REVIEW OF FACTORS AFFECTING

SHELF-LIFE OF

BEDDING PLANTS FOR

HORTICULTURAL DEVELOPMENT COUNCIL

Produced by:
John G Farthing
ADAS Huntingdon
Chequers Court
Huntingdon
Cambs PE18 6LT

Tel: 0480 52161

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A REVIEW OF EXPERIMENTAL WORK AND FACTORS AFFECTING THE POST-HARVEST (SHELF-LIFE) PERFORMANCE OF BEDDING PLANTS

SUMMARY/ABSTRACT

Shelf-life is a most important facet of production and is becoming increasingly significant as market outlets change and plants need to be grown to higher specifications. The factors affecting shelf-life have been widely investigated on pot plant subjects, especially foliage plants, but little has been undertaken on the bedding plant crop. The work on pot plants provides good background information on which to base a structured bedding plant investigational programme. This programme would include surveys and experimental work to investigate the subject in more depth and provide information for the industry to satisfy the 'new market' requirements.

The production of a quality plant still appears to be the major criteria for good shelf-life.

INTRODUCTION

Work on post-harvest (shelf-life) of ornamental plants is referred to in various guises as plant longevity, keepability, transportability, and keeping quality. All of these factors have been extensively examined in the pot plant sector especially in the United States when pot plant foliage sales increased in the early 1970's. Little, if any, research on the post-harvest of bedding plants was undertaken until the 1980's either in the States or on the Continent. The majority of the work in the United States was carried out at the Universities of Michigan, Florida and Georgia and in Europe at Aalsmeer and Arslev, and some very fundamental work at the Lee Valley Experimental Horticulture Station on Petal Shatter of Geraniums.

Post-harvest studies have increased recently both in the States, Europe and the UK and are mostly directly related to pot plant production.

The published information is mainly to be found in trade magazines and contains much information which is subjective and lacks any fully documented scientific evidence. Many multiple outlets also set standards for produce based largely on unreplicated trials and circumstantial evidence. The latter standards are flexible to fit market needs and supply situations.

Much of the scientific information is based on very diverse conditions and cultivars, thus making it difficult to make any general recommendations to the industry. Conover and Poole (1984) collected and summarised the scientific evidence on foliage plant post harvest work and manuals are to be produced by Ohio Florist's Association on flowering plants and foliage plants post-harvest.

The post-harvest (shelf-life) phase of the bedding plant crop appears to be affected by many factors which can be grouped together under 3 headings.

Production

This includes nutrition, watering, environmental manipulation at and prior to harvest, and use of growth regulants all of which form the basis of production of a quality plant.

Transportation

Temperature, duration of travel, noxious gas release and physical damage all affect the consequent shelf-life.

Outlets

Treatment of the product in shops, garden centres and multiple outlets relating to light, temperature, watering and aftercare can all affect the end product for the consumer.

It is fairly certain, though not scientifically proven, that all these factors are involved in the post-harvest (shelf-life) performance of bedding plants. Other unknown factors relating to plant physiology and genetic make-up of plants and even the effect of seed treatments, seed harvest technology can all influence plant growth and the consequential post-harvest (shelf-life) performance of bedding plants.

In previous post harvest studies, the effects of 'interior' environments played a major role, whilst in the bedding plant situation this factor is possibly of less importance. However, it still remains a factor where interior sales areas in garden centres and multiple outlets have inadequate light for good plant growth.

The ability to measure plant quality is the primary requirement of any post-harvest study to give a base line for any comparisons of data to be made. Quality needs to be quantified adequately. Conover (1986) described quality as a 'cultural perfection' and it is this type of product that we should aim to start with. Any quality below this, means that we begin with a product of lower standard and the effects of poor post-harvest treatment can only exacerbate its deterioration.

Quality is a very difficult parameter to measure. Normally, sophisticated numerical scales are used with sufficient but not excessive increments. Other methods are by visual assessment against the standards and by measured parameters, eg height, spread, branching, flower numbers, bud numbers, again related to a given specification. A further method is selection by panels which is entirely subjective. All of these have merit and are extremely useful, but a fully scientific method needs to be developed.

BENEFITS TO THE INDUSTRY

Bedding plant sales over the last decade have increased dramatically and diversified into outlets not originally considered by the industry. An increase in the post-harvest (shelf-life) performance of this crop which reduced losses by only 1% could be worth £600,000-£1,000,000 per annum to the bedding plant industry. The cost of this improvement if related to changes in production techniques would be negligible. Even if a complex chemical solution was advocated, the cost again would only be negligible when balanced against other present costs of production. This therefore appears to be a worthwhile area to explore which, after all, is only an extension of production.

METHOD

A literature review was undertaken and included computer searches through the databases of Agricola, Agris, Biosis and CAB 1. Searches were also made through the Ohio State University Library, and Michigan State University (Mitchnet) databases. Direct communications were made with Carleson at Michigan State and Nell at the University of Florida. Previous literature on pot plants reviewed by Barrett and Nell (1989) at the University of Florida has been examined. Visits have been made to Aalsmeer Research Station for Floriculture in Holland and Arslev Research Station for Floriculture in Denmark. Discussions were undertaken with the quality controller for the Dutch Auction. The subjective opinions of leading growers were also gained at various meetings to give a comprehensive picture of this topic.

LITERATURE SEARCHES

The evidence from the Literature Reviews of the databases available can be sub-divided into various categories. The references are in alphabetical order of experimenter and are shown in the References Section.

Production

Production practices have an influence on the shelf-life of bedding plants (Armitage, 1982a). A short review on the post-production handling of bedding and potted plants was presented at Michigan State University symposium (Barrat & Nell, 1989) and indicated that a wealth of information was available on pot plants, but very little was known about the bedding plant crop. Work at the Michigan State University on the keeping quality of Marigolds and Impatiens (Carlson, 1981) indicated that plants grown at lower temperatures in the latter part of the production period had a longer keeping quality than those kept at the growing temperature until market date. The keeping quality of Marigold and Impatiens was best at 10°C and 21°C respectively. When proceeded by optimum night temperatures they remained marketable for 17 and 15 days respectively, indicating that the higher the temperature towards the end of harvest the lower the shelf-life of the crop. This experiment showed at very high temperatures (32°C) keeping quality rapidly declined and plants remained marketable for only four days from harvest.

Nutrition

The majority of work undertaken at Gosford, New South Wales, Australia explored the extension of shelf-life of bedding plants using hydrogels in the potting media (Lamont & O'Connell, 1987). The influence of physical characteristics of substrate on the root system, which in turn affected the shelf-life of container grown plants, was demonstrated in Angiers (Lemaire, 1989).

Physiology

Various studies on CO_2 assimilation (Schultze, Beck, Scheibe Ziegler, 1985) and stomatal response, Brownleader, Collett, Highnam, Mitchell, Simpkins and Wilkinson, 1990) showed an inhibition of stomatal opening in Petunia Resisto. Abcissic acid was also involved during water stress and recovery in petunia (Vardi & Mayak, 1989) in later experiments. Work continued on the chloride absorption of root leaf and flower floral trusses (Hoekstra & van Roekel, 1986) and the effect of stylar ethylene production on the flower longevity of petunia (Hoekstra, 1986), and photoperiodic effect on Begonia semperflorens Hershey & Merritt, 1987b). All gave base lines on which to more fully understand the physiology of bedding plants to enable the effects of treatments to extend shelf-life to be fully understood.

Watering

Few references exist on the effect of watering on the shelf-life of the crop. However, Aalsmeer looked into the relationship of watering strategies to keeping quality of bedding plants (de Graaf, 1990). Armitage, Josh & Kowalski (1983) examined the effect of irrigation frequency on the shelf-life of petunias. The latter work indicated that frequency of irrigation was not significant when the plants were placed in cool post-production environments. In moderate or hot conditions however, plants irrigated with high frequency declined in quality most rapidly. Low moisture treated plants had slower flower development and senescence. These plants were of a better overall visual quality than plants from any other moisture treatments.

Growth Regulation

Extension of daylength was examined as an alternative to the use of growth regulants for growth control of bedding plants and proved not to be a satisfactory alternative (Graaf & Blacquiere, 1991). Growth regulation was proved to extend the shelf-life of bedding plants (Powell, 1974). In this work it was shown that foliar sprays of ethephon extended the shelf-life of Petunias by 14-28 days, whilst daminozide extended the shelf-life by only 7 days. Stocks responded better to sprays of daminozide, and chlormequat and ethephon. Ancymidol reduced plant height and extended shelf-life by 3-13 days. The plant height of Phlox was halved and saleable life increased by 7-15 days after sprays of chlormequat. The height of Nemesia was reduced by 28% with an ethephon spray and its shelf-life was extended by 5-10 days. The shelf life of Salvia and Antirrhinum was not affected by the application of growth regulants.

Temperatures

The temperature just prior to harvest appears to affect the subsequent shelf-life of bedding plants and thus the work in polythene structures (Farthing, 1983) on low temperature production of bedding plants, and the work at Rutgers University categorising plants which grow well at low temperatures (Merrit & Kohl Jnr, 1991), is useful to the industry and the researchers to establish good growing practices to extend the shelf-life of bedding plants. The work at Rutgers followed the same pattern as that of Lee Valley. Crops that grew well at low temperatures included Marigold, Petunia, Pansy and Lobelia. However, crops that took too long to bloom at low temperatures included Impatiens, Dianthus and Zinnia and Geranium; although having better shelf-life did not balance out with the economics of slow production.

Light intensity and air temperature were shown to effect the shelf-life of Petunia (Armitage, Josh & Kowalski, 1983) and the keeping quality of Marigold and Impatiens was affected by night temperatures and duration (Nelson, Armitage & Carlson, 1980). The environment affected the keeping quality of bedding plants when interaction of ethylene, temperature and light were examined on Begonia cheimantha (Armitage, 1982a).

Photoperiod

In addition to lighting affecting shelf-life (Hersey & Merrit, 1987b), Rutgers University showed that the photoperiod affected the form and shape of Begonia, and consequently its shelf-life.

Silver Thiosulphate (STS)

With the withdrawal of STS on environmental grounds, alternatives have been sought. Amino-acetic acid as Triton 100 has been examined at Wageningen (Harkema, Dekker & Essers, 1991) and has shown to be effective and increase the shelf-life of Carnations by 16 days. This material, though not at present having been used on bedding plants, may be a useful alternative.

Very recent work (Nell, 1992) and two commercial companies, Chrysal-Pokon BV of the Netherlands and Abbott Laboratories, North Chicago, Illinois, has found alternative materials to STS. The Dutch company has produced a material called Chrysal EVB which inhibits ethylene production and this is marketed in the States as Chrysal Wholesale.

Abbott Laboratories will this year be releasing a material, to be marketed as Florish, which contains a natural fermentation metabolite that inhibits ethylene biosynthesis in plant tissues.

Performance data and University testing of these products are very limited but it is hoped that all these materials may be trialed on bedding plants in the near future.

Ethylene

The inhibition of ethylene production by the use of STS over many years (Carlson, 1982; Hoyer, 1989; Heins, 1983a&b; Farthing, 1979) led to increased shelf-life of Geraniums and the reduction of petal shattering. This material is not now available to UK markets and is not considered environmentally friendly in most countries, thus alternatives will have to be sought. The material was used in observation trials on bedding plants (private communication Chappell & Farthing 1981) where flowers were kept on Alyssum.

Transport

Work in Aalsmeer over 3 years (de Graaf & Vogelgang, 1989) indicated that plants of Impatiens transported dry suffered less damage and consequently had improved shelf-life compared to those saturated root balls. It was noted that if dry transportation was used, the conductivity (EC) should be kept as low as possible to gain the best shelf-life and prevent any damage to the plants in their pre-transport stage. The majority of work undertaken in America on transportation of plant materials has been in relation to plug grown plants and to the transportation of pot plants. Storage of Marigolds was examined as far back as 1985 (Neff & Loomis, 1985). A summary of the pot plant work has been produced (Conover & Poole, 1984). Handling systems for foliage plants and flowering potted plants are at present being completed by Armitage and Blessington, respectively and will be available in the near future. All of this work relates to foliage and flowering pot plants but by extrapolation some may be used by researchers to develop techniques for the transportation of bedding plants in the UK.

VISIT TO THE DANISH RESEARCH STATION FOR PLANT AND SOIL SCIENCE DEPARTMENT OF FLORICULTURE, KIRSTINEBJERGVEJ 10, DK-5792 ARSLEV ON 13 AND 14 MAY 1992

Introduction

The visit was made to the station to meet Lars Hoyer, a leading experimenter in shelf-life of pot and bedding plants.

Shelf-life Facility

The shelf-life facility at Arslev has the ability to introduce ethylene at precise levels and to control humidity, temperature and light. The shelf-life room is operated to international conventions, ie temperature 20°C, light levels between 500 lux (15 W/m^2) and 2,000 lux (60 W/m^2) and RH 50-60%. Each experiment is approximately of 4 weeks duration.

In the shelf-life facility were three transport rooms and three "keepability" (shelf-life) rooms which had full environmental control. One further room which was capable of any combination of environments etc had been installed for speculative work and was felt by the Researchers to be a vital part of the system. A gas mixing facility was available for exposure of various gases at different concentrations to 24 boxes at a time which could then be placed in the keepability (shelf-life) or transport rooms.

Standard Experimental Technique

This consists of transportation at 2°C for up to 10 days and then keeping in the shelf-life room at 20°C in full light for up to 36 days.

Overview of Post-harvest and Shelf-Life Work at Arslev

The work, which had been carried out since the start of the project in 1982, involved exposure to ethylene and STS treatments. In addition, transportation field experiments and experiments on growing conditions relating to the shelf-life of mainly pot plants have been undertaken.

Campanula plants from 8 different growers were in the shelf-life rooms during the visit. The Campanula crop, one of the first crops examined, looked at the interaction of growing conditions, the effect of transportation and temperature.

The Kalanchoe trials considered the sensitivity of the crop to ethylene. Results indicated Kalanchoe cultivars could be grouped into: very sensitive, sensitive and not sensitive.

Whilst at present there were no long term projects, work was being undertaken to examine all crop production trials for their shelf-life capabilities. The effect of shelf-life related to root activity was also being examined.

Rieger Begonias in low light conditions in a growth room dropped the mature flowers and buds failed to develop, whilst in natural light conditions in the glasshouse plants flowered normally and developed their buds, indicating the effect was related to light and not temperature.

Impatiens kept in total darkness recovered easily within the greenhouse but not in the keepability (shelf-life) room in full light.

Primulas

Plants from 9 different growers were examined and subjected to simulated transportation for 4 days at 18°C then kept for 36 days in an interior environment. (Hoyer & Kristensen, unpublished) Plants from only one nursery wilted in the early stages, though others eventually collapsed at later stages. Some plants, however, did not collapse and had very extended shelf-lives. It is possible early sciarid attacks were a primary cause of this wilting. Experiments have recently shown the sciarid larvae can be vectors of pythium (Goldberg & Stangelellini, 1990). Three sprays of chemical were applied to this crop: after sowing; 3 weeks after potting and after the symptoms of attack or collapse had occurred; or when the plants were out on the nurseries. The crop was sown in July, potted in August, placed out to harden off in October and then harvested in January. It was noticed that the temperature when raised in the keepability (shelf-life) room to 20°C, increased the wilting, whilst lowering temperature reduced the collapse. The spray material used was

Vectobac. There was an increase in the collapse rate when the plants were frequently sprayed in the autumn. If the crops were sprayed immediately after sowing or potting there was an improvement in the post harvest performance. The problem only occurred in the red cultivars and was partially confirmed by another experiment (Hoyer, unpublished) which indicated a genetical link to resistance.

Chrysanthemum Frutescens

Brown tipping had appeared when a systemic insecticide had been used. The crop was very sensitive to changes in nutrition. Reducing the rate of cycocel sprays and increasing their frequency of applications had increased the shelf-life of the crop and reduced the total amount of growth regulant by 30-40%. Reduction of nutritional levels for 2-3 weeks before harvesting had increased the shelf-life of this crop though grower trials did not confirm these differences.

Pelargoniums

Winter production with supplementary lighting resulted in better consumer quality.

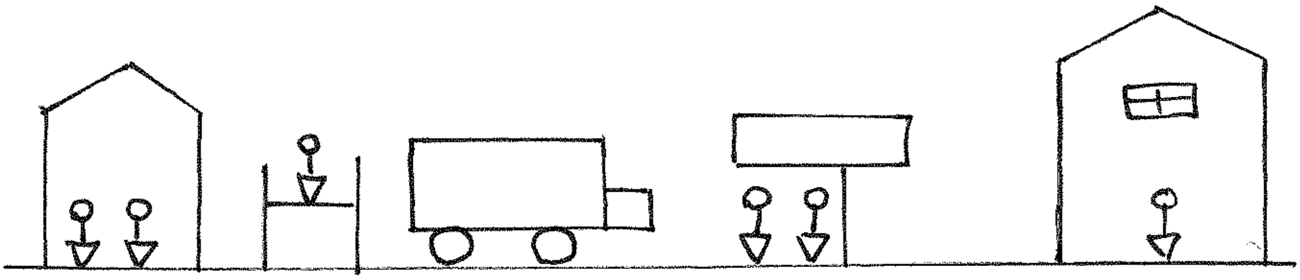
Vinca

This crop is extremely sensitive to ethylene concentrations even at very low levels.

Bedding Plants

Lars Hoyer considered growth retardants had little effect on the shelf-life of bedding plants. Genetic variations within plant material were more important and it was thought that most of the keepability problems of bedding plants would be solved by genetics (simply by selection). Many of the experiments at Arslev are designed to take plant material from various growers. This creates problems as previous crop history is difficult to ascertain.

The diagram below graphically illustrates the component parts of shelf-life and in the case of bedding plants the house at the end needs to be replaced with the consumers garden.



The average distribution time from Grower to Consumer of product in Denmark is :

Grower to Exporter	6 hours
Exporter to Wholesaler	66 hours
Wholesaler to Retailer	36 hours
Retailer to Consumer	120 hours
Total	228 hours (9.5days)

Campanula

The optimum transport conditions for Campanula was found to be 2°C giving an increase in flower colour. It took 10 days for the crop to go from the grower to the final customer. The experiment consisted of simulated transportation at 2°, 6°, 12° and 18° for 10 days, temperatures being maintained plus and minus 1°C. The plants again were from 3 growers. Nine varieties and were looked at in their keepability (shelf-life) rooms.

An increase in shelf-life can be obtained by a reduction of nutrition two weeks prior to harvest.

Poinsettia and Dracaenae

Poinsettia trials indicated that transport at 2° and 6°C were satisfactory and increased the shelf-life of the final product. The same temperatures appear to be satisfactory for Dracaenae.

Stephonotis and Gerberas

Stephanotis transported at 2°C resulted in spotting of the flowers. At 2°C Gerberas developed black spots; however, transportation at 16°C reduced their shelf-life.

Vincas and Exacum were both damaged at transport temperatures of 2°C. Begonias were better quality after 2-3 weeks when transported at lower temperatures. There was however a great variability on most subjects dependent on the source of plant material, indicating production systems have a major effect on shelf-life.

Roses and Chrysanthemums

With the rose crop flower colour intensified when the plants had been kept at lower temperatures. Chrysanthemums showed no difference at two weeks but as shelf-life continued after this, colour was better at lower temperatures.

Pelagonium and Aster

The optimum transportation temperature for Pelagonium was 6°C whilst flower colour of Aster was better at lower temperatures.

The effect of transportation on all of the crops was seen on plant material after the first two weeks, but not normally prior to this stage.

Ethylene

It had been noted that ethylene had been released from the walls of trucks. Sealing these walls had eventually cured this problem and improved the keeping quality of pot plants transported in trucks over long distances. Plant quality is affected by the length of time the plants remain in transport. The objective should be to reduce the transport stage as much as possible. One of the solutions to transportation of mixed loads was to run two truck temperatures. This was possible with the new trailer systems being developed on the continent. The cost of a 2 temperature truck system compared to a 3 temperature truck system was a quarter the price. Transportation at high temperatures caused condensation problems over time, but transportation for less than 1 day caused no substantial problems with condensation.

There was very little ethylene in the shops or multiple outlets due to the large volumes of air and the air exchange rates which were high in these premises, thus negating the problem.

Plant material should always be sold at the right stage and it was unlikely any approved chemical agent could be used to increase the shelf-life of bedding plants. There was a possibility, however, that if increase in sucrose levels in plants could be achieved it may have some effect. Any treatment must, however, be economic. It was more likely that plant grouping would have more effect than chemical treatments and that plant selection would also have a greater effect on the shelf-life of bedding plants than any other factor.

Lars Hoyer considered breeding was going to be the full answer to the increase of shelf-life especially of bedding plants.

New Guinea Impatiens - Hedaker A/S

There was a necessity to spray with STS prior to marketing and the reduction of temperatures was not undertaken on this nursery. The normal production temperature for Impatiens was 16-18°C in the summer. No Impatiens were cooled below 10°C as this was felt to be deleterious to the crop.

VISIT TO THE RESEARCH STATION FOR FLORICULTURE, AALSMEER, NETHERLANDS 15 MAY 1992

Introduction

A visit was made to the Aalsmeer Research Station to discuss the shelf-life of pot and bedding plants with Anneke Brandts, Jose Vogelgang and also Kasper Slootweg, who was responsible for the post harvest facility at Aalsmeer.

Nico Straver, Nutrition Chemist, could see no method that could be used to increase the shelf-life of bedding plants other than producing them in the best possible way and keeping the nutrition correct so that too soft a plant was not produced. He doubted whether there would be any chemical treatments that would increase the keepability other than those that produce a quality plant.

Shelf-life Facility

A new post-harvest building constructed by Geerlofs has now been commissioned and research is being undertaken on post-harvest performance of crops. The research claims that by improving quality, shelf-life and keeping quality of harvested and marketed floriculture products is enhanced.

Research topics are:

* The determination of consumer value.

* Keeping quality of new cut flowers with respect to consumer.

* Carrying out and developing standard quality tests for cut flowers and pot plants.

* Studying the processes which control the opening of flower buds.

* Research into influences of cultivation on the keeping qualities of plants.

* Factors which control the water balance of cut flowers of pot plants.

* The pre-treatment of cut flowers to realise a better keeping quality.

* The influence of transport on keeping quality of pot plants and cut flowers.

The internationally accepted standard for shelf-life testing has been adopted in this building, ie light intensity 3 watts/m², temperature 20°C and RH 60%. Effectively light levels of supermarkets and shops never reach these levels. The transport room is set to 15°C with a 70% RH and is in darkness. The average time for produce to go from the nursery to the consumer via the auction is approximately 2 weeks. Humidifiers and air dryers are installed in the shelf-life rooms to enable accurate control of humidity to be obtained.

J J M Van der Kleij, the Quality Control Consultant for the Dutch Floriculture Wholesale Board, was of the opinion that eventually some chemical treatment will be available to help with the extension of shelf-life of bedding plants, but that at high quality produce has better shelf-life.

The general impression from most of the research workers at Aalsmeer was that it was doubtful whether a chemical solution was feasible as most were not environmentally friendly and were being phased out. It was more likely that a natural substance would be found which would increase the shelf-life of bedding plants. Van der Kleij was of the opinion, as were all the researchers both in Holland and in Denmark, that a quality plant would always last longer however much it was abused.

GROWER OPINIONS

Grower opinions vary concerning the causes of poor shelf-life. Whilst most agree the problem occurs, shelf-life is an area of work where categorisation of problems and causes are extremely difficult to ascertain.

Most growers would agree a good quality plant will have a better shelf-life than a poorly grown plant. Also that a plant hardened off will also have a longer shelf-life. Methods to achieve this vary amongst growers and include different methods of growth regulation either by growth retardation or by water regimes. Other methods of controlling growth are by temperature and by hardening off and use of side ventilated tunnels.

Another area which growers agree is a problem, is that of the aftercare in either the supermarket or the garden centre, where a well grown plant can be easily spoiled in a very few days. This can happen by leaving it unpacked on Danish trolleys in the supermarket or garden centre for 2 or 3 days with the exclusion of light or, left in the back in the packing area in poor light conditions, or even under benches when storage space is at a premium, ready to be distributed later in the garden centre.

Under adverse conditions of poor weekend sales these plants can remain in these areas for 2-3 days, become drawn and in bad condition with a very poor shelf-life in this period.

Supermarket specifications in the States (Sullivan, Robertson & Staby, 1980; Siddles, 1982) are written by most supermarkets but are extremely flexible to take account of the market needs and plant availability. The supermarket specifications for the UK were not made available to me on my enquiries.

RECOMMENDATIONS FOR FURTHER WORK

1. A survey to identify major areas where the problem occurs starting at the consumer end.

2. Research into suitable alternatives to STS type materials.

3. A survey to identify multiple specifications.

4. Production trials on grower's holdings to enable plant material to be traced from a given source to the consumer end.

5. Create a list of cultivars and species with reference to their shelf-life capabilities.

6. Establish a full shelf-life facility at a UK experimental centre.

7. Produce a Code of Practice for retailers/wholesalers based on current knowledge.

8. Update this code annually in the light of current knowledge.

9. Experiments to establish by experimentation the effects of shelf-life on:-

10. Growth regulants.

11. Nutrition.

12. Temperature.

13. Water regimes and pH.

14. Undertake field trials on transport conditions of bedding plants from grower to wholesaler or garden centre. Check these against simulation in shelf-life facility.

15. Create a computer model for shelf-life.

16. Ensure that all trials undertaken on bedding plants have a shelf-life element built in to their proposal.

17. Establish a scientific method of assessing quality in bedding plants.

ANON. (1981). Sales of bedding plants in general food stores, Netherlands: 1979-1981 Aspects of family consumption. *Marche International des Fleurs Aetdes Feuillages* (20-21), 21-23.

ANON. (1983). Marigold: Care tips for the florist. *N.Y. St Flower Ind Bul* **153**, 6.

ANON. (1985). Bedding plants in supermarkets: How to care, handle and merchandise them. *Produce Marketing Almanac.* 117-119

ANON. (1986). Argylene product history and plant biology, Instructions in how to use Argylene. English Argylene brochure, *Argylene*, section 1,3,8.

ANON. (1989). Research into the sensitivity of bedding plants during transporation. *Vakbald voor de Bloemisterij* **4**, 172-173.

ABELS, F. B. & HEGGSTAD, H. E. (1973). Ethylene: an urban air pollutant. *J Air Pollution Control Assoc* **23** (6), 517-521.

ARMITAGE, A. M. (1982a). Environment affects the keeping quality of bedding plants. *Southern Florist and Nurseryman* **95**, (6) 19-21.

ARMITAGE, A. M. (1982b). Bedding plant shelf-life - where we are and where we are going. Proceedings of *International Bedding Plant Conference* (15th) 215-225.

ARMITAGE, A. M. (1982c). Keeping quality of bedding plants: Who's responsibility it it? *Florist Review* **171** (4438), 34-35, 39.

ARMITAGE, A. M. (1983). Keeping quality of bedding plants. *Florist Review* **172** (4461), 63-64, 66.

ARMITAGE, A. M.; JOSH,B. & KOWALSKI, T. (1983). Effect of irrigation frequency during greenhouse production on post production quality of Petunia hybrida Vilm. *Journal of the American Society for Horticultural Science* **108** (1), 115-118.

ARMITAGE, A. M. (1986). Influence of production practices on post production life of bedding plants. *Acta Horticulturae* **181**, 269-277. Georgia University, USA.

ARTECA, R. N. & SCHLAGNHAUFER C. D. (1988). Effects of shipping on quality of Pelargonium cuttings. *Hort Science* **23** (3), 730.

BARRETT, J. A. (1991). New-media - applied humectant can improve plants drought resistance. *Greenhouse Manager* **10** (5), 123.

BARRETT, J. A. & NELL, T. A. (1989). Post Production Handling of Pot and Bedding Plants. *Florida Agr. Expt. Sta.J. Series* No 10063

BOODLEY, J. W.; BING, T. C.; WEILER, ALBRIGHT, L.; DAUGHTREY, M.; SEMEL, M. & TOPOLESKI, L. (1984). Storage of seedlings. *Cornell Bedding Plant Guidelines for N.Y. State*, 1984:5.

BROWNLEADER, M.; COLLETT, A.; HIGHNAN, C.; MITCHELL, S.; SIMPKINS, I.; & WILKINSON, J. (1990). Inhibition of stomatal opening in the peeled epidermis of the Petunia Resisto leaf by omeprazole. *British Plant Growth Regulation Groups* 1990, (21), 387-388

CAMERON, A. C. & REID, M. S. (1981). The use of Silver Thiosulphate Anionic complex as a foliar spray II, Prevention of shattering in potted Geraniums. *Hort Science* **16** (3), 405.

CARLSON, W.; NELSON, L. J. & ARMITAGE, A. M. (1981). Bedding plants: Keeping quality of Marigolds and Impatiens. *American Vegetable Grower* **29** (1), 28-32.

CARLSON, W. (1982). STS eliminates petal shattering. *Flor. Rev* **170** (4409), 150-152.

CANNON, A. R.; HEINS, R. D. & FONDA, H. N. (1985). Influence of storage and mixing factors on the biological activity of silver thiosulphate. *Scientica Horticulturae* **26** (2), 167-174.

CHAPPEL, F.& FARTHING, J. G. (1981). Reduction of Petal Shatter in Seed Raised Geraniums. *Lee Valley Annual Review,* 12-20.

CHRISTIANSEN, I. (1988) Primula Vulgaris - Improve longevity following spraying with Argylene. *Gartner Tidende* **104** (3), 59.

CONOVER, C. A. & POOLE, R. T. (1984). Acclimatization of indoor foliage plants. *In Hort Reviews* **(6)**, 119-154.

CONOVER, C. A. (1986). Quality. *Acta Horticulture* **181**, 201-205

DEAN, S. & CARLSON, W. H. (1979). Effect of ethylene on the shipment of seed Geraniums (Pelargonium x hortorum Bailey). *Hort Science* **14** (3), 444-445.

DENEKE, C. F.; EVENSEN, K. B. & CRAIG, R. (1992). Regulation of petal abscission in Pelargonium x domesticum. *Hort Science* **25** (8), 937-940.

DOSTAL, D.; AGNEW, N. H. & GLADDON, R. J. (1988). Effects of ethylene exposure, AOA, and STS on corolla abscission of New Guinea Impatiens. *Hort Science* **23** (3), 773.

ET AL, (1982). Investigation of the keeping quality of number of Begonia cultivars grown in different greenhouse conditions. Aalsmeer Report, 80-82.

FARTHING, J.G. (1983). Bedding Plant Production in Low Cost Film Plastic Structures. *Lee Valley Annual Review,* 7-12.

FIELD, T. (1986). The effect of relative humidity, light intensity and temperature on keeping quality of Begonia x Cheimantha Everett. *Acta Horticulturae* **181**, 251-255.

GEHRING, J. M. (1979). Shelf-life extension of bedding plants. M.S. Thesis, Virginia Polytech, Inst. 39 pp.

GEHRING, J. M. & LEWIS, A. J. (1979a). Extending the shelf-life of bedding plants 1 (Ornamental and vegetable). *Florist Review* **165** (4278), 17, 60-61.

GEHRING, J. M. & LEWIS, A. J. (1979b). Extending the shelf-life of bedding plants 2 (Hydrogel). *Florist Review* **165** (4282), 30, 46.

GEHRING, J. M. & LEWIS, A. J. (1980a). Extending the shelf-life of bedding plants 3. (Anti-transpirants) *Florist Review* **165** (4286), 31, 65.

GEHRING, J. M. & LEWIS, A. J. (1980b). Effect of hydrogel on wilting and moisture stress of bedding plants. *Journal of the American Society for Horticultural Science* **105** (4), 511-553.

GELD, F. (1989). Effect of ethylene exposure, temperature and light intensity of keeping quality of Begonia x cheimantha. *Acta Horticulturae* **261**, 373-376. Department of Horticulture, Norway.

GIANFAGNA, A. (1958). Geranium flower life extended by Gibberellic acid treatment. *Florists Exchange and Hort Trade World* **131**, 14, 35.

GOLDBERG, N.P. & STANGEHELLINI, M.E. (1990). Are fungus gnats and shore files moving disease pathogens around your greenhouse? *Grower Talks* **54**(4), 40-45.

GOLDBERRY, K.; DORMAN, C.; ZANGGER, C.; PINTER, J. & IWISIKI, A. (1973). Shipping seasons problems and solutions, moving plants, material handling - Bedding plants. Proceedings of *National Bedding Plants Conference*, 78-89.

GRAAF VANSDER ZANDE, M. T. de (1990). Water strategies in bedding plant culture: effect on plant growth and keeping quality. *Acta Horticulturae* **272**, 191-196. Netherlands.

GRAAF, M. T. de & BLACQUIERE, T. (1991). Experiment on extending the daylength of bedding plants using different lamps. Controlled light not yet an alternative to inhibitors. *Vakblad voor de Bloemisterij* **46** (6), 68-69.

GRAFF, M.T. de & Vogelgang, J. (1989). Research into the sensitivity of Bedding plants during transportation. *Vakblad voor de Bloemisterij* **4**, 172-3

GRUBER, J. & EISENBERG, B. A. (1986). Response of Geranium and Impatiens to ethylene treatments when exposed to simulated shipping environments. *Hort Science* **21** (3), 694.

HARKEMA, H.; DEKKER, M. W. C. & ESSERS, M. L. (1991). Distribution of ameno-oxyacetic acid in cut carnation flowers after pre-treatment. *Scientia Horticulturae* **47**, 327-333.

HEINS, R. & FONDA, H. (1983a). Controlling petal shattering. *Long Island Horticulture News* June 1983:4.

HEINS, R. & FONDA, H. (1983b). Mixing STS. *Bedding Plants Inc News* **19** (5), 6.

HERSHEY, D. R. & MERRITT, R. H. (1987a). Influence offered for a period of crop productivity and form of Begonia semperflorens - cultorum grown as bedding plants. *J AM SSC Hortic CI* **112** (2), 252-256.

HERSHEY, D. R. & MERRITT, R. H. (1987b). Influence of photo period on crop productivity and form of Begonia x Semperflorens - Cultorum as bedding plants. *Journal of the American Society for Horticultural Science* **112** (2), 252-256 (11) 110 ref.

HOEKSTRA, F. A.; & ROEKEL, G. C. van (1986). Effects of interspecific pollination on stylar ethylene production and flower longevity in Petunia hybrida. *Acta Horticulturae* **181**, 105-112.

HOOGERWERF, A.; PLADDET, F. C.; KEMPKES, M. M. J. & DORN, W. G. (1989). Measurements of opinion on the relationship between environmental factors and keeping quality of ornamentals. *Acta Horticulturea* **261**, 241-248.

HOPPER, D. A. (1985). Bud abortion in Marigolds. *BPI News* **16** (4), 1-3.

HOWE, T. K. & WOLTZ, S. S. (1982). Symptomology and relative sensitivity of Marigold cultivars exposed to sulphur dioxide. *Penn Fl. Growers Bul* **342**, 8

HOYER, L. (1982). Reaction of potted plants on ethelene and darkness *Gartner Tidende* **98**, 670-671

HOYER, L. (1985). Bud and flowerdrop in Begonia elation 'Sirene' caused by ethelene and darkness. *Acta Horticulturea* **167**, 387-394

JESSEL, W. H. Jr & DUFFETT, W. E. (1981). Geranium plant (Good flower durability under outdoor summer conditions). Plant - United States Patent and Trade Mark Office (4778), 2p plate.

JOOSTE, J. H. (1980). Chloride absorption by root, leaf and floral tissues of Petunia hybrida, (Cut flower longevity). *Journal of South African Botany* **46** (3), 245-249.

KACZPERSKI, M. P. & ARMITAGE, A. M. (1990). Short term storage of plug grown bedding plant seedlings. *Hort Science* **25** (9), 1094.

LAMONT & O'CONNELL (1987). Shelf-life of bedding plants as influenced by potting media and hydrogels. *Scientia Horticulturae* **31**, 141-150.

LANGE, N. E. & HEINS, R. E. (1991). Cold storage of bedding plant plugs. *Hort Science* **26** (6), 770.

LEE, W. R.; BARRAT, J. E. & NELL, T. A. (1989). High temperature effects on the growth and flowering of Impatiens walleriana. Proceedings of *Proc Int Soc Hort Sci Syposium of Bedding and Pot Plant Culture* 29 April-4 May.

LEMAIRE, F. (1989). Influence of physical characteristics of substrate on root system of ornamental plants grown in pots and containers. *Agronomie* **9** (8), 795-801.

LOVELL, P J.; LOVELL, P. H. & NICHOLS, R. (1987). The control of flower senescence in Petunia (Petunia hybrida). *Annals of Botany* **60** (1), 49-59.

MAROUSKY, J. F. & HARBAUGH, B. K. (1979). Relationship of temperature, darkness and ethylene to leaf chlorosis of Geranium during simulated transit. *Hort Science* **14** (3), 434.

MERRITT, R. H. & KOHL, H. C. Jr. (1989). Crop productivity and morphology of Petunia and Geranium in response to low night temperature. *J M Soc Hortic Sci* **114** (1), 44-48.

MERRITT, R. H. & KOHL, H. C. Jr. (1991). Morphology in bedding plants to low light temperature and energy use implications. *Scientia Horticulturae* **45**, 295, 02.

NANGE, N. E & HEINS, R. (1991). Cold storage of bedding plant plugs. *Hort Science on Work* **26** (6), 769-770.

NEFF, M. S. & LOOMIS, W. E. (1985). Storage of French Marigolds. *Proc Amer Soc Hort Sci* **33**, 683-685.

NELL, T. A. (1990). Post production and handling of bedding and pot plants. *Acta Horticulturae* **272**, 311-317. Netherlands.

NELL, T.A. (1992). Taking silver safely out of the longevity picture *Grower Talks,* June, 35-42.

NELSON, L. J.; ARMITAGE, A. M. & CARLSON, W. H. (1980). Keeping quality of Marigolds and Impatiens as affected by night temperature and duration. *Florist Review* **167** (4318), 28-29, 62, 74.

PERRY, L. P. & HAZELARGG, A. (1983). Effects of Viterra 2 hydrogel on growth and shelf-life of bedding plants. *Hort Science* **18** (4 Sect 2).

POWELL, L. (1974). Growth regulators can extend shelf-life. *Commercial Grower* (4081), 465. Cleppa Park Horticultural Station, Cardiff, UK.

PRINCE, T. A. (1986). STS helps plants last longer. *Flower News* **40** (33), 36.

RUTLANDS, R. B. & AMY EYEI-MEI CHUNG (1971). Foliar absorption of collated iron from solutions of high pH and movement of absorbed iron within the leaf of Antirrhinum majus cv Texas. *Hort Science* **6** (5) 461-463.

SCHUTZE, E.D; BECK, E; SCHEIBE, R & ZIEGLER, P. (1985). Carbon dioxide assimilation and stomatal response of afro alpine grant rosette plants. *Orcologia* **65**(2), 207-213.

SIDLES, C. J. (1982). Marigold: Care tips for the florist. What to tell your customer. *Flowers & Preservatives* **3** (11), 69-70.

SULLIVAN, G. H.; ROBERTSON, J. L. & STABY, G. L. (1980). Post-harvest handling of nursery stock and bedding plants. *Management for Retail Florists. With applications to Nurseery and Garden Centres* ch 24, 505-525.

VARDI, Y.; & MAYAK, S. (1989). Involvement of abscisic acid during water stress and recovery in Petunia flowers. *Acta Horticulturae*, **261**, 107-112. Hebrew University, Israel.

WINTERS, A. F. (1974). Flower longevity in New Guinea Impatiens Introductions. *Hort Science* **9**, 20 (abstract).

WINTERS, S. F. (1977). Flower longevity in New Guinea Impatiens. *Hort Science* **12** (13), 261-263.

WISE, F. C. & FONTENO, W. C. (1980). Effects of growth regulators on post production performance of 'Happiness' Petunias. *Hort Science* **15** (3), 389-390.

WOLTZ, S. S. & WATERS, W. E. (1977). Susceptibility of some ornamentals to fluoride air pollution. *FLA Flower Grower* **14** (112), 1-3.