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Report to the Horticultural Development Council – Hardy Nursery Stock Panel

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Contents

Introduction

This report covers a number of talks and posters presented at the International Horticultural Congress run by the International Society for Horticultural Science, and which are of particular relevance to those involved in ornamental plant production. The Congress was divided into a series of colloquia, symposia, poster sessions and workshops. There were 23 Symposia in total, all running concurrently, but the majority of this report deals with papers presented in Symposium 18 – Nursery Crops - Development, Evaluation, Production and Use. Approximately 2,500 scientists attended the Congress with a particularly strong contingent from North American universities and institutes. Therefore, it was interesting to compare the standards of horticultural research carried out in the USA and Canada, and also the priorities set by their ornamental industry compared with that of the UK. Horticultural research and development in the USA is largely carried out by the Universities, and as these are State-based this tends to lead to rather an *ad hoc* compilation of research programs.

Although the papers cover a wide range of subjects, a number of themes became apparent during the duration of the Congress. The development of novel ornamental crops was quite high up the priority list, particularly for a number of Mid-West States in the USA and Canada. This was combined with a desire to understand and breed for greater stress tolerance, particularly drought and cold, so that a wider range of species and cultivars could be grown in these areas. The effects of climate change were also a cause for concern, with many scientists citing cases of altered climate in their countries and the possible impacts on crops. For example in Canada, there was increased freezing damage in nursery stock crops during winter 2001-02 due to a lack of snow cover. (Normally pots are stacked together and covered with snow to insulate them from the extremes of low temperature).

A move towards more ‘sustainable’ horticultural systems was also the subject of one symposium, with common objectives being more efficient irrigation, reduced tillage and conservation of soil carbon resources, minimising the use of pesticides and fungicides and better integrated crop management. There were a number of papers related to the reduced reliance on inorganic fertilisers for field crops, but interestingly, there was little, or no mention on the use of peat or its possible substitutes.

An area that appeared to be developing an increasingly high level profile was that of the psychological benefits that plants confer on people. Obviously, gardens and landscape have had an important role to play in the development of society and as a forum for relaxation, however, putting tangible benefits on specific aspects and determining just how these can affect people's well-being is proving a challenge for the scientific community.

Plant Introduction Schemes

The evolution and development of the horticultural retail industry depends on the introduction of new and novel plant types. Botanic gardens and arboreta have often been cited as being a useful source of novel or under-exploited plant material, however, introduction schemes initiated by such organisations have met with mixed success. One of the better examples was that of the British Colombia Plant Introductory Scheme. It is this scheme that is being used as a model for **The Chicagoland Growers Plant Introductory Program** (Ault). This is a corporate partnership between the Chicago Botanic Garden, the Morton Arboretum, and the Ornamental Growers Association of Northern Illinois. The partnership was set up in 1986 and to date has released 10 trees and shrubs, with 18 more woody plant types currently undergoing initial nursery production, with a further 18 genera being propagated for future evaluation. One of the main criteria for success within this scheme is the fact that it works collectively with industry professionals throughout North America, (i.e. 85 nurseries in 22 States are licensed to propagate and grow the Program's plants). In addition to 'widening the market place', this allows plants to be bulked-up quickly and launched onto the market at the one time throughout the northern United States and Canada. The program specialises in selecting, evaluating, producing and marketing new plants with proven performance under northern growing conditions. New plants are initially evaluated by a group of gardens, universities and municipalities, followed by production and field evaluations by co-operating nurseries. Once a plant's production figures reach a pre-determined quota, it is released for promotion and open market sales. Plants are promoted through **Plant Release Bulletins**, a colour flyer distributed to nurseries, landscape architects and horticulture researchers; presentations at trade shows and professional plant society meetings, articles in trade magazines and through catalogues and websites of participating nurseries.

Athens Select is a new marketing alliance formed between the New Crop Program (University of Georgia) and a number of plant propagation nurseries to promote new ornamental crops in the USA (Armitage). Historically, like botanic gardens, academic institutions have had limited success in long-term new crop introduction, but the New Crop Program formulae for success has been based on inviting industry partners to share the material from an early stage in the development process. New crops that possessed sales potential were quickly propagated, resulting in credibility and visibility for the Program from an early date. The University research facilities are used to determine propagation and scheduling techniques and solving production-related problems, whereas the industry partners' responsibilities is to promote and sell the plants.

Corr outlined a co-operative scheme involving the **Ball Horticultural Company** (specialising in the development and production of floriculture crops) and the **National Botanical Institute of South Africa (Kirstenbosch)** which meets the ethical guidelines set-up under the **Convention of Biological Diversity**. The guidelines incorporate information on how germplasm should be collected and developed, which require, amongst other things prior informed consent and benefit sharing with the country of origin of the species. In this case Ball provides financial support for facilities development and germplasm collection, as well as providing technology transfer. The National Botanic Institute identifies appropriate collection locations, collects germplasm using approved procedures, propagates the plant in question and carries out preliminary evaluations. Propagules are then sent to Ball for further evaluations on the marketability of the plant. **Intellectual property rights** can be held by either partner, or both, but in all instances Ball returns royalties to the National Botanic Institute. These may then be sub-divided to appropriate stake-holders within South Africa.

New Plant Introductions

In the southern states of the USA, *Abelia* x *grandiflora* has been used widely as a landscape plant and is tolerant of the climate and soils of this part of the USA. In a paper by Scheiber and Robacker, however, it was explained that *Abelia* x *grandiflora* is one of only two interspecific hybrids ever developed and released within the genus and there is considerable potential for exploiting other progeny through breeding. ***Abelia*** contains approximately 30 species that vary widely in a number of traits including **flower colour, flower size, growth habit and cold hardiness** and the first objective of the breeding programme is to determine the levels of compatibility between a number of the species. So far, intra- and inter-specific compatibility has been measured between 12 taxa of *Abelia*. *Abelia chinensis* ranked as the best maternal and paternal parent in both intra and interspecific crosses. Also, interspecific hybrids have been obtained between *A. chinensis* x *A. engleriana*, *A. chinensis* x *A. spathulata*, *A. chinensis* x *A. serrata* and *A. chinensis* x *A. zanderi*. Further crossing is now required to attain plants with full horticultural merit, but Scheiber and Robacker are confident that the genus will provide a number of new candidates for the landscape industry.

Another genus under-exploited from a horticultural point of view is ***Eucalyptus***. A breeding programme has been underway at the University of Adelaide for over 10 years (Delaporte and Sedgley). Development of *Eucalyptus* species for ornamental horticulture uses a combination of selection from established plantations and natural populations. In order to select superior individuals from the large number available, a list of essential characteristics was devised and these prioritised. These characteristics or selection criteria have been divided into primary and secondary criteria. Primary criteria relate to **morphological aspects**, particularly flower, foliage and bark form and colour. Secondary criteria relate to **performance characters** such as ease of propagation and vase shelf life for flowers and foliage. The breeding programme has crossed parent genotypes and is currently **evaluating 550 hybrid individuals** for their floricultural and horticultural merit. Only those individuals that demonstrate considerable superiority across all the criteria will be released for trialing and commercial production.

Crape Myrtle (***Lagerstroemia***) was a genera that was reviewed by Cabrera with the aim of developing new cultivars for the American and other landscapes. *L. indica*, although a native of SE Asia, has become naturalised in southern USA and is now the state plant of Texas. *Lagerstroemia* are favoured for their range of **flower colours** and their **exceedingly long flowering period** – some can flower for a period of up to 120 days. Additionally, many cultivars have an attractive **exfoliating bark** that provides interest when the plant is in a vegetative phase. Recent breeding programs in the USA and Europe, based primarily on *L. indica* and *L. fauriei* have enhanced the ranges of sizes and forms available, improved autumn colour characteristics and increased tolerance to both cold and powdery mildew. There are now approximately **300 ornamental cultivars** of *Lagerstroemia* available, some of which reputably can tolerate temperatures as low as –20ºC, and may have potential for wider cultivation in the UK.

Another genus that was being evaluated for use in Maryland, USA is ***Stylidium* spp. (triggerplants)** (Darnowski). These are mostly found in Australia, but species have a climatic range from the tropics to alpine regions. Many triggerplants present a number of horticulturally valuable traits, including spikes of brightly coloured flowers and the ability to grow on droughty, toxic or nutrient poor soils. Darnowski is currently evaluating different species for their horticultural merits and their potential for production in the USA.

Roses

Debener *et al.* have utilised molecular tools to understand more about **rose genetics**. Their work has largely focussed on analysing resistance to the two major pathogens, **blackspot** (*Diplocarpon rosea*) and **powdery mildew** (*Sphaerotheca pannosa*) as well certain morphological characteristics. After the isolation and characterisation of single spore isolates for blackspot and powdery mildew, analyses in segregating diploid rose populations revealed the presence of single dominant genes, i.e. for each pathogen one resistance gene could be mapped on the rose chromosome map. However, the resistance genes are quite specific to races of the pathogens and so one resistant gene does not necessarily confer resistance when the plant is exposed to a number of pathogen genotypes, nor protect the plant from infection should the pathogen evolve new races. Therefore, microsatellite markers have been developed to study the structure of *Diplocarpon* populations. In parallel, research has been undertaken to develop strategies for marker assisted selection of genes from wild populations of rose that have greater resistance to these two diseases. This enables other undesirable aspects of the wild species to be removed more effectively from the genetic constitution of future improved cultivars after back-crossing with wild progeny. The data from both the host and the pathogen should lead to the development of strategies for molecular breeding of roses.

A paper by Tan *et al.* suggested that one of the mechanisms determining resistance to **crown gall** (*Agrobacterium tumefaciens*) in rose related to the amount of **acetosyringone derivates** that are secreted by wounded cells. Resistant cultivars secreted less acetosyringone derivatives than the susceptible cultivars in terms of quantity and type. Therefore, the authors conclude that at least part of the resistance mechanism of crown gall disease is related to the exudation of these compounds, and that proliferation of the disease may depend on the release of these compounds.

In Brazil, experiments have been conducted to evaluate **rose rootstock performance** (Pivetta *et al.*). Two scion varieties were tested with a range of rootstock genotypes and plants were assessed (at 1250 m above sea level) for the number of **flowers per plant per month, shape, size, colour and number of leaves, thorniness, plant vigour and resistance to blackspot**. Results varied slightly depending on the scion cultivar, but rootstocks that performed well across both scions and will now be recommended for use were: *Rosa multiflora* 'Japones' and 'Kopmans', *Rosa* 'Natual Brier' and *Rosa manetti*.

Stress Tolerance

The aspect of **stress reduction in managed landscapes** was addressed by Iles. The definition of managed landscapes were areas comprising woody and herbaceous ornamentals, turfgrass and organic and mineral groundcovers as well as often incorporating aspects of hard landscape (paths, walls, stone or metal ornaments etc.) When well-designed, such landscapers provide numerous economic and quality of life benefits, however the vision of the designer is not always brought to fruition. Iles argued that the primary reason for this is the inability of the plant species chosen to overcome the abiotic and biotic stresses associated with a particular location.

The **causes of stress** to plants in the landscape are **not always easy to diagnose**. When trees demonstrate 'autumnal tints' in the foliage in June or July is it due to drought, heat, insect or fungus activity ? The primary objective is to marry plant and site, i.e. understand the constraints of the site then select plants that will tolerate those conditions. It would be logical to assume that plants that grow naturally in flood plains may not thrive on droughty soils. Even 'staple' landscape specimens that are recommended for their attributes or robustness need not be suitable for all sites or climates. For example, *Acer rubrum* 'October Glory' originated in the eastern USA, but doesn't perform well in the drier and hotter Mid-West States. Also landscape architects and managers need to be aware of fads and trends – *Crataegus crus-galli* (Cockspur hawthorn) was once recommended for street planting due to its stature and coloured berries, now however, it is often a blemish on the landscape, due to infection from rust and leafminer. Other 'alien' species can become invasive and outcompete the native flora, e.g. *Acer platanoides* in eastern USA.

Before planting in the landscape, **the nursery crop production can influence stress susceptibility and tolerance**. Standards exist to ensure quality and reliability of produce, but these need to be updated. Iles argues that rootballs need to be bigger to ensure survival after planting, or that there needs to be wider adoption of **hydrogels** for bare root material. He considered the large **transplant shock** sometimes associated with root and burlap tree relates to the fact that **75-90% of the root mass can be lost** during the lifting and transplanting. Even with containerised or container-grown material there may be residual problems associated with dense root matting or circling of the main roots. Although copper paints can help reduce the circling, there is concern over the use of copper in such pots from an environmental viewpoint – where does the copper end up after the pot is disposed of ? Iles advocates the **pot-in pot technique** and considers this grows a better specimen tree (although concedes the initial installation costs for the nursery with this system may be high). Indeed proper **water management** on the nursery is key to the success or failure of the finished plant, and that excessive water stress prior to planting should be avoided.

Clearly, management at the planting site is also critical – trees need to be planted with their collars at the level of the soil, not buried or standing proud and exposing roots to desiccation. Excessive use of **organic amendments** now appear to be best avoided, unless they are well-incorporated and allow good integration with the natural soil structure. Frequency of watering after planting is another controversial issue – recent evidence suggest that **frequent light watering is more beneficial that 2-3 heavy watering** events. **Mulching** with either organic or inorganic substrates is also recommended in maintaining soil moisture. There is still equivocal evidence as to whether introducing **mycorrhizae** species at the time of planting makes economic sense.

Root and Rhizosphere Studies

This session focussed on the problems of studying root systems in horticultural crops. Eissenstat [1] introduced the session by highlighting the **complexity of root systems** and that because of their dynamic nature how it was difficult to interpret single 'snapshot' results. Roots of different orders have different functions – transport, nutrient absorption and stability. Therefore, determining what is valid to measure and what is not is one of the main challenges. For example, there is little point in measuring the number of easily visible roots (e.g. > 2 mm diameter) when it is the number of very fine roots and root hairs that may be important in nutrient absorption studies. Determining whether roots are actually alive and functional is also an obstacle – and one of the greatest problems is determining **root turnover** – just how much of the root system is actively functioning ?

Even when evaluating how much or which part of the root system is critical, just harvesting the entire root system is a challenge in itself. In field situations how do you harvest the root system - this will to some extent be dictated by the size of the plant but even small plants can have deep tap roots or long lateral runner roots. For large field-grown trees and shrubs tree spades may be utilised, but it is likely that significant proportions of the roots system may sill be left behind. Washing rootballs with high pressure water or air jets to remove the soil will also result in loss of fine roots. Although high quality root scanners and appropriate sophisticated software are available to count harvested roots /root area, the results will only be as good as the time taken to harvest all the fine roots. In reality a compromise needs to be struck between the time and patience taken to harvest the roots and the number of repeat samples that need to be collected.

One mechanism to obtain a 'cross-section' of root activity is to use a **mini-rhizaton** – this is a transparent tube that can be inserted into the root system after a core of soil has been removed. Image capture equipment can then be used to map root development along the length of the tube. Cameras can now fit down a range of tube sizes (1-6 cm). The biggest challenge of this system, however, is getting the root systems to perform as if the tube were not there, i.e. disturbing the soil and leaving air gaps beside the tube may affect the growth response of the roots. Problems may also occur with the root core demonstrating roots that are atypical or not appropriate for the study in question – e.g. old roots close to the crown of the plant. Nevertheless the tube or perspex plate (root box) systems have the advantage in that the **development of individual roots can be monitored over time.** The systems have the advantage of being able to evaluate the anatomy, morphology and physiology of different root types. With increasing sophistication in **digital imaging** too, it is now possible to take a photograph of a cross-section of root system and using a colour gradation on a computer highlight the roots and count the number of pixels that correspond to that colour.

<u>Lynch</u> continued the discussion by stressing that the use of systems for analysing root systems should relate strongly to the focus of the experiment – basically, "what is easy, cheap and works for you". Good descriptive work based on visual observations was just as valid as trying highly technical approaches, when there were doubts over their accuracy or reproducibility. He felt some of the most elegant experiments were with **plants grown in containers** even if these represented unnatural situations (except of

course if you happen to be a researcher on nursery stock !!). He felt it was feasible to reconstruct the soil conditions that the plants predominately grew in – e.g. forest soils by careful matching the composition and density to that of the natural situation. The container design was also useful, because recently some had been modified to allow water to be incorporated into different sections of the soil profile. This also involved the use of mesh barriers that allowed the roots to growth through into different sections of the container, but because of their waxy surface where relatively impenetrable to water. Where the soil structure and composition was not relevant, then **sand culture** in containers was a feasible technique for harvesting entire root systems – placement of the rootball into a water bath resulting in the sand dropping away easily from the roots. Such systems had been useful in demonstrating how phosphorus availability affected root morphology, for example, the enhanced production of adventitious roots under low phosphate scenarios.

This aspect of the key **importance of root architecture on crop productivity** was taken up by Drost. He stated that some of the synergistic effects of altering root morphology alone could **double productivity** in some crops. Modifying aspects such as root branch angle could increase access to nutrients within the soil profile, but also increasing the number of **root branches** could enhance **cytokinin production**, which had a positive effect on the number of flowers induced. This latter phenomenon was demonstrated when a trench was cut in the soil and back-filled with gravel – roots penetrated the new substrate, but because of the high resistance levels to root growth – greater root branching was induced.

Root Systems and Drought

There is a lack of information on how irrigation practices affect root growth and activity. Research on fruit crops (Eissenstat [2]) suggested that in locally dry soil root growth was restricted. Exposure to dry soil however, does not necessarily kill roots and in *Citrus* and *Vitis* there were **no differences in root mortality between roots in dried soil**

and those kept moist. In *Citrus* particularly, roots rapidly recover their capacity for water and phosphate uptake after re-irrigation. Bravdo investigating the effects of soil drying in *Vitus* demonstrated **that water moved from the roots exposed to moist soil to roots in dry soil and actually exuded water into the dry rhizosphere**.

Caspari *et al*. claim that irrigation volume rather than placement determines the response of apple trees to deficit drought. Initial work on *Malus* 'Gala' and 'Fuji' showed that water savings of 30 % were achieved without detrimental affects on fruit size, quality or yield when **partial root drying (PRD)** was employed. In later studies PRD was compared to **deficit irrigation (DI)** regimes as well as fully watered controls, i.e. only 50 % of the control volume was added but DI corresponded to uniform application, whereas PRD was localised application. In these results there have been very few differences in the crop responses between the PRD and DI treatments with both techniques showing positive results. Results overall, indicate that **water savings of up to 50 % can be achieved without negative effects on fruit size, quality and yield.** In contrast to these results, Bravdo could find no benefits to the crop by imposing PRD treatments in *Vitis*.

Bravdo also reviewed irrigation strategies for viticulture crops in arid climates. Topics included the root environment, water availability, root aeration, mineral concentrations and physiological effects. Interestingly, he considered the soil as the worst substrate for growing plants in ! Most of the field irrigation in Israel relies on **drip**. Although being efficient in water use, drip has a number of disadvantages – for example **loss of moisture from the root zone by capillary movement and gravity, and the formation of a nutrient gradient within the soil**. Nitrogen which is relative mobile in the soil leaches away from the area immediately below the dripper, but can build up to high concentrations the edge of the wetted zone. In contrast, the less mobile potassium and phosphates tend to remain localised around the dripper.

The accumulation of roots around the dripper can also change their morphology with a predominance of thin, multi-branched roots. The increase in relative **number of root tips** can affect the ratio of vegetative to reproductive parts of the plant. Although evidence is still limited it is hypothesised that the **large number of small roots are increasing the numbers of flowers formed** on the vine. Bravdo briefly discussed the options for **automatic irrigation control** and the techniques that could be utilised to **monitor crop water use**. These included the **pan-evaporimeter, tensiometers** and **dendrometers** (the latter measure leaf thickness - correlations existing between leaf turgor and thickness). In field situations, Bravdo wondered if there may be opportunities in future to **manipulate the root zone** more effectively. For example, by creating a trench alongside the growing plants and back-filling this with gravel or perlite, then roots that penetrate this trench would be amenable to rapid uptake of nutrients or other growth regulating signals – for example rhizosphere pH could be altered or micro-nutrients be absorbed more readily.

Prive *et al.* continued the theme of instruments used for detecting water relations and drought stress. Nine different methods were used to evaluate water stress in raspberry: - **leaf water potential** (PMS pressure bomb), **photosynthesis** (LI-COR, LI-6200 portable leaf photosynthesis system), **chlorophyll fluorescence** (Hansatech FMS 2), **stomatal conductance** and **transpiration rate** (Li-1600 porometer), **soil moisture potential** (tensiometer) **volumetric water content** (HydroSense) **gravimetric** data (weighing) and remote sensing using a **spectroradiometer**. The best systems to detect the early symptoms of drought stress in the plant included the pressure bomb, porometer and photosynthesis. The best non-plant measures were gravimetric and volumetric water content, with the HydroSense being the most versatile. Results with the spectroradiometer showed that control plants had less reflectances than stressed plants, mainly in the near infra-red and short-wave infra-red regions. Further work is required to determine the precision of the spectroradiometer at lower levels of water stress than those imposed so far.

Nutrient Management

A three-year study was initiated by the University of Minnesota to gather data on **nitroge**n (N) and **phosphorous** (P) movement out from **the growing media of container**

nursery stock (Ristvey). Two species were chosen for the study:- *Ilex cornuta*. 'China Girl' (high nutrient use) and *Rhododendron* 'Karen' (low nutrient use), with plants of each type being either irrigated using overhead sprinklers or drip irrigation. Nutrients were applied at industry recommended rates, with controlled release fertiliser (about 29 g N per plant) and supplemental soluble feed (2.3 g N per plant) added over a 14 month period. During this period **irrigation methods did not affect N uptake** within species, although **total runoff was three times higher under the sprinklers** than the drip system (2.5 g vs 0.7 g N). Actual **uptake rates by the plant were very low** with only 6 –8 % of the nitrogen applied being used by each species. **Recovery rates were also relatively low** with only 17 % of the N being accounted for in the plant/substrate/ leachate fractions, suggesting that a large proportion of the N was locked up in microbial activity. The study is on-going but recent results appear to suggest that **proportionally higher amounts of P may be leached out of the containers**, and could be a cause for concern in terms of run-off water contamination.

Branch Induction

Neri *et al*. outlined in their paper the ability to **induce feather production** in cherry by a combination of leaf defoliation and cytokinin foliar sprays. Traditionally branch (feather) formation has been attempted in young nursery trees by excising the shoot apical tip. However, shoot pinching allows the release of an inconsistent number of laterals and these tend to have a different growth behaviour to that of a main shoot. Likewise, growth of the laterals can also be variable due to the dimension of the pinched portion, seasonal climate conditions and variety to rootstock interactions. As a result scion quality is negatively affected by shoot pinching because of the absence of a central leader, and by the irregular growth of the laterals induced. Growth regulators appear to be even more inconsistent in the number and vigour of laterals induced. In this research, **rather than remove the entire apical shoot tip, only the apical leaflets were removed, and then the apical region sprayed with cytokinins.** In a range of cherry varieties – *Prunus* 'Kordia', 'Celeste', 'Summit' and 'Sunburst', lateral shoots with low vigour and wide branch angle were formed consistently in numbers of between 3 and 6 feathers per tree. This very powerful technique allows nurserymen to **control scion quality in the nursery** and to produce 1-year old feathered plants for spindle training in high density cherry orchards. (Similar techniques have been used for *Malus* within the UK – Bonham and Cameron).

Young sweet cherry trees on seedling rootstocks can be excessively vigorous and slow to bear flowers and fruit after planting (Elfving). Single or double applications of **Prohexadione-calcium and ethephon, however, can control vigour and promote precocious flowering in such trees**. The optimum treatment appeared to be an application of both compounds in June, which either slowed growth significantly or induced the formation of a terminal dormant bud, but did not induce any secondary flushing. Such treatment also increased flower bud density the next spring up to 3 fold, with a subsequent increase in fruit production. Other papers studying the effects of prohexadione (Apogee) on apples showed the product had an effect on certain **pest populations** (Greene and Krawczyk) and **fire blight** (Cline and Hunter). The number of aphid colonies and the incidence of leafroller damaged terminals was reduced in those regions of an orchard treated with prohexadione. The use of prohexadione in combination with careful selection of rootstocks appears warranted when reducing the incidence of fire blight (*Erwinia amylovora*) on sensitive scion varieties.

Flowering

The role of **gibberellins** in flower induction was reviewed by King. Gibberellin action in this respect can be confusing due to variations in the types of gibberellic acid involved and differences in **flower promoting signals** in different plant genera. In studies with grass (*Lolium* spp) levels of GA_5 and GA_6 doubled at the shoot apex during the initial period of exposing plants to long-day photoperiods (i.e. the photoperiod required to induce flowers). Days later, there are larger (many-fold) increases in GA_1 and GA_4 content at the apex and these are considered to be secondary, (late acting) long-day stimuli involved in inflorescence induction. How GAs differ over time in their effectiveness to induce flowers reflects the action of the GA hydroxylase enzyme which breaks down and deactivates the GAs. Therefore, different GAs may be present at different stages in the induction process, depending on the concentration of the hydroxylase enzyme present. In addition the structure of a GA can also be chemically-hindered so that it is no longer a candidate for the hydroxylase. This sparing role between the gibberellins and the hydroxylase enzyme is thought to be the key to the floral induction process. In dicot species, inactivating enzymes could be particularly important in the promotion of growth and flowering by GA. Yet paradoxically, GAs are often quoted as inhibiting flowering, especially in tree species. However, unlike the responses associated with promotion of flowering by GAs, its inhibition appears to relate to a completely different controlling mechanism –namely that involving nutrient partitioning and diversion within the apex. The measurements of sucrose content of the shoot apex of *Fuchsia* indicate that GA inhibits its early flowering response in LD by diverting assimilates away from the apex and into the growing stem. Furthermore, it is certain that that flowering of *Fuchsia* is regulated by sucrose supply because apex sucrose content and flowering increased in parallel with increase in light intensity in non-inductive short days.

At a more practical level the **flowering stimulus in *Clematis*** was investigated by Enfield *et al.* *Clematis* are divided into 3 groups based on their pruning requirements (i.e. treatments that determine when and where flowers develop). The flowering response of 4 *Clematis* cultivars was examined after growing plants at different **photoperiods**. After a period of vernalisation it was found that *Clematis montana* ‘Mayleen’ (group 1) was day neutral, with plants flowering under all photoperiods. Similarly, *Clematis* ‘Pink Cameo’ (group 2) was also day neutral, however *Clematis* ‘John Paul II’ (also group 2) was an obligate long-day plant and only flowered after >13 hr photoperiods. The group 3 plant *Clematis* ‘Madame Julie Correvon’ was proven to be a long-day obligate cultivar too. **Growth in all species was terminated and dormant buds formed after photoperiods of 12 hr or less.**

Computer Modelling and Scheduling

Virtual plants are computer models that recreate the structure and simulate the development of plants. According to Prusinkiewicz, they are potentially useful as exploration tools, for example enabling researchers to provide '3-D' maps of growth responses or allowing breeders to envisage the form and habit of new cultivars prior to crosses being made. Other roles could involve teaching and landscape design packages. The modelling method is based on the theory of Lindenmayer systems (L-Systems). One aspect of this theory is the contrast between the relative simplicity of the model specification and the apparent complexity, intricacy and visual realism of the resulting forms. Prusinkiewicz claims that L-system models have the power to:

- Accurately **recreate the structure and development of plants**.
- Demonstrate how the **architectural parameters** (branching angle, elongation rate, vigour of branches) affects the appearance of plants.
- Simulate plant physiology and **investigate the effects of manipulations** (e.g. pruning) or different external conditions (light levels, water availability, crop spacing).
- Demonstrate **plant development** within an ecological context as well as in isolation.

With further refinement and calibration of the models, detailed simulation scenarios should be feasible across a broad range of crop types and help advance our understanding of the genetic basis of plant form.

In the retailing of **table-top christmas trees** in the USA, consumers appear to have a preference for newly-flushed trees compared to those with dormant buds. Therefore, it a major objective for growers to force their young trees into growth just prior to the time of sale. Research carried out by Duck *et al.* was aimed at investigating how the environmental variables controlling bud break (chilling, photoperiod and temperature) could be manipulated to synchronise budbreak with the pre-christmas sale period. The objectives of the trial were to determine the optimum combination of dormancy induction and chilling needed to force conifers to break bud and flush on the target date and to characterise species variation in response to forcing. Species evaluated included *Picea glauca* var. *densata*, *P. omorika, P wilsonii, P. meyeri, P. pungens*, *Abies procera* 'Frijsenborg Blue' and *A. nordmanniana-ambrolauria*. During the summer months seedlings were exposed to a short-day (9 hour photoperiod) for either 0, 2, 4 or 6 weeks at 20ºC and then exposed to different durations of chilling at 3ºC. After chilling treatments, plants were forced under long days (16 hours) at 20ºC. Results varied for the different subjects, but ***Picea omorika*, *P. glauca* var. *densata* and *P. wilsonii* generally were the most responsive across a range of treatments**. Therefore there appears to be good potential to schedule production to enhance the quality of product to the customer.

Bio-filtration

To control ambient air temperatures in offices, shops and homes, buildings are designed these days as almost air-tight capsules to minimise temperature fluctuations due to outside weather conditions. This **lack of natural ventilation** has given rise to **a public health issue**, however, with the build up of air borne contaminants thought to influence the well-being of the occupants (e.g. **'sick building syndrome'**). Amongst these potentially damaging contaminants are **volatile organic compounds** (VOCs). Traditionally VOCs would be removed through ventilation, but conditioning this air in terms of its temperature and humidity can represent a considerable expense. An alternative means of **air quality control** may be through **bio-filtration**. Here, air is forced through a wet biomass. Contaminants are absorbed in the aqueous component and then broken down by microbial activity. The traditional bio-filtration processes however, have relied on relatively high population of microbial organisms and hence required large amounts of organic matter or contaminants to 'feed' the system. In buildings such high levels of organic contaminants do not exist, and so one of the key modifications is simply to use green plants rather than large bio-filters full of micro-organisms. (Darlington *et al.*). Although the plants themselves (and the soil associated microflora) can remove the VOCs, the plants can also photosynthesise and so are not reliant on VOCs are their sole source of energy. A developed system integrates living green plants as packing material directly into a high surface area/low volume bio-filter than can remove significant amounts of VOCs and CO_2 (another indoor contaminant) from the indoor spaces and does not lower air quality through the generation of other VOCs or microbial spores. The use of **horticultural plants** has the added advantage of increasing the aesthetic appeal of the system.

The issue of plants and their use in supporting human life in **bio-spheres** was continued by Wheeler. Dr Wheeler is a plant physiologist working at the Kennedy Space Centre for NASA. NASA intend to **send a manned space craft to MARS** within 50 years, but the 3 year mission will only be successful if techniques to grow crops in space can be implemented. Due to the limited space on a space craft – any bio-system needs to be self-sustaining and research is required on how to provide resources and recycle them effectively. Whether the planned mission becomes reality or not, some of the developments undertaken by NASA may **have implications for improving horticultural production**, here on earth. Mars has light intensities only 50% of those encountered on earth, so developments on **electrical lighting** are likely to be required. Wheeler outlined that solar energy may be required to provide power for artificial lighting and that new systems such as those based on light emitting diodes (LEDs) which have up to 100, 000 hours of life, or micro-wave sulphur systems which are thought to be 35-40 % energy efficient may need to be adopted. Similarly, new materials would be required to be developed for the cladding of any greenhouses set up in Mars. These should have insulation properties to avoid heat loss to the Martian climate as well as be highly resistant to **U.V. radiation**. Wheeler concluded that other areas of crop production may benefit form NASA related research into aspects such as: **atmosphere management, phyto-remediation, attributes of candidate crops, cultural management, recycling of nutrients, new environmental sensors, seed technology and even new types of plant growth chambers.**

Health Benefits of Plants

The **health benefits of gardening** and the role of **horticultural therapy** have been widely discussed in recent years. There a number of research results that claim that involvement with gardening or other activities associated with an interaction with nature, e.g. contact with animals, views of landscape and wilderness experiences provide a sense of well-being and can improve **people's psychological health**. If proven, such claims could be beneficial to the horticultural industry that promotes gardening and the use of ornamental plants. However a paper by Frumkin suggests that some of these initial results can be difficult to interpret, and that **more detailed clinical epidemiological studies are required** before generalised statements regarding the health benefits of gardening can be claimed. For example he is critical of studies that claim that those people that undergo horticultural therapy are happier after the experience, or recover more quickly from illness, precisely because they may have had an interest in horticulture prior to being exposed to the therapy. That is, very few people who do not possess an interest in plants volunteer for this type of therapy – so in effect there is no scientific control group, and no means to make a valid comparison on the benefits of horticulture. Frumkin believes that future studies require much more considered thought and calculation before they are implemented and that these will require relatively large-scale investments in time and finances to ensure the experiments are scientifically robust.

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