GM and Drought Tolerance

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This briefing looks at the claims made by proponents of GM crops that the production of transgenic drought tolerant crops is very close to being achieved and that this will lead to a huge increase in the yields of crops needed to "feed the world". It also looks at alternative more sustainable approaches to dealing with chronic and acute water shortages in agriculture and horticulture.

Introduction

Proponents of GM crops[i] frequently link the technology with an ability to modify crop plants so that they can tolerate droughts and still produce a harvestable yield. All the major biotechnology companies are claiming to make progress towards GM drought tolerant crops by early in the next decade.[ii] Monsanto have recently claimed that they will double yields, based of 2000 crops, by 2030[iii].

Others involved in biotechnology have different opinions about progress in this area of genetic engineering of crops. For example Professor Ossama El-Tayeb, Professor Emeritus of Industrial Biotechnology at the University of Cairo, seriously questions whether drought tolerance through genetic manipulation will be achieved quickly[iv]:

> *"I wish to add that transgenicity for drought tolerance and other environmental stresses (or, for that matter, biological nitrogen fixation) are too complex to be attainable in the foreseeable future, taking into consideration our extremely limited knowledge of biological systems and how genetic/metabolic functions operate. Those who propagate the ideas that any biological function could be genetically manipulated are optimists who are probably victims of a consortium of "arrogant" scientists and greedy business who have strong control on policy making and the media."*

Droughts

Droughts are not new. Climate change experts predict they could become more severe:

> *"Many semi-arid and arid areas (eg, the Mediterranean basin, western USA, southern Africa and north-eastern Brazil) are particularly exposed to the impacts of climate change and are projected to suffer a decrease of water resources due to climate change. (high confidence)."*[v]

The impacts of drought on agricultural production can be very severe. For instance in France in 2006[vi], oilseed rape production fell 14 *per cent* despite a 100,000ha increase in area.

In Australia, prolonged drought in 2006/07 caused serious depression in crop yields:

> *"Output of the three main winter grains, wheat, barley and canola, is now forecast to be down by over 60* per cent *from last year and over a million tonnes less than during the 2002-03 drought."*[vii]

The impacts of droughts in Africa and Asia can also be severe. The Sahel zone drought in West Africa from 1972 to 1984 claimed 100,000 lives and made 750,000 people dependent on food aid[viii]. In 2006, a drought in south central provinces of China caused

650,000ha of crops to be lost and affected a further 6.7 million ha.

Prolonged lack of rainfall means that any plants will die and seeds simply will not germinate. The unpredictable nature of seasonal weather adds to the dilemmas facing the world's farmers.

Tackling Drought in Agriculture

Plants naturally pump water from the soil and out through tiny openings on their leaves called stomata by a process known as transpiration. These openings also allow carbon dioxide to be taken in by plants. Some plants have evolved to minimize water losses through transpiration, but they tend to grow very slowly, eg cacti. A minority of plants, for example sugar cane and maize, have evolved a different type of metabolism for sugar production called Carbon 4 (or C4), whereas most plants have a Carbon 3 (C3) metabolism. C4 metabolisms make better use of water than C3 in hot arid zones. However C3 plants are more efficient in cooler moister conditions.

Farmers require sufficient moisture in the soils to ensure that seeds can geminate, above ground green growth can occur, and fruits, grains or tubers can grow and ripen ready for harvest. Drought can occur at any stage of the growing process, and can cause a complete loss of crops or serious reduction in yield.

GM Progress?

Biotechnology industry spokespeople often give the impression that GM drought resistant crops are a just round the corner.

However, genetically engineering plants to be drought tolerant is a major step from where GM crops are now. The single gene traits of the first and second generation GM crops (herbicide tolerance and insect resistance (Bt)), have been found to work in plants. However, once in the field, resistance to weeds and insects may well render them unsustainable.

Drought tolerance is likely to involve several genes controlling the passage of water through normal plants, and is therefore proving much more difficult and may throw up unexpected complications. Pumping water from soil and out of the stomata on the leaves is what plants do naturally. Most plants can withstand a certain amount of water stress if they have a good root system, but this may limit growth or slow it. One proposed GM approach is to close stomata. This may have an impact on the exchange of vital gasses, ie carbon dioxide and oxygen, which enter the leave the plant via open stomata. Both water and carbon dioxide are needed to produce the sugars that plants need to grow and produce crops, and therefore changes in stomatal opening could have significant consequences for the biology of the plant.

Another possible way to genetically modify plants is to genetically engineer their basic physiology by switching from a carbon 3 (C3) to a carbon 4 (C4) metabolism. C4 plants are able to keep photosynthesis going whilst their stomata are closed thus saving water. Once again this is a major physiological jump for plants, and there may well be unforeseen consequences of such a change. Most crop plants and trees are C3 plants, and a minority, including maize, sugar cane, millet and sorghum, are C4. However despite this, maize and sugar cane (in dry areas) around the world are already heavily dependent on irrigation to produce a viable yield, showing that even a GM C4 plant would require a significant input of water.

Even if genetic modification could overcome these profound difficulties, which is far from clear, it would take years and come with a considerable cost. Meanwhile other non-GM techniques and technologies are available now, and they're far cheaper.

Minimising the Impact of Drought

There are many non-GM routes available to farmers now by which crops can be assisted to survive and flourish in dry conditions.

Increasing Soil Organic matter

Increasing the organic matter content of the soil greatly increases the chances of crops getting enough water to produce a harvest:

> *"To minimize the impact of drought, soil needs to capture the rainwater that falls on it, store as much of that water as possible for future plant use, and allow for plant roots to penetrate and proliferate. These conditions can be achieved through management of organic matter, which can increase water storage by 16,000 gallons per acre foot for each 1% organic matter. Organic matter also increases the soil's ability to take in water during rainfall events, assuring that more water will be stored. Ground cover also increases the water infiltration rate while lowering soil water evaporation."*[ix]

The key is therefore to look after the soil as the first priority. This means:

- practicing crop rotations, including grass/legume crops to improve soil structure;
- avoiding monocultures;
- avoiding excessive cultivation;
- avoiding excessive use of fertilisers, which reduces natural nutrient cycles;
- recycling organic matter (such as animal manure and crop waste) back into the soil;
- avoiding excessive use of irrigation, which can cause salt to build up in topsoil.

Water harvesting

There are several techniques for harvesting seasonal rainfall[x] to make it available for crops during dry seasons. For example:

- Small-scale check damns check the flow of water in river channels in periods of higher rainfall to allow the water to seep into soils, recharging aquifers below where it is stored until it is needed for irrigation. Check damns also prevent soil erosion and allow fertile silts to accumulate.

- Small-scale reservoirs for seasonal water storage can help conserve water for entire communities. In Sudan these are known as "hafirs".

- Ploughing along the contours of sloping land instead of across them reduces run-off and soils erosion and allows rainfall time to percolate into soil and aquifers.

- Micro catchments can be constructed using vegetation to funnel rainfall into storage pits for future use.

Drip Irrigation

Drip or trickle irrigation systems are a water-efficient alternative to spray irrigation in which water is delivered to plants in the correct amounts close to their roots. This avoids massive water wastage from overhead sprays due to evaporation in the air or from foliage and soil, blowing off target, run off from soil surfaces or uneven application. One major problem with drip irrigation systems is the cost of installation, which usually means that it is only viable for high value crops.

Agroforestry
Agroforestry is "a collective name for land-use systems and practices where woody perennials are deliberately integrated with crops and/or animals on the same land management unit"[xi]. In many areas of the world faced with environmental extremes such as intermittent and unreliable rainfall it can provide a more sustainable form of land management than large-scale crop monocultures.

Once established trees can be a source of food (berries, nuts and leaves to people and animals), raw materials (timber or rubber), fuel (firewood) and as a carbon store. Some tree species are also nitrogen fixing and therefore improve the nutrient status of soils. Being deeper rooted than crop plants, they bring essential minerals to the surface and make them available for other plants. They also protect soil from water and wind erosion. Agroforestry plantations can also protect water from contamination with chemicals or eroded soils. Growing of annual and permanent crops can take place between forested areas.

Agroforestry should not be confused with large scale, single species commercial forestry or plantations for the production of wood pulp, rubber or palm oil which can cause serious disruption to local communities and environmental harm such as biodiversity losses and lowering of water tables to the detriment of surrounding areas.

Traditional Plant Breeding
As noted above, water in the right amounts and quality is essential for crop plants to flourish. Traditional plant breeders continue to develop crops that do better in dry conditions. Essentially this means that they can make better use of available moisture to go from seed to harvestable crop before the water runs out. In Africa pearl millet and sorghum (both C4 plants) perform best in semi-arid regions:

> *"Early maturing varieties of these crops have proved especially useful for helping dryland communities get through the 'hungry season'. This is the period before harvest, when the previous year's grain supplies have been exhausted. The millet variety 'Okashana 1', for example, which was selected by farmers in Namibia and matures 4-6 weeks earlier than traditional varieties, spread in just a few years during the mid-1990s to cover half the country's millet area. The US$3 million investment required to develop and disseminate the variety was estimated in 1998 to be yielding annual benefits worth $1.5 million. At about the same time in southern Chad, an improved sorghum variety, which shows a 50 percent yield advantage over local materials, also spread quickly, generating benefits worth almost $4 million annually."*[xii] [xiii]

Traditional plant breeders have even made progress with crops such as maize (which is a crop normally hungry for water and nutrients)[xiv], barley[xv], rice[xvi], millet and sorghum.

Marker Assisted Breeding
Plant breeders are now able to use molecular biology techniques to identify genes conferring particularly characteristics in advance of crossing plants, which cuts out the need for expensive and unreliable field testing. Drought tolerance has been successfully incorporated into the genome of hybrid pearl millet in this way[xvii].

Conclusion

Growing plants in the absence of water is impossible. Every plant requires a certain amount of moisture to complete its cycle of growth to be point it produces a viable yield for farmers. Traditional plant breeding has produced varieties that already perform well in drier conditions, and certain crops, such as millet and sorghum, have evolved in dry conditions. Marker assisted breeding techniques can help plant breeders select drought tolerance specimens for breeding. However, land management, such as increasing the soil organic matter, is as important in buffering farmers against the impacts of drought.

Genetic modification has so far not produced a commercial drought tolerant variety in any type of crop. The genetic changes required involved several genes to alter the plant's physiology in a major way. Such changes may have impacts on other plant functions, which could be detrimental to the plant. It may take years to come up with a viable GM solution, if it proves possible at all, and GM will not deal with the challenges posed to farmers by climate change. Indeed, GM may divert research and development funds away from more sustainable long-term solutions based on good water and soil management and traditional plant breeding.

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[xiv] Ibid
[xv] Ibid
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