FUTURE OF RICE 2006

EXAMINING LONG TERM, SUSTAINABLE SOLUTIONS FOR RICE PRODUCTION

GREENPEACE

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FUTURE OF RICE 2006

A rice farmer with young plants which will be planted out into the main field after they have stayed 8 to 10 days in a smaller area, Rijara village.
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Cover images.
19 October 04 - Xin Jie, Yunnan, China - Greenpeace visits the world famous rice terraces of 'Tigers Mouth' near the small town of Xin Jie, Yunnan, China. The visit to the mountain terraces is part of the 8 day bus tour organised by Greenpeace to highlight the rice culture and diversity in the farming communities of Yunnan province, China. Yunnan is the homeland of rice to the Chinese nation and known as the source of rice culture to the whole world.
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A Hani farmer holds traditional rice seeds in his hands, Yunnan Province, China 24/06/04 © Greenpeace/Novis

CONTENTS

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Future of Rice - Executive Summary

Rice is the world's most important staple food - grown in over 100 countries, consumed regularly by over two billion people and the primary source of protein for millions. But the production of rice is at a critical crossroad if the future biodiversity of rice and rice farmers, producers and consumers is going to be protected.

The Greenpeace International report 'Future of Rice' highlights problems with current rice production and documents scientifically proven solutions currently used by rice farmers around the world. Sustainable rice production is already being achieved. The report presents an analysis of these sustainable rice production methods, which include traditional rice growing systems and cutting edge technologies.

The report's authors, Dr Emerlito Borromeo and Dr Debal, also examine genetic engineering which is frequently touted as a quick fix solution to agricultural problems.

Their analysis shows that genetic engineering, when compared to other rice breeding and production methods and to traditional rice growing practices, is ineffective, unpredictable, expensive and risky to human health, farming communities and the environment in rice growing regions.

They point to massive reductions in chemical use on farms in the Philippines and Iran; to reductions in chemical use and increased yields and incomes in Vietnam as a result of programs that reduce the use and increase the efficiency of fertilisers. In India farmers have reduced pest related crop losses through the re-introduction of beneficial predators, such as wasps. In Myanmar, predatory ants are spread in fields and feed on the eggs of problem pests. In China and many other countries, the use of fish or ducks in rice paddies has resulted in decreased pests, increased yields and an additional source of protein and income when the fish or ducks are harvested.

In 2006 two scandals erupted as unapproved genetically engineered (GE) rice contaminated the global rice supply, these two events provide a frightening insight into the real world implications of the growing of genetically engineered (GE) rice. Through field trials alone, large portions of the rice supply system became contaminated. Farmers, millers, traders and retailers around the globe are facing massive financial costs, including testing and recall costs, cancelled orders, import bans, brand damage and consumer distrust that could last for years. There is evidence that the Chinese rice variety may be harmful to human health. There is not enough data to determine if the US rice is safe. Neither of the GE rice varieties trialed in the US or China is approved for food consumption anywhere in the world, yet somewhere in the rice production process, which involves millions of people, unapproved GE rice contaminated the rice supply not only of both countries but the global rice market as well.

At least three multi-million dollar class action lawsuits have been filed by farmers and traders seeking damages from Bayer CropScience the company, responsible for the US contamination. The world's largest rice processor has already stopped buying US rice because of brand damage. In China, attempts by the Government to control the illegal sale and sowing of GE rice seeds have clearly failed. The contamination has spread like a plague across China and now into the global rice supply.

This report is not primarily about the risks and costs of developing GE rice, but about the compelling reasons why we should embrace rice knowledge developed by farmers over thousands of years and combine it with the best of modern biotechnology; not genetic engineering but science that is precise, predictable and acceptable to the public.

The report shows that GE rice and the risks that it brings are simply unnecessary.

There are estimates that there are as many as 140,000 varieties of rice developed during the course of our shared agricultural history. Many of these varieties have been developed for specific reasons - rice designed to grow in certain climates or in certain soil types; rice resistant to particular diseases or particular insects; rice that can grow in deep water; rice that resists drought. This diversity of rice traits and varieties represents the future of rice and those that depend on it.

Wedding gifts given by relatives and friends: homemade rice cookies and fresh pig heads. © Greenpeace/Li Zikang

GE technology is an attempt by large corporations to take from public hands this shared knowledge of rice and replace it with a technology that doesn't work. When Monsanto or Bayer, Syngenta or Dow promote a GE rice, what they are promoting is the patent they own over the rice requiring that farmers buy new seed from them every year. They are also promoting their chemicals that must be used on the patented rice. They are promoting a level of corporate control over food production that will unacceptably compromise the cost of and access to food, the diversity of food types, and the safety of food that we eat.

And for what? Do these high tech rice varieties offer massive increases in yield or a magic bullet that prevents diseases or pests? Do they offer long-term reductions in chemical and fertiliser use that will improve the environment, the quality of food or the health of farm workers? As this report makes clear, the answer is no, GE is no magic bullet and will cause more problems than it can possibly solve. At best it has promised much but delivered little, while ignoring the potential health, environmental and economic consequences of a technology that cannot be controlled. GE rice threatens the livelihoods of farmers, the health of consumers, the diversity of foods that our human history has provided us, and the health of the land upon which we depend for food.

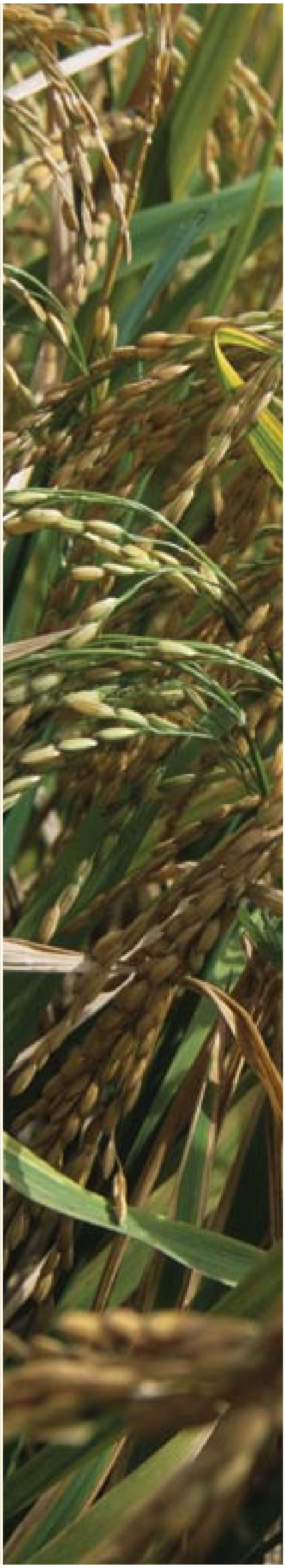
The report covers four broad areas.

1. Problems of Rice Production;
2. Genetically Engineered Rice;
3. Genetic Engineering - feeding the greedy not the world's hungry;
4. Solutions - the real cutting edge.

The first outlines the nature, scope and types of current rice production as well as the disease and pest problems that rice farmers face. The second examines genetic engineering; its lack of precision and predictability and reasons for questioning its safety and longer term usefulness. The report looks at the types of GE rice that are being developed and the myths that the GE industry has propagated about GE rice. Claims that GE rice will reduce chemical use, solve pest and disease problems and feed the world's hungry are shown to be false. The report makes it clear that the development of GE is about feeding corporate profits not the hungry of the world.

Finally, the report looks at real, cutting edge solutions that take advantage of new technologies such as marker assisted selection, of farmer knowledge, the diversity of rice varieties and the ecological realities of rice growing areas. Some of the solutions, such as mixed farming systems, not only solve pest and disease problems but create additional sources of income and food for farmers and communities. Many of the solutions ensure that farming communities continue to control their land and crops while reducing the environmental and health impacts that have come with industrial agriculture and large scale, chemically intensive monoculture farming systems. Use of marker assisted selection allows advancements in genetics to be used to identify and transfer beneficial traits in rice plants without genetic engineering and without risk.

Moving away from industrial agricultural practices and the treadmill technologies that genetic engineering embodies does not require an agricultural revolution - all these solutions exist and are used and working in various parts of the world. It does, however, require that governments invest in the long-term future of their farming and food production systems and that the rice industry recognize that its own long term viability rests with rice production systems that work and that its customers will accept.



Rice, growing in the Hung He Valley, Yunnan Province, China.
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INTRODUCTION

Rice (*Oryza sativa*) is the world's most important food crop. It is the main staple food of much of the population in Asia as well as Latin America, Africa and the Caribbean. Rice is cultivated in more than 100 countries, but most of the rice is consumed in the same country where it is produced. Only about 6% of world production is traded internationally. About 90% of the world's rice is grown and consumed in Asia (Hossain and Narciso 2004).

To the four billion people of Asia, rice is more than a staple food. From ancient times to modern history, rice has consistently been a part of Asian culture. In several Asian languages, the word for rice and food are synonymous. In Japanese, for example, the terms for breakfast, lunch, and dinner, are asa gohan (morning rice), hiru gohan (afternoon rice) and ban gohan (evening rice). In Sanskrit, the word for both "meal" and "rice" is "Anna". In China and Bangladesh, a polite way to greet a visitor is to ask "Have you eaten your rice today?"

Rice cultivation was considered as the basis for the social order and many ceremonies have arisen in connection with planting and harvesting rice. The grain and the plant are traditional motifs in Oriental art. It also occupies a major place in Asian religions and customs. Both Hindu and Buddhist scriptures make frequent references to rice, and in both religions, the grain is used as a major offering to the Gods.

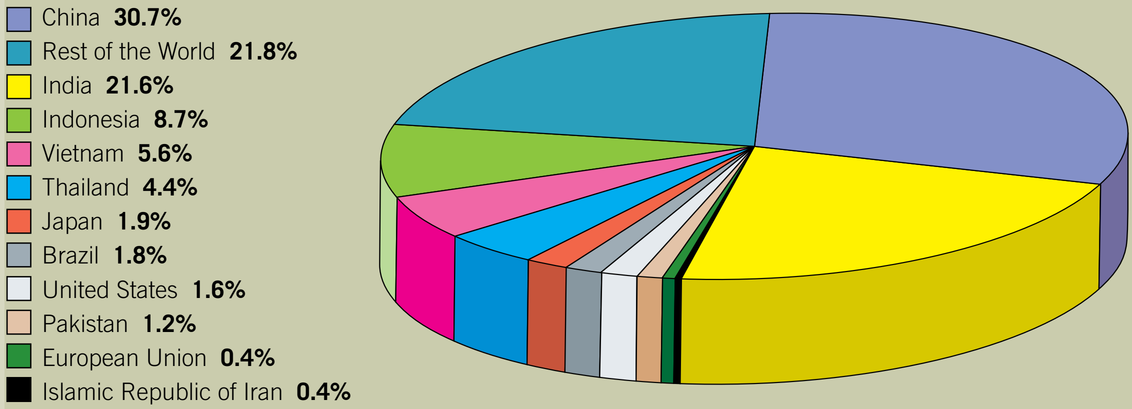
Rice is also an important source of employment and income in the rural areas of Asia (Hossain and Narciso 2004). Socio economic development, industrial growth and political stability are linked closely to sustainable supply of rice at low, stable prices. Rice occupies such an important position in most Asian countries that self-sufficiency in rice production is a political objective of many Asian governments.

Rice is arguably the most diverse cereal crop. Although the number of varieties are difficult to estimate, claims of 140,000 varieties of rice have been made. (Jackson, 1995). These varieties generally fall into three subspecies – indica, japonica and javanica. The differences between these groups evolved both geographically and culturally over thousand of years as farming groups relocated to different ecosystems. Indica rices have long grains and are usually grown in tropical climates Japonica rices have short round grains, which are sticky when cooked, and are usually grown in temperate climates. Javanica rices have long bold grains and are cultivated on a limited scale in Indonesia.

The rice gene pool is enriched by another cultivated rice species, *O. glaberrima*, the cultivation of which is limited to West Africa. In addition, there are about 20 wild rice species (Xie et al. 1998), all of which provide a reservoir of traits for the continuous improvement of modern rice varieties. For example, *O. utrimera* was used as the source for breeding varieties resistant to tungro disease, and *O. minuta*, *O. officinalis*, *O. latifora* for resistance to brown plant hopper. The Genetic Resources Center of the International Rice Research Institute (IRRI) holds more than 80,000 accessions of rice germplasm, 76,000 of which belong to *O. sativa*, 1250 accessions are *O. glaberrima*, and nearly 3000 accessions are wild species (Cottyn 2003).

In Asia, rice is grown in four ecosystems, namely the irrigated lowland, the rain fed lowlands, the deepwater and flood prone environment, and the upland ecosystems, which differ primarily in water supply and control. The irrigated rice ecosystem is characterized by level paddy fields with water control and where rice is grown in continuously flooded condition, except near harvest time. Cultivation is intensive, with at least two crops of rice grown and harvested annually in tropical regions and is frequently done with heavy use of fertiliser and pesticide. The area under irrigated rice constitutes roughly 53% of the world's rice area (IRRI 1995) and is the main food basket of Asia. The rain fed lowland ecosystem is characterized by paddy fields that are flooded, and this flooding is rainfall dependent. Conditions are diverse and unpredictable, and drought is a common problem. In the upland ecosystem, rice is directly seeded on dry or well drained soil on flat to deeply sloping fields. The crop is grown alone or in diverse mixtures in rotating or permanent fields. Rice in the flood prone ecosystem is grown in areas subject to temporary or long periods of submergence in floodwater ranging from 0.3 to 4 meters deep. The flood prone areas of South and Southeast Asia are mostly in the delta areas of large rivers such as the Mekong of Vietnam and Cambodia, the Irrawady of Myanmar,the Chao Phraya of Thailand and the Ganges of India and Bangladesh.

Figure 1: Distribution of the world paddy rice production (average 1999-2003, source UNCTAD 2004)



Problems of Rice Production

Rice production today faces a number of problems that threaten many rice producing Asian countries' ability to support the food needs of their rapidly growing populations. These constraints include pest outbreaks, diseases, soil degradation, scarcity of water, conversion of rice lands for industrial use, soil salinisation and adverse soil conditions.

Pests and Diseases.
Intensive rice production has seen an increased dependence on broad scale growing of single varieties (monoculture), the use of high yielding crop varieties, chemical fertilisers and pesticides, irrigation and mechanization which has resulted in large increases in agricultural output during the last forty years (Conway 2001). However, this major shift away from traditional rice production changed the agricultural ecosystems and biodiversity in the regions. This has resulted in increased plant health problems and loss of soil quality. These negative consequences have serious implications for yield and long term sustainability.

Monocultures of genetically uniform varieties of rice and major reductions in mixed cropping systems have led to rice becoming more vulnerable to pest and disease outbreaks. A pathogen or insect pest able to attack one plant can attack all and has a potentially unlimited opportunity to spread throughout the field. Trying to eliminate pests and diseases through the breeding of replacement varieties with single gene resistance to certain pests or diseases, has led to the rapid selection of strains that can overcome crop resistance, creating a constant need for new pest resistant varieties. It's a treadmill approach that is expensive and inefficient.

The heavy application of pesticide and fertiliser associated with modern rice farming has also contributed to problems with pests and diseases. Pesticide application, which is usually directed at leaf-feeding insects that inflict highly visible damage symptoms but have little effect on yields (Heong 2005) disrupts the normal food web development and increases the emergence of secondary pests. A classic example is the frequent outbreak of brown plant hopper (BPH) in the early 1970s. BPH populations are normally kept low by the wide range of their natural enemies. But regular use of insecticides in the tropics during the 1970s triggered large outbreaks of BPH. The stronger the insecticide, the faster the resurgence of BPH populations which lead to a large scale dehydration of rice plants, a symptom known as 'hopperburn'. Insecticides kill both BPH and their predators, but not the BPH eggs laid inside the stem of the rice plant, which remain relatively unharmed. When the larva hatch, BPH nymphs develop and quickly multiply in an environment free of predators. In unsprayed fields, the population of BPH does not increase to any significant level above their sprayed counterparts (Gallagher et al. 1994).

Rice insect pests also have the ability to develop resistance against pesticides, necessitating increased application dosages and/or development of new and more potent pesticide.

High rates of chemical fertilisers can lead to increased pest and disease infestations, thus prompting the farmer to become reliant on pesticides. Research has shown that crops with high nitrogen content – brought about by the use of chemical fertilisers – can make insect pests produce more eggs, survive better, live longer and become ecologically fitter (Heong 2005). High rates of fertiliser also affect the diversity of soil microflora, decreasing long term soil fertility. (Tilman 1998) It also causes pollution of ground water and causes ecological damage to rivers and lakes, which have become major concerns worldwide.

Scarcity of Water.
Rice production needs considerably more water than any other cereal crop: it can take up to 5,000 litres of water to grow just one kg of rice (Cottyn 2003). About half of all the freshwater used in Asia supports irrigated agriculture, and 90% of this flows directly to the rice paddies (Atlin 2005). Water scarcity is becoming a serious constraint to rice production. Urbanization in Asia is diverting irrigation water for domestic use. This competition for water is compounded by more frequent droughts. With the onset of global warming, an increasing proportion of the total arable land area in Asia is becoming drought-prone. The Indian state of Tamil Nadu, for example, once farmed around two million hectares of rice. In 2002 and 2003, drought reduced the area of irrigated rice production to less than 300,000 ha. More than 12 million ha of irrigated rice lands in South Asia alone are likely to face severe water shortage in the next 20 years (Atlin 2005).

Intrusion of salt water.
Related to the problem of water scarcity is soil salinisation in rice fields near coastal areas. As farmers draw increased quantities of water from the ground, the lowering of the water table allows the intrusion of seawater into the groundwater table thus preventing the cultivation of most varieties of rice.

Loss of agricultural land to industrial use.
Asia's booming industrial sector and fast growing cities are converting agricultural lands into land for human settlements and industrial use (Hossain 2005). The conversion of prime agricultural lands to domestic and industrial use has seen many rice farmers forced to farm in marginal lands, thus increasing problems such as iron toxicity (affecting approximately seven million ha), and acid sulphate soils (affecting approximately two million ha) which in turn causes a major drop in yields. (Haefele et al. 2004).

Different types of rice are growing on a test field of the Nayahrishni Center in Tangail. © Greenpeace/Nartea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Genetically Engineered Rice

The agro-chemical industry insists that genetic engineering is a solution to almost all of the major problems associated with rice production and to feeding the world's hungry through enhancement of the nutritional attributes of rice. Behind the pretext of solving the problem of world hunger, large agribusiness corporations are making a grab for ownership of the sources of life itself. With thousands of agricultural patents, ownership of the chemical industry and increasing control over the global seed industry, control over the production of food is now within sight of these transnationals. Control of food production means control over governments, citizens and the security and economic foundations of countries.

The leading multinational seed companies have invested heavily in both international and national research institutions hoping to develop and spread their GE plants. This technology threatens to radically reshape the food production systems of developing countries and block sustainable forms of agriculture like organics and community agriculture to the detriment of millions of Asian people.

Genetic engineering is an unnecessary and risky experiment, especially with the world's most important staple food crop.

"Even with the limited information currently available it is clear that plant transformation is rarely, if ever, precise and that this lack of precision may cause many of the frequent unexpected phenotypes that characterise plant transformation and that pose a significant biosafety risk." (Latham et al. 2006)

The United Nations Food and Agriculture Organization/World Health Organization Codex Guidelines on GE food safety confirm the unpredictable nature of the method (FAO/WHO 2003). The genetic engineering process can result in multiple copies of genes being inserted, genes may be in the forward or reverse orientation and there may be fragments of genes from the vector also transferred. Deletions and rearrangements of plant DNA are common occurrences. Mutations induced by the GE process may occur at the site of insertion or be genome wide (Wilson et al. 2004). Such effects occur regardless of the source of the gene and the method of genetic engineering. They are inherent to the process of genetic engineering. The implications of this crude technology include:

- the disruption of the plant's own genes and their abnormal functioning – this could lead to the production of unexpected toxins or anti-nutrients that could be harmful to people;
- increases or decreases in the activity of plant's owns genes through the introduction or disruption of control genes – this could increase or decrease the levels of naturally occurring toxins, allergenic proteins or other important substances produced by the plant;
- silencing (inactivation) of genes in future plant generations if multiple copies exist.

Field trials of GE rice in China have resulted in the illegal sale of GE seeds and significant GE contamination that has spread across into the food chain. It has, been found in baby food products in China and most recently been detected in rice products in Europe. This scandal, caused by the illegal sale and cultivation of unapproved rice varieties, has highlighted the dangers of allowing GE into the supply chain, particularly where informal and unregulated transactions are common. Commercial cultivation of GE rice has not been approved in China.

The genetic engineering industry has promoted no product more ruthlessly than its Golden Rice, yet it is still surrounded by scientific uncertainty. The shelflife of Golden Rice, the amount of pro Vitamin A that it can supply and, more importantly, the food safety of Golden Rice have never been established. Other approaches to combat vitamin A deficiency, such as home gardening, mixed cropping systems and community gardens are successful, effective, and improve nutrition in general. © Greenpeace/Nartea

Rice farming, Hoi An, Vietnam.
© Greenpeace/Adrian Beard

If GE rice is commercialized, it will lead to the contamination of other rice crops and may also contaminate wild rice varieties. Although rice is largely self-pollinating, pollen dispersal is strongly influenced by wind speed and direction and can travel up to 100 meters (Song et al. 2004). Gene flow (outcrossing) has been detected at 43 meters (Song et al. 2003). Therefore, some degree of contamination of neighboring non-GE rice is almost certain. Other possible sources of contamination include:

- Previous crops of rice. In many parts of Asia, farmers grow multiple crops of rice, sometimes as many as three crops in a year. Rice seeds that fall in the field during harvesting can germinate in subsequent cropping cycles for two years or more. If the first crop is GE, but not the next, there is potential for contamination of the non-GE crops for two years or more;

- Human handling, human behaviour, human error. Contamination is also likely to occur throughout the supply chain, either because of an absence of segregation of crops, a lack of enforcement or the sheer impossibility of preventing cross contamination in a trade that involves millions of producers, traders, millers and producers. Contamination, may occur during harvest, transport, storage and processing. In August 2006 GE rice contamination was reported in the US. The discovery of the long grain GE rice (Bayer's LL601, a herbicide tolerant GE rice that has not been approved for human consumption anywhere) in bins of commercial rice storage in Missouri and Arkansas resulted in a swift response from Japan, which immediately banned long grain rice imports from the U.S. The EU followed suit shortly after. The discovery also resulted in a plummeting of rice prices on the futures market. What is more remarkable here is that the unapproved GE rice which contaminated the stored rice grown in 2005 had not been grown since 2001 (Cline 2006).

The uncontrolled spread of GE rice is particularly risky in Asia, the centre of origin of rice. Wild species with which cultivated rice (*Oryza sativa*) can hybridize (interbreed or produce offspring), are widely distributed. *O. rufipion* and *O. nivara* can interbreed with cultivated rice, and the offspring of such interbreeding events (hybrids) occur in the field. These wild species are sometimes found as weeds in rice production areas. When wild and cultivated rice are found in the same regions, the production of hybrids between cultivated and wild rice is considered inevitable over time. Therefore, the introduction of traits such as disease resistance into GE rice will inevitably transfer to and contaminate wild varieties, potentially increasing the likelihood of them emerging as problem weeds. Such hybrids may also swamp natural wild varieties. Hybridization with cultivated varieties was one of the major reasons why wild rices, which used to grow abundantly in Taiwan during the 1920's, became extinct (Kiang et al. 1979).

The loss of wild species of rice threatens the wild ecosystems, flora and fauna and potentially a serious loss of genetic resources for current and future breeding needs. The right of people to have access to sufficient, safe and nutritious food is also threatened as the diversity of protected plant traits diminishes.

Listed below are some of the traits that have been incorporated into rice. None has yet been commercially cultivated. If any of these GE rice varieties is approved for commercial release, it will mean a radical increase in the exposure of the human diet to GE organisms. Exposing such a large number of people to the risks of GE food in a direct way and on an unprecedented scale is a very high risk proposal, for which there is no justification.

Hani women at their rice paddy carrying ducks, Lao Bo Village, Yunnan Province, China. Ducks play an important role in the long developed Hani rice-farming system. They are taken out to the paddy to clean up weeds and pests. In return, their manure serves as good quality fertiliser to nourish the rice. Ducks are quite effective paddy 'guards' as about one dozen of them is already able to maintain several acres of paddy field. In addition, farmers can sell the ducks for extra income. © Greenpeace/Novis

Pest and disease resistant genetically engineered rice

Two types of GE rice have been pushed close to commercial cultivation in China by pro-GE advocates: bacterial blight (BB) rice and insect resistant (Bt) rice.

BB rice is a generic term for transgenic rice varieties where a gene for bacterial blight resistance obtained from African wild rice *Oryza longistaminata*, called Xa21 has been introduced. This GE rice is intended to control bacterial leaf blight, a water-borne disease caused by the bacterium *Xanthomonas oryzae* pv. oryzae.

Rice farmers are unlikely to derive any long term benefits from the introduction of BB rice. Large scale cultivation of varieties with a single resistance gene will eventually lead to a breakdown in resistance (Leung et al. 2003) and can result in the appearance of more virulent strains (Wang et al. 2005). The bacterial blight pathogen is highly adaptable (Vera Cruz et al. 2000) and will likely overcome the single GE resistance mechanism.

The push to introduce BB rice poses unnecessary risks. This rice is unnecessary because bacterial blight is not a major agricultural problem in Asia (Savary et al. 2000), Bacterial blight resistance can be achieved through conventional (non GE) means, and there are other cultural methods of dealing with the disease.

In China, Ministry of Agriculture statistics show that bacterial blight is no longer a major disease for rice, with the total area of infection at less than one million hectares over the last five years, representing only around 1-2% of the total rice growing area. The Ministry has not conducted any national bacterial blight infection forecast in the past two years since the disease is no longer considered to be a serious, nationwide problem.

The Xa21 gene can be, and has been, introduced into rice by conventional breeding methods (Khush et al. 1990) and marker assisted selection (Chen et al. 2000). Elite rice lines containing multiple genes for resistance against bacterial blight, including the Xa4, Xa5, Xa7 and Xa21 genes have already been developed and have shown good performance in the field. This includes, among others, a line with the IR 64 background (a vastly popular variety in South East Asia) and Chinese hybrid rices such as Hybrid Guofeng No. 2 and Hybrid II You 218 (Leung et al. 2004). Furthermore, managing N fertiliser levels so as not to exceed the actual requirement of the crop could control bacterial blight (Reddy et al. 1979). There is no need to use genetic engineering and no need to take any of the risks that are inherent with the process of genetic engineering.

Bt rice

Bt rice is genetically engineered rice containing Bt genes, obtained from the soil bacterium, Bacillus thuringiensis (Bt), which enables it to produce toxins that are designed to kill larvae of rice stem borer pests in Asia such as the yellow stem borer (Scirpophaga incertulas) and the striped stem borer (Chilo suppressalis). Bt plants are essentially chemical factories, producing the toxin throughout the growing season. Bt rice is being promoted supposedly to reduce the huge amount of pesticide being applied in Asian rice fields.

There are several different types of GE Bt rice known to be under experimentation, either in the laboratory, or in field trials. These produce slightly different Bt toxins and include Cry1Ab; Cry1Ac and those that contain "fused" toxins Cry1Ab/Cry1Ac.

No food safety assessment has been finalized for any Bt rice. It is not known whether the genetic modification has resulted in potentially harmful unintended changes such as any toxic or allergic effects of the gene products. For Cry1Ac, there is concern over its potential allergenicity. Research indicates that the Cry1Ac protoxin is a potent immunogen (Moreno-Fierros et al. 2000; Vázquez-Padrón 2000). These research reports suggest extreme caution is required in the use of Cry1Ac GE rice, especially since rice is a staple food crop. The allergy concerns in relation to Cry1Ac or the fused protein in GE Bt rice could have regulatory consequences. For example, StarLink Bt maize was not allowed to be used in human food in North America because of the risk of allergies.

There is also no publicly available environmental assessment for any GE Bt rice. However, studies from other GE Bt crops such as maize (corn) and cotton give strong indications that Bt rice will have serious environmental consequences. Changes in populations of both pests and of natural enemies have been documented with Bt cotton. In China, significant reductions in populations of the beneficial parasites *Microplitis* sp. (88.9% reduction) and *Campoletis chloridae* (79.2% reduction), and increase in the populations of other secondary pests, including aphids, lygus bug, whitefly, Carmine spider mite and thrips have been observed in Bt cotton fields (Cui and Xia 1998, 1999). Research has also shown that the Bt toxin can persist in soils and retain it's insecticidal activity, threatening long-term soil health (Stotzky 2004).

Rice farmers are unlikely to derive any long term benefits from Bt rice if at all, as has been the case with Bt cotton farmers in China. A 2006 study of Chinese Bt cotton done by Cornell University showed that after seven years of wide scale Bt cotton planting, populations of other insects -- such as mirids -- have increased so much that farmers are now having to spray their crops up to 20 times a growing season to control them, resulting in a net average income of 8% less than conventional cotton farmers (Lang 2006).

GE insect resistant Bt rice has not been approved for cultivation anywhere in the world but illegal plantings have already been uncovered in China.

Bt rice is unnecessary because stemborer is a low level chronic pest. Based on an extensive survey of farmers' fields in Asia, stem borers were estimated to cause a mean yield loss of only 2.4% (Savary et al. 2000). Yield losses due to stemborer are often exaggerated because of the highly visible damage symptoms it causes. However, modern rice varieties, have high compensatory abilities. A mature rice plant consists of 12-30 tillers (or upright branches emanating from the base) each bearing a panicle (or a bunch of grain). Up to 25% damage to young tillers by stemborers can be tolerated without significant yield loss (Rubia et al. 1996) because the damaged tillers are replaced by new tillers or are compensated by other tillers. Up to 5% panicle death due to stem borers in most varieties does not cause significant yield loss (Rubia et al. 1996, Way and Heong 1994) because the dead panicles are compensated by fuller or heavier grains in the other panicles.

Herbicide Tolerant Rice

Genetically engineered rice that is resistant to herbicides has been developed by Monsanto (Roundup Ready rice, resistant to glyphosate) and Bayer (Liberty Link rice resistant to glufosinate).

Bayer in particular is seeking widespread approval for its GE rice, LL62, which has so far only been approved for cultivation and use as food in the United States and for food use in Canada.

The wide scale use of herbicide tolerant (HT) crops will inevitably lead to increased herbicide use and thus create even more dependence on toxic chemical inputs, increasing concerns about impacts on human health and the environment, and over time increase costs to farmers. A recent study based on nine years of United States Department of Agriculture data from the growing of herbicide tolerant soy in the US found that "Roundup Ready" soybean farmers use more chemicals at higher doses and get lower yields than farmers who grow conventional soy. The study also noted that weed resistance, particularly to glyphosate, is now a major problem in the United States and other agricultural countries, such as Australia that have heavy reliance on the use of glyphosate (Benbrook 2001).

It appears likely that the EU will ban glufosinate (Liberty or Basta) because of health concerns, calling into question Bayer's entire line of glufosinate resistant crops, including LL Rice.

The herbicides as well as the management regime of HT crops also have detrimental effects on faunal diversity. A key experimental study by Watkinson et al. (2000) has demonstrated that bird and mammal species populations decline as a result of cultivation of genetically engineered HT crops. The findings of this study were corroborated by a farm scale evaluation of genetically engineered HT crops in UK (Bohan et al. 2005). This new study shows that GE management of rapeseed and sugar beet led to fewer broad-leaved weeds. The flowers of these "weed" plants attract insects, and their seeds are also important for many bird species, such as the skylark, tree sparrow and bullfinch. Bohan et al. (2005) recorded a significant decline in bird and insect diversity in genetically engineered HT farm plots compared to conventional crop farms. Genetically engineered HT crops are clearly intended to promote unrestrained application of herbicides. They are meant to promote chemical agriculture, which is designed to eliminate farm biodiversity. There are numerous cultural practices to control weeds in traditional rice farms, where herbicides are unnecessary, and which provide additional on-farm income opportunities.

Golden Rice

Golden Rice is the generic name given to GE rice that produces beta-carotene (pro-vitamin A) in the endosperm. This name is derived from the yellow color of the polished grain. Golden Rice is intended to address the problem of vitamin A deficiency, which is a major form of malnutrition in developing countries. Between 250,000 and 500,000 children worldwide are partially or totally blind due to vitamin A deficiency (WHO and Unicef 1995).

For over five years the genetic engineering industry has promoted no product more ruthlessly than its Golden Rice, yet it is still surrounded by scientific uncertainty. The shelf life of Golden Rice, the amount of pro-vitamin A that it can supply and more importantly the food safety of Golden Rice has never been established. The complexity of the genetic engineering and the extent to which the metabolic pathways in the plant were changed increase the potential for unexpected and unpredictable effects, thus raising severe concerns concerning human food safety.

Even assuming that enough pro-vitamin A is available in the amount of grain normally consumed by Asian people, Golden Rice still cannot be the answer to the nutritional demands of the poor. Pro-vitamin A requires dietary fat for absorption in the human intestine. Thus, digestion, absorption, and transport of ß-carotene require a functional digestive tract, adequate protein and fat stores, and adequate energy, protein, and fat in the diet. Many children exhibiting symptoms of vitamin A deficiency, however, suffer from generalized protein-energy malnutrition and intestinal infections that interfere with the absorption of ß-carotene or its conversion to vitamin A (Torun and Chew 1998; Nestle, 2001).

Golden Rice, if introduced on a large scale, would serve only to perpetuate hunger by ignoring the complex social factors generating hunger and malnutrition. It will exacerbate malnutrition because it encourages a diet based on one staple. The high risks of growing and using GE Golden Rice as food to alleviate vitamin A deficiency are not at all justified by the theoretical benefits.

Other approaches to combat vitamin A deficiency, such as home gardening, mixed cropping systems and community gardens are successful, effective, and improve nutrition in general. The strategy of home gardens is a quite promising because an estimated 50% of the undernourished are small scale farmers and only 20% are urban poor who may not have access to a garden (FAO, 2004). For example, a study in Bangladesh showed that 75g of Indian Spinach, a low-cost green leafy vegetable available all year round in Bangladesh, provides enough pro-vitamin A on a daily basis (Haskell et al. 2004). It only takes two tablespoonfuls of yellow sweet potatoes, half a cup of dark green leafy vegetables or two-thirds of a medium-sized mango in a day to meet the vitamin A requirement of a pre-school child (Gilbert 1997). Fruits and vegetables could address a wide variety of micronutrient deficiencies, not just vitamin A deficiency. And there are many wild or easy-to-grow plants like jute (*Chorchorus capsularis*), mustard (*Brassica campestris*), and drumstick (*Moringa oleifera*), that contain higher ß-carotene than even the most optimistic projections for Golden Rice of the same weight (Rodriguez-Amaya 1997).

Golden Rice is draining funding and attention from real solutions to malnutrition and vitamin A deficiency.

Genetic engineering - feeding the greedy not the world's hungry

"There is no shortage of food on the planet." Kofi Annan, UN World Food Summit, 2/10/06.

Genetic engineering will not feed the world.We need to work on providing all people access to sufficient, safe and nutritious food to meet their daily needs, and ensure food control remains in the hands of communities and farmers that promote truly sustainable crop and food production.

Far from supporting the rights of consumers and farmers, the real purpose of GE agriculture in the developing world is to expand corporate control over food, including the world's most important staple food, rice. There is an intense race between genetic engineering corporations to control the global food-chain through development, planting, spreading, and entrenching an array of GE crops in yet another round of capital accumulation for agro-chemical business. The seed is the medium of control of the production process. With increasing control over seeds (http://www.etcgroup.org/documents/seedmasterfin2005.pdf) genetic engineering corporations are manipulating the DNA to support their core business-pesticides, fertilisers, and intensive agricultural practices with all their costly inputs. Genetic engineering is creating further technology dependency, especially on private sector biotechnology as the central mechanism of agro-chemical expansion. The infiltration of the business sector into both the international and national public research sector is further entrenching a narrow range of technologies, characterized by monocultures as the basis of intensive or agro-chemical agriculture. Pious pronouncements of moral concern about food shortages are cynically manipulated to influence governments and farmers in the developing world to adopt strategies of agricultural intensification. Genetic engineering technologies are portrayed as the 'only practical solution' yet the underlying causes of poverty and hunger and degradation of agricultural lands are studiously ignored. Government and research support for alternative approaches that are more culturally and ecologically appropriate such as agro-ecology, organic farming and community agriculture remains woefully inadequate.

Instead of addressing the core problems associated with industrialized agriculture, chemical corporations frequently fund and go into 'partnership' with public sector research institutions and have propped up the increasingly problematic system of current agricultural practices. These current practices result in;

- intensification of monoculture cropping;
- reduction of plant and food diversity;
- increased farmer costs;
- increased reliance on chemicals;
- exploitation of the environment and natural resources;
- reliance on inappropriate and expensive technologies.

SOLUTIONS – THE REAL CUTTING EDGE

Contrary to the claims of genetic engineering proponents, the real cutting edge solutions to the problems of rice production lie not in developing GE rice but rather in developing and/or adopting strategies that take advantage of ecological principles within agricultural systems, and integrating traditional farming practices with modern scientific knowledge. While these approaches could lead to sustained productivity using current rice varieties, including those that have been "defeated" by pest or disease under extreme monoculture (Zhu et al. 2000, Leung et al. 2003, Gallagher et al. 1994), efforts to develop new varieties that are adopted to and respond to the specific farmers conditions in Asia should be vigorously pursued. Marker assisted selection (MAS), which uses tools provided by modern biotechnology but which does not unpredictably disrupt the genome as genetic engineering does, should greatly facilitate these efforts.

"Existing biodiversity of rice varieties and their nutritional composition needs to be explored before engaging in transgenics." FAO http://www.fao.org/ag/AGP/AGPC/doc/field/commrice/pages/newsevents.html

ECOLOGICALLY DESIGNED AGRICULTURE AND PEST MANAGEMENT

The typical rice ecosystem offers a biologically diverse and dynamic environment for crop, microbial, floral, invertebrate (insects, spiders, mites, mollusks, crustaceans), and vertebrate populations to flourish (Schoenly et al. 1996; Settle et al. 1996). The diverse components of the ecosystem interact with one another so that an increase or decrease in population of one organism is subject to the check and balance imposed by populations of other organisms. Most rice pests are controlled by a complex and rich web of predators and parasites that live in or on the rice plant, paddy water or soil (Heong et al. 1992; de Kraker 1996; Matteson 2000). Early in the growing season, detritus and plankton-feeding insects allow generalist predators to establish and multiply in unsprayed paddy fields before rice-feeding insects come in (Settle et al. 1996; Wu et al. 1994). If undisturbed, these natural enemies normally keep pest populations at levels that do not cause serious economic damage (Way and Heong 1994).

The joy of golden harvest.

Farmers from Hubei observe tests on rice to detect genetically engineered varieties, Hubei province, China. Trading and growing GE Rice varieties is illegal in China. Greenpeace discovers the Anti-pest 63 variety being commercially traded and grown during several recent investigative trips. © Greenpeace

This information leads to two general strategies in dealing with pest problems. The first strategy involves avoiding practices that would disrupt rice ecosystem balance, and the second strategy consists of approaches that would enhance the biodiversity of the rice ecosystem.

The most disruptive practice that should be avoided or stopped outright is pesticide application, especially during the early stages (first 40 days) of crop growth. Early season insecticide application destroys ecological balance in the rice paddies. Insecticide application kills insect pests along with their natural enemies but the population of insect pests recovers faster than the predators (Heong and Schoenly 1998), Schoenly et al. (1996) used a food web analysis to examine the effects of insecticide on arthropod populations in Philippine rice fields. Insecticide application brought two ecological costs to the farmer – reduced abundance of many natural enemies and a four fold increase in herbivore population. The length of the food chain also decreased in the sprayed plots suggesting losses of predators through insect emigration and direct killing action of insecticide. In another study following insecticide application, the total population of herbivores was reduced by 1% while that of predators and parasitoids was reduced by 42 and 37% respectively. Plant hoppers (a rice pest) increased by 23% while spiders decreased by 61% indicating that insecticide spray favours plant hopper development (Heong and Schoenly 1998),

"Twelve percent of pesticides sold world wide are applied to rice crop, and no other single crop accounts for as much pesticide use. Rice farmers will continue to be the target of massive agrichemical industry marketing and promotion that is supported by financial resources dwarfing those of agricultural extension programs" *(Matteson 2000).*

The chemical revolution in agriculture has conditioned farmers to overreact to slight infestations and make routine preventive insecticide applications, especially during the early stages of crop growth. Rice farmers generally overestimate potential losses due to pests by more than 10-fold (Heong and Escalada 1999). Early season sprays are usually directed at leaf feeding insects such as leaf folders, whorl maggots, and thrips that inflict highly visible damage symptoms. Such highly visible damage often does not translate into crop loss due to the ability of the plant to compensate or replace damaged parts (Fabellar et al. 1994).

Successful and sustainable pest management should be devoted to reducing early season insecticide use and any other unnecessary sprays in order to reduce disruptions to natural biological control. It has been demonstrated that eliminating such sprays has no adverse consequence on yield. At the International Rice Research Institute (IRRI) farm, for example insecticide use was reduced by 95% from 3.8 to 0.2 kg active ingredient /ha/yr from 1993 to 2003 with no yield loss (Heong 2005). Pest abundance has also been reduced. In Vietnam a mass media approach to motivate farmers to stop early season spraying resulted in a 53% reduction in insecticide use (Heong et al. 1998) while yield remain the same. This approach subsequently spread to about two million farmers in the Mekong Delta, reducing application by as much as 70% (Huan et al. 1999). A study in the Philippines showed that about 80% of pesticide sprays used by rice farmers' spray were unnecessary (Heong et al. 1995) and this trend is widespread in Asia (Heong and Escalada, 1997a). Hundreds of farmers in the Philippines who participated in farmers' experiments to stop early season spraying reduced insecticide use by 60% (Heong and Escalada 1997b). In a field study in China, Huang et al. (2005) claimed that genetically engineered Bt rice reduced pesticide use. This reduction, however, might not be due to the real effect of Bt rice, but rather to the perception of farmers - farmers perceived that they needed to spray conventional varieties frequently and insect resistant Bt rice occasionally. The Chinese farmers in this study could also have reduced spraying of the conventional varieties without yield loss (Heong et al. 2005).

Another disruptive practice is excessive application of fertiliser, especially nitrogen. Existing fertiliser recommendations for rice often consist of one predetermined rate of nitrogen (N), phosphorus (P), and potassium (K) for vast areas of rice production, which wrongly assume that the need of a rice crop for applied nutrients is constant over time and over large areas. Such recommendation does not take into account the indigenous nutrient supply in the soil which varies greatly. There is thus a tendency to apply less or more fertiliser than what a particular crop actually needs in a given location and growing conditions. Fertiliser application in excess of what the crop actually needs leads to pest and diseases of the rice plant, damage to the environment, and low profit from farming.

The reproductive rates of most pest insects are proportional to the supply of certain amino acids in their diet. Excess nutrient fertiliser increases the supply of these amino acids in plant tissue, consequently increasing the pest eggs hatchability, nymphal survival, female longevity, and number of eggs laid, resulting in a net increase in the ecological fitness of pests (Heong 2005, Matson et al. 1997). The pest population increases too rapidly for natural enemies to control. High N fertiliser also favors the development of rice diseases such as rice blast, sheath blight and bacterial leaf blight.

An emerging system of rice production that integrates the management of plants, soil, water and nutrients, known as SRI, or the System of Rice Intensification is increasingly being adopted, according to reports, in many parts of Asia with astounding success (http://ciifad.cornell.edu/sri/yielduphoffrpt505.pdf). With SRI, seedlings are transplanted young (just 8-12 days old), singly, and at wide spacing (25x25 cm or upto 50x50 cm) to encourage greater root and canopy growth. The soil is kept moist but well-drained and aerated, with enough organic matter to support increased biological activity.

The system requires more labour for weeding (25 – 50%) than the conventional practices since weeds become a problem in unflooded fields. But this is more than offset by the savings in seed (up to 75%), water (up to 50%) and chemical inputs (up to 100%). The reported increases in yield have been variable, depending on soil quality and management skills of farmers, but could go as high as 50 to 100% (http://ciifad.cornell.edu/sri/).

SRI is environmentally-friendly. The plants are usually healthier and do not require pesticide application. In addition, unflooded soil has greater biodiversity and does not produce methane (http://ciifad.cornell.edu/sri/advant.html).

Maintaining a balance of nutrients in the soil is important. The slower release of nutrients from compost and green manures maintains the biological balance in the soil. Low levels of soil nitrates reduce the frequency and severity of pest outbreaks (Matson et al. 1997). Organic matter from compost also provides food for detritus feeding insects, which serves as food for the early establishment of predators during the early stages of crop development.

In the mid 1990's, a site specific nutrient management (SSNM) approach aimed at managing the nutrient requirements to increase mineral fertiliser use efficiency and achieve balanced plant nutrition was developed (Doberman et al. 2004). SSNM approach provides easy-to-follow tools and guidelines for supplying rice with nutrients as and when needed to achieve high yields while optimizing use of nutrients from indigenous sources (Pampolino et al. 2006). The SSNM approach involves three steps (1) establish an attainable yield target (which is location and season-specific depending upon climate, rice cultivar, and crop management), (2) estimate the fertiliser need in relation to the yield target with due consideration of indigenous nutrients from the soil, organic amendments, crop residue, manure, and irrigation water, and (3) apply fertiliser to fill the deficit between crop needs and indigenous supply and to maintain soil fertility.

SSNM has been implemented in Bangladesh, China, India, Indonesia, Myanmar, the Philippines, Thailand, and Vietnam. Field trials in China have shown that effective timing and rates of application of fertiliser resulted in significant grain yield increases over the traditional farmers' practice (Wang et al. 2001). In northern Vietnam, yield increased by as much as 15% during the high-yielding season and by as much as 8% in the low-yielding season, which resulted in a net benefit of US$150 per hectare per year for two crops have been recorded. In Bangladesh, yield increases from improved nitrogen management alone increased

Greenpeace China campaigner with 'Question Mark' sticking from rice seed speaks with local rice farmers about the threat of GE (genetically engineered) rice at the seed fair in Mitian village. Honghe, Yunnan, China. Greenpeace visits rice farmers as part of the 8 day bus tour organised by Greenpeace to highlight the rice culture and diversity in the farming communities of Yunnan province, China. Yunnan is the homeland of rice to the Chinese nation and known as the source of rice culture to the whole world.
© Greenpeace/Novis

net returns by about $50 per hectare per season. Improved nutrient management for rice resulted in more sustainable and environmentally benign cropping systems. The more efficient use of nitrogen fertiliser reduces the emission of greenhouse gases to the atmosphere and reduced the susceptibility of the rice plant to diseases and insect pests, thereby reducing the need for pesticides. (http://www.irri.org/irrc/impact/link%20SSNM%20achievments%20from%20SDC%20report.asp)

In addition to avoiding practices that tend to disrupt the natural balance in the rice ecosystem, enhancing habitat diversity and genetic diversity of varieties planted may also control pest and disease outbreaks. Habitat management is a strategy to conserve natural biological control by improving the availability of non-rice resources for predators. Non-rice habitats and non-crop areas adjacent to the rice field may be important refuges for less mobile predators like the spiders.

Diverse food and weed plants growing on farm margins contribute to the diversity in the agro-ecosystem, which can influence the diversity and abundance of insect herbivores and associated natural enemies in crop systems. Maintenance of undisturbed vegetation on the bunds of irrigated rice fields, and trimming after crop establishment may encourage beneficial species to move into the field, which is likely to enhance natural biological control of rice insect pests (Islam and Heong 1999).

Various kinds of plants e.g. garlic, African marigold, and celosia can expel pest insects. Certain weeds (mostly Umbelliferae, Leguminosae and Compositae) play an important ecological role by harbouring and supporting a complex of beneficial arthropods that aid in suppressing pest populations (Altieri 1999).

Traditional pest control strategies also include direct intervention and deployment of natural predators. In eastern India, traditional farmers often set a few plant wasp nests in the rice farm in order to control pests. Nests of potter wasps and predatory Vespa tropica are placed along the farm on large trees. In Tamil Nadu, India, farmers breed and spread spiders in the rice farm as a form of natural pest control.

Deployment of predatory ants is also a traditional method of pest control (Perfecto and Castiñeiras 1998). Predacious ants are sometimes employed by indigenous farmers of Myanmar and some parts of India to eradicate pest insect eggs and larvae such as the Leaf Folder, Cutworm and Stem Borer. In eastern India, the ant Oecophyla smaragdyna builds their nest by stitching together leaves of dipterocarp trees. Whole nests of this ant are placed in the rice field in anticipation of pest outbreaks.

Integration of fish culture and duck farming in rice cultivation are other examples of diversification that reduces pests.

Box 1. Mixed farming in Iran
In Iran a joint NGO United Nations Development Program project has been working with 26 participating farmers near the Caspian sea to train the local people to seek and use alternative livelihood methods such as mixed farming of paddy and breeding fowls and fish. At the same time organic production and gradual elimination of the use of pesticides by farmers was promoted since chemical pollution of water in paddy farms limits the rearing of fowls as an additional source of food and income In 2005, three years after the project was started the concrete achievements are now evident: crops production in the pilot area rose by 17-25%; pesticide application was 60-80% lower; fertilisers use was cut down by 50% (compost was used as a replacement); and IPM-trained farmers could save an average of $200 per hectare every season while increasing their yields. The farmers all reject the use of GE technology as unnecessary. (http://www.undp.org.ir/reports/IPM.pdf).

19 October 04 - Xin Jie, Yunnan, China - A rice farming family at work at the world famous rice terraces of 'Tigers Mouth' near the small town of Xin Jie, Yunnan, China. The visit to the mountain terraces is part of the 8 day bus tour organised by Greenpeace to highlight the rice culture and diversity in the farming communities of Yunnan province, China. Yunnan is the homeland of rice to the Chinese nation and known as the source of rice culture to the whole world. © Greenpeace/Novis

Box 2. China solution

Blast *(Magnaporthe grisea)* occurs throughout the rice world but is more prevalent in areas with a cool, wet climate. It is a recognized problem in upland ecosystems with low input use and low yield potential, as well as in irrigated rice ecosystems with high input use and high yield potential (Teng 1994). Fertiliser application and high planting density are known to exacerbate the severity of infection. Plant resistance is widely used to control the disease, but varieties often need to be replaced after a few seasons because pathogen populations quickly adopt and overcome the varietal resistance. Experiences in China demonstrated that the disease can be managed effectively through varietal mixtures.

Glutinous rice is highly valued in Yunnan, China, but like many varieties that have been "defeated" by rice blast, it cannot be grown profitably without multiple applications of fungicide. Rice farmers, guided by scientists have successfully controlled rice blast simply by interplanting one row of a susceptible glutinous variety among every four or six rows of the more resistant commercial variety. This simple step towards diversity led to a drastic reduction of rice blast (94 percent) and increase in yield (89 percent) of the susceptible variety. The mixed population also produced 0.5–0.9 tonnes more grains/ha than their corresponding monocultures, indicating high ecological efficiency. By 2001, this practice had spread to over 100 000 ha of rice in Yunnan, and is being tried in other provinces. Varietal diversity creates an entirely different condition that affects host pathogen interaction. First, a disease-resistant rice variety, interplanted with a susceptible variety, can act as a physical barrier to the spread of disease spores. Second, with more than one rice variety, there would also be a more diverse array of pathogen populations, possibly resulting in induced resistance and a complex interaction that prevents the dominance of a single virulent strain of the pathogen. Finally, interplanting changes the microclimate, which may be less favourable to the pathogen (Mundt 1994; Wolfe 2000).

Planting a diverse array of rice varieties to control diseases represents a classic example of an agricultural system that reintegrates the best of traditional agricultural knowledge and new ecological knowledge into the growth process. It's significant that the diversification program described here is taking place in an already highly intensive cropping system with grain yields approaching 10 MT ha-^{1}, which is among the highest in the world. [Zhu et al. 2000)]

Productivity increases attributed to the so-called 'Green Revolution' have been associated with the abandonment of traditional varieties that have been bred over thousands of years. These land races have been a major source of genetic diversity in agriculture, but many have disappeared with the green revolution. Diversifying the varieties planted has somewhat reversed this trend as old varieties that have been 'defeated' by diseases can be brought back into production.

Fish culture in rice fields reduces the use of pesticides and fertiliser. Common carp, catfish, and tilapia are fish species commonly raised in rice fields. Fish are able to reduce populations of rice leafhoppers and rice leaf rollers 2–6 times (Yinhe 1995) as well as rice planthoppers and the yellow stem borer (Fan 1995). Some fish feed on planthopper and leafhopper eggs on the outer leaf surface of the plant.

Releasing domestic ducks in rice paddies for pest control is traditionally practiced in many Asian countries. Ducks are generalist predators, feeding on snails, stem borers, leaffolders, grasshoppers, planthoppers and leafhoppers etc. Ducks have big appetites and could reduce pest populations quickly. In the Philippines ducks are released in irrigated farms to eradicate small snails and insects just before the final stage of land preparation as well as after harvest. In China, ducklings are released into the rice paddies 7 days after transplanting. In addition to controlling pests, ducks have been shown to remove 98.5-99.3% of weeds, including those that are resistant to herbicides. Rice-duck culture also leads to a healthier crop growth. Duck activities in the paddies oxygenate the water and strengthen the roots of rice plants. Ducks provide an acceptable level of stress to the rice seedlings that stimulates the plants to grow stronger and healthier. Duck's excreta then fertilize the soil providing nutrients, thereby saving farmers a lot of chemical fertiliser and pesticide while producing quality rice and meat. Furthermore, by oxygenating the water, ducks in paddy field reduce methane gas emissions.

Susceptibility to diseases is not simply a fixed genetic trait, but is related to growing conditions. In China, it has been convincingly demonstrated that even varieties that are susceptible to diseases could be profitably grown in mixed culture with resistant varieties (Box 2).

People use these bamboo baskets to catch eels, which are a natural environmental indicator since their number would decrease when chemical fertiliser or pesticides use increase. © Greenpeace/Ma Meiyan

Marker assisted selection

Despite the massive genetic erosion caused by the so-called 'Green Revolution' over the past four decades, enormous genetic diversity still exists among Asian rice landraces, which contain a wealth of valuable agronomic traits. These traditional varieties are valuable resources in developing new varieties that respond to specific production problems or conditions. Utilising the valuable genes from the rice genome has become easier with the advent of marker assisted selection (MAS).

"The genetic variety in wild relatives of the world's crop plants is only beginning to be explored. For instance, an estimated 80 percent of the total allelic diversity of rice and tomatoes remains untapped. Because many desirable traits in wild relatives are not expressed visibly in the plant, marker assisted breeding provides a critical tool for exploring the true potential of agriculture." *http://www.aps-pub.com/proceedings/1494/490405.pdf*

Marker assisted selection is a form of biotechnology that does not involve genetic engineering and is already benefiting conventional breeding programs in developing countries.

Marker assisted selection allows the breeder to see more clearly and more quickly what has happened each time plants are crossed. A typical breeding project may work in the following way:

- A crop plant (e.g. rice) is being attacked by a pest, and a wild relative of the crop is found to have resistance to the pest;
- The breeder wishes to transfer the resistance from the wild relative but without disrupting the crop's other traits;
- The crop and the wild relative are crossed, and the progeny are exposed to the pest to isolate the plants that have inherited the resistance;
- These plants will also have inherited many other unwanted traits from the wild parent as well; therefore the breeder crosses the offspring with the crop parent again (this is called backcrossing);
- The pest-resistant offspring are again isolated and again backcrossed.

The strategy is to continue isolating resistant offspring and backcrossing until a plant is achieved that has none of the wild plant's traits except for the desired pest resistance. The process can take a lot of time, especially since it's often necessary to grow each generation to maturity before testing for inheritance of the desired trait.

Such breeding can be greatly accelerated by the use of genetic markers. A marker is usually a distinctive section of DNA located close to the gene of interest. It may occur within the gene itself, in another nearby gene, or in the 'non-coding' DNA between genes. Since the marker is located very close to the gene, it will almost always be inherited along with the gene, and since it's highly recognisable it acts as a red flag indicating the presence of the gene of interest.

Rather than growing a plant to maturity and performing a test on the plant (such as exposing it to an agricultural pest), the breeder can check for the presence of marker in the plant's DNA. Marker assisted selection is the strategy of alternating between biotechnology (to select plants with desired traits) and conventional breeding (to produce each successive generation of plants).

Marker assisted selection is preferable to genetic engineering for a number of reasons:

- MAS allows the more rapid selection of desired traits from natural crosses;
- MAS preserves normal gene order through the use of natural processes;
- MAS allows selection for complex genetic traits such as drought resistance and salt tolerance which are governed by multiple genes that are extremely difficult or currently impossible to achieve through GE;
- MAS does not result in the release of genetically engineered organisms into the environment or food;
- With MAS, much of the early-stage breeding can be done in the lab, saving the time and money required to grow several generations in the field.

Many important plant traits are governed by many genes acting together, each having relatively small effects. These traits – called quantitative traits – include, for example, tolerance to drought and nutrient deficient soils. They have been difficult to understand and manipulate in conventional crop breeding programs and are completely beyond the reach of genetic engineers. These complex networks of genes, however, can now be identified and incorporated into conventional breeding programmes through MAS.

It is critical however, that MAS technology remain in public hands. If the genetic engineering corporations are allowed to own the technology and control or prevent access to its use, then farmers will be held to ransom by an industry dedicated to the extensive use of GE and chemicals. Publicly funded and controlled research and development of MAS varieties is absolutely critical to the effective and equitable use of this biotechnology.

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