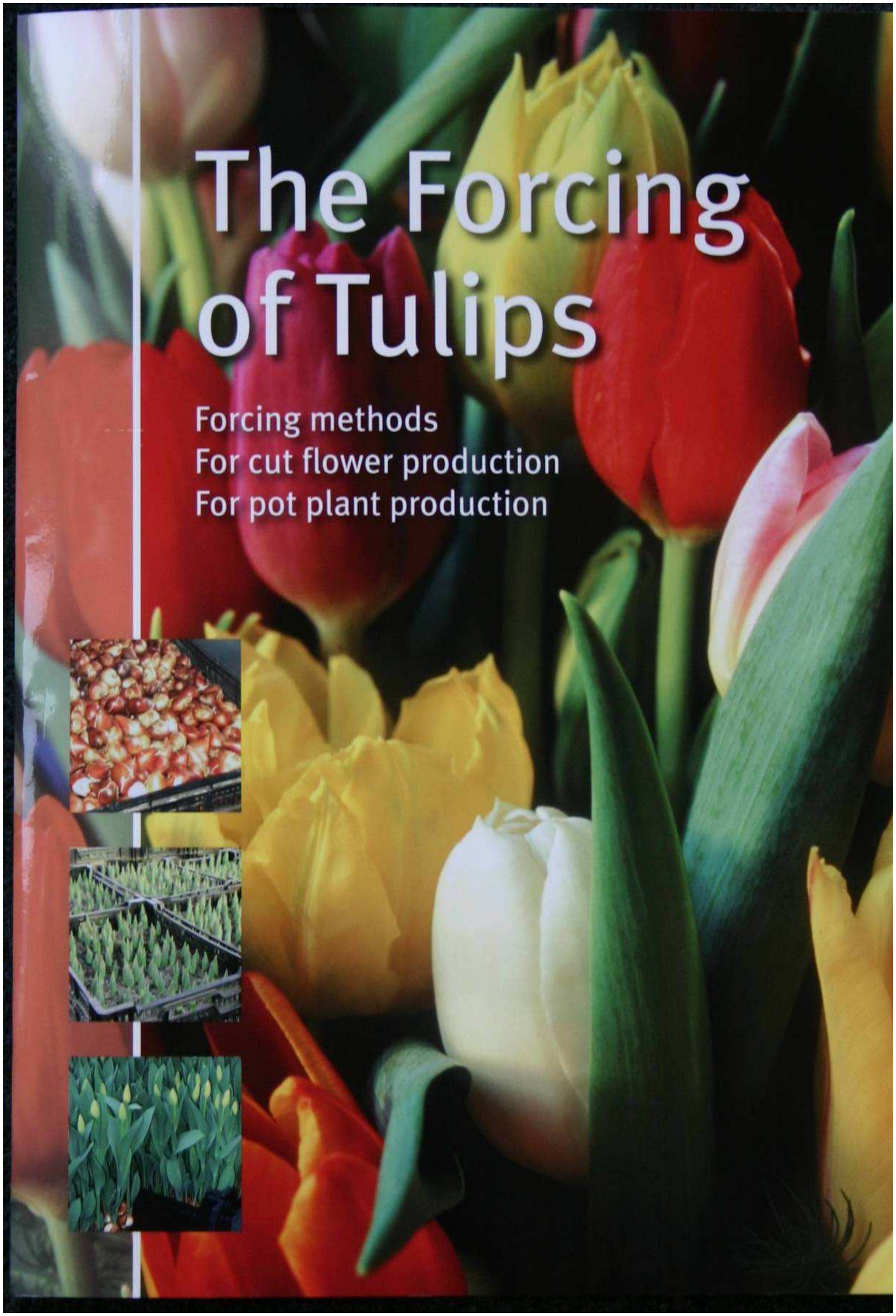
The Forcing of Tulips
Forcing methods
For cut flower production
For pot plant production

Accountability

The information in this booklet was based on data taken from several publications and brochures issued by Dutch research and communications agencies and the International Flower Bulb Centre (IBC). The author has attempted to supplement this information as carefully as possible with current insights and his own knowledge of tulip forcing. The result is a highly up-to-date booklet on this subject. In comparison to previous publications, this booklet includes a great deal of important supplementary information related to pot plant production, and the information about hydroponic tulip forcing is entirely new.

It is still important to discuss production methods thoroughly with your supplier. You can also contact your supplier for information you might want to have in regard to other production methods. The content of this booklet is aimed chiefly at providing basic knowledge and background information.

This information applies to cool and temperate climate zones.

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1. Introduction

1.1 Tulips

With a history of more than 400 years, the tulip has become one of the world's most important ornamental plants. Over the centuries, intensive hybridisation conducted primarily by growers in the Netherlands has resulted in strong and beautiful tulip cultivars. These cultivars, in many colours and shapes, are much-appreciated spring flowers in gardens and parks. The majority of tulip bulbs are, however, used for the production of cut flowers and, to a lesser extent, pot plants. Bulb production is still conducted in the Netherlands due to its favourable climate and high degree of professional expertise. Research and the distribution of information are subject to high standards. Production and trading companies use the very latest production and preparation technologies in order to supply the entire world with excellent products.

1.2 Botanical classification

Within the plant kingdom, tulips belong to the lily family (Liliaceae). Many bulbous plants such as Lilium, Hyacinthus, Muscari, Ornithogalum, Fritillaria, etc. belong to the Liliaceae. Characteristics of this family are that its members produce a flower with 6 petals and six stamens and that their seedpods are later formed above the base of the flower.

The tulip is also a bulbous plant. Its bulb is made up of scales growing from the base plate. These scales surround the apical meristem located in the middle of the bulb. The apical meristem develops gradually; this starts during the summer and lasts until the tulip produces its flower in the spring (or earlier if the tulips are forced). The assortment of tulips can be arranged alphabetically but is often encountered grouped into classes. Tulips used for forcing are found mainly in the following classes: Single Early, Double Early, Triumph, Darwin Hybrids, Parrot, Lily-Flowered, Single Late and Double Late.

1.3 Forcing tulips

Theoretically, tulips can be brought into flower year round. The most popular periods, however, are winter and early spring, previous to the time they would normally flower outside. To force good tulips, it is very important that the customer inform the supplier long enough in advance as to exactly which tulips he wants to force and when he wants to force them. This is because the treatment of the bulbs starts long before delivery (even immediately following the lifting of the bulbs) and has to be coordinated with the desired flowering period. There are also many different methods used for forcing (see Chapter 2). The tulip assortment includes thousands of varieties. Several hundred of these are used for forcing (some varieties being more commonly used than others). Suppliers have information about which varieties are best for forcing in certain periods of time, and also which forcing methods to use. Suppliers can also provide visual material that shows the individual varieties and lists their characteristics. It is also important that the supplier be provided with the climate data for the location where the tulips will be forced, and that he knows about what kind of facilities the customer has. Make sure that you have the time and capabilities to provide adequate handling of the bulbs at the time they are delivered.

1.4 Preparation of the bulbs after receipt

Upon receiving flower bulbs, you should remember that tulips are never physiologically dormant. They are living plants; growth continuing inside the bulb involves the production of moisture and the need for oxygen.

Unpacking the bulbs quickly after receipt is extremely important. They are usually delivered exactly at the time they should be planted. If the bulbs have to be stored for some time, this should be done under dry, properly ventilated conditions. The storage temperature will depend on the development stage of the bulbs and how soon (or how much later) the bulbs are to be forced. The farther along the bulbs are in their development, the lower the storage temperature should be. Refrigerated bulbs will always have to be stored under refrigerated conditions. If the bulbs should not receive any more cold treatment, 20°C is a good storage temperature until around mid-October at which time the temperature can be reduced to 17°C. Tulip bulbs are very susceptible to damage resulting from certain gases such as ethylene. For this reason, never store them in the presence of exhaust gases and/or fruit. Ensure that the tulip bulbs will receive enough fresh air. The point of departure in all this is that you continue to follow the supplier's instructions to the letter. Consult with your supplier if you have any questions. Always make sure that you have made the necessary preparations for production so that you are ready to start when the bulbs arrive.

1.5 Bulb sizes

During bulb production, main bulbs develop into bulbs large enough to produce a properly flowering plant. In the flower bulb trade, the sizes of these bulbs are given as the number of centimetres in circumference. The largest bulb size used in the trading of tulip bulbs is sieve size 12/+. Bulbs of this size have accumulated the greatest amount of reserve nutrients and will thus produce the largest flowers and be the most suitable for the earliest flowering period. Sieve size 11/12 is also commonly used, and so is sieve size 10/11, although the plants these bulbs produce will be noticeably lighter in weight.

2. The various methods of tulip flower production

2.1 Tulips must undergo a cold period

After lifting, the bulbs must first be subjected to sufficient warmth for proper flower initiation inside the bulb. Thereafter, the bulbs have to undergo a cold period to develop sufficient stem length and to be able to flower. In regions where the winters are cold enough, tulip bulbs planted in the field are subjected to this cold period under natural conditions.

Tulip bulbs that receive their cold treatment before the winter months can be brought into flower before their natural flowering date. This method is called forcing. Depending on the regional climate in which the tulip bulbs are produced, flowering as early as December is possible. The climate in which the bulbs are produced influences the development of the new tulip shoot until the bulbs are lifted and even afterwards.

As well as advancing the flowering time of tulips, their flowering may also be delayed. Cut tulips have been marketed as late as September, October and November for years now. These “ice tulips” are produced from bulbs that have been stored at low temperatures for an extended period of time.

Today, tulip bulbs are also produced in the Southern Hemisphere. Because these bulbs are thus six months early (or late) in their development, they can also be forced into flower in the autumn.

In order to advance the cold period, the bulbs are subjected to a number of temperature treatments. It is vital, in this process, that the bulbs not be cooled until the flower has been fully initiated inside the bulb, and in many cases, quite a while after this.

Cooling temperatures for tulips are 9°C and colder. Applying different temperatures will yield different results. Higher temperatures, for example, will mean:

- shorter flower stems
- a longer greenhouse period
- faster growth of stem and roots

There are various methods to produce tulips. They can be forced in trays filled with soil, forced in trays filled with water, forced in de border soil of the greenhouse, forced in pots, delayed in trays when using ice tulips or by using tulips from the Southern Hemisphere, and, finally, by means of field production. Each of these methods relies on one or more cold treatments. A diagram of these treatments is shown in Figure 1.

2.2 Forcing 9°C (pre-cooled) and uncooled tulips in trays filled with soil

Bulbs are planted in trays filled with soil and are then stored in a rooting room or buried in a standing ground. These methods, in which the bulbs receive their entire cold period in the rooting room or outside under natural conditions, produce “uncooled tulips”. Part of the cold treatment can also be applied to dry bulbs (9°C tulips) before they are planted in trays. After planting, their cold treatment will be resumed until completed.

2.3 Forcing pre-cooled tulips in hydroponic trays

This relatively new method has currently become one of the more commonly used forcing methods. For hydroponic forcing, the bulbs are always pre-cooled in a dry state and do not develop roots until the last weeks of the cold period when they are placed in hydroponic trays and left in a rooting room. They are then forced in the greenhouse.

2.4 Forcing 5°C tulips in the border soil of the greenhouse

In this method, dry bulbs are subjected to their entire cold treatment while stored in a cold room at 5°C or 2°C. Immediately following this cold treatment, the bulbs are planted in the greenhouse for flower production.

2.5 Forcing 9°C (pre-cooled) and uncooled tulips in de border soil of the greenhouse

Uncooled tulips receive most or all of their cold period in an unheated greenhouse. When forcing 9°C tulips, the dry bulbs receive part of their cold treatment in the cold room kept at 9°C.

2.6 Forcing tulips in pots

Instead of forcing tulips for cut flower production, they can also be used to produce flowering bulbous plants in pots. The method used is essentially the same as when forcing the bulbs in trays filled with soil. For pot production, however, once the bulbs are planted in pots they receive a shorter cold period in order to keep the tulips from growing as tall.

2.7 Delayed flowering when planting in trays

There are two methods used to obtain delayed flowering. The first is to use ice tulips. (The second is to use tulip bulbs produced in the Southern Hemisphere.)
In the first method, the tulips are planted in trays in October/November and left to root for 2 to 4 weeks at 9°C. After completing the rooting phase, the trays holding the planted bulbs are frozen and stored at -1.5 to -2°C. In order to prevent the trays from drying out, they are usually wrapped in plastic. Starting in September, these trays are generally placed in the greenhouse or in a cool place outside where the bulbs will flower.
This method is used to force a limited number of tulip varieties during the autumn. Unfortunately, the use of this method somewhat reduces both the quality of the flower and its keeping quality.
Flower bulbs produced in the Southern Hemisphere can also be delayed. Because their development is six months earlier or later, forcing them in the autumn will produce tulips of good quality. Since delaying the flowering of bulbs is not used nearly as much as advancing, these delaying methods are not discussed in detail here. If you want more information, you can **ask your supplier** for it.

2.8 Field production of tulips

Tulip bulbs can also be planted in the field for the purpose of cut flower production. To be successful, the winter has to be cold enough to terminate the bulb's "dormancy" and induce proper growth. Flowering will occur primarily in April and May. A certain amount of advancing can be done by covering the soil with canvas or plastic sheeting after the winter period. This production method will not be addressed in detail here.

3. Temperature treatment for flower development

3.1 Temperature treatment is usually conducted in the Netherlands

Tulips can be delivered to forcing facilities at any time. In general, however, suppliers deliver them when the bulbs are ready for planting or just before then. (But they can also be sent even earlier.) The dry warm storage given previous to the cold period is highly specialised work. The use of ventilation and circulation to control such insects as gall mites is particularly important. Maintaining the proper temperature is also important, and this means that the storage rooms have to be equipped with both heating and cooling systems. The most commonly used temperatures during the warm period are 20°C until 15 October and then 17°C thereafter. What is known as the intermediate temperature is also supplied as part of this warm period. As the bulbs' shoots lengthen, the temperature has to be kept lower. If the tulips are subjected to warmth for too long, the flower bud in the bulb will desiccate (also known as "heating"). This means that for batches of bulbs receiving the standard temperature treatment, maintaining the temperature at 17°C must not extend past mid-November. This is when the cold period must begin. There are then usually two possibilities: either plant the bulbs under cold conditions, or keep them in the dry state and maintain a temperature of 1 to 2°C. For certain purposes and for certain cultivars, better results are obtained by applying other temperatures. Your bulb supplier knows more about this. You must therefore consider the information in this chapter as being primarily background information.

3.2 Stage G

The new shoot inside the tulip bulb develops quite soon. The leaf, and later the flower, are formed shortly before and after the bulbs are harvested. The time at which the flower has fully developed inside the bulb is called "Stage G" ("G" being an abbreviation for the Greek word *Gynoecium*, meaning pistil).

Since the development of the leaf takes place largely below ground (before harvesting), the climate conditions during the growing season influence the rate at which this takes place and indirectly affect the subsequent phase and the time at which Stage G is reached.

Of crucial importance for the proper treatment of tulip bulbs for early forcing is to start the 5°C or 9°C treatment at the right time. This must take place after the bulbs have been subjected to the required minimum period at the intermediate temperature. If the cold period is started too soon, this may result in damage. Yet starting too late means losing valuable time.

If Stage G is reached later in the season, flower growers must expect that pre-cooled 9°C tulip bulbs being used for forcing in trays and the early 5°C tulip bulbs destined for field cultivation will be supplied later and will flower later.

3.3 Intermediate temperature

The intermediate temperature is the temperature at which the tulip bulbs (either dry or planted) are maintained from the time the flower is fully developed inside the bulb (i.e. when Stage G has been reached) until the start of the cold period. The optimum intermediate temperature is 20°C. This treatment promotes root growth and will prevent flower blast in most species. On 15 October, the intermediate temperature is reduced to 17°C. The minimum duration of the intermediate temperature treatment depends on the production method and the characteristics of the particular cultivar. It is advisable to comply with the recommended number of weeks.

The minimum number of weeks stated here applies to bulb sizes 12/+. If bulb sizes 11/12 or 10/11 are used for forcing, the intermediate temperature must be extended by 1-1.5 or

2-3 weeks. However, since the bulbs receive the necessary intermediate temperature treatment during storage in the Netherlands, this is of no concern to flower producers.

3.4 Stage determination

The cold period may be started once Stage G has been reached and the treatment at the intermediate temperature has been completed. Unfortunately, no fixed date can be given for this period, since it depends on the stage development in that particular year and batch of bulbs. A wide range of factors plays a role in this development; these factors include the climate of the previous growing season, the time at which the bulbs were lifted, the temperature treatment provided after lifting, characteristics of the cultivar and bulb size. Use should be made of stage research to determine whether or not the flower has developed fully. To do this, carefully cut open a bulb. Take out the apical meristem without damaging it and examine it with a binocular microscope (magnification of 25 to 30 times), or, if the flower has already developed, a 10-x magnifying glass.
The following botanical terms are used internationally for the flower's organs:
P = perianth (petals)
A = anther (stamen)
G = gynoecium (pistil)

The numbers and letters given after "Stage" indicate the various stages. Plus and minus signs after the stage indicate the transitional forms between the stages.

3.5 Stage properties

Leaf formation phases:
Stage I - apical meristem flat, leaf formation
Stage II - apical meristem round, leaf formation completed
Flower formation phase:
Stage P_1 - the outer 3 perianth leaves are formed
Stage P_2 - the inner 3 perianth leaves are formed
Stage A_1 - the outer 3 anthers are formed
Stage A_2 - the inner 3 anthers are formed
Stage A_1^+ - the gynoecium is visible, but still flat
Stage G - triangular swollen ovary with stamen is formed
Stage G^+ - all flower parts, including stamen, are clearly visible

4. Forcing in trays filled with soil: advantages, cooling and scheduling

4.1 Advantages of forcing in trays

Forcing in trays is the most commonly used forcing method for tulips. There are a number of reasons for this, including:

- Forcing in trays allows for better scheduling without being too dependent upon temperatures prevailing outside.
- Forcing in trays allows better labour scheduling.
- Relatively few diseases occur due to the low temperatures in the rooting room. This is an important advantage in view of likely future restrictions or even bans on the use of pesticides.
- Reduced energy consumption due to shorter periods in the greenhouse.
- Forcing in trays achieves a higher production of tulips per m^2 per forcing season.

4.2 Cooling

The cold period ensures that the tulips develop long enough stems. It also promotes a faster growth of the crop. When forcing in trays, the bulbs receive part of the cold period in the cold room as dry bulbs [9°C (pre-cooled) tulips]. After the bulbs are planted, they receive the remainder of the cold period in the rooting room or in a standing ground. (Alternatively, the bulbs can receive the entire cold period as planted bulbs. These bulbs are then called "uncooled tulips").
The duration of this cold period depends on the cultivar, the bulb size and the scheduled date for housing. For many cultivars, the cold period used in this forcing system lasts around 15 to 16 weeks. Yet some cultivars require much longer cold periods. In actual practice, your supplier will tell when a certain cultivar can be housed or give you information about the required cold period. The number of cold week applies to bulb size 12/+. If bulb sizes 11/12 or 10/11 are used for mid-early or late flowering of cultivars also suitable for early flowering, the cold period may be reduced by 1-2 weeks. In this case, these smaller sized bulbs will produce a somewhat shorter crop. As soon as the bulbs have had the necessary cold period, the trays can be placed in the greenhouse.

Extending the cold period has both advantages and disadvantages. By extending the period by one week, the greenhouse period is shortened by a few days. Extending the cold period can save somewhat on energy, but can also result in tulips that may become too tall and too limp. This is why this should not be done when forcing cultivars that already tend to be tall and limp. When forcing short sturdy cultivars, however, the cold period can easily be extended by a few weeks. This is why certain cultivars are more appropriate for early forcing and others for late forcing.

4.3 Cooling temperature

The temperature applied during the cold phase depends on the time at which the cold treatment is given, regardless of whether the bulbs are dry or planted when being cooled. Once planted, the bulbs will always have to be maintained at a low temperature in order to prevent diseases. The following schedule can be used as a guiding principle.

Table 1. Cooling temperatures for forcing 9°C (pre-cooled) and uncooled tulips in trays.

Cooling temperature	Period
9°C	Until 20 October
7°C	20 October - 10 November
5°C	starting on 10 November
5 - 2°C	starting on 1 December
2 - 0°C (once planted, no colder than –1.5 to -2°C)	depending on shoot length

You may decide to start by subjecting the dry bulbs to the cold treatment instead of planting them immediately. Reasons for doing so are:
- cost effectiveness: cooling dry bulbs takes up less room and is therefore cheaper
- the time at which you can or wish to start the cold period (and, indirectly, the date on which you wish to bring the trays into the greenhouse).

With regard to the last point, if this time is before mid-September, the cold period could better be given to dry bulbs. This is because bulbs produce insufficient roots - if any roots at all - before mid-September.

The duration of the cold period for dry bulbs may range from 2 to 8 weeks. A cold period of less than 2 weeks is not advisable; instead, plant earlier. A cold period longer than 8 weeks may lead to problems due to the early steady development of roots and shoots. Moreover, this longer cold period under dry conditions will not leave enough time for the rooting period after planting. This is why tulips are generally not planted after 15 December.

After the tulip bulbs are planted in trays (whether or not they have been subjected to a cold period as dry bulbs), they must receive the necessary cooling in the rooting room or in a standing ground outside. Starting on 1 December, the temperature in the rooting room must be reduced, the timing of which depends on the growth of the shoot. Leave a gap of at least 1 cm between the tips of the shoots and the bottom of the tray above.

4.4 Determination of the harvesting period

Your supplier will usually indicate when the first tulips can be housed. The earliest housing date can be calculated by knowing when the bulbs reached Stage G and then adding the number of weeks the bulbs were subjected to the intermediate temperature and the number of weeks of cold they will require. A cultivar that has to spend 2 weeks at the intermediate temperature and needs another 15 weeks of cold treatment, can be housed 17 weeks after reaching Stage G. Reversibly, if you want to harvest flowers at a certain time, you will have to subtract the period spent in the greenhouse and the time spent in cold treatment to arrive at the date when the bulbs should start their cold period. For example, if the desired harvesting period is around 6 March, subtract 21

greenhouse days to arrive at a housing date of 14 February and then deduct 16 cold weeks. This will mean that the cold period must begin on 25 October.
By using this method, you can calculate when the greenhouse will be filled with a certain batch and when it will become available for the next batch. Planting is done from mid-September to mid-December. Most tulips are planted in the order in which they will be housed. Most are planted in October and November. When cultivars that produce abundant roots (e.g. 'Monte Carlo') are planted much too late, their quickly developing massive root systems can cause the bulb to rise up out of the tray. This is why it is better to plant these cultivars somewhat earlier.

5. Forcing in trays filled with soil: greenhouse, trays and rooting medium

5.1 Greenhouse

The forcing of tulips in trays does not place any special demands on the greenhouse. Greenhouses built from glass or plastic are suitable for this purpose. Tulips do not have special light requirements either since they are not heavily dependent on light for producing good results. It is preferable, however, to choose a greenhouse that is approx. 3 metres high since this makes it possible to control the environment more effectively and to fit the greenhouse with an energy screen. Another very important point to consider is proper ventilation; many suitable systems are available for this.

5.2 Space utilisation

In the greenhouse, the trays are usually placed on benches that may be made from a variety of materials. The following sizes, which have been based on the average height of people working in the greenhouse, should be used:

width of side tables	60 cm
width of other tables	120 cm
height of table	65 cm
path width	45-50 cm
width of main path, if used	200 cm

In a standard-sized greenhouse, these dimensions will provide an efficient capacity of approx. 70%. An efficient capacity of 85% may be realised if mobile staging is used. The trays may also be placed directly on the floor instead of on benches. Then, instead of removing the trays after harvesting, simply stack the next layer of trays on top. This also creates a form of “bench”.

An example of the rule of thumb used to calculate the number of trays per gross greenhouse surface area of 500m^2 (for 75% capacity use) is as follows: trays (measuring 60 x 40 cm so that 4 trays cover 1 gross m^2) multiplied by 3 times the gross greenhouse surface area = 1500 trays.
Large tulip-forcing operations are increasingly making use of mobile benches. These are usually 120 cm. wide so that they can accommodate two trays placed side by side lengthways (2 x 60 cm.). These benches are available in lengths divisible by 40 cm. and are usually no longer than 560cm. They can be placed throughout the facility so that they can be filled with trays at a certain location and also emptied again. They are usually placed along a fixed line from which the tulips can be harvested from both sides. There are also benches that are 80 cm. wide to accommodate two trays placed side by side in the other direction (2 x 40 cm.); these benches can be situated allowing harvesting from just one side.

5.3 Heating

A greenhouse heating system is absolutely vital for maintaining constant temperatures. Its capacity will depend on the normal outdoor temperatures and the desired/necessary greenhouse temperature.
For the forcing of tulips, pipe heating is preferred for its heat distribution capacities. Although forced-air heating is also suitable, the main reason it is not ideal is that its capacity for distributing air throughout the greenhouse is inadequate. The resulting temperature fluctuations will yield an uneven crop and a greater number of rejects. Temperature fluctuations may be prevented by providing horizontal air ducting. Make

sure that the forced-air heaters in the greenhouse (including the hot-air blowers and CO_2 burners) are adjusted properly. Failure to do so, or leakage from flue pipes, may mean that ethylene will be released during combustion. This presence of ethylene will result in uneven growth, slow-growing crops, and leaves with a thin surface layer of wax. Even the smallest concentration of this gas (0.1 PPM) in the greenhouse may cause great damage due to flower blast. This is why it is important to have the heater checked prior to every forcing season.

5.4 Shading

Shading is essential for climate control. Moreover, it reduces energy consumption. Although tulips do not place high demands on light, it is still a quality factor that benefits leaf colour and keeping quality. The light-sensitivity of the tulip cultivar in question is the decisive factor. Cultivars that produce a lot of foliage or tend towards a pale leaf colour are usually more susceptible to light deficiency than others. The degree of shading will depend on the range of cultivars grown and the distribution of forcing over time. The use of mobile shading systems towards the end of spring is preferred.
Although shading systems may also be used to reduce energy consumption, quality should always come first. This is why the use of mobile systems is preferred. Permanently installed shading may be used, but the material used should have an open weave. The use of non-permeable materials such as plastic sheeting increases the risk of excessive RH levels in the greenhouse. We therefore strongly discourage the use of plastic sheeting if adequate ventilation is not being provided. High relative humidity may lead to flower blast, infection with Botrytis, or leaf, stem or flower topple. To prevent this from happening, inspect carefully and ventilate in time or, when necessary, remove the sheeting or screening during the spring.

5.5 Watering

In order to meet the tulips' water requirements, the plants must be watered regularly throughout cultivation. Watering by hand or with a hose is very labour-intensive, so flower growers are increasingly changing to either fully or semi-automated systems. There are three modern watering systems: sprinkler installation, drip irrigation systems and sprinkling booms. Since not all batches of bulbs will require the same amount of water, it is essential to regulate the water given.

The greenhouse sprinkler is inexpensive and highly suitable for the initial phase of cultivation. However, the more the foliage develops, the greater the risk of disease when using this system. The increase in leaf surface means an initial increase in evaporation following watering (and thus an increase in RH in the greenhouse) but this is then followed by reduced transpiration from the plants.
When the sprinkler heads are placed over the plants, hard water will leave white marks on leaves and flowers. The disadvantages of this system may be countered by placing the sprinkler pipes between the plants, if necessary with additional shielding. The applied water can be measured relatively easily by means of cups placed throughout the greenhouse.

The drip irrigation system ensures that water is released very slowly and that the foliage remains dry. This not only reduces the occurrence of diseases, but also keeps the stems clean and uses less energy and water. The water volume can be adjusted to meet the needs of each individual tray.

When the system is first installed, the soil on the buds in the trays may be too dry for the use of the drip-irrigation system alone. In this case, you should increase moisture levels in the soil immediately after installing the unit by means of hand watering or by using a sprinkler installation.

The most commonly used drip irrigation system uses hoses. This system has hoses with openings that release not more than 1 to 4 litres of water per hour despite a high circulation rate. Accelerating the circulation rate of the water prevents blockages in the system. The hose has drip openings at regular intervals. The number of openings per tray depends on the soil structure. Peat usually requires four drip openings per tray that will release 1 litre of water per hour. Due to the pressure-compensating characteristics of the hose openings, the release of water through the first and last opening is identical.

These systems are usually automated. Depending on the size of the batches of bulbs, the greenhouse is divided into a number of watering segments. A sprinkler unit ensures that automatic watering takes place when needed.

Sprinkling booms are often used in combination with mobile benches. If the benches move automatically, the locations of the sprinkling booms are often fixed so that the benches move beneath them. Also commonly used are movable sprinkling booms that can be moved from one bay to another. The rate at which these booms pass over the benches can be set in advance.

5.6 Trays for forcing

For tulip forcing, using the right trays is vital. In practice, this usually means the use of tulip export trays. These are 60 x 40 cm plastic trays with a height of 18 cm and an inside depth of at least 8.5 cm to allow for sufficient substrate. The layer of substrate underneath the bulbs must be at least 5 cm thick. This dimension is important not only because it takes this much substrate to support the plants but also because this much substrate is needed to act as a water and oxygen buffer that will then prevent the bulbs from suffocating due to an excess of water (and thus insufficient oxygen). When not enough water is available, the tips of the petals will fade in colour ,the buds will desiccate, and the leaves will turn yellow.

Another important factor is the bottom of the tray: it has to have enough slits. Openings at the bottom of the tray means fewer roots, and this reduces the risk of Trichoderma. An insufficient number of openings carries a risk, especially in the rooting room, that the bulbs will suffocate due to higher humidity levels. Openings that are too wide (wider than 2 mm) will allow the soil to dry out and damage the shoots growing in the trays below. Too many openings in the sides may allow the soil to dry out. Always stack trays in the rooting room so that they are at least 7 cm. apart, preferably 10-11 cm. apart. Above all, the trays must be sturdy and easy to handle and to stack.

In line with an old tradition, wooden trays are sometimes still in use, but their repeated use involves a greater risk of the transfer of diseases.

5.7 Cleaning the trays

Rhizoctonia, Pythium and Olpidium (see the section on Augusta disease in Chapter 17), the causes of grey bulb rot, root rot and Augusta disease, may survive in forcing trays. Therefore, disinfect previously used wooden forcing trays and clean previously used plastic trays. To prevent damage to a later crop, disinfect the trays in plenty of time before the forcing season begins and leave to dry for a few weeks. Plastic trays are cleaned with a strong water jet - remember to clean the corners!

The risks associated with the survival of pathogens are much greater when using hydroponic forcing than when forcing in a soil substrate. For more information about the cleaning of trays, see Chapter 10, cleaning the forcing containers.

5.8 The rooting medium (substrate/potting soil)

The substrate most commonly used for tray forcing is peat mixed with sand. These materials have to meet the following standards:

The planting soil must have the right composition.

A good mixture is 40-80% one-year-old frozen black peat (garden peat) + 60-20% peat moss. Preference is given to a mixture of 60% garden peat and 40% peat moss. To make sure that the plants do not fall over and in order to improve the water-air ratio in the substrate, it is advisable to add course sand (15%) to the mixture.

The structure should be neither too course, nor too fine.

A rooting medium with a course structure is difficult to work and will lose water too quickly. A structure that is too fine reduces water-drainage capacity and the air content of the soil. A lack of drainage must be avoided. During transportation, moist soil will settle even more, resulting in even further deterioration of the soil structure.

Proper water and air balance.

Provide a maximum of 80% moisture content and a minimum air content of 10% (at a suction tension of -10 cm). Rooting mediums that include peats that shrink are unsuitable. Soil can be allowed to settle by no more than 30%.

The rooting medium should not be too acidic.

Low pH levels will lead to root rot. A pH level of 6-7 is ideal. Even if an analysis is supplied along with the rooting material, have it tested anyway. If the pH level is too low, the medium will require additional treatment; 1 kg of calcium carbonate per cubic metre will raise the pH value by a factor 0.3.

The medium should not have an excessively high EC.

High salt levels in the soil will affect the rooting of the tulips. The EC should not exceed 0.5-1.0 at 25°C. This figure includes the addition of any fertiliser (adding fertiliser is not usually recommended anyway).

Sometimes, however, artificial fertiliser is added to increase the EC of the soil. This is done when growing certain cultivars such as ‘Monte Carlo’ and its sports that have the genetic trait of producing heavy root systems and thus tend to suffer from oedema and hollow stems. In these cases, increasing the EC to 1 to1.5 reduces such risks. (Also see the section on oedema and hollow stems in Chapter 17).

The medium must be free of pathogens such as Pythium and Rhizoctonia. The risk of damage caused by these pathogens greatly increases when using soil previously used for producing tulips or even other crops. Sometimes, the application of an agent to control Pythium is applied to the potting soil as a standard procedure. This disease, however, is much more prevalent when using poor potting soil that is low in oxygen and kept very wet.

6. Forcing in trays filled with soil: planting practices

6.1 Planting period

The planting period depends on the following factors:

- The fact that the preferred period is between mid-September and mid-December. Most tulips, however, are planted in October and November.
- The date scheduled for bringing the trays into the greenhouse.
- A minimum rooting period of at least six weeks after planting.
- Temperature in the rooting room (without climate control) or standing ground.
- Available space in the rooting room
- Allocation of labour
- Cultivars that can easily rise up out of the trays by their roots (e.g. 'Monte Carlo') should not be planted too late

In general, the earliest batches (these are also the ones that will be housed first) will be the first to be planted. The order in which the batches are housed thus becomes more or less the order for planting. Your supplier will usually draw up a schedule with you and indicate when planting should be done. Most tulips are planted in October and November. Planting earlier is possible if not enough labour will be available later on. Planting at a much later date is sometimes done for the purpose of using the rooting room twice, but this is not always desirable. Never plant tulips when the temperature exceeds 9°C because this can lead to rejects caused by disease. You should also avoid planting too early because this will make the cold period too long. Among cultivars that can easily become too tall and limp, this will lead to weak, flimsy plants. If the tulips are not yet sufficiently developed, they should not be planted at an excessively low temperature (also see the section on intermediate temperature in Chapter 3).

6.2 Planting

Fill the tray with at least 5 cm. of rooting medium and place the bulbs on top of the medium. This supports the bulbs properly while also providing room for them to develop a sturdy rooting system. This layer also provides a good water and oxygen buffer that will greatly reduce the risk of suffocation or desiccation. The tulips are placed upright in the trays by hand. This method of planting will ensure a more uniformly developing crop with flowers of the same height to facilitate harvesting.

After planting, cover the tulip bulbs with a 2 cm layer of sand to prevent the bulbs from pushing up through the rooting medium during their development and then falling over during harvesting. The sand will also help keep the tulips clean.
The quality of the covering sand is very important; if it is too fine or contains too many particles or silt, the medium may pan after watering and cause the bulbs to suffocate. This is why it is important to use coarsely grained sand (e.g. fluvial sand).

Most large forcing operations have planting lines in which the trays are placed on one side of the conveyor belt and then filled with a layer of potting soil from a soil-dispensing unit. Once the bulbs have been planted, another dispensing unit filled with sand deposits the sand on top. An irrigation unit and possibly a crate stacker complete the planting line.

6.3 Planting density

Planting density depends on the foliage produced by the crop, which, in turn, depends on the cultivar and planting time. Table 2 indicates the number of bulbs per tray according to these factors.
Planting density also depends on other whether forcing will take place under damp, low-light conditions or in a dry climate with plenty of light. Under the latter conditions, planting density may be increased.

Table 2. Guideline for the planting density of tulips in trays (60 x 40 cm), based on bulb size, early or late forcing, and foliage density.

	Early forcing			Late forcing		
Foliage	dense	normal	sparse	dense	normal	sparse
Bulb size 12/-	85	100	110	75	85	100
Bulb size 11/12	100	115	130	90	100	115
Bulb size 10/11	-	-	-	100	115	130

6.4 Watering

Next, thoroughly water the rooting medium in the trays. Also remember to water the corners of the trays. The quantity of water supplied is important. Adding too much water to a potting soil of only moderate quality can even suffocate the bulbs, especially if the sand used to cover them is too fine. In such a case, only the bulbs on the peripheries of the trays will dry out properly. Another problem related to excessive watering involves the risk of diseases such as Pythium and veinal streak. But not providing enough water is inadvisable as well; this can later lead to the drying out of the soil layer containing the roots and thus lead to damage caused by Trichoderma. In general, a good guideline would be to add 1 litre of water to each 40x60 cm tray filled with reasonably moist potting soil. After the excess water has drained out, conduct random checks for the uniformity of moisture throughout the trays. Another rule of thumb used to determine whether the medium is moist enough is to squeeze it. If hardly any water can be squeezed out, the moisture content in the medium is just right. Remember that this is only a guideline. Using a medium with the proper composition and structure encourages rapid and abundant root development. If you are planning on using dry wooden trays, test the moisture levels of the soil shortly after planting and then water again if necessary.

7. Forcing in trays filled with soil: rooting room and standing ground bed methods

7.1 Rooting room temperatures

In recent decades, most tulips have been planted in trays and then stored in refrigerated rooting rooms. Before these rooting rooms were available, the use of standing grounds was commonplace. (Because the latter method is so rarely used anymore, it will be not be discussed in great detail here.)

An important point to consider in the use of a rooting room is that the temperature in it has to be fairly uniform throughout. This is why the stacks of trays should not be grouped together to create overly large blocks and why it is important to leave around 10 cm. of space between the stacks and between the stacks and the walls of the rooting room. Placing excessively large stacks closely together into blocks will usually mean that the temperature will remain slightly higher in the centre of these blocks. And this will ultimately result in longer shoots and roots in these areas. After placing the trays in the rooting room, you should maintain the following temperatures.

Cooling temperature	Period
9°C	Until 20 October
7°C	20 October - 10 November
5°C	starting on 10 November
5 - 2°C	starting on 1 December
2 - 0°C (-1.5 to -2°C)	depending on shoot length

Around 1 December, the rooting room temperature may be reduced to 2-0° C, the exact temperature depending on the development stage of the shoot. The temperature may later be reduced even further to -1.5 to -2° C.

Start reducing the temperature around 1 December, well in time before shoot elongation accelerates, and remember to leave a gap of at least 1cm. between the shoots and the tray stacked over it. Never let the temperature rise since this may cause shoot development. The reduction of temperature should also be made gradually, degree by degree. If the temperature has already been decreased to around 0 to -2°C and subsequently rises again, the shoots will experience dramatic growth which, once started, cannot be stopped.

The temperature should not be kept too low either because tulips can easily freeze. Although there is a range of susceptibility to frost damage among tulip cultivars, a general rule applying to all of them is that the temperature as measured between the trays should not be allowed to drop much below –1.7°C. Should the temperature in an unrefrigerated rooting room happen to rise excessively (e.g. a week at 12 to 13°C), this will then count as only a half a week of cold treatment and will have to be compensated for.

7.2 Rooting room: humidity, soil and room

To obtain sound development of roots and shoots in the rooting room, the potting soil must contain sufficient water and oxygen. Improper moisture levels in the soil will soon lead to problems: the bulbs may suffocate or suffer from poor rooting, Pythium, topple, hollow stem and/or flower blast. Regularly check the moisture content of the soil in the trays located in various places in the rooting room (especially the trays near the ventilators). A general rule for measuring moisture level in the soil: squeeze the soil; if hardly any water is released, it is sufficiently moist.

In a rooting room in which the RH is maintained at the recommended 90 to 95%, the potting soil will not dry out quickly and the only watering needed will be just after planting. Once planting is done, the sand on the trays should not be allowed to dry out too quickly. If it does, the roots of rapidly growing cultivars can easily push the bulbs upward through the sand and even grow out of the tray. This occurs most often when the bulbs have been planted late in the planting season. If the RH falls below the recommended percentage, sprinkle some water on the floor of the rooting room. In general, however, the humidifier is set to maintain the proper RH and any water that evaporates condenses and drips back onto the surfaces in the rooting room. It would still be a good idea to check the moisture of the potting soil from time to time. If the root zone at the bottom of the tray dries out too much, this increases the risk of damage to the roots caused by Trichoderma. On the other hand, excessively moist soil can result in so many roots growing out of the trays that they disturb the air circulation between the trays. These roots will often later result in problems either in the rooting room or the greenhouse because when they dry out, they are more susceptible to damage by such pathogens as Botrytis cinerea.

7.3 Ventilation and circulation

Having any kind of automated ventilation system will be necessary only in the case of large, very tightly closed rooting rooms. In general, sufficient ventilation will be achieved by simply opening the doors upon inspecting the crop. Using ventilation in rooms without a climate control system to reduce the room temperature may dry out the medium and the roots. Having evaporation units close to the trays also poses a real threat to the bulbs. Check regularly and water if necessary.
For an even temperature distribution, a low level of air circulation will suffice. Any more air circulation may dry out the roots.
This is why automated systems are usually used in rooting rooms: the humidifier fan is in operation only when the rooting room has to be cooled. Even so, the stacks of trays should still be kept at a distance of 10 cm from the walls, and the stacks must not be placed so as to create overly large blocks. The placement of the stacks must allow a certain amount of air circulation throughout the trays.

7.4 Crop protection in the rooting room

There is not much point in trying to control certain diseases by the use of crop control agents in the rooting room since temperatures there are too low to encourage such development, and the forcing trays are not easily accessible. Many diseases such as Botrytis cinerea and Trichoderma may be prevented by providing the bulbs with the right storage conditions. Diseases may also be prevented by disinfecting the bulbs before planting (see the section on bulb treatment in Chapter 16). However, and especially when the rooting room cannot be kept tightly closed, measures should be taken to prevent damage to the bulbs by mice. Mice love to eat tulips!

7.5 Standing ground

A standing ground is a piece of land outside of the greenhouse where tulips in trays are planted. Until a little more than 30 years ago, this was the most commonly used method for supplying the cold treatment. It is still in use but usually only at smaller forcing operations. In those earlier days, wooden trays were usually used. But because this method is associated with heavy labour during the winter period and greater risks of damage by pathogens found in the soil of the standing ground, it has generally fallen into disuse.

To successfully use a standing ground, outdoor temperatures must be not much higher than the temperatures recommended here for rooting rooms. There are roughly two standing ground methods. The oldest is to plant the tulips in wooden trays filled with soil taken from the standing ground and then to cover the planted tulips with a layer of soil from the standing ground. When temperatures approach zero, a layer of material such as straw is used as mulch. The more recent method involves planting the bulbs in 40x60 plastic trays as described here for use in rooting rooms. These trays are then placed on the standing ground and covered with a thick layer of straw. Do not forget to scatter tubes filled with mice poison over the standing ground. Mice love to eat tulip bulbs! In case of a severe freeze, spread out bubble plastic on top of the standing ground. The same rule used in rooting rooms also applies to standing grounds: the temperature in the standing ground as measured next to the bulbs should not drop below –1.7°.

A few more suggestions:

- For a standing ground, choose a plot of land that has not been used recently for tulips. Always consider the possibility that Rhizoctonia might be present and take measures to control this in advance. One way would be to steam the standing ground.
- Choose a well-drained location as a standing ground. Tulips can easily suffocate due to excessive water.
- If the shoots become larger during the later forcing batches, it would be advisable to remove the straw from the trays so that the shoots do not grow through the straw. Then, if a severe freeze threatens, cover the tulips again with canvas!
- Keep the shoots from drying when removing the trays from the standing ground into the greenhouse under severe freezing conditions and strong winds.

8. Forcing in trays filled with soil: greenhouse climate and production procedures

8.1 Temperature

As soon as the required cultivars have received the necessary cold period, the trays may be moved into the greenhouse to be forced. Tulips may be placed in the greenhouse at a temperature of 18-20°C. From a quality standpoint, however, keeping temperatures just a few degrees lower (which will extend the production period by a few days) is recommended. Starting around 1 February, the temperature may be 16-18°C or a few degrees lower. Fluctuations in temperature should be avoided since this will halt growth development and increase the risk of flower blast and long necks. High greenhouse temperatures also pose a danger since they stimulate excessive growth that will then result in flower blast. If the cold period is exceeded by 2 to 3 weeks, the temperature in the greenhouse can be lowered by 1 to 2°C to ensure a quality crop.
Late in the spring, it can be more difficult to keep the greenhouse temperature low. Important means to remedy this situation are the application of more or less shading on the roof of the greenhouse and the use of a movable screen. It would also be a good idea to use slowly growing cultivars for late forcing. Your supplier can advise you in this matter.
Supplying heat beneath the trays is not recommended since it can easily lead to losses resulting from root rot, topple, flower blast and Trichoderma.

8.2 Relative humidity (RH)

The degree of relative humidity can make or break a crop. Insufficient humidity slows the development of the crop, thereby increasing energy consumption. Excessive humidity increases the risk of topple, damage caused by Botrytis tulipae, crops that are more limp and lighter in weight, and flower blast. Relative humidity should be kept between 60-80% and must be frequently checked, preferably as measured just above the crop. Most suitable for this purpose are accurate hygrometers. For computer-controlled greenhouses, test the recorded values against the values obtained by a hygrometer. Mild, wet springs in particular can lead to a rapid rise in relative humidity levels exceeding 80%. This makes it imperative to check humidity carefully. The RH can also be reduced by frequent ventilation. During still, dull weather, the greenhouse can be heated a little and ventilated at the same time. Horizontal air blowers encourage transpiration in the crop and lower the RH near the plants. To raise the RH when necessary, reduce the ventilation and sprinkle the pathways with water.

8.3 Light

For some cultivars that require more light, production under low light conditions (e.g. closed insulation) in combination with high relative humidity will result in pale leaves, plants that are tall and spindly, late leaf emergence ("cigars"), stem and leaf topple, and flowers with poor keeping quality. Genetically short, sturdy cultivars grown under low light conditions will become taller; they may even profit from these conditions. Later in the spring, it may be necessary to shade the greenhouse. (For more information about this, see "temperature" in Chapter 5: Shading.)

8.4 Pre-forcing

The forcing of tulips may be advanced by placing the trays, either stacked or not, in a "pre-forcing room" for a while before bringing them into the greenhouse. In this way, you can produce one or two additional crops per season. This method will reduce the forcing period by up to one week at the beginning of the forcing season, and by up to a few days later in the season.

How long the trays must remain in the pre-forcing room depends on the cultivar, the shoot length, actual temperature and the forcing season period. If the trays are stacked, the height of the shoots determines the distance between the trays. Pre-forcing usually takes place at temperatures not exceeding 16°C. When stacking the trays, leave sufficient room for the emerging shoots. Besides its obvious advantages, pre-forcing also has disadvantages. It is a more labour-intensive method which, later in the forcing season, may lead to excessively tall stems that are crooked at the base. This is why large forcing operations do not use this method unless it has been built into the entire production system or even automated.

8.5 Covering the crop

Covering the crop with an opaque cloth or dark plastic sheeting, however, is used during the first phase of production to obtain a somewhat taller crop, but this is useful only for genetically short cultivars. Be sure not to keep the crop covered too long, especially for tulips susceptible to topple. If you choose to use this method, make sure to remove all plants that are damaged or that have failed to emerge (usually due to Fusarium or Botrytis) immediately after housing.

8.6 Greenhouse period

The duration of the greenhouse period for a particular tulip cultivar depends on its storage temperature, cold period, and the relative humidity maintained during forcing. In general, the greenhouse period will last about 3 to 3.5 weeks. It will be longer for early forcing (approx. 4 weeks) than late forcing (approx. 2.5 weeks). This is why using quickly developing cultivars for early forcing and then more slowly developing cultivars for late forcing is recommended. There are lists that provide information about the recommended greenhouse period for the various cultivars. Your supplier can give you more information about this.

8.7 Disease control

Plants that develop insufficiently may be infected by fungi such as Fusarium (the pathogen that causes “sour”), Pythium or Botrytis tulipae (“tulip fire”), or may have received insufficient cold. Plants with hollow stems will also be stunted.
After bringing the plants in, remove all those plants infected with Fusarium or Botrytis. This measure will simultaneously prevent ethylene damage to the neighbouring plants and remove a potential source of Botrytis infection (“primaries”) for the remainder. Using fresh potting soil and keeping the RH from reaching excessively high levels will reduce the need to use crop protection agents. Conditions that promote the development of Botrytis may require agents to control this pathogen. (Also see “Botrytis tulipae” in Chapter 17).

9. Forcing in trays filled with water (hydroponic forcing): introduction and systems

9.1 Introduction

Hydroponic forcing is a relatively new method for forcing tulips for cut flower production. In itself, however, the hydroponic forcing of flower bulbs is not new. Even in the middle of the 18th century, bulbs were being forced at home in glass vases filled with water. In the 1960s, the first attempts were made to force tulips commercially using hydroponics; these efforts were picked up again in the 1990s. Once a number of technical production problems were solved during these years, the use of this method for forcing tulips started really taking hold in the late 1990s. Hydroponic forcing in trays is generally similar to forcing in trays filled with soil. Much of the information about these procedures is thus similar to that provided in chapters 4 through 8. What makes hydroponic forcing different will be addressed in the next few chapters. Over time, this method has developed into what is now one of the most important methods in forcing tulips for use as cut flowers. In the Netherlands, more than half the tulips are already being hydroponically forced. This is primarily due to a number of advantages provided by these methods. Taken as a whole, these advantages often reduce costs. The next section addresses both the advantages and disadvantages of hydroponic forcing.

9.2 Pros and cons of hydroponic forcing

The advantages as compared to forcing in trays filled with soil:

- A reduction in cost due to the fact that there is no need for potting soil.
- The forcing trays can be used several times per forcing season.
- Rooting rooms can be used several times per season and can thus be smaller.
- Harvesting tulips in hydroponic trays can be done more quickly than harvesting from trays filled with potting soil.
- Forcing tulips hydroponically results in somewhat faster growth, so that a somewhat lower greenhouse temperature can be maintained to save energy.
- The facilities and the product remain cleaner.
- Reduced risk of certain diseases and disorders such as Botrytis, Trichoderma, sweating (oedema) and hollow stems, and veinal streak. This means that disinfecting the bulbs is usually unnecessary.
- In general, few if any crop protection agents are required
- No problems associated with the tulips pushing up out of their trays.
- The tulips grow somewhat taller so that genetically short tulips can be used to grow longer stems.
- Hydroponic forcing has much less impact on the environment than forcing in trays filled with soil.

The disadvantages:

- The purchase of special trays to provide the tulips with the necessary support.
- The tulips will usually have to be planted at the same time that harvesting is being done.
- A rooting room is needed, for storing dry bulbs over long periods.
- Most hydroponic systems produce tulips that are slightly lighter in weight.
- More risk for certain diseases and disorders such as bacterial slime growth on the roots, leaf topple and brown roots.
- Risks associated with certain diseases if the trays or systems are not properly disinfected.
- The hydroponic trays have to be thoroughly cleaned by use of a cleaning system.

- Genetically tall tulips can become even taller.

9.3 Systems

If tulip bulbs are being forced in water instead of soil, they need support to keep the developing plants standing upright as they grow. This support is supplied by various commercially available systems as described here. The most common one involves fixing the bulbs by hand onto pins that keep them in place. These are usually the “pin trays” manufactured by BulbFust. The use of these trays involves fixing the bulbs onto two rows of pins in such a way that the centre of the bulb is located between the two rows of pins. This tray is then filled with water. The overflow holes on both of the short sides of the tray ensure that the water level does not reach higher than the bottoms of the bulbs. The tray is usually placed in the standard 40x60 cm forcing tray so that there are an inner and outer tray. More recently, BulbFust introduced an enlarged version of this tray that fits into the 50x75 cm mesh bulb trays. There are also special steel or aluminium benches or tray holders on the market that eliminate the need for using an outer tray. These are usually transported between the rooting room and greenhouse by a forklift truck.

Bulbs of any size can be planted on the same kind of tray. Because fixing them to the pins can damage the bulbs, it is important that the trays be transported to the rooting room soon after filling with water. Large tulip forcing operations also have machinery that places the bulbs upside down into openings after which a press pushes the hydroponic forcing trays onto the bulbs.

A second but less commonly used system is based on what is called the Flexi-tray. This consists of a rigid plastic sheet with pre-formed holes to hold the bulbs, the entire sheet being able to float on top of the water. Because the holes in the sheet have to conform to the size of the bulbs, the grower has to choose the tray that will best accommodate the size of the bulbs being used. By using a special watertight inner container, the sheets can be placed in the standard 40x60 cm. forcing tray or, if desired, directly into a watertight outer container. With this system, the bulbs are not damaged as much and for this reason can be stored longer in a dry state.

A third tray consists of a plastic holder that clamps the bulbs in place: the Holland Hydra-tray. Here again, it is necessary to use the properly sized tray to accommodate the bulb size. This tray does not fit into the standard forcing tray and is specially made for ebb and flow systems.

9.4 Simple flood versus ebb and flood systems

The hydroponic forcing of tulips started with the use of a special hydroponic forcing tray (inner tray) that fitted into the standard 40 x 60 cm forcing tray that was already being used when forcing bulbs in trays filled with soil. This method uses a simple flood system: the bulbs are “planted” in the inner tray that is then filled with water. The forcing tray with its inner tray is then placed in the rooting room to root. Once in the greenhouse, the water can be drained and replaced. In any case, the water is then maintained at a certain level. An estimated 95% of hydroponic forcing takes place using this method. For the most part, BulbFust trays are used for this type of system, and to a lesser extent, the Flexi-trays.

Research shows that the use of ebb and flood systems produce plants that are slightly heavier. The use of these ebb and flood systems recirculates the water, nutrients, etc. to make this system even more environmentally responsible. Around 2005, several forcing operations started using these systems due to their improved water replacement options. Due to the recirculation of water throughout the entire system, however, there is a greater risk of spreading diseases. This has also proven to be the case in regard to fungal diseases. This risk is much less when using simple flood systems where due to the individual water supply in each tray, any pathogens occurring in bulbs in a particular tray would be contained and limited to that same tray. No matter what type of hydroponic forcing system is used, the consistent re-use of these trays makes thorough cleaning of the trays after use a mandatory requirement.

10. Hydroponic forcing: production procedures and the control of diseases

10.1 Rooting

Just as in other forcing methods, the bulbs being forced hydroponically have to receive a cold period following the warm period. The warm period is essentially the same as when forcing in trays filled with potting soil. Sometimes, however, the temperature can start to be lowered earlier in November (from 17°C to, for example, 5°C) to decelerate shoot growth. In general, hydroponic forcing is very similar to forcing in potting soil. (For more information about forcing in potting soil, see chapters 4 through 8.)

An important difference as opposed to forcing in potting soil or other solid substrates is that all the tulips will receive the largest part of their cold period as dry bulbs in the cool store. If tulips spend a long time as rooted bulbs in water, this can lead to losses caused by bacteria infecting the roots (identified by their slimy roots). This is why the planting of the bulbs or fixing them onto the pin trays and rooting in water is done during a brief period before the trays are housed. How long this period lasts depends on the period in which forcing is done (tulips root much more slowly during early forcing than during late forcing) and on the rooting rate of the particular cultivar. In general, this means that it takes about 3 to 4 weeks for rooting earlier in the planting season and that this length of time gradually decreases to 1 to 2 weeks by the end of the forcing season. To establish the right planting time, one thus has to count back the number of weeks from the desired housing date to the rooting period. In addition to a schedule for housing, hydroponic forcing requires a second schedule for planting the bulbs. For most of the season, planting and harvesting will be done during the same period of time.

By the end of the rooting period, at which time the bulbs will be housed, the root mass should be no longer than 3 to 4 cm. It is important that the bulbs being forced hydroponically be ready to root previous to planting in water. This readiness can be seen when the root crown is more or less swollen. If a tulip bulb has not yet started to root within 1 to 2 weeks, there is a risk of “drowning” that results in bulbs known as “foamers”. These are bulbs that start to ferment, a process that can be identified by the air bubbles found in the water around the bulbs.

Before filling, nutrients (usually a combination of calcium nitrate and calcium chloride) are added to the water to give it an EC of 1.5 to 1.8 mS/cm^2. Make sure that all the trays are properly filled with water. This can be done with a special filling machine equipped with a metering nozzle. The water used is often tap water or water from the water reservoir. The pH of the water has to be approximately 6.

As the bulbs are stored longer, they produce shoots, the length of which depends on the cultivar. The growth of these shoots stops after a certain length of time. Be careful not to damage these shoots during planting.

10.2 Cooling temperature

Depending on the intermediate temperature required and the desired cold period, the bulbs will receive their cold period between around mid-August to the end of March. This has to be done properly, so it is very important that you make good arrangements with your supplier in regard to your forcing schedule.
The following table provides a generally applicable schedule:

Table 3. Optimum cooling temperatures for hydroponic forcing in trays

Cooling temperature for dry bulbs	Period
9°C	Until October 20
7°C	20 October – 10 November
5°C	From 10 November
1 – 2°C	From 1 December
Cooling temperature after planting in water (rooting temperature)	
5°C (9°C to 2°C)	November - March

The cold period used for hydroponic forcing is often somewhat shorter (by a half to one week) than what is given when forcing in potting soil. This is because bulbs forced hydroponically produced somewhat taller plants than those forced in potting soil. Do not reduce the cold period for cultivars that are genetically on the short side! To keep shoots short, especially in years when the bulbs have been harvested on an earlier date, it is possible to reduce the temperature of the stored bulbs earlier, e.g. down to 5°C on 1 November instead of 10 November.

The rooting temperature can easily be maintained at 5°C during the entire time in which the bulbs are planted in trays. If the planting schedule is running somewhat behind, it is possible to raise the temperature to 7 to 9°C, or, if the roots look as if they might grow too long, to lower the temperature to 3 or 2°C. For early forcing, it would be better to keep the temperature at 5°C because higher temperatures will not provide sufficient cold. When using planting systems that do not damage the bulbs when placing them in the trays (e.g. the Flexi tray), the bulbs can be planted earlier and placed in the dry state in the rooting room.
Sometimes, 5°C procedures are used for hydroponic forcing (see Chapter 11), but this is not possible for many cultivars. For this reason, consult with your supplier about this possibility.

10.3 Greenhouse climate

Because the hydroponic method results in faster growth, it is better to maintain a somewhat lower temperature than when forcing in soil. The recommended greenhouse temperature for early forcing is 17 to 18°C. From around 1 February, the temperature can be lowered by one or two degrees. Toward spring, it often becomes difficult to keep the temperature low enough, but by applying proper shading, it should still be possible. When forcing occurs quickly, plants produce a product that is much lighter in weight and there could be problems with topple and leaf topple. This is why it is important to use cultivars with a slower rate of growth for late forcing.
Just as with forcing in soil, the RH must not exceed 80 to 85% (measured just above the crop). Also ensure sufficient air circulation in the greenhouse. Very moist forcing conditions lead more quickly to leaf topple.

10.4 Leaf topple

One of the biggest problems in regard to production procedures used in hydroponic forcing is leaf topple. The first symptom of leaf topple is watery spots halfway up the leaves. Later, the leaves can shrivel and partially die back or crack open (usually horizontally). If the leaves remain wet, a secondary fungal growth can develop as the forcing period proceeds. This disorder develops among susceptible cultivars due to an “insufficient” supply of calcium to the leaves. Various cultivars are extra susceptible to this when forced hydroponically. Providing the plant with calcium during hydroponic forcing is apparently more difficult. To minimise this problem when forcing susceptible cultivars hydroponically, do not use any large-sized bulbs at the beginning of the season. Susceptible cultivars are often quickly growing ones such as ‘Leen van der Mark’, ‘Purple Prince’, ‘Monte Carlo’ and ‘Christmas Marvel’. Other requirements: apply a good basic fertiliser that includes calcium, do not exceed temperature requirements, keep the greenhouse temperature as constant as possible, and ensure proper evaporation (see ‘Leaf topple’ in Chapter 17).

10.5 Diseases specific to hydroponic forcing

If the roots remain in water too long, they can ultimately rot due to damage from bacteria. This is known as bacterial slime growth. The strong penetrating odour produced by the damaged roots is a clear symptom of this problem. This is why we try to house the tulips when their roots do not exceed around 3 to 4 cm. High water temperature is another factor that can increase the risk of bacterial slime growth. Some cultivars are more susceptible to this than others. Cultivars such as ‘Ben van Zanten’ and ‘Debutante’ produce more roots and are thus more susceptible. Bacterial slime growth also occurs more often when trays and systems still contain bacteria from a previous production period. The roots are also more susceptible to this damage if you damage the roots (e.g. when a stack falls over). But bacteria cannot tolerate dry conditions; a thoroughly dried tray will no longer contain many bacteria.

In recent years, more root rot caused by Pythium has been encountered during hydroponic forcing. The occurrence of this fungus was only sporadic during the early years of the application of this forcing method. It seems as if the fungus can more easily survive on trays, etc. so that it can then damage the roots of tulips. Susceptible cultivars include: ‘Leen van der Mark’, ‘Debutante’ and ‘Ile de France’. In serious cases, batches of trays emerge from the rooting room already showing shortened brown roots. In the greenhouse, this problem can be identified by the brown rings under which the root will wither and finally rot. The characteristic bad odour similar to bacterial slime growth, however, is missing. It is also possible to confuse this problem with Phytophtora, a less commonly occurring fungus that is very aggressive in water. This fungus also damages the bulbs and leads ultimately to the yellowing of the leaves. Research shows that Fusarium species can also be a factor in problems associated with hydroponic forcing.

10.6 Cleaning the forcing containers

A good first step to take in preventing diseases during hydroponic forcing is the careful cleaning of the trays, along with the inner trays. Systems that recirculate water are extra vulnerable because pathogens can remain behind in the systems. This means that the most important control method is still a thorough cleaning and sterilisation of all trays, inner trays, pipes, etc. that come into contact with the water in which the tulips are forced. To do this, you can use cleaning systems that provide steam cleaning, high pressure (even exceeding 100 bar!), follow-up spraying with an agent such as Jet 5 or hydrogen peroxide, steam treating rooting rooms (2 hours at 60°C - and remember that some products can become deformed at high temperatures!), or you might also want to give the bulbs a hot water treatment. The more porous the material used in making the trays, the more difficult it is to have a disinfectant reach all the spores found in these tiny depressions. We should actually be able to avoid the use of fungicides when using this environmentally responsible forcing method. There are now special cleaning systems on the market that clean the trays thoroughly by means of high pressure and then follow up with a spray including a disinfectant.

10.7 Other information needed specifically for hydroponic forcing

Bulbs that are meant to undergo hydroponic forcing are stored in a dry condition considerably longer than bulbs that will undergo other forcing methods. This is why it is important that the bulbs remain well protected by their brown tunics, especially when using them for late hydroponic forcing. Bulbs without tunics and/or damaged bulbs will eventually loose too much of their moisture and will often be damaged by Penicillium, a "storage fungus". These bulbs can better be used for early forcing. This fungus can also be found on the somewhat thinner tunics during the cooling period but this seldom results in damage during that time.

Watering does not differ much from forcing in potting soil. Drip systems are often used. The use of nutrients in the water is still being researched but at present is assumed to be the same as the nutrients provided during rooting when using other methods. A good EC level for this water is 1.5.

Bulbs with very thin tunics resulting from having been lifted too early can secrete a substance into the water that will result in a brown discoloration that makes the water more or less the colour of tea. The roots produced by these bulbs emerge with a brown colour. Trays containing these bulbs should be drained and then filled with fresh water. The roots will then grow out white.

11. Cultivating 5°C tulips in the border soil of the greenhouse: cooling and soil requirements

11.1 Cooling

After receiving the required warm period and intermediate temperature, the bulbs can receive their cold period. As discussed previously, tulips need a cold period to develop sufficiently long stems and to promote rapid growth and flowering. In the cultivation of 5°C tulips, the bulbs receive their entire cold period as dry bulbs before they are planted in the border soil of the greenhouse.
The length of the cold period depends on the time the bulbs were planted. This is because the shoots and roots will develop prematurely as warmer conditions approach. Darwin hybrid tulips require a longer cooling period to develop sufficiently long stems.

The following table indicates the optimum cold periods for different planting times. This table provides a general picture of the various treatments. The treatments will almost always be provided by the supplier in the Netherlands. He will indicate the proper cold period for each cultivar.

Table 4. Summary of the entire cold treatment for 5ºC tulips before planting.

Tulips groups	Cold treatment	Planting time
Darwin hybrid tulips	12 weeks at 5°C	until 1 Jan.
other tulips	9 weeks at 5°C	until 15 Nov.
	10 weeks at 5°C	15 Nov. - 22 Nov.
	11 weeks at 5°C	22 Nov. - 1 Dec.
	12 weeks at 5°C	1 Dec. - 1 Jan.
Darwin hybrid tulips and other tulips	12 weeks at 2°C	1 Jan. - 1 Feb.
	13 weeks at 2°C	1 Feb. - 7 Feb.
	14 weeks at 2°C	7 Feb. - 15 Feb.

Sometimes, instead of using late planting times (after approx. 1 February), it is better to plant 5°C (or 2°C) tulips earlier and keep the greenhouse cold for a while. Other options would be to schedule flowering in April in an unheated greenhouse or to plant uncooled tulips or 9°C tulips in the ground. For earlier flowering periods, it is also possible to use partial 5°C procedures. The bulbs will then have to receive the remainder of their cold in the greenhouse that is then kept sufficiently cold. Consult your supplier in regard to your options.
Be sure to plant at the recommended time. Only in exceptional cases may planting be postponed, and then by no more than 2 weeks. In this case, the bulbs would then receive two weeks of additional cold at 5 or 2°C (see Table 4). Although this benefits the rate of growth in the greenhouse, it also increases the risk of flower blast. The cold treatments given in Table 4 apply to bulb sizes 12/+ and 11/12. Large bulbs (size 13/+) receive one additional week of cold treatment.

11.2 Determining flowering period

One of the factors that determines the time at which the earliest 5°C tulips will flower is the moment at which the cultivar in question reaches Stage G. After reaching this stage, most cultivars are given an intermediate temperature treatment. Some other cultivars, however, start undergoing their cold treatment immediately after reaching Stage G. The harvest period can be calculated by adding the time required in the greenhouse. For batches intended for late flowering, the moment at which they should start receiving their cold period is not determined by the moment at which they reached Stage G but simply by counting back from the desired flowering time. Example: if the desired flowering period is 8 March; counting back 50 days gives a planting time of 18 January; by subtracting another 12 weeks for the cold treatment, the date on which to start the cold treatment would be 24 October.

11.3 Greenhouse equipment

The requirements for greenhouses do not differ much from those used for forcing in trays. It is important, however, to have the greenhouse equipped with a good watering system that uses a sprinkler system.
Tulips require careful watering. Poor leaf and flower quality may occur in areas of dry soil. For this reason, frequently check the spray nozzles on the sprinkler system.
Shading is also important. In general, greenhouse temperatures for 5°C production in border soil are lower than those for forcing in trays.
When spring approaches, the greenhouse may need to be shaded to keep part of the light out. Never let the greenhouse temperature exceed 20°C.
(For additional information, see Chapter 5: Shading)

11.4 Soil requirements

As a rule, tulips may be cultivated in any type of soil that is also suitable for the cultivation of horticultural crops under glass or plastic.
However, the soil must meet the following general requirements:

- good structure without any clods
- good drainage
- absence of fungal pathogens (see Chapter 16, General soil treatment)
- pH value preferably not less than 6
- low salt content (EC not exceeding 1.5 mS/cm²)
- low nutrient content

There is generally no need for fertilisers. The plants will derive sufficient nutrients from the bulb to be able to bloom satisfactorily. The addition of organic or artificial fertilisers shortly before or during the rooting phase is likely to cause damage to the root system.
A balanced water/air ratio in the soil is vital for good rooting. Meeting this requirement is actually the best way to prevent diseases from developing in the soil.
A low pH value may be raised by a factor 0.3 by adding 1 kg of calcium carbonate per cubic metre.
The salt content of the soil, i.e. the total value of water-soluble salt in the soil, should not exceed 1.5 mS/cm (1g./l.). In cases where the border soil is flooded, causing this maximum value to be exceeded, the damage may be limited by applying suitable water during cultivation, or, if this is not available, by keeping the soil moist at all times.
The chlorine content of the soil should not exceed 2 mmol. The maximum chlorine content tolerated in sprinkling water is 100 mg per litre. Normally, water with a higher chlorine content is essentially unsuitable.

According to these figures, tulip roots should be considered sensitive to high concentrations of salt and chlorine in the soil. For this reason, have the soil of the greenhouse tested for its salt content and pH value. If the salt content is too high, leach the soil. Also modify its pH value.

12. Production specifications for 5°C tulips

12.1 Bulb size

The following rules apply to bulb sizes:

- The larger the bulb, the relative bigger the flower will be, especially in the case of early forcing.
- Smaller bulbs generally yield smaller flowers and longer necks and result in higher losses.
- Later in the season (planting from around 15 January), a faster rate of growth may lead to shorter plants and smaller flowers. Larger bulbs will then yield the best results.

12.2 Peeling the bulbs

Peel the bulbs by carefully removing the brown tunic that surrounds the root crown.
Peeling 5°C tulip bulbs shortly before planting has the following advantages:

- there will be no root damage due to contact with residues left beneath the skin following a pre-planting bulb disinfecting treatment.
- bulbs can be planted at a shallower depth leaving the nose just visible; this helps to prevent Rhizoctonia damage.
- the roots develop evenly and the plants grow and flower uniformly.
- it allows early detection of diseased bulbs so that they can then be removed to prevent the spread of disease.

12.3 Planting instructions

Planting density depends on the cultivar, the bulb size and the harvesting period. Table 5 provides a general picture.

Table 5. Planting density for 5°C tulips

Planting time	Bulbs/m^2
early	± 325
middle	± 350
late	± 375

Peeled bulbs, in particular, can be planted with their noses above the soil level. In this case, the soil structure should be in excellent condition and watering will need to be done shortly after planting to prevent the bulbs from desiccating.
Plant tulip bulbs in loose soil. Do not press the bulbs roughly into the soil since doing so may damage the root base where the first root tips have usually emerged already.
Heavy soil or soil that is likely to pan must be covered with peat or straw after planting (but inspect for Rhizoctonia). This prevents deterioration of the soil structure when watering is carried out.

12.4 Greenhouse and soil temperature

When the bulbs are planted, it is vital that the soil surrounding them be at the proper temperature. Keep the soil temperature low during the first two weeks following planting, preferably 9-10°C or cooler, to prevent soft rot (see Chapter 17, Pythium and soft rot). This usually proves impossible, however, during early plantings made in October and November when outside temperatures are high. If the soil temperature in the greenhouse

exceeds 17°C, postpone planting by one or two weeks. Always plant under the coolest conditions and, where possible, take measures both before and after planting to keep the soil temperature low. Suitable measures are: shade before planting, cover the soil with straw, sprinkle with water (preferably cool) and ventilate thoroughly.
A proper greenhouse temperature ensures good crop quality, as demonstrated by sturdy well-proportioned plants, and rapid growth. High temperatures increase the risk of flower blast. Low temperatures result in the development of long necks (necks being the upper part of the stem) and smaller flowers. The following soil and greenhouse temperatures are recommended.

Table 6. Optimum soil and greenhouse temperatures for the cultivation of 5°C tulips planted on various dates.

Planting date	Temperature		
	At bulb level		Between the plants
	Start	After approx. 2 weeks	
October	9 – 10°C	16°C	18°C
1 - 15 November	9 – 10°C	16°C	18°C
16- 30 November	9 – 10°C	14-15°C	16-17°C
1 December onward	9 – 10°C	13°C	15°C

To save on energy costs, many growers keep the temperature lower than the levels stated in the table. For many tulips, this presents no problem but they will grow somewhat taller and heavier. If growth is seriously delayed, some cultivars can grow too tall, particularly in the upper part of the stem (the “neck”). Darwin hybrids are susceptible to this.

More than one batch of 5°C tulips is sometimes being produced in the same greenhouse. This makes it difficult to start growing each batch at a low temperature. Sometimes, this can be solved by keeping part of the greenhouse cool. As soon as heating this part becomes necessary, the adjoining part of the greenhouse can be screened off with a material such as plastic sheeting to keep it cold. And when this part has to be heated, the process can be repeated for the next batch of tulips. If this is not possible and all the batches are planted in a warm greenhouse, extra measures (usually dipping the bulbs in the appropriate fungicides) will have to be taken to control Fusarium as well as the soft rot caused by Pythium.

Yet another method applied is to plant ‘5°C tulips in trays’ as described in chapters 4 through 8. The rooting can take place at 9°C. As soon as the tulips are properly rooted and the roots reach the bottoms of the trays, the trays are placed on the border soil in the greenhouse where they can continue to grow down into that soil as they would do without being planted in trays first. This method somewhat reduces the risks associated with certain diseases due to the application of a lower starting temperature and the use of fresh potting soil in the trays.

12.6 Relative humidity

High humidity levels in the greenhouse reduce transpiration taking place in the tulip plants and this may lead to growth disorders such as leaf, stem and flower topple, and even flower blast. (For a detailed explanation of controlling relative humidity, see Chapter 8 for information regarding growth disorders, see Chapter 17, Disorders)

12.7 Watering

Before planting, apply water to lower the soil temperature. It is advisable to plant the bulbs in a slightly moist soil so that the first quantity of water applied will directly benefit root development. Water thoroughly after planting, preferably with a sprinkler system. This promotes rapid root development. During watering, take care to retain the soil structure. The plants require water throughout cultivation. Too much water, however, may lead to damage.

There are no real guidelines that can be given for watering frequency. This depends on a number of factors, including:

- soil structure
- development stage of the plants (denser foliage will produce more water generated by transpiration)
- weather conditions
- ventilation frequency
- cultivar
- total salt content

In practice, the following rule of thumb applies: the plants have access to sufficient moisture if the soil underneath the bulbs yields to pressure.
Schedule watering so that the plants can dry quickly thereafter, in any event, before evening. Ventilate the greenhouse after watering to lower the rapidly rising humidity levels. During the harvesting phase, plants remaining after others are harvested should be watered immediately.

12.8 Greenhouse period

The length of time a particular cultivar occupies the greenhouse depends on a number of factors, including the storage temperature of the tulips, the humidity in the greenhouse and the planting depth. Yet another essential factor, of course, is the greenhouse temperature. The greenhouse period lasts longer for early forcing than for late forcing. Your supplier can give you more information about the length of greenhouse periods for the various cultivars; in general, a greenhouse period for 5°C tulips lasts 45 to 60 days.

12.8 Inspections in the greenhouse

Checking the temperature and relative humidity in the greenhouse at crop level is absolutely vital. Once the tulips in the greenhouse are 5-10 cm tall, remove all tulips that have not emerged and all those that are infected with Botrytis. Ones that emerge very slowly or not at all could be infected with the fungus known as Fusarium. Remove these bulbs immediately since they release ethylene gas that can damage neighbouring plants. Plants that are infected with Botrytis (another fungus) even before emerging may also infect healthy plants by means of releasing their fungal spores. This is why it is important to be sure to remove these bulbs as carefully and quickly as possible.

13. Forcing 9°C (pre-cooled) and uncooled tulips in the border soil of the greenhouse

13.1 Cooling

Uncooled tulips that are planted in the border soil of the greenhouse either receive the entire cold period in the greenhouse or are pre-cooled at 9°C to give them part of their necessary cold period previous to planting.
Your supplier has the information about the cold periods you should maintain. The cold periods to be maintained for this forcing method are the same as those for forcing in trays. For many cultivars, this is around 16 weeks, but some cultivars require more.
To promote a healthy root system, tulips require at least six weeks of cold in the greenhouse. The optimum low temperatures for dry bulbs and for bulbs planted in the border soil of the greenhouse are as follows:

period	temperature
until 20 Oct	9°C
20 Oct - 10 Nov	7°C
10 Nov - 1 Dec	5°C
1 Dec - 15 Dec	2°C (dry bulbs)
from 1 Dec	5-2°C (planted bulbs)

If soil temperatures rise substantially by a few degrees following planting, the cold phase will have to be extended. The following rule of thumb applies: for every week in which the temperature is raised by one degree above the required temperature, postpone heating the greenhouse by one day.

13.2 Production methods

The production methods for 9°C and uncooled tulips are almost identical to the cultivation of 5°C tulips. However, the following points must be made. Plant as soon as the soil temperature in the greenhouse has dropped to 9°C or lower. Depending on the climate and the measures taken to lower the temperatures, this temperature is usually reached in mid-November. However, if the soil temperature is still too high, do not plant the bulbs but continue to apply the cold treatment to the dry bulbs. To avoid rooting problems and a reduction in quality, do not plant after 15 December.

Apply a layer of 1 to 2 cm of soil over the noses of the tulips in order to prevent the bulbs from pushing their way up through the soil and to ensure an even soil temperature.
The bulbs do not need to be peeled. Bulb sizes 11/12 and 10/11 are highly suitable for this method.
Once the bulbs have received their required cold period, the temperature in the greenhouse can be increased by reducing ventilation and/or by heating. The temperature may be increased to around 18°C. If forcing takes place at a very low temperature, some tulip cultivars will grow too tall. Depending on the greenhouse temperature and the variety selected, this forcing period will last around 20 to 40 days from the time the greenhouse starts to be heated.

14. Forcing in pots: introduction and production procedures

14.1 Introduction

As well as being forced for cut flower production, tulips can also be forced very successfully for pot plant production. To obtain a beautiful compact pot plant, it is important that tulips in pots not become too tall. For this reason, many cultivars used for cut flower production are less suited to pot plant production. In some countries such as the United States, tulips in pots are very popular. Many tulip cultivars are used there for pot plant production. They can be somewhat taller there as well. Interest in tulips as pot plants is also increasing in Europe. The use of tulip bulbs for producing pot plants has been taking place for a long time, particularly for use inside the home. Now, more and more tulips produced as pot plants are also being used on terraces or for planting in gardens. For many consumers, this is a second chance if they have forgotten to plant tulips in their garden in the autumn. Many bulbs in pots are also placed at gravesites. An advantage of placing these pots outside is that they can be placed there long before their normal flowering period. And, due to temperatures that are often low at that time, they have a very long flowering period. They can easily tolerate a few degrees of frost without much damage.

There are certain ways to obtain pots filled with short tulips. You can use “ordinary” forcing tulips that are genetically short, use tulips known as botanical tulips that are also genetically short, or keep tulips short by applying growth regulators. Pot plant production has many similarities to forcing tulips in trays. Much of this information can also be applied to pot plant production. An example is the use of 9°C cooled or uncooled tulips for pot plant production. (For more information, see chapters 4 through 8.)

14.2 The use of genetically short “ordinary” tulip cultivars

In forcing tulips for cut flower production, a somewhat shorter cold period easily produces short tulips when using certain cultivars in the current forcing assortment. The same is true for using these tulips for pot plant production. If the cold period for short cultivars such as ‘Abra’, ‘Seadov’, ‘Monte Carlo’, ‘Princess Irene’, ‘Arma’, ‘Kikomachi’, etc. is shortened by one or two weeks, these tulips will easily remain short in their pots. For cold periods of the right length, consult with your supplier. Remember, however, that when shortening the cold period of bulbs being used for the earliest forcing, the greenhouse period will be greatly lengthened, and this may even pose the risk that flower blast may occur. This is why it would be better to add the number of weeks that have been deleted from the cold period to the period when intermediate temperature is applied, previous to the cold period (also see Chapter 3). Certain cultivars are used almost exclusively for pot plant production, one of them being ‘Flair’. Previously, ‘Brilliant Star’ and its yellow sport ‘Joffre’ were very popular as pot plants (now much less so). However, these short tulips are now being forced in trays and then lifted early to be used, bulb and all, in Christmas flower arrangements. Once removed from the soil, however, the keeping quality of these tulips is not very good.

14.3 The use of botanical tulips

Botanical tulips are short, early-flowering tulips used in gardens. Many of these varieties are low-growing and are very popular. No wonder, then, that they make a very good choice for use in pot plant production. They usually belong to the Greigii, Praestans and Kaufmanniana groups. One problem associated with these tulips, especially the Praestans and Kaufmanniana cultivars, is that their keeping quality is usually not as good as ordinary tulips. But if placed outside, their keeping quality poses few problems.

Commonly used cultivars from the Greigii group are: 'Pinocchio', 'Red Riding Hood' and 'Plaisir'. From the Praestans group, these would be primarily 'Fusilier' and 'Unicum', and from the Kaufmanniana group, 'Showwinner'.

14.4 The use of growth regulators

It is also possible to keep tulips short by applying chemical agents. The one most often used for this is Bonzi, but the use of this agent is not permitted in all countries. In general, the cultivars that receive this treatment are tulips that are genetically taller than the ones described previously. It is still better, however to use genetically short varieties without the use of growth regulators. It is not advisable to use Bonzi for the earliest forcing period. Be careful about using/reusing soil previously treated with Bonzi. The agent is applied immediately after housing in the form of a solution containing 1 to 1.5 litres of Bonzi to 100 litres of water. Each 12-cm. pot would receive 100 ml of this solution.

14.5 Pot sizes, soil and planting

Commonly used pot sizes are 9 cm and 12 cm in diameter. Three bulbs are planted in 9-cm.pots and usually 5 in 12-cm pots. Other pot sizes are used as well. Sometimes, pots are transplanted to larger pots or baskets or mixed with other bulbs. The potting soil must be of very good quality. This means that it has to be able to hold moisture easily and also contain sufficient oxygen. The bulbs must also be of excellent quality. After all, it is always a problem when one plant out of 3 or 5 bulbs is missing. Do not water excessively when planting; if this is done, you run more risk of root rot caused by Pythium and hollow stems (oedema) among such cultivars as 'Monte Carlo'. If the potting soil becomes too dry and the root layer at the bottom of the pot dries out too much, this increases the risk of Trichoderma. Because tulip bulbs can work their way upward, this will have to be countered with enough pressure during the first period following planting. This can be accomplished by topping the bulbs with a layer of sand, the temporary placement of foam rubber strips, or by putting special racks on top of the pots.

14.6 Rooting room

The series of temperatures advised for forcing in trays (see Chapter 4, table 1) also applies to pot plant production. Do not let the shoots grow too tall in the rooting room. A shoot that is 5 cm tall (above the bulb or pot rim) is quite tall enough. Excessively tall shoots result in overly tall pot tulips. If it looks as if this will happen, promptly reduce the temperature to no lower than -1.5°C. Using a standing ground is another possibility. Remember that pots containing plants with overly tall shoots cannot be housed, so inspect them frequently for shoot length. If necessary, remove them from the standing ground and put them in an unheated greenhouse if they have not completed their cold period.

14.7 Other production procedures

The pots can be housed once the cold period has been completed. Provide water as needed, determining the need for moisture by first removing a clod of soil from a number of pots and feeling it. Drying out can lead to Trichoderma. Too much moisture entails the risk of problems such as hollow stems and Pythium damage. As a rule, the pots are ready for sale when the shoots are somewhat taller (6 to 10 cm) and nicely greened up. This requires a greenhouse that admits a lot of daylight. The pot can receive an insertable label with a photo and growing instructions. It can also be wrapped in a plastic sleeve. The latter is important particularly when the pots will be marketed in a further stage of development. The consumer will then more easily see what the product is going to look like, but the selling period is shorter.

15. Cut tulip production: harvesting and readying for sale

15.1 Harvesting

Tulips may be harvested once the flowers have developed colour. Darwin hybrid tulips, however, are harvested when the buds are partially coloured. The flowers must be closed when harvested to facilitate preparation for sale and transport.
In general, the entire plant is harvested, bulb and all. Compared to cutting or breaking off the tulips, this method of harvesting has the following advantages:

- because there are no bulbs or bulb remnants left in the greenhouse, this reduces the risk of soil-borne pathogens affecting later crops.
- if desired, the tulips can be stored, upright, for some days with the bulb attached (a good storage method in itself).
- when necessary, 2-3cm of additional length may be acquired by cutting the stem out of the bulb.

Depending on the cultivar and the greenhouse temperature, harvesting takes place once or twice a day. The harvested tulips must then be stored in a cooler location.

15.2 Bunching

Once harvested, the tulips are transferred from the greenhouse to the cold store where field heat is removed quickly. They are then bunched and processed. Cool product temperatures promote better keeping quality in the distribution chain and for the consumer. If the harvested tulips need to be stored for a longer period, they are best stored upright still attached to their bulbs until they are bunched.
The bulbs are removed automatically in a bulb-removing machine or by hand with a knife. The following should be kept in mind when bunching (which may take place on a bunching line)

- sort the flowers carefully according to quality
- all the flowers in the bunch must be the same length
- to prevent damage to the leaves, do not place the tape or rubber band at a location too high on the stem
- to prevent leaf damage, do not wrap the bunches too tightly in paper or plastic sheets/sleeves

15.3 Watering and cooling the flowers

The bunches are then stored in the cold store for 30-60 minutes in cold water (1-5°C) or placed directly in the cold room at 1-5°C. Do not add any preservatives to the water because this will result in longer necks among some cultivars! After watering, the flowers are stored upright in the cold store at a temperature of 1-5°C and a relative humidity of 90%. This last measure should be adopted only if there are no water droplets on the flowers. Botrytis spores can germinate only in these water droplets and then cause what is known as “fire” spotting on the foliage and flowers. If water droplets can not be avoided, the relative humidity should be set lower. However, bear in mind that a lower relative humidity causes the product to dry out even more, resulting in a decrease in flower and keeping quality.
Storing the tulips too long in the cold room will affect the quality and keeping quality of the flowers. For this reason, never keep the flowers for more than three days in the cold room.

16. Crop protection: soil and bulb treatment

16.1 General information

Most diseases in tulips are caused by fungal pathogens. Tulips can be damaged by a number of pathogens specific to tulips such as Rhizoctonia tuliparum and Botrytis tulipae. Other fungi such as Botrytis cinerea, Pythium and Rhizoctonia solani are commonly found on other plants but can also damage tulips. Many of these pathogens accumulate in the soil. This is why it is best to use fresh soil for tulips. When forcing in fresh potting soil or fresh water, many of these pathogens are entirely absent. When using border soil, it is better to use a system of crop rotation. The more often tulips are produced in the same soil, the greater the risk of certain diseases. If tulips are planted often in the same soil, these diseases will have to be controlled by such methods as steaming the soil and/or the application of chemical crop protection agents. In some cases, immersing the bulbs in agents specifically recommended for this will offer an effective means of protection.

The use of crop protection agents applied to the soil and the bulbs is subject to many changing legal approvals that usually vary according to country as well. Because this booklet cannot address all of them, check with your own agricultural information service or with your bulb supplier to find out which agents would be best for you to use. Chapter 17 provides information about various diseases. Table 7 indicates a number of diseases that can occur during various production methods.

Table 7. Production methods and a number of diseases that can occur

Production method:	To control diseases, particularly:
Hydroponic forcing using fresh water	usually none
Forcing in fresh potting soil (trays and pots)	sometimes Botrytis cinerea sometimes root rot caused by Pythium
Forcing in trays and pots but in previously used soil (is usually not recommended)	Rhizoctonia solani and sometimes R. tuliparum Root rot caused by Pythium sometimes Botrytis tulipae
9°C cooled and uncooled tulips in the border soil of the greenhouse or in the standing ground made up of fresh soil	Rhizoctonia solani Sometimes root rot cause by Pythium
Ditto, but in soil previously used to grow tulips	Rhizoctonia solani and sometimes R. tuliparum Botrytis tulipae Root rot caused by Pythium
5°C production	Fusarium oxysporum Root rot caused by Pythium and sometimes soft rot caused by Pythium Rhizoctonia solani Botrytis tulipae
Cooled bulbs that have to root in soil warmer than 10°C	In addition to the previously listed diseases, soft rot caused by Pythium
Extended production period under warm conditions (e.g. 5°C production)	In addition to the previously listed diseases, Fusarium oxysporum

16.2 General soil treatment: steam sterilisation

An effective and environmentally responsible way to kill pathogens, yet an increasingly expensive one due to rising fuel costs, is to sterilise the soil with steam. This method is

used chiefly when planting in the border soil or in a standing ground. Previous to treatment, the soil must be thoroughly loosened and may not be too wet. A temperature of 70 to 80°C at a depth of 30 cm must be maintained for at least an hour. This method is often used for 5°C production. It is still advisable to follow up steam sterilisation by working a chemical agent to control Pythium into the soil. In some cases, this fungus can easily grow back toward the upper layer of soil.
When controlling fungi that produce fungal wefts (e.g. Rhizoctonia tuliparum and Botrytis tulipae) flooding can be used. These fungal wefts will not survive being inundated for 6 weeks.

16.3 Additional soil treatment

Since Pythium fungi can grow (and grow back) quickly, adequate control of Pythium can not be achieved by the annual general soil treatment of steaming alone; a soil treatment before planting will be necessary. If the soil has not been treated with a general soil treatment before production, treat it before planting to control both Pythium and Rhizoctonia solani. Mix the fungicide evenly through the upper 20 cm. of soil.
Although fresh planting soil should theoretically be free of pathogens, it may still be infected with Pythium. It can thus still be necessary to add an agent to control Pythium to the potting soil/soil. This will be particularly necessary if the bulbs have been planted in warm soil for a long time and if the soil is very wet during production. Work all agents thoroughly through the soil.

16.4 Bulb treatment

Bulb dips are necessary especially when bulbs have to be protected from a number of pathogens such as Fusarium oxysporum, Pythium (that causes soft rot), Botrytis cinerea, and sometimes Rhizoctonia tuliparum. There are many agents that can be used for this purpose. Consult with your agricultural information service or bulb supplier about the right agents. The agents can also be applied to the bulbs by the bulb supplier even before they are delivered; in this case, they will not have to be applied again. In general, the bulbs are dipped in a solution containing the agents. The agents can also be applied to the bulbs by means of a shower. Table 8 indicates how to calculate the concentration of agents for each treatment method.

Table 8. Summary of the different methods of treatment and the relevant concentrations.

Method of treatment	Concentration
Long dip (15 min.)	1 x
Short dip (1 min.)	1.5 x
Shower (15 min.)	1.5 x
Shower (5 min.)	2 x

17. Diseases and disorders: cause and protection

17.1 Diseases caused by fungi

17.1.1 Botrytis cinerea

This fungus occurs mainly in damaged or weakened parts of the plants and beneath the tunic between the roots. Both the bulbs and the roots beneath the tunic may be infected.
The symptoms of the infected bulbs are:
One or more bulb scales are completely or partly soft and dark brown. There are large (2 to 3 mm), mat black flat sclerotia on the diseased tissue. In the parts above the soil the infected plants are brittle and will break readily. The flowers are an unusual bright shade. The leaves are also shiny because the wax layer is missing. Heavily infected plants remain short or don't emerge at all.
The symptoms of the infected roots are:
Only the roots or part of the roots of tulips planted in the controlled temperature store are infected. The fungus thrives in thick layers of roots at the bottom of the tray or on parts of the root that lie beneath the tunic of the bulb.
On these roots a white fungal weft develops, which later turns grey and is often covered with black sclerotia measuring 2 to 3 mm in diameter. Root masses on the bottom of the boxes where the roots are usually not surrounded by soil particles will display a dark brown root rot.
The symptoms of the infected shoots are:
Infected roots touch the tulip shoots emerging below; they may cause marks there, leading to “Ghost spotting”. It does not lead to so-called “spotted flowers” caused by Botrytis tulipae.

Cause

The disease is caused by the fungus Botrytis cinerea, also known as grey rot. It is distributed by spores. Moist conditions promote the infection. The disease is most commonly found in long-stored and where bulbs were planted late in the boxes. It is encouraged by the use of steamed soil or fresh peat-based substrate, as this does not contain any of its natural competitors. The use of boxes with minimal basal spaces, in which the roots accumulate on the bottom of the box, is not recommended. In border soil cultivation the presence of loose or lumpy soil and the addition of organic material will further add to the problem.

Prevention

Do not plant tulips in a purely peat-based substrate.

- Always mixes some coarse-grain sand or disease-free garden soil in the peat product (50%).
- Give the bulbs a fungicide treatment before planting.
- Prevent the bulbs from being damaged and drying out
- Disinfect forcing boxes
- After planting, cover the bulbs with a layer of course sand.
- Prevent the roots growing through the tray openings from drying out by using high humidity levels (90-95%).
- Always force tulips on open tables.
- Towards the end of the season when controlled temperature stores are partially empty, the R.H. can drop quickly. This can cause root damage during late forcing, which stimulate a ‘Botrytis cinerea’ attack. Check, especially during the latest period, precisely if the R.H. in the controlled temperature store is correct.

17.1.2 Botrytis tulipae

Primaries
Heavily infected plants do not open or are retarded in growth ("Primaries"). The lowermost, often twisted, leaves at the bottom of the stem develop greyish brown fungal hyphae with spores. The parts of the plant beneath the soil develop 1-2 mm large, mat black sclerotia.

Spotting
Germinating spores cause small, watery marks on the leaves and flowers. These marks are green at first but later turn to large white and brown spots ("Spotting"). Susceptibility to spotting depends on the species.

Cause
The disease is caused by the fungus Botrytis tulipae. The sclerotia and spores only germinate in moist conditions (free-standing water), at temperatures starting from appr. 1°C. The spores, originating from primaries, are spread quickly through the crop e.g. by watering or even air circulation, and can cause the feared spots within 24 hours on the leaf, and within as little as 10 hours on the flowers. From 15 February the spots will intensify. The fungus can survive up to two years in the soil by means of its sclerotia, even if no tulips are planted in the meantime.
The spores of the fungus Botrytis cinerea may also cause spots. However, these are much smaller and only occur on the leaves. They are called "Ghost spotting".

Prevention
- Treat greenhouse and standing ground soil with steam, flooding or apply a general soil disinfecting treatment in accordance with current recommendations.
- Disinfect the bulbs before planting and do not plant them too densely.
- Remove all bulbs that do not emerge immediately after the trays have been taken into the greenhouse, or from the border soil.
- After housing it may be necessary to apply a chemical treatment.
- Ensure that the crop remains dry during cultivation, especially at night. It is advisable to water directly on the soil and ventilate immediately to allow the crop to dry.
- Apply crop heating 40 cm above the crop (preferred) or use horizontally aimed fans (either of these measures dramatically reduces the risk of Botrytis infection).
- When flowering is imminent, the greenhouse is smoked with a suitable fungicide.
- Avoid free standing water collecting on the plant. The relative humidity must be 85-90% and the air must be circulated continuously.

17.1.3 Fusarium

Infected bulbs develop greyish brown spots during storage, occasionally with concentric rings and a clear yellow rim. They give off a distinctive, acrid smell and release ethylene. The bulbs shrivel up and become "loose" in their tunics. Even healthy bulbs may contain spores of this fungus. Depending on the circumstances (especially the soil temperature) the bulbs are infected from the base of the root crown in the first weeks after planting. Diseased bulbs will not emerge. In less serious cases growth will be retarded, flower tips will turn yellow and flower buds will desiccate. Longitudinal dissection of a bulb clearly shows that the stem turns brown from the base upwards. Bulbs infected with Fusarium release ethylene into the soil, which may lead to retarded growth and even bud blasting in neighbouring plants.

Cause

The disease is caused by fungus Fusarium oxysporum f-spec. tulipae. The disease can develop from Fusarium-diseased bulbs (primary infectors), healthy-looking bulbs but ones that are already infected with the fungus, and severely infected greenhouse soil. In box cultivation it thrives in high planting temperatures (above 13°C) and during long periods in the greenhouse. In the cultivation of 5°C tulips there is a high infection risk especially in early crops, as the bulbs are subjected to temperature treatments that encourage the development of the fungus.
Infected bulbs release ethylene gas, which during storage may lead to resin release, open shoots, "pole" plants i.e. those with multi-stems, bud necrosis and a somewhat greater risk of desiccated flower buds in the neighbouring bulbs.

Prevention

- Infected batches should be given proper ventilation treatment and if necessary stored separately. It may be necessary to remove diseased bulbs early on.
- Always remove diseased bulbs at planting.
- Disinfect bulbs or plant at soil temperatures of 9°C or less (5°C tulips at 12°C or less). Never plant in temperatures above 13°C. If necessary, plant later.
- Only use potting soil that has reached a low enough temperature.
- Make sure that the tulips have been given the appropriate weeks of cold treatment so that the greenhouse period will not have to be extended.
- Quickly remove all bulbs that do not emerge.

17.1.4 Penicillium

A Penicillium infection is recognised by brown discoloration's on the inside of the outermost bulb scales. These spots, which have developed as a result of mechanical or other damage during warm dry storage, become covered with a blue-green mass of weft and spores, and are just visible through the translucent bulb scale as grey, violet-brown spots. Under cooler and moister storage conditions, these spots are also seen on the outside of the bulb scale and are brownish becoming covered with a blue-green mass of weft and spores. Such spots become larger during storage. The infection slowly continues to spread within the bulb after planting.
The underlying bulb scales, basal plate and shoot usually remain undamaged during storage. Slightly damaged bulbs will produce a normal healthy plant. Moderately to heavily damaged bulbs will produce no plant or a stunted, weak, spindly one with pale green leaves. In certain cultivars, if the infection starts in a bulblet located under the tunic, the fungus will penetrate the basal plate and pass from there into healthy undamaged bulb scales, thus leading to the loss of the entire bulb.
Symptoms to look for among emerged plants.
Shoots that have emerged from bulbs which were damaged long before planting or damaged shoots on bulbs not planted deeply enough can become exposed to the air and become covered with this Penicillium fungus. In these cases, the tip of the outermost leaf will die and become covered in a blue-green weft. These kinds of infections will have no further consequences for the development of the flower but will have an adverse effect on the market value of the plant. Such damage from this fungus can be prevented if the mechanically damaged parts of the shoot are covered with moist soil immediately before or during planting.

Cause

The cause is a fungus, Penicillium hirsutum, which is commonly found in the surrounding environment.
Infection develops particularly on bulbs that have suffered mechanical damage that has occurred late (after August). This fungus can also affect bulbs that have been lifted early (with entirely white tunic) and which are then stored at fairly low temperatures and under sufficient dry. In this case, the tunic becomes covered with a blue-green weft but the underlying scales will not be affected.
The fungus can sometimes be present as an opportunistic organism on plants showing symptoms of leaf topple. Furthermore, the exterior of bulbs can easily become covered with a green fungus when they have been transported under moist conditions; such bulbs will usually produce a good plant.

Prevention

- After receipt, store bulbs in a well ventilated storage room with a sufficiently low RH.
- Avoid damaging the bulb and shoot.
- Disinfect the bulbs immediately before planting by following the appropriate recommendations.

17.1.5 Pythium - Root rot

The symptoms in a minor infection in the greenhouse are restricted to a partly rotted root system, without the plant actually being affected. Serious cases may lead to flower blasting and to shorter plants that occur in patches in the greenhouse. The infected roots in the soil are glassy or watery, often marked with a narrow brown stripe, and break off easily. When the disease develops the entire root system turns brown. Pythium can also show up in hydroponic forcing.

Cause

The disease is caused by soil borne fungi of the Pythium genus, especially P. ultimum. The fungi are active in soil temperatures above freezing. The risk of disease increases as the temperature and moisture content of the soil increases and also when the soil contains more water, has a looser structure or has a higher EC. An attack from Pythium occurs both during box cultivation and in the greenhouse. Susceptibility depends on the cultivar.

Prevention

- Use fresh and sufficiently cool (‹10°C) soil for the standing ground and greenhouse.
- Soil infected with Pythium generally requires an additional soil treatment according to current recommendations.
- The (border soil) of the greenhouse must have good structure and be free draining.
- Clean containers thoroughly.
- Use only peeled bulbs.

17.1.6 Pythium - Soft rot

Bulbs that are infected at an early stage often develop short shoots. The bulb tissue is weak and frequently coloured pink. The bulbs give off a typical, unpleasant odour similar to Fusarium bulbs. The shoot and root may seem healthy for a while, but will rot eventually.

If the attack occurs later during greenhouse cultivation, the bulbs are retarded in growth, the tips of the leaves turn yellow; the plants fall over and under certain circumstances the flowers may desiccate at a very late stage.

Cause

The disease is caused by certain strains of the soil borne fungus Pythium ultimum. The fungus attacks the bulbs mainly in the first few weeks after planting, in soil temperatures of 12°C or higher. Infected plants are found throughout the greenhouse. Seriously diseased tulips may even be surrounded by fully healthy plants.
Strains of the fungus can also cause root rot.
Cultivars differ in their susceptibility to this fungus.

Prevention

- For border soil (greenhouse) production, the soil temperature during at least the first two weeks after planting should be kept below 12°C and preferably lower than 10°C.
- Remove the tunic from the root wall and dip the bulbs before planting.
- The border soil of the greenhouse must have good structure and be free draining.
- Ensure the temperature in the greenhouse is below 12°C, preferably even below 10°C, in the first two weeks after planting the tulips in the border soil of the greenhouse.
- With box forcing use new and sufficiently cool (<10°C) standing ground and potting soil.
- Infected soil and used potting soil should be disinfected according to current recommendations.
- Clean the containers thoroughly.
- Use only peeled bulbs.
- After planting the bulbs, put the boxes in the controlled temperature store immediately and reduce the temperature quickly.

17.1.7 Rhizoctonia solani

The symptoms of this disease vary according to the cultivation method used.
Symptoms during cultivation in the greenhouse include:
Orange-brown spots and stripes develop on the outside of the shoot. Later the tissue splits as if it has been gnawed. The plants flower normally, but the tips of the bottom leaves are curved outward. Remove these leaves when bunching. In a more serious attack, the leaf is damaged and the bottom part of the stem develops oval, deeply set patches. These plants may be retarded in growth and will break easily when handled. The symptoms gradually worsen, resulting in poor growth of the shoot, and later rot. This is because the fungus attacks the bulb directly.
Symptoms in box cultivation:
When the boxes are brought into the greenhouse the shoots have small, brownish black patches and stripes. The plants will flower normally, although there is some damage, especially to the tips of the lowermost leaves.

Cause

The disease is caused by the fungus Rhizoctonia solani, which attacks the tulip shoot from the soil. When the nose of the bulb has not been covered, or after the shoot has emerged, the plants cannot become infected. The fungus is not found in fresh peat substrate. After the plants emerge, further fungus growth is halted. Susceptibility to the disease will differ with cultivar. The fungus is found on a range of agricultural crops including potatoes, salad, tomatoes, chrysanthemums and cereals as well as many other bulbous plants. It also thrives on composted organic material (straw, leaves, roots, etc). This means it can occur even if the previous crop cultivated in the soil was not tulips. Unlike Rhizoctonia tuliparum, this fungus thrives at higher temperatures (15-18°C).

Prevention

- Give infected soil a general soil treatment or treat the border soil of the greenhouse with an efficient fungicide. Incorporate the fungicide carefully through the top layer (10 cm) of the soil. Pay particular attention to the soil over the bulbs.
- Clean the forcing boxes.
- Carry out a bulb treatment.
- Preferably plant the bulbs for 5°C cultivation and for forcing in boxes so that the noses remain uncovered. Remove the tunic around the root wall!
- Cover the boxes with coarse-grain sand or gravel, leaving the noses exposed.

17.1.8 Rhizoctonia tuliparum

Bulbs throughout the crop fail to emerge. Upon inspection the roots of the diseased plants appear intact. The shoot, which develops normally, is diseased in the soil and starts to rot. The bulbs and shoot are occasionally covered with mycelium-coated soil often containing whitish grey to blackish brown sclerotia. The shape and size of these sclerotia vary greatly (from 1 mm to 1 cm), but they are easy to remove from the plants. The bulb scales develop large, greyish-brown marks with grey fungal tissue. Characteristic, brown rings are visible upon cutting the bulb in half. The entire bulb usually dies through rot. The focus of infection is usually delineated by plants that are retarded in growth and die prematurely. In a heated greenhouse the disease is brought to a stand still by applying higher temperatures.

Cause

The disease is caused by the fungus Rhizoctonia tuliparum. This fungus, which does not produce spores, usually attacks bulbous plants in winter, especially at soil temperatures of 13°C or less. Besides bulbous and tuberous plants, it will also attack perennial plants such as Sedum spectabile, Lychnis, Helleborus and Valeriana officialis.
The fungus can survive undisturbed by means of sclerotia. Seriously diseased bulbs can usually be attributed to the repeated planting of tulips in the same site. The fungal disease spreads by means of hyphae and sclerotia sticking to bulbs, tools, machines, shoes, seedlings, corms, tubers and rhizomes that are cultivated in the infected soil. Major damage only occurs when the bulbs are planted in the same site regularly. The disease is more common in uncooled tulips than in cooled ones as they stay in the standing ground longer.

Prevention

- Use fresh soil in the standing ground and fresh potting soil.
- Remove, flood or steam infected soil or treat it with a suitable fungicide.
- Clean infected forcing boxes.
- Destroy infected plants.
- Do not store infected soil in the vicinity of the standing ground.
- Treat the bulbs with a suitable fungicide before planting.
- Planting the bulbs late (appr. from mid November) will dramatically reduce the risk of disease attack.

17.1.9 Root-Fusarium

Diseased roots can be recognised by their conspicuous red colour that then turns brown. Roots that are not surrounded by soil, but growing at the bottom of trays and pots, will turn glassy, become limp and finally dissolve. Damage caused by Fusarium culmorum produces shorter tulips with brown vascular bundles at the base of the bulb and the foot of the stems and sometimes white dried-out tissue and cavities. An infection by Fusarium avenaceum causes the tulips to grow faster and produce light green, pinched and twisted leaves with partially green and sometimes strangely dented flowers. Affected tulips will flower before those not affected.

Cause

The causes of these diseases are two fungi: Fusarium culmorum and Fusarium avenaceum. These fungi are commonly found in soil and peat substrates and can become a problem in tulip forcing in boxes filled with peat substrate. The fungi will infect and damage the roots not surrounded by soil or substrate (i.e. the roots located at the bottom of boxes and pots). It is assumed that the fungi produce a poisonous substance that is absorbed through the roots and which then causes the symptoms observed in the upper parts of the plant.

Prevention

- Disinfect the boxes before planting.
- Never plant tulips in purely peat-based substrate and do not use previously used infected potting soil.
- When using peat products, mix these with an equal quantity of course-grain sand or disease-free garden soil (50%). It is also advisable to put in a 4-5 cm thick layer of substrate under the bulb as well as a 1 cm. thick layer of coarse sand on the bottom of the box.
- Disinfect the bulbs before planting.
- Keep the potting soil in the boxes sufficiently moist.
- Maintain a high relative humidity (90-95%) in the controlled temperature store and reduce the temperature quickly to ensure that the roots growing through the openings in the trays do not dry out and do not grow too long.
- After October, do not allow rooting to take place at temperatures above 5°C.
- Place the forcing trays on open table frames with sufficient space below to allow the roots that grow out from underneath the trays to dry as quickly as possible.
- The floors and walls in the controlled temperature store and the benches in the greenhouse should be disinfected at the close of the forcing season.

17.1.10 Trichoderma

Under unfavourable conditions the roots that are at the bottom of the tray may be infected by this fungus. The roots, which will eventually rot, develop a glassy look and are covered in fungal hyphae and later start to rot and turn light to dark brown in colour. The tips of the leaves of the diseased plants turn bright grey. At a later stage the tissue turns white and rapidly dries out. Bulbs can also become diseased through the root crown and display the same symptoms as if they were infected with Botrytis cinerea. The disease is most common during the late cultivation of tulips planted in peat substrate. Susceptible cultivars are ‘Ad Rem’, ‘Angélique’, ‘Capri’, ‘Prominence’, ‘Rosario’ and many others.

Cause

The disease is caused by the fungus Trichoderma viride. It releases a toxin that is transported through plants and causes the symptoms described in the tip of the leaves. The fungus is naturally present in all soil types and in peat-based substrate. However, it will only affect roots that are not surrounded by sufficient soil and are therefore weakened.

Prevention

- Disinfect the boxes before planting.
- Never plant tulips in purely peat-based substrate and do not use previously used infected potting soil.
- When using peat products, mix these with an equal quantity of course-grain sand or disease-free garden soil (50%). It is also advisable to put a 4-5 cm. thick layer of substrate under the bulb as well as a 1 cm. thick layer of coarse sand on the bottom of the box when planting cultivars susceptible to Trichoderma.
- Keep the soil in the trays sufficiently moist.
- Maintain a high relative humidity (90-95%) in the controlled temperature store and reduce the temperature quickly to ensure that the roots growing through the openings in the trays do not dry out and do not grow too long.
- Place the forcing trays on open table frames with sufficient space below to allow the roots that grow out from underneath the trays to dry as quickly as possible.
- The floors and walls in the controlled temperature store and the benches in the greenhouse should be disinfected at the close of the forcing season.

17.2 Diseases caused by viruses

17.2.1 Augusta disease

Diseased plants grow crookedly and remain short while necrotic brown, long patches and stripes appear on the leaves. The flowers of red-flowering species develop thin, dark veins. Brown spots can be observed on the new young developing bulbs. For the most part, the roots display brown rotting tissue.
The disease has a few typical characteristics. It often leads to great damage, whereby the infection may be limited to a few patches in a particular cultivar, while other cultivars remain healthy under identical circumstances. There are great differences between the susceptibility of the various cultivars. It may for example affect only two cultivars in the standing ground, but none of the others. Many growers will assume that the entire batch was diseased upon delivery, which is usually not the case. Susceptible cultivars include ‘Angélique’, ‘Apricot Beauty’, ‘Blenda’, ‘Inzell’ and ‘Prominence’.

Cause

The Augusta disease is caused by the tobacco necrosis virus, which is transferred to the roots by the swarm cells of the fungus Olpidium brassicae. The virus transfer from soil to the root depends on the moisture level and the temperature (above 9°C) of the soil. This is why Augusta disease occurs mainly in tulips planted too early in the standing grounds when temperatures are too high. Infected plants do not necessarily show symptoms of disease, however. This problem will usually occur suddenly when the plants have been exposed to major temperature differences; the type of soil will also be a factor in this. Both viruses and fungi have sets of host plants. So once infected, the soil will remain infected for years. Scattered diseased plants suggest second-year symptoms.

Prevention

- Use fresh planting soil, although this is not always sufficient since the virus can survive on other plants and weeds.
- Give the soil of the standing ground or the border soil of a unheated greenhouse a steam treatment (100°C for 30 minutes duration) or a chemical treatment and infected boxes should be included in steam treatment or should be disinfected.
- When using soil suspected of being infected, do not plant the bulbs until the ambient temperature has dropped to below 9°C.

17.2.2 Veinal streak

The so-called veinal streak emerges as twisted leaves, retarded growth and discoloured leaf veins. At an advanced stage the leaf develops glassy, withered patches. The flower buds of the diseased plants later develop watery, sunken stripes and often green marks. Especially susceptible cultivars include 'Montreux', 'Lustige Witwe' and 'Monte Carlo' and sports. A disorder related to veinal disease is evident in cultivars including 'Apeldoorn', 'Snowstar' and 'Gander' and sports. Although these tulips develop sufficient length and the discoloration of the veins is hardly evident, leaves will easily split lengthways.

Cause

This disease is often thought to be connected to tobacco ring spot virus, but a direct relationship between this virus and the disease has never been truly proven. For this reason, vein disease can only be categorised as a physiological disorders, which to the for this susceptible cultivars under wet and too cold conditions (‹ 15°C) in the controlled temperature store or in the greenhouse can occur. The type of soil is another factor in the occurrence of this disease.

Prevention

- Do not place susceptible cultivars in the standing ground, but rather in the rooting room.
- If using the standing ground for cold treatment, protect the bulbs from frost damage.
- Use potting soil with a good water/air ratio.
- On housing, do not water as long as the soil below the bulbs is still moist. Only water when really necessary and never too much in a single irrigation!
- Do not place the boxes on a moist and cold surface in the greenhouse, but instead on open tables (see Trichoderma).
- Keep the greenhouse temperature constant and never allow it to drop below 16°C.

17.3 Damage caused by pests

17.3.1 Aphids

The presence of aphids can be detected during storage by the development of red or brownish spots on the bulbs that are sticky with honeydew. These "sticky" bulbs will later turn black due to the development of honeydew fungi (sooty mould).
Aphids can be found primarily around the top of the bulb and at places where the brown tunic is loose or missing. If the bulbs have sprouted during storage, large numbers of aphids can be found on the shoots. This will result in the upper part of the lower leaf being damaged, misshapen and sometimes thickened after emergence.

When tulips are damaged by aphids in the greenhouse or in the field, round light green to yellow spots will be found on the leaves. Serious infestations will result in the leaf surface becoming misshapen and bumpy.

Cause

An infestation is caused by various species of aphids found in infested batches or coming in from the surrounding environment. These species include the tulip aphid (Dysaphis tulipae), the lily aphid (Aulacortum circumflexum), the green peach aphid (Myzus persicae) and the black bean aphid (Aphis fabae). In most cases, damage from aphids remains limited. What is more important is the fact that aphids can transmit viruses.
The tulip aphid is most commonly found during storage; the lily aphid is one of the aphids encountered during the greenhouse period, and the green peach aphid and the black bean aphid are primarily found on plants in the field. Aphids reproduce particularly well on bulbs stored for long periods at temperatures higher than 15°C. They seldom occur on cooled bulbs.

Prevention

- Do not allow bulbs to stay outside any longer than necessary.
- Regularly check the bulbs during storage and the plants in the greenhouse or in the field for the presence of aphids and apply aphid control measures as needed.

17.3.2 Bulb mites

These mites feed primarily on diseased bulb tissue that has already been damaged by fungi, bacteria and nematodes and remove diseased bulb regularly. But they can also feed on healthy tissue as well. In combination with ethylene, they can reach young flower parts in the shoot and damage them (bud necrosis). In a few cases, the young shoot can be damaged as well; this results in shallow pits, scratches on the outer sides of the shoot near the edge of the first leaf. The damaged tissue then turns a brownish colour. When the leaves emerge, they are not misshapen, but the damage caused by the feeding mites is still visible.

Cause

Bulb mites (Rhizoglyphus echinopus, Rhizoglyphus robini and Thyrophagus species) infest bulb tissue damaged by fungi, bacteria, nematodes or the surrounding environment and can also infest healthy bulb tissue.

Prevention

- Store bulbs under dry, properly ventilated conditions until the end of the storage period.
- Provide a properly ventilated storage room so that no ethylene can accumulate from Fusarium-diseased bulbs.
- In serious cases, apply a miticide according to current recommendations.

17.3.3 Wheat curl mite (“Tulip gall mite”)

Late in the season during warm storage, the outer bulb scale will often become dull and creamy to purplish-red in colour. Badly affected bulbs become limp, fail to produce roots and fail to emerge. Bulbs not so badly affected will root slowly and produce spindly plants. Leaves will sometimes remain curled up and stuck inside the nose of the bulb. Dark-flowering cultivars will display yellow or white stripe-like spots on their petals that may be confused with virus symptoms.

Cause

This problem is caused by Eriophyes tulipae, a long slender mite up to 0.2 mm. in length (invisible to the naked eye). An infestation by wheat curl mites can spread very quickly, the rate of spread depending on the speed at which the wheat curl mite develops (which in turn is highly dependent on the storage temperature, particularly when this exceeds 20°C). This means that an infestation is often a problem when the bulbs are stored for a long time under warm conditions.
In a storage room, it is easy for tulip bulbs that are not infested to become infested by the presence of infested batches. At lower temperatures (below 17°C), the mites develop so slowly that the bulbs will display no symptoms. Bulbs from batches that have been given early cooling treatment will always remain free of symptoms. An infestation can also result from contaminated containers!
Cultivars differ widely in their susceptibility to an infestation. Included in the particularly susceptible cultivars are 'Leen van der Mark', 'Esther', 'Oxford', 'Yokohama' and 'Rosario'.

Prevention

- Treat the storage room with an appropriate agent (e.g. Actellic) according to current recommendations immediately after delivery of infested batches of bulbs.
- Cool storage and early planting will prevent damage to the bulbs.
- Keep the storage room clean.

17.4 Physiological disorders

17.4.1 Flower blasting

This is the name given to the phenomenon in which some or all parts of the flower bud become desiccated. These symptoms can first be observed at the tips of the stamens and sepals and then until the base of the flower.
Common symptoms are bud blasting, green petals, whitening of leaf tips, desiccation of pistil and stamen and inadequate flower opening when held in water at the dealers. Desiccated flower buds are mostly not rotted, not mouldy or eaten by mites as it is the case with heart rot.
The problem may have been present even when the flower was inside the bulb; in this case, the flower remnant will be a pellicular tuft 2 mm. in length while other flowers will remain entirely or partially green with dried stamens. Flower blasting usually develops, however, during the second half of the greenhouse period.

Cause

Flower blasting in the bulb:
This can develop as a result of the bulbs having been temporarily exposed to an excessively high storage temperature after flower initiation or during transport (heating in transit), or have been stored too long during the autumn (after 15 November) at an excessively warm temperature (approx. 20°C). Cooled bulbs and susceptible cultivars are at greater risk for flower blasting.
Flower blasting in the greenhouse:
In this case the flower is always bigger than with flower blasting in the bulb. The elongation of the neck stays entirely or part back, so that the blasted flower sits between the leaves.

Flower blasting is caused by a variety of factors, such as cultivar-dependent characteristics, small bulb size, too brief intermediate temperature, too brief cold period, ethylene damage during storage or in the greenhouse released by Fusarium bulbs or heaters, high relative humidity and/or temperature in the greenhouse, water shortage, root suffocation and diseases.

Prevention

- Avoid the above situations.
- Avoid ethylene concentrations of more than 0.1 PPM by removing Fusarium bulbs from the batches, provide sufficient aeration, keep bulbs apart from cut flowers, vegetables and fruit, and avoid exhaust fumes (e.g. from forklift trucks).
- Avoid ethylene gas in the greenhouse by ensuring proper annual maintenance checks on the heating unit checks and by using heating equipment that uses outside air for combustion.

17.4.2 Chlorosis

From the time of emergence in the greenhouse or once the plants have been removed from the controlled temperature store and brought into the greenhouse, the leaves are light green to yellow-green in colour except for the leaf veins that retain their normal leaf colour. In some cases, the plants can be lighter in weight and flowering can be delayed.

Cause

Chlorosis (yellow leaves) is attributed to iron deficiency and occurs in all types of soil, but more commonly in sandy soils with a pH higher than 6.5. Cold wet growing conditions encourage the occurrence of chlorosis and it arises primarily in tulips produced in cold greenhouses. The symptoms disappear automatically when the greenhouse temperature rises.

Prevention

- Don't set the greenhouse temperature too low.

17.4.3 Ethylene damage

Flower blasting, gum formation, bud necrosis, short plants, poor rooting, and thin plants are symptoms of ethylene damage. Cultivars differ in their susceptibility to ethylene damage.

Cause

Bulbs infected with the Fusarium fungus produce ethylene gas. This gas has a major impact on plants – tulips in particular. It is a hormone that affects such processes as respiration and organ initiation. Ethylene damage will occur when concentrations are too high (> 0.1 PPM). The kind of damage depends on the stage in the plant's development, the concentration of the gas, how long the plant is exposed to the gas, and the temperature. At a temperature lower than 13°C, damage will be negligible. Ethylene is also produced by ripening fruit, vegetables and flowers as well as the incomplete combustion of oil, gas, coal and other fuels.

Prevention

- Prevent ethylene from entering storage rooms and the greenhouse.

- Reducing the temperature will limit any possible damage.
- For more prevention measures, refer to the various symptoms of ethylene damage!

17.4.4. Gum formation

Blisters in various sizes and shapes filled with a clear liquid that rapidly turns into a brown gummy substance form on the bulb scales. When a blister breaks it exudes the gummy mass that will then harden into a resinous substance.
In some cultivars, no blisters form on the bulb scales; instead, internal gum formation can occur around the young shoot.
Most symptoms of gum formation are observed in the outer bulb scale but can sometimes be a seen on inner scale as well. In some cultivars, gum forms inside the cells of the bulb scale but does not escape; this causes the colour of the bulb to change from white to beige.
Bulbs with symptoms of gum formation usually produce normal plants and flowers.

Cause
Gum formation is caused by the presence of ethylene (also see “Ethylene damage”)

Prevention
- Store uncooled bulbs in a room without any ethylene or at least where any concentration of ethylene is less than 0.1 PPM and also provide sufficient air circulation between the bulbs.
- Batches displaying excessive Fusarium symptoms should receive extra ventilation or even be stored separately.
- Discard Fusarium-diseased bulbs as quickly as possible.
- A batch of bulbs exposed to ethylene for whatever reason should not be processed for the first 10 days thereafter to limit gum formation problems.

17.4.5 Heart Rot (Bud necrosis)

Inside the main shoot of a bulb with bud necrosis a black rotten flower remnant will be present (flower necrosis) at the end of a stem that looks like a black stump. The leaves, however, are fully developed.
In the case of shoot necrosis, the entire main shoot is black and rotten; wispy leaves or shoots that produce flowers (“wispy plants”) develop from the daughter bulbs.

Cause
Bud necrosis develops stet the presence of ethylene results in space developing between the bulb scales earlier than normal and the reduction in the rate at which the young leaves surrounding the shoot elongate. This means that the young flower bud is not completely surrounded by leaves after reaching Stage G (a phenomenon also known as “open shoots”), thus making the stamens accessible to bulb mites. The bulb mites feed on the stamens causing rotting symptoms that lead to the destruction of the flower and/or shoot.
Open shoots develop before September as the result of exposure to ethylene for one to two weeks at a temperature of at least 17°C. Once open, the shoots remain open. Closed shoots will remain closed after September. When the temperature is kept below 17°C, the occurrence of open shoots and the activity of bulb mites decrease dramatically. Cultivars differ widely in their susceptibility to bud necrosis. Some cultivars, notably parrot tulips, can even develop open shoots without being exposed to ethylene; this is usually the

result of an excessively high storage temperature during the period before the bulbs reach Stage G.

Prevention

- Store uncooled bulbs in an ethylene-free store or at least where any concentrations of ethylene is less than 0.1 PPM and also provide sufficient air circulation between the bulbs.
- Batches showing excessive Fusarium symptoms should receive extra ventilation or even be stored separately.
- Remove Fusarium-diseased bulbs from the batch as quickly as possible
- When forcing cultivars that can easily develop open shoots without the presence of ethylene (i.e. parrot tulips), store them immediately after cleaning at 17°C or store them outdoors and then cool the bulbs as early as possible.
- Treat the store in which the bulbs are to be stored with a miticide used according to current recommendations.

17.4.6 Leaf Topple

Leaf topple is essentially the same problem as ordinary (stem) topple. It occurs primarily during hydroponic forcing and to a lesser degree when forcing in soil. It starts when the cell walls become weakened. The first symptoms are then watery-looking areas. Later, the surfaces on the leaves of some cultivars such as 'Purple Prince' can easily split open or dry out and then, if extremely affected, can constrict and bend over (as occurs with 'Leen van der Mark'). There is a great deal of difference in susceptibility to leaf topple depending on the cultivar. The rapidly growing cultivars are often the most susceptible.

Cause

Leaf topple develops due to an insufficient supply of calcium to the rapidly developing zones halfway down the leaves. When using hydroponic forcing, and particularly during an early forcing period, using large bulb sizes of certain cultivars will result in more problems with leaf topple. When forcing in soil, the problem develops particularly among cultivars with more or less rotten bulbs, bulbs with poor roots, or roots that have not properly emerged through the tunic. One cultivar particularly susceptible to leaf topple when forced in soil is 'Monte Carlo'.

Prevention

Take the following measures when using hydroponic forcing:

- Do not force too quickly
- Do not use any large-sized bulbs when forcing susceptible cultivars during the earliest forcing period
- Ensure proper transpiration by keeping the RH low enough (maximum: 80% as measured 110 cm. above the crop)
- Provide very effective air circulation through the greenhouse.
- Keep planting density low enough.
- When planting, use water with an EC of 1.5 (or slightly higher if using fertilisers contain calcium such as calcium nitrate).

Additional measures when forcing in soil:

- Ensure proper rooting. This can mean peeling the bulbs before planting if you are using bulbs that have undergone prolonged storage at low temperatures (e.g. 5°C production).

17.4.7 Topple

Calcium deficiency may produce glassy stems during the growth phase, which later fall over.
The top part of the stem becomes dark green and watery. The tissue shrinks, and the stem above the shrunken tissue, with the flower, falls over (topple).
The affected part of the stem remains attached to the rest of the plant, however, and does not break off entirely as is the case with boron deficiency.
Topple in leaves shows as watery, dark marks in the middle of the second or third leaf. They often release water drops, and in serious cases, the epidermis tears at right angles with the longitudinal direction of the leaves.
Another symptom is leaves displaying grey parts (especially in the middle). Topple sometimes occurs in the flower after harvesting. In this case, the petals display watery spots that soon turn white and pellicular.

Cause

Topple is caused by a high relative humidity in the greenhouse and/or poor rooting. This means little water is transported through the plants, leading to a calcium deficiency in the fast-growing parts of the plant. This increases the permeability of the cell membranes so that cell moisture leaks out of the cells.
Leaf topple cannot be avoided solely by keeping a low R.H; it develops especially with very big, poorly rooted or tunic-less partly moulded bulbs. Susceptibility depends on the cultivar. Highly susceptible cultivars include Kees Nelis, Leen van der Mark, Prinses Irene and White Dream.

Prevention

- Avoid high RH levels (over 80%) in the greenhouse at all temperatures.
- Avoid excessive cold phases in the greenhouse.
- Ensure healthy roots.
- Avoid excessive growth of the plants.
- Provide optimum evaporation between the plants by ensuring clearly observable air circulation between them. Do this by applying crop heating 40 cm. above the crop or by using horizontally-directed fans (the latter being the second choice!).
- Apply nitrogen in the greenhouse.
- Place the batches with topple in a solution containing 1% calcium nitrate after cutting.

17.4.8 Poor rooting and hard base

After planting, the roots fail to emerge from the bulbs; the root wall exhibits excessive swelling. A few roots sometimes develop but often grow upward between the first and second bulb scales and emerge at the top of the bulb.

Cause

Poor rooting and hard base can be the result of the following: the presence of ethylene in the soil as the result of Fusarium-diseased bulbs planted along with the rest of the bulbs; starting the cooling process too early; starting the cooling process at the right time, but at an excessively low temperature; the presence of wheat curl mites; and/or the after-effects of herbicide applications.

Prevention

- Prevent the causes listed above.

17.4.9 Salt damage

The roots remain short, grow crookedly and usually turn a light brown. The root tips are dark brown, sometimes thickened, and break-off easily.

Cause
Salt damage occurs in soils with an excessively high salt content (EC › 2) or in excessively acidic soils (pH ‹ 4). It can also occur following the incorrect application of fertilisers and/or incorrect use of fungicides.

Prevention
- Use a potting soil of good quality that does not have an excessively high salt content and/or is not excessively acidic.
- Add lime to substrates with an excessively low pH.
- Do not apply too much fertiliser (e.g. calcium nitrate to prevent “oedema” and hollow stems).
- Always uses the recommended rate of fungicides.

17.4.10 Oedema and Hollow stems

Oedema
Immediately after housing the plants in the greenhouse, they develop dark-green, watery patches that resemble frost damage. Thick drops of moisture are released in these damaged places. In forcing, this phenomenon is known as “oedema”. As soon as a larger leaf surface permits greater evaporation, the plants will stop sweating, without any further damage. In the cultivars Monte Carlo and sports, Cassini, Snowstar and others, the symptoms may even occur up to two weeks after housing.

Hollow stems
During the rapid development of the plants in the greenhouse a tear occurs lengthways in the stem which then develops into a hollow stem. The outside of the hollow stem contains small tears. Although the plant will flower, it flowers between the leaves, the bottom part of the stem is unusually thick and remains short. Although the hollow stems may occur in all tulip cultivars following frost damage, the two diseases only occur together in Monte Carlo and sports.

Cause
This typically physiological disorder occurs mainly in batches planted early (September/October). It seems there is slightly less risk during longer, warmer storage. Individual batches will vary greatly in their susceptibility to the disease. Plants that grow from the heaviest bulbs are particularly susceptible.
The cause of the disorder is excessive water absorption combined with limited evaporation. Climatic conditions that hinder evaporation of the plants or bulbs stimulate the development of “oedema” and hollow stems. This is, for example, the case when humidity levels of air and soil in the controlled temperature store are too high. Batches that are placed in standing grounds and covered with straw are less susceptible and rarely suffer from these disorders. Potting soil is not normally used as this entails a higher risk of disease. After all, plants in this soil grow relatively more roots and the soil usually contains a great deal of moisture.

Other factors that promote these disorders are the use of plastic boxes and a high relative humidity. Laboratory research has shown that there is a connection between the material of the forcing boxes (wood or plastic), the soil type and humidity.

Prevention

- Never use peat products as planting substrate without mixing with 50% coarse-grain sand or potting soil.
- If any glassy plants emerge, add 0.5 to 1.0 kg calcium nitrate per cubic metre substrate mixture or scatter at least 50 gram calcium nitrate per square metre of tray surface area and water lightly.
- Cover the tulips with plastic sheets after housing them.
- Stimulate the evaporation of the plants by applying crop heating or horizontally-directed fans and maintain a relative humidity of no more than 75%.

18. Glossary

Air circulation	The flow of air within a space and around plants or bulbs. The objectives of air circulation can vary: reducing relative humidity, getting fresh air to a certain location, achieving the proper temperature, etc.
Border soil	Greenhouse soil in which the tulips are planted and grown until harvest.
Box	Term used for the wooden boxes in which tulips are forced.
Bulb size (sieve size)	This number is the circumference of the bulb as measured in centimetres.
Bulb (or sieve)	size 11/12 means that the bulb is between 11 and 12 centimetres in circumference. Bulb (or sieve) size 12/- means that the circumference of the bulb is 12 centimetres or larger (as measured by a sieve with circular openings).
Cold period	A period of low temperatures that tulip bulbs must be subjected to in the dry and/or planted state in order to achieve a reasonable height within a reasonable growing period
Contamination	A pathogen (e.g. fungal spores) that is present on a bulb or in the soil. This does not mean, however, that the pathogen has attacked a plant.
Crop protection agents	The name given to most chemical agents that are usually applied to plants by dipping or spraying for purposes of preventing damage due to pathogens or pests.
Cultivar (cultivated variety)	The name given to a plant, following its scientific name, indicating that it has been selected or specifically bred and that its descendants will display the same or almost the same characteristics
Dipping	The immersion of bulbs in a bath containing dissolved crop protection agents.
Disease	The result of pathogens (parasites) such as fungi, bacteria or viruses on plants.
Disinfect	A term used to indicate the use of crop protection agents to protect bulbs from pathogens, usually by killing these pathogens.
Double tulips	A tulip that, instead of having the usual six petals, is filled with many more petals.
E.C. (electric conductivity)	A unit of measure indicating the conductivity of electricity and which is used to indicate the total content of various salts in soil or water.
Ethylene	Gas produced by: bulbs affected by Fusarium, the operation of internal combustion engines, gas heaters and the ripening of flowers and fruit. This gas has a highly adverse hormonal effect on tulips and is responsible for a sharp deceleration in shoot and

	root emergence and can also result in flower blasting.
Flower blasting	Inflorescences that are partially or entirely desiccated during the forcing process and display no colour. This can be the result of a variety of causes.
Forcer	The name given to person who forces bulbs (e.g. tulips) commercially.
Forcing	Advancing the natural flowering period of bulbs by the use of greenhouses.
Forcing batch	The name given to tulips of the same cultivar that are undergoing the same treatment and will come into flower at the same time in the same space.
Fungicide	A crop protection agent applied to control fungi.
Genus	A category of species that have enough characteristics in common that they are assumed to have a common ancestry. Examples of genera: Tulipa, Fusarium
Gum formation	A process (usually involving the presence of ethylene) in which bulbs produce a gummy substance.
Hydroponic forcing	The forcing of tulips in containers filled with water instead of soil or other substrate. These containers have a built-in support system that replaces the support provided by soil or other solid substrate.
Hyphae	Hyphal threads produced by fungi
Ice tulips	Tulips produced from bulbs that are planted in trays and then kept frozen for a long period which is far past their normal flowering period (usually until the autumn before the new forcing season starts) and then forced into flower.
Intermediate temperature	The period (in weeks) of warm temperature (usually 20°C) that the bulbs must receive prior to beginning the cold period.
Neck	Part of the stem between the uppermost leaf and the flower.
Oedema (sweating)	A physiological disorder common in tulip forcing in which the plant absorbs more water than it can release by means of transpiration. The plant looks dark and watery; the shoot often displays water droplets.
Peeling	Removal of the part of the tunic located at the root crown. This is done to facilitate rooting.
Perianth	The name of the set of petals (usually 6) that surround the other parts of the tulip's flower.
Pests	Animals that feed on plants.
Physiological disorder	Abnormal development of a plant due to exposure to adverse environmental conditions. Cultivar-specific susceptibility is usually a factor.
Potting soil	Soil containing a high percentage of peat products that is used for forcing bulbs in trays/boxes

Pre-cooled tulips	Tulips that have received part of their cold period in the dry state, e.g. a treatment at 9°C produces "9°C tulips". Another example of tulips that have received practically their entire cold period in the dry state are "5°C tulips".
Relative humidity (RH)	A percentage indicating the saturation of the air with water. An RH of 80% means that the air is 80% saturated with water.
Rooting room	The name given to a well-insulated room in which tulips receive part or all of their cold period and develop roots in either soil or water. The temperature in this room can be regulated by refrigeration (or, if necessary in occasional cases, by heating).
Scales	The white fleshy leaf-like parts of the tulip bulb in which nutritional reserves are stored.
Sclerotia	Fungal weft
Shading	Applying a chalk-based product to the exterior of the glass for the purpose of limiting light intensity. This can also be accomplished by closing a canvas or film sheet (usually located inside the greenhouse) to a certain degree. The latter method also saves on energy consumption during cold weather.
Shoot	The leaf parts surrounding the flower on a short stem, all of which have emerged from the bulb.
Sieve size	(see bulb size)
Single tulip	A tulip with just 6 petals.
Spores	A microscopic structure produced by fungi which functions in reproduction and dispersal. After dispersal, and under the right growing conditions, they can attack other plants and infect them with a disease.
Stage G	The stage of development of the bulb at which the last part of the flower has been initiated within the bulb. This part is the pistil, which, in Latin, is the gynoecium.
Tray	A container, usually made of plastic, in which tulips can be planted in potting soil and then forced. This term is also used to indicate containers used for the hydroponic forcing of tulips.
Tunic	The outermost, desiccated, brown-coloured scale that surrounds and protects the white fleshy inner scales of the bulb
Ventilation	The exchange of air: the replacement of air in the greenhouse with fresh air.