REPORT 44

# QUALITY CONTROL IN THE CHAIN
## Research into the marketing chain for trees

Ir. E.M. van Hees-Boukema and
dr. M.B.M. Ravesloot



1996, Applied Research for Nursery Stock

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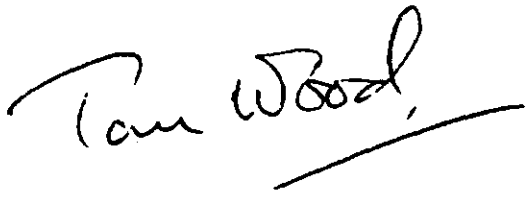
# Foreward To The English Translation

The Horticultural Development Council is pleased to publish this English language edition of the final report from the Dutch R & D project, "Quality control in the chain". Extensive research and development activities in Holland aimed to highlight problems in the supply chain for tree nursery products, and to discover the best ways of handling bare root plants.

I am sure this practical guide will be welcomed by plant producers and plant users alike. The problems of plant survival and subsequent establishment at all stages are addressed in a simple, user friendly way and valuable guidelines are given to standards of plant handling we can all attain and practice.

This is a valuable piece of research that can benefit our whole industry.

The translation was made possible by the kind co-operation of the Dutch Institute of Applied Research for Nursery Stock (Boomteelt Praktijkonderzoek), to whom we are very grateful.



**Tom Wood**
Chairman, HDC Hardy Nursery Stock Panel Chairman
November, 1995

# Foreward

*The project "Quality control in the chain" has been completed. An important step has been made towards the improvement of quality care of trees, especially during the phase between lifting by the producer and delivery to the client.*

*Before the definitive project was allowed to commence, the Werkgroep Kwaliteitsbevordering Boomkwekerijgewassen (Working Group Quality Promotion in Tree Producing Nurseries), a working group from the Boomteelt (Tree Crop) department of the Landbouwschap (Department of Agriculture), undertook a preliminary investigation. This identified a bottle-neck, and therein is given a detailed description of the research projects.*

*This caused the Ministerie van Landbouw, Natuurbeheer en Visserij (Ministry of Agriculture, Nature and Fisheries) and the Producktschap voor Siergewassen (Production of Ornamental Plants Department) to each contribute 50% to the costs of the project. Through the excellent co-operation of all the companies and the devotion of all concerned it has been possible to bring all the facts together and combine the conclusions and recommendations in this report.*

*A part of this project is a two year investigation into the determination of viability by the Instituut voor Agrotechnologisch Onderzoek (Institute for Agro-technology Research), followed by a second phase, whereby a practical assay method should be developed. Through the policy commission set up by the project steering committee, the research from the first two years has been evaluated, and the decision taken to stop the research. The overall outcome of the various parts of the investigation are positive. The up-to-date results of the collective efforts are here for you.*

*During the project many activities have been picked up and implemented. As well as investigation, advice has been given which has brought about the awakening of the target groups. This advice was supported by demonstrations, publication of articles and distribution of a poster and a folder.*

*In this way, attention has been drawn to improving conditions during delivery. The word has now been delivered to the companies. Practical measures, taken with good discussion, can prevent the loss of quality of the product. The result of the attention drawn to quality aspects will be an improvement of the image of the tree production nurseries in a competitive environment. Direction has been given through the project "Quality control in the chain". The task has now been given to the trade to complete!*

*On behalf of the project steering committee, we thank the authorities and company representatives who have assisted in the production of this report.*

***B. Ruys***, member of the steering committee, representative of the "Produktschap voor Siergewassen".

***C.H. van der Smit***, member of the steering committee, representative of the Department Boomteelt of the Landbouwschap.

# 1. INTRODUCTION

There are many links in the chain by which Dutch tree nursery products are sold. Each link represents a different action which must be taken to deliver the product. The aim is to maintain product quality during the process which occurs between lifting at the nursery and planting out by the end user.

Every action taken in the different links of the chain has an influence on quality. Some actions will not improve the quality. In fact, quality will be adversely affected by a needless or careless action, for example, lifting under poor conditions, wrong choice of transport etc. In a very short time, improper handling can destroy the quality of a product that has been grown with care for years.

The delivery of high quality products becomes ever more important, because consumers both at home and abroad have become more discerning. In order to maintain our position in the export market, the industry must pay attention to the necessity of an integrated quality control approach, whereby all the links of the chain are appropriate.

It is from this understanding of the problem that the working group on quality control in tree nurseries (W.K.B.) put forward the proposal for a project "Quality control in the chain". The purpose of the project was to prevent or limit the loss of quality within the supply chain. In order to reach this goal, research was commissioned which was supported by demonstrations. These activities aimed to raise the awareness of all the links in the chain.

Through the BPO (Boomteelt Praktijkonderzoek - Applied Research for Nursery Stock), an investigation was started into conditions during packing, storage and transport of tree nursery products.

The first step was a literature search. This was followed by a survey of around 80 nurseries and suppliers. Actions taken during supply were examined, as well as conditions under which they took place and their duration.

Random samples were taken during the survey, with measurements taken of the temperature and relative humidity in the sheds, sorting rooms, cold stores and during transport.

At the same time, 12 experiments were carried out.

In the regular research programme of the BPO, the following were investigated: machine lifting, defoliation and washing. The last two investigations have not yet been completed, and will be continued in future BPO programmes.

While the project was running, alongside the research, much attention was paid to providing information to all target groups, to urge them to pay attention to careful handling when delivering or receiving tree nursery material. The aim was to make all the links in the chain conscious of the importance of quality control. This was supported by various articles in the trade press and by various meetings.

The meetings were run in conjunction with demonstrations at all the Dutch research stations which showed the differences between plants that had been well handled and those which had been badly handled.

# 2. INVESTIGATION

## 2.1 Introduction

Four investigations were carried out at the Tree Crops Research Station (Proefstation voor de Boomkwekerij), under the title "The optimisation of storing, packing and transport of bare root tree crops" under the "Quality control in the chain" programme.

Three of the investigations were undertaken within the normal research station programme. These were machine lifting, defoliation and washing. The fourth was an experiment to determine the optimal conditions for packing, storage and transport of tree nursery products.

Conditions for handling bare root crops are central to this investigation. Most attention is paid to the activities of the producer and produce trader. Conditions during the growing of the crop and its transplanting are not considered, although they naturally influence the assessment and regrowth.

One part time scientific researcher and a full time senior technician worked on the project for two years, from September 1992 to September 1994. During this time there was a survey of the practices of commercial tree nurseries, a literature review and 12 experiments.

The results were presented in three sectional reports and in this summary final report. For a detailed account you are referred to the three sectional reports (not available in English, ed.). This summary report also gives the provisional results of the experiments on machine lifting, defoliation and washing.

# 2.2 Cold storage

### 2.2.1 Optimal storage conditions

From the literature review, it was evident that bare root crops can be stored for the longest period if they are lifted during winter and held at -2°C. By storing below freezing, there is the least chance of fungal growth, and the activity of the plant is at a minimum.

If plants are lifted early in autumn, it is not certain that they are fully hardened and dormant. With early lifted plants, there is also the risk of frost damage when they are stored below zero if they are not fully winter hardened. The same holds for plants that are lifted late in winter or early spring as they are already active. Plants that are lifted early or late are not suitable for long term cold storage. The best storage temperature for these plants is just above the freezing point.

If storage is only required for a few weeks, then a temperature just above freezing is good, even for plants that are dormant. The chance of fungal growth is greater, the respiration rate and the use of sugars and starch is higher, and the plants will be active earlier.

The results from the experiment with rose rootstocks (*Rosa canina* 'Inermis') bears out this general trend. After being stored for 11 weeks at -2°C, the nodes were less developed than at +4°C, and were not affected by fungi. After 11 weeks at +4°C, surface fungal growth was evident, mostly at wound areas. Plants emerged earlier after storage at the higher temperature, because of greater node development.

*Figure 1: Average temperature, desired value and maximum temperature variation in seven cool or freezing stores.*

| | Average temperature °C | Desired temperature °C | Temperature variation °C |
|---|---|---|---|
| **Cold store** | | | |
| 1 | 0.30 | +0 | 2.7 |
| 2 | 0.08 | 0.1 | 0.4 |
| 3 | 2.40 | +0 | 3.0 |
| 4 | 0.46 | +0 | 1.3 |
| **Freezing store** | | | |
| 1 | -3.8 | -1.0 | 2.9 |
| 2 | -1.7 | -1.5 | 1.4 |
| 3 | -1.0 | -2.0 | 0.2 |

### 2.2.2 Cold storage in practice

Temperatures present in the cold stores of several companies were measured during the survey (Figure 1). In practice, the working air temperature sometimes deviated from the desired temperature. It was also established that temperature differences exist in different parts of the coldroom. Only in very few cases were thermometers and control apparatus calibrated periodically.

In practice, swings of several degrees are not uncommon within the coldstores. These temperature swings are a by-product of the current practice of direct cooling, where the cooling unit itself sits inside the cold store. Frequent de-frosting, or where more than one unit is present in the cold store, de-frosting each unit in turn, will limit temperature fluctuations.

### 2.2.3 Plant temperature

The temperature measured in the bundle of plants is usually higher than the air temperature. This is because of heat production by the plants themselves, and heat produced by the decomposition of residual leaves.

The manner of packing the plants into the bundle and the cooling capacity of the store should be such that the plants are cooled quickly. Maintain space between the pallets and between the pallets and the walls. Packing materials slow down cooling. Packing materials or films should only be applied after the pre-cooling period. Remove as many residual leaves as possible. If there is peat residue around the roots in a pallet box, the temperature there will be higher than in the middle because of poor ventilation (Figure 2).

In practice, realising the desired temperature around the plant requires extra attention to detail.

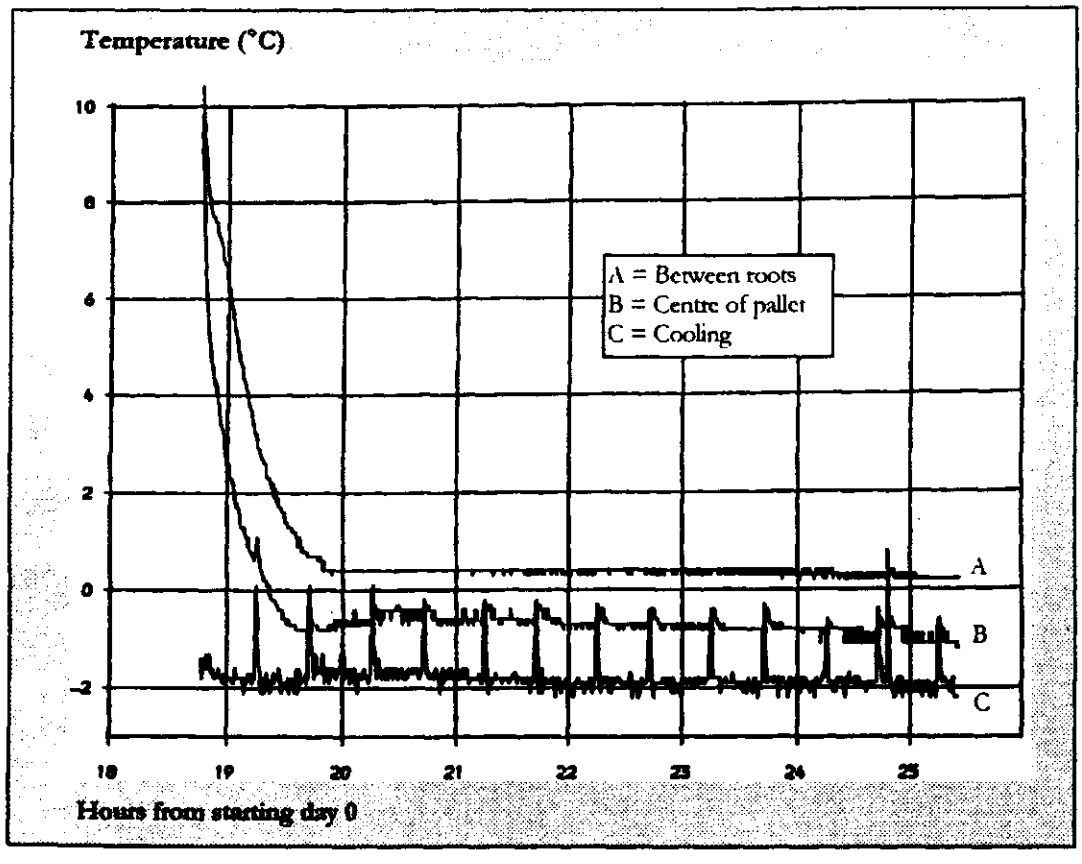



*Figure 2: Recording of plant and air temperature after the placing of a pallet of trees into a freezing room. After 48 hours the plant temperature remains constant. The temperature between the plants is higher than the air temperature. Between the roots which are covered with peat residue, the temperature is higher than between the crop in the centre of the pallet.*

### 2.2.4 Drying out in the cold store

In spite of the normally high relative humidity in a cold store, plants invariably dry out during cooling. Condensation on the cooling elements and the high rate of air displacement due to the fans causes moisture removal from the crop. Humidity is also lost by opening the doors of the cold store. It is therefore useful to protect plants from drying out.

One method of preventing drying out is the use of humidifiers. An experiment 'Comparison of different methods for cold storage of *Rosa* 'Diamond Jubilee', showed that when stored at -2°C, bare root or packed storage did equally well when the air was humidified. In spite of a storage time of nearly six months, no weight loss was recorded. The assessment percentage was practically 100%, and the transplanting was good.

### 2.2.5 Fungi

Temperature swings can lead to the formation of condensation. The chance of condensation is especially large when there is a high relative humidity, such as occurs in a cold store. Even small temperature differences will cause the plants to become wet. Condensation on the plants increases the likelihood of fungal damage.

This is an important reason to maintain a constant temperature in the cold store.

The trade press has reported that companies that have used buffer materials such as peat dust, sphagnum, sawdust and the like, around the roots to try and prevent fungal growth have found them to be either superfluous or harmful.

### 2.2.6 Great temperature changes

Until now it was not known whether large temperature changes are themselves harmful to the plants. Alternating freezing and thawing can cause damage through the formation of ice crystals between the cell walls which can damage the walls themselves.

Rose rootstock (*Rosa canina* 'Inermis') was unintentionally exposed to temperature swings greater than 12°C several times in its storing period, due to the long de-thawing of the cold stores. However, it showed no adverse reaction when transplanted.

In an experiment with *Alchemilla mollis*, one year whips of *Cornus alba* 'Elegantissima' and two year old seedlings (1+1) of *Quercus robur*, the influence of large temperature swings was investigated. After lifting in October or December the plants were stored at either -2°C or at -1°C. During the storage period the plants were taken out of the cold or freezing store three times for a four day period and placed into a warm shed. The temperature in these sheds was +17°C. As a control a proportion of the plants remained at -2°C for the whole of the storage period . The plants were all packed in polythene for the whole storage period , whether in the cold store or in the warmed shed. Thus, a drying out effect played no part in the experiment.

The results of this test showed that a large temperature swing or alternate freezing and thawing had no detrimental effect on the plants. A higher average storage temperature gave the plants an advantage, whereby the buds emerged quicker out of the eyes. The October lifted oaks which were frozen had a lower striking percentage. This shows that early lifted oaks are frost sensitive.

In practice the results of this experiment mean that the plants can be kept in a warm place, (for example in order to grade them), without being harmed, so long as the plants are covered or packed to protect them against drying out.

Also you must count on the fact that the plant, after being fully dormant, will become active under the influence of high temperatures. With some plants, this will occur when the storage period is interrupted to wash or grade the plants. In this case, a comment should be posted on the door that the time that the plants spend at a higher temperature should be limited to the minimum.

## 2.3 Storage in sheds

### 2.3.1 Shed climate.

Plants that are traded, will be stored in a shed for a time either by the producer or the merchant. Most sheds are not air conditioned and the plants are held un-packed.

During the survey, the conditions in these sheds between the months of January and April were measured. The measured temperature and relative humidity values were used to calculate a vapour pressure deficit. The vapour pressure deficit, apart from the wind speed, determined the rate of drying out. This was expected. The conditions in the sheds deteriorate as spring comes: the temperature rises, the relative humidity falls and therefore the vapour pressure deficit increases (Figure 3). The activity of the plants and the drying out both increase. Therefore the plants are no longer in the state of dormancy, but are suffering from drying out.

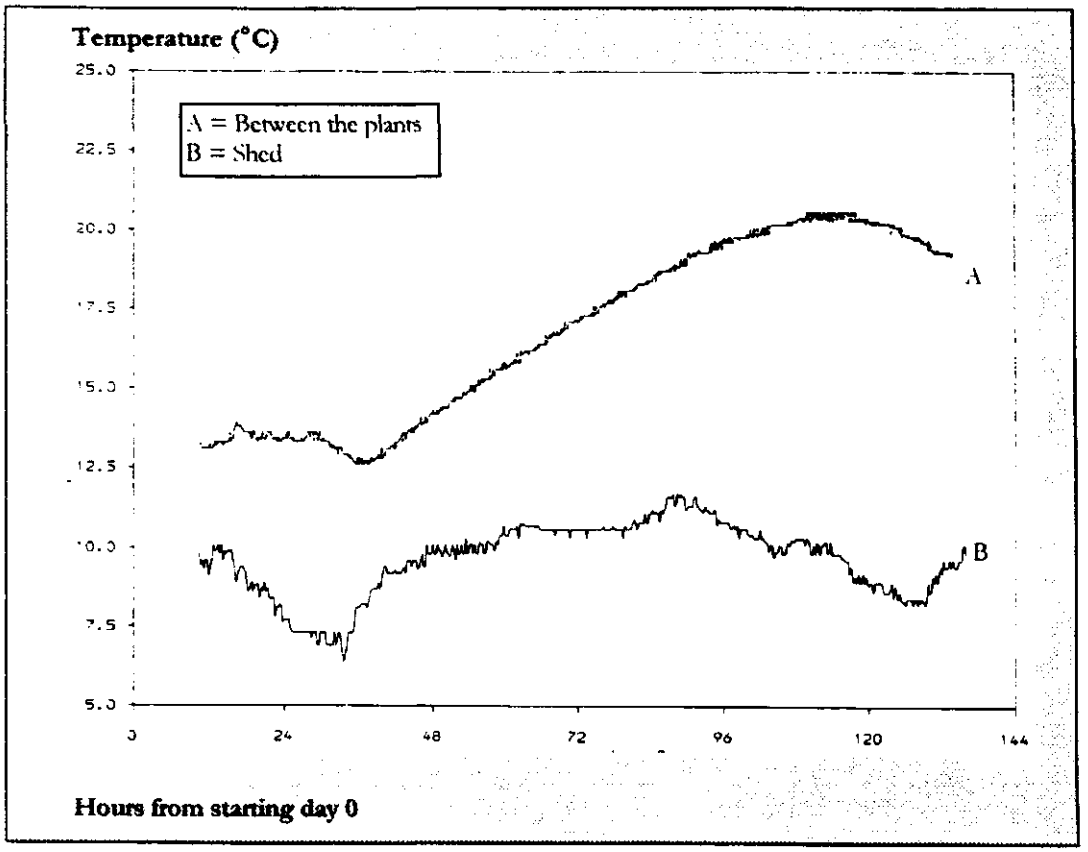
*Figure 3: Average temperature, relative air humidity and vapour pressure deficit in 34 sheds during the months January through May 1993.*

| Month | Temperature °C | r.h. % | Vapour pressure deficit N/m2 |
|---|---|---|---|
| January | 6.4 | 90 | 96 |
| February | 4.5 | 90 | 80 |
| March | 6.9 | 80 | 194 |
| April | 14.7 | 75 | 425 |
| May | 16.5 | 76 | 447 |

### 2.3.2 Plant temperature

*Figure 4:The air temperature in a shed and the temperature in a pile of un-graded rose rootstock of +/- 1m high. The measurements were made during January*

The temperature between the plants was measured in the sheds just as in cold storage. In a pile of rose rootstock about one metre high, a plant temperature o around 20°C was found, although the shed temperature only reached a maximum of 12°C (Figure 4). This sort of incident presumably causes more damage to the plants than would be indicated by the measured air temperature. The temperature can rise to undesirable levels when the heat generated by plants in stacks is not removed. In extreme cases it becomes dangerously hot and in a short time the whole batch of plants is lost.




The heating is aggravated by the presence of old leaves. Their decomposition releases a lot of heat. By lifting plants after the leaves have fallen and by removing any residual leaves heating can be prevented. If the temperature between the plants begins to rise, loosen up the plants and stack them in lower piles. Controlling plant temperature is essential.

### 2.3.3 Improving the shed climate.

There are many different types of sheds. Sheds with a uncovered floor have a higher relative humidity than sheds with a concrete floor. The climate in the sheds can be improved simply by having the doors kept closed as often as possible.

Other possibilities that improve the climate in the sheds are insulation, closing out the sunlight, removal of warm air out of the roof, active suction of cold humid air whenever the outside is colder that the shed, and the installation of humidifiers. The target temperature for the temporary storage of plants in sheds is around 5°C.

It is preferable not to heat the shed and to use a separate place to pack and grade the plants.

### 2.3.4 Climatic conditions in the grading room.

The grading room is too warm and dry for the plants because of the desired conditions for the personnel.

Measurements taken showed that the average vapour pressure deficit in the grading rooms was 350 $N/m^2$. This is roughly four times greater than the vapour pressure deficit in January and February in the sheds. The plants therefore dry out four times as fast.

The higher temperatures increase the activity of the plant and speed up shooting. The best way of limiting the damage caused to the plants is to keep the processing time as short as possible. It is better not to bring a bigger quantity into the grading shed than can be worked within a day. The graded plants should be returned directly back into storage.

Protect the plants against drying out by covering them. Hot air cannons in the grading room cause temperature swings and differences in r.h. are greater (Figure 5). On top of this is the large amount of air movement caused by the fans. One or the other can lead to very fast drying out of the plants. The use of hot air cannons is not recommended where bare rooted plants are being handled. Another reason for avoiding them is the chance that carbon monoxide and ethylene can be formed by improper adjustment of the burner.

Air humidifiers can improve the relative humidity in the grading shed.

*Figure 5: Average temperature and minimum and maximum values of temperature and r.h. in a hot air cannon warmed grading room.*

| Temperature | | | Relative humidity | | |
|---|---|---|---|---|---|
| Average | Minimum | Maximum | Average | Minimum | Maximum |
| 16°C | 9°C | 19°C | 80% | 56% | 97% |

### 2.3.5 Ethylene

Many vegetable and flowering plants are sensitive to ethylene concentrations higher than 0.3 - 0.5 microgram per litre of air.

Too high a temperature combined with light shortage and excessive ethylene concentrations are probably the most important causes of leaf yellowing, leaf-fall and flower abortion by crops that are handled during the growing or flowering phases.

The plant itself produces ethylene, but exhaust gasses and ripening fruits are also ethylene sources. Under adverse conditions the rate of ethylene production increases. Without good ventilation ethylene can accumulate.

The sensitivity to ethylene differs between species and even between cultivars, and will depend on other influences such as the temperature, the level of the concentration, the exposure time and the growth stage of the plant.

Until now it was not known whether short duration exposure to a high ethylene

concentration in the dormant stage had an influence on the storage and transplanting of tree crops. In order to investigate this, bundles of plants from four crops were exposed for a 24 hour period to ethylene concentrations of 0, 0.1, 1.0, and 5.0 ppm.

The crops were *Malus communis, Robinia pseudoacacia, Quercus robur* and *Rosa canina* 'Inermis'. The experiment was repeated twice, namely in December and in March. This was to determine if there is a difference between plants that are fully dormant and those which have already had their cold requirement.

The exposure to ethylene did not cause any perceptible effect on the taking percentage or on the growing out of the shoots. The conclusion is, that in contrast with crops in the growing or flowering phases, crops in dormancy have little sensitivity to short exposure to high ethylene concentrations.

Ethylene damage is easy to prevent through preventative measures. Avoid storage of plants in combination with fruit. First spray out and clean storage rooms where fruit has been stored. Use electric fork-lift trucks in preference. Burners should have a exhaust pipe to the outside. Ensure that there is always good ventilation.

# 2.4 Packaging

### 2.4.1 Drying out

From both the literature and the survey it was clear that the greatest problem in the selling phase of bare-root crops is the danger of drying out. Unless it is hot, drying out happens quicker than the exhaustion of energy reserves. In the chain there are many occasions when the chance of drying out is greatest; after the lifting in the field, during unprotected transport, in the sheds, in the grading room and at the planting site.

For the plants there may be a full working day lying outside uncovered after lifting. They normally remain for between four and eight hours in the grading room. In the marketing phase drying out can certainly add up by the successive trading and transport delays.

The moisture shortage can be replenished if the roots come into contact with water or are replanted. When the circumstances are adverse, then the plant will recover very slowly or dry out still further.

It is important that by every action one strives to limit drying out to a minimum. For this reason, handling times should be kept as short as possible. This calls for good work planning and organisation. Strive never to allow bare-rooted plants to lie outside unprotected. Carry off the plants directly after lifting, or at least protect them, and when loading or unloading plants never let them lie on the ground outside.

### 2.4.2 Damage limit

Until a certain level, drying out is a reversible process. Dry a plant still further and there will be effects on rooting and re-growth.

In an experiment with *Quercus robur, Rosa* 'Diamond Jubilee', and *Rosa canina* the critical drying out limit above which failures occur was determined. When plants were stored unpacked for up to 8 weeks, in the cold store, a weight loss of a maximum 20% was reached. In this case there were no failures. The critical level had not yet been reached. With both the rose cultivars no connection was established with the shoot viability. With oak a rise in weight loss (and with that a decline in the water content of the plant) led to the later opening of the buds (Figure 6). The water content of the shoots had a greater influence on the time between planting out and the emergence of the shoots than the water content of the roots.

In this test there was little influence due to drying out on the growth established. This is probably due to the cold and wet spring of 1994, whereby the plants were able to recover. In practice the circumstances after planting out are not usually so favourable. It cannot be concluded that the drying out is not important on the grounds of this test .

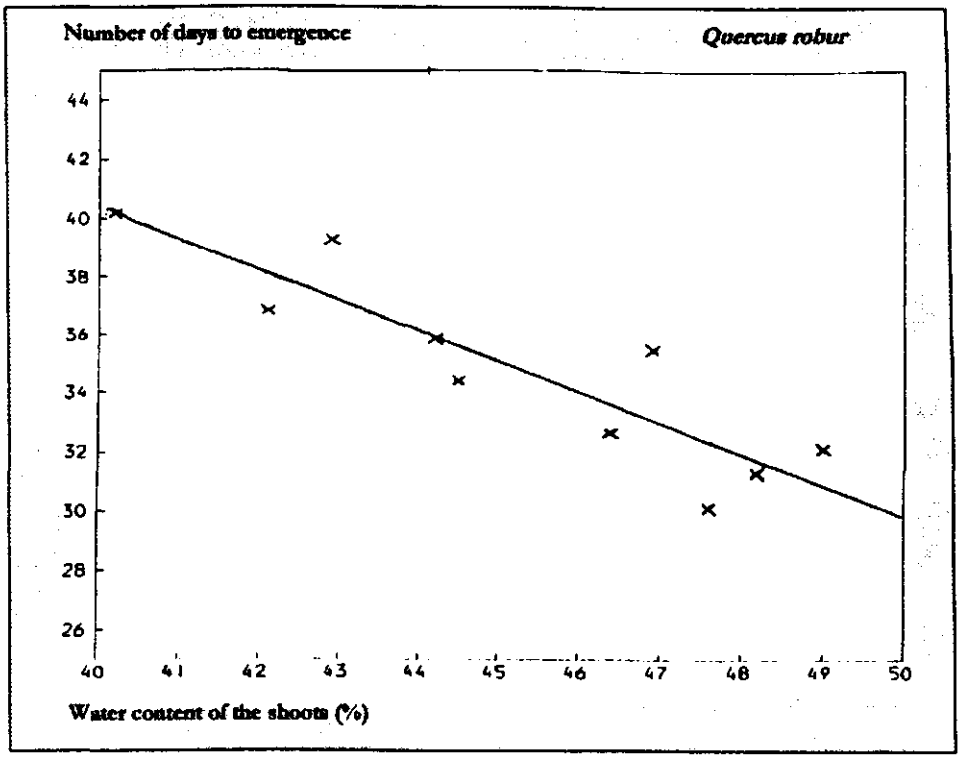



*Figure 6: The time between the planting out and the emergence of the shoots of* Quercus robur *in relation to the water content of the shoots. The lower the water content the later the shoot emergence.*

### 2.4.3 Protection against drying out

The protection of plants against drying out can be achieved in a number of ways; keeping the exposure time short, adjusting the climate in the place were the plants are kept, and the adjustment of the climate around the plant.

These methods can be applied at the same time. The adjustment of the climate around the plant principally comes down to the packaging of the whole of the plants or of the roots only, and covering the plants with covering material and the like. So long as the plants have not yet been graded and more or less handled in bulk, then covering materials are used. The plants are not always packed in the lifted phase for long. Plants are usually packed when they have already been sorted and graded. Standard plants are often prepared and then stacked on veenman pallets and then wrapped in polythene film. Other plant types, for example roses, shrubs and hedgerow plants are not packed before their delivery.

The functional requirements for the packaging and covering materials are as follows.

- Impermeability to water is important to prevent humidity loss from the plants.
- Water resistance is necessary so that the material maintains its strength when wet.
- The material should be impenetrable to light or else the temperature would rise as a result of the radiation. For storage in the dark, for example in the cold store, this is not necessary, but is whenever the plants are being worked upon and are temporarily placed outside.

- Oxygen and carbon dioxide permeability is desired, so that active crops do not suffocate.
- The material should be strong, so that during the processing there is no tearing or damage.

### 2.4.4 The use of bags during cold storage

Even with the high relative humidity in the cold store, it is also meaningful to protect the plants against drying out while they are in cold storage. Packaging is a method of limiting moisture loss.

An experiment was carried out on rose rootstocks using white polythene bags and five layer coated paper bags. The weight loss after 11 weeks storage at -2, +1, or +4°C was only 5%. Un-packaged plants were fully dried out after 7 weeks, in spite of an air humidity of at least 90% . The weight loss of the un-packaged plants was then +/- 35%.

Woven polypropylene bags limited the weight loss only slightly better than the un-packaged ones. The weight loss of the plants in woven polypropylene bags after 11 weeks was 22%.

This was detrimental to establishment and regrowth. One advantage of these polypropylene bags was that there was no formation of condensation or fungal growth present due to the open structure.

*In the chain but unprotected on pallets.*

### 2.4.5 Drying out in box pallets

Plants that are stacked into box pallets or tree pallets and transported, are usually arranged with the roots towards the outside. The branches lie truly protected, but the roots are exposed to drying out.

In two experiments, one in a cold store and one in a shed, it was investigated whether wrapping the pallets in pallet sleeves or stretch film and with the roots stacked to the inside was an improvement over the standard stacking method. The influence of the different treatments on fungal growth, plant temperature, and drying out during the storage period were all recorded, and establishment and regrowth observed.

The first experiment was carried out using *Quercus robur*. During January the plants were stored in an insulated shed. In a repeat experiment in March the plants were stored for two weeks.

The second experiment involved the storage of *Rosa canina* 'Inermis' in a cold store.

*Figure 7: The weight loss in percentage from the fresh weight of rose rootstock* Rosa canina *'Inermis' and the moisture percentage of roots and stems of two year old* Quercus robur *during storage in box pallets.*

| | *Rosa canina* 'Inermis' | *Quercus robur* | | | |
|---|---|---|---|---|---|
| | | January | | March | |
| | Weight loss | Moisture content | | Moisture content | |
| | | root | stem | root | stem |
| Fresh material | | 57.2 | 49.3 | 51.5 | 47.0 |
| Standard pack | 10.4 | 52.5 | 46.8 | 49.9 | 45.2 |
| Roots inside | 9.3 | 53.7 | 47.4 | 49.9 | 45.9 |
| Stretch film | 7.2 | 53.7 | 47.7 | 50.8 | 45.8 |
| Pallet sleeve | 6.2 | 52.3 | 47.5 | 49.7 | 45.7 |

*Figure 8: The average temperature in box pallets with two year old* Quercus robur *and rose rootstock (*Rosa canina *'Inermis').*

The results of both experiments were in the main consistent, however with 'Inermis' the differences in drying out and regrowth were not significant

Wrapping the pallet reduced the drying out, but increased damage through fungal attack. This was especially the case where pallet sleeves were used. Stacking the roots to the inside reduced the moisture loss, but less so than by wrapping the pallets (Figure 7).

| | Average temperature °C | | |
|---|---|---|---|
| | *Rosa canina* 'Inermis' | *Quercus robur* | |
| | | January | March |
| Fresh material | 0.7 | 6.1 | 8.5 |
| Standard pack | 0.9 | 6.7 | 8.4 |
| Roots inside | 1.2 | 6.8 | 9.8 |
| Stretch film | 1.7 | 6.4 | 8.9 |
| Pallet sleeve | 2.3 | 7.4 | 9.1 |

The differences in drying out between the treatments did not lead to differences in the establishment percentages.

Wrapping the pallet boxes and stacking with the roots to the inside had an influence on the temperature between the plants (Figure 8). The temperature between the plants followed the room temperature linearly. There was no problem with overheating. The higher temperature explained the visibly more advanced stage of the buds of 'Inermis' and the faster emergence of the buds of the oak as well as *Rosa canina* 'Inermis'.

### 2.4.6 Packaging of plants for delivery

*Figure 9 : Maximum temperature and minimum relative humidity in bags of various materials and the light transmissiveness of the materials. The bags were laid outside on the ground.*

In an experiment on the suitability of bags for the delivery of plants, the temperature paths were compared in bags manufactured from several materials which are often used commercially. The bags were laid outside on the ground. The temperature rose most in bags of material which let through the most light (Figure 9).

In a follow-up test, a few newly developed paper bags and a new polythene bag with a white outside and black inside were compared with the normally available all white or black polythene bags. The paper bags were coated with a water resistant coating made from a starch base. The coating forms no obstacle to the recycling of the paper. Bags with rose rootstock and whips were placed outside on the ground for a period of six days during April.

| Material | Maximum temperature °C | Minimum relative humidity % | Light transmission % |
|---|---|---|---|
| **Polyethylene** | | | |
| White PE | 32 | 16 | 58 |
| Green PE | 26 | 30 | 18 |
| Black PE* | 18 | 32 | 0 |
| Black/white PE | 15 | 54 | 0 |
| **Paper** | | | |
| Svenco papier | 23 | 37 | 1 |
| Weuerhaeuser | 19 | 31 | 0 |
| Monocoat paper | 16 | 45 | 0 |

*High density polyethylene

The temperature of the milky-white bags fluctuated greatly. During the day the temperature rose strongly under the influence of the sun's radiation, and during the night the temperature fell through radiation to below the outside temperature. In the black/white bags the temperature measured at night was lower than the outside temperature.

The establishment percentage of rose rootstocks packed in white polythene bags was lower than rootstocks that had laid outside unpacked. This was due to the high temperatures. The establishment and growing out of the plants packed in the paper bags was less than desirable in both crops. Furthermore, these bags

were insufficiently resistant to rain. The establishment and growing out was the best in those plants which were protected by the black or black and white polythene bags. These bags were found to be the most suitable for delivery.

### 2.4.7 Root dips

As an alternative to packaging to protect bare-root plants from drying out, it is possible to use a water absorbent polymer around the roots. These polymers can absorb up to 400 times their own weight in water. In dry form they are a fine granule; after the addition of water the polymer becomes a jelly-like porridge. A layer of root-dip around the roots protects them not only against drying out, but also provides a water reserve.

In an experiment using cold storage of rose rootstock *Rosa canina* 'Inermis' there was better establishment and out-growth of those plants with a root-dip compared to untreated plants. The rootstocks in this experiment were stored in a cold store during the period November/December for four weeks with and without root-dip. There was no benefit of using a freezing store.

In a second experiment five types of bush and hedging plants were stored with and without root-dip for a three week period in March. The types were; *Quercus robur, Fagus sylvatica, Betula pubescens, Crataegus monogyna*, and *Rosa canina* 'Inermis'. The average temperature in the shed was 7.5°C with a maximum of 15°C. The average relative air humidity was 78%.

The root-dip had a favourable effect on the moisture content of the plants at the end of the storage period. The root-dip on the rose rootstock was completely exhausted by the plants within three weeks. With the exception of the rose rootstock all the untreated plants died (figure 10).

A considerable proportion of the treated plants survived. However, there was also a quality reduction occurring in the form of dead tops, especially with *Crataegus*. Root-dip limits the occurrence of drying out, but the roots on the outside of the bundle did still dry out.

The use of root-dips has a number of practical obstacles for which answers must be found.

- The application of root-dips is laborious.
- It is still not clear whether the dipping of root bundles into a premixed container of dip is better than dusting the roots with powder and then spraying them with water afterwards.
- Slopping of the root-dip makes the work floor slippery.

| Crop | With root dip | Without root dip |
|---|---|---|
| *Betula pubescens* | 61.6 | 0.0 |
| *Crataegeus monogyna* | 50.0 | 0.0 |
| *Fagus sylvatica* | 75.0 | 0.0 |
| *Rosa canina* 'Inermis' | 80.0 | 43.0* |
| *Quercus robur* | 81.6 | 0.0 |

* Principally ground shoots.

*Figure 10: Establishment percentages of plants treated and untreated with root-dip, that have lain for three weeks in an unheated shed.*

# 2.5 Transport

### 2.5.1 Unprotected transport

Transport from the field to the shed or packing house often occurs unprotected commercially. The most important reason to protect the crop is to limit the influence of the wind which causes drying out. To illustrate this the travelling speed and the equivalent wind force is given in Figure 11.

*Figure 11: The travelling speed of the vehicle and the corresponding wind force.*

| Description | Travelling speed km/hr | Wind speed m/sec | Wind force (Beaufort scale) |
|---|---|---|---|
| Weak wind | 10 | 2.8 | 2 |
| Moderate wind, paper blows up | 20 | 5.0 | 4 |
| Strong wind, branches sway | 30 | 8.3 | 5 |
| Strong to hard, trees sway | 50 | 13.6 | 6 - 7 |
| Stormy, twigs break | 70 | 19.4 | 8 |
| Storm, tiles blown off | 80 | 22.2 | 9 |
| Strong storm, considerable damage | 100 | 27.8 | 10 |
| Very strong storm | 110 | 30.6 | 11 |
| Hurricane | 120 | 33.3 | 12 |

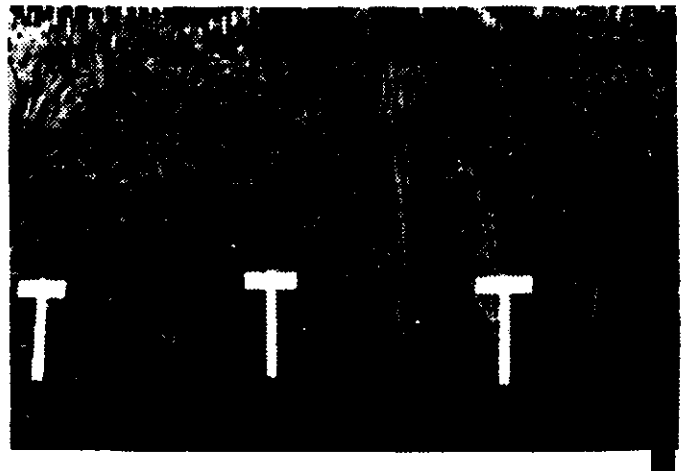
Short distances, low travelling speed, and wet or cloudy weather are all reasons why the grower omits the use of a cover. The heaviness of the cover makes the covering time consuming. There is a need for a lightweight cover that is also strong.

The cover must prevent the temperature rising under it due to the sun's radiation. Except for these extra considerations, the choice of covering material has the same requirements as that of the packaging materials.

### 2.5.2 Types of freight trucks

Most tree nursery crops are transported by road. There are three main types of truck used. Tilt trucks or trucks with a cover, closed trucks equipped with insulation, and fridge trucks.

To compare the advantages of each type of truck, temperature and relative humidity were measured over a few days in stationary vehicles parked in an empty loading room.



*Left* Forsythia *in April 1992 protected transport, 5 days allowed to lay and then planted: 16% dead plants.*

*Middle* Forsythia *and* Philadelphus *in April 1992 unprotected transport, 5 days allowed to lay and then planted:* Forsythia *100% dead plants and* Philadelphus *72% dead plants.*

*Right* Philadelphus *in April 1992 protected transport, 5 days allowed to lay and then planted: 10% dead plants.*

The temperature of the tilt trucks was found to follow the influence of the outside temperature and rose quickly as a result of the sun's radiation and fluctuated strongly. Silver coloured reflecting cover material did not reduce the influence of sunshine on the temperature. In the insulated trucks the temperature followed that of the outside. Sunshine had only a small temperature increasing effect on the temperature of the loading room. In the fridge truck the temperature remained around 6-7°C.

The desired temperature of 3°C was not reached thanks to an outside temperature of 8-15°C.

The cooling capacity of freight trucks is often insufficient to lower the temperature of the load. It is well known from measurements from transport to Italy, Poland, England, and Norway that the fridge trucks can hold the temperature of a pre-cooled product constant. In loaded tilt trucks the temperature between the plants swings very little. The influence of the temperature at loading is great. The plant temperature remains a few degrees higher than the outside temperature in the average transport vehicle. The relative air humidity is very high. For long distance transport this would mean that the crop would become active and that the climate would be ideal for fungal attack.

Insulated trucks limit the influence of the outside circumstances, but the heat from the loading room is maintained. Thus a low plant temperature at the time of loading, and the ability to ventilate are very important.

*Left* Forsythia *in April 1992 protected transport, allowed to lay for 5 days and planted: 16% dead plants.*

*Right* Forsythia *in April 1992 unprotected transport, allowed to lay for 5 days and planted: 100% dead plants.*

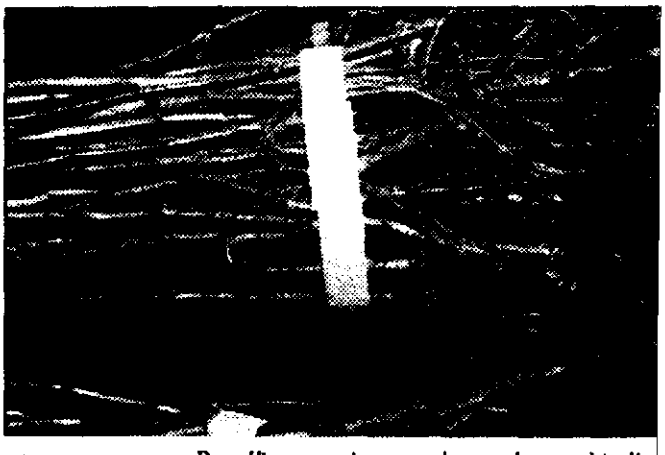
### 2.5.3 Loading and unloading

Plants that are not transported on pallets, such as avenue trees, have more chance of being damaged by loading and unloading. With plants what can happen often does. When loading there are often provisions present in order to carefully load the plants onto the vehicle. At the unloading place these may be absent, and damage can then occur to the branches and roots.

### 2.5.4 Binding materials

In practice it was established that wounding to the bark was being caused by the improper use of binding materials. This damage can be prevented by not over-tightening the band and not loading the bundles by lifting by the ties.

Part of the blame for the damage is due to selecting the wrong material. The compromise use of a binding material to secure the bundles and tie up the crowns proved that polypropylene string is the best. It is soft,



*Bundling using polypropylene binding material caused the least damage.*

elastic, lasting against moisture and reasonably priced. Sisal string is good whenever the crop is heeled in. An advantage of this material is that the string normally used is 3-3.5mm thick and is untwined. Wound string becomes thinner as tension is placed on it, and as a result causes deeper wounds in the bark.

Strings made from natural fibres are not recommended for bundling plants that will be clamped, as the material will rot. A disadvantage of plastic materials is the residue left. This residue can cause damage to ground working machines.

The development of a general purpose string type based on natural fibres with a known degrading time is needed.

Metal wire is the most suitable for bundling of rose rootstocks. The wounding that occurs through snaring is positioned above the grafting place. Of the binding bands tested, polythene bands and an elastic cord which were both broader than 3mm proved to be the most suitable.

### 2.5.5 Pot and container plants

Pot and container plants are, in contrast to bare root crops, marketed during their growing or flowering phase. There was only sparse information found in the literature about circumstances during the sale of these plant groups.

In order to get an insight into the optimum circumstances for pot and container plants a comparison can be made to those required for house plants. Leaf yellowing, leaf fall, flower fading and petal fall are the most important image spoilers. Attack by botrytis can also be a problem.

The deterioration is principally due to too high a temperature in combination with storage in the dark, exposure to ethylene, and drying-out. It is often a matter of a combination of factors.

Lowering of the temperature is the most important measure to prevent damage. Lowering the temperature reduces the plant's ethylene production and sensitivity, it slows the respiration rate and therefore the use of assimilates and slows the growth and flowering. Also the growth of fungi will be retarded. Reducing the formation of condensation by holding the temperature constant is likewise important to prevent fungal attack.

The marketing chain for floriculture crops is for the greater part conditioned. The optimal temperature is crop dependant, but for nursery stock during the growing season it would probably be in the region of 12°C. In the spring and autumn this temperature will lie lower. The sensitivity of plants to low and high temperatures depends primarily on the growth stage of the plants.

Mechanical damage can be limited by supplying the plants upright, by limiting the number of times that they are handled, and by not over packing them. The supply of pot and container plants in open trucks is not uncommon, but in view of the danger of wind damage it is undesirable.

# 2.6 Internal quality

### 2.6.1 Dormancy

Bare-root crops want to be lifted when they are in dormant. Their sensitivity to adverse conditions, such as dryness and cold, is then at its lowest. Plants that are lifted when they are not dormant are less winter hardened. If they are replanted before the winter has ended, then there is a greater risk of frost damage. Because early lifted plants are also less good to store, this risk cannot be circumvented by cold storage for the whole winter duration. The determination of the lifting date is therefore of paramount importance. The tendency to lift crops ever earlier is contrary to the quality demands that will be placed on the plants.

There is no sure method to determine whether a plant is fully dormant. Criteria which are currently used are, among others; date of leaf-fall, the presence of white roots, and the formation of a dormancy bud. Especially in the change over period between the growing and the rest phase, it is desirable to have at your disposal a good measurable criteria in order to fix the lifting date.

### 2.6.2 Vitality

Just as for the determinination of the resting state, clear criteria are required in order to determine the vitality of plants. Damage caused in the course of the selling phase is often not visible. A vitality assay should be formulated for this. Measuring the contents of metabolic products or hormones, varies not only with the vitality of the plant, but also with the resting state. Research by the ATO-DLO into the development of an assay for vitality showed that a reliable parameter is difficult to find. Measurements of the potential root growth and the water potential also have this limitation.

In Great Britain a method was developed to measure the level of cell damage and this gives the opportunity to make a vitality assay. With this method, root samples are placed into clean water. If cell walls are damaged then the cell contents will spill out. This increases the electric conductivity (EC) of the water. By measuring the EC of the sample the extent of cell damage can be determined. This method was designated by the term electrolytic leakage.

In this project the electrolytic leakage from roots was measured in a number of samples.

With *Quercus robur* there proved to be a significant linear relationship between the electrolytic leakage from the root samples and the water content of the plant. With the rising of the electrolytic leakage and the falling of the moisture content, the plants do take longer to grow out. With *Rosa canina* 'Inermis' and *Rosa* 'Diamond Jubilee' there was likewise a significant correlation between the moisture content in the plant and electrolytic leakage. A connection with establishment and growing out could not be proved, however.

*Quercus robur* lifted in October and stored at -2°C, had a higher electrolytic leakage than oaks that were lifted in December. The oaks lifted in October showed 85% failure, those lifted in December all survived. So, in this study, a connection existed between vitality and electrolytic leakage.

In Great Britain measurement of the electrolytic leakage from the fine roots of three conifer types has already been used to determine their vitality. The method is able to give results from the laboratory within 48 hours. How far the electrolytic leakage is dependant on the growing or rest state of the plant is still not known.

# 2.7 Mechanical lifting, washing and defoliation

At the same time as the investigation on the storage, packaging and transport of tree nursery produce, in the research programme of the Boomteeltpraktijkonderzoek (tree crops practical research) three other investigations were undertaken:

- the damage caused by the mechanical lifting of trees
- the influence of defoliation on crop quality
- preventing damage due to washing out root systems.

These topics will be separately reported at a later date. Because they are a part of the total chain investigation a few provisional results will be presented here.

### 2.7.1 Limiting the caused damage by mechanical lifting

A number of machines used commercially for lifting trees mechanically were assessed for the damage caused during the lifting process to a number of crop groups; shrubs and hedging plants, fruit trees, and standard trees. Damage was also assessed for the time spent in the shed. At the same time, practical experiences were recorded.

There was no damage to the establishment of plant material. The conclusion is that even by using a mechanical aid and lifting machines, plants can be lifted without damage. If damage is occasionally present, it must be the result of carelessness during lifting.

### 2.7.2 Prevention of damage when washing the roots

In different experiments the occurrence of quality loss due to washing or following washing was assessed.

Using two problem crops (*Dicentra spectabilis* and *Hydrangea petiolaris*) and two non-problem crops (*Astilbe japonica* and *Caragana arborescens*), samples were provided with different substrates. This was to facilitate the washing off, so that less damage would be caused to the root system.

At the same time the same crops were washed with a water pressure of 2, 4, and 8 bar (28, 56, and 112 p.s.i.). With these treatments the establishment of the crops was good, and no negative influence of washing was determined.

In 1994 6 shrubs and 6 potted plants (which were identified commercially as problem crops) were investigated. From these there were some failures with *Kerria* and *Potentilla* and with the potted plants *Delphinium* and *Aconitum*. The preliminary impression is that the cause of the failure by these crops was caused by a combination of washing and the applied transport and cross border customs simulations. Growing differences are still to be assessed.

The preliminary conclusion is that failure after washing only occurs in a limited number of crop types, and that these failures were amplified through other

factors in the supply chain. A washed crop requires extra care in the supply chain as it is more vulnerable. Establishment problems with washed crops in the final destination countries are most likely to be the result of careless handling in the chain.

### 2.7.3 Is early lifting possible without quality loss?

For the crop groups fruit trees, bush and hedging plants, and ornamental shrubs, experiments were carried out to find a suitable defoliation method whereby early lifting could be performed without a loss in quality.

Defoliation can be performed chemically, mechanically, or by hand. Mechanical defoliation using a lashing type machine resulted in damage to the bark and buds with *Malus* types and a low establishment in the following spring. Hand stripping leaves is too labour intensive. Chemical defoliation appeared to offer the most prospects, only with fruit trees is there some uncertainty. The samples showed that there are possibilities for an experimental material for chemical defoliation in the tree nursery.

Different concentrations of the material were applied at different times, alone and in combination with under cutting. For most crop types a concentration of 8% gave a quicker leaf-fall than 4%. The lifting time for most types could be between one and three weeks earlier.

With this limited advancement in the lifting time there was no quality loss in the spring establishment.

This research is still under way, and the spray application will be applied earlier and more often with crops with a naturally late leaf-fall (from December) to see if they can be lifted earlier (first half of October).

The question is how the plant quality will respond to these strong advancements in the time of lifting.

## 2.8 Research into vitality during storage, transport and after planting out

From January 1992 to May 1994 the ATO-DLO performed an investigation into the vitality of tree nursery crops during storage, transport, and after planting out. In order to create differences in vitality of the trees used, the trees were lifted one month before leaf-fall. There are physiological and biochemical definitions to describe the differences in vitality.

In the 1992/1993 season the re-growth of the trees which had undergone a handling stress was very much lower than those of the control plants. In 1993/1994 the treated plants did not differ from the control plants even though the growth and treatments were the same as the first season. A reduced vitality was not achieved in 1994, even with a second stress treatment in addition to the early lifting. This shows that vitality is very difficult to check and to manipulate.

As a basis for a vitality assay, it was attempted to ascertain if there was a connection between the re-growth (vitality) of the trees and the bud weight, the starch content of the fine roots, and the so called NMR-Imaging uptake of the buds (vitality parameters) and a few plant hormones.

While in 1992/1993 clear differences between the treatments were found, with respect to the relationship between bud weight and starch content of the fine roots, these proved not to be clearly the case in 1993/1994. The probable reason, shown by the results of the re-growth, was that there appeared to be no stress associated with the early lifting in the second season.

A connection between the re-growth and the results of the vitality parameters were observed, but the grounds on which the connection is based cannot be determined without further research. This was caused by the natural variability within the trees used. It may be possible to minimise this biological variation through strictly controlled circumstances (stress induced in a climate controlled room) and defined material (for example *in vitro* propagated or by using plug material).

In the season 1993/1994 there was also an investigation carried out to improve the establishment of trees which had undergone stress. Treatment of the root system with the hormone IBA (auxin) proved the most effective: the establishment increased from less than 20% to more than 60%. Clearly it has been shown that the establishment can be greatly improved by using specific hormones. Further investigation into this appears promising and necessary.

Unfortunately, through the advice of the commission that accompanied this project, the steering group of the project "Quality control in the chain" have come to the conclusion that the investigation will not be continued. The steering group came to that conclusion because in the second phase of the investigation there was no prospect of developing a practical assay method.

# 3. DEMONSTRATIONS

## 3.1 Introduction

Demonstrations were held on all the tree crop research stations in Holland, where plants were treated in a good and a bad manner. The purpose of this was to show the difference in the results of handling methods.

It must be remarked that holding demonstrations is not research. The results of demonstrations are not consistent. They do show clearly that if plants are not treated in a good manner then the risk of a reduction in quality increases. These risks can somewhat, but definitely not 100%, be compensated for through extra careful handling of the plants during delivery. The most striking results from the demonstrations are given per research station below.

## 3.2 Time of lifting

The time of lifting has the strongest influence on the storage and establishment of bare-root plants. In a demonstration in Boskoop, Zundert and Noordbroek with *Philadelphus, Pinus, Quercus,* and rose root-stock this was clearly shown.

All the plants were planted out in the spring and in the autumn a check was made on the establishment and re-growth. This showed that when the plants were not in dormancy, the risk of too early or too late lifting increased, and then the quality was seriously affected. To somewhat reduce this risk the delivery must be as careful as possible; the risk of a quality loss remains ever present.

*Unprotected transport on a truck.*

If the plants are lifted on time but remain unprotected for a long time, then the risk of dead plants is still high.

## 3.3 Protected and un-protected transport

Demonstrations with *Forsythia, Philadelphus, Catalpa, Quercus* and *Pinus* in Boskoop, Lienden and Zundert highlighted that unprotected transport was disastrous, especially with plants which are not dormant.

Of *Forsythia* that was transported unprotected in April 100% died. Also with *Pinus* the percentage dead was high whenever the plants were left to lie unprotected. Even over short distances at a low speed unprotected transport caused a quality reduction. Unprotected transport at high speed during dark, rainy weather caused the same drying out and damage as occurs after high wind speeds.

## 3.4 Protected and unprotected transport of visually attractive plants grown under glass.

A demonstration was carried out with protected and unprotected transport of visually attractive plants grown in pots under glass, over a distance of 25km in July, with variable low and high speeds. After transport, the plants were put back in the glasshouse and regularly checked for three weeks after the treatment.

Damage to the leaves ran as high as 30 percent. There was a great difference in sensitivity between the crops. *Picea* was not sensitive, while *Photinia* was badly damaged.

## 3.5 Plants allowed to lie protected and unprotected

Comparison of plants allowed to lie protected and unprotected brought clear differences to light. The plants were lifted in October or pulled up in April and following this treated or cooled. Again, there were great differences between the different plants. *Spiraea* tested in Boskoop and allowed to lie unprotected for 6 days in the spring, gave a failure rate of 100%. With *Acer* that was tested in Lienden the failure rate was less, and the growth was poor to reasonable. In Zundert there were also some cases of high failure rates after unprotected laying out. A clear conclusion is that allowing plants to lie unprotected is always detrimental to the quality and will affect their establishment and re-growth.

*Left The dead row on the left was raised in April 1992, left unprotected for 6 days laying outside and planted: 76% dead plants.*

*Right The row to the right of the dead row was raised in April 1992, left for 6 days protected laying outside and planted: 2% dead plants.*

## 3.6 Plants protected by sheets or packaged in plastic bags

Demonstrations in Boskoop with *Ligustrum*, in Zundert with *Pinus* and *Quercus* and in Noordbroek with *Rosa* and *Fagus* have shown that protection under sheeting or in plastic bags helped to maintain the quality.

Plants were lifted in December and treated or cooled. All the treatments were planted in the spring. With plants which were let to lie unprotected the failure rate rose; with *Ligustrum* to 100%. The damage was the greatest in the spring with plants which were not covered and which were not dormant.

## 3.7 Storage of perennial plants in cold stores

The storage of perennial plants in a cold store where the plants were packed in veenman pallets, gave a high failure rate in some cases. The demonstrations were carried out in Boskoop, and no fungicides were used.

It seemed that the high failure rate was due to the early period of lifting. The sampled *Campanula* and *Iris* were lifted in September. Through the combination of early lifting and cooling below zero the percentage of dead plants with *Iris* and *Campanula* was 88% to 100%. By cooling at 1°C the failure rate was less.

# 4. ADVICE ABOUT HANDLING IN THE CHAIN

## 4.1 Introduction

What many do not realise is the long journey that the tree nursery product covers from the nursery to planting out by the end user. The journey is not only long in distance or in number of in between stages, but sometimes above all also in time. Diverse dangers come to light. Everybody that handles the product can cause a quality loss.

Below is a list of treatments which have an influence on the quality of the product along the way between the nursery and the end user.

| | | | | |
|---|---|---|---|---|
| **Nurseryman** | Fertilizer<br>Crop protection<br>Under cutting<br>Irrigation<br>Lifting | | | |
| **Trade and transhipment** | | Transport<br>Storage<br>Packaging | | |
| | | | Grading<br>Defoliation<br>Washing<br>Bundling | |
| **Receiver** | | | | Laying out<br>Planting hole treatment<br>Planting |

Every careful treatment from the moment of fertilizing up to and including the planting will have an effect on the quality of the delivered bare root crop. A satisfied receiver is evermore the best client. All the treatments that take place have their own influence on the later growth of the crop.

Many demonstrations and investigations have shown the importance of careful handling of the product in the whole of the supply chain.

Although outside the scope of the present investigations, other advice can be given for the preservation of quality in the whole of the supply chain.

## 4.2 Handling by the producer

### 4.2.1 Fertilizing with prudence

For good growth the correct application of food stuff for the plant is required. The saying "if it does not work it does not harm" does not hold here. Too much fertiliser can result in a forced plant. Also, fertilizing too late can lead to these problems. A lush, less hardened crop often has a poorly developed root system. Also the crop will be supplied before it is fully hardened. In short, the delivered product does not satisfy the quality requirements.

Therefore do not simply fertilize, but follow the advice of experts. The Landbouw Voorlichting (Agriculture advisory service) can help you devise a good fertilizer plan. Make use of it.

### 4.2.2 Health through crop protection

In the past, only control was mentioned. A timely observation of pests and disease plays an important role. Prevention is often better than cure. It is necessary to be able to identify a disease when it occurs. A crop must be supplied free of pest and diseases.

Good control requires a knowledge of the materials used. Therefore find out about the proper measures. Do not make use only of available materials, but also consider using other materials. Think about the good protection of your crop before the delivery of the product.

### 4.2.3 Preventing drying out

Drying out is one of the greatest dangers that can occur. Under cutting is a good method by which to obtain a good branched root system, but it must be followed up with irrigation if the weather demands it. Bare rooted crops are especially at risk to this.

The weather plays an important role in under cutting and lifting. When it is very dry weather, ensure sufficient irrigation is applied. The plants must be fully saturated with water at least 24 hours before lifting. A plant that is fully saturated with moisture during its handling will have less risk of drying out.

### 4.2.4 Early lifting, time will tell

In the tree nursery lifting will take place at different times. This can be due to circumstances or because of the wishes of the client. Nevertheless there are limits. Lifting trees and plants too early when they are still in leaf, raises the risk of poor establishment. Also late lifting of crops that are already active carries the danger of poor establishment.

With demonstrations it was shown that too early lifting in some cases leads to a failure rate of more than 80%. Therefore, do not take any unnecessary risks and keep the lifting time within the limits. The client is not served by the early delivery of a poorly growing crop.

### 4.2.5 Careful lifting

The lifting of tree nursery crops costs a lot of time. Too great a work load or other reasons can sometimes mean that too fast and careless lifting can occur. With lifting, a portion of the roots are shortened. When this is done correctly there is a good balance between the top of the crop and its root system.

In all cases carefulness is required. Only thus is damage to the roots kept to a minimum. Bear in mind that a good and healthy root system forms the basis for the start of the growth of the crop in its new position.

# 4.3 Handling during selling

*The minimum requirement during transport is covering with a sheet. It is better to transport in a closed vehicle.*

### 4.3.1 Transport in the correct way

On the way from the producer to the end user the tree nursery product undergoes a series of treatments. Movement is by far the most important treatment. Fortunately this generally is done carefully, so no loss of quality occurs.


Loading and unloading is another story. It is labour intensive and sometimes heavy work. The way in which the loading and unloading takes place can have an influence on the quality.

### 4.3.2 Transport, a vulnerable time

Between lifting of the crop and planting out again, there is often a long path of handling and transit. Even when the distance is not that great, damage can easily occur during transit. This is especially the case with unprotected transport of crops without a soil ball or pot. What care has been taken during growing can quickly be taken away through unprotected transport. Damage is prevented by using a closed or well covered truck during transport.

The damage caused by unprotected transport was clearly demonstrated on different research stations. In some cases there were very high failure rates. Unprotected transport is fatal, certainly when it occurs with plants that are not dormant. During several days transport plants can easily dry out or overheat. With evergreen plants the leaf green can reduce. With plants with flowers or berries these can fall off. Much of the damage depends on the condition of the crop and the conditions in the freight truck.

Question for example how humid, how warm, or how light it is in the freight truck.

### 4.3.3 Store without risk

Lifted plants en route from nursery to client are stored in different ways. Plants are to be found outside, in a shed or in a cold store. The outside plants can be clamped, or lie on the ground not covered with a sheet. When the latter happens, quality loss can easily occur.

In a cold store, conditions are far easier to control. In a shed or outside, the conditions are far harder to control and are therefore far from optimal. Plants there often have to suffer from drying out. Demonstrations have shown that plants that are put down outside for a short or long time often give a high failure rate. A few hours laying unprotected can produce damage. Whenever plants are not in rest leaving them laying unprotected will cost a lot of money. The longer the plants lie unprotected, the greater the risk.

### 4.3.4 Grading for quality by eye

Next to grading by length or diameter, grading for the health of the crop is most important. In this way the overall quality can be judged.

In the field two types of grading occur; before lifting, plants are marked, and after lifting, plants are graded by hand. With this it is important that the plants do not lie unprotected for too long as this can cause a great loss in quality. Certainly with bleak and dry weather the risk of drying out is very great.

When processing, the plants are stored for a short or long time in the shed. In the shed there also exists the danger of drying out. By long duration storage under certain circumstances fungal growth can easily develop. This is most likely when there are still leaves or leaf debris present. Also during the grading procedure it is important that the quality is not allowed to decline.

### 4.3.5 Defoliation without danger

Plants lifted soon after leaf-fall in the autumn are mostly not fully hardened off. Often there will still be plenty of leaves on the crop. Because of this, transpiration can still continue, therefore the risk of drying out is very high. By defoliation you can attempt to prevent drying out. What method causes the least quality loss? On the research station at Horst the most efficient method of defoliation was searched for, whether mechanical, by hand, or chemical.

### 4.3.6 Washing with perspective

When exporting to different countries the roots of the plants must be washed in such a way that no morsel of soil remains. This treatment often results in a considerable reduction in quality, certainly when the storage thereafter is not done carefully. On the tree crop research station at Boskoop investigations were carried out as to how to limit or prevent this quality loss.

### 4.3.7 Careful bundling and tying

Plants without a soil ball or pot, so called bare rooted crops, are mostly delivered in bundles. Larger standards and fruit trees are supplied individually. It is of the greatest importance that the bundling and the tying is carried out carefully. Broken branches often originate from tying that is too tight. This undesirable quality reduction can be prevented by careful working. The same holds for the bundling. Operating with a bundling machine also requires careful working.

It is important to work accurately when bundling, so that the root necks of all the plants in the bundle sit at the same height.

## 4.4 Actions by the client

### 4.4.1 Extra care in setting out

With many extensive plantings there will usually be large numbers of the same type planted out. It then goes without saying that these crops may be set out at their definitive location before they are actually planted. Planting will start at the beginning of the scheme. The last plant that is put in the ground may have lain unprotected on the ground for a long time.

Depending on the condition of the plants and the prevailing weather conditions, the plants can run a great risk of drying out. There are various ways to improve on this, depending on the weather conditions and the condition of the plants, for example by only laying out a limited number of plants.

### 4.4.2 Improving the planting site

The result of a new landscape is dependant on the quality of the plant material and the conditions at the new growing place. An optimum growing site is also of great importance for the establishment of a new landscape. If the soil structure is not good, then measures must be taken to improve the ground. If the soil structure is so poor that a soil improver will not help, then the whole planting hole must be excavated and replaced with good topsoil. When planting holes are made mechanically for larger plants, for example using a soil auger, care should be taken that the walls of the planting hole are not smeared water-tight. This risk is present above all with soil of poor structure. The smeared wall must be broken up again before planting.

In many instances the planting hole of a standard tree will be equipped with a drainage pipe in order to improve the air content capacity of the soil. When necessary, water can also be supplied by this method.

### 4.4.3 Fore- and after-care of the plants

The plants must be positioned in such a way that the roots hang properly downwards and are divided as much as possible over the whole of the planting hole. The ground around the roots should be firmly pressed so that good contact exists between the roots and the soil particles. In this way the plants can take up water better and they are well anchored.

With larger specimens such as standard trees it is necessary to position tree stakes next to the tree.

Also ensure that the plant receives the necessary attention after planting. Water application can play a large role here.

# 5. PUBLICATIONS, LECTURES, AND GENERAL INFORMATION ACTIVITIES

During the period of the project diverse activities took place in the sphere of information. The emphasis lay on showing the results of the research, and the demonstrations of the diverse treatments, to maintain the quality in the various links in the supply chain of tree nursery products. An overview of the most important publications, lectures, and general information activities is given below.

**Reports**

In the course of the project various reports appeared aimed at giving an insight into the intention of the project and its progress. A summary of the reports can be broadly seen as follows:

- Preliminary investigation.
- Brochure 1993
  - Interim report of investigations.
  - Results of the demonstrations.
  - Information actions, shortened form.
- Brochure with full information actions.
- Research reports
  - Part report 1: Survey
  - Part report 2: Literature study
  - Part report 3: Experimental results
- Summary report of the whole investigation
- Report from the ATO-DLO research into vitality
- End report containing:
  - Overview of the most important investigation results.
  - Results of the demonstrations.
  - Information actions, shortened form.
  - Overview of the various information activities.

**Poster**

To underline the importance of good treatment in the different selling phases, a poster was planned with poignant advice about the correct handling of bare rooted tree nursery products. It consisted of an attractive illustration combined with a piece of information. The poster was distributed to the following interested parties:

3,500 Tree nurseries/suppliers
550 Researchers
225 Garden centres
270 Auctions
700 Gardeners
300 Advisers
525 Councils


"If you ask me they see you as fire-wood"

Unprotected transport is the death-blow of many a tree and plant.

**Cartoons**

One of the most important actions was the design of six cartoons, these were regularly published in the trade press of the target groups. These cartoons were also used in other publications for the groups concerned.

Regular repetition of these pictures has helped emphasize the importance of good handling of vulnerable bare-rooted tree nursery products.

**Folder hand-out**

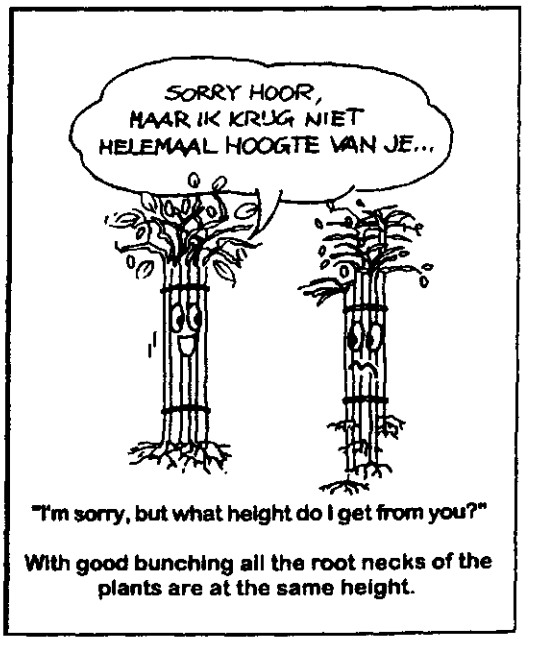
In this folder, which can be sent as a "reminder" to customers, is a short and concise entry on the most attractive actions in the chain. The folder was made with a run of 10,000 copies and is meant to support the earlier distributed poster.

**Slide series**

As enlightenment material a slide series was designed that was distributed inside the DLV and to advisers. The emphasis of this series lies on restoring the correct actions in the sale of bare-root tree nursery products.

**Lectures**

In total 65 lectures were held for different target groups. An overview was given of the most important results from the investigation, filled with poignant advice on the correct handling of the products.




"I'm sorry, but what height do I get from you?"

With good bunching all the root necks of the plants are at the same height.

**Articles**

In total 51 articles were published in different trade press, including:

| | |
|---|---|
| de Boomkwekerij | Fruitteelt |
| Tuin en Landschap | Oogst |
| Bloem en Blad | Agrarisch Dagblad |

Next to this was regular publication in several regional papers, news-letters and information sheets of study clubs and organisations. There was also attention paid to foreign countries through the "De Boomkweker", the information paper from PPH (Plant Publicity Holland), which is distributed in different countries. There was also a number of articles published in foreign trade press over this topic.

# 6. CONCLUSIONS AND RECOMMENDATIONS

## 6.1 Commercial Practice

**Organisation**
The majority of growers and traders were aware of the dangers of drying out of the plant. Almost everybody acknowledged the danger of letting bare-root plants lie unprotected in the field or unprotected (internal) transport. That this still occurs in practice points to organisational causes. Good planning is necessary, whereby the number of plants to be worked on is continually tuned to the available personnel capacity. Good communication between the links is indispensable for tight planning.

*Unprotected on pallets in the field; keep this period as short as possible.*

**Cool chain distribution**
The weathers' changeability remains an uncertain factor which hampers the carrying out of work plans and afterwards of agreements.

Cool chain distribution offers the chance to realise an improvement in spreading the workload. The influence of the climate on the activity of the plant development is controlled, and the selling season lengthened without cost to plant quality. In cool chain distribution clamping is superfluous. Cool chain offers above all the advantage if crops are to be supplied late in the season, and for parties for which the delivery call off is uncertain.

**Maintenance of refrigeration plant**
In practice the working temperature in cold and freezing stores often deviates somewhat from the set, desired air temperature of the store. This has an influence on the possible storage duration of the crops.
At the yearly service of the equipment the causes of these deviations should be traced and corrected. We recommend that analogue needle thermostats should be calibrated as often as possible. Digital thermostats exhibit less drift (course in respect to the zero point) than measuring equipment with an analogue mechanism. Therefore there is a preference for these digital thermostats.

**Drying out in the sheds**
The temperature in sheds rises as the spring advances, and displays greater swings throughout the 24 hour period. The relative air humidity falls and the vapour deficit rises. Plants therefore dry out quicker and are active earlier.

It is possible to improve the climate in the shed though working with the doors shut, wetting the floor of the work place at the beginning of the day, installing strip doors in the door openings, leaving the floor unsurfaced (for the greater part), or by installing humidifiers.

It is possible to control the climate in the shed by making use of cheap, cool, humid night air. Warm air can be extracted from the eaves using a fan. Shutting out the sun and working under fluorescent lights prevents warming up under the influence of the sun.

**Drying out in the grading room**
The results showed that the drying out of bare-rooted plants was around four times as quick in grading rooms as in the sheds at the same time of the year. If hot air burners are used in the grading shed then the evaporation rate is even greater.

In order to limit the moisture loss the time spent in the grading room should be kept to a minimum. The use of hot air burners is not advisable on the joint account of ethylene production and the high vapour pressure deficit and unpleasant working environment they create.

**Room temperature versus product temperature**
Measurements taken in the sheds and cold stores showed that the product temperature is mostly higher than the room temperature. So long as these differences are small this creates no problem for the viability. Problems can occur if residual leaves are present, the product was lifted too early, inadequate ventilation is possible through too closed a container (kuub crates), too tightly piled, or if insulating filling material such as peat dust is used.

Checking the room and product temperature can bring attention to problems in an early stage, and the stack method can be changed or the room temperature lowered.

**Covering of bare-rooted plants**
In most companies, the bare-rooted plants in the sheds have no extra protection. Plants in boxes or tree pallets are often stacked with the roots to the outside.

Covering plant lots in sheds or wrapping pallets with stretch film reduces drying out of the plants during storage in the sheds.

**Early lifting**
Although it is commercially desirable to bring forward the selling season, it is undesirable from a quality point of view. Early lifted plants are much less tolerant to moisture loss during their time in the selling chain and have low winter hardiness.

The disadvantage that follows is not fully removed through careful handling during the selling phase.

Even in a short selling chain early lifted plants have insufficient time to recover. Plants lifted before natural leaf-fall are unsuitable for long duration or frozen storage. If early delivery is really required, then give preference to potted or containerised plants, or potentially root-balled plants.

**Un-packaged handling**
Many bare-rooted plants are supplied un-packaged. Research has shown that protection against drying out during handling maintains the viability.

It is meaningful to strive for the use of one type of packaging material through the whole of the chain. This prevents unnecessary over packaging and simplifies the disposal of the waste. Black 0.1mm thick HDPE (high density polyethylene) film and co-extruded black/white PE film are suitable protection materials for both during storage and delivery.

**Root-dips.**
An alternative to packaging is the use of root-dips.

Root-dips consist of a water absorbent polyacrylic which offers protection against drying out. There are practical problems regarding the application of root-dips, and solutions must be found to these questions. Here lies a task for the manufacturer and the suppliers.

**Road transport**
Tilt trucks have little protection against high or low temperatures. With cold weather or heat or sunshine the chance exists of damage through frost or the temperature running too high. With closed, insulated trucks, the air temperature inside the vehicle follows the outside temperature, though there is a delay.

As with storage it is desirable to make use of temperature controlled trucks for transporting. This is certainly true for plants which must be transported over long distances, or for plants which are not dormant. The (pre-) cooling of plants and temperature controlled transport give the most security for the maintainance of plant quality.

**Loading and unloading**
The trading of crops without the use of pallets causes mechanical damage due to rough handling by hand. Broken branches are often not caused through binding, but through careless and/or incorrect loading.
The preference is to use boxes and upright transport of plants to prevent damage.

**Binding material**
The use of unsuitable binding materials causes damage to crops in the form of wounding on the bark. Use by preference single strand polypropylene string with a running yield of 1/400 or 1/600 m.kg. (each kilo gives 400 or 600 running metres of string). So long as the crop will not be held in cold storage for a long time, single strand sisal with a minimum thickness of 3mm is satisfactory.

Unsuitable but often used are; carnation wire, tomato or sweet pepper twine, and parcelling twine.

From an environmental point of view it is recommended that an improved binding material should be developed, one which is also suitable for long duration winter cold storage.

**Arrangements.**
Growers against their better knowledge take actions or leave protective actions out, which can exert a detrimental influence on the viability of the crop.

In order to prevent this, clear agreements are required between the producer, the supplier, and the client. Thoughts fall to the fixing of the earliest lifting date per season, compulsory protected (internal) transport, packaged delivery, and the giving of growing guarantees.

In the future there could be certification of companies or the use of ISO-norms in order to further advance the maintenance of plant quality during the selling phase.


**"It's normally a question of a good pedicure"**

**At the correct time and depth, under-cutting is of great importance for the future life of the plants.**

## 6.2 Following Investigation

### Covering sheets

The sheeting-over of plants for transport is laborious, heavy and time consuming work. To cover plants during transport a light, strong material is required, where the temperature underneath does not rise quickly. Research is required to find a useable material.

*Protecting the roots with a covering sheet.*

### Improving establishment

The drying out of plants is a reversible process inside defined limits. The effect of plunging the root system, potentially with the addition of hormones, on establishment was discussed in the literature with variable results. Further research into this subject may elucidate the benefits of this treatment.

### Crops handled in leaf

Crops handled in leaf came up for discussion only in the survey and the literature study. Ethylene and too high a temperature in combination with a shortage of light formed the most important reasons for damage. Investigation is required to determine specific requirements during the marketing of visually attractive crops in the different seasons.

### Rest condition

The moment when plants are fully hardened is normally commercially measured from the natural leaf-fall. An accurate determination of the rest condition is required in connection with fixing the time of lifting. Also the maximum storage duration and the choice of storage temperature are dependant on the dormancy position of the plant. In order to find suitable criteria to determine the level of dormancy, further research is required into the physiology of winter rest.

### Vitality

The Instituut voor Agrotechnologisch Onderzoek is also researching a method to determine viability. A connection between re-growth and the measurement of viability have been observed, but the grounds of the connection cannot be easily determined within the time span of this project. Consequently it was decided not to continue this research. At this time there is no method by which the viability of hardwoods in the chain can be measured .

Certainly the development of something like an assay is of great importance commercially. British research on conifers and orientation experiments during this project on deciduous wood have shown that a perspective exists for determining viability.

Research should go further, possibly with International cooperation, in order to develop a viability assay which is easily applicable in practice.

## 6.3 Demonstrations and Advice

Next to research, much attention was paid to the awareness process of the target groups. The demonstrations have clearly shown what follows as a result of good and bad handling.

There is also much attention paid to providing information about sales activities in the chain. This has contributed to raising the consciousness within the links of the marketing chain to the benefit of good actions in the sales of bare-rooted products.

In the near future, raising awaremenss should be continued. This can be done through lectures and articles asking to maintain attention on good quality control.

Also support can be granted to the information activities of third parties. Likewise there can be co-operation in the setting up of lesson material regarding this matter. Whenever possible demonstrations should be set up with this aim.

Co-operation can be given to the setting up and introduction of a piece of regulation in the area of handling of bare-rooted tree nursery products.

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## Authors


| | |
|---|---|
| Ir E.M. van Hees-Boukema (M. Hort. Sc.) | - text research results |
| Dr M.B.M. Ravesloot (M. Hort. Sc.) | - text research results |
| Ir N.A. Leek (M. For. Sc.) | - co-ordination of research programme |
| Ing Ch.J.J. Buddendorf (B. Agric.. Sc.) | - text ATO-DLO |
| J.G. Maas | - demonstrations, advice, project leader |
| F.A.M. Geers | - editor |

A good quality tree
begins between the ears