THE GREEN REVOLUTION

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Foreword

This chapter started life as lecture notes and graphical displays prepared by Douglas H. Norrie (with data up to 1975) for his class "Technology in Contemporary Society." In 1984 Fitzgerald-Moore amplified the notes and started an annual revision of the data. In 1996, the notes and graphs were turned over to Brian Parai to form the basis of a term paper under Fitzgerald-Moore's supervision. Parai's paper has been extensively quarried during the revision of this chapter in the series "Lectures on Technology". We wish to thank the following who provided additional input : Parampreet Singh Sekhon; Ravi Bhalla ; and Zaheer Baber.

Research is still in progress; many reference materials are not locally available; the paper must therefore be treated as an incomplete first draft. Readers' comments would be welcomed.

Introduction

The Green Revolution was the technological response to a world-wide food shortage which became threatening in the period after WWII. The Green Revolution transformed farming practice in many regions of the tropics and sub-tropics where the principal food crops were rice, wheat and maize, but the brief account that follows will be mainly focused on the Indian sub-continent. The ambivalence which is characteristic of all technology is expressed in this example by undesired ecological consequences, which are well documented, and by socio-economic consequences about which there is much less agreement.

From the time of independence in 1947 until 1965, agricultural production in India was unable to meet the country's needs. Severe droughts in the mid-1960s threatened famine which was averted only by substantial shipments of food grains from the United States.[1] "By the late 1960s, however, it had begun to look as if salvation was at hand." according to a popular account by Reay Tannahill[2] of the experimental work for which Norman Borlaug was awarded a Nobel peace prize in 1970. Tannahill continues:

> "Twenty years earlier the Rockefeller Foundation, in cooperation with the Mexican Government, had embarked on a wheat development programme that, in the intervening period, had increased Mexico's per-acre wheat yields by 250 percent. One of the great barriers to increased grain production in hot countries is that when traditional plants are heavily fertilized, they shoot up to an unnatural height and then collapse. If they are grown closely enough together to prevent this, one plant shades the other and the yield is reduced. During the Mexican experiments, however, and after tests involving 40,000 crossbreeds of plant, it was found that if a short stemmed grain were thickly sown at the right depth and adequately irrigated, it could take massive doses of fertilizer without becoming lanky and give spectacularly high yields.
>
> In 1962 the International Rice Research Institute was set up in the Philippines to find a rice as miraculous as the Pitic 62 and Penjamo 62 wheats, rice being at that time the main item of diet for six out of every ten people in the world."

Early trials of short-stemmed rice produced strains susceptible to the stem borer but eventually strains were produced with inbred resistance to some of the worst pests. The introduction of these new high yielding varieties (HYVs) of wheat, rice and maize became known as the Green Revolution.[3] The area of its most successful application has been mainly in the tropical wetlands of "less developed" or "newly industrializing" countries such as India,

Pakistan, Bangladesh, Indonesia and China.

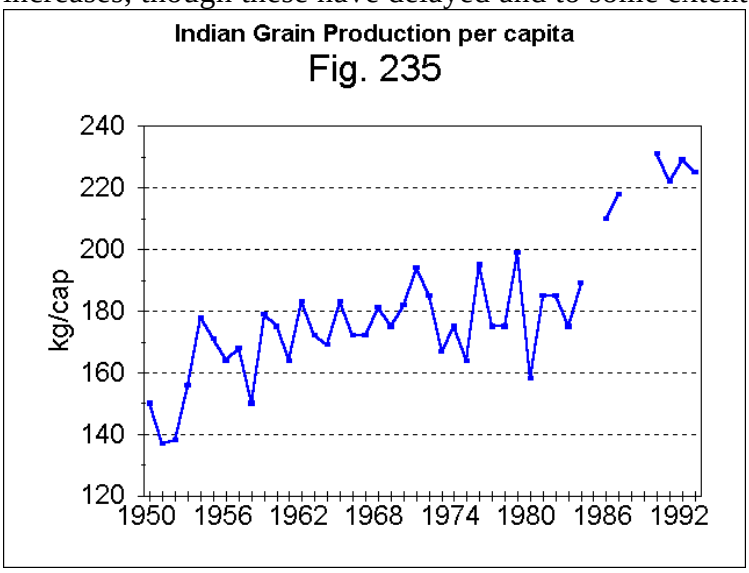
HYVs were not the product of genetic engineering: they were the result of traditional plant breeding methods, in which hybrids are produced by cross pollinating unrelated parents. Where they were properly introduced, HYVs resulted in increased crop production and reduced dependency on food imports

Production Increase

Due to their ability to respond with higher yields to increasing application of fertilizer and, in part, to their ability to produce two, sometimes even three, crops a year, HYV seeds have brought real and substantial increases in production. Production of rice and wheat in developing countries increased 75% between 1965 and 1980, with only a 20% increase in the area planted to these crops.[4] In Indonesia, rice yield in 1960 was 1.3 tonnes per hectare (t/ha). By 1994 it had risen to 4.3 t/ha. In India, production more than doubled between 1960 and 1993. During this period, total annual grain production rose from 77 Mt to 201.5 Mt[5] (Fig. 233).

The introduction of HYVs spread rapidly. By the mid-1980s, approximately 50% of the wheat and nearly 60% of the rice area of developing countries were sown to HYV strains: in 1983, China sowed 95% of its rice area and Latin America sowed 82% of its wheat area to high yielding varieties.[6] In India, with less than 100 ha of land sown to HYVs in 1965, over 50 million hectares had been converted by 1980; in Punjab the proportion of wheat and rice under HYVs was, respectively, 96% and 95% in 1978-79.[7] Presently, the HYV IR36 rice plant, developed by the International Rice Research Institute (IRRI), is planted on about 11 million hectares worldwide, making it the most widely grown variety of any crop.[8]

It is clear that the benefits of HYV seeds are significant. As intended, these seeds have decreased the reliance of developing countries on food grain imports, in spite of population increases, though these have delayed and to some extent neutralized the benefits (Fig. 235).



These 'miracle seeds' have probably averted famines and the starvation of millions of human beings. As Michael Lipton wrote in 1985:

> "If the farmers of the third world today used the same cereal varieties as in 1963-64, and everything else remained unchanged, then tens of millions of people would this year die of hunger.[9]

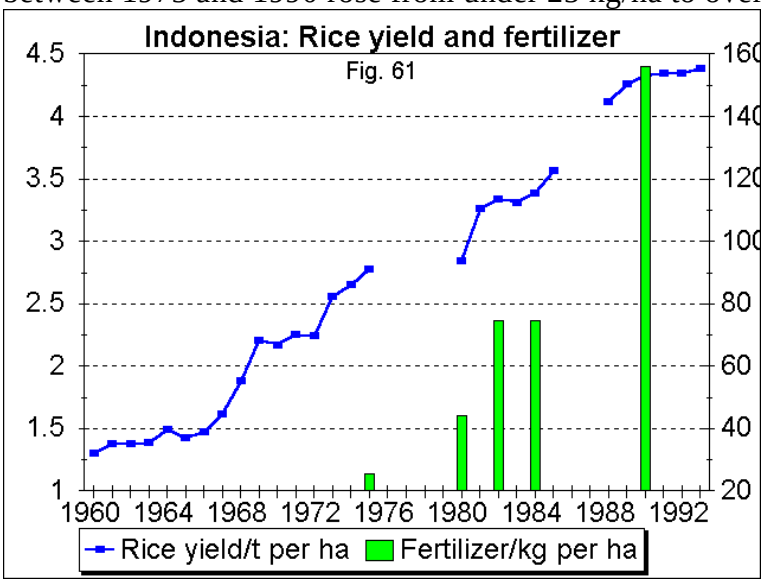
(This is a big "if" since the population explosion on which the disaster scenario was based may itself have been aggravated by the Green Revolution.)

The 'Package' of Inputs

HYVs are bred to respond to the added application of large quantities of nitrogenous fertilizer and water, without which they "perform worse than the indigenous varieties."[10] Thus the proper cultivation of HYV seeds requires a 'package' of inputs which includes not only chemical fertilizers and irrigation, but also biochemical programs to control for disease, insects and weeds, and increased mechanization.[11] For this reason, it has been suggested that it may be appropriate to replace the term 'High-Yielding Varieties' (HYVs) with 'Highly-Responsive Varieties' (HRVs).[12] An examination of the components of the package explains why the label HRV was suggested.

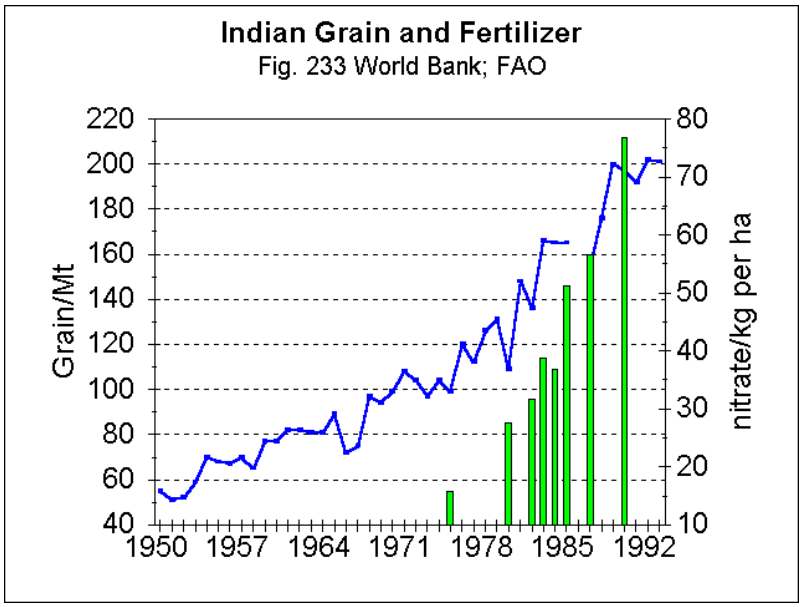
Chemical Fertilizer

Indonesia and India both provide examples of the increasing use of artificial fertilizers associated with HYV seeds. In Indonesia, the application of fertilizer in rice production between 1975 and 1990 rose from under 25 kg/ha to over 150 kg/ha.



Likewise, in India, average levels of fertilizer application in grain production rose from approximately 15 kg/ha to over 75 kg/ha between 1975 and 1990.[13] While HYV seeds are bred to use three or four times as much chemical fertilizers as traditional varieties, the amounts of fertilizer being applied are locally much greater.[14]

Figure 61 shows a more or less linear response of rice yield in to fertilizer in Indonesia. In India (Fig.233), aggregate grain production data suggest a mildly exponential response to nitrate fertilizer application. Note that in each case the steepness of the curves is purely a function of the plotting scale.



It appears that the aggregate levels of application are still too low for signs of diminishing returns to appear. This does not necessarily contradict the conclusion reached by Ninan and Chandrashekar[15] that "Indian agriculture has reached that phase where diminishing returns are in operation." because many other factors besides fertilizer enter into the production equation. In China, food production increased by over 50% between the mid-1970s and 1985 and this is largely attributed to equally significant increases of fertilizer application, which reached US. levels of 115 kg/ha by 1983.[16]

Water

In traditional farming, irrigation was used as a protective measure. In Green Revolution HYV farming it is a necessity. HYVs require greater concentrations of water for longer periods of the year than do traditional crops, moreover, where HYVs have been introduced they have often replaced crops such as millets and oilseeds which require little water. Between 1950-51 and 1965-66, 4.5 million new hectares came under irrigation worldwide. Between 1965-66 and 1979-80, 9 million new hectares were provided with irrigation.[17] .

The two sources of irrigated agricultural water, in India, are tube wells and canals. Tube wells require electrical pumps to pull the water out of underground aquifers. Canals are supplied by dammed reservoirs. Therefore the Green Revolution has necessitated an increase in the construction of tube wells, dams, and canals. By the end of the 1980s, tube wells and irrigation canals in India supplied roughly 20% of the world's irrigated land. By 1989, over 33% of the agricultural land in India was irrigated.[18] Specifically, the net irrigated area in 1950s was 21 million hectares. By 1980 it had grown to 39 million hectares. The expansion of the irrigated area, intended to allow greater exploitation of the yield potential of the new varieties[19], was made possible by government constructed dams and by tube wells drilled by individual farmers.

Pesticides

With the increased production of cash-crops in India, pesticide use has substantially increased. In the mid-1950s about 2 000 t of pesticides were used annually: by the mid-1980s more than 80 000 t. Just 80 000 ha of India's cropland received treatment with chemical pesticides in 1960, compared to today's 6 million hectares.[20] Because Green Revolution farming is characteristically based on genetically uniform monocultures, dependency on pesticides is high. Traditional varieties, over time, build up a resistance to locally occurring pests and diseases. When diseases do occur, varied strains will ensure that not all plants will

be victimized. However, this is not the case with genetically uniform HYVs. Likewise, traditional farming practices include crop rotation which prevents infestations from getting firmly established. This built in protection of diverse crops is not found in HYV farming

Additional Inputs

Farmers with extra profits often invest in new farming machinery, which intensifies the Green Revolution's commercial approach to agriculture. This includes the use of tractors, mechanical threshers and electric pumps. Tractors in Punjab, for example, increased from 1,392 in 1960 to over 260,000 some thirty years later.[21] With the introduction of such equipment, new needs are created - for fuels, electricity, and maintenance.

The components of the HYV 'package' are novel to traditional farmers and most of them have insufficient cash to purchase them. Thus, support systems which provide monetary loans are created, providing farmers with the means to purchase the new seeds, fertilizers, water credits for canal use and power for pumps used in tube wells. Marketing systems are also created to allow former subsistence farmers to sell their crops, often in order to service their loans and to provide them with an outlet through which they can purchase fertilizers or equipment. Thus there is a transformation from subsistence to commercial agriculture

Ecological Impacts

Amongst the ecological insults inflicted by the green revolution, the following have been identified: deteriorating soil quality; the overuse of water, poisoning from biocides and decreasing genetic diversity.

Soil

The Green Revolution, like all commercialized agriculture, tends to reduce the natural fertility of the soil. Because HYVs grow and mature faster, a second or third crop can be grown each year. However, the lack of fallows or winter crops such as sorghum, as well as continuous flooding or constant water cover, depletes the soil's micronutrient content. Chemical (i.e., commercial) fertilizers are used in ever increasing amounts, as there are no natural means of replacing soil fertility. Chemical fertilizers do not usually replace necessary trace elements in the soil. Moreover, the use of dwarf varieties leads to a reduction of the straw that is available to recycle organic matter into the soil. As HYVs are engineered to grow more efficiently, a larger portion of the plant becomes grain and less is subsequently available for fertilizer or animal feed.[22]

The Green Revolution also contributes to the salinization of the agricultural soil. Both salinization and water logging occur when agricultural land is over irrigated. As second or third crops are planted each year, rice growing land is inundated with water for longer portions of the year. This situation is made worse by badly maintained irrigation canals. The problem is that, without adequate drainage, water tables may be raised to the root zone, starving the plants of oxygen and inhibiting their growth. Surface evaporation leads to the deposition of salt which, according to Postel, "reduces crop yields and eventually, if the buildup becomes excessive, kills the crops." Postel estimates that salinity reduces yields on 20 million hectares in India, and that salinization has caused an additional 7 million to be abandoned.[23]

An increased use of chemical herbicides and pesticides has also reduced the soil's resistance to disease. By reducing naturally occurring organisms, chemical inputs allow disease to build up in the soils. Intensive, commercial agriculture contributes to additional

soil problems in India, as well as throughout the world. These soil problems include soil erosion resulting from irrigation on sloped land, reduced soil nutrient content, and over compaction of soil from the use of heavy machinery. A study, commissioned by the Society for Promotion of Wastelands Development in the 1980s, found that 39% of India's 329 million total hectares were degraded.[24]

The situation was very different earlier in the century, before the Green Revolution. Reviewing Northern India's soils, Alfred Howard said:

> "...field records of ten centuries prove that the land produces fair crops year after year without falling in fertility. A perfect balance has been reached between the manurial requirements of the crops harvested and the natural processes which recuperate fertility."[25]

In his presidential address to the Agriculture Section of the Indian Science Congress, G. Clarke stated that:

> "When we examine the facts, we must put the Northern Indian cultivator down as the most economical farmer in the world as far as the utilization of the potent element of fertility, nitrogen, goes. He does more with a little nitrogen than any farmer I ever heard of. We need not concern ourselves with soil deterioration in these provinces. The present standard of fertility can be maintained indefinitely."[26]

Water

The Green Revolution has also resulted in both the depletion and pollution of water. The heavy water use required by HYVs called for increased irrigation but in many areas this has led to water being overused. Tube wells used to irrigate HYV crops have led to draw down problems on the water table. As annual draft exceeds hydrological recharge rates, what S. Singh refers to as "Dark Zones," are created. These "deeper water tables" are evidenced in Punjab and Tamil Nadu. In Punjab, groundwater balance is negative in six out of twelve regions., and in at least three of these districts, the annual draft is more the double the annual recharge.[27] In Tamil Nadu, during the seventies, water tables in some areas fell 25-30 metres.[28]

> Parampreet Singh Sekhon, the son of a farmer from the Amritsar district, writes [29]
> "Due to the heavy water demand of some of the crops, such as rice, the fields are flooded in the months of July, August. The main form of irrigation is through tube wells, which draw water from the earth's water table. 20 years ago, one had to bore the land about 30 feet to reach the water table. Today, in the same places water has receded below 120 feet. P.S. All the above experiences are from the town of Patti, District Amritsar, Punjab, India.

As underground aquifers are further depleted by tube wells, submersible pumps are replacing centrifugal pumps, which are effective only to a certain depth. The move to submersible pumps has been made by more prosperous farmers who generally have large operational land holdings. The use of this method can draw the water table down to even greater depths. As a result, all farmers in an area may be forced to upgrade their pumps or

abandon tube well irrigation. Yet, if all farmers switch to submersible pumps, which are much more energy intensive than centrifugal pumps, the groundwater exploitation rate will be intensified. In Punjab, the groundwater balance is precarious in three-fourths of the total area. Water overdraft for irrigation threatens the sustainability of the irrigation system itself. As S. Singh concludes on the topic: "while assured irrigation facilitated the adoption of HYV technology...the HYV technology is gradually endangering the reliability and flexibility of the irrigation system of the state."[30]

Amongst other effects of the water demands made by HYV seeds are problems associated with the construction and use of dams (see chapter on Dams). They have a great effect on human life as new dams often require the displacement of large numbers of people. Ecologically, the effect of dams and canals is also a concern. Used to increase irrigation to improve agricultural yields, their effect may actually be disadvantageous to agriculture. For dams and canals greatly change the natural occurrence of water, leading to a possible impact upon climate, rainfall and monsoon patterns.

The use of short-stemmed varieties had another unexpected consequence in Bangladesh where they exhibited greater likelihood of flood damage in low-lying areas.

Biocides

Pesticides and herbicides are designed to kill pests and weeds that threaten crops. However, these biocides are a health hazard to the farmers who work with them, and also to the general population as a result of residues in food crops and contamination of drinking water. Many of the biocides exported to third world countries are considered too toxic for use in their countries of origin. Restricted or prohibited by industrial countries, DDT and benzene hexachloride (BHC) account for about three-quarters of the total pesticide use in India.[31]

In many less developed countries, without enforced regulation or proper understanding of the dangers, workers engaged in spraying seldom use even elementary protective devices. In a report entitled "Tropical Farmers at Risk from Pesticides," the IRRI (International Rice Research Institute) showed that 55% of farmers in the Philippines who worked with pesticides suffered abnormalities in eyes, 54% in cardiovascular systems and 41% in lungs.[32] Of the estimated 400,000 to 2 million pesticide poisonings that occur in the world each year, resulting in between 10,000 and 40,000 deaths, most are among farmers in developing countries.[33] In Bhopal, India, tens of thousands of people were poisoned by an accident at a Union Carbide pesticide manufacturing plant. This leak of toxic gas caused 2,000 deaths. This catastrophe is more dreadful to the public mind than the much larger chronic effects. (See chapter on Accidents]

These toxins also make their way into people through their food. The World Health Organization (WHO) has set tolerance limits of pesticide residues in food. In India, a study of food, including cereals, eggs and vegetables, found that 30% of the sample exceeded tolerable levels. Residues of DDT and BHC were both found in all 75 samples of breast milk collected from women in Punjab. However, these suspected carcinogens have not been directly related to an increase in diseases or deaths.

Again we quote the direct experience of Parampreet Singh Sekhon:

> Our daily cereal crops are heavily pesticide infested. We are slowly poisoning ourselves to death. People are aware of it but lack the will to curb pesticide use. I can cite the case of cow fodder. Cow fodder is also sprayed with pesticides, sometimes.

> Their milk is then used to make "ghee", after warming the butter. "Ghee" is used as we use cooking oil here in Canada. It is not unusual to see fertilizer grains crystallizing at the top when butter is being processed to form "ghee".

The risk caused by chronic, low level exposures to farm chemicals is intensified when they are present in runoffs, where they pollute both surface and groundwater. Contaminated drinking water is thus added to the list of biocide concerns.[34]

Sandra Postel suggests that, instead of quick-fix pesticide spraying "to maximize yield from a monoculture cropping system, farmers (should) consider whether crop rotation, intercropping, or a biological control agent might allow them to sustain profits while protecting groundwater form contamination."[35]

Genetic Diversity

Green Revolution farming can be characterized by its genetically uniform monocultures. The Food and Agriculture Organization of the United Nations has warned of a large scale loss of plant genetic diversity and the erosion of biodiversity. "The spread of modern commercial agriculture and the introduction of new varieties of crops are the main causes of the loss of genetic diversity."[36] On one level, genetic diversity is reduced when monocultures of rice and wheat replace mixtures and rotation of diverse crops such as wheat, maize, millets, pulses, and oil seeds. On a second level, genetic diversity is reduced because the HYV varieties of rice and wheat come from a narrow genetic base. Introduced as the sole crop on many farms in a region, these genetically narrow seeds replace the diversity of native systems. "A single genetic strain of wheat -*Sonalike*- was grown on 67% of wheat fields in Bangladesh in 1983 and 30% of Indian wheat foelds in 1984."[37] Shiva writes: "the destruction of diversity and the creation of uniformity simultaneously involves the destruction of stability and the creation of vulnerability."[38]

When single cultivars, such as the IR36 rice plant mentioned earlier, cover large numbers of fields, infestation can spread like wildfire. HYVs are bred to resist insects, diseases and environmental stresses. Chemical herbicides and pesticides, nonetheless, are deemed to be necessary precautions. The traditional strains that have co-evolved with the local ecosystems, are replaced by externally produced seeds. These new seeds are more prone to local pests and diseases.[39] As such, they need to be replaced, often within five years, but sometimes as often as every year or two. In contrast, traditional seeds are more durable as they build and maintain their resistances through gradual evolution.[40]

As the genetic background of HYV crops is narrow, their ability to resist disease and pests has declined relative to the ability of diseases and pests to overcome the resistant traits that have been bred into the seeds.

The whole ecosystem is, of course, affected. An interesting indicator is provided by the peacock which used to be abundant in some parts Again we call on our eye-witness[41]

> The natural flora and fauna of Punjab is fast becoming extinct because of heavy pesticide use. In Amritsar district, where Peacocks were common, it is now impossible to ever see one. In my 17 years I saw only one Peacock. It is not because the people are hunting them either. Because of the rarity of the bird the villagers are very protective and any hunting is discouraged.

In other parts of the world, fish, which used to be intercropped with rice in the paddies, have been eliminated, together with a valuable source of dietary protein, by the biocides.

Socio-Economic Impacts

Susan George has suggested, with some plausibility, that American interests pushed the Green Revolution "as an alternative to land reform and to the social change land reform would require"[42]. This is certainly in keeping with US CIA and foreign policy activities in general. However, the political consequences of the Green Revolution are much more difficult to evaluate than the ecological consequences.

Vandana Shiva, in her book, entitled *The Violence of the Green Revolution*, claims that the transformation from subsistence to commercial agriculture

> "changed the structure of social and political relationships, from those based on mutual (though asymmetric) obligations - within the village to relations of each cultivator directly with banks, seed and fertilizer agencies, food procurement agencies, and electricity and irrigation organizations. Further, since all the externally supplied inputs were scarce, it set up conflict and competition over scarce resources, between classes, and between regions...this generated on the one hand, an erosion of cultural norms and practices and on the other hand, it sowed the seeds of violence and conflict."[43]

Income Disparities

There is conflicting evidence as to whether the Green Revolution has had "spread effects" or, on the contrary, has intensified income differences either within or between regions.[44] Studies done at different times and in different places arrived at different conclusions. However, an extensive metastudy by Freebairn (1995)[45], using a data base of 307 publications (including case studies, analytical reports and essays) covering the period 1970-1989, led to the following general conclusions:

> "...the literature indicates increasing disparities in income following the introduction of the new technology, both interegional and even in the favoured zones among farmers (intraregional)." (p.266)

This can be attributed to a variety of factors. Within regions, not all farmers have the same financial standing. Some become dependent upon loans; loans are obtained more readily by those who already have land as collateral. For many small farmers, the new technology is too expensive to adopt, as the costs of the inputs are too high.[46] Since small farmers have limited access to new technology their yield is often smaller than that of medium to large scale farmers.[47] On the other hand, they make more effective use of their labour, and this may reverse the situation.[48]

In Punjab, between 1970 and 1980, many small holdings were unable to survive in the new capital intensive agriculture. Between 1970-71 and 1980-81, the total number of operational holdings in Punjab fell from 1,375,382 to 1,027,127.[49] Bhalla writes that, under HYV wheat and rice, "the distribution of operated land has shifted in favour of big farmers."[50]

There is, in some cases, a vested interest by landlords in keeping tenant farmer's production below the level at which they might escape from debt. This explains the reluctance of some landlords to allow tenants to bore tube wells[51] - a not untypical case of real people refusing to become profit maximizers as economic theory requires.

Unemployment

The early effects of the Green Revolution on employment were positive in Punjab. In fact, an acute shortage of labour developed[52]. Quite the reverse occurred in Mexico.

Those Punjabi farmers who do not use all of their return in paying for the inputs or in buying food often purchase farm machinery (often for status rather than economic reasons).[53] Mechanization displaces labour and leads to unemployment. As John Stackhouse says, "new seeds, electric pumps and tractors have darkened the future for many young people." In Punjab, he continues, young Sikhs who are no longer required on their fathers' farms often migrate to the cities where unemployment is high. Discontented, they make "easy targets for militant gangs," and the ensuing violence has seen policing costs rise to $200 million a year.[54]

In other instances tenants are unable to produce at rates deemed acceptably profitable to their landlords because they are unable to afford the expensive inputs. When they are forced off the land, they move to the cities to look for work. As unemployment increases, frustrations rise and crime worsens.

Similar effects were observed in Brazil where an earlier "Green Revolution", based on intensive farming in the 1950s, displaced the peasantry and gave rise to the infamous slums called *favelas*.[55]

Sustainability of the Green Revolution

Ninan and Chandrashekar write that the “emerging feature of Indian agriculture, whereby more inputs are required to produce a given level of output, indicates that it is becoming less efficient and more expensive.[56] Their analysis of the Green Revolution in India led them to the conclusion that: “Indian agriculture has reached that phase where diminishing returns are in operation, it is increasingly relying on scarce, costly external rather than local resources, input prices are rising faster than farm product prices, and terms of trade have turned adverse for agriculture.”[57]

Evidence to support this claim comes from a continuously cropped experimental plot at the IRRI in the Philippines. There, HYV rice has declined in productivity by 40 % over the last 20 years. Once dubbed “miracle rice,” HYV successes appear to be vanishing. A worldwide shortage of rice saw international prices double between January and December of 1995. Reportedly, only those countries which introduced HYVs later have not yet been affected. China is now importing foreign rice for the first time since 1949, and Bangladesh and Philippines show similar signs of decreasing productivity.[58]

Future trends in agriculture

The Green Revolution is preparing to give way to the Biorevolution based on genetic engineering. The Table below summarizes the important differences between the Green Revolution and the Biorevolution. In light of the diminishing productivity of the Green Revolution’s “miracle seeds,” biotechnology is already developing “super rice.” It is expected to increase production by 25% more than is realized by HYVs. The IRRI is genetically engineering this rice to have nodules on its own roots that can assimilate “free nitrogen” from the soil. Ideally, this rice will be able to photosynthesize by day and fix nitrogen by night, rather than trying to do both at the same. “Super rice” will require significantly less fertilizer than do today’s varieties. However, it will not be available until it can be cross-bred with disease and pest resistant strains. This will take another 20 years.[59] According to Monkombu Swaminathan:

“Biotechnology will provide the key to producing more food and other agricultural

commodities from less land and water in the twenty-first century without the adverse ecological implications associated with the high doses of mineral fertilizers and chemical pesticides being now used to make high-yielding varieties of rice, wheat, maize and other crops express their full potential."[60]

The chief political importance of the Biorevolution will be its control by Trans-National Corporations (TNCs)[61]

Characteristics	**Green Revolution**	**Biorevolution**
Crops affected	Wheat, rice maize	Potentially all crops
Other products affected	None	Animal products, pharmaceuticals, processed foods, energy.
Areas affected	Some locations in some LCDs	All areas, including marginal lands
Technology development and dissemination	Largely public or quasi-public sector.	Largely private sector
Proprietary consideration	Patents and plant variety protection generally not relevant.	Processes and products patentable and protectable.
Capital costs of research	Low	High
Research skills required	Conventional plant breeding and parallel agricultural sciences	Molecular and cell biology expertise plus conventional plant breeding skills
Crops displaced	The germplasm resources represented in traditional varieties.	Potentially any

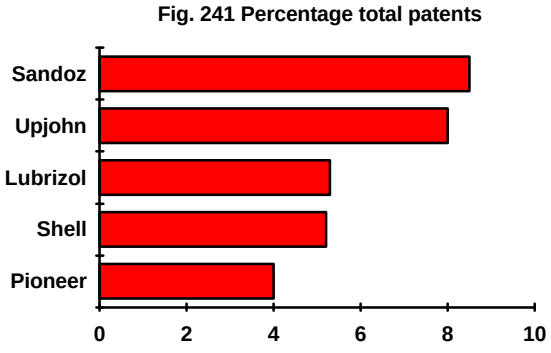
The extent of the changes caused by the Biorevolution have the capacity to greatly exceed those of the Green Revolution. Biotechnology is not, however, free from problems and the extent to which it will help meet future food demands may not be as great as Swaminathan suggests. Donald Duvick, for many years the director of research for Pioneer Hi-Bred International (one of the world's largest seed suppliers) says: "Biotechnology, while essential to progress, will not produce sharp upward swings in yield potential except for isolated crops in certain situations."[62] With its proposed 25% production increases, the biorevolution will still not be sufficient enough to address the needs a world population more than double what it is today.

Using biotechnology in agriculture also poses safety risks. By selecting which genes are deemed valuable, as well as resistant to pests, viruses and chemical biocides, biotechnology programs set agriculture up for devastating crop loss. Widespread famine could occur if genetically narrow and presumed pest and disease crops are overcome by a new and unexpected pest or disease. By removing genes from their local ecosystem, and thus natural competition, seed banks reduce the natural strengths of the seeds they are hoping to save.

The socio-economic ramifications of the Biorevolution also threaten to be extreme. The greatest issues are over patenting and monetary compensation for genetic resources. TNCs remove vast numbers of cultivars and wild strains from LDCs, without payment. It is

these TNCs who do most of the biotechnological research work.[63] The seed has become privatized, as the courts of the US. and its allies now recognize the legal right to patent genetic information.

Figure 241 shows the top five plant patent holders and the percentage of patents they hold. It is notable that four of them are major international chemical companies. Part of their research strategy is to develop patented strains that are resistant to their proprietary herbicides. This will produce a total system to which the farmer is tied.



According to Curtin, American companies which define genetic matter as a commodity make the claim that the Third World is stealing intellectual property from the First World. Yet, the genetic resources taken from the Third World are defined by First World as the "common heritage of mankind."[64] The implications of the Biorevolution are that it will not only threaten genetic diversity, but will make farmers dependent upon the private sector, rather than nature, for their seeds.

Sustainable Agriculture

The situation facing agriculture today is well summarized by Lester Brown and Hal Kane who claim that:

> "(1) there is no longer a backlog of unused technology, leaving farmers fewer agronomic options for expanding food output; (2) human demand is growing; (3) demands for water are pressing against the limits of the hydrological cycle; (4) use of additional fertilizer on currently available crop varieties has little or no effect on yields; (5) crop land is being lost to industrialization; and (6) social disintegration, often fed by rapid growth and environmental degradation, is undermining many national governments and their efforts to expand food production."[65]

There are many who question the appropriateness of the Biorevolution as the solution to these problems. Apart from attempts to curb population and a more efficient use of all resources, there is the possibility of a less technologically intensive approach to agriculture that would preserve genetic diversity.

The fact that there are indigenous seeds that, under certain conditions, have yields as high as the HYV strains is encouraging. Using modest amounts of fertilizer and traditional methods, there is evidence from India that yields from indigenous seeds can reach rates well beyond the minimum 3.7 t/ha characteristic of HYV seeds.[66] This is also true in Japan where Fukoaka, using no chemicals or other external inputs, has produced yields of rice over 6 t/ha.

The sort of solution that holds promise is illustrated by the example of a small peasant farmer on the Island of Panay in the Phillipines. He has developed an integrated system of farming based on the small aquatic fern called *Azolla* which fixes nitrogen. Some of the crop

he uses to feed his pigs, ducks and chickens. The effluent from the piggery, mixed with *Azolla* and fed into a gas biodigester, warms chicken incubators.[67] It is not likely that his research will receive enthusiastic support from the transnationals.[68]

Conclusion

As a technological innovation, the Green Revolution replaced "one way of life with another within a short span of two decades."[69] The example of Punjab shows that this speedy transformation from subsistence to commercialized agriculture has had enormous cultural, social, economic and ecological effects. It provides a striking case history of the ambivalence of technology and its unforeseen consequences, parallel to the "Future Shock" resulting from the information revolution experienced by Western industry. The lessons learned from it should enable policy makers to reduce the adverse effects of the coming Biorevolution based on genetic engineering. The study provides an excellent example of the contextual nature of deterministic influences (see chapter on Determinism). This is finely expressed by Freebairn[70]

> "This alternative view of the introduction of technological change in agriculture as a guiding orientation is that technology is only one part of an integrated agricultural structure. The limits of caste and class, landholding institutions, political power structure and social relations, farmers differential access to information and credit, rural labour relations, location and market conditions, and government farm price support and input subsidies all interact to influence, and in many respects *control, the ease and effectiveness of new technology* and the distribution among producers of the benefits from it." (our italics).

Perhaps Norman Borlaug who started it all should have the last word. In the first press conference he gave after his Nobel Peace Prize was announced he said that the work of his institute, and any similar work "would only win us all perhaps twenty years breathing space. The potential resources of food were limited. Unless the growth of population could be controlled, then we should destroy the species."[71]

Questions

1. What is meant by "The Green Revolution"?
2. What are the basic inputs of the Green Revolution?
3. Describe some social consequences that have been attributed to the impact of the Green Revolution in India.
4. What appear to be the most important ecological consequences of the Green Revolution?
5. What are the main features in which the Biorevolution will differ from the Green Revolution?

Endnotes

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[6] Figures compiled from Dalrymple, *Development and Adoption of High-Yielding Rice Varieties*; Dalrymple, "The Development and Adoption of High-Yielding Varieties"; Inter-American Development Bank, *Economic and Social Progress in Latin America: 1986 Report* (Washington, D.C.: 1986), both in Wolf, p. 15.

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[26] C.G. Clarke from M.K. Ghandi, p. 83, in Shiva, p. 103.

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