Chapter 6

Discussion and Conclusion

Genetic modification of plants can be exploited to meet the ever-growing need for food and novel plant-based products. But as with any new scientific field, there are many concerns about the possible risk of such genetically modified crop plants. These concerns have to be addressed allowing the production of a safe and environmentally friendly crop. Although such plants have undoubtedly economic benefits there are major concerns about the risks such plants might pose for the environment. This study has therefore tried to identify such possible risks on the South African flora and to highlight areas that need attention.

6.1 Environmental risks

Would a herbicide-resistant genetically modified plant pose a risk in South Africa? Resistance gene flow from a genetically modified plant is regarded as a typical risk. Several research groups have already recognized this undesirable consequence of gene flow (Reiger *et al.*, 1999; Dale, 1992; Ellstrand, 1988). In the case of a herbicide-resistant weed, such a weed would be difficult to control. It might develop resistance against most potent herbicides that are currently used for its control (Carpenter *et al.*, 2002). However, any transfer of an introduced herbicide resistance gene to a wild plant would only be effective when this plant is treated with the respective herbicide. Without such herbicide treatment, the resistance gene will be integrated into the host genome but without any further obvious consequence for the plant itself or its progeny.

Would herbicide-resistant maize pose a risk in South Africa? Maize does not have any sexually compatible wild or weedy relatives in South Africa with which out-crossing can occur. Teosinte, the closest wild relative of maize, grows only in Mexico and Guatemala but not in South Africa. Any risk of dispersal of any introduced gene into maize to a weedy relative does therefore not exist. Consequently, planting of genetically modified maize will not pose any significant risk to the South African flora regarding gene flow to wild relatives. This would be, however, in contrast to cotton. Cotton has wild or weedy relatives in South Africa and poses a certain degree of risk like transgene flow and harmful effects on non-target organisms.

Is gene flow to a cultivated crop a risk in South Africa? Gene flow from genetically modified maize can occur to non-modified maize under cultivation in South Africa. However, any gene flow between commercial varieties should be regarded more as a legal issue than as an environmental risk and any risk on the flora is negligible. As maize is wind-pollinated any out-crossing results in the production of fertile maize hybrids. Hybridisation significantly affects seed quality and is therefore not desirable (Agbios, 2001). Also, to control undesired hybrids, which might carry a herbicide resistance gene, a greater amount of a herbicide has to be applied for their control with the building up of resistance towards the herbicide and also a higher level of pollution of the environment. Generally, the resistance gene might disappear after five generations in case no herbicide is sprayed for plant control.

Does the creation of super weeds and volunteer plants pose a risk in South Africa? A genetically modified plant might turn into a super-weed and increase the chance of plant invasion. There is, however, evidence that the direct effect of an introduced herbicide resistance gene may be neutral with regard to fitness in natural environments as long as the herbicide is not applied (Raybould and Gray, 1994; Duke *et al.*, 2002). Crawley *et al.* (2001) found no evidence for enhanced weediness in genetically modified *Brassica napus* expressing a herbicide resistance gene. In South Africa, however, the chance of super-weed creation as a risk for the South African flora is extremely limited due to the lack of practise to apply herbicides on natural plant populations. This is also true for volunteer plants carrying as genetically modified plants multiple-herbicide resistance. This is a clear threat to commercial farming, including organic farming, but does not pose a threat to the flora as long as herbicides are applied for selection.

Are insect-resistant plants a risk for the South African flora? While herbicide-resistant plants generally pose a limited risk, the study identified an obvious risk for genetically modified plants carrying a gene for insect resistance, such as the Bt gene. This is specifically true for genetically modified cotton. Any gene flow and expression of the Bt gene in genetically modified plants and their wild relatives would affect both target and non-target insects feeding on both types of plants and would therefore also indirectly affect natural predators and pollen transfer by insects. In South Africa, the majority of Bt cotton is planted in Mpumalanga and North-eastern Kwazulu Natal. Gene flow from genetically modified Bt cotton (*G. hirsutum*; tetraploid) to wild cotton (*G. herbaceum*, diploid) when grown in close proximity is possible. But such a cross would very likely produce triploid sterile plants. However, as the study also showed, *G. barbadense* (tetraploid), which is an alien to South Africa but invaded South Africa from Northern Africa, has been sporadically found in the past in Natal and the Limpopo Province in close proximity to areas where Bt cotton is planted. Hybridization between *G. barbadense* and *G. hursutum*, which are both tetraploid, is possible through insect pollination. It produces a viable, fertile hybrid population with a hybrid vigor (Wendel *et al.*, 1992, Ano *et al.*, 1983; Schwendiman *et al.*, 1974) and back-crossing with one of the parents results in hybrid stabilisation (Munro, 1987). Consequently, there is a risk that in South Africa gene exchange might occur between tetraploid cotton due to insect pollination especially when planted in close proximity. In South Africa, the distance between Bt crop fields and *G. barbadense* is 30 km, which significantly reduces the risk of any gene flow. Pollen remains viable for about 12 hours, after this period the pollen looses its viability, thus the longer it takes for the pollen to reach a relative, the less the chance of out crossing (Govila *et al.*, 1969; Banks, 1998).

In South Africa, a further general risk for plants with a wild relative is that an adaptive resistance gene might enter a related wild population giving the progeny of some individuals a large competitive advantage. The genotype of these could, by "genetic hitch-hiking", sweep the population, eliminate other genotypes, and reduce the amount of genetic variation. This could also have practical implications when genetically modified plants are widely applied in South Africa, because important genes would be eliminated from a natural "germplasm bank" (Regal, 1994). For example, in the US more than 80% of seed varieties sold a century ago are no longer available. Less than 20% of vegetable seed varieties listed in a 1904 US national inventory are still commercially available today. Scientists have also warned that "genetic pollution" of Mexico's many maize varieties could lead to the loss of the world's most important and irreplaceable source of corn germplasm (World watch Institute, 2000; Cummins, 2002).

6.2 Administrative risks

Beside environmental risks, the study also identified as a risk the still existing inadequate expertise in South Africa for assessing risk of genetically modified plants including control and supervision of the GMO Act. The Executive Council set up under the GMO Act is not all-inclusive. It excludes scientists from the research institutions in the actual decision making process. From the literature survey it is evident that no comprehensive risk assessment study has been so far conducted on the eco-system and vulnerable species. As an immediate action, extensive training in bio-safety and risk assessment should be carried out. Further, despite the fact that the Act calls for an assessment to be conducted on both the environmental risk and the risk it may have on human health, the Act does not specify the basic standard as to what is an acceptable risk. There is also no provision for public participation in various structures designed by the GMO Act.

6.3 Actions for risk limitation

What type of actions should be considered to limit the current risks on the South African flora? Through risk limitation strategies gene flow can be reduced considerably. For example, this includes simple cultural practices. Crops might be planted so that they do not flower at the same time as their wild relatives or complete harvesting of an annual crop before flowering will prevent pollen formation and possible pollen transfer to wild relatives (Ellstrand and Hoffman, 1990). One interesting scientific strategy to prevent out-crossing is also to insert new genes into the chloroplast of the cell rather than the nucleus. Since the chloroplast genomes are not passed through the pollen, they will not transfer any introduced gene into the chloroplast (Brookes, 1998).

What further strategies could be followed to limit any gene flow from genetically modified plants to wild relatives in South Africa? From the literature survey 'distance isolation' can be considered as an important aspect to prevent gene flow to wild relatives. Results for the importance of distance isolation have been obtained from experiments investigating the effectiveness of isolation distance (Luna *et al*., 2001). Most self-fertilizing species including cotton, which is only partially pollinated by insects, require isolation distances of more than 200 m. In contrast, out-crossing species require 1000 m or more for isolation (Ellstrand and Hoffman, 1990). A recent study completed at the University of Maine found that cross-pollination by conventional maize, a wind-pollinated plant, with genetically modified maize in an adjacent plot was 1% at a distance of 30 m and declined to zero at a distance of 300 m. This suggests that it is possible to drastically limit the transfer of a gene from genetically modified to non-modified plants by following the same recommended planting distances currently in place to maintain purity in conventional plant varieties (Colorado State, 1999).

Insect pollinators, primarily bumblebees and honeybees, are agents for pollen dispersal in the cotton growing regions of the USA. An isolation distance of at least 400 m is required from other cotton to avoid insect pollination (Sumida, 1995). Further, buffer zones might prevent cross-pollination. A buffer zone is an area of non-genetically modified crops to prevent pollen drifting into nearby fields and pollinating other crops and weeds. It acts as a trap for pollen carried from the genetically modified plants by insects such as bees. Bees are most likely to visit the flowers on the buffer plants further away (CSIRO Australia, 2000). Estimates of the necessary width of buffer zones vary depending on the genetically modified crop. For example, cotton pollen has a low tendency to drift around, requiring only a small buffer zone. But for crops like maize where wind dispersal of pollen occurs, much larger buffer zones are required (CSIRO Australia, 2000). South African farmers seemingly maintain the recommended safety distance between the transgenic and cultivated crops (C. Laubscher, personal communication) reducing the risk of gene flow.

To limit any risks in South Africa, a tighter safety regime should also be established for genetically modified crops. This should be applied specifically to genetically modified plants with an obvious impact on the environment, such as Bt cotton expressing a toxin. It should also cover tightly controlled field trials in the country carried out by independent scientists to evaluate the short and long-term impact on the ecology under natural conditions. This is important, because the result under natural conditions may be different from the result under laboratory conditions. Estimation of risk should be done on a crop-by-crop basis in the region where the modified crop is to be cultivated and not only be based on experiences in different countries with different environmental conditions and ecology.

6.4 Conclusions

In general, there should be a more cautious approach in regard to the use and release of genetically modified plants in South Africa due to its possible impact on the environment. Although currently known risks in South Africa are rather minimal, several unknown risks might include potential ecological and human health risks that have not been studied in greater detail in South Africa. So far, various genetically modified crops have already/or will be released in South Africa including genetically modified maize and cotton, with soybean to follow and South Africa is among the few countries in the world rapidly introducing engineered crops. There is certainly a risk, which requires urgent attention, when a technology is deployed too fast without sufficient safeguards, regulations or public debate and proper risk assessment studies.