it is safe. There is no doubt that conventional pesticides cause severe and lasting damage to the environment, and Bt cotton can reduce that impact. However, it is also true that the effects of those pesticides, whilst undesirable, are essentially predictable and site specific. The novel threat of biotechnology as a means of pest control is that the spread and evolution of the transgenes themselves cannot be wholly predicted. So far the negative affects of the Bt gene have proved to be limited, however the potential of these genes to spread to other varieties and other crops is

considerable. How those genes may react and adapt in new environments and after consumption by insects, animals and humans should not be assumed to be benign.

Gene transfer

One of two major concerns related to transgenic crops is that the genes could outcross to weedy relatives and confer the benefits of the modified crop, thus making the weedy varieties very difficult to control in an agricultural environment. The other is that the transfer of genetic material from one organism to another could mean that wild relatives growing in non-domesticated environments could suffer an increased risk of extinction due to hybridization with GE crops. The transfer of genes is not dangerous in itself, but the loss of biodiversity that is caused by hybridization not only threatens the plant but could result in the loss of both capital and potentially useful resources (Altieri 2005; Conner et al, 2003). If transgenes allow biotech varieties to outgrow local flora to the detriment of the local varieties then the natural ecological balance maintained by complex systems of variant species and their own insect and animal ecosystems are threatened. The environmental safety concerns of this in cotton are generally regarded as low because of the limited movement of heavy cotton pollen, and because of natural genetic barriers that prevent crossbreeding with native cottons. Furthermore, cotton is not actually found as a weed in global production systems and therefore the threat of weedy relatives developing a resistance to bollworms is not a particular threat to the industry (Karihaloo & Kumar, 2009).

Nevertheless, the risk this process poses to other crops, such as herbicide tolerant cereals and soy, is considerable and must be fully incorporated into any decision to commercially release other GE crops in India. The infamous case of Berkeley scientist Ignacio Chapela who discovered that traditional corn varieties in remote areas of Mexico had been contaminated by genetically engineered varieties is clear evidence of the threat posed to biodiversity by gene transfer (Quist & Chapela, 2001). These results were particularly disturbing given the almost sacred nature of corn in what is considered the origin of its domestication, where the hybridization of native varieties could result in the loss of valuable resources. Although heavily disputed at the time, Chapela's findings but have since been proved correct. It is an outcome that is particularly concerning for developing countries like Mexico and India who are contemplating growing crops that are potentially dangerous to their unique biodiversity. Furthermore, the significance of this case is not just the implications for biodiversity, but what can be implied from the incredible lengths the biotech community went to cover up and discredit the findings. The power of the corporate machine to manipulate and

discredit scientific research provides a stern warning to consumers and commentators to remain conscious of corporate influence when being informed of the unmitigated benefits and safety of genetic engineering. This is discussed in greater detail in chapter 8.

Biodiversity

The concern inherent in the homogenization of species is that removing variety increases the vulnerability of crops to insect pests and diseases. If genetically engineered crops are too effective at eliminating pests and weeds they will contribute to the deterioration and simplification of agricultural ecosystems, the long-term effects of which we cannot know. It is of course arguable that the continued spread of conventional agriculture based on genetically narrow populations of uniform hybrids is actually a much bigger threat to genetic diversity than the spread of transgenes (Conner et al, 2006). After all, the loss of biodiversity is not a new threat created by biotechnology. The Pesticide Action Network (2007) estimates that modern intensive agriculture has been responsible for the loss of 75% of the genetic resources for food and farming over the last century. At present only twenty species of plant make up 90% of human plant use, three of which, (rice, corn and wheat) account for 60% of the calories and 56% of the protein derived from food crops (Conner et al; Thrupp, 2000). This decline in diversity has serious repercussions on natural biological resources, the overuse of which have been blamed for the reductions in yield growth witnessed in post Green Revolution India (Singh & Sindhu, 2004).

Anti-GE authors suggest that the spread of biotech crops will exacerbate the damage done by traditional agriculture and will narrow even further the genetic base of world food production (Altieri, 2005). Whilst there are now over 600 Bt varieties available in India, when Bt was first commercialized there were only three varieties. It is likely that the switch to Bt cotton by 80% of Indian cotton farmers has meant the effective loss of thousands of local varieties that have adapted over hundreds of years to local conditions. It is not impossible that the same effects of ecological stress witnessed after the Green Revolution may be manifesting themselves in regions such as the Punjab for whom the yield gains from Bt cotton have already started to diminish. Whilst the threat of GE varieties to biodiversity may be no less than current methods of agriculture, the difference is, with the spread of transgenes we cannot control how or what we are losing. It is always possible, (although economically and socially unfeasible at this stage) to stop pursuing current agricultural methods in the name of biodiversity. Once transgenic crops are released however farmers lose control of how those genes spread to the wild and how they adapt or change when they are there. The greatest

threat to biodiversity created by genetic engineering is that we cannot predict the full extent of the knock-on effects on insects, animals, humans and future food production.

The biotech industry's own answer to the threat of gene transfer is 'terminator technology.' This is the creation of genetically engineered crops that are infertile and thus supposedly cannot breed with local varieties hence solving the problem of hybridization. Terminator technology is hugely controversial, not least because it is not impossible that the terminator genes will cross-breed outside GE crops and render other species infertile, which would be devastating for the environment. Even without this threat, the technology provides the seed companies with overwhelming control over agriculture that would see farmers entirely dependent on them for seed supplies at whatever prices the companies determined. The seed contracts that farmers are already in with non-terminator stock are debilitating enough; by preventing farmers from saving or trading their seeds they destroy traditional replanting systems (Herrick, 2008). Farming skills and agricultural knowledge is still something that is passed down from generation to generation even in industrialized countries, but it is particularly important in developing countries where poor farmers are largely uneducated. The future of millions of resource-poor farmers and their families are therefore threatened when they no longer have the right to freely work their crops and share in agricultural knowledge which has been considered part of the 'common-wealth' for centuries.

Overview of ecological impacts

There are considerable difficulties inherent in trying to establish the full extent of Bt cotton's impact on the environments into which it has been released. Not only are soil and insect ecosystems incredible complex and naturally variable, but most agricultural environments have already been so badly damaged by conventional cultivation methods and chemical inputs that it is difficult to establish what the direct impacts of the Bt gene are, let alone what the indirect effects may be. Conner et al (2006) maintain that it will take decades or even centuries to really discover the ecological consequences of genetically engineered crops. It is therefore seen as unreasonable in some quarters to insist that biotech varieties guarantee no risk given that traditional methods pose very considerable risks to soil, water, insect and animal health as well as to the farmers who use those methods. At this stage there is very little scientific evidence to suggest that the impacts of Bt cotton on the environment are anything more than negligible. They certainly appear to allow a more benign pest management system than conventional techniques. Additionally, of all GE crops, the commercialization of Bt cotton appears to have done more for the environment than any other

agricultural development other than organic practices.

However, that does not mean that agricultural biotechnology is entirely benevolent and should be rolled out indiscriminately across the developing world. The viability of the technology relies upon its sustainability, about which there remain considerable concerns. Just because it may take decades to establish the true extent of the impact of biotechnology does not mean those impacts should be ignored or be assumed to be benign in the interim. Threats to beneficial insects and biodiversity are not new, but there is a novelty to these threats presented by the introduction of novel genes whose spread, adaptation, mutation and ultimate consequences cannot be fully known or predicted. Even proponents of biotechnology admit that soil, plant and insect ecosystems are incredible complex; at the end of the day we do not really know what damage we may be instigating by releasing organisms created under laboratory conditions into the wild.

The very complexity of the natural environment shows how closely it needs to be protected; much of the damage done by modern agriculture will take a long time to remedy and the loss of genetic diversity is irreparable. The methods that are being considered to alleviate agricultural damage must therefore not just be proposed to assure short-term food production or cost reductions, they must be introduced with a guarantee for the very future of agricultural production and environmental safety. Despite the effects of Bt cotton on pesticide use, lingering ecological questions surrounding genetic engineering make this guarantee impossible at this stage.

C: THE GLOBAL CONTEXT

Chapter 8. The international political economy of agricultural biotechnology

At the heart of the controversy surrounding genetic engineering in agriculture is the difficulty of establishing the true nature of biotechnology's impact on the social, economic and ecological environment of adopting countries. As the previous chapters demonstrate, there is tremendous variability in the findings of authors studying the effects of Bt cotton in India alone, let alone the impact of different GE crops in the other 24 adopting countries. The polarization of the debate on agri-biotech across politics, science, and academia makes it extremely difficult to establish the 'truth,' or even formulate an objective viewpoint on whether it is good for development. There is little middle ground in response to GE crops and food products; you are either for them or against them. Both the advocates and the critics have been equally proficient at influencing public opinion and accusing the other side of manipulating the data to suit their cause. The fundamental problem behind this and primary cause of consternation among critics is that genetically engineered crops are not independent entities, they are in fact closely associated with powerful corporate and economic forces.

The power of the biotech companies in the proliferation of GE crops is much maligned due to the effective monopoly companies such as Monsanto, Syngenta and DuPont have on the production and sale of GE seeds. There is also considerable concern regarding how much influence these corporations have on the research that appears to deem biotech crops as an unmitigated success and the only viable option to maintain sufficient food, fuel and fiber production for a burgeoning global population. Most worrying is how far the largest companies are willing and able to go to suppress negative research and discredit their critics, of which the most obvious example is Ignacio Chapela who found evidence of GE maize transgenes crossing into wild varieties in Mexico. The burgeoning corporate dominance over agri-biotech is not only dangerous for adopting farmers who plant GE crops unaware of the risks, but for the millions of people who eat food containing those crops and their derivatives having been convinced they are safe by the very companies who want to sell them.

There is considerable concern among developing countries regarding the power intellectual property rights (IPRs), supported by the TRIPs agreement of the World Trade Organisation have bestowed on agri-biotech companies. These allow providers to charge exorbitant amounts for GE varieties whilst preventing farmers from saving their seeds, and forbidding public institutions from producing their own varieties or even performing

independent research on the technology even if it is to improve it. IPRs facilitate the seed company monopoly that ensures developing country adopters are almost entirely dependent on western science and the corporate giants to provide their seeds. By ensuring that royalties from research and development continue to flow back to private companies, money is subsequently drawn away from public investment. Furthermore, biased WTO trade laws and insufficient international bio-safety regulations effectively vindicate the behavior of the biotech corporations who engage in bio-piracy and the proliferation of GE crops and foods often by nefarious means.

The viability of genetically engineered crops is not just dependent on the results of biotech crops in the field or the economic impact on its producers; the ability of countries of the South to genuinely benefit from agri-biotech in a development sense relies on a global agricultural and trade system that is fair and accountable. The economic and scientific data on GE crops is not sufficient to formulate a comprehensive judgment on the long-term viability of agri-biotech. The industry is wrapped up in a complex international political economy that influences economic development to a much greater extent than any technology could. Therefore, to fully determine the potential of GE crops and long-term viability of agri-biotech for developing economies four important issues must be analyzed: a) the role played by multinational biotechnology corporations, b) the significance of private over public investment, c) intellectual property rights and the global trade system, d) national and international regulations on the safety of biotechnology.

a) Multinational biotech corporations

Corporate ownership of biodiversity and the almost total control of biotechnological development by a handful of Western multinationals has become a major cause for concern among skeptics of genetically engineered crops. Agriculture and the rapid development of biotechnology in the last twenty years is at the heart of one of globalization's greatest challenges; the power of profit hungry multinational corporations to drive national and international policy. The rapid proliferation of biotech crops in some developing countries without sufficient acknowledgement of the economic and environmental risks involved is testament to the power of these corporations but has raised some ugly questions regarding the reality of their pro-poor maxims. The huge sums of money at their disposal enable biotech companies to promote their products to governments, effectively bypassing public participation in the choice of whether or not to adopt GE crops (Altieri & Rosset, 1999). In

India for example, the commercialization of Bt cotton was primarily a political and corporate decision in which farmers had little knowledge until the seed providers turned up in their villages touting the benefits of new insect resistant varieties.

Monopoly power

Three companies dominate the biotech seed industry: Monsanto, Dupont and Syngenta. Between them they control nearly 50% of the global proprietary seed market with combined seed sales amounting to over \$10 billion in 2007 (ETC group, 2009).¹⁵ These three companies receive 47 cents out of every US dollar spent on proprietary seeds, through which a corporate hegemony has evolved that controls hundreds of millions of farmers across the globe. These firms are still growing too, absorbing their rivals through mergers and acquisitions when the latter can no longer afford to compete or entering into joint ventures if they can, such as between Monsanto and the Maharashtra Hybrid Seed Company (Mahyco) in India. This process started in the 1990s and has transformed the competitive framework of the agricultural, chemical and seed business almost overnight as huge numbers of public companies have also been bought out (Shimoda, 1998). The broad based strategic biotech seed platforms that companies such as Monsanto have acquired since then have effectively turned the agricultural seed business into a monopoly driven by a handful of biotech giants. These companies patent the genes, varieties and processes involved in the creation of genetically engineered crops and then reap tremendous profits by controlling the entire supply chain. Additionally, the use of intellectual property rights to prevent farmers from saving their seeds or independent researchers from testing or adapting them perpetuates their power.

The development of the biotech monopoly, of which Monsanto is the face, has resulted in a drastic loss of choice in the seed market for farmers. In buying up the world's seed firms and driving the survivors out of business or into the arms of competitors, Monsanto is increasing its dominance of the global seed market, a quarter of which it already controls (Kambhampati et al, 2005). Indian cotton farmers are now faced with a situation where every community has either a direct Monsanto representative or their former seed suppliers are now predominantly owned or controlled by Monsanto. Poor farmers consequently only have a limited ability to resist the spread of biotech seeds when that is all that is available. Once farmers have been manipulated into buying GE varieties they are then faced with the significantly higher costs of the venture. In India the price differential of Bt cotton is three

¹⁵ Monsanto (US), \$4,964 million in seed sales in 2007, 23% global market share. DuPont (US), \$3,300 million, 15%. Syngenta (Switzerland), \$2,018 million, 9%.

times the price of conventional seeds, the profits from which are largely used to buy up the competition in the seed market, thus further perpetuating and augmenting the corporate monopoly.

Genetically engineered herbicide tolerant crops such as Monsanto's Roundup Ready (RR) soybeans are the clearest example of how biotech feeds the agricultural corporate monopoly. Monsanto profits three times from RR Soy; first from the price of the seed, secondly from the increased sales of Roundup, its own brand of glyphosate based broad-spectrum herbicide, and thirdly from the price hikes on both seeds and herbicide each year (Friends of the Earth, 2009). It is therefore no surprise that Monsanto is also the 5th largest supplier of agrochemicals in the world and that Roundup is the world's highest selling herbicide (ETC group, 2009). As these companies dominate more and more inputs and processes of agricultural production throughout the industrialized and developing world, the profits they make just fuel their hegemony.

It is intellectual property rights, protected by the WTO's Trade Related Aspects of Intellectual Property Rights (TRIPs) agreement, which have provided the agro-business multinationals with the legal apparatus to engage in monopolization. Bt cotton is the prime example; it is so expensive to cultivate that it is the ideal platform to take advantage of the costs of production to sell, innovate and develop a seed monopoly (Kumar, 2009). Monsanto patented the key genetic event (cry1Ac) that is used to make the Bt gene effective against cotton's lepidopteron pests, and therefore effectively 'owns' Bt cotton. Consequently, even though a host of seed companies sell a number of different Bt varieties they all rely on the same event, which must be licensed from Monsanto (Acquaye & Traxler, 2005). Not only does IPR protection mean Monsanto can prevent other companies from developing a generic Bt cotton variety, it also allows them to impose strict user agreements on farmers so that they cannot save or share seeds. This practice locks farmers into a cycle of dependence on the biotech companies and their licensed producers from whom they have to buy seed year on year at a higher and higher price. A portion of the ever-increasing costs of production always flows back to the biotech companies, which just strengthens their monopoly over poor farmers.

Influence on public opinion

Market domination of the biotech monopoly not only grants the multinationals control over farmers but has also enabled them to have a substantial influence on the scientific research that reaches the public domain. The prevalence of studies that are favorable to GE

crops published through overtly pro-biotech organizations such as AgBioForum overwhelms more critical research, with only fully flattering studies ever seeing the light of a peer-reviewed journal (Scientific American, 2009). The fundamental problem in biotech research is that scientists rely on the cooperation of the biotech companies to obtain the seeds to study in the first place and often the funding too. This means that the corporations also retain the ability to block experiments from publication if the findings are negative. The result is that hardly any truly independent research can be conducted on GE seeds. Consequently too many important issues have been glossed over and assumptions accepted about the realities of adopting biotech crops (Glover, 2009).

Safety and the ability to form an unbiased opinion is under threat when companies such as Monsanto have such a strong influence on political and public opinion. This is illuminated when statements that contradict prevailing economic norms are used to obtain a moral advantage and are subsequently accepted as true. For example there appears to have been a wide-spread acceptance of the assertion, emanating from the seed companies, that high yielding, low cost GE crops will be the answer to the problem of global hunger (James, 2007, 2008). This acceptance is baffling given the well-established understanding that hunger is not a consequence of a lack of food supply, but instead is a deficiency of food availability for the world's poor and marginalized as a result of very complex social and economic dynamics. Nevertheless, the continuing pervasiveness of the pro-poor argument for GE crops is symptomatic of the sophisticated public relations machines that are bankrolled by the multinational seed companies to promote their products.

Manipulation of scientific research

There is a large amount of ostensibly independent research that is directly or indirectly supported, funded and undertaken by the biotech companies. It is difficult to establish exactly to what extent and to what end this support is given, but it inevitably calls into question the reliability and objectivity of conclusions found in these studies. The ISAAA for example, a not-for-profit and supposedly independent organization that produces annual reports on the global status of commercialized GE crops is actually given funding by a number of biotech companies including Monsanto, Mahyco and Bayer (ISAAA Brochure, 2010). Yet its findings are widely referenced by public institutions and governments who portray their results as independent and objective. Similar examples are commonplace and yet the results of biased studies are widely reported as reliable. A Martin Qaim (2003) study that found yield increases of 80% with Bt cotton over non-Bt in India, and economic advantages

of thousands of rupees for Bt farmers, created a huge outcry once it was discovered that all the data was derived from Monsanto. The data came from scientifically conducted field trials and yet was claimed to be relevant for farmers all over the developing world.

Other studies on the impacts of Bt cotton in India have acknowledged the assistance of Mahyco, which has a joint venture with Monsanto for the production of Bt cotton seeds in India, and another personally thanks a former employee of Monsanto for his 'logistical support' (Morse et al, 2005, 2007a). These studies are but a handful among a large number produced by a group of academics from Reading University that have been widely criticized in academic circles for the methodological and presentational flaws of their studies on the success of GE crops (Glover, 2009).¹⁶ Nevertheless, they form the core of scientific research on Bt cotton, which is evident from their prevalence in the bibliography of this paper.

There is considerable evidence that the prevalence of pro-GE research is not just the result of more funding and better public relations, but also because of subversive tactics used to bury or discredit criticism or concerns about agri-biotech. The best example of this is the case of Ignacio Chapela, a Berkeley scientist who discovered evidence that five out of seven traditional corn varieties in Mexico, supposedly the cleanest, most natural source of the crop in the world, were contaminated with genetically engineered varieties (Quist & Chapela, 2001). The discovery was so controversial because Mexico sees itself as the center of origin for corn. The country has extensive biodiversity that the government tries to protect by banning the commercialization of transgenic crops, and yet the results were found in corn areas that were grown and maintained locally using traditional practices. Despite the Mexican governments attempts to restrict the proliferation of GE crops the North American Free Trade Agreement (NAFTA) means it is powerless to stop the import of millions of tonnes of US corn, 40% of which is genetically engineered but not labelled as such (Chapela, 2002; Robin, 2008). This grain is distributed around the country through the welfare food system, but because there is no differentiation between seed and grain in Mexico 'food grains' often find their way into fields. Corn plants cross naturally by wind pollination therefore the fear that Mexican corn would be uncontrollably affected by GE varieties appeared to be realized by Chapela's findings.

Chapela's study went on to cause a substantial controversy not just in Mexico and among critics of biotechnology for the threat to biodiversity it uncovered, but also because of the attempts to deny and discredit Chapela's findings. There were some initial concerns about

¹⁶ The Reading Group includes R.M. Bennett, Y. Ismael, U. Kambhampati and S. Morse.

the method Chapela used, which some argued was unreliable, but the debate escalated uncontrollably when the scientist became the target of a venomous smear campaign to try and discredit him on both a scientific and personal front. He was accused of being biased because of his affiliation with the Pesticide Action Network (PANNA) and for liaising with “fear-mongering activists” such as Greenpeace (Rowell, 2003:155). AgBioWorld the leading mouthpiece for pro-GE science and sentiment played an important role in trying to damage his credibility, fuelling the argument that he was an activist first and scientist second. The Internet became a virulent tool with anonymous and unknown people condemning Chapela to such a degree that by April 2002 *Nature*, which had published the findings, was under serious pressure to retract the article (Rowell). Chapela was subsequently denied tenure by Berkeley as a result of intimidation of the administration, which had recently accepted a \$25 million research grant from pharmaceutical giant Novartis.

After considerable technical searching on the part of Chapela’s supporters it was discovered that some of the authors who had attacked him online had worked for Bivings Woodall, a PR company that had worked for Monsanto in Internet advocacy campaigns. As numerous covered links began to be traced back to Monsanto it became increasingly clear that the biotech giant had been ‘guiding’ web based debates to attack the scientist and his findings. Chapela has since been vindicated after numerous studies conducted by Mexican scientists and one by the National Ecology Institute have all confirmed the contamination of Mexican corn, arguably on an even worse scale than was initially suggested in the *Nature* article (Robin, 2008; Rowell).

The extent Monsanto were prepared to go to discredit a well-respected scientist from a powerful research institution in an controversial case makes one wonder how much negative research from less significant sources simply vanishes under the weight of corporate pressure. AgBioWorld, and its online *Journal of Agrobiotechnology Management and Economics* (www.AgBioForum.com) is renowned for its close links with the biotech industry even though it claims not to receive funding from any corporate donors. The research published by the forum is overwhelmingly positive about genetically engineered crops, and with ISAAA forms the most prominent mouthpiece of the biotech industry. The lack of objectivism of these institutions, and the simple dearth of varied opinion or balanced research that reaches the public domain is seriously worrying. It removes from the public the essential evidence that allows people to form a balanced opinion on biotechnology. The majority of consumers, particularly outside Europe, do not understand the implications of biotechnology because they are unaware of the extent of skepticism surrounding the technology. The power

of the multinationals over research is a substantial conflict of interest that allows biotechnology to be run past society and political institutions without the necessary analysis or discussions.

Influence on public decision making

It is clearly within the interests of agri-biotech companies to support and publicize evidence that genetically engineered crops are safe, economical, reliable, pro-poor and environmentally friendly. However, too often government decisions and public opinion appear to be shaped or even lead by the convictions of those companies. Monsanto, Syngenta and Pioneer include in their user agreements the express prohibition to use their seeds for any independent research, and yet national governments have only limited scope to test new biotechnology. One of the biggest misperceptions about genetically engineered crops in the USA is that the Food and Drug Administration (FDA), which approves the commercial release of biotech crops, has tested these plants and declared them safe. In reality the FDA bases its approval on the assurance of Monsanto itself that the products are safe, and they are not required to undergo any significant independent testing (Scientific American, 2009). Furthermore, the US Department of Agriculture (USDA) has no authority to evaluate the potential health impacts of GE crops or of conventional crops after they have been contaminated. It is also not responsible for monitoring or enforcement of the commercialization of GE varieties. Governments only have to compare known components between GE and non-GE varieties, such as nutrients, allergens and toxins. Human trials for either toxicity or allergen testing are not required, neither are independent checks of the biotech companies' findings. The US government and subsequent adopting countries seemingly sidestep this huge conflict of interest, even though it has been highlighted as a cause for considerable concern among Monsanto's own shareholders (Monsanto shareholder vote, 2005).

The regulatory system has been similarly weak in India where Mahyco/Monsanto's biotech field trials were not opened up to independent scrutiny and approval of Bt cotton was essentially based on the assurances of the USA and its leading biotech company. No study was done on the impact of Bt cotton on beneficial insects or the development of resistance, nor was the cross pollination or contamination threat determined (CSA, 2005). Mahyco/Monsanto itself was then entrusted with certain responsibilities related to monitoring and regulatory aspects. Even though it was a clear conflict of interests this approval process was still permitted by the Indian biotech regulatory authority, the GEAC.

The malign influence of this corporate power was very apparent following the initial introduction and failure of Bt cotton in certain regions. Despite being aware of a number of reports that demonstrated the failure of Bt cotton in Andhra Pradesh the Indian government followed the Mahyco/ Monsanto line that the crop had shown a satisfactory performance. The CSA, Greenpeace and the Friends of the Earth among others, have subsequently accused the Indian government of gross misrepresentation of farmers after it was discovered that it had publicized positive reports on Bt cotton with evidence from ‘teams of experts’ that were actually made up of Monsanto employees (CSA).

At the heart of this problem in the United States in particular, is what is seen as the revolving door between the federal government and the biotech companies, especially Monsanto. Donald Rumsfelt, former US defense secretary was the CEO of a Monsanto subsidiary, Supreme Court judge Clarence Thomas used to work for Monsanto, Michael Taylor went back and forth several times between Monsanto and federal government agencies, and Linda Fischer moved from the Environmental Protection Agency to Monsanto in 1999 (Robin, 2008). These are not insignificant people; for many anti-GE commentators this personnel movement is the most likely explanation for the rapid approval of GE crops in the US. It also helps explain why the biotech companies have gained so much power in the international proliferation and regulation of their own products.

It is hard to deny that the US government and leading biotechnology corporations seem to be complicit in the desire to spread GE crops regardless of scientific evidence made available to them that suggest serious environmental concerns. Robin (2008), who studied Monsanto specifically for three years, states that the FDA has documents that prove they ignored safety warnings of genetically engineered organisms from their own scientists. This means that the US government, whose example and regulations are copied by developing countries across the globe, proclaims that GE food crops are as safe as conventional crops in spite of clear misgivings from within the FDA itself. Mahesh Batt (2009) goes as far as to call it a criminal conspiracy between the governments and the multinationals. The rhetoric surrounding GE crops is often unnecessarily strong but in this case there is no doubt that the relationship between the biotech companies and the governments who approve their products appears to be too close for comfort.

Accountability

A worrying characteristic of the corporate-government relationship is the lack of accountability. The law essentially lies with the corporations, as was demonstrated with the

infamous case of Canadian farmer Percy Schmeister who was accused of patent infringement by Monsanto. Monsanto found evidence Schmeister's Canola crop was contaminated with its patented RR variety and tried to sue him for unpaid seed costs of \$15 per acre. Schmeister had no idea that his crop was contaminated; he had been saving seed for thirty years, building up his own locally adapted variety and deliberately avoiding GE seeds. Yet novel transgenes contaminated his crop anyway. From the farmer's point of view his rights were the ones being infringed, after all it was Monsanto's biotech that had infiltrated his field against his will and cross-pollinated with his pure varieties. When the case came to court however the judge ruled in favor of Monsanto as according to the law it did not matter that Schmeister had not intended for Monsanto's crop to be in his field, it had been found there and therefore he was guilty (Holdrege, 2004). Schmeister had to pay a fine of nearly \$20,000 and was ordered to destroy all his seed saving from the 1998 harvest, effectively ruining the farmer's livelihood. Schmeister finally got justice in 2008 when he agreed to settle with the biotech company, who agreed to pay all the cleanup costs of the RR Canola. Unfortunately similar outcomes are not usually so positive. It was only possible for Schmeister because he had significant public support who helped provide the financial resources to fight Monsanto for over ten years, which the vast majority of farmers particularly in the developing world do not have.

Monopoly power and the sheer wealth of the biotech corporations brings certain leniencies that mean the companies can get away with behavior that would usually be illegal. Unlike Schmeister, most people who challenge the actions of the biotech companies simply do not have the financial resources to take on the economic, political and legal clout of these companies. This extends to the governments of developing countries whose economies are too fragile and too reliant on developed markets to take on the biotech companies, their governments and the WTO, whose rules protect them. The biotech companies are very aware of this and have taken advantage of their position to push GE crops ahead of official approval. There is a history of GE crops spreading in adopting countries before their governments officially approve them, which has led some commentators to accuse biotech companies of actively seeking to contaminate conventional crops with transgenic varieties so that governments are forced into officially approving them (CSA, 2005; Kumar, 2009; Rowell, 2003). Whilst this accusation is strongly denied the widespread proliferation of RR soybeans in Brazil and Bt cotton in India prior to formal approval is somewhat damning. The cause of the biotech companies is not helped by the evidence that they have engaged in nefarious behavior to bypass regulations. Monsanto was actually charged with bribery and corruption to the tune of \$1.5 million for spending over \$700,000 dollars in bribes in Indonesia to try and

bypass controls of its Bt cotton seeds, which fuels the accusations of unfair play (Gala, 2005a). However, the sheer size of these companies, who have profit margins in the billions rather than millions of dollars means that financial punishment on this scale is meaningless. It is certainly no deterrent against using all necessary means to extend the scope and penetration of GE crops.

Bio-piracy

One of the more controversial activities engaged in by the biotech companies, which is entirely legal under TRIPs and is facilitated by the institutional weakness of developing countries, is what has become known as biopiracy. TRIPs makes it mandatory for members to allow patenting of some life forms as well as IPR protection for plant varieties, even if the source of that genetic material is from outside the patenting country's borders. The implication is that foreign companies can obtain and patent indigenous knowledge and biological wealth of developing nations (Kohr, 2004). Consequently, bio-piracy is rife in the developing world; a copy of around 150,000 plant accessions collected all over India are now held with the US department of Agriculture. India has no control over these resources, and ironically its recent attempts to document traditional knowledge in order to protect it actually helps the US patent owners to use those plants. The most infamous case of bio-piracy is Basmati rice, whose genetic origins are in India, and which is considered a common entity that is always evolving and is accessible to all who wish to grow it. Yet, the genetic lines were patented by the US patent and trademark office for a Texas company called RiceTech. RiceTech then created a host of hybrid Basmati-like rice varieties, including Texmati, Jasmati and Kasmati, which it is able to sell in the US and back to Indians for a profit, and under patent (Kumar, 2009).

Bio-piracy effectively means that foreign companies, particularly the biotech multinationals, can take a natural resource from a specific country without any sort of granted permission or public recognition. The practice essentially means that the United States can patent an Indian plant but make Indian farmers pay for the right to grow it in the future. Biopiracy endangers the financial future of farmers and threatens traditional social relationships between farmers for whom access and techniques of crop growing have historically been considered part of the commons; something that is shared household to household and generation to generation. The US holds the world's largest collection of germplasm. This not only entitles it to earn billions of dollars from IPRs for the foreseeable future, but has been seen by some more extreme commentators as an attempt by the US,

through the biotech corporations, to control the future of the global food supply (Engdahl, 2005; Herrick, 2008).

Overview of the corporate monopoly

The power of agricultural biotechnology corporations is so extensive that a full analysis of their influence must be at the heart of any debate on the economic viability of genetically engineered crops for developing countries. The ability of these companies to influence scientific research, public opinion and political decisions is so overwhelming that it effectively takes much of the power away from developing country governments to make their own decisions about biotechnology. It must not be forgotten that the critics of genetic engineering are equally adept at manipulating the facts to put forth their opinion, but their power and resources pale in comparison in the face of the biotech juggernaut. Suppressing scientific evidence that clearly demonstrates the economic and environmental risks involved in growing transgenic varieties is dangerous to farmers and consumers, and also threatens the long-term future of agriculture and the environment. There should be no excuse for such actions as the only plausible explanation for discrediting work in the manner done to Ignacio Chapela is because highlighting the threats of GE crops is damaging to company profits.

The denial by the biotech industry that its primary motive is self-interest is shown up by Monsanto's withdrawal from Argentina in 2004 despite almost 90% market penetration of RR soybeans. Argentina has very weak IP protection for plant varieties therefore Monsanto's earnings were threatened by a thriving black market. The fact that Argentine farmers do not have to pay royalties when replanting RR seeds considerably weakens the company's argument that withdrawal was nothing to do with profits (Kesan & Gallo, 2005). Given the lingering concerns about GE crops safety for consumers and the environment must come before profit; there should be more accountability for firms to prevent self-interest clouding the real issues. Governments, particularly the US, should not be complicit in the actions of the corporations by failing to acknowledge risks or force independent scrutiny. It is in the interests of the rest of the world to demand that the products they accept from biotech companies and the political decisions they make are truly based on objective information. Monopoly power in the biotech industry is not in the interests of anyone other than the corporations themselves. This needs to be tackled by an increase in public investment and a complete redress of the international trade system and role TRIPS and IPRs play in facilitating and augmenting the monopoly.

b) Public versus private research and development

Part of the reason the agri-biotech monopoly has become so strong is because of severe underinvestment by public institutions, which fail to provide any sort of meaningful competition to private enterprises in terms of biotech innovation. Ismail Serageldin, the former chairman of CGIAR said that whenever the product and process patents in food and agriculture come into effect, it would result in “scientific apartheid” against the developing world (Sharma, 2003a). He argued that it would kill off any public investment in research and development in the developing world. 96% of all biotech research and development (R&D) is done in advanced economies, of which 70% is conducted privately, which would suggest that this situation has already manifested itself (Acquaye & Traxler, 2005). Developing countries as a group invested only 0.56% of agricultural GDP in 2000, only a ninth of the 5.16% developed economies invest, which is itself a pitifully low amount (World Bank, 2008). Intellectual Property Rights can only really help private companies who can derive a steady stream of income, whereas the climate for public investment in agriculture has been weak over the past few decades.

With the exception of China, the private sector has dominated the delivery of GE crops in all countries. The large biotech companies maintain that without IPRs they would not be able to recover the huge investment costs required in the development of a specific trait (Acquaye & Traxler, 2005). Consequently the seed companies have increasingly gained control of IPRs of seeds and other genetic resources. This gives them an advantage in exploiting the bio resources of developing countries and at the same time constrains the access to those resources (Thrupp, 2000). Public R&D simply cannot attract the investment necessary to compete with private companies and thus the power remains with private innovators, perpetuating the biotech monopoly. By controlling the development of most agricultural biotech and accessing substantial resources for marketing, these companies are subsequently able to influence not just the availability of the technology but also policy strategies. Without publicly provided alternatives and no private accountability biotech companies have been able to promote GE varieties with misleading marketing techniques that have left farmers confused and disappointed about seed choice and output expectations (Karihaloo & Kumar, 2009).

The greatest danger of the stranglehold of private enterprises on agri-biotech development is that small farmers will become dangerously dependent on annual seed purchases from a small pool of corporations. Choices will be limited by the rise of a few

private firms who set high prices and insist on IPRs that deny on-farm traditional seed saving or sharing. Until the emergence of biotechnology private control of intellectual property was not a significant barrier to agricultural innovation because traditional breeding worked mainly with seed stocks held in public gene banks and were available to all.

It is not too late for developing countries to tackle the biotech monopoly by increasing public investment in GE crops, and India, China and Brazil have all pledged significant resources over the next few years to try and do so. In 2007 India launched a national biotech development strategy focusing on biotech's potential to provide long-term benefits for agriculture, health and the environment. The government will boost funds for biotech by five times from 2007 to 2012 to a total of \$1.6 billion from \$362 million, including a target for the industry to generate \$7 billion by 2012 (Department of biotechnology, Government of India, 2007). India is already well set up for public R&D with nearly one hundred agricultural research institutions, it is just the necessary investment that has so far been lacking in response to private biotech corporations (Indian Council of Agricultural Research, 2009).¹⁷

Glover (2010) argues that to improve their power India and other developing countries should follow China's example where Bt technology was developed by public institutions as well as Monsanto, and has been released as open-pollinated varieties. Reducing the power of the corporations in the spread of China's GE crops means that not only can farmers retain seed for replanting, but prices for Bt cotton seed are a fraction of what they are in India. Increased public investment and participation in agri-biotech has the dual benefit of reducing the power of the corporate monopoly whilst at the same time improving the lot of the farmer.

Nevertheless, the dangers of agri-biotech are not removed by increased public investment; whether a private company or a public institution produces GE crops there still remains considerable economic, social and environmental misgivings. However, at least more public development brings with it greater accountability, increased scrutiny of the technology, and a more tangible and believable desire to spread GE crops for the right reasons. Eliminating the profit motive from genetically engineered crops is the only way to guarantee that biotech will proliferate because it really does help farmers and improve the environment. Better public R&D will ensure biotech and agro-ecological alternatives are made equitably

¹⁷ Indian Council of Agricultural Research (ICAR) institutions include: 4 universities, 45 research institutes, 17 national research centers, 6 national bureaux, 25 national directorates and project directorates. 97 in total of which 27 are dedicated specifically to crop science.

and broadly accessible. Greater competition from public institutions will force private companies to be more competitive in their pricing, and will help reduce bio-piracy if developing countries are able to acquire the property rights to their own resources.

c) Intellectual property rights and the international trade system

The power of the multinational biotech companies and rise of private over public investment in agricultural biotech is intrinsically tied to the international trade system and the role of intellectual property rights. IPRs of genetically engineered crops supported by the Trade Related Aspects of Intellectual Property (TRIPS) agreement of the WTO have provided the legal framework that has facilitated the rise of the biotech seed monopoly. Both are seen as particularly disadvantageous to developing countries seeking to develop their own biotech industries and protect their farmers from dependence on foreign inputs. The international trade system is skewed towards the developed world, which is a net producer of patentable knowledge whereas the South is a consumer and hence the money flows from South to North (Wade, 2003). Furthermore, the rules of the trade system prevent developing countries from absorbing the technologies the industrial economies have developed. They also inhibit the use of the policy instruments advanced and high performing Asian economies used to allow their own economies to develop, such as subsidies and tariff barriers. Developing countries are therefore not just disadvantaged when it comes to the production of their own agri-biotech, trade rules also prevent them from protecting their own farmers from artificially reduced prices in the international market.

IPRs & TRIPs

Intellectual property rights allow the owner of a patent to prevent others from making, using, selling or improving their invention. In 1980 the US Supreme Court ruled that isolated genes and genetically modified plant varieties could be patented, even though biological patents obviously blur the line between invention and discovery (Chan, 2006). According to the Supreme Court the important difference was not between things that are living and things that are not, but between products that are found naturally in nature and products that are man made (Çoban, 2004). Since then the distinction has become less clear. Until the biotech revolution at the end of the 1990s IPRs didn't tend to affect farmers at all despite the 1980 ruling. Researchers were protected through systems of "Plant Breeders Rights" outlined by the International Union for the Protection of New Varieties of Plants

(UPOV) whose aim was to promote international harmonization and cooperation between global plant breeders. Licenses were granted for innovations, but unlike modern IPRs they didn't tend to prevent farmers from using seeds for next year's planting, or prevent other breeders from further improving and adapting seeds (Victor & Runge, 2002:118). This changed with the commercialization of the first biotech crops when huge R&D costs and drawn out regulatory approval led biotech companies to seek IPRs to protect their developments. However, the simultaneous introduction of the TRIPs agreement, which enforces these regulations in other countries, means that IPRs effectively facilitated the creation of the biotech corporate monopoly.

IPRs and the TRIPs agreement that enforces are most damaging to developing countries. When India joined the WTO in 1995 it had to adopt TRIPs and alter its IPR legislation to allow the patenting of life forms, living organism derivatives, gene patents and components (Kumar, 2009). This has left the country open to virulent bio-piracy and has hindered local firms from absorbing modern technologies, including agricultural biotechnology, for which it has to pay foreign firms. IPRs favor innovators with profits at the expense of developing countries whose farmers are denied the newest technologies because of cost and public institutions are powerless to provide cheaper alternatives. Hence, despite the pro-poor rhetoric of the biotech companies, IPRs have been a major barrier against developing GE crops on behalf of the poor.

Part of the problem for developing countries is that TRIPs regulations on plant biotech are very confusing and relatively ambiguous. There are exceptions within exceptions that leave the agreement open to interpretation as to what constitutes a biological process, which is not patentable, and what is a microbiological or technical process, which are patentable. The danger for developing countries is that wealthy corporations from foreign countries have been able to interpret the rules as they desire to appropriate plant gene accessions even though the wording of the agreement appears to suggest that 'natural products' are not supposed to be patentable (Rao, 2002). Biodiversity is therefore easily threatened by corporate bio-piracy, which endangers developing countries' control over their own natural resources and can dispossess farmers of the right to cultivate, improve and share their seeds and their skills. Çoban (2004:752) presents the case that IPRs devalue farmers and give corporations power over them through "imposed scarcity." The legal framework of IPRs and TRIPs mean that non-scarce resources, such as the seeds reaped during harvest, can be turned into a scarce commodity by prohibiting farmers from reusing them. Forcing farmers to sell all their seeds means they have to rebuy seed stocks every year. This not only increases

corporate profits but also strengthens the biotech monopoly by creating dependence among farmers on the inputs from biotech multinationals, whatever the cost.

TRIPs limits developing countries' flexibility in using patented technology and hinders local firms from absorbing agricultural biotechnology (Wade, 2003; Kohr, 2004). The problem inherent in the relationship between biotech corporations and farmers is that the power remains with the seed suppliers who are able to impose extortionate prices on farmers for the use of their technology. TRIPs then prevents developing countries from producing their own generic varieties to circumvent this. The monopoly therefore strengthens, and the ability of the developing economy to compete on a technological or economic level is further diminished.

International Trade System

IPRs and the TRIPs agreement are part of a global system of trade that is inherently, and increasingly skewed towards industrialized countries and their wealthy multinational corporations. Property rights on agri-biotech mean that the royalties from GE crops flow from developing to developed countries with little reciprocal benefit sharing (Kohr, 2004). It was thought that the WTO and Uruguay trade round that resulted in TRIPs would help open up agriculture for developing countries, but the opposite has happened; domestic subsidies in the OECD have increased since the Uruguay round with little expansion of access to advanced economy markets. Wade (2003) argues that the 'development space' of poor countries has been constrained by trade liberalization over the past twenty years. New international laws make illegal many of the industrial policy instruments used by High Performing East Asian economies to mature their own industrial and technological capacities, and many of those used by the United States itself. TRIPs is an integral part of this as it prevents developing economies from benefiting from the technological developments of the US or European countries. Reverse engineering of pharmaceuticals and agri-biotech is strictly prohibited and hence developing countries are denied the opportunity to adapt foreign technology by producing similar or generic products themselves. The rules are such that even if Bt cotton were bad for the Indian environment, Indian biotech firms would not be allowed to improve it or make it more suitable for local cultivation.

There is a strong argument that IPRs should not even be a trade related issue nor be regulated by the World Trade Organization; IPRs and TRIPs facilitate monopolization of certain industries when the WTO's mandate is supposedly to work against protectionism. Industrialized countries, led by the US and EU have driven through international trade

regulations that greatly restrict the right of developing governments to follow policies that favor growth and technological development. Trade liberalization has forced developing countries to open up their economies to foreign investment and produce such as GE crops with promises of improved access for their own products in industrialized countries. The failure to uphold the second part of the bargain though is restricting development throughout the South.

There are many parts of the international trade system beyond TRIPs that impact negatively on developing country farmers; not least the Agreement on Agriculture, which permits advanced economies to increase their domestic subsidies whilst prohibiting equivalent behavior in developing countries. For India's 600 million rural poor an indirect subsidy of \$1 billion to provide cheaper electricity, water, fertilizer and seed was considered trade distorting by the WTO, and yet the billions of dollars handed out every year to American farmers is not (Sharma, 2004a). The US is proficient at exploiting a loophole in the agriculture agreement that allows it to increase subsidies by switching the 'boxes' they are regulated under; by switching products from the amber to the blue or green boxes, the US's farm subsidies are seen as 'indirect' and therefore not trade disturbing. The reality is that huge domestic agricultural subsidies for crops such as cotton mean that the US can produce very inefficiently and yet sell on the international market at artificially reduced prices that due to subsidies are often significantly lower than the cost of production. The implication for cotton farmers in India is that whilst they are much more efficient, they lose out in the market because international prices are depressed and therefore their already meager profits are further reduced.

To comply with international regulations the WTO makes developing countries remove non-tariff barriers in favor of set tariffs, which themselves have to be kept low. Ultimately, this means that the food import bill in countries like India is increasing faster than the export bill. Farmers are facing competition from cheaper imports of plantation crops, whole grains and commodities, while domestically produced food sits rotting in silos as farmers are unable to export it and the very poor cannot afford it. Developing countries are threatened by agricultural dumping from developed countries such as New Zealand, which sold dairy products into India at such low prices that it undermined entirely the Indian government's thirty-year struggle to create self-sufficiency in dairy through cooperatives (Kohr, 2004). At the end of the day WTO trade laws effectively enable an international institution that is supposed to be working towards development to actually contribute to the plight of poor countries that suffer under the weight of massive poverty and hunger.

One reason this situation has been able to persist so damagingly for so long is because of the institutional and economic weakness of developing countries (Wade, 2003). Developing countries' rights are unenforceable but their obligations to the WTO are imposed rigorously by industrial economies. In developed countries the opposite is true; their obligations are unenforceable but their rights strictly upheld. The costs of mounting a challenge against the EU or the US for failing to improve market access are simply too high for the majority of countries to contemplate. Even the EU tends to settle its differences with US about biotech crops through complicated agreements outside of WTO trade laws (Victor & Runge, 2002). For developing countries, even with economies the size of India or China, the US and EU markets are too important for them to jeopardize a prolonged trade war that could do even greater damage to the agricultural economy and its farmers. Developing countries must therefore think carefully about their policies towards agri-biotech as trade laws mean they can be threatened with WTO sanctions if they refuse to accept GE imports. The overall result is that in spite of concerns regarding the safety of GE crops in the vast majority of countries, the US can effectively force those countries to accept them as imports. Mexico is the prime example; it has banned the commercialization of GE crops to protect indigenous corn and backs the labeling of foods containing GE crops, however it was threatened with NAFTA sanctions for refusing to accept US corn imports that are 40% GE. Sri Lanka faced a similar situation when it was threatened with WTO sanctions by the US when it banned GE imports in 2000 (Government of Sri Lanka, 2001).

Political control of the global food supply

Actions like New Zealand's in India are a severe threat to local food security and self-sufficiency, nevertheless food aid permitted and encouraged by the WTO allows the dumping of GE crops regardless of the wishes and regulations of recipient countries. Some commentators have argued that this is an attempt by the biotech companies, in collusion with the US, to contaminate the world with GE crops in order to force approval (Rowell, 2003; CSA, 2005; Kumar, 2009;). It is also argued that this is being done for the United States and other OECD countries to gain political control of the international food supply, with biotech crops and their inclusion in food aid being used as a foreign policy tool and part of the US's negotiating kit (Sharma, 2003a; Herrick, 2008; Engdahl, 2005).

Both the biotech companies and the United States government obviously vehemently deny these claims, shielding themselves with the WTO laws that favor them and their own pro-poor moral stance. The US argues that the EU's strict labeling of GE crops and

foodstuffs is not only illegal and harmful to the US economy, but is stunting the growth of the biotech industry and therefore contributing to increased starvation in the developing world. Despite this rhetoric there is in fact considerable evidence of the US appearing to get rid of its surplus of GE crops on desperate but unwilling food aid recipients, in which the UN's World Food Program (WFP) is complicit. Food aid has been described as the last unregulated export market open to US farmers in the face of east Asian and European regulations that impose strict labeling and import rules of GE products (Walsh, 2000). Because many developing countries suffer severe and endemic hunger they have little choice in accepting food aid even if it comes in unlabeled bags containing GE grains. Ecuador, Bolivia & Guatemala have all been given food aid by the WFP that contained GE soy and cornmeal even though GE products are illegal in those countries. Herrick (2008) describes a crisis of morality in food distribution as GE and non-GE foodstuffs go unsegregated in aid packages regardless of whether agricultural biotech is wanted or even legal in recipient countries. This behavior does little to dispel the accusation that the US, with the complicity of the UN and WTO, is trying to force genetically engineered crops on the rest of the world through contamination and on desperate starving populations who have no choice but to accept.

The US has been able to get away with this behavior with the argument that food aid is not meant for planting, even though it is well known that the distinction in the US and EU between seed and grain is not observed in the rest of the world, where you "eat what you plant and plant what you eat" (Chapela, 2002). Unfortunately for starving countries the only way to prevent this behavior within current trade laws is to reject food aid entirely. Zambia turned away 100,000 tonnes of GE corn in food aid (\$6 million worth) from the US because it was in kernel form. African farmers do not eat the seeds they are given, they plant them, therefore there were legitimate concerns that transgenes would contaminate local crops and might penetrate throughout the food chain. Furthermore, to mill the kernels to be able to eat them would cost up to \$25 per tonne, which is simply not viable for impoverished and starving farmers (Herrick, 2008). The US government, USAID and WFP are very aware of the agricultural processes in developing countries, yet their refusal to alter the process of aid, for example by milling corn before delivery, undermines the altruism of food aid. Trade laws and Food aid are subsequently both guilty of allowing and perpetuating processes that ultimately places the profits of the biotech companies ahead of the developing world poor.

Overall impact of the global trade system

Whilst IPRs have been essential in the development of genetically modified crops they have also enabled the biotech industry to become a monopoly. Regardless of whether or not GE crops are good or bad for the economy or the environment, this monopoly is intrinsically bad for development. The fact that the economic, social and environmental verdict on GE crops is still widely debated makes monopoly power and international trade laws even more influential. Agricultural biotechnology provides an excellent example of how IPR and trade regulations harm local technological development, poor farmers and biodiversity. IPRs and the laws of the TRIPS agreement that protects them are just one part of a system that is inherently biased against developing countries. The international trade system is preventing growth through the very processes that rich economies benefited from but are now denied to poor countries. Multilateral trade laws and regulations are essentially designed by and for industrialized countries to protect their own economic interests. Furthermore, the ability of the US, with the complicity of the World Food Program, to force GE food crops on starving countries is arguably a blatant attempt to coerce the developing world into adopting agri-biotech. From a political and trade point of view the argument that GE crops are being developed with pro-poor intentions is particularly tenuous. Genetically engineered crops are not a viable development policy for developing countries if the crops, the farmers that grow them and governments that approve them are controlled and manipulated by a corporate biotech monopoly in the US and EU.

d) Bio-safety regulations

National regulations on genetic engineering of biological organisms are not uniform from country to country and have evolved out of existing agricultural regulations. These regulations have become increasingly insufficient to cover new and novel issues raised by the proliferation of biotechnology, which has introduced entirely new facets and threats to the environment and international food supply. Safety concerns have clashed with national interests and biotech companies whose burgeoning trade in GE crops has met with increasing consumer and regulatory resistance, particularly in the EU (Falkner, 2000). Many of the problems discussed in the sections above, such as industrial countries' ability to introduce biotech crops to developing countries with limited local regulation, engage in biopiracy, and dump GE food stuffs on countries where they are illegal has been facilitated by the incomplete and fragmented nature of biotech regulations. The Cartagena Protocol on bio-

safety has attempted to establish more concrete rules for the trade of biotech products and has attempted to include socio-economic considerations to biotech regulation, but there remain significant and worrying shortfalls.

National Regulations

There have been suggestions from both sides of the biotech fence that government regulations have been compromised due to the potential of regulators to be ‘captured’ by powerful interest groups who seek to drive their own agenda (Graff, Hochman & Zilberman, 2009). In Europe where biotech regulations are very precautionary with strict labeling laws of food containing genetically engineered products, the EU has been accused of capitulating to political and environmental activists such as Greenpeace and Friends of the Earth. In the US, the opposite is the case; government regulators are seen as being too closely aligned with the interests of the biotech companies. Unfortunately the latter scenario is neither wholly surprising nor fully avoidable. No-matter how detrimental they may be, as the primary producers and distributors of GE crops the biotech companies have the requisite scientific knowledge and experience to be the key advisors in the politics of biotechnology regulation (Newell & Glover, 2003). Similarly, the situation in Europe should not have been unexpected. Despite having some very large biotech corporations, as it stands Europe actually benefits very little economically from the biotech industry and has a comparative advantage in older technology that is seeing its market share displaced (Graff et al). Consequently, it is in European countries’ interests to ban biotech crops and limit their development so as to create a non-tariff barrier to biotech trade and thus protect prices for domestic producers

The US has repeatedly attacked the EU for its ‘precautionary principles’ in regulating GE products, arguing that they conflict with WTO science-based risk assessments (Falkner, 2000:299). This may be so, but it is also true that these principles conflict with the US’s own economic intentions; for the world’s leading exporter of GE products European regulations are a considerable trade barrier. However, given the long-term environmental, and hence socio-economic threats of genetically engineered crops it is the *failure* to follow such precautionary principles that should be cause for concern at the WTO. Crops are approved quicker in the United States than anywhere else and without any significant health, environmental or export market assessment imposed by either the FDA or USDA (Friends of the Earth, 2009). The absence of any requirement to impose traceability or labeling on GE food products increases the suspicion that in the name of economic interests the US is threatening the rest of the world with its profligacy and irresponsibility towards environmental

and food safety.

The power of the EU has meant that it has been able to resist mounting pressure from the US to break its resistance to GE. In developing countries on the other hand, their regulatory framework is often too weak to resist the spread of GE crops and then regulate them sufficiently and independently. Unfortunately it is the South and its poor farmers who have the lowest gains from agricultural productivity and yet incur the highest costs from environmental disruption caused by technology. Those who are worst affected also have the least say in any political-economic calculation (Graff et al, 2009).

India's Genetic Engineering Approval Committee (GEAC) is a relatively sophisticated regulatory body in relation to other developing countries, but even India's biotech regulations still contain potentially dangerous weaknesses and omissions. The GEAC can authorize approval and prohibition of any GE food product for import, export, transport, manufacture, processing or sale, and yet the Biological Diversity Act of 2003 fails to provide for an environmental assessment of GE crops (Sharma, 2004a). It is regulatory weaknesses that are responsible for the widespread proliferation of illegal and fake varieties across the country and over its borders. These weaknesses can also be blamed for the failure to ensure GE varieties would be adaptable to very varied climates and soils, and are therefore partly responsible for disastrous experiences of many early adopters of Bt cotton. The sufferings of Andhra Pradesh in particular can be blamed on little else than a complete failure of the regulatory mechanisms to protect farmers from foreign technology, the producers of which were the ones to assure its safety and economic advantages.

One reason for the political weaknesses and persistence of vested interests in the regulation of biotech is the lack of accountability. This is equally true in India as it is in the United States where the revolving door between the federal government and biotech industry appears to protect both. Sharma maintains that introducing one clause into the national biotech regulations to make the chairman of the GEAC personally accountable, with a jail sentence for example, for any health or environmental damage done by GE products would ensure that the entire regulatory process is overhauled (Sharma in Bhatt, 2009). An indication that necessary changes may be imminent in India was the government's rejection in February 2010 of the commercialization of Bt Brinjal, despite being approved by the GEAC in late 2009. Sharma (2010) calls environment minister Jairam Kamesh's decision to block the release of Bt Brinjal as the "triumph of good sense over bad science," and is possibly a turning point in India's attitude to GE crops, which has so far been overtly positive (James, 2007). The health concerns that prompted the rejection will hopefully lead to a stricter

regulatory mechanism for GE crops in India that places greater emphasis on health and environmental safety.

International regulations and the Cartagena Protocol

The limitations of national biotech regulations particularly in developing countries has led many to look to advanced economies as an example. Unfortunately, pursuing similar regulations to the US, which leaves much to be desired in regard to health and environmental safety, has left many developing countries exposed to the US's corporate zeal and covetous bio-piracy. The Cartagena Protocol, which came into effect in 2000, was an attempt to improve this situation in the wake of the WTO's failure to create a working group on biotechnology.¹⁸ The agreement endeavors to reconcile the respective needs of trade and the environment, and to address the limited international framework to deal with cross boundary aspects of the global biotech business. It also gave new impetus to many governments to develop national biosafety laws that would enable them to keep up with the rapid expansion of the agri-biotech sector. The agreement established international rules for trade in genetically modified organisms and reinforces the right of importing nations to reject GMOs on environmental and health grounds. Significantly, the protocol includes a liability framework to redress environmental damage caused by agri-biotech products, and allows the possibility of including socio-economic considerations in the biosafety regulatory approval processes (Newell & Glover, 2003; Falck-Zepeda, 2009).

The Cartagena protocol is neither a purely trade nor a purely environmental agreement, it is essentially a "decentralized risk assessment" that strengthens the nation-state as the primary source of environmental governance (Falkner, 2000:311). The agreement's main weaknesses are that it still fails to establish a global safety standard by which to judge the environmental impact of agri-biotech, nor does it protect developing countries from the laws of TRIPs. The protocol is certainly not perfect; as in most trade negotiations the dominant forces in Montreal were the industrialized countries, but due to the inclusion of the precautionary principle Cartagena is generally seen as a positive step for the environment. The agreement symbolized the important realization by developing countries of the need to safeguard their natural biodiversity as well as protect human health. There is still a need for considerable improvement in international regulations, with Newell & Glover (2003) calling

¹⁸ The Cartagena Protocol is also known as the Montreal Agreement.

for the construction of an entirely different set of controls for the development and release of genetically engineered crops and food products. Despite the Cartagena protocol, under current WTO rules the priorities and policy goals of its dominant members do not coincide with the food security and financial safety of the poor and therefore need to be entirely revised.

The regulatory mechanism of biotechnology, like the rest of the multilateral institutional framework, tends to favor industrialized nations over developing ones. Weaknesses in regulations have benefited the US in its dogged support of the spread of biotech crops and have prevented developing countries from being able to reject or sufficiently test incoming biotechnology. In spite of the lingering dangers associated with transgenic crops and foodstuffs it is Europe, which has steadfastly resisted the widespread acceptance of biotech crops, that has been the one to experience international consternation and almost constant pressure to relax its restrictions. For some reason the precautionary principle adopted by most countries in relation to GE products has been derided by the world's most powerful economy and the international institutions that are supposed to be protecting global development, trade and long-term environmental safety. The Cartagena Protocol is a step in the right direction, particularly through its address of the need to consider socio-economic factors when approving the 'safety' of biotech crops. Nevertheless, its continued failure to establish a global biosafety standard is a major flaw that should be redressed so that developing countries can be assured of the safety, reliability and economic viability of the technology they are heavily persuaded to adopt. Overall, there remain considerable concerns over the way commercial interests and scientific experts in the US, often from within the biotech corporate community, are able to influence regulations. There needs to be a more open and responsive regulatory process that can be trusted by consumers and developing country producers alike.

D: CONCLUSION

Chapter 9. Conclusion: Are biotech crops a viable development strategy?

Since the Second World War the world has been preoccupied with ‘development’ and how we can create the conditions in which ‘developing countries’ can achieve it. For the majority of countries of the South development means sustainable economic growth, the progression towards service based economies, higher standards of living (including less poverty, inequality and hunger), better healthcare, universal education, food security, and also economic self-determination and independence. The failure of sixty years of ‘development’ policies, based on the finest economic theories, newest technologies and support of a global multilateral framework complete with financial assistance, shows that it remains an elusive goal. The majority of the global population lives in countries that are still considered to be developing. It is subsequently an audacious move by the agricultural biotechnology community to suggest that genetically engineered crops can drive development and tackle some of the most complex economic, social and environmental problems of the developing world. The aim of this paper was to examine these claims to determine how far the adoption of GE crops is really a viable development strategy for developing countries. A thorough analysis of Bt cotton in India finds that whilst GE crops are technically proficient, the development claims lack substance.

Bt cotton is genetically engineered to be toxic to cotton bollworms, vehemently destructive pests that cost millions of poor farmers thousands of rupees from lost or damaged yields every year. That is the extent of the difference between Bt cotton and conventional cotton, yet theoretically this one change has the potential to bring considerable economic, social and environmental benefits to poor farmers, rural communities and hence the Indian economy as a whole. The problem with Bt cotton is not that the technology does not work; it is proven that planting Bt varieties can significantly reduce the incidence of bollworm infestation and therefore mitigate some of its negative consequences. The danger is that this one trait is being presented not just as a remedy for bollworms, but also as a technical solution to problems which involve much more complex social and economic dynamics. If poverty, hunger and the other tenets of underdevelopment were technical problems, they would have been solved a long time ago, not least by the Green Revolution.

Short-term economic viability

One of the overarching claims by proponents of genetically engineered crops has been that because they can increase production, they will bring economic growth. Through the analysis of Bt cotton in India, this paper finds that whilst GE crops can be an economic boon for a developing country, an incredibly complex interaction of variables is necessary for this to occur. India has the largest cotton growing area in the world but is also one of the least productive in terms of yield per hectare; therefore there is considerable potential for Bt technology to drive significant growth. Overall however, the commercialization of Bt cotton has had a positive but not revolutionary impact on the Indian economy. The agricultural sector has been experiencing relative decline in the face of strong manufacturing and service industries over the past few decades therefore rising raw cotton exports has been a clear benefit of the introduction of Bt varieties. Similarly, a revitalized textiles industry has greedily consumed increasing Bt induced cotton production, creating new jobs and stimulating the industry when events in international trade could have stalled it.

It is clear that economic gains have been realized in the two sectors where the production of cotton is a determining factor, but there is limited evidence to suggest that Bt cotton alone has been a direct cause of national economic growth. The recent performance of textiles is as much a consequence of well-placed and well-timed public investment as it is the increased availability of cotton. In agriculture, significantly improved yields have not been enough to reverse the sector's declining contribution to GDP, nor has increased production been able to create essential jobs in rural areas. Overall the experience of Bt cotton in India is a strong reminder that industrial growth and hence economic development are dependent on the right mix of policies not just the quality and quantity of natural resources. The positive impact on exports of either raw cotton or cotton textiles is not enough to assume that Bt cotton has been or will be a sustainable driver of national economic growth. We can even go as far as saying that the success of the textiles industry over the last eight years is a misleading advertisement of the potential of GE crops. No other agricultural commodity in India has anywhere near such strong or important ties to industry; consequently, the likelihood of a different GE crop playing such a significant economic role is negligible.

The overall economic viability of agricultural biotechnology must therefore be judged on the actual benefit GE crops provide for the farmers and communities that grow them, not just on the bottom line on the national economic balance sheet. Decades of underdevelopment in countries like India, China and Brazil have demonstrated that national economic growth does not necessitate 'development' for the majority of the population. This

is reinforced by the introduction of Bt cotton, which has improved the country's export earnings but not necessarily the livelihoods of the millions of farmers who grow it.

Medium-term socio-economic viability

For genetically engineered crops to be economically sustainable in the long-term, the rural population must realize economic and social gains directly. There are numerous studies that claim that agricultural biotechnology has brought dramatic yield and profit advantages to farmers, and has hence made a valuable and visible contribution to the amelioration of village life. The evidence from India, however, provides a much more circumspect vision of the socio-economic advantages of biotechnology for farmers and the rural poor. The vast majority of production, social, and economic indicators demonstrate that the impact of Bt cotton since its commercialization in India in 2002 has been variable at best. Whilst some farmers have gained, others definitely have not. Simply choosing to grow Bt seed provides absolutely no guarantee of yielding a bumper harvest, or of generating higher income. It is therefore unrealistic and unfair to farmers to claim that planting GE crops brings unmitigated advantages.

The success of cotton growing, like all farming, is the outcome of an incredibly complex interaction of variables including the skill of the farmer, his financial and physical resources, the quality of the soil, the benevolence of the climate and the infrastructural and market conditions in which a farmer can obtain credit, transport and store his produce and then sell it at a profit. The evidence of failed crops, escalating debts and frighteningly high suicide rates among the cotton-growing community strongly suggest that the performance of Bt cotton is not nearly as clear-cut or context independent as is suggested by the seed companies and the governments who promote its production. For the vast majority of farmers the promises of adopting Bt cotton have not materialized. The cost of cultivation remains high and seeds cost more than ever; yields are widely variable and profit margins are insufficient to service debts let alone improve a cotton household's overall economic situation. Improvements in local community services such as healthcare and education, which have been attributed to the introduction of Bt cotton, have proved to be the result of government intervention and strategic regional policies not burgeoning wealth from GE crops.

Bt cotton alone has not and will not improve the lot of the vast majority of impoverished farmers in India. Those wealthier farmers who cultivate rich, irrigate soils and who were already in the best position to take advantage of new technological developments have benefited most from Bt cotton and will likely continue to do so. The impoverished

millions who cultivate tiny plots of infertile soil without irrigation, without credit and without any form of social or market support will continue to struggle in spite of, and often because of new technology. Broad social and economic reforms are needed at both the national and global level to raise and stabilize cotton prices, ensure farmers are sufficiently knowledgeable to effectively implement new crops, and have an adequate support network to fall back on should yields fail. Small and resource poor farmers need significant government intervention, not new technology, to overhaul the socio-economic infrastructure that prevents them from improving their situation.

Overall development viability

The economic viability of Bt cotton for farmers is vital as it is linked to the overall development potential of GE crops in poor countries. Proponents of agri-biotech maintain that Bt cotton has made an important first step towards tackling poverty, generating greater equality and reducing hunger in India, and that other GE crops should be introduced to build on these foundations. It is suggested that the combination of multiple biotechnologies will combine to dramatically reduce rural poverty (James, 2007). Unfortunately, the experience of Bt cotton farmers suggests that rolling out Bt brinjal or transgenic Golden Rice will have neither an immediate nor a dramatic effect on national poverty and its associated plights if social and infrastructural reforms are not made beforehand.

Even if Bt cotton has improved the lives of some farmers, no matter how successful it is at a local level, at the end of the day the marginal profit advantages Bt cotton may confer on its 5 million producers is meager progress in the grand scale of Indian underdevelopment. It will not do to underestimate any success the technology may have had, but nor is it right to exaggerate its potential. As Sharma (2004b) succinctly argues, if poverty and hunger were a question of technology, then the Green Revolution would have resolved them long ago. Sadly for India, since the turn of the century poverty, inequality and malnutrition have all increased rather than diminished. To blame Bt cotton is unfair and unrealistic because these are complex social problems; however by this rule it should be equally unfair and unrealistic to tout GE crops as solutions to these problems. Biotechnology itself cannot tackle these immensely complex social problems. Contrary to the assertions of GE proponents, development is not simply a matter of bigger yields or higher profits. There is no quick fix to poverty, inequality or hunger; they are phenomenon that have always existed and continue to thrive in even the richest of economies today. Development will only occur with substantial political will and investment to overcome the underlying causes with relevant

economic and social reforms. From the experience of Bt cotton in India it is pertinent to conclude that GE crops cannot tackle the true causes of underdevelopment; hence, they should not be promoted as being able to do so.

Long-term environmental viability

The most important consideration in the decision to adopt GE crops must be their long-term effect on the environment. Whatever the impact on more immediate economic and social concerns, if crops cannot grow in the future because novel genetic developments have undermined the critical balance of the natural environment then these shorter term issues will be irrelevant. Since the commercialization of Bt cotton in India in 2002, considerable scientific evidence has been promulgated to suggest that new insect resistant biotech varieties are actually better for the environment than traditional cotton which relies heavily on chemical pesticides. The success of Bt cotton in facilitating the reduction in pesticide applications has been well publicized by the biotech companies and advocates of GE crops, however benefits are not as explicit as is suggested by the data or the public relations.

Bt cotton is not a panacea for the pest control problems of cotton cultivation. It is effective at tackling only a handful of the 160 pests that attack cotton, and its achievements are already threatened by the development of resistance among bollworms and proliferation of secondary pests. Cotton is still a very energy intensive, water inefficient and relatively dirty crop even with Bt varieties. There is no evidence to suggest that fertilizer applications have decreased since the adoption of Bt cotton, and therefore whilst the energy use inherent in the fabrication of chemical inputs can be diminished with pesticide reductions, it will not be halted by the proliferation of Bt. There will always remain a plethora of insect pests that need to be treated chemically unless the biotech companies can produce varieties that are stacked with enough genes to counter all pests, or a natural alternative to chemical inputs is found.

As with the economic and social elements of GE crops, biotechnology is only a viable solution to the environmental problems of agriculture if it is combined with the right policies, regulations and support. The failures of Bt cotton in some areas are the failures of the biotech companies, regulatory authorities and governments that allow new technology to be adopted without ensuring that farmers have the adequate knowledge to use it without harming themselves or the environment. At this stage most ecological threats appear to be negligible, but that does not mean that they are non-existent.

The danger of introducing novel genes into the natural environment is that we do not know how they will react, adapt and mutate once they are released. Seemingly small risks

to non-target insects such as bees could be disastrous if they escalate, not just for cotton but for hundreds of other plants and crops who rely on them as pollinators. Bt cotton may do considerably less damage to the environment than traditional methods, but that does not mean we should be blinded by the technology's effect on pesticide use and ignore more 'minor' concerns. The seemingly small dangers posed by chemical pesticides one hundred years ago are cruel realities today. Ignoring those early concerns has created a situation whereby today we have removed nearly three quarters of agricultural genetic resources. We should not be so short-sighted with genetically engineered crops whose future consequences may be even more debilitating. The future of food production is dependent on the health and safety of the natural world; with so much at stake, the attitude towards GE crops should be precautionary in the extreme. At this stage agricultural biotech cannot be said to be environmentally viable precisely because we do not and cannot know exactly what the long-term consequences of genetic manipulation in nature will be.

The political economy of agri-biotech

Agricultural biotech is wrapped up in an international political economy that is governed by and for the world's most advanced economies. As a result the final judgment on the viability of genetically engineered crops for developing countries does not just depend on their economic, social and environmental impacts in the field. The fact that the agricultural biotech industry is effectively a monopoly is critical to understanding the true nature of GE crops and the role they can play in development. Despite the pro-poor rhetoric emanating from the seed companies, massive profits lie at the heart of the desire to spread biotech crops. To compound matters, this hegemonic power is supported and exacerbated by international trade rules and multilateral institutions that are supposed to be fostering development.

Whatever the claims and intentions of the biotech companies, GE crops that remain dominated and governed by the direction, decisions and profit margins of a handful of American and Western European multinationals is neither safe for the future of international agriculture nor economically viable for developing countries. Farmers that have to rely on the whims of foreign seed producers to govern what, how and for whom they produce is a threat to national development and self-determination as well as a long-term risk for global food security.

The international community and developing countries in particular need to improve regulations for biotechnology and review how it is incorporated into the global trade system. A stronger and more comprehensive regulatory system is essential so that everyone

from seed suppliers, national economies and producers small and large can benefit from technological developments in agriculture. IPRs and TRIPs need to be reviewed so that innovation and development are protected and encouraged, but not at the expense of poverty and hunger. At present, the current system means the biotech monopoly does not just thrive but is self-perpetuating. It is a manifestation that pushes national governments and poor farmers into a dependency on the biotech companies, which influences their policies as much as their agricultural inputs. It has facilitated the unforeseen rise of bio-piracy and subsidence of national public institutions and research. Consequently developing countries stand to become increasingly reliant on, and indebted to, the biotech companies and the United States, which controls their agriculture and increasingly the rights to their own biodiversity.

The future of agriculture, food and the environment must be considered at risk unless these can be guaranteed by an independent, international, trustworthy and powerful regulatory and disciplinary body to oversee the development, assessment, approval and adoption of agri-biotech. The Cartagena protocol and failure to come to an agreement during the Doha round of trade negotiations does show that developing economies are finally starting to fight for a better deal in the WTO. However, GE crops will never be economically viable for developing countries if they continue to be controlled by a handful of companies in the industrialized world; in fact the proliferation of biotechnology is a dangerous and counter-development predicament.

Conclusion

By overlooking the rhetoric and promises of the agricultural biotechnology companies to focus on the tangible and measurable effects of Bt cotton on the national economy, the social and economic situation of farmers, and the environment, this paper concludes that genetically engineered crops are not a viable development strategy for developing countries. There are inherent dangers in using the experience of one country with one GE crop to formulate an overarching decision on the viability of agricultural biotechnology. However, the strength of the evidence in India against adopting biotech is extremely convincing. The experience of the Green Revolution has already clearly shown that increased production is not a sufficient foundation on which to generate national economic growth. Nevertheless it appears that the Gene Revolution is repeating and exacerbating the same mistakes all over again.

Development will not be determined by the introduction of a novel technology; genetically engineered crops are being proposed as a quick fix to very complex social and

economic issues that will require considerable political will to overcome. It will necessitate heavy investment nationally, and substantial economic clout and political determination internationally to level the global economic playing field. Developing countries do not operate on the same economic or political plane as industrialized countries; a major cause for concern regarding the development viability of GE crops is because developing countries have had such a limited role in both their development and proliferation.

Perhaps the strongest argument against genetically engineered crops, which ironically is not found in any analysis of the biotech varieties themselves, is the fact that they are not the only answer. Bt cotton for example, was introduced to tackle pest problems, and it has been proven that this can be done better and with potentially greater benefits by other means. Organic, biodynamic, agro-ecological, and indigenous knowledge systems are all economically viable alternatives to GE crops (Pesticide Action Network, WG4, 2007). Integrated Pest Management (IPM) has been heavily promoted in India over the last few years and has been found to be relatively successful. Introducing large areas to pest monitoring schemes, releasing bio-control agents, promoting biological fertilizers and providing trainings and demonstrations for farmers are all contributing to more sustainable farming practices including the reduction of pesticide applications (Karihaloo & Kumar, 2009). The system is very knowledge intensive as it needs to be specifically regulated for each area and has therefore faced some criticism (Martins et al, 2008). Its success depends on farmers better understanding their crops and consistently monitoring development to decide when to spray pesticides so as to limit not just the damage done by the pest but also the damage done by the chemicals. Nevertheless, whilst it may be knowledge intensive there is no doubt that IPM is a much more sustainable practice than planting GE crops, and therefore investment in the education and training it requires is wholly worthwhile.

Without doubt the best solution to pesticide damage and the most environmentally sustainable method of agriculture is the use of organic farming or non-pesticide management. It has also proved to be very successful. A study by the centre for sustainable agriculture in Andhra Pradesh found that organic cotton, grown without the use of chemical pesticides, had lower incidences of bollworms than Bt varieties (CSA, 2004). As with IPM, it is a relatively knowledge intensive practice that emphasizes pest management through prevention rather than cure. However, using these methods farmers have consistently reported a lower incidence of sucking pests and higher incidence of beneficial insects than have Bt cotton cultivators. Gala (2005b) argues that the reason non-pesticide management is not promoted is because it does not lend itself to corporate exploitation. Whereas the biotech industry is a multi-billion

dollar sector that relies on selling millions of tonnes of seed and chemical inputs, organic agriculture does not generate much income other than for farmers. Consequently there is little investment in research into organic methods particularly in the private sector, and hence the huge advantages of organic farming are ignored or perceived as unfeasible, when in fact it is the benefits of genetic engineering that are limited and the costs debilitating.

The arguments that organic or integrated pest management practices are too knowledge intensive to be viable is inaccurate and shortsighted. Agriculture *should* be a knowledge intensive practice; it is the responsibility of governments and regulatory authorities to ensure that farmers know how to grow crops that will help feed the global population but will not harm either the farmer or the environment in the process. It is true that some elements of genetically engineered crops have the potential to improve agricultural practices, but they also have the potential to severely harm the environment. If biodiversity is lost or ecosystems on which agricultural systems are dependent are inadvertently, but irreparably damaged, the consequences for global food production could be catastrophic. There needs to be better economic and institutional frameworks in which alternatives can flourish, not one dominated by multinational corporations whose promotion of biotechnology is arguably determined by profit margins rather than altruism.

Agriculture should not be something that relies on the simple acceptance of provisions from the biotech corporate machine, and blindly accepts their assertions that its seeds and inputs are benign. It is the responsibility of governments and of farmers to ensure that the crops they grow do not sacrifice the future of food production with short-term gains. From a long-term economic, social and environmental point of view, genetically engineered crops are not a dependable or viable development policy; a resolution which is strengthened with the knowledge that there are genuinely safe, socially beneficial, environmentally friendly and economically viable alternatives that are readily available.

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APPENDICES

Appendix A

India Map of principal cotton growing states



Appendix B

All- India Area, Production, Yield & Irrigation of Cotton 1950-51 to 2008-09

Year	Area (million hectares)	Production (million bales of 170 Kgs)	Yield (Kg/ Hectare)	Irrigation (% coverage)
1950-51	5.88	3.04	88	8.2
1960-61	7.61	5.60	125	12.7
1970-71	7.61	4.76	106	17.3
1980-81	7.82	7.01	152	27.3
1981-82	8.06	7.88	166	27.7
1982-83	7.87	7.53	163	29.0
1983-84	7.72	6.39	141	29.9
1984-85	7.38	8.51	196	28.5
1985-86	7.53	8.73	197	30.2
1986-87	6.95	6.91	169	31.1
1987-88	6.46	6.38	168	32.0
1988-89	7.34	8.74	202	33.0
1989-90	7.69	11.42	252	34.2
1990-91	7.44	9.84	225	32.9
1991-92	7.66	9.71	216	33.3
1992-93	7.54	11.40	257	34.6
1993-94	7.32	10.74	249	34.7
1994-95	7.87	11.89	257	34.2
1995-96	9.04	12.86	242	35.0
1996-97	9.12	14.23	265	35.8
1997-98	8.87	10.85	208	36.8
1998-99	8.78	11.53	225	34.9
1999-00	8.71	11.53	225	35.2
2000-01	8.53	9.52	190	34.3
2001-02	9.13	9.52	190	34.0
2002-03	7.76	8.62	191	33.1
2003-04	7.60	13.73	307	27.1
2004-05	8.79	16.43	318	36.9
2005-06	8.68	18.50	362	36.1
2006-07	9.14	22.63	421	35.0
2007-08	9.41	25.88	467	NA
2008-09	9.41	23.16	419	NA

Source: Directorate of Economics & Statistics, Ministry of Agriculture. Statistics at a Glance, 2009

Compilation of studies from ten publications on benefits of Bt over non-Bt cotton in India for the years 2001-2007

Publication	Centre for Sustainable Agriculture (CSA) (2005)									
	Qaim (2003)	RFSTE (2003)	ANGRAU (2003)	Barwale, Gadwal, Zeir & Zehr (Mahyco) (2004)	Morse, Bennet & Ismael (2005)	Qayum & Sakkhari (2005)	Bennet, Ismael & Morse (2005)	Qaim, Subramanian Naik & Zilberman (2006)	Morse, Bennet & Ismael (2007a)	Sadashivappa & Qaim (2009)
Subject	395 locations (Field Trial)	AP & Maharashtra	4 districts in AP	1090 farmers in 6 states	1275 villages, Maharashtra	3 districts in Anhara Pradesh	622 farmers in Gujarat	341 farmers in 4 states	Maharashtra	341-407 farmers in Maharashtra, Andhra Pradesh, Karnataka & Tamil Nadu
Year of study	2001	2002-03	2002-03	2002-03	2002-03	2002-03	2003-04*	2002-03	2002-03	2002-03
Bt	608	200	437	864	850	450	779	659	767	659
Non-Bt	337	1,000	684	536	611	690	606	491	415	491
Gain with Bt	271	-800	-247	328	239	-240	173	168	352	168
% gain with Bt	80%	-80%	-36%	61%	39%	-35%	29%	34%	85%	34%
Avg. Yield (Kg/acre)	11,872	3,300	8,807	-	17,380	9,360	18,579	13,735	17,259	13,735
Avg. Yield Value/Gross Revenue (Rs./acre)	6,573	16,500	15,063	-	12,578	14,931	13,756	10,357	8,576	10,357
% gain	81%	-80%	-42%	-	38%	-37%	35%	33%	101%	33%
Bt	4.19	-	3.10	3.68	3.01	-	-	4.18	-	4.18
Non-Bt	7.19	-	8.10	5.39	5.31	-	-	6.79	-	6.79
Gain with Bt	-3.00	-	-5.00	-1.71	-2.30	-	-	-2.61	-	-2.61
% gain	-42%	-	-62%	-32%	-43%	-	-	-38%	-	-38%
Bt	889	-	-	821	707	3,186	2,464	1,258	487	1,258
Non-Bt	1,497	-	-	1,587	1,624	3,410	3,723	2,128	517	2,128
Gain with Bt	-608	-	-	-766	-916	-224	-1,259	-870	-30	-870
% gain with Bt	-41%	-	-	-48%	-56%	-7%	-34%	-41%	-6%	-41%
Bt	1,497	-	-	1,528	1,491	1,600	2,424	1,573	1,423	1,573
Non-Bt	387	-	-	461	470	450	535	490	417	490
Gain with Bt	1,110	-	-	1,067	1,021	1,150	1,889	1,083	1,006	1,083
% gain with Bt	287%	-	-	232%	217%	256%	353%	221%	241%	221%
Bt	6,542	9,700	7,818	-	-	10,655	10,988	8,441	4,736	8,441
Non-Bt	5,560	5,750	7,312	-	-	9,653	10,007	7,224	3,622	7,224
Gain with Bt	982	3,950	506	-	-	1,002	981	1,217	1,114	1,217
% gain with Bt	18%	69%	7%	-	-	10%	10%	17%	33%	17%
Bt	5,330	-6,400	973	7,337	14,927	-1,295	7,650	5,294	12,523	5,294
Non-Bt	1,013	10,750	7,600	-	10,412	5,368	8,401	3,133	4,954	3,133
Gain with Bt	4,317	-17,150	-6,627	-	4,514	-6,663	-751	2,161	7,569	2,161
% gain with Bt	426%	-160%	-87%	-	43%	-124%	-9%	69%	153%	69%

Source: Compiled by author, 2010

All data has been normalised in acres not hectares therefore data may appear different to original source. (1 acre= 0.405 hectares)

* Study performed on F1 & F2-2nd generation or fake seeds.

RFSTE: Research Foundation for Science, Technology and Ecology

ANGRAU: The Acharya N G Ranga Agriculture University