Biotechnology seminar

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Biotechnology – what is it and what can it achieve?

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Introduction

My role in NSW Agriculture is to encourage the adoption of integrated weed management (IWM). The central objective of this work is to have farmers and extension agronomists manage herbicide resistance. Since genetically modified organism (GMO) crops offer a range of potential benefits and risks to producers in an IWM context, this paper will cover the topic at more or less the farm level.

I have compiled this paper using a number of sources, including newspaper reports, the media policy on GMOs for NSW Agriculture and an Australian Oilseeds Federation publication entitled 'Genetically modified oilseeds'.

What is biotechnology?

Biotechnology or gene technology is the deliberate addition, alteration or removal of small amounts of genetic material (usually genes) in an organism. These changes are aimed at altering the organisms' characteristics. The changes can be aimed at including a character not present, enhancing a naturally occurring characteristic or removing an undesirable characteristic.

While my interest lies in IWM and plants modified for resistance to herbicides (and insects), there are many examples of the scope of this technology. The following is a good example:

> Du Pont scientists have created a transgenic micro-organism that will convert the starch found in corn into a key polyester ingredient '3G' (trimethylene glycol). The scientists knew that some microbes could convert starch into glycol, while others could convert glycol into 3G. They have now created a hybrid microbe, using biotechnology, which can perform the complete transformation of corn starch to 3G. The resulting polyester is completely biodegradable and recyclable. The molecules can be 'unzipped' and used repeatedly. In addition, the process captures CO_2 from the atmosphere via photosynthesis.

Some other examples of the potential offered by biotechnology are as follows:

- A human gene transferred to corn allows the corn grain to produce antibodies that will work as tumour markers in patients having radiotherapy.
- Spanish workers are attempting to create a GM saffron flower which will have double the number of stamens, effectively reducing the cost of the worlds most expensive spice.
- Glowing plants… British scientists at Edinburgh University have developed sentinel plants which have been genetically modified with genes from a fluorescent jellyfish which makes the plants glow under UV when they are beginning to wilt.

Genetically modified plants are produced by the laboratory insertion of DNA from other species or organisms. These GM plants may have:

i. Insertions of DNA which could have occurred in nature by normal breeding but have been accelerated by laboratory splicing. (i.e. the DNA is from the same species or closely related species).
ii. Insertions of DNA from other plant species.
iii. Insertions of DNA from micro-organisms or animals.

The third category tends to create more unease because the long term effect on human health of these novel changes are not known.

Potential benefits of GMOs for farmers

GMO technology offers a range of exciting improvements in pasture and crop varieties. Below is a list of some examples:

- Modification of existing genes and the incorporation of new genes in canola to create both improved oil quality and speciality crops. Laurate canola is an example of a speciality crop where high lauric acid gives oil quality suitable for confectionary (specialized melting characteristics) industrial and personal care products.
- Oil content can be improved using the technology. Since producers are paid primarily on oil content, such improvements will have a direct benefit to producers.
- Protein quality of canola meal has been improved. This will provide an overall quality improvement for the farmer but will directly benefit meal users due to improved amino acid levels for livestock rations.
- Disease resistance. There is the potential for improving the resistance of canola to its most potentially devastating disease, blackleg. In addition, there is potential to provide varieties with resistance to diseases such as sclerotinia, which periodically causes severe crop damage.
- Stress tolerance. This work is still in the experimental stage. A range of genes are being evaluated for improving the plant's ability to handle stress from such factors as cold, drought and heat.
- Insect resistance.
- Herbicide resistance.

All of the above changes will have a direct impact on farmers, either in terms of production or quality of their products. The last two, insect and herbicide resistance are being widely evaluated by farmers. The rest of the paper will be devoted to covering the benefits and some potential problems these two options provide.

Herbicide resistance in crop varieties

In Australia, the area of a particular crop may be restricted by certain weeds. A good example of this is canola which, until recently, was restricted in area by such weeds as wild radish (*Raphanus raphanistrum*) musk weed (*Myagrum perfoliatum*), herbicide resistant annual ryegrass (*Lolium rigidum*) and vulpia (*Vulpia* spp.).

Triazine tolerant (TT) canola allows farmers to grow canola in areas infested by such weeds because they are susceptible to the triazine herbicides atrazine and simazine. TT canola is not a GM crop. However, the fact that the area sown has exploded in four or five years from zero to almost one million hectares or half the current crop exemplifies the potential of crops which open new opportunities for farmers.

Two GM herbicide resistant crops in the latter stages of development are Roundup Ready® and Liberty Link® canola . Liberty Link canola is resistant to glufosinate-ammonium. Roundup Ready crops are resistant to glyphosate. Even though both these GM products will have slightly different roles on farm, they will provide producers with new weed management opportunities.

Glyphosate is a broad spectrum herbicide. Developing crop varieties resistant to this herbicide means that (i) there is reduced need for a range of herbicides currently being used and (ii) weeds which were difficult to control or not controlled at all will be killed when glyphosate is used. This applies particularly to weeds which have developed resistance to other selective herbicides.

The source of glyphosate resistance in Roundup Ready crops was a microorganism , *Agrobacterium* sp. CP4. The resistance to glyphosate has been incorporated into a range of crops available in the USA including maize and soybean. Work is progressing in Australia towards producing Roundup Ready canola.

Roundup Ready canola will give producers a number of benefits:

- A herbicide-crop combination which will mange a wide range of weeds, with lower risk of the development of herbicide resistance.
- A potent tool for the management of weeds which have developed resistance to selective herbicides, particularly to the Group A, Group B and Group C herbicides.
- An alternative to currently available non-GM crops, particularly TT varieties.

Roundup Ready also offers significant environmental benefits. Glyphosate is a more benign molecule than many other herbicides. That is, in fields where it is grown, the use of alternative herbicides will decline. This applies particularly to atrazine and simazine which are currently being applied to one million hectares of canola.

The system is clearly not without problems. A very public issue is the market acceptability or otherwise of GM produce. There are many people of the view that retaining a 'GMO free' canola industry could provide a marketing advantage for Australian producers.

People involved in this debate need to consider the fact that a million hectares of TT canola are being grown in Australia, with every hectare being treated with atrazine. The availability of GM crops such as Liberty Link and Roundup Ready will reduce the farmers reliance on TT canola and so there will be a reduction in atrazine use. In other words, approval of these GMO crops will lead to the replacement of a clearly problematic herbicide with much more benign types.

The Roundup Ready varieties will be grown subject to a technology fee being paid. Farmers will not be able to retain seed for sowing the next season. Both these factors may be issues for some farmers, particularly the inability to retain sowing seed. In marketing this and many other new variety / herbicide packages, farmers are to be faced with a situation where the herbicide company controls not only the seed but the herbicide as well.

More problematic in the short to medium term is the potential for glyphosate resistant weeds to develop through the additional use of the herbicide. Glyphosate is already widely used in no-till cropping systems where resistance has occurred in annual ryegrass (*Lolium rigidum*). The extra exposure of the weed to glyphosate will increase selection pressure unless management changes are implemented.

Insect resistance in crop varieties

Throughout the world, crops such as cotton and maize are attacked by *Lepidopteran* pests. In Australia, the key pest is *Helicoverpa* spp. Yield and quality are both affected. In cotton for example, multiple applications of insecticide are made in each crop to control these pests. Prior to the implementation of integrated pest management in cotton, crops could be sprayed as many as 13 times for a variety of pests. In Northern America, the European corn borer causes estimated losses of $US 1 billion annually. Such losses would be composed of direct loss of grain yield, reduction in quality (processors often downgrade insect damaged grain) and the cost of insecticide applications. Insecticide resistance has become serious problem, with the potential useful life of widely used insecticides under threat.

Bt toxin is a natural insecticide produced by the soil bacterium *Bacillus thuringiensis*. Using biotechnology, the genes conferring the ability to produce Bt toxin have been introduced crops including cotton and maize. Bt crop varieties produce a toxin which protects them from *Lepidopteran* insect attack. In this way, the need for insecticide applications is reduced, and selection pressure for resistance to those insecticides is reduced.

Bt crops offer the farmer a number of advantages which flow from the reduced need for insecticide applications.

- In Australia, Bt cotton is known as INGARD® . These crops receive 70% less insecticide than normal varieties .
- Less insecticide being applied and so greatly reduced drift hazard and less non target (e.g. beneficial insect) damage.
- Less pesticide in the environment surrounding the farm and so reduced contamination of crops, waterways etc.
- More options in the integrated pest management strategies.

As with the herbicide resistant GM crops, Bt is not without problems for the farmer. First of all, there is a significant technology fee which is equivalent to the cost of the unused insecticides. Secondly, the Bt technology is potentially susceptible to the development of resistance. Because of the threat of resistance developing to Bt, there are restrictions on the region and total area of Bt cotton and the technology must be used in the context of an integrated pest management (IPM) program.

Growers are obliged to sow refuge areas of cotton adjacent to the Bt crop as part of the IPM program. The theory is that pests in the 'refugia' which are not subject to selection, will breed with any from the Bt area which may have developed resistance. This is based on the notion that the resistance gene is recessive and so heterozygote F1 individuals will be susceptible to Bt.

Note: Whether the trait is recessive or 'incompletely dominant' is presently under investigation, with significant implications for the strategy (Huang *et al.*).

Summary

At the extension worker and farmer level, biotechnology has much to offer with improvements in yield, quality and new market opportunities. Herbicide resistance and insect resistance in crops are ready examples of what biotechnology has to offer. Used wisely, innovations such as Roundup Ready products have the potential to alleviate many current production problems.

However, the technology, such as herbicide and pest resistant crops, comes at financial cost and has potential problems, not the least of which is resistance developing to the technologies themselves.

References

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