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

Mabutol-Afidchao, M.B.

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Author: Mabutol-Afidchao, Miladis B.
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Genetically Modified (GM) Corn in the Philippines

Ecological impacts on agroecosystems,
effects on the economic status and farmers' experiences

by Miladis B. Mabutol-Afidchao

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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 (*Systena 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 Sehrawat, 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 (Padget *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 *Bt*HT 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 *makapuno* 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 *Bt* corn (Mon 810).
1998	Limited, very confined field test of *Bt* corn.
1999	NCBP oversight, Monsanto Philippines conducted first field-testing of *Bt* 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 *Bt* corn
2000-2001	Public protests were regularly staged by NGO's such as *Kilusan ng Magbubukid sa Pilipinas* (KMP, literally translated as Peasant Movement of the Philippines); MASIPAG (acronym for *Magsasaka at Sayantipiko Para sa Ikauunlad ng Agham Pang agrikultura*), 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.
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 *Bt* 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 *Bt* 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 *Bt* 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 *Bt* corn pollen.
2003	About 40% of the *Bt* 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 *Bt* 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 *Bt* corn to human and animals. No toxic or Allergenic effect is associated with the approved *Bt* 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 *Bt*HT with 4,580 ha of plantation
2005	Monsanto received the permit for large scale propagation of stacked train *Bt*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 *Bt* corn (Mon 810) in the country.
2008	The *Bt* corn production reached 400,000 hectare.
2008	Stacked train corn hybrids, *Bt*HT (Mon810 x NK 603) of plantation reached 241,273 ha.
2011	Philippines was declared as the 13th 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?

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Asian Corn Borer (ACB) and non-ACB pests in GM corn (Zea mays L.) in the Philippines

Miladis M. Afidchao, C.J.M. Musters and Geert R. de Snoo

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Abstract

The Asian corn borer (ACB), *Ostrinia furnacalis* (Guenée), has become the most damaging pest in corn in south-east Asia. Corn farmers in the Philippines have incurred great yield losses in the past decades because of ACB infestation. *Bacillus thuringiensis* (*Bt*) and *Bt* herbicide-tolerant (*Bt*HT) corns have been developed to reduce borer attacks worldwide. This study assessed the extent of ACB and non-ACB pest infestations in both GM and non-GM corn in Isabela Province, the Philippines. Specific aims were to reinvestigate the efficacy of *Bt* corn in controlling ACB, to evaluate what parts of *Bt* corn plants are susceptible to ACB, to monitor the potential development of ACB resistance and to evaluate whether secondary pests dominate in an ACB-free *Bt* corn environment. The study involved preparatory interviews with farmers, site selection, field scouting and visual inspection of 200 plants along 200m transect lines through 198 cornfields.

Bt corn can efficiently reduce the ACB pest problem and reduce borer damage by 44%, to damage levels in *Bt* and *Bt*HT corn of 6.8 and 7%, respectively. The leaves of *Bt* corn were more susceptible, while cobs of *Bt* corn were less affected by ACB. Non-ACB pests were common in *Bt* toxin-free cornfields and reduced in non-GM cornfields where ACB was abundant. No secondary pest outbreaks were found in ACB-free *Bt* cornfields.

Bt and *Bt*HT corn hybrids containing the Cry1Ab protein performed well in Isabela Province. Reduced cob damage by ACB on *Bt* fields could mean smaller economic losses even with ACB infestation. The occurrence of ACB in *Bt* and *Bt*HT cornfields, although at a moderate and insignificant level, could imply the potential development of resistance to *Bt* toxin.

Introduction

The damage brought about by corn borer infestation constitutes a major constraint on agriculture in all of the world's corn-producing countries. According to the Food and Fertiliser Technology Centre (FFTC), even minor damage can lead to a low market value of corn. In China, the Asian corn borer (ACB), *Ostrinia furnacalis* (Guenée), is an important component of the lepidopteran pest complex for cotton and corn (He *et al*., 2003; He *et al*., 2006). In the Philippines, ACB has become the most damaging corn pest (Logroño, 1998). Tropical agriculture countries such as the Philippines are threatened by a high incidence of ACB, with a 27% corn yield reduction resulting from 40–60% corn borer infestation (Logroño, 1998). The rate of infestation can be as high as 80% when corn is planted late (Javier, 2004).

Most farmers prefer a readily available, labour-reducing and easy method of ACB control using insect-resistant (*Bt* and *Bt*HT) corn. *Bt* and *Bt*HT corns have a genetically built-in endotoxin Cry1Ab protein from the *Bacillus thuringiensis* (*Bt*) bacterium, which kills ACB as activated toxin binds to the midgut of the corn borer, leading to ion influx, cell lysis and the death of the susceptible organism (Schnepf *et al*., 1998; Hua *et al.,* 2001). *Bt*-protected corn reduces the damage rates by ACB (He *et al.,* 2006). In temperate countries, the use of *Bt* corn has become an effective tool to control European corn borer (ECB), *Ostrinia nubialis* Hb (Rice and Pilcher, 1997). Transgenic corn proved to be effective against ACB, reducing borer tunnels by 99% and leaf injury by 84% (Thomson *et al.,* 2010), and affording a yield of 9838 kg ha^{-1} (Dekalb 818 YG) compared with 7838 kg ha^{-1} with conventional corn (NK 8870) (Philippine NSIC, 2011).

Herbicide-tolerant corn (HT and *Bt*HT) is genetically modified to counteract the damaging effects of herbicides. Specifically, HT corn is protected from glyphosate through its genetically built in EPSP (5-enolpyruvylshikimate-3-phosphate synthase) cDNA, isolated from a glyphosate-tolerant petunia cell culture line. (Padget *et al.,* 1995). Cultivation of HT corn can lead to substantial environmental benefits (Cerdeira and Duke, 2006), as it allows minimal or zero tillage methods. A new investigation of ACB plant damage in the Philippines was carried out to ensure that endotoxin-containing *Bt* corn still exhibits the same efficacy in ACB control as in previous surveys. In the 2003-2004 growing season, Isabela farmers reported no borer damage in *Bt* corn, compared with 15% crop damage in non-*Bt* corn. In 2007-2008, non-GM corn farmers in Isabela encountered a low percentage of damage by ACB (4%), while *Bt* corn farmers reported zero damage (Gonzales *et al*., 2009).

The present study also included a comparative assessment between leaves, stems and cobs of *Bt* corn plants, to test whether plant parts exhibit different resistance to ACB, as the Cry1Ab protein that produces the *Bt* endotoxin is known to occur in different concentrations in different plant parts (Abel and Adamczyk, 2004; Székács *et al*., 2010a; Székács *et al*., 2010b). Previous studies (Halpin *et al*., 1994; Saxena & Stotzky, 2001) showed that *Bt* toxin is not the only feature specific to *Bt* corn. *Bt* corn also has a 33-97% higher lignin content than non-*Bt* corn (Saxena and Stotzky, 2001; Poerschmann *et al*., 2005). Lignin in a plant confers strength, rigidity and water impermeability, which contributes to its protection from borers and is effective against second-generation ECB (Ostrander and Coors, 1997). Differences in lignin content between plant parts could imply differences in resistance against and/or susceptibility to corn borer infestation.

This study also evaluated the recent actual field situation regarding the potential development of ACB resistance to *Bt* corn in the Philippines. In China, both field and laboratory (He *et al*., 2003; Wang *et al*., 2004; Chang *et al*., 2007) have been carried out to evaluate the resistance of *Bt*11 and Mon810 to ACB. Until 2009, only field surveys of ACB host plants other than corn were carried out in the Philippines (Caasi-Lit *et al*., 2004; Caasi-Lit *et al.,* 2009). Recently, Alcantara *et al*. (2011) provided direct evidence from laboratory bioassays that ACB populations in the Philippines have remained susceptible to *Bt* corn. Outside the laboratory, however, many factors should be taken into account, as the amounts ingested by the ACB, the mode of exposure and the sources of *Bt* toxin vary between plant parts, field situations and locations.

As reported in Gerpacio *et al*. (2004), other non-ACB corn pests in the Philippines, such as armyworm (*Pseudaletia unipunctata*) and common cutworm (*Spodoptera litura* Fabricius), can occur in GM corn and cause moderate to high yield losses. An evaluation was therefore made to establish whether widespread adoption of *Bt* and *Bt*HT corn could potentially cause outbreaks of secondary pests (non-ACB) in time. If these corn hybrids efficiently eradicated ACB, non-ACB pests could establish populations and encroach on the corn environment, where ACB is nearly or completely absent. Earlier studies showed that *Bt* corn can partially control and reduce the damage of other, non-ACB, pests such as corn earworm (*Helicoverpa zeae*), common stalk borer (*Papiapema nebris*) and armyworm (Pilcher *et al*., 1997; Lynch *et al.,* 1999). To verify this in a tropical environment, an investigation was made not only of the damage caused by ACB but also of plant damage by pests other than ACB.

To the present authors' knowledge, there has been no recent field research into ACB infestation since the emergence of new *Bt* corn hybrids. In particular, there is a lack of empirical studies in actual field situations assessing *Bt* and *Bt*HT performance and the susceptibility of ACB in the Philippines. Hence, the present study aimed to: (1) investigate once more the performance of widely cultivated GM corn in terms of ACB control; (2) determine the susceptibility of different plant parts containing *Bt* endotoxin to borer attacks; (3) assess the potential development of ACB resistance in a GM corn environment; (4) evaluate the potential build-up of secondary pests in an ACB-free GM corn environment.

Lastly, as environmental factors may affect the occurrence of ACB or non-ACB pests, and the spatial distribution of these factors is unknown, spatial variables (i.e. distance to the river, geographical location and elevation) of the cornfields were taken into consideration in the analyses to ensure that location factors did not bias the results.

Methods

Description of the study area

Isabela Province is situated in the north-east Luzon part of the Philippines (Fig. 1). It has a type III climate with an average rainfall of 1700 mm and an annual temperature of 27 ^{0}C (Gerpacio *et al.*, 2004). Clay loam and sandy loam are the most common soil types in the fields surveyed. Corn production in the province starts at the first monsoon rains, during April or May. The first cropping ends in August and most non-GM farmers start planting for the second crop immediately after harvest. By contrast, most GM corn farmers wait until November or December to start planting for the second cropping. This is because Isabela is a typhoon- and flood-prone area, and 90% of GM corn farmers whose fields are located in lowlying areas do not want to take the risk. The province is transected by the Cagayan River, and most of the cornfields suitable for corn production are located near this river. The distance from the cornfields surveyed to the Cagayan River ranges from 0.8 to 32 km. Elevation also differs between cornfields, ranging from 0.04 to 0.15 km above sea level. The size of the inspected cornfields ranges from 0.5 to 4 ha.

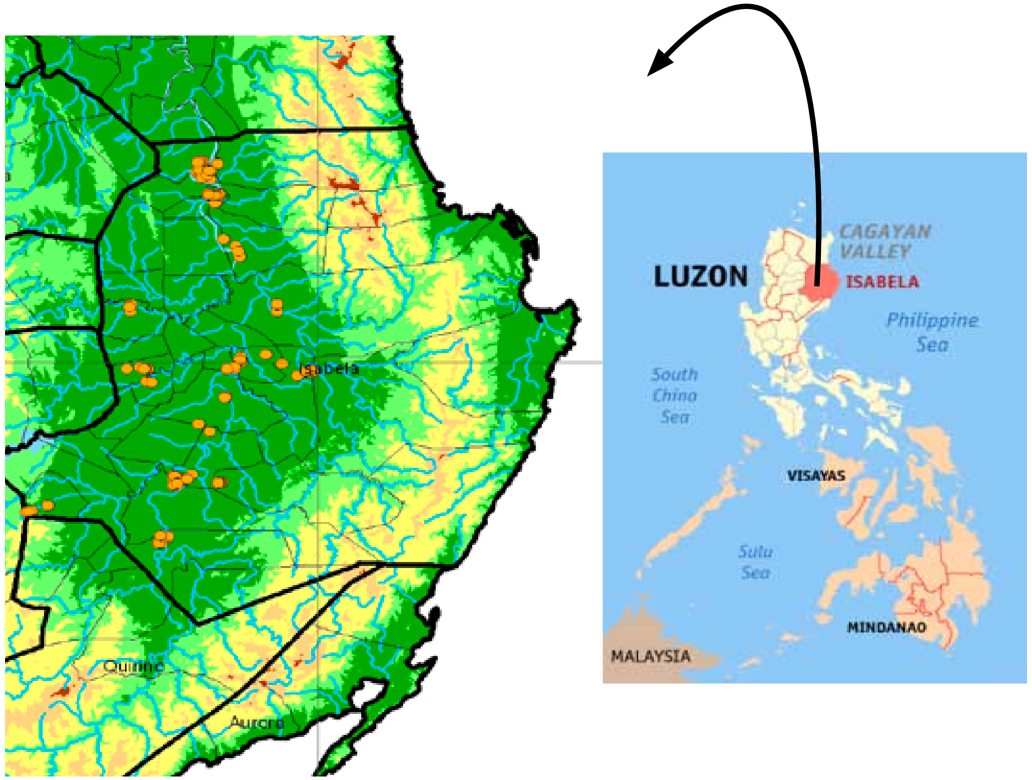


Figure 1. Map showing locations of 198 surveyed cornfields in 19 municipalities of Isabela province, in the Northeast Luzon part of the Philippines, during the 2010 wet growing season.

Selection of cornfields

As there are three GM corn hybrids (*Bt*, *Bt*HT and HT) that are widely cultivated in the Philippines, all three were included in the study. Non-GM corn was used for the comparison. The starting points for selecting field sites were villages with a high degree of adoption of GM corn and a history of serious ACB infestation. The authors interviewed village officials and/or municipal agricultural officers to find out the locations of corn areas. Prior to field inspections, interviews were held with farmers to ascertain the specific corn type planted in the fields. Permission to conduct visual inspections was obtained from the owners or current tillers of the fields. Forty-nine villages in 19 municipalities of Isabela were surveyed (Fig. 1). In all, 198 cornfields were individually inspected, in the post-flowering to mid-maturity stages, during the wet growing season of 2010 (Table 1).

Table 1. Numbers of GM and non-GM cornfields visited during the survey of 198 fields in Isabela province, The Philippines, in the 2010 wet growing season.

Municipality (n=19)	Number of Fields (n=198)	*Bt* (n=30)	*Bt*HT (n=91)	HT (n=14)	non-GM (n=63)
Angadanan	12	1	5	0	6
Aurora	10	1	8	0	1
Benito Soliven	4	1	3	0	0
Cabagan	19	6	6	2	5
Cabatuan	8	0	5	0	3
Cordon	9	1	3	3	2
Cauayan	9	2	5	0	2
Echague	19	5	10	0	4
Ilagan	7	3	3	0	1
Jones	10	0	7	0	3
Naguillan	8	0	7	0	1
Reina Mercedes	10	1	1	0	8
Roxas	5	0	3	1	1
San Guillermo	15	0	7	2	6
San Mariano	8	1	4	1	2
San Pablo	14	6	0	1	7
Sta. Maria	7	1	3	1	2
Sto. Tomas	14	0	7	1	6
Tumauini	10	1	4	2	3

Assessment of infestation

The authors re-investigated the performance of GM corn in terms of the control of ACB by means of field scouting (Fishel *et al.*, 2001) accomplished by determining the number of plants damaged in GM and non-GM corn. A 200 m transect line was established through the middle of each surveyed cornfield. Along this line, 200 plants were examined for probable signs of ACB infestation. ACB is a flat, scale-like, whitish lepidopteran that lays 25-50 eggs per egg mass (Gonzales *et al.*, 2009). Among the characteristic types of damage caused by ACB (Morallo and Punzalan, 2001) were: pinholes in leaves; big holes in stalks, the base of tassels or ear shanks; broken stalks and tassels; clumping of tassels; partial destruction of cobs; dropping of ears in severe cases (Fig. 2a). Damage by pests other than ACB (Fig. 2b) was recorded as the presence of injury damage characteristic of each specific pest.

The second objective was addressed by comparing the damage between plant parts by counting and recording the ACB-associated numbers of holes in leaves, cobs and stems. In addition, numbers of egg masses per plant were recorded to assess the behaviour of adult ACB on GM corn. The third objective was addressed by recording the extent of plant damage from ACB in all *Bt* and *Bt*HT cornfields. The percentage of damage per corn type was assessed, and the data produced in this study were compared with the findings of previous surveys in the Philippines, as reported by Gerpacio *et al*. (2004).

The final objective of this study, to assess the development of secondary pests, was addressed by counting the numbers of plants damaged by non-ACB pests. Among the non-ACB pests (Fig. 2b) observed during field inspections were aphids, black cutworm, armyworm, black crickets, grasshoppers, corn earworm, rootworm, termites and large pests such as birds and rats. Injury caused by black crickets and grasshoppers was indicated by the corrugated appearance of affected eaten leaf parts, going from the leaf margin towards the leaf midrib. Armyworm larvae cause irregular leaf holes with a maximum diameter of 0.6 cm, depending on the age and body size of the larvae. Damage by termites was very clearly identifiable, because of the evidence of plant injury created by soil line along the stem. Corn earworm injury was seen in the cobs as holes and feeding damage on the tips and soft parts of the husks and grains.

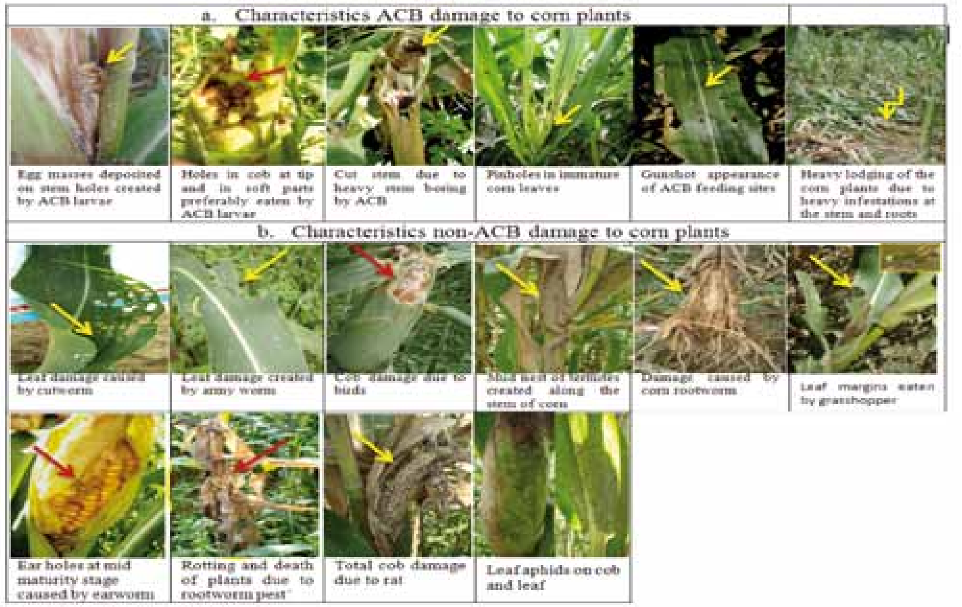


Figure 2. Observable damage symptoms of ACB (a) and non-ACB (b) infestations in corn plants surveyed in Isabela province, The Philippines, during the 2010 wet growing season.

Spatial variables

The authors tried to evaluate whether the present findings could be biased by spatial variables. Spatial data such as distance to the river, elevation and absolute and relative location of cornfields were gathered and incorporated in the statistical model. The distance of each field to the river was computed after obtaining the individual GPS (geographical position system, Garmin Vista eTrex) readings, and calculated in a GIS (geographic information system) using ArcGIS 9.2 software and the Hawth Tools extension. The relative locations of the cornfields were classified as southern, northern and central parts. As Ilagan is the capital of the province and centrally located (going from north to south), it was used as the georeference for the cornfield locations (Fig. 1). All cornfields belonging to towns to the north and south of the central town of Ilagan were categorised as northern and southern relative locations respectively. Absolute location is the actual location of the cornfield in GPS coordinates (*Y*-coordinates/longitude and *X*-coordinates/latitude).

Statistical analysis

Correlations between independent variables were analysed to identify the links between variables. Variables with low correlation values were selected for multivariate analyses. All data indicated the number of damaged plants per field (out of the 200 plants examined). Non-normally distributed data, assessed on the basis of residual plots (residual versus fitted, normal QQ, scale location and residual versus leverage) were ln(*x*+1) transformed.

Multiple regression analysis was carried out per response variable, i.e. ACB damage, non-ACB damage or overall damage. The independent variables that were included in the statistical model were corn types (*Bt*, *Bt*HT, HT and non-GM), relative location of the cornfield (southern, central or northern), absolute location (latitude and longitude), distance to the river and elevation.

All analyses were done using R statistics v.2.12.2. The proportional test in R was used to compare damage to different plant parts between *Bt* (*Bt* and *Bt*HT) and non-*Bt* (non-GM and HT) corn. Specifically, this two-sample test for equality of proportions was employed to determine the number of *Bt* and non-*Bt* plants showing ACB holes in leaves, stems and cobs, as well as the number of plants with egg masses. Only significant results are presented in Sections 3 and 4, unless otherwise indicated.

Results

Effects of GM corn on pest damage

The percentages of plants with damage associated with ACB and non-ACB pests are given in Table 2. One field had a very high number of plants damaged by non-ACB pests. This made the present data non-normally distributed, making it necessary to transform the data using ln(*x*+1). All the other values were natural log transformed. Corn type affected the amount of damage by ACB (Table 3, Fig. 3). Non-GM corn had the highest proportion of damaged plants, followed in descending order by HT, *Bt* and *Bt*HT corn (Table 3). *Bt* toxin in corn effectively reduced ACB damage by 44%, from 15.7% in non-GM to 6.8% in *Bt* corn (Table 2). Non-ACB plant damage did not differ between GM and non-GM corn types (Table 3, Fig. 4). Among GM corn varieties, *Bt* corn had the highest number of non-ACB plant damage (Fig. 4). On overall damage (i.e. plant damage caused either by ACB or non-ACB), there was a significant effect of corn types on plant damage (Table 3, Fig. 5). Non-GM corn exhibited the highest number of overall plant damage, while *Bt* corn had the lowest (Fig. 5).

Table 2. Percentage of plants with damage symptoms associated with ACB (for different plant parts) and non-ACB pests in 19 towns of the Isabela province during the wet growing season of 2010. (ACB-associated symptoms include holes in leaves, stems, cobs and the presence of egg masses, in different corn types).

Corn Types	Number of fields	Number of plants inspected	Percentage of plants with					
			ACB damage					
			Leave	Stem	Cob	Egg mass	ACB damage	non-ACB damage
Non-GM corn	63	12600	13.16	1.44	1.79	0.62	15.70	2.39
Bt corn	30	6000	6.45	0.17	0.80	0.27	6.80	2.03
*Bt*HT corn	91	18200	6.82	0.03	0.35	0.18	7.00	1.44
HT corn	14	2800	9.46	0.25	1.04	0.46	11.21	1.00
Total	**198**	**39600**	**8.97**	**0.52**	**0.92**	**0.35**	**10.03**	**1.80**

Table 3. Results of regression analysis showing the estimate and standard error of ACB-, non-ACB and overall plant damage per field, varying significantly per corn type. (P values: *** = P<0.001, ** = P<0.01, * = P<0.05, (*) = P<0.10).

	Estimate	Std. Error	t-value	Pr(>|t|)	R^2	p-value
ACB damage					**0.043**	**0.009****
Intercept						
- Non-GM corn	2.886	0.139	20.732	<2e-16 ***		
Contrast with intercept						
- *Bt* corn	-0.508	0.245	-2.073	0.040*		
- *Bt*HT corn	-0.587	0.181	-3.243	0.001**		
- HT corn	-0.101	0.326	-0.310	0.757		
Non-ACB damage					**0.011**	**0.158**
Intercept						
- Non-GM corn	0.617	0.128	4.822	2.87e^{-06} ***		
Contrast with intercept						
- *Bt* corn	0.506	0.225	2.249	0.026*		
- *Bt*HT corn	0.191	0.166	1.148	0.252		
- HT corn	0.063	0.300	0.208	0.835		
Overall damage (either by ACB or non-ACB)					**0.044**	**0.008****
Intercept						
- Non-GM corn	3.079	0.114	26.978	<2e-16 ***		
Contrast with intercept						
- *Bt* corn	-0.438	0.201	-2.180	0.031*		
- *Bt*HT corn	-0.495	0.148	-3.338	0.001**		
- HT corn	-0.173	0.268	-0.645	0.520		

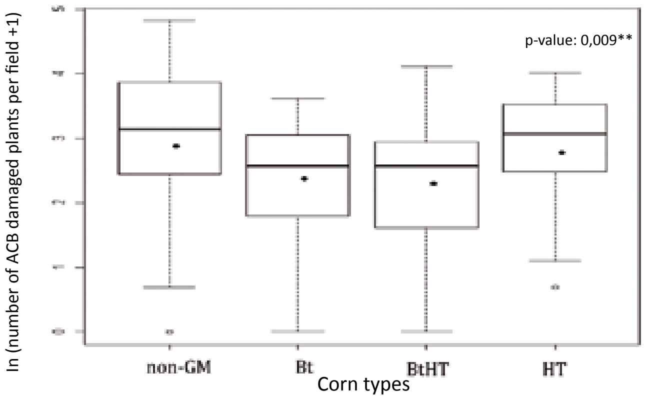


Figure 3. Numbers of plants with damage associated with ACB infestation, for the different corn types. The dark line is the median line, the black dot is the mean, the box encloses the interquartile range and the whiskers show the full range, with outliers shown as circles. Values were ln(x+1) transformed. P-values: *** = P<0.001, ** = P<0.01, * = P<0.05, (*) = P<0.10).

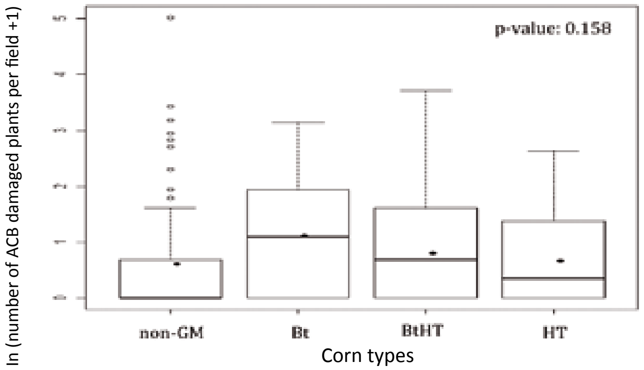


Figure 4. Number of plants with damage associated with non-ACB infestation, for the different corn types. The dark line is the median line, the black dot is the mean, the box encloses the interquartile range and the whiskers show the full range, with outliers shown as circles. Values were ln(x+1) transformed. P-values: *** = P<0.001, ** = P<0.01, * = P<0.05, (*) = P<0.10).

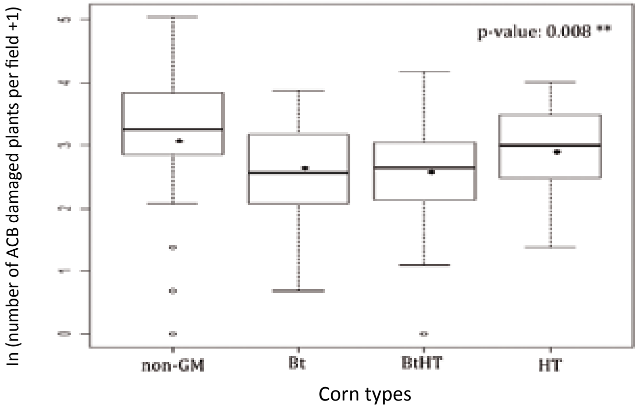


Figure 5. Overall plant damage caused by ACB and non-ACB pests for the different corn types. The dark line is the median line, the black dot is the mean, the box encloses the interquartile range and the whiskers show the full range, with outliers shown as circles. Values were ln(x+1) transformed. P-values: *** = P<0.001, ** = P<0.01, * = P<0.05, (*) = P<0.10).

ACB damage in different plant parts

Among the four corn types, non-GM corn consistently showed high numbers of leaf, cob and stem holes (Table 4, Fig.6) associated with ACB damage. Apart from leaf damage, the *Bt*HT corn showed the smallest proportion of ACB-damaged plants (Table 4).

Table 4. Estimate and standard error of plant part damage by ACB for different corn types, based on regression analyses. (P values: *** = P<0.001, ** = P<0.01, * = P<0.05, (*) = P<0.10).

	Esti-mate	**Std. Error**	**t-value**	**Pr(>|t|)**	**R²**	**p-value**
Leaf					**0.041**	**0.012***
Intercept						
- Non-GM corn	2.844	0.118	24.079	<2e^{-16}***		
Contrast with intercept						
- *Bt* corn	-0.490	0.208	-2.355	0.019*		
- *Bt*HT corn	-0.478	0.154	-3.113	0.002**		
- HT corn	-0.150	0.277	-0.543	0.588		
Cob					**0.066**	**0.001****
Intercept						
- Non-GM corn	0.836	0.105	7.983	1.22e-^{13}***		
Contrast with intercept						
- *Bt* corn	-0.427	0.184	-2.316	0.022*		
- *Bt*HT corn	-0.552	0.136	-4.049	7.44e^{-05}***		
- HT corn	-0.276	0.246	-1.121	0.264		
Stem					**0.017**	**0.094(*)**
Intercept						
- Non-GM corn	0.258	0.067	3.865	0.000 ***		
Contrast with intercept						
- *Bt* corn	-0.089	0.118	-0.757	0.450		
- *Bt*HT corn	-0.219	0.087	-2.518	0.012*		
- HT corn	-0.110	0.157	-0.700	0.484		
Egg masses					**0.009**	**0.191**
Intercept						
- Non-GM corn	0.376	0.074	5.047	1.03e^{-06}***		
Contrast with intercept						
- *Bt* corn	-0.104	0.131	-0.796	0.427		
- *Bt*HT corn	-0.208	0.097	-2.147	0.033*		
- HT corn	-0.055	0.175	-0.313	0.755		

The proportional test for *Bt* corn and non-*Bt* corn showed that the number of holes in leaves of infested plants was lower for non-*Bt* corn than for *Bt* corn. The number of ACB-associated holes in cobs and stems was smaller in *Bt* corn. The proportion of plants with egg masses was nearly significantly lower in *Bt* corn (Table 5).

Table 5. Proportional test for damage to leaves, stems and cobs as well as the presence of egg masses, for *Bt* and non-*Bt* corn

Variables	sample estimates	Chi-square	p-value
Leaf		184.6035	< 2.2e-16***
(non-*Bt*)	0.843		
(*Bt*)	0.975		
Cob		106.0798	< 2.2e-16***
(non-*Bt*)	0.083		
(*Bt*)	0.009		
Stem		24.6602	6.838e-07***
(non-*Bt*)	0.113		
(*Bt*)	0.066		
Egg masses		3.1937	0.07392(*)
(non-*Bt*)	0.040		
(*Bt*)	0.029		

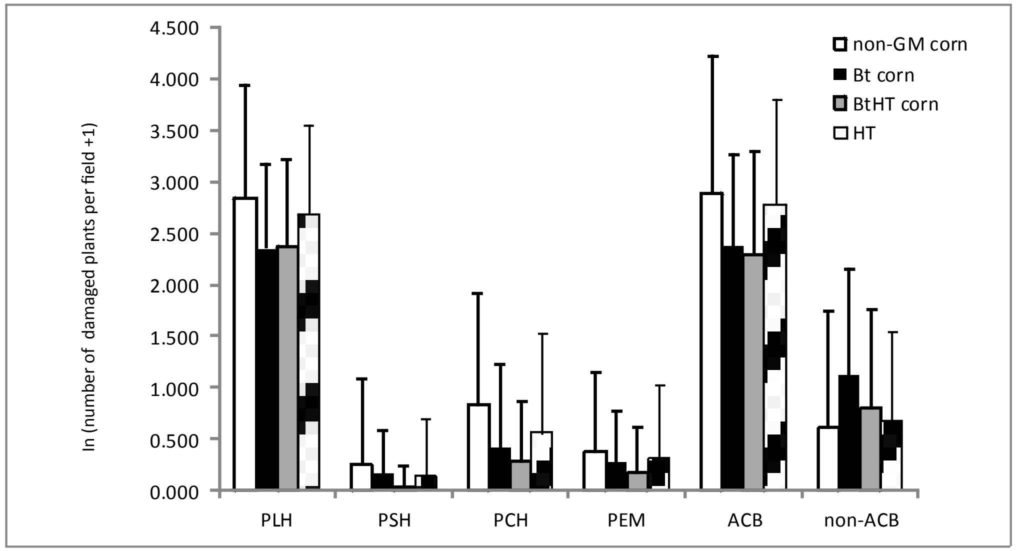


Figure 6. Numbers of damaged plants per field due to ACB and non-ACB pests, for different parts of corn plants (i.e. numbers of holes in leaves, stems or cobs, or number of egg masses. P-values: *** = P<0.001, ** = P<0.01, * = P <0.05, (*) = P <0.10.

Pest damage and spatial variables

Regression analyses of corn type and spatial variables as explanatory variables showed that the numbers of plants with ACB damage, with non-ACB damage and overall damage were hardly affected by spatial factors, except for the distance to the river. This was true for both ACB and non-ACB damage (Table6), but the effect of distance to river did not appear in the overall damage.

This is because ACB damage was positively correlated with the distance to the river, while non-ACB damage was negatively correlated with this distance (Table 7). Important here, however, is the fact that correction for spatial variables did not cause the significant effect of corn type on ACB and overall damage to disappear, nor did it introduce a significant effect on non-ACB damage.

ACB vs. non-ACB

A negative correlation was found between ACB and non-ACB plant damage (Table 7). Table 8 shows that ACB damage was lower in fields with higher non-ACB damage, and vice versa. The interactions between corn types were not significant (Table 8, Figs 7a and b).

Table 6. Results of multiple regression analyses showing the sum square values of plant damage per response variable (i.e. ACB, non-ACB or overall damage) per corn type. Spatial attributes of the cornfields, such as distance to the river, elevation and absolute and relative locations, were the explanatory variables included in the statistical model. (P values: *** = P<0.001, ** = P<0.01, * = <0.05, (*) = P<0.10).

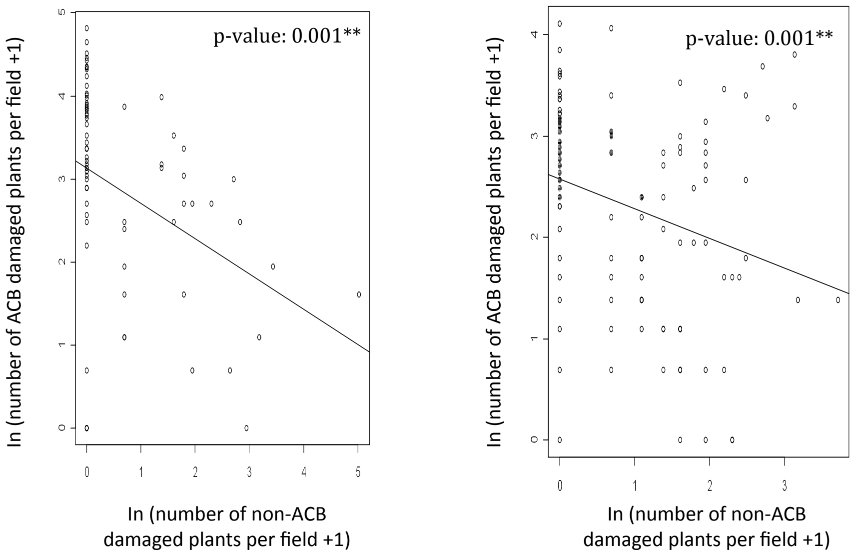
Between corn types	Sum Sq	Mean Sq	F-value	Pr(>F)	R^2	p-value
ACB damage					**0.068**	**0.009****
- Corn types	14.450	4.817	4.052	0.008 **		
- Relative location	0.009	0.004	0.004	0.996		
- Distance to river	5.188	5.188	4.364	0.038 *		
- Elevation	3.030	3.030	2.549			
- Latitude (X)	0.079	0.079	0.067			
- Longitude (Y)	1.021	1.021	0.859	0.355		
- Interaction (X*Y)	5.169	5.169	4.348	0.038 *		
Non-ACB damage					**0.067**	**0.010***
- Corn types	5.416	1.805	1.857	0.138		
- Relative location	6.804	3.402	3.499	0.032*		
- Distance to river	4.759	4.759	4.894	0.028*		
- Elevation	0.230	0.230	0.237			
- Latitude (X)	0.866	0.866	0.891			
- Longitude (Y)	2.633	2.633	2.708	0.102		
- Interaction (X*Y)	2.665	2.665	2.741	0.099(*)		
Overall damage (either by ACB or non-ACB)					**0.066**	**0.011***
- Corn types	9.938	3.313	4.132	0.007**		
- Relative location	0.902	0.451	0.563	0.571		
- Distance to river	0.461	0.462	0.576	0.449		
- Elevation	2.258	2.258	2.817	0.095(*)		
- Latitude (X)	0.012	0.012	0.014			
- Longitude (Y)	3.181	3.181	3.967	0.048*		
- Interaction (X*Y)	2.394	2.394	2.986	0.086(*)		

Table 7. Correlation matrix. Pearson coefficients in the upper right part of the matrix, P-values in the lower left part.

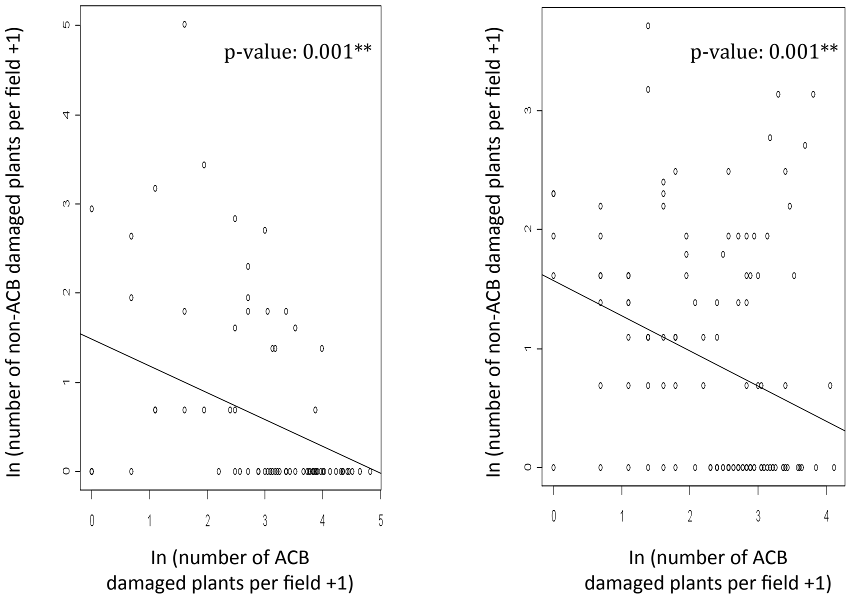
Variables		Pearson's correlation coefficient						
		ACB	Non-ACB	Relative location	Longitude	Latitude	Distance to river	Elevation
P-values	ACB	■	-0.341	-0.001	-0.015	-0.014	0.121	0.133
	Non-ACB	8.973e-07	■	0.010	-0.139	0.034	-0.120	0.125
	Relative location	0.984	0.892	■	-0.766	-0.474	0.216	-0.113
	Longitude	0.836	0.051	2.2e-16	■	0.346	-0.252	-0.224
	Latitude	0.849	0.636	1.646e-12	5.963e-07	■	-0.431	0.168
	Distance to river	0.088	0.093	0.002	0.000	2.249e-10	■	-0.064
	Elevation	0.063	0.080	0.113	0.001	0.018	0.371	■

Table 8. Results of regression analyses showing differences between ACB and non-ACB plant damage. The table represents the output of the minimal models selected after stepwise regression analyses. Values were ln(x+1) transformed. P-values: *** = P<0.001, ** = P<0.01, * = <0.05, (*) = P<0.10.

Between corn types	Sum Sq	Mean Sq	F-value	Pr(>F)	R^2	p-value
ACB-damage					**0.157**	**1.649e-07*****
-Non-ACB	29.178	29.178	27.152	4.809e-07***		
-Corn types (Bt and non Bt)	7.890	7.890	7.342	0.007**		
-Non-ACB* Corn Types	0.374	0.374	0.348	0.556		
-Elevation	6.384	6.384	5.940	0.016		
Non-ACB damage					**0.138**	**2.738e-06*****
-Non-ACN	23.832	23.832	26.542	6.372e-07		
-Corn types (Bt and non Bt)	0.347	0.347	0.387	0.535		
-Non-ACB* Corn Types	0.120	0.120	0.134	0.715		
-Elevation	4.348	4.348	4.842	0.029*		
-Longitude	4.151	4.151	4.623	0.033*		



Non-Bt corn (a) **Bt corn**



Non-Bt corn (b) **Bt corn**

Figure 7. Interaction correlation graphs of the number of plants with damage associated with ACB and non-ACB pests. Two models were used to test the negative correlations between ACB and non-ACB: (1) Model A, ACB as response variable and non-ACB as explanatory variable in the case of non-Bt corn (left) and *Bt* corn (right); (2) Model B, non-ACB as response variable and ACB as explanatory variable in the case of non-*Bt* corn (left) and *Bt* corn (right). Values are ln(x+1) transformed numbers of damaged plants per field.

Discussion

Performance of GM corn

In the present study, the high percentage of ACB-damaged plants in non-GM corn (with 15.7% of all plants showing some kind of damage) indicates that ACB is still a major pest problem in Isabela. Damage was considerably less in GM corn types, with both *Bt* and *Bt*HT corn showing a 44% reduction in ACB damage. ACB damage clearly dominated the overall damage (i.e. the damage attributed to ACB as well as to non-ACB pests). Specifically, the overall plant damage in *Bt* cornfields was significantly less than in non-*Bt* cornfields. This indicates the potentially beneficial effects of adopting *Bt* corn to reduce plant damage caused by corn pests, especially ACB.

The present findings confirm those of studies by He *et al*. (2006) and Thomson *et al*. (2010), which found evidence of reduced ACB damage in *Bt* toxin-containing corn. Field trials done by He *et al*. (2006) proved that Mon *Bt* corn is highly resistant to ACB damage. In the Philippines, field evaluation of two TC1507 *Bt* corn varieties by Thomson *et al*. (2010), assessed percentage reduction in borer tunnels and leaf injury at 99 and 84% respectively. The high discrepancy in the reduction in percentage of ACB damage between the present study and the findings of Thomson *et al*. (2010) could be mainly caused by differences in the cry protein compositions of the *Bt* corn varieties used. In the present study, all *Bt* corn types tested contained Cry1Ab protein, while Thomson *et al*. (2010), used *Bt* corn varieties containing Cry1F protein; hence, different cry proteins may vary in efficacy against ACB.

Bt plant parts susceptible to ACB

Comparison between the leaf, stem and cob parts revealed that the leaves are the most susceptible to ACB attack. Voracious leaf feeders such as ACB larvae mostly attack corn leaf because it is easy to chew and softer than stem and cob. Although the Cry1Ab protein was found in higher concentrations in leaves, its concentration fluctuates upon maturity, whereas the stems have a stable concentration of Cry1Ab protein throughout the growth stages (Székács *et al*., 2010b). As the present survey was done between tasselling and maturity growth stages, it is highly possible that the Cry1Ab concentration in the leaves was diminished, making them more susceptible to ACB attack. The lower level of cob damage in infected plants that was noted in *Bt* corn as compared with non-*Bt* corn implies that economic loss in *Bt* corn is minimal even when plants are infested by ACB. Likewise, kernel damage, which may trigger the growth of fungi causing mycotoxin contamination, could also be prevented by using *Bt* corn (Ajangaa and Hillocks, 2000).

Among corn types, *Bt*HT corn was much less affected by ACB damage to leaves, cobs and stems. As regards egg masses, there was no significant effect of corn type. This could indicate that adult ACBs do not recognise *Bt* corn plants. The present study thus provides field evidence that ACB oviposition preference was not affected by corn containing *Bt* toxin.

ACB resistance to GM corn

Some studies (Bourguet *et al*., 2003; Farinós *et al*., 2004; Alcantara *et al*., 2011; Tan *et al*, 2011) found little or no borer resistance to *Bt* toxin. In the present study, although *Bt* and *Bt*HT plants had the lowest numbers of damaged plants, they were not free from ACB infestation, as shown in Table 2. A very low (1-2%) incidence of ACB-damaged plants was anticipated, yet ACB proved to inflict damage to 6.8 and 7% of *Bt* and *Bt*HT plants, respectively (Table 2).

The first- and second-instar larval stages of ACB are leaf feeders, and they could die after feeding on corn plants with *Bt* toxin. If they survive the *Bt* toxin, they continue to develop into the third-, fourth- and fifth-instar larval stages. At these stages, the ACB larvae with their well-developed and powerful mandibles are able to inflict great damage to corn plants and produce large holes in stems and leaves. The present survey found mostly large holes in *Bt* corn plants, indicating that ACB larvae emerged, grew and transformed into third-, fourth- and fifth-instar stages. The fact that the ACB spent some of their lifetime eating on *Bt* corn plants means that they survive the effects of *Bt* toxin at least for some time.

Archer *et al*. (2000) evaluated four *Bt* varieties, Mon810 (Cry1Ab), *Bt*11 (Cry1Ab), *Bt* 176 (Cry1Ab) and CBH354 (Cry9c), for the control of south-western and European corn borers. Whereas the second generation of corn borers were controlled well by Mon810, *Bt*11 and CBH354, *Bt* 176 exhibited susceptibility to corn borers, and the damage rate was comparable with that in non-*Bt* hybrids. This shows that corn borers could potentially develop tolerance to some commercially available *Bt* corn hybrids, as in the case of event *Bt* 176.

Borers can develop a certain degree of resistance when continuously exposed to *Bt* toxin. The research by Huang *et al*. (2007) provided the first evidence that a target pest may develop resistance to *Bt* toxin. The study by van Rensburg (2007) found that substantial numbers of African stem borer larvae survived over the entire trial period, although the mean larval mass was less on Mon810 *Bt* corn than on non-*Bt* corn. Recent findings by Kojima *et al*. (2010) suggest that ACB could easily adapt to the chemical defences of its host plants. In view of these findings, plus the continued large-scale monocropping of *Bt* corn in the Philippines, there is a great risk of ACB resistance to *Bt* toxin developing via physiological adaptation. In particular, the presence and persistence of ACB in *Bt* cornfields is an indication that ACB could develop some adaptive characteristics, such as the development of resistance genes to Cry1Ab similar to those of the sugarcane borer, *Diatraea saccharalis* (Huang *et al.,* 2007).

Non-ACB pests in the GM corn environment

Pests such as the corn leafhopper *Cicadulina bimaculata* (Evans), corn earworm *Helicoverpa armigera* (Hübner) and corn leaf aphid *Rhopalosiphum maidis* Fitch (Litsinger *et al*., 2007) can reduce yields, although they are considered to be of less importance than ACB damage. In the present study, similar species of non-ACB pests may have caused higher plant damage in *Bt* corn. This suggests that *Bt* and *Bt*HT are only effective against ACB and do not offer defence against non-ACB pests. To some extent, this contradicts the findings of Pilcher *et al*. (1997) and Lynch *et al*. (1999), who found that *Bt* corn could partially control and reduce damage by pests such corn earworm and armyworm (*Pseudaletia unipunctata*).

Likewise, the high negative correlation between ACB and non-ACB damage might indicate that ACB is negatively influenced by the occurrence of non-ACB pests, or the other way around. In addition, the significant number of non-ACB-damaged plants in *Bt* fields suggests that non-ACB pests are resistant to *Bt* toxin. Yet this also indicates that, when ACB is continuously absent from *Bt*-protected fields, niche intrusion could take place and secondary pests could emerge and come to dominate in time. Further, the low percentage of ACB-damaged plants in *Bt* cornfields where significantly higher numbers of non-ACB pests were observed could also mean that ACB can detect the presence of competitors in the plants and look for other habitats with fewer or no competitors (Bernasconi *et al.,* 1998).

The trend lines in Figures 7a and b indicate that corn type was not responsible for the negative correlations between ACB and non-ACB pests, and that other factors should be considered. This is supported by Table 8, which shows no interaction effects between pest damage and corn type. There is no reason to assume that the high abundance of non-ACB pests is due to corn type; hence, at this stage the existence of secondary pest development cannot be confirmed.

Conclusion

In conclusion, *Bt* and *Bt*HT corn hybrids containing the Cry1Ab protein performed well in Isabela Province. This was manifested by the significant reduction (by 44%) in ACB damage in inspected *Bt* cornfields. The fact that ACB inflicted greater damage in *Bt* leaves than in stems and cobs indicates that leaves are more susceptible to ACB attack. The lower level of cob damage by ACB in *Bt* fields could mean smaller economic losses even when such fields are infested by ACB. The occurrence of ACB in *Bt* and *Bt*HT cornfields, although at a moderate and insignificant level, could, however, indicate the potential development of resistance to *Bt* toxin.

Acknowledgements

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Field assessment of the impact of genetically modified (GM) corn cultivation and its associated agricultural practices on in-field invertebrate populations in the Philippines

Miladis M. Afidchao, C.J.M. Musters,
Mercedes D. Masipiqueňa and Geert R. de Snoo

To be submitted

Abstract

Simplified agricultural practices, involving no tillage, no insecticide inputs and lower human labor requirements, are now the preferred corn farming system and have been generally adopted in the Philippines. This system involves cultivation of genetically modified (GM) corn such as insect-resistant *Bacillus thuringiensis* (*Bt*) corn and *Bt* plus herbicide-tolerant (*Bt*HT) corn. Adopting GM corn cultivation removes the need for insecticides and enables labor-intensive manual weeding to be replaced by methods involving herbicides. This is assumed to yield superior economic returns. Yet, the effect of GM corn on biodiversity is an as yet unresolved issue, especially in a biodiversity hotspot like the Philippines. The GM effects on biodiversity were studied in a six-hectare field experiment in Cabagan, Isabela, The Philippines, during the 2009 dry and wet cropping seasons, in order to evaluate the short-term effect of GM corn (i.e. *Bt* and *Bt*HT) on the community of in-field invertebrates. Our findings showed that the total invertebrate abundance, surface dweller abundance and species richness of surface dwellers and soil dwellers were significantly higher in non-GM cornfields than in *Bt* and *Bt*HT cornfields. Insecticide-sprayed non-GM cornfields harbored more invertebrates than unsprayed *Bt* or *Bt*HT cornfields. Chemical weeding may adversely affect invertebrates in both glyphosate- and Gramoxone-sprayed fields. Higher number of invertebrates was found in fully weeded fields (100% weed cover). Finally, this study provides evidence that complex agricultural farming in non-GM cornfields is more favorable for in-field invertebrates than simplified farming systems involving GM corn.

Introduction

Biodiversity decline in agroecosystems is often linked to modern agricultural practices (Flohre *et al*., 2011). One of the key aspects of such practices is the use of chemicals to increase yield and avert crop losses due to pests and diseases. However, pesticides have deleterious effects on humans and biodiversity (for reviews see Stoate *et al*., 2001; Geiger *et al*., 2010; Waggoner *et al*., 2011; Yadav and Sehrawat, 2011).

Advocates of agricultural biotechnology claim that genetically modified (GM) corn can potentially mitigate the impact of agricultural intensification, and that *Bacillus thuringiensis* (*Bt*) corn offers the best alternative to traditional insecticide treatment for the control of major agricultural pests (Chen *et al.,* 2008). The expectations of high yields, lower pesticide inputs and lower time investments attributed to GM corn have caused an upsurge in its adoption among major corn-producing countries. Among 55 countries having adopted *Bt* corn, 25, including the Philippines, publicly promote the commercial adoption of GM corn. In 2009, transgenic crops covered 135 million hectares in 25 countries (James, 2009). In the US alone, the area covered by *Bt* corn reached more than 22.2 million hectares, making up 63% of US crops (Hutchison *et al*., 2010). In the Philippines, the three GM corn varieties readily available on the market are *Bt* insect–resistant corn, Round-up Ready (RR)/herbicide-tolerant (HT) corn and stacked genes *Bt*HT corn. In 2009, GM corn acreage grew to 350,000 ha (James, 2009). In addition, the area planted with *Bt*HT corn in 2008 was 200,000 ha, which is a 300% increment from the 63,000 ha in 2007 (Poquiz, 2009). Currently, more transgenic herbicide-tolerant varieties are about to be introduced, which may imply a rapid advancement of the "*Gene Revolution*" in the Philippines.

The effectiveness of *Bt* endotoxin as a biopesticide has made *Bt* corn a popular variety for corn-growing areas with widespread infestations of the Asian corn borer (ACB), *Ostrinia furnacalis* Guenée. *Bt* corn's efficiency in killing corn borers is facilitated by the constitutive expression of the Cry1Ab endotoxin in all parts of the *Bt* plant (Wilkinson *et al.,* 1997; Roh *et al.,* 2007; Burkness *et al*., 2001). Although *Bt* toxin is harmful to ACB, it is still considered an environment-friendly toxin because it is highly specific, with few known adverse effects on non-target species (Glare and O'Callaghan, 2000). The *Bt* toxin has proved to be non-toxic to several non-target arthropods and pests in various laboratories (Sims and Martin, 1997; Escher *et al.,* 2000; Saxena and Stotzky, 2001; Alfageme *et al*., 2010; Bakonyi *et al*., 2011;) and field studies (Bhatti *et al*., 2005a; Bhatti *et al*., 2005b; Rauschen *et al*., 2009).

Herbicide-tolerant corn is protected from glyphosate by its genetically built-in ESP (5-enolpyruvylshikimate-3-phosphate synthase) cDNA, which was isolated from a glyphosate-tolerant petunia cell culture line (Padget *et al.,* 1995). This makes the HT plants tolerant to four times the concentration of glyphosate required to kill weeds. Glyphosate, a broad-spectrum herbicide is degradable (Cerdeira and Duke, 2006) and presents a limited risk of surface- and ground-water pollution, due to sorption onto charged soil minerals (Borggaard and Gimsing, 2008). Furthermore, HT corn was reported to benefit farmland biodiversity (Firbank & Forcella, 2000; Dewar *et al*., 2003; Freckleton *et al.*, 2004). Delayed spraying in HT corn enables weeds to grow, creating a microhabitat and food resource for arthropods and associated species. Finally, HT corn promotes no-tillage agriculture, which reduces soil erosion and the risk of surface water pollution, and produces more diverse soil biota (Holland, 2004), thus providing substantial environmental benefits (Cerdeira and Duke, 2006). However, some biodiversity conservationists do not support the idea that GM corn is the ideal option, as many vital issues still need to be addressed and many remain unresolved.

As regards *Bt* corn, there is the potential occurrence of *Bt* gene introgression (Arias and Rieseberg, 1994; Mikkelson *et al.,* 1996; Yin and Stotzky, 1997). The reinforced *Bt* gene function could transform other organisms into harmful, invasive and hard to eliminate species (Shen, 2006). The probable expression of new proteins apart from the intended transgenic products might produce unpredictable mechanisms such as pleiotropic effects (Uberlacker *et al.*, 1996). In addition, there is the potential development of resistance to *Bt* toxin (Altieri, 2000). A meta-analysis by Marvier *et al.* (2007) found that non-target organisms are more abundant in *Bt* corn yet, when compared to non-*Bt* corn with no insecticide application, some non-target groups are less abundant. Finally, other issues that still require answers are the non-target effects of *Bt* toxin and loss of biodiversity due to monocropping of GM crops (Linder and Schmitt, 1995; Arriola and Ellstrand, 1997; Altieri, 2000; Dutton *et al*., 2003; Andow and Hilbeck, 2004).

As for HT corn, the US National Research Council (NRC) recently reported the development of so-called "glyphosate-resistant weeds" near GM cornfields (Benaning, 2010), which may lead to the development of super-weeds such as *Amaranthus palmeri* (Brown *et al.,* 1996; Altieri, 2000; Hammond, 2010). There is a high risk that weed population composition may shift to naturally resistant species. A good example is the development of resistance to glyphosate by the population of horseweed, *Conyza canadensis* L (Owen and Zelaya, 2005). Pimentel *et al*. (1989) reported glyphosate to be toxic to some non-target beneficial organisms such as spiders, mites, carabids, coccinellid beetles and earthworms, as well as to aquatic organisms, including fish. In addition, it may accumulate in fruits and tubers due to its slow metabolic degradation in plants (Altieri, 2000).

The claim by proponents that GM crops will result in minimal use of pesticide remains questionable. U.S. government data from 1994 to 2005 reveal a 15-fold increase in the use of glyphosate since the nationwide adoption of HT crops (Anonymous, 2009).

We studied these opposing claims by conducting field experiments in the Philippines in order to reveal the effects of GM corn on biodiversity in actual farm scenarios. These effects can be assessed by comparing the abundance and species richness of invertebrates in farm-managed *Bt*, *Bt*HT and non-GM cornfields. The importance of in-field invertebrates for agroecosystems (Firbank *et al*. 2003), and their potential direct exposure to toxin and/or pest control chemicals (herbicides/insecticides), make them an interesting fauna category to focus on. The adoption of transgenic corn will lead to changes in agricultural practices, which may become very different from or similar to management practices using traditional corn hybrid varieties. One potential effect is that agricultural practices such as insecticide application, weed control (i.e. timing/frequency of application, types of herbicide and methods of weeding) and human/animal labor may be reduced due to widespread use of GM corn.

Our study intended to provide an overview of the effects of the adoption of GM corns and associated practices on in-field invertebrate populations. Hence, the experiment had two objectives: (1) exploring the potential impacts of *Bt* and *Bt*HT corn on invertebrate populations as compared to iso-hybrid non-GM corn; and (2) investigating the impact on invertebrate populations of alterations to the crop management systems associated with the adoption of *Bt* and *Bt*HT corn.

Methods

Study area

The study involved a field-based experiment conducted at five different sites in the northeast Isabela Province of the large island of Luzon, The Philippines, located in the town of Cabagan (17°25.650N; 121° 45.883E). Experimental fields covering 6 hectares were planted in the villages of Catabayungan (twice), Ugad, Garita, Cansan and Cubag for two consecutive cropping seasons in 2009. To ensure that there would be no residual effects of transgenic crops, we selected fields that had never been cultivated with any type of transgenic corn. In the case of the Catabayungan site, one corn type was planted on the same plot for the whole duration of the study.

Experimental design

The experimental design used a split-plot randomized complete block design (RCBD) including two experimental factors, i.e. corn type and agricultural practice. Each of three corn types was used on one-third of each one-hectare experimental cornfield. Different types of agricultural practice (i.e. herbicide and insecticide management and weeding methods) were assigned randomly to subplots within each corn type. Each treatment was replicated four times (Figure 1).

The three corn types that were planted included two transgenic corn hybrids, viz. *Bt* (DeKalb YG) and *Bt*HT (DeKalb YGHT), and a non-genetically modified (non-GM) iso-hybrid corn (DeKalb). A 2 m gap was left in between corn types to prevent edge effects. Hence, each plot was subdivided into ten sub-plots of almost equal size. Each sub-plot corresponded to one treatment, which consisted of a specific combination of agricultural practices and corn type (Figure 1). Within each sub-plot, samples of invertebrates were taken using four pitfalls, four sticky traps and four soil cores per sampling round.

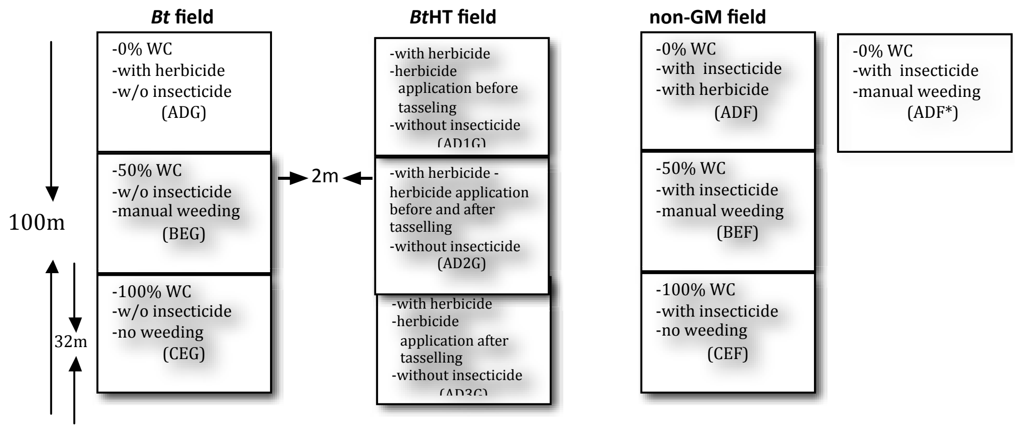

Figure 1. Experimental layout in a one-hectare experimental field. Split plots were used per corn variety. Letter codes were assigned to the plots, referring to treatment combinations of commonly used agricultural practices, per corn variety: AD1G (*Bt*HT corn, with herbicide, no insecticide and post-emergence herbicide application at an early stage), AD2G (*Bt*HT corn, with herbicide, no insecticide, two post-emergence herbicide applications), AD3G (*Bt*HT corn, with herbicide, no insecticide, one post-emergence application after tasselling corn stage), ADG (*Bt* corn, with herbicide, no insecticide, 0% weed cover [WC]), BEG (*Bt* corn, no herbicide, no insecticide, 50% WC), CEG (*Bt* corn, no herbicide, no insecticide, 100% WC), ADF (non-*Bt* corn with herbicide, with insecticide, 0% WC), ADF* (non-GM corn, no herbicide, with insecticide, 0% WC), BEF (non-GM corn, no herbicide, with insecticide, 50% WC), and CEF (non-GM corn, no herbicide, with insecticide, 100% WC).

Sampling techniques

Invertebrate traps and soil sampling points (Fig. 2) were set out along 100-m transect lines, which were laid out in the middle of the fields to prevent potential edge effects (Dively and Rose, 2003). A total of 1,584 pitfall collections, 792 sticky traps, and 264 soil core samples were collected over the entire duration of this study.

Aerial fauna

Our study used a technique similar to that used by Bhatti *et al.* (2005) for trapping foliage arthropods. Yellow sticky traps (8 x 13 cm) were used to collect aerial dwelling invertebrates. From January to March 2008, 120 traps (12 per field) were set up in Pilig Abajo for each corn growth stage. Then, from March to April 2008, a total of 120 traps were set up at all three sites (40 traps per site at three sites per field, 10 m apart). Sticky cards were attached to the tips of bamboo sticks (length: 91 cm) and placed vertically, 5-10 cm above the surface. The traps remained in the field for two consecutive nights and were collected on the third day.

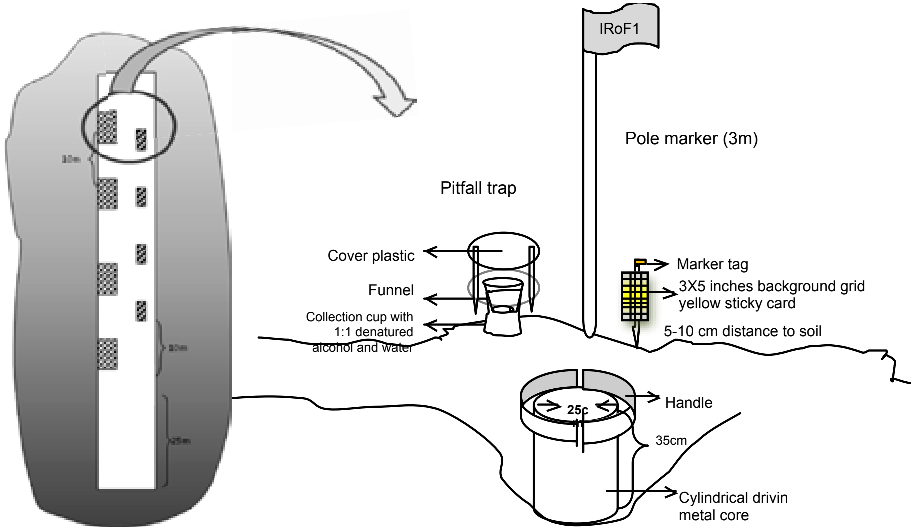

Figure 2. Locations of pitfall, sticky traps and soil core sample collection points in a transect line established in the middle of each farm.

Surface fauna

A pitfall sampling technique was used to sample surface-dwelling invertebrates (Ivanov and Keiper, 2009). The pitfall traps were constructed using 1.5 L plastic bottles. Each trap had a uniform mouth (diameter: 9.5 cm, length: 15 cm) and was buried with the mouth at ground surface level. From January to March 2008, 40 traps (four per field) were set up in Pilig Abajo for each corn growth stage. In March 2008, a total of 120 traps were set up at all three sites (40 traps per site at three sites per field, 10 m apart). A 1:1 mixture of water and alcohol was used as temporary preserving medium in the field. Traps were monitored thrice a week to ensure enough preserving medium remained in the traps. Pitfall traps were collected at the end of each week for two consecutive weeks.

Soil fauna

Soil fauna was sampled using soil cores (Ahmad *et al*., 2005). In each field, four soil cores (10 m apart) were collected in March 2008. Samples were collected close to the corn plant roots (2 cm away from the plant base), using a cylindrical metal core sampler (diameter: 25 cm; height: 35 cm). The samples were taken to the Botanical Laboratory of Isabela State University in Cabagan, Isabela, for sorting and safekeeping. Soil fauna were extracted by gradually pulverizing the soil using bare hands. The specimens were collected then stored in containers with denatured alcohol for preservation and, at a later stage, identification.

Taxonomic identification of invertebrate species

Initial identification and documentation of the specimens collected was performed at the Fauna Laboratory of Isabela State University, Cabagan, Isabela. Final species validation was done by experts of the Entomology division of the National Museum in Manila, Philippines. Each individual invertebrate was identified down to species level, whenever possible. Identified species were categorized into the following functional guilds: herbivores, detritivores, omnivores, predators, and parasitoids.

Weed cover

The effects of weed cover (WC) on invertebrates were determined by manipulating the weed cover in the field, either through manual weeding or by using herbicides. The variants used were zero (0), fifty (50) and one hundred (100) percent WC. The herbicides used to maintain the zero weed cover subplots were glyphosate for *Bt*HT and Gramoxone (paraquat) for *Bt* and non-GM corns. Controlled manual weeding was used to maintain the 50% WC subplots, while for 100% WC subplots, weeds were allowed to grow unrestricted. (Figure 3)

Pesticide management

Fields were treated with the traditional mode of liquid spraying, using an aluminum knapsack sprayer only for all non-*Bt* corn plots. Furadan (carbofuran) insecticide was applied twice (i.e. before and after the tasselling stage of the corn) to protect plants during the periods in which they are vulnerable to ACB infestation. But both *Bt* and *Bt*HT plots were left unsprayed, on the assumption that both corn types have the genetically built-in *Bt* Cry1Ab endotoxin, which is effective against ACB. All non-transgenic plots were insecticide-sprayed, while all *Bt* and *Bt*HT corn plots were insecticide-free.

Two post-emergence herbicide applications were applied before the plants reached a height of 0.10 to 0.20 m (Everman, 2010). Likewise, two herbicide Gramoxone (paraquat) applications were used for *Bt* and non-*Bt* plots. Additional herbicide was applied especially during the wet season, when weeds grow fast. Three different application timings were used for the *Bt*HT cornfields, to assess the potential effects of herbicide application on invertebrates. Treatments used were (1) one post-emergence treatment at the vegetative stage; (2) two post-emergence treatments during early and late development stages; and (3) one post-emergence treatment in the late growth stage.

Figure 3. Experimental plots showing varying percentages of weed cover (% WC): (a) 0% WC, herbicide-sprayed (upper left); (b) 0% WC, manually weeded (upper right); (c) 50% WC, manually weeded (lower left) and; (d) 100% WC or zero tillage (lower right).

Response variables

The response variables used to gauge the potential short-term, farm-scale effect of transgenic corn and its associated agricultural practices were the mean per-trap values of the abundance and species richness of all invertebrates and the abundance of individual guilds. Each invertebrate was counted, and whenever possible, identified to species level. All identified species were categorized into five groups based on their ecological role (guild), viz. herbivores, omnivores, parasitoids, predators and detritivores.

Statistical analysis

We performed data analyses using R Stat version 2.7. All tables present Wald tests for the explanatory covariates (fixed factors), based on the parameter estimates and their standard errors (Quinn and Keough, 2007). Mixed regression analysis i.e. Generalized Linear Mixed Model (GLMM) and Restricted Maximum Likelihood (REML) were used. GLMM was used to deal with the random and fixed factors. The random predictors in the model are plots, sites, cropping seasons and sampling method. The fixed factors were corn types and agricultural practices such as weed management, insecticide management and weeding methods. REML was employed to deal with the multi-level samplings with plots nested within corn stages and sites, which in turn were nested within cropping seasons. Either lognormal or Poisson models were applied, whichever fitted best, as shown by the histogram residuals. All data presented are natural log-transformed values of the mean per trap. A significance level of 0.05 was used (Rao and Balakrishnan, 1999). Only results with significant values are presented and discussed, unless otherwise specified. Lastly, we performed posthoc analysis using Bonferroni correction; the significance test is shown in the tables. This analysis was done by dividing the significance level by the number of models within that specific analysis.

Results

GM

Abundance and species richness

The pooled data from two consecutive cropping seasons related to 83,684 individuals, mainly comprising 55,226 aerial, 27,374 surface-dwelling and 1,084 soil-dwelling invertebrates (Table 1). Of all these invertebrates, 29% (23,875), 30% (24,782) and 42% (35,027) were collected in *Bt*, *Bt*HT and non-GM cornfields, respectively. The abundance of all invertebrates captured in non-GM corn plots was 19% (11,152) higher than in *Bt* corn and 17% (10,245) higher than in *Bt*HT cornfields. The mean (±SE) abundance per trap revealed the same pattern and showed significant differences between corn types (Table 2).

The total numbers of species captured using sticky cards, pitfall traps and soil cores were 105, 82 and 27, respectively (Table 1). The highest mean number of species captured per trap was observed in non-GM cornfields, followed by *Bt* cornfields and *Bt*HT cornfields (Table 2).

Table 1. Total counts of invertebrate assemblage collected in GM and non-GM cornfields in Isabela Province, Philippines during the dry and wet growing seasons of 2009. FG= Functional guild (H=herbivore, O=omnivore, Pa=parasitoid, Pr=predator, De=detritivores); ID= Types of invertebrate dwellers (AD= aerial dweller, SF = soil fauna, SD = surface dweller).

Species	**ID**	**FG**	**Abundance**
Empoasca fabae	AD	H	21348
Draeculacephala mollipes	AD	H	6015
Phaenicia sericata	AD	De	5010
Drosophila melenogaster	AD	De	4300
Micraspis discolor	AD	Pr	3802
Sciara sp.	AD	De	3367
Phormia regina	AD	De	1246
Aulacophora sp.	AD	H	1221
Erythroneura vitis	AD	H	1136
Rhysella nitida	AD	Pa	895
Cheilomenes sexmaculatus	AD	Pr	893
Olibrus sp.	AD	De	762
Oncocephalus confusus	AD	Pr	665
Liodontemerus sp.	AD	Pa	555
Germalus elegantulus	AD	Pr	450
Blatella germanica	AD	O	442
Phytodictus vulgaris	AD	Pa	349
Fannia sp.	AD	De	226
Amerimicromus sp.	AD	Pr	219
Tettigella viridis	AD	H	217
Aphidalestes sp.	AD	H	204
Salticus sp.	AD	Pr	179
Trichiohelcon sp.	AD	Pa	175
Onukia onuki	AD	H	148
Scirtes sp.	AD	H	147
Tetragnatha mandibulata	AD	Pr	127
Heppelates sp.	AD	H	103
Dermestres sp.	AD	H	97
Euphorocera claripennis	AD	Pa	94
Oxyopes sp.	AD	Pr	70
Teleogryllus sp.	AD	O	70
Ostrinia furnacalis	AD	H	46
Chelonus texanus	AD	Pa	42
Pteromalus sp.	AD	Pa	41
Euxesta sp.	AD	De	40
Myrmacea maxilosa	AD	Pr	38
Adelphocoris ropidus	AD	H	37
Solenopsis pergundei	AD	O	32
Ragoletis pomonella	AD	H	31
Syrphus ribesii	AD	O	30
Pyraus sp.	AD	H	28
Clerada sp.	AD	Pr	26
Pholcus phalingoides	AD	Pr	26
Diatraes sp.	AD	Pa	24
Digitress sp.	AD	Pa	24
Apanteles thomsoni	AD	Pa	19
Scolypopa australis	AD	H	16
Bruchus sp.	AD	H	14
Anolepsis longipes	AD	O	13
Clavicornaltica sp.	AD	H	10
Cercion calamorum	AD	Pr	9
Cexius angustatus	AD	H	9

Species	**ID**	**FG**	**Abundance**
Ploiaria regina	AD	Pr	9
Anacharis sp.	AD	Pa	8
Brachymeria sp.	AD	Pa	8
Scaphoideus festivus	AD	H	7
Andrena sp.	AD	Pr	6
Chortoicetus sp.	AD	H	6
Cofana spectra	AD	H	6
Apion sp.	AD	H	5
Hylemya platura	AD	H	5
Metoponium sp.	AD	H	5
Allenobius fasciatus	AD	O	4
Diacampus sp.	AD	Pa	4
Fornax sp.	AD	H	3
Goelerucella maculicollis	AD	H	3
Isidromus sp.	AD	Pa	3
Labidurata truncatu	AD	H	3
Nomadacris gutturosa	AD	H	3
Onthropagus sp.	AD	H	3
Opion sp.	AD	H	3
Adelocera sp.	AD	H	2
Ceriagrim liefiricki	AD	Pr	2
Cymidis sp.	AD	Pr	2
Iphiulax sp.	AD	Pa	2
Monomorium minimum	AD	O	2
Oceantatus quadrimaculatus	AD	H	2
Oecleus borealis	AD	H	2
Phocambe disparis	AD	Pa	2
Platyzosteria nitidella	AD	O	2
Solenopsis globularia	AD	O	2
Trachelus tabidus	AD	H	2
Agyra leucocephala	AD	Pr	1
Aufidus sp.	AD	H	1
Bubekia fallax	AD	Pa	1
Cocinella sp.	AD	Pr	1
Crematogaster clara	AD	O	1
Cyclas formicarius	AD	H	1
Dolichopus sp.	AD	Pr	1
Endomychus sp.	AD	Pr	1
Felisacus glabratus	AD	Pr	1
Gastrolinoides sp.	AD	H	1
Gracilaria sp.	AD	H	1
Hesperus sp.	AD	Pr	1
Heterothrips sp.	AD	H	1
Hister sp.	AD	Pr	1
Leptocorisa acuta	AD	Pr	1
Lucilia ilustris	AD	De	1
Neozelobia sp.	AD	De	1
Omyrus sp.	AD	Pa	1
Orosicus argentatus	AD	H	1
Pnyxia sp.	AD	De	1
Prosevania punctata	AD	Pa	1
Trigonotoma sp.	AD	H	1
Ugyops sp.	AD	H	1
Total individual of aerial dwellers =			**55,226**
Total species of aerial dwellers =			**105**

Species	**ID**	**FG**	**Abundance**
Oxyopes sp.	SD	Pr	4547
Solenopsis globularia	SD	O	4475
Albonemobius fasciatus	SD	O	3796
Monomorium minimum	SD	O	3084
platozosteria nitida	SD	O	2646
Drosophila melenogaster	SD	De	1748
Megacephala sp.	SD	O	1180
Myara sp.	SD	O	744
Hesperus sp.	SD	Pr	721
Megasellia sp.	SD	Pr	667
Pselaphus sp.	SD	Pr	491
Anolepsis longipes	SD	O	429
Adelocera sp.	SD	H	392
Labidura truncatu	SD	H	262
Sciara sp.	SD	De	257
Salticus sp.	SD	Pr	191
Cylisticus convexus	SD	De	188
Parcoblatta spp.	SD	O	185
Trigonoma sp.	SD	H	168
Draeculacephala mollipes	SD	H	163
Euxoa excellens	SD	H	140
Sippuna sp.	SD	Pr	112
Fannia sp.	SD	De	105
Adrisa sp.	SD	Pr	82
Myrmarachne maxillosa	SD	Pr	52
Solenopsis invicta	SD	O	51
Heppelates sp.	SD	H	49
Cymindis sp.	SD	Pr	38
Teleogylus sp.	SD	O	37
Brachymeria sp.	SD	Pa	24
Geophilus sp.	SD	Pr	24
Musca domestica	SD	De	20
Felisacus glabaratus	SD	Pr	16
Onthophagus sp.	SD	H	16
Lumbricoides sp.	SD	De	15
Empoasca fabae	SD	H	14
Aulacophora sp.	SD	H	13
Phitemera bicincta	SD	De	13
Americamus sp.	SD	Pr	12
Cocinella sp.	SD	Pr	12
Ostrinia furnacalis	SD	H	12
Rhysellia nitida	SD	Pa	12
Thiara sp.	SD	De	12
Cylas formicarius elegantulus	SD	H	10
Pachyndola sp.	SD	O	10
Tetigella viridis	SD	H	10
Oxidus gracilis	SD	De	9
Geophilomorpha sp.	SD	Pr	8
Pardosa pseudoammulata	SD	Pr	8
Callibaetis sp.	SD	O	7
Orosorius argentatus	SD	Pr	7
Rhagoletes cingulata	SD	H	7
Cleoporus variabilis	SD	H	6
Dolichopus sp.	SD	Pr	6
Glyptotermes sp.	SD	De	6
Coproporus sp.	SD	Pr	5
Deleaster yokoyamai	SD	Pr	5
Chelonus sp.	SD	Pa	4
Liodomentus sp.	SD	Pa	4
stegonium panicerum	SD	Pr	4

Species	**ID**	**FG**	**Abundance**
Syrphus ribessi	SD	O	4
Tineola bissellula	SD	H	4
Crematogaster minutissima	SD	O	3
Micraspis discolor	SD	Pr	3
Orchesia sp.	SD	H	3
Tetragnatha mandibulata	SD	Pr	3
Blatella sp.	SD	O	2
Cheilomenes sexmaculatus	SD	Pr	2
Cletus trigonus	SD	H	2
Coniotis sp.	SD	H	2
Diamma bicolour	SD	Pa	2
Geophilus erectus	SD	Pr	2
Phobocampe disparis	SD	Pa	2
Dictyotus caenosus	SD	Pr	1
Hister sp.	SD	Pr	1
Labidura riparia	SD	H	1
Metoponium sp.	SD	H	1
Nomadacris gutturosa	SD	H	1
Pinophilus sp.	SD	Pr	1
Scirtes sp.	SD	H	1
Talia sp.	SD	O	1
Trogoderma sp.	SD	H	1
Total individual of surface dwellers =			**27,374**
Total species of surface dwellers =			**82**

Species	**ID**	**FG**	**Abundance**
Lumbricoides sp.	SF	De	248
Pheiodole megacephala	SF	O	238
Phitemera bicincta	SF	De	165
Solenopsis invicta	SF	O	98
Solenopsis globularia	SF	O	55
Thiara sp.	SF	De	52
White grub	SF	H	46
Adrisa sp.	SF	Pr	27
Platozosteria nitida	SF	O	25
Dictyotus caenosus	SF	H	21
Oxyopes sp.	SF	Pr	20
Cylisticus convexus	SF	De	17
Geophilomorpha sp	SF	Pr	10
Geophilus sp.	SF	Pr	9
Titanolabis colossea	SF	De	8
Oxidus gracilis	SF	De	7
Sericesthis geminata	SF	Pr	7
Pselaphus sp.	SF	Pr	6
Salicus sp.	SF	Pr	6
Adelocera sp.	SF	H	4
Labiduratu truncatu	SF	H	4
Hirudiea medicinalis	SF	De	3
Pinophilus sp.	SF	Pr	3
Onthophagus sp.	SF	H	2
Cymindis sp.	SF	Pr	1
Phaeri sericata	SF	De	1
Syrphus ribesii	SF	O	1
Total individual of soil fauna (SF) =			**1,084**
Total species of soil fauna =			**27**

*GRAND TOTAL OF INVERBRATE INDIVIDUALS ACCOUNTED = **83,684***

Table 2. Results of the mixed regression analyses (REML) of the abundance and species richness of invertebrates per dwelling category, with corn variety as fixed factor and plot within site and cropping season as random factors. Mean per trap was ln (x+1) transformed. Sign B: significance after Bonferroni correction: *** = equivalent to p<0.001; * = equivalent to p<0.05.

	Bt	*Bt*HT	non-GM	Model	Chi-sqr	p	Sign B
	Mean ± SE	Mean ± se	Mean ± se				
Abundance	3.057±0.0456	3.056±0.046	3.162±0.0386	Lognormal	10.230	0.006	*
Species Richness	1.905±0.024	1.896±0.024	1.941±0.0196	Poisson	3.296	0.192	
Abundance per dwelling category							
Aerial	4.156 ±0.042	4.137 ±0.054	4.076 ±0.042	Lognormal	3.553	0.169	
Surface	2.762 ±0.039	2.783 ±0.038	2.979 ±0.036	Lognormal	16.598	0.000	***
Soil	1.235 ±0.107	1.180 ±0.105	1.335 ±0.092	Lognormal	1.419	0.492	
Species Richness per dwelling category							
Aerial	2.465 ±0.016	2.437 ±0.023	2.441 ±0.017	Poisson	0.267	0.875	
Surface	1.796 ±0.018	1.795 ±0.018	1.848 ±0.016	Poisson	6.343	0.042	
Soil	0.769 ±0.058	0.781 ±0.058	0.904±0.054	Poisson	5.255	0.072	

Abundance and species richness per dwelling category

Of the three types of invertebrates in terms of dwelling (aerial, surface-dwelling and soil-dwelling), only the abundance and species richness of surface-dwelling species showed differences between corn types (Table 1). Among surface dwellers, predators seemed to be more abundant in non-GM corn plots, whilst aerial predators were more abundant in *Bt*HT corn plots (Table 3).

Table 3. Results of the mixed regression analyses (REML) of the abundance of herbivore, detritivore, omnivore, predator and parasite invertebrates in general and for the three dwelling categories, with corn variety as fixed factor and plot within site and cropping season as random factors. Mean per trap was ln(x+1) transformed. Sign B: significance after Bonferroni correction: ** = equivalent to p<0.01; * = equivalent to p<0.05.

	Bt Mean se	*Bt*HT Mean se	non-GM Mean se	Model	Chi-sqr	P	Sign B
GUILDS							
- Omnivore	1.353±0.047	1.334±0.046	1.420±0.044	Lognormal	3.432	0.180	
- Herbivore	1.474±0.061	1.443±0.064	1.484±0.052	Lognormal	1.586	0.452	
- Predator	1.425±0.038	1.489±0.039	1.469±0.035	Lognormal	2.268	0.322	
- Parasitoid	0.392±0.027	0.388±0.026	0.408±0.024	Lognormal	0.930	0.628	
- Detritivores	1.392±0.050	1.330±0.049	1.405±0.042	Lognormal	4.644	0.098	
Aerial Dwellers							
- Omnivore	0.395±.0384	0.323±0.031	0.382±0.035	Lognormal	2.352	0.309	
- Herbivore	3.474±0.052	3.517±0.062	3.423±0.050	Lognormal	2.859	0.240	
- Predator	1.869±0.067	1.953±0.068	1.651±0.061	Lognormal	20.454	3.633^{e-05}	**
- Parasitoid	1.144±0.051	1.117±0.050	1.176±0.043	Lognormal	0.884	0.643	
- Detritivores	2.780±0.054	2.638±0.064	2.702±0.051	Lognormal	5.284	0.071	
Surface Dwellers							
- Omnivore	2.113±0.048	2.124±0.048	2.262±0.047	Lognormal	5.186	0.075	
- Herbivore	0.543±0.032	0.454±0.030	0.569±0.027	Lognormal	7.838	0.020	
- Predator	1.401±0.043	1.470±0.043	1.594±0.043	Lognormal	12.073	0.002	*
- Parasitoid	0.019±0.006	0.029±0.008	0.029±0.007	Lognormal	1.234	0.540	
- Detritivores	0.696±0.042	0.682±0.040	0.751±0.036	Lognormal	2.581	0.275	
Soil Dwellers							
- Omnivore	0.427±0.094	0.420±0.093	0.322±0.079	Lognormal	1.057	0.589	
- Herbivore	0.132 ±0.036	0.161±0.041	0.240±0.046	Lognormal	4.338	0.114	
- Predator	0.208±0.039	0.190±0.040	0.292±0.051	Lognormal	4.017	0.135	
- Parasitoid	-	-	-		-	-	
- Detritivores	0.714±0.010	0.644±0.095	0.780±0.083	Lognormal	1.480	0.477	

GM and its associated agricultural practices

Insect management

Our results show that the mean abundance of invertebrates per trap was higher in insecticide-sprayed fields than in unsprayed fields, and this pattern was found for all guilds. Insecticide-sprayed cornfields featured the highest mean number of species per trap (Table 4).

Table 4. Results of the mixed regression analyses (REML) of the abundance and species richness of all invertebrates and of the individual guilds, with insect management type as fixed factor and plot within site and cropping season as random factors. Mean per trap was ln(x+1) transformed. Sign B: significance after Bonferroni correction: ** = equivalent to p<0.01.

	Insect Management (non-GM, *Bt* and *Bt*HT)					
	no insecticide (*BT*&*Bt*HT)	with insecticide (non-GM)	Model	Chi-sqr	P	Sign B
	Mean se	Mean se				
Abundance	3.056±0.032	3.162 ±0.039	Lognormal	10.224	0.001	**
Species Richness	1.900±0.017	1.941 ±0.020	Poisson	3.187	0.074	
- Omnivore	1.344±0.032	1.420 ±0.043	Lognormal	3.282	0.070	
- Herbivore	1.458±0.044	1.484±0.052	Lognormal	0.803	0.370	
- Predator	1.457±0.027	1.469±0.035	Lognormal	0.121	0.728	
- Parasitoid	0.390±0.019	0.408±0.024	Lognormal	0.906	0.341	
- Detritivores	1.361±0.035	1.405±0.042	Lognormal	2.034	0.154	

Weed management

Herbicide-sprayed and unsprayed plots

An analysis of the invertebrate abundance on herbicide-sprayed and unsprayed cornfields showed that this abundance was higher in unsprayed than in herbicide-sprayed cornfields (Table 5). The omnivore guild was found to be more abundant in unsprayed cornfields (Table 5).

Table 5. Results of the mixed regression analyses of the abundance and species richness of all invertebrates and of the individual guilds, with weed management type as fixed factor and plot within site and cropping season as random factors. Mean per trap was ln(x+1) transformed. Sign B: significance after Bonferroni correction: ** = equivalent to p<0.01.

	Weed Management (non-GM, *Bt* and *Bt*HT)		Model	Chi-sqr	P	Sign B
	no herbicide	with herbicide				
	Mean se	Mean se				
Abundance	3.146±0.034	3.051±0.036	Lognormal	8.984	0.003	**
Species Richness	1.930±0.018	1.903±0.019	Poisson	1.829	0.176	
- Omnivore	1.426±0.038	1.322±0.036	Lognormal	7.027	0.008	**
- Herbivore	1.472±0.047	1.465±0.049	Lognormal	0.072	0.789	
- Predator	1.458±0.031	1.465±0.030	Lognormal	0.047	0.828	
- Parasitoid	0.399±0.021	0.396±0.021	Lognormal	0.034	0.854	
- Detritivores	1.403±0.038	1.354±0.038	Lognormal	2.595	0.107	

Gramoxone vs. glyphosate

The abundance of invertebrates in glyphosate-sprayed cornfields was equal to that in Gramoxone-sprayed fields, as was their species richness (Table 6). Of the different guilds, predators differed between the herbicide types in that they were more abundant in glyphosate-sprayed cornfields (Table 6).

Table 6. Results of the mixed regression analyses of the abundance and species richness of all invertebrates and of the individual guilds, with the type of herbicide as fixed factor and plot within site and cropping season as random factors. Mean per trap was ln(x+1) transformed.

	Types of herbicide (non-GM, *Bt* and *Bt*HT)		Model	Chi-sqr	p
	Glyphosate (*Bt*HT)	Gramoxone (non-GM &*Bt*)			
	Mean se	Mean se			
Abundance	3.056±0.047	3.048±0.047	Lognormal	0.113	0.736
Species Richness	1.896±0.024	1.898±0.024	Poisson	0.351	0.553
- Omnivore	1.334±0.046	1.278±0.050	Lognormal	0.857	0.354
- Herbivore	1.443±0.064	1.491±0.062	Lognormal	0.620	0.431
- Predator	1.488±0.038	1.395±0.040	Lognormal	3.868	0.049
- Parasitoid	0.388±0.027	0.398±0.028	Lognormal	1.924^{e-06}	0.999
- Detritivores	1.330±0.049	1.381±0.049	Lognormal	1.048	0.306

Timing and frequency of application

Timing and frequency of herbicide application produced no effects in terms of the abundance and species richness of all invertebrates and the individual guilds (Table 7).

Table 7. Results of the mixed regression analyses of the abundance and species richness of all invertebrates and of the individual guilds, with timing and number of post-emergence herbicide applications as fixed factor and plot within site and cropping season as random factors. Mean per trap was ln(x+1) transformed.

	Frequency and period of herbicide application (*Bt*HT)			Model	Chi-sqr	P
	once, early	once, late	twice			
	Mean se	Mean se	Mean se			
Abundance	3.137±0.080	3.026±0.080	3.005±0.082	Lognormal	4.632	0.099
Species Richness	1.919±0.040	1.925±0.041	1.845±0.043	Poisson	4.298	0.117
- Omnivore	1.425±0.083	1.294±0.077	1.284±0.080	Lognormal	3.572	0.168
- Herbivore	1.475±0.113	1.443±0.108	1.410±0.110	Lognormal	1.066	0.587
- Predator	1.507±0.067	1.495±0.066	1.465±0.069	Lognormal	0.387	0.824
- Parasitoid	0.400±0.047	0.407±0.048	0.358±0.043	Lognormal	1.570	0.456
- Detritivores	1.316±0.084	1.392±0.086	1.280±0.083	Lognormal	2.912	0.233

Weeding methods

The abundance of invertebrates differed for the different weeding methods. Chemical weeding appeared to be unfavorable for invertebrates, while manual weeding led to a higher mean abundance, but the highest value was obtained by no weeding (Table 8). Of the different guilds, omnivores and detritivores were found to be more abundant in manual weeding and no-weeding plots, respectively (Table 8).

Table 8. Results of the mixed regression analyses of the abundance and species richness of all invertebrates and of the individual guilds, with weeding method as fixed factor and plot within site and cropping season as random factors. Mean per trap was ln(x+1) transformed. Sign B: significance after Bonferroni correction: * = equivalent to p<0.05.

	Methods of Weeding (non-GM, *Bt* and *Bt*HT)			Model	Chi-sqr	P	Sign B
	chemical weeding	manual weeding	no weeding				
	Mean se	Mean se	Mean se				
Abundance	3.051±0.036	3.144±0.045	3.148±0.054	Lognormal	8.991	0.011	*
Species Richness	1.903±0.018	1.925±0.023	1.938±0.028	Poisson	2.132	0.344	
- Omnivore	1.322±0.036	1.432±0.051	1.418±0.057	Lognormal	7.095	0.029	
- Herbivore	1.465±0.049	1.476±0.060	1.466±0.074	Lognormal	0.136	0.934	
- Predator	1.465±0.030	1.427±0.039	1.503±0.051	Lognormal	2.455	0.293	
- Parasitoid	0.396±0.021	0.400±0.027	0.398±0.034	Lognormal	0.036	0.982	
- Detritivores	1.354±0.038	1.370±0.049	1.451±0.060	Lognormal	6.095	0.047	

The 50% weed cover (WC) found to exhibit the highest numbers of invertebrates. Of the different guilds, omnivore and detritivore abundance exhibited slight differences depending on the percentage of WC. Omnivores and detritivores were abundant in 50% WC and 100% WC plots, respectively (Table 9).

Table 9. Results of the mixed regression analyses of the abundance and species richness of all invertebrates and of the individual guilds, with percentage of weed cover (%WC) as fixed factor and plot within site and cropping season as random factors. Mean per trap was ln(x+1) transformed.

	Percent Weed Cover (%WC) (*Bt* and non-GM)			Model	Chi-sqr	p
	Zero WC	50% WC	100% WC			
	Mean se	Mean se	Mean se			
Abundance	3.135±0.045	3.232±0.054	3.202±0.053	Lognormal	3.745	0.053
Species Richness	1.954±0.022	1.976±0.027	1.975±0.027	Poisson	1.383	0.240
- Omnivore	1.353±0.049	1.487±0.065	1.427±0.057	Lognormal	2.742	0.098
- Herbivore	1.543±0.063	1.558±0.076	1.526±0.077	Lognormal	0.010	0.921
- Predator	1.466±0.038	1.467±0.048	1.526±0.052	Lognormal	1.576	0.209
- Parasitoid	0.424±0.028	0.420±0.034	0.418±0.035	Lognormal	0.009	0.924
- Detritivores	1.408±0.051	1.424±0.062	1.476±0.062	Lognormal	2.751	0.097

Discussion

Invertebrates and GM (Bt and BtHT) corn

The results of our previous study (Afidchao *et al.*, Chapter 4) of more than two years of transgenic cornfield cultivation indicated that transgenic *Bt* and *Bt*HT corns could adversely affect the abundance and species richness of invertebrates. One of the plausible reasons for this phenomenon is the accumulation of *Bt* toxin in the corn environment over time. The present study, covering two cropping seasons, yielded consistent results supporting the findings of the previous study. Similar findings were obtained for both *Bt* and *Bt*HT.

The findings indicate that the *Bt* protein not only affects the target pest but also other non-target organisms, which is consistent with findings on seven species of Macrolepidoptera in farmland areas in Germany (Schmitz *et al.,* 2003). Likewise, the mini-review of 20 peer-reviewed publications by Lang and Otto (2010) recorded that 52% of the laboratory-based publications and 21% of the field-based observations reported the *Bt* protein having an adverse effect on Lepidopteran caterpillars.

The current study found evidence that short-term cultivation of GM corn can have an impact on the abundance of invertebrates, and specifically found that in a tropical humid environment like the Philippines, non-target organisms were more abundant in insecticide-sprayed non-GM cornfields than in insecticide-free *Bt* cornfields (Table 4). This clearly contradicts the meta-analysis by Marvier *et al.* (2007), which concluded that non-target organisms were more abundant in unsprayed *Bt* cornfields than in sprayed non-*Bt* cornfields. The discrepancy may be due to different ecological conditions in the study areas, as all studies collated in the meta-analysis by Marvier *et al.* (2007) were done in temperate regions. It is highly likely that the behavior, sensitivity and tolerance to toxin differ between non-target species in different agro-ecological conditions. Some related examples are provided by the studies by Garcia (2011) and Römbke *et al*. (2007) on earthworms under tropical and temperate conditions.

Although the effect size seems small, the effects of GM corn on non-target invertebrates imply that GM corn is not environmentally risk-free, and that continued cultivation of such novel varieties could entail a loss of biodiversity. Non-GM cornfields appeared to provide more favorable habitats for in-field invertebrates, emphasizing the need for more sustainable stewardship practices such as the maintenance of non-*Bt* corn refugia (Hutchison, *et al.,* 2010).

Our short-term experiment with the cultivation of GM corns showed that the abundance and species richness of surface dwellers were significantly lower in *Bt* and *Bt*HT GM cornfields than in non-GM fields. This result, combined with the significantly high level of Cry1Ab protein detected in various species of ground beetles by means of ELISA tests (Zwalen and Andow, 2005) suggests that predators are exposed to high *Bt* risks.

Surface-dwelling herbivores seemed also adversely affected in *Bt*HT cornfields, and were more abundant in non-GM cornfields. Herbivores survive in a habitat that consists largely of weeds. Although most pests belong to this guild, their important ecological role, especially in the food web, should not be ignored. Teodorescu and Cogalniceanu (2005) reported that the species richness and number of individuals of aboveground arthropods could be an indicator of biological diversity, and the best indicator of human-induced impacts. Hence, the significant reduction of surface dwellers in our GM fields, consisting mainly of aboveground arthropods, may suggest a disturbed agro-biodiversity that can be linked to the Cry1Ab toxins in the GM fields.

Finally, our previous study (Afidchao *et al*., Chapter 4) shows that long-term cultivation of GM corn does not affect surface dwellers, but that it is the aerial and soil-dwelling invertebrates that are the most affected groups. This appears to contradict our findings in the current study, where surface dwellers were the most adversely affected. This could be due to the fact that drastic changes in the environment may initially impact on surface dwellers, which later become tolerant to toxin and are able to recover their populations, whilst bio-magnification effects of toxin in the corn agro-ecosystem due to continuous GM corn cultivation could not be tolerated by the aerial and soil-dwelling species, thus could affect their population in the long run.

Invertebrates and GM-associated agricultural practices

Insect management

Pesticides are known to have an adverse impact on an ecologically stable agro-biodiversity, by causing massive mortality among non-target taxa and reducing species richness (Geiger *et al*., 2010; Teodorescu and Cogalniceanu, 2005). The most severely affected are the in-field organisms that are directly exposed to the toxin. Reduction of these toxic chemicals could be achieved by zero insecticide application, which is the practice supposed to be adopted by *Bt* and *Bt*HT corn farmers. It is on this premise that many *Bt* toxin containing corn varieties have been promoted as an environmentally friendly alternative to conventional varieties. In the context of the adoption of *Bt* corn, insecticide inputs were expected to be minimized or totally avoided. However, our earlier study (Afidchao *et al.,* Chapter 4) found that *Bt* fields are not free of pesticides and have a lower abundance of invertebrates. In the current study, we found significantly higher abundance and species richness of invertebrates in insecticide-sprayed non-GM cornfields than in unsprayed GM (*Bt* and *Bt*HT) cornfields. This finding explicitly shows that in the short term, insecticide-free *Bt* cornfields are not necessarily more favorable for invertebrates than insecticide-sprayed non-GM cornfields.

Weed management

The weeding method based on herbicide seems to have an adverse effect on the abundance of invertebrates. The most severely affected guilds in *Bt* and *Bt*HT herbicide-sprayed fields were the omnivores and detritivores. This suggests that the use of herbicides such as glyphosate and Gramoxone may in the end have a major ecological impact (Blackburn and Boutin, 2003). A beneficial effect of no weeding was observed specifically among omnivores and detritivores. Weeding per se could have a direct influence in terms of biodiversity loss and reduction of food availability for wildlife within fields (Beringer, 2000)

Glyphosate has been reported to be environment-friendly or risk-free compared to other broad-spectrum herbicides (Knezevic and Cassman, 2003), but our findings do not support this notion. Although the predator guild was slightly more abundant in glyphosate-sprayed fields than in non-sprayed fields, this difference was no longer significant after Bonferroni correction (Table 6). Hence, our study does not support the view that glyphosate-resistant corn may be acceptable as a risk-free alternative.

The absence of weed cover may adversely affect the abundance and species richness of in-field invertebrates, since most of this fauna depends for survival on weeds (serving as food source as well as habitat). This was supported by our findings, as a 50% WC seemed to provide the most suitable habitat for invertebrates, especially those of the omnivore guild, while 100% WC was most suitable for the detritivore guild. This finding is consistent with those of Blumberg and Crossley (1983), who found that no tillage yielded a greater diversity of soil surface arthropods than conventional tillage. In our current study, a major reduction (90%) in weed cover due to the application of herbicides like glyphosate in *Bt*HT corn fields had direct negative effects on in-field invertebrates. In contrast, reduced-tillage (50% WC) or no-tillage (100% WC) agriculture may provide substantial environmental benefits (Cerdeira and Duke, 2006) especially to various invertebrates.

Conclusion

The current study clearly highlights the advantage of non-GM cornfields in terms of the abundance and species richness of all invertebrates and of the ecological guilds. In terms of the agricultural practices assessed, insecticide-sprayed non-GM fields were more favorable for invertebrates than unsprayed GM fields. Our field evaluations, comparing two GM corn varieties, showed that GM *Bt* corn poses less of an environmental risk to invertebrate ecosystem populations than *Bt*HT corn. This was shown by the greater abundance and species richness of all invertebrates and of the different guilds, with the exception of predator species, which were more abundant in the *Bt*HT cornfields. Regimes with no herbicide application generally favor invertebrates, whereas chemical weeding greatly reduces their populations. Finally, our findings provide evidence that neither intensive farming nor farming systems using biotechnology crops safeguard biodiversity, especially that of invertebrates, which play key roles in crop production and balancing the agroecosystem. Although the adoption of *Bt* and *Bt*HT corns may allow simplified production systems, the current study suggests that the more complex production systems associated with the conventional corn varieties are more ecologically sustainable.

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Invertebrate abundance and species richness in transgenic and non-transgenic cornfields in the Philippines

Miladis M. Afidchao, C.J.M. Musters, Mercedes D. Masipiqueňa,
Denyse J. Snelder and Geert R. de Snoo

To be submitted

Abstract

This study examined the effects of large-scale and long-term use of transgenic corn varieties on the abundance, species richness, and guilds of non-target invertebrates in a wet tropical environment. The study was conducted in 30 fields, including non-transgenic cornfields for comparison, and distributed over three lowland sites in the Philippines. The transgenic corn varieties *Bt* (*Bacillus thuringiensis*) and *Bt*HT (*Bt* Roundup Ready) in this study were introduced to the area in 2002 and 2005. Information on aerial, surface, and soil-dwelling invertebrates were gathered during the mature stage of corn development using sticky-trap, pitfall-trap, and soil-core sampling technologies along 100 m transect lines laid out in the middle of 1.4 to 3.8 hectare fields. A total of 21,639 non-target invertebrates representing 129 different species were identified at the three sites, including surface (69%), aerial (26%), and soil (5%) dwellers. The non-*Bt* cornfields had significantly higher abundance and species richness of all non-target invertebrates than the *Bt* and *BtHT* fields (p-values, 0.001 and 0.020 respectively). Likewise, the abundance and species richness of aerial (p-values: 0.010 and 0.009, respectively) and abundance of soil (p-value: 0.03) dwelling non-target invertebrates were notably higher in the non-*Bt* cornfields. Cornfields' soil chemical properties such as pH, potassium and nitrogen content also influenced the abundance of invertebrates; however corn varieties indicated a stronger influence. Most importantly, the effects of these confounding variables did not take away the effect of corn varieties.

Introduction

One promising way of increasing profits in crop production is the use of genetically modified crop varieties, which possess novel genetic characteristics introduced to protect them against pest infestation or herbicides. Varieties available for corn (*Zea mays* L.) include HT (Herbicide tolerant), *Bt* (*Bacillus thuringiensis*), and *Bt*HT (*Bt* Herbicide tolerant). The first of these is a variety modified to be resistant to the glyphosate-containing herbicides used to control weeds, while the second is a variety able to produce a bacterial toxin with proven efficacy against the Asian Corn Borer (ACB; *Ostrinia furnacalis* Guenée), and the third is a combination of the two. In the Philippines, the Department of Agriculture approved *Bt* corn for direct use in December 2002, making the country the first in Asia to commercialize a transgenic food crop. This was followed by the approval of the *Bt*HT corn variety for commercial technology demonstration in the 2005 dry season planting (Gonzales *et al.,* 2009).

Transgenic corn varieties are believed to offer a number of advantages compared to non-transgenic varieties. They produce higher yields and allow for effective utilization of scarce land because of improved pest resistance and nutrient utilization. Specifically, *Bt* corn has been shown to produce higher yields than a near-isogenic non-*Bt* variety (Qaim and Zilberman, 2003; Dilehay *et al*., 2004; Rice, 2004; Stanger and Lauer, 2006) and to significantly reduce pesticide use (Yorobe & Quicoy, 2006; Dillehay *et al*., 2004). *Bt* corn has delivered important improvements in grain quality through significant reductions in the levels of mycotoxins found in the grain (Hammond *et al*., 2004; Wu, 2007; Folcher *et al*., 2010). Furthermore, *Bt*HT corn is suitable for no-tillage agriculture, a system of planting crops without plowing in order to reduce soil erosion and nutrient loss. Benefits like these directly or indirectly contribute to livelihood improvement and poverty alleviation among farmers.

James (2010) reported a significant increase to one billion hectares in transgenic crop production in 2010. The Philippines was the first Asian country among the 29 mega transgenic crop adopting countries. The adoption of transgenic corn in the Philippines has increased remarkably since its first field testing in 2001, as potential economic benefits made it an attractive alternative to conventional corn varieties. To date, the country ranked 13th, with more than 500,000 hectares planted with transgenic corn by about 270,000 small farmers (James, 2011). Such large-scale use of transgenic corn varieties, however, may considerably change agroecosystems, raising the question of long-term sustainability.

Transgenic crops may affect non-target organisms. For example, *Bt* corn can have adverse effects on non-target invertebrates like Common Swallowtail, *Papilio machaon* L. (Lang and Vojtech, 2006), the larvae of the herbivorous African cotton leaf worm *Spodoptera littoralis* (Meissle *et al*., 2005a), and the generalist predatory ground beetle *Poecilus cupreus* L. (Meissle *et al.,* 2005b), and can exert a sublethal behavioral effect on honey bees (Romero *et al*., 2008). Romero *et al*. (2007) confirmed that the *Bt* Cry1Ab protein has negative effects on non-target insects, including the parasitoids *Cotesia marginiventris* (Hymenoptera). A 200-day feeding experiment by Zwahlen *et al*. (2003) showed that *Bt* corn litter reduced the weight of adult earthworms by 18%, compared to a 4% gain when fed with non-*Bt* corn**.** Further, reduced application of insecticides in areas under *Bt* cotton cultivation may cause an outbreak of non-targeted pests, as happened with the Mirid bug *Creontiades biseratense* in China (Lu *et al.,* 2010).

All the above-mentioned studies refer to impacts of *Bt* corn under temperate conditions. To our knowledge, none of the peer-reviewed articles reflects the potential impact of transgenic corn in a wet tropical environment like the Philippines. Furthermore, quantitative and evidence-based risk analyses are still needed to settle ongoing controversies over the ecological impact of transgenic crops. A meta-analysis of 42 field experiments involving *Bt* corn and insecticide application (Marvier *et al*., 2007) indicated that non-target organisms are more abundant in *Bt* cornfields without insecticide application; but if comparison is made with non-*Bt* cornfields without insecticides, some non-target groups prove significantly less abundant. This means that *Bt* corn is more environment-friendly than non-*Bt* corn, but only under the assumption that non-*Bt* corn always requires insecticides, while *Bt* corn never does. The effects of transgenic corn requires further study in tropical agro-ecosystems, considering that the meta-analysis referred to above was based on controlled field experiments in temperate agroecosystems. The Philippines, with its relatively long-term practice of large-scale transgenic corn cultivation, provides an excellent environment for such studies.

There have been only a few, non-reviewed field studies on the impacts of transgenic corn on non-target organisms in the Philippines (Alcantara, 2004; Javier *et al*., 2004; Alcantara *et al*., 2008). While these studies showed no negative effects of *Bt* corn, they mainly focused on aboveground arthropods, particularly the aerial fauna, and not on surface- and soil-dwelling invertebrates. As such, it is imperative to conduct studies covering invertebrate-corn interactions in all layers of the agroecosystem, to improve our ecological understanding of the impact of large-scale application of transgenic corn.

This study aimed to generate solid data on the effects of transgenic corn on invertebrates in a Philippine setting, representing a wet tropical environment. Specifically, this study assessed the impact of long-term cultivation of transgenic corn (*Bt* and *Bt*HT) on non-target organisms in terms of changes in abundance, species richness, and guilds of invertebrates found in different ecosystem layers, including aerial-, surface-, and soil-dwelling species.

Methods

Study area

The study was undertaken in the province of Isabela (17^{0}20’N; 121^{0}53’E) in northeast Luzon, the Philippines. Isabela is among the top six yellow corn producing provinces in the country, with a total area of 101,901 hectares used for corn cultivation, comprising 31,190 hectares of river floodplains (frequently flooded), 23,276 hectares of broad plains (occasionally flooded), and 47,436 hectares of hilly land (Anonymous, 2006).

The selected research sites cover the lower floodplain areas along the Cagayan River in the municipalities of Cabagan (near Pilig Abajo village), Tumauini (near Tunggui village), and Ilagan (near Angassian village). All sites have been major corn areas for more than 50 years. White corn was the most cultivated variety up to the mid-1980s, when yellow corn became economically viable due to the rapid increase in demand for animal feed. In recent years, transgenic corn varieties have become widely cultivated in the area.

The Cabagan and Ilagan sites are classified as first-class cornfields because of the favorable moisture and nutrient content of the clayey alluvial soils. While monocropping is the basic practice in Tumauini and Ilagan, multiple cropping with tobacco, legumes or vegetables is common practice in Cabagan (Fig. 1). The corn-based cultivation systems are all rainfed, with yields during both the dry (November to April) and wet (June to October) seasons. Corn growth and development normally take 110-120 days.

Figure 1. Study sites showing examples of mono-cropping system at the Ilagan and Tumauini sites (left photo) and a multiple-cropping system at the Cabagan site, where legumes are planted beside conventional corn (center photo) and tobacco planted near conventional and *Bt* corn (right photo)

Sampling

The research, which was conducted during the dry cropping season from January to May 2008, started with a study of the differences between the various corn growth stages, i.e. the vegetative, tasselling, and maturity stages, from January to March.

Five fields with transgenic corn and five with non-transgenic corn were selected at three sites, totaling 30 cornfields. Since isolated and small sized fields could affect the abundance of aerial invertebrates (Prasifka *et al.,* 2005), which might bias the results, the study included only large fields (ranging from 1.4 to 3.79 hectares, Table 1) that were not isolated. The selected fields were located almost at the center of a large area of continuous corn landscape, so surrounding riparian habitats were assumed to have negligible effects on infield biodiversity.

Sampling of invertebrates from different habitats within the cornfields was accomplished with the same techniques used in a previous study (Afidchao *et al*., Chapter 3). Yellow sticky cards, pitfall traps and soil cores were used for aerial species, aboveground dwellers and belowground dwellers, respectively. Yellow sticky cards were used thrice per cropping season (i.e. during the vegetative, tasselling and maturity stages of the corn). Four sticky traps were placed within each sub-plot and left in the fields for two nights. Pitfall trap samplings were done twice per major corn stage per cropping season. Soil cores were taken with an improvised metal core during the maturity stage of the corn, to prevent damage to the standing crop.

Table 1. Average (±se) field size and soil physico-chemical characteristics of the 30 cornfields surveyed in Isabela province, The Philippines

	Physical Characteristics		Chemical Characteristics					
Corn variety	Field Size (hectare)	Soil Texture	Soil pH	% N	P (ppm Olsen's Mtd)	K (ppm H2SO4 Etxn)	%OC	%OM
Bt	3.79±3.39	Sandy to silt loam	5.76±0.73	0.76±0.17	10.19±8.91	92.78±51.63	0.49±0.25	0.85±0.43
*Bt*HT	1.86±1.60	Clay to silt clay	5.69±0.68	0.71±0.20	11.79±8.23	80.42±18.30	0.50±0.19	0.86±0.33
non-*Bt*	1.40±0.92	Sandy to silt loam	5.79±0.63	0.75±0.25	11.27±8.69	106.83±61.96	0.52±0.17	0.90±0.29

The main physical and chemical characteristics of the soils in the different cornfields are presented in Table 1. All *Bt* fields surveyed had been cultivated with *Bt* corn for a minimum of two consecutive years. Although the *Bt* and *Bt*HT corn varieties in this study were from genetically different corn lines, they were presumed to be similar, both containing the Cry1Ab protein only (Rauschen *et al*., 2009; Rauschen *et al*., 2010). More than half (18 out of 30) of the fields surveyed had been subject to pesticides, viz. insecticides (trade names: Furadan or Cymbush) or herbicides (Round-up Ready or Gramoxone), using a lever-operated knapsack sprayer (Table 2).

Table 2. Pesticides used by the farmer respondents (N = 30) on the cornfields surveyed (N = 30) during the first cropping season of 2008 in Isabela Province, The Philippines

Corn variety	Farmers	Insecticides	Active Ingredients	Farmers using the insecticide	Herbicide[4]	Active Ingredients	Farmers using the herbicide
Bt	9	Furadan Cymbush	Carbofuran[1] Cypermethrin[1]	2 1	HT	Glyphosate[2]	4
*Bt*HT	6	Cymbush	Cypermethrin[1]	1	HT	Glyphosate[2]	4
non-*Bt*	15	Furadan Cymbush	Carbofuran[1] Cypermethrin[1]	3 3	HT Gramoxone	Glyphosate[2] Paraquat[3]	1 1

[1] Source: Snelder *et al*. (2008)
[2] Source: Williams *et al.* (2000)
[3] Source: www.syngenta.com/en/products_brands/gramoxone
[4] Round-up Ready

Confounding variables

Information on confounding variables (i.e., cornfields' size, elevation and location, chemical inputs, plant height, percent weed cover, and soil physical and chemical properties) was gathered and considered in the analysis. Pesticide input was estimated by interviewing 30 farm-owner respondents about the use of pesticides in their fields. Plant height measurements were taken at the cob development stage. Soil analysis used four samples from each cornfield, weighing a minimum of one kilogram per sample. Samples were analyzed at the Regional Soil and Water Laboratory of the Department of Agriculture in Tuguegarao City. Soil texture was determined using the "Texture-by-Feel Method" (Franzmeier & Owens, 2008). Soil chemical properties were analyzed following standard methods, i.e. a 1:5 soil-water ratio to determine soil pH (Mahaney *et al*., 2007), the Walkley-Black method for organic matter (OM), the Kjeldhal method for total nitrogen (N), the Olsen/Bray method for available soil phosphorus (P), and the flame photometric method for exchangeable soil potassium (K).

Statistical design and analysis

Statistical analyses used the Restricted Maximum Likelihood (REML) and Generalized Linear Mixed Model (GLMM). These models were used to be able to include both fixed (corn stage, corn variety, isolines, cornfields physical characteristics, soil physico-chemical properties and chemical applications) and random factors (site, field within site, sampling method) in the analyses (Quinn and Keough, 2007).

For each response variable, we firstly employed a general model including corn stage and corn variety and all the chosen confounding variables, including isoline, as fixed factors. Also, the random factors were included. The general model was then simplified using a stepwise regression analyses. Model simplification involved gradual elimination of the confounding variables. For that a Maximum Likelihood fitting of the models was applied and subsequent models were compared based on AIC. The final model has the lowest AIC value, but may retain confounding variables with low p-values. We will call this the 'best fitting model'. In order to meet the model assumptions, natural log transformations were applied after adding 1 to the abundance or species number. The analysis was performed in R Statistical software version 2.7.3. Bonferroni correction was done by dividing the significance level by the number of models within the specific analysis.

Results

Growth stages

The sampling of non-target invertebrates during three different corn growth stages produced 31,171 individuals, including 8,557 aerial and 22,614 surface dwellers, belonging to 63 aerial and 56 surface species. Invertebrate abundance and species richness were significantly different between corn stages, with aerial dwellers being most abundant during the vegetative stage, while surface dwellers dominated the maturity stage (Fig. 2). However, no significant interaction was found between corn stage and corn variety (*Bt* versus non-*Bt*), neither in terms of abundance nor of species richness (Table 3). These results justify the focus of the study on one growth stage, that of maturity, in the next sections.

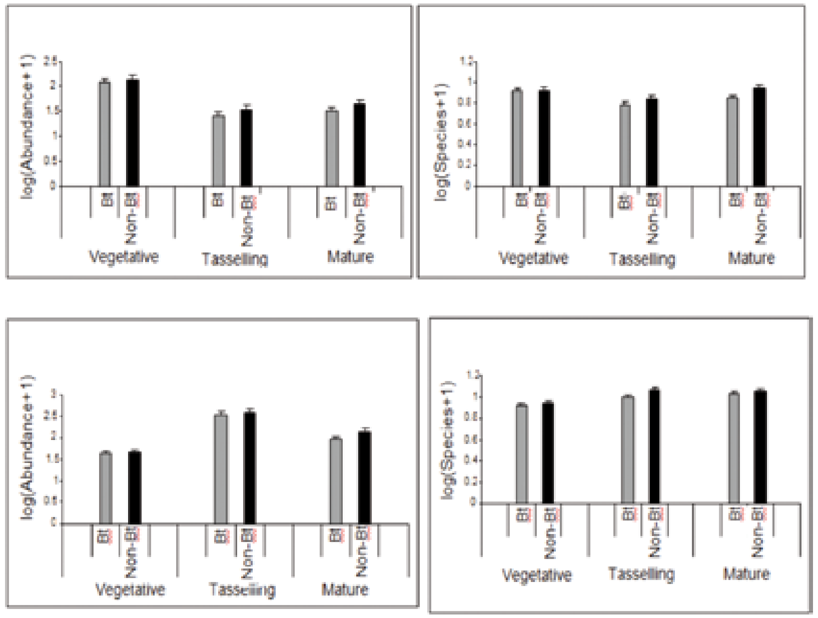

Figure 2. Estimated means (±se) of abundance (left graphs) and species richness (right graphs) of non-target aerial- (upper graphs) and surface- (lower graphs) dwelling invertebrates per corn stage of each corn variety, from the mixed regression analyses (REML, table 3)

Table 3. Results of mixed regression analyses (REML) of abundance and species richness of surface-dwelling and aerial invertebrates, with growth stages and corn variety as fixed factors and field as random factor. (n.d.f.: numerator of degrees of freedom; d.d.f.: denominator of degrees of freedom; Sign B: significance after Bonferroni correction: ** = equivalent to p<0.01; * = equivalent to p<0.05; (*) = equivalent to p<0.10).

	Wald stat.	n.d.f.	F	d.d.f.	p	Sign B
Abundance of aerial species						
Growth stage	244.22	2	122.11	106.0	<0.001	*
Corn variety	1.10	1	1.10	8.0	0.325	^{ns}
Stage*Variety	1.01	2	0.51	106.0	0.604	^{ns}
Abundance of surface species						
Growth stage	412.27	2	206.14	106.0	<0.001	*
Corn variety	1.02	1	1.02	8.0	0.341	^{ns}
Stage*Variety	3.66	2	1.83	106.0	0.166	^{ns}
Species richness of aerial species						
Growth stage	20.15	2	10.08	106.0	<0.001	*
Corn variety	2.57	1	2.57	8.0	0.147	^{ns}
Stage*Variety	3.84	2	1.92	106.0	0.152	^{ns}
Species richness of surface species						
Growth stage	39.46	2	19.73	106.0	<0.001	*
Corn variety	2.70	1	2.70	8.0	0.139	^{ns}
Stage*Variety	0.85	2	0.43	106.0	0.654	^{ns}

Varieties: transgenic vs. non-transgenic corn

At the three research sites (Table 4), 21,639 individual non-target invertebrates were recorded, belonging to 129 different species. Sixty-nine percent or 14,995 individuals were surface dwellers, 26 percent or 5,585 individuals were aerial dwellers and only five percent or 1,059 individuals were soil dwellers.

Table 4. Total counts of Invertebrate assemblage collected in transgenic and non-transgenic corn fields in Isabela Province, Philippines during the dry cropping season 2008. FG= Functional guild (H=herbivore, O=omnivore, Pa=parasitoid, Pr=predator, De=detritivore); ID= Types of invertebrate dwellers (AD= aerial dweller, SF = soil fauna, SD = surface dweller)

Species	FG	ID	Abundance
Empoasca fabae	*H*	*AD*	2171
Drosophila melanogaster	De	*AD*	844
Sciara sp.	De	*AD*	615
Circulife tenellus	*H*	*AD*	358
Phaenicia sericata	De	*AD*	276
Micraspis discolor Fabr.	*Pr*	*AD*	262
Aphidalestes sp.	*H*	*AD*	179
Dicampus sp.	Pa	*AD*	113
Heppelates sp.	*H*	*AD*	77
Allonemobius fasciatus	O	*AD*	57
Pnyxia sp.	De	*AD*	45
Tetragnatha mandibulata	*Pr*	*AD*	44
Cheilomenes sexmaculatus	*Pr*	*AD*	40
Ephydra sp.	*H*	*AD*	31
Rhysella nitida	Pa	*AD*	30
Draeculacephala mollipes	*H*	*AD*	28
Erythroneura viridis	*H*	*AD*	28
Phytodictus vulgaris	Pa	*AD*	27
Solenopsis invicta	*O*	*AD*	27
ZZ-Species D	*Pr*	*AD*	26
Fannia sp.	De	*AD*	23
Aulacophora sp.	*H*	*AD*	22
Xestocephalus sp.	*H*	*AD*	20
Salticus sp.	*Pr*	*AD*	18
Tettigella viridis	*H*	*AD*	17
Orchesia sp.		*AD*	16
Oxyopes sp.	*Pr*	*AD*	15
Myrmarachne maxillosa	*Pr*	*AD*	14
Chelonus sp.	Pa	*AD*	12
Olibrus sp.	De	*AD*	10
Telleogryllus sp.	*O*	*AD*	10
Isdromus sp.	Pa	*AD*	9
Dolichopus sp.	*Pr*	*AD*	7
Tetragnatha sp.	*Pr*	*AD*	7
Diatraes sp.	Pa	*AD*	6
Andrena sp.	*Pr*	*AD*	5
Phormia regina	De	*AD*	5
Rhagoletis pomonella	*H*	*AD*	5
Scirtes sp.	*H*	*AD*	5
Cocinella sp.	*Pr*	*AD*	4
Gastrolinoides sp.	*H*	*AD*	4
Heterothrips sp.	*H*	*AD*	4
Phobocampe disparis	Pa	*AD*	4
Amerimicromus sp.	*Pr*	*AD*	3
Chortoicetus sp.	*H*	*AD*	3
Labidura truncate	*H*	*AD*	3
Solenopsis globularia	*O*	*AD*	3
Syrphus ribesii	*O*	*AD*	3
ZZ-Species A	*O*	*AD*	3
ZZ-Species B	De	*AD*	3
Balaurara sp.	*O*	*AD*	2
Conocephalus sp.	*H*	*AD*	2
Eurema hecabe	*H*	*AD*	2
Geocoris sp.	*Pr*	*AD*	2
Hesperus sp.	*Pr*	*AD*	2
Labidura sp.	*H*	*AD*	2
Liodontomerus sp.	Pa	*AD*	2
Oncocephalus cenfusus	*Pr*	*AD*	2
Pholcus phalangoides	*Pr*	*AD*	2
Solenopsis pergundei	*O*	*AD*	2
Adelphocoris ropidus	*H*	*AD*	1

Species	FG	ID	Abundance
Agrypnus sp.	*H*	*AD*	1
Apion sp.	*H*	*AD*	1
Aufidus sp.	*H*	*AD*	1
Cercion calamorum	*Pr*	*AD*	1
Cylas formicarius elegantulus	*H*	*AD*	1
Draeculacephala sp.	*H*	*AD*	1
Euphorocera sp.	Pa	*AD*	1
Euxoa excellens	*H*	*AD*	1
Fornax sp.	*H*	*AD*	1
Goelerucella maculicollis	*H*	*AD*	1
Hemiptarsemus sp.	Pa	*AD*	1
Iphiaulax sp.	Pa	*AD*	1
Lucilia ilustris	De	*AD*	1
Meteosus sp.	Pa	*AD*	1
Metoponium sp	*H*	*AD*	1
Ostrinia furnacalis	*H*	*AD*	1
Perkinsiella sp.	*H*	*AD*	1
Scaphisoma sp.	*Pr*	*AD*	1
Sericesthis geminate	*Pr*	*AD*	1
Syrphus torus	*O*	*AD*	1
Tachys sp.	*Pr*	*AD*	1
Trichiohelcon sp.	Pa	*AD*	1
ZZ-Species C	*H*	*AD*	1
Total # of AD Individuals			**5,585**
Total # of AD Species			**84**
Hesperus sp.	Pr	SD	5499
Pselaphus sp.	Pr	SD	2637
Myara sp.	O	SD	1949
Sippuna sp.	Pr	SD	1172
Oxidus gracilis	De	SD	701
Drosophila melanogaster	De	SD	667
Albonemobius fasciatus	O	SD	599
Adelocera sp	H	SD	365
Solenopsis invicta	O	SD	307
Solenopsis globularia	O	SD	197
Cocinella sp.	Pr	SD	137
Labidura truncate	H	SD	131
Cymindis sp.	Pr	SD	93
Sciara sp.	De	SD	93
Hister sp.	Pr	SD	78
Micraspis discolor Fabr.	Pr	SD	70
Lumbricoides sp.	De	SD	46
Monomorium minimum	O	SD	43
Platyzosteria nitidella	O	SD	39
Callibaetis sp.	O	SD	35
Phaenicia sericata	De	SD	35
Adrisa sp.	Pr	SD	19
Draeculacephala mollipes	H	SD	17
Heppelates sp.	H	SD	15
Ctenicera resplendens	H	SD	11
Brachymeria sp.	Pa	SD	8
Euxoa excellens	H	SD	8
Thiara sp.	De	SD	7
Chortoicetus sp.	O	SD	6
Musca domestica	De	SD	4
Anoplolepis longipes	O	SD	1
Onthophagus sp.	H	SD	1
Osorius sp.	Pr	SD	1

Species	FG	ID	Abundance
Pachycondyla sp.	O	SD	1
Ploiaria regina	Pr	SD	1
Tetragnatha mandibulata	Pr	SD	1
white grub	H	SD	1
Total # of SD Individuals			**14,995**
Total # of SD Species			**36**
Anomalomyrma taylori	*O*	*SF*	292
Lumbricoides sp.	*De*	*SF*	222
Solenopsis globularia	*O*	*SF*	67
Nabis ferus	*Pr*	*SF*	60
Thiara sp.	*De*	*SF*	53
Oxidus gracilis	*De*	*SF*	47
Adrisa sp.	*Pr*	*SF*	42
Oligomyrmex nitidulus	*O*	*SF*	37
Anoplolepis longipes	*O*	*SF*	36
white grub	*H*	*SF*	31
Xylion sp.	*Pr*	*SF*	31
Cerapachys augustae	*O*	*SF*	25
Pheidole megacephala	*O*	*SF*	16
Monomorium minimum	*O*	*SF*	12
Oxyopes sp.	*Pr*	*SF*	12
Sericesthis geminate	*Pr*	*SF*	12
Titanolabis colossea(Dohrn)	*Pr*	*SF*	11
Paratrechina longicormis	*O*	*SF*	9
Cylisticus convexus	*De*	*SF*	6
Blatella sp.	*O*	*SF*	5
Nomadacris gutturosa	*H*	*SF*	5
Pselaphus sp.	*Pr*	*SF*	4
Geophilomorpha sp.	*Pr*	*SF*	3
Hesperus sp.	*Pr*	*SF*	3
Platyzosteria nitidella	*O*	*SF*	3
Coniontis sp.	*H*	*SF*	2
Dermestes sp.	*H*	*SF*	2
Geophilus electricus	*Pr*	*SF*	2
Pinophilus sp.	*Pr*	*SF*	2
Cryptopone mjobergi	*O*	*SF*	1
Cymindis sp.	*Pr*	*SF*	1
Nomius pygmaeus	*Pr*	*SF*	1
Onthophagus declivis	*H*	*SF*	1
Stegobium panicerum	*Pr*	*SF*	1
Talia sp.	*O*	*SF*	1
Trogoderma sp.	*H*	*SF*	1
Total # of SF Individuals			**1,059**
Total # of SF Species			**36**

*GRAND TOTAL OF INVERBRATE INDIVIDUALS ACCOUNTED=**21,639***

The non-*Bt* corn plots had the highest non-target invertebrate abundance and species richness, while the *Bt* corn plots had the lowest abundance and species richness (Table 5). This same pattern emerged for the aerial, surface, and soil dwellers. The apparent significance of the difference for the aerial dwellers did not hold under Bonferroni correction for multiple models (Table 6), but may indicate relatively large differences in this group. The lowest abundance of aerial dwellers was found for *Bt*HT corn (Table 6).

Our best fitting models show that soil pH, potassium and nitrogen have significant influence on invertebrate abundance and that nitrogen also has a slight effect on species richness. However, the effects of soil chemical characteristics did not take away the effect of corn variety. Non-*Bt* corn has highest abundance and species richness (Table 5).

Regarding the effects of confounding variables on different invertebrate dwellers (Table 6), the best fitting models show a high effect of soil pH and a slight effect of soil organic matter content on the aerial abundance but greater effect was manifested of corn variety. For aerial species richness, herbicides manifested a slight influence but greater effect is manifested of corn variety.

The pesticide application rate was highest in *Bt* cornfields, with herbicides applied most frequently in *Bt*HT and insecticides most frequently in non-*Bt* cornfields. However, application of pesticides did not differ significantly between the corn varieties (Table 7, Fig. 3).

Table 5. Results of mixed regression analyses (REML) of abundance and species richness of all invertebrates, with corn variety, soil pH, soil nitrogen (N), and soil potassium (K) contents, as confounding variable/fixed factors and field within site within sampling method as random factor. Mean abundance per dweller was ln(x+1) transformed. SD = standard deviation. P-values in italics are of contrasts. Sign B: significance after Bonferroni correction: ** = equivalent to p<0.01; * = equivalent to p<0.05; (*) = equivalent to p<0.10).

	Mean± SD	F value	p-value	Sign B
I. Total Abundance				
Variate				
Corn variety		7.384	0.0011	*
- *Non-Bt corn (Intercept)*	3.490 ± 1.405			
- *Bt* corn	3.146 ± 1.491		*0.0019*	*
- *Bt*HT corn	3.162 ± 1.382		*0.3553*	ns
Covariates				
Soil pH		6.311	0.0126	*
N		6.080	0.0143	*
lnK		7.333	0.0072	*
II. Total Species Richness				
Variate				
Corn variety		4.129	0.0197	*
- *Non-Bt corn (Intercept)*	7.511 ± 4.129			
- *Bt* corn	6.824 ± 3.266		*0.0069*	*
- *Bt*HT corn	7.028 ± 3.113		*0.2455*	ns
Covariates				
N		4.616	0.0326	(*)

Table 6. next Page (page 85):

Table 6. Results of mixed regression analyses (REML) of abundance and species richness of aerial, surface and soil invertebrates, with corn variety, corn isolines, weed cover (WC), plant height (PH), soil texture, insecticide, herbicide, ln(x+1) field size (lnAr), ln(x+1) field elevation (lnElev), field longitude (Longi) and latitude (Lat), soil organic matter (OM), soil pH, soil nitrogen (N), soil phosphorus (P) and soil potassium (K) contents as confounding variable/fixed factors and field within site as random factor. Only the best fitted models are given. Mean abundance per dweller was ln(x+1) transformed. SD = standard deviation. P-values in italics are of contrasts. Sign B: significance after Bonferroni correction: ** = equivalent to p<0.01; * = equivalent to p<0.05; (*) = equivalent to p<0.10).

Tabel 6.

	Mean± SD	F-value	p-value	Sign B
I. ABUNDANCE				
1. Aerial Dweller				
Variate				
Corn variety		5.635	0.0099	*
- *Non-Bt corn (Intercept)*	3.885 ± 0.568			
- *Bt* corn	3.500 ± 0.540		*0.0050*	*
- *Bt*HT corn	3.360 ± 0.380		*0.0412*	ns
Covariates				
OM		4.132	0.0533	ns
pH		5.796	0.0181	(*)
2. Surface Dweller				
Variate				
Corn variety		0.931	0.4123	ns
- *Non-Bt corn (Intercept)*	4.688 ± 0.625			
- *Bt* corn	4.619 ± 0.515		*0.2635*	ns
- *Bt*HT corn	4.500 ± 0.486		*0.0614*	ns
Covariates				
Isolines		3.648	0.0126	(*)
pH		8.573	0.0043	*
lnElev		12.594	0.0023	*
Longi		6.622	0.0191	(*)
3. Soil Dweller				
Variate				
Corn variety		4.161	0.0275	ns
- *Non-Bt corn (Intercept)*	1.897 ± 1.035			
- *Bt* corn	1.320 ± 0.672		*0.0365*	ns
- *Bt*HT corn	1.625 ± 1.068		*0.0144*	(*)
Covariates				
lnK		6.237	0.0144	(*)
II. SPECIES RICHNESS				
1. Aerial Dweller				
Variate				
Corn variety		5.787	0.0089	*
- *Non-Bt corn (Intercept)*	7.967 ± 1.965			
- *Bt* corn	6.556 ± 2.335		*0.3061*	ns
- *Bt*HT corn	7.250 ± 1.700		*0.6839*	ns
Covariates				
Herbicides		7.512	0.0114	(*)
2. Surface Dweller				
Variate				
Corn variety		1.366	0.2921	ns
- *Non-Bt corn (Intercept)*	10.450 ± 2.134			
- *Bt* corn	10.528 ± 2.360		*0.2635*	ns
- *Bt*HT corn	9.792 ± 2.519		*0.0614*	ns
Covariates				
Isolines		5.324	0.0058	*
ST		4.520	0.0242	(*)
pH		11.716	0.0009	*
lnElev		3.049	0.1063	ns
Longi		2.767	0.1221	ns
Lat		9.519	0.0094	(*)
3. Soil Dweller				
Variate				
Corn variety		2.034	0.1731	ns
- *Non-Bt corn (Intercept)*	4.117 ± 1.795			
- *Bt* corn	3.389 ± 1.572		*0.4525*	ns
- *Bt*HT corn	4.042 ± 1.829		*0.7277*	ns
Covariates				
Isolines		2.194	0.0981	ns
PH		2.034	0.1731	ns
N		1.295	0.2582	ns
Insecticides		1.310	0.2692	ns
lnAr		3.360	0.0855	ns

Table 7. Results of mixed logistic regression analyses (GLMM) of pesticide use, with corn variety as fixed factor and site as random factor. (n.d.f.: numerator of degrees of freedom; d.d.f.: denominator of degrees of freedom.

Pesticide use models	Wald stat.	n.d.f.	F	d.d.f.	p
All pesticides ~ Corn variety	2.07	2	1.03	27.0	0.369
Herbicides ~ Corn variety	6.26	2	3.11	24.1	0.063
Insecticides ~ Corn variety	0.89	2	0.44	27.0	0.646

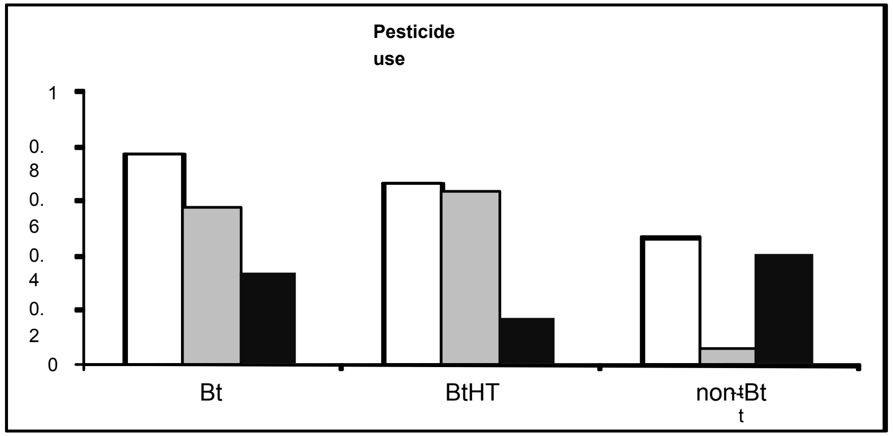

Figure 3. Estimated frequency of pesticide use per corn variety (GLMM, table 6). Open bars: all pesticides; grey bars: herbicides; black bars: insecticides

Functional guilds

For all functional guilds except parasitoids species, the highest abundance and species richness were recorded in non-*Bt* cornfields. Parasitoids were found to have higher species richness in *Bt* corn though not significantly different from other corn variety. Omnivores and detritivores were shown to have relatively large differences, although the differences were not statistically significant under Bonferroni correction for multiple testing (Table 8).

Table 8. Results of mixed regression analyses (REML) of abundance and species richness of all herbivore, detrivore, omnivore, predator, and parasitic invertebrates, with corn variety, corn isolines, weed cover (WC), plant height (PH), soil texture, herbicide, ln(x+1) field elevation (lnElev), soil organic matter (OM), soil pH, soil nitrogen (N), soil phosphorus (P) and soil potassium (K) contents, as confounding variable/fixed factors and field within site within sampling method as random factor. P values: *** = p<0.001, ** = p<0.01, * = <0.05, (*) = <0.10. Abundance and species richness of all the functional guilds were ln(x+1) transformed. SD = standard deviation. P-values in italics are of contrasts. Sign B: significance after Bonferroni correction: ** = equivalent to p<0.01; * = equivalent to p<0.05; (*) = equivalent to p<0.10).

	Mean± SD	F value	p-value	Sign B
I. ABUNDANCE				
1. Predator				
Variate				
Corn variety		1.182	0.3126	^{ns}
- *Non-Bt corn (Intercept)*	1.725 ± 1.322			
- *Bt* corn	1.566 ± 1.354		*0.0671*	^{ns}
- *Bt*HT corn	1.601 ± 1.367		*0.8956*	^{ns}
Covariates				
Isolines		2.264	0.0468	^{ns}
PH		3.882	0.0527	^{ns}
lnElev		2.863	0.0950	^{ns}
2. Herbivores				
Variate				
Corn variety		1.636	0.2013	^{ns}
- *Non-Bt corn (Intercept)*	1.400 ± 1.181			
- *Bt* corn	1.255 ± 1.322		*0.0796*	^{ns}
- *Bt*HT corn	1.175 ± 1.104		*0.9088*	^{ns}
Covariates				
pH		2.102	0.1483	^{ns}
lnP		2.422	0.1208	^{ns}
3. Omnivores				
Variate				
Corn variety		3.170	0.0478	^{ns}
- *Non-Bt corn (Intercept)*	1.426 ± 1.376			
- *Bt* corn	1.198 ± 1.209		*0.0026*	(*)
- *Bt*HT corn	1.152 ± 1.192		*0.2586*	^{ns}
Covariates				
ST		2.911	0.0400	^{ns}
OM		2.634	0.1088	^{ns}
pH		4.019	0.0460	^{ns}
lnK		6.417	0.0119	^{ns}
Herbicide		9.639	0.0027	*
4. Detrivores				
Variate				
Corn variety		2.494	0.0892	^{ns}
- *Non-Bt corn (Intercept)*	1.982 ± 1.256			
- *Bt* corn	1.786 ± 1.194		*0.0336*	^{ns}
- *Bt*HT corn	1.725 ± 1.187		*0.1064*	^{ns}
Covariates				
lnElev		3.687	0.0585	^{ns}
5. Parasitoids				
Variate				
Corn variety		1.327	0.2711	^{ns}
- *Non-Bt corn (Intercept)*	0.114 ± 0.348			
- *Bt* corn	0.102 ± 0.296		*0.5362*	^{ns}
- *Bt*HT corn	0.044 ± 0.188		*0.0818*	^{ns}
Covariates				
N		4.335	0.0383	^{ns}
lnK		2.613	0.1072	^{ns}

	Mean± SD	F value	p-value	Sign B
II. SPECIES RICHNESS				
1. Predator				
Variate				
Corn variety		1.811	0.1708	^{ns}
- *Non-Bt corn (Intercept)*	0.960 ± 0.580			
- *Bt* corn	0.879 ± 0.681		*0.4368*	^{ns}
- *Bt*HT corn	0.874 ± 0.597		*0.6065*	^{ns}
Covariates				
Isolines		2.111	0.0622	^{ns}
2. Herbivores				
Variate				
Corn variety		2.713	0.0725	^{ns}
- *Non-Bt corn (Intercept)*	0.750 ± 0.513			
- *Bt* corn	0.632 ± 0.509		*0.0105*	^{ns}
- *Bt*HT corn	0.703 ± 0.540		*0.6550*	^{ns}
Covariates				
pH		8.047	0.0049	*
N		2.432	0.1201	^{ns}
3. Omnivores				
Variate				
Corn variety		2.043	0.1365	^{ns}
- *Non-Bt corn (Intercept)*	0.695 ± 0.621			
- *Bt* corn	0.616 ± 0.616		*0.0147*	^{ns}
- *Bt*HT corn	0.661 ± 0.604		*0.3720*	^{ns}
Covariates				
Herbicide		2.272	0.1358	^{ns}
4. Detritivores				
Variate				
Corn variety		3.020	0.0545	^{ns}
- *Non-Bt corn (Intercept)*	1.076 ± 0.458			
- *Bt* corn	0.961 ± 0.478		*0.0375*	^{ns}
- *Bt*HT corn	0.961 ± 0.538		*0.0663*	^{ns}
5. Parasitoids				
Variate				
Corn variety		1.419	0.2480	^{ns}
- *Non-Bt corn (Intercept)*	0.085 ± 0.239			
- *Bt* corn	0.087 ± 0.240		*0.8632*	^{ns}
- *Bt*HT corn	0.038 ± 0.160		*0.1061*	^{ns}
Covariates				
N		4.857	0.0284	^{ns}

Discussion

Growth stages

The high abundance of non-target aerial invertebrates in the vegetative stage and the low abundance in the tasselling stage can be attributed to plant height and density of canopy. These corn plant characteristics limit the flight of aerial dwellers only in the inner parts of the cornfields, whereas aerial dwellers can move freely in a field with an open and lower density of canopy field. This result supports the study by Alston *et al*. (1991) which found larger Corn Earworm, *Helicoverpa zea* (Boddi) and larval populations in more open canopies. Similarly, the within-plant distribution of Fall Armyworm, *Spodoptera frugiperda* (J.E. Smith) was highest in the pre-tasselling stage, mostly in the wrapped leaves of the whorl (Labate 1993). The findings of the survey by Hagen *et al.* (2010) using fly traps also coincides with our result, with more abundant aerial arthropods recorded in both native and invaded forests with lower canopies.

Abundance and species richness

This study demonstrates that the abundance and species richness of all non-target invertebrates are slightly lower in *Bt* cornfields than in non-*Bt* cornfields. Pesticide input did not confound these results, i.e., the abundance and species richness remained lowest in *Bt* cornfields, whether or not pesticides were used. These results confirm the study by Marvier *et al*. (2007), albeit that in their case the adverse effects on non-target invertebrates were only demonstrated for experimental *Bt* fields under equal management as the non-*Bt* control fields, i.e. involving no pesticide use. It should be noted however that the adverse effects of *Bt* corn in our study were weak. In addition, increasing or decreasing pH and nitrogen compositions of the soil directly or indirectly favored invertebrate abundance which is probably due to the response of species to the presence of these chemicals or pH state supportive to their physiological needs. A study by Fischer and Führer (1990) showed that soil acidity plays a major role in the nematode's ability to parasitize Cephalcia nymphs and soil with pH levels below 4.0 may limit the nematode's host-finding. Moreover, invertebrates can tolerate soil acidity at different ranges like termites which are most tolerant to acidity with maximum abundance at pH 4 to 6 and coleopteran larvae are abundant only in soils with high pH whilst ants are not affected by soil acidity (Lavelle *et al*., 1995). Also, as stated in Lavelle *et al*. (1995), invertebrates are abundant and active population may exist in soil with pH 3.8 to 4.0.

On invertebrate dwellers

Abundance and species richness of non-target surface-dwelling invertebrates were not affected by transgenic corn varieties. This finding supports previous studies (Toschki *et al*., 2007; Peterson *et al*., 2011) in temperate regions, which concluded that some non-target species such as carabid beetles and spiders were not affected by *Bt* corn. The results of the current study further indicate that aerial and soil-dwelling species are more susceptible to *Bt* corn. The transgenic *Bt* and *Bt*HT corn had lower abundance and species richness of aerial species, and we also found a nearly significantly lower abundance of soil-dwelling species, though significance was lost after Bonferroni correction.

The unintended effects of *Bt* toxin on the abundance and species richness of the aerial- and soil dwelling invertebrates other than the target pest species (ACB) may be caused by numerous factors. One conceivable reason is the accumulation of *Bt* pollen in the axils of the leaves and its deposition within the cornfield (Hansen-Jesse and Obrycki, 2000; Li *et al.,* 2005). Furthermore, the ability of aerial dwellers to move from one plant to another may expose them to high concentration of *Bt* toxin in wind-dispersed pollen even outside fields (Koziel *et al*., 1993; Fearing *et al*., 1997). Although Obrist *et al*. (2006) found no or negligible amounts of Cry1Ab protein in some predators (hemerobiids*, Nabis sp*., *Hippodamia sp., Demetrias sp*.), the dilution of protein in the animal body may vary between species and groups of organisms. *Bt* toxin has been detected in aphids, a herbivore, with a mean concentration of 2.0±0.8 ppb (Burgio *et al*., 2007).

Cry1Ab delta-endotoxin, the active component of *Bt* corn seeds in the Philippines, persists in the soil, and can still be detected after 240 days in tillage and 200 days in no tillage cornfields (Zwahlen *et al*., 2003). After four consecutive years of *Bt* corn cultivation, the Cry1Ab protein can be detected even in the rhizosphere soil (Icoz *et al*., 2008). Soil properties of cornfields may also play a critical role in Cry1Ab protein absorption. An increase in the amount of surface clay particles and a decrease in organic carbon content will lead to an increased absorption capacity (Nguyen and Jehle, 2007). The fields we surveyed consist of clayey soils, and the organic carbon contents in the *Bt*HT and *Bt* cornfields are lower than in those in the non-*Bt* cornfields (Table 2). The persistence and absorption of Cry1Ab protein in the field soils (Saxena and Stotzky, 2000; Saxena *et al*., 2002) may have been one of the factors causing the decreased abundance of non-target aerial- and soil- dwelling invertebrates in the *Bt*HT and *Bt* cornfields.

Lastly, as noted from our analysis on confounding variables, some soil chemical properties of the surveyed cornfield could potentially affect the aerial or foliage dwelling invertebrates. Since foliage dwellers, mostly herbivores, are not feeding on the soil but feed on plant parts, hence the effect is considered to be indirect. Our result was supported by previous studies done by Prudic *et al*. (2005) and Kinney *et al*. (1997). Their studies showed that alteration of soil chemical properties can have indirect effects to the insect's performance. The alteration of soil chemistry can modify plant chemistry as well as the performances of insects particularly the herbivory insects (Prudic *et al*., 2005; Kinney *et al*., 1997). In particular, Prudic *et al*. (2005) showed that fertilized fields increased the availability of soil nutrients which in turn caused the host-plant's foliar nitrogen to increase and its chemical defense against pests to decrease. Also, Kinney *et al*. (1997) found out that the feeding performance of the Penultimate gypsy moth larvae (*Lymantria dispar*) can be affected by elevated CO_2 and NO_3 in the soil. The increased soil CO_2 and/or low NO_3 caused the plants to increase the concentrations of starch, condensed tannins and ellagitannins increased which can affect larvae feeding performance.

Guilds

Among the functional guilds recorded in the *Bt* cornfields, the omnivores seem to be affected the most in terms of abundance and species richness. This may be explained by the way *Bt* toxin spreads through the food web. Groot and Dicke (2002), for example, refer to direct effects of *Bt* corn when non-target invertebrates feed on plant parts containing the toxin, or indirect effects when they prey on herbivores containing the toxin. These effects also vary between species, depending on differences in *Bt* toxin ingestion (Head *et al*., 2001; Raps *et al*., 2001; Obrist *et al.,* 2005). In addition, ingestion is not the only way in which non-target species can be affected. Experiments by Prasifka *et al.* (2007), for instance, attributed the decreased weight and feeding habits of monarch butterfly larvae to the avoidance behavior of larvae when exposed to *Bt* expressing anthers. In the meta-analysis by Wolfenbarger et *al.* (2008), omnivores were more abundant in insecticide-sprayed non-*Bt* corn than in non-sprayed *Bt* corn, and the high abundance of omnivores, mostly soil-dwelling, was associated with a reduction in the population of predators, greatly affected by insecticide spraying. Overall, they found that the pesticide effect was stronger than the *Bt* corn effect. In the current study, we found no difference in the influence of pesticides between corn types. Hence, the low abundance of omnivores in *Bt* corn indicates that other causal factors must be taken into account. Omnivores are phytophagous as well as entomophagous invertebrates. Their ability to change prey and feed on plant materials allows them to survive in an environment inimical to specialized entomophagous invertebrates (Coll and Guershon, 2002). However, this also makes them more susceptible to toxin exposure. Nonetheless, further research is needed to uncover the mechanisms.

Conclusion

The study shows that long-term and continuous cultivation of transgenic corn has an impact on humid tropical corn-based agro-ecosystems, in terms of reducing the abundance and species richness of non-target invertebrates. Our results seem to contradict earlier studies in temperate regions, where endotoxin from *Bt* and *Bt*HT corn affected only the targeted pest species (ACB) (Candolfi *et al.,* 2004). As large-scale monocropping of transgenic corn is currently highly prevalent in the Philippines, precautionary measures or effective refuge strategies should be considered to abate serious implications for the biodiversity and sustainability of corn agro-ecosystems. Nonetheless, this study suggests that more research is needed to enable continuous monitoring and to address some emanating ecological issues about recently released *Bt*, *Bt*HT and HT corn lines.

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Analyzing the farm level economic impact of GM corn in the Philippines

Miladis M. Afidchao, C.J.M. Musters, Ada Wossink,
Orlando F. Balderama and Geert R. de Snoo

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Abstract

This paper analyses the farm economic viability of GM corn as compared to non-GM corn iso-hybrids in the Philippines. Data was collected from 114 farmers in Isabela province including non-GM, *Bt*, *Bt*HT and HT corn farmers. Results of univariate analysis showed that non-GM corn was not statistically different from GM *Bt*, *Bt*HT and HT corn in terms of production output (PO), net income (NI), production-cost ratio (M) and return on investment (RoI). Multivariate econometric analysis for the agronomic input variables showed a higher RoI at P=0.05 for *Bt* corn as the only difference between seed types. Next, pest occurrence and severity variables were included in the regression to address endogeneity and the Blinder-Oaxaca-decomposition method was used to further investigate differences between growers of *Bt*HT corn and non-GM corn into an endowment and a coefficient effect. The BO analysis showed that *Bt*HT corn has a negative impact on RoI as revealed by the negative signs of the overall mean gap and the characteristics and coefficient components. Contrary to RoI, the overall mean gap indicated that adopting *Bt*HT corn could potentially increase non-GM growers' income mainly from better control of corn borer pest even though mean levels of corn borer occurrence are lower for non-GM growers.

Introduction

The adoption of GM corn, cotton and soybean improves yields and reduces pesticides usage (e.g., Klotz-Ingram *et al.*, 1999; Thirtle *et al.*, 2003; Huesing and English, 2004; Gianessi, 2005). A recent meta-analysis by Finger *et al.*, (2011) of 203 publications on GM corn and cotton provides evidence that these crops lead, on average, to a higher economic performance than conventional crops. Other studies have confirmed these higher averages for specific countries.

In the US for example, the observed overall adoption of glyphosate-resistant crops translated to an annual saving of $1.2 billion for US farmers in 2001 (Gianessi, 2005). Edgerton *et al.* (2012) estimate that *Bt* corn enabled US farmers to harvest an additional 8.4 million ton of corn in 2010, i.e., an additional average yield benefit of 0.51 ± 0.95 t/ha. In addition, there are important non-pecuniary benefits when adopting GM corn such as increased management flexibility and convenience, savings on machinery use, and human health benefits from reduced handling and use of pesticides (Marra and Piggot, 2006; Brookes and Barfoot, 2009).

Similar estimations have been made for developing countries. For the year 2007, the farm income gains in these countries were estimated at $302 and $41 million for *Bt* and HT corn, respectively (Brookes and Barfoot, 2009). The yield increasing effects of GM corn is considered of most importance for developing countries. This is because yield gaps (the difference between farmers' field results and the genetic potential of a crop) tend to be larger in developing countries (Edgerton *et al.,* 2012). Thus, the most obvious pecuniary benefit is increase in yield (Finger *et al.*, 2011; Raney, 2006; Qaim & Zilberman, 2003). In addition there would also be non-pecuniary benefits but no studies have been undertaken to value these for farmers in developing countries (Raney, 2006; Brookes and Barfoot, 2009).

Contrariwise, GM corn and the results reported in studies such as those listed above remain a matter of great controversy. The first issue is with data collection. Yield data for the hybrids might be from breeding programs (field trials) and not from actual production fields. Yield and pesticide usage data from field/farm surveys also has limitations. The main problem with surveys is that neither the early adopters nor the fields chosen for the GM crop are randomly selected leading to a selection bias and this, again, makes a comparison with the non-GM crop problematic (Stone, 2011). Second, studies often provide a partial analysis of yield levels, returns and cost for pest control whereas it is the change in the gross margin which is decisive for farmers' income (Wossink and Denaux, 2006). A further critique is that average figures are misleading and that the performance of GM crops is variable, socio-economically differentiated, and contingent on a range of agronomic and institutional factors (Raney, 2006; Smale *et al.*, 2009; Glover, 2010; Mutuc *et al.*, 2011). There is particularly a need for further evidence on the experience by small, resource-poor farmers. GM crop technology is seen as being capable of benefiting these farmers but this is conditional on institutional settings. For example, the perspective that planting GM seeds would improve the life of poor farmers has been challenged as they have to buy new seeds every season and this makes them dependent on seed suppliers. Finally, many studies build on cross-section data, so that longer term effects have not been analysed (Marvier *et al.*, 2007; Krisna and Qaim, 2012).

Against this background, the present paper evaluates the farm level economic impact of pesticide producing (*Bt*), herbicide tolerant (HT) and stacked gene (*Bt*HT) corn in the Philippines. Asian countries have been slow in the uptake of GM crops that are grown for food and feed and the Philippines is the first and so far only country in Asia to have approved the commercial cultivation of GM corn. After *Bt* corn was first commercialized in the Philippines in 2003, there was a dramatic increase in its adoption. Corn production increased tremendously because yield and farm income levels with *Bt* corn were significantly higher (Yorobe and Quicoy, 2006; Anonymous, 2011). By 2010, GM corn was grown on over a quarter million hectares by 270,000 small-scale, resource-poor Filipino farmers (James, 2010).

In Isabela province, the focus of this paper, yield of *Bt* corn per ha was reported to exceed yield of conventional corn by up to 33% in the 2003-2005 seasons. In 2008-2009, *Bt* and *Bt*HT corn yields surpassed conventional corn by 4-5% and by 13-22%, respectively (Gonzales *et al.,* 2009). Previous studies on the social and economic impact of GM corn in the Philippines (Gonzales *et al.*, 2009; Yorobe and Quicoy, 2006) reported that increased yield and income were the driving factors for the high level of GM corn adoption in the country. Mutuc *et al.* (2011) confirmed the yield enhancing effect of *Bt* corn under poor weather conditions. Yet, a recent study (Afidchao *et al.*, Chapter 6) found striking evidence of negative farmer perceptions with regard to the statement if GM corn could improve their present economic status.

These conflicting findings motivated us to conduct a more in-depth study of the economics of GM corn hybrids in the Philippines. We focus at the farm level rather than at the national level or field level and at the variability across farms/farmers. We take explicitly into account that GM corn seed is substantially higher in price and hard to afford by a resource poor farmer. This price can be up to 84% higher than for non GM-corn depending on the type and number of transgenic traits included in the seed. Thus, to deal with the farm economic issues we seek to know and answer the research question: Is GM corn more economically viable and worth the investment than non-GM corn at the farm level? We investigate farm level differences by corn variety in expenditure for agricultural inputs (labour, seed, and fertilizer costs), gross and net return, production-cost ratio and return on investments. Econometric analyses were done to evaluate if and how agronomic variables (i.e. labour costs, agricultural inputs, corn types and farm area) affect production cost, total return, net income, production-cost ratio and return on investment.

This paper further contributes to the literature by employing the Blinder-Oaxaca decomposition method (Blinder, 1973; Oaxaca, 1973) to decompose the observed differences in economic performance between GM adopters and non-adopters into two components, namely a characteristics effect and a coefficients effect. This decomposition technique is widely used in labour economic applications to study mean outcome differences between groups. For example, the technique is often used to analyse wage gaps by gender or race. More recently it is also used in other areas (Park and Lohr, 2010; Tárrega *et al.*, 2010; Wu *et al.*, 2012). The counterfactual exercise answers the question, what would happen to the GM adopters if their distribution of characteristics was as for the non-GM adopters but if they maintained the returns to their characteristics? A comparison of the counterfactual and estimated performance distribution for the GM group and the non-GM group yields the part of the performance difference that is attributable to differences in covariates (farm and farmer endowments). The remainder of performance difference is then attributable to differences in returns to covariates. To the best of our knowledge, no other study has employed this decomposition technique to investigate the GM-economic impact nexus.

Material and methods

Area description: GM Corn and the family farm in the Philippines

The Philippines has a total of 9.6 million hectares (32%) agricultural land area of which 51% and 44% are arable and permanent croplands, respectively (Anonymous, 2011). There are ~1.8 million corn farmers in the country and 60% of these cultivate yellow corn. Mostly, these farmers are categorized as small, semi-subsistence farmers with a farm area of less than 4 hectares (Gerpacio *et al.*, 2004). All corn in the country is grown on rainfed non-irrigated land. The cornfields of these small farmers are mostly situated in marginal places. In contrast, most of the large-scale plantations of yellow corn are found in well-situated lowland or upland areas.

Small-scale farmers and their families perform the major agricultural activities such as seeding, harvesting and weeding. These households plant one corn variety, sometimes intercropped with tobacco, fruits (pineapple) and vegetables. Post-harvest activities include de-husking, shelling and grain drying which is done manually by both family and hired labour. Harvested corn is sun-dried immediately after harvest (Gerpacio *et al.*, 2004). This is accomplished on drying pavements at home or on the barangay multipurpose pavements but mostly along paved or asphalted national highways and provincial roads notably in the case study region of Cagayan Valley. The small-scale farmers are dependent on trader-financiers for full-season input financing because they lack the necessary capital. Farmer's payback their loans with a certain interest (~7-15%) either in cash or in corn product upon harvest. The trader-financier decides on the terms of condition of the payback agreement. For large-scale farmers that have large cornfields (cornfield size of more than 3 hectares) hired labour and mechanized farming are common practices.

Among the sixteen regions in the Philippines, the Cagayan Valley region ranks first in terms of corn production. Isabela province in the Cagayan Valley region was chosen as the case study area for the farm level economic assessment. In this province, farm demonstrations showcased the advantages of using GM corn including both its pecuniary and non-pecuniary benefits. One of the non-pecuniary benefits of GM corn, especially of *Bt*HT (insecticide plus herbicide tolerant) corn is that less labour inputs are required for weed management. With proper spraying of herbicide, the weed problem can be reduced or totally controlled. Since GM corn seeds cost are higher than the available commercial iso-hybrid corn in the market, high income and large-scale farmers were the first adopters of this technology. More recently small scale and poor farmers have also adopted the technology. However many poor farmers cannot afford to buy herbicides and still resort to manual weeding in *Bt*HT corn employing the labour force of the (extended) family on a cooperative basis.

Survey

The survey was conducted from October to December 2010 to obtain data for the wet growing season. In order to select our respondents within the group of general farmers who were best able to give us the first-hand information we needed, we applied a purposive sampling technique. Purposive sampling was accomplished of 114 corn farmers in the province of which 42, 8, 44 and 20 were non-GM, *Bt*, *Bt*HT and HT corn adopters, respectively (Table 1). Ninety-percent of the respondents were classified as small scale farmers with farm sizes of not more than 3 ha. Only 10% of the respondents were large scale farmers with farm sizes of 4 to 8 ha.

A self-structured questionnaire was used during the face-to-face interview of the respondents who were from 10 municipalities and 33 villages of the province. The questionnaire was structured to obtain information on respondents' farming background and on costs and returns, i.e. labour cost, input cost and other expenses. The labour cost encompasses the labour service fee for man machine day, man animal day and man day entailed during land preparation and cultivation practices (ploughing, harrowing, furrowing, off-barring and hilling-up), chemical application (fertilizer application and spraying of insecticide and herbicide) and pre- and post-harvesting practices (seed planting, harvesting, threshing, hauling and drying) for the 2010 wet growing season. The service fees for man day include both paid labour (hired labour) and non-paid labour (labour by family members). The corresponding wage per farming practice (e.g. harvesting, spraying) employed was calculated by multiplying the number of labourers to the existing standard service fee given per labourer per day (e.g., harvesting cost=10 persons [paid and unpaid labourers] x $4.65 per man day). Input cost covers the payment for the seeds, fertilizers, pesticides and other expenses entailed from land preparation to post harvest.

Prior to employing statistical analyses of the data, the total cost of production (TCP), gross income (GI) or production output (PO), net income (NI), production-cost ratio (M) and return on investment (RoI) were computed in US$ per hectare. Table 2 reports the summation of all the expenses entailed throughout the production to harvest period that was obtained as TCP. The PO refers to the total yield in kg of the 2010 wet season multiplied by the prevailing prize of corn grain per kilogram. The NI was calculated by subtracting TCP from PO. The production-cost ratio (M) was computed as the quotient of the production output and the total cost production per hectare (M=PO/TCP). Finally, the RoI was calculated by subtracting the net income to the product of interest rate paid on loans (IR) and the total cost of production (TCP) i.e. RoI = NI-(IR x TCP).

Univariate and multivariate analysis

A univariate analysis was first employed to evaluate differences on the respondents' information, farming background and production cost and to deal with the single response variables (i.e. corn types, agronomic inputs). A Holm-Bonferroni post hoc test (Quinn and Keough, 2007) was used to assess significant differences of the responses between GM and non-GM adopters.

While the means for production cost, total return, net income, production-cost ratio and return on investment provide the realistic farm economic result of the corn types under farm conditions, a comparison of these means by seed type would be misleading. A correct comparison needs to account for the fact that it is not just (a) the corn type that differs but at the same time (b) many other agronomic inputs and (c) farm characteristics as well. This confounds the impact of seed type on the economic results.

Multivariate analysis was used to evaluate how production output (PO), net income (NI), cost-production ratio (M) and return on investment (RoI) by seed type are directly or indirectly affected by other agronomic input variables. For comparison of the individual response variable between corn types the following conventional production function specification was estimated:

$$y_i = \alpha + \beta_n x_{ni} + \varepsilon_i \qquad (1)$$

where y_i denotes the response variables (i.e., the natural logs of PO, NI, M and RoI) in US$ ha^{-1} of farm i; α is the intercept and x_{ni} is a vector of the natural logs of the explanatory variables 1…, n of farm i, including labour cost in US$ ha^{-1}, agricultural input cost (fertilizer, seeds or pesticides) in US$ ha^{-1}, area planted, corn type, and ε_i is the error term with the usual classical properties. The estimated model was formulated following the Cobb-Douglas production function approach of Yorobe and Quicoy (2006) which is linear in the natural logs of the variables.

Starting from the full model for each of the response variable, stepwise regression analyses were performed through gradual elimination of those variables with insignificant p-values. The final model retains the variables with significant p-values. This enables evaluation which agronomic input variables have influence on the response variables tested in this study. The tables present only the results from the final model obtained after the series of stepwise regression analyses. All econometric analyses were performed using R stat. version 2.12.2.

Blinder-Oaxaca decomposition between GM and non-GM corn

The agronomic production function in eqn (1) above covers only part of the heterogeneity among the farmers that is expected to affect their input and output decisions. To proxy farmers' individual production environment a common approach is to include addition variables in the production function. Particularly important in this context is that GM seed and pesticides are applied in response to pest problems. This can give rise to endogeneity of pesticide use decisions and seed type selection and thus inconsistent parameter estimates. Following Mutuc *et al.* (2010) we included a pest occurrence and a severity variable in the production function to eliminate this potential bias.

Next, to the extended equations the Blinder-Oaxaca decomposition technique was applied to further investigate the mean differences in the response variables between GM and non-GM corn farmers. We assumed that GM corn has advantages compared to non-GM corn in terms of the responses because farmers will not shift to GM corn otherwise. Thus we expect that the non-GM corn have a lower mean of responses as compared to GM *Bt*HT corn.

For the decomposition, the extended equation is estimated separately for two groups of farmers (by seed type):

$$\bar{y}_{\mathrm{GM}} = \bar{x}_{\mathrm{GM}}\hat{\beta}_{\mathrm{GM}} + \hat{\alpha}_{\mathrm{GM}} \quad \text{for } n_1 \text{ obs} \qquad (2)$$

$$\bar{y}_{\mathrm{nonGM}} = \bar{x}_{\mathrm{nonGM}}\hat{\beta}_{\mathrm{nonGM}} + \hat{\alpha}_{\mathrm{nonGM}} \quad \text{for } n_2 \text{ obs} \qquad (3)$$

Recall that residuals sum to zero in eqs (2) and (3). Next, the mean gap in performance between the two groups of parcels, $\bar{y}_{\mathrm{GM}} - \bar{y}_{\mathrm{nonGM}}$, is split into two parts:

$$\bar{y}_{\mathrm{GM}} - \bar{y}_{\mathrm{nonGM}} = \underbrace{(\bar{x}_{\mathrm{GM}} - \bar{x}_{\mathrm{nonGM}})\hat{\beta}_{\mathrm{GM}}} + \underbrace{\bar{x}_{\mathrm{nonGM}}(\hat{\beta}_{\mathrm{GM}} - \hat{\beta}_{\mathrm{nonGM}} + \hat{\alpha}_{\mathrm{GM}} - \hat{\alpha}_{\mathrm{nonGM}})} \qquad (4)$$

Mean gap = Characteristics effect + Coefficients effect

where $\bar{x}_{\mathrm{GM}}$ and $\bar{x}_{\mathrm{nonGM}}$ refer to the means of the explanatory variables, and α and β are the intercept and the coefficient estimates on the explanatory variables for the two samples, respectively. The eqn (4) follows the proposed decomposition formulation of Neumark (1988). Subtracting and adding $\bar{x}_{\mathrm{nonGM}}\hat{\beta}_{GM}$ to the right hand side of eqn. (4) and rearrangement gives the decomposition in the characteristics and coefficients effect. An alternative and equally valid formulation in eqn (4) multiplies differences in mean observables characteristics by difference in non-GM coefficient estimates and multiplies differences in coefficient estimates by GM mean observable characteristics.

In eqn (4), the first term of the right-hand side is the part of the performance differential 'explained' by group differences in the predictors, i.e. the part of the gap attributed to differences in observed individual characteristics. The second term is attributable to differences in returns to co-variates, this is the unexplained "coefficient" part. It is important to recognize that this second term includes also all potential effects of differences in unobserved variables. In our case, it is the part of the gap that is due to different returns to the field characteristics and input levels. This second part answers the question if the growers non-GM corn were to switch to GM corn overnight but nothing else observable changed (i.e. the field/farmers' characteristics remained the same) would this lead to better results? A further detailed decomposition examines the percentage contribution of each individual explanatory variable to the total raw differential between the two samples to assess the comparative impact.

A decomposition of the mean gap as discussed above is only useful if the two compared equations are significantly different. Thus, first a Chow test for the difference between eqns. (2) and (3) is required; the null hypothesis is that the parameters of the two equations are equal, meaning that all the independent variables have uniform effects for both subgroups. The formula of the Chow test is:

$$F = \frac{\left(RSS_{\mathrm{pooled}} - \sum RSS_j\right) / (k+1)}{\sum RSS_j / (n_1 + n_2 - 2k - 2)} \qquad (5)$$

where RSS_{pooled} is the residual sum of squares (RSS) in the pooled regression, ΣRSS_j is the sum of the RSS from the two subgroup regressions, k is the number of predictor variables in the model and n_1 and n_2 are the number of observations in the subgroups (Otineno, 2009). The Chow test statistic follows an F-distribution with $k+1$ and n_1+n_2-2k-2 degrees of freedom.

Results

Respondent's information and farming background

As shown in Table 1, the mean age for the farmers' respondents, of which 25% are female, ranged from 43 to 50. Almost all (94%) of the respondents are married with mean household size of 5-6 members. Respondents have been living in their respective municipality for 35 to 43 years. Most of them reached high school or had a high school diploma or 10th grade. Almost all farmers (98%) in the sample practice mono-cropping. Respondents do not differ significantly in any of these characteristics by corn type.

On Asian Corn Borer (ACB) infestation, respondents vary in responses on the occurrence, concerns on damage and severity of ACB infestations (Table 1). All farmers encountered weed problem but their level of concern varies. Further analyses, revealed large differences between non-GM and *Bt* farmers' responses about: a) concerns on weeds pest and; b) the Asian corn borer (ACB) problem (Table 1). The non-GM respondents were less concerned about weeds pest in their farms than the *Bt* respondents. Likewise, a difference was noted between non-GM and *Bt* farmers' responses about the existence of the Asian corn borer (ACB) problem in their fields. All non-GM respondents confirmed that they have encountered the ACB problem whilst only part of the *Bt* farmers did encounter the ACB problem in their fields.

GM vs. non-GM corn: Production Cost

The total cost of production (TPC) was obtained by summing up the overall cost entailed by farmers per corn type in one hectare corn production (Table 2). This includes all cost components (labour and agricultural inputs) entailed from pre-harvesting to post harvesting activities. Table 2 showed that non-GM corn had significantly lower mean total cost of production than the total cost of production incurred when using GM corn hybrids.

Univariate analyses showed that the total input cost differed between GM and non-GM corn (Table 2). Agricultural input cost between GM corn types, i.e. *Bt* vs. *Bt*HT vs. HT, did not differ but all these GM corn types differed from non-GM corn. This corresponds to the big difference in seed cost between GM and non-GM corn. Seed prize of non-GM corn was statistically lower than GM corn. Seeds costs of all the GM corn types were more than 60% higher than non-GM corn. The cost incurred by non-GM farmers for pesticide use was statistically similar to that by GM farmers (Table 2.2). Total labour cost per hectare of production showed no difference between corn types.

Table 1. Respondents' information and farming background. Similar superscript letters represent no differences between corn varieties at P<0.05 after post-hoc analysis using Bonferroni test

Respondents' Information	**non-GM (n=42)**			***Bt* (n=8)**			***Bt*HT (n=44)**			**HT (n=20)**			**F**	**Sig**
	Mean	**±**	**sd**	**Mean**	**±**	**sd**	**Mean**	**±**	**sd**	**Mean**	**±**	**sd**		
Age	49.29	±	8.97	43.38	±	8.90	46.84	±	12.49	49.50	±	12.34	0.939	0.424^{ns}
Household size	6.43	±	3.12	5.00	±	0.54	5.70	±	2.46	6.30	±	2.64	0.980	0.405^{ns}
Years residing in the area	41.95	±	16.88	34.63	±	18.10	41.00	±	15.89	43.35	±	16.91	0.560	0.643^{ns}
Highest educational attainment[1]	3.93	±	1.96	4.75	±	1.91	4.00	±	1.95	4.70	±	2.20	1.040	0.378^{ns}
Cornfield information					±			±			±			
Area of farm devoted to the new variety[2]	1.33	±	1.36	1.56	±	0.82	2.06	±	1.43	1.85	±	1.44	2.104	0.104^{ns}
Weeds problem[3]	0.71	±	0.46	0.75	±	0.46	0.59	±	0.50	0.60	±	0.50	0.657	0.580^{ns}
Concerns on weeds pest[4]	2.61^{a}	±	0.67	3.50^{b}	±	0.93	2.91^{ab}	±	0.94	2.95^{ab}	±	0.97	2.794	0.044*
Asian corn borer (ACB) problem[3]	1.00^{a}	±	0.00	0.71^{b}	±	0.49	0.82^{ab}	±	0.39	0.89^{ab}	±	0.32	3.431	0.020*
Concerns on ACB pest[4]	3.12	±	0.83	2.75	±	1.39	3.07	±	0.77	2.95	±	0.83	0.517	0.671^{ns}
Severity of ACB damage[5]	3.72	±	1.02	3.13	±	1.55	3.42	±	1.03	3.40	±	1.23	0.968	0.411^{ns}

[1] Scale: 1-No schooling; 2- Elementary level; 3- Elementary graduate; 4- High School Level; 5-High School graduate;

[2] Scale: in hectare

[3] Scale: Yes-1, No-0

[4] Scale: 5- Highly concern; 4- moderately concern; 3- concern; 2-unconcern; 1- Highly unconcern

[5] Scale: 5- Highly severe; 4- severe; 3- moderately severe; 2- negligible; 1- Highly negligible

Table 2. Cost of production (labour, agricultural inputs, other expenses. Values are in US$ per ha at 1US$:42.50 Philippine pesos). Similar superscript letters represent no differences between corn varieties at P<0.05 after post-hoc analysis using Bonferroni test. P values: *** = p<0.001, ** = p<0.01, * = <0.05, (*) = <0.10)

Production cost	non-GM (n=42)			*Bt* (n=8)			*Bt*HT (n=44)			HT (n=20)			F-value	p-value
	Mean	±	sd	Mean	±	sd	Mean	±	sd	Mean	±	sd		
Total Production Cost	504.70^{b}	±	138.68	669.92^{a}	±	70.67	633.39^{a}	±	110.94	603.12^{a}	±	115.95	9.982	0.000***
1.Total labour cost	***208.60***	***±***	***52.12***	***231.90***	***±***	***61.90***	***228.36***	***±***	***47.58***	***220.17***	***±***	***39.61***	***1.336***	***0.267***^{ns}
Ploughing	42.13	±	20.91	38.09	±	13.69	36.47	±	16.82	37.41	±	14.44	0.776	0.510^{ns}
Harrowing	8.64	±	7.44	7.53	±	11.77	9.85	±	10.58	10.91	±	11.96	0.362	0.780^{ns}
Furrowing	1.34	±	6.84	2.94	±	8.32	1.30	±	3.48	1.59	±	4.04	0.220	0.882^{ns}
Second harrowing	1.01	±	6.54	2.94	±	8.32	1.12	±	3.64	0.00			0.664	0.576^{ns}
Basal application	4.91	±	4.98	9.03	±	4.93	5.50	±	4.44	7.34	±	6.52	2.165	0. 096(*)
Side dress	5.90	±	4.96	6.62	±	3.44	7.85	±	5.29	6.55	±	6.01	1.025	0.385^{ns}
Planting	25.04	±	10.37	24.82	±	7.41	29.39	±	10.06	28.05	±	15.14	1.264	0.291^{ns}
Off-baring	8.10	±	7.97	8.59	±	9.55	5.88	±	8.46	3.79	±	7.84	1.496	0.220^{ns}
Hilling-up	3.03	±	5.89	4.12	±	8.03	2.98	±	6.71	1.76	±	4.51	0.336	0.799^{ns}
Total spraying	8.49	±	9.18	8.65	±	7.48	8.94	±	7.72	5.89	±	4.31	0.736	0.533^{ns}
Insecticide Spraying	2.87	±	3.97	2.35	±	4.53	2.86	±	4.93	1.06	±	2.70	0.990	0.400^{ns}
Herbicide spraying	5.17	±	6.85	6.29	±	6.00	5.60	±	5.76	4.84	±	4.70	0.150	0.929^{ns}
Fungicide Spraying	0.45	±	1.82	0.00			0.48	±	2.25	0.00			0.478	0.698^{ns}
Harvesting	30.84	±	8.67	37.06	±	14.38	33.88	±	6.98	36.29	±	10.60	2.344	0.077(*)
Thresher	35.30	±	13.65	39.58	±	16.52	39.84	±	13.96	42.49	±	16.16	1.338	0.266^{ns}
Hauling	14.23	±	9.94	18.85	±	7.67	19.46	±	12.86	17.11	±	7.76	1.770	0.157^{ns}
Drying	18.84	±	10.36	20.32	±	10.41	22.79	±	10.57	19.48	±	8.92	1.177	0.322^{ns}
2.Total input cost	***262.84***^{b}	***±***	***106.92***	***393.68***^{a}	***±***	***79.84***	***369.10***^{a}	***±***	***88.46***	***354.51***^{a}	***±***	***88.08***	***11.071***	***0.000****
Seed costs	90.01^{b}	±	32.46	152.35^{a}	±	33.55	163.71^{a}	±	32.11	168.00^{a}	±	26.14	49.120	0.000***
Total Fertilizer	165.44	±	88.71	238.38	±	79.93	198.73	±	81.08	181.86	±	72.57	2.309	0.080(*)
Organic	126.86	±	12.85	157.12	±	29.79	148.13	±	12.70	156.06	±	18.39	0.821	0.485^{ns}
Inorganic	36.59	±	85.09	81.26	±	68.39	50.60	±	77.41	34.89	±	79.07	0.886	0.451^{ns}
Pesticides	7.39	±	8.57	2.94	±	8.32	6.67	±	11.73	4.65	±	8.71	0.678	0.567^{ns}
3.Others expenses	***33.26***	***±***	***51.79***	***44.35***	***±***	***26.27***	***35.93***	***±***	***27.10***	***28.45***	***±***	***26.58***	***0.380***	***0.768***^{ns}

GM vs. non-GM: Production and Income

The *Bt*HT and HT corns exhibited the highest gross income or production output (PO) as compared to *Bt* and non-GM corn hybrids (Table 3). *Bt*HT and HT corn out yielded non-GM corn by 8% and 7% but non-GM corn out yielded *Bt* corn by 1%. However, there was no statistical difference in PO between GM and non-GM corn.

The computed net income (NI) showed that *Bt*HT exhibited the highest NI followed in descending order by HT, non-GM and *Bt* corn hybrids (Table 3). *Bt*HT and HT corn net income were higher than non-GM corn by 7% and 5%, respectively. The NI of non-GM corn was higher to *Bt* corn by 15%. However, statistics shows that NI was not different between corn types.

The net-cost ratio (M) was computed by corn type. The lowest net-cost ratio was observed for *Bt* corn; yet, this did not differ statistically from other GM corn types and was found to be not significantly different from non-GM corn (Table 3). Finally, we measured the performance of each corn types under study in terms of return on investment (RoI). *Bt*, *Bt*HT and HTcorn had, respectively, 28%, 10% and 6% higher RoI than non-GM corn (Table 3). Yet, the efficiency as reflected from the computed RoI of non-GM corn was found to be statistically not different to the GM corn hybrids.

Table 3. Production output, net income, production-cost ratio and return on investment between corn types categories using univariate analysis. (Values are in US$ per ha at 1US$:42.50 Philippine pesos).

	non-GM (n=42)			*Bt* (n=8)			*Bt*HT (n=44)			HT (n=20)			F-value	p-value
	Mean	±	sd	Mean	±	sd	Mean	±	sd	Mean	±	sd		
PO	1,103.98	±	539.36	1,071.84	±	455.98	1,299.17	±	372.12	1,272.12	±	442.09	1.671	0.177^{ns}
NI	612.28	±	489.98	436.12	±	456.77	687.54	±	345.17	684.21	±	410.63	0.940	0.424^{ns}
M	2.28	±	1.01	1.698	±	0.70	2.158	±	0.59	2.208	±	0.71	1.231	0.302^{ns}
RoI	503.23	±	341.66	885.64	±	676.05	618.39	±	417.93	572.16	±	424.53	2.046	0.112^{ns}

PO=Production Output
NI=Net Income
M=Production-cost ratio
RoI=Return on Investment

Multivariate analysis

We applied production function analysis to PO, NI, M and RoI. Before the analysis, we first evaluated the residual plots (residual vs. fitted, normal Q-Q, scale-location and residual vs. leverage) for its normal distribution. Data that were non-normally distributed were ln(x+1) transformed. Data presented here are results of the minimal model per response variable obtained after series of stepwise regression analyses.

In explaining the variation in PO, costs of threshing, harvesting and plowing were found to have the largest effect. Among input cost, differences in seed cost seems to be important as expected from the summary statistics in Table 2. The R^2 value was estimated 0.53 for the final model used (Table 4 column A).

Table 4 (column B) shows the multi-agronomic variables that are affecting NI. Area planted and fungicide spraying had the highest impact on NI. The R^2 estimate values are 0.39 for the final model.

On M, variables such as area, fertilizer and labour costs for thresher showed great influence (Table 4 column C). The R^2 estimate values are 0.39 for the final model.

This analysis showed that *Bt* corn had a significantly higher RoI than non-GM corn (Table 4 column D), although the overall effect of corn type was not significant (table 3) whilst none of the other tested agronomic variables did have an effect (R^2: 0.05).

Blinder-Oaxaca decomposition

Next the regression equations as above were extended with a pest occurrence and a severity variable to eliminate potential endogeneity bias. The equations for two response variables (i.e. RoI and NI) and *Bt*HT and non-GM corn were selected for the BO analysis on the basis of the results obtained after subjecting the extended regression models for all the response variables to a Chow test as shown in Table 6.

For the decomposition, the RoI and NI equations are estimated separately as discussed above. The regression results for return on investment (Table 7, column 4 and 5) show that among the assessed variables, corn borer occurrence and costs of labour, seeds and pesticides manifested significant negative effects on GM corn. It is interesting to note that together with farm size and fertilizer, corn borer severity showed positive effects on GM corn's RoI. For non-GM corn, the costs of seeds and pesticide have significant positive effects. All other variables including corn borer occurrence and severity show significant negative effects on non-GM corn's RoI.

The estimated models were then used to split the observed gap between corn types in two portions (Tables 7, last three columns). The sum in the bottom row of Table 7 shows that of the overall raw gap of -3.397 for RoI only 21% (-0.705) can be explained by differences in characteristics of the two samples. The remaining 79% (-2.692) can be attributed to the coefficient or unexplained effect. Notice that the gap is negative and thus the switch to GM corn would mean a drop in RoI for the farmers on average. The last two columns of Table 7 present the contribution of each explanatory variable to the explained and the unexplained component, respectively. In terms of the explained part, most important contributions to explaining the negative gap come from the seed cost (147%) followed by some distance by labour costs (20%). Notice that all the other characteristics reduce the gap (negative percentages).

For NI, the regression results in Table 8 show that among the assessed variables, seed cost, fertilizer cost and corn borer severity carry negative signs. These are variables which manifest negative effects on NI. Farm size, labour cost and pesticide cost have positive signs hence, exhibit significant positive effects on NI for both corn types. Further analysis shows that the two main parts of the mean gap (1.144) have opposite signs; we find a small negative characteristics effect (-23%) and a large positive coefficient effects (123%). In particular, among the explanatory variables of the negative characteristic components, seed cost has the largest percentage (112%) followed by fertilizer cost (61%). Except for farm size and labour cost, the remaining characteristics contribute to increasing the negative gap (positive percentages). Contrary to RoI, the overall gap indicates that adopting GM corn could potentially increase the growers' income. The results in the last two columns of Table 8 show that the mean income advantage from switching to *Bt*HT corn is mainly due to better control of corn borer pest.

Table 4. Estimates of agronomic variables identified to affect PO, NI, M and RoI ha^{-1} employing series stepwise regression analyses. All data was natural log (ln) transformed. P values: *** = p<0.001, ** = p<0.01, * = <0.05, (*) = <0.10); L_i= man labor cost ha^{-1}; I_i= agricultural input cost ha^{-1}; SE = standard error.

	(A) Production Output (PO) [r^2=0.526]	**(B) Net Income (NI) [r^2=0.391]**	**(C) Production-Cost Ratio (M) [r^2=0.386]**	**(D) Return on Investment (RoI) [r^2=0.053]**
	Estimate ± se	Estimate ± se	Estimate ± se	Estimate ± se
Intercept				
Corn types (C_i): Non-GM corn	3.698^{**} ± 0.743	-1181.230 ± 297.630	1.029 ± 0.262	503.190^{***} ± 63.990
Contrast with intercept				
-*Bt* corn	-0.011 ± 0.144	-193.200 ± 133.710	-0.085 ± 0.086	382.560^{*} ± 159.970
-*Bt*HT corn	0.036 ± 0.103	-15.450 ± 77.290	-0.018 ± 0.050	115.220 ± 89.460
-HT corn	-0.002 ± 0.121	-34.550 ± 96.260	-0.037 ± 0.061	69.010 ± 112.660
Covariates				
Plowing cost (L_{1i})	-0.002^{**} ± 0.050			
Furrowing cost (L_{2i})	-0.056^{*} ± 0.047	-92.860^{*} ± 41.630	-0.047^{*} ± 0.026	
Second harrowing cost (L_{3i})	-0.124^{*} ± 0.058			
Insecticide spraying (L_{4i})	0.081^{*} ± 0.031			
Harvesting cost (L_{5i})	0.112^{**} ± 0.118			
Thresher cost (L_{6i})	0.575^{***} ± 0.081	$125.050^{(*)}$ ± 77.030	0.286^{***} ± 0.052	
Side dress cost (L_{7i})		$-66.590^{(*)}$ ± 31.130	-0.048^{*} ± 0.020	
Fungicide spraying (L_{8i})		504.290^{***} ± 82.010		
Seed cost (I_{1i})	0.143* ± 0.125			
Fertilizer cost (I_{2i})			-0.178^{***} ± 0.041	
Area planted (A_{ri})	0.077** ± 0.024	83.940** ± 25.000	0.045** ± 0.016	

Table 5. Correlation values (upper) and p-values (lower) between corn agronomic variables ha^{-1}. (PO= production output/yield; NI = Net income; M= Cost-production ratio; RoI= Return on investment; TPC= Total Production Cost). P values: *** = p<0.001, ** = p<0.01, * = <0.05, (*) = <0.10), ns = not significant

	Variables	Pearson's correlation coefficient											
		PO	**NI**	**M**	**RoI**	**TPC**	**Labor cost**	**Fertilizer cost**	**Seed cost**	**Pesticide cost**	**Area planted**	**ACB**	**Weeds**
P- values	PO	■	0.898	0.724	0.096	0.425	0.344	0.237	0.273	0.006	0.300	-0.025	-0.031
	NI	< 2.2e-16***	■	0.863	0.075	0.160	0.209	0.014	0.138	-0.017	0.287	-0.090	-0.016
	M	< 2.2e-16***	< 2.2e-16***	■	0.104	-0.014	0.001	-0.116	-0.007	-0.077	0.171	-0.067	-0.060
	RoI	0.309^{ns}	0.428^{ns}	0.271^{ns}	■	0.079	0.009	0.025	0.157	-0.064	0.000	-0.022	-0.109
	TPC	2.48e-06***	0.090$^{(*)}$	0.035*	0.401^{ns}	■	0.579	0.795	0.506	0.272	0.222	0.129	0.074
	Labor cost	0.000***	0.026*	0.994^{ns}	0.926^{ns}	1.5e-11***	■	0.188	0.073	0.073	0.061	0.026	0.052
	Fertilizer cost	0.011*	0.884^{ns}	0.002**	0.794^{ns}	<2.2e-16***	0.045*	■	0.270	0.076	0.346	0.111	0.084
	Seed cost	0.003**	0.144^{ns}	0.939^{ns}	0.095$^{(*)}$	9.6e-09***	0.441^{ns}	0.004**	■	-0.089	0.310	0.224	0.003
	Pesticide cost	0.952^{ns}	0.857^{ns}	0.414^{ns}	0.497^{ns}	0.324^{ns}	0.437^{ns}	0.423^{ns}	0.086$^{(*)}$	■	-0.089	-0.091	0.150
	Area planted	0.001**	0.002**	0.069$^{(*)}$	0.997^{ns}	0.018*	0.516^{ns}	0.065$^{(*)}$	0.001**	0.349^{ns}	■	0.083	0.209
	ACB	0.788^{ns}	0.341^{ns}	0.476^{ns}	0.816^{ns}	0.172^{ns}	0.784^{ns}	0.240^{ns}	0.016*	0.337^{ns}	0.378^{ns}	■	0.069
	Weeds	0.741	0.868	0.527	0.248	0.431	0.586	0.374	0.973	0.110	0.025	0.468	■

Table 6. Chow test outcome for production output, net income, return on investment and cost-production ratio. P values: ** = p<0.01, ns = not significant

Response variable	df numerator	df denominator	RSS_{BtHT}	$RSS_{non\text{-}GM}$	ΣRSS	F	p-values
Production output	8	70	3.252	9.120	13.210	0.592599	0.955569^{ns}
Net Income	8	70	21.380	198.940	298.978	3.12391	0.000158**
Return on Investment	8	70	177.493	106.396	358.910	2.31229	0.003652**
Cost-Production Ratio	8	70	50.719	119.100	168.703	0.057502	1.000000^{ns}

RSS = residual sum of squares in the pooled regression; ΣRSS= sum of the RSS

Table 7. The Blinder-Oaxaca decomposition of the return on investment (ROI) of GM and non-GM corn types. P values: ** = p<0.01, * = <0.05, (*) = <0.10), ns = not significant

Explanatory Variables	**Characteristics**		**Coefficients**		**ROI GM evaluated at means**	**ROI non-GM evaluated at means**	**Mean Gap**	**Characteristics Effects (share in %)**	**Coefficients effects (share in %)**
	$\overline{X}_{GM}$	$\overline{X}_{nonGM}$	$\hat{\beta}_{GM}$	$\hat{\beta}_{nonGM}$	$\hat{\beta}_{GM}\overline{X}_{GM}$	$\hat{\beta}_{nonGM}\overline{X}_{nonGM}$		$(\overline{X}_{GM}-\overline{X}_{nonGM})\hat{\beta}_{GM}$	$\overline{X}_{nonGM}(\hat{\beta}_{GM}-\hat{\beta}_{nonGM})$
Intercept	1.000	1.000	11.413	6.806	11.413	6.806	4.607		4.607 (-171%)
Farm size	2.182	1.500	0.042^{ns}	-0.341^{ns}	0.091	-0.512	0.602	0.028 (-4%)	0.574 (-21%)
Labor cost	228.341	208.571	-0.007^{ns}	-0.002^{ns}	-1.598	-0.417	-1.181	-0.138 (20%)	-1.043 (39%)
Seed cost	163.818	90.024	-0.014^{ns}	0.033**	-2.293	2.971	-5.264	-1.033 (147%)	-4.231 (157%)
Fertilizer cost	198.750	165.405	0.004^{ns}	-0.007$^{(*)}$	0.795	-1.158	1.953	0.133 (-19%)	1.819 (-68%)
Pesticides	6.727	7.429	-0.287^{ns}	0.318^{ns}	-1.931	2.362	-4.293	0.201 (-29%)	-4.495 (167%)
Corn borer severity	3.659	3.439	0.127^{ns}	-0.730*	0.465	-2.510	2.975	0.028 (-4%)	2.947 (-109%)
Corn borer occurrence	1.091	1.119	-2.689$^{(*)}$	-0.123^{ns}	-2.934	-0.138	-2.796	0.075 (-11%)	-2.871 (107%)
Sums					**4.007**	**7.405**	**-3.397**	**-0.705 (100%)**	**-1.692 (100%)**

Table 8. The Blinder-Oaxaca decomposition of the Net Income (NI) of GM *Bt*HT and non-GM corn types. P values: (*) = <0.10), ns = not significant

Explanatory Variables	Characteristics		Coefficients		NI GM evaluated at means	NI non-GM evaluated at means	Mean Gap	Characteristics Effects (share in %)	Coefficients effects (share in %)
	$\overline{X}_{GM}$	$\overline{X}_{nonGM}$	$\hat{\beta}_{GM}$	$\hat{\beta}_{nonGM}$	$\hat{\beta}_{GM}\overline{X}_{GM}$	$\hat{\beta}_{nonGM}\overline{X}_{nonGM}$		$(\overline{X}_{GM}-\overline{X}_{nonGM})\hat{\beta}_{GM}$	$\overline{X}_{nonGM}(\hat{\beta}_{GM}-\hat{\beta}_{nonGM})$
Intercept	1.000	1.000	4.522	5.321	4.522	5.321	-0.799		-0.799 (-57%)
Farm size	2.182	1.500	0.113^{ns}	0.526^{ns}	0.247	0.788	-0.542	0.077 (-29%)	-0.619 (-44%)
Labor cost	228.341	208.571	$0.010^{(*)}$	0.012^{ns}	2.215	2.461	-0.246	0.192 (-73%)	-0.438 (-31%)
Seed cost	163.818	90.024	-0.004^{ns}	-0.001^{ns}	-0.655	-0.108	-0.547	-0.295 (112%)	-0.252 (-18%)
Fertilizer cost	198.750	165.405	-0.005^{ns}	-0.003^{ns}	-0.954	-0.568	-0.386	-0.160 (61%)	-0.226 (-16%)
Pesticides	6.727	7.429	0.074^{ns}	0.013^{ns}	0.495	0.093	0.402	-0.052 (20%)	0.454 (32%)
Corn borer severity	3.659	3.439	-0.014^{ns}	-0.182^{ns}	-0.053	-0.627	0.574	-0.003 (1%)	0.577 (41%)
Corn borer occurrence	1.091	1.119	0.762^{ns}	-1.660^{ns}	0.831	-1.858	2.689	-0.021 (8%)	2.710 (193%)
Sums					**6.648**	**5.504**	**1.144**	**-0.263 (100%)**	**1.407 (100%)**

Discussion

GM corn effect on Cost

One of the most often highlighted reasons for non-GM corn adopters is the high cost of seed per hectare of corn production (Afidchao *et al.*, Chapter 6). This study once again shows that cost of seeds per hectare was far higher for GM corn than for the leading conventional corn hybrids available on the market. This is also one of the main factors influencing the high level of total production cost for GM corn (Tables 2).

Reduction of pesticides usage is one of the benefits that was promised to be achieved when using GM corn (Mutuc*et al.*, 2011; Brookes and Barfoot, 2009; Kleter *et al.*, 2007; Wilson *et al.*, 2005; Huang *et al.*, 2003; Rice, 2003). Yet, our study showed that pesticide cost entailed in all corn types are statistically the same. Our result confirms results reported by Afidchao *et al.* (Chapter 6) where *Bt*HT and HT farmers perceived no reduction in pesticides usage and exposure. This is likewise supported by the findings of Wossink and Denaux (2006) where efficiency of pest control cost between transgenic and conventional cotton found no statistical difference. Finally, the claim that pesticides usage can be reduced was not supported by our study as shown in Table 4. Although, it has been shown in US and Europe that GM corn reduce pesticide and its environmental footprints at 14% reduction rate (Brookes and Barfoot, 2006). Also, a savings of $25-$75/acre due to no insecticide is achieved with *Bt* corn (Rice, 2003). This reduction in pesticide usage observed in US was not manifested at the farm-scale level in Isabela province plausibly due to *Bt* farmers' fear and anticipation of yield loss by pests other than ACB. Hence insecticide spraying is usually done even with *Bt* seed and by HT farmers who opted to have manual weeding due to financial constraints (no money to buy herbicide).

GM corn effect on production, income and return on investment

In terms of yield or production output, our result for conventional and *Bt* corn was similar to the comparisons of yield in 2004-2005 and 2007-2008 in the Philippine provinces of General Santos City and Isabela, respectively where conventional corn was statistically higher than GM corn (Gonzales *et al*., 2009).

*Bt*HT and HT corn produced on average higher yields, *Bt* corn lower than non-GM corn, but these differences were not statistically significant. This shows that GM corn has no straight forward overall advantages compared with non-GM corn. *Bt* corn may produce higher yields (Dilehay *et al.*, 2004; Stanger & Lauer, 2006; Qaim & Zilberman, 2003; Rice, 2003) but other additional points should be taken into account when assessing economic returns. As stated by Dilehay *et al.* (2004) and Stanger & Lauer (2006), *Bt* corn has higher grain moisture, lower test weight and higher harvest & seeds cost; these counterweigh increased yield and might result in adding no benefits when using GM corn. Ma and Subedi (2005) show that on the same maturity, non-*Bt* corn accumulates more nitrogen and leads to highest grain yield. In addition, low to moderate infestation of corn borer provides no advantage in using *Bt* corn. According to

Wolf and Vögeli (2009) using *Bt* corn, an increased yields of up to 15 percent can be obtained when infestation is severe to very severe but at low and moderate infestation conventional maize hybrids are superior when appropriately grade-selected.

The severe to moderately severe ACB infestation in the respondents' cornfields (Table 1) indicate that ACB is still a pest problem in Isabela province. Under high pressure of corn borer infestations, *Bt* corn should have yield advantages. However, in our study the production in GM corn did not exhibit significant yield advantages compared with non-GM corn (Table 3). In the same vein, the reduction of weeds incidence using herbicide tolerant (*Bt*HT and HT) corn varieties (Table 1) did not result in economic advantages compared with non-herbicide tolerant corn varieties (non-GM and *Bt* corn) (Table 3).

In our study, the RoI did not significantly differ among corn types thereby supporting the experimental data of Nolte and Young (2002). Nolte and Young (2002) found no differences between GM herbicide tolerant and conventional corn hybrids in terms of economic return in their 1999 field experiment. Although they have seen significant variations between these corn types in 2000 yet the grain yield effect was stronger than the corn type effect. However, in our study, econometrics showed that RoI could be positively influenced by corn types specifically; *Bt* corn had a significantly higher RoI than non-GM corn (Table 4).

The findings of our study on non-significant difference in mean PO, NI, M and RoI among corn types (Table 3) do not show more profits when using GM corn. In particular, our data did not affirm that *Bt* corn adoption could provide higher yield (Stanger & Lauer, 2006; Dilehay *et al.*, 2004) and higher profits (Qaim & Zilberman, 2003; Rice, 2003). Hence, this does not support the general concept that GM corn provides higher income than non-GM corn. Relatively, our study supplement the data of Baute *et al.* (2002) which refuted the notion that *Bt* corn hybrids in general are higher yielding compared to conventional corn.

Lastly, past studies (Yorobe and Quicoy, 2007 and Gonzales *et al.*, 2009) stated that the farmers that adopted GM corn found it profitable, i.e. the farmers with high risks of ACB, have adopted GM corn by now. Yet, in our present study we found that with moderately severe ACB infestation as observed by the respondents (see Table 1), GM corn did not manifest advantage in terms of profit. This means that further increase of GM corn is no longer profitable, although it might have been in the past.

Agronomic variables effect on PO, NI and M

Several variables could substantially affect PO as shown in Table 4. Labour cost, agricultural input cost and area planted are the influential variables on PO. On labour cost, plowing, harvesting and thresher are noted to greatly affect PO. Among the agricultural inputs, seed cost was shown to have great influence on PO. This may indicate that an increase in PO could require a high input of seeds. Lastly, area planted could as well influence PO. Increasing area planted results to a higher PO and this was supported by the positive and significant correlations of PO.

The relationship between PO and NI was strong and positive as shown in Table 5. Yet econometric shows different inputs have an effect on NI. For NI fungicide spraying is the most important input, followed by the area planted.

The agronomic variables like area, fertilizer and labour costs for furrowing, side dress fertilizer application and thresher are shown to influence M (Table 4). This demonstrates that an increase in area devoted to corn leads to an increase in production cost and production output. On the other hand, fertilizer cost that constitutes around 33 to 44% in the cost production depending on corn types (Gonzales *et al*., 2009), showed a significant negative correlations to M. This directs us to the point that any increase in fertilizer inputs does not warrant higher production (correlation= -0.116; p-value: 0.002, table 5). Lastly, an increase in production or yield also entails an increase in thresher cost with positive significant correlations of 0.589 (p-value= 5.448e-12, table not shown).

Finally, the econometric analysis revealed that among the tested agronomic variables, area planted is the variable that has encompassing positive influence to PO, NI and M. This further mean that any increase in area of corn plantation may contribute to the increase in yield and income as well as production cost.

Blinder-Oaxaca decomposition of return on investment and net income

The RoI and NI as such showed insignificant differences between GM and non-GM corn types and suggest that GM corn does not show superior economic performance compared with non-GM corn (Table 3). Thus, the cultivation of an iso-hybrid non-GM corn seems to have comparable economic results in terms of RoI and NI based on this partial analysis. The application of BO analysis in this study served to check whether other characteristics (such as agricultural input, cost and cornfield pest history) that vary at the same time as seed type could explain some of the difference and thus might confound the overall assessment and determination of which corn type is worth investing. For GM *Bt*HT and non-GM corn growers, the two largest subsamples in this study, the Chow test revealed that there are indeed concomitant differences in the other underlying characteristics (Table 6).

The BO technique served to compare the contribution of independent variables RoI and NI between GM *Bt*HT and non-GM corn through the distinction of an observable characteristics effects and an unexplained coefficient effect. The coefficient component can have a different sign from the characteristics component and this can give insightful information in particular. If both components have the same sign, differences in RoI or NI are as expected. A situation of opposite signs and a substantial coefficient effect is often associated with discrimination in the sociological and labour economics literature in which the Blinder-Oaxaca decomposition is commonly applied.

The last two columns of Table 7 show that for RoI the sums of the two components have identical signs (negative). However for individual variables differences in signs do occur. For both pesticide costs and for corn borer occurrence there is a negative impact on the RoI which is unexpected given the lower average for these variables for the non-GM sample. Finally, the intercept is responsible for most of the coefficients effects indicating the contribution of unobservable characteristics (such as physico-chemical characteristics of cornfields) to the difference in RoI.

In contrast, in case of NI, the sums of the two components shown in the last two columns of Table 8 do not have identical signs. The characteristics effect making up a small portion (23%) of the gap bears a negative sign. This indicates a negative effect on NI by the differences in *Bt*HT and non-GM farmers' observable characteristics which is mainly attributed to seed costs and costs of fertilizer inputs. However this is counteracted by the coefficients or unexplained component which has carry a positive sign and is mainly due to pesticide input, corn borer severity and occurrences. In general, this shows that *Bt*HT has disadvantages on NI based on observable characteristics yet, could provide economic advantage overall due to better pest control even for cornfields less heavily infested with corn borer pest and also due to savings on pesticide costs.

Conclusion

This study focused on small-scale farmers as they constitute the majority of corn farmers and are usually at the bottom in the economic production spectrum. They are likewise the most vulnerable groups easily malleable to be influenced with new introduced technologies that promise superior economic gains. The vast increment and wide-scale cultivation of GM corn in the Philippines is attributed to risk-averse farmers as well as driven by economic benefits offered by these novel varieties. While it is true that past studies showed the adoption of GM corn could increase yield and provide more profits to farmers, our study showed no difference in production output between corn varieties anymore. This study showed that GM corn adoption does no longer directly provide superior economic advantage against non-GM corn considering all the variables studied.

We found that the Blinder-Oaxaca decomposition technique usually used in racial and gender discrimination studies can as well be applied to agriculture economic related studies. Employing this technique allowed us to compare and identify variables with marked influences on the results of our study. Finally, this study can be undertaken on a larger scale to obtain more information on the economic benefits from GM corn technology overtime viz a viz its wide scale adoption in different economic settings and locations.

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GM Corn Adoption and Farmers' Experiences in the Philippines

Miladis M. Afidchao, C.J.M. Musters, Orlando F. Balderama
and Geert R. de Snoo

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Abstract

After almost a decade of widespread cultivation of genetically modified (GM) corn in the Philippines, the country ranks 12th among the 21 largest biotech-crop producing countries worldwide. Information on the level of adoption and farmers' experiences with GM corn is essential for agricultural and environmental policy-makers, for future decisions and guidance. Hence, this study describes the farmers' experiences and standpoints on GM corn by studying: (1) farming background and agricultural practices; (2) reasons for adoption by GM corn farmers and non-adoption by non-GM corn farmers; (3) barriers to and satisfaction with GM corn adoption; and (4) perceived shifts in standpoints after GM corn adoption. A total of 188 corn farmers (using *Bacillus thuringiensis*/*Bt* corn, herbicide tolerant/HT corn, *Bt*HT corn, non-GM corn and mixed cultivation) from 11 municipalities in Isabela were interviewed for this study. Respondents affirmed that corn borers and weeds are problematic pests, but levels of concern of the severity of damage differed. The foremost reason for not adopting GM corn was the cost of seed. Although especially the *Bt* and *Bt*HT farmers perceived a negative shift in their standpoints after GM corn adoption, they kept using it, for reasons that need to be explored.

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Introduction

Modern genetically modified (GM) crop production is a highly contentious issue in developed as well as developing countries. In Europe, GM corn is grown in limited areas because of strictly implemented co-existence regulations and bans on one type of GM corn, the *Bt* (*Bacillus thuringiensis*) corn cultivation (Beckman, 2006). In addition, the European public's perception of biotechnology is characterized by widespread opposition to GM foods (Gaskell *et al*., 2000). In Sweden, an opposing view prevails, as farmers foresee no benefits from GM corn adoption and fear low market acceptance and risks to human health and the environment (Lehrman and Johnson, 2008). By contrast, a meta-analysis done by Areal *et al*. (2012) on the economic and agronomic impact of commercialized GM crops in both developed and developing countries provide recent evidence that GM crops (i.e. corn, cotton and soybean) perform better than their conventional counterparts in agronomic and economic (gross margin) terms.

In a developing country like the Philippines, importing and approving *Bt* corn became the most controversial issue regarding the use of genetically modified crops. Anti-*Bt* corn advocates were active to stop further field-testing and adoption of *Bt* corn (Gonzales *et al.,* 2009). Explicitly, religious leaders, policy makers and some non-government organizations (NGOs) exhibited a more conservative stand (Torres, 2006). At the same time, *Bt* corn support groups coming mainly from academic and government institutions made great efforts to enhance peoples' knowledge about the benefits of *Bt* corn through organized public campaigns to dissemination information (Gonzales et al*.,* 2009). There was also great emphasis in documenting the safety of *Bt* corn, with a well-established biosafety system. The commercial use of *Bt* corn has continued to prosper after the Philippines' Department of Agriculture (DA) approved *Bt* corn for commercial application on December 4, 2002. In 2012, the country ranked 12th among the 18 GM mega-countries with 0.8 million hectares planted with GM (*Bt*, HT/herbicide tolerant and *Bt*HT) corn (James, 2012), and Isabela province became the top producer of yellow corn in 2010, with an annual production of 835,002 metric tons (Philippine BAS, 2011). As stated in the 2012 Manila Bulletin, in the Philippines 600,000 hectares corn areas were cultivated with GM corn (Aguiba, 2012).

One of the important stakeholders in the GM debate are the farmers (Johnson *et al.,* 2007), as they are the primary users, and their favorable views on GM corn have contributed to its rapid adoption. The adoption of new technology by farmers depends on numerous factors. Different studies identified different factors such as: 1) profitability or income (Fender and Umali, 1993; Cary and Wilkinson, 1997; Fernandez-Cornejo, 2001); 2) farmers' risk preferences (Pope and Just, 1991); 3) influence of society, social media utilization, and social conformity (Moser and Barrett, 2002; Bandiera and Rasul, 2006; Prokopy *et al*., 2008); 4) farm size (Fernandez *et al*., 2001), 5) farmers' characteristics, behaviour or attitudes (Conley and Udry, 2001; Howley, 2012) and; 6) environmental awareness and concern (Prokopy *et al*., 2008).

For GM corn technology, adoption of this technology may lead to a higher benefits for farmers than non-GM corn (Popp and Lakner, 2013). For instance, the adoption of a specific GM corn, *Bt* corn, by Spanish farmers was triggered by its higher average yields, low risk of corn borer damage and better quality of the harvest (Gómez-Barbero *et al*., 2008). Likewise, the US farmers' major reason for adopting *Bt* corn was the reduced yield losses. In addition, the econometric analysis by Alexander *et al.* (2003) found that Iowa farmers' adoption of *Bt* corn was significantly influenced by gross farm income, previous acreage allocation, agreement with the statement that farmers will benefit from biotechnology, total corn acreage, and concern regarding European corn borer yield damage. Other attributes also include a communication factor (Dinampo, 2002), the level of informedness or knowledge about GM corn features (Gyau *et al*., 2009) and first-hand experience of farmers after adopting it (Kaup, 2008).

In the Philippines, 70% of the stakeholders interviewed by Aerni (2001) agreed that GM corn can help solve problems on decreased yield and reduced income that can be brought about by Asian corn borer (ACB), *Ostrinia furnacalis* (Guenée), infestation. Specifically, *Bt* corn can efficiently reduce the ACB pest problem and reduce borer damage by 44% (Afidchao *et al*., 2012). Furthermore, earlier studies in the Philippines have provided specific information on farmers' experience (Masipiqueña, 2004), *Bt* corn profitability (Yorobe & Quicoy, 2006), determinants of adoption, socio-economic impacts and challenges faced by farmers (Gonzales *et al*., 2009). Recent studies in the Philippines showed evidences regarding the economic benefits of adopting *Bt* corn (Yorobe & Smale, 2012; Mutuc *et al.,* 2011), willingness of farmers to pay for *Bt* corn seeds (Birol *et al*., 2012) and the incidence of higher yields, lower insecticide use, and reduced seed utilization diminishes progressively with increasing farmer's propensity to adopt *Bt (*Mutuc *et al*., 2013). This current paper contributes to the new knowledge by making comparative analysis on the small-scale farmers' standpoints before GM corn adoption and changes in standpoints after having experienced adopting GM corn.

This study aimed to assess the present experience and standpoints on GM corn based on interviews with 188 farmers by studying (1) the farmers' background and agricultural practices; (2) the reasons for adoption by GM farmers and non-adoption by non-GM farmers; (3) barriers to GM corn adoption; and (4) the perceived shifts in standpoint after GM corn adoption. The study is descriptive and is focused on the comparison between farmer types, i.e., the differences between non-GM adopters, *Bt*, *Bt*HT and HT farmers in their experiences, their standpoints and their perceived shift in standpoints on GM-corn.

Methods

Description of study areas

The study was conducted in the northern part of the Philippines. The country consist of 9.6 million hectares (32%) devoted for agricultural production. The country's agricultural land area are categorized to arable (51%) and permanent (44%) croplands. Sixty-percent (60%) of the ~1.8 million corn farmers in the country cultivated yellow corn. Most of these farmers are semi-subsistence, having a farm of size less than 4 hectares, rain fed and mostly situated in marginal places. The country comprised of sixteen regions in which the Cagayan Valley region ranks first in terms of corn production attributed to the vast corn production in Isabela province. Isabela, the study site, is the second largest province in the Philippines and agriculture is the main economic activity. The province is one of the major corn granaries in the country. In the province, the highly suitable areas for corn production cover 38% or 405,270 ha (Figure 1) of the total land area. All farmlands of the surveyed municipalities are non-irrigated, mainly rainfed and located mostly near the Cagayan River. All the municipalities surveyed have been major corn areas for more than 50 years. White corn was the most cultivated variety up to the mid-1980s, when yellow corn became economically viable. The economic viability, availability of technology and credit of yellow corn makes it the most commonly cultivated corn type now. Almost all farmers we interviewed (81.9%) used yellow corn when they started corn production due to the rapid increase in demand for animal feed. Hybrid yellow corn have been proliferated in the market and became widely adopted in 1990s to late 2000. In recent years, due to corn borer pests, GM corn varieties became the best option to counter corn borer pestation and became the most widely cultivated corn variety in the area. Monocropping is the basic practice in some of the surveyed municipalities such as Tumauini and Ilagan, while multiple cropping with tobacco, legumes or vegetables is common practice in other municipalities such as Cabagan, Cordon, San Pablo and Sta. Maria.

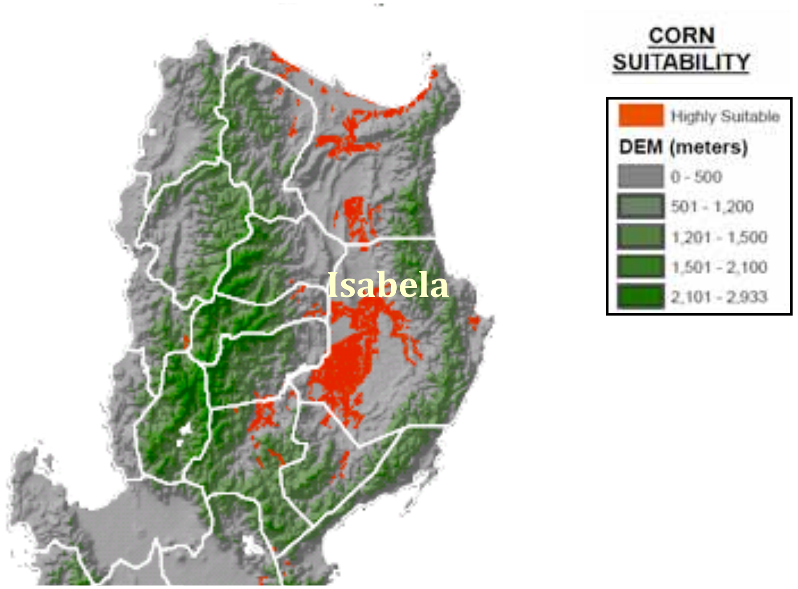

Figure 1. Location of the study area

Corn cultivation by respondents

Filipino farmers cultivate GM corn varieties (*Bt*/*Bacillus thuringiensis*, HT/herbicide tolerant and *Bt*HT) in order to address problems caused by Asian corn borer (ACB), *Ostrinia furnacalis* Guenée, and weed pests. *Bt* corn is modified for ACB suppression and elimination (Roh *et al.,* 2007), while HT corn is glyphosate tolerant (Padgette *et al.,* 1995), a broad spectrum herbicide. Stacked trait *Bt*HT helps farmers protect their crops both from ACB as well as making their crops tolerant to four times the concentration of glyphosate required to kill weeds. The iso-hybrid non-GM corn has the same characteristics as the GM corn, but does not have genes that protect the plants from corn borers and herbicides.

Survey method

Face-to-face interviews were conducted in Isabela province in 57 villages in 11 municipalities (Figure 1 and Table 1). These villages and municipalities were chosen for their vast production of yellow corn. According to interviewed farmers, they keep on changing corn varieties every cropping season depending on the availability of the commercial corn seeds and capital. Therefore, no secondary data are available of the population of farmers planting specific GM corn varieties. Hence, the study employed a purposive sampling technique (Tongco, 2007). This sampling technique was used to serve a very specific purpose, i.e., to select farmer-respondents that can be regarded as key informants who could provide detailed information regarding their farming experiences and standpoints before and after adopting GM corn. Additional criteria were considered in the selection of the farmer-respondents as follow: a) farmers who cultivated the corn types of interest; b) farmers who were available in the area during the survey; c) farmers who expressed willingness to provide first-hand information. During the data gathering not all the visited municipal villages were planting the four corn types of interest. For example *Bt* corn was mostly planted in the municipalities of Jones and Echague and has diminishing adoption in other municipalities. Hence, Table 1 shows unequal numbers of corn types' farmer respondents per municipality. All farmers were interviewed only once. In total, 188 respondents were individually interviewed between September and December 2010, of whom 79, 24, 46, and 18 were non-GM, *Bt*, *Bt*HT and HT farmers, respectively. The other 21 respondents were categorized as mixed farmers or farmers who planted more than one corn type during the survey period.

The interview utilized a self-constructed questionnaire which covered the respondents' demographic profile, general farming practices, knowledge, standpoints and experiences on GM corn adoption. Brainstorming was accomplished during the formulation of the research questions to specify relevant and appropriate questions which could directly provide answers to the objectives of this study. Some questions used by Useche *et al.* (2009) were adopted for the questions intended for HT corn adopters. Specifically, under one major question made, research statements were listed for respondents to easily choose their answers by putting checks on the box of their choice. If they cannot find their answer on the provided list, there is a space below the list where they can specify their answer. In addition, beside each research statement there is a column where farmers were asked to indicate their choices on five-point Likert scales (i.e. "highly agree" (5), "agree" (4), "moderately agree" (3), "disagree" (2) and, "highly disagree" (1). Some questions, relating to farming and the pest history of the corn fields, used other options, ranging from "frequently" (5) to "never" (1). This strategy was done to help farmers respond quickly. The research questionnaire was translated into local dialects considering that most of our potential respondents are native speakers of dialects. Likewise the questionnaire was pretested to five farmers in the Cabagan municipality. Some questions which was hardly understood by the respondents were eliminated in the final constructed questionnaire. For each farmer interviewed to complete the questionnaire, we needed to return to them twice. Validation of statements/questions was not accomplished due to financial and time constraints.

Data Analyses

The farmers' responses were summarized using mean and standard deviation (SD). The data normality was checked using the Shapiro test and because most data were found to be non-normally distributed, a non-parametric, Kruskal-Wallis analysis was performed to test the difference between non-GM, *Bt*, HT and *Bt*HT farmers Perceived shifts in the standpoints of the GM farmers were assessed using the Wilcoxon test to compare their stated standpoints "before" and "after" adopting GM corn. Analyses with significant values ($p<0.05$) are presented in the results section, unless otherwise specified. All analyses were done using the R-Stat version 2.13.1.

Results

Farming background and agricultural practices

Characteristics of farmer-respondents

A considerable percentage (42%) of the 188 respondents had not adopted GM corn, while 47% had adopted GM, viz. HT corn (10%), *Bt*HT corn (24%) or *Bt* corn (13%). The other 11% respondents were categorized as mixed farmers. Tables 1 and 2 show the number of farmers' respondents per municipalities interviewed and their socio-demographic profiles, respectively. All respondents reported that they had been introduced to new technology and/or farming innovations by attending seminars related to seed variety selection, planting technique, fertilizer application, and technological innovations in harvesting and post-harvest operations.

Information about the cornfields

Soil analysis, fertilizers, farm size currently used to grow different corn varieties and pest incidence were recorded (Table 2.2). Fertilizer application differed among respondents, with mixed farmers differing from *Bt*HT and HT farmers. In terms of farm size, there was a difference between mixed farmers and farmers cultivating other corn types, in that mixed farmers had a larger farm, with a mean farm size of 3 ha.

Farmers consistently reported having encountered pest problems (Table 2.2d). Pests commonly observed in the fields by the farmers included corn borers, earworms, armyworms, and leafhoppers. The respondents differed with regard to ACB infestations and the level of concern about damage (Table 2). As regards the level of concern, differences were observed between mixed and non-GM farmers. Non-GM farmers were concerned about the damage that ACB can do to their fields, whilst mixed farmers were not. The perceived severity of ACB infestation differed among respondents. Non-GM, *Bt*HT and HT farmers reported negligible damage from ACB (Table 2.2e). Another problem encountered by farmers was weeds. The overall analysis showed that the different types of farmers differed in the reported occurrence of weeds. (Table 2.2f).

ACB pest was controlled by using pesticides, resistant varieties and treated seeds (Table 2.2g.1). Likewise, weed was controlled by farmers through mechanical cultivation, rotary hoeing, use of herbicide-tolerant seeds, and herbicide application. Mixed farmers differed from non-GM and HT farmers in the use of pesticides to control ACB and weeds. Likewise, they noted different effects of chemicals on pests and percentages of pests destroyed (Table 2.2h). Respondents differed on the weeding methods applied: non-GM and *Bt*HT farmers differed from HT farmers. Except for HT farmers, all other respondents used rotary hoeing to eliminate weeds. Mixed farmers differed from *Bt*HT farmers regarding the use of herbicide-tolerant varieties (Table 2.2g.2).

Table 1. Number of farmer respondents interviewed cultivating GM and non-GM corn types per municipality.

Municipality	Number of Respondents/Corn Type					Subtotal	Percentage
	Bt	*Bt*HT	HT	non-GM	Mixed		
Cabagan	0	3	1	7	2	13	6.91
Cauayan	0	3	2	1	0	6	3.19
Delfin Albano	0	1	1	0	0	2	1.06
Echague	6	10	1	19	11	47	25.00
Ilagan	2	9	0	6	0	17	9.04
Jones	13	2	0	4	0	19	10.11
San Guillermo	0	8	0	15	3	26	13.83
San Pablo	0	1	2	5	1	9	4.79
Sta. Maria	2	5	7	9	4	27	14.36
Sto. Tomas	1	2	1	8	0	12	6.38
Tumauini	0	2	3	5	0	10	5.32
Total	24	46	18	79	21	188	100.00

Table 2. Respondents' characteristics and corn field information. (Mean ± SD; chi-squared values obtained from Kruskal-Wallis non-parametric analyses, using type of corn cultivated by respondents as the fixed factor). T = Kruskal-Wallis Chi-squared Test: * = P < 0.05, ** = P < 0.01, *** = P < 0.001, and ns = not significant. SD = standard deviation.

	Non-GM (n=79)			***Bt* (n=24)**			***Bt*HT (n=46)**			**HT (n=18)**			**Mixed (n=21)**			**Kruskal-Wallis chi-squared (df=4)**	**T**
1. Respondents' Demographic Profile	Mean		sd	Mean		sd	Mean		sd	Mean		sd	Mean		sd		
Age	46.70	±	9.90	43.20	±	8.47	45.20	±	11.26	48.30	±	13.74	47.20	±	10.04	5.115	ns
Household Size	6.10	±	2.65	5.30	±	1.69	5.60	±	2.38	5.70	±	2.37	5.30	±	2.41	4.326	ns
Highest educational attainment[1]	4.30	±	1.59	4.40	±	1.84	4.20	±	2.06	4.40	±	2.06	4.80	±	1.48	2.373	ns
Current farm tenure[2]	1.50	±	0.73	1.40	±	0.58	1.40	±	0.69	1.30	±	0.58	1.40	±	0.59	3.979	ns
Trainings/seminars attended e.g. Seed selection[3]	4.68	±	0.53	4.94	±	0.25	4.71	±	0.60	4.50	±	0.52	4.78	±	0.43	5.886	ns
2. Area, Management and Pest incidence of cornfields																	
a. Farm/soil analyzed before every cropping[5]	2.45	±	1.35	2.68	±	1.13	2.43	±	1.33	2.28	±	1.23	3.10	±	1.41	11.121	*
b. Fertilizers (organic and inorganic) applied[4]	0.92	±	0.27	0.82	±	0.40	0.74	±	0.44	0.67	±	0.49	1.00	±	0.50	9.340	*
c. Area of the farm devoted to the new variety?[6]	1.59	±	1.70	1.92	±	0.97	2.02	±	1.44	1.67	±	1.40	3.02	±	1.91	9.337	*
d. Pest incidence (Insects[4])	4.80	±	0.41	4.78	±	0.44	4.50	±	0.51	4.67	±	0.52	4.75	±	0.50	3.874	ns
e. Asian corn borer incidence																	
Asiatic corn borer infestation in the field[4]	0.82	±	0.39	0.67	±	0.48	0.84	±	0.37	0.94	±	0.24	0.42	±	0.51	13.105	**
Concern about ACB damage[7]	3.15	±	0.82	2.83	±	1.34	2.96	±	0.90	3.17	±	0.71	2.40	±	1.39	10.106	*
Severity of ACB problem[8]	3.09	±	1.10	2.26	±	1.05	3.16	±	1.26	3.72	±	0.90	2.20	±	1.32	31.066	***
f. Weeds incidence: Presence of weeds problem[4]	0.84	±	0.37	0.92	±	0.28	0.64	±	0.48	0.61	±	0.50	0.60	±	0.50	7.526	*
g. Control measures: *g.1 On ACB:* Pesticide application[3]	4.55	±	0.71	4.38	±	0.65	4.37	±	0.74	4.23	±	0.83	4.54	±	0.66	4.439	ns
g.2 On Weeds: Mechanical cultivation[3]	4.86	±	0.35	4.80	±	0.41	4.93	±	0.27	4.00	±	0.00	4.43	±	1.09	20.167	***
Rotary hoeing[3]	4.86	±	0.35	4.88	±	0.34	4.73	±	0.46	4.29	±	0.49	4.56	±	0.53	18.084	***
Herbicides[3]	4.91	±	0.29	4.81	±	0.40	4.74	±	0.45	4.67	±	0.58	4.50	±	0.55	4.911	ns
Planted herbicide resistant seed[3]	5.00	±	0.00	4.50	±	0.71	5.06	±	0.24	5.00	±	0.00	4.40	±	0.89	12.293	**
h. Rate of pests destroyed after applying pesticides[5]	2.56	±	1.34	3.14	±	1.24	2.33	±	1.30	1.56	±	0.78	3.16	±	1.17	17.098	***

[1] Scale: 1-No schooling, 2-Elementary level, 3-Elementary graduate, 4- High School level, 5-High School graduate, 6-Vocational course, 7-College level and 8- College graduate; [2] Farmers´ tenure scale: 1-Owner, 2-Tenant and 3- Lessee; [3] Scale: 5- Highly agree (HA), 4-Moderately agree (MA), 3-Agree (A), -2-Disagree (D), -1-Highly disagree (HD); [4] Scale: Yes-1, No-0 ; [5] Scale: 5-Frequently, 4-Once, 3-Sometimes, 2-No, 1-Never; [6] Hectares; [7] Scale: 5-Highly concern, 4-moderately concern, 3-concern, 2-unconcern, 1-Highly unconcern; [8] Scale: 5-Highly severe, 4-severe, 3-moderately severe, 2-negligible, 1-Highly negligible]

Reasons to adopt GM corn

Respondents were asked whether they changed corn varieties in the past to find a variety that reduces agricultural inputs, increases yield, and produces more income. Figure 2 summarizes the percentage of respondents who cultivated specific corn types during the past 2008, 2009 and 2010 planting periods. Non-GM corn adopters mostly changed to different non-GM corn lines. Some GM corn adopters have switched to GM corn only recently. This was reflected by the decrease in non-GM corn adopters, from 67% to 42%, compared to notable increases of 4%, 14%, and 7% for GM *Bt*, *Bt*HT, and HT adopters, respectively, between the years 2008–2009 and the 2010 planting period (Figure 2).

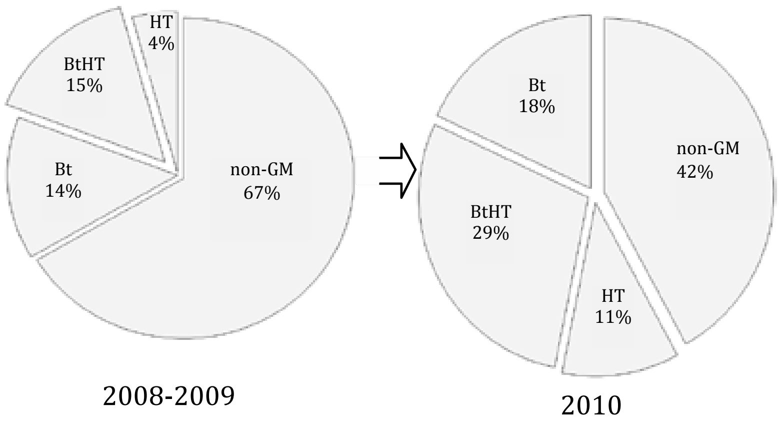

Figure 2. Percentage of corn type respondents' showing the relative number of farmers who said that they had switched from non-GM to GM corn hybrids. Data were based on the responses of interviewed farmers about the corn types that they have planted during the 2008, 2009 and 2010 planting periods.

Sources of information, knowledge, and pest management with GM corn

Except for the use of other farmers as a source of information, which differed between respondents cultivating different types of corn, similar responses about the first four of the sources of information on GM corn listed in Table 3a were obtained between types of farmers. As regards the source of GM corn seeds, respondents mostly obtained their seeds from commercial stores (*Bt*, *Bt*HT, and HT) and middlemen (*Bt*HT) (Table 3b). The reported use of company salesmen/agents as a source of seeds and farmers' awareness of GM corn resistance to corn borers/weeds showed that *Bt*HT farmers differed in their responses from *Bt* and HT farmers (Table 3c).

Respondents still applied pesticides (i.e. insecticides and herbicides) even with the use of GM corn seeds (Table 3d). The quantities of insecticides used per hectare differed between GM corn respondents, with a lower mean value of 1.32 L for *Bt* farmers and higher mean values of 1.96 L and 2.0 L for *Bt*HT and HT farmers, respectively (Table 3d2).

Table 3. Background information on GM corn farmers. (Mean ± SD; chi-squared values obtained from Kruskal-Wallis non-parametric analyses, using type of corn cultivated by respondents as the fixed factor). T = Kruskal-Wallis Chi-squared Test: (*) = P < 0.10, * = P < 0.05, ** = P < 0.01, *** = P < 0.001, and ns = not significant. SD = standard deviation.

GM farmers background information	Bt (n=34)			BtHT (n=56)			HT corn (n=19)			Kruskal-Wallis chi-squared (df=2)	T
	Mean		sd	Mean		sd	Mean		sd		
a. Source of information^1											
Seed producers	1.59	+	1.44	4.62	+	0.62	2.26	+	1.56	43.560	***
Seed company personnel/technician	1.68	+	1.49	4.31	+	0.79	1.37	+	1.12	33.353	***
Government extension worker	1.21	+	0.84	3.82	+	1.08	1.00	+	0.00	43.341	***
Commercial outlets/stores.	3.59	+	1.84	4.57	+	0.68	3.42	+	1.74	5.416	*
Other farmers	2.50	+	1.86	4.52	+	0.60	1.53	+	1.26	26.322	***
b. Source/s of *Bt* seeds. (Company salesmen/agent^1)	5.00	+	0.00	2.86	+	1.22	4.50	+	0.58	8.122	*
c. Extent of knowledge on GM corn											
Aware that *Bt* transgenic corn is resistant to corn borer?^{2}	0.94	+	0.25	0.79	+	0.41	1.00	+	0.34	7.357	*
d. Pest management/pest control practice											
1.Applied insecticides even with GM corn	1.82	+	0.39	1.60	+	0.49	1.84	+	0.38	6.659	*
2. Insecticide application per hectare ^{3}	1.32	+	0.47	1.96	+	1.14	2.00	+	0.61	11.513	**
3. Chemical used: Insecticide^3	4.75	+	1.00	4.55	+	0.76	4.63	+	0.50	4.638	(*)
Herbicides^3	5.00	+	0.00	4.20	+	0.71	4.52	+	0.85	3.093	*

^{1}Scale: 5- Highly agree (HA), 4-Moderately agree (MA), 3-Agree (A), 2-Disagree (D), 1-Highly disagree (HD); ^{2}Yes-1; No-0; ^{3}Liters.

GM corn adoption

Economic benefit in terms of increased yield derived from GM corn was the most commonly reported reason why farmers decided to adopt GM corn. As regards the anticipation of corn borer problems, differences exist between *Bt* and HT farmers. *Bt*HT and HT farmers both differed from *Bt* respondents regarding the following reasons: being convinced by the explanation about resistance to corn borer, GM corn fitting well with existing corn production practices, reduced overall corn production costs, recommendations from the university or extension agents, recommendations from seed dealers/consultants, recommendations from neighbors, having followed the advice of friends, reducing the insecticide exposure of farmers and reducing insecticides in the environment. The different types of farmers differed with regard to the arguments of reduced labor requirement and of wanting to try it out of curiosity (Table 4).

Non-adoption of GM corn

Seventy-nine non-GM respondents were asked for their reasons for not planting GM corn hybrids (Table 5). Ninety-five percent of the non-GM farmers agreed with the statement that the market price of GM corn seeds is too high compared to that of iso-hybrid non-GM corn. Secondly, 54% of the respondents did not anticipate a probable occurrence of corn borer. Thirdly, the seeds cannot be replanted and farmers have to purchase new seeds every cropping season, a statement with which 53% respondents highly agreed. Fourthly, the statement that planting GM corn requires higher investments was agreed with by 43% of the respondents. Lastly, the statement that GM corn seeds are sensitive to drought was agreed with by 42% of the respondents. Respondents disagreed on: (1) not anticipating having weed problems and (2) the statement that continued use of HT and *Bt* corn leads to resistance in ACB and weeds. Finally, 74% of the non-GM respondents disagreed with the statement "*No plan to adopt other new corn varieties*".

Table 4. Farmers' reasons for adopting GM corn. (Mean ± SD; chi-squared values obtained from Kruskal-Wallis non-parametric analyses, using type of corn cultivated by respondents as the fixed factor). T = Kruskal-Wallis Chi-squared Test: * = P < 0.05, ** = P < 0.01, *** = P < 0.001, and ns = not significant. SD = standard deviation.

Reasons for GM corn Adoption[1]	*Bt* (n=34)			*Bt*HT (n=56)			HT corn (n=19)			Kruskal-Wallis chi-squared (df=2)	T
	Mean		sd			sd	Mean		sd		
Anticipated having corn borer problems	3.74^{a}	+	1.31	3.11^{ab}	+	1.69	2.68^{b}	+	1.86	3.892	ns
Convinced of explanation on resistance to corn borer	3.50^{b}	+	1.48	2.29^{a}	+	1.67	1.47^{a}	+	1.02	20.024	***
Fits well with existing corn production practices	3.76^{b}	+	1.37	2.87^{a}	+	1.72	2.16^{a}	+	1.61	10.871	**
To reduce overall corn production costs	3.35^{b}	+	1.25	2.56^{a}	+	1.62	1.84^{a}	+	1.50	10.557	**
To reduce the labor required to grow corn	3.91^{a}	+	1.54	2.45^{b}	+	1.65	2.73^{c}	+	1.76	27.591	***
Wanted to try it	3.74^{a}	+	1.48	2.23^{b}	+	1.62	1.26^{c}	+	0.81	29.957	***
Recommendation from university or extension agents	3.29^{b}	+	1.49	1.95^{a}	+	1.42	1.21^{a}	+	0.71	26.609	***
Recommendation from seed dealers/consultants	4.03^{b}	+	1.40	2.91^{a}	+	1.74	2.84^{a}	+	1.83	10.167	**
Recommendation from neighbors	3.42^{b}	+	1.52	2.07^{a}	+	1.55	1.32^{a}	+	0.82	23.490	***
Followed advice of friends	3.21^{b}	+	1.68	1.87^{a}	+	1.36	1.32^{a}	+	0.82	22.292	***
Less insecticide exposure to farmers	2.91^{b}	+	1.69	1.96^{a}	+	1.47	1.37^{a}	+	0.83	13.126	**
Less insecticide in the environment	2.47^{b}	+	1.48	1.71^{a}	+	1.33	1.26^{a}	+	0.73	11.328	**

[1]Scale: 5- Highly agree (HA), 4-Moderately agree (MA), 3-Agree (A), 2-Disagree (D), 1-Highly disagree (HD)

Table 5. Farmers' reasons for not adopting GM corn.

	Reasons for not adopting GM corn[1]	n	Mean		sd
a. On Production:	Price of GM seed is too high	76	4.63	+	0.65
	Seeds cannot be recycled for the next cropping season	63	3.35	+	1.65
	Did not anticipate having corn borer problem	65	3.11	+	1.60
	Did not anticipate having weeds problem	61	2.36	+	1.24
	GM seeds might require higher insecticide inputs	58	2.64	+	1.50
	Require more intensive agricultural regimes	54	2.54	+	1.56
	May not be effective against ACB/weeds.	57	2.14	+	1.19
	Require higher cost of investment.	56	3.18	+	1.75
	GM corns are sensitive to drought, typhoons and/or floods.	57	2.74	+	1.60
b. On Post Production:	Concerned about getting a lower price for GM corn.	54	2.89	+	1.69
	Concerned about having trouble selling GM corn produce.	52	2.56	+	1.49
	Concerned about having to segregate GM from non-GM corn.	53	2.66	+	1.62
	Not satisfied with GM corn yields.	54	2.78	+	1.58
	Satisfied with the current corn variety being use.	53	2.89	+	1.76
	No plan to adopt other new corn varieties.	50	2.26	+	1.51

[1]Scale: 5- Highly agree (HA), 4-Moderately agree (MA), 3-Agree (A), 2-Disagree (D), 1-Highly disagree (HD)

Barriers and Satisfaction with GM corn

Bt and HT farmers differed in their responses regarding observed yield differences between non-GM corn and GM corn (Table 6a). Respondents cultivating GM corn consistently reported satisfaction with it (Table 6b). The overall analysis of the reasons for being satisfied with GM corn, as listed in Table 6c, showed differences between farmers cultivating different types of corn. *Bt* and *Bt*HT farmers differed from each other, but HT farmers did not differ from *Bt* and *Bt*HT farmers regarding the reasons for being satisfied, viz. that GM corn is effective in controlling corn borers/weeds, results in less infestation by other pests/diseases and yields good grain quality. *Bt* and *Bt*HT farmers differed from HT farmers in their response to the question about increased yield as the reason for satisfaction. *Bt* and HT farmers differed in their response to the question about large savings on pest control chemicals and on labor/time as reasons for satisfaction, but *Bt*HT farmers did not differ from *Bt* and HT farmers in this respect. *Bt* farmers differed from *Bt*HT and HT farmers as regards reasons for satisfaction with GM corn, like corn with quality kernel (i.e. big, clean and no marks of being infested by pests) commanding higher selling price, allowing longer storage than other corn and yielding higher profits. All respondents were willing to plant GM corn again (Table 6d) and would allocate parcels of land ranging from 1.8 to 2.1 hectares (Table 6e) for the following cropping season. Finally, despite the satisfaction reported by GM respondents, they also encountered barriers in the use of GM corn (Table 6f). The most commonly mentioned barrier was the high cost of seeds (Table 6g).

Shift in standpoints after GM corn adoption

On production

Respondents were asked about their standpoints of corn production before and after using GM corn hybrids that is based on their actual experience (Table 7a). After GM corn adoption, *Bt* respondents indicated that they had changed their standpoints from moderate agreement to slight agreement with the following statements: (1) GM corn is the best option to reduce pests; (2) GM corn reduces the possible emergence of other pests, and; (3) GM corn leads to large savings in labor/time. *Bt*HT farmers said that they had changed their standpoint from moderate agreement to high agreement with the statement that GM corn is the best option to reduce pests, but had shifted to disagreement with the statement that GM corn is easy to use and requires fewer agricultural interventions.

On post-harvest aspects and marketing

On post-harvest aspects of GM corn, we evaluated respondents' standpoints on the potential market value of GM corn (Table 7b), asking them about storage life, grain size & quality and market prize. After adoption, *Bt*HT respondents said that they had shifted their standpoints from slightly agreeing to highly disagreeing with the statement that GM corn grains fetch higher prices. The standpoints of HT farmers about the statement that GM corn grains have a longer storage life had shifted to highly disagreeing after adoption. Seventy-one percent of *Bt*HT farmers reported a significant shift in their standpoint regarding the selling price of *Bt*HT corn.

On the overall impact of GM corn

The survey also evaluated the perceived change in standpoint of respondents towards the overall impact on their lives of using GM corn (Table 7c), by asking questions about the claims that GM corn could improve farmers' lives and is worth investing in. Sixty-eight percent of the GM corn respondents did not agree that their economic status had improved after they had started using *Bt* corn. A similar percentage of respondents did not believe that *Bt* corn is worth investing in. A significant number of respondents said that they had shifted their standpoint and now perceived a negative effect of *Bt* corn on farmers' economic status (Table 7c). A similar trend was observed for *Bt*HT (Table 7c), where of 21% and 29% of the respondents said that they changed their standpoint toward disagreement in regard to the statements that *Bt*HT is worth investing in and could improve the lives of farmers, respectively.

Table 6. Respondents' reported satisfaction with and barriers to the use of GM corn. (Mean ± SD; chi-squared values obtained from Kruskal-Wallis non-parametric analyses, using type of corn cultivated by respondents as the fixed factor T = Kruskal-Wallis Chi-squared Test: * = P < 0.05, ** = P < 0.01, *** = P < 0.001, and ns = not significant. SD = standard deviation.

Satisfaction and Hurdles with GM corn	***Bt* (n=34)**		***Bt*HT (n=56)**		**HT corn (n=19)**		**Kruskal-Wallis chi-squared (df=2)**	**T**
	Mean	**sd**	**Mean**	**sd**	**Mean**	**sd**		
a. Did you observe yield differences between non-GM corn and GM corn?¹	0.84^{a}	+ 0.37	0.67^{ab}	+ 0.47	0.47^{b}	+ 0.51	7.303	*
b. Are you satisfied with the performance of GM corn?¹	0.97	+ 0.17	0.96	+ 0.19	1.00	+ 0.00	0.676	ns
c. Satisfaction: Reasons²								
Effective in controlling corn borers/weeds	4.35^{a}	+ 1.01	3.59^{b}	+ 1.58	3.32^{ab}	+ 1.53	8.965	*
Lesser infestation of other pests/diseases	4.03^{a}	+ 1.40	3.18^{b}	+ 1.66	3.21^{ab}	+ 1.48	8.766	*
Good grain quality of the produce	4.09^{a}	+ 1.29	2.94^{b}	+ 1.68	3.44^{ab}	+ 1.42	11.312	*
Increase yield	4.15^{a}	+ 1.40	3.71^{a}	+ 1.37	1.89^{b}	+ 1.37	26.762	***
Big savings on pest control chemicals	3.47^{a}	+ 1.48	2.91^{ab}	+ 1.66	2.11^{b}	+ 1.52	8.193	*
Big savings on labor/time	3.59^{a}	+ 1.48	3.05^{ab}	+ 1.73	2.37^{b}	+ 1.86	4.278	ns
Corn ear/grain commands very high price	3.79^{b}	+ 1.59	2.27^{a}	+ 1.57	1.42^{a}	+ 1.07	28.584	***
Could be stored longer compared to other corn	3.48^{b}	+ 1.44	2.29^{a}	+ 1.51	1.42^{a}	+ 1.02	23.504	***
Higher profit	3.59^{b}	+ 1.48	2.34^{a}	+ 1.58	1.53^{a}	+ 1.26	21.722	***
d. Are you planning to plant GM corn again this next cropping season?¹	0.97	+ 0.17	0.98	+ 0.13	0.95	+ 0.23	0.642	ns
e. How many hectares would you plant GM corn?³	1.98	+ 0.79	2.08	+ 1.19	1.83	+ 1.00	0.890	ns
f. Did you encounter hurdles/impasses in using GM corn?¹	0.52	+ 0.51	0.64	+ 0.48	0.67	0.48	1.722	ns
g. Hurdle: Reason²								
Expensive cost of seeds	4.93^{a}	+ 0.26	3.76^{b}	+ 1.57	2.95^{b}	+ 1.78	15.787	***

¹Scale: Yes-1; No-0; ²Scale: 5- HA(highly agree), 4-MA (moderately agree), 3-A (agree), 2-D (disagree), 1-HD (highly disagree); ³Hectares.

Table 7. Comparison of standpoints before and after switch to GM corn to assess changes in respondents' position before and after adopting GM (*Bt*, *Bt*HT and HT) corn. The F- and p-values show the variations and differences on farmers' standpoints at pre- and post-adoption. Paired-samples t-test, two-tailed. * = P<0.05, ** = P < 0.01, and *** = P < 0.001. NS = not significant. SD = standard deviation.

Standpoints on GM corn before and after adoption¹	***Bt* corn (n=34)**						***Bt*HT corn (n=56)**						**HT corn (n= 19)**					
	Before		**After**		V	**P-value**	**Before**		**After**		V	**P-value**	**Before**		**After**		V	**P-value**
	Mean	sd	Mean	sd			Mean	sd	Mean	sd			Mean	sd	Mean	sd		
a. On Production																		
Best option to reduce pests	3.39	+ 1.77	2.67	+ 1.80	75.60	*	4.02	+ 1.45	3.70	+ 1.65	102.50	(*)	3.47	+ 1.78	3.53	+ 1.84	6.50	ns
Reduce other pests and diseases	4.09	+ 1.26	2.94	+ 1.77	176.50	**	3.30	+ 1.66	3.00	+ 1.70	257.00	ns	3.37	+ 1.71	3.53	+ 1.84	48.00	*
Big savings on labor/time	4.09	+ 1.53	2.82	+ 1.86	142.00	**	3.22	+ 1.66	3.16	+ 1.74	145.50	ns	3.11	+ 1.88	2.89	+ 1.73	15.00	ns
Require less agricultural regimes							2.70	+ 1.69	2.02	+ 1.60	102.50	ns	1.79	+ 1.48	1.63	+ 1.50	10.00	(*)
b. On Post-Production																		
Grains could be stored longer	2.06	+ 1.44	2.09	+ 1.63	17.50	ns	2.00	+ 1.44	1.73	+ 1.44	186.00	*	1.68	+ 1.06	1.21	+ 0.63	9.00	ns
Grains have higher selling prize							2.60	+ 1.74	1.63	+ 1.24	225.00	***	1.68	+ 1.25	1.42	+ 1.07	8.00	ns
c. On overall impact of GM corn																		
Worth to invest	3.55	+ 1.56	2.09	+ 1.63	166.50	***	2.37	+ 1.57	1.69	+ 1.32	162.00	**	1.37	+ 0.90	1.21	+ 0.63	4.50	ns
Could uplift farmers' life.	3.70	+ 1.51	2.09	+ 1.51	171.00	***	2.21	+ 1.42	1.52	+ 1.11	159.00	***	1.37	+ 0.90	1.16	+ 0.50	7.50	ns

¹Scale: Yes-1; No-0; ²Scale: 5- HA(highly agree), 4-MA (moderately agree), 3-A (agree), 2-D (disagree), 1-HD (highly disagree);

Discussion

Farming background and agricultural practices

In this study, there were no differences in respondents' characteristics (Table 2.1) such as gender, age, formal education and farm size between farmers cultivating different types of corn (non-GM corn; HT, *Bt*HT and *Bt* GM corn; and mixed farmers). This indicates that none of the respondents' characteristics influenced the level of GM corn adoption. This finding is in line with those of previous studies (Gyau *et al.,* 2009; Lehrman and Johnson, 2008), which also found that age, gender, education and farm size did not influence the level of GM corn adoption. Similar findings by Gómez-Barbero *et al*. (2008) in which farm size found to have no significant statistical relationship to *Bt* corn adoption among the 402 farm surveyed in Spain. In contrast, the findings of Fernandez-Cornejo and McBride (2002) provide data showing that GM crops (specifically HT soybean and HT corn) adoption in the USA was influenced by farm size.

As noted by Lynch *et al.* (1999), pests such as corn earworm (*Helicoverpa zeae*), common stalk borer (*Papiapema nebris*) and armyworm (*Pseudaletia unipunctata*) were moderated and damage was partially controlled with *Bt* corn. In our study, however, farmers reported that the prevalence of armyworm and other insect pests was comparable to that in non-GM corn. In the case of HT corn, adopters reported no reduction of pests, which is acceptable because HT corn is intended only for weed control and does not possess genes to produce toxins killing pests like ACB.

Reasons to adopt GM corn

Farmers tend to change their corn varieties from time to time for economic reasons. Also, relevant knowledge about scientific evidence played a crucial role in the decision to adopt new technologies, (*Sturgis et al*., 2005) and sufficient knowledge could lead to rational and objective opinions. In Germany, poor adoption of GM corn was linked to low levels of knowledge among non-GM adopters (Gyau *et al.,* 2009). In the Philippines, participation by farmers in conferences or training courses, and information dissemination by the government's Department of Agriculture (DA) and seed technicians had stimulating effects and contributed greatly to the rapid adoption of GM corn (Gonzales *et al*., 2009). This is in agreement with our findings, which showed that significant numbers of GM farmers among our respondents had thorough knowledge about GM corn features (Table 3.c). Well-informed respondents developed trust in the use of GM corn, which correlates with our results in terms of larger farm sizes being allocated to GM corn production. In addition, significantly lower levels of concern about corn borer infestation (Table 2.e) indicate that the adoption of *Bt* and *Bt*HT corn led to develop trust and assurance among farmers that their crops are protected from corn borer attacks. The high levels of knowledge about and trust in GM corn influenced the level of adoption. Consequently, the high level of adoption has resulted in a further rise of GM corn cultivation in Isabela and the Philippines in general.

Sources of information, knowledge, and pest management with GM corn

All GM corn farmers among our respondents acquired their seeds from commercial stores/

outlets. This means that the GM seeds are readily available at every commercial center in corn producing municipalities. This could be an additional factor explaining the high degree of adoption of GM corn in the Philippines. In the survey by Kondoh and Jussaume Jr. (2006), one reason for non-adoption was the lack of availability of GM corn seeds. When this GM corn became readily available, the attitudes and willingness of the non-GM farmers in the US to adopt GM corn changed considerably.

GM corn adoption

The perceived benefits offered by GM corn have induced farmers to switch to GM corn production. The attributes that were found in our study to induce farmers to switch to GM corn cultivation include higher yields, reduced labor, reduced agricultural inputs, problems with pests and curiosity. Most of these boil down to economic viability of GM corn. Our study confirmed that the greatest perceived benefit of GM corn was increased yield. This is similar to the findings by Dilehay *et al.* (2004), Stanger & Lauer (2006) and Qaim & Zilberman (2003). Economic benefit always seems the key criterion for farmers to adopt GM crops (Chong, 2005). A meta-analysis by Areal and Rodriguez-Cerezo (2012) of the economic and agronomic performance of genetically modified (GM) crops (i.e. *Bt* cotton, HT soybean and *Bt* corn) in both developed and developing countries in six regions worldwide showed that GM crops perform better than their conventional counterparts in agronomic and economic terms. In particular, GM corn farmers in Iowa (USA), South Africa and Denmark reported a yield increase when using GM corn (Wilson *et al*., 2005; Gouse *et al*., 2005; Lawson *et al*., 2009). In the Philippines, significant increases in yields, lower insecticide use and reduced seed utilization of GM corn farmers were the most important determinants in increasing the propensity to adopt GM corn (Yorobe and Quicoy, 2006; Mutuc *et al*., 2013).

Non-adoption of GM corn

The high seed cost was the most important reason for most (96%) respondent-farmers to keep using conventional corn. The current prices of non-GM corn seeds range from 2,400-4,000 pesos (US$56-94) for one hectare. By contrast, current prices of GM corn seeds for a 12 kg bag (9 kg GM seed and 3 kg refuge non-GM seed) range from 4,300 to 5,300 pesos (US $ 101-124 at $1:42.5 pesos), and since farmers have to buy two bags of GM corn seeds per hectare, the total cost per hectare ranges from 8,600-10,600 pesos (US$ 202-248). A 10-15% increment on the usual price will be added when seeds are borrowed from the outlets or acquired through a middleman (a person who finances farmers' agricultural expenses at interest rates of 10-15% per growing season). The current prices of GM corn seed mean that poor farmers can hardly afford to buy it. Additional agricultural inputs like fertilizers, pesticides and machineries rental mean that farmers will think twice before adopting this technology, despite perceived benefits.

The willingness of non-GM respondents to try GM corn in the future would mean that they are becoming aware of its purported economic benefits. As mentioned earlier, one major reason for farmers to switch to another variety was to find seeds that address all their major concerns, particularly regarding yield quantity, grain quality, seed cost and pest problems. However, the relative inaccessibility, in terms of high cost of seeds, still hampers the adoption of GM corn. If GM corn became more affordable, hence more accessible to poor farmers, then adoption of GM corn in the Philippines would considerably increase.

Barriers and Satisfaction with GM corn

First-hand experience with GM corn influences farmers' decisions on whether to change their corn variety (Kaup, 2008). Farmers' satisfaction with GM corn (i.e. more benefits than risks) ensures that they develop trust in these varieties and continue to adopt them. Higher profits and reduced labor/time investments were the most important stated benefits and the main cause of satisfaction among respondents cultivating *Bt* corn. This confirms previous findings that increased yields (Stanger & Lauer, 2006; Dillehay *et al*., 2004; Qaim & Zilberman, 2003; Rice, 2003), and hence higher profits, are achieved by adopting *Bt* corn.

Previous study by Rice (2003) identified time and labor savings as among the intangible benefits of GM corn in South Africa. Specifically for *Bt* corn, Kruger *et al*. (2009) and Wilson *et al.* (2005) identified convenience or ease of management as one of the benefits of this technology in the US. In addition, Marra and Piggot (2006) found that despite recent increases in the system costs of the Roundup Ready soybean, there is an inelastic demand response to this technology that is linked to its non-pecuniary benefits. In the present study, however, respondents stated that this benefit was only true for *Bt* and *Bt*HT corn, while respondents cultivating HT corn significantly disagreed and reported that the amount of time/labor spent when using these varieties seemed comparable to that using non-GM corn. One plausible reason noted during the interviews is that some respondents refrained from spraying herbicides in order to limit field expenses, but instead utilized their family members doing manual weeding. Some of the respondents sprayed too early, so weeds still emerged at a later stage. When other insect pests emerged, respondents sprayed with insecticides to minimize the damage to crops. This shows that although farmers are well informed about the features of GM corn (Table 1.1) financial constraints and lack of technical knowledge about proper management of GM corn meant that GM corn benefits were not always achieved.

Shift in standpoints after GM corn adoption

Results of our examination of what the respondents perceive to be changes in their agricultural practice and standpoints show that all farmers keep on using pesticides, although *Bt* farmers use lower volumes of insecticides. This is quite alarming because of the well-known consequences for human health and the environment of large-scale use of pesticides. These results contradict those of past studies (Brookes and Barfoot 2006; Kleter et al. 2007; Wilson et al. 2005; Rice 2003). Brookes and Barfoot (2005) showed that since 1996 to 2004 GM corn technology enables pesticide use to be reduced globally by 172 million kg and reduces the environmental footprint linked to pesticide use by 14%. A global reduction of about 224 million kg of pesticide active ingredients used from 1996 to 2005 was realized, with a corresponding 15% reduction in hazards to the environment (Brookes and Barfoot 2006). In the US, increased adoption of GM crops was associated with reduced pesticide use (Kleter et al. 2007). Savings of $25-$75/acre relative to no insecticide use have been achieved with *Bt* corn (Rice 2003). In addition, South African and US *Bt* farmers benefited from less exposure to insecticides as a result of reduced or zero use of chemicals with GM corn (Wilson et al. 2005).

Overall, the farmers perceive a negative shift in their standpoints towards GM corn after adoption. In particular, *Bt*HT and HT farmers did perceive less economic advantages of using GM corn than they had expected (Table 7c). Of course, the fact that farmers now say that their standpoints before adopting GM-corn were more positive than they are now does not mean that their standpoints really are changed. However, this perceived shift in standpoint could indicate disappointment in the economic benefits of GM-corn that is worth further investigating. Nevertheless, the farmers kept using the technology, because of the perceived major savings in labor and time investment, or because of the ease of managing weeds (Table 7a). These could be regarded economic benefits too, but obviously not by the respondents. Some farmers reported during the interviews that they depended on the middlemen for their agricultural inputs, especially seeds and fertilizers (Table 2b) and sometimes they could not freely decide which corn type to use. The middlemen are profit-oriented and can largely influence farmers' decisions on the variety to use since they are main sources of major agricultural inputs such as seeds, pesticides and fertilizers.

Conclusion

In conclusion, the farmers' adoption of GM corn can be influenced by their positive standpoints, knowledge about the advance features of GM corn and first-hand successful venture on GM corn cultivation. Likewise, GM corn profitability (i.e. combination of increased yield and lesser insecticide inputs) and easy access to GM corn seeds are the most noted reasons for rapid adoption of GM corn in Isabela province. In contrast, the high price of GM seeds formed a barrier for non-GM farmers to switch to GM corn. Explicitly, *Bt* corn farmers experienced reduced usage of insecticide inputs. On the other hand, experiences of *Bt*HT farmers revealed GM corn to be comparable with non-GM corn in terms of fewer agricultural interventions and market prices of the produce. HT farmers experienced the occurrence of insect pest and shorter storage life of the corn harvest. The *Bt* and *Bt*HT farmers said that they had changed their standpoints negatively concerning whether GM corn technology is worth their investment and could improve their economic status. Nevertheless, they tended to go on using it, for reasons that require further detailed studies. Finally, the Philippine government should look into possibilities to lower the high cost of GM seeds by provision of subsidy.

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7

Conclusions, Recommendations and Future Research

Conclusions

In the context of an earth ecosystem under continuous threat with the attendant rapid loss of biodiversity at all levels, the need for continuous assessment of the potential repercussions of new innovations to our ecosystem becomes necessary. This must be done, not to prevent or hamper the advancement of innovations, but to improve them.

In particular, the claimed pecuniary benefits of GM corn (Chapter 1) reflect its fast adoption worldwide. GM corn technology was shown to have low risk for biodiversity in temperate regions. But, scientifically based evidence in a humid tropical country such as the Philippines is very meager. The country is one of the few identified biodiversity hotspots in the world with a huge segment of its agricultural areas now dominated by GM crops.

The known efficacies of *Bt* and *Bt*HT corn to eradicate corn borers have been supported by numerous field trials and large-scale cultivations worldwide. Nevertheless there are emerging issues relative to the introduction and cultivation of *Bt* corn. One is the development of corn borer resistance to *Bt* toxin. Secondly, the potential emergences of secondary pests (non-ACB) in fields where the primary pest (ACB) is eradicated. With a decade of *Bt* corn cultivation in the country, a reinvestigation of the efficacy of *Bt* corn against ACB is timely and necessary. The study presented in Chapter 2 once again has shown that *Bt* corn is a variety that can help farmers to reduce ACB pest problem. Nevertheless, the noted incidence of ACB at 7% both for *Bt* and *Bt*HT cornfields is remarkable. The observed ACB damage of the 4th to 5th instar larvae leads us to the premise that ACB survived and spent a large portion of their lifetime in a *Bt* corn plant. Hence, development of *Bt* toxin resistance by ACB may soon be occurring in Isabela province of the Philippines.

Furthermore, in GM cornfields, ACB damage was low whilst non-ACB damage was high. In non-GM cornfields the ACB damage was high and the non-ACB damage low. Yet, regression analyses showed no interaction between corn type and ACB or non-ACB damage, which means that no development of secondary pest can be assessed yet.

To assess if the findings of Marvier *et al*. (2007) also holds true in a tropical humid environment, an experimental study was done on the corn agriecosystem under GM corn cultivation and its associated agricultural managements (Chapter 3). The study directly follows the assumptions that when using corn containing *Bt* toxin, no insecticides must be applied because the plants are protected against ACB pest. In the case of herbicide tolerant crops, herbicides sprayings were done following the recommendations of the manufacturers and practices of the farmers. This means that when using HT corn, weed cover is drastically reduced or eradicated hence, freeing the farmers from the weed pest problem.

Our results did not conform to the findings of Marvier *et al*. (2007) and the comparison of insecticide-free *Bt* corn and non-GM corn treated with insecticides in Chapter 3 clarifies that in tropical environments such as in our study, insecticide-free GM corn can elicit more risks to invertebrate communities than non-GM corn treated with insecticides. The modification of agricultural practices associated with GM corn cultivations does not warrant the safety of the environment as claimed or ensure a more biodiverse field ecosystem.

In Chapter 4 the results obtained indicated that in a tropical environment, GM corn containing *Bt* toxin does in the long term affect other non-target organisms in the actual field setting. Although, soil chemical characteristics seem to have an effect, these effects did not take away or dampen the influence of corn variety which among the tested variables manifested the strongest negative effect on the abundance and species richness of invertebrates. Furthermore, the aerial and soil-dwelling invertebrates that are likely to play key ecological roles in the field agro-ecosystems seem to be the most affected. The findings of this study did not directly contradict local researches done by Javier *et al* (2004) and Alcantara *et al*. (2008) that showed *Bt* corn is environment friendly as claimed. This study was conducted after over five years of *Bt* corn cultivation in the Philippines whilst their studies were experimental field evaluations when a *Bt* toxin effect was still premature to investigate. The meta-analysis of Marvier *et al* (2007) showed that *Bt* corn is more beneficial compared to non-GM corn treated with insecticides. This applies under the assumption that with *Bt* corn use, the plants are protected from damage brought about by pests and hence does not require insecticide inputs. In real field situations, however, there are other pests that could also cause great damage to corn plants and this justifies farmers' use of insecticides even with *Bt* corn adoption.

The cornfields inspected in Chapter 4 showed no variation in terms of pesticides used. This is because some GM corn farmers claimed that they sprayed pesticides when they observe pests other than ACB. Finally, the conclusion in Chapter 3 was reinforced by the study presented in Chapter 4 wherein non-target organisms are affected. Short-term cultivations of GM corn affected surface dwellers (Chapter 3) whilst its long-term effect was manifested in aerial and soil dwellers (Chapter 4). This does not contradicts Javier *et al*. (2004) who found that beneficial insects mostly foliage or aerial dwellers were not affected in a GM cornfield but it enhanced previous findings that other groups of invertebrates not covered by their study were found to be affected. Finally, these studies illustrate that other groups of invertebrates usually neglected must be given attention and considered to be as important as aerial invertebrates as they may play key functions in the agroecosystem's stability or sustainability. The ending message of Chapter 3 and 4 is that GM corn widely cultivated in the Philippines could reduce the infield biodiversity of invertebrates and hence the necessity of other controls measures or alternative strategies that can mitigate or prevent the impact of GM corn to the agro-ecosystem.

Chapter 5 focused on answering the question whether GM corn is worth investing by the farmers. Among the important considerations of farmers to adopt a technology is the assurance that they can obtain a higher crop yield. Past studies have shown that adoption of GM corn increases yield and provide more profits to farmers. Nonetheless, the results of interviews of the farmers showed no difference in production output between corn varieties. This study has shown that among the independent variables tested, corn borer occurrence, labor cost, seed cost and fertilizer cost manifested the highly influential determinants for production output. For net income, corn borer occurrence, labor cost and corn borer severity count as the most influential determinants. In conclusion, our data demonstrates that at the moment, GM corn hybrids do not explicitly have an economic advantage to farmers compared to conventional non-GM corn hybrids and that GM corn adoption does no longer directly give economic advantage against non-GM corn in the Philippines.

On the issue raised by opponents of GM technology that GM corn manufacturers extract all monetary gains from the farmers (Greenpeace 2000). This is unreasonable because farmers have to make their own decisions or choice on what corn variety they would like to purchase. Farmers are not obliged to buy any variety of GM corn and could stick to their traditional variety if they opted to. However, there are strong driving forces that influence them to decide whether to adopt GM corn or not (Chapter 6). Like any technology introduced to the farmers, the claimed pecuniary and non-pecuniary benefits convinced the farmers to try GM corn. If farmers are satisfied with their first-hand experience with the new technology they will continue to use the same corn variety. Finally, in Chapter 6, the study demonstrated that the level of GM corn adoption by farmers was shown to be influenced by the perceived economic advantage, extent of knowledge, level of satisfaction and extent of first-hand experience. Respondent farmers surveyed and interviewed affirmed that corn borers and weeds are problematic pests, but levels of concern and perceptions of the severity of damage differed. The foremost reason for not adopting GM corn was the cost of seed. Lastly, there was a perceived negative shift in the standpoints of the farmers after GM corn adoption, yet they kept using it, for reasons that need to be explored.

Final Conclusion

Based on actual field evidences gathered for this thesis, it can be stated that GM corn may not be the innovation that can solve problem on yield losses attributed to ACB and weed pests without any negative environmental effects. This statement may appear simplistic but the data gathered and analyzed are consistent and significant enough to be ignored.

Based on the ecological studies:

1. *Bt* and *Bt*HT corn hybrids containing the Cry1Ab protein performed well in Isabela province Philippines.
2. *Bt* leaves are more susceptible to ACB attack.
3. The occurrence of ACB in *Bt* and *Bt*HT cornfields, though at a moderate and insignificant level, could however indicate the gradual potential development of resistance to *Bt* toxin.
4. No secondary pest outbreak was found in ACB-free *Bt* cornfields.
5. Non-GM cornfields harbor more invertebrates.
6. Between the two GM corn varieties, GM *Bt* corn poses less of an environmental risk to invertebrate ecosystem populations than *Bt*HT corn.
7. Insecticide-sprayed non-GM fields were more favorable for invertebrates than unsprayed GM fields.
8. Regimes with no herbicide application generally favor invertebrates, whereas chemical weeding greatly reduces their populations.
9. Long-term and continuous cultivation of transgenic corn has an impact on humid tropical corn-based agroecosystems, in terms of reducing the abundance and species richness of non-target invertebrates.
10. Our results seem to contradict earlier studies in temperate regions, where endotoxin from *Bt* and *Bt*HT corn affected only the targeted pest species (ACB).

Based on the economic study:

1. Production output did not statistically differ between GM and iso-hybrid non-GM corn.
2. GM corn adoption does no longer directly give economic advantage against non-GM corn considering all the economic variables studied.
3. The influential independent variables (i.e. labor cost, seed cost, fertilizer cost and farm size) that are noted using the Blinder-Oaxaca decomposition technique confirmed the results of our econometric analysis.

Based on the social study:

1. Farmers switched to GM corn due to their perceived yield increases, better insect control, reduced costs of inputs and curiosity.
2. Knowledge about GM corn and accessibility of GM corn seeds influenced the adoption of GM corn.
3. High price of GM seeds formed a barrier for non-GM farmers to switch to GM corn.
4. After *Bt* corn adoption, respondents perceived reduction in pesticide inputs, but not on labor/time, and indicated concerns about potential repercussions for human health and the environment.
5. After *Bt*HT adoption, respondents viewed *Bt*HT to be comparable to non-GM in terms of fewer agricultural interventions and market prices of the produce, and that its toxin content may affect non-target organisms.
6. After HT adoption, respondents have negative perceptions on the emergence of other pests and on the storage life of the corn produce.
7. A negative shift in the standpoints after adopting GM corn cultivation was perceived by the farmers but they tended to go on using it.

Recommendations

1. *Bt* and *Bt*HT corn are recommended for planting in the area where there is high infestation of ACB.
2. Since the most susceptible plant part to ACB attacks is the corn leaves then it is recommended that new *Bt* seed technology must develop in which the *Bt* toxin is mostly concentrated on leaves to narrow the target pest.
3. Refuge strategies must be fully and strictly implemented by the farmers especially to areas with monocropping and large-scale plantation of GM corn as vital mitigating measure for ACB resistance development to *Bt* toxin.
4. Presence of non-ACB pests in surveyed *Bt* cornfields may indicate potential development of secondary pest hence, it is highly recommended that close monitoring not only on ACB pest but as well on non-ACB pests to ensure no secondary pest outbreak in the future.
5. Similar study must be conducted on new developed and commercialized corn lines of *Bt* and *Bt*HT. The use of herbicides in a HT corn must be minimized to maintain at least 30-50% weed cover needed to support the survival of weed dependent invertebrates.
6. Development of GM corn hybrid that is selectively efficient to compete with weeds for soil mineral, water and nutrients so that spraying of herbicide becomes unnecessary.
7. As large-scale monocropping of transgenic corn is currently highly prevalent in the Philippines, precautionary measures or effective refuge areas should be considered to abate serious implications for the biodiversity and sustainability of corn agroecosystems.
8. More research is needed to enable continuous monitoring and to address some emanating ecological issues about recently released *Bt*, *Bt*HT and HT corn lines.
9. This study can be undertaken on a larger scale to obtain more information that are not otherwise inconformity with our present findings that may show changes in the economic benefits from GM corn technology overtime viz a viz its wide scale adoption in different economic settings and locations.
10. Farmers need to consider all economic variables in their decisions to adopt GM corn.
11. Assessment of *Bt* and *Bt*HT corn specifically on the aspect of perceived risk on human health and environmental health.
12. The Philippine government should look into possibilities to lower high cost of GM corn seeds.

Future Research

1. Since the study presented in Chapters 3 and 4 found varying groups of invertebrate fauna that were affected at different periods of GM corn cultivation i.e. surface dwellers were found affected at short-term cultivation and aerial and soil-dwelling found affected by long-term cultivation of GM corn, a longer duration of time is necessary to document the changes to allow for a better understanding of the dynamics of corn plant and invertebrate interactions and come up with bioindicators for environmental changes in corn agroecosystems.
2. Many GM crops are on the verge of introduction in the Philippines. There are many crucial issues emanating especially the commercial release of *Bt* rice and *Bt* eggplant which are both on the green house evaluations. Experiences from the case of GM corn where there is almost a decade of experience of crop production should serve well to provide a post technology assessment of the impact of GM crops on the lives of people and the environment.
3. Introduction, implementation and proper monitoring of insect refuges as a mitigating management scheme to prevent the development of ACB resistance to *Bt* toxin and still allow for invertebrate biodiversity flourishing is needed.
4. Prior to renewal of any GM seed permit there must be a nationwide post evaluation that ensures GM crop does not pose a graver threat to biodiversity and that baseline information from the initial risk assessment process conducted prior to the commercial approval shall serve as basis for comparison. This also includes a proper accounting of all invertebrate species and populations present prior to new GM crops introduction.
5. An independent body of the government, and not one funded by the GM seed company, should be tasked with primary responsibilities for the post risk assessment of GM corn so that credibility of the findings would not be questioned by opposing bodies. This is because the issues are public interests issues with implications for environmental safety, human health and biodiversity. As it stands now almost all post risk assessments for GM crops are fully funded by GM companies in partnerships with local governments, government agencies or local academia.
6. Techniques developed for risk assessments applicable to the humid tropical country should be standardized and shall serve as a uniform tool or techniques for pre- and post-evaluation processes.

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

Genetically modified corn has become the prototype crop to answer the increasing demand for food or feed production. The Asian corn borer (ACB), *Ostrinia furnacalis* (Guenée), has become the most damaging pest in corn in Southeast Asia. Corn farmers in the Philippines have incurred great yield losses in the past decades because of ACB infestation. *Bacillus thuringiensis* (*Bt*) and *Bt* Herbicide Tolerant (*Bt*HT) corn have been developed to reduce borer attacks worldwide. Introduction of other transgenic crops for increased food production are likewise being field tested but *Bt* corn field testing has generated the most controversy among the products of biotechnology because of fears with regards to its bio-pesticide content. Sorting out scientifically validated claims of both protagonists and antagonists proves difficult. Concerning biodiversity, few and unpublished studies have been conducted in a humid tropical environments like the Philippines. This is also true for the socioeconomic effects on farmers. With almost a decade of GM corn cultivation in the country, post technology adoption assessments becomes necessary to better understand if indeed the goals for which it was promoted and adopted were fully or nearly satisfied.

To seek answers to the issues surrounding the introduction and nationwide adoption of GM corns in the Philippines, the thesis focused to find answers on the general question: How can genetically modified corn and its attributed changes in agricultural practices affect the agro-ecosystem's biodiversity and the economic status and social life of the farmers?

Biodiversity

As indicators for biodiversity, both beneficial (i.e. non-pest) and non-beneficial (ACB and non-ACB pests) infield invertebrates were assessed. In particular, this study focused on the issue of how efficient is the continued adoption of GM corn technology to resolve the question on ACB infestation in the Philippines (Chapter 2). The study involved preparatory interviews with farmers, site selection, field scouting and visual inspection of 200 plants along 200 m transect lines through 198 cornfields. *Bt* corn can efficiently reduce the ACB pest problem and reduce borer damage to plants by 44%, to damage levels in *Bt* and *Bt*HT corn of 6.8% and 7% of the plants, respectively. No secondary pest outbreak was found in ACB-free *Bt* cornfields. Reduced cob damage by ACB on *Bt* fields could mean smaller economic losses even with ACB infestation. The occurrence of ACB in *Bt* and *Bt*HT cornfields, though at a moderate and insignificant level, could imply the potential development of resistance to *Bt* toxin.

Also, this study presents the field experimental results measuring the effects of GM corns and its associated changes of agricultural practices (pesticide and weeding managements) to the invertebrate community (Chapter 3). The GM effects on biodiversity were studied in a six-hectare field experiment in Cabagan, Isabela, during the 2009 dry and wet cropping seasons. Our findings showed that the total invertebrate abundance, surface dweller abundance and species richness of surface dwellers and soil dwellers were significantly higher in non-GM cornfields than in *Bt* and *Bt*HT cornfields. Insecticide-sprayed non-GM cornfields harbored more invertebrates than unsprayed *Bt* or *Bt*HT cornfields.

Finally, the study likewise focused on the longterm effects of GM corn on species richness and abundance of infield invertebrates (i.e. aerial, surface and below-ground dwellers) (Chapter 4). This chapter includes the survey of cornfields with a minimum of two years cultivation of GM corn. The field abiotic factors that served as confounding factors included soil pH, soil fertility and soil nutrient contents which were controlled as permissible or taken into account during data analysis. The study was conducted in 30 fields, including non-transgenic cornfields for comparison, and distributed over three lowland sites in 2008. The transgenic corn varieties *Bt* and *Bt*HT in this study were introduced to the area in 2002 and 2005. The non-*Bt* cornfields had significantly higher abundance and species richness of non-target invertebrates than the *Bt* and *Bt*HT fields. Likewise, the abundance and species richness of aerial and abundance of soil dwelling non-target invertebrates were notably higher in the non-*Bt* cornfields. The effects of confounding variables did not take away this effect of corn varieties.

Socio-Economics

Chapter 5 presented the economic domain of this study. This paper tried to provide some realistic answers to issues and concerns on whether GM corn is worth investing, especially for small scale farmers. The producers of GM corns' claim that GM corn could alleviate farmer's lives, encouraged critics from various groups to refute it in the media for they believe that it is an empty promise to the farmers. Hence, to help shed light to the issues, an updated economic evaluation of crop impacts and investment analysis of both GM and non-GM corn productions were dealt in this part of the thesis. Data were collected of 114 farmers in Isabela province including non-GM, *Bt*, *Bt*HT and HT corn farmers. We analyzed the effects of agriculture inputs (labor, seed, and fertilizer costs) on the difference between GM and non-GM corn in production output, net income, production-cost ratio and return on investments per ha. Results showed that non-GM corn was not statistically different from GM *Bt*, *Bt*HT and HT corn in terms of production output, net income, production-cost ratio and return on investments per ha. Also, a Blinder-Oaxaca analysis was used to decompose the mean gaps of return on investment and net income between GM and non-GM corn. Results using this analysis showed that among the independent variables tested, corn borer occurrence, labor cost, seed cost and fertilizer cost manifested the highly influential determinants for return on investment. For net income, corn borer occurrence, labor cost and corn borer severity count as the most influential determinants. In conclusion, our data demonstrates that at present GM corn hybrids do not explicitly manifest economic advantage compared to non-GM corn hybrids.

The social aspect presented in Chapter 6 focussed on the documentation of corn farmers' attitudes, standpoints and predicaments on the release and adoption of GM corn technologies. The hurdles faced by the farmers in adopting GM corn and why some farmers did not plant GM corn despite various massive advertisements made by seed producers gave particular outlook on farmer's willing/unwillingness to adopt GM corn technology. A total of 188 corn farmers (using *Bt* corn, HT corn, *Bt*HT corn, non-GM corn and mixed cultivation) from 15 municipalities in Isabela province were interviewed for this study. The level of GM corn adoption proved to be influenced by the perceived economic advantage, extent of knowledge, level of satisfaction and extent of first-hand experience. Respondents affirmed that corn borers and weeds are problematic pests, but levels of concern and standpoints of the severity of damage differed. The foremost reason for not adopting GM corn was the cost of seed. Although there was a negative shift in the attitudes of the farmers after GM corn adoption, they kept using it, for reasons that need to be explored.

Conclusions and recommendations

Overall, the following main conclusions and recommendations can be drawn from this thesis:

a. Conclusions:

1. *Bt* and *Bt*HT corn hybrids containing the Cry1Ab protein performed well in Isabela province. This was manifested by the significant reduction (by 44%) of ACB damage in inspected *Bt* cornfields.
2. No secondary pest outbreak was found in ACB-free *Bt* cornfields.
3. The current study clearly highlights the advantage of non-GM cornfields in terms of the abundance and species richness of invertebrates. Between the two GM corn varieties, GM *Bt* corn poses less of an environmental risk to invertebrate ecosystem populations than *Bt*HT corn.
4. Long-term and continuous cultivation of transgenic corn has an impact on humid tropical corn-based agro-ecosystems, in terms of reducing the abundance and species richness of non-target invertebrates.
5. Production output did not statistically differ between GM and iso-hybrid non-GM corn.
6. GM corn adoption does no longer directly give economic advantage against non-GM corn considering all the variables studied.
7. Farmers switched to GM corn due to their perceived yield increases, better insect control, reduced costs of inputs. Knowledge about GM corn and accessibility of GM corn seeds influenced the adoption of GM corn.
8. High price of GM seeds formed a barrier for non-GM farmers to switch to GM corn.
9. After *Bt* corn adoption, respondents perceived reduction in pesticide inputs, but not on labor/time. Also, they viewed *Bt*HT to be comparable to non-GM in terms of fewer agricultural interventions and market prices of the produce, and that its toxin content may affect non-target organisms. After HT adoption, respondents have negative standpoints on the emergence of other pests and on the storage life of the corn produce. A negative shift in the standpoints after adopting GM corn cultivation occurred, but the farmers tended to go on using it.

b. Recommendations:

1. *Bt* and *Bt*HT corn are recommended for planting in the areas where there is high infestation of ACB.
2. Presence of non-ACB pests in surveyed *Bt* cornfields may indicate potential development of secondary pest. Hence it is highly recommended that close monitoring be done not only on ACB pests but as well on non-ACB pests to ensure no secondary pest outbreaks in the future.
3. Similar study must be conducted on new developed and commercialized corn lines of *Bt* and *Bt*HT. The use of herbicides in a HT corn must be minimized to maintain at least 30-50% weed cover needed to support the survival of weed dependent invertebrates.
4. As large-scale monocropping of transgenic corn is currently highly prevalent in the Philippines, precautionary measures or effective refuge areas should be considered to abate serious implications for the biodiversity and sustainability of corn agro-ecosystems.
5. More research is needed to enable continuous monitoring and to address some emanating ecological issues about recently released *Bt*, HT and *Bt*HT corn lines.
6. Farmers need to consider all economic variables in their decisions to adopt GM corn
7. The Philippine government should look into possibilities to lower high cost of GM corn seeds.

Genetisch gemodificeerde (GM) mais op de Filippijnen: *gevolgen voor het agro-ecologische system, gevolgen voor de economie van de boeren en de ervaringen van boeren*

Genetisch gemodificeerde (GM) maïs is het voorbeeldgewas geworden om te voldoen aan de stijgende vraag naar voedsel en veevoer. De Aziatische Maïsboorder (AMB), *Ostrinia furnacalis* (Guenée), is op dit moment het plaagorganisme van maïs dat de meeste schade toebrengt in Zuidoost Azië. Maïsboeren op de Filippijnen hebben de laatste tientallen jaren grote oogstverliezen geleden door AMB. Om de schade door boorders wereldwijd te verminderen zijn *Bacillus thuringiensis* (*Bt*) en *Bt* Herbicide Tolerante (*Bt*HT) maïs ontwikkeld. Hoewel er ook andere genetisch gemodificeerde voedselgewassen zijn geïntroduceerd die nu in het veld worden getest, heeft het testen van *Bt*-maïs geleid tot de sterkste controversie rond de biotechnische producten omdat men bang is voor de plaagdodende werking ervan. Het beoordelen van de wetenschappelijke claims van zowel voor- als tegenstanders blijkt moeilijk. Wat biodiversiteit betreft zijn er weinig gepubliceerde onderzoeken die zijn uitgevoerd in vochtig tropische omgevingen zoals op de Filippijnen. Dit geldt ook voor het onderzoek naar de sociaaleconomische gevolgen voor de boeren. Na bijna tien jaar van het verbouwen van GM-maïs op de Filippijnen wordt een evaluatie noodzakelijk om na te gaan of de doelen waarvoor deze maïs werd ingezet werkelijk zijn bereikt.

Dit proefschrift probeert dan ook de volgende algemene vraag te beantwoorden: Wat zijn de gevolgen van genetische gemodificeerde maïs en de daarmee samenhangende verandering in de landbouwpraktijk voor de biodiversiteit van het agro-ecologische systeem en voor de economie en het sociale leven van de boeren?

Biodiversiteit

De biodiversiteit werd vast gesteld aan de hand van zowel de onschadelijke als schadelijke ongewervelde dieren die in het maïsveld voorkwamen. In de eerste plaats richtte de studie zich op de vraag hoe effectief het continu toepassen van GM-maïs is in het voorkomen van AMB schade op de Filippijnen (hoofdstuk 2). Deze studie omvatte enquêtes onder boeren en gewasinspecties aan de hand van 200 maïsplanten langs een 200 m traject in 198 velden. Daaruit bleek dat in *Bt*-maïs 44% minder schade optreedt in de planten en dat de schade wordt teruggebracht tot 6,8% en 7% van, respectievelijk, de *Bt*- en *Bt*HT-planten. Er werd geen secondaire plaaguitbraak gevonden in de velden zonder AMB. Verminderde schade aan kolven op *Bt*-velden kan betekenen dat er zelfs bij AMB-schade er verminderde economische schade optreedt. Het feit dat er wel degelijk AMB-schade gevonden werd in *Bt*- en *Bt*HT-velden, zij het op laag niveau, kan betekenen dat er bij AMB zich immuniteit tegen het *Bt*-endotoxine kan ontwikkelen.

Daarnaast presenteert dit proefschrift de resultaten van een veldexperiment waar de gevolgen van GM-maïs en de daarbij horende inzet van gewasbescherming voor de gemeenschap van ongewervelde dieren werden onderzocht (hoofdstuk 3). Dit experiment werd uitgevoerd op een 6 ha groot veld in Cabagan, Isabela, in het droge en natte seizoen van 2009. Er werd gevonden dat de totale abundantie van gewervelde dieren, de abundantie van de op de grond levende dieren en de soortenrijkdom van de op de grond en in de bodem levende dieren significant hoger was in de niet-GM-velden dan in de *Bt*- en *Bt*HT-velden. Dus er kwamen meer ongewervelde dieren voor in de met insecticiden behandelde niet-GM-velden dan in de niet behandelde *Bt*- en *Bt*HT-velden. Tot slot richtte de studie zich op de gevolgen op de lange termijn van GM-maïs op soortenrijkdom en abundantie van ongewervelde dieren in maïsvelden (hoofdstuk 4). Hiervoor werden 30 maïsvelden bestudeerd, verdeeld over drie locaties die alle voor ten minste twee jaar werden bebouwd met GM-maïs. De abiotische factoren bodem pH, bodem vruchtbaarheid en bodemnutriënten werden beschouwd als stoorvariabelen waarvoor werd gecontroleerd tijdens de analyses. De studie werd verricht in 2008; *Bt*- en *Bt*HT-maïs werd in het gebied geïntroduceerd in respectievelijk 2002 en 2005. De niet-GM-velden hadden een hoger abundantie en soortenrijkdom aan ongewervelde dieren. Ook de abundantie en soortenrijkdom van vliegende dieren was hoger, evenals de abundantie van de op de grond levende dieren. Controle voor de stoorvariabelen nam dit gevolg niet weg.

Sociaaleconomische gevolgen

Hoofdstuk 5 behandelt de economische gevolgen van GM-maïs voor met name kleine boeren. De claim van de producenten van GM-maïs dat dit het leven van boeren zal verbeteren heeft veel kritiek ondervonden van belangengroepen en heeft veel aandacht in de media gekregen omdat het een lege belofte zou zijn. Vandaar dat hier een vergelijking van de huidige economische gevolgen van het verbouwen van niet-GM met GM-maïs is gemaakt. De gegevens werden verzameld van 114 boeren in de provincie Isabela die niet-GM, *Bt*-, HT- of *Bt*HT-maïs verbouwden. De gevolgen van de productiekosten (kosten voor arbeid, zaad, gewasbescherming en kunstmest) bij de verschillende maïs-variëteiten op productie, netto inkomen, productie/kosten verhouding en winst op investering werden geanalyseerd. De resultaten laten zien dat niet-GM-maïs statistisch niet verschillend was van GM-maïs in termen van productie, netto inkomen, productie/kostenverhouding en winst op investering in dollars per ha. Daarnaast werd een Blinder-Oaxaca analyse uitgevoerd om het verschil in winst op investering en netto inkomen tussen niet-GM en GM-maïs verder uit te splitsen. Daaruit bleek dat het voorkomen van AMB, de arbeidskosten en de kosten voor zaad en kunstmest een sterke invloed hebben op de winst op investering. Het netto inkomen wordt sterk beïnvloed door het voorkomen van AMB, de arbeidskosten en de ernst van de schade door AMB. Concluderend laten de resultaten zien dat er op dit moment geen duidelijk economisch voordeel is voor boeren van het toepassen van GM-maïs.

De sociale gevolgen van het toelaten van GM-maïs en het toepassen ervan worden in hoofdstuk 6 beschreven in termen van de houding ten opzichte van en de opvattingen over GM-maïs van boeren. De moeilijkheden die boeren tegenkomen wanneer ze GM-maïs planten en het feit dat sommige boeren weigeren GM-maïs te verbouwen ondanks the grootschalige reclame ervoor door de zaadproducenten geeft inzicht in de bereidheid van boeren om de GM-maistechnologie te accepteren. In totaal werden hiervoor 188 maisboeren (die niet-GM, *Bt*-, HT-, *Bt*HT-maïs of een mix van deze variëteiten verbouwden) uit 15 gemeenten van de provincie Isabela geënquêteerd. Het al dan niet toepassen van GM mais werd beïnvloed door het vermeende economische voordeel, de kennis erover, de tevredenheid ermee en de eigen ervaring ermee. De boeren bevestigden dat AMB en onkruid problematische plagen vormen, maar de bezorgdheid en de standpunten over de ernst van de schade verschilden tussen boeren. De belangrijkste reden om GM-maïs niet te verbouwen was de kosten van het zaad. Hoewel de houding van boeren ten opzichte van GM-maïs in negatieve zin veranderde na ervaring met het verbouwen van GM-maïs, bleven de boeren het verbouwen om redenen die nader moeten worden onderzocht.

Conclusies en aanbevelingen

De volgende algemene conclusies en aanbevelingen kunnen uit deze studie worden gehaald:

a. Conclusies:

1. *Bt*- en *Bt*HT-maïs, die het CryAb-proteïne bevatten, zijn effectief in de provincie Isabela op de Filippijnen. Er is een significante reductie (van 44%) vastgesteld van de schade door Aziatische Maïsboorders (AMB) in *Bt*-maïsvelden ten opzichte van niet-*Bt*-maïsvelden.
2. Er werd geen secondaire plaag gevonden in AMB vrije *Bt*-velden.
3. Deze studie laat duidelijk het voordeel zien van niet-GM-velden in termen van de abundantie en soortenrijkdom van ongewervelde dieren. Binnen de GM-variëteiten, vormt het *Bt*-maïs een minder groot milieurisico voor de gemeenschap van ongewervelde dieren dan *Bt*HT-maïs.
4. Langdurige en continue verbouwing van GM-maïs heeft gevolgen voor het agro-ecosysteem in de zin dat de abundantie en soortenrijkdom van niet-plaagsoorten ongewervelde dieren vermindert.
5. De maïsproductie in dollars per ha was niet statistisch verschillend tussen GM en iso-hybride niet-GM-maïs.
6. Het overgaan op GM-maïs geeft op geen van de gemeten variabelen nog langer economisch voordeel ten opzichte van niet-GM mais
7. Boeren gingen over op GM-maïs vanwege een vermeende toename van de oogst, beter plaagcontrole en verminderde kosten. Kennis over GM-maïs en de beschikbaarheid van GM-maïs zaad beïnvloedde de overgang naar GM-maïs.
8. De hoge prijs van GM-zaad vormde een barrière voor niet-GM-boeren om over te gaan op GM-maïs.
9. Na het verbouwen van GM-maïs ervoeren de boeren een verminderd gebruik van pesticiden, maar niet van werktijd. Ook beschouwden zij *Bt*HT- als vergelijkbaar met niet-GM-maïs in termen van landbouwkundige ingrepen en marktprijzen en dachten zij dat het endotoxine ervan ook niet-doelsoorten zou kunnen beïnvloeden. Na het verbouwen van HT-maïs hadden boeren een negatief standpunt over het optreden van ander plagen en de opslagtijd van de maïs. In het algemeen was een negatieve verschuiving in standpunten ten opzichte van GM-maïs vast te stellen na het verbouwen van GM-maïs, maar boeren bleven doorgaan het te verbouwen.

b. Aanbevelingen:

1. Het verbouwen van *Bt*- en *Bt*HT-maïs wordt aanbevolen in gebieden met hoge kans op AMB-schade.
2. De aanwezigheid van niet-AMB-plagen in *Bt*-maïsvelden kan op de mogelijke ontwikkeling van secundaire plagen wijzen. Het wordt daarom aanbevolen om niet alleen AMB-plagen goed in beeld te brengen, maar ook die van andere dieren om uitbraken van secundaire plagen in de toekomst te voorkomen.
3. Studies als deze moeten in de toekomst worden uitgevoerd op nieuwe lijnen van *Bt*- en *Bt*HT-maïs. Het gebruik van herbicide in HT-maïs moet worden beperkt zodat minstens 30-50% van de bedekking door onkruiden intact blijft voor de overleving van onkruidafhankelijke ongewervelde dieren.
4. Omdat grootschalige monoculturen van GMmaïs nu veel voorkomen op de Filippijnen zouden voorzorgsmaatregelen en ontsnappingsgebieden moeten worden overwogen om ernstige gevolgen voor de biodiversiteit te voorkomen en de duurzaamheid van het agro-ecosysteem te garanderen.
5. Meer onderzoek is nodig om continue monitoring mogelijk te maken en nieuwe ecologisch problemen die met nieuwe *Bt*-, HT- en *Bt*HT-lijnen zouden kunnen ontstaan tijdig aan te pakken.
6. Boeren moeten alle economische aspecten van hun beslissing om over te gaan op GM-maïs in beschouwing nemen
7. De Filipijnse overheid zou de mogelijkheden moeten onderzoeken om de hoge kosten voor GMmaïs zaad terug te brengen.

Curriculum Vitae

Miladis Bautista Mabutol-Afidchao, the youngest of the five children of Prof. Rogelio G. Mabutol Sr. and Dr. Concepcion B. Mabutol, was born on August 7th, 1975 in Santiago City, Isabela, Philippines. She took her Bachelor of Science in Biology degree at the Isabela State University in Echague, Isabela. She then completed her masters degree in Biology at the same University where she studied and screened plants with active compounds effective as biocontrol agents against the disease Fusarium wilt (*Fusarium moniliforme*) in corn. From 2007 to 2008, she took MSc coursework at the Conservation Biology Department of Leiden University as an integral part of the PhD course requirements. From 2008 to 2013 she did her PhD research at the same institution on a research project “Genetically Modified (GM) Corn in the Philippines: Ecological impacts on agroecosystems, effects on the economic status and farmers’ experiences”, under the supervision of Prof. Dr. Geert R. de Snoo and Dr. C.J.M. Musters as her promoters. She then started working as University Biologist II at the Isabela State University Research Office based at the Cagayan Valley Regional Resources Research Consortium complex, Echague, Isabela Philippines. During her stint as Biologist, she was in-charge of the Tissue Culture laboratory and Anthelmintics research projects of the Research Department of the University. In June 2004, she was transferred to assume teaching as Assistant Professor 1 of the Isabela State University in Cabagan, Isabela. To date, she is an Assistant Professor IV in the ISU Cabagan campus teaching various Biological science subjects. She is married to Dr. Pablo M. Afidchao Jr with whom she has two daughters, Cachleini Noemi and Nadezna Razel.