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Genetically Modified Maize: Less Drudgery for Her, More Maize for Him? Evidence from Smallholder Maize Farmers in South Africa

MARNUS GOUSE [b], DEBDATTA SENGUPTA [a], PATRICIA ZAMBRANO [a] and JOSÉ FALCK ZEPEDA [a,*]

[a] *International Food Policy Research Institute (IFPRI), Washington, DC, USA*
[b] *University of Pretoria, South Africa*

Summary. — Genetically modified (GM) crop technologies have made great strides since its first introduction in 1996. Although there is an extensive and growing body of literature on the economic impact of the adoption of GM crops in both developing and developed economies, there is only scant evidence that the technology has had any specific and distinguishable impact among female and male farmers. In economies where female farmers and female household members have a significant and often differentiated role in agriculture production, it is crucial to be able to answer this question. This paper presents quantitative and qualitative results from a study of the gender-specific adoption and performance effects of insect resistant (Bt) and herbicide-tolerant (HT) maize produced by smallholder farmers in the Kwa Zulu Natal province in South Africa. The findings indicate that women farmers value the labor-saving benefit of HT maize alongside the stacked varieties which offer both insect control and labor saving. Higher yields are the main reason behind male adoption, while female farmers tend to favor other aspects like taste, quality, and the ease of farming herbicide-tolerant (HT) crops. Women farmers (and also children) saved significant time because less weeding is required, an activity that has traditionally been the responsibility of female farmers. The newer stacked varieties were preferred by both male and female farmers and seemed to be in high demand by both groups. However, lack of GM seed availability in the region and poor market access were possible limitations to the adoption and spread of the technology.

Key words — women farmers, GM maize, gender, technology adoption, Africa

1. INTRODUCTION

Genetically modified (GM) crops, have been one of the fastest adopted agricultural technologies in recent history (Khush, 2012). Initial adoption in 1996 was limited to commercial producers in a handful of countries mainly the United States, followed by Argentina, and Canada. Over the years farmers in Latin America and Asia have been adopting the technology at a fast pace. However, commercial production of GM crops in Africa has been limited to South Africa, Egypt, Burkina Faso, and more recently Sudan. Among them, South Africa is the only country where smallholder farmers have been producing a subsistence food crop using GM technology for more than a decade.

A substantial number of scholarly articles assessing the impact of GM crops in developed and developing economies has been reviewed by different authors (i.e., Smale *et al.*, 2009; Areal, Reisgo, & Rodriguez-Cerezo, 2013; Finger *et al.*, 2011, Klu¨mper & Qaim, 2014). The majority of these published articles have not taken into consideration gender differentiated impacts. However, with increased adoption of these technologies in developing countries, notably South Africa and given the important role female farmers and household members play in smallholder production systems in some regions of the world, it has become apparent that gender-differentiated assessment of adoption and impacts of GM crops demands further attention.

While numerous studies have shown that technology introductions in agriculture are gender differentiated and that these differences have relevant policy implications, (Peterman, Behrman, & Quisumbing, 2010; Quisumbing & Pandolfelli, 2009), few have studied the gender differentiated impact of GM crops in detail. Subramanian and Qaim (2010), 2009), Subramanian, Kirwan, Pink, and Qaim (2010) and Zambrano, Smale, Maldonado, and Mendoza (2012) have made some first advances suggesting that women and men farmers and household members derive differentiated benefits from the cultivation of GM crops. These studies have analyzed the impact on women farmers in cultivating Bt cotton in India and Colombia. The findings are context specific for the regions studied and will require further analysis to make wider generalization. Little, if any, gender-focused work has been done in Africa, although some authors (Morse & Bennett, 2008; Thirtle, Beyers, Ismael, & Piesse, 2003) have mentioned some gender aspects in their evaluation of insect-resistant (Bt) cotton in South Africa. Recent work on GM maize in KwaZulu-Natal by Gouse (2012a) and Regier and Dalton (2013) have collected gender disaggregated data for GM maize but there has not been any substantial analysis regarding the differentiated effects on men and women farmers. Determining the gender implications of the adoption of GM crops is thus a quite relevant task at hand.

There is also a critical gap in our understanding of the labor effects of different GM crop technologies and how that affects technology adoption and use among men and women farmers. Despite the fact that the assessment of herbicide-tolerant (HT)

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maize technologies in South Africa (Gouse, 2012b) and other regions of the world confirmed that one of the main technology benefits is the reduction in weeding labor and management time, these differentials have not been analyzed from a gender perspective. In the South African context, in particular, in the KwaZulu Natal (KZN) province, land supply is abundant while labor is in short supply. Increased migration of agricultural workers to urban areas and a high incidence of HIV/AIDS have diminished labor supply in the region (Gouse, Piesse, Thirtle, & Poulton, 2009). However, due to customary laws, it is still difficult for woman-headed households to access land as well as labor (Assefa & Van Den Berg, 2009). For this reason technologies such as herbicide-tolerant (HT) maize, that is a labor-saving technology, has the potential to play an important role in alleviating the time and labor constraints faced not only by women head of households but by all other household members.

This paper attempts to fill this important gap in the literature by analyzing gender-specific effects of cultivating GM maize in the northern region of KwaZulu-Natal (KZN) in South Africa. It summarizes findings from a University of Pretoria and International Food Policy Research Institute (IFPRI) project studying the gender-specific adoption and performance effects of smallholder farmers who plant GM maize. We present household member gender-focused findings based on two approaches pursued in the examination of Bt and HT maize cultivation by small-scale farmers. First, we quantitatively analyze gender disaggregated, original field data collected by Gouse (2012a), Gouse (2012b)). Second, we make use of qualitative data collected through small group discussions conducted with men and women farmers in two sites, Hlabisa and Simdlangentsha in KZN in order to better understand some of the nuances of household decision making and specific responsibilities in the maize production system. This paper is organized as follows. In the next section we provide an overall background of the current literature that informs our research and present an overview of Bt and HT maize adoption in South Africa. In section three we describe the study design including the field survey and small group discussions used for the analysis and present the results. Finally, we conclude by outlining specific findings and lessons from the analysis conducted in South Africa.

2. BACKGROUND

The overall assessment of commercialized GM crops has shown that the use of Bt technologies has reduced insect damage and insecticide applications while increasing gross income. HT technologies in most cases decreased the use of more toxic herbicides and have reduced management time (Areal *et al.*, 2013; Klu¨mper & Qaim, 2014) though there are substantial variation according to cropping system and geographical location (Smale *et al.*, 2009). The benefits to smallholder farmers in developing countries using the technology has also been documented and found to be positive (Azadi *et al.*, 2015; Graff, Roland-Holst & Zilberman, 2006; Klu¨mper & Qaim, 2014; Subramanian & Qaim, 2009). Research from South Africa and Philippines show that smallholder farmers have received significant benefits from cultivating GM maize (Yorobe & Quicoy 2006; Gouse *et al.*, 2009). While Bt maize in Philippines has been responsible mainly for higher yields, analysis of HT maize in South Africa shows that there are significant labor-saving benefits (Regier & Dalton, 2013; Sanglestsawai, Rejesus, & Yorobe, 2014; Assefa & Van Den Berg, 2009).

(a) *Gender and agriculture*

What these studies have not shown are the differentiated effects that the technology has had on men and women farmers. Women play a fundamental role in agriculture, especially in Africa. The Food and Agriculture Organization (FAO, 2011) estimated that female share of agricultural labor is almost 50% in Sub-Saharan Africa, compared to 43% for the developing countries in general. As has been underscored by the extensive and growing body of literature on gender and agriculture (FAO, 2011; FAO, IFAD, & ILO, 2010), women's roles and responsibilities in agriculture—within the household and the community—are complex, diverse and multifaceted (Doss, 2001; Doss & Morris, 2001; Meizen-Dick *et al.*, 2011; Quisumbing & Pandofelli, 2009). Studies suggest that, despite the wide variability among regions and countries, women farmers play a major role in labor-intensive activities such as planting and weeding, among many other agricultural activities (Schultz, 2004; Meizen-Dick *et al.*, 2011). Time-use studies (Charmes, 2005; Fälth & Blackden, 2009; Bardasi & Wodon, 2009) have also shown that women not only have substantially less free time than their male counterparts, but are more often confined to performing time-intensive and socially unrewarding activities such as fetching of water and fire wood. Women, compared to their male counterparts, also devote disproportionally more time to multiple on-farm and off-farm responsibilities.[1]

When considering Sub-Saharan agriculture, Dey Abbas (1997) asserts that the most relevant area of gender asymmetries tend to be the availability and control of household labor for farm activities. Uptake of productivity enhancing technologies are more limited for female farmers, especially in female-headed households. It is interesting to note that even when women have the financial and cultural possibility of hiring labor, they find it challenging to manage hired male labor (Zambrano *et al.*, 2012).

Beside the cultural constraints described so far, another factor that appears to have made labor a key factor limiting production, particularly for female farmers, is the higher male participation in off-farm activities. With increasing number of male household members absent from the rural household, the role of women in maintaining and producing cash crops (Ezumah & Di Domenico, 1995) has increased, blurring even further the difference between male and female crop production (Carr, 2008; Doss, 2001) and making labor a more limiting input for *de jure* or *de facto* female-headed households or plot managers.

In the South African context, especially in the former homeland areas in KZN and the Eastern Cape, it has been documented that women farmers, both in woman-headed households as well as in homesteads headed by men, have unequal access to labor (Hull, 2014). While woman-headed households have problems accessing both land and labor for farming, women farmers within homesteads headed by men have to depend on their status in the household and with the household head to access family labor (Hull, 2014).

In the complex and often under-studied agricultural household environment, the role of technology and its adoption and use, especially that of a GM crop, still requires more study.

(b) *Gender and the Potential Factors Impacting Farmers' Adoption Decision*

Compared to a considerable body of literature on female farmers and technology adoption, the number of publications on female farmers and adoption of genetically modified crops is limited. Three publications on Bt cotton adoption by South African smallholder farmers refer to female farmer labor saving as technology impact and adoption motivation but stop short of discussing possible differences between men and women farmers (Bennett, Buthelezi, Ismael, & Morse, 2003; Bennett, Morse, & Ismael, 2006; Thirtle *et al.*, 2003). Subramanian and Qaim (2009), Subramanian and Qaim (2010) and Subramanian *et al.* (2010) were able to capture gender-differentiated labor market and income effects of Bt cotton in a Maharashtra village in India. The study shows that adoption of Bt cotton is associated with an increase in female labor (hired labor required for sowing, weeding, and harvesting) while a decrease in the need for insecticide applications (a male activity) meant that male family members could spend more time on other income-generating activities.

In the first study to specifically focus on transgenic crops and women farmers, Zambrano *et al.* (2012) study Bt cotton perceptions and experience of women cotton farmers in Colombia. The study found that women farmers tend to favor insect-resistant cotton varieties, for their reduction in insecticide applications. This meant that they were able to hire less male laborers to do insecticide application—a task that has been traditionally performed only by men in Colombia. A technology that reduces the need for manual weeding was perceived to be particularly attractive for women farmers when female and children in the household were in charge of this arduous activity. The opposite is true for women who sell their weeding skills as a reduction in hired weeding labor would mean losing a source of income. It was also found that women farmers appeared to have more difficulty accessing or sharing information due to time restrictions as a result of domestic responsibilities. However, when information actually reached women farmers, they seem to follow instructions more judiciously than their male counterparts, a fact that potentially translates into better management of the technology (Zambrano *et al.*, 2012). In the next section we describe how GM maize was introduced in South Africa.

3. GM MAIZE IN SOUTH AFRICA

In 1998, Bacillus thuringiensis (Bt) gene inserted into maize hybrid to make them resistant to the maize stem borer, were approved for commercial use by the government in South Africa. Three years later South Africa commercialized Bt white maize, the first GM crop for direct human consumption. Figure 1 clearly shows that Bt as a single trait was initially the preferred technology in South Africa, reaching its peak in 2009 with 48% of the total area under maize cultivation. The trend was reversed to some extent with the release of HT maize in 2003. Herbicide-tolerant (HT) crops offer farmers a way of fighting weeds that is compatible with no-till methods, which help preserve topsoil. The use of Bt as single trait dropped further with the release of Stacked maize (BR) consisting of both Bt and HT traits in 2009–10. By the 2012–13 production season, GM maize adoption reached 85% of the total South African maize area with Bt maize as single trait covering 29%, herbicide-tolerant (HT) maize as singe trait covered 13% and Stacked maize consisting of both Bt and HT traits, 43% (Van der Walt, 2012).

It is important to underscore that these adoption rates, to a large extent, represent adoption mainly by commercial farmers producing the bulk of the South African maize crop. Estimating the number of smallholders that have adopted GM maize is not a simple task. Availability of smallholder data is limited and complicated by an unclear separation between subsistence, smallholder and emerging (larger scale but previously disadvantaged) maize farmers. Seed companies have difficulties identifying the end user as seed is sold by distributors, or supplied in bulk to municipalities, projects, or agri-development groups and many farmers share seeds with neighbors or members of their farmer association. Gouse, Kirsten, and Van Der Walt (2008)- estimated that the number of smallholder maize farmers who planted GM maize in 2007–08 reached approximately 10,500 This estimate is based on seed company information, seed sales and assumptions regarding seed quantity, bag sizes, and seeding rates. Seed companies have informally reported that sales of GM seed to smallholders have increased since 2007, but even if this growth is happening the number is still modest, particularly if we take into account that that there are an estimated 240,000 small-scale farmers in South Africa, and close to 1.5 million subsistence farmers.

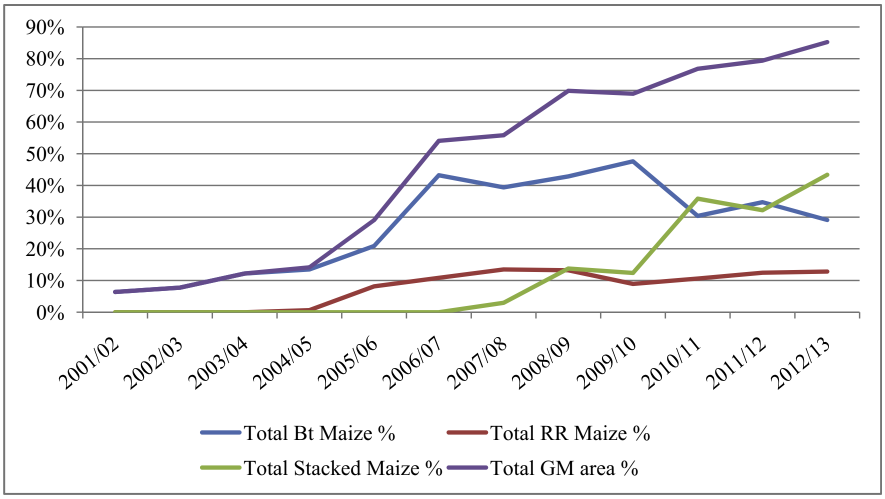
4. DESIGN AND METHODS

In order to examine the gender differentiated impacts of the adoption and use of GM maize in South Africa, the study made use of two distinct and sequential approaches. The first approach is a quantitative analysis of survey data collected in the Hlabisa district in KZN over a period of eight cropping seasons stretching from 2001 to 2010. After initial data analysis, a set of gender-specific questions were identified that were used in the second approach, small group discussions with women and men farmers in the Hlabisa and Simdlangentsha regions conducted in 2013. Qualitative analysis of the small group discussions were done to understand how adoption between men and women farmers differed due to qualitative aspects like perception and taste, which are not always captured through quantitative survey data.

(a) *Quantitative survey*

The University of Pretoria started collecting information in 2001 to examine the smallholder GM maize experience. The first data collection was from six areas where Monsanto representatives had held information workshops in 2001 explaining and introducing Bt maize. A sample of 368 farmers were drawn from the first adopters in the region. [2] Thus, starting in 2001, smallholder farmers in different areas of South Africa have been planting Bt and also, after its introduction in 2003–04, HT maize, although intermittently (Gouse, 2012a; Gouse, 2012b). According to Gouse (2012a, 2012b), smallholders have been planting GM maize on a continuous basis in only two areas in South Africa. The first of these areas surrounds the northern KZN town of Hlabisa. The second area is the Simdlangentsha district near the border to Swaziland. These two areas were surveyed by the University of Pretoria team over the years and the farmers' experience with both Bt and HT seed recorded. Data were collected from Hlabisa farmers for eight seasons, from 2001–02 to 2007–8 and again 2009–10.

Table 1 shows the number of farmers surveyed in Hlabisa each year during the course of a number of consecutive projects. It is important to underline that the results from Hlabisa are not representative of smallholder maize producers in South Africa. No other smallholder maize production area has seen this level of independent continuous adoption, which may indicate that Hlabisa farmers and/or their supply chain have different characteristics not present in other maize production regions. For this reason the experience of Hlabisa farmers with



Source: Gouse (2012b) and for recent years Van Der Walt (personal communication, 2012).

Figure 1. *Percentage of Total South African Maize Area Covered by GM Maize.*

Table 1. *Number of farmers surveyed in Hlabisa according to season and seed type*

Season	Number of farmer surveys	Number of useable plots	Bt plots	HT plots	BR plots	Conventional plots
2001–02	59	58	58	0	0	58
2002–03	67	78	31	0	0	47
2003–04	135	188	64	2	0	122
2004–05	78	68	17	3	0	48
2005–06	121	125	39	22	0	64
2006–07	87	95	21	35	0	39
2007–08	102	97	12	38	19	28
2009–10	96	95	0	65	14	16

GM maize (2001–02 to 2009–10) should be viewed only as a case study.

Although the initial idea was to collect data for consecutive seasons, the sample had to be adjusted from season to season as not all farmers in the initial sample could be followed over the years. Some had no access to GM seeds, while others decided to stop planting GM maize, influenced by weather and personal reasons.

The 2002–03 to 2005–06 sample consisted of purposively selected GM maize seed adopters and randomly selected non-GM hybrid maize producers; the 2006–07, 2007–08, and 2009–10 samples were mainly the same group of adopting and non-adopting farmers (balanced panel of 68 farmers for all three and 97 for last two seasons). Although for all seasons, close to the total population of GM adopters were surveyed, the number of farmers by seed type was quite small as adoption remained limited. The small sample size limits analytical rigor by seed type and farmer gender, but the overall season sample still makes it possible to make reliable inferences regarding adoption preferences of farmers and production system comparisons.

(b) *Small group discussions methodology and description*

The small group discussions were designed following the methodology developed and outlined by Zambrano *et al.* (2012). The purpose of this methodology is to elicit responses to the issues which cannot be addressed in depth in a quantitative survey. For this specific study, the selected participants came from a subset of farmers who had participated in Gouse (2012a) quantitative surveys and as such these were maize production decision makers and not only household members. The farmers were subdivided into men- and women-only groups. These were in-turn divided by type of maize cultivated (GM and non-GM). Thus there were four sub-groups: male farmers cultivating GM maize, male farmers cultivating non-GM maize, female farmers cultivating GM maize and female farmers cultivating non-GM maize. Each sub-group had approximately 10 farmers. There were activities which were performed as a group and several within each subgroup.

While the quantitative survey derived the labor-time devoted to GM maize cultivation by men, women, and children, the aim of the qualitative discussion groups was not only to find out who did what activity, but also who in the household took the decision and who contributed labor toward each specific activity. All the activities in GM maize production for the Bt, HT and Stacked variety (comprising of both Bt and HT traits) were elicited from participants and listed in order starting from land preparation to harvesting and final sale. Also included were tasks related to who sold the maize in the market and who had access to the money from sales. The groups indicated whether they made decisions regarding which activity is to be done, or just followed assigned tasks. Another discussion centered on enquiring which of the varieties available to the farmer was most and also least preferred. This gave us a general understanding about which varieties were popular among which group of farmers and the reasons for such preferences. A third activity aimed to understand why men and women farmers chose the varieties they currently plant and then compare that to the GM varieties.

Interestingly, men and women farmers had divergent opinions regarding benefits and problems related to the same varieties. Apart from a varietal problem that both male and female groups that planted GM maize referred to, the responses were different between men and women farmers showing the differing perceived benefits each group gets from GM maize cultivation.

(c) *Household demographics in Hlabisa*

The household demographics in the study area provide a necessary background and context to interpret results from the analysis done in this paper. According to the 2011 South African census, 54% of households in the Umkhanyakude Municipality, where Hlabisa is located, are headed by females. This is in line with other rural municipalities female headed household percentages like Umzinyathi (59%) and Sisonke (55%) but high compared to an urban municipality like Thekwini (40%) that includes the larger Durban metropolitan area (StatsSA., 2011). The relatively low number of households headed by males has been attributed to migration to urban areas in search of employment opportunities (Posel, 2001) and the effect of high HIV rates. This has left a large percentage of households headed by elderly with little formal education. Children below 16 years make up the largest share of the household. This percentage has decreased in the last decade, due to a negative population growth (Hlabisa Municipality, 2010; Muhwava & Nyirenda, 2008).

An example of the prevalence of HIV is outlined by Chimbindi, Herbst, Tint, and Newell (2010): in 2005, 40% of pregnant women in rural KZN lived with HIV and 27% of 15–50-year-old females and 14% of males were HIV positive. This most likely had labor implications for all farming households, but it likely has had a larger effect on women farmers.

The average maize plot size surveyed in Hlabisa is less than half a hectare and remained relatively consistent over three study seasons 2006–07, 2007–08, and 2009–10. Maize covers 88% of arable land (in Hlabisa) but farmers also planted vegetables including potatoes, beans, sweet potatoes, tomatoes, spinach, and pumpkins on a small scale. In 2007–08, 39% of the farmers in Hlabisa intercropped mainly beans or pumpkins with maize. Most households in Hlabisa have cattle and chickens and about half of the households own goats. Some households have a working motor vehicle, but most have electricity, a television, a radio, and at least one working cell phone. Monthly welfare grants from the government is the main source of income for most of the population. Crop production is not a main income source for most of the households and income-generating propensity for crops are regarded as quite low by farmers. According to a Hlabisa Municipality (2010), about 79% of the community receives an income of less than R2000 (about 275$ in 2010) per month. The welfare grants in the form of old age pension, child grants, and other government grants are the major income source. Remittances from family members working in urban areas also play a big role, especially where young children are being looked after by grandparents. Wage income is the main income source for only 16% of households.

The value of crop production for many of these rural households should not be measured in the income it generates but in the replacement value of the food households do not need to buy, because of self-sufficiency. The success of the season is determined predominantly by rainfall—in Hlabisa only 13% of farmers sold grain in the drier 2006–07 season, while 64% of households were able to sell grain in 2007–08 and 66% in 2009–10 when the area received more rain and the distribution was more conducive to maize production.

(d) *Gender and household decision-making*

Women play an important role in maize production in the small scale and subsistence milieu, in South Africa. The main reason for this trend is that more male household heads (compared to females) tend to be more involved with off-farm income-generating activities, leaving the senior female to produce the staple food. Table 2 disaggregates GM maize adoption by gender of the household head and maize decision maker, but information on gender of both the household head and the maize decision maker was not collected for all seasons.

Comparisons between male and female household heads and maize decision-makers for 2003–04 and 2004–05 suggest that fewer female-headed households adopted Bt but that adoption was higher in male-headed households and male-headed households where maize production decisions are made by females. In 2001–02, 82% of the 368 households surveyed in the four provinces reported that the household head made maize production decisions. Though females headed 30% of households they were the maize decision maker in 41% of households.

In each season, close to the total GM maize adopting population was surveyed and it is clear from Table 2 that adoption of Bt, HT and the Stacked variety, by female farmers, was considerable. In 2006–07, 2007–08 and 2009–10, 55%, 65% and 65% of GM adopting households were headed by females.

(e) *Characteristics of early adopters of GM maize in Hlabisa*

Farmers in Hlabisa who first planted Bt seed in 2001 were those who attended Monsanto's workshops in 2001 and received free seed samples. In the following season, when the seed was not supplied for free and only a limited quantity of seed was available to be purchased, adopting farmers were few as they were not able to get hold of Bt seed. Hence, it was only from the 2003–04 season that farmers had access to Bt seed and were able to make purchase decisions. Thus the 2003–04 Hlabisa farmers are considered here as early adopters.

In 2003–4, a total of 135 farmers were surveyed in Hlabisa and data were collected for 188 maize plots. Out of the total, 20 farmers planted both Bt and conventional maize, 15 planted two plots of conventional maize and two planted two Bt plots. These figures differ slightly from those indicated in Table 1 as not all farmers' production data was ultimately usable. Of the 77 farmers who planted Bt in 2003–04, 43 farmers had planted Bt in 2001–02 and 48 farmers in 2002–03. 91% of the farmers indicated that the main reason why they planted Bt maize was higher yield. Of the non-adopters, 52% indicated that Bt maize seed was too expensive and another 27% indicated than they could not afford Bt seed - the slight difference being the willingness to buy but inability to afford the seed. This means that almost 80% of non-adopters indicated the price of the Bt seed as the main reason for not adopting. Of the conventional maize-planting farmers, 11% indicated that they did not plant Bt maize as they had no knowledge about this type of seed, or have not heard about Bt seed.

Given the presumed self-selection bias of the sample and the small number of seed-type-specific farmers, it is statistically unfeasible to make any generalizable conclusions. It is, however, possible to cautiously make preliminary inferences from Table 3 that the households in Hlabisa who first adopted Bt

Table 2. *GM maize adoption according to gender of household head and maize decision maker in Hlabisa*

Season	Gender of HHH or decision maker	Conventional	Bt	HT	BR	Total
2001–02	Male HHH	40	40			80
	Female HHH	15	15			30
	Male decision maker	29	29			58
	Female decision maker	23	23			46
2002–03	Male decision maker	15	25			40
	Female decision maker	29	30			59
2003–04	Male HHH	53	48			101
	Female HHH	32	14			46
	Male decision maker	31	33			64
	Female decision maker	54	29			83
2004–05	Male HHH	33	18			51
	Female HHH	14	3			17
	Male decision maker	23	11			34
	Female decision maker	24	10			34
2005–06	Male HHH	21	20	12		53
	Female HHH	28	17	10		55
2006–07	Male HHH	19	11	13		43
	Female HHH	19	11	22		52
2007–08	Male HHH	7	6	13	8	34
	Female HHH	21	6	25	11	63
2009–10	Male HHH	4	0	24	6	34
	Female HHH	12	0	43	9	64

Note: In some seasons, due to incomplete data the household head and decision maker totals are not equal and because partial adopters are indicated as GM adopters the totals differ from those of Table 1.

Table 3. *Comparison of Hlabisa Bt adopters and non-adopters (2003–04 season)*

	Farmers planting conventional	Farmers planting Bt maize
Households headed by males	69%	77%*
Household head older than 60	48%	56%*
Household head with no formal education	25%	37%*
Average number of people in the household	9.3	10.8*
Main income sources		
Pension	20%	35%*
Other government grants	13%	8%
Permanent wage income	34%	18%*
Maize production	10%	16%*
Households with cattle	59%	68%*
Average seed quantity planted in 2003–04	6.5 kg	7.1 kg
Number of farmers	85	62

Statistical significance of difference between two groups.
* statistically significant at 90% level.

maize had household heads who were slightly older, with less formal education and had more household members. More Bt planting households had cattle and planted slightly more maize than their conventional maize-planting counterparts. The main income source indications are more noticeably different. Old age pension and government grants are the main income sources for 43% of Bt planting households compared to 33% of conventional maize-planting farmers; the percentage of conventional maize-planting households whose main income source is permanent wage income is almost double that of Bt households; and 16% of Bt households, compared to 10% of conventional maize households has maize as the main income source.

It would thus seem as if Hlabisa farmers who were the early adopters of Bt maize were more dependent on agriculture, and thus possibly more committed to maize production than their conventional maize planting counterparts.

HT maize was first adopted by a substantial number of farmers in 2005–06. Table 4 compares conventional hybrid, Bt and HT producers for the 2005–06 season and it is clear that (referring back to the 2003–04 comparison in Table 3) some differences between Bt adopters and conventional hybrid planters still exist but others are less pronounced and not statistically significant. The similarity between conventional maize users and Bt adopters might mean that Bt has become a more "normal" agricultural input and not only adopted by the farmers whose households are highly dependent on maize or those hoping to produce a substantial surplus.

The difference between the farmers who planted HT maize and those who planted conventional and Bt is apparent.

Table 4. *Comparison of Hlabisa conventional, Bt and HT maize seed adopters (2005–06 data)*

	Conventional hybrid	Bt	HT
Households headed by males	39%	54%**	55%**
Household head older than 60	43%	41%	55%
Household head with no formal education	15%	16%	5%**
Household head with primary education	43%	49%	57%**
Average number of people in household	8.7	9.6	7.7
Average number of people in household older than 60	0.66	0.59	0.83
Main income source			
Permanent wage income	12%	14%	27%**
Old age pension and other grants	73%	78%	55%**
Average maize plot size	0.46 ha	0.48 ha	0.46 ha
Average seed quantity planted	5.12 kg	5.82 kg	5.09 kg
Number of farmers	49	37	22

** Indicates 95% statistical significance of difference to parameters of conventional hybrid planting farmers

Comparing with Table 3, it is evident that as with the early Bt adopters, the first HT adopting households are headed by comparatively elderly men. However, in contrast, these household heads seem to be slightly better educated and the households smaller (less members) and less dependent on pension and government grants. Though the average maize plot size for HT and conventional maize-planting farmers were identical, it can be argued that due to smaller household size, more elderly household members, and more permanent off-farm income-earning members, there is a lower available labor supply. The increased wage income, on the other hand, means greater capability to purchase relatively more expensive HT seed and herbicides. This also compares well with similar research that find HT maize producing households typically have greater labor constraint than non-HT and even non-GM producing households (Regier & Dalton, 2013).

When one considers the fact that the total or close to the total population of GM seed adopters were surveyed, and that in 2006–07 the bulk of the GM maize adopting sample consisted of female-headed households (Table 2), it would appear that in Hlabisa, female farmers were able to access and adopt GM seed. In addition, based on the adoption level in 2009–10 and from our focus group discussions, it would seem as if female farmers especially favored HT seed.

Another factor that was found to have a significant impact on Bt maize adoption is farming association membership, with membership being positively associated with Bt maize adoption. The female decision maker and farmers' association link is interesting. Gouse (2012b) found that in 2003–04 less female farmers were members of farmer associations compared to male farmers. This factor is crucial as it highlights one critical limitation that female farmers' face. Access to new technology is not only access to seeds. Information regarding new technologies is often disseminated through farmer association meetings. Membership of farmers' associations is often limited among female farmers thus limiting their source of information about new agricultural techniques and methods at the early stages of introduction.

5. RESULTS AND DISCUSSION

Literature reviews by Smale *et al.* (2009) and Qaim (2012) Finger *et al.* (2011) on farm-level impacts of GM crops generally center around a broad set of indicators.

Box 1 Set of possible farm-level impacts

- Increase in gross margin and net profit
- Yield impact due to improved pest (insect or weed) control
- Decrease in the number of insecticide applications and associated labor (Bt)
- Change in the use and expenditure on herbicides (HT)
- Increase in seed expenditure due to a higher GM seed cost
- Decrease in the need for manual weed control
- Increase in off-farm income due to pest-control time saving

Gouse (2012a, 2012b) describe results from the assessment of Bt and HT maize adoption impacts on yield, pesticide and herbicide use, seed prices, gross margin, and net farm profit in South Africa. These results show, that despite significant yield increases with Bt maize (12% on average over 6 seasons at 90% confidence level), adoption rates for the HT and Stacked varieties (consisting of both Bt and HT traits) have risen substantially since its introduction and in many instances farmers have replaced Bt with HT or Stacked maize varieties.

(a) *Quantitative findings*

(i) *Impact of HT maize adoption on labor*

In order to determine the impact of Bt and HT maize adoption on labor use, detailed labor data were collected and analyzed for the 2006–07, 2007–08, and 2009–10 seasons (See Tables 5 and 6). Hourly maize production activity-specific data were collected, through a number of surveys throughout the production seasons, for all household members involved in maize production activities.

In 2006–07 and 2007–08, most HT adopting farmers use animal drawn plows to open furrows and then planted there by hand. This method of conservation tillage farming (also known as "Planting without Plowing" or PWP) has been recommended by government extension officers in the region to combat local soil erosion. This practice especially lends itself useful when planting transgenic HT or Stacked maize varieties (Gouse, Piesse and Thirtle, 2006) as weed management is easier with plants that are tolerant to specific herbicides. In

Table 5. *Preference Matrix, Hlabisa*

Criteria	Item	Assigned value for	Female grouped by type of variety planted						Male grouped by type of variety planted					
			GM	Conv	GM	Conv	GM	Conv	GM	Conv	GM	Conv	GM	Conv
			Opinion about variety with respect to assigned value for conventional						Opinion about variety with respect to assigned value for conventional					
		Conv.	Bt		RR		BR		Bt		RR		BR	
Availability	Seed	10	4	6	22	8	22	8	5	4	6	4	4	4
Cost	Seed	10	22	20	86	30	110	40	6	29	8	47	25	69
	Weed control	10	9	30	40	30	35	30	25	40	7	125	7	125
Time spent	Land Preparation	10	3	−30	4	−30	4	−30	26	30	8	8	4	8
	Weed control	10	20	−35	8	−35	8	−35	28	10	6	2	6	2
Physical effort	Weed control	10	5	−40	5	−40	5	−40	26	10	5	2	5	2
Insect control		10	16	15	9	15	8	15	2	–	19	52	2	–
Yield		10	8	15	38	15	61	15	14	58	11	58	37	58
Quality	Green maize	10	12	50	65	50	83	50	15	35	11	35	51	35
	Grain	10	5	−20	55	−20	55	30	36	27	30	27	43	27
Taste		10	4	22	5	22	6	42	26	7	26	7	26	7
Profits		10	5		122		122		28	10	24	10	68	10
Drought tolerance		10	6	20	45	20	58	20	22	18	20	18	30	18

Table 6. *Labor use comparison for farmers using manual weeding (Bt+Conv) vs (HT+BR) with broad-spectrum herbicide in Hlabsia, South Africa. Figures indicated in 7-h man (person) days*

Row Labels	Farmers/plots	Land prep and planting	Herbicide application	Manual weeding	Harvesting	Total family labor
2006–07	95					
Bt+conv	60	13.5	0.0	18.8	9.1	41.4
HT+BR	35	16.9	3.9	0.0	13.6	34.4
p-value of difference		*0.09*	*0.00*	*0.00*	*0.00*	*0.05*
2007–08	97					
Bt+conv	40	11.5	0.5	16.9	11.4	40.4
HT+BR	57	5.6	5.3	0.2	10.4	21.5
p-value of difference		0.00	0.00	0.00	0.23	0.00
2009–10	98					
Bt+conv	16	14.0	0.2	20.6	10.4	45.2
HT+BR	82	4.9	2.6	0.5	7.4	15.4
p-Value of difference		*0.01*	*0.00*	*0.00*	*0.07*	*0.00*

A *p*-value larger than 0.1 means the difference is not statistically significant at the lowest acceptable significance level of 90%.

2009–10, 96% of the farmers who combined land preparation and planting by using hand and hoe, planted HT or Stacked variety maize. It would appear as if HT adopters in Hlabisa have decided that the most cost- and labor-effective way to plant is to just "open plant and close" using a hoe and no plowing is done. This is in line with the planting without plowing practices recommended by the Agricultural Research Council. Though some farmers made use of tractors or animals, to prepare a seed bed, the majority planted by hand. In the study area, however, Bt maize adoption had very little impact on saving on insecticides and the related application labor because of minimal insecticide usage by smallholder maize farmers.

Because some of the seed-specific samples are rather small, in order to compare labor usage, farmers were grouped according to production systems. i.e., farmers that planted Bt and conventional hybrid farmers controlling weeds by hand and hoe were grouped together and HT and farmers planting Stacked variety using a post-emergent broad-spectrum herbicide (glyphosate) were grouped together (Table 5).

While land preparation and planting labor indications are somewhat distorted by the use of tractors and animal traction by some farmers, the labor indications for herbicide application, manual weed control, and harvesting are believed to be an accurate reflection of labor days spent by household members.

(b) *Gender-specific labor impact of HT maize adoption*

Figure 2 presents labor data collected for all household men, women, and children involved in the various maize production activities, irrespective of household gender or seed type. Data in Figure 2 are expressed as the average labor commitment share for men, women, and children, relative to the total activity-specific required labor time investment. Zero values were excluded from the calculation, so for example child weeding hours were only included for households where children took part in manual weeding.

It is clear from Figure 2 that the time share for men, women, and children vary somewhat through the three seasons depending on available resources and services.

Land preparation is mainly done by male household members especially when machinery and oxen are used, whereas planting is done by mainly female household members.

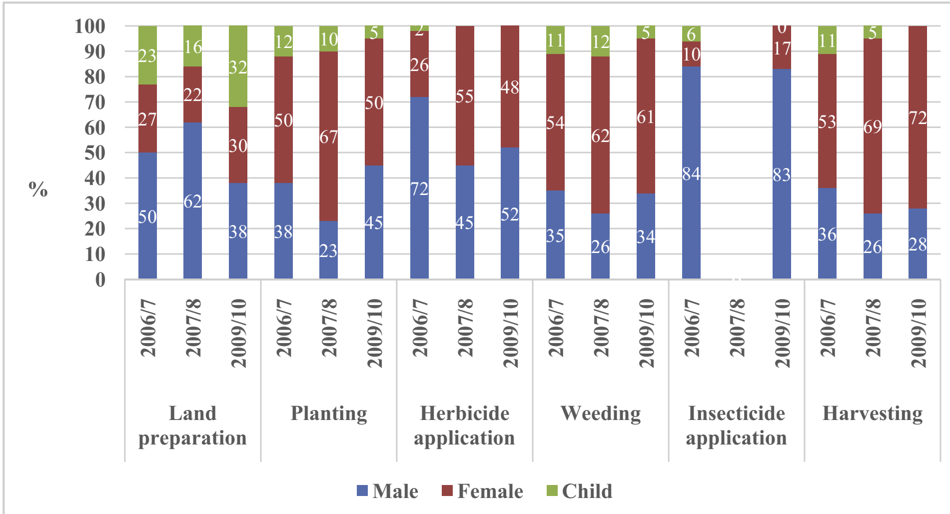


Figure 2. *Household member maize production labor commitment indicated as share of total labor effort.*

Herbicide application and the necessary insecticide application are done by men while women and children tend to be responsible for fetching water for insecticide spraying. Female household members perform the bulk of the manual weeding and harvesting.

By applying the activity-specific household member time commitment shares to the differences between labor use for Bt + conventional and HT + Stacked in Table 5, it is possible to calculate the household member-specific herbicide tolerance technology labor impact indicated in Table 6. The difference in labor use was calculated by deducting Bt + conventional maize's labor requirement from that of HT + Stacked maize. A negative sign in Table 6 thus means that herbicide-tolerant maize required less labor and that the HT trait had a labor-saving effect.

In herbicide-tolerant maize-adopting households in Hlabisa in 2006–07, male household members saved 0.64 seven-hour labor days through the season (about four and a half hours) while female household members saved 5.4 labor days and children about a day. In this season substantial weeding labor savings, 6.6, 10.2, and 2.1 days respectively for males, females, and children, were partially replaced by increased demand for land preparation and planting labor, herbicide application by predominantly males and increased harvesting labor. In interpreting these findings it is good idea not to look at the total labor use savings but rather at the individual activities as the physical effort of manual weeding cannot be compared to that of, for instance, herbicide spraying.

In 2007–08, the adult female members in HT and Stacked maize adopting households in Hlabisa were able to spend more than 10 weeding days (72 h) less in the maize field compared to their Bt and conventional maize planting counterparts. In 2009–10 females in herbicide-tolerant maize-adopting households saved more than 12 weeding days and males almost 7 days.

In the 2007–08 survey, as well as during the focus group discussions, HT and Stacked variety adopting farmers were asked what they and their household members did with their saved time. Generally household members spent more time doing what they would normally do, when not weeding. Male household members tended to spend more time tending to cattle and goats. Males also spent more time on off-farm income-generating activities like building, wood work, "piece jobs", hunting, or spending more time on permanent employment. Females spent most of their extra time doing housework (cleaning and cooking) and working in their own or community vegetable gardens. Children in both areas spent more time relaxing (playing, swimming and watching TV) and doing school homework and housework. The trend was clear and consistent across male and female farmers cultivating GM varieties.

(c) *Qualitative discussions*

Structured small group discussions also shed light on the relationship between productivity changes, adoption and gender related issues. Most GM-maize cultivating farmers, both male and female, said that they practiced planting without plowing, a no-till approach where mechanized or animal traction land preparation and manual weeding are replaced with planting by hand held hoe and chemical weed control. The Stacked variety along with single trait HT maize most lends itself to a no- or conservation tillage production system. This was also evident, as both men and women farmers unanimously said that they preferred the stacked variety compared to the single Bt trait. Women farmers cultivating conventional maize reported not having much knowledge about herbicide and insecticide use. Male farmers planting conventional maize did not use herbicide but did apply insecticides on their crops. (See Table 7)

Both men and women cultivating GM varieties expressed that they spent considerable less labor time than when cultivating conventional hybrids or traditional varieties. Farmers ranked HT and the stacked varieties highly. Even farmers, both men and women, who cultivated conventional maize varieties, suggested that there could be significant time savings involved when cultivating HT and Stacked variety maize.

However, it was difficult to tease out whether the increase in yields from cultivating GM maize ultimately offset labor saved in weeding with increased labor required for harvesting. Subramanian and Qaim (2009) for Bt cotton in India found that this increase in labor required during harvesting might be coming from hired female labor and not from household females. However, in the social milieu of Hlabisa, women

Table 7. *Herbicide-tolerant maize adoption impact on household labor (7 h man days/ha)*

	Maize production activity	Male	Female	Child
Hlabisa				
2006–07	Land preparation and planting	1.50	1.31	0.60
	Herbicide application	2.81	1.02	0.08
	Weeding	**−6.59**	**−10.16**	**−2.07**
	Harvesting	1.63	2.40	0.50
	Total	−0.64	−5.44	−0.90
2007–08	Land preparation and planting	−2.52	−2.64	−0.77
	Herbicide application	2.15	2.63	0.00
	Weeding	**−4.33**	**−10.33**	**−2.00**
	Harvesting	−0.28	−0.73	−0.04
	Total	−4.99	−11.07	−2.81
2009–10	Land preparation and planting	−6.21	−2.37	−0.55
	Herbicide application	1.25	1.15	0.00
	Weeding	**−6.82**	**−12.23**	**−1.00**
	Harvesting	−0.85	−2.18	0.00
	Total	−12.63	−15.63	−1.55

farmers often are part of working groups (*Ilima*) where a group of farmers take turns doing mainly planting and weeding on each other's maize plots and members are "paid" with food and drink. This was mentioned in the focus groups as one of the sources of labor which women farmers counted on. While this group helped other women farmers in planting and weeding, some focus group farmers also alluded that they used the group's help during harvest time.

Since most maize is often cultivated for household consumption, especially by women farmers, quality perceptions were more important than the yield factors. Farmers (both men and women) ranked quality of green maize from the GM varieties (especially HT and Stacked variety) much higher than the non-GM variety. Farmers who cultivated non-GM maize, especially women farmers were not aware of this aspect and were very surprised to hear that. Again it was observed that the stacked variety consisting of both Bt and HT traits was ranked higher than Bt.

The ranking is opposite for taste of the green maize. The taste difference between the GM and traditional green (fresh) maize came out more as a varietal difference. Farmers did not rank the GM varieties or the non-GM hybrids highly. Women farmers seem to be more concerned about the taste (as most of them grow maize for household consumption) and ranked all GM varieties lower than traditional ones compared to men who cultivate GM maize. Here, it needs to be clarified that the traditional varieties which were considered to be of "good" taste were mostly non-hybrid local open pollinated varieties (OPVs).

To assess to importance of women farmers' contribution in the smallholder production system in KZN, the small group discussion had questions to understand whether women farmers (both in female- and male-headed households) had independence in making their own seed and planting decisions, or whether they simply completed assigned tasks from the household head or operations manager.

In Hlabisa, women farmers planting GM maize make input purchase and production decisions, irrespective of the household head's gender. Within the women-only focus groups, all the women said they took these decisions by themselves. Very few women said they involve another household member, even their husbands, in the decision-making. Since most of the women planted the stacked maize variety, using a no-till approach, they did not use insecticide and applied herbicide after germination. They reported that these decisions too they made themselves and they used household labor or hired help to spray herbicide. Regarding the benefits of GM crops, men cited yield as the main reason they planted GM varieties. To the men farmers Bt maize was the variety of choice. Cost- and time-saving benefits were followed by the perceived drought-tolerant properties of the new stacked variety consisting of both Bt and HT traits. What was surprising was that women farmers termed quality of the maize as the number one reason for planting the stacked maize. Though this comes only from the focus and small group discussions, it is interestingly different from the previously held notion that women farmers like GM maize in terms of their yield, but are concerned about the taste and quality compared to traditional maize or conventional hybrids. Both men and women farmers in the focus groups felt that the newer varieties in which the stacked traits were inserted were of better quality and hence comparable to the non-GM hybrids, with the added benefits of Bt and HT.

In the focus groups, women farmers in Hlabisa ranked the time saved from GM maize (HT and Stacked) cultivation very highly. The high seed price was a concern for both men and women farmers, coupled with inability to find GM seed when needed. Women farmers pointed out that the seeds were not always available which was corroborated in the data as a distribution problem which was later partly addressed by Monsanto. Men felt that lack of a market for selling the extra yield deterred them from cultivating the GM varieties. Women did not find this a problem as their crops were mostly for subsistence with only a small proportion allocated for the local market.

Among the non-GM cultivators, women farmers did not seem to know much about GM crops while men farmers, though they did not cultivate GM, had a fair idea about the benefits and problems of the GM varieties. Women farmers knew about some of the benefits of cultivating GM maize from their neighbors and friends, but did not know much about the seed types. This factor is reflective of gender-specific disparities in technology adoption. Lack of information about new varieties and their specific benefits feature more prominently among women farmers than men. Both men and women farmers not cultivating GM maize thought the production cost of GM maize to be much higher than that of conventional maize. In contrast, there was not enough information about the potential benefits from GM cultivation which often offset the costs. Regier and Dalton (2013) for the same research area found that the labor-saving aspects of HT maize significantly reduced costs. There is also some cost offsets associated to Bt maize due to increased yields (Gouse, 2012a).

6. CONCLUSIONS

This study shows that even though women maize farmers in South Africa appear to be slow in adopting new technologies, they can potentially benefit more from the introduction of GM technologies than their male counterparts due to their specific roles in the smallholder production system in KZN, South Africa. Women farmers seem to value the weed control benefit of herbicide-tolerant HT maize than the borer control benefit of Bt maize. In a community where the majority of farmers are elderly and HIV/AIDS and out-migration constrains household supply of labor, a labor-saving technology (ease of production) of the HT and stacked varieties seem to be preferred by women farmers over gross income or yield increases from Bt varieties. Also, the newer stacked variety consisting of both Bt and Ht traits seem to bring the benefits of both yield increases as well as labor saving to women farmers in the region. With these traits coming in superior varieties more suited to local conditions, both men and women farmers seem more satisfied cultivating GM maize varieties.

While we clearly find that women farmers save in weeding time by cultivating the HT and stacked maize, it was not clear if this was offset due to higher demand for labor during harvesting. The existence of the "working groups" of farmers made calculating actual time spent in harvesting/weeding and planting often difficult. However, in a social context where women farmers are increasingly having to act as *de facto* decision makers in small holder production systems, the existence of such groups have made accessing labor a little easier for women farmers.

A plethora of researchers studying African agriculture have, over the last forty to fifty years, identified the labor demand bottleneck during the crucial land preparation, planting and weeding time as a crippling hindrance to crop yield and production expansion. This seasonal labor shortage is exacerbated by more recent out-migration to cities in search of employment and a substantial share of Sub-Saharan Africa's agricultural land is lying fallow. A technology that can result in labor-saving during the crucial labor demand period, can result in increased time spent on other food and cash crops and/or expansion of the cropping area. It is argued that herbicide tolerance holds substantial potential for African farmers due to the labor-saving impact combined with the yield improvement that can be expected when weeds are controlled effectively. However, adoption of herbicides by African smallholders has been notoriously low due to a number of reasons including issues of affordability, timely and predictable availability and support through training and information dissemination. It can be expected that these same factors will limit the adoption and thus the substantial benefits farmers could have derived from HT crops. Development and sustainment of functioning input and output markets require political will and long-term investment in infrastructure and support services.

NOTES

1. "For example, at the 2005 UNDP Unpaid Work and the Economy: Gender Poverty, and the Millennium Development Goals. Global Conference: 54.conference at Levy in New York, Jaques Charmes provided information gathered in Africa (mainly from time use surveys). He noted that with core domestic activities (preparing meals and washing up, washing and ironing, and care of children), the gap between women and men is huge: women's contribution varies from 13 or 12 times men's (for preparing meals) and 10 or 9 nine times(for both meals and washing up) in Madagascar, Benin, and Mauritius, to 2 or 4 times in Ghana and South Africa respectively. Childcare takes 13 times more of the time of women than of men in South Africa, 7 times in Benin, 6 in Madagascar, 3 in Mauritius, and nearly 2 times in Ghana. Charmes' is just one of many reports in both the developed and developing world that show such pronounced gender differences." http://mpra.ub.uni-muenchen.de/11082/1/MPRA_paper_11082.pdf.

2. When Bt maize was first introduced to small-scale farmers in 2001, Monsanto, owner of the technology, identified and selected nine areas across the Mpumalanga, KwaZulu-Natal (KZN), Eastern Cape and Limpopo Provinces in South Africa where subsistence farmers or rural households produce maize under dry-land conditions. Monsanto invited around 3,000 male and female farmers to workshops held in their nearby areas and informed participants in their local language about the characteristics of Bt maize. Monsanto also distributed free Bt seeds to all workshop participants along with non-GM hybrid seed (isoline) so farmers could compare their performance side by side. When HT maize was approved for commercial release during the 2003/04 season, Monsanto planted a couple of demonstration plots in locations near areas where smallholder farmers had already planted Bt maize in previous seasons. The characteristics of HT maize were explained by Monsanto representatives at farmer days and herbicide application demonstrations were done on the maize plots. Pamphlets written in local language explaining in a stepwise fashion how and when herbicide should be applied were distributed. The seed company also supplied additional training to government extension officers on the use of herbicides to enable them to advise and assist farmers.

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