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Review

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Commercialization of Genetically Modified Ornamental Plants

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Abstract

The ornamental industry encompasses cut flower, pot plant, turfgrass and nursery stock production and is an important part of the agricultural sector. As internationally traded commodities, cut flowers and plants are an integral part of the economy of a number of developing countries in South America, the Caribbean and Africa. Genetic modification (GM) is a tool with great potential to the ornamental horticulture industry. The rapid progress in our knowledge of plant molecular biology can accelerate the breeding ornamental plants using recombinant DNA technology techniques. Not only is there the possibility of creating new, novel products the driver of the industry but also the potential to develop varieties requiring less chemical and energy inputs. As an important non-food agricultural sector the use of genetically modified (GM) ornamental crops may also be ideal for the intensive farming necessary to generate pharmaceuticals and other useful products in GM plants. To date, there are only a few ornamental GM products in development and only one, a carnation genetically modified for flower colour, in the marketplace. International Flower Developments, a joint venture between Florigene Ltd. in Australia and Suntory Ltd.of Japan, developed the GM carnations. These flowers are currently on sale in USA, Japan and Australia. The research, development and commercialisation of these products are summarised. The long term prospects for ornamental GM products, like food crops, will be determined by the regulatory environment, and the acceptance of GM products in the marketplace. These critical factors will be analysed in the context of the current legislative environment, and likely public and industry opinion towards ornamental genetically modified organisms (GMO's).

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The ornamental horticulture industry

The ornamental horticulture industry is very diverse, but can be considered to generally encompass non-food horticultural applications. In these plants the final product is not further processed, such as would be the case for a wood or fibre crop, or a crop used in feed, such as a forage crop. The production of plants (indoor plants, bedding plants, flowering and foliage pot plants, hanging baskets) and cut flowers are the mainstays of the industry. Production of trees and shrubs for landscaping, and Christmas trees, is also important. The breeding, propagation, production, distribution and wholesaling activities associated with the delivery of the final product to the consumer creates specialist growing and distribution businesses. Good examples are the production of bulbs and plants for flower production or rootstock material for nursery plants. The seedling, propagation and growing on of plants destined for pot plant or bedding plant use are also important activities. There are many allied secondary businesses that contribute to the importance of ornamental horticulture as an agricultural sector. These include manufacturing of florist's sundries, nursery equipment and supplies, chemicals, fertilisers and marketing support materials at retail level. This multiplier effect is most clearly shown for the turfgrass industry. This specific application of ornamental horticulture, the cultivation of grasses for turfgrass applications in landscaping and amenity development (Lee 1996), is included in parts of this review. Whilst the breeding and establishment of turfed areas is significant, this particular ornamental product is quite unique in that the physical areas are huge and the long-term economic inputs subsequent to establishment are very considerable. Once a grassed area is established for amenity or landscaping purposes, there must be a significant outlay on chemicals, equipment and labour in the subsequent years of maintenance. In just one state of the USA alone, Virginia (VASS 2000) the 1998 value of turfgrass related labour, contract services, equipment, supplies, new turf establishment and capital improvements exceeded 1.3 billion US$.

Economic value of the ornamental horticulture

It is very difficult to accurately ascertain the value of the ornamental horticulture industry across the world. Not all countries keep reliable statistics of their domestic industry, and trade statistics are typically accumulated at the importer level, or by the value of production. Subsequent mark ups after distribution and retail to the end consumer vary considerably within a country and with the time of year. Data does exist however, and some good sources of information are the United Nations Comtrade statistics, the Union Fleurs, Dutch and Japanese auction statistics, the Dutch flower council and the United States Department of Agriculture (USDA). This information is available at the following web sites;

http://emi.h.chiba-u.ac.jp/gmn/MNFlowE.html
http://www.ams.usda.gov/fv/mncs/fvwires.htm
http://unstats.un.org/unsd/comtrade/
http://www.unionfleurs.com/
http://www.flowercouncil.org

The worldwide production value of flowers and plants is approximately 50 billion EURO (Union-Fleurs 2000), and about 15-20% of this production is traded (Las 2002). If we extrapolate from the per capita consumption data provided by the Dutch flower council (International Floriculture, June 2002) the global consumption value at consumer level is somewhere between 100 to 150 billion EURO. Expenditure on the production and establishment of turfgrass is likely to be between 50-100 billion EURO, based on a very rough extrapolation (VASS 1998).

As an intensive, complex industry, ornamental floriculture provides a wealth of employment opportunities. There are around 30,000 florists in the USA alone, for example. In the Netherlands, nearly 100,000 people are employed in the production, distribution and sale of ornamental plants. (http://www.flowercouncil.org). In production countries such as Colombia and Ecuador and Kenya, flower-growing operations provide employment to economies where jobs are often scare, particularly in regional areas.

The global trade in cut flowers and plants

Flowers, bulbs and plants are internationally traded commodities. This is particularly the case for cut flowers. In their own right cut flowers are significant commodities, accounting for a third of the value of the ornamental horticulture market. While there are no comprehensive and completely reliable data on all cut flower markets, the estimate of the Dutch flower council (International Floriculture, June 2002) suggests a retail value of 27 billion EURO in just the USA, Japan and the most populous European countries combined. By value, the most popular cut flower is the rose. Other popular flowers include chrysanthemum, tulip, carnation, gerbera and lily. However, the diversity of cut flowers is enormous. Thousands of varieties are sold through the Dutch and Japanese auctions each day.

The flower market has historically been supplied by local (in-country) growers. This has dramatically changed in Europe and the USA, with more and more cut flowers now being internationally traded and supplied from specialised growing and exporting countries. This is most evident for the USA market where, because climatic conditions are ideal for growing high quality and lower cost flowers all year round, specialist growers in Colombia and Ecuador now largely supply the USA. In 1997, 83% of the most popular flower species were imported into the USA, compared with only 4% in 1971. Now, well-established trade routes exist between Latin America and the USA for the efficient importation and distribution of cut flowers. In Europe most flowers are supplied from within Europe, although there is a trend to increasing imports from outside the European community. European countries that import huge numbers of fresh cut flowers are Germany, the UK, Netherlands and France (Laws 2002). Key countries that supply the flowers for these markets are Ecuador, Colombia, Kenya, Israel, Zimbabwe, Thailand and Turkey. The huge Dutch auction system remains the logistical hub for the import and distribution of cut flowers throughout the whole of Europe, and beyond (Union Fleurs 2000).

The Japanese market seems to show a different trend with local flower production increasing 51% since 1985. In 1997, 83% of the Japan flower market was supplied from Japan's 146,000 flower Growers. There are also considerable imports into Japan, from the Netherlands, South America and Thailand.

Potential application of genetic modification

Rapid progress in plant molecular biology has great potential to contribute to the breeding of novel ornamental plants utilizing recombinant DNA technology. A trend in recent years has been to define genetic modifications as being directed towards output, or consumer traits, on the one hand and producer traits on the other hand. This is a useful definition for applications in ornamental horticulture, as output traits can be considered as any modification directed at the end consumer. Producer traits can be considered as varietal improvements likely to benefit the producer/ grower, distributor or retailer. Producer trait types of improvement may not be immediately obvious in the final product, which might take the form of a floral arrangement or a punnet of seedlings for a garden bed.

Output, or consumer traits

Novelty is extremely important in the ornamental horticulture industry. Breeders continually strive to bring wild plants into domestication or use mutation breeding or hybridisation to develop new varieties. Competition is fierce, and breeders are quick to incorporate any new varieties into their breeding programs. In any particular crop breeders compete with each other to sell their varieties to growers, and the growers have a seemingly limitless choice of colour and types. Perhaps the biggest potential of genetic modification is therefore the creation of novelty in ways that is not possible by conventional breeding. Whilst novelty comes in many forms, the most obvious to the consumer will be in plant or flower shape, architecture and size, and the form and colour of the flowers and foliage. Only the imagination of the breeder, and the ability to convince the end consumers they are purchasing something unique and/or desirable will limit what can be created.

Florigene/Suntory have focussed on the generation of novel flower colour in the major cut flower species. Our progress with carnation will be described in more detail later in this paper. The Florigene/Suntory program on colour modification of the important cut flowers is ongoing, and remains focussed on rose gerbera and various pot plant species.

More information on genes that could be used for the alteration of plant architecture and height can be obtained at the website of a commercial company operating in the area, Novaflora (www. novaflora.com), and at Clark et al. (2002). To date, there are no GM ornamental products commercially available that have been modified in this way.

There are groups in the USA, Israel and New Zealand working on the development of novel perfumes, or introduction of perfumes, into cut flowers and pot plants by genetic modification. Rose or carnation flowers that smell like citrus plants or freesias, or terpene producing pot plants that could act as natural air fresheners are examples of directions the technology could be applied. Whilst various genes are being identified (Vainstein et al. 2001), there are no commercial products on the horizon.

Colour modified carnation an example of a consumer trait

The colour-modified carnation that has been developed by Florigene, in collaboration with Suntory Limited, the Japanese alcohol and non-alcohol beverage company, is a consumer trait product. The genetically modified Moon series carnation varieties produce mauve, purple or violet flowers, and can be seen at the Florigene website (www.florigene.com). These varieties were developed by an *Agrobacterium*-based transformation method (Lu et al. 1991) from carnation varieties that produced white or cream flowers. The change in colour is due to the novel production of delphinidin-based anthocyanins in the flowers of transgenic plants (Holton et al. 1993; Holton and Cornish 1995; Tanaka et al. 1998; Mol et al. 1999).

Flower colour is primarily due to the presence of anthocyanins and carotenoids. Yellow and orange flowers normally contain carotenoids. The anthocyanins pelargonidin, cyanidin and delphinidin 3-glucosides are coloured pigments, responsible for pink, mauve, red and blue shades of flowers. Flowers that produce delphinidin-based pigments generally have a violet-blue shade. The anthocyanin biosynthesis pathway is an intermediate of the phenylpropanoid pathway and an early critical enzyme is chalcone synthase, which catalyses the biosynthesis of 4, 2', 4', 6'-tetrahydroxychalcone. This compound is converted to naringenin by the enzyme chalcone isomerase and naringenin is subsequently converted to the dihdroflavonol dihydrokaempferol (DHK) by the enzyme flavanone 3-hydroxylase. DHK can then be hydroxylated at the 3'position by the enzyme flavonoid 3'hydroxylase (F3'H) to produce dihydroquercetin (DHQ), or at both the 3' and 5' positions by the enzyme flavonoid 3', 5' hydroxylase (F3'5'H) to produce dihydromyricetin (DHM). The colourless dihydroflavonols (DHK, DHM or DHQ) are then subsequently converted to the coloured anthocyanins by the enzymes dihydroflavonol 4-reductase (DFR), anthocyanidin synthase and flavonoid-3 glucosyltransferase, with DHK being converted to the brick-red pelargonidin-based pigments, DHQ being converted to the red cyanidin-based pigments and DHM being converted to the purple-blue delphinidin-based pigments. The flavonoid 3'5' activity is therefore necessary for biosynthesis of delphinidin-based anthocyanins. Critically, F 3'5'H does not occur in carnation normally, as the gene encoding the F3'5'H enzyme is not present in this species. Therefore carnation cannot produce delphinidin-based pigments.

The genetic modification Florigene has carried out has resulted in the expression of F3'5'H genes in specific, white cultivars of carnation. These white cultivars were selected on the basis of lack of activity of both flavonoid 3'-hydroxylase and dihydroflavonol reductase but with the rest of the anthocyanin pathway intact. Expression of the flavonoid 3'5' hydroxylase gene results in the production of the dihydroflavonol dihdromyricetin. Addition of a petunia DFR, (which has a higher specificity for DHM over DHQ and cannot utilise DHK) ensures that only delphinidin-based pigments are produced in the petals. Because delphinidin-based pigments are not found in carnations naturally, the flowers from the genetically modified plants are a unique colour. So far, six commercial varieties of carnation have been developed using this strategy.

Producer traits

The potential applications of gene technology directed towards producer traits in ornamental horticulture are just as exciting as they are in the major food crops (Wagstaff et al. 2002). Improvements to disease resistance (eg. *Fusarium*, mildews, *Botrytis*), productivity and post harvest longevity are all possible, as are traits perhaps a little further on the horizon such as aphid, mite and thrip resistance. Insect control is probably the number one problem in ornamental horticulture, not only because of the cost of control but because of the difficulties residual insects pose for exported goods at quarantine. Control of all diseases and pests demand chemicals and labour in intensively managed ornamental crops, and represents a considerable portion of production costs. Other genetic modification programs could be directed towards control of flowering time, dwarfing (eliminating the need for chemical treatment) and improved rootability in woody species.

Long life carnation - an example of a producer trait

Vase life is a critical breeding objective in cut flowers. Strategies to use genetic modification to improve vase life are reviewed by Van Altvorst and Bovy (1995). For flower growers and distributors vase life is of critical importance to the long-term sustainability of their business.

Florigene has had a long-term project on the development of improved vase life in carnation. This is a good example of a producer trait, because in this case the genetic modification has the same effect as chemical treatment of the flowers. For consumers, flowers either have or do not have good vase life. They know little of the need for correct post harvest treatment by growers to maximise vase life. In contrast, there are also examples where modification of vase life by genetic modification could be considered a consumer trait, I the absence of any alternate means to obtain the same result.

The deterioration of a carnation flower following its removal from the plant is triggered by the endogenous synthesis of a plant growth regulator, ethylene. Ethylene is produced by the flower as a result of the activity of two enzymes, ACC synthase and ACC oxidase. ACC synthase catalyses the conversion of S-adenosyl methionone to 1-aminocyclopropane-1-carboxylic acid and ACC oxidase (also called ethylene forming enzyme) catalyses the conversion of 1-aminocyclopropane-1-carboxylic acid to ethylene.

Ethylene causes the senescence and deterioration of carnation flowers within 5-12 days after harvest, depending on the variety. The flowers produce the ethylene, but sufficient amounts of external ethylene will also induce senescence. Chemicals are available which prolong carnation flower longevity. Silver ions are thought to prevent ethylene perception by blocking the ethylene receptor, preventing the autocatalytic production of ethylene production by the flower. The most widely used formulations contain silver. The genetic modification Florigene has carried out has been to insert a cDNA of petal specific carnation ACC synthase back into carnation. The expression of the cDNA causes, by co-suppression, inhibition of the production of ACC synthase enzyme. This inhibits the production of ethylene, resulting in plants whose flowers have an enhanced vase life, without the need for chemical treatment. Expression of the cDNA is not petal-specific, but has a petal specific effect due to the cosuppression activity of the ACC synthase fragment (flower senescence associated ACC synthase) used to make the construct. We have carried out transport simulation tests in which flowers from carnation plants genetically modified for enhanced vase life were grown in Israel and shipped to the Netherlands for vase life testing. In these experiments, the transgenic flowers, which were not treated with chemical, had as good a vase life as silver treated flowers from non-GM plants of the same variety. Genetic modification of carnation by introduction of a modified ethylene receptor gene has also been successful in our hands, and in the hands of Dutch researchers. In these experiments the flowers were also resistant to externally applied ethylene.

While the vase life of carnation flowers can be maximised by chemical treatment of flowers at the time of harvest, genetic modification offers several advantages.

Firstly, the most widely used preservative solutions, which contain silver ions, could be replaced. The use of silver by the carnation industry is worldwide. Silver metal is only mildly toxic but silver nitrate, a salt commonly used by growers to prepare preservative solutions, is more toxic, and is a skin irritant. Preservative chemicals are also potentially polluting.

Secondly, from a grower perspective use of the genetically modified variety will save the grower both chemical and labour (changing water and solutions) costs.

Thirdly, wholesalers and retailers can be sure that the genetically modified carnation has a good vase life, without the possible risk that a grower has incorrectly treated the flowers. The consumer can enjoy carnation flowers with an excellent vase life, in the knowledge the flowers have been treated with fewer chemicals. To date, the long vase life carnation has not been commercialised.

Ornamental plants as protein factories

The potential use of ornamental plants as sources of secondary metabolites or proteins the so-called "pharming" of "plants, or plants as factories" concept, is an area that has not been explored significantly. There are a number of advantages inherent in the use of the correctly selected ornamental plants for this purpose.

Firstly, ornamental products are typically non-food crops and there would be no possibility of co-mingling in the food supply chains. They are also readily identifiable in the extraction process-for example if protein synthesis was specific to the flowers of the transgenic plant.

Secondly, gene dispersal can be eliminated as a possibility by selection of a non-flowering target crop, such as a foliage plant or a sterile flowering variety. Many ornamental plants are introduced species and with judicious selection it would also be possible to select species where there were no wild relatives anywhere near the production area.

Thirdly, ornamentals are intensively managed and harvested. It is quite normal to produce flowers, for example, in effectively hydroponic conditions. The flowers could readily be harvested for processing, in the same way that pyrethrums and oils are extracted.

Ornamental products in the pipeline

This review concerns the commercialisation of GM ornamental products. At this time there is only one product of this type on the market, and that is the colour modified "Moon" series carnations Florigene and Suntory have developed. Whilst there is research on various aspects of genetic modification in ornamentals, in the private sector and at both universities and research institutes, this research appears to be producing little that is heading towards commercial development in even the medium term. A measure of the "pipeline" is the number of field trials in place, which will be discussed now.

A recent, very comprehensive review of GM products in the pipeline has been prepared by the Joint research centre of the European Commission (Lheureux et al. 2003). Whilst the focus of that review is European, it also takes in North American developments in the expectation that eventually the European market may open up to imports of GM products. That review only identifies modification of flower colour as a potential GM product for the future. The same report (Lheureux et al. 2003) points towards a fairly dramatic decline in research on GM plants in Europe, further reducing the potential of potential products from there.

A review of the Japanese field trial situation shows that Suntory are the only company to have a commercial ornamental product in that country, and that is the "Moon" series carnation. Suntory are also working on the modification of flower colour in torenia and virus resistance in petunia. Neither of these initiatives has yet lead to a commercial product. Kirin of Japan is researching viroid resistance in chrysanthemum, and this research had progressed to field rial stage in 2002 (MAFF 2002). Research on fungal resistance in bentgrass and zoysiagrass by Japan Turfgrass has not progressed beyond contained trials (MAFF 2002).

As might be expected, far more activity has, and is, occurring in the USA. The Information Systems for Biotechnology Program (ISBP) at Virginia Tech maintains a database of US field trials. This database (http://www.nbiap.vt.edu/cfdocs/fieldtests1.cfm) and the USDA-APHIS site notifying permit applications is a valuable resource. An analysis of the ISBP database is summarised at Table 1, and this shows quite significant activity in the USA, directed towards both producer and consumer traits. The Scott's company are well progressed, and it may be that their turfgrass products (Lee 1996) may be the next commercial products available in the ornamental area. Specifically, this product will most probably be glyphosate tolerant bentgrass for use in golf courses (Harrimann et al. 2003).

For further review of what might be in the pipeline outside of Europe, Japan and the USA it is possible to now see on line the status of trials in various parts of the world. A review of the Biosafety Information Network and Advisory Service (BINAS) database of field trials in developing countries (http://binas.unido.org/binas/trials.php3ln), suggests GM trials are only occurring with food crops. This impression is reinforced by analysis of the database links maintained by the Information Systems for Biotechnology Program at Virginia Tech at http://www.nbiap.vt.edu/cfdocs/globalfieldtests.cfm. In Australia, the "Moon" series carnation is the only ornamental GM crop in trial or the marketplace.

Commercialisation

Uptake of GM technology in ornamental horticulture

While GM varieties of several major food crops are now in commercial production, uptake in ornamental horticulture has been far slower. In part, this is because breeders very largely drive innovation in the industry, and they are likely to be the ones who would eventually use the technology to develop new varieties. Many breeders are specialist, small companies without the resources necessary to undertake the research and development. However, adoption of GM technology by the ornamental industry can probably be attributed to two major reasons.

One important reason could be that the majority of breeders are based in Europe, or have European operations. There remains an ambivalent attitude to GMO's in Europe, and there is subsequently believed to be a market acceptance risk asso-

Table 1. Summary of US field trials with ornamental horticultural plants

Crop	Trait	Organizations
Anthurium	Xanthomonas resistance	University (U.). Of Hawaii
Begonia semperflorens	Herbicide resistance, colour modification	Scott's
Bermuda grass	Drought and salt tolerance	Rutgers University, U of Georgia
Chrysanthemum	Virus resistance	Yoder bothers
Creeping bentgrass	Disease resistance, herbicide tolerance, drought tolerance, salinity tolerance, sod web worm resistance, growth rate altered, aluminium tolerance, heat tolerance	Scott's, Rutgers, Kansas State U., U of Nebraska, U of Rhode Island, Pure seed testing, Michigan State U
Dendrobium	Disease and virus resistance, colour modification	Univ of Hawaii
Gladiolus	Virus resistance	Agricultural Research Services USA
Kentucky bluegrass	Drought and salinity tolerance, herbicide tolerance, disease resistance, growth rate altered	Scott's, Rutgers
Marigold	Herbicide resistance, colour modification	Scott's, Ball Helix
Pelargonium	Herbicide resistance, colour modification, disease resistance	Scott's, Sanford Scientific
Petunia	Herbicide resistance, disease resistance, colour modification, extended vase life, male sterility	Scott's, Pan-American seed, Rogers NK, U of Minnesota, Sanford scientific
Rhododendron	Phytophthora resistance	U of Connecticut
St Augustine grass	Growth rate altered, herbicide resistance	Scott's
Velvet bent grass	Herbicide resistance	U of Rhode Island

ciated with developing a GM product.

The second reason is that the cost of developing a product, when weighed up against potential returns, is significant. The equation effectively limits the economic argument for development to just the most widely grown, high profile ornamental products, such as the major cut flowers, and a few pot plant species such as geranium. Research is not necessarily the main cost component, and trials are a normal part of new variety development. It almost inevitable that components of the technology utilised (such as promoters, transformation technique, selectable marker) will need to be licensed. These are additional costs. As the regulatory environment has developed, more and more supporting information is also required, particularly for molecular analysis, and this is extremely expensive. Such data packages do not distinguish between food and non-food crops aside from the fact that food safety assessments are, usually, not required. Another legislative area to be aware of is the Plant Breeder Rights legislation in any country in which growing or marketing of a GM ornamental product is planned. As a result of essential derivation legislation enacted in many revised national Acts since the early 1990's, the owner of a genetically modified variety will be considered to have essentially derived it from the owner of the parental variety. This makes the selection of parental variety, and seeking the collaboration of a breeder partner, a further consideration, and additional cost.

Consumer vs. producer traits

Commercialisation of a producer trait is likely to be more difficult than for a consumer trait, because the potential returns are lower. In the simplest sense the return to the technology developer would need to be justified on the basis of savings made by the grower and/or distributor. There is little opportunity to "market" the benefits of the producer trait to the end consumer, and it is that end of the chain where the greatest returns are our joint venture, International Flower Developments. Variety protection is quite normal in the horticultural industry and the addition of patent rights adds an additional layer of protection.

Selection of lines for further trials. As is usually the case, from any one transformation experiment many individual transgenic lines are produced. In our hands, some of these events produced flowers with no colour change, but many had novel flower colours. From this population it was necessary to select lines for further trials. We did that on the basis of the colour, the stability if the colour (avoiding any flowers where we suspected chimeral transformation), the normality of the flower (as measured by size and number of petals, for example) and a preliminary molecular analysis. We do not consider for commercialisation any transgenic events where preliminary Southerns indicate the presence of extra border integration.

Field trials. Field trials are carried out in collaboration with the breeder of the parent variety. In that respect, it would be wise for any group considering development of a GM ornamental variety to work closely with conventional breeders. The purpose of our trials is to select lines that are as close as possible to the parental lines in terms of characters that are most important to the flower trade. This requires careful measurement of productivity, quality and flower vase life. The same trials are used to generate data for regulatory submissions.

Regulatory approval. Typically, before commercial trials can be begun regulatory approval is required. This is a difficult, unpredictable task.

Commercial trials. Commercial trials establis productivity, and identify any handling or post harvest requirements that may be specific to the GM variety. This data is required to establish a production cost, which is required in our case because the Florigene "Moon" series flowers are grown under contract to Florigene.

Production and marketing. Florigene's flowers are produced in Australia, Ecuador and Colombia. From South America they are exported to the USA and Japan. These two production centres could also serve Europe. Both Ecuador and Colombia have ideal climates for flower production, well motivated and highly skilled flower growers and good logistics for air transport. Florigene's "Moon" series carnations are marketed to wholesale and retail florists in the USA. Japan and Australia.

Outlook

The legislative environment

There is no question that the most difficult part of the commercialisation process at the moment lies in the regulation of GM organisms. The environment remains uncertain, as countries apply the Biosafety protocol, and there is also a definite trend to increased, rather than decreased scrutiny. The amount of data required, and the regulatory procedure itself, also varies considerably from country to country, and is subject to change. The scrutiny by regulatory bodies demands ever more detailed molecular analysis, toxicological data and other safety data. A constant source of frustration is that the same amount of scrutiny is not afforded to non-GM plants as is to GM plants. In ornamentals there may be no assessment of non-GM plants at all, outside of various quarantine assessments of potential weediness. In the case of ornamentals most national quarantine authorities maintain lists of prohibited species, and that is because there is a history of introduction of ornamentals that have subsequently become weeds. A visit to any reasonably sized local nursery will reveal the presence of noxious weeds and poisonous plants which pose a clear and present danger to the environment and health. This stands in stark contrast to the amount of testing that the "Moon" series carnation, a very innocuous product, faced. The imposition of regulations simply because an ornamental product is a GMO is therefore a barrier to commercialisation of GM ornamental varieties.

Government policies

The uncertainty surrounding the regulatory process is inextricably linked to the politics of GM technology. The major regulatory issues are the gradual introduction of national laws to adhere to the Cartagena Biosafety treaty, and the continuing moratorium on new GM releases in Europe. Surrounding these legislative decisions there continues to be lobbying to restrict application of GM technology, particularly in food crops. At a lesser level are decisions by national, state and even city councils to impose bans an all GM products. Largely these are symbolic (though none the less damaging to the industry), but in some cases destructive. For example, the New Zealand government has supported long-term research on the development of transformation protocols and GM varieties of Lisianthus and Cyclamen. At the same time, there continues to be a debate in that country about the pros and cons of biotechnology per se. The resulting implementation of stringent regulatory and legislative hurdles will surely hamper any prospect of commercial development of GM varieties in that country, an opinion already voiced by the chief executive officer of HortResearch in that country (Collins 2003). Already, through blanket decisions, Florigene's own GM products have been removed from some markets. For example, a recent decision by the Tasmanian government in Australia to ban all GM plants through their state government quarantine laws has effectively banned Florigene products from that market place. Such decisions, based on political expediency, rather than science, pose a severe threat, as they present so much uncertainty as to present a risk in even expending money on research.

Acceptance in the marketplace

There are concerted efforts to demonise GM products. Non-government organizations (NGO's) in many countries are waging these campaigns. Such groups are opposed to genetic modification in agriculture, under any circumstances. Their motivation seems to be the generation of campaign funds, and the promotion of organic agriculture. While the primary focus of scare campaigns has been food crops, and ornamentals are not a high profile target, this does not mean that GM applications in ornamental horticulture would be exempt from direct or indirect attacks. In Europe, for example, the supermarket chains continue to be very wary of carrying GM products of any description. It is also the case that in the ornamental industry the consumer exists at many levels. There are propagators, nurserymen, wholesalers, exporters, importers, wholesalers, retailers and the final consumer. All play a role in deciding whether to carry or market GM products, and all are potentially open to the pressure tactics employed by some NGO groups. Retail of ornamental products is also becoming more complex. In addition to the traditional florist for example, flower can be purchased through supermarkets, by mail order, or over the internet.

The bland statements of the NGO's, media and politicians that the public do not want GMO's are not correct. It is ironic that NGO groups, who have spent years demonising GM technology, now state that the public don't want the products. In Tasmania, for example, the public could not buy our flowers, even if they wanted to! In the case of Florigene flowers our product has been accepted in the market place. The flowers are not labelled as GMO, except in Europe, but it is common knowledge in the trade that Florigene varieties are genetically modified. All wholesalers are told ahead of purchase and the information is available through our web page, the address of which is in all our advertising (www.florigene.com). Various trade magazine and press articles have also focussed on he genetic modification aspects of the Florigene varieties. In Australia, point of sale information explaining the genetic modification process was also made available.

The simple fact is that the general public have not had a great deal of opportunity to chose whether or not they would purchase a GM product. This is because the products are either not on the supermarket shelf at all, or the benefits have not been marketed to the consumer. In the longer term, I believe the wider community will come to accept genetic modification of plants, and first acceptance will be for non-food crops such as flowers and pot plants. Aside from the fact that ornamental plant GMO's are not typically food cops, there is also the advantage that the benefits are consumer trait driven. A new type of cut flower, or a lawn that requires less watering or mowing are traits that provide a visible, and interesting, benefit to the consumer.

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