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Lecture

Transgene Flow in South African Commercial Maize Cultivation

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Background and aim

South Africa is one of a few countries in Africa that has introduced genetically modified (GM) crops. First generation GM maize has been commercially grown in SA since 1997 (Department of Agriculture 2005). In 2008, South Africa was ranked eighth in terms of global commercial GM production that included cotton, soybean, yellow and white maize (James 2009). Gene flow from GM crop to non-GM crop may have several consequences including: the development of resistance in target insects for Bt crops; the contamination of landraces; loss of trade in processed and bulk grain commodities; the contamination of the food chain by experimental, industrial or pharmaceutical GM crop . Thus, similar to other GM producing countries, SA has to deal with considerations to minimize or prevent comingling through the use of isolation distances, where necessary, for GM field trials and coexistence (Huffman 2004; Moschini 2006). A further consideration is that specialist GM crops including pharmaceutical production, nutritional enhancements, and bio-fuels are expected to become a reality within the near future. Minimizing gene flow for different applications from contained use through to environmental release is an important consideration. In the past, several studies have recorded different distances of cross pollination for maize, using a variety of field trial designs under different environmental conditions (Aylor et al. 2003; Bannert and Stamp 2007; Burris 2001; Byrne and Fromhertz 2003; Della Porta et al. 2008; Garcia et al. 1998; Henry et al. 2003; Jemison and Vayda 2001; Luna et al. 2001; Ma et al. 2004; Paterniani and Stort 1974; Stevens et al. 2004). However, these trials have usually been small plots and not on the scale of commercial farming. Furthermore, very few of these studies have made specific recommendations with regard to the ideal isolation distance required in terms of different stringencies for minimizing cross pollination. For example, different tolerances for comingling may apply to field trials under contained use compared to the production of maize engineered for bio-fuels. There is also no published data regarding the extent of cross pollination for maize in South Africa and regulators have to base decisions on available data not necessarily applicable to South Africa. Thus the aim of this study, conducted from 2005 to 2007, was to determine the extent of maize cross pollination under South African conditions in the context of commercial farming practice, that could inform the regulatory decision making process with regard to GM field trials.

Materials and methods

Field trials were planted with a central plot of yellow GM maize (0.0576 Ha) surrounded by white non-GM maize (13.76 Ha), in two different geographic regions over two seasons with temporal and time isolation to surrounding commercial maize planting. Cross pollination from GM to non-GM maize was determined phenotypically, across 16 directional transects, every 2 m up to 100 m and thereafter every 10 m up to 300 m. Pollen was captured during flowering in four wind directions and genotyped using PCR. Pollen counts during flowering were compared to weather data as well as percentage cross pollination. The data was transformed logarithmically and mean percentage cross pollination compared to high cross pollination.

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Results and discussion

Although there was general congruency between wind data, pollen load and cross pollination, it is evident that wind data and pollen load do not solely explain the directional extent of cross pollination. We suggest that swirling winds and other biotic factors may have contributed to this incongruence. The highest cross pollination ranging from 54% to 82% occurred at two meters from the pollen donor and declined sharply up to between 20 to 25 m, a trend similar to other studies (Henry et al. 2003; Jemison and Vayda 2001; Luna et al. 2001; Ma et al. 2004). Interestingly, a low percentage plateau of cross pollination was observed up to the furthest distance sampled. There was a high correlation of logarithmically transformed mean percentage cross pollination of distance (R^2=0.97). Based on the logarithmic transformation of cross pollination over distance, 50 m is sufficient to minimize cross pollination to between <1.0% to 0.1%, 159 m for <0.1% to 0.01% and 501 m for <0.01% to 0.001%. However, an important consideration when using mean cross pollination values is that the potential of cross pollination to occur, may be under estimated. To test this hypothesis, we performed a logarithmic transformation of high values of cross pollination over distance. It is interesting to note that there was a high correlation for high values of cross pollination over distance (R^2=0.95). Based on these values, a theoretical isolation distance of 135 m is required to ensure a minimum level of cross pollination between <1.0% to 0.1%, 503 m for <0.1% to 0.01% and 1.8 km for <0.01% to 0.001%. However, it is not practical to apply such stringent isolation distances, especially when different minimum levels of comingling may be required. We therefore suggest that a combination of temporal and distance isolation be combined, taking into account the GM maize pollen sources within the radius of the most stringent isolation distance required. We also investigated graphical shifts in percentage cross pollination over distance, over the different locations at which trials were planted. We noted that a shift in percentage cross pollination over distance was similar to the comparison of mean compared to high values for cross pollination. Based on the incongruence between pollen load, environment and cross pollination, as well as taking into consideration the comparison of mean compared to high values of cross pollination, we suggest that pollen load, environment and reproductive physiological characteristics are factors in determining cross pollination.

Based on these data, the following is recommended to achieve minimal cross pollination at different threshold levels:

- **Field trials:** To minimize out-crossing to a non-detectable level (0.01%-0.001%) the isolation distance should be at least 1.87 km. It may be difficult to achieve this in practical terms and it is suggested that a combination of spatial and temporal isolation be used taking the following into consideration:
  - Apply a four week temporal isolation up to a minimum distance of 503 m to the nearest maize planting
  - Apply a two week temporal isolation up to a minimum distance of 1.87 km to the nearest maize planting
- **GM seed production:** To prevent the development of illegal stacked events during seed production the recommendations for field trials should be applied.
- **Non-GM seed production for export purposes:** In order to comply with export requirements for non-GM seed, i.e. GM is not detectable, the recommendations for field trials should be applied
- **Non-GM production:** Depending on the required threshold for non-GM production the following measures can be applied:

- 1% threshold: A minimum isolation distance of 135 m should be applied. It may be difficult to achieve this in practical terms, instead it is suggested that a combination of spatial and temporal isolation be used taking the following into consideration:
    - Apply a four week temporal isolation up to a minimum distance of 36 m to the nearest maize planting
    - Apply a two week temporal isolation up to a minimum distance of 135 m to the nearest maize planting
- 0.1% threshold: A minimum isolation distance of 503 m should be applied. It may be difficult to achieve this in practical terms, instead it is suggested that a combination of spatial and temporal isolation be used taking the following into consideration:
    - Apply a four week temporal isolation up to a minimum distance of 135 m to the nearest maize planting
    - Apply a two week temporal isolation up to a minimum distance of 503 m to the nearest maize planting

References

Aylor DE, Schultes NP, Shields EJ (2003) An aerobiological framework for assessing cross-pollination in maize. Agr Forest Meteorol 119:111-129 http://tinyurl.com/2wqza2k

Bannert M, Stamp P (2007) Cross-pollination of maize at long distance. Eur J Agron 27: 44-51 http://tinyurl.com/2urbdn4

Burris JS (2001) Adventitious pollen intrusion into hybrid maize seed production fields. Proceedings of 56th annual corn and sorghum research conference 2001. American Seed Trade Association, Inc., Washington, DC http://www.amseed.com/govt_statementsDetail.asp?id=69

Byrne PF, Fromherz S (2003) Can GM and non-GM crops coexist? Setting a precedent in Boulder County, Colorado, USA. Food, Agriculture and Environment 1:258-261 http://www.colby.edu/biology/BI402B/Byrne & Fromherz 2003.pdf

Della Porta G, de Ederle D, Bucchini L, Prandi M, Verderio A, Pozzi C (2008) Maize pollen mediated gene flow in the Po valley (Italy): Source–recipient distance and effect of flowering time. Eur J Agron 28:255-265 http://tinyurl.com/33voft5

Department of Agriculture (2005) Understanding genetically modified organisms (GMOs). http://www.nda.agric.za/doaDev/sideMenu/biosafety/doc/understandingGMOs.pdf

Garcia MC, Figueroa JM, Gomez RL, Townsend R, Schoper J (1998) Pollen control during transgenic hybrid maize development in Mexico. Crop Sci 38:1597-1602

Henry C, Morgan D, Weekes R, Daniels R Boffey C (2003) Farm scale evaluations of GM crops: monitoring gene flow from GM crops to non GM equivalents in the vicinity: Part one forage maize, DEFRA report EPG/1/5/138. http://www.cib.org.br/estudos/estudos_cientificos_ambiental_14.pdf

Huffman WE (2004) Production, identity preservation, and labelling in a marketplace with genetically modified and non-genetically modified foods. Plant Physiol 134:3-10 http://www.plantphysiol.org/cgi/content/full/134/1/3

James C (2009) Global status of commercialized biotech/GM crops: 2009. ISAAA Briefs no. 41. Ithaca, NY: International service for the acquisition of Agri-biotech applications http://tinyurl.com/ybtvqwb

Jemison JM, Vayda ME (2001) Cross-pollination from genetically engineered corn: Wind transport and seed source. AgBioForum 4:87-92 http://www.agbioforum.org/v4n2/v4n2a02-jemison.htm

Luna SV, Figueroa JM, Baltazar BM, Gomez RL, Townsend R, Schoper JB (2001) Maize Pollen Longevity and Distance Isolation Requirements for Effective Pollen Control. Crop Sci 41: 1551-1557. https://www.agronomy.org/publications/cs/abstracts/41/5/1551

Ma BB, Subedi KD, Reid LM (2004) Extent of cross fertilization in maize by pollen from neighbouring transgenic hybrids. Crop Sci 44:1273-1282

Moschini G (2006) Pharmaceutical and industrial traits in genetically modified crops: Coexistence with conventional agriculture. Am J Agr Econ 88:1184–1192 http://www.econ.iastate.edu/sites/default/files/publications/papers/paper_12666.pdf

Paterniani E, Stort AC (1974) Effective maize pollen dispersal in the field. Euphytica 23:129-134 http://www.springerlink.com/content/j46770764q814u54/

Stevens WE, Berberich SA, Sheckell PA, Wiltse CC, Halsey Horak MJ, Dunn DJ (2004) Optimizing pollen confinement in maize grown for regulated products. Crop Sci 44:2146-2153 http://www.springerlink.com/content/j46770764q814u54/