APPLIED PLANT RESEARCH
PRAKTIJKONDERZOEK
PLANT & OMGEVING

HANDBOOK FOR MODERN
GREENHOUSE ROSE CULTIVATION
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Handbook for Modern Greenhouse Rose Cultivation

Applied Plant Research
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PREFACE

This manual has been realised thanks to the co-operation of many, working in a number of companies and institutes. Without their help this manual could not have been written in such a short period. Thanks are therefore due to:

**LTB Advice and Accountancy:** D. Duys, J. Schouten

**DLV Aalsmeer:** M. van Lent

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**Association of Flower Auctions in the Netherlands (VBN)**

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Joop de Hoog jr.
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INTRODUCTION

For today's glasshouse grower, knowledge is a production factor of increasing importance. In order to keep pace with present developments it is vital for a holding to keep abreast of all information from research and practice. The growing process becomes more and more complicated, due to increasing refinement of all equipment, but also market, society and government place increasing demands on the grower.

An inventory of research issues in spring 1997 by the National Committee Rose of the LTO-NTS clearly indicated that growers increasingly need background information on the various factors which play a role in the growing process. The growing manual that was then available: 'Teelt van kasrozen', however, gives insufficient information on these backgrounds and is, moreover, strongly outdated. A new manual with extensive background information may support growers and their staff in the various processes and support them in decision making. By enhancing, for example, insight into pests and diseases, diagnosis can be made sooner. As a result, damage may be reduced and the amount of pesticides applied may be limited.

In consultation with the National Committee Rose of LTO-NTS a list has been drawn up of subjects to be treated in the manual. This list served as a basis for the table of contents. The former crop specialist Rose, mr J. de Hoog, has taken the final responsibility for the compilation of the material and the quality of the manual. Various components of the manual have been supplied by researchers of PPO and other institutes.

Thanks to the efforts of all authors, an up-to-date description of the cultivation of (glasshouse) rose is now available: a compilation of literature, background information and practical knowledge collected in a manual which will prove its usefulness in the coming years.
1. GENERAL

This cultivation manual deals with various aspects of the cultivation of (glasshouse) roses as cut flowers. The general information about origin of the rose and the current range of varieties is followed by chapters on economic importance and organizational structure. From Chapter 4 onwards the botanical characteristics of the rose are the central issue in chapters with mainly cultivational information. The subjects successively dealt with are: water and nutrient supply, starting material, crop build-up, glasshouse climate, harvest and vase life, and pests, diseases and disorders. The last two chapters are devoted to quality control systems and biological cultivation.

1.1 ORIGIN AND NOMENCLATURE

According to the generally accepted taxonomy there are 120 species belonging to the genus Rosa. The species are found in the northern temperate climate zones and in the subtropical parts of the world. This includes an area from the polar circle to New Mexico, to Ethiopia, to the Himalayas, Bengal and the south of China in the Far East. The classification is complicated due to the large amount of published names, mostly ill-defined and inconsistent. The development of hybrids by crossbreeding during many centuries makes it almost impossible to distinguish the pure species from the hybrids, garden roses with Latin names and many synonyms.

Of the many species only eight from three different geographical regions (Far East, Europe, and eastern part of the Mediterranean) have contributed to the development of the modern rose varieties. The taxonomic position of the various types involved in the development of the cultivated rose is given schematically in Figure 1, which shows the wild ancestors of the garden rose.

The modern rose and most types of the genus rose form the sub-genus Eurosa and are part of the family of the Rosaceae. Most types flower in spring and summer. One type, *Rosa moschata autumnalis* (*R. x noisettiana*) flowers in autumn and may be a short-day plant. *R. damascena semperflorens* (damask rose) with recurrent flowering is perhaps a hybrid from the autumn-flowering *R. moschata autumnalis* and the *R. gallica*. The most significant event in the development of the present-day cut rose took place at the end of the eighteenth century, when derivatives of *R. chinensis* and *R. gigantea* with recurrent or constant flowering were introduced from the Far East. Possibly they were the product of many generations of breeding in China, Japan and India. Subsequent mutations and crossbreedings with roses from Europe and the Middle-East resulted in the modern varieties with recurrent flowering. This type is now used in glasshouse cultivation. Further information in this manual is based on these species only.

1.1.1 Botanical characteristics

Roses are woody shrubs with composite leaves occurring spirally on the stems with the main flower. The shoots mostly have a number of labial leaves at the base. The horticultural classification of the various roses is described in different books dealing with the history of the rose and gardening. A very extensive work is 'Rosen, Rosen, Rosen' by G. Krüssmann. The classification is based on the number of flowers in the inflorescence, the size of the flower, shoot length and plant shape. The most important groups are Tea-hybrids with one or more flowers per stem; Polyantha with clusters of many small flowers; Polyantha hybrids or Floribunda and Grandiflora, with a number of flowers in between those of the two previous groups. The groups represent the different lines used in breeding.
Wild ancestors of the garden rose

Figure 1. Diagram of the taxonomic positions of the species of the genus Rosa. The species in the dark rectangles are part of the development of modern rose varieties. Those mentioned between the dotted lines play a minor role in the development of rose varieties (from: Zieslin, N., and R. Moe, CRC Handbook of Flowering).
Varieties can be distinguished by colour, shape of the thalamus, shape and position of the sepals, shape of the petals, shape of the bud, shape of the open flower, etc. The flower bud, for example, may be round, oval, pointed, slim or urn-shaped. The open rose may be quartered (flowers look frayed), shapeless, rosette-shaped, beaker-shaped etc. The petals may or may not unfold in a horizontal position. Of most rose species the flower has five sepals and five petals. Currently, varieties have been developed with more petals. Some literature sources suppose that the number of petals and the number of stamina are constant. The number of petals however, decreases as the cultivation temperature rises. The number may drop to a basic number of 5 at a temperature of 27°C or higher, when also often many intermediate shapes of petals are formed. The formation of a higher number of petals at a low temperature is accompanied by a decrease of the length-width ratio of the petals and supplementing of the honey tray by a rapidly multiplying tissue. These changes result in misshapen flowers called bullheads. Low temperatures may also lead to a more intense anthocyanin formation and enhance the flower colour.

1.2 CURRENT ASSORTMENT

The current rose varieties in the Netherlands are divided into various classifications. Auctions divide the assortment into hybrid tea roses, sweet hearts and spray roses. Breeders and growers add intermediate-flowering roses. Spray roses are perhaps the most easily distinguishable. A stem with at least three flower buds is called a spray and may be delivered at the auction as such according to the VBN (Dutch National Flower Auction Association) standards. For the classification in hybrid tea and sweet hearts, no objective standards were available until recently. Everyone had own more or less objective standards, such as stem length, bud size, flower diameter, number of stems per square metre. In 1996 the VKC (Permanent Judging Comittee) set up the registration standard for the classification of roses into the hybrid tea and sweet hearts. The flower diameter is measured in an angle of 45 degrees (with the eye), from the flower base. If the flower diameter is less than 9 cm the variety is classified as sweet heart. If the flower diameter is 9 cm or more the variety is classified as hybrid tea. Once the classification is disputed the second standard becomes valid. Sweet hearts between 8 and 9 cm flower diameter can be categorized as hybrid tea roses if the breeder points out that in the production phase the average length of the stem will be around 90 cm. He has to offer the VKC roses again which are at least 90 cm. Another possibility is that the breeder indicates that the flower diameter at complete opening is at least 10 cm. Also in that case the breeder has to offer the VKC roses again which are completely opened and have a diameter of at least 10 cm. For the intermediate types no standardisation has been agreed upon. The problem is that in this group two limits (upper and lower limit) have to be determined and checked.

Recent years showed a considerable expansion of the assortment of roses. An increasing number of breeders concentrated on rose breeding. Officially in 1992 249 different varieties were on sale at the Dutch auctions. In 1997 this increased to 422 varieties. In that year 37 new hybrid tea varieties, 26 new sweet heart varieties and 7 spray roses were added. So the assortment has broadened enormously. While the supply showed an increase of 30% over the last 5 years, the number of varieties grew with 65%. As a result, selecting a new variety becomes more difficult and marketing more complicated. In 2000 the number of varieties sold at the Dutch Auctions was 490.
There are various ways of presenting the current range of varieties grown in the Netherlands. First, the acreage can be given in numbers of hectare per variety. However, growers are not obliged to state the acreage with a certain variety in the so-called May-census, so that the data have to be collected in another way. In recent years the Board of Horticulture conducted inquiries among growers. Growers are not obliged to participate, so that the acreages per variety are not complete. According to the compulsory May-census of the Central Bureau for Statistics in 2000 roses were grown on an area of 950 ha. In total 76% of the growers responded to the early 2001 inquiry of the Board of Horticulture and gave a prognosis for 2002. The acreages and the percentages give an indication of the rise or fall of a variety.

**Hybrid tea roses**
The acreage of Hybrid tea roses grew in 2000 with 2% with respect to 1999. In the prognosis for 2002 growers predict a 1% extra increase in Hybrid Tea acreage. The dominant position of First Red is still obvious, although it is losing terrain very fast: in 1998 it was grown in almost 26% of the Hybrid Tea acreage, while in 2001 the acreage First Red has decreased to 13%. The growers prognosis for 2002 shows a further decrease to 10% of the acreage.
The large number of varieties becomes also clear if one considers the distribution of the acreages over the varieties.

**Sweet hearts**
The share of sweet hearts in the total rose acreage seems to decrease slowly. Despite the pressure of the total acreage of sweet hearts becoming smaller, there are a number of varieties of which the acreage still increased considerably. These include the varieties Sacha and Escimo. Frisco is no longer leading the sweet hearts segment; also the acreages of the varieties Gabriella, Kiss and Mercedes are becoming smaller. Several varieties in the sweet hearts category have a considerable acreage.

**Spray roses**
Spray roses are grown both outdoors and in glasshouses. Outdoor cultivation is generally no longer regarded as profitable in The Netherlands and is on its decline. The spray rose variety Diadeem is being cultivated in 2001 on an outdoor acreage of about 2 hectares. Two more hectares are down to the outdoor culture of other spray rose varieties, a modest increase compared to 1999. The grower’s prognosis for 2002 shows a decrease in outdoor spray rose acreage to 1.6 ha Diadeem and 1.4 ha other varieties. Gracia is nowadays the most important variety for the glasshouse cultivation of sprays.
Table 1. Acreage of Hybrid tea roses in the Netherlands (source: Board of Horticulture, Bloemen in zicht, Roos, 2000)

<table>
<thead>
<tr>
<th>Variety</th>
<th>Acreage in ha Jan-Feb 2001</th>
<th>Acreage in ha Jan-Feb 2002</th>
<th>In % 2001</th>
<th>In % 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Red</td>
<td>62.2</td>
<td>43.4</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>Grand Prix</td>
<td>35.8</td>
<td>35.5</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Red Berlin</td>
<td>32.5</td>
<td>30.3</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Vendela</td>
<td>24.7</td>
<td>20.5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Passion</td>
<td>24.5</td>
<td>27.9</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Sphinx</td>
<td>16.5</td>
<td>16.7</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Trixx!</td>
<td>14.8</td>
<td>9.3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Bianca</td>
<td>14.3</td>
<td>9.6</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Akito</td>
<td>11.6</td>
<td>11.4</td>
<td>2</td>
<td>3</td>
</tr>
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<td>Naranga</td>
<td>8.4</td>
<td>6.6</td>
<td>2</td>
<td>2</td>
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<tr>
<td>Queensday</td>
<td>8.0</td>
<td>8.0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Ballet</td>
<td>7.3</td>
<td>7.3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Indian Femmal</td>
<td>6.7</td>
<td>6.1</td>
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<td>1</td>
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<tr>
<td>Renate</td>
<td>5.8</td>
<td>5.5</td>
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<td>1</td>
</tr>
<tr>
<td>Cream Prophyta</td>
<td>5.6</td>
<td>4.8</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Gold Strike</td>
<td>5.2</td>
<td>4.8</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Valentino</td>
<td>4.9</td>
<td>4.8</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Noblesse</td>
<td>4.1</td>
<td>3.5</td>
<td>1</td>
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</tr>
<tr>
<td>Ruby Red</td>
<td>3.7</td>
<td>3.7</td>
<td>1</td>
<td>1</td>
</tr>
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<td>Leonidas</td>
<td>3.4</td>
<td>2.1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Poison!</td>
<td>3.4</td>
<td>3.4</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Other varieties</td>
<td>169.4</td>
<td>161.7</td>
<td>35.8</td>
<td>37.9</td>
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</table>

Table 2. Acreage of sweet hearts in the Netherlands (source: Board of Horticulture, Bloemen in zicht, Roos, 2000)

<table>
<thead>
<tr>
<th>Variety</th>
<th>Acreage in ha Jan-Feb 2001</th>
<th>Acreage in ha Jan-Feb 2002</th>
<th>In % 2001</th>
<th>In % 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sacha</td>
<td>19.0</td>
<td>17.4</td>
<td>11.3</td>
<td>12.2</td>
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<tr>
<td>Escimo</td>
<td>17.6</td>
<td>15.1</td>
<td>10.5</td>
<td>10.5</td>
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<tr>
<td>Frisco</td>
<td>14.7</td>
<td>7.5</td>
<td>8.7</td>
<td>5.2</td>
</tr>
<tr>
<td>Golden Gate</td>
<td>9.9</td>
<td>9.6</td>
<td>5.9</td>
<td>6.7</td>
</tr>
<tr>
<td>Surprise</td>
<td>8.6</td>
<td>6.1</td>
<td>5.2</td>
<td>4.3</td>
</tr>
<tr>
<td>Candid Prophyta</td>
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<td>7.9</td>
<td>5.1</td>
<td>5.5</td>
</tr>
<tr>
<td>Red Champ</td>
<td>6.2</td>
<td>5.1</td>
<td>3.7</td>
<td>3.5</td>
</tr>
<tr>
<td>Sunbeam</td>
<td>6.2</td>
<td>5.7</td>
<td>3.7</td>
<td>4.0</td>
</tr>
<tr>
<td>Jazz</td>
<td>5.4</td>
<td>3.0</td>
<td>3.2</td>
<td>2.1</td>
</tr>
<tr>
<td>Aloha</td>
<td>3.5</td>
<td>2.1</td>
<td>2.1</td>
<td>1.4</td>
</tr>
<tr>
<td>Kiss</td>
<td>3.5</td>
<td>2.3</td>
<td>2.1</td>
<td>1.6</td>
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<tr>
<td>Amore</td>
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<td>Gabrielle</td>
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<td>2.4</td>
<td>2.0</td>
<td>1.7</td>
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<tr>
<td>Esther</td>
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<td>3.0</td>
<td>1.8</td>
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<tr>
<td>Lambada</td>
<td>2.9</td>
<td>2.9</td>
<td>1.7</td>
<td>2.0</td>
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<tr>
<td>Madelaine</td>
<td>2.7</td>
<td>2.5</td>
<td>1.6</td>
<td>1.8</td>
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</table>
Table 3. Acreage of spray roses in the Netherlands (Source: Board of Horticulture, Bloemen in zicht, Roos, 2000)

<table>
<thead>
<tr>
<th>Variety</th>
<th>Acreage in ha Jan-Feb 2001 glasshouse</th>
<th>In %</th>
<th>Acreage in ha Jan-Feb 2002 glasshouse</th>
<th>In %</th>
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<tbody>
<tr>
<td>Gracia</td>
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<td>13.8</td>
<td>2.9</td>
<td>11.9</td>
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<td>Macarena</td>
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<td>Lydia</td>
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<td>8.6</td>
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<td>6.5</td>
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<td>Flair</td>
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<td>3.9</td>
<td>1.3</td>
<td>5.4</td>
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<td>Cream Gracia</td>
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<td>Princess</td>
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<td>-</td>
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<td>0.3</td>
<td>1.1</td>
<td>0.3</td>
<td>1.2</td>
</tr>
<tr>
<td>Rumba</td>
<td>0.1</td>
<td>0.5</td>
<td>1.5</td>
<td>0.6</td>
</tr>
<tr>
<td>Other spray rose varieties</td>
<td>13.8</td>
<td>49.0</td>
<td>13.3</td>
<td>54.3</td>
</tr>
</tbody>
</table>

Most important varieties with respect to auction turnover
Another indicator of which varieties are the most frequently cultivated is the turnover per variety at the Dutch flower auctions. However, at Dutch auctions roses from abroad are marketed as well. Their share can be found in the data presented in Chapter 2. The tables below give the top-ten of hybrid tea roses, sweet hearts and spray roses, listed in order of turnover share.


<table>
<thead>
<tr>
<th>Variety</th>
<th>% supply</th>
<th>Price (ct/piece)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Red</td>
<td>16.6</td>
<td>21.5</td>
</tr>
<tr>
<td>Red Berlin</td>
<td>6.5</td>
<td>3.9</td>
</tr>
<tr>
<td>Grand Prix</td>
<td>3.6</td>
<td>2.9</td>
</tr>
<tr>
<td>Trixx!</td>
<td>3.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Bianca</td>
<td>3.2</td>
<td>4.1</td>
</tr>
<tr>
<td>Vendela</td>
<td>2.9</td>
<td>1.8</td>
</tr>
</tbody>
</table>
In percentages the supply of hybrid tea roses increased by 13.5 % with respect to 1999. The average price increased as well in relation to that of 1999. The share of First Red is still enormous, but considerably decreased in 2000. Of all First Red roses sold, 29% comes from abroad while for Noblesse this is 78%. Konfetti is listed thanks to the import, since 95% of this variety comes from abroad. Inversely, less than 0.5% of the sold Grand Prix or Passion are imported, and Red Berlin is not even listed among the import varieties.

Madelon disappeared from the top 10 in 1997. This orange-red variety was the leader of the Hybrid tea rose acreage for years. The fragmentation of the assortment is underlined by the percentage of the total number achieved by the top 10: not yet 50%.

The sweet hearts experienced in 2000 a 2.7% reduction in turnover as compared to 1999. The supply decreased in 2000 by 10.2%. The average price increased by 2 cent. The sweet heart assortment also has a clear front runner with Frisco. Lambada and Mercedes, in particular, come for more than 80% from abroad, while for Frisco or Escimo this is in 2000 respectively 36 and 30%. (The share of imported Frisco to the total supply was in 1997 only 8.7%.)


<table>
<thead>
<tr>
<th></th>
<th>% supply</th>
<th></th>
<th>Price (cts/piece)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frisco</td>
<td>15.2</td>
<td>17.7</td>
<td>18.6</td>
</tr>
<tr>
<td>Escimo</td>
<td>9.0</td>
<td>7.6</td>
<td>7.2</td>
</tr>
<tr>
<td>Sacha</td>
<td>7.9</td>
<td>7.9</td>
<td>7.3</td>
</tr>
<tr>
<td>Lambada</td>
<td>5.1</td>
<td>5.4</td>
<td>5.9</td>
</tr>
<tr>
<td>Golden Gate</td>
<td>4.7</td>
<td>3.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Mercedes</td>
<td>3.5</td>
<td>4.8</td>
<td>5.9</td>
</tr>
<tr>
<td>Surprise</td>
<td>3.3</td>
<td>3.8</td>
<td>3.3</td>
</tr>
<tr>
<td>Jazz</td>
<td>3.2</td>
<td>3.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Rodeo</td>
<td>2.6</td>
<td>2.9</td>
<td>3.5</td>
</tr>
<tr>
<td>Amore</td>
<td>2.5</td>
<td>3.2</td>
<td>2.7</td>
</tr>
<tr>
<td>Total top 10</td>
<td>57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweethearts total (x 100 stems)</td>
<td>2000</td>
<td>1999</td>
<td>1998</td>
</tr>
</tbody>
</table>
More and more spray roses are produced abroad. The varieties Rumba (96%) and Diadeem (93%) are almost entirely from abroad. It is clear that the Dutch spray roses fetch higher prices, if you compare, for example, the prices of Surprise and Gracia with those of Rumba and Diadeem.

Every year the turnover of roses at Dutch auctions increases. In 2000 the turnover increased with 11.3% to Dfl 1,427 million, although the number of roses supplied, 3.2 billion, did not significantly changed with respect to 1999. The share of hybrid tea roses is rising at the cost of that of sweet hearts, although the share of the sweet hearts is still the greatest. The effect of imported roses at Dutch statistics is considerable. Since the prices for imported roses are mostly lower than for the Dutch roses, this might result in a distorted picture of the average prices.

In the colour statistics red still appears to be by far the most frequently sold colour, with a number of 875 million stems in 2000 and an average price of Dfl 0.54. Red is followed by yellow with 736 million stems and an average price of Dfl 0.39, pink with 385 million stems and an average price of Dfl 0.40. The best paid colour in 2000 was blue (painted) with Dfl 1.20, followed by green with Dfl 0.74. Table 7 presents the shares of the colours (numbers of stems expressed in %) in the supply of all roses in 1992, 1997 and 2000 at the VBN auctions. The decrease of the colour pink is considerable.


<table>
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<td>26.2</td>
<td>22.8</td>
<td>25</td>
<td>26</td>
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<tr>
<td>Diadeem</td>
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<td>18.0</td>
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<td>Viviane</td>
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<td>4.0</td>
<td>3.0</td>
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<td>54</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>Macarena</td>
<td>7.1</td>
<td>4.7</td>
<td>2.2</td>
<td>61</td>
<td>74</td>
<td>101</td>
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<td>0.9</td>
<td>0.0</td>
<td>61</td>
<td>85</td>
<td>--</td>
<td></td>
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<tr>
<td>Gracia</td>
<td>3.0</td>
<td>3.6</td>
<td>2.8</td>
<td>65</td>
<td>61</td>
<td>76</td>
<td></td>
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<tr>
<td>Flair</td>
<td>2.9</td>
<td>3.3</td>
<td>2.7</td>
<td>58</td>
<td>71</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td>Lydia</td>
<td>2.9</td>
<td>5.1</td>
<td>5.5</td>
<td>62</td>
<td>52</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Softy</td>
<td>2.8</td>
<td>3.5</td>
<td>4.4</td>
<td>25</td>
<td>23</td>
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<tr>
<td>Surprise</td>
<td>2.5</td>
<td>5.2</td>
<td>7.3</td>
<td>76</td>
<td>64</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>Total top 10</td>
<td>68.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total spray roses (x 1000 stems)</td>
<td>2000</td>
<td>160,080</td>
<td>153,259</td>
<td>142,269</td>
<td>42</td>
<td>41</td>
<td>43</td>
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</table>
Table 7. Share of the colours (%) in the supply of all roses in 1992, 1997 and 2000 at the VBN auctions

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<tr>
<td>Red</td>
<td>32.7</td>
<td>31.4</td>
<td>27.3</td>
</tr>
<tr>
<td>Yellow</td>
<td>16.1</td>
<td>20.1</td>
<td>23.0</td>
</tr>
<tr>
<td>Pink</td>
<td>30.3</td>
<td>18.4</td>
<td>10.4</td>
</tr>
<tr>
<td>Orange</td>
<td>5.0</td>
<td>8.2</td>
<td>10.7</td>
</tr>
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<td>Salmon</td>
<td>2.5</td>
<td>7.0</td>
<td>6.3</td>
</tr>
<tr>
<td>White</td>
<td>7.3</td>
<td>6.9</td>
<td>10.0</td>
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<td>Cream</td>
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<tr>
<td>Bicolour</td>
<td>*</td>
<td>2.0</td>
<td>2.6</td>
</tr>
<tr>
<td>Purple</td>
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<td>1.7</td>
<td>2.2</td>
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<td>Miscellaneous</td>
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<td>1.1</td>
<td>1.8</td>
</tr>
<tr>
<td>Brown</td>
<td>*</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Mixed</td>
<td>*</td>
<td>0.3</td>
<td>0.9</td>
</tr>
</tbody>
</table>
2. ECONOMIC SIGNIFICANCE

The significance of the rose for the Dutch Horticulture can be divided into its significance for the trade and the significance for the production sector itself. The significance for trade is outlined on the basis of turnover and import of roses at the Dutch auctions. The importance of Dutch production is described using characteristics such as acreage, turnover, profitability and competitive power of the Dutch holding. Prices of Dutch roses are compared to those of imported roses.

2.1 DEVELOPMENTS IN AUCTION SUPPLY, ACREAGE, IMPORT AND EXPORT

During the last two decades rose production has developed from an important nationally grown floricultural product to an international trading commodity. Although in the strongly expanding auction turnover of floriculture the share of cut flowers has decreased, the rose has managed to maintain its position providing 25% of the total turnover of cut flowers. During the last few years this share has even increased due to imports (see Table 8). Imports play an increasingly significant role in the turnovers achieved at Dutch auctions, with rose accounting for 30%.

Table 8. Developments in the auction turnovers (in million guilders) since 1975 and the related position of roses

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Auction turnover floriculture Netherlands</td>
<td>113</td>
<td>2059</td>
<td>3082</td>
<td>4225</td>
<td>4781</td>
<td>5688</td>
<td>6699</td>
<td>6293</td>
</tr>
<tr>
<td>Imports</td>
<td>-</td>
<td>-</td>
<td>274</td>
<td>429</td>
<td>632</td>
<td>929</td>
<td>973</td>
<td>1083</td>
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<tr>
<td>Auction turnover cut flowers Netherlands</td>
<td>962</td>
<td>1648</td>
<td>2336</td>
<td>2903</td>
<td>3166</td>
<td>3745</td>
<td>3690</td>
<td>4091</td>
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<tr>
<td>Imports</td>
<td>-</td>
<td>-</td>
<td>165</td>
<td>393</td>
<td>576</td>
<td>856</td>
<td>901</td>
<td>999</td>
</tr>
<tr>
<td>Auction turnover roses Netherlands</td>
<td>230</td>
<td>373</td>
<td>487</td>
<td>654</td>
<td>817</td>
<td>954</td>
<td>960</td>
<td>1056</td>
</tr>
<tr>
<td>Imports</td>
<td>-</td>
<td>-</td>
<td>14</td>
<td>109</td>
<td>174</td>
<td>303</td>
<td>331</td>
<td>369</td>
</tr>
<tr>
<td>Roses as % cut flowers</td>
<td>24</td>
<td>23</td>
<td>20</td>
<td>23</td>
<td>26</td>
<td>27</td>
<td>28</td>
<td>26</td>
</tr>
<tr>
<td>Imported roses as % of all roses</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>14</td>
<td>18</td>
<td>33</td>
<td>35</td>
<td>38</td>
</tr>
</tbody>
</table>

In Dutch glasshouse floriculture the acreage of roses manages to maintain a level of ca. 23% of the cut flower acreage, which has remained rather stable since 1990, comprising about 900 ha. Increasing flower imports, in which the rose has a significant share, resulted in a stabilization of the cut flower acreage, but not to a reduction of rose cultivation in the Netherlands (see Table 9). The Dutch grower has achieved a strong position in Europe because the collective marketing through the auctions resulted in an extensive network of wholesale and retail traders. Additionally, the distance to the markets is limited, and road transport cheap and reasonably efficient. Education and research facilities are excellent and good communication among growers exists.

The production areas elsewhere in Europe are small and strongly focused on local markets. The most northern production areas are highly dependent on assimilation.
lighting and cheap electricity. In all European countries, the rose growing areas are slowly decreasing.

The acreage of roses grown outside Europe, is growing fast, and is large compared to the Dutch acreage. The most important rose supplier of The Netherlands is Kenya, good for a third of the total import value. This value has grown considerably since 1995, with a yearly average of 39%. Also Zambia and Ecuador achieved a significant growth (see Table 10). The import of roses from these countries to Dutch auctions amounted to 210 million Dfl in 1999 already, which was 61% of the total turnover of imported roses (see Table 8). Roses from these areas also reach European markets via direct sales, particularly supermarket chains and special auctions, such as TFA. Statistics relevant to the share of the supermarkets have not been processed, but TFA’s had in the year 2000 (personal communication) a share of 21.5% of the roses imported by all the Dutch auctions (VBN-auctions + TFA).

Growers in Israel have been building up experience since the early 1970s, and their nurseries are mostly family business. Light levels are favourable in comparison with Europe, but summers are too hot to grow a high-quality product. The African holdings are still young and are characterised by their large scale, foreign investment and Dutch and/or Israeli management. Since the holdings are situated on upland plains, both the light levels and the temperature are favourable year-round. In the production areas in South America (Colombia and Ecuador), with more than ten years of experience, the holdings have grown in size and number. Location of the holdings on upland plains is favourable with a good year-round climate. The holdings are large-scale and marketing is mostly direct to North America, but also to the Dutch auctions. The share in the total import of Ecuadorian roses is growing fast (Table 10).

Table 9. The developments in the production areas of glasshouse floriculture, cut flowers and roses in the Netherlands (in ha)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Acreage glasshouse floriculture</td>
<td>3060</td>
<td>3976</td>
<td>4275</td>
<td>5140</td>
<td>5518</td>
<td>5546</td>
<td>5528</td>
<td>5921</td>
<td>9114</td>
</tr>
<tr>
<td>Acreage glasshouse cut flowers</td>
<td>2608</td>
<td>3275</td>
<td>3419</td>
<td>3938</td>
<td>4063</td>
<td>3655</td>
<td>3622</td>
<td>3962</td>
<td>4062</td>
</tr>
<tr>
<td>Acreage glasshouse roses</td>
<td>650</td>
<td>766</td>
<td>758</td>
<td>889</td>
<td>919</td>
<td>906</td>
<td>931</td>
<td>950</td>
<td>968</td>
</tr>
<tr>
<td>Roses in % of cut flowers</td>
<td>25</td>
<td>23</td>
<td>22</td>
<td>23</td>
<td>23</td>
<td>23</td>
<td>24</td>
<td>24</td>
<td>24</td>
</tr>
</tbody>
</table>

Source: Horticultural statistics 1999 supplemented with CBS

Import of roses totally depends on air transport. Rose is a product that can be packed with a high product value per m³ and has, partly as a result of this, achieved a strong position in these foreign production areas. Current cheap air transport is important for the profitability of these areas, although restrictive measures concerning the environment are soon to be expected. It is uncertain how freight will develop in the future.
Table 10. The trend in Dutch auction supply of roses according to country of origin, since 1995 (in million Hfl)

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Total rose import</td>
<td>152.5</td>
<td>220.3</td>
<td>275.9</td>
<td>334.2</td>
<td>343</td>
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<tr>
<td>Netherlands</td>
<td>81.7</td>
<td></td>
<td>95.4</td>
<td>96.0</td>
<td>95.0</td>
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<tr>
<td>Kenya</td>
<td>36.4</td>
<td>59.4</td>
<td>85.9</td>
<td>110.5</td>
<td>135</td>
<td>750</td>
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<tr>
<td>Zimbabwe</td>
<td>33.6</td>
<td>42.9</td>
<td>57.9</td>
<td>66.7</td>
<td>55</td>
<td>360</td>
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<tr>
<td>Ecuador</td>
<td>11.5</td>
<td>14.4</td>
<td>25.6</td>
<td>38.9</td>
<td>42</td>
<td>1366</td>
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<td>57.4</td>
<td>55.1</td>
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<td>5.7</td>
<td>6.7</td>
<td>5.2</td>
<td>3</td>
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Acreage (Ha)

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<td>Total rose import</td>
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<td>95.4</td>
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<td>38.9</td>
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<td>1366</td>
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<td>55.1</td>
<td>55.7</td>
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<tr>
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<td>11.8</td>
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<td>5.4</td>
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<td>5.2</td>
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<td>5.1</td>
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</tr>
</tbody>
</table>

Source: Kwin 2000 / Eurostat / Board of Horticulture, supplemented with other sources

The import of flowers in general and of roses in particular supplements the supply of Dutch flowers available for trading. The Netherlands is not only a flower-producing country, but Holland is also the centre of worldwide flower export. 1.7 billion of the more than 3.2 billion roses supplied at the Dutch auctions in recent years are exported again. The position of the rose in the total export of cut flowers is of considerable importance. The share in the value had risen to more than 25% in 1997 and was in 1999 19%(Table 11). Germany is traditionally the largest customer for Dutch roses, but although its share is dropping steadily, in 1999 it represented still 42% of the total rose export value. Export to countries outside Europe is still very limited. The American market buys increasingly fewer roses and the export of roses to Russia has dropped considerably since 1998.

The Dutch production of roses is concentrated in several areas. Large centres can be found in the provinces of North and South Holland. The North Holland acreage has become smaller in recent years, partly as a result of the horticulture area Sloten being destined for house building. A number of growers moved to young centres in other provinces, resulting in growing areas in the northern Netherlands and the Flevopolders. In the North of the Netherlands the rose growing areas are concentrated around the Drenthe villages of Emmen and Klazienaveen. The standstill in the increase of the rose area is expected to continue in coming years. An inquiry among rose growers indicated that 83% of them do not intend to expand. The increase in the growth of the acreages in importing countries is one of the arguments they mention for not making new plans.

Table 11. Acreages of roses in the various provinces of the Netherlands, in ha

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Netherlands, total</td>
<td>758</td>
<td>889</td>
<td>919</td>
<td>906</td>
<td>931</td>
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<tr>
<td>4 northern provinces</td>
<td>17</td>
<td>41</td>
<td>62</td>
<td>72</td>
<td>74</td>
</tr>
<tr>
<td>Flevoland</td>
<td>24</td>
<td>37</td>
<td>50</td>
<td>48</td>
<td>51</td>
</tr>
<tr>
<td>Gelderland/Utrecht</td>
<td>34</td>
<td>47</td>
<td>58</td>
<td>56</td>
<td>60</td>
</tr>
<tr>
<td>North Holland</td>
<td>329</td>
<td>331</td>
<td>303</td>
<td>287</td>
<td>287</td>
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<tr>
<td>South Holland</td>
<td>333</td>
<td>395</td>
<td>396</td>
<td>389</td>
<td>308</td>
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<tr>
<td>Zeeland</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>91</td>
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</table>
Table 12. Trends in Dutch rose export to various countries

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Export in Dfl (x 1000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cut flowers</td>
<td>2,581</td>
<td>3,527</td>
<td>3,889</td>
<td>3,772</td>
<td>3,721</td>
<td>5,711</td>
<td>5,679</td>
<td>6,274</td>
</tr>
<tr>
<td>Rose as % of cut flowers</td>
<td>17</td>
<td>18</td>
<td>22</td>
<td>25</td>
<td>25</td>
<td>19</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Total rose</td>
<td>431</td>
<td>622</td>
<td>873</td>
<td>931</td>
<td>921</td>
<td>1,092</td>
<td>1,063</td>
<td></td>
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<tr>
<td>Germany</td>
<td>275</td>
<td>369</td>
<td>480</td>
<td>478</td>
<td>437</td>
<td>484</td>
<td>451</td>
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<tr>
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<td>26</td>
<td>61</td>
<td>109</td>
<td>131</td>
<td>133</td>
<td>168</td>
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<tr>
<td>Switzerl.</td>
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<td>34</td>
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<td>33</td>
<td>48</td>
<td>36</td>
<td>51</td>
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<tr>
<td>Austria</td>
<td>15</td>
<td>25</td>
<td>41</td>
<td>48</td>
<td>44</td>
<td>51</td>
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<tr>
<td>UK</td>
<td>17</td>
<td>37</td>
<td>37</td>
<td>36</td>
<td>43</td>
<td>71</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>Belgium/ Luxembourg</td>
<td>-</td>
<td>-</td>
<td>24</td>
<td>29</td>
<td>30</td>
<td>38</td>
<td>31</td>
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<tr>
<td>Sweden</td>
<td>18</td>
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<td>22</td>
<td>30</td>
<td>24</td>
<td>25</td>
<td>22</td>
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<tr>
<td>Italy</td>
<td>3</td>
<td>13</td>
<td>17</td>
<td>22</td>
<td>24</td>
<td>53</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>Denmark</td>
<td>11</td>
<td>14</td>
<td>23</td>
<td>29</td>
<td>19</td>
<td>26</td>
<td>23</td>
<td></td>
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<tr>
<td>Other</td>
<td>38</td>
<td>45</td>
<td>54</td>
<td>95</td>
<td>117</td>
<td>115</td>
<td>112</td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>13</td>
<td>10</td>
<td>-</td>
<td>2</td>
<td>11</td>
<td>11</td>
<td>10</td>
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<tr>
<td>Russia</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>21</td>
<td>24</td>
<td>29</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

Source: PVS Horticultural statistics 1985-1996; Eurostat 1996/1999; E: Estimation *) to 1990 excluding Belgium/Luxembourg

2.2 PRICE DEVELOPMENT AT DUTCH AUCTIONS

The number of roses supplied at Dutch auctions has risen between 1990 and 2000 by 48%. This did not lead to a reduction of the prices, on the contrary, the average price rose from 36.3 to 45 cent per stem. This price rise can be attributed to an increase in the supply of hybrid tea roses by almost 100% since 1993. The advent of the varieties Madelon and First Red will undoubtedly have contributed to this. The increase of sweet hearts in this period remained limited (13%).

The hybrid tea roses of Dutch origin fetched better prices during the last 2 years, perhaps because of First Red. The prices of imported roses, particularly from Israel and Africa, lagged behind (Table 13). The price of imported hybrid tea roses has dropped in recent years and continues to lag behind Dutch produce. Only South American roses are able to compete with the Dutch, as far as prices are concerned.

The decreasing prices can be partly explained by the length of the import season, which has to meet less and less restrictions. The sweet hearts of Dutch origin maintained the same price level in recent years, while the imported sweet hearts attract lower and
lower prices (Table 13). The position of the roses of Dutch origin has become stronger in the course of the years due to previously mentioned developments. The differences in price between the sweet hearts of various origin are, however, much smaller than with the hybrid tea roses. The supply of spray roses is relatively small, supply of Dutch origin being slightly on the decline and resulting in a small price rise. The supply from Africa, however, increases and is at present even greater than the supply from the Netherlands, while prices for the African product have fallen strongly.

Falling prices of imported roses and the relatively great demand for Dutch produce does not mean that the battle for the rose market is over, although the position of the Netherlands is not unfavourable. The increase in assimilation lighting since 1990, currently already applied on 78% of the rose acreage, will certainly have contributed to this.

The most important quality characteristic of rose is stem length. Price variations between products of different suppliers can be mainly ascribed to the stem length, even though a variety effect is present as well.

Table 13. Price development for roses of various origin on Dutch auctions in cts/stem. (Source: VBN)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Hybrid tea roses</td>
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<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>52</td>
<td>56</td>
<td>55</td>
<td>62</td>
<td>65</td>
<td>67</td>
<td>65</td>
<td>69</td>
</tr>
<tr>
<td>Rest of EC</td>
<td>52</td>
<td>56</td>
<td>55</td>
<td>62</td>
<td>78</td>
<td>99</td>
<td>58</td>
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<tr>
<td>Israel</td>
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<td>38</td>
<td>29</td>
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<td>28</td>
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<tr>
<td>Africa</td>
<td>48</td>
<td>50</td>
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<td>41</td>
<td>39</td>
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<td>36</td>
<td>37</td>
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<tr>
<td>South America</td>
<td>80</td>
<td>81</td>
<td>73</td>
<td>57</td>
<td>62</td>
<td>71</td>
<td>72</td>
<td>64</td>
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<tr>
<td>Asia (India)</td>
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<td>47</td>
<td>36</td>
<td>36</td>
<td>38</td>
<td>34</td>
<td>44</td>
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<tr>
<td>Sweet hearts</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>32</td>
<td>31</td>
<td>48</td>
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<td>Israel</td>
<td>39</td>
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<td>32</td>
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<td>26</td>
<td>24</td>
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</tr>
<tr>
<td>Africa</td>
<td>35</td>
<td>34</td>
<td>33</td>
<td>30</td>
<td>28</td>
<td>24</td>
<td>25</td>
<td>26</td>
</tr>
<tr>
<td>South America</td>
<td>48</td>
<td>41</td>
<td>31</td>
<td>26</td>
<td>30</td>
<td>29</td>
<td>57</td>
<td>65</td>
</tr>
<tr>
<td>Asia (India)</td>
<td>40</td>
<td>40</td>
<td>24</td>
<td>26</td>
<td>25</td>
<td>25</td>
<td>22</td>
<td>27</td>
</tr>
<tr>
<td>Spray roses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>46</td>
<td>43</td>
<td>45</td>
<td>50</td>
<td>56</td>
<td>59</td>
<td>56</td>
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<tr>
<td>Rest of EC</td>
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<td>-</td>
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<td>-</td>
<td>44</td>
<td>34</td>
<td>20</td>
<td>23</td>
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<tr>
<td>Israel</td>
<td>43</td>
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<td>37</td>
<td>59</td>
<td>53</td>
<td>50</td>
<td>17</td>
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<td>22</td>
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<td>35</td>
<td>31</td>
<td>27</td>
<td>27</td>
<td>26</td>
<td>25</td>
</tr>
<tr>
<td>South America</td>
<td>68</td>
<td>63</td>
<td>47</td>
<td>33</td>
<td>37</td>
<td>47</td>
<td>37</td>
<td>42</td>
</tr>
<tr>
<td>Asia (India)</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>33</td>
</tr>
</tbody>
</table>

Varieties with that with difficulty yield stems of sufficient length give good prices for the longest stems. In addition to stem length, bud size and stem diameter have a demonstrable effect on the price.
A second important aspect for the market price of rose is the characteristics of the variety. Some colours, for example pink, do not seem attractive at the moment. Red, on the other hand, is paid well. The highest prices are paid for specific varieties and for novel introductions. High prices only persist as long as the supply is limited. It is difficult to predict if the market price will exceed the cost price when supply increases. Among the varieties with a small share in the total auction supply many are newcomers, only very few of which make it to the top-10 and remain there for several years. The supply of new comparable varieties with better growing characteristics or changes in the market demand determine how long a variety can survive in the top-10. The demand for roses in general is slightly on the decline in the Dutch market. The rose survives relatively well in the floricultural assortment (see Table 14). The slightly improved price is mainly due to marketing activities.

Table 14. Consumption of flowers in the Netherlands per household (Source: Board of Horticulture, Bloemen in zicht, Roos, 1999)

<table>
<thead>
<tr>
<th>Purchases per household</th>
<th>Money wise (in Hfl)</th>
<th>In percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total flowers</td>
<td>65.71</td>
<td>64.91</td>
</tr>
<tr>
<td>Roses</td>
<td>10.56</td>
<td>11.21</td>
</tr>
<tr>
<td>Mixed bouquets</td>
<td>25.54</td>
<td>23.36</td>
</tr>
</tbody>
</table>

2.3 TRENDS IN BUSINESS RESULTS

The future prospects for the Dutch rose holdings are determined to a large extent by the financial results obtained on the holdings. Business accounting is done by the Agricultural Economics Institute and by various accountancies. The number of rose nurseries participating in the administration of the Agricultural Economics Institute is rather limited and fluctuating. The number of rose growers participating in the former business economic accountancy of the farmers’ union (LTB), nowadays renamed “LTB Consultants and Accountants” is greater and more constant. Particularly the better and more progressive growers are participating in the latter, which is also apparent from the business data. The participating growers (LTB) have switched to growing media with assimilation lighting for 95%, while nationally only 78% of the rose acreage is lit and about 76% is grown on substrate.

Developments on the nurseries can be seen in the average business data of the last decade (Table 15). On these nurseries rose cultivation developed from an unlit soil-grown crop to a crop largely grown on substrate under assimilation lighting, so increasing the energy consumption from 50 to 80 m²gas/m² glasshouse. The consequences for the financial results were that both yields and costs per m² glasshouse have considerably increased. Labour is still responsible for most of the operating costs, with a share of 30%.

Table 15. Trends in business results on Dutch rose nurseries during the last decade

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Area with substrate</td>
<td>85%</td>
<td>94%</td>
<td>95%</td>
<td>33%</td>
<td>40%</td>
<td>51%</td>
<td>59%</td>
<td>65%</td>
<td>76%</td>
<td>82%</td>
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</tbody>
</table>
### Area with assimilation lighting

<table>
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<tr>
<th>Gas consumption (m$^3$/m$^2$)</th>
<th>94</th>
<th>93</th>
<th>95</th>
<th>60</th>
<th>71</th>
<th>81</th>
<th>78</th>
<th>86</th>
<th>90</th>
<th>89</th>
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<tr>
<td></td>
<td>80.4</td>
<td>80</td>
<td>81.8</td>
<td>58.6</td>
<td>63.5</td>
<td>62.4</td>
<td>70.4</td>
<td>71.1</td>
<td>74.2</td>
<td>89.9</td>
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</tbody>
</table>

### Result (Dfl/m$^2$)

| Total yields                  | 118.26 | 121.64 | 122.93 | 88.50 | 98.40 | 100.60 | 104.40 | 105.20 | 110.00 | 111.47 |
| Total costs                   | 118.92 | 117.91 | 122.10 | 88.10 | 93.50 | 102.80 | 108.30 | 110.40 | 112.70 | 114.19 |
| Net business result           | 0.86  | 3.73 | 0.83 | -1.60 | 4.90 | -2.20 | -3.90 | -5.20 | -2.60 | -2.72 |
| Ditto per Dfl 100- costs      | -1.0  | 3.0 | 1 | -1.8 | 5.2 | -2.1 | -3.6 | -4.7 | -2.4 | -2.0 |

### Specification of the costs

<table>
<thead>
<tr>
<th>Source: LTB Adviseurs en Accountants</th>
</tr>
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<tbody>
<tr>
<td>Comment: to 1991 the tax costs of interest and depreciation are mentioned. Subsequently these are business-economically-calculated costs</td>
</tr>
</tbody>
</table>

### Despite the change-over to substrate and lighting the business results showed a declining trend and became slightly negative between 1992 and 1997. It should be noted here that the change-over of the fiscal to the business-economic calculation of the interest and depreciation doubled the interest costs in 1992 as compared to 1991, from Dfl 6.87 to Dfl 12.37. This is an ongoing effect after 1992 of counting in the interest on one’s own property as costs for the business. If one takes this difference into account, the business result appears to have been reasonably stable during a decade. The developments on rose nurseries are rather different from those on the average cut flower nursery. This is clear from the comparison of the business results of the cut flower nurseries in the LEI accountancy with the results of the rose nurseries that are part of these (Table 16). Yields per m$^2$ glasshouse have increased much more strongly on rose nurseries than on cut flower nurseries. In 1988/1989 the rose nursery realised a monetary yield of about Dfl 75.00 per m$^2$, a reasonable average for cut flower nurseries, in 1995/1996 the yield has risen to more than Dfl 100,-- which is more than Dfl 15.00 above the average for all cut flower enterprises. On the other hand, the costs also have risen more strongly than on the cut flower holding, but to a lesser extent so that the rose holding has developed from a relatively poor to a rather healthy financial glasshouse business.

### Index numbers

<table>
<thead>
<tr>
<th>Source: LTB Adviseurs en Accountants</th>
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<tbody>
<tr>
<td>Comment: to 1991 the tax costs of interest and depreciation are mentioned. Subsequently these are business-economically-calculated costs</td>
</tr>
</tbody>
</table>

### Despite the change-over to substrate and lighting the business results showed a declining trend and became slightly negative between 1992 and 1997. It should be noted here that the change-over of the fiscal to the business-economic calculation of the interest and depreciation doubled the interest costs in 1992 as compared to 1991, from Dfl 6.87 to Dfl 12.37. This is an ongoing effect after 1992 of counting in the interest on one’s own property as costs for the business. If one takes this difference into account, the business result appears to have been reasonably stable during a decade. The developments on rose nurseries are rather different from those on the average cut flower nursery. This is clear from the comparison of the business results of the cut flower nurseries in the LEI accountancy with the results of the rose nurseries that are part of these (Table 16). Yields per m$^2$ glasshouse have increased much more strongly on rose nurseries than on cut flower nurseries. In 1988/1989 the rose nursery realised a monetary yield of about Dfl 75.00 per m$^2$, a reasonable average for cut flower nurseries, in 1995/1996 the yield has risen to more than Dfl 100,-- which is more than Dfl 15.00 above the average for all cut flower enterprises. On the other hand, the costs also have risen more strongly than on the cut flower holding, but to a lesser extent so that the rose holding has developed from a relatively poor to a rather healthy financial glasshouse business.

### Table 16

<table>
<thead>
<tr>
<th>Materials/crop</th>
<th>6.06</th>
<th>6.17</th>
<th>6.97</th>
<th>3.99</th>
<th>4.27</th>
<th>4.74</th>
<th>5.14</th>
<th>5.08</th>
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<td>energy</td>
<td>22.31</td>
<td>22.46</td>
<td>21.59</td>
<td>14.37</td>
<td>15.58</td>
<td>16.09</td>
<td>18.07</td>
<td>18.00</td>
<td>19.63</td>
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<td>8.05</td>
<td>8.85</td>
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<td>7.79</td>
<td>7.77</td>
<td>8.09</td>
<td>7.96</td>
<td>8.25</td>
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<td>labour</td>
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<td>35.75</td>
<td>37.01</td>
<td>27.86</td>
<td>29.84</td>
<td>32.50</td>
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<td>Interest</td>
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<td>6.57</td>
<td>6.87</td>
<td>12.37</td>
<td>11.70</td>
<td>10.64</td>
<td>10.66</td>
<td>9.18</td>
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<td>other</td>
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<td>11.71</td>
<td>5.92</td>
<td>7.37</td>
<td>7.80</td>
<td>8.95</td>
<td>10.20</td>
<td>9.79</td>
<td>10.35</td>
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</table>

### Index numbers

<table>
<thead>
<tr>
<th>Source: LTB Adviseurs en Accountants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comment: to 1991 the tax costs of interest and depreciation are mentioned. Subsequently these are business-economically-calculated costs</td>
</tr>
</tbody>
</table>

### Despite the change-over to substrate and lighting the business results showed a declining trend and became slightly negative between 1992 and 1997. It should be noted here that the change-over of the fiscal to the business-economic calculation of the interest and depreciation doubled the interest costs in 1992 as compared to 1991, from Dfl 6.87 to Dfl 12.37. This is an ongoing effect after 1992 of counting in the interest on one’s own property as costs for the business. If one takes this difference into account, the business result appears to have been reasonably stable during a decade. The developments on rose nurseries are rather different from those on the average cut flower nursery. This is clear from the comparison of the business results of the cut flower nurseries in the LEI accountancy with the results of the rose nurseries that are part of these (Table 16). Yields per m$^2$ glasshouse have increased much more strongly on rose nurseries than on cut flower nurseries. In 1988/1989 the rose nursery realised a monetary yield of about Dfl 75.00 per m$^2$, a reasonable average for cut flower nurseries, in 1995/1996 the yield has risen to more than Dfl 100,-- which is more than Dfl 15.00 above the average for all cut flower enterprises. On the other hand, the costs also have risen more strongly than on the cut flower holding, but to a lesser extent so that the rose holding has developed from a relatively poor to a rather healthy financial glasshouse business.
Table 16. Differences in yields, costs, and business results between rose and cut flower nurseries during the last decade

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Differences in results (Dfl/m²)</td>
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</tr>
<tr>
<td>Total yields</td>
<td>-0.27</td>
<td>5.51</td>
<td>8.64</td>
<td>10.10</td>
<td>9.49</td>
<td>11.01</td>
<td>9.63</td>
<td>13.94</td>
<td>19.16</td>
</tr>
<tr>
<td>Total costs</td>
<td>2.15</td>
<td>8.83</td>
<td>12.93</td>
<td>9.70</td>
<td>7.31</td>
<td>11.12</td>
<td>16.69</td>
<td>10.67</td>
<td>14.62</td>
</tr>
<tr>
<td>Net business result</td>
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<td>-3.32</td>
<td>-4.29</td>
<td>0.40</td>
<td>2.18</td>
<td>-0.11</td>
<td>-7.07</td>
<td>3.27</td>
<td>4.54</td>
</tr>
<tr>
<td>Item per Dfl 100.00 costs</td>
<td>-3.33</td>
<td>-3.30</td>
<td>-3.59</td>
<td>0.84</td>
<td>2.99</td>
<td>-0.71</td>
<td>-5.85</td>
<td>4.64</td>
<td>4.81</td>
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</table>

Assimilation lighting not real reason for improvement of results

In 1994 LTB Consultants and Accountants together with the Research Station for Floriculture and Glasshouse Vegetables investigated the causes of the difference in net business result among 54 rose nurseries. The investigation mainly concerned nurseries with sweet heart varieties. Although in the past the differences in net business result were almost entirely explained by the differences in yield per m², for this group of nurseries this appeared to be only 49%. The cause of the yield difference could be divided into production differences (17%), production and price difference as a result of variety choice (27%) and difference in realised average price for the same variety (10%). A second, important cause for the difference in net business result are the cost differences between nurseries (40%), almost entirely costs related to assimilation lighting. The extent of assimilation lighting had great consequences for both yield and cost level, but it hardly affected the net business result. In previous years the assimilation lighting positively affected the realised average price, in 1994 this was no longer the case.

Effect of scale is limited

The effect of the holding size on the net business result is limited. The advantages of a greater nursery are a relatively lower labour requirement, in which the number of regular staff is determined by the number of roses to be processed. The area of the nursery is not so important. In addition to the necessary labour for harvesting and processing, one man-year is required (the entrepreneur), irrespective of the holding size. Particularly on small nurseries this leads to a disproportionally heavy and expensive labour requirement. More about the factor labour in section 3.1.
3. DUTCH ROSE NURSERY

The vast majority of Dutch glasshouse rose nurseries are specialized holdings with a glasshouse of ca 1 ha. A small part of the rose cultivation takes place as secondary crop alongside pot plants, forced shrubs or summer flowers. Growing roses in Northern Europe requires high investments in glasshouses, lighting equipment, CO₂ supply and processing machinery. Increasingly investments are necessary in environmental measures, to prevent the emission of nutrients and pesticides and to reduce gas consumption. Rose cultivation is labour intensive and characterized by a considerable heat requirement and energy consumption, particularly during winter. Energy is used for heating, lighting and CO₂ supply. The acreages under assimilation lighting and on substrate in the Netherlands have already increased to 527 ha (78%) and 516 ha (76%), respectively. The latter data relate to 2001. There are no unambiguous figures on the intensity of the lighting used on Dutch holdings. Until the early 1990s mostly 35-50 μmol/m² (3,000-4,000 lux) was used, later growers occasionally tended to increase the intensity to 70-120 μmol/m² (7,000-10,000 lux). Also, only estimates are known of the growing media used. The major part of the area on substrate consists of rockwool, followed by cocopeat. The share of cocopeat is under pressure, although it is cost-effective and growers are enthusiastic about the rapid growth on this substrate. Growing on clay granules has almost completely disappeared, while perlite and pumice are slowly expanding.

3.1 AREA AND LABOUR REQUIREMENT

Area

The average holding size of rose nurseries has increased in recent years. In 1997 the average holding size was slightly over 1 ha. If the current trend continues, nurseries with an average size of 1 ha will become increasingly frequent in the coming years. According to Central Bureau of Statistics (CBS) figures, the areas between 7,500 and 15,000 m² contain almost 40% of the nurseries (table 17). Growers were asked in a Flower Board-enquiry about the future of their nursery in the coming five years. The results are given in Table 18, and are subdivided into expansion, no expansion, and the motivation. In general growers appear to have a negative view of the future of their nursery.

A modern nursery has a width of 120 m or more, with a path in the middle, as the advent of appliances resulted in increasing width. The ideal glasshouse/plot shape is square. All sections into which the nursery is subdivided are then also rectangular. New nurseries are often divided into four or eight control sections for ventilating, heating and screening. The number of sections depends on the exact nursery size, the number of varieties to be grown and the different times of planting for crop replacement. Dividing walls are usually no longer present. Due to the square shape of the holding, operating can be efficient and labour can be saved, thanks to short distances without obstacles. An unfavourable nursery width (for example less than 50 m), may result in a gas consumption which is sometimes 2 m³/ m²/year higher than that of a nursery with a width of more than 100 m. These are annual costs, caused by the many walls with heat loss and, in addition, climate control is often more difficult and the glasshouse climate is unfavourable. To prevent this, extra investments are necessary.
Table 17. Classification of rose nurseries on the basis of nursery size (source: CBS)

<table>
<thead>
<tr>
<th>Nursery size in class</th>
<th>Number of nurseries CBS 1997</th>
<th>Number of nurseries in % CBS 97</th>
<th>Area in ha 1997</th>
<th>Area in % 1997</th>
<th>Number of nurseries CBS 1998</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-1,000 m²</td>
<td>26</td>
<td>3.0</td>
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</tr>
<tr>
<td>1,000-2,500 m²</td>
<td>46</td>
<td>5.3</td>
<td>8</td>
<td>0.9</td>
<td>40</td>
</tr>
<tr>
<td>2,500-5,000 m²</td>
<td>115</td>
<td>13.3</td>
<td>41</td>
<td>4.5</td>
<td>104</td>
</tr>
<tr>
<td>5,000-7,500 m²</td>
<td>152</td>
<td>17.6</td>
<td>93</td>
<td>10.3</td>
<td>138</td>
</tr>
<tr>
<td>7,500-10,000 m²</td>
<td>150</td>
<td>17.4</td>
<td>129</td>
<td>14.2</td>
<td>142</td>
</tr>
<tr>
<td>10,000-15,000 m²</td>
<td>190</td>
<td>22.0</td>
<td>228</td>
<td>25.2</td>
<td>186</td>
</tr>
<tr>
<td>15,000-20,000 m²</td>
<td>91</td>
<td>10.6</td>
<td>153</td>
<td>16.9</td>
<td>97</td>
</tr>
<tr>
<td>20,000-30,000 m²</td>
<td>71</td>
<td>8.2</td>
<td>166</td>
<td>18.3</td>
<td>80</td>
</tr>
<tr>
<td>&gt;30,000 m²</td>
<td>21</td>
<td>2.4</td>
<td>87</td>
<td>9.6</td>
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</tr>
<tr>
<td>Total</td>
<td>862</td>
<td>100</td>
<td>906</td>
<td>100</td>
<td>843</td>
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</table>

Table 18. Results of enquiry ‘Future of rose nurseries’

<table>
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<tr>
<th>Expansion</th>
<th>No expansion</th>
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<tbody>
<tr>
<td>17% of the growers</td>
<td>83% of the growers</td>
</tr>
<tr>
<td>1. Scale size advantages</td>
<td>1. No space available</td>
</tr>
<tr>
<td>2. Favourable market developments</td>
<td>2. Low profitability</td>
</tr>
<tr>
<td>4. Technological developments</td>
<td>4. Poor prices</td>
</tr>
<tr>
<td>5. Switch over</td>
<td>5. Too much import</td>
</tr>
</tbody>
</table>

Labour requirement

Labour costs are the most substantial costs in the cultivation of roses in Holland. Labour research at the Research Station Naaldwijk pointed out that the labour requirement, depending on variety and growing method, may amount to ca 1,25 to 2 h per m²/year. At an average hourly wage of Dfl 31,00 this means that the labour costs fluctuate between Dfl 40,- and 60,- per m²/year. The LTB comparison, however, gives lower figures. It is clear, that the share of labour costs has been reasonably stable throughout the years. For almost a decade the labour costs are a little above 30% of the turnover. The labour requirement is determined basically by the production. Of the total labour hours more than 90% is directly related to the production (harvesting, grading, disbudding). Due to the large production differences between hybrid tea and sweet heart varieties the variations in labour are large. The labour for hybrid tea varieties (such as First Red) is about 1.15 hour per m², while sweet heart types require almost 2 hours of labour per m². See Tables 19 and 20 (source: T. Hendrix, PBG Naaldwijk).

More information on both harvesting and grading is presented in sections 3.2.4 and 3.3. Research in 1994 indicated that per sweet heart stem as much labour is necessary on large nurseries as on small nurseries. On nurseries with sweet heart roses the relation between the number of full-time jobs and the production appeared to be strong. For hybrid tea roses the amount of labour appeared to increase more than proportionally when total production increases. There appeared to be no question of suboptimal
production. For nurseries with the highest production the additional yield due to higher production appeared to compensate amply for the extra labour costs.

### Table 19. Labour hours per 1000 m² First Red

<table>
<thead>
<tr>
<th>Action</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>Total</th>
<th>% in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>St/m²</td>
<td>8</td>
<td>8</td>
<td>11</td>
<td>13</td>
<td></td>
<td></td>
<td>15</td>
<td>17</td>
<td>18</td>
<td>20</td>
<td>20</td>
<td>18</td>
<td>14</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>% waste</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>8</td>
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<td>6</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>St + waste</td>
<td>8.1</td>
<td>8.2</td>
<td>11.3</td>
<td>13.5</td>
<td>15.9</td>
<td>18.4</td>
<td>19.8</td>
<td>21.6</td>
<td>21.2</td>
<td>18.7</td>
<td>14.4</td>
<td>11.2</td>
<td>9.1</td>
<td>91</td>
<td>63</td>
</tr>
<tr>
<td>St/ha</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.38</td>
<td>0.38</td>
<td>0.44</td>
<td>0.47</td>
<td>0.51</td>
<td>0.51</td>
<td>0.45</td>
<td>0.52</td>
<td>0.4</td>
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<td>0.33</td>
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<tr>
<td>Task. ha.</td>
<td>22</td>
<td>23</td>
<td>19.6</td>
<td>19.8</td>
<td>20</td>
<td>21</td>
<td>21</td>
<td>18.6</td>
<td>18.2</td>
<td>19</td>
<td>17.7</td>
<td>19.4</td>
<td>22</td>
<td>213.7</td>
<td></td>
</tr>
<tr>
<td>Hours ha.</td>
<td>29.6</td>
<td>31.3</td>
<td>37</td>
<td>44.6</td>
<td>53</td>
<td>64.3</td>
<td>68.3</td>
<td>67</td>
<td>64.3</td>
<td>59.3</td>
<td>42.5</td>
<td>36.3</td>
<td>33.3</td>
<td>632</td>
<td>55</td>
</tr>
<tr>
<td>H.</td>
<td>9</td>
<td>8.1</td>
<td>12.7</td>
<td>15.1</td>
<td>17.8</td>
<td>20.5</td>
<td>22.1</td>
<td>24.1</td>
<td>23.7</td>
<td>20.9</td>
<td>16.1</td>
<td>12.5</td>
<td>10.2</td>
<td>213.7</td>
<td>19</td>
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<tr>
<td>H.</td>
<td>8.8</td>
<td>8.8</td>
<td>12.3</td>
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<td>H.</td>
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<td>81</td>
<td>66</td>
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st = stems; ha. = harvest; task. = task time; h. = hours; grad. = grading; disbud = disbudding; cr.h. = crop husbandry; tot. = total; gl. = growing labour

### Table 20. Labour hours per 1,000 m²; Frisco, multi-year crop

<table>
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<tr>
<th>Action</th>
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<th>4</th>
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<th>11</th>
<th>12</th>
<th>13</th>
<th>Total</th>
<th>% in %</th>
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</thead>
<tbody>
<tr>
<td>St/m²</td>
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<td>25</td>
<td>26</td>
<td>34</td>
<td>46</td>
<td>46</td>
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<td>28</td>
<td>24</td>
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<tr>
<td>% waste</td>
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<tr>
<td>St + waste</td>
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<td>29</td>
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<tr>
<td>St/ha</td>
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<td>0.1</td>
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<td>1.3</td>
<td>1.7</td>
<td>1.8</td>
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<td>14.1</td>
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<tr>
<td>H.</td>
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<td>175</td>
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<td>197</td>
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<td>189</td>
<td>169</td>
<td>150</td>
<td>113</td>
<td>103</td>
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</tbody>
</table>

Table hours per 1,000 m²; Frisco, 2-year crop

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<td>St/m²</td>
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<tr>
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<td>0.1</td>
<td>1</td>
<td>1.3</td>
<td>1.7</td>
<td>1.8</td>
<td>2</td>
<td>1.9</td>
<td>2</td>
<td>1.8</td>
<td>1.4</td>
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<td>128</td>
<td>97</td>
<td>88</td>
<td>1881</td>
<td></td>
</tr>
</tbody>
</table>

**Abbreviations:** see Table 19

If the costs per 100 roses decline, while the business size is increasing it is due to economy of scale. For roses the number of full-time labour force per total number of
produced roses is a measure of the scale effects. For sweet heart roses the number of full-time workers per million produced roses is on average 2 (average production per nursery 3.4 million stems). A production of 9 million stems results in 1.8 full-time workers. The cause of this small difference is the constant percentage of labour irrespective of the total production. As a result, for sweet heart roses there is hardly any or no scale effect.

The conclusion might be that there are still only very few labour-saving techniques in use or that the technology (for example a bunching machine) is insufficiently utilized. For hybrid tea roses the number of full-time jobs per million produced roses decreases from 5.1 at a production of 0.9 million stems to 2.4 at a production of 5 million stems. At 7.2 million stems again 2.8 full-time workers are needed per million stems. For hybrid tea roses the turning point for the number of full-time workers per million stems seems to be at a production of 4.5 million stems. Below this line there are scale advantages, above it the labour per million stems increases again.

3.2 GLASSHOUSE EQUIPMENT

3.2.1 Glasshouse

In principle, roses can be grown in all types of glasshouses, and the general principles are also valid for rose production. A good glasshouse has a maximum light transmission, while a free space above the crop (> 2m) results in a more equal glasshouse climate. Increasingly, glasshouses tend to get higher, wider and stronger. In the Netherlands the glasshouse cover normally consists of glass, although recently acrylate sheets also occur. The disadvantage of these glasshouses is that some UV-b light is let through, which results in increasing blackening of the flowers of red varieties. Generally speaking the following glasshouse types are in use in The Netherlands:

- **Venlo-type.** Traditionally Venlo glasshouses have a span width of 3.20 m. The usual 6.40 trellis girder is being replaced more and more by an 8 m trellis girder composed of 2 spans of 4 m. The glasshouses have a gutter height of 4 to 4.5 m. As a result the air capacity has increased in such a way that it is comparable to that of the wide-span glasshouse, with advantages for the climate control.

- **Wide-span glasshouse.** Wide-span glasshouses of various proportions (6.4 m, 8 m, 9.6 m, 12.8 m, 16 m or 18 m) have climatic advantages when compared to the ‘old’ Venlo-type, due to the larger volume and the corresponding, more stable climate control. In addition they often have roof ventilation with a larger ventilating capacity. Moreover, insect netting can be mounted more easily in this through-roof ventilation. Wide-span glasshouses continually being improved. The building costs are being reduced and the light transmission improved. Still, wide-span glasshouses occur mainly in the region of Aalsmeer, while in the rest of the country mostly the Venlo-type is used.

By using wider glass the section area of the Venlo-trellis girder glasshouses increased to 4 m with 3.20 m bays and to 4.5 m with 4 m bays. Occasionally even glass with a width of 112.2 to 150 cm is used for the glasshouse cover.

The roof-slope is a significant aspect with respect to light transmission and the pollution of the glasshouse cover. Roof-slope with a 8 m trellis girder is 23.8°, with other types 22°. The slope of the glasshouse roof of several wide-span glasshouses has been reduced from 27° to 22°.
The ventilation of Venlo glasshouses is done with 2 or 3 ventilation windows. These are 1.04 or 1.20 m deep, respectively. They are usually opened with a rib-rail mechanism.

In wide-span glasshouses the roof ventilation is opened mostly with a rack drive system.

Many different forces may affect the glasshouse construction, i.e. wind, snow load, the weight of the construction and the equipment. These forces must be intercepted and led to a fixed point (ground). For this purpose various techniques are available, such as trusses and shores. The construction has to meet certain standards. This may be NEN 3859 (horticultural glasshouses) or NEN 3851 (building constructions). If a glasshouse does not meet these standards, it can not be insured.

**Screening**

In rose cultivation screening is mainly used to optimize the glasshouse climate in summer and to save energy in winter during cold nights (outside temperature below 8-10°C). In Dutch floriculture screening installations are used on 75% of the nurseries. After the drop in gas prices in 1985 and 1986, the screening installations present are no longer used to obtain maximum energy savings. Within the framework of the Multi-Year Agreement on Energy (see section 3.4) renewed possibilities for the screening applications are being investigated.

There are various types of screening fabric available, the choice depending on the purpose for which it is used. For energy saving, close-weave fabric is used with low light transmission. When the same screen is used in summer as awning, this type of screen cannot be closed too far, because the temperature may then rise too much. Screening during periods with high irradiation may improve the flower colour and may help avoiding large transitions. This prevents some varieties (particularly red ones) from flower bud problems (edges).

The use of a mobile screen has an advantage when compared to lime-shading the glasshouse roof, because it offers more flexibility. On the other hand, lime shading keeps the heat outside the glasshouse.

The choice of a type of screen, the type of drive and the way in which the screen is fitted into the glasshouse determine how large the screening package will be in folded condition. This manual does not go into great technical detail. For this, one should apply to the installers.

Assimilation lighting in The Netherlands has been subject to limiting measures with respect to the light emission, as a result of actions of neighbouring growers and environmental pressure groups. Indirect lighting may have adverse effects on crops in adjacent glasshouses. Side-wall screens are on the whole adequate to prevent this. Since assimilation lighting is regarded by part of the population as unnatural light and landscape pollution, legal measures have come into force compelling growers not to cause any light emission between 20.00 and 24.00 h. If growers still want to light during this period they have to apply overhead screening, limiting the emission. Temperature and air humidity are supposed to increase under a closed screen, resulting in problems. Research at the Aalsmeer Research Station pointed out that with the help of an overhead screen (LS obscura black/white) in which 2.5% of the strips are omitted, resulting in a fabric with narrow chinks, light emission through the glasshouse roof is 4 to 5% of the light intensity inside the glasshouse. With an overhead screen, light emission can almost entirely be avoided. The reflection of the white underside of the screening fabric results in an even greater light intensity inside, a light gain of
approximately 4%. The experimental results did not indicate any production differences as a result of screening. Research further pointed out that when the screens are closed during high outside temperatures, the glasshouse temperature may be 4 to 5 degrees higher than in an unscreened compartment, despite ample ventilation. In principle, these temperatures could be compensated for in the early night or during daytime, so that negative quality effects were avoided. The effect on the air humidity appeared to be limited. Closing the screen at an outside temperature below 10°C resulted in energy saving. At higher outside temperatures the heating boiler may even be switched off and the heat released by the lamps and the heat/power cogeneration is sufficient for heating all glasshouse compartments. Installing and using an overhead screen adversely influenced the business result. The interest and depreciation of the investment (between Dfl 150,000 and 180,000 per ha) and the yield loss as a result of shadow effects of the installation are greater than the advantage of the lower energy costs. The annual business result was negatively affected between Dfl 20,000 and 47,000 per ha. In existing glasshouses often adjustments are necessary to be able to install the screens, resulting in an additional, non-recurrent loss of Dfl 20,000 to 50,000 per ha. The costs of installing the screen must be set off against the output of extra hours of lighting. Whether this output will be negative or positive will differ from situation to situation.

**CO₂ distribution and production**

CO₂ supply in rose cultivation, to boost yield and quality, is becoming more and more common and should be a standard cultivation measure. The plant physiological consequences of the use of CO₂ are discussed in detail in section 7.5.

**CO₂ distribution**

In order to provide the entire glasshouse adequately with CO₂ the system should be geared to an even distribution throughout the entire crop. Distribution should take place by diffusion and current. The best way to benefit from CO₂, even under otherwise unfavourable circumstances, is by installing tubes in the bed, under the crop. One of the drawbacks of overhead distribution of CO₂ through a distributing conduit up in the glasshouse, is that the major part of the CO₂ disappears through the ventilation windows, when they are opened, together with the upward heat flow, without having been useful to the plants.

In the central supply of CO₂ a fan forces the CO₂ into the glasshouse through a large, usually plastic duct. When flue gases are used a greater or lesser amount of air can be mixed through to obtain the desired concentration. For a proper distribution calculations should be made of tube diameters, fan size, perforation distance in the tubes and the size of the tubes.

The central duct is equipped with flow apertures, to which the distributing conduits (tube, PVC-pipe or tubylene pipe) are connected, one for each bed. Standard practice is one hole of 0.8 mm diameter on every 100 cm of tube. If this standard distance is combined with a distance of, for example, 60 cm in other tubes, the distribution of CO₂ becomes uneven. Apart from the standard tube of 40 mm diameter, there is also a larger tube of 60 mm available, which has the advantage of a lower pressure loss. In addition, tubes are available with suspension facilities. These tubes can be suspended on a slope, so that the condensation water can run away. Condensation develops due to the cooling down of the flue gases. For each m³ of gas roughly 0.4 l water is released. It is important to discharge this water properly. When the conduits and the tubes contain much water this gives a bubbling noise and may result in blockage of the
conduits. This leads to large pressure differences in the system, and wide fluctuations in CO₂ concentrations.

An oversized fan gives excessive pressure, resulting in an increasing resistance in the conduits. As a consequence the pressure differences increase. A fan that is too small builds up too little pressure, so that at the end of the distributing conduits the pressure is much too low. The pressure can be corrected with the help of so-called throttle plates. Occasionally, when the system is being installed, the wrong plates or no plates at all are mounted. At the beginning of the distributing conduit the pressure is higher than at the end. Therefore the throttle plates have a smaller diameter at the beginning. Once installed the tubes tend to be forgotten. Fallen leaves, condensation water etc. may give rise to large pressure differences. By measuring the system, or having it measured, great improvements can be obtained. Measuring is done with U-tubes, so that the pressure is equal everywhere. However, differences between CO₂ –meters may occur. Calibration may lead to improvements.

CO₂ production
The price for pure CO₂ is too high for many nurseries, if compared with boiler flue gas. It may be worthwhile, however, to investigate whether the costs counterbalance the purchase of heat storage and a flue gas purifier. In any case when using pure CO₂ no heat surplus is being built up, because no burning takes place. Rose growers with assimilation lighting, generating their own energy for lighting often have a surplus of heat that they cannot utilize immediately. A solution for this heat surplus might be storage in a tank, or for example supply to an adjacent nursery growing vegetables that does not have a heat surplus.

The grower himself can produce CO₂ by burning natural gas. Burning 1 m³ of gas releases 1.8 kg CO₂. On this basis the price per kg CO₂ can be calculated and compared it to the use of pure CO₂. CO₂ can also be generated with hot air (CO₂) heaters. The drawback of this system is that such heaters produce shadow and the adjustment should be monitored closely, because insufficient burning may lead to damage. In addition the distribution of the CO₂ is less even.

Heat produced by burning gas by day for CO₂ application can be stored in a tank and used later. On a rose nursery a heat buffer of 80 to 100 m³ per ha is necessary. This capacity is sufficient but soon appears to be too small when the nursery is expanding.

Carbon dioxide can also be obtained from flue gases released by the use of heat/power cogeneration. These gases should be purified first. In principle there are currently 3 ways of purification, which occasionally have teething troubles. As yet, the flue gas purifier is not generally applied. Before purchasing such equipment, it should be taken into account that:
- such an installation is only profitable when CO₂ is applied frequently
- a combination with heat storage is obligatory
- mostly more flue gases have to be moved due to the lower CO concentration in the flue gases than in the boiler flue gas (heavier equipment)
- the flue gases must be cooled properly (moisture problems)
- mains connection is obligatory for the redelivery of energy
Heating

The heating system has to meet certain general requirements so that under certain (extreme) circumstances a minimum glasshouse temperature can be maintained. For heat generation a cylindrical three draught flame tube is mostly used. Other heat sources are for example the assimilation lighting, heat from the heat storage and heat from the heat/power cogeneration.

The most frequently used heat distribution system is the well-known Tichelmann system. In every spiral the hot water covers the same distance and the amount of water per spiral is equal. The water in the return pipe runs in the same direction as the water in the supply distribution pipe. The distribution of the water over the pipes is virtually ideal and the heat emission is the same everywhere.

In Dutch rose glasshouses normally at least 8 heating pipes (diameter 51 mm) are installed per 6.40 m glasshouse span. The pipes are mostly positioned near the soil so that good heat circulation in the crop is guaranteed (to avoid humidity problems); they are sometimes also used for the internal transport systems (so-called pipe-rail system) in the paths. Occasionally the overhead heating is left out altogether although the risk is that with insufficient heating flower buds become wet, resulting in Botrytis problems. Generally, therefore, the heating system is divided into an upper and a lower network. Mostly the lower network is the primary network. The crop can thus be heated with water from the boiler condenser, heat/power cogeneration and heat storage. The condenser is mostly connected to the upper network, or to a separate lower network for low-level heat. When the heat demand increases the overhead network can gradually be switched on. The overhead network can also be used for transport purposes (monorail).

Assimilation lighting

Particularly during the winter season assimilation lighting is used increasingly in rose cultivation to stimulate the photosynthesis and to increase production and quality of the stems. Physiological consequences of the use of assimilation lighting are discussed in section 7.4.

The application of lighting in Dutch rose growing is still on the rise. Not only the area equipped with lighting is still growing, but also the installed capacity. Until recently, in most cases 400 Watt lamps were used. The most common supplier of lamps for the rose grower is still Philips. Other suppliers try to get a share of the market (General Electric, Osram, Sylvania). Various experiments have been carried out with the different lamps. The differences appeared to be only small and of no significance to the crop. As the use of lighting increased growers became more interested in the 600 Watt lamp. For the same light level less lamps have to be installed, resulting in lower costs for the fittings and reduced shading by the fittings. The lamps deliver 9% more lumen/W. The energetic value of the 600 Watt lamp is 10% higher. A 400 Watt lamp gives 55,000 lumen, the 600 Watt lamps 90,000 lumen (Dutch figures). The normal period for the application of assimilation lighting is between 1 September and 1 May. Outside this period the lamps are switched on in dark periods only. The lamps burn during the night and are switched on and off at certain global radiation levels which vary per grower. In general terms the limit is set at a value of 100 to 200 Watt/m² outside global radiation. This means that during the winter the lamps are usually also switched on during the day.

The lamps of the assimilation lighting can be placed in different fittings and the fittings increase the profitability of the lamps. Use of aluminium reflectors results in a diffuse light pattern. There are various suppliers of fittings: Philips, Poot, and Industria are the
most common for rose growers. The various fittings are suitable for 400 or 600 Watt lamps and can be equipped with different reflectors. So-called dome reflectors (with a radiation angle of 55°) have a square light beam. These lamps should be positioned sufficiently high above the crop. A 600 Watt lamp in a dome reflector should be 250 to 280 cm above the crop. For super wide-beam lights (radiation angle 75°) a distance of 0.90 to 1.20 m is sufficient. Normally a wide-beam light is up to 250 cm above the crop.

To obtain a uniform growth the lamplight should be distributed as evenly as possible. To this purpose installers have programmes available which take the requirements of crops and glasshouse in which the lamps will be hung, into account and consultants make calculations for growers. The Dutch consultancy organization DLV carries out a so-called matrix calculation in which the precondition Emin/Emax > 80% should be met. The number of fittings depends on the desired light level and the type of lamp used. The various possibilities, the costs, the capacity per fitting, the light yield and the light distribution must be considered.

A good cable network should be installed and the voltage losses checked (more than 2% is unacceptable). Voltage losses reduce the light yield of the lamp. With a 400 Watt lamp a voltage loss of 1% gives 3% light loss and with a 600 Watt lamp 5% light loss! Of the lamp capacity 85 to 90% is ultimately converted into heat. As a result, the lighting also heats the glasshouse. Up to 8,000 lux (about 80 μmol/m²/s installed capacity), the released heat can be usefully applied. When a grower generates his own energy with the help of a heat/power cogenerator, 3 times as much heat is available. When this is used in the glasshouse it limits the possibilities to realise the desired CO₂ concentration. Heat storage increases both the energy utilization and the possibilities for realising a higher CO₂ level. The combination of heat/power cogeneration with heat storage results in gas saving and more CO₂ (see also the section on CO₂).

**Sulphur evaporators**

For the preventive control of mildew, electric sulphur evaporators can be used. In the trays, sulphur is molten and evaporated. The vapour spreads throughout the glasshouse and lands on the upper side of the leaves. With respect to installation and maintenance the following points should be considered:

- Limit voltage loss between the various evaporators; equal voltage gives equal heat development and even evaporation of sulphur.
- Vertical suspension stimulates the ventilation and the distribution. For each 100 m² apply one 100 Watt sulphur evaporator. For rose growing there are no clear research results indicating the number of evaporators per area.
- Two or 3 applications per week are mostly sufficient.
- Take care of the proper adjustment of the air slide and the distance between the sulphur trays and the heat source.
- Make sure that the trays are properly filled.

Incorrect application may lead to a short circuit and in combination with plastic materials in a modern glasshouse this could cause fire with extensive damage. An alternative for the sulphur evaporators is the sulphur gun. One application per week is sufficient.

In 1997 the Research Station in Naaldwijk investigated the application of the evaporators in sweet pepper and tomato crops. The recommendation from research is to evaporate sulphur for 8 hours with one evaporator per 1,000 m², which is distinctly less than in rose cultivation; perhaps the application in rose needs to be adjusted.
Evaporating sulphur was not acutely toxic for the predatory mite *Amblyseius degenerans*, but frequent evaporation hindered the colonisation of the crop.

3.2.2 Growing systems

Growing in soil

In general, soil-grown crops are grown on 3 beds per 6.40 m glasshouse width. The beds have become wider due to improved surface utilization and efficiency of labour (max. bed width of 143 cm). Table 21 gives some examples of bed widths and space utilization with various glasshouse proportions based on a path width of 70 cm.

Table 21. Bed width and space utilization with various glasshouse proportions

<table>
<thead>
<tr>
<th>Glasshouse lay-out</th>
<th>Approx. bed width</th>
<th>Space utilization in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 beds/3.20 m</td>
<td>100 cm</td>
<td>62.5</td>
</tr>
<tr>
<td>4 beds/8.00 m</td>
<td>140 cm</td>
<td>70</td>
</tr>
<tr>
<td>3 beds/6.40 m</td>
<td>143 cm</td>
<td>67.5</td>
</tr>
</tbody>
</table>

Using wider beds results in improved space utilization. Research showed that production and flower weight are higher. It is important to investigate the possibilities of each nursery, taking the assortment, the expected crop structure and the thorniness and stem length of the variety into account. These factors could negatively affect harvest labour with wide beds. A labour advantage arises when, with wide beds, a path is left out (reduced walking distance per m² glasshouse).

A good distribution of the plants on the bed is important, particularly in the first year, as leaves, ground shoots and scion wood are less frequently in each other’s way, while the available space is utilized optimally. 4 rows of plants per bed are mostly planted. For a good distribution on the bed the plants are placed in triangular arrangement.

Table 22. Distance between the rows with various bed widths

<table>
<thead>
<tr>
<th>Width of bed + path</th>
<th>Number of rows</th>
<th>Distance between rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.60 m</td>
<td>3</td>
<td>33 cm</td>
</tr>
<tr>
<td>2.00 m</td>
<td>4</td>
<td>32 cm</td>
</tr>
<tr>
<td>2.13 m</td>
<td>4</td>
<td>36 cm</td>
</tr>
</tbody>
</table>

The desired plant distance in the row for a soil grown crop can be calculated with the following formula:

\[
\text{Rows per bed} \times 100 \quad \text{plants per gross m}^2 \times (\text{bed + path width})
\]

For example: bed + path width is 213 cm
Number of rows per bed is 4
Desired plant density is 8 plants per gross m²

\[
\frac{4}{8 \times 2.13} \times 100 = 23.5 \text{ plant distance}
\]
Growing in substrate

There have been considerable developments in substrates and growing systems in recent years. At the start of substrate growing the substrate was placed on the soil in rows with the same number of rows as in soil-grown crop. Also the number of plants per m² remained about the same. More information on plants densities is given in 6.1.

To save on water and nutrients and due to critical environmental measures, gutter systems have been developed which were initially placed on a slope on the ground, and later were placed higher and higher. This development was also related to new cutting methods, in which crop build-up was less important. The low-growing bush could easily be grown in the heightened system in which bending was restricted. More information about the cutting methods is given in 6.2. The systems developed further under the influence of the selection of a certain substrate material (slabs, containers), the choice of certain young plants (often related again to the choice of substrate), and the selection of a certain type of rose or variety. All in all, a wide range of systems has developed in the course of the years.

The number of plant rows is being discussed in relation to substrate growing. In global terms 3 to 4 beds per 6.40 or 8.00 m are placed and the number of rows per bed varies from 2 to 4. The lowest number (2 rows of plants per bed) is a development of recent years, as the effect of bending out the stems and the harvest method on short pieces of wood require a good overview of the plant.

Almost all systems currently in use are heightened. As a result, the air can circulate through the crop and the glasshouse climate is improved. After bending in the leaves are not on the ground, so that they are not smashed by being trodden upon and there is a better microclimate as a result of improved air circulation under the leaves.

In a system with 2 rows of plants per bed (so-called 2-row system) the distribution of the plants is less efficient than in systems with more rows per bed because the plant distance within the row is smaller. For low productive (often hybrid tea) varieties this is less relevant than for the sweet heart varieties with a high production. More shoots mean more problems with cutting and more competition for light (quality loss). There are possibilities to vary the distance between the 2 rows:

1. For varieties for which the heavy stems have to be bent it is usually better to bend the stems inwards so that treading damage remains limited. The space between the rows is then greater. For bending inwards the grower must lean over the crop or with the arms through the upright branches, which may also lead to damage.

2. When all branches are bent outwards the two rows can be closer together and there is more room in the path for bending. The distribution of the bent shoots is worse and the risk of bending over one another is greater. The 2 situations described above are presented in Figures 2 and 3.

In the two-row system there is sometimes the tendency to use less growing medium per m². This is at the expense of the water buffer per m². Standard practice is a substrate volume of 21 l per m². A two-row system with 4 beds per 6.40 m means 30% more path when compared to other systems, which increases the risk of treading damage. As compared to 3 beds per 6.40 m, however, there is a better light distribution in the crop.
A system with 4 rows of plants per bed is mostly laid out with 3 beds per glasshouse span of 6.40 m. The leaf and shoot distribution are good if sufficient room is left between the middle rows. Bending is often more difficult in a 4-row system, because one has to look more for an open space to bend the stems into. The 4-row system is also placed on the ground without elevation. By building up a crop first, it is possible to distribute the cutting points evenly over the bed and still maintain sufficient air circulation under the plants. Spider mite control may sometimes be difficult in a 4-row system. Particularly in the centre of the bed the crop may be harder to penetrate. For optimal heat distribution in a 4-row system it may be favourable to have heating in the centre of the bed, and not only on the outer edges in the aisle. Actually the 4-row system is suitable for all varieties.

A system with 3 rows per bed is sometimes used when the growing medium is in a container (cocopeat, perlite). The criteria for the bed distribution are similar to those of the other systems. The drawback of a 3-row system is that the middle row is further away from the central path. Cutting and especially bending of this middle row may therefore be somewhat more difficult. In the container systems the substrate volume is often somewhat greater: 25 l per m². Since there are often 3 plants with 3 drippers per container the levelling of emission and evaporation differences is limited. In container systems attention should be paid to the drainage discharge. An open gutter, in the absence of heating among the crop, results in bad climate, and leaves and other debris accumulate in the gutters, so that the water must be filtered well. In addition it is more difficult to bend the shoot deeply. The plants should be placed near the edge so that bending does not need to be done over the container. In a system in which substrate and gutters are placed diagonally on the aisles the shoot distribution over the bed is very good. The light interception is optimal.
Figure 4. Transverse system. Root rot does not spread rapidly over the entire bed.

In this system a smaller percentage borders directly on the main path and damage by treading is minimal. Bending is more difficult because one has to look for an empty space where the stem can be placed. In the middle of the bed spider mite control may be difficult. Due to the heating under the bed the circulation and heat distribution are good. The substrate in this system is in small separate pieces. With a proper sterilization, infection of a root fungus will not spread rapidly through the bed.

Discharge of drainage water
In all substrates the highest moisture content is at the underside. The water accumulating there, the drainage water, has to be discharged because otherwise the substrate remains saturated for too long, which may result in root death (oxygen deficiency). When the substrate is in gutters, the water that drains away at the underside should be able to run away freely. Wrapped slabs should drain though slits in the plastic wrapping. Due to the slope of the gutters, the water can run away. An adequate sideways slope in the gutter is about 1 cm.

Various gutter systems are available, made of different materials. When choosing a gutter attention should be paid to fitting in the existing system, possibilities of re-use, possible costs of discharge and durability of the gutter. Gutters should also be equipped with separate drainage water discharge. The roots growing out of the bottom of the substrate should not be allowed to grow into the drainage water discharge and cause blockages. This can be done by a covering plate, countersunk in the drainage gutter. Root tips that grow outside the slab dry out and die off before coming in the drainage water discharge. As a result the roots of the various slabs and plants do not make contact so that further infection of root rot can be prevented.

3.2.3 Water supply
In a soil crop water supply on the ground and overhead can be used. Overhead water supply is done with a sprinkler circuit. Nozzle distances and number of tubes depend on the number of beds. Overhead irrigation is not applied frequently anymore as growers want to keep their crop as dry as possible, due to the risk of Botrytis. Ground watering
can be done with conduits (irrigation) tubes or drip lines. Water supply systems with CNL drippers make short water supply periods possible also in the soil. After the water supply period they close and the dripper remains under pressure and does not leak. As a consequence fewer emission differences develop. This is an advantage as compared to tubes and conduits.

In growing media water supply can be done with spray pens, drip lines and irrigation tubes. In the Netherlands the system with the tubes is rarely used because growing media are almost never placed loose in the system. The drawback of spraying pens is that drops of water can come on the crop. When the leaves stay wet for some time problems like leaf drop and fungi such as Botrytis may occur.

Due to problems with other systems, drippers are most frequently applied in substrate grown rose crops.

Different types of drippers are available. Never stick the dripper too deep into the growing medium: blockage may otherwise occur due to moss and algae growth.

Both in soil and in substrate more water is supplied than can be evaporated by the crop. Apart from the fact that water is used for transpiration and growth, there is transpiration from the soil surface. Also water is needed for leaching to avoid accumulation of salts. In the glasshouse soil, groundwater level, soil type and the related capillary rise of the groundwater play a key role in the determination of the water supply (see also 4.3.4). The humidity of the soil can be determined with a soil sampling drill.

The most important factors for the degree of transpiration of roses is the amount of radiation intercepted by the crop, the effect of heating and the leaf mass of the crop. Application of assimilation lighting may lead to additional increase of water consumption. At a lighting period of 20 h with 3,500 lux (ca. 40 µmol) an extra consumption of 0.3 l/m² per day should be taken into account. With the application of mobile benches the water consumption is ca. 15-20% higher than in a crop without benches, due to the larger area grown, leading to increased leaf mass.

When roses are growing in a substrate it is possible to recirculate the surplus of water supplied and re-use it. This results in a considerable saving in the amount of water and fertilizers. More exact data are given in section 4.4.3.

When growing takes place in soil, it is more difficult to accurately determine the water supply and thus restrict the emission of water and fertilizers to the soil. The introduction of tensiometers was an improvement, because the tensiometer makes it possible to keep the soil at the correct humidity without much leaching out. Mostly one 'station' per glasshouse compartment is installed with 3 tensiometers at depths of 15, 35 and 55 cm (depths depending on soil type and the presence or absence of disturbing layers). Based on the suctions measured in the various layers water is supplied. The combination of tensiometer and drippers may lead to substantial savings in water. To determine the correct water supply strategy some experience is needed, so that all rootable layers are sufficiently moist. This is the case at a suction value between 10 and 30 hPa. A computer connection is necessary. The grower can then continuously make graphs and monitor the moisture condition.

To avoid leaching of fertilizers into the soil the fertilization should be adjusted. At several depths samples should be taken to determine the nutrient condition of the soil.
For water storage, storage tanks or a water reservoir are commonly used. In view of the total legislation with respect to environmental demands both substrate and soil growers should take the collection of rainwater, condensation water and recirculation water into account. For the storage of rainwater a capacity of 500 m$^3$ per ha glasshouse is obligatory. For a reservoir of 4,000 m$^3$ an area of 2300 m$^2$ is needed. The area needed depends on the depth of the reservoir, which is related to the type of soil and the groundwater level. If there is no room for a reservoir, storage tanks are used which need less space.

For soil grown crops surface water can be used at the start of the crop, provided the salt level is not too high. For substrate grown crops such water is not used, due to the grave consequences which certain infections (fungi, nematodes) from the water may have. There are various alternatives, such as spring water, rainwater, tap water and reverse osmosis water. In the composition of the accompanying fertilization the quality of the water should be taken into account (see 4.3.3).

3.2.4 Harvesting

Depending on variety and yield, about 55 to 65% of the labour is required for harvesting. With the exception of a short greenhouse span and lower yields (when the harvested stems can be easily carried in one’s arm) a trolley should be used for harvesting. The difference in labour requirement between a monorail trolley or a pipe-rail trolley is small. With high yields and a wide glasshouse span a double pipe rail trolley is recommended, because the storage capacity of a pipe rail trolley is greater. The type of scissors used for harvesting mainly depends on bed width. For normal bed widths, 3 beds per 6.40 m span, ordinary scissors are sufficient. With larger bed widths, 3 beds per 8 m span or wider, extended scissors are preferred.

The amount of labour for harvesting per unit is heavily influenced by the production per m$^2$ per harvest, and the harvest method. With high production the labour requirement per unit is lower than with lower production. However, per m$^2$ the harvest labour increases with higher productions, because the decrease of the harvest labour per unit of produce becomes increasingly smaller.

The cultivation method and the harvest method have significant effects on the labour for harvesting per unit. As a result of changing views on plant physiology, rose cultivation has become different. Instead of cutting away blind and poor shoots growers increasingly bend them in the course of the year and this leads to a less “tidy” crop. This effect was reinforced by a different method of harvesting. Until the early 90s roses were harvested mainly by upper cut or under cut. Currently most roses are cut just above the point where the stem has sprouted from the bush. As a result the plants look “untidy” as more leaves are maintained than with the former way of cutting.

But the labour required for harvesting per unit has increased as the grower must search for where the stem should be cut. Due to these measures and the strong production increase as effect of assimilation lighting and extra CO$_2$ supply the labour requirement for harvesting has strongly increased.

3.3 WORKING AREA

The working area should be set up in such a way that the processing can be easily carried out. The area should be sufficiently spacious in order to store temporarily the bunching machine, the produce to be graded and the graded roses. Transport routes from the glasshouse, from and to the grading machine and the cold store should not cross one another.
The best light for working is daylight. However, no direct sunlight should reach the working place. If the working area is located at the south side of the nursery, the windows on the south side should be equipped with awnings to prevent inconvenient irradiation.

If work takes place under artificial light, this should be strong enough (see section on grading for more details).

For a nursery of 2 ha a working area of at least 500 m$^2$ is necessary. The entrance should be sufficiently high, so that trucks can pass under the overhead door (4 * 4 m). There must be room for storage of buckets and stacking trolleys.

Increasingly the working area is being provided with floor heating. The drains should be connected to the sewer. A high attic gives the possibility of storage. The roof should be insulated so that the working climate is pleasant. The working area should also provide space for office and computer rooms, canteen with kitchen, toilets (ladies and gentlemen), storage of tools, fertilizers and pesticides.

The working area is built mostly in combination with the boiler house, which must be well insulated to prevent noise pollution.

**Grading and packing**

Due to the increasing use of the bunching machine the labour requirement for grading and packing has decreased with about one third. Still the use of a bunching machine is not recommended for all nurseries. At least 7.5 million roses should be processed annually to use such a machine profitably. For less roses, starting with 1 million stems a year, from a business-economic point of view a vibrating machine is preferred.

The following ergonomic criteria should be also observed:

- The sound level may not exceed the 80 dB(A) limit. When this limit is exceeded measures should be taken to prevent it or ear-protecting devices should be handed out to workers.

- Working height must be adjusted to the stature of the persons working at those places. If the height is not adjustable it should be fixed in accordance with the tallest person and devices such as platforms etc. should be supplied to the shorter persons to bring their work on the proper height.

- The working height should be adjusted to standing work. If sitting, adapted chairs should be supplied (adjustable in height and with footrest).

- Good lighting is very important for the quality of grading. On all working places where attention should be given to the quality of the produce, the lighting level should be at least 1,000 lux.

- All machines in use on the holding must be designed and built in accordance with the machine guideline or with the European law with respect to safety and health (CE-marking)

- To reduce one-sided stress and monotony it is recommended to rotate all tasks over all workers, with no separate harvesting or grading teams.

**Cooling**

The cold store is used for temporary storage of the flowers out of the glasshouse before being processed or for storage after grading and packing. During weekends the flowers are often stored for more than one day because Sunday’s harvest is not processed until Monday. Harvested roses are kept at a temperature of ca 2 to 4°C. The relative humidity in the cold store should be below 80%. Too wet conditions may lead to increased Botrytis problems. Remove roses that are past flowering, and leaf debris as these may also lead to infection. The area required depends on the number of roses to be stored and sometimes on the working method. Are all rose harvested and placed in
water trays in the cell first before grading is done or is processing done faster so that there is more room because the water trays have been moved out? The most frequently used standard is 3.5 to 4 m² per 1000 m² glasshouse.

The capacity of the refrigerating apparatus must be sufficient. Insulation should be adequate and the walls vapour tight. Other factors influencing the capacity are the use of the door, the volume and the temperature of the produce and the size of the store. Moisture discharge takes place by means of the evaporator through condensation on the element. Automatic defrosting subsequently results in water discharge. An oversized evaporator makes too little operating hours and dehumidifies insufficiently. A small evaporator makes many operating hours but it takes too long for the produce to get really cold.

The location of the cold store should fit into the working procedures. Try and avoid unnecessary walking. Auction trolleys should easily fit the door, which must therefore be at least 3.10 m high.

Pesticides and fungicides: storage and equipment

For the application of pesticides and fungicides Dutch growers must have a licence, follow the guidelines on the packaging, work only with registered compounds and store them according to the various rules. These rules are mentioned in, for example, the AMvB (Parliamentary Decree) ‘Glasshouse environmental management’. The aim of these laws and regulations is protection of user and environment.

Pesticides must be stores in a closed cupboard with hazard warning stickers. No leakage from the cupboard may occur and liquid compounds are placed in a small drip-tray. During preparation and application of the products nothing may leak into the surface water. There are various rules for preparation and cleaning the spraying equipment. Remnants of pesticides may not be discharged in the sewer or the ditch, but saved until the next spraying. Make sure, when filling the spraying tank, that the product is not put into the tank first and then the water. It then often happens that foam develops, runs out of the tank and disappears down the drain. It is better to make the solution in a half-filled tank, or prepare a stock solution and add this to the water and mix it.

In water-collection areas and their immediate surroundings the rules for the application of certain pesticides are stricter. Some compounds may not be applied at all in such areas. This is mentioned on the labels and mostly concerns herbicides.

The method of application affects the emission to air, water and soil. The Research Station Naaldwijk carries out research into how the effectiveness of pesticides can be increased and how the emission to the soil can be reduced. The application equipment should be properly adjusted, so that unnecessary use of pesticides is prevented. For High Volume equipment testing is obligatory for field sprays. Such a test will also be implemented for glasshouse horticulture. Important points to check up on are the right nozzles (no wear; correct emission) and pressure. In addition to the effect of the equipment the density of the crop is important. The denser the crop is the less compound will end up on the ground. The deposition on glasshouse roof and walls is minor when compared to that on the ground. With application of an LVM more compound reaches the ground than with spraying. The small droplets from the LVM combined with the air movement result in a less ‘filtering’ effect of the crop and more compound reaches the soil.

In the application technology the following classification is made:
1. Low Volume techniques such as:
The first two techniques are mainly used in Dutch rose cultivation.

2. High Volume techniques, such as:
   - a spray gun connected to a spray trolley
   - a spray mast or spray robot

In the selection of an application technique it is important whether one opts for:

a. Space treatment. Mostly used for the control of flying and crawling insects. Often compounds with a vapour effect are used.

b. Spray treatment, used for the control of fungal diseases, insects, larvae and eggs.

Sub a. Space treatment

Compared to spraying, space treatments take little time. One drawback is that not all pests can be killed with the help of a space treatment. They are particularly suited for flying insects. Only the top of the leaves is touched effectively in a space treatment (fumigation, evaporation, jet engine spray (fog), LVM and spray cans). In a dense crop the very fine droplets do not penetrate very well. A fog treatment only covers the top of the leaves in the top of the crop. It should be checked that the pesticides and any carrier compounds and propellants do not mix with the suction air of the heating.

LVM

LVM gives a fine mist in the glasshouse. Air is forced through a nozzle of 0.6 to 0.08 mm at a pressure of 0.35 to 0.6 bar (depending on the type of LVM). The carrier liquid, mostly water, is mixed with the compound, filling up the glasshouse. Less than 10 l spraying liquid per ha is used. For one hectare 2 LVMs are needed with 6 supporting fans. The fans keep the glasshouse air moving and keep revolving until at most 30 minutes after the treatment. Subsequently the compound is allowed to land on the crop. After the space treatment the glasshouse must be locked for 2 to 3 hours. The treatment is usually carried out with little wind, dry crop and small fluctuations in temperature.

Fog (jet engine spray)

The fog works according to the principle of a jet engine. The pesticide is dissolved in a carrier liquid or water and is taken along with the exhaust gases into the glasshouse. The liquid is atomized in this way to droplet sizes of 10 to 30 um.

Electrostatic spraying

This is applied on a very limited scale in The Netherlands, in contrast to the USA, for example. Through air support electrically charged droplets are moved to the top and underside of the leaves. The plant attracts as it were the negatively charged droplets, like a magnet. When a charge of 800 volt is given, the droplets are 30 to 50 um in size.

Ad b. Spraying treatments

To achieve a good spray result, the following factors must be taken into account:

- drop size
- nozzle distance
- position of the nozzles, nozzle material, maintenance
- riding or walking speed
- equipment, application method, settings
- height of the mast

The pump must be carefully chosen. Large pumps use more electricity and the compound becomes hot. For instance, if you want to spray 30 l per minute, a pump capacity of 55 l leads to revolving of the liquid in the tank. The smaller the drops are, the less spraying liquid is needed. Small drops, however, penetrate the crop less effectively. The size of the droplet is affected by:
- type of nozzle
- nozzle opening
- so-called top angle
- working pressure

Of the various types of nozzle the T-jet is preferred. The so-called spray profiles overlap without touching. There are also double T-jets available which are even more satisfactory. The distance between the nozzles depends on the top angle (see below) and on the mast height. When this distance is too small or too great the crop is sprayed unevenly since the overlap is not correct. In general in glasshouse floriculture a spray boom with a top angle of 110° and a nozzle distance of 50 cm is applied. To distribute the liquid evenly the nozzles should overlap without the spray profiles touching one another as the small droplets lump together to large drops. The distribution over the leaf is then poor. By positioning T-jets at an angle of 15° to the spray mast, the profiles overlap in the crop and not in the air.

The opening of the nozzle gives a measure of the drop size and how many litres of water per minute the nozzle can emit.

The spraying liquid leaves the aperture in the nozzle in the shape of a thin film that is stretched out. At a certain moment the film breaks and drops develop. The angle between the 2 edges of the film is the top angle. In horticulture mostly angles of 80° (vertical mast) to 110° (horizontal mast) are used. Nozzles with a great top angle give a good distribution over the crop, already at a small distance. The top angle given by the manufacturer is only valid to the maximum given pressure. Most nozzles are developed for a pressure up to 5 bar. A nozzle with a greater top angle is less sensitive to higher pressures. Be careful with very high pressures!

The right pressure should be set with a good manometer on the mast. A pressure on the mast of 10 to 12 bar gives a good spraying result. At a pressure of 20 bar very small droplets are formed which float instead of landing on the crop.

The height of the spray mast depends on the top angle, nozzle distance and the desired overlap. The mast may swing so sufficient height must be maintained.

The walking rate or the riding speed affects the penetration of the compound into the crop. With higher speed the penetration is less. 30 meter per minute is a good speed for a spraying mast and the rate must be constant. This can be automated by using an electric reel.

Always wear protective clothing and the recommended masks when applying pesticides. Clothing and masks should be maintained well, and the filters replaced regularly. Clothing and gloves should be washed with soap regularly. With the fog, wear ear protection.

Frequent use of spraying powders rapidly wears out the nozzles. When the equipment is not used for a prolonged period of time, the pump, tank, sieves and filters must be
cleaned with soap. Filters and nozzles should be cleaned after each spraying with water and a toothbrush. The degree of wear can be measured by collecting the emission of a nozzle in a measuring jug for one minute.

**Boiler house, heat-power cogeneration and heat storage**

On most nurseries the minimum installed capacity is 1.5 million Kcal h\(^{-1}\) ha\(^{-1}\). Then there is no heat-power cogeneration present. If cogeneration is present, an installed capacity of 1.0 to 1.2 million Kcal h\(^{-1}\) ha\(^{-1}\) (1.2-1.4 MW) is sufficient. Usually the boiler is a low-pressure three draught flame tube boiler, capable of a steam pressure of 0.5 bar. The boiler has a modulating, low NO\(_x\) burner (< 60 mg NO\(_x\)) and a flue gas condenser. A combi-condenser gives the greatest saving and the residual heat is used in the lower network (the network with the lowest temperature) and if necessary stored in the heat buffer.

The size of the expansion tanks depends on whether there is a heat buffer and of the way the heating is installed.

The electricity needed for assimilation lighting make generation with a heat/power cogeneration often more economical than buying it through the electricity grid. The installation is usually the grower’s property, but sometimes also that of the public service corporation. The use of the heat/power cogeneration is one of the most important options for energy saving. The exact answer to the question whether an installation is interesting for a nursery, depends on the heat and energy demand, restitution fee by the energy company, maintenance costs and gas price.

Nurseries with assimilation lighting, heat/power cogeneration, condenser and CO\(_2\)-supply via the boiler often have a storage facility for heat of at least 80 m\(^3\)/ha. Surplus heat can temporarily be stored and used at the moment it is needed. At that moment the boiler need not be switched on.

### 3.4 ENVIRONMENTAL DEMANDS

In this section some important Dutch laws containing regulations with respect to environmental demands are briefly. For more information growers are referred to the executive and supervising authorities.

**Soil Protection Act**

In this legislative framework it is written that building may only take place on clean soil. There are various categories with different degrees of pollution allowed: a-value (clean), b-value (light to moderate pollution) and c-value (must be cleaned up). In principle with new developments soil research has to be carried out for the so-called ‘clean soil declaration’. For new houses the soil has to meet the a-value. For glasshouse, working area, and boiler house the local authority may settle for the b-value. The b-value is a ‘fit-for-use declaration’ which states the percentage of soil which is allowed to be polluted.

Via the Soil Protection Act the use of fertilizers is also regulated. The law contains a discharge decree, setting up rules for the discharge of substances into the soil, such as brine (waste product of reverse osmosis), fertilizers and pesticides.

**Environmental Management Act**

This law is in force since 1993, regulating the environmental legislation integrally. It comprises all environmental laws, with the exception of the Surface Water Pollution Act, the Air Pollution Act and the Soil Protection Act. The first environmental law
(Nuisance Act, 1875) and a number of other laws have disappeared with the advent of the Environmental Management Act. In this framework for glasshouse horticulture the ‘Decree Glasshouse Environmental Management’ came in force on 1 May 1996.

Requirements in more detail:
- Existing nurseries without environmental permit should report to the local authorities. They had until 1 May 1997 to comply to the requirements.
- Existing nurseries with an environmental permit (or a valid Nuisance Act permit) do not have to report
- Existing nurseries planning to renovate or expand should report this one month in advance
- Establishing a new nursery should be reported to the local authorities at least one month in advance. From the start the nursery has to meet the regulations with regard to storing, preparing and using pesticides, storing fertilizers, recirculation, heat/power cogeneration, cooling capacity, emergency electricity unit, waste, soil protection, sound pollution, light pollution (assimilation lighting), measuring and registration liability, distance of the nursery to ‘sensitive objects’ and houses, and storage of carbon dioxide (CO₂)

**Surface Water Pollution Act**
This law is in force since 1970, intending to reduce the pollution of the surface water. Groundwater is outside its scope (falls under the Soil Protection Act). The Act forbids the discharge of waste, polluted or noxious substances, in whatever form, into the surface water.
As of 1 November 1994 the Discharge Decree is in force, in order to clean up the emissions of pesticides and fertilizers. Water and nutrient supply should be adjusted to the crop’s need.

**Air Pollution Act**
This law contains, together with the Environmental Management Act requirements with respect to the boiler, concerning reduction of noise, smell, danger, emission of soot, sulphur dioxide and nitrogen oxides.

**Multi-Year Crop Protection Plan (MJP-G)**
On behalf of the glasshouse industry the Board of Agriculture made an agreement with the government to reduce the use of pesticides in the floricultural sector 1995 by 50% as compared to the reference period 1984-1998, and in 2000 by 65%. Progress checks pointed out that the sector is on schedule and that a levy on pesticides is not necessary. The MJP-G stimulates the development of closed cultivation systems, substrate crops, improved application techniques for pesticides, biological and integrated control, reduction of growth regulators, glasshouse disinfecting and cleaning compounds.

**Multi-Year Agreement Energy Glasshouse Horticulture (MJA-E)**
On the basis of the MJA-E the glasshouse industry had the task to achieve a 50% higher energy efficiency (energy consumption/unit of produce) in 2000 as compared to 1980 and a lower CO₂ emission (energy consumption) as compared to 1989. Also the emission of other noxious gases such as NOx must be reduced. In 1997 the average energy efficiency had increased to 35%, but since it remained at that point, intermediate targets were set up.
Reduction of the CO₂ emission can only be realised through energy saving. To achieve this, investments will have to be done, for example in flue gas (combi) condensers,
climate computers, heat/power cogeneration, heat storage and low NOx burners. The government wants to stimulate these investments and there are various regulations for financial support. Growers pay a levy per m³ gas for the MJA-E, with which activities are being subsidized such as energy check-up of glasshouse climate equipment and controls by public service corporations and energy consultancy. For example, a consultant may be asked to draw up an energy saving plan.

**Pesticides Act**
The use of pesticides is part of this legislative framework. The implementation (such as locking up pesticides) is taken care of by the Pesticides Decree. Certain empty packaging must be rinsed in the spraying machine with a rinsing installation according to a by-law of the Board of Agriculture. Since 1990 it is indicated on all labels whether a packaging must be rinsed and in what way the empty packaging should be disposed.

### 3.5 ECONOMIC PROSPECTS OF ROSE GROWING IN THE NETHERLANDS

Setting up an up-to-date, new rose nursery in The Netherlands requires an investment of Dfl 300,-/m² with a glasshouse area of 15,000 m² (see Table 23). This investment is high because growing is done no longer in soil but mostly on a growing medium, with a recirculating water supply system. In addition lighting of the crop is necessary, partly on business-economic grounds, partly from the point of view of competition, to be able to realise the desired quality and yield in winter. Flue gas purification and heat storage, particularly with respect to efficient energy use when generating one's own electricity, make lighting an expensive investment. The annual costs of the investment amount to more than Dfl 50,-/m², taking all aspects mentioned above into account. The general business costs for contributions, insurance and tax result in an additional Dfl 5.25.

#### 3.5.1 Quantitative information for Glasshouse Horticulture

The balance is the difference between yield and the direct costs, the costs directly associated with the production in a certain year. It is an important economic index relating to the financial affairs around crop and nursery. Both for comparing crops and for comparing nurseries, and for determining the position of the nursery the balance sheet offers good possibilities. The information on balance calculation and the standard to be maintained for the various crops can be found in the Quantitative Information for Glasshouse Horticulture (KWIN), an annual publication of the Dutch Research Stations. The balance calculation is presented in Table 24. The data recorded in KWIN set the standard for a modern business situation and as a result are not representative for the average nursery.

For yield determination not only is the production relevant but also the distribution of the production over the year. The auction price for Dutch supply, which is used for yield calculation, fluctuates in the course of the year. Therefore, both yield and price are presented per 4-week period.
Table 23. Replacement value and annual costs of a modern rose nursery with a glasshouse area of 15,000 m² and a plot size of 2 ha

<table>
<thead>
<tr>
<th>Description</th>
<th>Investment</th>
<th>Depreciation</th>
<th>Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working area 350 m² (including canteen)</td>
<td>375</td>
<td>151250</td>
<td>7.0 10588 0.5 756</td>
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<tr>
<td>Cold store 55 m² (including unit 4 kW)</td>
<td>380</td>
<td>28900</td>
<td>5.1 1476 1.7 505</td>
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<td>Boiler house 100 m²</td>
<td>400</td>
<td>40000</td>
<td>7.0 2800 0.5 200</td>
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<td>Boiler 232 kW/m²; 200 kcal/m².hour</td>
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<td>160000</td>
<td>7.0 11200 1.0 1600</td>
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<td>CHP unit 675 kW (A31 We)</td>
<td>750</td>
<td>541250</td>
<td>10.0 54125 1.7 17665</td>
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<tr>
<td>Flue gas purifier</td>
<td>325000</td>
<td>10.0 32500</td>
<td>3250</td>
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<tr>
<td>Heat buffer 200 m³</td>
<td>170000</td>
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</tr>
<tr>
<td>Boiler 232 kW/m²; 200 kcal/m².hour</td>
<td>45000</td>
<td>15.0 6750</td>
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<td>Central CO2 supply (5.5 kWh) + distribution</td>
<td>37019</td>
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<td>40000</td>
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<td>Emergency electricity unit</td>
<td>170000</td>
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<td>5.0 850</td>
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<td>22500</td>
<td>7.0 1575</td>
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<td>Bunching machine</td>
<td>325000</td>
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<td>Fertilizer application equipment</td>
<td>40500</td>
<td>15.0 6075</td>
<td>5.0 2025</td>
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<td>Storage liquid fertilizers</td>
<td>30000</td>
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<td>EC + pH meters</td>
<td>1500</td>
<td>25.0 375</td>
<td>5.0 75</td>
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<td>Lvm/spraying trolley/sulphur gun</td>
<td>37520</td>
<td>10.0 3752</td>
<td>5.0 1876</td>
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<td>Venlo-glasshouse</td>
<td>60.40</td>
<td>906006</td>
<td>7.0 63420 0.5 4530</td>
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<td>Concrete path (2.5 m, f40, /m²)</td>
<td>12500</td>
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<td>237273</td>
<td>15.9 37768 5.0 11884</td>
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<tr>
<td>Lighting equipment complete [5]</td>
<td>53.00</td>
<td>795000</td>
<td>10.0 79500 1.0 7950</td>
</tr>
<tr>
<td>Water conduit + pump</td>
<td>7500</td>
<td>7.0 525</td>
<td>5.0 375</td>
</tr>
<tr>
<td>Trickle installation + supply conduits</td>
<td>2.50</td>
<td>37500</td>
<td>15.0 5625 5.0 1875</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>3.15</td>
<td>47250</td>
<td>12.5 5906</td>
</tr>
<tr>
<td>Aluminum gutter (20 cm)</td>
<td>7.52</td>
<td>112840</td>
<td>12.5 14105 1.0 1128</td>
</tr>
<tr>
<td>Levelling + profiling</td>
<td>0.45</td>
<td>6750</td>
<td>18.0 1215</td>
</tr>
<tr>
<td>Anti rooting fabric</td>
<td>1.20</td>
<td>18000</td>
<td>15.0 2700 1.0 180</td>
</tr>
<tr>
<td>Substrate sleeved in (f/slab)</td>
<td>5.63</td>
<td>84401</td>
<td>12.5 10550 5.0 4220</td>
</tr>
<tr>
<td>Heater</td>
<td>50000</td>
<td>15.0 7500</td>
<td>5.0 2500</td>
</tr>
<tr>
<td>Miscellaneous (2.5%)</td>
<td>115000</td>
<td>10.0 11500</td>
<td>5.0 5750</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Investment</th>
<th>Depreciation</th>
<th>Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total depreciations</td>
<td>459773</td>
<td></td>
<td>459773</td>
</tr>
<tr>
<td>Maintenance total</td>
<td>97997</td>
<td></td>
<td>97997</td>
</tr>
<tr>
<td>Interest on half the investment amount</td>
<td>6.5</td>
<td>2298479</td>
<td>149401</td>
</tr>
<tr>
<td>Interest on soil</td>
<td>6.5</td>
<td>1000000</td>
<td>65000</td>
</tr>
<tr>
<td>Total annual costs nursery</td>
<td>772171</td>
<td></td>
<td>772171</td>
</tr>
<tr>
<td>Total annual costs per m² glasshouse</td>
<td>51.48</td>
<td></td>
<td>51.48</td>
</tr>
</tbody>
</table>

49
The labour required is associated closely with the production, in which both total production and distribution over the year are important. It is known from labour studies that the labour requirement per harvest is determined by both the number of stems to be harvested and the number of roses to be harvested per linear meter bed.

In the balance calculation a distinction is made between a one-year old crop and a multi-year crop. During the first year the yield is slightly lower, and in addition the costs for plant material, substrate, etc. are only in the first year of cultivation. In the accounts, the reduced balance is regarded as an investment, which is written off in subsequent years.

3.5.2 Business result

The average balance that can be realised over a 4-year cropping period appears to be insufficient to cover the costs of labour, depreciation, and interest of the investment and the general business costs on a modern Dutch rose nursery. The average rose nursery does not seem to be capable of a profitable exploitation either, but the height of the various costs may sometimes be slightly different (see Table 5).

Standard figures on the capital demand, the labour requirement and the height of the balance posts are thus not a guideline to be followed, but an indication to compare one’s own situation with.

3.5.3 Crop replacement

Replacing an old by a young crop may have serious consequences for the future of the nursery. It is not only the decision when to change over, but also which variety can be planted.

The decision to replace and the moment of replacing may be economically supported by calculating the balances of both the existing and the new crop. The balance of the old crop must then be compared in the current year with the average of the balances to be expected in the new crop over the entire cultivation period. The labour requirement of the crops has to be taken into account as costs. The optimum moment for replacement has come when for the coming year the balance of the existing crop is lower than the average balance of the new crop.

The average balance of the new crop is affected by the choice of the variety with related production and price expectation. Calculation of the average balance over the entire cultivation period makes it possible to compare crops which last for different numbers of years. From a business-economic point of view the crop with the highest balance should be chosen, on the condition that the nursery is able to carry the risk that the balance will turn out to be lower by incorrect estimates of the starting points.

The calculation of the balances of crops over several years is not simple. Software to simplify this calculations was developed by the Aalsmeer Research Station (Benninga, 1994)
### Table 24 - Balance budget for perennial cut flowers per gross m² excl. VAT

<table>
<thead>
<tr>
<th>Cultivation</th>
<th>Rose Frisco, wide beds, rockwool, lit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component</td>
<td>Initial year</td>
</tr>
<tr>
<td>Planting period</td>
<td>Period 1</td>
</tr>
<tr>
<td></td>
<td>From period 3</td>
</tr>
</tbody>
</table>

#### Yields

<table>
<thead>
<tr>
<th>PERIOD (STEMS)</th>
<th>YIELDS</th>
<th>NUMBER</th>
<th>PRICE MONET.</th>
<th>GAS-</th>
<th>GR. LABOUR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>3.9</td>
<td>3.9</td>
<td>150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>8.9</td>
<td>8.9</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1.0</td>
<td>0.37</td>
<td>0.37</td>
<td>7.6</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>10.5</td>
<td>0.33</td>
<td>3.47</td>
<td>6.9</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>29.4</td>
<td>0.37</td>
<td>10.94</td>
<td>4.6</td>
<td>125</td>
</tr>
<tr>
<td>6</td>
<td>34.6</td>
<td>0.24</td>
<td>8.38</td>
<td>3.9</td>
<td>145</td>
</tr>
<tr>
<td>7</td>
<td>36.7</td>
<td>0.24</td>
<td>8.70</td>
<td>3.9</td>
<td>160</td>
</tr>
<tr>
<td>8</td>
<td>42.0</td>
<td>0.17</td>
<td>7.19</td>
<td>3.2</td>
<td>185</td>
</tr>
<tr>
<td>9</td>
<td>42.0</td>
<td>0.23</td>
<td>9.47</td>
<td>3.0</td>
<td>185</td>
</tr>
<tr>
<td>10</td>
<td>42.0</td>
<td>0.23</td>
<td>9.74</td>
<td>3.4</td>
<td>185</td>
</tr>
<tr>
<td>11</td>
<td>36.7</td>
<td>0.29</td>
<td>10.57</td>
<td>4.7</td>
<td>160</td>
</tr>
<tr>
<td>12</td>
<td>29.4</td>
<td>0.35</td>
<td>10.16</td>
<td>5.4</td>
<td>125</td>
</tr>
<tr>
<td>13</td>
<td>28.3</td>
<td>0.35</td>
<td>9.83</td>
<td>7.6</td>
<td>125</td>
</tr>
<tr>
<td>TOTAL (A)</td>
<td>332.6</td>
<td>0.27</td>
<td>88.83</td>
<td>67.0</td>
<td>1620</td>
</tr>
</tbody>
</table>

#### Attributed costs

<table>
<thead>
<tr>
<th>BALANCE ENTRY</th>
<th>QUANTITY</th>
<th>PRICE AMOUNT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant material</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>Gas (heating) (m³)</td>
<td>3.150</td>
<td>23.63</td>
</tr>
<tr>
<td>Gas (CO₂) (m³)</td>
<td>67.0</td>
<td>17.52</td>
</tr>
<tr>
<td>Lighting (kWh)</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Crop protection</td>
<td>1.55</td>
<td></td>
</tr>
<tr>
<td>Fertilization</td>
<td>0.60</td>
<td></td>
</tr>
<tr>
<td>Interest circul. capital</td>
<td>88.83</td>
<td></td>
</tr>
<tr>
<td>TOTAL (B)</td>
<td>88.83</td>
<td>1.00</td>
</tr>
</tbody>
</table>

| BALANCE (A - B) | 38.31 |

Starting points:
- Plant material: cuttings
- Costs plant material include licences
- Costs of levelling are part of costs DPM
- Growing in gutters: 3 rows per bed, 3 beds per 6.40 m, incl. recirculation
- Costs of assimilation lighting see costs DPM
- Yield prices are prices of lit Frisco
- Lighting 45 W/m² installed capacity: 3,700 h
- Labour for substrate installation taken into account
- Labour data with bunching machine

### Table 24 - Balance budget for perennial cut flowers per gross m² excl. VAT

<table>
<thead>
<tr>
<th>Harvest period</th>
<th>Year-round</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component</td>
<td>Fully productive</td>
</tr>
<tr>
<td>PERIOD (STEMS)</td>
<td>NUMBER</td>
</tr>
<tr>
<td>1</td>
<td>23.0</td>
</tr>
<tr>
<td>2</td>
<td>25.0</td>
</tr>
<tr>
<td>3</td>
<td>26.0</td>
</tr>
<tr>
<td>4</td>
<td>34.0</td>
</tr>
<tr>
<td>5</td>
<td>46.0</td>
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<tr>
<td>6</td>
<td>46.0</td>
</tr>
<tr>
<td>7</td>
<td>50.0</td>
</tr>
<tr>
<td>8</td>
<td>50.0</td>
</tr>
<tr>
<td>9</td>
<td>52.0</td>
</tr>
<tr>
<td>10</td>
<td>48.0</td>
</tr>
<tr>
<td>11</td>
<td>38.0</td>
</tr>
<tr>
<td>12</td>
<td>28.0</td>
</tr>
<tr>
<td>13</td>
<td>24.0</td>
</tr>
<tr>
<td>TOTAL (A)</td>
<td>490.0</td>
</tr>
</tbody>
</table>

#### Attributed costs

<table>
<thead>
<tr>
<th>BALANCE ENTRY</th>
<th>QUANTITY</th>
<th>PRICE AMOUNT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant material</td>
<td>51.0</td>
<td>71.0</td>
</tr>
<tr>
<td>Gas (heating) (m³)</td>
<td>0.262</td>
<td>18.57</td>
</tr>
<tr>
<td>Gas (CO₂) (m³)</td>
<td>71.0</td>
<td>18.57</td>
</tr>
<tr>
<td>Lighting (kWh)</td>
<td>1.55</td>
<td></td>
</tr>
<tr>
<td>Crop protection</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Fertilization</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>Packing</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>Auction costs</td>
<td>143.24</td>
<td></td>
</tr>
<tr>
<td>Interest circul. capital</td>
<td>143.24</td>
<td></td>
</tr>
<tr>
<td>TOTAL (B)</td>
<td>33.18</td>
<td></td>
</tr>
</tbody>
</table>

| BALANCE (A - B) | 110.06 |

Starting points:
- For investment in rockwool see costs DPM
- Growing in gutters: 3 rows per bed, 3 beds per 6.40 m, incl. recirculation
- Costs of assimilation lighting see costs DPM
- For investment in rockwool see costs DPM
- Growing in gutters: 3 rows per bed, 3 beds per 6.40 m, including recirculation
- Costs of assimilation lighting see costs DPM
- Yield prices are prices of lit Frisco
- Lighting 45 W/m² installed capacity: 3,700 h
- Labour data with bunching machine
- Interest circulat. capital only of initial year
- Own CHP installation

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4. WATER AND NUTRIENT SUPPLY AND ROOT ENVIRONMENT

4.1 PHYSIOLOGY OF THE ROOT

4.1.1 External and internal structure and function

The functions of roots are anchorage, water and nutrient uptake, hormone production, transport and storage. To obtain a better insight into the factors determining the growth and functioning of roots, it is useful to know more about the external (morphological) and internal (anatomical) structure.

When we study the root of a seedling or cutting from the lower end the following components can be distinguished: root tip, elongation zone, root hair zone and lateral root zone (see Figure 5).

Figure 5. Root of a seedling

The root tip serves to protect the meristem where the cell division takes place. It is the place where chemical and physical signals are received. The elongation zone is the place where the signals of the root tip are translated into more or less elongation of the cell walls.

In the root hair zone the formation of the root hairs takes place. Root hairs are epidermis cells with a lifespan of several days. Their formation is probably induced by the hormone ethylene. As a result of the formation of root hairs the effective uptake surface of the root becomes greater. After the root hair zone, secondary roots may develop in the lateral root zone. In some crops after some time a lignification of the
outer layer of the root occurs. In the rose, this exodermis is dark brown to black and can only let through water and nutrients on certain spots.

Energy is required for the ion uptake, which is supplied by the root respiration. Since the active uptake ion concentrations in the root cells are considerably higher than in the surrounding root environment, and since the cell membranes are semi-permeable, water can be taken up via osmosis. Where the endodermis has not yet fully developed, for example in the root tip and the elongation zone, undifferentiated uptake of water and nutrients may continue to take place. For an element such as calcium this form of uptake, determined mainly by the underpressure in the xylem vessels (developed as a result of transpiration) is very important.

4.1.2 Influence of underground factors on root growth

A great number of factors directly influence the growth, elongation and branching of roots. A number of responses of the roots to external factors are functional in the sense that stress is reduced as a result of them. The saying that 'a plant always grows towards a limiting factor' is valid in most cases. Often phytohormones are directly or indirectly involved in the response to external influences. Various groups of phytohormones play a role in root growth and formation:

- auxins play a key role in root growth and the initiation of the lateral root formation. These auxins are transported by the phloem from the growth tips of the sprout where they are produced and accumulate in the root. Concentrations of 10⁻⁹ mol/l may be sufficient to promote cell elongation. Excessive auxin concentrations inhibit root growth, directly or indirectly through ethylene formation.
- Cytokinins are produced in the root tips; high cytokinin concentrations inhibit elongation and the formation of lateral roots. By cutting off the root tip lateral root formation is highly stimulated. This effect is comparable to the removal of the apical dominance of a growth tip by pinching. As a result of this the auxins inhibiting the development of the axillary buds, are removed.
- Ethylene is formed mostly as an effect of stress conditions, and can promote the root elongation in low concentrations (< 1 mg/l). High concentrations inhibit root growth but on the other hand promote the thickness and the root hair formation. As a consequence of ethylene intercellular cavities may develop in the bark tissue, the so-called aerenchym tissue. Under certain conditions, these cavities or air channels may facilitate the vertical transport of oxygen.

4.1.3 Soil chemical factors

A number of factors affect root growth, and may be of greater or lesser importance in horticulture. A distinction can be made between chemical, physical and microbiological factors. These three are dealt with below, in 3 subsections.

Soil chemical factors:

Minerals

Particularly nitrogen deficiency strongly stimulates root growth (with the exception of phosphate, the other elements have very little influence), while seriously inhibiting shoot growth. This results in a reduction of the root/shoot ratio. The roots become finer and more branched under deficient conditions, while the root hair formation is stimulated. A well-developed root system does not always mean that the growing conditions are optimal. The consequence of this effect in the soil is that a greater
volume of the soil can be ‘tapped’ for available nitrogen. Another effect is that under deficient circumstances root growth is greatly stimulated where local fertilization occurs. Local stimulation of the root growth results in an increased risk of drought stress when fertilizatier is applied to the top layer. The mechanism explaining the local increase in root growth may be as follows: locally higher N concentrations in the root increase the phloem discharge and the respiration. The increased lateral root formation is probably the result of higher auxin concentrations (coming from the phloem).

**Salt**

Excess salts (high EC-level, exceeding 2.5 to 3 mS/s) in the soil solution often has comparable results to drought stress. The root/shoot ratio can be lowered, and particularly the cell elongation of the shoot may be inhibited as a result of internal water stress.

As with drought stress the abscisic acid concentrations (hormone) in the roots are higher and the cytokinin formation is reduced. Salt accumulation may occur when, for example, poor quality irrigation water is used, or with uneven water distribution in soil or growing medium. Sometimes salt stress is consciously used. This is not the case in rose cultivation, but in bedding plant cultivation and the propagation of fruit vegetable crops salt stress is used as growth regulation.

**Organic compounds**

On decomposition of organic matter such as straw, green manure, but also by the decomposition of root remnants under wet conditions phenols and fatty acids may be released which inhibit root growth. In some organic root media nitrogen may be fixed by high microbial activity, which may result in nitrogen deficiency.

**pH**

pH levels between 5 and 7.5 hardly affect root growth, on the condition that nutrient elements are available. With high pH free NH₃ may develop and lead to harmful effects (for example when urea is used). With low pH levels (<5) the cell elongation may be inhibited. The element calcium plays a role in the protection against low pH. At low pH levels toxicity of metals such as Cu, Ni, Zn, Al, Fe and Mn may play a role in certain soils. In modern rose cultivation with balanced nutrition these problems are of course not relevant. In the nutrition for substrate crops throughout the year globally ca 10% of the nitrogen is given as ammonium (NH₄) to keep the pH between 5 and 6. In peaty potting soils Dolokal (CaCO₃ + MgCO₃) is given for this purpose. In soil grown crops up to 50% NH₄ may be applied, depending on the content of calcium carbonate.

4.1.4 Soil physical factors

**Oxygen supply**

Depending on the circumstances, the age and the crop, 25 to 50% of the carbohydrates formed (sugars) from the photosynthesis is transported to the roots. In the root these sugars are used for root growth, maintenance processes and ion uptake. About 50% of these photosynthates is used in respiration. The diffusion of gases takes place considerably faster in the air than in the water. This may result in local exhaustion and accumulation of gases in substrates with a high water content. Consequently, pores in the root medium are important for the exchange of gases. When rose cuttings are taken under water, aeration of the nutrient solution appears to have distinctly positive effects on root formation and root length. By placing rockwool blocks on other
(6 cm high) rockwool blocks, so that the air content increases from ca 4 to 20%, the same effect is achieved (see Table 25).

Table 25. Effect of aeration and increasing the air content in substrate on root formation and root porosity of rose cuttings

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Longest root/cutting (cm)</th>
<th>Number of roots/cutting</th>
<th>Root porosity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient solution aerated</td>
<td>4.0</td>
<td>21</td>
<td>4</td>
</tr>
<tr>
<td>Nutrient solution not aerated</td>
<td>2.8</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td>Rockwool block</td>
<td>3.1</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>Rockwool block on rockwool block</td>
<td>4.0</td>
<td>20</td>
<td>6</td>
</tr>
</tbody>
</table>

A medium with a sufficiently high air content is of key importance for an undisturbed root development. This is not only for the oxygen supply: CO₂ accumulation may have an inhibiting effect on root growth in concentrations of 3 to 5% (compared to 0.03% in the outdoor air).

Another consequence of wet conditions may be accumulation of ethylene around the roots, which might lead to increased root porosity. Due to this air channel formation with some plants oxygen supply can still take place through internal transport under low-oxygen conditions in the root environment. For rose, however, this does not seem to be very relevant, in view of the relatively low porosity (Table 25).

**Water supply**

Water deficiency, just like salt stress and nutrient deficiency, results in a reduction of the shoot/root ratio, so that per unit of leaf area the rooted volume in the soil increases. The phytohormone abscisic acid is formed in the roots as an effect of moisture stress. As a consequence of moisture stress the number of root hairs increases.

Since moisture supply can also determine the availability of ions, particularly ‘slow’ ions such as phosphate, adequate water availability is also needed for optimal root growth as well as a minimum air content. As a result, in substrates with a low water retaining capacity nutrition will have to be supplied more often to prevent deficiency.

**Soil density/ rooting volume**

The elongation growth of roots decreases with increasing penetration resistance of the soil or substrate. Crop differences in sensitivity for penetration may be the consequence of genetically determined variations in diameters of the roots. The diameter increases as a result of inhibition of the longitudinal growth.

In compact soils the inhibitions may be greater under wet than under dry circumstances, while penetration then requires less force. In that case oxygen deficiency or ethylene accumulation may be the cause of the inhibition of root growth. Reduction of the rootable volume has a similar effect as soil compaction. Even if water and nutrients are not limiting factors, this effect occurs, indicating that hormonal effects probably also play a role in this process.

**Temperature**

Under suboptimal temperatures (very low or very high values) roots get shorter and thicker, and the lateral root formation is strongly inhibited. The production of abscisic acid increases and that of cytokinins decreases. The root/shoot ratio decreases, possibly as a result of the reduced production of cytokinins.
4.1.5 Microbial factors

Micro-organisms in the rhizosphere may have both a root growth inhibiting and promoting effect. Inhibition may occur due to pathogens or cyanide producing bacteria, while growth promotion is often the result of auxin production or an antagonistic effect of micro-organisms on pathogens. The research into the effect of micro-organisms on root growth is often difficult, because the diversity of micro-organisms is so great. In addition, the development of micro-organisms may depend on the same external factors as are valid for root growth and for release of root exudates. It is therefore difficult to say how important the rhizosphere micro-organisms are for root growth under practical conditions.

4.1.6 Relation root growth/shoot growth

Root growth of plants should not be judged without taking the shoot growth into consideration. With rose, the aerial parts are harvested and the roots have maintain an undisturbed supply of water, minerals and hormones. When conditions are optimal, as described in the subsections above, a small but efficient root system will develop. Temporarily unfavourable conditions that might disrupt gas exchange or moisture and mineral supply may also have consequences for the shoot. Adjustment of shoot and roots will generally take place, but stagnant growth is almost always inevitable. More information on the development of the shoot can be found in Chapters 6 and 7.

4.2 NUTRIENTS

4.2.1 Macro and micro elements

In general roses consist of 75 to 85 % water, the rest is so-called dry matter. This content varies per variety and per plant part (stem, leaf). The major part of the dry matter consists of organic compounds such as sugars, starch, cellulose. About 10% consist of inorganic compounds, mostly called (nutrient) elements or nutrients. Table 26 shows the average composition of the dry matter of rose. Although these elements are only a minor part of the composition of the plant, they play a significant role. The elements potassium (K), calcium (Ca), magnesium (Mg), phosphorus (P), nitrogen (N) and sulphur (S) are taken up by all plants in relatively large quantities. In the case of the rose, this is also valid for the element silicon (Si). For this reason we call these macro-elements. Of iron (Fe), manganese (Mn), zinc (Zn), boron (B), copper (Cu) and molybdenum (Mo) much smaller quantities are needed. They are therefore called the micro-elements. All these substances are called essential elements (nutrients), since the plant cannot function without them. If one of these elements is present in insufficient quantities, deficiency symptoms are observed. A number of these are pictured and described in Chapter 4.2.4. Frequently, however, growth inhibition occurs before deficiency symptoms are visible.

In addition to the elements mentioned above other elements can be found in the analysis of plant material, which have been absorbed by the plant. This, however, does not mean to say that they are essential for the plant to function. Sodium (Na) and chlorine (Cl), for example, are almost always found. The role of these elements is, however, limited and the necessary quantities are at the level of trace elements.
Table 26. Guide values for the average chemical composition of rose. Contents in μmol per kg dry matter, except K-sap, Cu and Mo

<table>
<thead>
<tr>
<th>Element</th>
<th>guide value</th>
<th>deficiency</th>
<th>toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter %</td>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>nitrogen</td>
<td>1700-2800</td>
<td>&lt;1430</td>
<td></td>
</tr>
<tr>
<td>potassium</td>
<td>580-900</td>
<td>&lt; 460</td>
<td></td>
</tr>
<tr>
<td>K-sap, mmol/l</td>
<td>250-280</td>
<td>&lt; 65</td>
<td></td>
</tr>
<tr>
<td>Phosphorus</td>
<td>100-200</td>
<td>250-450</td>
<td>250-80</td>
</tr>
<tr>
<td>Calcium</td>
<td>90-160</td>
<td>70-100</td>
<td>80</td>
</tr>
<tr>
<td>Magnesium</td>
<td>2-15</td>
<td>20-50</td>
<td></td>
</tr>
<tr>
<td>Sulphur</td>
<td>20-50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>1.0-2.7</td>
<td>&lt; 0.9**</td>
<td></td>
</tr>
<tr>
<td>Chlorine</td>
<td>1.1-2.7</td>
<td>&lt; 0.5</td>
<td>&gt;5.5**</td>
</tr>
<tr>
<td>Iron</td>
<td>0.3-0.8</td>
<td>&lt; 0.25</td>
<td></td>
</tr>
<tr>
<td>Manganese</td>
<td>2.8-5.6</td>
<td>&lt; 2.0</td>
<td>&gt;9.0*</td>
</tr>
<tr>
<td>Zinc</td>
<td>80-250***</td>
<td>&lt; 50***</td>
<td></td>
</tr>
<tr>
<td>Boron</td>
<td>15-30***</td>
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<td></td>
</tr>
<tr>
<td>Copper</td>
<td>20-60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molybdenum</td>
<td>20-60</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* = in old leaves
** = highly dependent on cultivar
*** = μmol/kg dry matter

The role of many other elements is obscure (for example cobalt (Co), vanadium (V)) or unknown (at least for the rose). Other elements are soon toxic, for example nickel (Ni), chromium (Cr), bromine (Br), lithium (Li) and aluminium (Al). Although these elements are not functional for the plant, or may even be toxic, uptake takes place to some extent, because they are sometimes present in large quantities in the root environment. Plants are not always capable of excluding uptake completely. This is, for example, the case with the element aluminium (Al), which is present in an absorbable form only at very low pH values (<4). The borderline between essential and toxic is vague, since all elements may be toxic to the plant, provided the concentration is high enough.

4.2.2 Uptake of nutrients

Root tips can be regarded as an open system until the water reaches the Casparian bands and water with dissolved ions can flow freely in and out. Ions are sucked inwards in the root tips via the water flow. In this open system the actual uptake takes place, into the lignified cells of the root. Uptake also takes place by the cells of the epidermis with the root hairs. The ions enter through the cell membrane. As described above, all must be transported via the endodermis to the xylem vessels. The epidermis and the lignified cells are connected through plasma with the endodermis, which makes transport to the endodermis possible.

A number of theories have been developed to explain the process of uptake although much, however, remains unclear. The concentration in the cell is higher than outside. Uptake of an ion often means transportation against the concentration gradient; this
requires energy. Exchange takes place with another ion with the same charge, or simultaneous uptake of a negatively charged ion. There is also a passive uptake that requires no energy. On the surface of the membrane there are negatively charged areas. Cations (positively charged ions) are adsorbed here. The inside of the membrane is mostly more negatively charged than the outside. As a result, the cations are as it were drawn in, even though this transport is directed against concentration difference. For the anions this passive uptake is not significant. How exactly the active transport of ions through the membrane takes place is not yet completely known. One of the current theories is the so-called 'Carrier'-theory. Carriers are protein-like compounds, bound temporarily to an ion. They transport the ion through the membrane and disconnect the ion at the inside of the membrane.

Carriers can be destined for only one particular type of ion, for example potassium. This is the basis for the selectivity of the uptake. As a result, the composition of the plant may differ considerably from the composition of the nutrient solution. There is, however, the possibility that the same carrier transports ions that are related, such as potassium and sodium. This is the origin of the concept of antagonism. If, for example, more potassium is present, as compared to calcium, the place of calcium on the calcium carrier can be taken in by potassium ions, which may result in calcium deficiencies.

The speed with which ions are taken up depends on the concentration in the external solution and the more ions present, the more are taken up. For certain ions this is bound by a maximum, whereas for others it is not. Nitrogen is taken up to a certain level but from a certain concentration onwards, the uptake is inhibited by itself. Boron, for instance, is not inhibited. Uptake continues until the plant has poisoned itself.

Once an ion has arrived within the cell membrane, the cell plasma, then it moves from cell to cell via the plasma. The ions are not hindered by the Casparian bands and can pass the endodermis and end up in the xylem vessels. Transport then takes place, either through root pressure, or through the transpiration flow. In principle all nutrient elements are first transported to the transpiring parts of the plant (the leaves), where the xylem vessels are present and where the underpressure is greatest. From the leaves the nutrient elements can then be distributed further. Via the sieve tubes the nutrient elements, together with the assimilates produced by the leaves, are transported to plant parts with little or no transpiration, such as growth tips, buds, fruits, but also root tips. However, not all elements end up in the sieve tubes. Calcium, for example, after it has reached the leaves with the xylem vessel flow, is fixed and cannot be transported further, or only to a very limited extent and this is also the case for boron. Therefore the growth tips are completely dependent on root pressure for calcium supply. As a result of root pressure, transport takes place not only to the leaves, but also to the plant parts without transpiration. The plant parts that have little transpiration therefore always have low contents of these elements, for example the bud of the rose or young shoots.

Mobile and immobile elements
Some nutrient elements can easily be transported from one plant part to another. This is the case when somewhere in the plant deficiency develops and old leaves in particular, then serve as storage. A well-known example is magnesium deficiency in tomato. If the root system functions less adequately during certain periods, insufficient Mg can be taken up. Mg from the old leaves is then transported to the young leaves. As a result, Mg deficiency develops in the old leaves. Elements that can easily be moved are called
mobile elements, examples of which are potassium, magnesium, nitrogen and phosphorus. Other elements can be moved only with difficulty, the immobile elements, such as Ca, Fe and B. Deficiency of an immobile element will always first be manifest in the young leaves. With mobile elements deficiency symptoms mostly show in the old leaves while the apex of the plant is still healthy.

Transpiration and mineral management
It has been explained that water transport and distribution of part of the minerals are closely connected to one another. For optimum nutrition therefore a well-balanced nutrient solution is required, but certainly also a good climate control. Excessive transpiration may lead to accumulation of minerals in the transpiring leaf and deficiencies in the growth tips. Insufficient transpiration also causes problems because then insufficient supply of certain minerals to the leaves takes place.

4.2.3 Function of individual nutrients

Nitrogen (N)
Nitrogen is by far the most important nutrient element, as far as the number of particles (mol) which are taken up is concerned. Expressed in weight (g) the figure is lower because it is a light element. Nitrogen is an indispensable component of all amino acids. Amino acids are the building blocks of proteins (such as DNA = the chromosomes; the genetic material), enzymes, vitamins, and especially chlorophyll. Nitrogen can be taken up in 2 ways, as nitrate (NO₃⁻) and as ammonium (NH₄⁺). In the plant all nitrate is first converted into ammonium, in order to be built into the amino acids. Part of the nitrate is used in the plant to regulate the osmotic value of the cell sap. As an essential building block for proteins nitrogen is therefore important for plant growth. Nitrogen deficiency initially leads to growth inhibition, and since all kinds of important proteins are lacking, the entire plant functions less well and as a consequence is more sensitive to pests and diseases. Nitrogen is transported by the xylem vessels to the leaves, and converted there by way of a metabolic process, into organic compounds (amino acids) and subsequently distributed further over the other plant parts, back to the roots, for instance. Via protein decomposition (for example chlorophyll in old leaves), nitrogen becomes available again and can be re-used by the plant. Nitrogen can be redistributed easily in the plant, so that when deficiency occurs nitrogen will first be taken from the old plant parts.

Potassium (K)
The element potassium does not occur in the dry matter of the plant but is in solution for virtually 100%. It is mostly present in the vacuole of cells and its primary function is to realise an osmotic value of the cell sap; it is therefore responsible for cell turgor. Potassium plays an essential role in the regulation of the cell tension of the guard cells of the stomata. Therefore potassium plays important for the water relations of the plant. Together with calcium, potassium has a key role in the permeability of the cell membranes. Without potassium in the cell sap many enzyme reactions in the metabolic cycles cannot take place. Occasionally potassium is described as the element for quality because of its effect on cell firmness (osmotic value, turgor, membrane stability). Deficiency will therefore be apparent first in a limp crop or produce. In many crops (fruit vegetables, carnation) this effect is obvious. Research with rose, however, did not indicate that potassium deficiency affects stem quality. Just like nitrogen deficiency potassium deficiency
shows first in the oldest plant parts, from where potassium is redistributed to the young leaves.

**Phosphorus (P)**
Phosphorus is an essential component of a number of proteins, such as DNA (the genetic material) and in ATP (compounds facilitating energy transfer, so that metabolic processes can take place). A number of enzymes also contain P. Also phosphate is very mobile in the plant, therefore deficiency is not immediately disastrous, since phosphate is remobilised in the older plant parts. In a subsequent phase certain reactions cannot take place properly and the development of the plant is affected, resulting in reduced shoot growth and flower development and smaller leaves.

A frequently heard observation is that phosphate stimulates the root development. This, however, is a misunderstanding; phosphate is necessary for root growth, but this is the case with all nutrient elements. Rather, a low P-level in the root medium stimulates the root formation because the plant starts searching for phosphate.

**Magnesium (Mg)**
For the major part magnesium is present in the chlorophyll and without magnesium chlorophyll is inactive. Furthermore this element is necessary for a number of enzyme functions. Magnesium is mobile in the plant and with deficiency chlorophyll in the old leaves is broken down and magnesium transported to the young leaves. Therefore magnesium deficiency is visible first in the old leaves but not in the very oldest. Apparently it cannot be withdrawn from the latter; it is fixed in the organic matter. Experiments with rose indicated that a relatively high level of magnesium is necessary for sufficient growth. Although no deficiency symptoms were observed, the production appeared to rise by application of more magnesium.

**Calcium (Ca)**
Calcium is absorbed as Ca-ion, almost solely by the root tips. Calcium is poorly distributed in the plant as it is transported almost exclusively by the xylem, rather than by the phloem. The root pressure must be sufficiently high during non-transpiration periods (night) to supply sufficient calcium to young, non-transpiring parts. Calcium is used for building up membranes and cell walls and a large part of the calcium in the plant is present in fixed form; a small proportion is free Ca. Deficiency in the leaves develops under extremely low transpiration, for example with high air humidity. In addition Ca deficiency develops at places with a low xylem supply, such as young shoots. Young leaves and growth tips die off. Furthermore the crop is more sensitive to fungal diseases, so that stem death may occur. Ca deficiency may also develop as a result of excessive NH₄ or K contents, or a high EC level in the nutrient solution.

**Sulphur (S)**
The plant takes up sulphur as SO₄ but it is not easily transported. Sulphur is required in certain amino acids and is as such indispensable for the formation of certain proteins. Sulphur deficiency is almost unknown in growing practice. It occurs if non-sulphate-containing fertilizers are used and if the irrigation water does not supply sulphate either. It is similar to N deficiency, but S deficiency mainly occurs in young leaves, since S is not easily transported to the young parts.

**Silicon (Si)**
Silicon is different to other nutrients, not being an essential element: plants can develop perfectly well without it. However, plants appear to benefit from the uptake of silicon.
Silicon is passively absorbed in the form of silicic acid and transported with the transpiration flow to the leaves. There it is deposited between the cell walls, particularly at the epidermis. In many crops (cereals, cucumber) it has been shown to increase the resistance against diseases (mildew) and pests (insect and mite damage. This has not yet been demonstrated for rose. Rose takes up considerable amounts of silicon, and practical experiments have indicated that the production is increased by Si.

Iron (Fe)
This element functions mainly as electron donor or acceptor in a range of chemical reactions in which electron transfer takes place. Iron is also needed in certain enzymes. Iron is present in the plant both in fixed and in free form. Using crop analysis on the basis of dry material total Fe is determined although this says little about the amount of free Fe. This latter form determines whether there is sufficient iron in the plant. Iron is poorly transported in the plant, so that Fe deficiency always occurs in the youngest leaves. Fe deficiency is undoubtedly the most frequently occurring deficiency. It mainly occurs with high pH in the root environment: the high concentration of HCO₃ hampers Fe uptake causing poor root development in too wet or too cold soil or substrate. Excessive Zn or Mn concentrations hinder Fe uptake.

Manganese (Mn)
Manganese is taken up as Mn-ion. It is required for enzymes, especially a number of enzymes that have a key role in the photosynthesis. It is poorly transported in the plant, but not as poorly as Fe. For this reason Mn deficiency occurs in the young plant parts, but not in the very youngest. The symptoms are chlorosis between the veins but the midrib and the large lateral veins remain green. Deficiency occurs with high pH level in the soil. Toxicity also frequently occurs and depends strongly on crop and variety. Initially chlorosis develops, later MnO₂ is deposited in the older leaves. This is visible as purple-reddish spots in the leaf tissue. Manganese toxicity may induce iron deficiency: chlorosis develops in the young leaves. Manganese toxicity occurs for example after steaming of certain clay and loam soils. So much Mn is then available that this is taken up in great quantities by the plant.

Copper (Cu)
Copper is taken up as Cu-ion. It occurs frequently in a complex form, bound to organic molecules (chelates). Copper is required for a number of enzyme functions, the most important of which are those for respiration and for the lignin formation. Copper is immobile in the plant. Deficiency is characterised by disruption of the bud formation and flowering, resulting in the formation of deformed buds. Dieback of growth tips is also mentioned in the literature, and chlorosis, followed by necrotic spots in the leaf. The colour of the crop is pale. Little is known about copper toxicity, but its main symptom would be dieback of the roots.

Zinc (Zn)
Zinc is taken up as Zn-ion. Zinc is also an essential component of various enzymes, especially those that are responsible for cell elongation of stems and petioles. Zn deficiency may develop as a result of P toxicity and a low Zn concentration in the nutrient solution. Symptoms are slow growth, short internodes, deviant colour, bushy appearance and deviant leaf shape. Zinc toxicity gives growth inhibition, and often conspicuous veins, which sometimes have a purple colour. Especially chlorosis develops in young leaves by iron deficiency.
Photo 1. Healthy shoot and shoot with potassium deficiency. Note the light leaf color and the pale flowers.

Photo 2. Top leaflet of a full-grown five-leaflet leaf with magnesium deficiency.

Photo 3. The light leaf color and the pale flowers indicate sulfur deficiency.

Photo 4. Calcium deficiency in full-grown five-leaflet leaves, in various stages.

Photo 5. Zinc deficiency in a mature shoot (I), compared to a healthy shoot. Note the light leaves and the pale flower color.

Photo 6. Zinc toxicity in a young plant on water culture. The first shoot managed to develop well.
Photo 7. Iron deficiency in advanced stage

Photo 10. Boron deficiency (l) in a mature shoot, manifest in malformed petals (Photo: J. Bijdevaate, Substratus)

Photo 8. Manganese deficiency

Photo 11. Five-leaflet leaf of scion wood with symptoms of boron toxicity

Photo 9. Lower five-leaflet leaves of a mature shoot, with manganese toxicity (l) and healthy leaf

Photo 12. Bacteria in the stems cause bent-neck and flaccid leaves and flowers
Zinc toxicity may occur under galvanized pipes where leakage occurs or with collection of rainwater as Zn is released from the gutters.

**Boron (B)**

Boron is taken up as B(OH)$_4$ and as H$_3$BO$_3$. It is required for the transport of carbohydrates (sugars) to cells. It also seems to play a role in the stability of the cell wall.

Poor root development and death of the growth tips characterize B deficiency. Light deficiency symptoms are a somewhat limp crop and occasionally some chlorosis, particularly on the older parts. At a later stage wilting occurs; fruits and leaves become misshapen. The rose easily takes boron up, with a strong accumulation of boron in the (older) leaves. Boron toxicity in rose is frequent, and particularly with certain varieties and in combination with certain rootstocks the leaf edge of old leaves becomes chlorotic and later necrotic. Symptoms move upwards towards the top of the plant.

**Molybdenum (Mo)**

The plant takes up molybdenum as MoO$_4$ ion. Its function is known in two enzyme systems, which regulate the conversion of NO$_3$ into NH$_4$ in the plant. Deficiency is manifest in chlorosis of the old leaves between the veins. Despite persistent rumours among growers the role of molybdenum in rose is unclear; Mo deficiency could not be induced in experiments.

### 4.2.4 Deficiency and toxicity symptoms

Much research has been carried out into the optimal mineral composition of the rose. This was not simple as the content of minerals was very variable, depending on the stage of the plant, the circumstances under which the plant has grown (type of water, rootstock, growing medium), and the variety. Furthermore the minerals are not evenly distributed over the plant. As the leaf gets older, the internal ratios of minerals fluctuate strongly. This distribution is related for a considerable part to the internal transport.

The symptoms of deficiency and toxicity are not always clear and are not described unambiguously in the literature. Due to the factors described above (variety, growing conditions etc.) but also due to effects of supply (slowly built-up deficiency, or acute deficiency) the symptoms may deviate from a general description.

Of all nutrients a deficiency can be caused by an absolute shortage in the root environment. In addition, for some elements deficiency may develop in relation with other factors. High concentrations of one element may inhibit uptake of another; this is called antagonism. Other factors are soil temperature and pH. The latter may be responsible for a nutrient not being present in an available form. Finally the plant itself may be the cause of a deficiency. For example, due to poor root development the plant may have insufficient capacity for uptake. Or, alternatively, due to high transpiration the internal distribution is out of balance. This makes it difficult to determine solely on the basis of symptoms whether and how the nutrition must be adjusted. It should first be established what the exact cause of the deficiency is.

What follows is a brief description of the most significant characteristics of deficiency and toxicity of all elements. Colour pictures are presented of the most frequent deficiency symptoms.
Nitrogen deficiency
The growth decreases. Initially the leaves become light green, starting with the older leaves. The leaves become smaller and the distances between the internodes become shorter and petals shorten. The flowers are clearly lighter in colour than usual.

Nitrogen toxicity
In fact, this does not occur, just like toxicity of most main elements is not specific. High concentrations of nitrogen and other main elements give a high EC and can be described as salt stress. Due to an unbalanced ion composition the uptake of other elements can also be adversely affected.

Phosphate deficiency
Decreasing growth, with small leaves and shoots. The leaves show a dark green discoloration, some varieties show a purple discoloration on the underside of the midrib of young leaves. This discoloration should not be confused with that of young leaves in certain 'red' varieties.

Phosphate toxicity
Unknown phenomenon; perhaps high P may limit the uptake and mobility of Fe and Zn in the plant.

Potassium deficiency (Picture 1)
Decreasing growth and shorter stems. In a more advanced stage desiccation of the buds and sepals, and in some cases necrosis at the edges and leaf tips of older leaves may occur.

Potassium toxicity
See nitrogen toxicity

Magnesium deficiency (Picture 2)
Symptoms do not show on harvestable stems, but always in the leaves on the old wood. Along the edges of old leaves a band is visible with light blotchy, greyish white mesophyll between the veins (in the shape of a horseshoe). The vein remains green. It is more frequent in winter than in summer.

Magnesium toxicity
See nitrogen toxicity

Sulphur deficiency (Picture 3)
The leaves become pallid green, sometimes yellowish, particularly on the young shoots. The flower colour is considerably paler.

Sulphur toxicity
See nitrogen toxicity

Calcium deficiency (Picture 4)
Dieback of the roots occurs. Deformed leaves never occur in the top of the stems, but in the slightly older leaves on stems which are nearly ripe. At the edges and tips of these older leaves lesions develop. The tip and edge become tough, bend slightly downward and the shining appearance becomes a lustreless greyish green. Brittle and
misshapen sepals occur. Necrosis in the petals of red varieties is related to calcium deficiency as well. Increased sensitivity to Botrytis.

*Calcium toxicity*
See nitrogen toxicity

*Zinc deficiency (Picture 5)*
Initially chlorosis in all leaves of young shoots is observed. The internodes get shorter, at a later stage the plant shows bushy growth and occasionally dieback of the growth tip. Sometimes leaves with a deviant shape are observed (more pointed, nettle-like).

*Zinc toxicity (Picture 6)*
Zinc toxicity induces iron deficiency. In addition glassy lesions are formed in old leaves along the midrib and other veins. These lesions are transparent when held against the light, and remain light green, while the rest of the leaf turns yellow first and brown later. Subsequently the leaf drops.

*Iron deficiency (Picture 7)*
Chlorosis (yellowing) between the veins in young leaves. Initially the vein is still green, but turns also yellow later. The chlorosis is already present at a very young stage so that growing shoots of red varieties are coloured pink instead of deep red. In serious cases necrotic lesions develop in the leaves (dieback).

*Iron toxicity*
Unknown. With other crops toxicity is known of certain chelates.

*Manganese deficiency (Picture 8)*
Chlorosis in young leaves of growing shoots, strongly resembling Fe deficiency, but somewhat more blotchy and in slightly older leaves. A further difference with Fe deficiency is that with Mn deficiency part of the leaf along the vein remains green. It is sometimes difficult to tell the difference between Fe and Mn deficiency, because in later stages the entire shoot becomes chlorotic.

*Manganese toxicity (Picture 9)*
Small black dots on old, fully grown, transpiring leaves; black necrotic lesions in the wood and a poorer growth of the main shoot. Simultaneously Fe deficiency may be visible at the top of the plant (Fe/Mn interaction). Severe yellowing of the leaves on the scion occurs. The lowest leaves of the youngest shoots also show discoloration, but to a lesser degree; also, at closer scrutiny they show small necrotic dots and they easily drop. Growth and shoot formation are insufficient and in severe cases purple brown dots or lesions show on the wood.

*Boron deficiency (Picture 10)*
Short and bumpy sepals with rumpled edges. Small, misshapen, short, spoon-shaped, downward-bent, thick leaves, which easily break due to a lack of elasticity (brittle). In a more advanced stage the growth tip dies off in the top. Side shoots start to develop, resulting in a so-called broom structure.
**Boron toxicity (Picture 11)**
The dentate margins of older leaves turn brown and black. The rest of the leaf remains green. At a later stage the leaf margin burns. The leaves fall from the plant while the midrib remains behind.

**Copper deficiency**
The youngest leaves are small and chlorotic at the tips. Later chlorosis develops between the veins. If the deficiency becomes serious, the leaves become a parchment-like yellow/white. At a later stage the growth tip dies back. The side shoots develop, but remain small.

**Copper toxicity**
In young leaves a light red colour develops, later turning into chlorosis between the veins. Fe deficiency develops.

**Molybdenum deficiency**
No clear symptoms are described in literature. In research experiments Mo deficiency could not be induced.

**Molybdenum toxicity**
Unknown.

### 4.3 GROWING IN SOIL

#### 4.3.1 Preparations

**Soil type**
Roses can be grown on various types of soil, both clay, peat and sandy soils are suitable. There are a few important requirements the soil has to meet. A soil suitable for rose cultivation has the following characteristics:
- good, homogeneous stable structure
- good permeability
- homogeneously structured soil profile
- good drainage and constant groundwater level

A good structure is important for optimal air and water management. A good structure means a soil with sufficient large (macro) and small (micro)pores, good cohesion of the soil particles, which should be disturbed as little as possible by tillage or irrigation. The larger (macro)pores facilitate that the water supplied is transported rapidly in the soil. The micropores are necessary to retain sufficient moisture in the soil profile. The division between macropores and micropores, however, should be such that under wet conditions sufficient air is present in the profile.

A good permeability is extremely important to quickly drain the water to the subsoil during extensive water supplies. Stagnant water in a profile during cultivation results in root death due to oxygen deficiency. In addition soil life does not function adequately and reduction of chemical compounds may occur (for example manganese, iron), with harmful consequences for the crop.

A homogeneous soil profile means that there are no disturbing layers. Such layers (for example a layer with heavier clay than the rest of the profile) result in disrupted permeability and root formation.
The groundwater level must be absolutely constant. Fluctuations in groundwater level cause root death. Lower levels force roots to penetrate deeper into the soil. When the groundwater level subsequently rises, these roots die off.

Clay and sandy clay soils
Clay soils, provided they have the above characteristics, have been found to give the best results. The most suitable soils have a declining soil profile, meaning that the soil becomes increasingly less heavy with depth. Apart from the requirements described earlier the soil should have a sufficiently high content of calcium carbonate (CaCO₃, > 1%). Soil with a too high content of CaCO₃ (> 2.5%) may give problems in the form of severe chlorosis. Fertilization then needs to be adapted (see section 4.3.2). Clay and sandy clay soils should contain sufficient organic matter (see section 4.3.2). The lighter the soil the higher the risk of panning of the upper soil layers during prolonged rose crops. This can be avoided by lightly mixing the topsoil with coarse organic matter.

In principle cropping on heavy clay soils is possible but requires careful handling of the soil structure. Particularly during the construction of a new glasshouse or with other activities using heavy equipment, the soil structure can be damaged. To improve or maintain the structure coarse organic matter (white peat, fibre peat or composted bark) should be ploughed in.

Peat soils
Cultivating in peat soil is feasible, but an adequate drainage system should be present. Almost all peat soils are in areas with high groundwater levels, where additional drainage is necessary. Peat soils retain water easily, so that problems with oxygen deficiency due to excessive water supply may readily occur. Particularly in the winter months the soil remains wet for long periods, and water supply should be carried out cautiously. Occasionally peat soils may have a low pH, so that liming is required. This again should be conducted carefully, since excessive liming accelerates the decomposition of the peat, leading to problems with the structure. A CaCO₃ content of 0.3 to 0.4 % is sufficient.

Sandy soils
Rose cultivation on sandy soils is not so frequent. In the new cultivation areas in The Netherlands (Klazienaveen and Limburg) roses are occasionally grown in sand. In these soils the organic matter supply is extremely important. The moisture retaining capacity is small, while permeability in some sandy soils may be also problematical. In addition sandy soils are low in minerals. The right choice of organic fertilization can make the soil profile suitable for rose growing. The CaCO₃ content should at least be 0.2%. In diluvial sandy soils (East and South Netherlands) this may be too low so that extra liming is often necessary.

Drainage
A constant groundwater level of minimal 70 cm is required, but 90 cm is preferred. In those cases drainage is necessary. The standard drainage distance is one drainage tube per 3.20 m. Since due to the ban on methyl bromide and the availability of cleaner surface water, intensive leaching is no longer necessary, drainage distance in a well-permeable soil may be increased to 4 to 5 m. In view of environmental legislation a closed drainage system with additional drainage is recommended. In addition, plots located in the west of the Netherlands, such as many polder areas, have fluctuating
ditch and groundwater levels because of rainfall or severe moisture extraction by the crops in summer, but also by a regulated summer and winter level regime. This is not so suitable for the crop and additional drainage to 80 or 90 cm is recommended. To prevent undesired seepage, it may be necessary to set the pumping level 10 to 20 cm higher than the drainage level.

**Soil tillage**

Soil tillage before planting should be restricted as much as possible, since it mostly is at the expense of the soil structure. Ploughing in organic matter is necessary and homogenizes the soil after a preceding crop. The only recommended action is digging, in clay soils with a clod buster. The soil is loosened to a depth of ca 30 cm. The soil should not become too fine, therefore milling is not recommended.

If disturbing layers are observed in the profile, it is desired to have deep soil tillage carried out. In a glasshouse doubledigging can be done to a maximum of 40 to 45 cm. Loosening up and breaking the layer can be done to a depth of maximum 50 cm. If the disturbing layers are deeper, there are no further possibilities in a glasshouse with the current equipment. For new glasshouses yet to be built subsoil ploughing is a possibility, this can be done to ca 80 cm. In all cases after deep soil tillage light digging and levelling of the top layer is necessary.

4.3.2 Supply of Organic matter and base dressing

Adequate organic matter is very important for rose cultivation. Regular supply of organic fertilizers increases the content of organic matter in the soil and this content is one of the factors determining the structure of the soil. A regular organic fertilization will in most cases increase the moisture retaining capacity of the soil, and reduce the sensitivity to panning of the top layer (slaking). In addition organic fertilization affects the chemical soil fertility and organic fertilization boosts soil life.

On decomposition, organic matter releases CO₂. This may be of particular significance in glasshouses, because this CO₂ may contribute considerably to the increase of the CO₂ content in the glasshouse air.

**The Fertilization Act**

The use of animal fertilizers in The Netherlands was regulated in 1986 in the ‘Use of Animal Manure Act’. Annually no more than 100 kg P₂O₅ (44 kg P) in the form of farmyard manure or something similar may be applied per ha (10,000 m²). This corresponds with a farmyard application of 300 kg per are (Table 27).

Since 1 January 1993 the ‘Other Organic Fertilizers Act’ (BOOM) is operative for other organic fertilizers. This act mainly regulates concentrations of heavy metals in these fertilizers. In Table 27 the maximum permitted applications in tonnes per ha per year are given for a number of organic fertilizers. It also shows the amounts in kilogrammes of organic matter, nitrogen, phosphate, potassium, cadmium, copper, lead and zinc which are supplied with maximum permitted application. Research into the chemical composition of organic fertilizers is carried out at Rikilt in Wageningen (especially for trade and arbitration) and at the BLGG in Naaldwijk.

When animal fertilizers are delivered, delivery certificates have to be produced. These certificates should be kept for at least 2 years. They must be shown on demand.

**Application of organic fertilizers**

The selection of the type and amount depends on many factors and a well-founded advice is hard to give, since the effect of the application is difficult to measure.
At crop rotation on clay and sandy clay soils application of organic fertilization is necessary if the content of organic matter is less than 2 or 3%. With contents between 3 and 8% some fertilization is recommended; with percentages above 10% it is not necessary and even not advised since excessive contents of organic matter in a clay soil make the structure too dense. The heavier the soil, the coarser the chosen material. For light clay and sandy clay soils finer materials such as upgraded black peat are possible. For sandy soils the organic matter content should not become too high, because with these soil types it compacts the structure too much.

Table 27 - Maximum permitted application of animal fertilizers, compost types and purification sludge

<table>
<thead>
<tr>
<th>Type of fertilizer</th>
<th>Permitted Appl. (*)</th>
<th>SUPPLY (per ha per year)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>org. matter tot.</td>
<td>N</td>
<td>P₂O₅</td>
<td>K₂O</td>
<td>Cd</td>
<td>Cu</td>
<td>Pb</td>
<td>Zn</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(ton/ha/yr)</td>
<td>(kg)</td>
<td>(kg)</td>
<td>(kg)</td>
<td>(g)</td>
<td>(g)</td>
<td>(g)</td>
<td>(g)</td>
<td></td>
</tr>
<tr>
<td>Cow slurry</td>
<td>69</td>
<td>2100</td>
<td>304</td>
<td>125</td>
<td>380</td>
<td>2</td>
<td>208</td>
<td>76</td>
<td>347</td>
</tr>
<tr>
<td>Pig slurry</td>
<td>32</td>
<td>805</td>
<td>208</td>
<td>125</td>
<td>218</td>
<td>2,3</td>
<td>703</td>
<td>22</td>
<td>1222</td>
</tr>
<tr>
<td>Chicken slurry</td>
<td>12</td>
<td>720</td>
<td>127</td>
<td>125</td>
<td>73</td>
<td>1,3</td>
<td>216</td>
<td>7</td>
<td>767</td>
</tr>
<tr>
<td>Cow manure</td>
<td>33</td>
<td>2300</td>
<td>182</td>
<td>125</td>
<td>116</td>
<td>2</td>
<td>223</td>
<td>82</td>
<td>372</td>
</tr>
<tr>
<td>Dry chicken manure</td>
<td>4</td>
<td>820</td>
<td>107</td>
<td>125</td>
<td>98</td>
<td>1,6</td>
<td>251</td>
<td>?</td>
<td>903</td>
</tr>
<tr>
<td>Mushroom compost</td>
<td>6</td>
<td>2088</td>
<td>119</td>
<td>91</td>
<td>169</td>
<td>3,1</td>
<td>300</td>
<td></td>
<td>120</td>
</tr>
<tr>
<td>Biowaste compost</td>
<td>6</td>
<td>1080</td>
<td>72</td>
<td>36</td>
<td>60</td>
<td>4,6</td>
<td>252</td>
<td>690</td>
<td>1128</td>
</tr>
<tr>
<td>Heather compost</td>
<td>6</td>
<td>1870</td>
<td>26</td>
<td>8</td>
<td>3</td>
<td>3,3</td>
<td>72</td>
<td>420</td>
<td>402</td>
</tr>
<tr>
<td>Bark compost</td>
<td>3</td>
<td>1495</td>
<td>39</td>
<td>6</td>
<td>9</td>
<td>8,1</td>
<td>30</td>
<td>99</td>
<td>564</td>
</tr>
<tr>
<td>Compost of:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- public garden waste</td>
<td>6</td>
<td>505</td>
<td>60</td>
<td>24</td>
<td>66</td>
<td>3,6</td>
<td>168</td>
<td>570</td>
<td>636</td>
</tr>
<tr>
<td>- roadside mowings</td>
<td>6</td>
<td>1045</td>
<td>150</td>
<td>55</td>
<td>55</td>
<td>3,3</td>
<td>204</td>
<td>342</td>
<td>858</td>
</tr>
<tr>
<td>- glasshouse vegetables</td>
<td>3</td>
<td>700</td>
<td>49</td>
<td>35</td>
<td>112</td>
<td>3,6</td>
<td>78</td>
<td>93</td>
<td>1380</td>
</tr>
<tr>
<td>- household waste</td>
<td>3</td>
<td>520</td>
<td>33</td>
<td>18</td>
<td>21</td>
<td>6</td>
<td>360</td>
<td>1350</td>
<td>1800</td>
</tr>
<tr>
<td>Water purification sludge</td>
<td>2</td>
<td>650</td>
<td>118</td>
<td>120</td>
<td>96</td>
<td>6,4</td>
<td>886</td>
<td>482</td>
<td>2362</td>
</tr>
</tbody>
</table>

*) The animal fertilizers are expressed in tonnes ‘wet’ product. Composts and sludge types are expressed in tonnes dry matter
The organic matter should not be ploughed in too deep, particularly in clay soils, because this may result in oxygen deficiency during decomposition. Excessive organic matter may damage the soil structure.

Many of the organic materials used by growers are waste products of industry (including factory farming). It should be realised that these industries will increasingly be paying to get rid of their waste products. The price a grower now has to pay is already entirely determined by transport costs.

Farmyard manure
Farmyard manure includes the following categories: cow manure, pig manure, horse manure, old or fresh manure, high or low straw content. Its use is bound to legal regulations (see Table 27). Fresh manure for young plants should be advised against because of the risk of ammonia damage. In view of the risk of plant diseases, nematodes, etc. farmyard manure must be applied before steam-sterilising the soil. As the soil is heavier and the straw-content lower, farmyard manure can have a puddling effect. With fresh manure with much straw nitrogen is fixed first and extracted from the ploughed layer. This should be taken into account when applying fertilizers.

Chicken manure
Chicken manure is available in ‘fresh’ and ‘dried’ (expensive) form. Also a distinction can be made between pure chicken manure or manure mixed with peat litter or sawdust (chicken litter manure). Chicken manure is rich in nutrients the contents of which may fluctuate strongly. The risk of excessive contents and ammonia burning is present. The annual application is ca 100 kg per are (not dried!).

Spent mushroom compost
This is a fine, loose manure which spreads easily. In addition to manure mixed with hyphae, it also contains clay and peat particles. It has a slow and relatively small fertilizing effect that is of special significance for potassium. The manure raises the pH.

Slurry
Slurry is a mixture of solid and fluid excrements. If a contracting firm carries out application, the use of slurry is saves labour. The slurry is then supplied by tankers and sprayed on the spot in the glasshouse. Annual application: 500 to 800 l per are. The organic matter content and the nutrient value are about half those of farmyard manure. It owes its effectiveness to nitrogen, phosphate and potassium. The Fertilization Act also applies to the use of this manure.

Cacao waste lime
Cacao waste lime is an industrial (waste) product. It contains much calcium carbonate. The material can be fresh (poison!) or old (forced). It has an effect on both organic matter supply and other nutrient elements, particularly lime.

Bark
This waste product of the paper industry can be fresh or composted. If fresh bark is used some extra nitrogen should be applied for decomposition. Bark mostly contains manganese. It may lead to problems with manganese toxicity on acid soils. Bark falls under the regulations of BOOM.
Straw (chopped)
This material has, as organic matter, a rather short effectivity period. The decomposition of straw requires plenty of nitrogen: 2 to 3 kg calcium ammonium nitrate per 100 kg straw. This nitrogen is released shortly afterwards. Straw supply is between 100 to 150 kg per are.

Sewage sludge
In the past, sewage sludge was applied, sometimes mixed with other materials. Currently its use must be strongly advised against in view of the content of heavy metals, particularly cadmium. The BOOM regulations also apply to this material.

Peat products
Peat litter and upgraded black peat are frequently applied peat products. They contain little or no nutrients and have an acidifying effect.
- Dredged peat is rich in calcium. Peat litter and upgraded black peat used to come from the eastern peat districts of The Netherlands but currently they come from abroad. Dredged peat came from the west of Holland.
- Peat litter is made of slightly decomposed white peat, the upper part of the peat stratum
- Upgraded black peat forms from frozen, strongly decomposed black peat, the lower part of the peat stratum. Regular application of peat acidifies the soil, which may be prevented by extra liming. The combination of calcium + (oligotrophic) peat stimulates boron deficiency.

Crop shredding
Sometimes crops are shredded and ploughed in after cultivation. This is a form of organic matter supply. Shredded crops contain relatively high potassium and chloride. Extra nitrogen should be given, because some fixation as a result of decomposition occurs. This nitrogen becomes available for the plant again at a later stage.

Fertilizers Order
Fertilizers traded and transported in The Netherlands fall under a Fertilizers Order drawn up by the government which standardises fertilizers and soil improvers. These requirements mainly concern organic matter contents and other value-determining components of fertilizers, rather than the harmful components. In the Fertilizers Order states that fertilizers, when applied properly, should not have any negative effects on soil, crops, humans or animals. But fertilizers may sometimes contain substances which have negative effects only in the long term or at high dosages, which is the case with heavy metals, PCBs etc. The Fertilizers Order has not yet drawn up legal maximum standards for these substances, but these will come in due course.

Waste products as fertilizers
If waste products are used as fertilizers or soil-improvers, the user himself should monitor the quality. If application of these substances pollutes the soil, the user has to face the consequences: cleaning or digging off the soil, or a ban on growing certain crops. It may also have consequences when buying or selling the soil. Soil with high amounts of phosphate, heavy metals, dioxine, etc. is worth less than clean soil. In other words: the freedom to use certain substances does not protect against the consequences. Therefore, be very critical about the use of all kinds of fertilizers,
particularly waste products and investigate whether a product will not lead to problems, now or in future. If no satisfactory answer can be given, this sort of products should not be used. Instead of fertilizing one may be dumping waste and as a result probably violating the Soil Protection Act. Recently the government in The Netherlands increased the sanctions for environmental offences.

**Base dressing**

Prior to a new rose crop the soil used to be fertilized to bring the nutrient level to the desired standard. Recent viewpoints maintain that this is only necessary for phosphate. The other minerals can be applied better and more efficiently with the sprinkler circuit. Prior to the cultivation some basic data should be known. If this is not the case, the layers 0-25 cm and 25-50 cm, first and second spit respectively, should be sampled. Necessary basic data are: pH-KCl, CaCO$_3$, organic matter and lutum fraction, PAL figure and/or Pw value. This data can determine whether liming and/or phosphate fertilization is necessary.

**pH and liming, pH-KCl**

The pH is a measure for the acidity of the soil. To measure the pH a suspension of soil and a KCl-solution is prepared. The pH greatly influences the availability and the uptake of trace elements. Trace elements are less available as the pH is higher, but a low pH may also bring risks as the availability may be so great that toxicity occurs. This has happened with manganese after steam-sterilizing. In contrast to the other trace elements the availability of molybdenum decreases when the pH drops.

The minimum guide values for pH-KCl are given in Table 28.

**Table 28. Minimum guide values pH-KCl**

<table>
<thead>
<tr>
<th>Soil type</th>
<th>PH-KCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diluvial sand</td>
<td>6.0</td>
</tr>
<tr>
<td>Alluvial sand</td>
<td>6.3</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>6.5</td>
</tr>
<tr>
<td>River clay</td>
<td>6.5</td>
</tr>
<tr>
<td>Marine clay</td>
<td>6.7</td>
</tr>
<tr>
<td>Peaty clay</td>
<td>6.3</td>
</tr>
<tr>
<td>Peat</td>
<td>5.5</td>
</tr>
</tbody>
</table>

For clay and sandy clay soils the pH has additional importance for the structure. When pH is low too few Ca ions are available on the clay particles and the structure becomes too compact. Furthermore a significant parameter for the pH is the CaCO$_3$ content. This indicates whether sufficient buffer is present to prevent pH drop and consequently loss of structure. On the basis of these 2 figures a recommendation for liming can be given. In Table 29 the desired pH-KCl and CaCO$_3$ levels for each soil type are given in global terms. The calculation of the necessary calcium application is rather complex and is not dealt with here.

A distinction is made between maintenance liming and restorative liming. The first will frequently be applied on sandy soil with a small reserve of CaCO$_3$ and consists of 5 to 10 kg calcium fertilizer per are. Restorative liming may occasionally consist of large applications up to 100 kg calcium fertilizer and more per are. It is sometimes claimed that large calcium applications should be divided over various dosages. It has, however,
been empirically established that in glasshouse crops the entire calcium supply is best given in one application and as soon as possible. Although there are various calcium fertilizers available, the most frequently used is dolomite marl. In order to obtain a rapid effectivity the calcium fertilizers is best spread over dry soil, ploughed in lightly, and subsequently dug in deep.

Table 29. Desired pH-KCl and CaCO₃ content per soil type

<table>
<thead>
<tr>
<th>Soil type</th>
<th>pH KCl</th>
<th>CaCO₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dilluvial sand</td>
<td>5,9</td>
<td>0,2 %</td>
</tr>
<tr>
<td>Alluvial sand</td>
<td>7,0</td>
<td>0,4</td>
</tr>
<tr>
<td>River clay</td>
<td>6,2</td>
<td>0,4</td>
</tr>
<tr>
<td>Loess</td>
<td>6,0</td>
<td>0,4</td>
</tr>
<tr>
<td>Peat</td>
<td>5,4</td>
<td>0,4</td>
</tr>
<tr>
<td>Marine clay &lt;30 % silt, org. matter &lt; 5 %</td>
<td>6,5</td>
<td>0,8</td>
</tr>
<tr>
<td>idem org. matter &gt;5 %</td>
<td>6,2</td>
<td>0,5</td>
</tr>
<tr>
<td>Marine clay &gt;30 % silt, org. matter &lt; 5 %</td>
<td>6,5</td>
<td>1,0</td>
</tr>
<tr>
<td>idem org. matter &gt;5 %</td>
<td>6,2</td>
<td>0,5</td>
</tr>
</tbody>
</table>

**Calcium fertilizers**

The basic material for calcium fertilizers is calcium carbonate. In The Netherlands this material is found in large amounts in the east and south of the country. The Fertilizers Order categorizes the calcium fertilizers with the soil-improvers. Fertilization with these products aims to increase the pH and improve the structure. Table 30 gives the most important calcium fertilizers for use in glasshouses.

Table 30. Some calcium fertilizers

<table>
<thead>
<tr>
<th>Name and primary components</th>
<th>Acid binding value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium magnesium carbonate</td>
<td>Over 50, 3-11% Mg</td>
</tr>
<tr>
<td>CaCO₃ + MgCO₃</td>
<td></td>
</tr>
<tr>
<td>Ground limestone</td>
<td>53</td>
</tr>
<tr>
<td>CaCO₃</td>
<td></td>
</tr>
<tr>
<td>Lime marl</td>
<td>35</td>
</tr>
<tr>
<td>CaCO₃</td>
<td></td>
</tr>
<tr>
<td>Powder lime</td>
<td>60</td>
</tr>
<tr>
<td>Ca(OH)₂</td>
<td></td>
</tr>
<tr>
<td>Lime sludge</td>
<td>ca 20</td>
</tr>
<tr>
<td>CaCO₃ + organic matter</td>
<td></td>
</tr>
</tbody>
</table>

Calcium mixture is a coarsely sieved, undried calcium carbonate. The other calcium fertilizers are dried and ground and are finer. The fineness of calcium fertilizers determines the effectivity, the finer the better. According to the Fertilizers Order, this fineness has to meet certain requirements. If the adjective Dolomite is added to the name of the calcium fertilizers, guarantees should be given with respect to the magnesium content. The magnesium occurring in, or added to the calcium fertilizers is bound to carbonates and as a consequence poorly water-soluble. Powder lime is burnt calcium carbonate, treated with water. It has a rapid effectivity and is mostly used on a curative basis (so do not use for maintenence liming).
After application of liming the fertilizer should be intensively mixed with the soil. During
liming never use fertilizers containing ammonium. This immediately results in
development of NH₃ (ammonia) gas that is very harmful to the crop.
In addition to the structure, the pH-KCl is of significance to determine whether steam
damage may occur. As a result of soil steaming much manganese can be released in
certain soil types. This effect is stronger as the pH is lower. If steam damage is to be
expected, determination of the manganese active value is recommended. If the content
is higher than 2 μmol/kg, the risk of manganese toxicity after steaming is present.
Higher calcium applications may slightly alleviate the problem.

Phosphate fertilization
Phosphate is slightly mobile in the soil. It precipitates in the form of all kinds of salts,
particularly with iron (Fe) and aluminum (Al), but also with calcium (Ca). Phosphate
precipitates especially in soils with clay particles and in soils with a high pH. Phosphate
may leach only on acid sandy soils. As a result it is difficult to apply phosphate with the
sprinkler circuit, because the major part of the phosphate will accumulate in the top
layer. Base dressing, followed by soil tillage is a better method because only then
phosphate can be distributed over the root zone.
Through basic research, in which the PAL-value is determined, an impression can be
gained of the P-reserve of the soil. To determine the phosphate condition in the soil the
PAL determination in combination with P in the 1:2 volume-extract is applied. Before
planting a new crop, basic research with PAL determination should be carried out. Table
31 gives the valuation of the phosphate condition of the soil, with the corresponding
recommended application.

Table 31. Schedule for the determination of the phosphate application, expressed in kg
P per 100 m², depending on the PAL-value found and the P concentration in the 1:2
volume-extract

<table>
<thead>
<tr>
<th>PAL-figure</th>
<th>P (1:2) mmol/l</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 - 20</td>
</tr>
<tr>
<td>** &lt; 0.05 **</td>
<td>4.0</td>
</tr>
<tr>
<td>0.06 - 0.10</td>
<td>3.0</td>
</tr>
<tr>
<td>0.11 - 0.15</td>
<td>**</td>
</tr>
<tr>
<td>0.16 - 0.20</td>
<td>**</td>
</tr>
<tr>
<td>0.21 - 0.25</td>
<td>**</td>
</tr>
<tr>
<td>&gt; 0.25</td>
<td>**</td>
</tr>
</tbody>
</table>

Other nutrient elements
For rose cultivation a high nutrient condition of the soil is not necessary at the start.
The most efficient way of fertilizing is using the water supply. Sometimes a base
dressing is preferred and then a number of aspects should be borne in mind. The depth
to which fertilizers should be dug in may be of great importance as shallow digging
makes the upper soil relatively salt. This may lead to problems on light soils. The best
way is to dig them under to a depth of one spit (= 30 cm). Deep ploughing in organic
fertilizers may result in local oxygen deficiency on slaking and lumpy soils. The water
regime is significant or even decisive because on the one hand application of too much
water will prevent salt damage, while promoting oxygen deficiency on the other. In
addition deep ploughing of fertilizers is necessary if the soil is heavily leached prior to
cultivation.
Mineral fertilizers can be applied to the soil in two ways:
1. Spreading and subsequently mixing with the soil
2. Washing in

Washing in can be done in several ways:
a. scattering, washing in and subsequently mixing with soil
b. scattering and subsequently washing in
c. dissolving and washing in via the concentration meter

The fertilizers used in methods b and c must be completely dissolved in water. These fertilizers are: sulphate of ammonia, calcium nitrate, ammonium nitrate, magnesium nitrate, potassium nitrate and magnesium sulphate. The fertilizers calcium nitrate and magnesium sulphate cannot be dissolved together in one container (formation of gypsum = potassium sulphate).

First it must be calculated how much water is necessary to replace the more or less salt deficient soil moisture. With a depth of 30 cm and a moisture content of 30 or 40 vol. %, 90 to 120 l water per m¹ is needed to obtain a salt upper soil. By mixing with the water that has to be replaced, the increase of the nutrient level will not be restricted to 30 cm, but penetrate to a depth of an estimated 40 cm.

4.3.3 Fertilization during cultivation

In general a top dressing is applied during cultivation using the sprinkler circuit. In addition to saving labour this method of top dressing has various advantages. For example, a much better distribution of fertilizers is obtained. Furthermore, it is possible to apply the fertilization in small amounts, so that large fluctuations in the nutrient condition can be avoided. Fertilization via the sprinkler circuits connects the fertilizer supply more or less automatically to the water supply; the losses due to leaching out are thus corrected simultaneously with the water supply.

Fertilizers

Not all fertilizers used in horticulture are suitable for top dressing via the sprinkler circuit. One of the requirements they have to meet is that they should quickly dissolve in water. In addition they must not leave any residue on the crop after irrigation. Table 32 presents fertilizers that are suitable for top dressing via the sprinkler circuit.

Apart from the simple fertilizers mentioned above, a large number of compound fertilizers are available, composed especially for top dressing via the irrigation water. In The Netherlands there are numerous compound fertilizers changing annually. Furthermore the composition is modified from time to time. It is therefore not very useful to mention them here. The EC-value is mostly stated on the packing. Urea appears not to affect the EC. This fertilizer can therefore only be applied if mixed with another fertilizer.

The EC-value of a fertilizer indicates to what extent the EC of the water is increased, if 1 gram of that fertilizer is dissolved in 1 l water. Dissolving 2 g potassium nitrate increases the EC of the irrigation water with $2 \times 1.35 = 2.7$ units.

For example:
Dosage of 2 g potassium nitrate per l water:
a. Reading EC-value from Table 32. For 1 g 1.35 scale units EC, so for 2 g 2.7
b. Reading EC of the irrigation water; suppose that 1.0 is found
c. Adjusting to $1.0 + 2.7 = 3.7$

Table 32. EC-values of fertilizers

<table>
<thead>
<tr>
<th>Fertilizer Composition</th>
<th>EC-value mS.cm$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium nitrate $\text{KNO}_3$</td>
<td>1.35</td>
</tr>
<tr>
<td>Chilean nitrate $\text{NaNO}_3$</td>
<td>1.3</td>
</tr>
<tr>
<td>Calcium nitrate (solid) $5(\text{Ca(NO}_3)_2\cdot2\text{H}_2\text{O}),\text{NH}_4\text{NO}_3$</td>
<td>1.24</td>
</tr>
<tr>
<td>Calcium nitrate (liquid) $5(\text{Ca(NO}_3)_2\cdot2\text{H}_2\text{O})$</td>
<td>0.63</td>
</tr>
<tr>
<td>Ammonium nitrate (liquid) $\text{NH}_4\text{NO}_3$</td>
<td>0.86</td>
</tr>
<tr>
<td>Magnesium nitrate (liquid) $\text{Mg(NO}_3)_2\cdot6\text{H}_2\text{O}$</td>
<td>0.54</td>
</tr>
<tr>
<td>Ammonium sulphate $(\text{NH}_4)_2\text{SO}_4$</td>
<td>1.9</td>
</tr>
<tr>
<td>Urea $\text{CO(NH}_2)_2$</td>
<td>0.0</td>
</tr>
<tr>
<td>Mono-ammonium phosphate $\text{NH}_4\text{H}_2\text{PO}_4$</td>
<td>0.86</td>
</tr>
<tr>
<td>Mono-potassium phosphate $\text{KH}_2\text{PO}_4$</td>
<td>0.68</td>
</tr>
<tr>
<td>Potassium sulphate $\text{K}_2\text{SO}_4$</td>
<td>1.54</td>
</tr>
<tr>
<td>Magnesium sulphate $\text{MgSO}_4\cdot7\text{H}_2\text{O}$</td>
<td>0.94</td>
</tr>
</tbody>
</table>

The fertilizers in Table 32 may also be used in mixed form, with the exception of calcium nitrate that cannot be mixed with ammonia sulphate, potassium sulphate, mono-ammonium phosphate, mono-potassium phosphate and magnesium sulphate.

Applying fertilizers with overhead irrigation may result in leaf burning. For this reason irrigation from below is preferred, or the concentration should be so low that these problems do not arise. When determining the concentration attention should particularly be paid to the amount of ammonia nitrogen. Research results indicated that burning occurred from 4 $\mu$mol $\text{NH}_4$ per l onwards with overhead irrigation. For more sensitive crops the concentration will have to be even lower. The effect of the urea nitrogen is probably the same as that of ammonium nitrogen. Fertilizers not containing ammonia, can often be applied in concentrations of 2 to 3 g per l.

For top dressing the fertilizers presented in Table 32 or a mixture of them are used. Also compound fertilizers are widely applied. The fertilizer is chosen on the basis of crop and soil analysis results, irrigation water quality and cultivation circumstances. In the first place attention is given to nitrogen and potassium supply, but apart from these also calcium and magnesium are important. Sulphate is mostly present in sufficient amounts and top dressing with phosphate can also usually be omitted. Sometimes trace elements need to be given, especially boron.

The amount of fertilizer applied is expressed as concentration of the irrigation water supplied. The fertilization is more or less connected to the water supply. This is necessary because with large amounts of water part of the fertilizers is leached out. By continuously adding fertilizers to the irrigation water, the leaching is more or less compensated for. The concentration of fertilizers to be applied depends on the same factors as the fertilizer choice. Mostly between 0.5 and 1.0 g per l water is applied.

*Nutrient solutions*

Using a number of simple fertilizers, mixtures are prepared containing all necessary nutrients in optimum ratios for rose. The mixture can continuously be applied to the
irrigation water in a certain concentration. Based on the soil analysis certain elements or the entire concentration can be adjusted.

Every 4 to 6 weeks soil samples are taken and analysed. For the analysis of glasshouse soil the 1:2 volume-extraction method is used. On the basis of the analytical data, a nutrition recommendation is drawn up. For this recommendation both simple and compound fertilizers are used. A drawback of compound fertilizers is that the ratios between the elements are fixed. In addition these fertilizers do not contain the element calcium. This may be a problem when rainwater is used, since this type of water does not naturally contain calcium.

For the composition of the nutrition recommendations for the other crops, see ‘Bemestingsadviesbasis Glastuinbouw’, published by PBG.

The principle of giving top dressing recommendations on the basis of soil analysis results is based on regulating the concentration and the composition of the nutrient solution depending on the analytical results. The N-content in the 1:2 volume-extract determines the concentration to be applied. The other nutrient elements are given in relation to the nitrogen. High or low contents of a certain element in the 1:2 volume-extract are corrected by a decrease or increase, respectively of the concentration of that element in the nutrient solution. Quantification takes place by calculating in advance the proportion of all elements in the 1:2 volume-extract in view of nitrogen and adjusting the composition of the nutrient solution accordingly.

**Soil analysis data**
The recommendation is given on the basis of analytical data obtained using the 1:2 volume-extract method. The contents of cations and anions are expressed in μmol per l extract and the conductivity (EC) in mS per cm at 25°C. The recommendation involves the following determinations:
- Cations: NH₄, Na, K, Ca, Mg
- Anions: NO₃, Cl, SO₄, P
- EC

**Evaluation analytical data**
In the evaluation of the analytical data the initial values are an assessment adjusted to the crop. Guide values for rose are given in Table 33. Only clearly deviating figures are indicated. In addition a check is carried out whether the analytical data are within the limits of the recommendation.

The EC-value is calculated on the basis of the contributions to the EC of the individual fertilizers. Phosphate and the trace element boron are not normally applied, only when necessary. In the standard composition the main part of the nitrogen is given as nitrate. Possible adjustments in the composition may make it necessary to apply more nitrogen in the form of ammonium in order to make the ion sums in the nutrient solutions balanced.

Attention should also be paid to the proportions of the various nutrient elements. As a rule, the anion proportions do not systematically influence the cation uptake and vice versa. The proportions of cations and anions do, as a rule, influence the uptake of certain cations and anions, respectively. In the composition of the recommendation this should be taken into account.
Table 33. Guide values for rose

Standard nutrient solution

<table>
<thead>
<tr>
<th>Element content in %</th>
<th>EC-value (l g l^-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH₄</td>
<td>K</td>
</tr>
<tr>
<td>0,9</td>
<td>3,5</td>
</tr>
</tbody>
</table>

Guide values and limits for the analytical data in the 1:2 volume-extract

<table>
<thead>
<tr>
<th>Guide value</th>
<th>EC</th>
<th>NH₄</th>
<th>K</th>
<th>Na</th>
<th>Ca</th>
<th>Mg</th>
<th>NO₃</th>
<th>Cl</th>
<th>SO₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>Too high</td>
<td>1,0</td>
<td>0</td>
<td>1,5</td>
<td>0</td>
<td>2,0</td>
<td>1,2</td>
<td>4,0</td>
<td>0</td>
<td>1,5</td>
</tr>
<tr>
<td>Too low</td>
<td>1,4</td>
<td>0,5</td>
<td>2,5</td>
<td>4,0</td>
<td>4,0</td>
<td>2,0</td>
<td>8,0</td>
<td>4,0</td>
<td>4,0</td>
</tr>
</tbody>
</table>

**Trace elements**

Except boron, trace elements are not part of the standard nutrient solution. Under normal conditions iron, manganese, copper, zinc and molybdenum are available in sufficient amounts in the soil. If boron is not present in the irrigation water, application of B is called for. The B-level in the 1:2 extract should be between 10 and 20 umol/l, standard application for rose is 10 umol/l.

**Ca application**

Apart from adjustments on the basis of Ca 1:2 extract, the Ca application is also corrected on the basis of pH and CaCO₃. Correction of Ca is done if the pH or the CaCO₃ content exceeds a fixed value (depending on soil type, percentage of organic matter and silt; see 'Bemestingsadviesbasis Glastuinbouw'). The correction consists of two adjustments. In the first adjustment Ca is partly and in the second entirely removed from the nutrient solution.

**Nutrition and water quality**

Not all types of water are suitable for use in glasshouse soil. The salt content (EC, Na and Cl) must not be too high. Particularly if the drainage water is being re-used the input of salts should be low. The EC of the initial water should be lower than 1,0, Na and Cl not higher than 3,0 mmol/l. When surface water is used normally enough SO₄ is present and savings can be made on K, Ca and Mg. Nitrogen is present in low concentrations for growing. Trace elements certainly need not be applied. An average analysis gives a reasonable picture of the composition. The EC of ditch water, however, may fluctuate strongly, as a result of precipitation, drainage, etc. In case of spring water, analysis may be necessary to be able to adjust the dosage properly. Various nutrient elements may be present in spring water as well.

**Re-use of drainage water**

Drainage water consists usually not only of the surplus of water from the soil profile, but also of water coming from surrounding ditches or adjacent plots into the system. Seepage may be involved as well, sometimes with a high salt concentration. The quality of the drainage water therefore strongly depends on the hydrology of the plot. When recirculation of the drainage water is used the same limitations are valid with regard to
Photo 13. Effect of transportation on bud opening of Frisco. Left: 0 days of transport, centre: 3 days of transport, right: 2 days of transport

Photo 14. Rose root infected by the root-knot nematode Meloidogyne hapla; root-knot 1-2 mm in size

Photo 15. Agrobacterium tumefaciens, causing a crown gall on grafting spot

Photo 16. Yellow rose aphid, Rhodobium porosum

Photo 17. Common rose aphid, Macrosiphum rosae

Photo 18. Yellow peach aphid on rose bud
Photo 19. Cotton aphid, Aphis gossypii, on Cyclamen

Photo 20. Foxglove aphid, Aulacorthum solani

Photo 21. Potato aphid, Macrosiphum euphorbiae

Photo 22. Butterfly of the beet armyworm

Photo 23. Caterpillar of the beet armyworm

Photo 24. Butterfly of the leaf roller
the water quality of the irrigation water. The drainage water has to be diluted to such a
degree that the concentrations of Na and Cl remain below 3 mmol/l. As rainwater or
desalinated water is used more intensively, more drainage water can be processed. In
situations with seepage the amount of drainage water can be so much greater than the
demand, particularly in low-light periods, that there are great surpluses. In consultation
with the permit-issuing authority a solution for this surplus should be found.
The nutrient solution can simply be adjusted to the composition of the drainage water.
Various calculation programmes are available for this purpose.

4.3.4 Water supply in soil

Due to a number of environmental laws it is important to fine-tune the water supply in a
soil-grown rose crop as much as possible to the crop's demand. Of course the soil type
should also be taken into consideration.
A considerable buffer stock of water in the soil is always available to the plant. It is
therefore not necessary, as it is in substrate grown crops, to immediately supplement
the amount of water taken up by the plant. Supplying water every 2 or 3 days is
sufficient in the summer, in winter even once a week. The drawback of more frequent
water supply is that the crop becomes wet. On the other hand, in spring and summer it
might be desirable for the glasshouse climate to supply water more often. The reference
point for the current environmental legislation is that water supply is adjusted to the
crop's requirement and this can be continuously calculated with the aid of transpiration
models, in which radiation, pipe temperature and assimilation lighting are the most
important factors. The water supply is then determined by the sum of the calculated
transpiration over a certain period. The transpiration sum calculated has to be increased
with a correction factor for fluctuations in the system and for the fact that not all plants
have the same amount of transpiration. To avoid dry spots therefore a greater water
supply than the calculated transpiration is needed. It is obvious that the best results are
obtained with a uniform irrigation system. Research on a large number of nurseries
showed that if the groundwater level was lower than 85 cm under surface level more
water was supplied during May, June and July, than on nurseries with a more shallow
groundwater level of 70 cm or less below surface level. The latter group consisted
mainly of sandy soil nurseries, while in the former mostly clay soils occurred.
In principle water supply in soil grown crops can be done with the water supply
calculation model. Feedback is important also for soil crops, for which tensiometers and
hygrometers may be used for continuous measurement. They may form part of the
water supply calculation model. The first tests of the model in some chrysanthemum
crops in soil with tensiometers and/or hygrometers seem to indicate good prospects. In
these experiments the tensiometer and/or hygrometer were incorporated into the model
as feedback.
Where no feedback is possible calculation of the water requirement (transpiration and
growth model) can still be a useful guideline to adjust the water supply to the
requirement of a rose crop. The influence of soil and groundwater will have to be
estimated by the grower himself.

Water supply and soil type

Soil types show great differences in permeability and water-holding capacity. Sandy
soils retain the least water, peat soils the most, while clay soils are inbetween. With
many years of organic matter supply, however, sandy and sandy clay soils may obtain a
reasonable water-holding capacity, while heavy clay and peat soils may retain less
water as a consequence of becoming poorer. The less moisture the soil retains, the
more frequently water will have to be supplied although even in clay soils, it is better to apply frequent, or short watering, since with long watering much water will leach away through large pores and cracks.

The capillary conductivity and the groundwater level also play a significant role. The higher the level of the groundwater, the more water the crop will extract from the subsoil, and water supply can be restricted. With the same groundwater level the significance of capillary rise in peat soils is greatest and in sandy soils smallest. Therefore on peaty soils the moisture in winter may be so great that water does not have to be supplied. One of the disadvantages may be that salinization of the upper soil layers is slow. This should be monitored through regular analyses of the first and second spits.

4.4 GROWING IN SUBSTRATE

4.4.1 Growing media

For rose it is important that the rooting medium meets a number of important requirements. The plant should receive enough support, the root should be able to take up oxygen, the substrate should supply sufficient water and the chemical characteristics should be known. Light materials or materials which shrink considerably may give too little support. This is mostly not a problem for materials currently in use. Water and air distribution is of great importance because it is vital that the roots always have sufficient water and oxygen available. Research into the growth of rose cuttings (Figure 6) in rockwool at various pressure heads showed that not all growing media are so suitable. At higher pressure heads from -10 cm to 2 cm the air content decreases and the shoot is clearly smaller. Cuttings are apparently very sensitive. A mature plant is less sensitive and has the possibility to adjust to a low-air environment, because the root porosity of rose increases in a low-air environment. Gas transport can then take place to zones where the possibilities through the substrate are poor. The plant does this by making air channels, which can be measured by determining the root porosity. Chemically speaking there are substrates which have virtually no influence on the root environment: inert substrates. A number of other substrates do influence the root environment, such as cocopeat, peat. Of course, this must be taken into consideration. The durability and manageability of the substrates are important. Growing media can be roughly divided into 2 groups: slabs and loose material. Slabs are mostly wrapped in plastic films. In general these are easily manageable, which is a considerable advantage when preparing the glasshouse for the new crop. When using loose substrate trays or buckets will have to be purchased. The reliability and the service of the manufacturer is also an important consideration when choosing a substrate.

Mineral wool

Rockwool is the most widely known mineral wool, but glasswool also belongs to this group. The substrate is normally delivered in slabs. Granules and blocks of rockwool are not used in rose cultivation. The material has a large water-holding capacity, but it also releases water very easily. In addition, rockwool, once dry, is very difficult to re-moisten. The pore distribution of rockwool slabs is such that the moisture is not uniformly divided over the height of the slab. The rockwool at the bottom of the slab is almost always completely saturated, while the top the material may be completely dried out. Water supply should therefore be such that the whole slab remains moist, but does not become very wet. This means continuous compromises; if too little water is
given part of the slab dries out and water buffer and root volume severely decrease. If too much water is given the air content decreases strongly, resulting in the risk of oxygen deficiency for the roots. Both situations are undesirable because they have an adverse effect on yield. From a chemical point of view mineral wool is virtually inert. A low pH, however, may affect rockwool so that the fibre loses its stability and the substrate becomes mushy and may collapse. When used correctly mineral wool can be applied for several years.

Fig. 6. Shoot length of rose after propagation period in rockwool (Baas et al., 1997)

Growing on rockwool slabs

Plastic substrates
There are 3 plastic substrates available: polyurethane foam (PU), phenolic resin (PR) and urea formaldehyde (UF) although for rose cultivation they are hardly used. Phenolic resin
(Oasis) is actually only used for propagation (plugs) and in anthurium cultivation. On experimental scale some experience has been gained with UF foam. PU foam slabs are the most widely used and applied in the form of granules in orchid cultivation. Mostly it is used in mixtures with peat or rockwool.

PU-foam is a very dry substrate with consequently a small water buffer. As a result of the small water buffer the frequency of water supply must be higher than in rockwool otherwise drought stress may occur, leading to yield loss. This is the reason why peat or rockwool is added to the granules. The water uptake capacities of the slabs increase in the course of the cropping period as a result of root development. Old slabs therefore take up more water than new ones. The pore distributions in the PU foam is such that the foam at the bottom of the slab is very wet and in the upper part of the slab very dry. From a chemical point of view PU-foam is inert and lasts for many years.

Other mineral growing media
Pumice is a substrate of volcanic origin. It is available as pumice and ‘washed sand’. Perlite is roasted volcanic rock, while clay granules are produced by baking clay. Pumice and clay granules belong to the heavier substrates making the handling of these substrates less attractive. The rather coarse pumice and clay granule types available have a very small water buffer. A high frequency of water supply to avoid drought stress and realise sufficient replacement of the nutrient solution is necessary. Watering should be done from above because the capillary effect is small. Perlite has a much greater water buffer. Due to very coarse pores in the coarser versions of this material, oxygen supply is not a problem. In fine perlite, ‘washing sand’ and flugsand this may be difficult.

Good substrates of mineral origin have little effect on the chemical composition of the substrate moisture. There are, however, materials available in which the salt content is too high. To avoid problems a substrate should be certified.

The materials mentioned can be used for several years, although perlite is rather brittle and easily becomes finer and the intermediate fraction should be used. Growing on clay granules is decreasing. Sometimes the granules are used in the bottom of a container with cocopeat on top to facilitate drainage. Pumice is used on a small scale only but first results of experimental plantings are positive.

Organic substrates of natural origin
Peat, cocopeat, and wood fibre are of vegetable origin. There are many variations of these substrates available, from coarse to fine and from fibrous to granulated material. This means that there are many different physical characteristics. When using peat as growing medium mostly a somewhat coarser stable peat is used such as Irish peat. Peat naturally absorbs plenty of water but to guarantee adequate oxygen supply, it is vital to create sufficiently large pores. Water transport and consequently water distribution in peat substrate is generally very good, but the peat should not dry out, because, in contrast to the mineral substrates and cocopeat, peat becomes water repellent after drying.

Coir dust and coir chips also naturally absorb plenty of water. Coir dust is used in rose cultivation and this substrate is less sensitive to drying and the oxygen supply is adequate.

Most substrates based on wood have a limited water buffer, which may easily result in drought stress. Form a chemical point of view these substrates are not inert, which means that they may influence the chemical composition in the root environment. This need not always be a problem because on the other hand this implies that there is a certain buffer of chemical elements. Peat has a naturally low pH and should therefore
be limed first. When used for several years the copper content should be monitored closely. Cocopeat generally contains a lot of sodium and potassium, and should therefore be pre-treated, if possible, so that these elements are superseded from the adsorption complex. Wood fibre has a large proportion of easily degradable parts so that micro-organisms grow profusely. As a result, nitrogen is fixed before being available to the plant. Therefore a surplus of nitrogen should always be applied and an almost continuous replacement of the nutrient solution will have to take place, since nitrogen deficiency has an immediate effect on production. The extent to which the nitrogen fixation develops strongly depends on the type of wood fibre. In addition, there is the risk of substances, phenolic compounds, being released from the wood, which may also inhibit growth.

With the exception of coarse peat, it is not practical to use organic substrates for more than one crop, especially because they are difficult to steam-sterilize. Experimental data from rose cultivation indicated that cocopeat and peat can be used for several years. Cocopeat is being used on an increasing scale.

**Basic guidelines**

A substrate recommendation for rose cultivation has been set up based on experiments with rose and practical growing experience. There appear to be many possibilities because so many different substrate materials are available. All chemical, biological and physical standards to which substrates have to comply have been incorporated into basic guidelines. Since there are so many possibilities, the recommendation remains rather general. Two things seem to be important; the air content and the method of irrigation. The recommendation differs from crop to crop. Certain crops require a lot of oxygen around the roots, others less. Secondly, substrates with a low water content require a more frequent and/or different water supply. For example, coarse clay granules in buckets are suitable as substrate, but water supply is not optimal until good spraying pens are used and the frequency is sufficiently high.

**Table 34. Substrate recommendations for rose cultivation**

<table>
<thead>
<tr>
<th>Substrate**</th>
<th>Water supply system</th>
<th>Growing system</th>
<th>Thickness (cm)</th>
<th>Recommendation Air*</th>
<th>Water*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-formed, e.g. Wood fibre, peat, coir dust, perlite, pumice</td>
<td>drippers or spraying pen</td>
<td>trays/containers</td>
<td>5-15</td>
<td>10-60</td>
<td>20-55</td>
</tr>
<tr>
<td>Non-formed, e.g. Wood fibre, peat, coir dust, perlite, pumice</td>
<td>ebb/flow or spraying pen</td>
<td>trays/containers</td>
<td>10-20</td>
<td>40-90</td>
<td>20-75</td>
</tr>
<tr>
<td>formed, e.g. Rockwool, glasswool, cocopeat</td>
<td>drippers</td>
<td>slabs</td>
<td>5-7,5</td>
<td>15-80</td>
<td>15-85</td>
</tr>
</tbody>
</table>

* %, according to method CEN at –10 cm pressure head (Kipp et al., 1998)
** not all examples mentioned automatically comply with the standards, i.e. when choosing a substrate the standards should be taken into consideration and the fraction distribution should be adjusted

A small water buffer has both a positive and a negative side. Although water supply is frequent giving sufficient control with respect to fertilization, one drawback of a small water buffer is that the risk of stress of the roots is also greater. Certain parts of the
roots may easily dry out so adversely effecting the functioning of the root. Table 34 gives a list of the recommendations for the various growing systems for rose. When choosing the substrate the length of the cultivation period must be taken into consideration because for long cultivation periods stable materials are preferred. More information and supplementary standards can be found in the Basic Guidelines for Substrates and the International Substrate Manual (Kipp and Wever, 2000). Figure 7 shows which substrates were used in 1995. In recent years the area with cocopeat increased while the area with clay granules decreased. The total area of substrate has increased but it is not known exactly what area is down to which substrate. In section 3.3.2 the systems are described which are used in combination with certain substrates.

Fig. 7. Acreages of substrates for rose in 1995 (Wever, 1995)

4.4.2 FERTILIZATION

Nutrient solutions
In substrate crops the rooted volume and consequently also the stock of minerals available for the plants is limited in comparison to the situation in soil. To avoid exhaustion the plants should be frequently provided with minerals. Shortages may rapidly occur particularly of nutrient elements that are taken up by the plants in considerable quantities, such as potassium and nitrogen. Apart from a few exceptions growing media do not contain nutrient elements, and all necessary nutrients must be supplied. It is important that the supply of nutrient elements is adjusted to the requirement of the crop. This requirement is not only based on the absolute uptake of an element, but also the mutual relations of elements in the root environment necessary to realise optimum contents of nutrient elements in the plant. Since there is great difference in ‘uptake rate’ between elements, the proportions between nutrient elements realised in the root environment are different from those at uptake. Due to unbalanced application certain elements may accumulate strongly, as is the case with water with high salt concentrations.

A nutrient solution is a solution containing all nutrient elements necessary for the plant in optimum concentrations and proportions. For every crop, and in some cases also for certain substrates, so-called standard nutrient solutions have been composed. These are
composed in such a way that the sum of cations and anions of the main elements are equal in equivalents. This makes calculation of a recipe for a nutrient solution from the available fertilizers (fertilizer recipe). For trace elements no balanced ion balance is calculated, because it is not necessary to take the accompanying cation or anion in the fertilizer into account. For the calculation method of the fertilizer recipes, see booklet no. 10, from the series 'Nutrient solutions for glasshouse horticulture'.

Using the standard nutrient solution for rose the correct proportions in the trickle water are obtained. This composition deviates from the optimal concentrations and proportions in the root environment. Higher concentrations are needed near the root of ions that are taken up with more difficulty, such as Ca, Mg and Fe. Other ions, such as NH₄ and B, which are taken up quickly, require a much lower concentration in the root environment. Table 35 shows the standard nutrient solution for free drainage and for closed systems. For closed systems the nutrient solution has been calculated so that the desired composition of the trickle water is achieved using an average analysis of the drainage water, at a mixing percentage of ca 30%.

The cultivation is based on the standard nutrient solution. Depending on a number of situations adjustments are carried out. There are standard adjustments at the start of the cultivation period and a number of adjustments dependant on the growth phase. In addition adjustments are carried out on the basis of analytical results of samples from the root environment.

Table 35. The standard nutrient solutions for rose for open and closed growing systems and the guide values in the root environment

<table>
<thead>
<tr>
<th></th>
<th>Open growing system</th>
<th>Closed growing system</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC mS cm⁻¹</td>
<td>1.6</td>
<td>0.7</td>
</tr>
<tr>
<td>NH₄ mmol l⁻¹</td>
<td>1.5</td>
<td>0.8</td>
</tr>
<tr>
<td>K</td>
<td>4.5</td>
<td>2.2</td>
</tr>
<tr>
<td>Ca</td>
<td>3.25</td>
<td>0.8</td>
</tr>
<tr>
<td>Mg</td>
<td>1.125</td>
<td>0.6</td>
</tr>
<tr>
<td>NO₃</td>
<td>11.0</td>
<td>4.3</td>
</tr>
<tr>
<td>SO₄</td>
<td>1.25</td>
<td>0.5</td>
</tr>
<tr>
<td>P</td>
<td>1.25</td>
<td>0.5</td>
</tr>
<tr>
<td>Fe µmol l⁻¹</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>Mn</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Zn</td>
<td>3.5</td>
<td>3</td>
</tr>
<tr>
<td>B</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Cu</td>
<td>0.75</td>
<td>0.5</td>
</tr>
<tr>
<td>Mo</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Adjustments based on growing system and substrate
In growing systems in which more water is regularly supplied than required by the plant, leaching of water and minerals takes place. In this drainage water the EC is almost always higher than that in the supply, but, more importantly, the ion ratios have shifted in comparison to the nutrient solution supplied. As a rule, the bivalent ions such
as Ca, Mg, and SO₄ have increased compared to the monovalent ions, such as K and NO₃. For growing systems in which the drainage water is re-used, different ion ratios should be used, in order to prevent too strong an accumulation of ions such as SO₄, Mg and Ca. It does not matter, in this case, whether only 10% of the water supply is recirculated or that the nutrient solution is being pumped round at high frequency. The determining factor is whether or not leaching takes place. For this reason separate nutrient solutions have been drawn up for systems with free drainage and for closed systems. See also Table 38.

The nutrition needs to be adjusted for some substrates. The most important issues are dealt with below. Substrates that are not mentioned do not need adjustments.

**Water cultures**
In growing systems without solid substrate, such as NFT, aeroponics and water culture, more so-called water roots are formed, which are longer and thicker than those grown in soil or substrate. Particularly the uptake of Fe is restricted, which makes it necessary to supply more Fe.

**Glass wool**
Initially this product is rather high in boron, as a result of manufacturing. This easily washes out, so that there are no long-lasting after-effects. Leave B out of the irrigation scheme at the start of the cultivation period and do not supply it for the first few weeks. On the basis of analysis start supplying B again.

**Peaty substrates**
For crops in peaty substrates the same nutrient solutions are applied as for rockwool crops, with the exception of copper. This element should be given in double concentration. Although the peat may have been fertilized previously, the amount of nutrients is significant only at the start.

**Polyphenol foam**
With plastic foam (polyphenol) the pH can easily fall. Therefore less NH₄ should be applied.

**Coir dust**
This material deviates from the other substrates in that it can fix cations to the so-called adsorption complex. This complex is naturally occupied by K and Na. Application of Ca via the nutrient solution results in strong adsorption of Ca and release of K and Na. To prevent this problem in some cases the material is treated with Ca in advance. Untreated or partly treated material will require considerable extra Ca supply at the beginning and strong leaching to get rid of the Na. At the start of the cultivation one should therefore be on the alert.

**Closed growing systems**
The most important differences between systems with free drainage and closed systems is that the composition in the drainage water will partly determine the proportions in the trickle water. With the usual leaching percentages the drainage water will determine about 30 to 40% of the total EC of the trickle water. It is a matter of major concern that the composition of the trickle water corresponds to the proportions in the standard nutrient solution for free drainage. Also the guide values for the root environment are equal in this respect for closed systems and for free drainage. A point
of interest is how the application of nutrient elements (from fertilizers) can best be adjusted to the composition of the drainage water to achieve the desired composition of the irrigation water. If no leaching or loss of nutrient elements occurs, this means for closed systems that on average the supply of nutrition should correspond with the crop uptake. If this is not the case, either exhaustion or accumulation develops.

For closed systems there are three methods for controlling the nutrition:
1) Continuous immediate use of drainage water (disinfected or not), in which the standard nutrient solution for closed systems is applied, henceforth called recirculation solution.
2) Direct use of drainage water, in which the fertilizer recipe is calculated on the basis of an analysis of the drainage water, called the drainage water analysis method
3) Drainage water is collected and stored for a period of time, in which the fertilizer recipe is calculated on the basis of the composition of the stored drainage water, called interim storage method.

The aim of all 3 methods is to realise the same trickle solution. For the recirculation solution this is based on the average situation. During the cultivation period regular shifts occur in the uptake proportions and adjustments are therefore necessary. With the drainage water analysis method the trickle solution can be approximated rather closely. However, since this is based on a random indication of the drainage water and since at most once a week sampling and subsequent adjustment will take place, the proportions may fluctuate considerably. The ideal situation is achieved with the interim storage method. The trickle solution is again closely approximated and furthermore the composition is constant, as long as the stock is used. However, the calculated fertilizer recipe is valid only with selected initial values, such as the EC of the irrigation water and the drainage percentage to be used. The advantages of the interim storage method are only reached with advanced and consequently expensive application equipment.

In Tables 36 and 37 two calculation examples are given of how the composition of the irrigation water can be achieved.

Calculation example 1
Situation with use of the recirculation solution
Drainage percentage = 20
Set irrigation EC = 2.3 mS.cm-1

Table 36. Calculation of the composition of the irrigation water with continuous direct use of drainage water; situation only for cations

<table>
<thead>
<tr>
<th>Desired trickle solution</th>
<th>recirculation solution</th>
<th>composition drainage water contrib. from drain 20% contrib. from fertilizers</th>
<th>composition trickle water</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC 2.3</td>
<td>1.5</td>
<td>3.5</td>
<td>0.7</td>
</tr>
<tr>
<td>NH₄ 1.25</td>
<td>1.0</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>K 8.75</td>
<td>6.5</td>
<td>8.0</td>
<td>1.6</td>
</tr>
<tr>
<td>Ca 4.25</td>
<td>2.75</td>
<td>8.0</td>
<td>1.6</td>
</tr>
<tr>
<td>Mg 2.0</td>
<td>1.0</td>
<td>4.6</td>
<td>0.9</td>
</tr>
<tr>
<td>Na 0</td>
<td>0</td>
<td>1.6</td>
<td>0.3</td>
</tr>
</tbody>
</table>
The contribution from the drainage water is calculated by taking 20% of the EC and the concentrations present in the drainage water. The contribution from fertilizers is calculated by the remaining part of EC-value to the irrigation EC (in this example 2.3), in which the contribution of the separate ions is a result of the proportional share of ions in the recirculation solution.

Calculation example 2.
Situation with analysis of drainage water and interim storage of drainage water
Drainage percentage = 20
Set irrigation EC = 2.3 mS.cm⁻¹
The average drainage water composition is valid for both methods, with the distinction that in the method with interim storage much greater volumes are concerned.

Table 37. Calculation of the composition of the drainage water with the drainage water analysis method and the interim storage method; situation only for cations

<table>
<thead>
<tr>
<th>Desired trickle solution</th>
<th>Composition from drainage water</th>
<th>Contrib. from drain 20%</th>
<th>Contrib. from fertilizers</th>
<th>Composition from trickle water</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC 2.3</td>
<td>3.5</td>
<td>0.7</td>
<td>1.6</td>
<td>2.3</td>
</tr>
<tr>
<td>NH₄ 1.25</td>
<td>0.1</td>
<td>0.1</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>K 8.75</td>
<td>8.0</td>
<td>1.6</td>
<td>7.15</td>
<td>8.75</td>
</tr>
<tr>
<td>Ca 4.25</td>
<td>8.0</td>
<td>1.6</td>
<td>2.65</td>
<td>4.25</td>
</tr>
<tr>
<td>Mg 2.0</td>
<td>4.6</td>
<td>0.9</td>
<td>1.1</td>
<td>2.0</td>
</tr>
<tr>
<td>Na 0</td>
<td>1.6</td>
<td>0.3</td>
<td>0</td>
<td>0.3</td>
</tr>
</tbody>
</table>

The contribution from the fertilizers is calculated in this case from the difference between the desired irrigation solution and the contribution of each of the nutrient elements from the drainage water. If the irrigation EC or the percentage drainage water used changes, the fertilization solution will have to be adjusted.

It is of great importance that the correct procedure is followed for the calculations of the fertilizer recipe or the proportions of the fertilizers in injection systems.

Water quality

EC, sodium and chloride
Water can contain certain salts and this should be taken into account in the composition of the nutrient solution. As far as nutrient elements are concerned they can be subtracted from the amounts to be supplied. Sodium (Na) and chloride (Cl) are lumber salts and are not, or only to a very limited degree, necessary for the plant. The total EC, Na and Cl determine the general quality of the irrigation water. Water with an EC lower than 0.5 and Na and Cl less than 1.5 mmol/l is essentially suitable for substrate growing. In closed systems, however, the Na content may increase, since the uptake concentration of the rose is low, less than 0.1 mmol l⁻¹. Regularly part of the solution will have to be drained off. Theoretically, even with the use of rainwater
draining is required, because (in the west of the Netherlands) this water contains on average ca. 0.2 mmol.l⁻¹ Na. In practice this will not be so detrimental, since small losses (leaks) are usually sufficient not to allow Na to accumulate further, both in the plant and in the substrate. Normally chloride is not a problem, because the uptake capacity of this ion is much higher.

Calcium, magnesium and bicarbonate
Bicarbonate (HCO₃⁻) causes a rise in the pH of the root medium. HCO₃⁻ in the water must be neutralised with acid for substrate crops. The following reaction develops:

\[
\text{HCO}_3^- + \text{H}_3\text{O}^+ \rightarrow \text{H}_2\text{CO}_3 + \text{H}_2\text{O} \rightarrow 2\text{H}_2\text{O} + \text{CO}_2
\]

The acid is included in the schemes for nutrient solutions as part of the set of fertilizers. For every mmol HCO₃ in the water 1 mmol acid is needed. For a stable pH control it is better that not all HCO₃ is neutralised but that several tenths of millimol are left as a remainder. The small pH rise resulting from this remaining HCO₃, can be kept well under control with an acid regulation on the application equipment. For the concentrated fertilization solution phosphoric acid and/or nitric acid are used. Usually so much phosphoric acid as phosphate is needed is first filled in the recipe. This is cheaper than applying phosphate in the form of mono potassium phosphate. The remainder is then supplemented with nitric acid. When completely liquid fertilizers are used the amount of acid needed is obtained by adjusting the caustic/acid balance. The concentration in the acid container is mostly ca 100-150 mmol per l. This depends on the technical design of the control system.

If the water contains HCO₃, Ca and/or Mg are almost always present. If the concentrations are higher than 0.4 to 0.5 mmol per l, a correction is carried out. It is essential for the calculation method that the required acid and the corrections for Ca and Mg are equal in equivalents. This means that the number of millimoles acid applied is equal to twice the reduced number of millimoles Ca and Mg.

Scheme code
For irrigation water with diverging concentrations of HCO₃, Ca and Mg recipes have been drawn up for the preparation of nutrient solutions. These schemes are provided with a code: a letter and usually 3 numerals. Scheme codes with the letter A are adapted to water containing HCO₃, Ca and Mg. The first figure of the code represents the amount of acid taken up in the scheme to neutralise the HCO₃. The second and third figures indicate the amount of Ca and Mg subtracted from the required concentration. For the amounts of acid the scheme codes rise in steps of 0.5 mmol per l, and the amounts of reduced Ca and Mg with steps of 0.25 mmol/l. To avoid decimals in the scheme code, the number of mmol acid is multiplied by 2 and the mmol Ca and Mg by 4. For example: scheme A.5.4.1 contains 2.5 mmol acid per l, and 1.0 and 0.25 mmol per l Ca and Mg, respectively, have been deducted. The choice of the correct scheme on the basis of the chemical composition of the water is as follows: 0.5 mmol per l is subtracted from the HCO₃ concentration and subsequently rounded down to half a unit in such a way that at least 0.4 and at most 0.8 mmol HCO₃ remains. The result is the amount of acid in mmol per litre. After duplication this is the first figure of the code. Subsequently the Ca and Mg concentrations are rounded down to 0.25 mmol per litre. The results are quadrupled and are the second and third figure of the code, respectively. The corrections of acid, Ca and Mg should be equal in equivalents. The sum of the second and third code figure should therefore be equal to the first figure. If
this is not the case, the second and third figures are chosen in such a way that the best suitable scheme for a particular water quality is obtained. Table 38 gives an example of the choice of a scheme.

**Exceptional schemes**
Apart from HCO₃, Ca and Mg also SO₄, K or NO₃ may be present in the water. If the concentrations are of any significance, they also need to be corrected. This method is about the same as described for Ca and Mg. SO₄ is corrected in steps of 0.25 mmol per litre and NO₃ and K in steps of 0.5 mmol per litre. These schemes are referred to as B-schemes. The code consists of 6 numerals. The significance of the first 3 figures is the same as described above. The fourth, fifth and sixth figures represent SO₄, NO₃ and K, respectively. For easy reference a slash is placed between third and fourth figures. On the basis of the composition of the water the best fitting scheme will have to be selected. Total corrections of cations should be equal to that of anions. This means that the sum of the first, fourth and fifth code figure is equal to the sum of the code figures two, three and six. Example: the scheme B 6.8.1/3.1.1 contains 3 mmol acid and the following amounts have been deducted: 2 mmol per litre Ca, 0.25 mmol per litre Mg, 0.75 mmol per litre SO₄, 0.5 mmol per litre NO₃ and 0.5 mmol per litre K.

Table 38. Example of determination of the correct scheme, adapted to the water quality

<table>
<thead>
<tr>
<th>Supposed analysis irrigation water</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>HCO₃</td>
<td>4.7</td>
</tr>
<tr>
<td>Ca</td>
<td>1.9</td>
</tr>
<tr>
<td>Mg</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Determination first code figure:

<table>
<thead>
<tr>
<th>HCO₃</th>
<th>4.7 – 0.5 = 4.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>round</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Multiplication:

<table>
<thead>
<tr>
<th>2 x</th>
<th></th>
</tr>
</thead>
</table>

1st figure:

8

Determination second and third figure:

<table>
<thead>
<tr>
<th>Ca</th>
<th>1.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>round</td>
<td>1.75</td>
</tr>
</tbody>
</table>

Multiplication:

<table>
<thead>
<tr>
<th>4 x</th>
<th></th>
</tr>
</thead>
</table>

2nd figure:

7

<table>
<thead>
<tr>
<th>Mg</th>
<th>0.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>round</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Multiplication:

<table>
<thead>
<tr>
<th>4 x</th>
<th></th>
</tr>
</thead>
</table>

3rd figure:

1

The best fitting scheme is thus scheme A 8.7.1

**Trace elements**
Corrections for the application of trace elements may sometimes be necessary. With rainwater this is the case for Zn. In spring water Mn, B, Zn, or Cu may occur but every case must be analysed. Partial or complete omission of the trace elements concerned
from the nutrient solution is regarded to be sufficient. No separate scheme codes are available for this purpose.

**Guidelines for the preparation of nutrient solutions**

Schemes for standard nutrient solutions are calculated for 1 m³ of concentrated solution. The Ca-containing fertilizers (such as calcium nitrate) must be dissolved separately from the fertilizers containing sulphate (for example magnesium sulphate, potassium sulphate) because in concentrated solutions gypsum (CaSO₄) precipitates. As a precautionary measure phosphate fertilizers are separated from the calcium containing fertilizers, since with pH levels higher than 6.0 precipitation of calcium phosphate (CaPO₄) may occur.

The concentrated nutrient solution is prepared in 2 separate containers. The A-container contains calcium, the B-container sulphate and phosphate. The trace elements, with the exception of iron chelate, are added to the B-solution. The other fertilizers may be added to both A- and B-container. As a rule ammonium nitrate is added to the A-solution, and magnesium nitrate to the B-solution. Potassium nitrate is divided over both containers in such a way that the total number of kg in both containers is about equal.

During preparation of the concentrated nutrient solution the fertilizers are not added before the containers are half full of water. It is important to adhere to the order in which the fertilizers are mentioned in the scheme. For liquid fertilizers it is vital that the acids are dissolved first, the bases later. With carbonate containing fertilizers CO₂ is released during preparation of the solutions. This is a rather violent reaction in which a lot of foam develops. Furthermore, when using liquid fertilizers it is recommended to measure the pH of the concentrated solution after preparation of the containers. In both, its level should be between 5.0 and 5.5. If this is not the case, extra acid or base must be added.

As a rule the recipes are calculated for 100 times concentrated solutions. A dilution of 1:100 gives the standard nutrient solution. Schemes calculated for other EC levels than those of the standard nutrient solution are no longer 100 times concentrated, but lower at higher EC values, or higher at lower EC values. Otherwise the concentration of the solution would become too high, which might give problems when dissolving a number of fertilizers.

As we have seen, the concentrated nutrient solutions are prepared in 2 separate containers. It is essential for the composition of the nutrient solution that the contents of both containers are sucked out evenly. In addition to the rules mentioned above the acids and the bases should be added to the B-solution as much as possible in liquid fertilizers. All trace elements are added to the A-container.

**Iron chelates**

For schemes with high acid the EDDHA iron chelate is broken down by the low pH. When DTPA is added there is the problem of poor dissolvability at low pH. Therefore, in principle the iron chelate is added to the A-container. The maximum amount of acid which may be dissolved in the A-container is 2.5 kg of nitric acid per m³ 100 x concentrated solution. Iron chelates are broken down by light. Therefore nutrient solutions must be protected against light as much as possible. This is also the case for the concentrated solutions and the stock containers for concentrated liquid iron chelate.
Trace element solutions
The preparation of concentrated trace solutions requires special attention, especially when the fertilizer borax is used. Borax is strongly alkaline. This does not play a role in solutions of the main elements, in view of the relatively small amount, but with purely trace elements it is relevant. The procedure is as follows: first dissolve borax, then neutralise the pH with nitric acid to pH level 4.0. Only then dissolve the other trace elements. When boric acid is used this problem does not occur.

EC value
The EC of a nutrient solution is an important value as it is a measure of the total concentration of ions. For plant nutrition a certain minimum concentration of nutrient ions (EC) is necessary. For rose this minimum level has never been determined. It is estimated at about 1 mS/cm. EC levels exceeding 3.5 lead to loss in yield, the stems become shorter and thinner, the flower buds smaller and the number of stems harvested decreases.

Uptake concentration
For all crops the EC level in the root environment is the starting point for control. On the basis of the measured EC, the EC of the nutrient solution to be applied via the trickle irrigation is adjusted. In general the trickle EC is lower than the desired EC in the slab. This is caused by the fact that the so-called uptake concentration of the plant (the nutrient uptake related to the water uptake) is lower than the concentration aimed at in the root environment.

The uptake concentration of plants depends on a number of factors. Nutrient elements are necessary for plant growth. The higher the growth rate, the more nutrient elements are needed and this means that with increasing irradiation the need for elements also becomes greater. However, the transpiration also increases with higher irradiation. Frequently, the increase in transpiration is greater than the increase in nutrient uptake. The uptake concentration then decreases. Nutrition experiments in which the uptake of water and nutrients were accurately monitored, showed that uptake concentration is higher for young plants than for old plants and that with high irradiation (= transpiration) the uptake concentration decreases. Also in periods of strong growth, for instance after harvest, the uptake concentration may increase. When setting the EC level, these effects should be taken into account, such as a radiation-dependent decrease of the EC.

EC value trickle water
Although the EC value of the nutrient solution in the root environment is the basis for reference, the EC value of the trickle water also determines the plant’s response, since an important part of the roots is located under the dripper.

Scheme EC value
The standard nutrient solutions are calculated with a certain EC value in mind. This is the EC necessary on average to maintain the guide value for the EC in the root environment. Apart from the uptake concentration, there are 2 more factors determining the EC to be applied; the EC as a tool to control growth and the leaching percentage. As far as the former is concerned, for rose the EC is consciously increased in the low-light period of the year, and lowered in summer during high water consumption. As to the latter, due to leaching a certain quantity of salts disappear from the system. To maintain the desired EC in the root environment a higher EC of the trickle water than
the uptake concentration of the plant is necessary. The higher the leaching percentage the greater this difference will be.

For closed growing systems where no leaching takes place, the EC value of the standard nutrient solution is equal to the average uptake concentration of the crop. During the growing period the EC which is applied will not be constant. It is still necessary that the standard nutrient solutions are calculated for an EC value specific for each crop. This is essential for schemes adjusted to the water quality: the acid necessary for the neutralisation of HCO₃ is part of the set of fertilizers and is as a result related to the EC applied. With a higher dosage the amount of acid may become greater than the HCO₃ concentration in the irrigation water, so that the pH becomes too low. Reversely, insufficient HCO₃ is neutralised and the pH remains too high. There is a certain margin because not all HCO₃ is neutralised. Moreover it is possible to adjust the pH slightly using the supply equipment.

Within a 20% deviation from the standard EC no adjustments need to be carried out. With large deviations the system becomes disorganised and adjustment of the nutrient solution is necessary. Not only is the application of acid no longer adjusted to the HCO₃ present, the adjustments to Ca, Mg and possibly SO₄ are no longer in compliance with the initial situation.

There are 2 possibilities for adjustments. The first is to choose either a higher or a lower coded scheme. The new scheme code is found by applying the following formula:

\[ \text{Scheme code new} = \text{scheme code old} \times \left( \frac{\text{EC standard solution}}{\text{EC applied}} \right) \]

A second method is to calculate the existing scheme on the basis of a modified standard EC. This is done by lowering the amount of acid in the scheme with the same factor as the EC value is increased. With this modified nutrient solution a new scheme is calculated, with the same scheme code. The total amount of fertilizers per m³ is, however, calculated globally on the same weight, in order to avoid too highly concentrated solutions. The scheme is then no longer 100 times concentrated, but lower or higher, depending on the direction of the EC-modification.

If necessary part of the acid prescribed in the scheme can be added to the acid container for the pH control. This prevents the pH in the trickle water from becoming too low, in case too much of the concentrated solution is supplied due to fluctuations in the controls.

Measuring the EC

The EC in the root environment is an important value for optimal results. It is important that the EC is measured regularly and accurately. Wide variations in the distribution of salts in the substrate may occur and particularly between 2 drippers values can be very high. These seriously affect the EC of a mixed sample. To determine the EC it is therefore wise to separately collect and measure samples both from under and between the drippers.

pH

Apart from the EC value the pH of the nutrient solution in the root environment is important. Plants are capable of growing in a wide range of pH values. Values lower than 4 may cause damage, because the root tissue is affected. Also the uptake of Mn may become so strong that Mn toxicity may occur. With low pH there is a reduced availability of Mo. For sensitive crops in a young stage this may lead to Mo deficiency.
Values higher than 7 do not immediately affect growth. In the long term, however, deficiency symptoms may occur, because some elements such as manganese, zinc, boron, iron and phosphate are less readily available. Figure 8 shows the effect of the pH on the contents of P, Fe, Mn, Zn, B, Cu and Mo in rose leaves. With high pH the uptake of P, Mn, Zn and Cu is reduced. For Fe and B the effect in this example is not so clear, but in other experiments it has been observed. In contrast, the Mo contents decrease with reducing pH values.

Figure 8. Effect of pH in the root environment on the contents of trace elements in young rose leaves

**pH guide value**

Research indicates that rose grows well with low pH values, and that high pH values easily lead to chlorosis. The guide value has therefore been set at 5.2. pH values of more than 6 should be avoided. In case the pH of the substrate is too high, it is important that the pH of the irrigation water is regulated at values around 5.2. In practice a value of 5.5 is mostly adhered to.

**pH and ion uptake**

The method of the neutralisation of the HCO₃ in the irrigation water has been explained above. Accumulation of HCO₃ leads to severe pH increase in the root environment. Apart from the supply of HCO₃ via the water, HCO₃ may also accumulate in the root environment because HCO₃ ions are released by the roots. With the uptake of ions, ion exchange takes place. With cation uptake the roots release an amount of H ions which is equal in equivalents to the amount of cations taken up. On the other hand for anion uptake exchange takes place with OH and HCO₃. If the uptake of anions and cations is equal in equivalents, the pH value in the root environment does not change. If the cation uptake is greater than the anion uptake, there is a net surplus of H-ions and the pH decreases and reversely, the pH rises. The uptake ratio of cations and anions can be influenced by changing the NH₄/NO₃ in the nutrient solution to be applied. For rose, ca 15% of the N in NH₄ form is sufficient for a more or less stable pH. Increase of the NH₄ share in the nutrient solution gives pH reduction in the root environment.

During the growing period of a crop the uptake ratio of cations and anions will not be constant. The pH changes resulting from this may be counteracted by adjusting the NH₄ concentration in the nutrient solution. Occasionally, for example just before or after a harvest, the cation uptake is so great, due to the great potassium uptake, that no NH₄ should be applied.
Adjustments related to the pH

With too high pH values in the root environment extra NH₄ is supplied. Increase of the NH₄ application, however, is bound to certain limits. High NH₄ concentrations may hamper Ca uptake and also cause strong local pH reduction near the roots. With too low pH values in the substrate the amount of NH₄ in the nutrient solution is first lowered, or left out completely. If this is not effective enough, in extreme cases the pH may be increased with HCO₃⁻. For this purpose mostly potassium bicarbonate is used. This has to be applied separately to the nutrient solution, because otherwise precipitation may occur.

When using the solid fertilizer calcium nitrate, 0.2 mol NH₄ per mol Ca is always supplied. Increase of the amount of (solid) calcium nitrate therefore always implies increase of the NH₄ supply.

Influencing the degree of acidity in the root environment through the pH of the trickle water has only limited possibilities. pH values lower than 5.0 must are not advised due to the risk of affecting the rockwool fibre. pH values higher than 6.2 are not advised in view of precipitation of calcium phosphates, which give rise to blockage of the water supply system.

Measurement of the pH

Parallel to measuring the EC, regular determination of the pH in the root environment is necessary. Within a glasshouse, and also within a rockwool slab great differences in degree of acidity may occur. Particularly where additional trickling occurs the pH may be much lower than between drippers. This is due to the fact that NH₄ is taken up relatively faster than other ions. Between drippers more nitrate and bicarbonate is taken up than may accumulate. If so-called mixed samples are taken, moisture from both under and between the drippers added together, this HCO₃⁻ has a buffering effect, so that the pH in the sample reaches the value predominant between the drippers. The pH of the moisture collected between the drippers appears to have great influence on that of the mixing sample. It is therefore recommended, when determining the pH, to take separate measurements under and between the drippers.

The pH of the drainage water may deviate strongly from that in the root environment. A clear relationship between both values is generally lacking. Therefore measuring the pH in the drainage water is of little interest for the determination of the pH in the root environment.

Proportions during the cropping period

In general terms the standard nutrient solution reflects the uptake proportions between the nutrient elements, averaged out over the cultivation period. However, since plants go through different stages the uptake proportion is not constant.

Standard adjustments

There are a number of standard adjustments:

1) For saturation of the substrate at the beginning of the cultivation period the proportions are given which are the guide values for the concentrations in the root environment. This means that the nutrient solution is adjusted to higher Ca and Mg concentrations and lower K concentration. In addition extra B is recommended. The NH₄ is lowered, to avoid pH decrease at the start, due to relatively high NH₄ supply.
2) At the start of the cultivation period, for 10 weeks extra Ca, reduced K, and extra Fe are supplied.

3) From 2 weeks before the first harvest for 3 weeks extra K is given, and less Ca. From mid-September onwards, gradually the NH₄-supply is lowered to 0. Mostly from 15 February it is built up again.

Adjustments on the basis of analytical results

On the basis of research the ion proportions have been established that are necessary in the root environment to obtain optimal nutrition of the plant with minerals. These optimal ion proportions are laid down in the so-called guide values for the nutrient condition. Regular samples have to be taken of the nutrient solution from the slab (rockwool, glass wool) or the drainage water (granular substrates), and investigated for main and trace elements. For peaty substrates and cocopeat the material itself is sampled and analysed by means of the 1:1.5 volume-extract. Table 39 shows a survey of the guide values for rose for nutrient solutions from the root environment and samples of peat or cocopeat (1:1.5 extract).

The standard nutrient solutions are composed in such so that on average the guide values are reached. The ion proportions of the guide values in the root environment are clearly different from the proportions in the standard nutrient solution. In general the concentrations of the monovalent ions such as K, NH₄ and NO₃ in the root environment are relatively lower than those of the bivalent ions, such as Ca, Mg and SO₄. This is because the monovalent ions are taken up more quickly than the bivalent ones. For Ca and Mg it is also necessary that the concentrations in the root environment are relatively high; consequently accumulation has to take place and at low concentrations the plant is incapable of taking up sufficient.

Table 39. Guide values for the nutrient solution from the root environment and for that from organic substrate using the 1:1.5 extraction method

<table>
<thead>
<tr>
<th>Determination</th>
<th>nutrient solution</th>
<th>1:1.5 extract</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC mS cm⁻¹</td>
<td>1.8</td>
<td>1.0</td>
</tr>
<tr>
<td>pH</td>
<td>5.2</td>
<td>5.2</td>
</tr>
<tr>
<td>NH₄ mmol l⁻¹</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>K</td>
<td>5.0</td>
<td>2.3</td>
</tr>
<tr>
<td>Na</td>
<td>&lt;8.0</td>
<td>&lt;2.5</td>
</tr>
<tr>
<td>Ca</td>
<td>5.0</td>
<td>2.3</td>
</tr>
<tr>
<td>Mg</td>
<td>3.0</td>
<td>1.1</td>
</tr>
<tr>
<td>NO₃</td>
<td>12.5</td>
<td>5</td>
</tr>
<tr>
<td>Cl</td>
<td>&lt;8</td>
<td>&lt;2.5</td>
</tr>
<tr>
<td>SO₄</td>
<td>3.0</td>
<td>1.7</td>
</tr>
<tr>
<td>HCO₃</td>
<td>&lt;1.0</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>P</td>
<td>0.9</td>
<td>0.8</td>
</tr>
<tr>
<td>Fe μmol l⁻¹</td>
<td>25</td>
<td>12.5</td>
</tr>
<tr>
<td>Mn</td>
<td>3</td>
<td>1.0</td>
</tr>
<tr>
<td>Zn</td>
<td>3.5</td>
<td>1.4</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Cu</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Mo</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>
During the cropping period the proportions between the nutrient elements in the root environment will vary continuously. Often variations in the ion proportions are unpredictable, because they are connected to several factors such as climate, plant load, plant stage, etc. Therefore regular checks of the composition of the nutrient solution in the root environment are required. The analysis will indicate whether adjustments are necessary.

Fertilization in closed systems

Adjustments
In general the proportions of nutrients in closed systems may change more quickly than in growing systems with free drainage. Necessary adjustments will therefore have to be taken sooner and will be larger. Care is needed as too extreme adjustments may soon lead to undesired fluctuations in the concentrations of certain ions. Since in a closed system all that is supplied is either taken up by the plant or accumulates in the system, the supply must carefully be adjusted to the need of the plants. The uptake can only be predicted roughly. On the basis of regular analyses the nutrient solution which is supplied must be adjusted. In future it may be possible to measure the ion concentrations continuously directly in the root environment. Until then the uptake of a certain element can be predicted to a certain extent by means of growth models.

4.4.3 Water supply

Good water and air management in the root environment is important in rose cultivation, in soil as well as on substrate. A plant should have sufficient water and oxygen available. When water supply is too high or too low, it is liable to suffer. Since 1987 research at the PBG Naaldwijk on water supply calculation models has been done for rose and other crops. Initially this model was developed for substrate grown crops, but with a few adaptations it can also be used for soil grown crops. The model is based on the calculation and/or measurement of the factors: crop transpiration, water uptake for fresh weight growth and the measurement of the amount of drainage water after each water supply. The measurement of the drainage is an essential component of the water supply calculation model, since it is used for feedback and correction for a possible difference in calculated and measured water consumption. Too low or too high water supply can thus be prevented. The drainage correction makes the model a lot less sensitive to crop activities and changes in the substrate.

For calculation of the crop transpiration global radiation (outside), glasshouse air temperature, pipe temperature and air humidity outside the glasshouse are used. On a daily basis, there is a close linear relationship between the global radiation and the crop transpiration. Below a radiation level of ca 1,100 – 1,200 J cm\(^2\) (winter, spring) and 800 – 900 J cm\(^2\) (fall) there is an increasing linear effect of heating on transpiration.
The water consumption partly depends on the variety. During the night, differences of 100% may occur between varieties, while by day differences may amount to 5 to 10%. One variety may have greater transpiration at night than another, while during the day the reverse may be true.

**Trays and balances**
Apart from the use of a water supply calculation model, trays or balances can be used to control the water supply.

In a tray are a number of plants and the water supply is controlled by means of measuring the water level in the tray. In many cases measurement of the amount of drainage water is also connected to the tray, to be used for control and correction. In general trays measure the water consumption. Balances only measure the transpiration but in newer constructions with balances the amount of drainage water is also measured. Both data can be applied in a water supply control.

A measuring tray and a balance must function well and, if connected, be able to measure the amount of drainage water accurately. The plants on the tray and the balance must be comparable with the other plants in the glasshouse. One of the problems is that great differences in water consumption may occur within a glasshouse. At least 4 measuring units per hectare are necessary for a reliable average. The optimum is one measuring unit per watering compartment with the possibility to control and correct. Balances can be part of the water supply calculation model but they may also function separately.

**Leaching**
For crops on both substrate and soil more water must be supplied than can be taken up in the slab or locally in the soil (excess). This prevents salt accumulation and corrects at each watering the difference in water content, caused by differences in transpiration. As a result the slabs are more or less equally wet after a water supply. There is no consensus among growers as to how often and when leaching must be carried out. This discussion often takes place in conjunction with possible seasonal changes and in
the level of the moisture content. Whether variations in moisture content are positive is still under investigation. Practical experience and research indicates that a relatively high leaching percentage is desired in rose cultivation, 50% seems a good value.

Irrigation frequency
In addition to the discussion on whether or not water should be supplied at night, growers also discuss how frequently water should be supplied. Experiments with a water supply from once to 10 times a day with a number of vegetable crops (the total daily amount of water being the same) have not demonstrated any difference in yield and/or quality. In order to let the water supply function well and to be able to carry out the necessary corrections, the irrigation frequency with substrate crops should not be too low, not even on dark days. Frequencies lower than 5-6 times a day are too low, also on low-light days, and a maximum of 30-35 times a day on sunny days is possible.

Changes in moisture content of the slab
In rose cultivation the slab is used for several years in most cases. Research shows that, as the slabs get older, the drainage out of the substrate slabs becomes increasingly slower. The slabs collapse a little, so that the moisture is retained longer. Moreover, more and more organic remnants remain in the slab and salt accumulation takes place. All this has considerable consequences for the moisture content of a slab and the drainage percentage as measured after each water supply. As a result, the risk of oxygen deficiency with excess watering increases even more. There are indications that new slabs may also show considerable variations in the course of the day in water content, without this being connected to water extraction from the slab by the crop. Exact control of the drainage percentage per water supply according to the set point is not technically feasible and not necessary either for optimal plant growth. As yet, achieving the set drainage percentage on average per day seems adequately effective.

Requirements on the water supply system
In order to be able to supply water properly, a number of details need to be known in advance:

- The water emission of the drippers (or a different type of water supply system) must be known and converted into mm (mm = litre per m²). It is vital that all drippers have the same water emission and that the emission does not change in the course of a growing period. Regular checks on a large number of drippers in a glasshouse or glasshouse compartment (20-40 measuring points per (glasshouse) compartments) are necessary.
- It may occur that water meters deviate too much (deviations of +10% to −10% are no exception)
- This also applies to drainage measurements. Regular checks are very necessary. Correct reading of the meters does not say anything about the correct mutual distribution among drippers or other water supply systems.
- The capacity of the water supply installations must be at least 1.5 l per m² per hour.

4.4 Slab temperature

Research in the Netherlands in 1988-1989 indicated that a slab temperature in the range 15 – 26°C has no effect on yield and quality of var. Madelon under both a standard heating temperature of 18°C and a lower heating temperature of 15°C. Positive effects of an increased root temperature in experiments abroad were found particularly under sub-optimal air temperatures, including glasshouse temperatures.
below 15°C. Under these temperature levels the yield, however, was reduced. In Canada the effects of a root temperatures of 13°C, 18°C and 23°C were investigated at a night temperature of 13°C and a day temperature of 23°C. Under this temperature regime a positive effect was found of the root temperature of 23°C with the variety Gabriella. The variety Samantha did not show higher yield, but did have longer stems. Also in Israel positive effects were found in a glasshouse in which the night temperature dropped as low as 8°C. In a subsequent trial with constant night temperature of 18°C the effect was not observed.

In America there was one trial where the effect of the soil temperature as related to the air temperature was investigated. In the trial with ‘Sonora’ with young plants (the first 16 weeks), under normal air temperatures (20 day/16 night), the best yield and quality were found at 18°C soil temperature and not at 25°C. With lower air temperature (16 day/11 night) a soil temperature of 25°C did have a positive effect, and the yield was better than with normal air temperature without heating. With older plants, however, (start of the experiment after 12 weeks propagation) the air temperature appeared to be of much greater significance than the soil temperature, and a high soil temperature does not have a compensating effect then at low air temperatures. This corresponds with research results in The Netherlands.

To conclude it can be stated that:
- positive effects of an increased root temperature were mostly found with sub-optimal air temperatures
- positive effects of an increased root temperature were mostly found in young plant stages. This is a general phenomenon, in the youngest crop stages the root formation is an important process, influenced by the temperature in the root environment.
5. YOUNG PLANT MATERIAL

5.1 BREEDING

In the history of breeding and the development of the current assortment roughly three periods can be distinguished, based on the developments taking place in those periods. The first period is from the prehistory to about the year 1875, the second is from 1875 to 1967, and the last period starts in 1967. The first period, of about 5,000 years, is the longest and this era ends around the year 1875 with the discovery of the specific crossbreeding and the publication of Mendel’s laws on inheritance. Breeders still use these laws and the qualitative inheritance. In 1967 biotechnology was introduced into rose breeding, which brings us to the current, third period.

It is generally accepted that in antiquity rose types were collected in the wilderness and planted in gardens with collections. Various types and also varieties were grown before the Christian era in gardens in China, Persia, Mesopotamia, Egypt, Greece and Italy. It is not known whether these roses from antiquity were seedlings or already vegetatively propagated. Fact is that during this entire period new varieties only developed by sowing seed grown from natural pollination. The development of the various types of roses and subsequent hybrids was a slow process. The introduction of new genotypes and the exchange of types and varieties took place via travellers. With their help the genetic variation available to the grower was expanded. This same variation, however, became narrower by the choice of certain types, while it was not known sometimes what the female parent was and when a certain cross had developed. Instinctively one only knew that a neighbouring plant in the collection of roses had a relation with the new form. Growers did not know that several characteristics could be passed on by cross-breeding.

It was only at a later stage that it was discovered that from the initially mainly diploid varieties (2 pairs of chromosomes) new varieties developed which are mainly tetraploid (4 pairs of chromosomes). Today the most important varieties are almost exclusively tetraploid. It should be noted that especially among continually flowering varieties, the vigour of the plants increases with the ploidy level. If this knowledge would have been used by breeders, interesting possibilities would have been generated for the introduction of characteristics from diploid types into tetraploid varieties. Otherwise these characteristics would cost two generations of cross-pollination.

Currently taxonomists distinguish 240 to 300 different roses. It has, however, been established that only 10 to 20 genotypes of these types have contributed to the development of the modern rose. Since most roses are not incompatible, one would expect that more types would have been involved. Probably the use of the 10 to 20 types was not a coincidence. The availability, attractive characteristics and good seed formation will undoubtedly have played a role. For more information, see the extensive work by Krüsemann, 'Rosen, Rosen, Rosen'.

It is clear that the genetic basis of the present rose is much narrower than one would expect, and that there are more than enough possibilities for breeding in certain characteristics.

Early in the 20th century rose breeding accelerated and breeders started to work more and more in glasshouses. Due to the lack of incompatibility many forms and colours developed. Since there are various applications of roses (cut roses, garden roses, climbing roses, to name just a few) breeders concentrated on the different categories
which had to be suitable for a particular environment. Nowadays most breeders are specialised, but there are some companies breed roses for different environments. The fact that the glasshouse rose for cut flower cultivation brings in 3 to 5 times as many royalties as a garden rose makes the former group attractive to breeders. Since the genetic variation among the current varieties is great, success in breeding is still expected. Gradually a new classification developed for cut roses, mainly as a result of auction purposes: small-flowered, medium-large-flowered, large-flowered and spray roses.

Generally speaking there is no difference between breeding of garden roses and that of cut roses. In the selection process breeders sometimes use positive, but mainly negative selection in the seedlings. Roughly 99% of the seedlings are removed at the first selection. This method of selection, which has now been used for a century leads to a kind of genetic erosion. Most breeders select on external characteristics, which are manifest under selection conditions (phenotype selection). In combination with the negative selection method the result may be that many properties which are not noticeable by external characteristics, are thrown away. The current cut rose is adapted to glasshouse cultivation and in the collection of a certain breeder the various manifestations can be seen. The uniformity of these varieties with respect to bud shape, flower shape, flower size, number of petals, stem length and thorn characteristics, is still increasing. Of several varieties, different colour mutants are available which together form a product group.

In 1967 the biotechnology entered rose breeding when in the UK for the first time somatic embryogenesis was applied on a climbing rose. In view of the volume of rose cultivation globally more attention for scientific breeding research with rose is required. Compared to other crops, little attention has been paid to rose breeding. Scientific research on rose concentrated on taxonomy, cytology, physiology, morphology, cultivation conditions and the testing of varieties and rootstocks. Breeding targets on the inheritance of characteristics such as facilitating the process of cross breeding, improving the process of direct and indirect selection, adaptation to low energy input, and the resistance to pests and diseases are rare and lag behind developments in for example fruit growing. The breeding research that has been carried out was done by universities and horticultural institutes. For future improvements there are several methods, the most frequently applied and cheapest being the introduction of new genetic information by cross breeding. The second option is offered by biotechnology. Initially the principles of biotechnology were in the hands of universities and institutes. Now large chemical groups, commercial laboratories and older companies have been investing in biotechnology. Important aims for this sort of breeding might be: resistance against bacteria in the vase water, resistance against insects, resistance against mildew and/or black spot and the introduction of new colour pigments. Other important characteristics to which attention could be given: resistance against Agrobacterium, nematodes, rootstocks with a greater vigour, odour, introduction of daylength sensitivity, facilitating controllability and synchronous growth and harvest. It is obvious that there are already differences between varieties in their sensitivity to certain infections or in the presence of a certain characteristic showing genetic influences. Building in patented genes into a variety which is already under protection of breeder’s rights, weakens the position of the traditional breeder. However, in this respect legislation for the protection of varieties is being adapted.
Crossing roses. Stamina of the rose to be pollinated have been removed

5.2 PROPAGATION

The choice of cultivation on the rose’s own root or on a rootstock is often a subjective one. The breeder selects the new rose seedlings on their own roots, indicating that cultivation on the own root is possible. Reasons for using rootstocks are mostly an expected increase of flower production and/or improvement of flower quality (see section 5.4). Other criteria to opt for rootstocks are resistance against pests and diseases, continuous harvest possibility, and buffer potential against differences in environmental conditions. The growing medium used also plays a role here. In soil-grown crops many grafted bushes and grafted plants are still used. In substrate crops cultivation on rose’s own root or with vegetatively propagated rootstocks is increasingly applied. In the following subsections the various propagation methods are discussed.

5.2.1 Cutting

Cut roses
In the propagation of cut roses in general use is made of harvest-ripe flower stems. ‘Blind’ flower stems, however, may also yield good results. The ripeness of the stem and the bud is important because soft wood sooner suffers from rot. For cuttings only the buds with five-leaflet leaves are used; these are cut 4 to 5 cm below the bud and stuck into the cutting substrate (cutting soil, cocopeat plug, rockwool block). Rooting is stimulated by dipping in auxin (mostly indole butyric acid in solution or powder formulation). The concentration used depends on the variety. The sensitivity to auxin is also influenced by the season. High concentrations may be harmful, since they inhibit rooting and induce ethylene which may lead to loss of cutting leaves and inhibition of bud break. For propagation purposes in general only good five-leaflet leaves without black or breaking buds should be used. To avoid blackrot the cuttings may be treated with a fungicide before being stuck.
The cuttings should be rooted under controlled conditions in propagation tents or climate cells. Experiments at the Research Station in Aalsmeer are always carried out in a polyethylene propagation tent at 24-28°C, 800 ppm CO₂, 98-100% RH. Assimilation light (HPI) is switched on 48 h after the cuttings are placed in the plugs.

There are various factors which may affect the propagation result:

- Rootability generally depends on genotype. With new varieties or when in doubt always carry out a rooting experiment first with a concentration range of rooting hormone (auxin) to determine the optimal quantity.
- Buds at various positions on the flower stem show different rooting and budding behaviour. Genetic factors also play a role. In experiments carried out at the Research Station cutting buds of First Red closest to the flower appeared to root and shoot more rapidly. For Frisco and Kiss these were the buds in the middle positions (Figure 10).
- The effect of the circumstances under which the ripe stem material is grown is very important. Stems of First Red of 4 different origins, rooted under the same conditions demonstrated a greater difference in shooting between the origins than between the various positions (Figure 11). This also indicates that there may be seasonal differences in propagation results.

Figure 10. Rooting and shooting behaviour of 3 varieties with buds in various positions

Figure 11. Greater difference in shooting between origins than between positions on the stem

**Rootstocks**

Rootstocks should be vegetatively propagated to maintain the good properties. This can be done by stenting, root grafting (see section 5.2.3), or cuttings. The production of rootstock cuttings is virtually the same as by cut roses. The rooting results depend on the quality of the rootstock wood: lignified wood gives good results, wood that is too soft results in extra losses due to blackrot. To ensure good rooting the base is dipped into 0.5% IBA-powder, mixed if necessary in a 1:1 ratio with captan (83%). The cuttings are rooted under the same conditions as cut rose cuttings. After rooting the rootstocks can be used as stock plants or, after the bud and cutting leaves have been removed, can be grafted with a cut rose variety.
The rooting result depends on the genotype and the age of the stock plant. Sometimes rooting problems can be solved by using stock plants propagated from tissue culture. Due to rejuvenation (or re-invigoration) cuttings of these plants often root faster and better (see section 5.2.3).

5.2.2 Tissue culture

The advantage of propagation in tissue culture is that the plants produced are free from diseases and pests, because the original plant material is a young growth tip grown under sterile conditions. The plants produced are fairly uniform and often somewhat more vigorous. Propagation is carried out in specialised laboratories. The produced plants still need to be rooted and hardened off. The main drawback of tissue culture is the high cost price. This means that application remains limited to cases where an obvious surplus value can be obtained (for example improved rooting). Also for accelerated market introductions of new varieties tissue culture is used to build up a stock plant collection.

Material from tissue culture may show increased shooting but due to competition among these shoots stem quality may be lower in comparison with other propagation methods.

5.2.3 Stenting

Stenting is a rapid propagation method in which a cut rose is placed on an unrooted piece of rootstock. Rooting of the rootstock and fusion between graft and rootstock take place simultaneously. Pieces of a stem from which the axillary buds and leaves are cut away are used as a rootstock. As a result infection with nematodes and Phytophthora can be avoided, because the material has not been in contact with the soil. In the technique of stenting the base of the graft and the top of the rootstock are cut in $30^\circ$ angles, both sections fitted on one another and fixed (for example with a clothes-peg).

Stenting experiments at the PBG pointed out that the success percentage appeared to be influenced by the quality of the rootstock and scion wood, stenting precision and the rooting temperature.

The stock plants for rootstock wood should be raised in the glasshouse as outdoor wood gives poorer results. The wood should be sufficiently lignified and contain enough reserves. Hardened-off wood generally gives good quality and constant results from the end of October. In summer the results are varied due to the occurrence of blackrot. Generally speaking blackrot can be reduced by avoiding the use of soft wood. For these reasons it is better not to use the upper 15 internodes of the rootstock stem.

The success percentage is influenced further by the rootstock genotype and the age of the stock plants. Rooting is more problematical with older stock plants although using stock plants from tissue culture may postpone this effect. In particular with Sturcinq (selection from so-called STUR-research) the difference in rooting between rootstock wood from stock plants from cuttings and from stock plants from tissue culture was large (50% as compared to more than 80% well rooted).

The same is valid for the variety to be grafted as for rootstock wood. Slowly grown, lignified grafting wood yields better stent results. Using pesticides immediately prior to stenting may adversely affect the stent results. After harvesting the graft wood must
immediately be placed in water and stored as briefly as possible. Storage should be done in a cold storage room.

The success percentage mentioned above was the number of well-rooted stentlings. In addition the fusion between graft and rootstock is important. There are varietal effects but also other aspects. Particular care should be taken that graft and rootstock are about equally thick with a short, smooth section so that the (cambial) cell layers are in good contact with one another. Differences in thickness or a stentling with overhanging sections result in excessive callus growth on the sections. Later in the cultivation this may grow into a large, hard knob on the grafting surface which looks about the same as infection by Agrobacterium tumefaciens.

After the rootstock base has been dipped into IBA-powder the stent is placed into a substrate and fusion and rooting takes place in propagation tents. The temperature during the stenting period should be between 24 and 28°C, the RH between 98 and 100%. Excessive temperatures during the summer period result in increased losses due to blackrot. Extra CO₂ (to about 800 ppm) results in a higher rooting percentage and less quality loss as a result of leaf yellowing.

![Stenting; rootstock cut just above the axillary bud (no root suckers)]

5.2.4 Grafting

Bench grafting takes place on specialised holdings. The glasshouse should have benches with heating pipes underneath. The benches should be sufficiently deep (35 to 40 cm) and covered with (plastic) panes. Bench grafting is done from January to April, while the propagation methods in the previous section can be conducted all year. The rootstocks have been raised outdoors in the previous year and brought in and kept frost-free during the winter. In the bench-graft season the rootstocks are brought in and
cut off several centimeters above the root collar. The straightest side is cleaned, and
the bark subsequently cut in and loosened. The scion of the variety is cut diagonally
and pushed in-between the rootstock and fixed with cotton string or plastic tape. The
cotton must be biodegradable and should not contain synthetic fibre. The scions should
be cut from well-lignified wood. The grafts are covered on benches in humid, pure peat
litter. The roots should not come above the ground to avoid fermentation. Temperature
is maintained at 28 to 30°C, at a high relative humidity of 95% and during the first
days no ventilation takes place. The grafts are checked regularly for Botrytis. As the
fusion progresses, ventilation is increased, so that the plants are well hardened-off at
delivery. When lifting from the benches and planting out, the grafts should be kept
moist. The plants are then active and have white roots. After 2 to 3 weeks the grafts
are sufficiently fused to be planted out.

Until about 1980 rootstocks from seed were used for grafting, mostly of the *Rosa
canina* type. On young seedlings cut rose varieties are placed after removal of the aerial
buds, by way of whip or cleft grafting. The advantage is then that the rootstock is
already well rooted. The drawback, however, is that there were variations in
characteristics between different seedlings, that there is a risk of soil-bound diseases
such as nematodes or Phytophthora in the material and that this method is very labour-
intensive. Along with further developments of substrate growing, the rise of new types
of rootstocks (see section on rootstocks) and the stenting technique, the use of
vegetatively propagated rootstocks has strongly increased. As a result good
characteristics are preserved, soil-bound diseases prevented and grafting is often
slightly easier due to the somewhat softer wood.

*Grafted plants on benches*

5.2.5 Root grafting

Root grafting is an intermediate form between grafting and stenting. Instead of a piece
of stem of a rootstock plant, a piece of root of about 5 cm long and 3 mm thick of a
rootstock from seed is used. On this a cut rose variety is placed with the stenting
technique. This technique was developed for rootstock plants which had insufficient
aerial shoots available. In addition, it may be an alternative for propagating (or through
rejuvenation by tissue culture), for rootstocks for which stenting is difficult due to poor
rooting. Several usable pieces of root from a root system can be used, but this method
requires a lot of labour and a high level of expertise.
5.2.6 Half-year bushes

For this propagation method the rootstocks are planted and ridged up in early spring in rows. Planting should be done before the end of February, otherwise the growing season may be too short. Before oculating, the soil around the root collar is removed. Usually rootstocks with a root collar diameter of 5 to 8 mm are used. In May-June oculation takes place. A T-formed cut is made in the root collar and the bark is loosened. The bud, cut from the scion, is pushed between the broken bark. The junction is folded in with a piece of rubber, stuck at the back with a hair pin (Fleischauer). About 3 weeks after inoculation the bud and the bush have slightly grown together. The shoots are removed and the rootstock stops thickening. A bush is formed out of the oculated bud, the quality of which depends on the growing conditions in summer. Shoot length before delivery is at least 10 cm.

The dormant bud method is rarely used. These bushes are oculated in June and July. In the subsequent fall the rootstocks are lifted and the shoots above the bud removed. A dormant bud is a root with root collar and a bud on top which has grown together and can serve as plant material for glasshouse cultivation. During the cultivation of half-year bushes disease control should get the necessary attention. For lifting in spring the bushes should be sufficiently mature. Storage and transport should also be done with care. Freezing and desiccation may give rise to serious problems during regrowth.

Growing half-year bushes in Limburg, The Netherlands

5.3 QUALITY REQUIREMENTS OF YOUNG PLANT MATERIAL

The requirements the young plant material for rose cultivation should meet, are divided into 2 categories, both for the variety and the rootstock to be used. On the one hand the conditions the material to be propagated has to meet, on the other hand those demanded by the grower of the young plant to be delivered.
5.3.1 Conditions on the propagation material

A number of objective quality criteria can be drawn up for the material for propagation. In addition to requirements with respect to health and external uniformity, in future higher demands will be placed on internal (physiological) uniformity.

Health
The wood to be used for propagation must come from healthy plants from a healthy glasshouse. There are objective criteria for this and control methods as used by the NAKB. Furthermore, any application of pesticides should be known in detail (time, dosage, type), since some agents shortly after application may have an adverse effect on the propagation result.

Uniformity during propagation
In general this is taken to mean even rooting, even growth and little die-back. The rooting conditions (temperature, relative humidity, light, CO₂) are partly responsible for this; in addition there is a considerable effect of the initial material itself and the circumstances under which this material has grown. Factors that play a role are:
- genotype
- effect of position of bud on branch
- origin

For uniform propagation it is important to avoid mixing of batches of cutting wood from different origins. Grading on position may be considered if heterogeneity should be reduced even further. From a point of view of costs, this is preferably done at the beginning of the process when the buds are cut, rather than at a later stage. Furthermore careful agreements must be made between propagator and grower on delivery time(s) and numbers.

5.3.2 Optimal growing material

For good and healthy material growers usually contact a propagation company. Proper consultation and mutual confidence are important, as are good and clear arrangements. Making a checklist may be helpful. In addition to the specific points on the checklist there are general trade and delivery conditions in force. There is almost constant consultation between representatives of the National Rose Committee of the LTO-Groeservice and the VRV (Association of Rose Propagators) about the content of these conditions. Once the order has been confirmed the propagation phase starts. It is important that the grower himself is involved in this. Regular visits to the propagator once the material has been set up, are necessary.

The quality of the growing material in rose cultivation is the extent to which the delivered young plant material meets the demands of the customer (grower). Of course subjective considerations play a role (rootstock or own-root, choice of the growing system, choice of substrate type), but apart from these there are objective factors valid for all propagation methods used.
- Health. The initial material for the cultivation should be free of diseases and pests, excluding the risk of introduction of diseases.
- At delivery the cutting must be well rooted in the substrate and adequately hardened-off. Preferably the five-leaflet leaves must still be present.
- After planting out the plants should quickly take root and grow evenly. Growth stagnation means delay in production.

A significant difficulty in rose cultivation in glasshouses is the heterogeneous development of rose bushes, despite the development of high-quality measuring and control systems for glasshouse climate. Growing measures such as pruning or bending may reduce the differences, but never annihilate them. Much of this heterogeneity is caused by heterogeneity in the young plant material.

5.4 ROOTSTOCKS

In contrast to fruit growing, where rootstocks with large differences in characteristics (from dwarfing tree to standard tree) are used, for rose cultivation rootstocks are selected mainly on vigour. In fruit growing, viticulture and water melon cultivation it is known that some rootstocks have a production increasing effect due to modified uptake and translocation of nutrients and/or production of cytokinins. Research carried out at AB-DLO suggests that this is also the case with rose rootstocks.

5.4.1 Aim of rootstocks

In current cut rose cultivation rootstocks are being used to influence flower production (vigour) and flower quality of the varieties grafted on the rootstock. There are various rootstocks which differ in their effect on vigour and quality. The number of stems harvested is a reliable measure for vigour. Research with rootstocks with varying vigour and Sonia ‘Sweet Promise’ as graft, indicated that rootstocks particularly affect the sprouting of axillary buds, both in number and in time. As a result of inducing more ground shoots and a higher degree of branching, vigorous rootstocks supply more stems per plant earlier, consequently a higher yield. Because plants with more branches have a greater leaf area, varieties grow better on strong than on weak rootstocks.
Cut rose varieties can also be grown on their own roots. In The Netherlands this technique is rarely being applied in soil-grown crops. In New Zealand, on the other hand, growing on rootstocks is exceptional. The number of stems harvested is not always less than when a rootstock is used. Production and quality, however, do not always go together when using rootstocks. Low light conditions, as in Dutch winters, may result in lower flower quality. The increase of the quantity of assimilation lighting resulted in better quality. Whether this is a result of the interaction graft-rootstock is not clear. Israeli workers say there is, but according to Dutch researcher De Vries there is no such interaction. De Vries says the vigour of graft and rootstock is mainly additive.

There are both clonal and non-clonal rootstocks (see also section 5.4.2). In general clonal rootstocks have a greater vigour and more homogeneity than seedling rootstocks.

Apart from the influence of rootstock on growth and development of the graft, rootstocks are also known to differ in sensitivity to and/or effect on:
- pH, nutrient condition (uptake of minerals and salt tolerance) and humidity under which cultivation takes place;
- climate factors;
- disease resistance;
- life cycle;
- compatibility;
- winter hardiness.

5.4.2 Classification of rootstocks

The current assortment of rootstocks is divided into classes in accordance with plant taxonomy on the basis of external characteristics such as growth habit, leaf shape and thorn shape. The rootstocks used in commercial practice mainly come from 4 of the total of 9 classes:

A. Pimpinellifoliae: Moneyway;
B. Caninae: Inermis-types (including STUR-clones), Spektaculair and Verschuren;
C. Synstylae: Multiflora types; Jeanine, Ludiek, Multic, Marleen and Helenae
D. Chinensis: Indica major, Manetti

The rootstock ‘Natal Briar’ which is currently used is missing in this list since it is unclear what the precise origin of this rootstock is and to which class it belongs.

Sub A. Moneyway is a rootstock known for its great vigour in the form of a large number of bottom breaks. The stems it produces, however, are thin and consequently of a lesser quality.

Sub B. Inermis types are by nature winter-dormant. If growing temperature is high enough and assimilation lighting is applied the rootstock will not go dormant. The seedling-rootstock usually applied in The Netherlands was increasingly available in clonal form in recent years, but it is not used frequently anymore. This is mainly the work of the Foundation for the Improvement of Starting Material Rose (STUR). This type of rootstock is particularly valued for its quality.

Sub C. Rootstocks from the group of Multiflora types are known for their great vigour. They have no winter dormancy. A crop which is not sufficiently hardened off in the
colder season may give rise to disease problems. An additional disadvantage of this rootstock may be a less intense flower colour and more misshapen flowers (so-called bullheads). Not every variety can be grafted onto this rootstock: occasionally there is incompatibility. ‘Multic’ has a rather high temperature demand. If temperature is too low, quality problems may occur.

Sub D. ‘Manetti’ from the section Chinensis is known for its finely branched, compact root system. This rootstock is frequently used in California (USA). Indica ‘Major’ is not winter dormant. Under decreasing temperatures, however, production drops considerably. Various clones of the Indica ‘Major’ exist for more than 150 years. Several clones, however, are infected with the apple mosaic virus and/or the Prunus Necrotic Ringspot Virus. This rootstock is noted for its high production. However, it does combine with quality, since the stem firmness is sometimes insufficient.

Another method of classifying rootstocks is the subdivision on the basis of propagation method in 2 main groups:
1. Seedlings
2. Vegetative or clonal rootstocks

Sub 1. The category seedling-rootstocks comprises the so-called Edelcanina’s. Most noted are Rosa canina ‘Inermis’, Rosa canina ‘Pollmer’ and Rosa canina ‘Brög’s Stachellose’. Originally these rootstocks were used for garden roses because of their winter hardiness. In glasshouse rose cultivation they are appreciated for their positive effect on the quality of the harvested roses.

Rosa multiflora is an old seedling-rootstock, not used in The Netherlands for glasshouse cultivation because there were difficulties with propagation. The rootstock is noted, though, for its high production.

Sub 2. Vegetatively propagated rootstocks are understood to be rootstocks which are being vegetatively propagated for years, such as Rosa indica ‘Manetti’ and Rosa indica ‘Major’. Since these are both not hardy, they are not used in The Netherlands, with or without good reason. Several clones of Rosa indica ‘Major’ are available. These were developed by mutations and/or unintended crosses. More recently clonal strains were developed from Rosa canina ‘Inermis’. This work was done by the STUR.

5.4.3 Effect of rootstock on yield and quality

Experiments in which different rootstocks are compared have been carried out for years. Mostly 2 parameters are compared, yield and quality of the harvested product (De Vries and Dubois). Dutch researchers have compared 40 rootstock trials, carried out in the period between 1925 and 1988. One of the salient aspects in comparing the flower production is that there are always differences between the averages of the rootstocks but that these often do not differ significantly due to considerable variation in the results. Incidentally the trials were rarely set up for statistical analysis. This was mostly caused by the low numbers of plants used. In addition, despite the large number of duplicates contrasting conclusions about the same rootstock were found. The differences found in trials after 1988 are reliable. Research at the Research Station in Aalsmeer indicated differences between the various rootstocks. The experiments concerned were carried out with ‘Escimo’. The quality of the harvested roses was best
Rose seed hedges of *Rosa canina 'Inermis' in Groningen (Netherlands)

on the Inermis rootstock clones 'Sturcinq' and 'Sturtri'. Escimo on its own root, Escimo on 'Helenae' (Multiflora-type) and Indica 'Major' gave a higher yield but a slightly poorer quality.

In general a certain series of rootstocks appears to induce the same increase in flower production in different varieties. If the 'top 12' of rootstocks is selected from 23

Figure 12. Average flower production of cut rose varieties, induced by 12 rootstocks used in 23 different experiments, expressed as percentage of the experimental average. Bars indicate the standard deviation. Source: Dubois et al.1990, Prophyta, 5, 117-119
glasshouse trials, and subsequently in each of these trials the flower production of
varieties on rootstocks (if possible in the second year) is expressed in percentage, we
see the results as shown in Figure 12.

It must be noted that only *Rosa canina* differs almost significantly from *Rosa multiflora*,
but in the other cases the differences are very small and statistically not significant. The
tendency as presented in Figure 12 is not always present. Fluctuations in the
production, as influenced by season and cultivation method, are observed. Indica, for
instance, is a rootstock with a greater heat demand than others. A forced winter
dormancy is expressed in a lower yield with *Rosa indica* than achieved with *Rosa
canina*.

Since seedling rootstocks are not genetically uniform, both in Israel and in the
Netherlands, a start was made with clonal propagation of these rootstocks and
comparison of production and quality. Clonal rootstocks are characterized by the fact
that they generally induce a greater vigour than seedling rootstocks. Apart from the
production obtained with varieties grafted on the rootstock, other characteristics of the
rootstock are observed. Particularly the propagatability (rooting and compatibility) plays
an important role here, in addition to thorn characteristics and sensitivity to mildew and
spider mite. Research lead to the conclusion that there is a difference in production and
quality between the various clones.

A definition of what is to be understood by a good stem quality is hard to give. Stem
length and diameter may be good parameters.
With propagatability the percentage of success is important. The rootstock ‘Natal Briar’
yields a higher percentage of success by means of stenting than the Inermis-clones
from the STUR research.
Furthermore, the flower colour plays an important role. Mostly the flower colour of
roses is more intense when grown on a rootstock instead of on their own roots. Still,
some rootstocks such as *Rosa multiflora* and ‘Natal Briar’ may yield lighter flower
colours.

Which rootstock should be used for a specific variety? An important question for many
growers, all over the world. It should be clear that we are often dealing with given
growing conditions which are called optimal. Research will then have to determine
which plant combination has the best fit. The use of a rootstock may mean that for a
different plant treatment adjustment of the glasshouse climate is required. The
production of roses is not only influenced by the vigour of the graft-rootstock
combination. The rate of bud outgrowth and the percentage of blind shoots may also be
affected by other external conditions. Indirectly the amount of basal shoots formed and
the growth of the (lateral) roots play a role in the production. The aim of the grower
must be clear. Yield and quality do not always go hand in hand. In Dutch STUR
research attempts have been made to combine these characteristics. In practice there
are often diverging opinions on the possible suitability of a certain rootstock for a
certain variety.
Generalising results is dangerous. If a comparable result is to be achieved, the
circumstances will have to be imitated. In most experiments recording of the realised
climate, nutrient conditions, amount of water supplied, etc. is not taken into
consideration.
5.4.4 Factors affecting yield of variety/rootstock combination

Compatibility
It is known that problems may occur in the fusion of graft and rootstock. This poor result may be manifest immediately at propagation in the form of poor compatibility, as has been observed several times with Rosa multiflora cathayensis, or it may be considered as physical barrier at the grafting place. The compatibility or incompatibility seems to depend on the presence or absence of direct cell contact. An attempt has been made to find an explanation for the possible incompatibility in the production of toxic substances which are produced after wounding. Research in Israel indicated that there are great differences between the various tested clones of Rosa indica 'Major', as far as compatibility with the graft and the rooting are concerned. In this research the clonal selection of the rootstocks for each individual variety should be continued.

Dutch researchers (De Vries) conclude in their experiments that the vigour of rootstock clones is partly determined by the variety grafted onto the rootstock and that there is a correlation between the thickness of the grafting place, the root weight and the quantity of basal shoots.

From a practical point of view it is very easy for growers to check afterwards whether there is a good connection between graft and rootstock. Aerial parts and roots are removed from lifted plants. The grafting place is boiled in water for about 1 hour. The bark can then be removed so that the grafting place can be carefully inspected. The vascular connection of rootstock and graft should be smooth and show no major irregularities.

Temperature
Lower temperatures may cause a higher percentage of bullheads. The relation rootstock-bullheads is not entirely clear and requires more research. It is evident that there is a relation between the amount of light, growing temperature and quality of the harvested product. The activity of the various rootstocks depends on the prevailing temperatures. Possibly winter dormancy plays a role in a prolonged period of low temperatures. A brief reduction of the growing temperature, however, also affects the yield and quality of varieties that have no winter dormancy.

Light
Increase of the light level results in less blind shoots. Blind shoots are observed mostly in, and immediately after, low light periods. A higher percentage of good flowering stems may consequently be obtained by a combination of higher light level with CO₂ supply. The production of the amount of assimilates is then higher, in favour of the product.

Other factors
The amount of roots is known to influence the aerial growth. There is a correlation between the number of basal shoots and the number of stems harvested. When roses are harvested once-over (on-flush system) this results in massive dieback of the roots. Apart from aerial pruning, also genetic factors of graft and rootstock are involved in this dieback. Furthermore the composition of the nutrient solution might play a role. For a high-quality, continuous production growers should take care not to apply the on-flush system too frequently and avoid problems with the availability of moisture and nutrients.
Currently in The Netherlands experiments are being carried out on a practical scale with the application of hormones to stimulate (basal) shoot formation. It is obvious that the consequences are not always predictable.
6. CROP STRUCTURE

6.1 PLANTING

The general conditions for the quality of the young plants have been treated in 5.3; always begin with good and healthy starting material!

6.1.1 Planting out

Immediately after planting the young plants demand the necessary attention. Different types of young plant material all have their own specific points of special interest. At planting out bushes or grafted plants have a well-branched root system. The roots should be placed in the soil as straight as possible and the plant holes should be sufficiently deep. On no account the roots should be folded into the plant hole as this disturbs easy growth.

Grafted plants should be planted very carefully. The root system is already active and the white root tips are visible. The plant holes should therefore be sufficiently deep in order to avoid root break. In addition the ent or graft should not be below ground level. Make a little hole around the grafted plant and keep the place free of the soil, because the plants are deep enough as they are. In this way Botrytis infection can be avoided.

Before planting the bushes, plant holes need not always be made. The bushes and grafted plants can also be dug in dipped before planting in a solution which helps to prevent infection by root fungi. After planting the plants must be drenched, so that the soil or the substrate closes around the roots.

Cuttings and stentlings have white active root tips protruding from the substrate. As few as possible of these should be damaged at planting out. Root fungi can readily penetrate through cracks in the roots.

Only the plants showing roots on the outside of the pot or plug should be planted. When the plant is still insufficiently developed and the roots do not come into contact with the growing medium, outgrowth is insufficient. The position and direction of the original cutting leaf is important. At bending, the primary shoot or scion is bent straight over or in the direction of the cutting leaf, where there is room to lay down the package of leaves.

6.1.2 Start of the cultivation

_Grafted roses, cuttings and stentlings_

During the first 2 weeks after planting out, a day and night temperature of 20-22°C is maintained. Due to natural irradiation day levels may even reach higher values. Levels of more than 30°C should, however, be avoided. The air humidity during the first weeks is kept rather high (above 70-80%) because the young plants are very sensitive to leaf burning. On sunny days plants can be kept wet with a hose so that the air humidity remains sufficiently high. Restrict ventilation to prevent the relative humidity dropping too fast.

By the time the plants show distinct growth and the roots have sufficiently penetrated the soil or substrate, ventilation may be increased and temperature levels decreased.
This should be done gradually because the plants are still weak and sensitive to leaf burning. Moderate screening may also be helpful. Do not begin to harden off the plants too soon. The first period should be used for crop growth, and when hardening off is pinched too early the scion wood will lignify more and bend less easily. Allow the scion wood to grow out and remove the flowers. By removing the flowers as early as possible the upper buds will sprout and thus lignification is prevented. At a certain moment the scion wood will have developed so heavily that it will fall over. This stimulates the formation of bottom breaks. The scion can be placed in the desired direction by bending (see section 6.5). If the scion wood falls over or is bent too soon, the quality of the bottom breaks will be insufficient. Immediately after planting a treatment may be carried out with a compound that inhibits the development of root fungi.

**Half-year bushes**

Directly after planting the half-year bushes, check for Botrytis and spray if necessary. During the first 4 to 5 weeks the bushes should be kept frost-free. A longer period is not harmful, but is not necessary. After this period the temperature is raised to the desired level (to 20°C). The small bushes are not trimmed. The first flowers are cut short to leave sufficient leaves on the crop and to promote bottom break formation. Strategy for air humidity and ventilation is the same as for grafted plants.

**Dormant buds**

The forced bushes are given the desired temperature immediately after planting. Directly after outgrowth of the bud a firm stem with flower is formed. This can be cut, mostly on the second five-leaflet. Alternatively the shoots may be pinched, after which the buds start to sprout and are harvested. For varieties which form bottom breaks less easily, pinching may mean that plants sprout only on the pinched part and do not form new bottom breaks. Air humidity and ventilation can be regulated as with grafted plants, cuttings and stentlings.

**Bushes**

After planting out the bushes are sensitive to Botrytis, so preventive control should be applied. After planting out the bushes are kept cold (frost-free) for 8 to 10 weeks. Subsequently the temperature may be raised to the desired level. The bushes are cut back to a good bud before raising the temperature.

**6.1.3 Plant density**

In soil and substrate grown crops the plants can be distributed over the bed in different ways (see also section 3.2.2, growing systems), depending on the system and the number of beds. Canadian research showed that a distribution of the plants over 2 parallel rows is the best option with respect to light distribution, yield and quality. In the Netherlands opinions differ on this. The distribution of plants also affects the plant density and this influences crop structure. Research has been done into how an equal yield can be obtained with lower plant density using cultivation activities such as harvest methods and bending. As plant material of rose is expensive, using fewer plants may save costs.

**Effect of crop structure and yield**

In general a higher plant density leads to a decrease of stem weight and diameter of the harvested flowers. The number of (primary) bottom breaks formed per plant, however,
does not vary with different plant densities. Also the quality of the bottom breaks is not substantially lower with more plants per m$^2$ (Table 40).

Table 40. The effect of the plant density on the bottom break formation; number and quality (source: M. Kool, 1994)

<table>
<thead>
<tr>
<th>plant density plants/m$^2$</th>
<th>bottom breaks number/ plant</th>
<th>number/ m$^2$</th>
<th>diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.7</td>
<td>1.5</td>
<td>11.6</td>
<td>8.5</td>
</tr>
<tr>
<td>11.6</td>
<td>1.5</td>
<td>17.7</td>
<td>8.4</td>
</tr>
<tr>
<td>17.4</td>
<td>1.3</td>
<td>23.2</td>
<td>8.0</td>
</tr>
</tbody>
</table>

The competition for the amount of light, therefore, does not seem to be important for the small number (at that moment) of developing (basal) shoots. When a greater number of plants is planted per m$^2$ in total more bottom breaks per m$^2$ will develop. When these bottom breaks are the basis of the crop, in which harvesting will be done by upper cut (later possibly by undercut), a certain competition will develop between the shoots. The quality of the stems grown at higher plant densities will decline in the course of time.

When the bottom breaks are harvested densely (cut on the first scale) to very densely (knuckle cut harvest, Japanese method), plant structure can hardly affect yield. Differences in yield are then caused by light interception and will be of a qualitative kind. When equal light interception is created by bending, it might be supposed that if plants produce more stems per plant at lower plant densities, the plant density is hardly a relevant factor. This has been investigated both at Wageningen University and at the Research Stations. Despite bending there were differences in yield in stems per variety and plant density, which might be explained by the light interception. With more plants per m$^2$ bending results in a greater leaf package than with lower plant density, despite the fact that attempts have been made to make equal leaf packages. Under lower plant densities the individual plant produces distinctly more leaves in the leaf package. Table 41 presents the results of 2 years of research in Aalsmeer.

Table 41. Yield (number of stems/gross m$^2$ of 4 varieties grown at 3 different plant densities, the number of stems per plant and the yield expressed as percentage of the yield with 10 plants/m$^2$. Production period: week 13 1996 to week 6 1998. Source: J. de Hoog.

<table>
<thead>
<tr>
<th></th>
<th>10 pl/m$^2$</th>
<th>7.5 pl/m$^2$</th>
<th>5 pl/m$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Red</td>
<td>241(24.5)(100%)</td>
<td>213(28.4)(88%)</td>
<td>173(34.5)(72%)</td>
</tr>
<tr>
<td>Bianca</td>
<td>334(33.4)(100%)</td>
<td>328(43.7)(98%)</td>
<td>288(57.7)(86%)</td>
</tr>
<tr>
<td>Mercedes</td>
<td>381(38.1)(100%)</td>
<td>351(46.8)(92%)</td>
<td>288(57.7)(77%)</td>
</tr>
<tr>
<td>Frisco</td>
<td>578(57.8)(100%)</td>
<td>512(68.3)(89%)</td>
<td>466(89.2)(77%)</td>
</tr>
</tbody>
</table>

Effect on quality
The quality of the harvested roses in all trials is affected by the plant density. The total harvested weight and its variations in an Aalsmeer experiment corresponded with the
harvest method (see 6.3). Table 42 gives the results of the research carried out in Aalsmeer during the period 1996-1998. The general tendency is the same for all varieties, although the level may differ.

Table 42. Average stem weight (g) of 4 rose varieties grown at 3 different plant densities. Period week 13 1996 to week 6 1998. Source: J. de Hoog.

<table>
<thead>
<tr>
<th>Variety</th>
<th>10 pl/m²</th>
<th>7.5 pl/m²</th>
<th>5 pl/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Red</td>
<td>48,4</td>
<td>52,4</td>
<td>55,3</td>
</tr>
<tr>
<td>Bianca</td>
<td>46,5</td>
<td>47,4</td>
<td>49,5</td>
</tr>
<tr>
<td>Mercedes</td>
<td>26,7</td>
<td>28,1</td>
<td>30,4</td>
</tr>
<tr>
<td>Frisco</td>
<td>23,9</td>
<td>25,3</td>
<td>26,7</td>
</tr>
</tbody>
</table>

**LAI and light interception**

Data from Wageningen University (M. Kool, 1996) indicate that 86% of the production of rose can be explained by light interception, consequently by the leaf area. The quantity of leaves expressed in m² per m² growing area is the so-called LAI (Leaf Area Index).

For roses, 1 MegaJoule of light results in a dry-matter production of 2.5 g. The efficiency with which the crop uses the available light is expressed as light conversion efficiency. The basis of this is the following calculation:

a. Calculate the total light sum in the period
b. Take the transmissivity of the glasshouse roof (mostly between 62 and 70%), expressed in MJ/m²
c. Add to this the amount of assimilation lighting (47% of this is used by the plant for photosynthesis)
d. Measure or estimate how much light is intercepted by the plant (70-90%)
e. Multiply the various preceding factors. The result is the amount of MJ/m² which is used by the crop.
f. Divide the dry matter production in g/m² by the amount of light used by the crop; the result indicates how effectively the light is used by the plant.

The amount of light plays an important role in the photosynthesis (hence in production) and the quantity of leaves determine how efficiently the plant uses this. In The Netherlands there is a great difference in the amount of light in the various seasons. Many leaves in winter (LAI of 5 and higher) combined with a low amount of light results in the maintenance respiration of this leaf package being greater than the net photosynthesis (see Chapter 7). In winter utilization of the light is more efficient than in summer, and there are differences in efficiency between varieties. The higher efficiency in winter may partly be explained by the frequently higher carbon dioxide concentrations in the glasshouse. In summer, on the other hand, saturation of the photosynthesis may occur, particularly as a result of water stress.

In winter the crop can not cope with the large leaf area, so it is better to minimize the amount of leaves. This can be done by reducing bending in winter and undercutting or pruning. As excessive amount of leaves leads to shading of lower leaves so that these will drop. Optimum LAI at a given moment depends on light conditions during the year and growers should make use of this. The number of developing flower stems can be influenced by the pruning method. Try to limit sprouting even if the average stem weight is determined for only 20% by the light interception.
6.2 BOTTOM BREAK FORMATION

Bottom breaks are vigorous shoots developing at the base of the plant. They constitute the frame of the rose bush and determine the potential flower production. Bottom breaks develop from buds in the axils of the bud scales at the base of the plant. In general there are 6 to 7 potential bottom break buds. The buds are secondary buds present in the bud used for propagation. The number depends on age and position of the bud (see also section 7.2.1). Generally only the lower 2 of the potential bottom break buds develop into actual bottom breaks. If later a third or more bottom break develop, they come from the axillary bud of one of the 2 already grown bottom breaks. Every bottom break appears to be connected to only a certain part of the xylem in the root. This can be demonstrated by adding coloured water to the shoot or the roots, so that the xylem (and water) transport routes become visible. The underlying hypothesis is that as soon as a bottom break sprouts the xylem of a root is surrounded by new xylem. This xylem is responsible for the transport to the new shoot. The new shoot may surround the entire old xylem like a ring. As a result the xylem part directly connected with the primary shoot or first bottom break may be restricted in capacity. In the end this may lead to death of the old shoot.

The formation of bottom breaks and the quality of the shoots can be affected in different ways. Much work has been done by M. Kool of Wageningen University. His dissertation was one of the sources of information for this section.

By bending the primary shoot the sprouting of the (usually 2) most bottom breaks, which are present as secondary buds in the bud used for propagation, is promoted. These are the first bottom breaks. The later the bending of the primary shoot takes place, and the longer this has been able to develop, the more the initial crop growth increases and heavier bottom breaks with a greater diameter are formed. Sprouting of the buds on the horizontally bent primary shoot (scion, scion wood) inhibits sprouting of the bottom breaks. Removing the sprouts on the scion wood increases the number and diameter of the bottom breaks. In practice this is never done by growers.

When the number of bottom breaks per plant is limited, for example by breaking them away, this positively affects the diameter and the weight of the remaining bottom breaks. The growth rate is not affected. Increasing plant density gives more bottom breaks per m². The number of bottom breaks per plant, however, does not change. The plant density hardly affects the quality of the developing bottom breaks, because in this stage of growth there is enough room for outgrowth of the shoots. Table 43 gives some results which clarify the effect of delayed bending on the formation and quality of bottom breaks.

Table 43. Effect of the moment of bending (days from T0) of the primary shoot on the development time, diameter and weight of the bottom breaks. Source: M.T.N. Kool, 1996

<table>
<thead>
<tr>
<th>Treatment (days from T0)</th>
<th>development time</th>
<th>diameter (mm)</th>
<th>dry weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>57,3 (a)</td>
<td>9,4 (a)</td>
<td>30,3 (a)</td>
</tr>
<tr>
<td>14</td>
<td>55,6 (a)</td>
<td>9,9 (ab)</td>
<td>31,0 (a)</td>
</tr>
<tr>
<td>28</td>
<td>46,6 (b)</td>
<td>10,4 (b)</td>
<td>32,2 (a)</td>
</tr>
<tr>
<td>42</td>
<td>38,5 (c)</td>
<td>10,7 (b)</td>
<td>35,6 (a)</td>
</tr>
</tbody>
</table>
Research by M. Kool pointed out that there is a clear relation between plant structure and flower production. Investment in plant structure at the beginning of the cropping period is always accompanied by yield reduction. Delaying the shoot formation by bending later and restriction of the number of bottom breaks considerably lowered the yield, in particular the first 8 months of the research. This is compensated for, however, in the 2 subsequent years. The relation between the number of bottom breaks and the final production is not equally clear in all publications. According to M. Kool, the flower production is clearly less related to the number and the diameter of the bottom breaks than to the number and the diameter of the branchings of the second order. According to D.P. de Vries, there is a distinct relation between the number of bottom breaks and subsequent yield. There is, according to him, a difference in the number of bottom breaks that can be formed, depending on variety and/or the use of a certain rootstock. It is therefore important to select on varieties or rootstocks which form more bottom breaks by nature. De Vries ascribes the differences in number of bottom breaks partially to the degree of apical dominance present in the rose. The competition between bottom breaks on one and the same plant at the beginning of a cropping period is greater than between individual plants. This difference in competition is not expressed in later years in the total production weight, in the number of new-formed bottom breaks or the number of dead bottom breaks. New bottom breaks compete with the old ones, which is clearly visible in a reduced diameter increase and an increased dieback percentage of old bottom breaks. The average stem weight of stems from new bottom breaks is considerably higher than that of stems from old bottom breaks.

The hormone cytokinin stimulates sprouting of bottom breaks. In addition to the fact that the method is illegal, it is also not completely without danger. The concentration has to be exactly correct, to prevent uncontrolled sprouting.

Apart from 'mechanical' influences, various climatic conditions may play a role in the development and quality of bottom breaks. The time of the year influences the diameter of a bottom break. Bottom breaks formed early in the year (April) are thinner than those developed in May-June. Later in the year, however, the early bottom breaks are thicker again. This is caused by the quantity of xylem that is greater in the bottom breaks formed earlier. With summer plantings attention must be paid to the quality of the bottom breaks. Light quality has consequences for future production potential of the bottom break.

Light is important for the sprouting of the buds and consequently for the sprouting of the bottom breaks. More light and light that reaches the place of sprouting directly, promotes outgrowth of the bottom breaks. When the buds are kept in the shadow or when shading is applied they show hardly any development. The combination of more light and a slightly higher temperature also promotes the sprouting of the bottom breaks. Furthermore a slightly higher relative humidity stimulates the sprouting of bottom breaks. For this reason many Dutch growers maintain higher average temperatures in the glasshouse at the start of the cultivation period (20-22°C) and keep the RH as high as possible. As soon as the bottom breaks have developed the values are lowered to avoid adverse effects on quality.

The use of rootstocks may positively affect the formation of the number of bottom breaks. The extent to which the rootstock produces the hormone cytokinin affects the aerial sprouting.
6.3 HARVEST METHODS

Pruning methods not only determine the architecture of a crop, they also have a great effect on yield and quality. For rose the top dominates the growth of the lower buds. This phenomenon is called apical dominance. Partly as a result of the hormone production (auxin) in the growing-points, the lower buds are kept from sprouting. By removing the growing-point, for example by pinching or harvesting the stem or bending the stem, the lower buds get the chance to sprout. At that moment they take over the function of dominant growing-point and in turn keep the lower buds in dormancy.

Apart from apical dominance the sink/source relations are also important in the harvest of roses. This is often unconsciously neglected. ‘Sink’ refers to the places in the plant where assimilates are taken and consumed. ‘Source’ relates to the places where the assimilates are produced. Assimilates are the building blocks, the energy for all activities in the plant. The most important activities are growth, maintenance, and development. Growth is division and elongation of cells, resulting in increase volume and dimensions. Assimilates are formed (sources) in the green leaves. Growth and development are sinks. In rose, growth mainly takes place in the tips of the stems and in sprouting axillary buds. Cell division, elongation, separation of leaves and finally the flower buds take place. The roots are strong sinks as well. At harvest the source/sink relation is sometimes seriously influenced. At harvest a strong sink (the flower) and a major part of the source (leaves) are removed. The more leaves removed, the longer it therefore may take before the buds develop. An exception is formed by the so-called ‘leaf breaking’. This method has been applied for years to promote outgrowth, especially in winter. By removing the leaflet near the bud no more hormones are sent to the bud at the base of the leaf and consequently it can grow more easily. Leaf breaking can be an effective method for varieties having difficulty with sprouting. Care should be taken not to damage the bud while breaking. Harvest stems as closely above the bud as possible. Leave as little of the wood above the leaf axil as possible. Fungi can penetrate easily by way of these ‘coathooks’ and, in addition, their presence seems to inhibit the sprouting of the buds.

Harvesting by upper cut or by undercut

On the bottom breaks the so-called laterals of the first order are formed, when the bottom break is harvested or pinched. The upper cut harvesting method leaves one or more buds on this first-order lateral. When one of these buds sprouts this is called lateral of the second order (fig. 13). When harvesting by upper cut a grower may choose the number of buds left behind on the lateral of the order where he harvests. Above the first bud with incomplete leaf a bud mostly develops with a three-leaflet leaf (cutting on three-leaflet leaf) and above that the five-leaflet leaves develop (cutting on first or second five-leaflet leaf).

Harvesting on a bud located on a lower order is called harvest by undercut. The stent lower order is always thicker, and the buds which may be present and which are the harvest stimulated by the harvest are always of a better quality. Harvest by undercut is therefore usually aimed at rejuvenation with a better quality sprouting. Harvest by undercut can be done on the same positions as harvest by uppercut. Alternating harvest by undercut (winter, restricting the number of laterals and leaves) and by upper cut (spring, summer, fall) is still applied. The search for the correct harvest point is, however, labour intensive, and for this reason harvest methods have been developed, in combination with the installation of new growing systems, with the aim to reduce the labour required for harvesting.
Knuckle cut harvest and cut on the first scale

When a heightened growing system is not available, the crop may be built up slightly higher by harvesting the bottom breaks higher. The crop is brought to a certain height and a leaf package produced without bending. The leaves on the crop are the source for the new sprouting.

![Diagram of plant with labels for 1st order, 2nd order, and bottom break.]

However, when bottom breaks are harvested close to the base, the sprouting of the other bottom breaks is promoted. These are again shoots of heavy quality, a good foundation to build on. However, there has to be sufficient leaf mass as basis for the plant. This can be achieved by bending stems. A separate section is devoted to this subject (6.5). By constantly harvesting a short distance above (on the first scale) or closely above (on the knuckle) the lateral, a limited number of buds which may sprout remain under the lateral. The restricted sprouting results in high quality. It depends on the variety as to which harvest method is followed, since one variety buds more easily than the other.

Table 44. Number of stems/gross m$^2$ (% as compared to cut on the first scale) and average stem weight with 2 harvest methods. Period week 16 1996 – week 6 1998. Source: J. de Hoog, 1998b

<table>
<thead>
<tr>
<th>Variety</th>
<th>Stems/gross m$^2$</th>
<th>Stem weight</th>
<th>Stems/gross m$^2$</th>
<th>Stem weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Red</td>
<td>193 (86%)</td>
<td>54.7</td>
<td>224 (100%)</td>
<td>49.7</td>
</tr>
<tr>
<td>Bianca</td>
<td>274 (76%)</td>
<td>51.6</td>
<td>359 (100%)</td>
<td>43.9</td>
</tr>
<tr>
<td>Mercedes</td>
<td>305 (82%)</td>
<td>30.7</td>
<td>375 (100%)</td>
<td>26.1</td>
</tr>
<tr>
<td>Frisco</td>
<td>456 (80%)</td>
<td>27.6</td>
<td>568 (100%)</td>
<td>23.0</td>
</tr>
</tbody>
</table>
Various experiments have shown that the harvest method is not a determining factor for the total amount of biomass produced. The biomass is only distributed differently. Growers may opt for production or quality. With harvesting on the knuckle the production is lower but quality higher. Care should be taken that enough leaves are present, which can be achieved by bending.

6.4 PRUNING

By nature the rose is a deciduous shrub which is dormant in winter. Dormancy can either be broken or prevented by maintaining sufficiently high temperatures. Depending on the situation, roses might be given a period of dormancy, so that they can recover and yield high quality next year. Application of pruning combined with a period of dormancy is only done in soil grown crops without assimilation lighting. Crops grown on substrate (almost always in combination with assimilation lighting) are virtually always heated continuously in winter and kept at the desired quality level by the harvest method (by upper cut or by under cut, see section 6.3).

The condition of the crop determines the decision whether or not to continue with that crop. If in November the quality of the stems is unsatisfactory already and many stems show flower bud atrophy it may make sense to prune the roses. By pruning rejuvenation is achieved because the bushes have to grow shoots from below which are often of a better quality. Pruning is done after a period of dormancy. Pruning height depends, among other things, on the age of the crop. In a one-year crop as a rule pruning is done on the lateral of the bottom breaks. In subsequent years increasingly higher; mostly pruning is done on the wood that has grown as first harvest after the previous pruning. Equal height should be maintained as much as possible. Very thin and dead wood is cut away entirely.

Dormancy period
The duration of the dormancy period for pruning is 4 to 6 weeks, depending on the variety. Although roses can stand quite a lot of frost, it is better not to allow the temperature to drop below freezing point, to avoid freezing of the heating system. Furthermore, when the crop is not sufficiently hardened off and subsequently is exposed to frost, considerable damage may occur.

In general the dormancy period lasts from November to the end of February during the winter period in the Netherlands. The time depends on the moment harvest is terminated and the moment the grower starts heating again. Heating after a dormancy period can be done from the beginning of December to early March. Pruning later than early March is impossible because then even a crop in an unheated glasshouse will start sprouting under the influence of the natural temperature rise. When pruning is done late the crop may start production even without heating. When pruning is started sooner and heating subsequently takes place, it is known as forcing. It can be started any time during winter. The earlier it is started, the lower the quality may be. The bud formation depends on the quantity of light, and in January this is not yet sufficient.

Forcing
After pruning and, if necessary, fertilization, the soil is moistened and heating can be started to re-activate the crop. It is advisable not to start immediately with a high
temperature. It is better to let the buds swell first at a temperature of 10-12°C. After a week temperature may rise to 20-22°C. During the day temperature may even increase further, as a result of natural irradiation.

Night temperature should not get below 17-18°C until the buds are visible. Lower temperature may lead to dieback of the flower bud. During the first weeks of heating up the relative humidity is kept high (70-80%). Since the crop only has few leaves, the transpiration is kept low. Ventilation can be started, depending on the weather conditions. Particularly during the first days the grower should be careful. At first harvest it is important that enough leaves continue to be available for the crop to give a good subsequent harvest. Frequently harvest takes place on a five-leaflet leaf.

Pruning green

A cultivation method halfway between continuous heating and forcing is the so-called green pruning. This method is based on the fact that after mid-January the crop will show better growth again as a result of improved weather conditions. Pruning green is applied mostly in soil grown crops, but may also be used in unlit substrate crops. Particularly varieties for which continued heating is difficult may be pruned in this way without long periods passing without any harvest at all. Well into December the roses are still harvested. Subsequently the temperature is lowered for 3 weeks to 10 to 12°C. Then growth stops, but the leaves remain on the plant. Because net assimilation continues, the wood of the plant becomes heavier. From mid-January onwards the crop is cut back to a good bud. Do not cut back too deeply, and make sure the crop has enough leaves. After cutting back the temperature is gradually increased to 18 to 20°C. Bushes that do not have sufficiently thick wood are preferably not pruned green but placed in the cold and pruned completely.

Finishing flowering in summer

In summer the crop may be allowed to finish flowering for some time. Possible reasons:

- labour saving
- moving flowering to a more favourable time
- letting the crop rest

The time to finishing flowering is mostly related to auction prices. When roses have to be harvested for a low price one may decide not to harvest them. This is often in combination with reduced availability of labour. The most favourable period for allowing the crop to finish flowering is between mid-July and the end of August. Let the crop finish flowering for at most 4 weeks. Past flowered roses can best be broken out to avoid thrips and Botrytis.

At the end of the flowering period the crop is cut back to a good bud. Depending on the crop a certain amount of leaves and wood is left behind. An early start with this method (for example in June) may give the risk that the next harvest after cutting away the roses that have not flowered is again in a low-price period. During the flowering period, water supply, fertilization and crop protection should be given sufficient attention.

Partly finishing flowering

In the on-flush system the quality of the stems in the end declines. If abandoning harvesting for a certain period the possibility to let the crop partly finish flowering exists. The roses are not trimmed at once after the flowering period but several times a week the ripest flowers are cut off. The advantage of this is that finishing flowering can
be started at any moment, while harvest can be started at any time as well. Take care that crop husbandry continues in this period.

**Pinching**

During the cultivation period shoots can be pinched for several reasons. Part of the shoots can be pinched to get a crop out of harvest. The crop is then built up further and pinching the crop is an investment for the future because a greater leaf area is formed and more buds are available for sprouting. At first pinching is at the expense of production and when pinching is done at a young stage, the harvest should be expected to be delayed with 3 to 4 weeks. It should therefore be regarded as an investment for the future.

From stems with a bullhead or a crooked bud, the flower bud can be removed in summer, so that the upper 2 or 3 buds rapidly sprout and form a (short) flower stem. The stem below the deformed flower is removed and a new flower bud takes over. After mid-October this pinching method should not be applied anymore. In The Netherlands the amount of light then becomes the limiting factor and the competition between the growing shoots results in reduced quality and more flower bud atrophy.

### 6.5 BENDING

The amount of leaves is primarily determinant for the production of roses (see also section 6.1). Bending the stems has become an essential part of rose cultivation in recent years to obtain a certain leaf area. The bent stems are the ‘factory’ for plant growth. Sugars are formed in the leaf (photosynthesis, see 7.1) from CO₂ and H₂O, and are used as building blocks for the plant. Measurement of the photosynthetic rate is possible by measuring the CO₂ uptake of the leaves. The rate at which CO₂ is taken up depends on light and temperature, but also on CO₂ concentration, leaf position and leaf age. To obtain more insight into the function of the leaf and the frequency of bending various experiments have been and are still being carried out.

In the 1970s and 1980s in the US research was carried out into the effect of leaf age on the photosynthesis. The maximum CO₂ uptake takes place before the leaf is fully grown. These leaves are on stems which are still growing and which have not yet flowered. When leaves have reached their maximum size the CO₂ uptake gradually decreases to 50% of the reference value. This happens in a period of 12 to 14 days. A leaf seems to remain active for 70 days. Figure 14 shows the uptake of CO₂ as plotted against the leaf age. The roses are grown at a CO₂ concentration of 500 ppm. On the horizontal axis the leaf age is given with 2 values. The value directly above the axis is the number of days after the red colour has disappeared from the underside of the leaf. The lower scale indicates how many days before that the previous rose has been harvested. It seems therefore that for adequate photosynthesis always sufficient young leaves must be present.

The American research only gives insight into leaves which have not been bent. Shading on the stem appeared to have a negative effect. If the shade was taken away, recovery of the photosynthesis appeared to be possible. The improvement, however, was marginal as compared to the maximum uptake of CO₂. With present-day bending methods the stems are bent over one another. The shading leads to leaf drop of the underlying leaves.
Figure 14. CO₂ uptake of rose ‘Forever Young’ grown at a concentration of 500 ppm at various leaf ages (horizontal axis). Source: Aikin and Hanan, 1975.

Research at Wageningen University indicated that the CO₂ uptake of the variety Madelon of shoots with a bent position during a measuring period of 15 days is 14% lower than of stems left standing. During the first ten days the CO₂ uptake of the horizontal shoots may be 30% lower than that of vertical shoots. This is probably caused solely by bending and not by the position of the shoot on the plant. After 10 days the CO₂ uptake of the horizontally bent shoot is the same again as of an unbent shoot.

From 1997 till 1999 experiments were carried out at the Research Station in Aalsmeer into the effects of bending on the yield and quality of roses. Despite the fact that in the research bending was done during all seasons, this was not apparent in the measured leaf area (LAI). In high-light periods the LAI in treatments where bending was carried out, was considerably higher. In winter the LAI was the same in all treatments. Probably due to a limited amount of light it was not possible for the plant to keep the large leaf package alive. The plant dropped the leaves and regulated the amount of leaves itself. After one year of observations the treatment with the highest degree of bending appeared to result in the lowest yield and total harvested weight. Stem quality, however, was the best. Regular bending is recommended, but care should be taken that not too many good stems, which can otherwise be harvested and sold, are bent.


<table>
<thead>
<tr>
<th>Method</th>
<th>Frisco</th>
<th>First Red</th>
</tr>
</thead>
<tbody>
<tr>
<td>prod. stem wt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>method 1</td>
<td>227</td>
<td>89</td>
</tr>
<tr>
<td>method 2</td>
<td>221</td>
<td>77</td>
</tr>
<tr>
<td>method 3</td>
<td>184</td>
<td>75</td>
</tr>
<tr>
<td>method 4</td>
<td>169</td>
<td>68</td>
</tr>
</tbody>
</table>

In method 1 only the primary shoot is bent at the start of the cultivation period. Subsequently only what grew on this shoot was bent. In method 2 the primary shoot and the first flush bottom breaks are bent. Subsequently only what appeared on the bent package was bent. Method 3 is the control. The primary shoot is bent and part of the (lighter) bottom breaks. Subsequently every 2 weeks bending was carried out. A visually healthy leaf package was maintained by bending stems with a crooked neck.
and of lesser quality. In method 4 the primary shoot is bent, part of the bottom breaks, and during the fortnight one in 5-6 (Frisco) or one in 3-4 (First Red) stems were bent. Bending in a multi-row system can be difficult. Do not bend between November and January. If necessary pinch a thin stem to spare leaves. Bending may result in ‘empty’ spaces in the crop for the rest of the year.

Bending can be done both from below and from above. Mostly bending is done directly on the bud. A sprouting bud after bending develops slower than when the stem would be cut at this bud.
7. GLASSHOUSE CLIMATE

7.1 Photosynthesis and respiration

7.1.1 Photosynthesis

Green plants belong to the few organisms capable of converting energy from sunlight into chemical energy in the form of carbohydrates such as sugars. In this process CO₂ from the air and H⁺ from water are bound to organic compounds that are used by the plant for growth.

In general terms the reaction in photosynthesis is as follows:

\[ \text{Carbon dioxide} + \text{water} + \text{energy} \rightarrow \text{sugar} + \text{oxygen} \]

\[ 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{light} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2. \]

The reaction takes place in the green parts of the plant, mainly in the chloroplasts. The light intercepted by the chlorophyll is converted into chemical energy and fixed in high-energy compounds (light reaction). During the light reaction water is separated as well, resulting in oxygen. The compounds (ATP and NADPH₂) give off the energy again in the so-called Calvin cycle, in which the CO₂ is fixed (dark reaction). The names light reaction and dark reaction indicate when the process takes place. The dark reaction, however, for a large part also takes place in the light because then the high-energy compounds develop.

The water required for the photosynthesis reaction is mostly sufficiently available. From this it may be concluded that apart from temperature, CO₂ and light are the most important controlling factors of the photosynthesis. When the light intensity and CO₂ concentration increase, the photosynthetic rate will increase as well. Increase of the photosynthetic rate may result in increase in productivity.

Carbon dioxide (CO₂) is taken in through the stomata. The enzyme Rubisco, that fixes the CO₂ from the air and is responsible for further processing, very often also fixes – by accident – oxygen. This is rather frequent, due to the much higher oxygen concentration (20%) as compared to carbon dioxide (0.035% = 350 ppm), the more so because in the leaf the concentration of carbon dioxide is even much lower than 0.035% due to the active photosynthesis. After fixation with oxygen the light energy which was subsequently caught by the chlorophyll, is lost for building into the carbon. The only defence plants have is developing an enormous amount of the enzyme Rubisco; it is the most frequent protein in plants and probably also the most frequently occurring protein on earth. Roses belong to the class of C₃ plants, the photosynthesis taking place in this way.

There are plants that have a system with which they can avoid the problem of extremely low CO₂ concentrations and fixation of oxygen to Rubisco. In the leaves of C₄ plants the place of CO₂ reception is separated from the place of further processing. In this case CO₂ is dealt with by a different enzyme that cannot react with oxygen. This enzyme transfers the CO₂ to a carrier molecule that subsequently travels to the special ring of cells enclosing Rubisco. There the CO₂ is passed on to Rubisco and processed further as in the normal route. Since the CO₂ is offered ready-made, and since Rubisco
is not in contact with the air (oxygen), losses due to ‘mistakes’ are avoided, and the efficiency increased.

The names C3 and C4 type of photosynthesis derive from the first compound in which the carbon dioxide is built in: in a molecule with 3 C-atoms in the ‘normal’ system, in a molecule with 4 C-atoms in the C4-type.

Apart from the C3 and C4 types of photosynthesis there is a third system: the CAM-metabolism. Here the reception and building in of carbon dioxide are separated in time. In these plants the stomata are open at night, catching the CO2. It is fixed in malic acid, so that the leaves become more acid at night. Since it is dark further processing cannot take place; this does not happen until the next day, after the passing over of the carbon dioxide to Rubisco. The advantage is that the stomata remain closed by day - the carbon dioxide being in already - so that transpiration is limited. This type of photosynthesis is common in desert and steppe plants.

In conclusion it can be argued that normal photosynthesis (C3 type) takes place via reception and further processing of carbon dioxide simultaneously and at the same place, so that the efficiency is low and water loss high.

With C4 photosynthesis the reception and building in is spatially separated, which considerably increases the efficiency.

With CAM the reception and building in are separated in time, which considerably limits the water loss.

7.1.2 Respiration

The fixed energy from the photosynthesis may become available for the plant again by decomposing sugars. The decomposition of sugars is called respiration or combustion. This process can be presented as follows:

\[ C_6H_{12}O_6 + 6CO_2 \rightarrow 6CO_2 + \text{energy} \]

The released energy can be used by the plant for growth and maintenance.

7.1.3 Photosynthesis and light

Of these 2 factors light has the greatest effect on net photosynthesis. Rose is a crop with a high light requirement. Photosynthesis is saturated only at very high light levels. The leaf photosynthesis has a reasonably high capacity (almost 20 \( \mu \text{mol CO}_2 \text{ s}^{-1} \text{ m}^{-2} \)). Various sources use different points of light saturation. For example:
- light response curve maximum at ca 450 \( \mu \text{E m}^{-2} \text{s}^{-1} \) (American research)
- light response curve maximum at ca 500 \( \mu \text{E m}^{-2} \text{s}^{-1} \) (Dutch research)
- light response curve maximum at ca 800 \( \mu \text{E m}^{-2} \text{s}^{-1} \) (Canadian research)

The production of roses closely follows the light level, with a delay of almost two months. This equals the time between sprouting and flowering. Differences measured in photosynthesis may also be caused by the orientation of the beds (south orientation being better than north), the location of the glasshouse (shade effects), etc. More information about the role of light in section 7.4.
7.1.4 Photosynthesis and CO₂

There is also an effect of CO₂ on photosynthesis. This effect was studied at the University of Guelph in Canada. Increasing the CO₂ level results in a higher photosynthesis, depending on the light level. This can be converted immediately into a higher production. In addition there is an increased export of assimilates and respiration at a high CO₂ level.

The normal response to an increased CO₂ level is that the stomatal resistance increases (closing), so that a higher water potential develops in the tissue. As a result leaves may become larger (greater LAI). Increase of CO₂ level may also reduce the number of stomata.

The ion uptake rises when CO₂ level increases. Particularly the uptake of nitrate and phosphate is stimulated, even in a low-nutrient environment.

More information on the effects of CO₂ can be found in section 7.6.

7.1.5 Photosynthesis and temperature

Of the factors affecting photosynthesis temperature has the smallest effect. Optimal photosynthesis takes place between 20 and 25°C at ca 350 ppm CO₂. The optimal leaf temperature for photosynthesis, however, also depends on age. A leaf reaches highest photosynthesis just before it is fully grown. At the Research Station in Aalsmeer, this effect was studied more closely in leaves on bent stems. Increase of the CO₂ level also results in a higher temperature optimum of the photosynthesis.

Temperature effects on sprouting and growth of roses are described in section 7.3.

7.2 TRANSPIRATION

Transpiration is a vital process for plants, necessary for cooling the leaves and for transport of water and nutrients.

The transpiration of a crop strongly depends on the difference in vapour pressure in the cavity behind the stomata in the leaf and the surrounding glasshouse air. In addition the plant resistance plays an obvious role. Apart from air humidity, light radiation and temperature are important factors.

Transpiration is the emission of water vapour by the plant to the surrounding air. This happens via the stomata of the leaf. In the stomata the air is always saturated with water vapour. Because the surrounding air is mostly drier than the saturated air in the cavities, water vapour will diffuse as a result of the concentration difference. If the stomata are more open the resistance is lower and the diffusion is faster.

Transpiration is in fact a combination of evaporation and water vapour transport.

Transpiration in a plant takes place when the water in the cells around the cavities of the stomata turns from liquid into vapour form.

Transpiration also occurs through the cuticula (cuticular transpiration), but this is only a fraction of the transpiration through the stomata (stomatal transpiration).

The transpiration rate (water vapour transport) changes as the difference between the moisture content in the leaf and the glasshouse air changes, but also as the resistance changes. This resistance is formed by the internal resistance (size of the stomatal aperture) and the external resistance. The external resistance depends on the rate with which the air passes the leaf. In most situations the resistance is virtually constant. The internal, or stomatal, resistance may fluctuate strongly. If the stomata are almost entirely closed, the total resistance is high and the tranpiration low. If the stomata are wide open the resistance is low.
The aperture of the stomata is affected by various factors: light, vapour pressure difference, CO₂, (leaf) temperature and availability of water. Light is by far the most important factor in the control of the stomata. Under high light the stomata are open. The humidity difference is also important. With a great humidity difference or water deficit the stomata close themselves to protect the plant against dehydration. The effect of transpiration is to cool the leaf surface. Transpiration of water requires energy. This is extracted from the cells around the stomatal cavities, which in their turn extract it from neighbouring cells. As a result when the sun shines a transpiring leaf is considerably cooler than a non-transpiring leaf. Cooling of the crop also leads to cooling of the glasshouse air, so that on a sunny summer day a glasshouse with a crop may be noticeably cooler than an empty glasshouse. Part of the radiation heat of the sun is used to evaporate water instead of directly heating up the glasshouse air.

**Vapour pressure difference**
The difference between the vapour pressure in the leaf and that of the glasshouse air is the driving force for transpiration. This difference is called vapour pressure difference leaf-air. This is not the same as vapour pressure deficit (humidity deficit) of the glasshouse air. The vapour pressure difference between leaf and glasshouse air and the vapour pressure deficit between the unsaturated and saturated air are only equal if the leaf temperature is the same as the glasshouse temperature. Often, however, this is not the case as the leaf temperature of plant parts in the sun, may be several degrees higher than of those in the shadow. Leaves in the shadow often have about the same temperature as the glasshouse air. Because the leaves in the sun have a much higher temperature, the vapour pressure in the leaf is much higher, and consequently also the vapour pressure difference leaf-air. As a result they evaporate more than leaves in the shadow, despite the fact that the vapour pressure deficit of the surrounding air is the same. The driving force for crop transpiration, therefore, is not the vapour pressure deficit but the vapour pressure difference between leaf and air.

**Effect of air humidity**
The crop transpiration affects the air humidity of the glasshouse, the leaf temperature and indirectly also the stomatal aperture. This is a kind of feedback. It is therefore not always simple to distinguish cause and effect. The effect of the vapour pressure difference on transpiration consists of a direct effect (suction pressure by vapour pressure difference) and an indirect effect (stomatal closure), which are opposing factors. Normally the stimulating effect of a large vapour pressure difference is by far the strongest, and the transpiration will increase as the vapour pressure difference increases until the stomata are fully closed. Then only the much smaller cuticular transpiration remains.

**Effect of radiation**
Despite the significance of air humidity on transpiration, the most important factor determining transpiration is the amount of radiation, from the sun or from heating pipes. Solar radiation has two effects on transpiration:
1. Increasing radiation heats up the crop, so that the vapour pressure difference between leaf and direct surroundings increases.
2. As a result of increased sunlight the stomata open further.

On increasing solar radiation the vapour pressure difference leaf-air becomes greater and the total resistance smaller. These two consequences of increased radiation have a
similar effect: increase of transpiration at higher radiation. The first effect can also be achieved by applying more radiation through the heating pipes (heating). Heating has no direct effect on the stomata, but on the temperature of glasshouse air and crop. A higher pipe temperature (pipe radiation) results in a greater vapour pressure difference, which makes the transpiration increase as well. When heating and ventilating an extra large vapour pressure difference is achieved because the glasshouse air is replaced by drier outside air, resulting in greater transpiration.

Root pressure
The transpiration is stimulated because water vapour is extracted from the leaves by the suction force of the vapour pressure difference. This suction force penetrates to the roots of the plant. This means that there is a suction in the entire plant, responsible for water uptake through the roots. If there is no or only little transpiration (especially at night) the suction almost totally disappears. In such a situation a different process becomes important, namely the root pressure. This is to say that instead of suction from the leaves, a force from the roots causes the water uptake. One of the causes of root pressure is that in the plant cells the salt concentration is higher than in the growing medium (so-called osmotic pressure).

7.2.1 Variety effect
Research pointed out that rose varieties may demonstrate great variations in transpiration under similar climatic conditions. A clear example is the variety Renate that has a considerably higher transpiration than First Red. In an experiment in spring First Red evaporated 33-40% less by day and 26-34% less by night than Renate. It was observed that the stomatal aperture/resistance of the various varieties is not the same under otherwise equal glasshouse circumstances, and this may be the explanation of the differences in transpiration and consequently in water consumption.

7.2.2 Response of transpiration on cultivation activities
Especially in rose cultivation various activities strongly affect transpiration and consequently water requirement:

- Various experiments showed that spraying certain pesticides may reduce the transpiration and consequently the water requirement by 30-40% for a number of days.
- Bending the primary shoot reduces the transpiration of rose for more than a week, the first day even by 50%. After a week or so the reduction is no longer apparent.
- A complete rose crop on flush immediately reduces transpiration by as much as 70%. Within three days the transpiration is taken over for 100% by the ‘old’ leaves, if sufficient green ‘old’ leaves are present. By way of drainage measurement and feedback such disturbances are corrected.
- Active crop is being continually harvested (leaves).

A significant point that has to be taken into consideration is that in a glasshouse large differences in transpiration and consequently in water requirement may occur. These differences occur both systematically, for example to the left and right of a gutter, and incidentally between individual plants. Differences in transpiration between rows/beds of roses and individual plants may rise as high as 30 to 40% in a few hours. These large differences between rows/beds occur with sunny weather. During the morning the
rows of parts of a bed which intercept more light evaporate considerably more than rows which intercept less light, while during the afternoon it is the other way around, due to the turning of the sun. Due to the differences mentioned in transpiration in a glasshouse a certain quantity of extra water should always be given and the growing medium should have a sufficiently large water buffer. For a sunny day a stock of at least 5 to 6 l per m² is required.

7.2.3 Effect of CO₂ concentration on water consumption

The CO₂ concentration in a glasshouse is important for the stomatal aperture. The stomatal aperture in its turn affects the crop transpiration and consequently the water consumption. As the CO₂ concentration becomes higher, the stomata will close. The closure also depends on the type of crop, and even different varieties in the same crop may show different responses. It has been observed at an increase of the CO₂ level from 350 to 700-800 ppm that the stomatal aperture declines by 40%. The effect on water consumption depends on the circumstances, but in general it is relatively small.

7.2.4 Effect of plant size on water consumption

In addition to climatic factors the plant size, the degree of light interception by the rose crop, affects the water consumption. A rose crop shows maximum transpiration at a given amount of radiation in a condition in which maximum soil cover and/or radiation interception is reached (LAI > 3). As a result of cultivation activities, such as harvesting, bending, pruning and leaf drop at certain moments the light interception may be (temporarily) below maximum, even in fullgrown plants.

7.2.5 Water consumption during the night (dark period)

Research showed that the water consumption of a rose crop during the night, both in absolute and in relative terms, may be rather high. During the summer months, when there is no or only little heating, about 5 to 8% of the total water consumption takes place during the (short) night period. In winter, with long nights and much heating, this percentage may increase to more than 50% of the total water consumption per 24 h. Both the water taken up for fresh weight increase and the energy introduced into the glasshouse by heating, contribute to a relatively high water consumption during the night.
Whether the water taken up during the night should be supplemented, is still a point of discussion among growers. Research with water supply or no water supply during the night with vegetable crops did not show any clearly significant difference in yield or quality.

7.2.6 Effect of assimilation lighting on water consumption

Artificial lighting increases the crop transpiration by 20-30% on a day. This is caused by the fact that the plants photosynthesize longer and stomata are open longer. Furthermore, the plants are heated. The difference in increase in percentages between night and day is rather large. Although the crop transpiration during the night is often low in absolute terms, the effect of artificial lighting during the night may be considerable in percentages. When the lamps are switched on, the plants do not experience night.

For each variety the effect of artificial lighting is different. The variety Renate evaporates under natural light more than First Red or Frisco and this difference in response is also observed under artificial lighting. The differences between varieties are, however, not of the same order during the growing season and be opposite for the day and the night periods. The capacity of the lamps also determines the effect on crop transpiration. The influence during the night of lighting with SON T plus 400 Watt lamps (1 lamp per 10 m²) may amount to more than 400% for 24 hours' lighting and by day to 22% (lamps switched on at values below 150 W m²). With 18 hours' lighting, values of 215% at night and 7% by day were measured as compared to not lighting.

7.2.7 Water requirement and water supply

In The Netherlands, differences in transpiration and water requirement may fluctuate from day to day between 1.5 and 6 l/m²/day. Under extreme circumstances the water consumption in summer may even increase to 7 to 8 mm per day. On such days the transpiration per minute may rise to 14-20 gram per m². In the water supply an extra 30 to 50% is added to leach, which means that the water supply equipment should have sufficient capacity. A correct water supply, in accordance with the requirement, is essential for optimal growth and production of roses. It is important to choose the right quantity and the right time for each watering during the day. Even if sufficient water is supplied per day, too much or too little must not be given per watering, nor should the water supply start too early or too late. Large fluctuations are not conducive to good growth. Water supply based on feeling or only on radiation is certainly not always optimal.

Growers may have very different water supply methods. There are often very great variations between Dutch rose nurseries, which range from 800 to 2400 mm per year. In general terms one third of the nurseries are (too) economical, one third supply according to requirement and one third give much or too much water. In the past, but at present as well, the volume given at watering is often based on feeling. Although systems are available to adjust the water supply to the crop’s requirement, only in recent years do growers show more interest in accurate control and automation of the water supply.
7.3 CROP DEVELOPMENT

7.3.1 Axillary buds

The present glasshouse rose is a perennial crop continuously forming new flower shoots, when flowers are harvested. Within the crop large variations may exist in the quantity and the quality of the developing stems. In recent years rose growers tried to limit these variations by crop treatments. More information is to be found in chapter 6. Within the same crop various developmental stages occur, from a sprouting axillary bud to a harvest-ripe stem. Information on the rate at which the developmental process takes place and the final quality can be found in the last sections of this chapter, where the most important factors affecting growth and development are dealt with.

Axillary buds are the foundation of the bush structure and the flower production of roses. In vegetative propagation the axillary bud forms the starting point for the aerial part of the new plant. Bottom breaks developing at the basis also develop from axillary buds. Also the occurrence of branching is based on whether or not the axillary buds sprout. Every shoot starts its development as bud in the axil of a rose leaf. Research at Wageningen University (dissertation C.A.M. Marcelis-van Acker) rendered much information on the build-up of axillary buds. An axillary bud is a non-elongated, partly developed shoot located in the leaf axil. The axillary bud is formed by a so-called axillary meristem that is just above every leaf primordium. The sprouting of the axillary bud depends on various factors and is correlatively inhibited by the influence of other parts of the plant.

There is one bud in every leaf axil. The axillary bud contains a telescoped version of the lower part of the future shoot. In the axils of the outer bud scales of this so-called primary axillary bud there are already (secondary) axillary buds. These first secondary axillary buds appear when the leaves, in the axil of which is the primary bud, unfold. In the primary bud itself already seven leaf primordia are initiated. During subsequent development of the shoot the number of leaves in the primary bud increases to about eleven, while the number in the secondary bud rises to about 4. In the axillary bud the pith cells are equal in size. The cells contain sugar and starch. The number of pith cells in the diameter remains unchanged when the bud breaks. After sprouting the diameter of the pith increases by cell elongation. The final diameter is reached rather quickly after breaking. The shoot diameter appears to be correlated with the pith diameter and the pith represents the primary growth of a shoot. The development of the axillary bud can be distinguished into 2 periods:

1. initiation and development of the bud until the correlative inhibition is removed;
2. bud break and development until harvestable shoot.

Axillary buds should have reached a certain minimum stage of development before being capable of breaking. As soon as this stage is reached, the bud can break after removal of the correlative inhibition. During the correlative inhibition the leaf division of the meristem continues, albeit on a lower level. As a result both the number of leaves and leaf primordia in the bud, and the weight of the bud increase, as it gets older. The bud remains vegetative, however (does not form a flower), even if this period lasts a year. The transition to the generative stage only takes place after breaking of the bud. The total number of leaves (including scale-formed leaves) increases as the bud from which the shoot is formed, gets older. Length, weight and leaf area of the shoot, however, are not clearly influenced by the age of the bud. The number of pith cells increases as the bud gets older, so that the potential girth of the future shoot also
increases. The buds in the upper leaves of a stem often appear to be more generative and then only contain some leaves and a flower bud. A flower bud is soon visible then, and often these upper (3) axillary buds are regarded as part of the inflorescence. The lower buds are vegetative. The height at which a stem is pruned appears to affect the growth of the shoot that is subsequently formed. By varying pruning height, both position and age of the bud which will sprout, and the number of leaves remaining on the stem vary. Differences in final size of the newly formed shoot appear to be caused largely by differences in assimilation supply as a result of variations in the quantity of leaves.

The development rate of bud to shoot is clearly influenced by the temperature. The average temperature is then the most significant. More information is given in section 7.5. The moment the flower bud becomes visible in the sprouting shoot coincides with the moment the elongation of the stem is maximal. Length and weight of the flower shoot increase as the temperature gets lower. A period with lower temperatures may result in synchronization of sprouting. The effects of temperature may be partly caused by a side-effect on the assimilation supply. Apart from temperature there are other factors affecting the breaking of a bud. In some varieties the buds break faster and more easily than in others, probably due to a difference between varieties in apical dominance and correlative inhibition of buds. A low relative humidity may have a strong negative effect on bud break.

7.3.2 Flower bud initiation

The induction and flower development of rose takes place as soon as elongation in a growth tip occurs. This moment, the moment of breaking of the bud, usually happens two weeks after harvest of the flower shoot above the bud. There is no day length interaction in the flower initiation of the rose. The rose is a day-neutral plant. The temperature has little influence on flower initiation, though it affects the number of sepals (see 1.1.1) and flower malformations (see 9.8.1).

The flower initiation of rose is described in two ways: via a process divided into 10 stages and a process that develops in 8 stages. Basically the two divisions correspond, the former being more detailed.

The microscopic observations to determine the 10 stages were carried out with the varieties ‘Baccara’ and ‘Pink Sensation’. The 10 stages can be described as follows:

0. Vegetative. Apex hemispheric; third leaf primordium clearly trilobate
1. Generative. Top of apex flattened; surface corrugated
2. Three or four sepals of about the same size are visible; last appendices formed by the vegetative apex; now separated from it by elongation
3. All sepals formed.
4. Primordia of the petals are present, sepals slightly curved
5. Sepals curved inwards, five petals are present
6. Sepals have the same size as the receptacle and are laced at the bottom. Number of petals increased to 10.
7. More than 20 petals present
8. Sepals three times as large as the receptacle. The oldest petals are half as long as the sepals
9. Primordia of the stamina are present, but not yet those of the carpels
10. First initiation of the carpels present
Figure 16 demonstrates the 10 development stages.

In conclusion, the flower initiation of rose corresponds to that usually found with higher plants.

Figure 16. Flower initiation of rose divided into 10 stages. Source: J.S. Horridge and K.E. Cockshull, 1974

Figure 17. Flower initiation of rose divided into 8 stages. Source: D.P. de Vries et al., from Moe and Kristoffersen

L = leaf, F = flower primordia, se = sepal, p = petal, st = stamina, pi = pistil, h = filament
The process in 8 stages has been described for the variety ‘Baccara’ by researchers from Norway. They came up with the following classification:

1. Vegetative meristem
2. Flattening of the apex
3. The primordia of the sepals become visible
4. The primordia of the petals become visible
5. and 6. Development of the style and stamina primordia
6. Anthers become visible
7. Filaments present

The illustration of the 8 stages is given in Figure 17.

7.3.3 Stem quality

For the time (\( DT = \) developmental time) that is necessary to grow from bud break to harvestable shoot, various factors are relevant. The most important is the average temperature (see also 7.4). The higher the average temperature, the shorter the developmental time. In addition the period of the year (season) is an important factor in developmental time. Both with a high and a low growing temperature the development in the Netherlands in December takes about 7 days longer than in for instance August or April. This indicates that light plays a major part as well. Furthermore there are of course variations among varieties. Light has a positive effect on the development time of a shoot.

The stem quality can be expressed in different ways. Stem length and stem weight may be a measure for quality. Unfortunately the two do not always coincide. The stem weight is expressed usually in fresh weight. In general a higher cultivation temperature leads to a lower fresh weight (see also 7.4.1). In addition there is a distinctly positive

Figure 18. Time of bud break to harvest as related to the average growing temperature and the time of the year with Sonia (From: G.A. van den Berg, 1987)
effect of light. Under the same light levels, the stem weight is higher in autumn than in spring. This is caused by the fact that the stem is in development for some time and has received less light in total in spring than in autumn, when this is preceded by the summer period. The relative humidity also affects the stem weight (see also 7.7). A higher relative humidity also gives a higher fresh weight. The weight of the flower bud as fraction of the total shoot weight increases in winter and decreases in spring. In summer the share of the bud weight in the total weight is smallest. In winter the bud weight as fraction of the fresh weight of the stem decreases as the temperature is higher. In spring this is just the other way around.

The shoot length has its optimum at an average cultivation temperature of about 18°C. At a constant cultivation temperature and increase of the night temperature the stem length declines. Also the stem length is positively affected by the amount of light. At an equal light level in spring and fall roses are taller in the fall. This may also be caused by higher relative humidity in the fall because the relative humidity also has a positive effect on stem length. Various researches indicated that the CO₂ supply affects stem length and stem weight as well. To what degree depended on the variety (see also 7.6).

### 7.3.4 Flower bud atrophy

Basically every bud on the leaf axil of a rose can grow out to a stem with a flower. However, a certain percentage of the stems do not yield flowers. Such stems are called ‘blind’. In 1934 researchers found out that blind shoots are preceded by the abortion of the flower bud at an early stage of development. The first signs of abortion already occur during development of the petals. A ring of dead cells develops under the flower bud and this subsequently dies off. Development of flower bud atrophy usually occurs in the period between the formation of the petals and the formation of the pistil. Since the flower induction and the flower bud development take place as soon as the growth tip starts to elongate (see also section 7.3.2) the grower cannot distinguish whether or not a young sprouting shoot will form a flower.

#### Variety effects

In general blind shoots have fewer leaves and the stems are thinner and of a lighter colour, as compared to flowering stems. The sensitivity to flower bud atrophy is variety-dependent. Heredity is therefore important. Flower bud atrophy is a physiological process, also related to the vigour of a variety. The CPRO-DLO in Wageningen demonstrated that it is possible to select on the sensitivity to flower bud atrophy within a population of rose seedlings. The competition between shoots plays also a role in blind shoots. When 2 buds sprout on the same stem it is sometimes observed that one of the two buds, usually the lower one, is blind. Apical dominance comes into this, which means that a higher, breaking bud suppresses the sprouting of the lower bud. The upper bud sprouts more rapidly and attracts the nutrition and hormones more strongly than the lower buds. As long as there are sufficient assimilates there is no problem. However, if this is not the case, as in winter when the quantity of light is the limiting factor, the lower shoots often become ‘blind’. Thick, vigorous stems are less sensitive than thin ones. Apparently, they suffer less from a lack of assimilates.

#### Hormones

The role of hormones is clear. A low auxin level stimulates flower bud atrophy. Flowering shoots have a higher gibberellin, auxin and cytokinin content. Non-flowering
shoots contain a higher abscisic acid content. The question of cause and effect arises. Spraying various plant hormones has fluctuating, unpredictable effects on flower bud atrophy and often causes (growth) malformations. It is not practically feasible to reduce the flower bud atrophy with hormone sprayings.

**Light level**
An increase of the light level results in less blind shoots. Blind shoot are observed mostly in, or immediately after, low-light periods. In addition to supply of extra light by assimilation lighting, a combination with CO₂ supply has a positive effect in reducing the number of blind stems. At a higher light level and CO₂ concentration the production of the quantity of assimilates by the plant is higher as well.

**Temperature**
Increasing the cultivation temperature affects the flower bud atrophy in two ways. First, it has a direct, reducing effect on blind shoots. Second, it has an indirect, stimulating effect on blind shoots. Stems grown at a higher temperature, under low-light conditions, yield thinner shoots which are more sensitive to blind shoots. In low-light periods, the second effect dominates the first, resulting in increased blind shoots. When with a constant 24-h temperature the night temperature is increased and the day temperature is diminished, this results in reduced flower bud atrophy. The improved flower bud formation may be explained by the theory that the flower bud in the night draws more strongly from the stock of assimilates than the developing leaf, while by day this is the other way around. Because a lower day temperature has no effect on the photosynthesis, while it does reduce the use of assimilates by day, at night more assimilates are available for the flower bud.

The question is what a grower should do to reduce flower bud atrophy. In the first place the 24-h temperature should not be allowed to become too high, with respect to the quality of the stem. Finally, there is the effect of the variety, and the aim the grower has in mind. Some varieties are more sensitive than others. Does a grower prefer to grow fewer stems of good quality at a lower cultivation temperature, or more stems with increased blind shoots and of poorer quality at higher temperatures?

7.3.5 **Plant hormones**

The application of plant hormones in rose cultivation is still in its infancy. The compounds are being used for certain sub-processes, for example propagation (stimulation of rooting) but the effectiveness may be much better. Expertise and insight into the effect of various plant hormones are necessary. The natural growth regulators control developmental processes in the plant, for example in rooting, length growth and branching. Also in senescence hormones play a role. In animals (mammals) hormones are produced in one particular place and subsequently transported through the body to do their job at very low concentrations. In plants the production may take place in several places. Therefore discussions are going on whether to call these substances hormones or growth regulators. From a social point of view the name hormone is an emotionally charged word. Therefore in plant breeding the name growth regulator is increasingly applied.

It is obvious that one should be careful in the application of growth regulators. This section should be regarded as background information on the effect of certain growth regulators and not as a 'book of recipes' for a certain application. Accurate dosage of
the compounds is vital. The compounds are already effective at very low concentrations and high dosages may lead to serious and permanent growth disturbance. To date, 5 groups of hormones are known: auxins, cytokinins, gibberellins, abscisic acid and ethylene.

**Auxins**

Auxin is the earliest known hormone, with indole-3-acetic acid or IAA as most important natural representative. Auxins are especially formed in the growth tips of stems, in leaves, in flowers and in seeds of growing fruits. In these organs they promote the cell elongation and the related metabolism, probably also the compound uptake from the nutrient phloem. Auxin is transported in the plant from top to bottom from cell to cell via the parenchym and from the leaves also via the sieve tubes. Thus it moves to the roots, where apparently it can quickly be inactivated, because otherwise the root growth which is sensitive to auxin, might be inhibited.

Auxins not only affect growth by cell elongation, they also play a role in division and differentiation of cells. This is clear, for example, from the effects of auxin on the formation of adventitious roots.

Auxins are being applied for the rooting of roses (see also 5.2.1). For this purpose IBA is more effective than IAA or NAA. Follow the recommended concentration closely. This depends on various factors (variety, time of the year). It seems that the duration of the treatment is important. It is better to apply a lower concentration for a longer time than exposure for a short time to a high concentration. In the production of grafted plants or root grafts no hormones are applied.

**Cytokinins**

The production (biosynthesis) of cytokinins mainly takes place in the root tips. In the transpiration flow they are transported to the aerial parts, and, after transition in the vascular bundle to the phloem, to the developing organs, particularly when these produce auxins. Since the formation of cytokinin depends on the root activity, cytokinins function as messengers for signals from the root environment. Factors impeding root growth such as water deficit, shortage of certain nutrients or oxygen deficiency (too wet substrate) reduce the cytokinin content of the bleeding sap and consequently inhibit the aerial development. Particularly in the interaction with auxins the cytokinins control growth, branching and senescence of the shoot. Also in the development of the adventitious organs, such as, for example the formation of bottom breaks, cytokinins play a role. Cytokinins possibly also play a role in breaking the dormancy of buds. Various cytokinins have been practically tested for the promotion of bottom break formation and rejuvenation of a rose crop. Extensive study has been conducted as well into the formation of cytokinins in various rootstock types and the effect of this on the development of shoots. This research indicated that there are quantitative relations between the export of cytokinins from the roots and the development of the shoot, and between the genotype of the rootstock and the cytokinin concentration in the bleeding sap. This information may be used in future in the selection process of a certain rootstock (Dieleman, 1998). Environmental factors and plant treatment, however, also often have severe consequences and an indirect effect on the hormonal balance, so that the practical application becomes difficult. External treatments with cytokinins are not legal in The Netherlands.

**Gibberellin**

The biosynthesis of gibberellin may take place in virtually all plant parts. Gibberellins (GA) circulate through the entire plant through the xylem vessels and sieve tubes, and
promote the growth of the shoot. On the one hand this is an indirect effect; gibberellins increase the auxin level by promoting the auxin synthesis and/or inhibition of the auxin decomposition (the auxin saving effect of gibberellins). Gibberellins induce the cell division in the subapical and intercalary meristems. The gibberellin synthesis can be inhibited artificially by application of synthetic regulators, which are applied as growth retardants to inhibit length growth. In a rose crop this is not necessary. Gibberellins also play a role in the breaking of seed dormancy and promote germination. GA is sometimes used in tissue culture in combination with other hormones.

Abscisic acid
While cytokinins and gibberellins have a dormancy breaking effect, abscisic acid has a dormancy inducing and growth inhibiting effect. Abscisic acid is formed mainly in the chloroplasts of the chlorophyll cells. They accumulate in the membranes and may be released quickly under stress conditions, possibly as a result of the decline of the cytokinin supply from the roots under these circumstances. Abscisic acid is also issued by the leaves, both via sieve tubes and xylem vessels, especially to the growing parts. In full-grown tissue ABA stimulates senescence. Under unfavourable conditions the synthesis of auxin, cytokinin and gibberellin usually decreases, but that of abscisc acid continues or even increases.
The growth regulator abscisic acid is not applied in rose cultivation.

Ethylene
Ethylene is very similar in effect to abscisic acid. Generally it inhibits growth of the young cells and promotes senescence of mature tissues. Like abscisic acid the effect of ethylene is the opposite of that of the other 3 hormones. The inhibition of cell division is cancelled by cytokinin. The cell elongation that is promoted by auxin is inhibited by ethylene.
The formation of ethylene may take place in all plant parts, particularly under stress conditions, such as drought, heat, cold, or mechanical damage. As senescence hormone ethylene is active in flower wilting. Ethylene may be released as a result of inadequate combustion of fuel and give rise to serious damage. Ethylene is not applied in rose cultivation.

7.4 TEMPERATURE STRATEGY
The average growing temperature and the temperature strategy influence the growth and development of roses. The problem is that there is often also a combination with the effects of other factors such as light, relative humidity and CO₂. In other sections therefore, this section or one of the following sub-sections have often been referred to. In the following sections the effect of temperature on the various processes is dealt with in detail. A complete temperature strategy for a rose crop is not given, because variety differences also play a role. Section 7.4.1 discusses the effect of the (average) growing temperature on characteristics like sprouting, development rate, stem weight and stem length, numbers and the relation between number and stem quality. Section 7.4.2 deals with the temperature rise after sunset. This is a temperature strategy with a specific aim which became popular in the mid nineties, and which is still frequently applied. Finally, section 7.4.3 deals with the phenomenon of temperature integration.
7.4.1 Cultivation temperature

The average temperature or the temperature during a certain time of the day influences the development of the rose. Since various tracks and components can be distinguished, the section has been subdivided. A excellent reference guide for the effects of temperature on growth and development of rose is the dissertation of G.A. van den Berg, 'Influence of temperature on bud break, shoot growth, flower bud atrophy and winter production of glasshouse roses'.

Bud break
When a rose is harvested it is vital that the bud immediately below the cut breaks as soon as possible, because from this bud a new rose develops. Each day such a bud does not develop is loss of time and therefore loss of production. The variety differences in bud break may be considerable. Research at the Research Station Aalsmeer indicated that Sonia has a much easier bud break than Ilona. One variety needs a higher temperature for bud break than another. With Ilona the bud break immediately declines as soon as the temperature drops below 20°C. In Sonia the bud break is less easily inhibited when temperature drops to 17°C. With lower temperature the bud break is severely inhibited. Of current varieties such data are not exactly known so that growers have to rely on the information provided by the breeder. In general, higher average 24 h temperatures (15 to 21°C) lead to faster bud break. For bud break the 24 h temperature seems most important. Whether the heat is supplied by day or at night is less relevant. Experimental results indicate that at a night temperature of 24°C and a day temperature of 16°C the buds breaks just as fast as with a night temperature of 16°C and a day temperature of 24°C. From the point of view of energy efficiency, savings can be obtained if at night heat were supplied under a closed screen. The usual situation in practice is still that the night temperature is set lower than the day temperature.

The researcher Berninger has quantified the effect of light and temperature on 3 development stages of Sonia. For the so-called stage 1 (shoot 0 to 1 cm) he reached the conclusion that the bud break rate is only a function of the average glasshouse temperature: Y = 6.5 + 0.048 (27.6 - T)^2.

Development of bud break to harvest
A higher glasshouse temperature results in a higher yield in numbers of stems. In general it may be stated that an increase of temperature leads to yield increase, but also to shorter and lighter roses when the average 24 h temperature exceeds 18°C without lighting (Dutch light conditions). There is a linear relation between the number of stems harvested and the average 24 h temperature in the range 15 to 21°C. Research, however, demonstrated that there are variations between varieties: Sonia responds more strongly to a temperature rise than Ilona. Differences in day and night temperatures have no effect on the development rate when the average 24 h temperature remained the same. According to Berninger there are more relevant factors after sprouting than just temperature. He argues that in stage 2 (1 cm to visible bud) there is a strong influence of the quantity of light, apart from temperature, on sprouting rate: Y = k * PAR^0.17 * f(T). In the last stage of development, stage 3 (visible bud to start of flowering) light is less important than in stage 2: Y = k * PAR^0.06 * g(T)
**Stem weight**

As Van den Berg’s dissertation explains, the average stem weight decreases with increasing average 24 h temperature. He tested among others the varieties Sonia and Ilona at average 24 h temperatures between 16 and 22°C. The variety effect is clearly visible but also the time of the year and the corresponding light sums. Van den Berg’s research was still carried out in soil without assimilation lighting. Figures 19 and 20 show the results.

The stem weight in Van den Berg’s experiments was not only affected by the average temperature, but also by the difference between day and night temperature. His research demonstrated that the lowest stem weights are found at high day (25°C) or night temperatures (22°C). The highest stem weights develop under low day (15°C) or night temperatures (12°C). It is clear that the amount of light should be taken into consideration. There may be a difference in level when more or less light is available.

Differences between day and night temperatures may also affect the stem weight. However, there are variations between varieties, but also between research results. A great negative difference (DIF) between day and night temperature lowered the stem weight of Ilona while in contrast Sonia produced heavier stems at low night and high day temperature. Recent research into the effects of early night prolongation at the Research Station Aalsmeer showed no noticeable reduction of the stem weight of First Red, even though the temperature difference between day and night was slightly smaller (-5°C) (Vogelezang, J. and J. de Hoog, 1998).

![Figure 19. Sonia and Figure 20. Ilona grown in soil in a glasshouse. Model for the relation between fresh weight (g/stem) as related to the moment of bud break and the average growing temperature (Source: Van den Berg, 1987)](image)
**Stem length**
The response of the shoot length on the average 24 h temperature in the research of Van den Berg showed an optimum at an average 24 h temperature of 18 to 19°C. Both higher and lower temperatures resulted in shorter roses. Figure 21 shows the results of research with Sonia. In more recent research into the effects of temperature integration Buwalda (1997) demonstrated that alternating temperatures have little effect on stem length. It is clear that the time of the year and the current light conditions play a role in stem length.

Research results are not unequivocal about the effect of a difference between day and night temperature on stem length. According to Van den Berg a high night temperature reduces the stem length when the average 24 h temperature remains the same. More recent research into the effects of a temperature rise after sunset (during which for a short period of 4 h the temperature is increased) showed that the temperature strategy DIF had no reducing effect on the stem length of First Red. Recent experiments with energy saving measures using temperature integration with First Red, in which negative DIF of 3 to 4°C was applied, did not show any negative effects on stem weight or stem length. Foreign research pointed out that noticeable effects of negative DIF only occur at great differences between day and night temperature. Norwegian researchers found a reduction of 3 to 4 cm at 17/19°C as compared to 20/20°C or 23/14°C day/night temperature. German experiments demonstrated only little difference in stem length between temperature strategies with a negative DIF of 4°C, irrespective of the average temperature level (ca 14, 18 and 22°C). Both a positive and a negative DIF caused significant length differences as compared to equal day and night temperature.

![Figure 21. Total shoot length of Sonia in relation to the moment of bud break and ambient temperature. Source: Van den Berg, 1987](image)

**Production as related to stem quality**
Circumstances promoting the quality, such as a higher fresh and dry weight, often delay the flower development. Increasing the average 24 h temperature results in a
distinct production increase in terms of numbers of stems, but may just as easily lead to shorter and lighter roses. A high production of lower quality is no help to the grower. Try to find the best strategy for your crop under the given circumstances.

7.4.2 Temperature rise after sunset

In research of Van den Berg with Sonia, the percentage blind shoots was reduced as a result of a higher night temperature at equal average 24 h temperatures of 19°C. This effect was already visible if for 2 to 3 hours after sunset a temperature rise of 18.5 to 24°C was applied. The increased temperature treatment began at sunset. A possible explanation of the reduction in blind shoots in the temperature strategy may be the transport of assimilates to the developing flower shoots. The research was conducted without assimilation lighting.

It is not clear, however, whether a temperature strategy such as the temperature rise after sunset, discussed above, really has a positive effect on the carbohydrate relationships of the developing shoots and consequently contributes to the improvement of flower quality suggested by growers. This hypothesis has been tested at the Research Station for Floriculture and Glasshouse Vegetables in 1997. Prior to the research, cuttings were taken from First Red and in 3 months a bush was built up with bent stems. Subsequently the plant material was transferred to conditioned climate glasshouses. Four temperature strategies were applied in duplicate with an average 24 h temperature of 19°C: the same day and night temperature, a temperature rise after sunset for 4 h of 24°C following the day with compensation in the latter part of the night, a high day and low night temperature (positive DIF of 5°C) and a low day and high night temperature (negative DIF of 5°C). In the treatment with the constant temperature and the treatment with temperature rise after sunset assimilation lighting was used during the temperature rise after sunset. During the day and during lighting hours CO₂ was applied to a level of 700 ppm. Yield data and crop samples to determine the carbohydrate contents were collected during 2 consecutive harvests.

The course of carbohydrate contents during 24 h corresponded to expectations: in leaf parts at the end of the day the highest contents of starch and sucrose, which gradually declined in the course of the night. Both from the amount of sugars measured and from the increase in fresh and dry weight of the flower buds it became clear that an important part of the nocturnal transport to the flower bud took place during the early night. However, no extra stimulating effect was apparent from a temperature increase during the early night, irrespective of whether or not assimilation lighting was used. Temperature rise after sunset did not lead to a boost of shoot sprouting, a larger flower bud or longer vase life. Rather, a (light) decline in stem length and bud height could be observed. The risk of blue buds therefore seemed to be higher when temperature rise after sunset was applied. No conclusion can be given on the effect on flower bud atrophy, because this did not occur at all.

The research confirmed that the glasshouse temperature can be varied within 24 h without adverse effects on production and product quality. This offers prospects for the application of energy saving climate controls, such as for instance temperature integration.

Some growers say they observe clear results of the application of temperature rise after sunset. At the end of the day they limit ventilation so that the heat remains in the glasshouse. Perhaps that as a result of ventilation restriction the relative humidity and the CO₂ concentration reach a higher level and are responsible for a positive effect. The
experiments at the Research Station were carried out in conditioned glasshouses, where the other factors such as CO$_2$ were kept equal in all treatments.

7.4.3 Temperature integration

The plant’s response to the average temperature instead of to the temperature fluctuations during a certain period is known as temperature integration. Using temperature integration savings can be obtained in heating energy, without loss of production or quality, because the grower can choose the most cost-effective way to reach a certain average temperature. Heat losses can be restricted by reducing the glasshouse temperature, for instance with strong wind or low outdoor temperature. The low temperatures are then compensated for at a more favourable time, for example during the night under an energy screen or by day during sunny weather. In general the effects of temperature deviations are supposed to have an integrating character; they are determined by the size of the deviation in °C, multiplied by the exposure period (time) and consequently expressed in degree hours or degree days. Integrating a deviation of 4°C, for example, during 2 days, has the same effects as a deviation of 2°C during 4 days.

Energy reduction by applying temperature integration increases as the integrative capacity of a crop is greater. Not only the integrative capacity (in degree hours) is then determinant but also the maximum limit of temperature deviation (°C). It is obvious that yield and quality should not suffer; it is therefore important to investigate where the limits of tolerance for temperature deviations are and these may differ for each variety. Research demonstrated that in general the integrative capacity of roses is great. The effect of the light level is only very indirectly a determining factor.

The operative principle of temperature integration is explained by the balance between production and processing of carbohydrates. Literature research (source: Buwalda, 1996) points out that the balance between the production and processing of carbohydrates may play a significant role in determining the integrative capacity of plants. The production (in the photosynthesis) then mainly depends on external factors such as light and CO$_2$, while the processing is mainly temperature dependent. The temporary storage of assimilates performs a buffering function. The condition of this buffer (carbohydrate level or carbohydrate status) is also an important signal for the regulation of quite a number of physiological processes. Also development processes, which are highly temperature determined, may be affected by the carbohydrate content. Assimilates will accumulate under circumstances that the production dominates the processing (low temperature and/or high light level), while the content will decline at higher temperature and/or low light level, when the processing of assimilates exceeds the production. However, it seems important to avoid extreme levels of assimilation buffer, because excessive content of free carbohydrates may lead to production loss by feedback inhibition of the photosynthesis, while on the other hand exhaustion may have negative effects on both production and crop quality (thickness growth, shoot development, blind shoots).

Meanwhile various experiments have been carried out in which roses were exposed to regular temperature changes. In 1997 and 1998 experiments were carried out with a temperature integration within 24 h and over longer periods (control for several days). An integrating 24 h control has been compared with a reference compartment, both at Klazienaveen Research Station, and with 2 growers. The control was tested for various ranges (to 8°C). No differences in production and quality were observed in the
experiments. Energy reduction depends on the settings. As in all other traditional controls it remains possible to limit factors such as pipe temperature and ventilator position. In addition the presence of an energy screen affects energy consumption. In the winter an energy saving of 5-10% appeared to be feasible at the Research Station. On glasshouse holdings the saving was lower because the growers had built in a number of limitations for the control. This control method has been incorporated into a computer programme. It should be noted that this control seems to offer prospects for rose cultivation and may result in an energy saving of ca 10%.

7.5 LIGHT

7.5.1 Natural light

Virtually all natural light on earth comes from the sun. The sun is a black radiator, meaning that the great heat of the sun is responsible for the emission of light, just like the radiation of a candle. The spectrum of such black radiators is continuous, and contains all kinds of light colours, and much heat radiation. It is called warm light. On the other hand, cold light develops because excited electrons of the molecules of a gas fall back to the ground state, the released energy being emitted as light. This happens for example in TL tubes and SON-T lamps. The spectrum of cold light sources is discontinuous, and shows severe ups and downs. When the sunlight reaches the earth it is already slightly less continuous because ozone, CO₂, but particularly water in the atmosphere filter out large parts from the spectrum.

Most radiation on earth has a wavelength between 300 and 800 nanometer. Radiation contains more energy as the wavelength is shorter. Below 350 (-380) the energy becomes excessive and is harmful to life, for example directly to DNA. This is ultraviolet light. Levels between 350 and 750 are visible light. This is also the area that is utilized by plants for photosynthesis. For more information, see Bakker, J.A. et al., Qualitative side-effects of assimilation lighting (in Dutch), PBG, Report 53.

![Figure 22. Energy distribution of solar radiation over the short-wave area at the top of the atmosphere and at sea level. Source: Robinson, Handbook of geophysics, New York, 1960](image-url)
Light is for plants a source of both energy and information. Plants detect the direction of the light, the intensity, the quantity over a certain period, the light spectrum, the duration and consequently also the season. The rose is day-neutral for flower initiation, and as a result seems to do nothing with this information about daylength. The quality of light in a Dutch glasshouse varies, due to the altitude of the sun and due to day length differences. In The Netherlands the light sum per day rises and falls with the seasons. The highest day sum is realised around the longest day of the year (21 June). Figure 23 gives the day sum of the photosynthetically active radiation, based on the global radiation.

Response of rose to natural light
Rose is a light-requiring crop; the photosynthesis becomes saturated only at very high light levels. The leaf photosynthesis has a reasonably high capacity (almost 20 μmol CO$_2$ s$^{-1}$ m$^{-2}$) and only at 800-1,000 μmol saturation occurs. According to Israeli researchers saturation may already occur at 700 μmol. They argue that the light compensation point of leaves is 2-23 μmol/m$^2$, while the curve observed in the Netherlands is around 10 μmol/m$^2$. The production of roses follows the light level very closely, lagging about 4 to 5 weeks behind. This is about the time necessary for the development of the bud. Effects have been described of the orientation of the beds (south being better than north) and the location in the glasshouse. Screening part of the light results in proportional production loss, also of roots and therefore it should only be used to promote quality, for example in summer to keep a good flower colour.

The position of the buds on a stem determines the sprouting under the influence of light. The upper bud (top) always breaks. Buds located lower on the stem sometimes do

![Figure 23](image_url)
not break. The buds in the middle of the stem break depending on the quantity of light and of the R/FR (red/far red) ratio in the light. This is the normal ‘shade avoidance’ response to low quantities red and large quantities of far red (FR): the plants have too many neighbour plants, start to elongate without branching. This phenomenon also explains the extra shoot sprouting with SON-T assimilation lamps as compared to assimilation lighting with incandescent lamps. Due to the absence of FR in SON-T the sprouting is not inhibited.

The number of blind shoots shows negative correlation with light (see also section 7.3.4). Screening light results in increased number of blind shoots and the young shoots are the most sensitive, 10 to 20 days after cutting the flower. Removal of part of the stem above the shoot is responsible for sprouting of this shoot. Both light level, daylength and R/FR ratio are important. They affect the source/sink ratios in the plant. Higher light levels result in more bottom breaks. Covering the place where bottom breaks develop at the base of the plant, inhibits the development and outgrowth of these shoots. Even if the shoots are ‘set free’ with the aid of cytokinins (BA) light restriction may be responsible for the fact that the buds do not develop further.

Light also affects the pigmentation and the corresponding flower colour. If the light level declines, the cyanidine declines as well, while the pelargonidine level remains the same. As a result roses become more blue. This phenomenon occurs mainly with the old variety Baccara. Blue discolorations in rose are also ascribed to a pH effect in the substrate.

In polyethylene tunnels and greenhouses with a stegdoppel cover, sometimes blackening of petals is observed. The combination of low temperature and UV-B transmission may induce this phenomenon (see also section 9.8). The disorder does not occur in PVC tunnels. As long as glasshouses are used in The Netherlands problems with UV-B will not occur, because this is not transmitted through the glass.

7.5.2 Assimilation lighting

The development of flowering shoots depends on temperature, day length and light level. In moderate regions, such as The Netherlands, day length and light level show season-dependent fluctuations in the course of the year, which is reflected in the production of roses. The lowest production is observed 4 to 5 weeks after the period with the lowest irradiation.

Application of assimilation lighting during periods with low natural light may strongly enhance the production of roses, the extent to which depending also on the variety. By increasing the number of lamps and fittings per unit of area the heat produced by the lamps becomes a problem. In many cases the heat must be discharged by extra ventilation, so that air humidity and CO₂ concentration decrease.

Low applications of assimilation lighting already result in more roses. This effect is not photoperiodic, but is a result of additional shoot growth and lower incidence of blind shoots. When assimilation lighting was introduced in rose cultivation in 1985, lighting was done to a level of about 30 μmol. Since then the lighting level increased and currently the average level amounts to 55 μmol and the level is still rising. Growers increasingly generate the electricity needed themselves, and if possible the heat is stored in a storage tank.

It is obvious that increase of the light sum determines how much extra production is obtained with assimilation lighting. Doubling the number of lamps so that the roses are grown with addition of 4,250 lux (50 μmol) as compared to 8,500 lux (100 μmol) does not mean to say that the light sum is doubled. The light sum is the sum of natural light
and the amount of artificial light. Table 46 gives the production of six varieties grown under different levels of lighting. Although in this experiment the number of stems was influenced by the extra lighting the increase was not entirely linear as was found in other experiments. The quality, however, did not increase (Table 47)

Table 46. Number of stems harvested per gross m² glasshouse during a lighting season (week 39 1996 to week 16, 1997). Source: De Hoog, 1997

<table>
<thead>
<tr>
<th></th>
<th>Unlit</th>
<th>50 µmol</th>
<th>100 µmol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frisco</td>
<td>93</td>
<td>170</td>
<td>219</td>
</tr>
<tr>
<td>Sacha</td>
<td>102</td>
<td>179</td>
<td>217</td>
</tr>
<tr>
<td>First Red</td>
<td>38</td>
<td>59</td>
<td>78</td>
</tr>
<tr>
<td>Madelon</td>
<td>42</td>
<td>64</td>
<td>72</td>
</tr>
<tr>
<td>Sonia</td>
<td>42</td>
<td>72</td>
<td>85</td>
</tr>
<tr>
<td>Charmilla</td>
<td>57</td>
<td>92</td>
<td>109</td>
</tr>
</tbody>
</table>

Table 47. Harvested weight (kg/m²) and average stem weight (g) in various light treatments during a lighting season (week 39, 1996 to week 16, 1997). Source: De Hoog, 1997

<table>
<thead>
<tr>
<th></th>
<th>Unlit</th>
<th>50 µmol</th>
<th>100 µmol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frisco</td>
<td>2.1 kg / 22.2 g</td>
<td>4.1 kg / 23.9 g</td>
<td>4.9 kg / 22.6 g</td>
</tr>
<tr>
<td>Sacha</td>
<td>2.5 kg / 24.4 g</td>
<td>4.6 kg / 25.8 g</td>
<td>5.6 kg / 25.9 g</td>
</tr>
<tr>
<td>First Red</td>
<td>1.7 kg / 44.9 g</td>
<td>2.9 kg / 49.4 g</td>
<td>3.7 kg / 46.6 g</td>
</tr>
<tr>
<td>Madelon</td>
<td>1.7 kg / 41.6 g</td>
<td>3.2 kg / 50.3 g</td>
<td>3.6 kg / 50.9 g</td>
</tr>
<tr>
<td>Sonia</td>
<td>1.4 kg / 32.7 g</td>
<td>2.7 kg / 37.4 g</td>
<td>3.2 kg / 37.5 g</td>
</tr>
<tr>
<td>Charmilla</td>
<td>2.0 kg / 35.6 g</td>
<td>3.6 kg / 38.5 g</td>
<td>4.2 kg / 38.7 g</td>
</tr>
</tbody>
</table>

The production of roses is affected both by daylength and by light level. In lighting research at the PBG-sites in Horst and Klazienaveen a linear relationship was found between the light sum received during the winter period and the production of Madelon. The relation between the daylight sum and the production, however, appeared to depend on the day length. A day length of 20 h resulted in more, but lighter stems than a day length of 16 h. The energy-efficiency of the crop was better at the 16 h than at the 20 h day length.

The effect of assimilation lighting is greater at a higher night temperature (for example 18°C as compared to 15°C night temperature). The development rate hardly increases as a result of assimilation lighting, although it is stimulated by the slightly higher growing temperature due to heat emission of the lamps. It is clear in all reports that assimilation lighting leads to higher production. CO₂ application is very important. Insufficient supply may annihilate a major part of the increased yield to be obtained with assimilation lighting (sometimes even more than 40%).

Opinions vary on the effect of the application of lighting on the quality of roses. It is occasionally reported that length and weight decline, other reports assert the opposite. It is clear that often other factors affect the quality/production ratio than just the amount of light (e.g. temperature, plant density, pruning method, etc.). Also opinions
differ on the effect on vase life. A clear consequence of lighting is increased water consumption and therefore a risk of damage by post harvest treatments to extend the vase life. A dark period of 4 h is recommended due to the changes in the rhythm of the stomata. Other symptoms reported: leaf curling, bent necks (Jacaranda), discolorations of flowers and leaves, increase of leaf area and changes in leaf morphology. The increasing quantity of light may also have indirect effects on leaf temperature.

7.5.3 Light colours

In natural light the red/far red (R/FR) ratio is about 1:2. Under the crop’s canopy, most of the red has been intercepted by the leaves, and the ratio becomes about 0:2 or even lower. Many plants show a ‘shade avoidance’ response; with a low R/FR they start to elongate more, and branch less, and more blind shoots occur. The solar spectrum is said to change considerably during dusk, but this effect is not very severe, and in addition only apparent with clear weather. With overcast weather the level R/FR has dropped to zero by the time the spectrum shifts.

In research with spectral filters lower R/FR ratios resulted in lower chlorophyll content in the leaves and longer stems. With red light directed towards the axillary bud, bud break could be stimulated, according to Israeli research. Under light limiting conditions more shoots came into flower if the day ended with red light than if it ended with far red light. According to the Dutch experiment, far red gave more blind shoots (Maas and Bakx, 1997).

In research at the former AB-DLO institute (Wageningen, The Netherlands), where the latest experiments in this field have been carried out, the specific effect of red and far red light was investigated more closely in view of a possibly reduced application of assimilation lighting (J. Bakker et al., 1997). For plants with one or a few shoots treatment with red or far red at the end of the light period did not have any demonstrable effect on the percentage of flowering stems. At a light period of 12 h, lighting at the end of the day with red light accelerated the shoot development and flower bud development by 2 or 3 days. The final quality of the harvested stems, grown with red or far-red lighting at the end of the day did not change very much. The stems treated with far-red after-lighting were only somewhat longer (5-10%). The light intensity and the duration of lighting are therefore the most important.

Filtering out blue light from lighting in climate cells resulted in increased elongation and more investment of dry matter in stems, at the expense, however, of the leaves. In glasshouse experiments at the PBG (J. Bakker) lack of blue in SON-T light as compared to HPI-T light was, however, not evident. Probably the blue part of the sunlight was sufficient.

7.6 CO₂

To stay alive and to be able to grow, plants convert carbon dioxide (CO₂) into sugars (carbohydrates). This is done in the photosynthesis process. When the stomata of the leaves are open, the CO₂ can flow into the leaf and reach the assimilating cells. When the availability of CO₂ is a limiting factor for the assimilation, less sugars are formed than would have been possible, hence the crop will grow less. CO₂ supply in the glasshouse would increase the efficiency of the assimilation process. Apart from this direct effect there is a second way in which the CO₂ concentration influences the synthesis of sugars. As the first step in the assimilation process, the formation of a C6
compound from CO₂ (C₁) and a C₅-compound, competition takes place between CO₂ and oxygen. When the oxygen is fixed instead of the CO₂, we call this photorespiration, which is at the expense of sugar production. Thus, an increased CO₂ supply may also indirectly stimulate assimilation by suppression of the photorespiration.

CO₂ supply in rose cultivation, to increase yield and quality, is applied more and more frequently (see also section 3.2.1). Data from various literature sources and practical experience indicate that the quality (stem length and stem weight) may be greatly improved when CO₂ enrichment to values higher than outdoor concentrations is applied. For rose, weight increase at CO₂ supply varies from 4 to 20%. In Germany it was found that for the rose Mercedes only the fresh weight increased when the grading classes were investigated collectively. Norwegian researchers found an increase in dry weight in the whole plant of Frisco and Kiss, ratio of the fresh weight of the stem as compared to that of the leaf and the fresh weight of the flowers at a CO₂ supply to a level of 700 ppm. The researchers Mortensen and Moe conducted their research with young plants and maintained one shoot per plant. The Germans Hendriks and Hackbarth worked with bushes of several years. In England the researchers Cockshull and Hand ascribed the increased production they found with Sonia ‘Sweet Promise’ particularly to the lower number of blind stems at a CO₂ concentration of 1,200 ppm and to the stimulation of a larger number of axillary buds to growing out of flower shoots at 1,200 and 1,600 ppm. In general the stem length and diameter of rose increases due to CO₂ supply. In an experiment with Sonia at an increased CO₂ supply (850 ppm) the elongation rate and consequently also the length increased. Whether CO₂ results in advancing the harvest is point of discussion. Various researchers present contradictory results in this respect. The vase life was not affected by CO₂ enrichment, according to research where the vase life was investigated as well.

In a preliminary experiment at the Research Station in Horst (The Netherlands) in the winter of 1996-1997, the effect on production and quality was not unequivocal per variety. First Red responded better to an increased CO₂ concentration than Bianca. The conditions were sub-optimal, while the amount of lighting and lighting period were not representative for current rose cultivation.

In 1998-1999 subsequent research was carried out at the Research Centre in Aalsmeer with the variety “Indian Femma!”. Three CO₂ levels (350, 700 and 1400 ppm) were combined with 2 light levels (45 µmol, 85 µmol). Roses grown under a high CO₂ level and high light level produced more stems. These stems were longer and heavier compared to those grown under lower CO₂ and light conditions. No difference in vase life was registered. The results of this climate research show that it is possible to raise production and quality at the same time. Research with harvest methods, plant distance and bending always showed a lower stem quality and weight when a higher production was reached (De Hoog, 2000, PBG report 239).

Although in almost all previous research stimulating effects of CO₂ were observed, there is little agreement on the exact scope of these effects. Practical questions of growers, such as how much extra production results from a certain investment in CO₂, the prevailing seasonal effects, and under what circumstances an investment in extra CO₂ in the glasshouse may be expected to yield more profitability than extra assimilation lighting, can not be adequately answered at this moment.

The effects of CO₂ supply in rose depend on many different factors. The strong mutual influence shown by various factors (interaction) and the great effect of the season and
weather conditions (such as irradiation, wind velocity, precipitation, outdoor temperature) make these effects difficult to reproduce and to quantify. As well as by the season and the climate, the effects of CO₂ may be influenced by the following factors:
1. Technical factors, such as vertical support height of the glasshouse, light transmission, size of the ventilators, position of CO₂ supply, number and lighting duration of assimilation lamps
2. Glasshouse climate factors that affect the availability of CO₂: the amount of irradiation, ventilation setpoint, relative humidity-ventilator opening control;
3. Factors affecting assimilation: light quantity and daily light sum, light interception (LAI), temperature, previous history;
4. The crop: different varieties, rootstocks, age of the plants, crop structure and harvesting method, harvest effect
5. Factors that may limit the production: availability of water, nutrition and oxygen in the root environment, pests and diseases, toxic substances.

Practical application of previous research in The Netherlands and abroad is only possible when all these effects are taken into account. In principle this can be done on the basis of a combination of glasshouse and crop models. Although a productions modelling project is currently in progress, it will probably take some time before such data are available for use on commercial nurseries.

7.7. RELATIVE HUMIDITY

The consequences of high air humidity can be both positive and negative. Negative aspects usually are the occurrence of certain diseases such as Botrytis and mildew. The effect of the relative humidity may depend on other cultivation factors, but also, for example, on the variety. In addition the effects may vary between young plants, vegetative phase and flowering.

During the rooting phase, the transpiration of the leaves is minimal when a relative humidity of almost 100% is maintained. As a result the water balance inside the plant remains in equilibrium and root formation can take place. As soon as the root function they can attract sufficient water and the plant is hardened off by gradually reducing the air humidity.

During the cultivation phase of roses the air humidity in winter seems unimportant. Canadian researchers investigated the effect of continuously high air humidity, achieved with a misting installation, compared to a fluctuating, uncontrolled air humidity. Temperatures were equal in both treatments, on average 23.9°C by day, and 16.8°C at night. The moisture deficit was with the continuously high air humidity by day on average 4.5 g/m³ and at night 3 g/m³ (average RH 82%). With the fluctuating humidity the RH was considerably lower (69%). Under the low-light conditions in winter the production of roses did not increase. Only in combination with assimilation lighting (18 h) there was a slight increase in production at high air humidity. At a day length of 24 h the effect of air humidification was even negative with a number of varieties.

In summer the roses responded completely differently. This was related with other climate conditions such as temperature, and water supply to the roots and the variety used. Increasing the air humidity by humidification leads to lower temperatures in summer compared to a glasshouse without humidification. The reduction is mostly between 1.5 and 2°C while sometimes the amount of radiation declined with ca 8%. 159
Despite the lower temperature and the light reduction the yield in stems and the quality of the roses was at least equal to those of the unmisted glasshouses.

A continuous air humidity resulted with the varieties Royalty and Samantha in a distinctly higher production than in a comparable glasshouse where the plants were grown with varying RH (Table 48). Both the number of harvested roses per plant and the length of the harvested roses increased. The increase appeared to be related to the variety grown. The relative humidity in the glasshouse was 79%. In the fluctuating, uncontrolled glasshouse, the relative humidity varied between 30 and 80% (average 55%).

Table 48. Effect of the relative humidity on the production and external characteristics of rose in summer. Source: Darlington et al., 1992

<table>
<thead>
<tr>
<th></th>
<th>Royalty</th>
<th></th>
<th>Samantha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Constant (high) RH</td>
<td>Varying (low) RH</td>
<td>Constant (high) RH</td>
</tr>
<tr>
<td>Number of flowers</td>
<td>5.5</td>
<td>4.8</td>
<td>3.9</td>
</tr>
<tr>
<td>Length (cm)</td>
<td>49.7</td>
<td>44.6</td>
<td>52.2</td>
</tr>
<tr>
<td>Leaf area (cm²)</td>
<td>526</td>
<td>248</td>
<td>566</td>
</tr>
<tr>
<td>Internode length (cm)</td>
<td>7.5</td>
<td>5.1</td>
<td>7.1</td>
</tr>
</tbody>
</table>

The positive effects of air humidification could probably be ascribed to reduction of the water stress during periods with high irradiation. At the Research Centre in Aalsmeer the air humidity was also varied in an investigation into the effect of calcium on the quality of rose. Between week 8 and week 52 (1996) in 2 compartments air humidification was applied when the moisture deficit was greater than 2 g/kg (85% RH at 18°C). In 2 other compartments no air humidification was applied. Because in the period from May to October the realised differences in RH probably remained small as a result of frequent ventilation, the screening was closed in this period at a light level exceeding 100 W/m². On average, differences in RH were realised of 19%. On summer days this could rise to 30% without the temperature being affected. The differences in RH resulted in differences in transpiration of on average 21%. In summer the differences were sometimes even greater. A high RH restricts transpiration and due to application of the screen, water stress probably did not occur. As a result differences in production were not observed (see Table 49). In the treatments with high RH, 6-10% more stems were formed. The stem weights were, however, lower. Probably this was also caused by the early closure of the screen (LS-15).

Table 49. Effect of air humidification on production and quality of First Red grown on cutting and on Natal Briar. Source: R. Baas, personal communication

<table>
<thead>
<tr>
<th></th>
<th>First Red/cutting</th>
<th>First Red/Natal Briar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RH low</td>
<td>RH high</td>
</tr>
<tr>
<td>Week 15 to 50, 1996</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stems/m²</td>
<td>93</td>
<td>103</td>
</tr>
<tr>
<td>Stem weight/g</td>
<td>46.6</td>
<td>44.2</td>
</tr>
<tr>
<td>Kg/m²</td>
<td>4.2</td>
<td>4.4</td>
</tr>
</tbody>
</table>

No differences were observed in quality characteristics (vase life, flower opening, Botrytis infections) as a result of the treatments.
7.8 GROWTH MODELS

Development of growth models can assist the grower in:
- planning before the harvest; how to control the crop in such a way that at a certain date the highest number of roses can be harvested
- quality control. How can different climate factors provide roses of a specific quality at harvest
- collecting more knowledge on exactly what variables affect the production of roses.
- optimization of the production process
- incorporating growth models into the climate control so that further crop manipulation can be done automatically

Work is now being done onto develop a growth model for rose in America, France and The Netherlands. Different components are fitted together to achieve a total model for the crop growth of rose. The growth models consist of various sub-models which describe the different processes and physiological mechanisms of the growth of roses. These include:
- a model for the photosynthesis of leaves
- a model for the distribution of dry matter over the plant
- a model for shoot growth
- a model for shoot development

As yet, a total model is not available, even though the influence of the various factors on the different components of growth is known (see the sections above). Quite a lot of hypotheses remain to be investigated before a manipulated growth of a rose crop is reached, so that a previously defined product reaches the consumer.
8. HARVEST AND VASE LIFE

8.1 HARVEST METHOD

Various aids and appliances can be used for harvesting the rose (see also section 3.2.4). Preferably a trolley should be used for harvesting, except with short glasshouse bay lengths or with varieties with low production levels (when the stems can be easily placed in one arm). With high production levels and long glasshouse bays a double pipe-rail trolley is recommended, because the storage capacity of a pipe-rail trolley is greater. The type of secauteurs to be used for harvesting depends mainly on the bed width. With normal bed width, 3 beds per 6.40 m bay, ordinary secauteurs will suffice. With greater bed widths, 3 beds per 8 m bay of even wider, extended secauteurs are preferred.

Cutting method, the number of cutting points and the crop structure can all influence the subsequent development of production and quality (see section 6.2). Most varieties are harvested once a day. For only a few varieties it is recommended to harvest twice a day. These varieties usually have a fast flower bud opening, so that when harvest is not conducted twice a day the percentage of overripe flowers is too high and these will have to be graded out.

8.2 POSTHARVEST TREATMENTS

After harvest the roses are transported dry to the grading room or directly placed in water in the harvest tray.

If the roses are kept dry, grading and bunching should be carried out as soon as possible after harvest. Desiccation should be avoided by preventing high temperature levels and irradiation by sunlight. Placing the roses temporarily dry in the cold storage room only makes sense if there the RH is high and air movement low.

If the roses are placed directly in water in a harvest tray in the glasshouse, the water should contain a post harvest treatment in the correct concentration. For more information see the product specification Rosa of the Dutch Flower Auctions. The water in the harvest tray should be changed regularly (once every few days), and the tray cleaned with a brush and if necessary with chlorine. The high temperatures in the glasshouse in combination with many leaves in the water, and fresh incisions, are responsible for a rapid bacterial pollution of the water. The bacterial content of the stem should be less than 1 million bacteria per g. The auctions check this content by means of stem samples.

Grading and bunching should be done in as short a time as possible to prevent extra desiccation. If the stems are cut to a specified length, sharp tools should be used. The processing room should be kept clean; leaf debris may be a source of Botrytis infection. Getting the flowers in and out of the cold-storage room should be restricted as much as possible to limit the condensation moments, and thus avoid Botrytis infection.

The roses should be kept in the cold-storage room at a temperature of 2 to 5°C until transport to the auction. Higher temperatures lead to prolonged ripening and progressive senescence, while lower temperatures may lead to cold damage. Here again the roses should be placed in water with the right concentration of post harvest treatment and the trays should be regularly changed and cleaned.
The roses should be transported to the auction as fast as possible; storage leads to quality loss. Transport should also be as cool as possible. To maintain the quality, storage and transport in water is recommended (2 to 5°C). If the flowers are transported dry in boxes, they should be well secured and the buds protected from damage by rolling the bunches in paper. Fermentation should be avoided by precooling. Precooling is done by blowing or sucking forced cold air through the boxes. A wet system is preferred because it prevents moisture loss. Precooled boxes can be stacked compactly so that warming is avoided as much as possible. Precooled boxes should be cooled during further transport.

8.3 QUALITY

8.3.1 Internal and external quality

The instructions of the auction can be used to assess external quality. Apart from the general quality requirements, batches of roses should be free from growth defects such as bullheads and crooked necks. Bear in mind that unripe harvested roses are not less perishable than riper ones. Often unripe harvested roses open less adequately. As yet there is not a predicting measurement of the internal quality (vase life). As long as such a measurement is lacking, growers can have flowering tests carried out to gain insight into the quality of the produce.

Roses are graded according to length, ripeness and number of potentially flowering buds. The stems in the bunch should be even at the bottom. For packing instructions, see the product specification Rosa of the Dutch Flower Auctions.

8.3.2 Factors affecting the vase life

One of the most important factors affecting the vase life is the variety choice (see 8.3.3)

The circumstances during cultivation also influence the vase life. The effect of the length of the dark period when using additional lighting is a well-known example. A too short or absent dark period can lead to malfunction of the stomata, and thus to a very high transpiration during the vase life, because the stomata do not close any more. High transpiration during vase life places high demands on the water uptake of the stems, but the water uptake capacity declines as a result of the long lighting. This makes the stems very sensitive to vascular blockage by air (after dry storage) or bacteria, so that bent-neck, wilted flowers or dried leaves will occur sooner or later. Also leaf burning may occur as a result of excessive uptake of post harvest treatment agents (prolonged post harvest treatment period). The effect of the dark period varies per variety. Some can be lit for 24 hours without a clear negative effect on the vase life (e.g. Frisco). Others need a dark period of at least 4 hours.

Another factor during cultivation influencing vase life is the Relative Humidity (RH) in the greenhouse during the last few weeks before harvest. A comparison between 35 Dutch nurseries growing the variety ‘First Red’ (Marissen and Benninga, 1999) showed that in January the RH explained 20% of the differences in vase life between the nurseries. A higher RH led to a shorter vase life. An estimation of the RH-effect showed
that a 4% higher RH could lead the loss of one day of vase life. Strong fluctuations of
the RH had a negative effect.
Besides RH, the number of small (<10 cm) developing shoots in the crop at the
moment of harvest was of influence on the vase life. The more small shoots, the longer
the vase life. Also, a riper bud stage at harvest was correlated with a longer vase life.
Light intensity had little effect on vase life, which also was shown in an experimental
approach. Only one out of six varieties showed a small increase in vase life when the
level of supplemental lighting was increased from 0 to 50 and 100 μmol.m².s

Calamities during cultivation with respect to climate, crop protection, nutrition and
diseases may reduce vase life.

Botrytis infection leads to pockmarks on the sepals, which grow into brown lesions,
finally resulting in total collapse of the flower. Botrytis can be avoided by not leaving
crop debris in glasshouse and processing room and preventing condensation
(temperature differences), since free water is necessary for the germination of spores.

Bacteria in the flower stem cause bent-neck, wilted flowers and poor opening of the
flowers (see photo 12). Operational hygiene may prevent bacterial growth. The water in
the harvest trays and in the storage trays in the cold-storage room should be changed
regularly and the trays cleaned with a cleaner or a disinfectant (e.g. chlorine). Use a
brush to remove the “nested” bacteria in corners and scratches. Always add the right
concentration of post harvest treatment; lower concentrations have no effect at all, or
may even lead to the opposite effect.

For optimal vase life, retailer and consumer should follow these tips:

Retailer
• optimal storage temperature: 2-5°C
• storage in clean water
• there are special compounds available to keep the water clean for longer
• with cold storage the leaves may remain on the stem; use clean water (change
daily) or post harvest treatment
• cut off stems first with sharp pruning secauteurs or other sharp tool
• use clean buckets and trays (always clean with chlorine)
• when putting roses up for sale, always place them in water; storing or exposing
them dry may reduce vase life severely
• always give your customers cut flower food; pay attention to the concentration;
high concentration may lead to leaf burning

Consumer
• allow the roses to draw themselves full of clean water
• use clean vases (clean with chlorine) and place the flowers in cold water
• add nutrient for cut flowers in the recommended concentration
• remove the lower leaves; there should be no leaves in the vase water; this promotes
bacterial growth and may lead to bent necks and/or wilted flowers
• cut ca 1 cm off the stems with a sharp knife
• thorns do not need to be removed; injuries on the stem can be penetrated by
bacteria
• never flatten or peel the stems
• do not place the flowers in a drafty spot or in direct sunlight

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• fill up the vase regularly with water (if necessary with nutrient for cut flowers)
• if roses start wilting the stem ends can be cut again, rolled in paper, stored in a cool place in cold water so that they can draw themselves full again and placed in a vase again (with cut flower food).

8.3.3. Reference test

In 1990 the development of the reference test was started. The Research Station in Aalsmeer carried out the research into the test methods. The Dutch Flower Auction Association and from 1998 the Foundation Reference Test Ornamentals, with representatives of breeding, cultivation, auction and trade, supervised the development of the reference test. The Foundation was responsible for the policy of testing and the implementation of results. The aim was to ban roses with a poor post harvest performance from the Auctions.

In a reference test varieties were assessed for their vase life. The length of time the flowers retain their ornamental value, is determined by a combination of factors; sensitivity to transport, to Botrytis infection and to bacteria in the vase water are examples of such factors. It is an empirical fact that there are great differences in vase life between varieties. In addition the cultivation method and the season may be important. During the development of the reference test it has been demonstrated that the effect of the variety, the genetic component, is greater than the effect of the cultivation. This makes it possible to set up a reference test for rose, an assessment of the variety’s vase life.

In the reference test, the factors that may be of great influence on the vase life, are tested separately. These factors are:
- Potential vase life. In this component the potential of the variety is determined. What is the maximum period for roses to be in the vase and how far and how fast do they open?
- Transport sensitivity (see photo 13). In this component the effect of a dry and a wet transport simulation of 4 days at 8°C on the vase life and the degree of opening is determined. It is also investigated whether there are problems with leaf desiccation and leaf drop.
- Botrytis sensitivity. In this component the roses are sprayed with Botrytis spores and stored under conditions favourable to Botrytis. The degree to which a flower is infected is determined.
- Sensitivity to vascular blockage. In this component the roses are stored in contaminated water. Contaminated water leads to vascular blockage, symptoms of which are bent neck, and flowers failing to open. The degree to which these symptoms occur is determined.

For new varieties the test can still be carried out by breeders. They know the performance of their varieties. When selecting a variety you can apply to them for the test results.

At the end of 2000 the Auctions stopped their activities with the reference test, and the Foundation Reference Test Ornamentals dissolved. The developed tests methods however, are still available at the Research Station.
9. PESTS, DISEASES AND DISORDERS

In this chapter 30 diseases, pests and disorders are described. In the classification of the various groups of diseases or pests the common names and classifications used in practice are included. Section 9.2 deals with the nematodes, 9.3 with the bacterial diseases, 9.4 with the insects and mites, 9.5 with the fungi and 9.6 with the viruses. In 9.7 specific attention is given to biological control and integrated pest management. In section 9.8, some physiological disorders are discussed, such as bullheads, flower bud problems and humidity leaves.

The following aspects are covered for each disease or pest:
- recognition: the symptoms for recognizing the pest or disease
- life cycle and dispersal: information on various developmental stages, optimal conditions for development and the various methods of spread.
- Control: tips to prevent infection or spread of pest or disease.

Pesticides and herbicides are not mentioned, as this publication would soon be outdated due to frequent changes in the assortment. Up-to-the-minute crop protection recommendations can be found in the publication Crop protection Cut Flowers (in Dutch, published by DLV) and the Crop Protection Guide (in Dutch, published by the Phytopathological Service).

With the help of the identification table (section 9.1) a pest or disease can be identified. This may be helpful if the pest or disease is unknown. It should, however, be realised that many diseases (particularly fungi) and pests are hard to distinguish. When in doubt, always ask for expert advice or send a sample to the Phytopathological Service (http://www.minlnv.nl/international/). Information on crop protection can be found in the Crop Protection Data Bank (GBK) on the internet. The GBK contains information on diseases, pests and weeds, and on registered crop protection compounds. The URL-address is http://www.bib.wau.nl. The GBK does not offer the possibility of identification of the attackers. For information on the GBK, contact the Helpdesk of the Library of Wageningen University, +31 (0)317 484440.

9.1 IDENTIFICATION TABLE

With the help of the identification table even the cause of poor growth or disorder can be determined in a number of cases. Particularly in fungal diseases, the disease symptoms may often show so much similarity that this diagnosis does not lead to the correct identification. In such cases, leave the diagnosis to specialists. The table deals only with the symptoms caused by pests or diseases. Disorders caused by other factors (for example climatological or fertilization problems) cannot be diagnosed using the table. Similarly, viruses are not included in the table.

Start at point 1 and follow the directions.

1. Unusual growth or symptoms on:
- Leaves  
  - Flower  
  - Buds  
  - Stems  
  - Subterranean plant parts  
  - Whole plant

**2. Leaves**
- on leaf/leaves spots with unusual colour  
- leaves are malformed  
- insects present on the leaves

**3. Flower**
- spots in various colours on the flower parts  
- damage of the flowers

**4. Buds**
- insects observed on the buds

**5. Stems**
- discoloration on the stem or the stem base  
- disorders or malformations of the stem

**6. Subterranean plant parts**
- injuries or deformities observed  
- unusual growth of the root system  
- animal organism observed on roots or in soil

**7. Whole plant**
- poor growth or growth inhibition  
- wilting  
- insects observed with the naked eye  
- haze of various colour on all plant parts

**8. Small or greater spots of unusual colour on the leaves**

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>White powdery fungal fluff on leaves that can be rubbed off</td>
<td>9.5</td>
</tr>
<tr>
<td>Upper side of the leaf, green-yellow sunken spots, finally yellowing and dieback. Scarlet spore heaps on the underside of the leaves.</td>
<td>9.5</td>
</tr>
<tr>
<td>Black spots with a characteristic frayed edge. Frequently yellow discoloration around the spots. Leaves drop prematurely.</td>
<td>9.5</td>
</tr>
</tbody>
</table>
Leaves are small, spiky, with grey-brown spots. Later desiccation and leaf drop.

Curling of leaves with small, yellow or brown spots. Leaves are often shining and sticky

Leaves a silvery, pallid colour, often only on one shoot

Leaves have silvery, sometimes blending spots, which get brown later. Black dots between spots

Black, sticky substance on the leaves

Purplish-red to grey-black leaf spots followed by yellowing. On leaf underside dirty white fungal fluff

9. Malformation visible in leaves

Leaves damaged by severe gnawing

Leaves curled as a result of spinning. A caterpillar is in the sheath

Smaller leaves, leaf yellowing, leaf drop

Wilting of the leaves on one or several stems. Often recovery at night

Malformation of young, not fully-grown leaves

Semicircular bites from the leaf edges

10. Insects present on leaves

Snow-white, winged insects on underside of leaves

Small, spider-like animals, mainly observed on the underside of leaves

11. Spots in various colours on flower parts

Petals show red spots and are
slightly malformed

Little brown spots, which may grow fast. Finally whole flower may rot

A white powdery fungal fluff covers flower buds

Brown dots on the petals and at the tops of the sepals

12. Visible damage on flowers
Flower buds damaged by gnawing

13. Insects observed on the buds
On the buds of young shoots numerous 2-3 mm long insects can be seen with 2 protrusions on the abdomen

14. Discoloration on stems
Downward development of yellowing of the stems limited by a purple zone

Brown-red to brown-black, elongated spots of several mm to 2 cm or more

White, powdery fungal fluff on stem which can be rubbed off

Irregular spots that are purple-red at first and become black and bladder-like later

Scarlet spore heaps, from which a brown powder emanates

Brown/purple coloured, crust-like fruiting bodies develop on dead stems

On dying stems sharply limited brown-coloured necrotic spots. Black dots are observed on these spots

Small, oval to round spots, which gradually expand. A light-brown centre in dark-brown surroundings. Occasionally bark bursts open

Black spot 9.5
Botrytis 9.5
Powdery mildew 9.5
Thrips 9.4
Caterpillars 9.4
Aphids 9.4
Verticillium wilt 9.5
Downy mildew 9.5
Powdery mildew 9.5
Black spot 9.5
Rust 9.5
Silverleaf 9.5
Stem dieback 9.5
Common canker 9.5
15. Stem is unusual or shows malformations
Brown, deep-furrowed knots of irregular form observed on stems

On the borderline between air and soil bark is eaten away

16. Roots show injuries or deformities
Root system partly or entirely rotten

Severely blunted roots, coloured brown. Dark brown to black stripes observed on the roots

On the rinsed roots gall-like swellings are observed of varying size

17. Unusual growth of the root system
Wart-like brown knots on the roots

Poor outgrowth combined with gnawing damage on the roots

18. Animal organism on roots or in soil
1 to 10 mm long, white, transparent larvae with a brown head

Dirty-white, arthropodal animals with 12 pairs of legs. Up to 1 cm long with very long antennae

19. Poor growth or overall growth inhibition
Plants are weak and show excessive growth. Hard, brown knots on various parts

Failing or poor bud break, thin, short shoots and overall dieback of the bush

Severe inhibition of growth, especially of young plants

Rather sudden yellowing and dieback

Pallid, yellow-grey appearance, especially on plants on warm and dry places

Root knot
Black vine weevil
Root rot
Root lesion nematodes
Root knot nematodes
Root knot
Black vine weevil larvae
Garden centipede
Root knot
Root rot
Garden centipede
Black vine weevil
Spider mite
Poor growth, discoloration and dieback, often starting locally
Root-lesion nematode 9.2

Poor growth, yellow leaf colour, followed by wilting
Root-knot nematode 9.2

20. Overall wilting of the plant
During warm weather wilting of the Leaves on one or more stems; recovery at night
Verticillium wilt 9.5

Wilting and yellowing of stems and leaves
Stem dieback 9.5

21. Insects on all parts perceptible with the naked eye
When plants are touched, large quantities of snowwhite ‘flies’ fly up
Whitefly 9.4

On the underside of the leaves small spider-like animals, sometimes with cobweb
Spider mite 9.4

Caterpillars of various length are observed on the plants, falling rapidly when agitated
Caterpillar beet armyworm 9.4

Leaves are gleaming and sticky, insects with 2 protusions on abdomen
Aphids 9.4

When parts of the crop are shaken out over a sheet of white paper, small elongated insects are observed
Thrips 9.4

Coating on all plant parts perceptible, first gleaming, later greasy black
Aphids 9.4

Small, spider-like animals perceptible
Spider mite 9.4

22. Haze of various colours, observable on all plant parts
Grey-brown, dusty fungal fluff, may be observed on all parts
Botrytis 9.5

White, powdery fungal fluff on all parts, that can be rubbed off
Powdery mildew 9.5
9.2 NEMATODES

In soil various species of root nematodes may occur. The most significant for rose cultivation are: the root-knot nematode *Meloidogyne hapla*, the root-lesion nematode *Pratylenchus penetrans* and *P. vulnus* and the virus transmitting nematode *Xiphinema diversicaudatum*. Depending on soil temperature the life cycle of the nematode species is 30 to 50 days, resulting in 7 to 10 generations a year.

For rose growers in soil *P. vulnus* is the most harmful nematode. Five nematodes per 100 ml soil may result in a 30% lower flower production after one year. In pot experiments with 18 *M. hapla* and 39 *P. penetrans* per 100 ml soil at the start of the cropping period the flower production declined, in comparison to uninfected roses with 18% after 13 months’ cultivation with *M. hapla*, and 25% after 17 months cultivation with *P. penetrans*, respectively. In these periods the stem weight decreased with 11%. The direct injury of the virus transmitting root nematode *X. diversicaudatum* is small. The most severe damage is caused by transmission of viruses, such as the mottle vein mosaic virus. Fortunately, the nematode has difficulty surviving under glasshouse conditions and will be only a slight problem in rose cultivation.

Switching from growing in soil to systems independent of the soil will prevent many problems with nematodes. Nevertheless root nematodes may also occur in crops grown independent of the soil especially when plant material that has rooted in soil is used, such as root grafts, and when unsterilized surface water is used.

It seems that root nematodes cause less damage in artificial substrates (for example rockwool) than in the natural substrates (soil and peat). Furthermore, experiments have pointed out that *P. vulnus* has difficulty surviving in a rose crop on rockwool.

**Symptoms and dispersal**

Infection by root nematodes can be recognised by locally poor growth. Growth inhibition, yellow leaf colour, shorter and thinner flower stems with smaller leaves and buds, and increased flower bud atrophy are signs of infection. Under warm conditions wilting may occur.

Subterranean infections by root-knot nematodes are easiest to discover: the roots swell and small root-galls or knots develop (Photo 14). These knots contain swollen, pear-shaped, milk-white females, which are unable to move. In rose the knots are not always easily visible, being usually only a few mm in size. A female of *M. hapla* lays several hundred eggs, which are deposited outside her own body in a gelatinous matrix, the so-called egg sack or egg mass. Egg masses are occasionally observed on the outside of the roots.

The presence of root-lesion nematodes is difficult to observe on lignified roots. An infection can only be seen on the not yet lignified, white roots in the form of dark-brown to black stripes, called lesions. Lesions develop because the cells, which are pricked by the nematodes, die off. Root-lesion nematodes spend the major part of their life in the roots, but remain, in contrast to the females of the root-knot nematode, vermiform and can leave the roots, looking for other roots. The female of the root-lesion nematode can deposit several dozens of eggs.

*X. diversicaudatum* spends its whole life outside the roots and only pricks the outer cells. Especially the root tips are pricked for food uptake, and consequently they may swell.
slightly and become brown-black in colour. Root systems infected by nematodes are less well developed, but this may have other causes.

**Control**
The greatest damage by root nematodes is done when the infection takes place directly after planting. A clean start is a prerequisite. Old glasshouse soil and soil in newly built glasshouses must be sterilized. Even when no nematodes have been observed in the samples, sterilization is usually required due to the presence of other root diseases. Soil infested with nematodes cannot be made 100% nematode-free. Control during the cropping period remains necessary, but is not easy. Pesticides that directly kill the nematodes are not available and the systemic nematicides are compounds with a paralysing effect. If paralysis persists long enough, the nematodes will eventually die from starvation. Systemic agents should only be applied on the basis of analytical results of a nematode sample. These samples should be collected just before the following recommended crop control time. Systemic nematicides are broken down in nature and as this process becomes more rapid after a number of applications, the agents become less effective. To counteract an accelerated breakdown, restrict the use of the compounds and alternate them.

To keep the crop free from nematodes, nematode-free plant material should be used, and care should be taken that no infested soil particles are brought into the glasshouse with tillage equipment. Visitors should use the central path only and move among the plants; if necessary provide them with clean shoes.

In The Netherlands, nematodes may also occur in surface water, especially *M. hapla*, *P. penetrans* and *X. diversicaudatum*. For disinfection of water against nematodes, only heat treatment and UV are suitable. When using the so-called “red iron” the effectiveness of UV may be insufficient. Ozone, hydrogen peroxide and sand and lava filters are not suitable because not all nematodes are removed from the system. An alternative for a clean start is to switch to substrate. Such growing systems should be installed on a nematode-free soil.

9.3 **BACTERIA**

**Symptoms**
*Agrobacterium tumefaciens* (crown gall bacterium) is responsible for gall (tumor) formation, especially on the lower parts of the shrub. This often occurs at the graft and moves from there on downwards to the root collar and the roots. The galls are irregular in shape, brown, with deep furrows (Photo 15). They vary strongly in size. At first the galls are soft, later hard and lignified. Severely infected plants are weakened and suffer because the tumor block the water transport to the higher plant parts and they consume the nutrients necessary for the plant. Galls strongly similar to those caused by *A. tumefaciens*, may also be caused by other factors. Wound tissue (callus formation) as a result of a bad stenting technique may externally give the same symptoms. It is therefore important to have an expert determine what the cause of the excessive growth of the tissue is.

**Life cycle and dispersal**
The bacterium stimulates the plant to unlimited cell division, resulting in excessive tissue growth in the form of tumors. The infected plant parts are completely used by the
Photo 25. Leaf roller on rose: empty pupa, web and eggs

Photo 26. Golden twispot

Photo 27. Butterfly of Duponchelia

Photo 28. Pupa of Duponchelia

Photo 29. Larva of Duponchelia

Photo 30. Specific damage of the vine weevil: frayed leaf edge
Photo 31. Leaf infested by spider mite

Photo 32. Flower damaged by western flower thrips (Frankliniella occidentalis)

Photo 33. Greenhouse whitefly on underside of leaf

Photo 34. Leaves infected with powdery mildew

Photo 35. Botrytis on the stem

Photo 36. Botrytis in the flower may lead to considerable damage
bacterium and although they remain vital, they no longer function for the plant. This ends only when the plant dies. Once the glasshouse soil is infected the bacterium remains in the soil for a long time and it penetrates the plant if the plant is injured. Root tumours develop when during planting the plants are damaged. Usually the bacteria are dispersed by infected soil and plant material. Some rootstocks are known to be more sensitive than others and warm conditions cause a fast expansion of the infection. Crown gall infections are therefore found more frequently in France and Africa. Import of possibly infected young plant material should be avoided. In addition unfavourable growing conditions such as a heavy, wet soil may promote infection.

Control
Excessive callus growth need not be caused by a bacterium. Therefore it should be determined first whether or not *A. tumefaciens* is involved. Control of the bacterium seems impossible as chemical compounds are not available, and if they were, they might be dangerous for humans since they contain antibiotics. In the past, research has been carried out on the use of the bacterium *Agrobacterium radiobacter* (k84) as antagonist. *A. radiobacter* has no adverse effects on the plant and prevents the crown gall bacteria from further infecting the plants. *A. radiobacter* could be used preventively but is as yet not being applied in practice.

Prevention of the disease is important and starts by careful hygiene. Young plant material should be healthy and soil or substrate should be clean, disinfected by steaming. Infected plants should be removed and shears and tillage equipment sterilized. At the end of the cropping period the crop should be removed and not shredded, because steam does not adequately penetrate the shredded woody parts containing the bacteria.

9.4 INSECTS AND MITES

Aphids
Aphids are insects, which suck up plant saps with their sucking mouthparts, withdrawing food from the plants and leaving saliva that cause malformation of the leaf tissue. Some aphids do not damage the plant, but numbers of aphids may rapidly increase. The population development can be monitored by checking the crop regularly. Aphids are capable of rapid multiplication due to the fact that in the glasshouse they multiply asexually. These aphids are female and only produce daughters. The eggs already hatch in the aphid mother and they produce living young. As a result aphids are able to multiply seven times as fast as other insects. Sexual multiplication is often limited to a short period in the fall.

Symptoms
Since aphids consume a surplus of sugars, these are excreted. This forms a sticky layer, the honeydew and for an ornamental crop such as rose this is unacceptable, because on the honeydew sooty mould may develop. The white cast-off skins on the crop are a sign of the presence of aphids.

Usually the aphids on rose are not winged. When the number of aphids becomes too great and food-shortage threatens, winged specimens develop. These are responsible for
dispersal to new plants. Winged aphids are caught on yellow sticky traps. Aphids are spotted by crop monitoring. Aphids can also transmit certain viruses, but in roses this is a marginal problem. By far the greatest number of the aphid types is specialised on one or a few crops. When they remain on the ‘wrong’ plant, they die without offspring. Most species are not harmful for rose. The small group of aphids that can live on many types of plant are the injurious types in glasshouses and are dispersed globally with plant material. These species are adapted to a warm climate, so that multiplication in the glasshouse is guaranteed. The best known species are the green peach aphid (*Myzus persicae*), cotton aphid (*Aphis gossypii*), foxglove aphid (*Aulacorthum solani*) and potato aphid (* Macrosiphum euphorbiae*). Other species of aphids occurring in rose are yellow rose aphid (*Rhodobium porosum*) and the ordinary rose aphid (*Macrosiphum rosea*).

**Yellow rose aphid** (Photo 16)
Characteristics of adults: medium size, 1.2 to 2.5 mm, visible knots on the head. Light to dark green, antennae longer than the body. Siphons (protrusions at the backside of the body) are long and lightly coloured with a dark tip at the end. Only occurs in glasshouses and usually live in young, partly not yet unfolded leaves.

**Ordinary rose aphid** (Photo 17)
Characteristics of adults: medium size, 1.5 to 3.5 mm, no distinct knots on the head. Dark green to reddish, antennae longer than the body. Siphons very long and black. Dark knees and feet.

**Green peach aphid** (Photo 18)
Characteristics of adults: medium size, 1.5 to 2.3 mm, light to dark green, sometimes reddish. Siphons straight with minor thickening, dark tip. Forehead knots between antennae, pointing at each other. Antennae reach to the siphons. Short cauda (tail).

**Cotton aphid** (Photo 19)
Characteristics of adults: small 0.9 to 1.8 mm, light yellowish green, dark-green to black. Siphons short and black.

**Foxglove aphid** (Photo 20)
Characteristics of adults: medium size, 1.8 to 3.0 mm. Light yellow to brownish green. At the base of the siphons dark green spot. Siphons are light green, rather long, with dark tip. Forehead knots. Antennae longer than body. Tail finger-shaped, medium size. The winged female has very distinct dark zones on the abdomen.

**Potato aphid** (Photo 21)
Characteristics of adults: big 1.7 to 3.6 mm, usually green, sometimes yellowish or pink, often shining with a dark green stripe on the back. Siphons long with a dark tip. Forehead knots not parallel, reddish eyes. Antennae much longer than body. Long legs, drops easily. Tail long, finger-shaped.

**Life cycle and dispersal**
Under favourable conditions aphids can produce five descendants per day, which are already mature after 9 days. Thus aphids are able to build up a large population in a short
time. When there are too many aphids on a plant, females with wings develop, which migrate to other plants. Aphids are 'stickers'. They can be dispersed from glasshouse to glasshouse via plant material and clothing. Winged specimens can disperse autonomously, or be taken with the wind.

Control
Try to localise the patches where the aphids were found and treat them there. If the infection expands all plants in the entire glasshouse should be treated. Some strains of the green peach aphid and the potato aphid are immune to the recommended pesticides. Alternate pesticides from different chemical groups to avoid resistance. Note that against cotton aphid other pesticides should be used. Keep the glasshouse and its surroundings free of weed. Selective aphicides can be used in combination with natural enemies when the population becomes too large. Consult your supplier of biological control agents about the deployment of these compounds. In glasshouses where few chemical compounds are used natural enemies sometimes spontaneously enter the glasshouse, such as parasitic wasps and hover flies.

Caterpillars

Recognition and life cycle
Caterpillars are larvae of butterflies and moths. The larvae of several species of butterflies and moth cause damage to rose. Caterpillars have a well-developed head with firm jaws. Most caterpillars eat leaves, flower buds and flowers and are very voracious. In a short time they can eat away large parts of a plant. Small caterpillars mainly eat from the underside of the leaves, and cause so-called 'window-gnawing'. Larger caterpillars eat holes in the leaves. The most significant harmful caterpillars in rose are those of the leafroller moth (Clepsis spectrana), the beet army worm (Spodoptera exigua) and the golden twinspot (Chrysodeixis chalcites). The caterpillars of the butterfly Duponchelia fovealis also occur in rose.

Beet armyworm (Photos 22 and 23)
The beet armyworm is an insect occurring in the Netherlands since 1976 and was imported from the United States, on plant material. At that moment the beet armyworm was already resistant against various groups of insecticides. In the course of the years this resistance has only increased. The adult beet armyworm is a small inconspicuous moth of ca 15 mm length and a wingspan of 17 to 31 mm. The moth is grey-brown with light kidney-shaped spots on the forewing. During the day they hide and becoming active during dusk. Then they lay heaps of eggs on the underside of the leaves. The eggs are first green but later become grey and finally black. The female covers them with grey hairs and scales, so that they are barely noticeable and dry out less rapidly. In the course of her life a butterfly can produce between 800 and 1,000 eggs. The egg stage lasts 2 to 4 days, depending on the temperature. The young caterpillars are yellowish to green. The colour of the mature caterpillars is very variable, confusion with caterpillars of other butterfly species can occur. The sides the caterpillars are yellow-striped with a dot on each segment. The caterpillar has, in addition to the 3 pairs of thorax legs (fore legs), 4 pairs of abdominal legs (hind legs) and therefore walks normally, in contrast to caterpillars with 2 pairs of hind legs.
which make a looping movement (Looper). Young caterpillars only eat the epidermis at the underside of the leaves, resulting in the so-called window-gnawing. At a later stage the caterpillars eat holes in the leaves. They become ca 25 mm long and can also damage the flower buds and the flowers. The caterpillars can walk well and occasionally cover relatively great distances, so that damage can be widespread. When caterpillars move into the ground to pupate, then can hardly be controlled. The pupal stage lasts about one week. If the moth comes out of the pupa, mating takes place and eggs are laid again. The entire development takes about 4 weeks at 25°C. Due to the high egg production and the short development time an infection may become serious in a short time.

Leafrollers (photos 24 and 25)
A frequent leaf roller in glasshouse is the nocturnal Clepsis spectrana. This leaf roller regularly occurs in rose. The moth has a wingspan of ca 20 mm. The wings are ochre, each coloured with 2 brown spots, the front two forming a V-shape. The moth deposits her eggs on leaves in packages of 10 or 70. The caterpillar is dark brown with light spots, a dark brown to black head, slightly hairy, has 4 hind legs and is ca 2.5 cm long. The caterpillars gnaw on leaves, flower buds, flowers and stems, and make webs in which they hide. As a result of the webs the leaves curl. When the caterpillar is disturbed it makes twisting movements and lets itself down on a thread. The caterpillars pupate in webs in rolled leaves, hence the insect’s name. The leaf roller moth is an indigenous insect, adjusted to glasshouse conditions and occurring year-round in all stages in the glasshouse. The winter dormancy stage is skipped in the glasshouse. The leaf roller moths fly well and deposit their eggs in various places in the glasshouse. Spread to other glasshouses is possible through the ventilators, especially during warm nights when the ventilators are open for a long time.

Gamma moth and golden twinspot (Photo 26)
Examples of nocturnal moths which may cause damage in rose are the gamma moth and
the golden twinspot. Caterpillars of the gamma moth are loopers. They become ca 40 mm long, with a yellow-green head. The caterpillar is green with a light stripe on the sides with a dark spot on each segment. During walking the caterpillar makes a swinging movement with the head. The butterfly is brown to grey with a white spot on the wings looking like the Greek letter gamma and has a wingspan of 30 to 40 mm.

Another example of a looper is the golden twinspot. This moth is brown to gold-coloured with a wingspan of 32 to 37 mm. The wings have 2 conspicuous drop-like spots. The caterpillar becomes 50 mm long and looks like the caterpillar of the gamma moth. Loopers can be recognized by the way they walk. Since the caterpillar only has two hind legs it bulges its back during walking and places the hind legs against the fore legs, subsequently places the fore legs forward and straightens its back.

*Duponchelia fovealis* (photos 27, 28 and 29)
The butterfly *Duponchelia fovealis* is observed more and more frequently in Dutch glasshouses. This insect also occurs in rose. The caterpillars hide away in moist places in the heart of the plant or move near the roots, both in substrate and in soil. Sometimes they penetrate into the plant tissue. As a result the caterpillars are hard to control and the pest is responsible for an increasing number of problems. Until now the damage in rose remains limited.

The butterflies are light to dark brown, on the fore wings a white, winding line can be seen. The wingspan is 9 to 12 mm. The abdomen is long and often bent upwards. In the males the abdomen is slightly longer and slimmer than with the females. The eggs are deposited on the leaves, often on or near the veins, and are initially pinkish red. As the eggs get older they become darker, and by the time they hatch the young larva is visible in the egg. After about a week the eggs hatch. The young caterpillars move downwards. In rose the caterpillars often occur in dying organic material on soil or substrate. Sometimes the bark and the lower leaves are gnawed. Caterpillars can be found in webs and have a preference for moist places. After about 4 weeks the caterpillars are full-grown and pupate in cocoons on the soil. After 10 days to 2 weeks the adults emerge from the pupae and the cycle is complete.

The butterflies of *Duponchelia* can fly well and are thus responsible for dispersal. In addition *Duponchelia* is a polyphagous insect, which means that the insect can reproduce on many crops, which may promote dispersal.

**Control measures**
With pheromone traps outside the glasshouse flights of the beet armyworm can be observed. The first butterflies fly outdoors in May. Lamps and the heat in the glasshouse attract the butterflies. The use of ultraviolet catching lamps may give an impression of the activity of beet armyworms in the glasshouse. Spread of eggs and caterpillars can take place with plant material and pupae with soil.

Young caterpillars of the beet armyworm are sensitive to pesticides. Spraying should be done within a couple of days, particularly on spots with ‘window-gnawing’. Older caterpillars are insensitive to pesticides. Fogging or misting treatments can be applied to control the moths. The moths can also be caught with catching lamps, reducing egg deposits and caterpillar development. A small numbers of caterpillars can be caught manually, as ‘mechanical control’. The Florida caterpillar is successfully controlled biologically with Spod-X, a viral agent on a biological basis.
The butterflies of the leaf roller can be caught with a UV catching lamp. Furthermore spatial treatments control the butterflies although the young caterpillars are in rolled leaves and are therefore difficult to reach with chemical agents. Sometimes parasites (parasitic wasps) spontaneously enter the glasshouse from outside and parasitize the caterpillars of the leaf roller, considerably reducing the numbers as a result. In such a case application of pesticides against other diseases or pests should be done carefully, since these parasites are sensitive to chemical agents.

The moths of the gamma moth and the golden twinspot can fly well and deposit eggs throughout in the glasshouse. Moths enter the glasshouse through open ventilators and deposit eggs on the roses but the moths can be caught with UV catching lamps. Spatial treatments can be applied to kill the moths and young caterpillars. Crop spraying controls young and old caterpillars. Many species of caterpillars are sensitive to the insect pathogenic bacterium *Bacillus thuringiensis* (Bt) which should be eaten by the caterpillars. The caterpillars die of paralysis after 1 to 5 days. Release of the egg parasite *Trichogramma* may reduce a caterpillar population. These small parasitic wasps deposit an egg in the egg of the caterpillar. Other stages (caterpillars, pupae, moths) are not killed and have to be controlled with a selective insecticide.

*Duponchelia* has only recently occurred in The Netherlands, and only limited research has been done into chemical control. Control of the moth can also be done by spatial treatment and a catching lamp may also be helpful. Biological control can be conducted with the insect parasitic nematode *Heterorhabditis*. This application is relatively expensive. The nematodes must be sprayed under low pressure and with a large nozzle into the heart of the plant. The best application time is the evening, because the nematodes are sensitive to UV-light and dry out in the daytime. An alternative biocontrol method is bacterial preparations of *Bacillus thuringiensis*. The crop should be thoroughly wetted with the preparation because the caterpillars must ingest the compound.

**Black vine weevil** (*Otiorrhynchus sulcatus*)

The black vine weevil is notoriously difficult to control. The insect is regularly observed not only in glasshouses but also in private gardens with roses. Apart from *Otiorrhynchus sulcatus* there are some other species such as *Otiorrhynchus singularis* (spotted black vine weevil) and *Otiorrhynchus ovatus* (small black vine weevil), which have similar life cycles. In general *Otiorrhynchus sulcatus* occur most frequently in glasshouses. They have a black-brown colour, have six legs, are about 1 cm long and wingless: the beetles do not have membranous back wings and cannot fly. In Northern Europe only females that multiply asexually are found. A female can produce hundreds of eggs during her lifetime and the eggs are deposited in the soil. After about 3 weeks the larvae hatch and they cause damage by gnawing on the roots. As a result plant growth is disturbed and due to water deficit plants may yellow and die off. The larvae are cream-coloured and full-grown larvae are ca 1 cm long and pupate in the soil. The beetle that emerges from the pupa usually remains in the soil or under debris during the day. During the night they gnaw on leaves and stems. They always start eating at the leaf edge, resulting in the typical damage in the form of a serrated leaf edge. The beetles are observed from May onwards outdoors and the larvae hibernate in soil during the winter. In the glasshouse the life cycle is much shorter.
due to the lack of winter dormancy, and with higher temperatures both beetles and larvae are seen almost throughout the year. The beetles cannot fly, but walk well and can spread considerably. They are polyphagous and eat all crops. *Otiorrhynchus sulcatus* are found in large parts of the world.

**Control**
The beetles hide by day and are active at night and strips of wood appear to be favourite hiding places. Part of the control is to turn these strips and kill the beetles by hand. Plants infected by the larvae should be removed. For adequate control there are separate treatments for beetles and larvae. The larvae of *Otiorrhynchus sulcatus* are controlled most effectively by application of the insect parasitic nematode *Heterorhabditis*. The insect parasitic nematode *Steinernema feltiae* also has a controlling effect on larvae. For proper effectiveness of the nematodes the soil temperature should be at least 13°C. Above 27°C the effect of the nematodes declines. After about one week the larvae are parasitized and become darker. Biocontrol with nematodes kills the larvae faster than chemical control.

**Spider mite** (Photo 31)

Spider mites (*Tetranychus urticae*) occur generally, both in glasshouse and in outdoor crops. They seem to be an eternal threat to rose cultivation and many controls are carried out throughout the year. With the new system of bending roses, and the resulting thick package of leaves at the base of the crop, chemical control has become more difficult. Reaching the spider mites with the spraying liquid is a problem. Biological control with predatory mites and gall midges offers prospects.

**Life cycle and symptoms**
Spider mites belong to the large group of Acari and are related to spiders. They have eight legs, in contrast to insects that have 6 legs. Spider mites feed only on plant saps by pricking and sucking plant cells. Usually they occur at the underside of leaves. The emptied plant cells become yellow and are visible on the upper site of the leaves as yellow spots. With increasing damage the leaves become entirely yellow and drop. With large numbers of spider mites even webs are noticeable, teeming with mites. If this is the case, the problem has been noticed too late. The colour of the spider mites may vary from light yellow or light/dark green to red or even brown/black. The round eggs are predominantly deposited on the undersides of the leaves and have a clear colour at first. Later they become dull. The larvae have six legs and are whitish just after hatching. Later, after nutrient uptake, the larvae become yellow green and 2 dark spots appear on the underside. After a dormancy period the nymphs develop which have 8 legs. After again a dormancy and nymphal stage the mites mature. The developmental time from egg to egg is to 36.4 days at 15°C, 16.6 days at 29°C and 7.3 days at 30°C. Under favourable conditions a female produces ca 129 eggs at 20°C. Spider mites prefer warm and dry conditions. At lower temperatures and less light, winter forms of spider mite females develop. These hide away in cracks and chinks. In spring the females become active again and produce eggs developing into new population.

**Spread**
Spread of spider mites frequently takes place via clothing of workers. For this reason, a rapid recognition of a spider mite attack is important. But spider mites may also disperse
via infected plant material and spinning threads. When the crop quality declines spider mites move via adjacent plants to crop of better quality and develop a new population there. Spider mites arrive with the plant material so new plant material should be checked for insects and mites, and appropriate measures taken.

**Observation and control**

Spider mites cannot be observed on sticky traps, as they have no wings. Weekly crop control is necessary to discover the start of a spider mite attack. These often develop on the same place and they can be marked with a coloured clothes peg, so that it is clear where control should take place. A ground plan showing the spots may be helpful. A computer programme is now available for the registration of pests (Koppert, Biocontrol). One or a few spider mite attacks can be controlled locally, with many patches or overall spread, the entire glasshouse should be treated. Spider mites live on the underside of the leaves, so this is where the spraying liquid should be applied. Due to the short life-cycle, spider mite may become resistant to acaricides. It is important to acaricides from different chemical groups, after three treatments with the same acaricide, an acaricide from another group should be chosen.

**Biocontrol**

Biological control of spider mites can be done with predatory mites. A very voracious predatory mite is *Phytoseiulus persimilis*. This tropical predatory mite released in spider mite foci sucks all spider mites empty. When there is no food left, they become cannibals and die out. *Phytoseiulus* mites prefer a temperature of 18°C or more and a relative humidity of at least 70%. The current cultivation method with a thick leaf package at the base of the crop gives the predatory mites more chance to survive. Another predatory mite, *Amblyseius californicus*, is less voracious, but survives longer. Also the predator *Feltiella acarisuga* can be used. The adults of this gall midge are very good at locating foci of infestation where they lay their eggs. The emerging larvae feed on the eggs and spider mites.

**Thrips (Photo 32)**

In the Netherlands about 150 thrips species (*Thysanoptera*) occur. The western flower thrips (*Frankliniella occidentalis*) and the tobacco thrips (*Thrips tabaci*) are most frequent in glasshouse crops. The specific characteristics can only be distinguished in adult specimens using a microscope.

**Life cycle and recognition**

The life cycles of the western flower thrips and the tobacco thrips are similar. The western flower thrips develops from egg, two larval stages and two pupal stages to adult insect in about 3 weeks at 20°C and 2 weeks at 25°C. Thrips multiply by depositing eggs in soft plant tissue. The larvae have a round and elongated body, are mostly cream coloured and mobile. Western flower thrips pupates in the soil, but also under fallen leaves. Pupal stages are not active and do not take up food. The adult thrips, both male and female, are winged and very mobile. After mating, the females produce 40 to 70 eggs and the cycle starts again. If no mating takes place, asexual multiplication may occur. Western flower thrips mostly lives in flower buds, growth tips and flowers. The hidden lifestyle makes control difficult. Using a mouth quill thrips imbibe plant sap. The empty cells fill with air and
become silvery at first, later these spots become brown by dying tissue. Some species scratch away tissue, resulting in abrasion damage and excrements can be seen in the form of small black dots. Thrips in rose causes damage of petals and sepals. Severe infection also leads to damage in the growth tips of shoots and leaves.

Dispersal
Although adult thrips can fly, spread over large distances is mostly by wind. In glasshouses thrips enter via the ventilators, but also by draught through open doors. Thrips infection is local in the beginning and further spread takes place from there. Thrips eggs and larvae may also arrive with plant material. Western flower thrips can transmit tomato spotted wilt virus and impatiens spotted wilt virus, but to date these are no problem in rose cultivation.

Control
Chemical control of western flower thrips in rose is difficult. As the trips live in the flower buds and the folded leaves the insects are well protected. A small thrips population is easier to control than large populations. Regular scouting is important and with yellow and blue sticky traps thrips can be spotted, on the blue trap generally somewhat sooner. Pesticides based on vapour often give the best result. Flowering roses are breeding grounds for thrips and one flower may contain as many as 130 thrips. Remove mature flowers, also at the base of the plants. Hypoaspis is a soil predatory mite controlling thrips pupae. Amblyseius cucumeris controls the first larval stage of thrips. Orius predatory bugs control adult thrips and thrips larvae, but do not multiply in rose. Consequently, only a short-lived result is to be expected. There is a great variation in sensitivity to thrips among the various rose cultivars. This partly determines the success of the control with natural enemies. Despite the presence of predatory mites the thrips population density may get too high by insects entering from outside. Chemical correction is then necessary.

Glasshouse whitefly and tobacco whitefly
In glasshouse roses there are 2 types of whitefly, the glasshouse whitefly (Trialeurodes vaporariorum) and the tobacco whitefly (Bemisia tabaci). In rose the glasshouse whitefly is more common but occasionally also the tobacco whitefly may occur. The tobacco whitefly has been imported with plant material and has developed resistance to many insecticides. In other crops the tobacco whitefly is feared because of virus transmission, but to date this is not a problem in rose.

Life cycle and recognition
Glasshouse whitefly (Photo 33)
Adult glasshouse whiteflies are ca 1.5 mm long and mainly occur on the underside of the leaf. The eggs are deposited on the underside of the leaves. While imbibing the plant sap the whiteflies turn round and lay eggs, occasionally resulting in circles of eggs. The eggs are green-white at first and become dark after some days. The egg stage is followed by four larval stages and the pupal stage. At 15°C the cycle takes about 2 months, at 25°C ca 3 weeks. The number of offspring strongly depends on the crop inhabited by the whiteflies. The first larval stage is mobile, the other larval stages are stuck on the underside of the leaves. The pupa has the shape of an oval box, has a whitish colour and anchored with quills and mostly a wreath of wax threads. Because the adult glasshouse
whiteflies suck up much plant sap they take up an excess of sugars, which in its turn is secreted as honeydew. On this honeydew sooty mould may develop, which leads to growth inhibition by reduced assimilation.

**Tobacco whitefly**
The tobacco whitefly follows the same development as the glasshouse whitefly, though they show external differences. The adult flies of the tobacco whitefly are smaller than those of the glasshouse whitefly. The wings of the tobacco whitefly are placed more vertically against the body, while the wings of the glasshouse whitefly have a more horizontal position. The eggs of the tobacco whitefly are yellow-green when they are just laid. The eggs keep this colour, while the older eggs of the glasshouse whitefly become dark.

**Spread**
Dispersal is conducted by the adult whiteflies. When agitated they fly up and away over a distance of at most several metres. Often the attack starts locally and then gradually expands. The whiteflies can be transported over great distances on infected plant material. In the fall the whiteflies of outdoor populations enter the glasshouse through the ventilators. Usually they are not a problem. Spread can also take place via clothing.

**Control**
When controlling by means of spraying the spraying liquid should reach the place where the whiteflies are, on the underside of the leaves.

**Biocontrol**
Biological control of whitefly can be conducted with parasitic wasps, predatory bugs and an insect pathogenic fungus. The parasitic wasp *Encarsia formosa* deposits an egg in the larva of the whitefly. About 2 weeks after release the first parasitized pupae can be observed. Pupae of glasshouse whitefly are black, pupae of tobacco whitefly are light-brown. Through a round hole the new parasitic wasp leaves the pupa. The minimum temperature for *Encarsia* is 17°C, but regularly higher temperatures are better. The parasitic wasp *Eretmocerus californicus* also parasitizes the larva of the whitefly. About 2 weeks after release the first parasitized pupae are observed, both the glasshouse and the tobacco whitefly having a yellowish colour. The adult parasitic wasp leaves the pupa through a round hole. The parasitic wasp *Eretmocerus* prefers temperatures of 20°C and higher.

The predatory bug *Macrolophus caliginosus* is active on all stages of the whitefly with a preference for eggs and larvae. With a sucking proboscis whitefly eggs and larvae are emptied. The skins are left behind on the plant. These predatory bugs also live on other insects. In certain crops, for example gerbera, this predatory bug pricks the plant, resulting in damage. To date in rose no damage by *Macrolophus* has been observed.

The insect pathogenic fungus *Verticillium lecanii* can infect whitefly larvae and pupae. With standard spraying equipment the fungus is sprayed on the undersides of the leaves. The fungal spores germinate on the insects at an air humidity of 80% or higher. After germination the hyphal threads penetrate the insect, the fungus developing within the insect, which is killed after 7 to 10 days. When relative humidity is high enough white fungal fluff develops with conidia on the infected insects. The newly formed conidia may in turn infect other whitefly larvae and pupae.
**Garden centipede**

The garden centipede (*Scutigerella immaculata*) is found in almost the whole of Europe and North America, in several places in Africa and on a few islands, such as Hawaii. From the beginning of the 20th century garden centipedes are known to cause damage in a variety of crops. In The Netherlands garden centipedes are generally observed only in glasshouses.

**Life cycle and recognition**

The garden centipede is at most 9 mm long, agile and lucifugous, with long, ever-moving antennae. It has no eyes. Garden centipedes live in the soil, where they feed on yeasts, fungi, bacteria and roots of all kinds of plants. The eggs are white and spherical, 0.5 mm in diameter and are laid in groups of 4 to 25. The first larval stage has 6 legs and is not very mobile. After 24 to 36 h the first sloughing occurs and the larva starts to crawl through the soil. After every new sloughing the larva has one pair of legs more than before it. Also the numbers of body segments and antenna parts increase. After 6 larval stages the adult garden centipede appears with 12 pairs of legs. These adult garden centipedes continue to slough monthly. In the 4 years of the centipede’s life the number of sloughings may amount to 50. The developmental time strongly depends on the temperature and from egg to adult stage takes about 160 days at 10°C, 87 days at 20°C and 53 days at 25°C. The first larval stage of garden centipede (6 legs) is sometimes confused with white springtails. Under a magnifying glass a springtail always appears to have a spring fork under its body.

**Spread**

Garden centipedes have a thin skin, are very sensitive to drying out and need a relative humidity of 98 to 100%. In practice only glasshouse soil ready for planting has the optimum moisture content for garden centipedes. Humus soil is favourable not only for the moisture content but also because of the presence of (saprophytic) fungi on the humus which may serve as food when living roots are lacking. When the soil dries out, the garden centipedes move actively to humid places. Garden centipede prefers temperatures between 15 and 20°C. In summer the upper layer of the soil may be warmer, causing migration to
deeper layers. Spread may also take place by moving soil, via soil sticking to plants and plants in pots with soil. The garden centipede is not capable of making passages in the soil and uses existing cavities, cracks and worm-passage to move around. They may occur deep in the soil, as deep as the groundwater. They can be found in all types of soil, except pure sand.

**Damage**
The garden centipede is found in many crops, also in glasshouse roses. The damage consists of gnawing of young roots. Growth and yield may decline as a result. Root gnawing may lead to root rot by bacteria and fungi. Especially recently planted roses with a weak root system are sensitive to root gnawing. The relation between numbers of garden centipede and damage is unclear. Research into the number of garden centipedes and damage indicated that there was no difference in yield and quality between plots with 5 and 65 garden centipedes in a sample of 6 l soil. The characteristic of the garden centipede to go to deeper soil layers inhibits effective control with insecticides or steaming. Chemical control of garden centipede becomes more and more difficult because registration of a number of insecticides has expired.

**Biocontrol**
Little is known about the effect of predators and parasites under natural conditions. In 1986 a survey of natural enemies of the garden centipede was made and predatory centipedes and predatory mites were considered to be the most promising. These predators use the cracks and passages also used by the garden centipedes to move around.

9.5 **FUNGI**

**Powdery mildew** (Photo 34)

**Recognition**
In glasshouse roses infection by powdery mildew (*Sphaerotheca pannosa*) may occur throughout the year. On the leaves, mostly on the top, a white, powdery, fungal fluff develops, consisting of hyphal threads (mycelium) and spore carriers. With severe infections the fungus is also observed on the undersides of leaves. The fungus may also infect stems or flower buds. Infection with powdery mildew of a young leaf leads to malformation because the tissue will die off as a result of the infection. On full-grown leaves brown spots develop. In contrast to downy mildew the fungus can easily be rubbed off the leaves, because it grows on the surface. Downy mildew grows in the leaves. The original leaf colour is not affected initially, in contrast to an infection with downy mildew.

**Life cycle and dispersal**
An infection of powdery mildew starts with the spore landing on a leaf (or on the stem or the flower) and subsequently the spore must germinate. No water is required for this, since the spore consists for 70% of water. Germination usually takes place at night. In this period the relative humidity (RH) is generally higher than by day. A high RH promotes germination. Waterdrops on the leaves inhibit germination but after drying the leaf is more
sensitive to infection. Dispersal takes place mainly by air movement and to a lesser degree by humans or animals. After germination the fungus penetrates the leaf with haustoria (sucking organs). The haustoria are responsible for uptake of water and nutrients from the plant for the fungus. On the leaf the mycelium is formed, on which spore carriers develop, producing spores. When the spores are full-grown, and capable of germination, they are released. This process is called sporulation, and takes place usually by day, around noon. The spores are spread through the air and spread is greater with draught, broken windows, open doors, etc. Despite their own high moisture content the spores do not live long and if they do not germinate on living plant material they die within 2 or 3 days. The developmental rate of an epidemic varies. In a young crop the mildew is often less frequent. In older crops with a great package of leaves the control is more difficult and the risk of new epidemics is greater. No relationship whatsoever has been found between the duration of an epidemic and the climate conditions. In view of the limits of temperature and RH within which the fungus can grow, it is impossible to control the mildew by climate settings.

**Control measures**
Real prevention of an infection is almost impossible. In the assortment of rose varieties, there are variations in the sensitivity to mildew infection, so that choosing a less sensitive variety is one of the possibilities. Draught and gusts of wind in the glasshouse should be avoided. Broken windows and poorly closing doors and ventilators should be fixed. Take into consideration that fans cause draught as well and that ‘blowing the crop dry’ promotes the spread of mildew. It is important that new crops have a clean start; check the starting material. Also pay attention to roses outside the glasshouse; they may infect the plants in the glasshouse. Chemical control is possible with various agents. Avoid scorching the leaves and alternate compounds for adequate control. Compounds are the most effective when application is carried out three times in 10 days. Sulphur is a natural compound that can be used for control. Check after control whether the fungus has been killed. Look over the leaf; if a sort of pillow of upright hairs (the spore carriers) can be observed, then it may be assumed that the fungus is still alive and forming spores. Try to work with a damage threshold, which may result in considerable reduction of the use of compounds and prevent resistance development. There are various compounds available with a so-called plant-reinforcing effect. These compounds are responsible for inhibition of the development of powdery mildew. In the coming years more attention will be paid in research to compounds with an antagonistic effect with respect to powdery mildew.

**Botrytis** (Photos 35 and 36)
Botrytis or grey mould is caused by *Botryotinia fuckeliana* (syn. *Botrytis cinerea*) which appears on dead spots as grey-brown, dust-making fungal fluff. This consists of mycelium and spore carriers. In principle Botrytis can infect all aerial plant parts. In substrate crops Botrytis is manifest only in the postharvest stage as lesions (pocks) on the flowers. One infection is sufficient to make an entire flower rot away.
Life cycle and dispersal

*Botrytis cinerea* is found globally on a wide variety of plants. Generally it is a weakness pathogen as living plants are infected under certain unfavourable conditions, which may be: excessive relative humidity, high crop density, cold, light deficiency, excessive nitrogen application. Mostly infection takes place on dying material via wounds (pruning, harvesting) or on dead plant parts. From these parts the fungus may penetrate into healthy plant tissue. Flowers are so tender that they may be infected even without wounding. On healthy flower parts it is only possible to penetrate the tissue in the presence of moisture. This is the case already at a relative humidity of 90% and higher. Apart from humidity the temperature is also important for a successful infection. The spores require a temperature of 29°C and RH of 90% for 6 to 8 hours to be able to infect a flower successfully. At the same temperature spores need 20 h of RH 95% or more to penetrate a leaf. Germination of the spores is possible at a temperature between 0 and 30°C. The spores penetrate the plant tissue by first locally dissolving the epidermis with enzymes and by exerting mechanical pressure (via a germination tube). Spore carriers from the mycelium develop and branch at the tips and large quantities of spores are produced. These are easily dispersed through the air and via splashing water and the spread of the spores occurs throughout the glasshouse. Spores of Botrytis are almost always present in the glasshouse air, in varying quantities although no clear patterns can be observed in these variations. The chance of survival of the spores increases as the RH increases and the irradiation decreases.

Control measures

The removal of infected and fallen plant parts is very important because they are an source of infection and this should be done as soon as possible. Plant parts on the ground may cause dispersal of spores, particularly in soil-grown crops, as it is difficult to keep the material on the ground dry.

Reducing the RH to below 90% by heating and ventilating diminishes the risk of infection. There are various chemical possibilities to control the fungus. There are great variations in sensitivity among varieties to Botrytis infection of the flowers in the post-harvest stage. A testing method has been developed to test the sensitivity of a variety. The method is also applied in the reference test (8.3.3). The possibilities for biocontrol of Botrytis are being worked on, mainly with fungi having an antagonistic effect.

Dieback

Various fungi may cause dieback of stems, viz. *Coniothyrium fuckelii* (cause of common canker), *Lasiodiplodia theobromae* (cause of branch dieback) and grey mould (*Botryotinia fuckeliana*; syn. *Botrytis cinerea*). With the naked eye it is usually impossible to determine which fungus is involved but an expert is recommended to determine what disease is involved. The grey mould is dealt with in the separate section on Botrytis.

**Common canker (Coniothyrium fuckelii)** (Photo 37)

**Recognition**

The first symptoms are small yellow to red spots on the bark that expand gradually. The spots begin to colour light brown in the centre, with dark-brown tissue at the edges. Infected surface tissue dries out and shrinks. It occasionally happens that the bark bursts open releasing very many black spore bodies. On infected stems yellow bands may
develop, which turn brown at a later stage. When the stem loses its bark due to the canker, the stems above the canker spot wilt and die. The disease can only enter through wounds. Common canker therefore usually begins after harvest at the end of a cut stem, where a stump is left. In addition common canker may also develop on minor wounds.

**Life cycle**
The symptoms appear initially at the junction of rootstock and graft under warm and humid conditions. The development of the fungus continues in the dead wood when the plants are planted in the glasshouse. Especially under stress conditions plants can be sensitive to the disease, for example when they are stored and when the bushes are just planted.

**Control measures**
Open wounds should be avoided. Harvest should be done as closely above the node as possible without the bud being damaged, leaving the smallest possible stump. The stumps mostly die off on the first node.
The canker establishes quickly on dead and dying tissue. If harvesting is done closely to the node the plant will produce wound tissue quickly and thus cover the wound and prevent infection of canker. Infected shoots should be cut off on a node under a visible infection. It is important to avoid wounding the plant further, therefore sharp tools should be used.

**Branch dieback** (*Lasiodiplodia theobromae*) (Photo 38)

**Recognition**
As the name implies, branches of the plant die off. Sometimes the whole plant dies. On the branches sharply designated, brown necrotic spots develop. The necrosis extends so that leaves and stems wilt and turn yellow, above the infected spot. On the necrotic parts black dots may become visible, the fruiting bodies of the fungi.

**Life cycle and dispersal**
Dieback is caused by a tropical fungus also occurring in the Mediterranean. The fungus is known as a weakness pathogen as especially weak crops are infected. The fungus penetrates the plant from above through cutting wounds, and then grows downwards through one or more vascular bundles. This is the explanation for the fact that branches with both a green and a dead side can be observed. The branches above the infection are not attacked but wilt nevertheless because the supply of water and nutrients is suddenly cut off.
The fungus produces very many spores and is dispersed with the wind, water, soil and insects. The spores (conidia) can still germinate for 4 months and the mycelium is viable for a year. All aerial and subterranean parts can be infected. Warm conditions are optimal for growth of the fungus.

**Control measures**
Avoid very high growing temperature and relative humidity. Make sure the crop shows active growth by stimulating transpiration by heating and ventilating simultaneously. In case of infection it may be helpful to cut away the stems at an early stage. This should be done before sporulation.
Silverleaf (Photo 39)

Silverleaf (*Chondrostereum purpureum*) is responsible for a silvery colour on the upper side of the leaves. The fungus secretes certain substances, which loosen the epidermis from the mesophyll. Due to the changing light reflection the leaves become silvery and pallid. Usually the phenomenon is observed on only one shoot at first, later on more shoots. The disease continues until the whole plant dies. Infected stems show a partial brown discoloration and die. On the dead wood brown/purplish, crust-like fruiting bodies develop.

**Life cycle and dispersal**
The fungus is a so-called wound parasite. The fungus may infect the healthy plant if spores penetrate an open wound caused for example by harvesting. Through the wound the fungus grows further and further into the plant and may even grow as far as the roots. Spores from fruiting bodies that develop on dead wood form a serious source of infection. They spread through the air. The spore may come from diseased roses as well as from other infected crops. Wooded banks or stacks of firewood may therefore be infection sources. In addition, apple trees, plum trees, but also willows, poplars and alder trees are good host plants. The fungus can also be spread via infected rootstocks or grafts. In rose cultivation stems for cuttings are often taken from a cultivation glasshouse, it is important that these glasshouses are kept free of silverleaf.

**Control measures**
The spores are dispersed through the air. Harvesting or crop treatment may induce wounds which may serve as an entrance for the fungus. It is important to find the sources of spore formation and remove them. The various sources may, however, be both inside and outside the glasshouse. Cutting away the infected shoot deeply and destroying it may save a plant. Mostly, however, this is done too late. The best thing to do is to prevent the development of fruiting bodies in the glasshouse by removing the infected plant (including the roots). Chemical or biological control of the fungus is not possible.

Rust (Photo 40)

Rust infection (*Phragmidium mucronatum*) can be recognized by red spore heaps on the underside of the leaves and on the petioles and shoots. On corresponding areas on the top of the leaves green-yellow sunken spots develop and the spore heaps break through the epidermis. Finally the leaves become entirely yellow, dry out, shrivel and drop.

**Life cycle and control**
Rust grows under the surface of the plant tissue and draws food from the cells. It is a biotrophic parasite (feeding on living material) living mainly on leaves and stems. Under favourable conditions spores are formed that are responsible for massive spread and have only a short life cycle. The spores are dispersed via water and wind and infect the leaves through the stomata. An uninterrupted period of 2 to 4 hours of humidity is needed to allow the fungus to infect. Infection can thus take place when condensation occurs and the leaves remain wet sufficiently long. The optimum development temperature for the fungus is 18-21°C. The fungus can develop resting spores with thick walls which give it
Photo 37. Infection of the stem by Coniothyrium (detail)

Photo 40. Rust on underside of leaf: aecidiospores (orange) and teleutospores (black)

Photo 38. Lasiodiplodia on rose

Photo 41. Black spot

Photo 39. Crusty bodies of silverleaf

Photo 42. Symptoms of downy mildew on leaves
Photo 43. Rose bushes infected by Verticillium

Photo 44. Cylindrocladium scoparium may lead to death of the plant

Photo 45. Gnomonia radicicola on roots

Photo 46. Virus symptoms on rose leaves

Photo 47. In some varieties bullheads occur more frequently than in others

Photo 48. Rose with humidity leaflets
the possibility to survive under less favourable conditions. The resting spores survive in fallen leaves.

**Control measures**
The control of rust is difficult and so infection with rust should be avoided. The young plant material should be clean and infected material should be removed and destroyed, including the fallen leaves. Overhead irrigation should be avoided and the crop should be dry during the night. The air humidity should be kept sufficiently low by heating and ventilating. Be sure to avoid dispersal via clothing, hands and tools.

**Black spot** (Photo 41)
Black spot (*Diplocarpon rosea*) may give rise to problems, especially in outdoor rose crops. On the leaves brown-black spots are formed with a characteristically frayed edge. Sometimes large parts of the leaves become black by blending of the various spots. The area around the spots often becomes chlorotic, and the leaves drop prematurely. About 10 days after infection in the centre of the spots fruiting bodies are formed, which may be observed with a magnifying glass. They are small, dark bladders with a greyish slime on top. The stem parts may be infected as well. Frequently irregular spots develop, crimson at first, black and bladder-like later. They remain small and the stems do not die. Sepals may show red spots and be slightly deformed.

**Life cycle and dispersal**
Young leaves are the most sensitive to infection and if they remain wet for at least 7 hours infection will follow. A high relative humidity alone is not sufficient as the spores should remain in water. The optimum development temperature for the fungus is between 15 and 27°C. About 10 days after infection the fruiting bodies are formed. At low air humidity the fruiting bodies break through the surface tissue of leaf or stem and the spores come out as a slimy mass. On the edges of the spots the formation of fruiting bodies and spores continues. The spores, surrounded by the slime, are spread by splashing water, via mouth parts of stinging-sucking insects, by humans (clothing, tools) and by fallen leaves. There are variations in sensitivity to black spot among cultivars.

**Control measures**
Preferably use less sensitive varieties. Take care that the crop remains dry or dries quickly after irrigation or spraying. Remove the fallen, infected leaves and cut away deeply, because the fungus survives in infected parts.

**Downy mildew** (Photo 42)
Downy mildew, caused by the fungus *Pseudoperonospora sparsa*, may give rise to problems, especially in autumn. The relative humidity is then high, activating the fungus. The fungus can infect all rose varieties, but damage is not equally severe in all varieties. In general, infection is limited to the young plant parts and symptoms mostly occur on leaves, stems, petioles and petals and sepals. On infected leaves purple-red to grey-black spots appear, subsequently the whole leaf yellows. On the underside of the leaves whitish fungal fluff develops. The leaf drops soon afterwards. The first symptoms on the leaf often
look like those of scorching by pesticides. Also on stems and petioles brown-red to brown-black, elongated spots develop, varying in size from several mm to more than 2 cm.

**Life cycle and dispersal**

Downy mildew spores only flourish under humid conditions. The spores require a thin layer of water to germinate and penetrate the plant. Penetration takes place through natural apertures such as stomata. A relative humidity of less than 85% results in considerable reduction of the infection. The optimum temperature for spore formation is 18°C. The spores do not develop at temperatures below 5°C, and die if the temperature is 27°C or more during 24 h.

In contrast to the powdery mildew, the mycelium grows in the plant tissue and the spore carriers stick out through the stomata. At the end of the spore carrier the spores are produced and easily released by air movement or during irrigation or spraying. New infections then develop elsewhere. In addition to spores responsible for direct dispersal during cultivation, the fungus in the infected tissue also forms thick-walled resting spores which remain in the soil. After decomposition of the surrounding plant tissue the spores are released and a new infection can develop.

**Control measures**

Because downy mildew fungi grow safely in the plant, certain chemical compounds can only prevent spread to other plants. Infected plants cannot be cured and must partially or completely be removed and destroyed.

Infection can be avoided by watering from below. In any case, be sure the crop is dry at the beginning of the night, by ventilating and/or heating, particularly during periods with gloomy, humid weather.

Keep the air humidity below 85% and avoid large temperature fluctuations, which may lead to condensation. Remove infected parts (leaves) and steam-sterilize the soil to kill remaining spores.

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**Verticillium wilt (Photo 43)**

Verticillium wilt (*Verticillium albo-atrum*) leads to leaf yellowing and leaf drop. Occasionally the leaves and the plant wilt by day, and straighten again at night. During high transpiration leaves and branches do not regain their old moisture tension and remain limp. The phenomenon may be observed on one or several branches, while other branches show normal growth. Wilting may even occur on one side of a branch. One of the most characteristic symptoms of the disease is a yellowing of the stems, starting from above, bordered by a purple zone. The branches die off downwards.

**Life cycle and dispersal**

Verticillium is a vascular parasite, penetrating the plant via the roots and blocking the vascular bundles. As a result the plant suffers water deficiency and wilts. The fungus also secretes substances that are poisonous to the plant, accelerating death. A plant may be infected for a long time without visible symptoms. Only when several xylem vessels have been blocked, do problems arise with water supply. A cutting, taken from an infected plant, carries the infection and will demonstrate symptoms later. Further spread takes place via spores, which are dispersed via infected soil particles and via water. In addition spores can also be spread with dust by the wind and on shoes spores can also dispersed from one
place to another. No dispersal takes place during crop treatments. In the soil the fungus develops sclerotia (resting spores) which are able to survive for years, periods of 10-20 years being possible. The various rootstocks show variations in sensitivity to verticillium. *R. manetti* is less sensitive but is not used as rootstock in the Netherlands.

**Control measures**

Chemical control of verticillium is not possible. Deep steam-sterilizing (preferably with under pressure) may reduce infection in soil-grown crops. However, sources of infection always remain behind in the soil, and switching to substrate growing is not always the solution. Infection may also take place via the plant material or penetrate the substrate via dust and soil particles from the infected subsoil. Prevention is, therefore, vital. When switching to substrate the heating pipes, glasshouse construction etc. should be sterilized and of course clean young plant material should be used. Place disinfecting trays near the glasshouse compartments, to prevent dispersal via shoes. Infected plants should be removed, and should under no condition be shredded because the fungus is in the stem and is difficult to steam-sterilize.

**Root rot**

In soil-grown and substrate-grown rose crops various problems occur with fungi causing root and foot rot. The fungi concerned are *Cylindrocarpon destructans, Cylindrocladium scoparium, Gnomonia radicicola, Phytophthora* sp. and *Pythium* sp. The *Phytophthora* type which causes problems in substrate crops, has no official name yet. However, this *Phytophthora* type, and *Gnomonia radicicola* are not known to cause problems in soil-grown rose crops. This is also the case with the other 3. To date the problems in soil-grown crops seem to be less serious than expected, while in substrate-grown crops they have become more manifest during the last decade. The reasons for these differences are that roses on substrate grow in a much wetter environment than in soil and that the root temperature is higher in substrate. Moreover the fluctuations in growing conditions are larger in substrate grown crops, while there is an increased risk of dispersal of root diseases.

**Recognition**

Generally infection of the roots results in various symptoms above ground, including growth inhibition, deficiency symptoms, leaf yellowing and browning, leaf drop, increased flower bud atrophy, shorter and thinner flower stems with smaller leaves and buds. On warm days wilting symptoms may occur. Somtimes dieback is observed, especially in infections with *Cylindrocladium scoparium*. Infected roots are partly or entirely rotten and brown to brown-black. With an infection by the pathogen *Pythium* the epidermis of the roots can be easily stripped off. Since one or more of the other soil fungi usually precede such an infection, further diagnostic research is necessary. It is difficult to see if other fungi are involved from the subterranean and aerial symptoms. Root nematodes may show almost the same symptoms.

**Life cycle and dispersal**

The spread of soil fungi mainly takes place via infected plant material and infected water and soil. Reservoir and surface water must be regarded as infected. Dispersal in the
direction of the drainage occurs with all fungi. Spread is also possible via the re-circulation water. In addition to infected hands and tools also pets can spread fungi.

**Cylindrocarpon destructans**
This is a commonly occurring parasite attacking weak plants. It may be a pathogen in a number of crops, including rose. This particularly happens when the crop is under stress conditions and humid conditions promote infection. Optimum growing temperature of the soil fungus is 20-21°C.

**Cylindrocladium scoparium** *(Photo 44)*
This frequently occurring fungus may lead to problems in a great number of crops. Apart from root rot also foot rot and even leaf spots occur. With foot rot the part of the plant base in the substrate shows cracks and becomes dark-brown to black. The plant tissue under the bark decomposes. To survive the plant sometimes produces new tissue just above the infected spot, but mostly the plant dies. For the development of leaf spots humid conditions are necessary, so that the propagation phase is a vulnerable period. The optimum temperature for fungal growth is 25 to 30°C. Spread of the fungus can also take place through the air. The fungus also produces forms that can survive low temperatures for several weeks and retain their germinative power in the soil for several years.

**Gnomonia radicicola** *(Photo 45)*
As far as we know this fungus only attacks roses. Problems usually occur in crops on their own roots and to-date only in substrate grown crops. As the crop gets older and shows more vigour, a subterranean infection will show less or even no aerial symptoms at all and these symptoms may disappear completely. Nevertheless, the flower production may then decline with 10-30%. Therefore the roots must always be examined when yields are disappointing. Optimal growing temperature for the fungus is 21 to 23°C. As a rule, symptoms may become visible from six months after planting.

**Phytophthora sp.**
This fungus, which has as yet no official name, is capable of infecting well-growing crops. As far as we know this fungus only attacks roses and problems only occur in substrate crops. Because the infection remains limited to the roots, recovery is possible. In experiments with roses on rockwool the aerial symptoms gradually disappeared after 3 to 4 months after planting on infected slabs. Especially in a recently planted crop clear, aerial symptoms are possible. The fungus spreads via zoospores, moisture being necessary. When the substrate is wetter, more root rot develops and the change of recovery becomes smaller. Optimal temperature for fungal growth is 25 to 27°C.

**Pythium sp.**
Pythium sp. are common soil fungi known as ‘weakness’ pathogens, thriving on moisture. Unfavourable growing conditions may lead to Pythium infection. Optimum temperature for infection is around 20°C. The fungus spreads via zoospores. These spores can move in water and settle on plant material. After some time the spores may germinate and infect new plants.
Control measures
A clean start is a prerequisite. Use disease-free material, soil, irrigation water (reservoir, surface and re-circulation water), growing system and glasshouse construction. The effectivity of disinfecting a growing system (gutters, trays, drippers and ducts) becomes higher as all root remnants, algae and other organic material are removed. Use an adequately permeable disinfected soil and avoid introducing infected soil particles into the glasshouse via soil tillage equipment, tools, hands and shoes. Place a permanent disinfecting tray at the glasshouse entrance. Keep pets, such as cats and dogs, outside the glasshouse.

To disinfect water against all soil fungi the following methods can be used: heating, UV, ozone, and hydrogen peroxide. Slow sand and lava filtration are only suitable against Phytophthora and Pythium.

When switching to substrate the growing system should be placed on a disease-free subsoil. Covering the soil is sometimes not sufficient to prevent disease. First a top layer of about 10 cm should be disinfected. In case of infection the cause should be first determined, subsequently control measures can be taken. Use the recommended compounds.

9.6 VIRUS DISEASES (Photo 46)
Virus diseases are rarely a problem in glasshouse roses in The Netherlands. For the sake of completeness 2 virus diseases are described, viz. mosaic and vein mosaic mottle virus.

Mosaic
Mosaic is caused by the necrotic ring spot virus of Prunus. Infection takes place by vegetatively propagated rootstocks (Rosa indica major and Rosa manettii) or infected propagation wood. Use virus-free rootstocks only and plant healthy plants only.

Vein mosaic mottle virus
The leaves show chlorotic speckiness or sometimes mottle. The plant lags behind in growth Symptoms occur locally. Vein mosaic mottle is transmitted by the free-living root nematode Xiphinema diversicaudatum. When changing crops the soil should be sterilized.

9.7 BIOLOGICAL AND INTEGRATED PEST MANAGEMENT
Biological control of pests and diseases involves control using natural enemies and natural crop protection agents, including predators, parasites and micro-organisms. Total biological control in current rose cultivation is difficult. Ventilators should be equipped with mesh and air humidifiers should be installed to improve the climate for the natural predators. Both the costs of these measures and the high infection pressure mean that in the Netherlands glasshouses total biocontrol is rare. Natural enemies of the pests have been mentioned in the relevant sections on the various pests and diseases discussed above. Integrated pest management involves the use of crop protection techniques and strategies in which chemical control is the final resort. Guided control, cultivational and hygienic measures, mechanical and biological control, and corrective chemical control, are all components of integrated pest management. Practical experience on integrated pest
management under the supervision of suppliers, consultants and researchers is being carried out and the results are positive.

Guided control involves intervention in the development of a pest or disease. The right moment to intervene is the point at which the costs of crop damage exceed those of control. It is therefore not a technique but a method and the point of intervention is also called damage threshold. Using guided control considerable savings on the quantity of chemical pesticides can be realised.

In the application of integrated pest management growers should take the following points into consideration:

**Scouting**
Observation, also called scouting, is an important tool in both biological and integrated pest management. The observations are carried out preferably on fixed places at a fixed time. Pests and diseases should be recognised by the scout, who should also be able to determine how the pest or disease develops or spreads. In addition the scout observes whether the beneficial organisms do their job, or what the result is of previous controls. On the basis of these observations a strategy for further control is decided upon. The grower and/or scout should know which compounds can be used, if and when chemical control is carried out and how to avoid negative effects on the effectivity of the beneficial organisms.

**Cultivational measures**
Measures with a crop-protecting/pest controlling effect are called cultivational measures. A good example is the use of resistant and tolerant varieties. There are only few rose varieties with a resistance against a certain pest. It is clear, on the other hand, that there are differences in tolerance to certain pests and diseases. Examples are variety differences in sensitivity to mildew, Botrytis and whitefly. If a grower sees to it that the crop grows well, problems will often be less severe. Try to avoid large temperature fluctuations, so that the crop does not become wet and fungi do not get a chance. If water supply is limited, soil fungi will not thrive.

**Hygienic measures**
Measures inactivating infection sources and preventing the dispersal of pests and diseases, are known as hygienic measures. Remove crop debris on which, for example, Botrytis might develop. Remove weeds on which diseases and pests might survive. Clean tools regularly, preventing spread of pests and diseases. Always start a crop clean and use clean young plant material preferably inspected and provided with a certificate of the NAKB (General Netherlands Inspection Service). Should the material not meet the requirements action can be taken.

**Mechanical control**
Mechanical pest and disease control is by mechanical means. Insects are kept out by mesh in the ventilators. The soil or the substrate can be covered. Catching lamps and sticky traps can be used to catch winged insects. Infected plants and plant parts can be removed, transported in a bag and taken away. An example is a local infection of aphids. Cut away branches covered with aphids, before the winged specimens disperse.
Biological control

The use of natural enemies against pests and diseases is called biological control. Examples of possible biological control are mentioned in the previous section with the corresponding pest. Obviously the recommendations of the supplier on how and under what circumstances the natural enemies should be used, should be adhered to. Try to monitor the effectivity of the natural enemy. Should chemical control still be necessary, natural compounds should be used leaving the biological control intact as much as possible.

Chemical control

Integrated pest management uses chemical control only correctively. When chemical control proves to be necessary, selective compounds should preferably be selected, with only a short after effect. Natural enemies can then be used again soon after application.

9.8 PHYSIOLOGICAL DISORDERS

Physiological disorders are visual symptoms, often caused by sudden changes in climatic conditions and availability, uptake and distribution of water and/or nutrients.

9.8.1 Bullheads (Photo 47)

Bullheads are flower buds with a deviating length/width ratio. This is caused by an increased number of petals with a narrow and blunt shape. The ornamental value of the flower declines because frequently the flowers do not fully open.

Other characteristics of the bullheads are less well visible. In normal flowers there is a non-functional nectary between the stamina and the ovary. In bullheads this nectary is absent. In normal flowers, during differentiation of the carpels an invagination of the receptacle is formed, while in the malformed bullheads the receptacle remains flat. The following factors have been suggested as the cause for the flat shape of the flower:

1. Due the greater number of petals, the inner petals are responsible for the inadequate opening of the outer ones.
2. The shape is the result of the abnormally increased size of receptacle
3. Both 1 and 2 play a role.

Causes of the development of bullheads

Temperature

Low temperatures increase the number of petals, resulting in more bullheads. A low temperature during differentiation of the petals should therefore be avoided. In various experiments, a temperature of 12-15°C was considered too low. A continuously higher temperature (20-24°C) leads to a decline in the number of bullheads. Temperature is known to affect not only the number of petals but also the number of stamina. This effect, however, is not necessarily related to the development of bullheads. Research conducted with the variety Motrea shows, on the other hand, that high temperatures during leaf and flower initiation of the rose shoot stimulate the formation of bullheads. It is not clear however whether the bullhead definition holds for the deviating flower bud observed in Motrea. In this variety, green leaflets are visible in the heart of the flower bud. During the elongation phase of the stem and the flower formation low
temperatures promote the formation of bullheads. Research results indicated that higher
day and night temperatures lead to a lower percentage of bullheads. A higher (day and)
night temperature results in a more rapid development in all flushes than a lower
temperature. Product quality however, should not be neglected, since firmness declines
with higher temperatures.

**Pruning**

Pruning method combined with a subsequent low temperature clearly affects the formation
of bullheads. In experiments carried out so far, results indicated that cutting on a low
internode of a harvestable stem promotes the formation of bullheads. An exact description
of how far to cut back, is usually not given. Only once it is mentioned that cutting was
done on the third internode (with three dormant buds beneath the cut).

**Varieties**

The most obvious cause of bullhead formation seems to be the choice of variety. There are
large differences between varieties in the development of bullheads and flower bud
atrophy. It is therefore obvious that the bullhead formation has a genetical component.
Large flowered varieties are more sensitive to unfavourable temperatures, light and pruning
methods than Floribunda types. In Norwegian research 7 different varieties were grown.
Bullhead formation in Baccara, Garnette, Zorina and Carol could be ascribed to the low
temperature. The other cultivars (Dr A.J. Verhage, Super Star and Fire King) were
insensitive. Baccara was the most sensitive, which means that in the genus Rosa there
must be a genetic influence for the sensitivity for bullheads.

**Rootstocks**

As yet, little research has been done into the effect of rootstocks on the development of
bullheads. Only in The Netherlands the conclusion was reached that the use of rootstocks
with Baccara grown under the same conditions, gave differences in the number of
bullheads formed.

9.8.2 Black flower edges

In a number of varieties rather suddenly black, brown, or ‘blue’ edges may appear on the
petals. Usually initiation of this phenomenon is visible just before cutting, but more often
the problem becomes manifest only after harvest. During vase life these edges may
completely annihilate the ornamental value of the rose. Exploratory research did not clarify
the cause. Microscopic investigation indicated that the inner cell layers of the petal die, but
it is not clear how and why. It is clear, though, that the problem mainly occurs with red
varieties. It often starts in late spring, with rapid transitions from moderate temperatures
and relatively low light intensity to bright and warm weather, combined with cool nights.
The problem is observed in both soil-grown crops and in substrates.
In the US a relationship with calcium deficiency has been demonstrated. This has also been
demonstrated in The Netherlands, where additional leaf problems were observed with low
calcium levels (see calcium deficiency). Seasonal influences (periods with a high irradiation
lead to more problems), however, appear to be of equal importance.
The only advice for this problem is to apply a thin layer of lime on the greenhouse or
screen when a variety sensitive to black edges is grown, and large weather fluctuations are
expected. In addition, great differences between the day and night temperature should be avoided.

9.8.3 Brown flowers

In a number of red varieties - mostly in wintertime - discoloration occur of the outer petals. Initially a brown 'blush' is visible on the bud, not to be confused with the black shade frequently observed on red buds, which does not cause problems during vase life. The brown discoloration continues during vase life. Buds do not open fully and flowers become brown or black, leading to a total loss of ornamental value. A short experiment indicated that low light intensities during winter aggravate the problem. In addition, in buds showing problems a lower sugar and starch content is measured than in buds without brown discoloration. Microscopically it can be observed that initially the outer cell walls are affected (especially the sub-epidermis), demonstrating that this problem differs substantially from the problem of black edges (9.8.3).

9.8.4 Petal blackening

There are a few red varieties that show a black sheen especially in spring, on the outside of the bud. The problem appears to be more severe after several days of high irradiation. Also in areas with more sunshine such as the growing areas in Africa, India and South and Central America it is more frequent. In the end this discoloration does not lead to clear damage, but it reduces the ornamental value. It seems to be caused by an increased sensitivity to UV light. Greenhouses with acrylate and polyethylene cover give more problems, because more UV light is transmitted. Lime-shading or screens may help, but these measures also limit the amount of light, adversely affecting production.

9.8.5 Humidity leaflets (Photo 48)

The cause of the humidity leaflets is not always clear. They seem mainly to be a result of large climate fluctuations in spring and fall. The young, non-lignified tissue is probably particularly sensitive to sudden low relative humidity conditions, inducing turgor loss. If this situation continues for a longer time, or if the turgor loss is severe, irreversible damage i.e. cell death may occur, particularly on the edges of the leaf. Since the scorching occurs at the edges of the leaflets, and the dead cells do not grow along with the rest, the leaflets often have a bulging and round appearance. There are differences in sensitivity to humidity leaflets between varieties.
10. QUALITY CONTROL SYSTEMS

Quality control systems are developed to assist the grower in controlling and optimising complete management of the whole nursery. This comprises all processes, from purchase and/or production of young plant material, to marketing the finished product. Implementation of quality control may provide clear advantages. Good insight into the total business operations, both in a qualitative and in a quantitative sense, can enhance staff motivation, create uniform working protocols and save costs. Tasks, responsibilities and competence become clear (Table 50).

Table 50. Scheme of tasks, responsibilities and competence (TRC-scheme)
+ = main responsibility
0 = qualified to advise
x = responsible if + is absent (deputy)
e = executive

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<td></td>
<td></td>
</tr>
<tr>
<td>Control harvest</td>
<td>+</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grading</td>
<td>x</td>
<td></td>
<td>+</td>
<td></td>
<td>O</td>
<td></td>
</tr>
</tbody>
</table>

When accurate information is available about the product (for example, weight, length) and production method (for example, environmentally friendly grown, number of stems per bunch) accurate information and guarantees can be given to the market and consumer. Quality control may create more flexibility with respect to the changing market demands and increase uniform quality and additionally be able to provide guarantees for this. A quality control system enhances the reliability of the supplier (grower). The reactions in the market to developments in quality control systems are positive.

Anticipation of developments in the market is essential for the continuity of glasshouse production. Growers' associations are formed, both in floriculture and in the vegetable sector to tackle specific (market) demands. Quality control systems are a means for these associations to support targets and provide guarantees, both to the markets and to the members. Mutual arrangements, for example, about growing regulations and quality policy, become part of the control system. Figure 24 gives an example of the quality system for maintenance, complaint treatment/improvement processes.
Figure 24. Example of control of the quality system for maintenance, complaint treatment/improvement processes

Quality control system Rose

Process Harvesting and Processing

Preparation

Instruction employees

Harvesting

Work instruction harvesting

Implement changes and correct employees

Implement changes and correct staff

Check working method and product

Check working method and product

Place in water and cool

Pack and place in water

Transport to processing area

Prepare trolleys

Cold storage

End of procedure harvest and processing, followed by order operating procedure

Is product quality satisfactory?

Yes

No.

Remove product from batch

Correct harvest Workers

Reclassify product?

Yes

No

destroy product

Hang in bunching machine

End of procedure harvest & processing

if no bunching machine available, describe alternative way of bunching and packing
In the quality control system the quality of the production process and of the product can be monitored, but also optimisation of labour conditions and environmental care can be included. Controlling and recording operational procedures provides a basis for agreements, which can then be implemented and used as a product guarantee. A quality control system then develops into a continuous process of improvement.

In a quality control system, each business can give specific interpretation to:
- agreements on tasks, responsibilities and competence.
- agreements on working methods: what should be done in which way, by whom and when.

The process of setting up a quality control system is done in stages. Operational processes are analysed and optimised step by step, often under the supervision of trained external consultants. It is vital to involve everyone in the business. Various activities are carried out in a project, such as beginners’ training for participating growers and their staff, a so-called zero-measurement and individual guidance and group meetings.

The starting point for development of systems include the international standard for quality, ISO 9002. A fully implemented system may eventually lead to the certification, as business and/or growers’ association.
11. BIOLOGICAL CULTIVATION

Consumers prefer products that are grown in an environmentally friendly way. Biological cultivation may be an answer to this although biological cultivation is more than just biological control (section 9.7) of pests and diseases. The Dutch government stimulates the move to biological cultivation.

Biological cultivation is understood to mean a crop, in which the sensitivity to pests and diseases is limited in such a way, by biological balance in the soil, that chemical control is no longer necessary. This balance in the soil is reached by well-balanced organic fertilization, combined with a rich aerobic soil life of micro-organisms, that may be responsible for high yield and high quality. The application of chemical pesticides as well as artificial fertilizers is forbidden in this cropping method.

In addition to biological cultivation, integrated cultivation is currently used in horticulture. Integrated cultivation has fewer restrictions when compared to biological cultivation, and is based on technical possibilities (for example the use of plastics and artificial media as substrates) to obtain an economic optimum in management.

Biological cultivation, on the other hand, demands certain adjustments before a grower can comply with the standardisation for the certificate of the biological produce.

11.1 CHANGE-OVER TO BIOLOGICAL CULTIVATION

Several general measures can be taken in order to change-over to biological cultivation. These are related to maintenance or improvement of soil fertility and the biological activity of the soil. Growing in an inert substrate is prohibited in biological cultivation. Some general measures are:

1. The growing of legumes, green manure crops and deep-rooting crops as a preceding crop
2. The inclusion in the soil of organic material in composted or uncomposted state, originating from biological holdings
3. The control of parasites, diseases and weeds by a combination of measures, such as selecting suitable varieties, fitting a crop rotation scheme, use of natural enemies of parasites and (mechanical) weed control;
4. The application of biological compounds, according to the EU-regulation 'Biological products'
5. The use of biologically-grown starting material

In the Netherlands biological cultivation of roses is still very limited. The EU-guidelines for biological agriculture indicate that in general the change-over period from traditional rose cultivation to biological rose cultivation is 2 years, i.e. 2 years after the start of the biological cultivation can the produce be traded with the EKO-certificate. The EKO-certificate is a certificate issued by the Dutch control organisation SKAL if the cultivation method meets the guidelines of biological cultivation.

For flower growing (short duration) the change-over period can be reduced to 6 months or 1 year. SKAL finally determines from which moment on the produce may be marketed as
‘biologically grown’. In the intermediate period the produce may be traded as originating from a change-over holding. Organic fertilization, scouting for pests (see 9.7) and using natural enemies may help keep the change-over period as short as possible.

11.2 CHOICE OF VARIETY

In principle all rose varieties from the current traditional cropping methods can be used in biological cultivation. In practice differences have been observed among varieties in sensitivity to pests and diseases. This can be taken into consideration in the selection of a variety for the biological crop. Important criteria to consider are:

- tolerance for powdery mildew;
- reduced sensitivity for Botrytis (crop and flower bud);
- less attractive to insects such as whiteflies, thrips and aphids;
- less sensitive to soil fungi and nematodes (also important for rootstock selection);
- good possibilities for propagation on rootstock; for soil-grown crops use of rootstock is recommended.

It will be difficult to find varieties that meet all criteria. However, once the weak points of a variety are known these can be taken into account. A few varieties with positive characteristics: First Red, Texas, Kiss, Ambiance, Starlite, Femma, Emerald, Lambada, Black Beauty, Escimo, Bianca, and Vivian (spray) and the Prophyta-types. The breeders or their sales representatives may point out to the grower which variety can be recommended for which cultivation method. Preferably the recommended varieties should be grown experimentally at the expense of the breeding company. This has the additional advantage that demand for diversity can be better anticipated. As long as biological cultivation is so limited in volume, growers will plant more than one variety.

11.3 FERTILIZATION

Biological cultivation is obliged to use organic fertilizers from biological agriculture or horticulture. However, when not enough of this specific organic manure is available, manure from traditional agriculture/horticulture may be used. There are several types of organic manure available suitable for application. In addition to cow, pig and chicken manure as base dressing, bone meal, vinasse (extracts), Nakamag and Kieseriet are examples of what is allowed. Top dressing can also be applied in the form of blood meal, horn meal, feather meal, Siapton and Aminogreen. In addition there are several composite organic fertilizers such as FAForiet, Biotrissol, DCM, Guano and Cofuna, but also biowaste compost, dried animal manure and mealworm manure. The use of urea is prohibited.

About 50% of the nitrogen in stable manure is released during the first year, when using blood meal all is released in the first year. Good phosphate fertilization is only possible prior to cropping an a top dressing is virtually useless due to the poor solubility. The average annual uptake of fertilizers by a rose crop in soil when biological fertilizers are applied is given in Table 51.
Table 51. Average annual uptake of fertilizers in a rose crop in soil when biological fertilizers are used

<table>
<thead>
<tr>
<th>Uptake kg/ha/yr</th>
<th>N</th>
<th>P₂O₅</th>
<th>K₂O</th>
<th>MgO</th>
<th>CaO</th>
<th>SO₃</th>
<th>Na₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAF 9-3-3 73 kg/are</td>
<td>656</td>
<td>240</td>
<td>833</td>
<td>154</td>
<td>593</td>
<td>308</td>
<td>110</td>
</tr>
<tr>
<td>Sulphate of potash and magnesium 20 kg/are</td>
<td>656</td>
<td>219</td>
<td>219</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>614</td>
<td>200</td>
<td></td>
<td></td>
<td></td>
<td>1,000</td>
</tr>
</tbody>
</table>

11.4 CROP PROTECTION

The idea behind biological cultivation is that a strong (well-growing) crop is less sensitive to pests and diseases. All activities are therefore aimed at creating a steadily growing, strong crop. Many diseases are, however, soil-bound and may pose a serious problem when in several successive cropping periods the same crops are grown in the same soil, this being aggravated when the soil has a poor structure. Improvement of the structure and stimulating soil life are important measures to avoid problems.

Basically steam sterilisation is permitted, but it may soon be expected that standardisation will prescribe a maximum of once every 6 or 8 years. Plant extracts with a preventative effect, that are on the list of the EU regulation may be used as pesticide, on the condition that they are registered according to Dutch law, for example Neem and garlic extract.

Examples of measures to control some important pests and diseases:
- root knot nematode
  - steam-sterilising
  - nematode-killing fungus *Artrobotrys* (no experimental evidence for effectiveness)
- free-living root nematodes and root lesion nematodes
  - healthy plant material
  - steam-sterilising the soil
- leaf aphids
  - avoidance excessive growth
  - use of natural enemies
  - Savona, a compound based on soap
  - Natural pyrethrins, e.g. Spruzit
  - Insect mesh
- black vine weevil
  - control of larvae with nematodes of *Heterorhabditis* and *Steinerema carpocapsae*
• removal of soil and plants with larvae
  - millipedes
  • a drier climate
  - caterpillars
  • bacterial preparation Bacillus thuringiensis
  • insect mesh
  • catching lamp with water tray
  • application of pheromones (still being investigated)
  • natural enemies, such as predatory wasp Trichogramma

• mildew
  • variety selection
  • preventive sulphur application
  • application of Milsana
  • application of Vital/Algan

• Verticillium
  • steam-sterilization of the soil
  • avoidance of wet spots in soil

• Pythium
  • good soil structure
  • varied soil life

• Rhizoctonia
  • good soil structure
  • open crop
  • no water supply at high temperatures
  • removal of infected material

• Botrytis
  • open crop
  • avoidance of crop damage
  • removal of infected material
  • good climate control
  • steady growth
  • biological control (still under investigation)

• whitefly
  • use of biological control
  • insect meshing
  • pyrethrine (Spruzit)
  • Savona (soap)
In addition to these measures a good monitoring system with sticky traps is very important.

11.5 INFORMATION

Various agencies are active in consultancy on biological cultivation. There is also a growers’ association (SKAL) which is the control organisation also involved in the standardisation of cultivation method for biological cultivation.

Addresses:
SKAL: Control Organization for Biological Production Methods
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8000 AJ Zwolle
The Netherlands
Telephone +31 (0)38 – 4226866
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