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The Challenges and Opportunities Associated with Bt Maize in Sub-Saharan Africa

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Bt maize technology involves developing hybrid maize crops that incorporate genes developed from the soil dwelling bacteria Bacillus thuringiensis (Bt). The primary benefit of Bt maize technology is the heightened crop protection from stem borers, which are maize pests that can inflict serious crop losses. Bt maize has been grown in Mexico, South Africa and several countries in the EU, with more limited Sub-Saharan Africa (SSA). This report provides a summary of literature on the potential benefits associated with Bt maize production in SSA, as well as literature highlighting some potential challenges. Research studies of Bt maize in the Philippines and South Africa are also briefly reviewed.

There is little peer-reviewed literature available with evidence challenging the assumed benefits of Bt maize for smallholder farmers in SSA (Smale et. al 2009). As a result, we also reviewed research briefs and conference proceedings available from reputable international organizations. Although some of the available literature references the ethical concerns over Bt maize production, we focused on searching for science-based discussions related to any potential biodiversity, biosafety, or socio-economic impacts of Bt maize technology for smallholder farmers in SSA. In addition, there is literature available on Bt cotton and other transgenic crops in Sub-Saharan Africa, however, we focused on literature related to Bt maize for this summary. A more in-depth look at the literature on Bt cotton and comparison to Bt maize technology could be prepared upon request.

KEY FINDINGS

- Bt maize is expected to provide significant yield benefits for smallholder farmers in SSA by reducing crop loss from stem borers. However, the size and the consistency of the benefits associated with Bt maize in SSA are not conclusive. Studies on the impacts of Bt maize are unclear due to small sample sizes, selection bias and endogeneity of farmer's decision to grow a Bt crop and apply insecticides. In addition, the extent of the gains associated with Bt maize depends on the geographic location of the research studies, length of period between adoption and observed impact, and other factors. Finally, as Smale and others note, there are relatively few peer reviewed articles or case studies providing evidence on the extent of gains from Bt maize. Of the articles that are available, there are relatively few different authors, which suggests a narrower range of opinions (Smale et. al 2009).

- The available literature estimates that crop losses due to stem borers in Kenya are approximately 14 percent of annual harvest or a total of 400,000 tons of maize with a value exceeding $90 million (De Groote, 2002). This significant loss is commonly cited as motivation supporting the potential benefits associated with Bt maize production.

- Other possible benefits of Bt maize technology include increased food security and reduced pesticide use and costs (Smale, Owour et al., 2004). In addition, the technology does not involve significant input costs and can be disseminated easily to farmers in SSA (Smale, De Groote et al., 2006).

- The available literature indicates that the more tolerant a variety is to stem borers, the larger the area farmers in SSA are likely to allocate to maize regardless of whether it is a hybrid or local variety. According to Smale's findings, "farmers would show greater interest in using maize varieties that are resistant to stem borers, whether a hybrid or local variety." This preference is believed to underscore the significance of crop losses to stem borers in SSA (Smale, De Groote et al., 2006).

- The demand for Bt maize as well as the potential benefits of this technology vary across agro-ecological zones in SSA. The observed adoption rates of Bt maize remain lower in the more marginal maize producing environments in SSA than in high-potential agricultural zones. In Kenya, adoption rates for improved maize varieties, including Bt maize, have reached nearly 90 percent in zones with high-production potential (Smale, De Groote et al., 2006).

- The literature indicates that the potential risks associated with Bt maize production include the evolution of resistance and uncontrolled flow of transgenes (Smale, De Groote et al., 2006). We were unable to find scientific, peer-reviewed literature demonstrating that Bt maize has adverse consequences for human health or non-target species. Of the limited studies[1] that have been done on Bt maize, Smale cites studies from the GAO and FDA, which state that there is no evidence to date that Bt maize presents human health risks that are not also associated with conventional maize (GAO, 2002).

- In a research brief, Smale and others note that farmer demand for hybrid maize seeds, including Bt maize, often increases with education. However, educated male farmers tend to shift away from

[1] See Smale et. al 2009 for a count of publications on transgenic crops.

agriculture or toward cash crops as their education increases. Because of this relationship, these authors suggest the potential for a negative relationship between the education of male farmers and demand for hybrid Bt maize seed. They also note, however, that women tend to remain heavily involved in production even as their education increases (Smale, De Groote et al., 2006).

Key Organizations and Authors

IRMA Project: A majority of the literature available on Bt maize in SSA is associated with the Insect Resistant Maize for Africa (IRMA) project[2]. The IRMA project is a collaborative effort between the International Maize and Wheat Improvement Centre (CIMMYT) and the Kenya Agricultural Research Institute (KARI) to develop genetically modified maize varieties. In addition to developing maize varieties, the goals of the project include creating a better understanding of potential environmental and social impacts of Bt maize, as well as regulatory systems and intellectual property law associated with the technology. Field projects and initial impact studies conducted by the IRMA project provide some evidence of the field-level benefits of Bt maize technology in SSA, primarily the reduced crop loss due to stem borers. However, the literature available is limited and no other characteristics of the variety beyond pest resistance and yield potential are noted in the published literature. The IRMA project is focused in Kenya, therefore much of the literature available on Bt maize in SSA is focused in this region. Several authors note that Kenya is an attractive place for Bt maize production because the regulatory environment for GM technology is relatively accepting. In addition, Kenya has one of the highest per capita maize production rates in the world, which suggests that increased yields could result in significant benefits for farmers (Mugo, De Groote et. al, 2005).

Commonly Cited Authors: Melinda Smale (IFPRI, now at Oxfam), Hugo De Groote (CIMMYT) and George Owuor (CIMMYT) are authors of the most commonly cited articles related to Bt maize in Africa. Much of the information presented in this summary comes from research papers and briefs from these authors. There is little other empirical evidence to either support or challenge claims around Bt maize in SSA.

Bt Maize in the Philippines

Several research studies offer insights into the potential benefits and challenges associated with Bt maize production in the Philippines where the crop is grown commercially. In a 2006 publication, Yorobe and Quicoy predicted Bt maize adoption rates and net returns using sample data from 107 Bt and 363 non-Bt growers in four provinces. They found that per-unit yields and incomes were higher and insecticide expenditures were lower for Bt growers. In addition, they concluded that major determinants of adoption were risk perceptions, education, training, and use of hired labor. "Increasing the probability of adoption by

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[2] See project website: http://www.cimmyt.org/english/wpp/gen_res/irma.htm.

10% increased net farm income by 4.1%," an adoption elasticity that is "higher than those observed in developed countries" (Yorobe and Quicoy 2006 in Smale et. al 2009).

Bt Maize in South Africa

Two studies by Gouse and others provide preliminary evidence about the impacts of Bt maize in South Africa. Using farm-level survey analysis of small and large scale farmers, they found:

- Bt maize increases smallholder maize farmer income except in years with significantly low borer infestation levels.
- The yield value depends on the extent that farmers utilized the additional grain for home grinding and consumption, substituting for more expensive store purchases.
- In one study that in the fourth consecutive season with scant rainfall, Bt maize and non-Bt hybrid yields were similar.
- That Bt may provide an affordable insurance against unforeseen pest outbreaks but increases in seed cost or technology fees could easily impact the benefits of Bt maize to smallholder farmers in South Africa.

Brief Overview of the Benefits of Bt Maize Production in Sub-Saharan Africa

Overall, the literature on Bt maize technology suggests that adopting Bt maize could lead to several significant benefits for farmers. The advantages of Bt maize technology include the following:

1) **Increased yields due to decreased losses from stem borer damage:** Bt maize addresses problems associated with stem borer damage, which is a major challenge to small farmers in SSA. In multiple publications, De Groote establishes through statistical analysis and field-level surveys with farmers that stem borers are a major constraint to maize production. De Groote calculates maize yield losses based on a survey of 1400 farmers by CIMMYT and KARI spread over different agro-ecological zones in Kenya, as well as field-level measurements of crop losses. The results show that crop losses average 14 percent per annual harvest. The estimates across the zones ranged from 11 percent loss in the highlands of Kenya to 21 percent in the dry areas. These estimates are commonly cited throughout the literature in support of the potential benefits of Bt maize in SSA, and Kenya specifically because of the prevalence of stem borers. In a follow-up publication, De Groote states, "Based on the importance of maize as a food and cash crop, farmers' perceptions of the importance of stem borers and loss assessment, we can conclude that there is a large demand for the technology." He notes that potential demand could be especially high

in Kenya if an effective gene against B. fusca, a particular type of stem borer, can be found (De Groote 2002).[3]

2) **Improvements in food security:** Bt maize could increase yields of food crops and some researchers believe, reduce yield variability and risk. If this occurs, widespread adoption and spread of Bt maize technology could lead to improvements in food security. These benefits could be significant in Kenya, in particular, where population growth has exceeded food production (Owuor, Smale et. al, 2004).

3) **Ease of dissemination:** The technology of Bt maize is embedded in the seed and, therefore, dissemination is quick and inexpensive. The ease of dissemination is particularly important in areas where extension services are unavailable. Although this is a potential benefit associated with the technology, some have noted that the uncontrolled spread of Bt maize through cross-pollination or seed mixing and recycling could lead to a loss in farmers' choices between GM and non-hybrid varieties (Owuor, Smale et. al, 2004). Some have claimed that the spread of GM crops, including Bt maize, could result in lost trading potential because GM crops are banned in some countries. We were unable to find any published literature to support or refute this claim. The flow of transgenes through cross-pollination or seed mixing could make it difficult for farmers to produce non-GM crops.

4) **Reduced pesticide use and costs:** Smallholder farmers in SSA face economic obstacles to addressing stem borer losses because of the high cost of pesticide inputs. Bt maize technology is a low-cost option for addressing the challenges that smallholder farmers face in protecting yields from stem borer attacks. We were unable to find peer-reviewed literature to suggest that the reduced need for pesticide leads to increased use of positive inputs such as fertilizer.

Challenges and Risks Associated with Bt Maize

Despite the potential benefits of Bt maize in SSA, the spread of GM technology in Africa has contributed to concerns related to possible biosafety and biodiversity impacts. In addition, potential challenges associated with Bt maize production could occur due to variation in adoption rates across agro-ecological zones in SSA and other socio-economic factors, which are summarized below. The potential biodiversity and biosafety risks associated with transgenic varieties have been subject to significant controversy in the international community and the scientific evidence is either inconclusive or unavailable. Much of the literature that is available tends to be advocacy-based rather than supported by scientific evidence. Table 1 on the following

[3] B. fusca is prevalent in the highlands and mid-altitude zone of western Kenya and reduces yield by tunneling the stalk and shank of the ear.

page outlines commonly cited biosafety and biodiversity risks associated with Bt maize and an explanation of scientific evidence that either supports or challenges these risks.

COMMONLY CITED BIOSAFTEY AND BIODIVERSITY RISKS ASSOCIATED WITH TRANSGENIC PLANTS AND BT MAIZE
1. Flow of Transgenes Several publications note that the possibility of gene flow through cross-pollination is very high for maize. Cross-pollination is particularly prevalent when landholdings are fragmented; varieties are planted close together; and farmers recycle, exchange, or mix maize seed. Reuse of maize seed is common in most of SSA, which increases the potential for cross-pollination to occur (Smale, De Groote et. al, 2006).
2. Evolution of Resistance Limited crop diversification in SSA and dominance of Bt genes contribute to the potential risk of stem borer resistance to Bacillus thuringiensis (Bt). The risk of Bt resistance is further increased by the practice of mixing and recycling of seed. In addition, Bt genes are single genes that result in significant pest mortality. This strong impact on pests may lead to greater pressures for mutation and eventual resistance to Bt technology (Smale, De Groote et. al 2006). While Bt resistance has been documented in laboratory settings, we were unable to find published literature with evidence on field-evolved Bt maize resistance. Several authors note that field-evolved resistance has not yet been documented (Tabashnik, Carrière et. al, 2003). In their book, Hilbeck, Adnow and others describe how the potential for resistance risk varies geographically throughout SSA. Due to these differences, the risks associated with the evolution of resistance are likely to vary throughout the region. More specifically, factors that influence the potential risks associated with the evolution of resistance include the type of stem borers in the region, how quickly the spread of Bt maize technology occurs, pest species and larval movement, the proportion of area devoted to maize production, and other agro-climate related factors (Hilbeck et. al, 2006).
3. Effects on Nontarget Species The literature available on Bt maize indicates that the risks to nontarget arthropods are negligible (Smale, De Groote et. al, 2006). The effects of Bt technology on nontarget species remain unknown.
4. Human Health According to IFPRI and the Government Accountability Office (GAO), no studies have found health risks associated with Bt maize that are not associated with conventional maize varieties (GAO 2002).

In addition to the potential for biosafety and biodiversity risks, there could be other challenges to spreading Bt maize technology in SSA in a way that will benefit smallholder farmers. A brief overview of these challenges is presented below. A more detailed analysis of these factors could be prepared upon request.

Geographic and Socio-economic Factors Influencing Potential Benefits for Smallholder Farmers

Geographic Variation in Adoption

In general, improved varieties of maize have spread more slowly through marginal production areas where yield potential is lower than in high-potential areas.[4] However, the available literature indicates that the more

[4] Again, much of the literature on the potential demand and adoption of Bt maize in SSA focuses on Kenya. There is some literature available on the spread of Bt maize through Mexico, Europe and South Africa, which the author could

tolerant a variety is to stem borers, the greater the amount of maize area farmers in SSA are likely to allocate to it regardless of hybrid or local variety (Smale, De Groote et. al, 2006). More detail on literature examining adoption rates for hybrid seeds in SSA or Kenya specifically could be reviewed upon request.

Education

Studies on the potential demand and adoption by Smale, De Groote and others suggest that education may have a negative effect on hybrid maize adoption for male farmers while women are expected to remain heavily involved in food production regardless of the variety across all agro-ecological zones in Kenya (Smale, De Groote et. al, 2006).

Livestock Assets, Wealth, and Labor

Econometric estimations suggest that wealth in livestock assets is positively related to demand for hybrid seeds in both high- and low- potential zones in Kenya. In the high-potential zones, increased wealth is found to be positively related to a higher proportion of area dedicated to hybrid maize. In the low-potential areas, specifically on the coast of Kenya, the more important maize is in the cropping system, the smaller the proportion of area dedicated to growing the local variety relative to a hybrid.

Smale and De Groote note that input-market access increases the probability that a farmer will grow hybrid maize and that a greater proportion of hired labor in the village is associated with a smaller proportion of maize area dedicated to growing the hybrid varieties. They suggest that one explanation for this difference could be that more labor is dedicated to cash crops than to maize because the economic returns to labor are higher (Smale, De Groote et. al, 2006).

In summary, this information suggests that various factors including education, gender, input-market access, seed prices, and labor intensity could influence the demand and adoption of Bt maize in SSA (Smale, De Groote et. al, 2006). Overall, however, the published literature on Bt maize is relatively sparse, limiting the evidence that supports or refutes claims of its costs and benefits.

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explore further upon request. For a case study of yield improvements in South Africa, see Keetch, D.P., Webster, J.W., et. al (2005).

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