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Grower Summary

Headline

- There is currently a good, sufficient range of post-harvest treatments products available for use with cut flowers in the UK but to ensure availability of such products in the future, the cut flower industry needs to forge closer links with post harvest treatment manufacturers and PSD.

Background and expected deliverables

Cut flower quality is at its optimum at harvest and will quickly deteriorate thereafter. The longevity of the cut stems post-harvest will depend on a
number of factors: the growing conditions pre-harvest; the varieties grown; the flower stage at harvest; the post-harvest handling regime and the post-harvest treatment given.

Post-harvest treatments for cut flowers are used to improve the quality of the stems and prolong their life through the supply chain from grower to packer / wholesale market, from packer / wholesale market to retailer and then on to the end consumer.

Product quality and post-harvest performance are two of the key criteria that supermarket retailers in particular expect of the cut flowers that they sell.

Therefore, where possible, it is important to ensure all aspects of the growing cycle and post-harvest handling process are managed to enhance and maximise the product quality and performance, and essential to this is the use of post-harvest treatments.

Post-harvest chemical treatments are based on a number of active ingredients as follows:

- plant growth regulators
- hydrating agents
- biocides
- acidifiers
- sugars

In June 2004 the EU ruled that '*Disinfectants used for the purpose to preserve sugar containing products before use in cut flower treatments and / or prevent bacterial or other microbial growth in the flower water are considered to be biocides and fall under Directive 98/8/EC*'

However, despite this ruling, post-harvest treatment products currently containing ingredients classified as biocides may be reviewed and their classification altered. Growth regulators, used in some post-harvest treatments, are classified as plant protection products.

Therefore, it is important for the industry to understand the situation with respect to post-harvest treatment products currently available for use and, to gain an understanding as to the potential options available as 'alternatives' to those products.

The objectives of the project were to:

- Assess the future threat to cut flower post-harvest treatments currently in use in the UK

- Highlight the potential commercial impact on growers, packers, retailers and end consumers if products are no longer available in the future
- Identify priorities for R&D and technology transfer opportunities to ensure commercially available 'alternatives' going forward

Summary of findings and conclusions

Currently in the UK there is a good, sufficient range of post-harvest treatments products available for use with cut flowers.

However, this range could be reduced if manufacturers decide not to register certain products in the UK in the future, in particular the anti-ethylene treatment Chrysal AVB, which may not be registered for use and this will potentially affect a number of growers of certain summer cut flower species.

Registration of products takes time and money and therefore the manufacturers of the post-harvest treatments need to be sure that they have a commercially viable product. EU rulings may affect the product development potential of the post-harvest treatment manufacturers going forward and this will in turn affect the range of products available for use in the UK.

Post-harvest treatment products are a key factor in maintaining post-harvest product quality and maximising longevity and ultimately end consumer satisfaction. However, they are only one part of the post-harvest handling process and product quality and performance can also be affected or enhanced by many other factors both pre- and post-harvest and these should not be ignored.

Lessons can be learnt from the food industry, in particular the fresh produce industry, on key product handling issues such as temperature management throughout the supply chain and product storage methods.

The ‘back-to-basics’ approach of gaining a far better understanding of how plant cells die and programmed cell death (PCD) is believed, by one post-harvest treatment manufacturer, to be fundamental in the future product development process.

Research work on ‘natural’ biocides and ‘green chemicals’ has produced some interesting results, with some products being commercialised. This work could be utilised further for ‘alternative’ cut flower post-harvest treatments but in many cases these ‘alternative ‘ ingredients may be affected as much by legislation and registration costs as current ‘chemical’ ingredients.

A better, more in-depth understanding of the work carried out on cut flower post-harvest handling, for example at Wageningen ATO-DLO, could be very interesting and possibly key to new product development. There may be technology transfer opportunities with centres of excellence such as ATO-DLO that could benefit the UK industry both in the short and long term.

The UK industry as a whole, through a body such as the HDC, needs to develop a relationship with the key post-harvest treatment manufacturers. The packers and retailers work closely with these companies but if they, together with the UK cut flower growers, were able to ensure that manufacturers better understood the need to keep key post-harvest treatment products available this would be beneficial to the UK industry going forward.

Action points for growers

- In the short term growers and packers should be encouraged to continue to consider how they can better improve product post-harvest life by reviewing their post-harvest handling processes, looking at temperature management, lead times from harvest to consumer and ensuring they are using industry best practices.

- The process of registration of products in the UK may be aided by HDC representation of their member's interests to the post-harvest treatment manufacturers and the PSD.

Science Section

Introduction

Ideally, a cut flower would be harvested when the visual quality is at its optimum and sold straight from the field or glasshouse to the end consumer.

However, this is not practical for the large majority of growers supplying their customers, whether they be supermarkets, the wholesale markets or florists. Cut flowers are living biological systems that will deteriorate after harvest. The product is required to withstand the rigors of the post-harvest handling process from grower to packer or wholesale market, from wholesale market or packer to retailer and from retailer to end consumer.

The complete process from harvest to end consumer is termed 'post-harvest'.

Extending the post-harvest life of cut flowers requires knowledge of all the factors that can lead to loss of quality and the knowledge of technologies that can minimise the rate of deterioration.

One of these technologies is the action and use of chemical post-harvest treatments. The purpose of this study was to better understand the post-harvest treatments available to the growers and packers in the UK and the potential threats to these going forward.

Loss of quality in a cut flower post-harvest tends to be categorised as physical loss i.e. damaged product and / or quality loss due to physiological and compositional changes within the cut flower stem. Loss of quality during the post-harvest process can arise from one or a combination of the following: mechanical damage; poor temperature control and management; water loss; incorrect or no use of chemical post-harvest handling treatments; poor hygiene.

Post-harvest handling treatments are generally based on a number of active ingredients in varying concentrations.

These active ingredients include:

- sugars
- biocides
- acidifiers
- hydrating agents
- plant growth regulators

The action and composition of these treatments have been developed over the years based on the post-harvest physiology of the particular groups and types of cut flower, their individual requirements and the requirements and expectations of the end consumer.

Sugars – these are the primary active ingredient as a source of nutrition to complete the flower development, bud opening and maintenance of flower colour.

Biocides – are used to protect the sugar in the post-harvest treatments and to slow down and reduce the growth of microorganisms in the post-harvest treatment solutions. Some of these biocides have a slow release action to manage the microbial growth over a period of time.

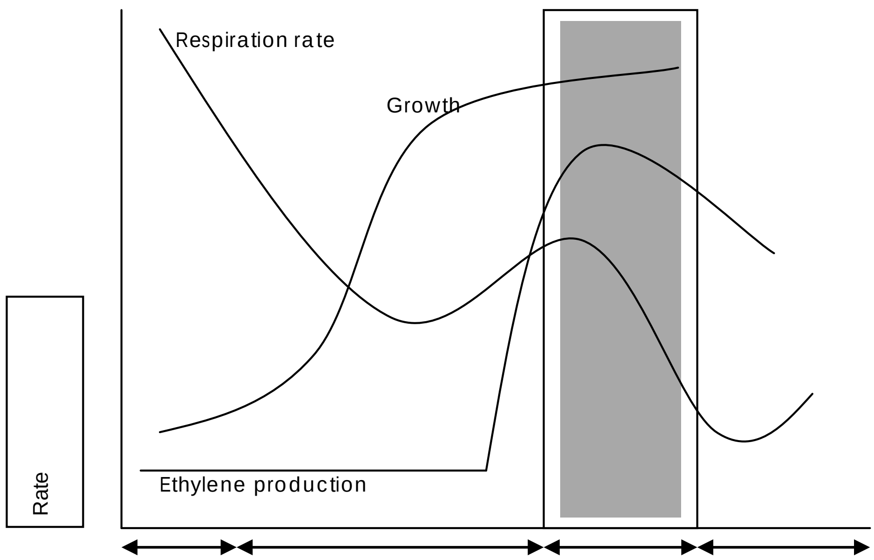
Acidifiers – such as citric acid, are included in most post-harvest treatments to aid water uptake and to help reduce the pH of the solution thereby helping to prevent the growth of the microorganisms.

Hydrating agents – help where there has been a loss in stem, leaf or flower turgidity. They work by lowering the surface tension of the water solutions and help by dissolving any air pockets within the cut flower stems and aid the flow of water up the stems.

Plant growth regulators – these directly influence the physiological processes within the cut flowers, an example is sodium silver thiosulphate (STS). It works by slowing down the internal production of ethylene and reducing the effect of external ethylene upon the cut flower stem. Due to their effect on the physiology of the cut flowers plant growth regulators are classified as plant protection products, i.e. pesticides, and are registered as such.

In order to better understand the action of the post-harvest treatments, it is important to understand the process of the death of a cut flower stem. Cut flowers are 'living' structures, even after harvest the cells will continue to perform most of the metabolic reactions and physiological functions that would have occurred when still attached to the plant.

The life of a cut flower stem can be divided into three major physiological stages: - growth, maturation and senescence. See Figure 1.



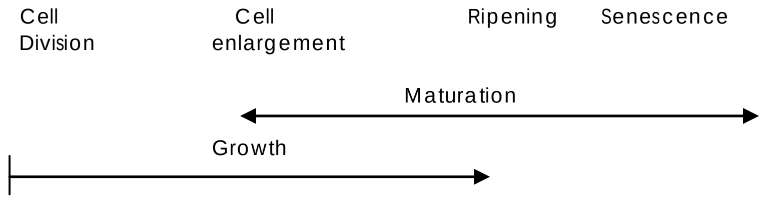


Figure 1: Growth and respiration. (Adapted from Teixeira da Silva, J. 2003)

Senescence can be defined as the period when ageing and final death of the tissue takes place. Ripening and senescence can start on the plant before the cut flower stem is harvested. Cut flowers can be harvested before maturation has commenced through to the start of senescence, depending on the type and variety of cut flower.

Plants respire, taking up oxygen and giving off carbon dioxide and heat. They also transpire (i.e. lose) water. When a cut flower stem is attached to a plant the losses due to respiration and transpiration are replaced by the plant's physiological systems. After harvest respiration and transpiration continue but the cut flower stem no longer has a natural supply of water, the products of photosynthesis (e.g. sucrose and amino acids) and minerals. If these are not supplemented the stem has to rely solely on its food and water reserves and deterioration begins.

Therefore, in order to prolong the post-harvest life of a cut flower stem there is a need for good post-harvest practices when handling the product and in many cases the need for post-harvest chemical treatments.

Research and Findings

Key post-harvest treatments currently used in the UK

The key post-harvest treatments used, or available for use within the UK cut flower industry currently, are listed in Table 1.

This table also shows, where known, the current status with respect to registration of the product in the UK, and if not registered, if there is any future intent to register. See 'Commercial development of post-harvest treatments' section on the registration process.

Table 1: Post-harvest treatment products currently available for use in the UK

Product	**Manufacturer**	**Action of post-harvest treatment**	**Registered outside of the UK**	**Registered in the UK**	**Intent to register in the UK (where known)**
Chrysal BVB	Pokon & Chrysal	Keeps leaves green and fresh	USA	Not yet	Yes
Chrysal AVB	Pokon & Chrysal	Pre-treatment to prevent ethylene damage and aids flower retention	USA NL	Not yet	TBC
Chrysal Lily and Alstroemeria T-Bag	Pokon & Chrysal	Keeps leaves green and fresh and stimulates water uptake	Not yet necessary	Not yet	TBC
Chrysal RVB Clear	Pokon & Chrysal	Aids rehydration	No	Not yet necessary	Yes
Chrysal CVB	Pokon & Chrysal	Inhibits bacterial growth	NL	No, not yet necessary	No
Chrysal CVBn / Gerbera	Pokon & Chrysal	Inhibits bacterial growth	For NL in progress	No, not at present	Yes
Chrysal SVB	Pokon & Chrysal	Keeps leaves green and fresh	NL	No	No
Chrysal Professional 1	Pokon & Chrysal	Aids rehydration	No, not necessary	No, not necessary	Yes
Chrysal Professional 2	Pokon & Chrysal	Aids rehydration	No, not necessary	No, not necessary	No, not necessary
Vitabric PRO	Vitabric	Aids rehydration and inhibits	Application in progress	Yes	

		bacterial growth			
Vitabric PRO premium	Vitabric	Aids rehydration and inhibits bacterial growth	Application in progress	Yes	
Vitabric TPT	Vitabric	Reduces leaf yellowing and inhibits stem growth	yes	Trial Permit available	Yes
Vitabric IPT	Vitabric	Prevents leaf yellowing and inhibits bacterial growth	yes	Trial Permit available	Yes
Floralife H100	Floralife	Aids rehydration and inhibits bacterial growth	*		
Floralife H200	Floralife	Aids rehydration and inhibits bacterial growth	*		
Floralife PRG	Floralife	Inhibits bacterial growth	*		
Floralife PAL	Floralife	Prevents leaf yellowing and inhibits bacterial growth	*		

* Floralife Inc have not been able to give specific information on their products but have stated that "…. Floralife Inc. would continue to source its biocide active ingredients from registered European suppliers who defended their products under Directive 98/8/EC ….."

Key Products

Two of the key types of product used that may be affected either by the registration process and / or classification of ingredient, but also the decisions by the post-harvest treatment manufacturers not to register the product in the UK, are the anti-ethylene products and products that contain biocides.

Anti-ethylene treatments

Over 40 years of research have gone into the development of products for ethylene sensitive flowers, for example, carnations, delphinium, larkspur and pinks.

STS (sodium silver thiosulphate) -

Currently the only effective treatment available to growers in the UK is sodium silver thiosulphate (STS) in the form of Chrysal AVB.

AVB is registered by Pokon & Chrysal in the USA and The Netherlands but is not currently registered in the UK, and currently there is a question mark as to whether they will register it in the UK.

Chrysal AVB is used throughout the UK grower base, especially in the summer cut flower season. There are human and environmental toxicity issues and the used solution must be disposed of in the correct manner, and currently is the only product commercially available for use.

Other post-harvest treatments that have been developed for ethylene sensitive flowers are as follows: -

AOA (Aminooxyacetic acid) –
The development of AOA began in 1980. It was developed as an organic / environmentally friendly alternative to STS. Its drawback is that it only gives protection against endogenously (internally) produced ethylene and not exogenous (external) sources of ethylene.

This mode of action is different from that of STS, which protects against both endogenous and exogenous ethylene through the silver ions acting as an ethylene binding site blocker.

The manufacturer invested many years and money into the development of AOA. It was a more costly product than STS and was only really effective on carnations. In addition, there were issues with respect to toxicity to humans. The work and production of AOA by this particular manufacturer ceased and it was not progressed to registration. Another manufacturer has produced a successful alternative to AOA but will not be progressing this product as it estimated that it will cost them 3 million euros to register the product.

1-MCP (1-methylcyclopropene) –

This is an anti-ethylene product that can be applied as a gas. It has low or no mammalian toxicity and low or no environmental impact. It works in the same way as STS providing protection against both endogenous and exogenous ethylene. However, it can only currently be used on ornamentals in the USA. In Europe it is only registered for use on edible produce and there are no plans by the manufacturer, at the time of writing, to register its use for ornamentals.

AVG (Aminoethoxyvinylglycine)-

AVG works in a similar manner to AOA by providing protection against endogenously produced ethylene, but is more effective than AOA. However, it is very expensive and is therefore unlikely to be developed for commercial use within the ornamental industry.

Other anti-ethylene alternatives –

- Sugar has been known to give an anti-ethylene affect but is required in very high concentrations. This consequently leads to the need for high doses of biocide to counteract the effect the high levels of sugar, which in turn would affect the classification and registration claims against any biocide used

- Genetic engineering has been effective in using antisense gene technology to prevent the production of ethylene during senescence, leading to longer shelf and vase life. However, the retailers, to date, have shied away from selling any genetically modified products, including ornamentals products

- Carbon dioxide has been found to act as a competitive inhibitor in the action of ethylene (Salunkhe et al 1990). High levels of carbon dioxide can lead to the suppression of ethylene damage to plant tissue.

There is on-going research into and the use of controlled atmosphere storage in the fresh produce industry, where the levels of gases in the atmosphere can be controlled giving an atmosphere different to that of normal air. A decreased concentration of oxygen and an increased concentration of carbon dioxide slows down the respiration rate of the produce being stored and any potential microbial contaminants. Results between different types of produce, and between different varieties within a species, can vary considerably and can therefore limit the types of product that can be stored together, as they may require different atmospheres for optimum storage conditions.

Biocides

In the 1970's there were two main types of biocide available to use in ornamental post-harvest treatments: -

- Aluminium sulphate – this is a relatively weak biocide. It acts as an anti-oxidant and gives a precipitate, leaving a cloudy solution once the post-harvest treatment had been diluted

- 8 hydroxyquilaminesulphate – this biocide gave no precipitation, and therefore a clear post-harvest solution, but gave off a very strong odour. But, as with aluminium sulphate, it is not, in relative terms, a good biocide

In the 1980's a new generation of biocides were developed which gave rise to the 'clear' post-harvest treatment formulations that are currently in use.

There is a third generation of biocides, which could potentially be utilised but are currently very costly.

The 2004 EU ruling, with respect to biocides used in cut flower post-harvest treatments, recognised that the biocides were present to preserve the sugar in the products prior to use with cut flowers, and could therefore be classified as biocides rather than plant protection products as they did not have a direct physiological effect on the cut flower itself.

However, there are EU directives regarding the concentrations of biocides that are allowed to be used in products. Therefore, the manufacturers have needed to review any formulations that are currently in use and where necessary, adjust any formulations of biocides being used, and in addition, to consider their product development priorities going forward in relation to these directives.

Commercial development of post-harvest treatments

The commercial development of post-harvest treatments for the cut flower industry has been established for many years.

In the UK there are currently three suppliers: -

- Pokon & Chrysal
- Vitabric
- Floralife

Between them these companies supply a range of products to the industry which include: pre-treatment products for growers; transit solutions / products for packers and retailers; flower food products for use by the end consumer.

In order to develop a range of products such as these different requirements need to be met aiming to prolong the post-harvest life of the cut flower for as long as possible throughout the different stages of the supply chain. As discussed previously the products are based on a number of ingredients: sugars, acidifiers, hydrating agents and chemical additives, which in some products include pesticides or biocides.

If the post-harvest treatment manufacturers add raw materials to their formulations that qualify as pesticides or biocides, they may only do so if these raw materials have been 'notified' to the EU authorities and are subject to a review program.

The manufacturers of these raw materials, who supply the post-harvest treatment manufacturers, are responsible for ensuring that their raw materials are 'notified' to the EU.

The post-harvest treatment manufacturer will take the different raw materials available and create a formulation for a particular post-harvest treatment. They, or their importer, are then responsible for the registration of this formulation, if registration is required under the laws of the country where the product is applied. Registration is required if the formula meets the criteria for being considered as a "pesticide" or "biocide". It is important to note that the fact that a product contains a pesticide or biocide does not automatically imply that the product itself also needs to be registered.

The timescale from the initial development of a new post-harvest treatment through to the registration of a product formulation (if required), in the country of use, can take many years. The post-harvest treatment manufacturers have to be sure that the years of investment in the product development, and the cost of registration, are commercially viable, and consequently, that once registered, the new post-harvest treatment will give them a return on their investment. The cost of registration of a new product can amount to more than one million euros.

Even though the UK is an EU member state, if a product is registered in another EU Member State, it is still necessary to register it separately in the UK.

However, if a product is already registered in another EU member state, for example The Netherlands, and the post-harvest manufacturer wishes to register this product in another EU member state, i.e. the UK, then an application can be filed asking for registration based on "mutual recognition".

In order to achieve registration of a product there needs to be information provided on the initial product trials, laboratory and field research, proof that the product is effective and has been trialed in representative conditions e.g. with growers and throughout the different seasons. Also there needs to be proof that the product is harmless to humans, animals and the environment.

Current status for registration of post-harvest treatment products

- Raw material manufacturers of products that qualify as pesticides or biocides are required to 'notify' these products to the EU.
- The review program for existing pesticides is expected to be ready by 2008, and for biocides it is thought to be around 2010.
- Once the list of submitted chemicals has been agreed on at EU level then the post-harvest treatment manufacturers can start the process of registration of their post-harvest treatment formulations
- Registration can take up to 2 years
- The post-harvest treatment manufacturers need to decide on which products to register, and in which countries, in line with commercial viability

What effects will the process of registration have on the use of post-harvest treatments in the UK going forward?

- One manufacturer believes that the costs of registration and the registration procedures will inhibit the development of new post-harvest treatments going forward. This particular manufacturer believes, in their view, that the EU rulings prioritise consumer safety over commercial consideration and this will lead to the end consumer purchasing cut flowers with reduced quality and vase life performance. For example, one of the manufacturer's products uses chlorine salt that is widely used in swimming pools and dishwasher tablets. However, they have to however register the product for use in vase water and believe that this will take about 2 years and cost them at least 300,000 euros. Thereafter, if they wish to add a component to the product they are required to re-register the product again, potentially costing another 2 years and 300,000 euros. They will seriously consider the commercial viability of this and believe it may stifle any product development potential.

- There is concern from the post-harvest treatment manufacturers with respect to the current EU rulings and legislation on pesticides and biocides in relation to post-harvest treatments. It is felt that the current situation demotivates the manufacturers, preventing the development of better and environmentally friendlier alternatives. In addition, it will lead to a less competitive environment which will, in turn, have an effect on the end consumer. Treatments currently available are under threat from potential changes in legislation

- Any 'non-chemical' alternatives as post-harvest treatments under the current EU legislation will be as costly to register as any current 'chemical' post-harvest treatments and the manufacturers are not therefore encouraged to consider these as viable options

What are the alternatives to 'chemical' post-harvest treatments?

On talking to a number of individuals within the ornamental horticulture industry there is a strong feeling that whilst the post-harvest treatments currently available to us as an industry are important in the post-harvest handling process, these must not be relied on solely. Of particular concern are the issues, as discussed above, with respect to registration of the products and potential lack of products available in the future.

It is felt that there needs to be a better understanding of the whole pre- and post-harvest process and possible effects of this on product quality and longevity. There also needs to be a better understanding of the post-harvest physiology of cut flowers and a more in-depth knowledge and understanding of how plant cells die.

<u>Pre- and post-harvest handling process</u>

Many factors will affect the post-harvest quality and longevity of a cut flower, and in turn the potential effectiveness of any post-harvest treatments applied. The following should be considered:

Pre-harvest: -

- variety grown
- growing conditions
- light levels
- growing temperatures
- fertilisation
- watering regimes
- humidity
- pest and disease control

Post-harvest: -

- flowerstage at harvest

- time of harvest
- temperature at harvest
- method of harvest aiming to reduce handling and physical damage
- humidity in storage
- the effects of ethylene
- the quality of water used to administer post-harvest treatments
- temperature management throughout the supply chain

Temperature Management

Temperature is one of the key factors to consider in the post-harvest process. Temperature can have great influence on the deterioration of freshly harvested product.

Temperature can influence: - the breakdown of stored organic substrates (i.e. carbohydrates); the release of energy which in turn releases heat; changes in the colour and physical appearance of a product; loss of weight through water loss; the production of ethylene and the rate of pest and disease development.

The rate of the deterioration of a product is proportional to its respiration rate (Kader in Cool Chain: An Integrated Temperature Management System for Fresh Produce. Bishop *et al.* 2002).

Lessons can be learnt for ornamental products from the temperature regimes applied in the fresh produce industry. A better understanding of the cool chain from the point of harvest of a cut flower through to the point of sale is required. Successful cool chain management requires integrity at each stage and is only as effective as its weakest link. (Bishop et al, 2002)

There will be an optimum temperature range for each type of product, therefore temperature control is paramount. Moving freshly harvested product from high ambient temperatures to cold stores that are initially too cold, or too long at cold temperatures, can lead to 'chilling injury'. 'Chilling injury' causes tissue damage. The stage of harvest of a product is also important influencing susceptibility to 'chilling' injury.

Each link in the cool chain is dependent on the ones before. Maintaining the correct temperatures is critical and any increase in temperature at any point in the chain will lead to an irreversible loss of post-harvest product quality at a later stage.

Do we know enough about the temperature control and the optimum temperatures required throughout the post-harvest supply chain? How do different cut flowers react at different stages and to different temperature regimes? What are the best practices that should be implemented for each type of product? Do we know enough about the effects of pre-cooling, taking a product harvested at high ambient temperatures and placing it in an interim 'cool' store before subjecting it to the 'normal' cut flower storage temperatures for cut flowers? Is the temperature management throughout the transport systems in the supply chain good enough?

<u>Cell Death</u>

One post-harvest treatment manufacturer believed there needed to be a 'back-to-basics' approach to look at how plants cells die and referred to the concept of Programmed Cell Death (PCD).

Cell death is a normal process of the life of a multi-cellular organism, and is described as an active process in which a cell suicide pathway is activated resulting in a controlled disassembly of the cell (Kanellis *et al.* 1999).

It has been found that ethylene is a mediator in the process of cell death in plants (Kanellis *et al*. 1999). Cell death can also occur via normal cell development; environmental stress (infection, wounds, low concentrations of toxins); and severe injury such as heat, freezing or high concentrations of toxic chemicals.

A variety of processes occur during plant development and can be included in the general definition of PCD i.e. where cells in a specific location or with a specific function die at a specific moment in time. If the senescence of flower parts and leaves were considered to be a form of PCD, then ethylene can be described as contributing to PCD (Kanellis *et al.* 1999)

The concept of PCD may differ from senescence in that it includes the 'switch' that starts senescence, presumably genetically controlled process that may be modified by environmental factors. Senescence is a major part of PCD and extensive research has been carried out on senescence in plants. However, there appears to be a very limited amount of research carried out on the concept of PCD in plants, and in particular the role that ethylene has to play. Experiments looking at ethylene and PCD have shown that increases in ethylene can lead to increased cell death and that inhibitors of ethylene production, such as STS, have shown that ethylene is a key factor in cell death.

From Salunkhe *et al.* (1990) plant hormones, other than ethylene, also appear to have a roll in the regulation of senescence. For example, cytokinins in rose petals decreased as the flower aged and external applications of cytokinins delayed senescence in several types of cut flowers. Gibberellic acid also gave rise to changes in flower size and helped to extend longevity.

It is believed that research into PCD in plants has lagged behind that of other organisms (Lam *et al.* 2000). However, the advances in genomic sciences, molecular genetics and cell biological technologies will aid the advance of PCD research in plants. This together with an understanding of pathways in cells such as cell cycles, hormone signalling, plant pathogen interactions and cloning of marked genes will enable scientists to better understand PCD in plants.

However, this research is on-going with long term results and implications. Will it lead to the better control of post-harvest quality and longevity of cut flowers?

<u>'Natural' Biocides</u>

Work has been carried out within the fresh produce industry on the control of post-harvest diseases on freshly harvested fruit and vegetables through the use of 'natural' biocides.

The work was commissioned through the need to find alternatives to chemically synthesised fungicides and food additives.

An example of a 'natural' biocide investigated for fresh produce is cinnamic acid as a preservative for fruit. Fruit dipped in the acid showed delayed bacterial and fungal spoilage and increased shelf life.

Whilst microbial spoilage of cut flowers may be less of an issue than spoilage of edible products, biocides are currently used in cut flower post-harvest treatments to protect the sugar ingredient present in some of the products. What other 'natural' biocides found to be of use in the fresh produce industry could be utilised in the ornamental industry?

Antifungal ‘natural’ biocides, for example, antagonistic microorganisms or antifungal metabolites from plants or microbes have also been investigated. These have been described as ‘green chemicals’ and have been investigated by Wageningen ATO-DLO. These have been found to be effective in controlling rot on tulips and hyacinth bulbs.

Work has been carried out on e.g. *Penicillium hirsutum* which causes rot. Benomyl has been used to control this but several resistant strains of the penicillium have developed. The Wageningen work found, through a screening programme, effective antagonistic fungi. However, optimum temperature and humidity regimes had to be employed for the antagonistic fungi to be most effective.

Natural, antimicrobial compounds found in plants include phenols, organic acids, phytoalexins and essential oils. Again work at ATO-DLO focused on essential oils and their components. From this work, volatile monoterpenes and aldehydes have been the main focus in studies related to crop protection and the development of biopesticides.

Carvone, the main monoterpene in the essential oil of caraway seeds, has shown to have a powerful antifungal effect and has been commercialised in The Netherlands by Luxan in collaboration with ATO-DLO to give Talent™.

Compared to chemical pesticides, biopesticides tend to be more specific, more complex, less robust and require an in-depth understanding / knowledge with respect to ecosystems interactions (Hall *et al.* 1999).

From 1996 – 1999 the EU funded a project, with ATO-DLO as the co-ordinator, looked at ‘Production, Processing and Practical Applications of Natural Antifungal Crop Protectants’ aiming to develop non-chemical crop protection products utilising antagonistic microorganisms or antifungal metabolites from microbes or plant origin for food and non-food crops.

Work already carried out in this area could potentially be utilised further to develop 'alternative' post-harvest treatments for cut flowers. However, any potential legislative and toxicological aspects would need to be considered, and may be prohibitive.

Priorities for R&D and Technology Transfer

It is felt at this stage in the review of cut flower post-harvest treatments setting priorities or giving recommendations for specific R&D work into the development of 'new' post-harvest treatment products would not be appropriate.

Any R&D work in developing 'new' products would need to be carried out in conjunction with the key post-harvest treatment manufacturers, for it to be most effective and beneficial, and if any effective post-harvest treatment were found, it would normally need to be registered for use and the manufacturers are better placed to manage this process.

Some suggestions for potential areas for R&D and technology transfer, for discussion with the HDC Cut Flower R&D / Technical Committee:

- Improved temperature management throughout the cut flower post-harvest handling process, from field / glasshouse / polytunnel through to outloading of product to the retailer, in general and for specific, key products.

- The integrity of the temperature management process controlled by the retailer, or those companies contracted by the retailer to manage their product distribution to their stores, through to the end consumer.

- The development of protocols for the post-harvest handling of specific, key products.

- Alternative storage methods for harvested cut flowers, for example, controlled atmosphere storage of key crops – the problems, the potential benefits, the positive or negative affects on product quality and performance.

- Technology transfer opportunities with centres of excellence such as Wageningen ATO-DLO – best practices, workshops, study tours

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