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Genetically modified (GM) corn in the Philippines : Ecological impacts on agroecosystems, effects on the economic status and farmers' experiences

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General Introduction

Genetically Modified (GM) corn in the Philippines

The Philippines, a country being powered primarily by an agricultural economy, has an expanding population of more than 92 million Filipinos (Anonymous, 2010a). The rapidly increasing population requires agricultural production to become more intensified to answer the ever increasing food demand. In the Philippines, corn (*Zea mays* L.) is second to rice as the most important crop. In spite of the fact that almost 3 million hectares are devoted to the cultivation of this crop annually, production in the past decades showed that it is not enough to meet the local needs due to low yield. In fact, before the introduction of high yielding and pest resistant corn varieties (like *Bacillus thuringiensis/Bt* corn) in 2002, corn production was inefficient having an extremely low mean yield of 1.52 mt/ha. in 1996 (Reyes *et al.*, 2009).

A cornfield is a complex environment with many factors that can interact to influence the growth of a corn plant (Wright and Rich, 2004). These factors can be biotic and abiotic. Important natural biotic factors are pests such as grubs (*Phyllophaga spp.*), wireworms (*Agriotes lineatus*), seed maggots (*Delia platura*), grasshoppers (*Melanoplus differentialis*), crickets (*Gryllus sp.*), armyworms (*Spodoptera frugiperda*), flea beetles (*Systema spp.*), aphids (*Rhopalosiphum maidis*) and Asian corn borers (*Ostrinia furnacalis* Guenée), diseases (fusarium wilt, leaf blights, anthracnose, leaf spot, stalk & root rots), nematodes, birds, and weeds. Important natural abiotic factors are climate (typhoons, floods, heat and drought), soil types and nutrients. Problems such as pests and diseases force farmers to resort to intensive use of pesticides. However, pesticides can have well known deleterious effects on human health, the environment and biodiversity (de Snoo, 1997; Stoate *et al.*, 2001; Geiger *et al.*, 2010; Waggoner *et al.*, 2011; Yadav and Sehwat, 2011).

The Asian Corn Borer (ACB), *Ostrinia furnacalis*, became the most devastating insect pest and became the major constraint to corn agriculture. A small damage could bring low market value of the corn that affects not only the yield but also affect the quality of the kernel. In other Asian countries like China, ACB is considered the most destructive pest in corn (He *et al.*, 2003; He *et al.*, 2006). The Philippines is not exempted by the huge damage brought about by ACB. Records show that ACB could reduce yield by 27% (Logroño, 1998) and the damage could be even worse when corn is planted late (Javier, 2004). The larval stage is the destructive stage of ACB. The larvae are voracious feeders, with powerful mandibles they use for tunnelling in all parts of the corn (Caasi-Lit *et al.*, 2009) and finally causing plants to lodge, and reduce the flow of sap and nutrients. They are hard to eradicate using broad spectrum pesticides because of their ability to hide themselves within the stem and cobs.

Aside from insect pests, weed is the second most important corn pest. Weeds compete with available plant nutrients, minerals and water from the soil resulting to poor growth and development of corn plants hence, reduced yield (Figure 1 left). In the Province of Isabela, farmers identified *Racboellia cochinchinensis* (Lour.) locally known as “*Marapagay*” as the most destructive weed pest for corn. This weed is highly prolific and could cause stunted growth of corn plant and reduced yield (Figure 1 center). To mitigate this problem, either manual weeding or soil tillage is applied. However, this is laborious, time consuming and also expensive (due to high cost/labor). Therefore, farmers in general resort to use herbicides. However, herbicides like Gramoxone (paraquat) and Roundup (glyphosate) are non-selective and cause systemic effects that could affect corn plants resulting to wilting or, worst, death when improperly sprayed (Figure 1 right).



Photos taken by the author

Figure 1. Weed covered cornfields and herbicide effect on weeds and corn plants due to improper application of herbicide.

Brief history of GM corn technology

Genetically Modified (GM) corn hybrids are products of modern biotechnology via modification of genes known as genetic engineering. *Bt* corn was first commercialized in US in 1996 and is produced by agribusiness Monsanto Inc. in the United States of America. *Bt* corn is a variant of maize, genetically modified to produce the bacterial *Bt* toxin, which is poisonous to insects. Its known “active ingredient” is derived from a naturally occurring soil borne bacterium, *Bacillus thuringiensis* (*Bt*) that is found worldwide. *Bt* produces a crystalline protein (Cry1Ab- endotoxin) that is toxic to specific groups of insects, for example Lepidopterans. The endotoxin is a stomach poison that must be ingested by the insect, after which the insect dies. The mechanism involves the activation of the *Bt* toxin in the digestive tract of insects where it leads to cessation of feeding and paralysis of the gut, thereby retarding the passage of undigested food (Glare & O’Callaghan, 2000).

As cited in Sanahuja *et al.* (2011), *Bt* was discovered in 1901 by Shigetane Ishiwatari, a Japanese biologist who investigated the cause of the sotto disease and rediscovered in 1911 by Ernst Berliner when he had isolated a bacteria that had killed a Mediterranean flour moth (*Anagasta kuehniella*). In 1956 Fitz-James Hannay and Angus Hannay discovered that *Bt* protein crystal is the reason why moths were killed, which is the start of researches on *Bt* and the *Bt* crystals. By 1977 there were 13 different strains of *Bt*, all still only effective against moths. But also in 1977 the first strain was found that was toxic to flies. The next strain found in 1983 to be toxic to beetles. Today there are thousands of strains and many encode for crystals and over a thousand types of *Bt* that produce over 200 types of protein crystals which are toxic against a wide variety of insects and some other invertebrates.

The Herbicide tolerant (HT) corn is another novel product of genetic engineering which allows farmers to spray broad spectrum herbicides onto their standing corn plant. It has to be noted that HT corn is a corn variety of herbicide-tolerance and not herbicide-resistance, which means that the HT corn develops the capability of withstanding/assimilating the herbicide without being negatively affected or getting killed. Herbicide tolerant (HT) corn was first introduced in 1999 in US (Owen and Zelaya, 2005). HT corn is genetically modified to counteract herbicides’ damaging effects, specifically of glyphosate. Glyphosate [N-(phosphonomethyl) glycine] can kill plants by inhibiting the biosynthesis of aromatic compounds via the shikimate pathway (Kishore *et al.*, 1992). The HT corn is protected from glyphosate with its genetically built-in EPSP (5-enolpyruvylshikimate-3-phosphate synthase) cDNA isolated from a glyphosate tolerant petunia cell culture line (Padgett *et al.*, 1995). Its glyphosate tolerant gene was isolated from a common garden Petunia, *Petunia hybrida*, which is flowering plant endemic to South America, primarily Southern Brazil and Argentina, and live in a variety of habitats from grasslands to mountain foothills (Anonymous, 2010b). Further analysis of a *Petunia hybrida* cell culture (MP4-G) tolerant to 1mM glyphosate revealed a 15- to 20-fold increased level of 5-enolpyruvylshikimate-3-phosphate synthase in the herbicide-tolerant strain (Steinrücken *et al.*, 1986).

Benefits of GM corn technology

Promoters of agricultural biotechnology claim that GM corn can potentially mitigate the impact of agricultural intensification and *Bt* corn offers the best alternative to traditional insecticides for the control of ACB (Chen *et al.*, 2008). Likewise, Monsanto Philippines claims that GM corn offers a golden opportunity for poor farmers to increase their yields thus improving their livelihood and alleviating poverty through: a) protection of crops from insect damage; b) lower pesticide use; c) increase food production and quality; and d) ecological sustainability (<http://www.monsanto.com>), accessed May 4, 2012). Hence, the driven expectations of high yields, lower pesticide inputs and savings in time management caused an upsurge in GM corn adoption in all major corn-producing countries.

In particular, GM corn cultivation is claimed to provide both pecuniary and non-pecuniary benefits for the farmers. The most common pecuniary benefit is increase yield (Finger *et al.*, 2011; Raney, 2006; Qaim & Zilberman, 2003) through reduction of damage in stem by 99% and leaves by 84%. Cultivation of *Bt* and *BtHT* corn produced an average yield of 2,000 kg ha⁻¹ in the Philippines (Thomson *et al.*, 2010) and this brought positive yield impact in 1996-2006 compared to conventional corn (Brookes *et al.*, 2010a). In addition, Brookes and Barfoot (2010b) listed the most important non-pecuniary benefits with GM corn as follows: (1) ease of management, (2) savings on machinery, (3) lower pesticides use and (4) risk-free to human health. These non-pecuniary benefits were equal to 21% total direct income benefits in 2007 and 25% total cumulative direct farm income in the USA for 1996-2007. Likewise, in the USA, a reduction of 34.6 million kg of pesticides (9.6%) for 1996-2007 (Brookes and Barfoot, 2010a) was a good example of non-pecuniary benefits when using GM corn.

On biodiversity issues, *Bt* corn promise solutions to environmental problems associated with intensive use of pesticides. Although *Bt* corn contains a toxin that is harmful to ACB, the toxin is considered environment-friendly because it is highly specific with few known adverse effects to non-target species (Glare and O'Callaghan, 2000). The foregoing claim invites further verification studies because of the claim that *Bt* toxin is highly specific to ACB yet the same time admitting that non-target species are affected. Many research studies done both in laboratory (Bakonyi *et al.*, 2011; Alfageme *et al.*, 2010; Sims and Martin, 1997; Escher *et al.*, 2000; Saxena and Stotzky, 2000) and fields (Rauschen *et al.*, 2009; Bhatti *et al.*, 2005a; Bhatti *et al.*, 2005b) supported the non-toxic effects of *Bt* Cry1Ab protein to several non-target arthropods and pests. Lots of studies seem to confirm that *Bt* has no negative effects on soil-dwelling invertebrates such as earthworm, woodlouse, pillbug, collembolla and mites, (Clark and Coats, 2006; Escher *et al.*, 2000; Clark *et al.*, 2006; Griffiths *et al.*, 2006). Finally, the meta-analysis of 42 studies on nontarget invertebrates done in temperate countries by Marvier *et al.* (2007) indicates that unsprayed *Bt* corn is more environmental friendly than insecticide sprayed non-*Bt* corn.

Equally, there are many benefits when using herbicide tolerant crops. Broader spectrum of weed control, reduced crop injury, less herbicide carry-over, price reduction for "conventional herbicides", use of herbicides that are more environmental friendly, new modes of action for resistance management, and weed management flexibility and simplicity are among the

commonly cited benefits by Knezevic and Cassman (2003). In addition, economic advantage of HT corn was visualised in the developing countries with the farm income gain of \$40.8 million in 2007 (Brookes and Barfoot, 2010b) and a savings of \$1.2 billion by US farmers similar to cost cutbacks in herbicides, tillage and hand weeding (Gianessi, 2005). Environmentally, HT corn brings several benefits even with glyphosate application. Glyphosate is a chemical yet considered to be a relative risk-free herbicide because it is degradable (Cerdeira and Duke, 2006) and produce limited risk of surface and ground water pollution (Borggaard and Gimsing, 2008). Some studies are claimed to have shown that farmland arthropods were benefited by HT corn (Dewar *et al.*, 2003; Firbank and Forcella, 2000; Freckleton *et al.*, 2004). Such claim needs verification because it is out rightly inconsistent with the general logical assumption that more weeds will harbour more insect species.

Timeline on GM corn in the Philippines

As mentioned above, one promising solution to increase corn production is the development of technologies or corn varieties with novel traits to address the important current problems of corn farmers. In the Philippines, the agricultural sector have been taking steps so that several research agencies and institutions are studying the best possible way of increasing crop yield, allowing crops to thrive in different environmental conditions, developing low-cost and eco-friendly fertilizers and eradication of pests. Furthermore, to address the problem of ACB and weeds, the Philippine Department of Agriculture (DA) allowed GM corn cultivation in the country in 2003.

Table 1 enumerates the timeline of marked historical development of Biotechnology in the Philippines in general and that of *Bt* corn in particular showing how GM corn was gradually incorporated in the farming practices prospers in the corn agricultural landscape and became the leading corn hybrid ever adopted by the farmers in the country. The rapid adoption of *Bt* corn was attributed to the successful multi locational field testings in the Philippines in 2000 which was immediately followed by its commercial release in 2003 along with government approval and endorsement by former Philippine presidents through their policy statements. The important go signal for *Bt* commercialization in the country comes with the government's Department of Agriculture Administrative Order No. 008 series of 2002. Notable in the timeline are the presence of government bodies or institutes that are mandated to promote Biotechnology in general as well as significant legislations such as "The Plant Variety Protection Act" (Republic Act 9168) and government administrative issuances such as the Department of Agriculture Administrative Order No. 8 for the Regulation of Plant and Plant Products produced through modern biotechnology. The history of biotechnology and *Bt* corn technology in the Philippines can be described as in a state of transition with sporadic instances of mistrust and unacceptance of the technology by the public with government institutions ending up coming to the rescue in defense of newly adopted biotechnologies. Such sporadic mistrusts are expected in newly introduced technologies which are often diluted with misconceptions mixed up with valid issues. Towards the end of the last decade majority of corn farmers shifted to GM corn technology and its subsequent varieties and improvements transforming entire corn lands to GM cornfields. It could be said at this point that to date the country, being the 13th GM crop producing country in the world (James, 2011), is at the beginning of the gene revolution and at the end of green revolution.

Table 1. Philippine timeline of marked activities from biotechnology development to GM corn technology introduction and nation-wide large-scale adoption (Ebora *et al.*, 2005; Cabanilla 2007; Gonzales *et al.*, 2009).

| Period | GM Historical Timeline |
|--------------|--|
| 1960s-70s | Propagation technique using embryo rescue for mutant <i>makapuno</i> coconut was developed at University of the Philippines – Los Baños College of Agriculture |
| 70s | Micropropagation and embryo rescue techniques for orchids were also developed |
| 1979 | BIOTECH in University of the Philippines – Los Baños, now called the National Institute of Molecular Biology and Biotechnology, was established through a Presidential Decree and became the first biotechnology R&D institute in the Philippines. |
| 1980 | Establishment of National Institutes of Biotechnology and Applied Microbiology (BIOTECH) |
| 1987 | Scientists from the UPLB, the International Rice Research Institute (IRRI), and Department of Agriculture constituted an ad hoc committee on biosafety and proposed the formulation of a national policy on biosafety to the national government. |
| 1986 to 1992 | DOST marked biotechnology as a flagship of high-end technologies, recognizing it as a “strategic tool for achieving sustained economic development”. |
| 1990 | Former Pres. Corazon C. Aquino established the National Biosafety Committee of the Philippines (NCBP) by Executive Order (EO) 430. The Committee is responsible for regulating the importation, transfer, research and development, and use of genetically modified organisms and potentially harmful exotic species in the country. |
| 1990 | Research and Development, Biotechnology high priority in Science and Technology. |
| 1990 | Institute of Plant Breeding (IPB) in UP Los Baños and PhilRice able to developed marker technologies that are useful in crop improvement |
| 1992 | The Seed Industry Development Act of 1992 mandated IPB to lead in plant biotechnology activities. |
| 1992-1998 | During the term of then President Fidel Ramos, Biotechnology remained as a major program of DOST’s Science and Technology Program. |
| 1995 | The 5-year Crop Biotechnology Program was approved by Pres. Ramos, with first year budget of PhP 65M. |
| 1997 | Section 83 of Agriculture and Fisheries and Modernization Act (Republic Act 8435) explicitly allocates 1% of agriculture’s Gross Value Added to agricultural research. The Act holds specific provisions for a biotechnology program and a mandated budgetary allocation. |
| 1997-1998 | IPB developed facilities and manpower for cloning plant genes and transformation. |
| 1997 | Contained testing of <i>Bt</i> corn (Mon 810). |
| 1998 | Limited, very confined field test of <i>Bt</i> corn. |
| 1999 | NCBP oversight, Monsanto Philippines conducted first field-testing of <i>Bt</i> corn in South Cotabato. |
| 2000 | Papaya transgenic plantlets at IPB; PhilRice conducted screen house testing of XA-21 rice, which is resistant to bacterial blight |
| 2000 | Former Pres. Joseph Ejercito Estrada issued a National Policy to use biotechnology as a strategy to improve agricultural production, modernize Philippine agriculture and enhance rural development. |
| 2000 | Multi locational field tests of <i>Bt</i> corn |
| 2000-2001 | Public protests were regularly staged by NGO’s such as <i>Kilusan ng Magbubukid sa Pilipinas</i> (KMP, literally translated as Peasant Movement of the Philippines); MASIPAG (acronym for <i>Magsasaka at Sayantipiko Para sa Ikaunlad ng Agham Pang agrikultura</i>), South East Asia Regional Initiatives for Community Empowerment (SEARICE), Greenpeace, and the Philippine Greens. |
| 2001 | Former Pres. Gloria Macapagal Arroyo signed policy statement on modern biotechnology for national development. |

| Period | GM Historical Timeline |
|--------------|--|
| 2001 | Department of Agriculture Administrative Order (DA AO) No. 8, 2002 – Regulation of Plant and Plant Products produced through modern biotechnology. |
| 2001 | Monsanto Philippines and Pioneer-HiBred conducted multi locational field trial of <i>Bt</i> corn. |
| 2002 | Administrative Order (AO) 008 Series of 2002, issued by the Department of Agriculture in April 2002, made commercial adoption of crop biotechnology |
| 2002 | Bureau of Plant Industry Director approved commercial scale planting of the field-tested <i>Bt</i> corn. |
| 2002 | Enactment of The Plant Variety Protection Act (Republic Act 9168) |
| 2002 | Issuance of Department of Agriculture Administrative Order No. 8 “Rules and Regulations on the Importation and Release Into the Environment of Plants and Plant Products Derived From the Use of Modern Biotechnology” – a science-based biosafety measure that ensures the integrity of human and animal health, and the environment. |
| 2003 | Monsanto and Pioneer Hi-Bred reported total gross sales of PhP1.7 billion, or roughly US\$30 million. |
| 2003 | Non-government organizations (NGOs) led by Greenpeace International held a hunger strike in front of the Department of Agriculture building to stop the commercialization of <i>Bt</i> corn |
| 2003 | Dr. Terje Traavik, a scientist from the Norwegian Institute of Gene Ecology reported the incident of at least 106 lumad (indigenous people) from Polomolok, South Cotabato sought medical treatment due to infections allegedly caused by 60-day-old <i>Bt</i> corn pollen. |
| 2003 | About 40% of the <i>Bt</i> corn planted in a 0.75 hectare land in Bicol and South Cotabato provinces was damaged by stalk rot resulting to poor harvest of only around 2,000 kg, half of the expected 4,000 kg normal yield. |
| 2003 | Approval of NK603 corn for food, feed and processing by BPI. |
| 2004 | Dr. Terje Traavik presented the results of the ongoing research at the Biosafety Symposium in Kuala Lumpur, Malaysia and reported that some 39 farmers in Mindanao developed immunity to antibodies because of exposure to <i>Bt</i> corn. |
| 2004 | Department of Agriculture (DA)’s Bureau of Plant Industry (BPI) issued a statement that it has Made a “thorough review on the safety of <i>Bt</i> corn to human and animals. No toxic or Allergenic effect is associated with the approved <i>Bt</i> corn variety”. |
| 2003 to 2004 | Multi location field trials of NK603. |
| 2004 | Local government units (such as the Bohol province) expressed opposition to GMOs and declared themselves as GMO free and passed Provincial Ordinance No. 2003-101. Otherwise known as the ‘safeguard against GMOs. |
| 2004 | Monsanto applied a permit for the commercial propagation of NK603 corn. |
| 2005 | Issuance of permit for commercial propagation of NK 603 with trademark Roundup Ready (RR), a glyphosate resistant corn. |
| 2005 | Initial deployment of <i>Bt</i> HT with 4,580 ha of plantation |
| 2005 | Monsanto received the permit for large scale propagation of stacked train <i>Bt</i> HT corn hybrids (Mon810 x NK603). |
| 2006 | National Biosafety Framework (NBF) under EO 514 |
| 2007 | Plantation of NK603 zoomed to more than 120,000 ha. |
| 2007 | Renewal of propagation permit. The Bureau of Plant Industry (BPI) approved the 5-year extension of the commercial production of <i>Bt</i> corn (Mon 810) in the country. |
| 2008 | The <i>Bt</i> corn production reached 400,000 hectare. |
| 2008 | Stacked train corn hybrids, <i>Bt</i> HT (Mon810 x NK 603) of plantation reached 241,273 ha. |
| 2011 | Philippines was declared as the 13 th mega producing country of biotech crop in the world. |

Issues on GM corn technology

Despite the known advantages of using GM corn, a wide range of issues and concerns are forwarded by the active antagonist groups of non-government organizations (NGOs). These NGOs are long-term promoters of sustainable agriculture and they question the feasibility of the GM corn promises and point out the many threats that GM corn may pose to biodiversity and to the future of sustainable agriculture. Although, in 2002-2003 some of Catholic clergy became very active during the anti-campaign rallies against *Bt* corn, at present the church seems to be uncertain about its stand on GM corn in the country (Cabanilla, 2007).

Accordingly, *Bt* endotoxin in corn is to be considered as a biopesticide and just like any pesticides it could have diverse effects on human health, pest management, and the environment and food systems. Some of the major issues and concerns raised are as follows:

On environment

1. The ability of the *Bt* corn to produce toxin may be passed on to other plants through cross-pollination, thereby dispersing this ability in places and species where it may be prove harmful (cited by Gonzales *et al.*, 2009). E.g., it may transform other organisms into invasive and hard to eliminate species to agro-ecosystems (Shen, 2006).
2. Non-target toxic effects of *Bt* toxin (Altieri, 2000; Andow and Hilbeck, 2004; Dutton *et al.*, 2003; Arriola and Ellstrand, 1997; Klinger and Ellstrand, 1994; Linder and Schmitt 1995). For example, Cry1Ab protein from GM crops can affect the soil ecosystem and soil biota like nematodes and fungi, (Meadows *et al.*, 1990; Turrini *et al.*, 2004). This is attributed to the persistence of *Bt* toxin (25-30% Cry1Ab protein) in the soil for 234 days (Tapp and Stotzky, 1998) and stays on litter for at least 8 months (Zwahlen *et al.*, 2003). Likewise, the glyphosate used for HT corn reported to be toxic to some non-target beneficial organisms such as spiders, mites, carabids, coccinellid beetles and earthworms as well as to fish (Pimentel *et al.*, 1989).
3. Potential development of secondary pest like in the case of Cotton Mirid bug (*Pseudatomoscelis seriatus* Reuter) outbreak in China (Lu *et al.*, 2010).
4. The simple and significant selection pressure by HT crops and concomitant use of the herbicide could change the vegetation diversity through enhanced weediness (Brown *et al.*, 1996; Altieri, 2000; Hammond, 2010). For example, the reported increasing in prominence in some agriecosystems of some weeds like Asiatic dayflower (*Commelina cumminus* L) common lambsquarters (*Chenopodium album* L) and wild buckwheat (*Polygonum convolvulus* L) (Owen and Zelaya, 2005).
5. Potential development of resistance to *Bt* toxin (Altieri, 2000) by the ACB and to glyphosate herbicide by some weeds (Owen and Zelaya, 2005). Resistance to the *Bt* toxin by the ACB will develop once low levels of *Bt* toxins are introduced, thus enabling ACB to survive and become “super bugs” that are resistant to the toxin and breed such resistance into succeeding generations (cited by Gonzales *et al.*, 2009). Also, the continuous application of glyphosate may lead to the development of the so-called “glyphosate resistant weeds” alongside of GM cornfields and the fear of the creation of super weed like *Amaranthus palmeri* and horseweed (*Conyza canadensis* (L) Cronq) which are known to be resistant to N-(phosphonomethyl) glycine i.e. as glyphosate (Benaning, 2010; Owen and Zelaya, 2005).

On Socio-Economic issues

The development of *Bt* corn Mon810 cost around \$2.6 million (128 million Philippine pesos). This includes the entire process of product development, from concept initiation done in the US in 1985 to implementation of post commercial approval requirements in 2004. The biggest costs were incurred in the conduct of post-commercial application activities followed by 17 multi-location field trials across the country. Project spending was highest in 2002 when field trials and supporting studies were being completed and the product stewardship plan was being developed. It has also been discovered that two-thirds of total cost went into activities conducted in compliance and support to government regulatory requirements (Manalo and Ramon, 2004).

The high cost of investment is reflected on the high price of GM corn seeds available in the market (Zonio, 2004). Besides, farmers cannot recycle the seeds and need to buy new seeds every growing season because farmers may be sued for patent infringement; this creates an economic dependence of farmers on seed producers to corn seeds and agrochemicals. Also, as cited by Gonzales *et al.* (2009), there are no markets for *Bt* corn although this is refuted by the rapid adoption of *Bt* corn.

On human health

As cited in Gonzales *et al.*, 2009, the following are the most prominent health related issues being raised against GM crop which are more of perceived concerns:

1. GM crops are hazardous because these carry new proteins that may cause allergies and other reactions and;
2. The development of GM crop may create antibiotic resistant microbes or vectors utilized in genetic engineering of *Bt* genes which may transfer antibiotic resistance genes to other bacteria infecting humans, thus rendering life saving antibiotics useless.

Research objectives

While some resistance was noted during the initial phases of GM corn introduction, particularly during field tests in some areas of the country, overall government approval and support, coupled with massive media information campaigns and stakeholders mobilization, completely shifted to favor eventual adoption. This has made the Philippines the first country in Asia to have a biotechnology crop for food. *Bt* corn was commercially planted beginning 2003 and biotech corn since has a steady massively increasing adoption rate of 5% every single year as farmers and stakeholders experience or perceive improved economic gains.

It is against this backdrop of economic benefits primarily that often environmental concern becomes sidelined in the equation of sustainable practices in agriculture. From the above, it is clear that many issues relating to the environment, biodiversity, economic and social issues warrant further research investigation and validation studies.

The main objective of this research undertaking is to provide a realistic and updated assessment on the impact of GM corn after a decade of continuous cultivation and rapid adoption in the Philippines. This is done from a third party academe-based approach as a way to minimize research results bias. Qualitative and quantitative approaches and procedures were employed to cover the ecological, economic and social domains of this thesis. Specifically, it aimed to:

1. provide a summary and background information in the context of the success and wide-scale adoption of GM corn in the Philippines in the last decade;
2. reinvestigate the efficacy of GM corn containing *Bt* toxin against the Asian corn borer (ACB) as well as its potential effects to a non-ACB pests community;
3. determine the impact of GM corn and its associated changes on agricultural practices on an invertebrate community in the cornfield ecosystem;
4. evaluate the impact of long-term and continuous cultivation of GM corn on the corn agro-ecological system;
5. substantiate claims of agricultural productivity and;
6. assess farmers' perceptions and attitudes about GM corn.

The study has been conducted in the Philippines to address the above objectives. The methods for obtaining answers to the aforementioned objectives are as follows; For the first objective, secondary data (such as books, research articles and digital information materials) from inside and outside the country have been collated and served as reference lines to establish the background information in the success of GM corn in the Philippines. Objective 2 was addressed by actual surveying of 198 GM and non-GM cornfields for the possible occurrence of ACB and non-ACB pests. Percentage infestation specific for corn pests was calculated using the data of characteristic symptoms of pests. The third objective was accomplished by establishing a six hectare experimental field designed to compare the effects on an invertebrate's community present and of the actual agricultural practices associated to GM and non-GM corn. Objective 4 was carried out through careful selections of cornfields that have been continuously cultivated with GM corn for not less than two years. For objectives 3 and 4, collections and monitoring were accomplished using pitfall traps, sticky cards and soil cores to account for different invertebrate dwellers. Finally, for objectives 5 and 6, one to one interviews with the farmers were conducted. Self-structured questionnaires were used to extract local knowledge and primary information of the farmers relative to GM and non-GM corn cultivation. Econometric and Blinder-Oaxaca decomposition methods were employed for objective 4.

Finally, the imperative to conduct environmental and socio-economic impact assessment after long years of continuous GM corn adoption is timely. The study done here to assess the effects of long-term cultivation of GM corn is an example of post evaluation of a technology to ensure that it is sustainably viable. To seek answers for issues surrounding the introduction and nationwide adoption of GM corn in the Philippines, this research undertaking would like to focus on answering the following five major questions as follows:

1. What is the effect of GM corn on ACB and non-ACB pests; and which among these agricultural pests are benefited and vulnerable in a GM and non-GM corn environment?
2. What is the impact of GM corn management systems on invertebrate communities in terms

of its species abundance and richness; and is GM corn cultivation more environment-friendly than non-GM corn?

3. What is the impact of the long-term cultivation of GM corn to the abundance and species richness of infield invertebrates in a humid tropical country like the Philippines?
4. Is GM corn economically more viable than non-GM in terms of production output, net income and return on investment among small scale farmers? and;
5. What are the farmers' standpoints and experiences on GM corn?

References

- Alfageme, F.A., Bigler, F. and Romeis, J., 2010. Laboratory toxicity studies demonstrate no adverse effects of Cry1Ab and Cry3Bb1 to larvae of *Adalia bipunctata* (Coleoptera: Coccinellidae): the importance of study design. *Transgenic Research* 20(3): 467-479.
- Altieri, M.A., 2000. Commentary: The ecological impacts of transgenic crops on agroecosystem health. *Ecosystem Health* 6(1): 13-23.
- Anonymous, 2010a. Philippine National Statistics Office. Nationwide Census. In: <http://www.census.gov.ph/content/2010-census-population-and-housing-reveals-philippine-population-9234-million>.
- Anonymous, 2010b. The Northern Biologist 15th Annual Newsletter. Department of Biological Sciences. Northern Illinois University.
- Andow, D. and Hilbeck, V., 2004. Science-based risk assessment for non-target effects of transgenic crops. *Bioscience* 54(7): 637-649.
- Arriola, P.E. and Ellstrand, N.C., 1997. Fitness of interspecific hybrids in the genus *Sorghum*: persistence of crop genes in wild populations. *Ecological Applications* 7(2): 512-518.
- Bakonyi, G., Dolezsai, A., Mátrai, N. and Székács, A., 2011. Effects of consumption of *Bt*-maize (MON 810) on the Collembolan *Folsomia candida*, over multiple generations: A laboratory study. *Insects* 2(2): 243-252.
- Bhatti, M.A., Duan, J., Head, G.P., Jiang, C., McKee, M.J., Nickson, T.E., Pilcher, C.L. and Pilcher, C.D., 2005a. Field evaluation of the impact of corn rootworm (Coleoptera: Chrysomelidae) - protected *Bt* corn on foliage-dwelling arthropods. *Environmental Entomology* 34:1336-1345.
- Bhatti, M.A., Duan, J., Head, G.P., Jiang, C., McKee, M.J., Nickson, T.E., Pilcher, C.L. and Pilcher, C.D., 2005b. Field evaluation of the impact of corn rootworm (Coleoptera: Chrysomelidae) - protected *Bt* corn on ground-dwelling invertebrates. *Environmental Entomology* 34:1325-1335.
- Borggaard, O.K. and Gimsing, A.L., 2008. Fate of glyphosate in soil and the possibility of leaching to ground and surface waters: a review. *Pest Management Science* 64(4): 441-456.
- Brookes, G. and Barfoot, P., 2010a. *GM Crops: Global socio-economic and environmental impacts 1996–2008*. Dorchester, UK: PG Economics Ltd.
- Brookes, G. and Barfoot, P., 2010b. Co-existence of GM and non-GM crops: case study of maize grown in Spain. <http://www.gmo-safety.eu> [accessed on 7 August 2011].
- Brookes, G., Yu, T.S., Tokgoz, S. and Elobeid, A., 2010. The production and price impact of biotech corn, canola, and soybean crops. *AgBioForum* 13(1): 25-52.
- Brown, J., Thill, D.C., Brown, A.P., Mallory-Smith, C., Brammer, T.A. and Nair, H.S., 1996. Gene transfer between canola (*Brassica napus* L.) and related weed species. *Annals of Applied Biology* 129(3): 513-22.
- Caasi-Lit, M.T., Sapin, G.D., Beltran, A.K.M., de Leus, E.G., Mantala, J.P. and Latiza, S.A., 2009. Larval survival and ovipositional preference of the Asian corn borer, *Ostrinia furnacalis* Guenee, for some alternate host plants at different growth stages. *Philippine Entomologist*, 23(2): 184-185.
- Cabanilla, L.S., 2007. Socio-economic and political concerns for GM foods and biotechnology adoption in the Philippines. *AgBioForum* 10(3): 178-183.
- Cerdeira, A.L. and Duke, S.O., 2006. The status and environmental impacts of Glyphosate-resistant crops: A review. *Journal of Environmental Quality* 35: 1633-1658.
- Chen, M., Zhao, J.Z., Collins, H.L., Earle, E.D., Cao, J. and Shelton, A.M., 2008. A critical assessment of the effects of *Bt* transgenic plants on parasitoids. *PLoS ONE* 3(5): 2284.
- Clark, B.W. and Coats, J.R., 2006. Subacute effects of Cry1Ab *Bt* corn litter on the earthworm *Eisenia fetida* and the springtail *Folsomia candida*. *Environmental Entomology* 35, 1121–1129.
- Clark, B.W., Prihoda, K.R. and Coats, J.R., 2006. Subacute effects of transgenic Cry1Ab *Bacillus thuringiensis* corn litter on the isopods *Trachelipus rathkii* and *Armadillidium nasatum*. *Environmental Toxicology and Chemistry* 25, 2653–2661.
- Dewar, A.M., May, M.J., Woiwod, I.P., Haylock, L.A., Champion, G.T., Garner, B.H., Sands, R.J.N., Qi, A.M. and Pidgeon, J.D., 2003. A novel approach to the use of genetically modified herbicide tolerant crops for environmental benefit. *Proceedings of the Royal Society, London Series B* 270: 335-340.
- Dutton, A., Romeis, J. and Bigler, F., 2003. Assessing the risks of insect resistant transgenic plants on entomophagous arthropods: *Bt*-maize expressing Cry1Ab protein as a case study. *Biocontrol* 48(6): 611-636.
- Ebora, R.V., Ampil, A.C., Palacpac, M.B. and Custodio, C.G. Jr., 2005. Commercialization of *Bt* corn in the Philippines: A status report. Printed by Asia-Pacific Consortium on Agricultural Biotechnology (APCoAB), Dev. Prakash Shastri Marg, Pusa Campus New Delhi-110012, India.
- Escher, N., Käch, B. and Nentwig, W., 2000. Decomposition of transgenic *Bacillus thuringiensis* maize by microorganisms and woodlice *Porcellio scaber* (Crustacea: Isopoda). *Basic and Applied Ecology* 1(2): 161-169.
- Finger, R., El Benni, N., Kaphengst, T., Evans, C., Herbert, S., Lehmann, B., Morse, S. and Stupak, N. 2011. A Meta-analysis on farm-level costs and benefits of GM crops. *Sustainability* 3(743-762).
- Firbank, L.G. and Forcella, F., 2000. Genetically modified crops and farmland biodiversity. *Science* 289: 1481-1482.
- Freckleton, R.P., Stephens, P.A., Sutherland, W.J. and Watkinson, A.R., 2004. Amelioration of biodiversity impacts of genetically modified crops: predicting transient versus long-term effects. *Proceedings of the Royal Society, London Series B* 271: 325-331.
- Geiger, F., Bengtsson, J., Berendse, F., Weisser, W.W., Emmerson, M., Morales, M.B., Ceryngier, P., Inchausti, P., 2010. Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. *Basic and Applied Ecology* 11(2): 97-105.
- Gianessi, L.P., 2005. Economic and herbicide use impacts of glyphosate-resistant crops. *Pest Management Science*, 61: 241–245.
- Glare, T.L. and O'Callaghan, M., 2000. *Bacillus thuringiensis: biology, ecology and safety*. John Willey and Sons Ltd., Chichester, UK.
- Gonzales, L.A., Javier, E.Q., Ramirez, D.A., Cariño, F.A. and Baria, A.R., 2009. Modern biotechnology and agriculture: A history of the commercialization of biotech maize in the Philippines. Book. A Publication of STRIVE Foundation. ISBN 978-971-91904-8-6.
- Griffiths, B.S., Caul, S., Thompson, J., Birch, A.N.E., Scrimgeour, C., Cortet, J., Foggo, A., Hackett, C.A. and Krogh, P.H., 2006. Soil microbial and faunal community responses to *Bt* maize and insecticide in two soils. *Journal of Environmental Quality* 35, 734–741.
- Hammond, E., 2010. Genetically engineered backslides: The impact of glyphosate-resistant palmer pigweed on agriculture in the United States. Third World Network. 131 Jalan Macalister 10400 Penang, Malaysia. ISBN: 978-967-5412-27-1.

- He, K., Wang, Z., Bai, S., Zheng, L., Wang, Y. and Cui, H., 2006. Efficacy of transgenic *Bt* cotton for resistance to the Asian corn borer (Lepidoptera: Crambidae). *Crop Protection* 25(2): 167-173.
- He, K., Wang, Z., Zhou, D., Wen, L., Song, Y. and Yao, Z., 2003. Evaluation of transgenic *Bt* corn for resistance to the Asian corn borer (Lepidoptera: Pyralidae), *Journal of Economic Entomology* 96(3): 935-940.
- Javier, P.A., 2004. *Bt* corn is safe to beneficial arthropods. AgriNotes, a digest of research and extension breakthroughs in agriculture and food, College of Agriculture, UPLB, Philippines.
- James, C., 2011. Global status of commercialized biotech/GM crops: ISAAA Brief No. 43, Ithaca, NY.
- Kishore, G.M., Padgett, S.R. and Fraley, R.T., 1992. History of herbicide-tolerant crops, methods of development and current state of the art: Emphasis on glyphosate tolerance. *Weed Technology*, 6(3): 626-634.
- Klinger, T. and Ellstrand, N.C., 1994. Engineered genes in wild populations: fitness of weed-crop hybrids of *Raphanus sativas*. *Ecological Applications* 4:117-120.
- Linder, R. and Schmitt, J., 1995. Potential persistence of escaped transgenes: Performance of transgenic oil-modified Brassica seeds and seedlings. *Ecological Applications* 5: 1056-1068.
- Logroño, M., 1998. Yield damage analysis of Asian corn borer infestation in the Philippines. General Santos City, Philippines: Cargill, Phil. Inc. In: Yorobe, Jr. J.M. and Quicoy, C.B. 2006. Economic impact of *Bt* corn in the Philippines. *Philippine Agricultural Scientist Journal*. 89(3): 258-267.
- Lu, Y., Wu, K., Jiang, Y., Xia, B., Li, P., Feng, H., Wyckhuys, K. and Guo, Y., 2010. Mirid bugs outbreaks in multiple crops correlated with wide-scale adoption of *Bt* cotton in China. *Science* 328:1151-1154.
- Manalo, A.J and G.P Ramon., 2004. The cost of product development of *Bt* corn event Mon810 in the Philippines. Biotechnology Coalition of the Philippines (BCP). In: <http://www.agbioforum.missouri.edu/v10n1/v10n1a03-manalo.htm>
- Marvier, M., McCreedy, C., Regetz, J. and Kareiva, P., 2007. A meta-analysis of effects of *Bt* cotton and maize on non-target invertebrates. *Science* 316: 1475-1477.
- Meadows, J., Gill, S.S. and Bone, L.W., 1990. *Bacillus thuringiensis* strains affect population growth of the free-living nematode *Turbatrix aceti*. *Invertebrate Reproduction and Development* 17, 73–76
- Monsanto.com, 2012. In: <http://www.monsanto.com/Pages/results.aspx?k=benefits%20of%20Bt%20corn&start=21>. Accessed May 4, 2012.
- Owen, M.D.K and Zelaya, I.A., 2005. Herbicide-resistant crops and weeds resistance to herbicides. Special Issue, *Pest Management Science* 61(3): 301-311.
- Pimentel, D., Hunter, M.S., Largo, J.A., Effroyson, R.A., Landers, J.C., Mervis, F.T., McCarthy, C.A. and Boyd, A.E., 1989. Benefits and risks of genetic engineering in agriculture. *Bioscience* 39: 606-614.
- Qaim, M. and Zilberman, D., 2003. Yield effects of genetically modified crops in developing countries. *Science* 299(5608): 900-902.
- Raney, T., 2006. Economic impact of transgenic crops in developing countries. *Current Opinion in Biotechnology* 17: 1-5.
- Rauschen, S., Schaarschmidt, F. and Gathmann, A., 2009. Occurrence and field densities of Coleoptera in the maize herb layer: implications for Environmental Risk Assessment of genetically modified *Bt*-maize. *Transgenic Research* 19(5): 727-744.
- Reyes, C.M., Domingo S.N., Mina, C.D and Gonzales, K.G., 2009. Climate variability, seasonal climate forecast and corn farming in Isabela, Philippines: A farm and household level analysis. Philippine Institute for Development Studies. Discussion Paper Series No. 2009-06. In: <http://www.docstoc.com/docs/36079857/Climate-Variability-SCF-and-Corn-Farming-in-Isabela-Philippines>.
- Sanahuja, G., Banakar, R., Twyman, R. M., Capell, T. and Christou, P., 2011. *Bacillus thuringiensis*: A century of research, development and commercial applications. *Plant Biotechnology Journal* 9: 283-300.
- Saxena, D. and Stotzky, G., 2000. Insecticidal toxin from *Bacillus thuringiensis* is released from roots of transgenic *Bt* corn in vitro and in situ. *FEMS Microbiology Ecology* 33(1): 35-39.
- Shen, R.F., Cai, H. and Gong, W.H., 2006. Transgenic *Bt* cotton has no apparent effect on enzymatic activities or functional diversity of microbial communities in rhizosphere soil. *Plant Soil* 285: 149-159.
- Sims, S.R. and Martin, J.W., 1997. Effects of the *Bacillus thuringiensis* insecticidal proteins Cry1A (b), Cry1A(c), CryIIA and CryIIIA on *Folsomia candida* and *Xenylla grisea* (Insecta: Collembola). *Pedobiologia* 41: 412-416.
- Snoo de, G.R., 1997. Arable flora in sprayed and unsprayed crop edges. *Agriculture, Ecosystems and Environment* 66: 223-230.
- Steinrücken, H.C., Schulz, A., Amrhein, N., Porter, C.A. and Fraley, R.T., 1986. Overproduction of 5-enolpyruvylshikimate-3-phosphate synthase in a glyphosate-tolerant *Petunia hybrida* cell line. *Archives of Biochemistry and Biophysics*, 244 (1): 169-178.
- Stoate, C., Boatman, N.D., Borralho, R.J., Carvalho, C.R., de Snoo, G.R. and Eden, P. 2001., Ecological impacts of arable intensification in Europe. *Journal of Environmental Management* 63(4): 337-365.
- Tapp, H. and Stotzky, G., 1995. Insecticidal activity of the toxin from *Bacillus thuringiensis* subspecies kurstaki and tenebrionis adsorbed and bound on pure and soil clays. *Applied and Environmental Microbiology* 61, 1786–1790.
- Thompson, G.D., Dalmacio, S.C., Criador, A.R., Alvarez, E.R. and Hechanova, R.F., 2010. Field performance of TC1507 transgenic corn hybrids against Asian corn borer in the Philippines. *Philippine Agricultural Scientist* 93(4): 375-383.
- Turrini, A., Sbrana, C., Nuti, M.P., Pietrangeli, B. and Giovannetti, M. 2004. Development of a model system to assess the impact of genetically modified corn and aubergine plants on Arbuscular mycorrhizal fungi. *Plant and Soil* 266, 69–75.
- Waggoner, J.K., Kullman, G.J., Henneberger, P.K., Umbach, D.M., Blair, A., Alavanja, M.C.R., Kamel, F., Lynch, C.F., Knott, C., London, S.J., Hines, C.J., Thomas, K.W., Sandler, D.P., Lubin, J.H., Jay, H., Freeman, L.E. and Hoppin, J.A., 2011. Mortality in the agricultural health study, 1993-2007. *American Journal of Epidemiology* 173(1): 71-83.
- Wright, D. and Rich, J., 2004. Field corn production problems: A diagnostic guide. In: <http://edis.ifas.ufl.edu/ag201>. Accessed May 13, 2013.
- Yadav, A.S. and Sehrawat, G., 2011. Evaluation of genetic damage in farmers exposed to pesticide mixtures. *International Journal of Human Genetics* 11(2): 105-109.
- Zonio, A., 2004. Anti-*Bt* corn protest heats up Thursday, May 27 issue of Sunstar as retrieved from the worldwide web: <http://www.sunstar.com.ph/static/gen/2004/05/27/news>.
- Zwahlen, C., Hilbeck, A, Gugerli, P. and Nentwig, W., 2003. Degradation of the Cry1Ab protein within transgenic *Bacillus thuringiensis* corn tissue in the field. *Molecular Ecology* 12, 765-775.