GM and Saline Tolerant Crops
September 2008

This briefing examines claims that GM saline tolerant crops are close to being available to farmers to enable them to produce crops on land damaged by salination. It looks at the causes and solutions to salination and the likelihood of progress being made by using non-GM approaches.

What is salinity?
The soil is full of many different salts which contain minerals and nutrients essential for plants to grow and for crops to produce a viable yield. Salinity becomes a problem if the concentrations of salts in the soil become toxic to plants. Saline soils mainly occur in hot and arid regions of the world.

What are the causes of salinity?
Salination of soils can occur naturally by the weathering of mineral rich rocks which in areas of low rainfall can accumulate in the root zone of plants (the top metres of the soil into which roots penetrate). In coastal regions inundation of agricultural land by the sea, for instance during tropical storms, can cause salination of soils.

Human activity is a major contributor to salination of soils. There are two ways in which this can take place.

1. Salinity from ground water rising into the root zone of plants can take place when land is cleared of deep-rooted native trees and shrubs. The rising ground water transports salts into the root zones of shallower-rooted crop plants.

2. Saline irrigation water is another cause of soil salinity in hot countries and is a main cause of salination in countries such as India. Irrigation water is often pumped from rivers or ground water, and if it is over used on poorly drained soil, water can evaporate from the surface layers leaving a deposit of salt in the upper layers that can be toxic to plants or seriously restrict their growth. Alternatively inefficient irrigation that applies more water than the crop can take in causes ground water to rise beneath the crop, dissolving salts in the subsoils and bringing them up into the root zone. If groundwater reaches two metres beneath the surface growth can be inhibited.

Where groundwater is extracted close to the sea, salt water intrusions can take place into the voids in aquifers vacated by freshwater, as has happened in Iran on the coastal plans of the Persian Gulf and Caspian Sea.[i]

The permeability to water of some soils can be damaged if irrigation water contains high levels of sodium, which displaces other elements like magnesium and calcium, from soils aggregates. This causes a deterioration of soil aggregates resulting and a reduction in soil moisture through the soil (also known as sodic soils).

Where are saline soils?
Salinity is global problem affecting every continent, bar Antarctica. Estimates of the true extent vary. Some put the total area of land world wide at one billion hectares[ii], while the FAO UNESCO estimate the:

> *"total area of saline soils is 397 million ha and that of sodic soils is 434 million ha, which are not necessarily arable but cover all salt-affected lands at global level. Of the current 230 million ha of irrigated land, 45 million ha are salt-affected soils (19.5 per cent) and of the almost 1,500 million ha of dryland agriculture, 32 million are salt-affected soils (2.1 per cent) to varying degrees by human-induced processes".*[iii]

Even the European Union has serious problems, for instance in the Carpathian Basin in Hungary. In Spain three *per cent* of 3.5 million hectares of irrigated land is seriously damaged and a further 15 *per cent* under threat.[iv] Some sources report that up to 20 *per cent* of irrigated land is affected and two *per cent* of dryland agricultural land.

How do plants grow in saline soils?

Salinity affects plants differently at different stages of their development. For instance in some species seedlings many be very vulnerable while mature plant can cope with the same level of salt. There are two main mechanisms for dealing with high salt levels in soils: some plants stop salt (sodium) being taken up by the roots, and others transport salts to vacuoles in the shoots away from areas where vital cell functions take place.

GM salt tolerant crops – a solution?

Genetic engineers aim to transfer genes from salt tolerant species (for instances those adapted to a very salty environment such as salt cress (*Thellungiella halophila*), or from crops that have in-built salt tolerance such as barley.

However, "Salt tolerance is complex both genetically and physiologically"[v]:

> *"...molecular studies have shown the possibility of single gene-controlled salt transport mechanisms. Although this was valuable information, the expert was not sure how it could lead to the development of salt tolerant transgenic plants in the foreseeable future. Plants in the fields provide a wide and diverse range of responses to the fluctuating salt concentrations. However, currently used laboratory techniques did not simulate these field situations in real time and therefore, could not be considered plausible working models for studying salinity tolerance in a practical manner. The expert noted that some success had been achieved in tackling drought tolerance and salinity tolerance through conventional methods and through molecular technologies like marker-assisted selection. However, he strongly cautioned against expecting miracles in this sector, at least in the foreseeable future, because of the complexity of the interactions and systems"*.[vi]

So far, no saline tolerant GM crops have reached the stage of commercialisation despite repeated claims of breakthroughs going back several years, for example in oats[vii], rice[viii], wheat[ix] and tomatoes[x].

Sustainable options for restoring salinated land

Progress is being made on several fronts toward tackling salination of agricultural soils, including the breeding of salt tolerant varieties using conventional breeding techniques.

Prevention

Preventing salination in the first pace is essential to prevent further agricultural land becoming unproductive. It is important that prevention is made priority and should not be delayed because of the promise of salt tolerant varieties, whether genetically engineered or conventionally bred.

Techniques for preventing salinisation of soil include:

- Use of water-efficient irrigation so that water is applied at rates crops can cope with.
- Regulation of ground water abstraction to prevent over pumping and the intrusion of saline waters from the sea.
- Building of dykes and levees to prevent sea water inundating farm land in tropical storms (this would also help protect communities living near coastlines).

Rehabilitation of salinated soils

There are a number of techniques which have been developed to rehabilitate salinated soils including:

- Leaching (flushing) of soils using "clean" water to wash salt out of the root zone.
- Leaching using natural rain fall, often using a salt tolerant crop such as millet[xi], to produce food while this takes place.
- Planting of deep-rooted trees and shrubs to lower water tables beneath crops.
- Improved drainage of irrigated land.
- Improving infiltration of irrigation water using cultivation techniques.
- Incorporation of organic matter to improve infiltration.
- Using mulches to reduce evaporation losses.
- Incorporating crop residues into the soil (NB this needs to be considered when proposing the use of crop residues as the feedstock for secondary biofuels).
- Using green manures to increase soil organic matter and permeability of soils.

The development of salt tolerant crop varieties
Salt tolerant traits exist naturally in many crops. With the help of marker assisted breeding (identifying desirable genes in individual plants before crossing takes place) conventional breeding can proceed much faster.

Examples of successful incorporation of saline tolerant into major crops include:

- **rice:** BRRI Dhan 40 and BRRI Dhan 41 have been very recently released by the Bangladesh Rice Research Institute for growing in the coastal region during the wet season.[xii]
- **wheat:** salt tolerant durum wheat has been bred in Australia and is undergoing field trials.[xiii]

Seed treatments
A group of researchers in Pakistan have developed a method of priming wheat seeds with cytokinins for use in salinated soils. Early results of fields trials indicate improved growth and grain yields, although the mechanisms for this remain unknown.[xiv] xiv. The research seems promising enough to merit additional funds to develop the techniques and test long-term viability and safety.

Conclusion
Salinity is a global problem that has been in part created by bad irrigation practices in every continent. It is essential that the spreads of salinated soils is halted and then reversed using a variety of management techniques and prevention strategies. Conventional breeding has succeeded in selecting saline tolerance in some species. No GM salt tolerant varieties have so far been brought to the point of commercial release. The genetic engineering changes required to produce a salt tolerant crop are more complex than used in GM crops currently on the market. There are a whole range of management techniques already in use to restore salinated soils. In view of the areas of good land already despoiled by salt, restoration should be the priority.

GM Freeze c/o Rose Cottage, Farness, Poyntzfield, The Black Isle IV7 8LYTel: 0845 217 8992
Fax: 020 7837 1141 Email: enquiry@gmfreeze.org Web: www.gmfreeze.org
Registered office: 94 White Lion Street, London N1 9PF

i Khel, M. "Saline Soils Of Iran With Examples From The Alluvial Plain Of Korbal, Zagros Mountains", Proceedings of the International Conference Soil and Desertification – Integrated Research for the Sustainable Management of Soils in Drylands, 5-6 May 2006, Hamburg, Germany at www.desertnet.de/proceedings/content/Kehl.pdf

ii See http://eusoils.jrc.ec.europa.eu/library/themes/Salinization/

iii See www.fao.org/ag/AGL/agll/spush/

iv *Ibid*

v Society for Experimental Biology, *Bulletin,* July 2005. See www.sebiology.org/publications/Bulletin/July05/salinity.html

vi FAO. *Report of the FAO Expert Consultation on Environmental Effects of Genetically Modified Crops*. 16-18 June 2003, Rome. See ftp://ftp.fao.org/docrep/fao/field/006/ad690e/ad690e00.pdf

vii See http://crop.scijournals.org/cgi/content/abstract/45/6/2218

viii See www.scidev.net/en/news/gene-for-salt-tolerance-found-in-rice.html

ix See www.biotechnews.com.au/index.php/id;1548103697

x See www.sciam.com/article.cfm?id=gm-tomato-plant-doesnt-sh

xi See www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/86965/pf242-millet-for-reclaiming-irrigated-saline-soils.pdf

xii FAO/AGL Global Network on Integrated Soil Management for Sustainable Use of Salt-affected Soils (undated). See www.fao.org/ag/AGL/agll/spush/

xiii See www.csiro.au/files/mediaRelease/mr2002/Prsaltol.htm

xiv Igbal M and Asraf M, 2006. *Wheat Seed Priming in Relation to Salt Tolerance; growth. yields and levels of free salicylic acid and polyamines.* Ann. Bot. Fennici, 43:250-259.