BRIEFING PAPER ON HERBICIDE TOLERANT GM CROPS (India)[1]

HT GM CROPS IN THE PIPELINE IN INDIA

- MONSANTO'S (Mahyco-Monsanto Biotech) ROUNDUP READY FLEX COTTON
- DOW AGRO SCIENCES' WIDESTRIKE GM COTTON
- MONSANTO'S GM CORN (HT BT CORN)
- PIONEER OVERSEAS GM MAIZE
- BAYER'S GLYTOL GM COTTON

In India, several herbicide-tolerant transgenic crops (referred to as HT GM crops) are in various stages of trials (box). In a context where HT GM crops occupy more than 83% of the total GM crops planted in the world (industry data, 2010) including 21% planted under stacked traits (herbicide tolerance coupled with other trait/s) and at a time when there is a push to commercialise HT GM crops in India, it is important to understand the implications of this product for India's people and environment. This Briefing Paper is being written at a time when illegal HT Bt cotton has already begun spreading into several cotton-growing belts of India (Minutes of Genetic Engineering Approval Committee meetings – GEAC – India's apex regulatory body from the 98th meeting, confirming that samples from Andhra Pradesh, Madhya Pradesh and Gujarat have tested positive for this as-yet-unapproved GM cotton).

What are herbicides?: Herbicides are chemicals which are used to kill unwanted plants or 'weeds'. Many of these act by interfering with the natural growth of plants considered 'weeds', by imitating plant hormones. There are different modes of action by which herbicides end up controlling or killing a plant – excessive oxidation, chemicals that act on the cell membrane, that mimic plant growth regulators like auxin, inhibition of DNA synthesis and synthesis of some amino acids etc., are some of the modes of action of these chemicals called herbicides. Herbicides are broadly classified under Pesticides and like other pesticides can be either contact poisons or systemic poisons. While some of them have broad spectrum action, others work on specific plants (monocots etc.). However, most end up impacting environmental resources and living organisms other than the intended ones.

In countries like the USA (where only around 1% of the population is engaged in farming), herbicides constitute about 70% of all pesticides used in farming; worldwide, herbicides constitute 48.7% of the world pesticides market, followed by insecticides (24.3%), fungicides (23.6%) and others (3.5%). In India, insecticides continue to be the largest used pesticides in agriculture, with 20% of the pesticides being herbicides/weedicides (ICRA, 2008). Informal reports indicate that the use of herbicides is rapidly on the rise.

The most commonly-used herbicides include: 2,4-D, atrazine, glyphosate, glufosinate ammonium, paraquat, pendimethalin, dicamba, fluroxypyr, metalochlor etc. In India, Isoproturon, butachlor, fluchloralin, paraquat etc., are the most consumed herbicides. Glyphosate, especially under the brand name of Roundup from Monsanto is touted to be the widest-selling herbicide especially in a country like the USA. It is a broad spectrum, non-selective, systemic herbicide. Some reports suggest that glyphosate products constitute 60% of the world's non-selective herbicides market.

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This paper will focus more on glyphosate amongst the various herbicides and glyphosate-resistant GM crops (brand name: Roundup Ready) given that they constitute the highest share of GM crops cultivated.

What are herbicide-tolerant genetically modified (HT GM) crops?:
Since herbicides end up affecting the main crop to be harvested in a field (apart from other unintended impacts of course), the technology of genetic engineering has been deployed to create herbicide-tolerant GM crops, which will allow farmers to spray herbicides, usually the broad spectrum kind, on a standing crop (unlike pre-emergent herbicides etc.) and destroy weeds. It has to be noted that this technology is of herbicide-tolerance and not herbicide-resistance, which means that the HT GM plant develops the capability of withstanding/assimilating the herbicide without getting destroyed. For instance, in Roundup Ready GM crops (the brand name for Monsanto's trait of herbicide tolerance, for a plant to withstand Monsanto's brand of glyphosate), a gene from an agrobacterium strain CP4 (CP4 EPSPS), that is resistant to glyphosate is inserted. This gene encodes for a version of an enzyme called EPSPS that is highly tolerant to inhibition by glyphosate, which in turn works by specifically binding to and inactivating EPSPS enzyme (this enzyme is important in the biosynthesis of certain aromatic aminoe acids which are essential for a plant's survival).

The biotechnology industry, which incidentally has a handful of players that are both into trait/seed and agro-chemical businesses, claims that use of herbicide tolerant GM crops would reduce the overall chemical use in agriculture and would particularly decrease the use of the older generation, 'more toxic' herbicides. In regions where de-weeding by other methods (preventive, mechanical and cultural practices) is somewhat difficult, including because of non-availability of farm labour and livestock, the uptake of herbicide tolerant crops has been seen to be quite high (referred to sometimes as the 'convenience effect').

However, the implications of this technology in other situations - where the use of "weeds" for food and fodder is not unknown, where labour and livestock availability for manual and mechanical weed control is high and in fact, agri-work force derives the largest number of employment days from the de-weeding operation, where injudicious chemical usage is potentially high and where official regulation of either the GM technology or chemical usage is lax – should be well assessed before deploying the technology. This Briefing Paper, based on such reasoning proffers a word of caution and precaution both on herbicides as well as herbicide-tolerant GM technology.

It is to be noted that 97% of edible cultivated GMOs among cultivated ones are grown in South and North America. All these plants have been modified to tolerate (herbicide tolerance) and/or produce one or more pesticides (insect resistance).

Most GM cultivation in the world is under HT crop (62% as HT trait and 21% as stacked); within this, HT soybean occupies nearly 52% of the total biotech crop extent (69.2 mn hectares out of 134 mn hectares, as claimed by industry figures); biotech maize, which is also herbicide-tolerant is at 31% and HT canola at 5%. It is important to note that most of this HT trait is incorporated into Monsanto's proprietary seed, sold under the brand name of Roundup Ready GM crops. 90% of American soybean acres and 80% of US corn acres are reported to be planted with Monsanto's proprietary GE traits.

Any environmental concerns with herbicides and HT GM crops?[1]: A briefing paper by Friends of the Earth (FoE, 2004) points out that impacts include loss of farmland biodiversity, increased herbicide residues in food and animal feed and water courses, spread of herbicide tolerant genes to related weed species and neighboring crops, weeds developing resistance to the herbicide etc[2].

Herbicides are known to create resistance in weeds (against those chemicals) since there is a selection pressure put on these plants. Herbicide tolerant GM crops seem to exacerbate the problem. It has been found that weed resistance is now reported from more than fifteen million acres in the USA. Further, while two decades of herbicide usage did not create as many resistant weeds, in the decade of herbicide-tolerant GM crops expanding, 30 new glyphosate-resistant weeds have emerged.

One of the main problems as some researchers have found with the advent of HT GM crops is the over-simplification of weed control which has led to use of a single herbicide like glyphosate by growers at escalated levels of active ingredient and for multiple times during the crop season without worrying about effects on the crop. Studies show that the number of active ingredients used on at least 10% of treated soybean hectares has declined from 11 in 1995 to only one (glyphosate) in 2002.[3] Glyphosate use increased from less than five million to more than 50 million pounds per year (USDA, 2003)[4].

Herbicides like glyphosate do have non-target effects including on other organisms. Some of the unintended effects include inhibition of non-target enzymes resulting in iron deficiencies in some cropping systems. It has been observed that herbicides like glyphosate can reduce winter hardiness in trees and their resistance to fungal diseases; similarly, clover planted 120 days following herbicide treatment showed reduced nitrogen fixation and growth. The US EPA has also stated that many endangered plants may be at risk from glyphosate use. Widespread use of these chemicals leads to habitat loss for some organisms, predictably, including birds and amphibians.

Glyphosate is extremely toxic to the soil life. One application can cause a dramatic plunge in the number of beneficial soil microorganisms and arthropods. Studies show a reduction in the species that build humus, thus it contributes to the decline in soil organic matter. Reported soil half-life (lives) for glyphosate ranged from days to months and were in part dependent on the level of soil microbial activity[5]. In soil, glyphosate has a half life of between 3 and 215 days, depending on soil conditions and temperature while in water, it is 35-63 days.

Glyphosate exposure damages or reduces the populations of earthworms. A New Zealand study showed that 5% of the usual application rate caused delayed development and increased death in earthworms.

Glyphosate significantly reduces the activity of nitrogen-fixing bacteria. These bacteria transform soil nitrogen into forms that plants can use. Studies of Soybeans grown for nitrogen fixation showed a reduction in the number of rhizobium bacteria and the nitrogen they produce when Glyphosate was used for weed control.

Other studies show that Glyphosate herbicides increase the susceptibility of plants to (more than 40) diseases. This is partly because glyphosate reduces the growth of

mycorrhizal fungi and other beneficial fungi that help plants absorb nutrients and help fight disease. Plants suffer more disease, as there is an increase in the soil pathogens and a decrease in beneficial species that control diseases after an application of glyphosate.

The advent of HT GM crops has increased the use of herbicides like glyphosate in particular and this has led to documented weed shifts and weed resistance (referred to as "super weeds") in USA, Argentina, Australia, Brazil etc.

HT GM crops have increased herbicide use by a total of 382.6 million pounds over 13 years swamping a modest 64.2 million pound reduction in chemical insecticide use attributed to Bt crops in the USA. From 2007 to 2008, herbicide use on GM herbicide tolerant crops rose 31.4% and these two crop years accounted for 46% increase in herbicide use over 13 years[6]. It has been seen that overall chemical use has increased along with per unit land chemical use and number of times of application. Reports suggest that the GM RR soy model in South America has led to deforestation, loss of soil fertility, increased dependency on chemical fertilizers, erosion of soils and potential desertification in addition to environmental health impacts being witnessed. A study of the nutrients in Argentinian soils predicts that they will be totally consumed in 50 years at the current rate of nutrient depletion and increase in soybean area.

The UK government's farm scale evaluation of GM crops for 3 years showed that the cultivation of HT GM crops damaged biodiversity (the range of vegetation growing in the trial fields and on their margins was assessed in addition to measuring the abundance of animal life. It was found that there were also fewer weed species and weed seeds to provide food for wildlife.

While the current destruction of Amazonian rainforest areas cannot be classified as a direct consequence of herbicide tolerant GM crops, in countries like Argentina, there has been a massive shift in land use after the entry of herbicide tolerant soy, with large landholdings now being put to such GM crop cultivation meant mostly for exports, making inroads into pristine rainforest. By 2009, expanding rapidly, over half of the Argentinian cultivated land came under GM soy cultivation. Where 6.2 mn hectares were planted to soy in Argentina in 1997, the area expanded to 19 million hectares in 2009, and transgenic soy was 98.9% by 2009[7].

There is also the issue of genetic contamination from these GM crops to other wild plants and non-GM plants. A genetically modified (GM) crop – GM Canola - has been found thriving in the wild for the first time in the United States last year by a team of scientists led by Cynthia Sagers of University of Arkansas. Sagers and her team found two varieties of transgenic canola in the wild — one modified to be resistant to Monsanto's Roundup herbicide (glyphosate), and one resistant to Bayer Crop Science's Liberty herbicide (gluphosinate). They also found some plants that were resistant to both herbicides, showing that the different GM plants had bred to produce a plant with a new trait that did not exist anywhere else. What's worth noting is that many samples were often at large distances from areas of agricultural production[8]. Such contamination has been reported in many other instances too.

Any health concerns with herbicides and HT GM crops?: Different health effects of herbicides and HT GM crops have been documented through many scientific studies. The risk of Parkinson's Disease has been shown to increase with

occupational exposure to herbicides and pesticides and the herbicide paraquat is suspected to be one environmental factor causing Parkinson's disease[9].

In the USA, in California, glyphosate is one of the most commonly reported causes of illness or injury to workers from pesticides[10]. Studies show that glyphosate can cause some chronic health effects including birth defects. Some feeding studies have shown reduced weight gain, blood and pancreatic effects. A Swedish scientific team showed through an epidemiological study that exposure to glyphosate is a risk factor for developing Non-Hodgkin lymphoma[11]. Another study showed alterations in estrogen-regulated genes after exposure to diluted concentrations of glyphosate[12].

Research from Ontario, Canada found that a father's exposure to Glyphosate was linked to an increase in miscarriages and premature births in farm families. Glyphosate caused a decrease in the sperm count of rats and an increase in abnormal and dead sperms in rabbits. Pregnant rabbits exposed to Glyphosate had a decrease in the weight of their babies[13].

Glyphosate and Roundup formulations have been found in studies to be endocrine disruptors (interfering with functioning of hormones) and to be toxic and lethal to human cells; in animals, they disturb hormone and enzyme function, impede development and cause birth defects. Glyphosate affects the levels and functioning of multiple liver and intestinal enzymes in rats and is toxic to female rats, causing skeletal malformations in their fetuses.

It has been reported that while the active ingredient of glyphosate might be relatively non-toxic, the formulations are toxic in several ways.

What is important to note in the case of HT GM crops is the potential synergistic effects – the herbicide's active ingredient, the unknown adjuvants in the formulations and the metabolites (like 'POEA', one of the most prevalent pollutants found in water bodies around the world, which has been implicated in ocular burns, redness, swelling, blisters, nausea and diarrhoea) and the genetic engineering individually as well as together could lead to potential health hazards and there are obviously no studies designed for such synergistic effects, showcasing our inability to even ask the right research questions when it comes to biosafety assessments. On top of this, given that resistance is building up to glyphosate with HT GM crops, farmers are being advised to use increasingly potent mixtures of herbicides.

When it comes to transgenic crops, the transformation process is imprecise and can cause widespread mutations, resulting in potentially major changes to the plant's DNA blueprint. These mutations can directly or indirectly disrupt the functioning and regulation not just of one or even of several but of hundreds of genes, leading to unpredictable and potentially harmful effects. A study comparing Monsanto's GM Bt maize with non-GM equivalent varieties found unintended changes resulting from the GE process. The study found that GM seeds responded differently to the same environment as compared to their non-GM equivalents as a result of the genome re-arrangement derived from gene insertion. Significant cellular changes were seen in the liver, pancreas and testes in a rare long-term feeding study where mice were fed GM soy for 24 months[14]. In another study, mice fed GM soy over their entire lifetime showed more acute signs of ageing in their liver[15]. Rabbits fed GM soy showed enzyme function disturbances in kidney and heart[16].

Some scientists tried to assess the level of necrosis (cell death due to injury, disease or lack of blood supply) and apotosis (programmed cell death) due to exposure to various dilutions of Roundup products and the active ingredient, the metabolite, the formulant etc.[17] They found that cellular death was caused within 24 hours for all types of cells tested for. The scientists concluded that 'it is very clear that if glyphosate or its formulant or metabolite has a small toxic effect on embryonic cells alone at low levels, the combination of two of them at the same final concentration is significantly deleterious'. The findings are noteworthy since the metabolite is more stable and present at more levels in soil, plants, food and water compared to the active ingredient. It should also be noted that in regulatory regimes, no MRL has been set for glyphosate's main metabolite – AMPA, which has been found in soybeans at high levels of up to 25 mg/kg. Recent research testing the effects of Roundup formulations found that both AMPA and an adjuvant called OPEA kill human cells at extremely low concentrations while another study found that AMPA causes DNA damage in cells.

It has also been found recently (Carrasco et al, 2010) that glyphosate, the main active ingredient of Monsanto's Roundup causes malformations in frog and chicken embryos at doses far lower than those used in agricultural spraying and well below maximum residue levels in products approved by EU, for instance[18]. This group of scientists took up such research after reports of high rates of birth defects in rural areas of Argentina where planting of RR soy in large monocultures led to higher use of the herbicide. The study, referring to 'women exposed during pregnancy to herbicides delivered offspring with congenital malformations including microcephaly, anencephaly and cranial malformations' concludes that the 'direct effect of glyphosate on early mechanisms of morphogenesis in vertebrate embryos opens concerns about clinical findings from human offspring in populations exposed to glyphosate-based herbicides in agricultural fields'.

When it comes to herbicide use connected to HT GM crops, in April 2010, a report by a Commission set up by the provincial government of Chaco in Argentina analysed health statistics in the town of La Leonesa and other areas where soy and rice crops are heavily sprayed. It was reported that the childhoold cancer rate tripled from 2000 to 2009 and the rate of birth defects increased nearly 4-fold over the entire state of Chaco.

It is a point of concern that Maximum Residue Limits (MRLs) of glyphosate are being revised upwards in the case of GM crops by various regulatory and international bodies (by 200 times in some instances). In India, glyphosate is registered for use in tea plantations (the Central Insecticides Board and Registration Committee website says so; however, there is no regulatory oversight on the ground for actual use or even recommendations); a notification by the Ministry of Health (GSR No. 517(E) dated 10/8/2004), prescribing limits of Pesticide Residues in Food Articles, prescribes 1.0 mg/gm as the residue for glyphosate in tea.

Any impacts on yields? GM crops are often hyped up as resulting in higher yields though there have been no technological breakthroughs on the transgenic technology front with any intrinsic potential to increase yields. A review of over 8200 university-based soybean varietal trials found a yield drag of between 6 to 10 percent from GM RR soy compared with non-GM soy. Controlled comparative field trials suggest that half the drop in yield is due to the disruptive effect of the GM transformation process.

A report called "Failure to Yield", released last year, after analyzing data from more than 20 years of research and 13 years of commercialization of GM crops in the United States, concluded that GE has done It is found that compared to non-GE yields, overall or aggregate yield effect of GE has done little to increase overall crop yields[19]. Most of the yield gains in USA are found to be due to traditional breeding or improvement of other agricultural practices.

On HT soy and HT corn, the report had this to say: "Although not extensive enough to develop precise yield estimates, the best data show that transgenic herbicide tolerant soybeans and corn have not increased operational yields, whether on a per-acre or national basis, compared to conventional methods that rely on other available herbicides. The fact that HT soybeans have been so widely adopted suggests that factors such a lower energy costs and convenience of GE soybeans also influence farmer choices.

Claims of higher yields from Monsanto's new generation of RR soybeans (RR2 Yield) have not been borne out either. A study in 5 US states of experience of farm managers who planted RR 2 soy in 2009 concluded that the new varieties did not meet the yield expectations.

USDA confirms mixed performance of GM crops saying "GE crops available for commercial use do not increase the yield potential of a variety. IN fact, yield may even decrease….Perhaps the biggest issue raised by these results is how to explain the rapid adoption of GE crops when farm financial impacts appear to be mixed or even negative".

Explanations for the lowered yields of RR soy range from the GE process altering the plant's physiology leading to less effective nutrient uptake; to the use of glyphosate on these HT GM crops being responsible for the reduction in nutrient uptake in plants and for making them more susceptible to diseases; to the additional energy consumption by the HT GM plant to resist glyphosate leaving it with lesser energy for grain formation and maturity.

Any socio-economic implications?:

Exorbitant Seed Prices: There are genuine concerns over the near-monopolistic control of the seed supply in many countries by GM companies. In the United States, this has led to large increases in GM RR soy seed costs – as much as 230 per cent in 2009 over 2000 levels – undermining the economic sustainability of soy farming.

The story is similar in the case of conventional and GE corn seed. In 2009, the GE corn to conventional corn seed premium was 69%, with GE seeds costing $235 per unit. Conventional corn seed prices were less than $100 per unit through 2007. Corn growers planting the first-ever, eight-trait stacked GE variety of corn (called "SmartStax" corn) will pay 2.1-times more per unit than farmers planting conventional seeds and almost four times more than conventional farmers just ten years back[20].

This is an area of immediate concern here in India too, given that the Union Government in India is refusing to include price control under regulation of the seed sector in a new statutory regime being envisaged (called the Seeds Bill 2010) and at

a time when seed prices are already sky-rocketing, as seed technologies move into the hybrid and GM era in several crops. The Bt Cotton seed price controversy in India, played out also in front of the Monopolies & Restrictive Trade Practices Commission had a well-argued case against the exorbitant seed and royalty prices being levied.

IPRs and Royalties: Transgenic technology is closely inter-linked with rigid IPRs. Companies like Monsanto have become trait sellers in a new hierarchy developing in the seed industry through which royalty income is being amassed. To control royalties, Monsanto went to the extent of filing lawsuits against European soy importers in the Netherlands and Denmark, accusing them of illegally importing soy meal from its patented GM soybeans from Argentina. This was done after such a royalties regime was not heeded to by planters there nor supported by statute. However, the European Court of Justice ruled against the company in these lawsuits.

Rural Employment: In India, the largest employment that poor rural workers find is through the manual de-weeding operation. It is incongruous on the part of the State that on the one hand, tens of thousands of crorers of financial outlays are invested in propping up and enhancing rural employment through NREGS (National Rural Employment Guarantee Scheme) while on the other hand, agricultural technologies like herbicides and herbicide-tolerant crops are allowed to proliferate, destroying existing employment opportunities. Given the socio-economic concerns with regard to herbicides and HT GM crops in India, the Task Force on Agricultural Biotechnology set up by the Government of India and headed by Dr M S Swaminathan, made the following recommendation: "Such areas of biotechnological applications, which can reduce employment and impinge on the livelihood of rural families, should be avoided. Breeding for herbicide tolerance, for example, may have low priority on this account in several parts of India where there are large numbers of landless labour families".

Farmers' access to non-GM seeds impacted: It is being reported from various places and has been experienced in India too with regard to cotton seed, that entry of GM seed has meant a rapid erosion of choices for farmers and non-GM seed is made unavailable by numerous methods. HT GM seeds will be no different; as it is, in crops like Maize (the most advanced in the HT GM crops pipeline is Monsanto's HT Bt maize), Monsanto (which has been recorded as monopolistic in its behaviour in India and being investigated for its anti-competition behaviour in the USA) has a control over the majority of the hybrid seed segment already and this is a further cause of concern in case GM maize is approved. In Brazil, it is reported that Monsanto is imposing quotas on seed dealers which require them to sell not more than 15% non-GM soy seed. All of this is bound to lead to lesser seed choices for farmers.

Research restrictions: IPRs, which are closely linked to modern biotechnology – its processes and products – are being used by seed companies to direct research in specific directions and to ensure research that would suit their interests. Independent research is stifled by this and Indian scientists are yet to acknowledge the pitfalls that potentially lie in store on this front.

Are there no alternative options?: There is much documentation available on the food and fodder value (in addition to biomass value for bio-fertilisation of land) of plants that are considered "weeds" and how these uncultivated foods are a great source of nutrition for the poorest in many countries. Therefore, it appears that

our very understanding of "weeds" has to change from that of destroying them with chemicals to controlling them in farming through a variety of means which enhance livelihoods of the poorest. In countries like India, where rural labour availability is not a problem at all, it makes immense sense to emphasise on labour intensive practices, to ensure that they get adequate employment, coupled with decent living wages paid to them, in turn supported by remunerative prices for farmers. Civil society groups are also coming up with newer proposals to the government for subsidizing labour component in "bio-fertilisation" of lands, which in turn requires biomass of different kinds including 'weeds'.

In modern agriculture science, "integrated weed management" approach is advocated, which emphasizes on many practices for weed control: selection of a well-adapted crop variety or hybrid with good early season vigor and appropriate disease and pest resistance; appropriate planting patterns and optimal plant density; improved timing, placement, and amount of nutrient application; crop rotation; tillage; cover crops; mechanical cultivation; and biological control methods etc. It is obvious that trying to control weeds by one or two methods or worse, chemicals, puts pressure on the weeds to select for resistance and to adapt to these methods/chemicals.

Further, pest management in corn has been shown to be effective through dozens of ecological farming approaches and practices which do not require either chemical pesticides or GM solutions.

ON MONSANTO'S GM MAIZE:

In India, Monsanto is undertaking field trials on a GM maize product which is both insect-resistant and herbicide-tolerant (MON89034 X NK603). Elsewhere, this is known by YieldGard VT/PRO brand name. The field trials on two transgenic corn hybrids with brand names 900M Gold and HiShell have been approved by the Genetic Engineering Appraisal Committee at BHU, Varanasi in Uttar Pradesh; at Begusarai in Bihar; at Bhagalpur in Bihar; in TNAU, Coimbatore in Tamil Nadu; in UAS, Dharwad in Karnataka; in ANGRAU, Karimnagar in Andhra Pradesh; in MPUAT, Udaipur in Rajasthan; in AAU, Vadodara in Gujarat and DWSR, Jabalpur in Madhya Pradesh. Other open air cultivation plots have been allowed under new categories of trials called Insect Resistance Management trials in Begusarai and Bhagalpur in Bihar, in Aurangabad in Maharashtra, in Coimbatore in Tamil Nadu, Davangere in Karnataka and Warangal in Andhra Pradesh. "Seed production research trials" were also allowed in Kurnool and West Godavari districts in Andhra Pradesh apart from actual seed production allowed in Kunigal taluka in Tumkur district and Sindagi taluka of Bijapur district in Karnataka. Like all open air trials, there is a serious threat of contamination from these trials.

This GM Maize has stacked traits with cry2Ab2 and cry1A.105 Bt genes (Event MON 89034) & cp4epsps (Event NK603) gene inserted into maize, engineered for insect resistance (lepidopterans) and tolerance to the herbicide Roundup (with the active ingredient glyphosate). The toxins engineered into the plant are supposed to protect the plant from fall armyworm (Spodoptera sp.), black cutworm (Agrotis ipsilon), european corn borer(Ostrinia nubilalis) and the corn earworm (Helicoverpa zea). The genes are from soil bacteria (Bacillus thuringiensis and Agrobacterium).

Products containing MON89034 were planted commercially for the first time in the USA in 2009 and EU has not permitted this product for cultivation but only for imports for food/feed etc. The specific genes used in this novel product are not much in use at present and it is not clear how well they have been characterized. The Indian regulators have allowed the open air trials to take place mostly based on data provided by the crop developer itself, that too from other countries.

These trials pose a variety of concerns some of which are listed in the following sections. Apart from the fact there are health and environment related biosafety concerns, a strong concern also arises around Monsanto, the largest seed company in the world which is the product developer, given its known anti-farmer, monopolistic behaviour.

Health concerns: A 2009 study compared an analysis of blood and organ system data from trials with rats fed three main commercialized genetically modified types of maize which are present in food and feed in the world. Approximately 60 different biochemical parameters were classified per organ and measured in serum and urine after 5 and 14 weeks of feeding. GM maize-fed rats were compared first to their respective isogenic or parental non-GM equivalent control groups, followed by comparison to six reference groups, which had consumed various other non-GM maize varieties. Analysis clearly reveals for the 3 GMOs new side effects linked with GM maize consumption, which were sex- and often dose-dependent. Effects were mostly associated with the kidney and liver, the dietary detoxifying organs, although different between the 3 GMOs. Other effects were also noticed in the heart, adrenal glands, spleen and haematopoietic system[21].

Another study examined the effects of stacked GM crop NK603 x MON810 in different models of long term feeding studies. The study showed GM maize fed to mice significantly reduced their fertility over three to four breeding cycles within one generation[22]. Similar effects were found in mice fed GM maize and bred over four generations; although the results did not reach statistical significance in any one generation, the trend was unmistakable, more pups lost and smaller litters in the GM-fed mice. Results from a long-term feeding study with mice were interpreted as showing that consumption of a genetically modified corn developed by Monsanto (NK603 x MON810) led to lower fertility and body weight.

A 2008 study evaluated the gut and peripheral immune response to genetically modified (GM) maize in mice in vulnerable conditions[23]. The results showed that very young and old mice are more susceptible to immunological insults.

In one study with transgenic maize, the transgenic seeds responded differentially to the same environment as compared to their respective isogenic controls, as a result of the genome rearrangement derived from gene insertion[24]. The above are only some examples of the potential toxic and unpredictable effects of transgenic maize.

Environmental concerns: Target pest developing resistance is a distinct possibility, along with target weeds. Further, it is found that one pest will be swapped for another[25]. Some Bt maize lines were found to be significantly more susceptible to aphids, and this could be because of higher amino acid levels in bt maize[26]. Authors point out that this is either a welcome or an undesirable side effect. Further, newer research shows that there could be new toxicity pathways to GM crops, like stream ecosystems being impacted. A study demonstrates that insect-

resistant crops producing Bt toxins can affect ecosystems via unexpected pathways because interactions in the natural environment are complex and not fully understood[27].

Larvae of the monarch butterfly exposed to Bt maize anthers (the part of the flower that carries the pollen) behave in a surprisingly different way, compared to other larvae exposed to non Bt crops, it was found[28]. Butterflies moving away from Bt crops were most likely trying to avoid the Bt toxin. Another study performed aquatic ecotoxicity tests on the standard organism, the water flea or Daphnia magna. D. magna fed GM-maize showed a significantly reduced fitness performance: The mortality was higher, a lower proportion of females reached sexual maturation, and the overall egg production was lower compared to those fed conventional maize[29]. Although the study may have limitations, it shows that GE Bt maize could be toxic to aquatic (insect) life and this could result in ecosystem level effects.

The European corn borer, one of the primary insects Bt is meant to target, has been shown to be capable of developing resistance to the Bt protein[30].

Further, data from the USA, based on comparison of yields achieved by transgenic and conventional corn-herbicide systems, has shown that all systems (conventional or transgenic) produced statistically equivalent yields if they incorporated post-crop-emergence herbicide applications, usually spread over the crop. Based on reviewed research, a report called "Failure to Yield" summarized that it does not appear that transgenic HT corn provides any consistent yield advantages over several non-transgenic herbicide systems.

Data from USA also points out to concerns related seed prices of such products. It is estimated in the United States that corn growers spent 4% to 11% of gross market income per acre on seed from 1975 through the beginning of the GE era in 1996 and 11 to 17% of operating costs per acre. GE corn, however, has become much more expensive as a percent of gross income and operating costs – in 2009, GE corn seed accounted for 19% and 34% of gross income and operating costs per acre, about twice historic trends.

There are serious concerns around seed choices that would be available to farmers with Monsanto's GE maize entering the picture (Monsanto already has a strong hold in the hybrid maize market in the country).

References:

[1] This Briefing Paper used material from several other briefing papers heavily, including PAN-UK's Fact Sheet on Glyphosate (1996), Caroline Cox's Glyphosate Fact Sheet from Journal of Pesticide Reform (1998 revised 2000), Friends of the Earth's Briefing Note on Herbicide Use & GM crops (2004), Third World Network's Note for MOP4 of Cartagena Biosafety Protocol on Special Threats to the AgroEcosystem from the combination of GE crops and Glyphosate (2008), GLS Gemeinschaftsbank eG and ARGE Gentechnik-frei's "GM Soy: Sustainable? Responsible?" (September 2010) by Antoniou et al

[2] Friends of the Earth, Herbicide Use & GM Crops, Briefing Note, February 2004

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