FACT SHEET:

Breeding plants for salt and drought tolerance: genetic engineering not needed

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Plant traits such as drought tolerance, salt tolerance or nutrient content are controlled by a complex combination of several genes. While some advocate the use of genetically modified (GM) crops with these traits, modern breeding and selection technologies such as marker assisted selection (MAS) are a much more effective tool.

Why genetic engineering doesn't work

Commercial GM crops predominantly involve simple traits, such as herbicide tolerance and insect resistance, that only involve single genes. While GM can insert genes into a plant, controlling the inserted genes presents more of a problem.

Genetic engineering approaches for complex traits take two forms. Either many genes are inserted (for example, Golden Rice, or CSIRO's RNAi wheat) or only a single primary gene that is highly (or over-) expressed. Both are clumsy approaches that disregard the complexity of gene expression.

Altering a biochemical pathway with genetic engineering or introducing a new biochemical pathway has a high probability of disturbing plant chemistry. Unexpected effects do occur. For example when researchers attempted to create Golden Rice that was high in provitamin A (beta-carotene), an unexpected pathway in the rice converted lycopene (tomato red) into beta-carotene (yellow)[1]. Not only does this throw up issues of food safety and environmental risks, it clearly demonstrates that genetic engineering is not the appropriate tool to produce complex traits controlled by several genes at once.

The effective alternative: Marker Assisted Selection

Marker Assisted Section (MAS) utilises knowledge of genes and DNA to 'speed up' conventional breeding without the risk of creating a GM organism. While MAS uses genetic markers to identify desired traits, no gene is artificially transferred from one organism into another one. Specific DNA fragments (markers), which are closely linked to specific traits, are identified. After crossing, the offspring is screened for the presence of the marker, and hence the desired trait. It is more effective than traditional breeding because there is no need to grow the plant under stress conditions to identify the presence of the desired trait.

Breeding for drought and salinity tolerance

In a recent review by the German Federal Nature Conservation Agency (BfN)[2] MAS was reported to have high potential to breed new traits, and could utilise wild species and landraces to capture traits not seen in current high yielding commercial varieties.

The report concluded that:

"MAS presents not only an alternative but may be in the long run superior to genetic engineering *approaches whenever the primary, secondary, or tertiary gene pool are the source of desired traits […] In contrast,* ***genetic transformation results in rather unpredictable integration sites, copy numbers and often spontaneous rearrangements and losses."***

It was found that MAS was particularly suited to breeding for complex traits because "*the targeted recombination of a multitude of genes can be done efficiently with MAS. Computer based crossing schemes can greatly reduce the number of crosses needed (SØRENSEN 2009) and MAS can help in the early detection of desirable recombinants which would go undetected based on the phenotype alone. Thus* ***MAS can accomplish what would be very difficult to achieve using a transgenic approach".*** *(emphasis added).*

The successful use of MAS to produce drought and salinity tolerant wheat in Australia

Drought and salinity are serious problems for large swathes of Australia's wheat growing regions. While some boldly claim that GM crops are the magic bullet solution, MAS is much more likely to produce plants that can cope with these hostile conditions.

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Many successful varieties of drought and salinity tolerant crops have already been produced using conventional breeding (see "Smart Breeding"[3] – Greenpeace's review of crop development using MAS). In Australia, these successes include Drysdale and Rees[4] drought-tolerant wheat varieties.[5] Drysdale is now a flagship CSIRO product . CSIRO has also successfully developed salt tolerant durum wheat (typically used for making pasta) using MAS that yields 25% more grain in saline soils.[6] Recent trials of CSIRO salt-tolerant MAS bread wheat also showed a 25% yield increase.[7]

New screening techniques for salt tolerant varieties of barley are also encouraging;

> *Plant breeders can now combine modern selection techniques, such as IR thermography, with traditional plant breeding to produce more salt tolerant wheat and barley varieties[8].*

MAS for enhanced nutrition

MAS is an effective alternative to genetic engineering strategies for biofortification of crops. Successful examples include increased levels of pro-Vitamin A (beta-carotene) in maize[9]:

> *"… a team of plant geneticists and crop scientists recently identified genetic markers that are associated with higher levels of provitamin A in maize. With the help of these markers, provitamin A concentration in maize kernels can now be easily assessed. Scoring the target gene is not only cheaper than the previous methods used to assess provitamin A levels, it is also well within the capabilities of those developing countries that need biofortified maize. Moreover, the information needed for the marker assisted selection is being made freely available for breeders worldwide in this specific project. This is in contrast to GM Golden Rice, which is a proprietary technology that has been made (partially) available to those who have the expertise to make use of it. In summary, if maize varieties with increased pro-vitamin A contents are considered a valuable tool to combat vitamin A deficiencies, they can easily be bred using MAS without the need for genetic engineering."*

If a vitamin pathway exists within a path, such as iron-rich varieties of rice, then MAS can be used to increase the iron content. Of course, if a plant does not contain iron, it cannot be enriched. This is why we still, and always will, need a balanced diet.

Investing in MAS

In order for MAS to proceed rapidly as an effective plant breeding tool, genome sequencing and identification of molecular markers must be available in the public domain instead of locked up under intellectual property laws. Although some crop genomes are public, such as rice and maize, extra public research efforts are needed to sequence other major crops like wheat to speed up the application of marker-assisted selection.

Diversity and a balanced diet: less sexy, but still effective

In recent years, MAS has yielded many breeding successes, producing plants resilient to climate extremes including drought, heat and cold. It should be emphasised, however, that none of these varieties alone will be able to contribute to food security in a changing climate. For erratic weather with rapid sequences of droughts, floods, storms and heat waves, only a mixed cropping system using a range of crops and varieties can provide the necessary diversity and resilience. Similarly, access to a healthy and nutritious diet with fruit and vegetables is the only way to ensure adequate nutrition.

The future of farming

MAS is a rapidly developing technology. Combined with other advanced selection tools, it provides the means to develop crops with desired agronomic traits, especially in a climate change-affected world. MAS respects species barriers and is accepted by the public. By contrast, genetic engineering is crude and old fashioned, and more likely to give rise to unexpected and unpredictable effects. Genetic engineering is not the most effective tool to develop crops with complex traits such as drought and salinity tolerance, nor is it necessary. Ultimately, biodiversity in what we grow and what we eat is the answer.

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Notes

1. Schaub, P., Al-Babili, S., Drake, R. & Beyer, P. 2005. Why Is Golden Rice Golden (Yellow) Instead of Red? Plant Physiology 138: 441–450.
2. Brumlop, S & Finckh, M.R. 2011. Applications and potentials of marker assisted selection (MAS) in plant breeding. Final report of the F+E project "Applications and Potentials of Smart Breeding" (FKZ 350 889 0020) On behalf of the Federal Agency for Nature Conservation http://www.bfn.de/fileadmin/MDB/documents/service/Skript_298.pdf
3. http://www.greenpeace.org/australia/en/what-we-do/Food/resources/reports/Smart-Breeding/
4. http://www.greenpeace.org/australia/en/what-we-do/Food/resources/reports/Smart-Breeding/
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7. Increasing wheat yield on salty soils. http://www.csiro.au/files/files/pl25.pdf
8. Ibid.
9. Greenpeace 2009. Smart Breeding. Marker-Assisted Selection: a non-invasive biotechnology alternative to genetic engineering of plant varieties. http://www.greenpeace.org/australia/en/ what-we-do/Food/resources/reports/Smart-Breeding/