RICE

GENETICALLY ENGINEERED RICE
- NOT SUSTAINABLE AGRICULTURE

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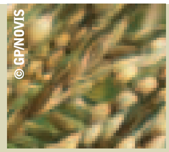

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introduction

The genetic industry is trying to commercialise genetically engineered (GE, sometimes called genetically modified, GM, or transgenic) rice because they believe GE rice will open the Asian engineering market to other GE crops (Brookes and Barfoot 2003). In the near future, herbicide-tolerant, insect and blight resistant GE rice could be commercialised.

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i GE VARIETIES OF RICE UNDER DEVELOPMENT

There is a great deal of active research on GE rice (see Box 1). Most of these varieties are only at the earliest stages of development. For example, "Golden rice," genetically engineered to produce pro-vitamin A (beta-carotene), is still at the "proof of concept" stage (Coffman *et al.* 2004). Two GE varieties that are tolerant to herbicides, however, could be commercialised in the near future. Monsanto is developing GE glyphosate (Roundup) tolerant rice and the pharmaceutical and agro-chemical giant, Bayer, has developed GE ammonium glufosinate (Liberty or Basta) tolerant rice, or LibertyLink rice. LibertyLink rice can be grown and sold in the US but is not commercially grown, presumably because of concerns regarding exports. Bayer has initiated an application for marketing GE LibertyLink rice as food and feed in the EU (EC Joint Research Centre 2003/4).

BOX 1: GENETICALLY ENGINEERED RICE VARIETIES IN DEVELOPMENT

traits projected to be commercially available by 2005

Glyphosate tolerance
Glufosinate tolerance
Resistance to bacterial blight (Xa21 gene)
Resistance to stem-borers (Bt genes)

traits projected to be commercially available after 2009

Virus resistance
Blast and sheath blight resistance (chitinase, PR5)
Resistance to other insects such as brown plant hopper (protease inhibitors, lectins)
Biofortification – beta-carotene, iron bioavailability, zinc
Abiotic stresses – drought and salt tolerance, submergence
Yield

source: Brookes and Barfoot (2003); Khush and Brar (no date).

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GE rice varieties that are toxic to certain insects are also being developed. These most often contain the *Bacillus thuringiensis* (*Bt*) endotoxin gene, which is also used in GE *Bt* corn and cotton. The principal target pest for *Bt* rice is the yellow stem borer (*Scirpophaga incertulas*). Other GE varieties that are being developed include: GE rice resistant to other major pests (such as brown planthopper); GE rice resistant to pathogens (bacterial blight, rice blast); biofortified rice (beta-carotene, iron and zinc); and rice resistance to abiotic stresses (drought, salinity, submergence) (Sharma *et al.* 2003; Jia 2004). Researchers are also pyramiding (or stacking) multiple GE genes into rice, trying to make GE rice that is resistant to multiple insects, or both disease and insect-resistant (Jiang *et al.* 2004; Maqbool *et al.* 2001).

The International Service for the Acquisition of Agri-biotech Applications (ISAAA) estimates that most of these traits will only be available for commercial use in five to eight years. The only applications predicted to be commercially available in the short term are herbicide tolerant varieties, *Bt* rice, and rice resistant to bacterial leaf blight (Brookes and Barfoot 2003).

ii THE ENVIRONMENTAL AND ECONOMIC COSTS OF GE HERBICIDE-TOLERANT CROPS

There are now eight years of experience with the commercial growing of GE crops in the USA. "Roundup Ready" soybeans were introduced in the mid-1990s; proponents claimed pesticide use would fall and the environment would benefit. Recent data, however, proves otherwise.

Pesticide use in the USA has increased overall with GE crops (Benbrook 2003). Whilst there has been a reduction in insecticide use in the USA on *Bt* crops, this is small in magnitude compared to the vast increase in herbicide use and does not include the amount of insecticide produced by the GE *Bt* plants (Benbrook 2003). Herbicide usage has increased in the USA for several reasons, but primarily because several weeds are becoming tolerant to the herbicides used with herbicide-tolerant crops, notably glyphosate, the active ingredient in Roundup, used with Roundup Ready crops (Benbrook 2003). There have been numerous reports from across the USA of new glyphosate tolerant weeds developing in GE crop fields (ISHRW 2004). Glyphosate tolerant weeds are now also being found in Argentina, Chile, Malaysia, Australia and South Africa (ISHRW 2004; Branford 2004). Feral stands of oilseed rape in Canada are found to be resistant to three different herbicides, contaminated by two GE herbicide tolerant varieties (Hall *et al.* 2000). These oilseed rape plants have to be controlled with alternative herbicides, such as the notorious 2,4-D (Orson 2002). Hence, the cultivation of GE herbicide tolerant crops leads to increased usage of herbicides and ultimately, to the use of more aggressive herbicides.

The increase in herbicide usage is highly likely to lead to decreases in wild plant abundance and diversity with damaging consequences for insects, birds, mammals and even humans that depend on those plants and associated food webs. Importantly, increased herbicide use also has cost implications for farmers. Herbicide tolerant crops, including GE herbicide tolerant rice, pose serious threats to the environment. In the long-term, herbicide resistant weeds will make GE herbicide tolerant crops a problem for farmers as well.

iii THE ENVIRONMENTAL AND ECONOMIC DANGERS OF GE INSECT RESISTANT AND OTHER GE PEST RESISTANT CROPS

There has been a lot of controversy regarding the impact of GE insect resistant *Bt* crops (e.g., *Bt* maize) on the environment, as well as the long-term economics of GE *Bt* crops. These controversies will also apply to GE insect resistant and other GE pest (e.g., bacteria, viruses) resistant rice. GE insect resistant and other GE pest resistant rice could cause considerable harm to ecosystems, including agro-ecosystems, by harming non-target species and further endangering wild rice populations. GE insect and pest resistant rice will create additional economic costs through the evolution of pest resistance to GE rice and the creation of more aggressive weeds.

non-target species may be harmed

GE crops that produce *Bt* protein are intentionally toxic to certain organisms. Other GE varieties may be unintentionally toxic. In either situation, important organisms such as natural enemies of pests or soil organisms could be harmed by exposure to GE organisms.

There has been a lot of controversy surrounding the potential impacts of some varieties of GE *Bt* maize on the iconic monarch butterfly in the USA. Of course, there are also less photogenic but more ecologically significant insects that could be affected by GE *Bt* crops in the USA and elsewhere in the world, including by *Bt* rice. However, hardly any studies on potential *Bt* toxicity from GE plants have been conducted in rice growing areas. Many regions where rice is grown are tropical or sub tropical and these tend to

be rich in biological diversity. In highly biodiverse areas, it may not be possible to test even a fraction of the insect species that may be threatened by *Bt* toxicity because there are so many species that may be at risk – some may not even have been identified yet. Recent evidence from China demonstrates that GE *Bt* rice pollen found in sufficient quantities on mulberry trees, poses a hazard to silkworms (Fan *et al.* 2003). Such findings should be cause for serious concern.

Ecosystems are complex and poorly understood. Impacts on one insect could have significant effects elsewhere in the ecosystem (Snow *et al.* 2004; Knols and Dicke 2003).

"Negative non-target effects on one species or a group of species may cause a cascade of ecological changes that result in the disruption of biotic communities or in the loss of species diversity or genetic diversity within species." **(Snow *et al.* 2004)**

The GE *Bt* toxin is persistent. It is known to remain for nearly a year in some soils (Stotzky 2002; Saxena *et al.* 2002; Zwahlen *et al.* 2003). It is not known what the short or long-term effects of the persistence of *Bt* produced by GE *Bt* plants could be: for example, will it accumulate in the field under certain conditions and reach highly toxic concentrations? GE *Bt* rice will raise the same questions that currently puzzle ecological scientists regarding the effects and impacts of GE crops on non-target species and ecosystem soil health.

pests can evolve to overcome GE insect resistant crops

Many of the GE varieties of rice under development confer resistance to some type of plant pest or pathogen, whether insects, weeds, fungi, viruses or bacteria. Past experience (see, for example, Hillier and Birch 2002) in chemical control of organisms would indicate that insects, weeds, or pathogens will also eventually develop resistance to GE varieties of rice: for example, the yellow stem borer developing resistance to GE *Bt* rice. Resistance development will bring about a range of consequences – from ecological impacts to economic losses.

"It is widely assumed that resistance to transgenic Bt crops will occur … Loss of Bt-based controls because of the evolution of resistance would probably increase use of insecticides that are more harmful to the environment or human health in some crops."
(Ecological Society of America, Snow *et al.* 2004)

In the United States, the Environmental Protection Agency (EPA) has complex requirements for planting of GE *Bt* refugia (areas of non *Bt* corn) to slow down the build up of insect resistance (USEPA 2001). However, there have been concerns that these requirements may not be enough (Knight 2003). In addition, refugia may not be practical on small farm holdings in Asia and elsewhere, which are very different to the large acreages planted in the USA, a problem identified with *Bt* cotton in India (Jayaraman 2002).

Evolution of resistance to *Bt* in insects means that the GE *Bt* crop will stop being effective at controlling the insect pest and the GE crop will eventually require increased insecticides. Who will pay the price when these GE products fail? Unfortunately it will be farmers and the environment.

more aggressive weeds can be created

Outcrossing has been shown to occur between rice and wild and weedy relatives (e.g., Langevin *et al.* 1990; Lu *et al.* 2003; Gealy *et al.* 2003; Chen *et al.* 2004; Messeguer *et al.* 2004; Song *et al.* 2003). Some varieties of GE rice, for example, insect resistant (*Bt*) or virus resistant rice, may have a fitness benefit compared to non-GE rice. If these GE varieties outcross with wild or weedy rice, they could create wild or weedy relatives with increased ecological fitness that then become more abundant and aggressive.

"If the transgenes are responsible for resistance to biotic and abiotic stresses (such as disease and insect resistance, drought and salt tolerance, and herbicide resistance) that can significantly enhance the ecological fitness of weedy and wild populations, the escape of these transgenes will probably cause ecological problems, e.g., producing aggressive weeds. Such weeds might get out of human control, and result in unpredictable damage to local ecosystems." **(Chen *et al.* 2004).**

wild rice populations and crop genetic diversity could be further endangered

GE rice could have an impact on populations of the wild ancestor of rice, Oryza rufipogon, which is an endangered species in China (Gao 2004). This could happen either by swamping of populations by GE contaminated rice with an ecological advantage (for example, GE *Bt* rice) or by integration of a gene that ultimately proves detrimental to the wild rice. According to Chen *et al.* (2004): ***"When transgenes escape to and***

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persist in populations of wild relative species, the fast dissemination of the transgenic hybrid individuals might contaminate the original wild populations. Sometimes, the aggressive spreading of hybrids with better ecological fitness could even lead to the extinction of endangered wild species populations in local ecosystems."

As with all GE crops, there is a serious threat to crop diversity. Crop genetic diversity is important for food security. For example, if a disease sweeps through the rice population worldwide, locally bred traditional varieties could be of great importance to breed or locate resistant varieties. If GE rice were responsible for the extinction of traditional varieties, rice consumers all over the world would suffer the consequences. Therefore, the importance of GE contamination of centres of origin or diversity for crops cannot be underestimated.

"Transgene escape from cultivated rice varieties to their weedy and wild relatives through gene flow has become an indisputable fact. There is, therefore, an urgent need for a thorough assessment of the ecological consequences of transgene escape, including such aspects as the ecological fitness of the hybrids and progeny of cultivated and wild rice, the density and establishment of escaped genes in wild populations, and their impact on general biodiversity." **(Chen et al. 2004)**

iv IRREVERSIBLE DAMAGE TO CROP DIVERSITY – LESSONS FROM MEXICO

Gene flow from GE plants could affect the genetic diversity of traditional locally bred varieties or landraces of crop plants. One of the worst-case scenarios of genetic engineering contamination is already happening in Mexico, where local varieties of a major food crop, maize, have become contaminated with GE maize (Quist and Chapela 2001; CEC 2004). There are many parallels and similarities between the Mexico GE maize contamination case and the possible GE contamination of rice in Asia if GE rice is commercialised.

"These issues that have emerged for maize in Mexico are likely to be relevant to other countries and food crops, including rice."
Bellon and Berthaud (2004)

Mexico is a centre of origin and diversity for maize. Maize was first domesticated in Mexico and many locally bred varieties are grown. Similarly, rice was domesticated in Asia and many locally bred traditional varieties of rice are grown across Asia. Just as Mexico is a centre of origin and diversity for maize, so is Asia a centre of origin and diversity for rice.

Mexico has a complete prohibition on the planting of GE maize in place because of the concerns about the danger GE maize poses to the maize centre of diversity. Despite this prohibition, GE maize has been found contaminating traditional farmer varieties of maize. The contamination probably occurred originally because GE maize imported from the USA for food and animal feed was unwittingly planted by farmers (Quist and Chapela 2001; CEC 2004). Growing the GE maize has now resulted in contamination of local traditional varieties through cross-pollination. This GE contamination will be extremely difficult, or maybe impossible, to eliminate.

GE contamination of traditional varieties poses a particular threat to community seed supply systems. It is a traditional practice for farmers in Mexico to save seed from one harvest to the next sowing and seed exchange between farmers is common (in contrast to the hybrid system where seed is brought from a seed merchant each year). As the GE contamination case in Mexico has shown, once contaminated, farmers will inadvertently exchange GE contaminated seeds, which will enter supplies of saved seed. The tradition of locally bred varieties and seed exchange is very similar for rice in parts of Asia. Similar to Mexico, if GE rice is commercialised and traditional varieties of rice become GE contaminated, the contamination will be very difficult to eradicate and will persist and spread through traditional practices.

"Given that farmers' practices in some traditional rice systems encourage gene flow between different types of rice, it is very likely that if these farmers plant transgenic [GE] rice, some gene flow to other varieties and species can be expected." **Bellon and Berthaud (2004)**

conclusion

GE rice is not sustainable agriculture. The evidence demonstrates that GE crops cause harm to the environment and GE rice could prove costly for farmers. GE rice threatens the endangered populations of wild rice in Asia and could cause long-term damage to rice diversity upon which rice consumers all over the world depend. **Therefore, GE rice should not be commercialised and all field trials should be discontinued.**

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