

Gladiolus as cut flowers

Introduction

The Gladiolus species make up a genus belonging to the family Iridaceae, or iris family. The genus is composed of many species native to southern and central Africa as well as the Mediterranean region including an area stretching from the Alps to western Asia. A number of these species have been used to develop the commercial varieties now in cultivation. The name of the genus comes from gladius, which is Latin for 'sword'. (Sword Lily is also an English common name for these plants.) The name describes the shape and upright position of the plant's long, pointed leaves. Legend also has it that crowds in Roman arenas would shower the winning gladiators with the small-flowering gladioli species then found growing locally in the wild.

The Gladiolus thus became a symbol for force and victory. Centuries of hybridisation and selection have resulted in today's many varieties that display a wide range of flower shapes, flower colours, and growth and flowering habits. Targeted breeding efforts have also made great im-

provements in the quality of these plants with regard to their flowering period, vase life and resistance to diseases. In addition to the varieties that have long been in commercial production and are no longer subject to breeders' rights, new varieties displaying improved characteristics are still being produced. Many of these new varieties are now protected by breeders' rights. The income generated by these royalties contributes to the continuing development of new varieties, including small-flowering varieties, which can then be used for other uses such as garden plants and pot plants. In the Netherlands, cut flower production takes place both in the field and in greenhouses. Both methods can also be used in other countries, but this depends very much on the local climatic conditions. Despite the fact that the Gladiolus is not a major product, either in the Netherlands or globally, consumers are very familiar with this flower and it has very high scores for recognition. In the Netherlands, the famous 'International Four Days Marches Nijmegen' contributes to making the Gladiolus a household name by calling the final stretch of its route 'the Via Gladiola'.

Plant characteristics

The Gladiolus is a corm, actually a swollen stem where nutrients are stored, and is covered by 4 to 6 fibrous tunics. Each of the tunics that overlap each other down the side of the corm covers its own growth point (meristem) and protects it from mechanical damage, loss of moisture and damage from insects and diseases. The buds located highest on the corm are the largest and, due to apical dominance, will be the first to develop. After planting, one or more shoots will emerge. The number of shoots that develop depends on the species (group), cultivar, corm size and the corm's physiological condition. If the buds located higher on the corm have been damaged, bud(s) located lower on the corm will develop into the main shoot(s). For the purpose of cut flower production, when corms are used for one harvest only, the preferred objective is to have each corm produce only one shoot. For most varieties, just one stem per corm produces a heavier, better quality flower. Depending on the variety and growing conditions, crop height ranges from 60 to 150 cm. Each plant consists of 8 to 12 long narrow leaves measuring 1 to 8 cm. in width, most of which are upright.

The flower stem, also known as a spike, emerges from the leaves with a double row of trumpet-shaped florets 3 to 15 cm in diameter. Besides a wide range of flower size, the Gladiolus are also available in a very wide range of flower colours, shapes (ruffled, deeply cut, etc.) and colour

combinations. During every growing season, the plant produces one or more new solid corms on top of the old corm which then shrivels and dies. Cormels develop at the base of the new corm. These can continue to grow into small new corms, with cormels, in the next growing season, (these are the ones that are replanted for corm production). Flower initiation begins simultaneously with the appearance of the third leaf. This period of growth is fairly critical, and it is a time when any disruption to growth can lead to poor results. During this phase, the new corm is being formed on top of the old one. The new corm produces a number of contractile roots that take over the function of the old corm's roots. A disruption occurring during this period often decreases or hinders growth results in reduced flower initiation. In turn, this leads to a shorter or less well developed spike, or even flower bud blasting. Not every corm is capable of producing a flower stem; this depends on the corm size, planting density and light intensity and duration).



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Gladiolus development

Their genetic characteristics such as disease resistance and vigour are usually the same as the large-flowering gladioli. An example of this is the 'Glamini™'. Besides their use as shorter cut flowers in mixed bouquets, corm sales for use as garden and/or pot plants has definitely increased. Also belonging to this group is the Butterfly type: a type between the large-flowering and small-flowering gladioli with florets half the size of the large-flowering gladioli – about 7 cm. across – with an arching upper petal. Nanus types This group consists of a small number of varieties resulting from crosses between *G. colvillei*, *G. nanus* and *G. ramosus*. These small flat corms produce a plant with a short stem and spike with smaller florets 5 to 10 cm. across. This classical 'species' type is a good choice for extra early flowering and can produce multiple flower stems per corm. If protected from frost, these varieties are also suitable as garden plants.

Cultivar groups

The majority of cultivars used for cut flower production are varieties with long sturdy spikes bearing large florets. The others are the short-stemmed, small-flowering Nanus varieties. Large-flowering gladioli This is the most familiar type of gladiolus. Their florets measure at least 10 cm. across and are arranged alternately in a long row along the spike. They have been bred with the objective of having all the florets open toward one side of the spike because this increases their ornamental value. Good quality spikes are at least 75 cm long. These longer and heavier spikes make them more difficult to handle during harvest and distribution. Consumers, too, realise that a vase of gladioli takes up a relatively large amount of space. This type is usually sold and arranged as straight bunches.

Small-flowering gladioli In the search for smaller, less substantial flower spikes, shorter types having flower stems 65–75 cm. in length were developed. Large-flowering cultivar: 'Hunting Song' Large-flowering cultivar: 'Large-flowering cultivar: 'Peter Pears' White Prosperity' Small-flowering cultivar: 'Cindy' Small-flowering cultivar: 'Richmond' Small-flowering cultivar: 'Bangladesh' Gladiolus x colvillii 'Albus' Gladiolus nanus 'Prins Claus' Gladiolus ramosus 'Robinetta'

The corms

When small corms are planted and grown under the proper conditions, they will generate new larger flower-grade corms that will produce cormels. These larger corms are used for flower production. Meanwhile, the cormels are replanted to maintain corm production. During this first stage of production, cormels develop into small corms not yet ready to produce flowers (the finished size depending on their original size and the vigour typical of that variety). The propagation factor of a certain batch of corms and/or cormels will depend largely on the genetic characteristics of its variety and where it is planted for production purposes. Modern corm production is mechanised and

conducted on a large scale. For this reason, it is carried out only by specialised farming operations. In the Netherlands, national inspection services such as the Flowerbulb Inspection Service (BKD) and the Plant Protection Service (Plantenziektenkundige Dienst, or PD) have responsibility for monitoring quality by conducting inspections not only in the field but also when the corms reach the service building, and before shipment. Corms are supplied according to size; corm size indicates the circumference of the corm as measured in centimetres (cm.). Examples of these sizes are 14 cm. and larger (quoted as 14+ or 14/-), 12/14, 10/12, 8/10, 6/8, etc. The corm size is a determining factor in the quality of the flower. Larger corms produce flowers earlier than smaller corms. Larger corms also produce more (and larger) florets per stem and (depending on the cultivar or cultivar group) more flower stems. Gladiolus as cut flowers.

The planting material used for producing flowers

Making the most efficient use of available light is possible by selecting varieties that not only tolerate a low light intensity but also have a more slender habit. Obviously, a good balance has to be found between the corm size used, planting density and growing conditions in order to achieve flowers of the desired quality. An unheated greenhouse provides less control than a heated one, but even in an unheated greenhouse attention should be given to providing protection from freezing temperatures, since gladiolus plants and corms cannot tolerate any frost. After planting in the greenhouse, the soil is usually covered with clear plastic sheeting (perforated or unperforated) to create a thin, warmer air buffer above the emerging shoots. The proper control of high RH levels in this microclimate requires a

great deal of attention. The plastic sheeting will be removed shortly after the crop emerges. Fleece or acrylic film can also be used as a cover. The latter gives less light transmission but can be removed at a later stage of growth. Getting the plants to flower at the same time is very important because this minimises damage to neighbouring plants when pulling out at harvest. This also reduces the housing period which is also advantageous for planning successive production periods. The flower harvesting period can be reduced by using planting material of a very uniform corm size. It would be better, for example to plant corms of size 10/11 than 10/12. Providing a uniform soil structure, soil temperature and quantity of water will also help to achieve this goal.

Production under plastic sheeting

Another way to harvest gladiolus flowers earlier than they would bloom naturally is to use early-flowering varieties and then cover the soil with plastic sheeting after planting them. During the period when there is still the danger of ground frost, the soil is covered with plastic sheeting or acrylic film. This is one of the ways to start outdoor production as early as possible. Securing the plastic sheeting properly will be necessary, in order to keep the wind from blowing it away. Determining when to remove the plastic is also very important; if not done soon enough, the chance of leaf tip burn increases. Once the height of the plants has needed the removal of the plastic sheeting, the crop will still have to be protected if the possibility of ground frost is predicted, but this can be done with air-permeable acrylic film instead of plastic sheeting.

The Netherlands

Although labour and energy are expensive in the Netherlands, growers need to market gladioli as early in the spring as possible. It is during this period when there are no gladioli available from import sources and also when growers can obtain relatively high yields from crops raised under cover. Growers also aim for a peak in production for special days. Not all varieties, however, are suitable for early flowering in the spring. Varieties with an average or long production period can be eliminated automatically. The 'quicker' maturing varieties, besides requiring a shorter growing period, must also tolerate lower light conditions when their shoots emerge so that they can still produce good, healthy plants. Flower growers have a number of technological options available to them for forcing.

Forcing

Only the cultivars listed as suitable for forcing in greenhouses should be used for this purpose. Planting in a greenhouse environment makes it possible to more easily control

production. Ventilation, shading and possibly heating can compensate for periods when temperatures are too warm or too cold. Planting in the greenhouse is usually done in beds in order to maximise the use of space. For an early production period, it is important not to plant the corms too closely together because light intensity will be low. A high planting density coupled with insufficient light results in reduced flower production and lower quality. A single layer of support material (nylon or metal chrysanthemum mesh) is usually used to keep the plants upright during growth and harvesting.

Greenhouse production

The fastest way to force gladioli into flower is in a heated greenhouse. The use of active heating (heating combined with ventilation) makes it possible to obtain optimum temperatures and RH conditions for proper growth and development. The best heat source is radiant heat produced by hot water running through pipes in the greenhouse. Heat produced by heaters is an option, but it is dangerous due to harmful combustion gases: incomplete combustion produces ethylene! The release of ethylene must be avoided at all times because it can damage the crop (even leading to flower bud blasting). The addition of CO₂ can stimulate plant growth.

Greenhouse production

After planting, the soil was covered with plastic sheeting or acrylic film.

Summer field production

The vast majority of gladiolus flowers supplied by Dutch growers are produced in the field. The corms are planted out in beds or rows by machine. This is a fully mechanised system. The flower spikes are harvested by hand, with the aim of achieving the shortest possible harvesting period per crop. Planting in the field can be done no earlier than one to two weeks before the danger of ground frost has passed. During this period, the growth of the corm is still occurring below the soil surface. If frost is predicted just as the first shoots are emerging, a possible solution would be to irrigate the crop for a short period just before sunrise. By selecting certain corm sizes and varieties, it is possible to draw up a planting programme that provides successive flowering periods and crop harvesting that follow each other in quick succession, for a manageable distribution of labour. Other countries There are great differences between the various other production regions in the world. In many cases, the danger of ground frost is very real. In some production regions, this means finding covered growing methods for early production. Often, the solution is to use partially open greenhouses (preferably using relatively tall greenhouse constructions) with a plastic cover. In most cases, pipe heating is not available but heaters are sometimes used. At production regions located at high elevations where light levels are high, it may be necessary to grow the crop in an open greenhouse in order to filter out excessive light intensity. Sometimes, the area where the crop is grown will allow growing to be started earlier than in the Netherlands. And a higher 24-hour temperature usually accelerates production as well. A winter that begins later and/or with higher winter temperatures than in the Netherlands often provides the possibility of more production cycles. If this is possible, crop rotation will have to be considered. Planting gladiolus directly after a previous gladiolus crop in the same soil increases the risk of losses due to disease. The choice of variety depends on the grower's country and the planting season; ask your supplier which varieties would be best for your situation.

Receipt of planting material

Shipments of corms should always be removed from their packaging material immediately after receipt and be placed in a building with plenty of air circulation. This prevents them from being subjected to the higher temperature and humidity inside the packaging material that could encourage fungal development and possible premature emergence of shoots and roots. Untreated material should be treated immediately before planting. When feasible, chemicals can be combined to provide a single immersion treatment. Find out from your supplier of crop protection agents which substances can be used in combination. An increase in environmental awareness is resulting in a decline in the number of approved chemicals. Check with your national or regional levels of government to see which chemicals are approved.

Storage

Ensure that the material can be planted soon after receipt. If this is not possible, store it for a short period under the driest possible conditions in a well ventilated building at 17 - 20°C. Material that must be stored longer should be kept at 2 - 5°C, but always discuss this with your supplier first. The best storage is provided in a well insulated cold store with controlled temperature and ventilation. Storing in flat crates or containers with a wire mesh bottom is preferable. Avoid putting too many corms in a single crate. The circulated air should be able to flow through the corms in the crates. Provide the cold store with good air circulation. Arrange stacks of crates at least 5 cm. away from the walls. Besides keeping the air moving, it is important to ensure there is frequent exchange of air from the outside. Manage the RH by discharging excessively humid air. Frequently check the condition of the corms and pay special attention to the development of storage diseases and pests (thrips at 17 - 20°C, or Botrytis and Penicillium rot at a low temperature and a high RH).

Salt sensitivity

Gladioli are sensitive to salt. High concentrations of salts delay root growth and can also endanger flowering due to the plant's reduced ability to absorb water. The root system hardens and becomes brittle and more susceptible to physical damage. The roots turn yellowish to brown in comparison to healthy roots. Taking a soil sample at least 6 weeks prior to planting is a good way to determine the pH, salt concentration, chlorine content and the presence of nutrients so that these conditions can be corrected. The EC rating should not exceed 1.0. The advice for soils with a high salt concentration is to irrigate more frequently.

Nutrient levels

Gladioli do not benefit from a heavy application of fertiliser but from the consistent availability of sufficient nutrients. A heavy application of fertiliser is inadvisable due to the risk of excessively high salt concentrations and an increased reduction in the plants' resistance to diseases. It is impossible to provide an unequivocal general recommendation, since fertilising depends very much on such factors as soil type, rainfall (frequency and quantities), existing nutrient levels and the salt concentration. For this reason, always begin by taking a soil sample before planting, so that fertiliser can be added according to the recommendations provided.



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A consistent programme of watering will increase the plant's absorption of nutrients as well as its needs for such nutrients. Always adjust fertilising to the needs of the plant. Periodically check the crop and take soil samples. In most cases, the first application of fertiliser can be made a few weeks after emergence. During the first few weeks after planting, the plant gets most of its nutrients from its own corm and the young developing roots are extremely sensitive to high salt concentrations. During the early stages of growth, providing a few applications to maintain nitrogen levels will be enough. Do not use any phosphate fertilisers that contain fluorides such as triphosphate fertilisers. Using phosphate fertilisers low in fluorides is preferable. In most cases, a good time to apply nitrogen fertiliser is when the third or fourth leaf appears. If necessary, a nitrogen fertiliser can be applied up to two weeks before flowering. Most fertilisers can be added to the irrigation water in the greenhouse. Application in granular form is another option. Also available, in addition to fast-acting fertilisers, are the slow-release kinds. To prevent leaf burn and to ensure that the nutrients penetrate the soil properly, irrigating heavily with plain water after the application of fertilisers is recommended.

Soil

Gladiolus can be grown with good results on most soil types as long as the soil absorbs enough moisture from the groundwater during dry periods and also allows excess water to drain off quickly enough. The most ideal soil is a sandy loam with good drainage. Be sure that the field is as flat as possible; shallow spots will often be wetter and result in uneven development. Wet compact soils hinder root development. Too much water keeps the plant from absorbing nutrients and encourages root rot.

Structure

Good soil structure depends on having a balance between the quantities of water and air in the soil. Soil structure can be improved by adding organic material. If the soil structure has to be improved, this should be done in plenty of time before planting. If the soil is wet, postpone planting for a few days to prevent permanent damage from the weight of machinery. On more moisture-retentive soils, it is sometimes better to plant on raised beds or ridges. The condition of the soil can be retained or improved by the periodic (annual or biennial) addition of organic material such as compost, leaves, straw, hay, or stable manure. They improve both the drainage and the nutrient levels of the soil. Ideally this would be applied in the autumn. It is better not to add any stable manure to heavy soils; this makes the soil too 'sticky'. Sand or lava sand would be good alternatives for this kind of soil.

pH

A pH value between 6 and 7 is essential for root development and the potential for absorbing nutrients. Soil that is too acidic (< pH 5) can increase the risk of fluorine toxicity and the elements manganese, aluminium and iron

will be absorbed in excessive quantities. In this case, soil improvement is often the only solution. Soil that is too alkaline (pH > 7.5) will keep the plant from absorbing the available phosphorus, manganese and iron, and the plant is therefore unable to receive the necessary nutrients. A symptom of iron deficiency is light yellow-green foliage with green veins. It is sometimes necessary to adjust the form in which fertilisers are added to improve the pH of the soil. Consistently adding organic material in advance of planting can reduce or even eliminate this problem. Having a soil sample taken every year to determine the pH, the nutrient levels and the EC rating of the soil is recommended.

Temperature

Planting in the field can be done as soon as there is no more danger of ground frost. Low soil temperatures increase the risk of rotting because the corms then grow slowly, if at all. Planting should wait until the soil temperature is high enough. Growth begins at temperatures of around 13 - 15°C. Pathogen-free soil It is best to plant gladiolus corms in fresh soil. Fields in which gladiolus (or plants related to the Gladiolus such as Iris, Ixia, Freesia and Crocosmia) has been grown earlier should either be avoided or sterilised before planting. This is because soil-borne diseases such as Stromatinia Corm Dry Rot and Fusarium Rot that do not result in visible symptoms during production can heavily damage the succeeding crop. For these crops, a crop rotation of at least six years is recommended. Vertical crop rotation using deep ploughing is another possibility. With this method, a large plough is used to plough down to 30 cm. under the topsoil whilst bringing up fresh soil from the layer below. Steam sterilisation of the soil for 2 hours at 60 - 70°C controls Fusarium, Stromatinia Corm Dry Rot, nematodes and other organisms living in the soil. Along with the harmful organisms, however, the beneficial ones are killed as well. This means that after steaming, pathogens such as Pythium and Rhizoctonia can develop at a faster rate due to the lack of their natural enemies. Steaming can start once the soil temperature has reached at least 10°C. Preparations for planting can then start two to three days after steaming and after leaching the soil to reduce its salt content. Steam sterilisation is used in greenhouses and sometimes outside on frequently used fields. The application of chemical disinfectants in liquid form to disinfect soil is another possibility. Most of these products require a minimum soil temperature of 12 - 15°C to be effective. Approved chemical soil disinfectants vary greatly from country to country. In the Netherlands, a field treated with one of the additives approved in this country cannot be re-entered until 2 to 5 weeks after application.

Not all chemicals are as effective as steaming for controlling all of the disease and pests listed above. An increase in environmental awareness is resulting in a decline in the number of approved chemicals. Check with your national or regional levels of government to see which chemicals are approved.

Watering

Irrigation water which has an EC of 0.5 mS/cm. is acceptable. Rainwater usually has an EC of around 0.1 mS/cm. The EC in wells or surface water can differ greatly from season to season, so it would be advisable to have these sources of irrigation water sampled periodically. In greenhouses, the chloride level should not exceed 200 mg/l; for field production, it should be under 600 mg/l. If using irrigation water with a relatively high chloride level, it would be advisable to keep the soil wetter at all times to prevent an increased salt concentration should the soil dry out. When using rainwater alone, a boron deficiency can develop in certain soils.

Planting

One of the factors in being able to harvest according to a tight schedule is the use of very uniform planting material. You might want to agree with your supplier to have corms that are normally supplied as size 10/12 graded more precisely into sizes 10/11 and 11/12. It is also important to minimise differences in production methods so uniform soil structure and uniform watering are essential. Plant the corms in soil that is sufficiently moist but not overly wet. Irrigate the soil a few days before planting. If this is done, getting growth off to a good start can usually be achieved without the need for watering during the first two weeks. If the soil is no longer moist enough after planting, be sure to provide irrigation to avoid problems in development during the first weeks after planting. If the soil is wet, postpone planting for a few days to prevent damage to the soil structure.

Planting depth

Planting depth depends on the soil type, location (greenhouse or field), corm size and planting period. In the greenhouse, where the plants are supported by mesh, the corms are often planted just a few centimetres beneath the soil surface. In fields with heavy soils, large corms are planted at a maximum depth of 10 cm. but this depth could be increased by another 5 cm. on lighter soils. Smaller corms can be planted at shallower depths. Corms planted deeper will flower a few days later but these plants will not fall over as easily and will require less (if any) support material. If the crop is still being subjected to too much wind, the ridges can be earthed up higher. For a spring planting, corms are planted at an average depth of 5 to 10 cm. but this depth can be increased to 10 to 15 cm. for a summer planting, to benefit from a lower soil temperature that will encourage good rooting before emergence. Remember, however, that a deeper planting will delay flowering for a number of days.

Planting techniques

Corms can be planted on raised beds or ridges. Where drip irrigation is used, row planting would be preferable. For overhead irrigation (in the greenhouse) or for supplementing

natural rainfall (in field production), either method could be used. Ensure that the corms are planted deeply enough (approx. 10 cm.) by earthing up enough soil to create the ridges or raised beds. Planting in the greenhouse is often done manually. In this case, a layer of mesh material can be arranged over the beds as an aid to distributing the corms evenly. Later, as the crop grows, the mesh will also serve as support material. If additional support nets are to be used, they should be installed immediately after planting to keep the shoots from being damaged later. Mechanical planting methods are used for field production. For lower planting densities, a potato-planting machine can be used to drop the corms into individual holes. This is relatively time-consuming (20 hours/ha.). When planting by machine, check periodically to see that the corms are still being planted at the correct depth and quantity per linear metre. Although not a generally widespread practice, applying a mulch of composed straw, pine needles, etc. could help to control soil temperature. This would keep soil temperatures cooler during spring and summer and warmer during the winter. During periods of ground frost, a thick layer of mulch can limit frost damage. It also improves soil structure, thus keeping the soil from silting up during rain and irrigation, and reducing the evaporation of moisture from the soil.

Planting in the field using a tractor pulling a precision planting machine

Planting in a way that exceeds the recommended planting densities results in tall limp plants that sometimes fall over. The desired quality will not be attained, spikes will not reach optimum length, and flower blasting can even occur (also refer to the section on light in the chapter on greenhouse production). The microclimate among these plants will also be adversely affected, thus encouraging the occurrence of diseases.

Weed control

Always make a clean start: planting in weed-free soil will save work later on. Also check for weed development during the first weeks after planting, but before the gladiolus shoots have emerged: efficient pre-emergent weed control can often provide substantial savings in both herbicides and labour. For this reason, apply the approved weed-control herbicides according to the instructions and well in advance of the moment when the gladiolus shoots emerge. If the crop starts to emerge during spraying, be aware of possible crop damage and adjust concentrations, herbicides and frequency of application accordingly.



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Planting density

The factors in determining planting density include planting time, planting depth, corm size, soil type and varietal properties such as vigour and uniform development. Planting too closely together (too many corms/m²) will have an adverse effect on quality. This is why planting at the lowest suggested density is recommended. For row planting,

the rows are generally kept 30 to 60 cm. apart and the corms are spaced at 5 to 15 cm. along the row. The number of corms/m² depends very much on the planting time, planting depth, corm size, soil type and varietal properties. This table provides a general guideline for each corm size. Spring planting in the field with a precision planting machine.

Corm size in cm.	6/8	8/10	10/12	12/14	14/-	
Quantities of corms						
per gross m ²	40 – 50	30 – 45	35 – 40	30 – 40	30 – 40	16

Light

Insufficient light during the critical period when the third to fifth leaf appears can even lead to the complete desiccation of the flower stem ('blindness'). Insufficient light during the appearance of the fifth to seventh leaf will mean the loss of a few buds on the spike. For greenhouse production, it is particularly important to encourage transpiration and ensure healthy root systems during periods of low light. The amount of light to be made available to the plant can be based on a combination of these factors:

- corm size
- planting density
- planting depth

Larger corms will produce plants with a greater volume than will smaller corms. In order to ensure that enough light can reach the leaf surfaces during cultivation, larger corms will have to be planted at lower densities than small corms. Planting the corms more deeply produces sturdier plants; plants that are sturdy and straight will also receive more light. Also to be considered is shade generated by buildings, walls, tall plants and trees. Ensure maximum light permeability during difficult periods by cleaning the glass and structural components in advance. Spreading the ground surface of the greenhouse with light-coloured materials such as sawdust and Styromul granules help reflect light through the plants during early stages of growth. If HPS lamps are available, they could be used but this is seldom if ever applied in practice.

Temperature

Gladioli can be grown without encountering problems when temperatures between 10°C and 25°C are maintained, but high temperatures, particularly in combination with lower light intensities, will have to be avoided at all costs during the critical period of flower bud initiation. And higher temperatures at the end of this critical period can result in a decrease in the number of florets per spike. The plant's growth and development will cease at 24-hour temperatures averaging below 10°C. If a cold period lasts too long, various growth disorders and growth defects can occur. Gladioli cannot tolerate frost: the result will be crop damage or the complete loss of the crop. If 24-hour temperatures average

below 10°C and ground frost are expected, planting in a cold or slightly heated greenhouse is recommended, but planting at this time of year will also be accompanied by conditions of lower light intensity. Only a very few varieties in the commercial assortment can tolerate 24-hour temperatures that average 27°C. The maximum average daytime temperature for gladioli is about 27°C. Gladioli can tolerate a shorter period of temperatures exceeding 25°C (sometimes even up to 40°C) if the RH is high and the moisture level in the soil is sufficient. For greenhouse production, temperatures are kept above freezing until mid-February. This is followed by two weeks at 12°C. This temperature can be raised to 15°C until April. The remainder of production can take place at 17 to 20°C. Night temperatures can dip 3 to 5 degrees beneath the average target value for daytime temperature without causing problems.

Ventilation

Being able to ventilate a greenhouse is extremely important. Wide fluctuations in temperature and the accompanying wide fluctuations in relative humidity should be avoided. Being able to ventilate also reduces the risk of leaf tip burn. Temperatures inside covered production systems will rise faster than they do outside. Be prepared for this by progressively increasing ventilation. Consistent proper ventilation will prevent limp plants with excessive foliage growth. Try to ventilate sufficiently (keep vents opened to 2% at all times) to develop tough, sturdy plants that are more resistant to attack by pests and diseases. The vents can be opened as soon as greenhouse temperatures permit. Anticipate outside conditions and try to maintain the most constant indoor climate possible. Close the vents earlier at the end of the day to conserve heat during cold nights. On the other hand, ventilate as early as possible on warm days.

Shading

In most cases, the use of a shading system will rarely be required. If available, use a retractable system. Closing (or partially closing) the shading system on time can help control greenhouse temperatures during days of high insolation (sunny days). During cold periods, the shading system can be used to conserve energy in the evening, night and early morning. Permanent shading is used only during periods of high light intensities or during the hottest periods.

Relative humidity

When the relative humidity is too high, a thin layer of moisture collects on the surface of the leaves. If this occurs, the plant is less able to control its exchange of gases with the surrounding atmosphere. In general, the RH will be higher in the morning than during the remaining daytime hours. Prevent an excessively high RH by ventilating before this can occur. Even a small opening in the vents will quickly produce a moderate, steady release of excessive moisture. A brief burst of heat early in the morning will activate the plants and help reduce the RH. (It should be remembered that Botrytis fungi develop particularly easily at a high RH.) High-density planting often leads to a microclimate with a high RH. This situation can be prevented by ventilating, possibly combined with a temporary increase in temperature. On the other hand, higher temperatures can result in an RH that is too low. During warmer periods, keep the top layer of soil wetter so that evaporation from the soil contributes to more moisture in the air. In extreme cases, a brief pulse of overhead irrigation can help. Most importantly, avoid sudden fluctuations in RH. Besides stress, this can result in leaf burn because the plant's rate of transpiration cannot keep up with such fluctuations.

Watering

Either too much or too little water will retard growth. This will result in shorter flower stems, reduced flower and corm development, greater vulnerability to diseases such as root rot, and a greater risk of flower blasting. Making enough water available during spike development is absolutely essential. Both the quantity of water per irrigation session and the frequency of watering depend on the weather and the state of the crop's development. Always base watering on the availability of moisture within the root zone. Take soil samples periodically, and run visual checks to see if the soil is sufficiently but not overly wet. Make sure that every system is distributing water uniformly so that dry or wet spots are prevented. Check water distribution periodically. Ideally, overhead irrigation will be used during the first period of production (until the appearance of the spikes); after spike development, drip irrigation will be used. In this case, select the spray heads that produce the smallest possible droplets; this keeps the soil from silting up. When using drip irrigation, create a uniform distribution by installing enough emitters. Providing water in short intermittent bursts (for building up soil moisture levels) is better than a single long irrigation session. Overhead

irrigation is best avoided in areas of high RH. Overhead irrigation is best conducted during the morning so that the crop can dry off before evening. This helps prevent the risk of Botrytis infection. Overhead irrigation can be used on warm days to cool the crop and/or to increase the RH when this is needed. This method can also be used for the purpose of rinsing off the crop after applying fertiliser or for removing residues. Be aware that the improper use of overhead irrigation can damage the flowers, create spotting on petals, cause taller plants to fall over and increase the risk of diseases spreading. When watering from below, be sure to use enough pressure to get the water properly distributed beneath the plants.

Shading system

In field production, it is usually not possible to build up the moisture level in the soil by watering intermittently. Instead, try to start irrigation promptly in response to the moisture level in the soil. Do not wait until the soil is too dry.

Nutrients

It is impossible to provide a general fertilising recommendation. The most important basis for obtaining an accurate picture of nutrient levels in the soil is provided by a soil sample taken far enough in advance of planting (also see 3.2.6: nutrient levels). If in doubt, ask your production advisor or supplier for advice. Make sure that the soil contains a sufficient buffer of nutrients at the beginning of production but remember that the corms will be using the stored nutrients in their old corm for their main source of energy to grow during the first month. Avoid fluctuations during the critical period when flower initiation occurs. After this period, it may be necessary to take another soil sample at least two weeks before harvesting to determine the need for a top dressing. Leaf colour often betrays the level of nutrients being absorbed by the plant. If a top dressing proves necessary, make sure that the moisture level of the soil is high enough to enable the absorption of the fertiliser.

Crop checks

Whether growing in a greenhouse or in the field, check the crop periodically (at least weekly). When growth rate slows, discolourations appear or the plants appear limp, the prompt identification of these problems can often facilitate their timely correction, simply by the use of limited labour and resources. A healthy crop looks nice and green. Soil that is dry on the surface should not be a problem as long as the roots have access to enough water. Check for dry and wet spots.

Field production

Methods to control growth are also available for field production. A good example is covering with plastic sheeting or acrylic film after planting, to increase the temperature in early spring and thus shorten production time. In the summer, be aware that high temperatures are possible in smaller fields surrounded with tall plants or trees. On the other hand, taller plants can serve as windbreaks.

Light

No light means no photosynthesis and, thus, no growth. This makes light necessary for flower development as well. During periods of low light (early spring and late autumn production), it will be important to admit as much light as possible and use a lower planting density. In field production, shade generated by trees or buildings can result in slowed growth rates; portions of a field can thus flower at a later time. This can often have an adverse effect on the quality of the harvest as well. Shading may be necessary, however, in warmer regions or areas exposed to high light levels.

Windbreaks

To protect the crop from high winds, windbreaks should be erected on the windward side of the field, or, if the field is more protected/ exposed to gentler winds, a shelterbelt of tall plants should be planted around it. High winds, particularly when they occur during the harvesting period, can cause plants to fall over after their neighbouring plants have been removed. Once blown over, these plants will grow crookedly and will no longer be worth harvesting. Use can be made of natural windbreaks (tall plants such as maize that can be planted either next to or in the fields) or windbreak material that can be positioned in and around the field and held in place by posts.

Irrigation

Open field producers usually depend on natural rainfall supplemented by irrigation to provide their watering needs. Make periodic checks based on a soil sample taken at the root zone to see if irrigation is required. There is no need for concern if the upper layer is dry; this is usually advantageous because it will prevent the spread of fungal diseases.

Crop protection

The best way to avoid pests and diseases is a healthy start to production. This begins with the purchase of healthy corm material that is planted in weed-free, pathogen-free soil. If weeds are present, they will compete with the gladiolus plants for nutrients, light and water and will thus reduce the yield and quality of flower production. In addition to chemical weed killers, mechanical methods can be used. Best weed control results by controlling it during the first production phase when the gladiolus plants have not yet covered the majority of the ground surface.

Hoing and weeding does involve some labour, but these jobs can easily be mechanised. Mulching by applying various organic materials suppresses weed growth and it also reduces evaporation from the soil. In the greenhouse, light-coloured mulches can help reflect excess light. Having periodic health checks helps to identify the presence of pests in their early stages. Initiate adequate measures immediately; do not wait for a serious infestation. In the case of newly established, localised infestations, it will not be necessary to subject the entire crop to control measures, so this will reduce the quantities of chemicals used as well as labour costs. Use only those crop control chemicals that are approved; consult your supplier or your national government concerning the agents currently approved. Read the instruction leaflet and use the recommended amounts and application techniques for best results. Do not use improper chemicals; this can result in damage to the crop and the environment. Clean all equipment after use. Do not carry out any control measures during the warmest parts of the day. When applying certain chemicals, it is better to allow the crop to dry off before evening; in these cases carry out the control measure during the morning hours.

Harvesting activities

The flowers should be harvested at least once a day; during fine growing weather, harvesting twice a day may be necessary. The entire plant is usually harvested, no matter whether production is in the greenhouse or the field. This often increases the length of the flower stem as supplied. The old corms and partially formed new corms are discarded along with the other unused parts of the plant and then destroyed. Harvest the stems without dew or moisture whenever possible. A drier product will have less risk of developing a fungal infection during storage and transport. Harvest when the stems have reached the correct stage preferred by the market and avoid cutting immature stems. The florets on immaturely cut stems will not open properly. There are various ways of harvesting:

- Pull the plant out corm and all, bunch and trim to length in the field
- transport directly to the processing shed and grade and bunch there
- Cut off the stem and leave the corm in the ground, bunch and trim to length in the field
- transport directly to the processing shed and grade and bunch there

Use clean harvesting containers and knives. Cut downward at an angle between the leaves to harvest the longest stem possible. If the corm is not being pulled up (so that the corms can develop for another harvest) leave a plant that has at least four leaves intact. Remove excess and damaged leaves from the flower stem. Place the harvested stems upright in harvesting containers, place the containers in the shade, and send the material periodically to the packhouse. Make sure that the stems are held upright at all times.

Harvesting and processing

In the Netherlands, field-grown gladioli flowers are harvested from June to mid-November. During harvesting, processing, packaging, storage and transport, it is important to keep the harvested stems upright in all cases. If left in a horizontal or slanted position, the tip of the flower stem will start to bend upward. After a while, this bend in the stem becomes more rigid. Later, when the stem is placed in an upright position again, the tips of the flower spikes will remain crooked. So avoid this by ensuring that the stems are stand in up nice and straight even before harvesting by adjusting the level of the support netting in time. The use of deep pails/containers to hold the flower stems during storage and transport is recommended.

Harvesting stages

The necessary maturity level of the flower stems at the time they are supplied can sometimes differ by region, but will definitely differ between various areas of a country and between countries. So this will have to be taken into account in determining when to harvest. For direct trade, it is often possible to supply more mature stems than when sending the stems to auction. Stems harvested from early and late crops can be harvested at a slightly more mature stage than stems harvested during the summer months. Flower stems are ready to harvest as soon as the lowest flower bud displays colour. Harvesting when too mature will result in damage. Bunches are immediately placed upright in their containers.

Grading

Begin grading according to similar levels of maturity. Less mature stems can be stored longer than mature stems. In general, gladioli are stored and delivered without water. Within a graded bunch, the length of each stem covered with flower buds should be approximately the same. Make sure that the tips of the stems are all at the same height. Then cut the bottoms of the stems to the same length. Grading is usually done at 5 cm. intervals starting at 65 cm. All the stems in each bunch should be of about the same weight. Include thinner stems in shorter bunches.

Bunching

The buyer usually specifies the number of stems per bunch. There is a definite trend toward filling each container with larger numbers of unbunched stems. Make sure that the containers are filled with bunches exhibiting a single grade and a single level of quality. Containers must be completely filled; this prevents crooked stems. But the containers must

not be too full either; if too full, the stems can be damaged. When using auction trolleys to transport products having different lengths, it is possible to fill each trolley with two layers of products. Unlike other cut flowers, gladioli are seldom packaged in flower sleeves.

Storage

Store the stems in an upright position in containers without water in a properly ventilated cold store at 2 - 5°C. Ensure that the storage period is as short as possible (no more than a few days). Any storage will adversely affect vase life. If longer storage is necessary, it would be best to store the stems in containers filled with water to which nutrients for cut flowers have been added. Avoid putting moisture-laden stems into storage; let them dry thoroughly in the packhouse first. Prevent condensation from forming on the stems by minimising temperature differences between the place where they are grown and the packhouse; keep these areas cool and dry. Even tiny droplets can result in spots caused by Botrytis fungus. Pulling up flowers with corm attached, bunching, and trimming to length. An elastic band is wrapped around each bunch of 10 stems and the bunches are then put on a tall cart for transport.

Preparing for delivery

When loading the gladioli onto auction trolleys, be sure not to let any stems protrude from the sides of the trolley since this will result in damage during transport. The use of stretch wrapping film or twine will prevent these problems. Make sure that all the trolleys are full to keep the containers from shifting position. Label each trolley with the name of the variety, its grade and the quantities. Accompany the shipment with a consignment note containing the correct information. Accurate administrative processing is becoming increasingly important for registration at the auction. Buyers are seeing the product to a lesser degree. Instead, they have to rely more and more on the information accompanying a shipment (buying at a distance over the Internet by using a reliability index). Flowers are transported to the auction in an upright position in auction containers. Flowers held in an upright position in containers without water are loaded into Danish trolleys (CC trolleys) for transport to the buyer. Instead, obtain information well in advance from your dealers, suppliers and local levels of government. Follow the instructions for using these chemicals. Alternate between chemicals, in order to prevent a build-up of resistance. Pay particular attention to the listed active ingredients. Based on the group in which an organism is classified, it is often possible to achieve successful protection by implementing a strategy (control measure/application technique or chemical) recommended for a similar organism in that group.

Dry Rot (*Stromatinia gladioli*)

Dry Rot is caused by a fungus known as *Stromatinia gladioli*. This disease occurs chiefly in field production. In warmer regions, it is rare or is found only in cold winter production periods. The fungus develops most rapidly at lower temperatures and when the soil contains an average or higher level of moisture. The fungus grows underground where it spreads from infected to healthy plants. The fungus produces brown to black sclerotia that can survive for very long periods (several decades) in the soil. Infected corms often exhibit loosely fitting tunics. The symptoms of infection are often found predominantly on the underside of the corm. Brown to black rings are visible at the heights at which the bases of the former leaves were implanted. Between these rings are many dark brown or black spots, frequently with a somewhat raised yellow-brown margin. The spots are somewhat sunken and scab-like. These corms can mummify during storage. Identification in the field

Spreading areas of infected plants develop at random locations and can ultimately spread throughout an entire field. After an initial period of healthy growth, the plant turns yellow and brown, starting at the outer leaves. The plants then wither and die. By that time, the outer leaf sheaths are usually seriously infected. Characteristic, very small, round, black fungus structures (sclerotia) can be seen developing on these infected leaf sheaths. The corms do not rot. Brown spots, later growing larger, are visible on the roots. Sclerotia are found on these spots as well.

Measures for prevention and control. Avoid planting out gladiolus corms in infected soil. For this reason, a preventive measure would involve finding out if gladioli have ever been planted in the field being considered for production. Using a field with fresh soil is highly recommended for producing gladiolus flowers. This brochure focuses on discussing the most prevalent diseases and pests. Diseases and pests affecting a crop in one country will be unlike those of another country due to climate differences.

Prevention

Following a good crop rotation programme can interrupt the life cycle of harmful soil-borne organisms or can help minimise their accumulation. At the end of production, remove as much crop debris as possible. This will reduce the survival of a pathogen on plant and root debris left in the soil or among new gladiolus corms collected from

the soil and then stored. It would be preferable to plough the field prior to a period of frost so that plant debris could freeze. Depending on the availability of chemical soil disinfectants, agricultural soils can be sterilised in plenty of time before production begins. In addition to the application of chemical soil disinfectants in liquid form, this can also be achieved by steaming or flooding. For both chemical disinfecting and flooding, the soil temperature must be high enough to be effective. By immersing the corms in a solution containing mainly fungicides immediately prior to planting, a small regulated volume can be used to control a large number of pests and diseases. Consult your supplier concerning the application of chemicals. Pre-soaking the corms or subjecting them to a temperature treatment before immersion is sometimes important. Do not immerse more material than can be planted soon after treatment. Once the corms have been treated, they should not be allowed to return to their dry state or be put back into storage.

Biological control

Besides chemical crop protection agents, the number of options for controlling pathogens and pests by using their natural enemies is increasing rapidly. Many greenhouses in particular are already using these natural predators as a control method. A large percentage of pests such as aphids, thrips, white fly and red spider mites can be controlled consistently by releasing their natural predators. Fungal preparations or nematodes are also being used to control certain harmful fungi. Consult your supplier about these options. Chemical crop protection agents

There are major differences between countries regarding which crop protection agents have been approved, and which of their application techniques can be used for gladiolus flower production. In general, the number of approved agents is decreasing. As a preventive measure, it would be advisable to immerse propagation and production material (corms and cormels) in an approved fungicide that is effective at controlling this fungus for 15 - 30 minutes before planting. Remove all visibly infected plants along with their corms and cormels at the time when the disease is identified.



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Botrytis Blight (*Botrytis gladiolorum*)

Botrytis gladiolorum can infect the corm, leaves and flowers. Sclerotia can form on all parts of the plant, including the corm. Under damp conditions, this fungus produces masses of spores above ground that are distributed by the wind. The sclerotia formed underground are large, black, and flat and range in size from 1-9 mm. Under excessively damp conditions, corms and harvested products in cold stores can also be infected. The infection of leaves and stem occurs at cool temperatures (approximately 10°C) and under damp conditions. If the plant remains wet for too long, the infection spreads to other leaves. This disease occurs very often in a crop in which corms have been planted too closely together and also in unventilated greenhouses where the RH reaches excessively high levels.

The symptoms and degree of infection can vary greatly. In the least severe cases, the corm displays small, dark brown to black spots (1 - 2 mm) on the upper side of the corm

(spetterbotrytis in Dutch). In more severe cases, the corms become completely soft and rotten and turn a reddish-brown colour (*Botrytis* corm rot). The corm then shrivels up on drying and mummifies. The infected corms sometimes look normal from the outside but will display a white mycelium, sometimes with black sclerotia, beneath their tunics. Identification in the field Often, the first symptoms (wet brown decaying leaf tissue) appear on the neck of the plant at the surface level of the soil. The plant turns yellow and sometimes falls over. The round light brown spots appearing on the leaves later turn dark brown. Later in the season, large, dead, grey-brown spots develop on the leaf tissue. During wet weather, a grey fungal weft appears on the infected spots. Germinating spores can also infect the flowers which results in Remove diseased and damaged corms during planting. Prior to planting, immerse the corms for 15 - 30 minutes in an approved fungicide intended for controlling this fungus.

Fusarium (*Fusarium oxysporum* f. sp. *gladioli*)

Fusarium oxysporum is a fungus that causes damage predominantly during the warmer growing season. This fungus develops most rapidly at temperatures above 18°C and when the soil is relatively moist and/or the RH is high. The fungus spreads mainly through the vascular strands, thus leading to the disruption of the transport of nutrients. The stem can completely collapse. This fungus generates large numbers of spores that can easily spread and that can also survive many years in the soil. The disease can also be spread by soil that remains clinging to the corms. Iris, Freesia, Ixia and Tritonia are also susceptible to being infected by *Fusarium oxysporum* f. sp. *gladioli*.

Dark brown to reddish-brown deeply sunken rotting spots, often containing concentric rings, develop from the basal plate of the corm. Also frequently present is a white fungal weft (mycelium). Seriously infected corms mummify during storage and will not emerge after planting. Identification in the field Severely infected corms will not emerge. A less severely infected corm will produce a plant that grows crookedly. At first, only the leaf tips turn yellow. Over time, the entire plant turns brownish yellow and finally dies. The infection can sometimes occur during the last phase of production; in this case, plants do not exhibit above-ground symptoms. The young corm can be infected through its contractile roots or by the older corm. The basal plate of the corm turns light to dark brown. This discolouration spreads to the central part of the corm and spreads outward from there.

are not planted annually but at intervals of several (6, for example) years in the same location. Avoid planting out in infected soil. Disinfect the soil in plenty of time before planting. Corms infected with *Fusarium* Plants withering as a result of a *Fusarium* infection Corms exhibiting symptoms of *Botrytis*. In the field, the tips of infected leaf sheaths that have emerged above the soil surface can turn brown. The leaves directly above the soil surface sometimes exhibit elongated, dark brown stripes that extend downward into the tunics of the future corms that are still white. Under damp conditions, a mycelium and mass of spores is also sometimes visible. Follow a good crop rotation programme. Remove diseased corms before planting. Prior to planting, immerse the corms for 15 - 30 minutes in an approved fungicide that is effective at controlling this fungus.

Measures for prevention and control

Follow a good crop rotation programme in which gladioli



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Penicillium Storage Rot (Penicillium)

This fungus develops during the storage of the corms where it affects mainly the tunics and prematurely emerging root tips. The root tips also dry out, and the corm tissue becomes damaged. Brown water-soaked spots also develop in the corm tissue. Eventually, the corms can become entirely overgrown with a fungal weft and covered with spore masses but this does not have an adverse effect on the usefulness of the corm. In severely damaged corms, the deeper corm tissue is infected as well. Severely damaged corms will either fail to emerge or will emerge but produce

weak plants. Measures for prevention and control Keep the relative humidity low during storage. The corms have to have enough air circulation flowing around them. For this reason, do not fill the mesh containers and crates too full. Remove all damaged and infected corms. Penicillium is predominantly a storage disease. Weak-looking plants in the field can be removed. When selecting packaging material, and during transport, remember that corms release moisture and that this will require sufficient ventilation measures to get rid of it.

Root Rot (Pythium)

Pythium is a fungus that occurs only when a plant is weakened in some other way, and it usually develops in combination with other pathogens. In many cases, growing conditions have been disrupted or are not up to par. The rotting symptoms are often caused by a combination of pathogens/pests. Often, corms infected with Pythium are also infested with root lesion nematodes and other fungi and bacteria. colourless, water-soaked spots (pokken in Dutch). The flower ultimately turns brown and slimy.

Measures for prevention and control:

- Plant the corms as quickly as possible after receipt. If the corms have to be stored, keep the relative humidity low and provide good air circulation during storage.
- Follow a good crop rotation programme.

- Remove all damaged and infected corms.
- Before planting, immerse the corms for 15 - 30 minutes in an approved fungicide that is effective at controlling Botrytis.
- Keep the crop dry by not planting too closely together and by keeping the upper layer of the soil quite dry.
- Ventilate the greenhouse and turn on the heat to dry the crop if necessary.
- Water in the morning so that the crop can dry off before evening.
- If necessary, spray the crop with an approved fungicide that is effective at controlling Botrytis. Also make sure when spraying that the agent reaches the under surfaces of the leaves.
- Remove infected plants along with their corms.

Curvularia Disease (Curvularia trifolii)

The symptoms are usually limited to the lowest part of the corm. Elongated, slightly roughened light brown to blackish-brown stripes and spots appear on the tunics. Dark-coloured margins and/or round to irregularly shaped blackish-brown dry spots can develop on the nodes. Sometimes, larger, depressed grey-brown to dark brown spots that may look like a symptom of Fusarium appear on the corm. Symptoms of Curvularia on a corm: stripes and spots on tunic and surface of the corm tissue. Foliage displaying symptoms of Botrytis: a) small spots on the leaf and b) grey-brown spot with grey fungal weft Corms with spots caused by Curvularia Disease Corms infected with Penicillium exhibiting a fungal weft be lost. At soil level, infected leaves display many mycelia to which soil particles cling.

Measures for prevention and control:

- Follow a good crop rotation programme and include only those host plants that are not susceptible to this fungus. By the time leaves have developed, the plant quickly loses its susceptibility to being infected with this fungus. This is why ensuring rapid emergence is important.
- Disinfecting the soil with an approved fungicide that is effective at controlling this fungus would be a possible option.

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- Remove all damaged and infected corms.
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- Water in the morning so that the crop can dry off before evening.
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Measures for prevention and control:

- Follow a good crop rotation programme and include only those host plants that are not susceptible to this fungus. By the time leaves have developed, the plant quickly loses its susceptibility to being infected with this fungus. This is why ensuring rapid emergence is important.
- Disinfecting the soil with an approved fungicide that is effective at controlling this fungus would be a possible option.

Crown Rot (Sclerotium)

This fungal disease occurs mainly in warmer regions. No infection will occur at temperatures below 13°C, and the fungus grows best at 20°C. The fungus has many host plants and can survive for a long time in the soil. The plants grow normally at first but develop a coarse white fungal web containing large (1 - 2 mm) sclerotia on the underground parts of the plant. These sclerotia will later turn light to dark brown. The corms can eventually become entirely soft so that the entire plant collapses. It can quickly spread to neighbouring plants.

Measures for prevention and control:

- The necessity to apply crop protection measures depends very much on the temperature and the occurrence of the fungus in the soil.
- Plant corms in fresh soil and follow a crop rotation programme.
- Disinfecting the soil with an approved fungicide that is effective at controlling this fungus would be a possible option.

Hard Rot (Septoria gladioli)

Dark brown or black sunken, scabby, irregularly shaped spots occur mainly on the under side and sides of the corm. This fungus attacks the surface of the corms and is not visible until the tunics are removed. The infected tissue desiccates. Severely diseased corms shrivel and can mummify. From emergence to flowering, individual areas of the crop display poor growth. The plants flower late or not at all. Some plants die prematurely. The roots of such plants have often largely rotted away. Unlike Dry Rot, no sclerotia are present.

- After the crop emerges or in the event that a Pythium infection is expected, a fungicide to control Pythium can be added to the irrigation water and sprinkled over the crop according to current recommendations. Preferably, this treatment should be applied at night. The crop should be irrigated with water for three minutes both before and after treatment. The pre-irrigation improves the effectiveness of the fungicide and the post-irrigation removes the fungicide residues from the crop.

Measures for prevention and control:

- Ensuring good soil structure is an effective preventive measure. The structure should not be so compact that the soil will remain wet for too long.

Rhizoctonia Disease (Rhizoctonia solani)

This fungus has many host plants (including potato and beet) and can quickly build up high population densities in the soil. Identification in the field The symptoms of Rhizoctonia Disease are light to dark brown depressed oval spots on the parts of the stem below the soil surface. The spots that have developed can entirely encircle the young stems and cause them to die. In a more severe case, the tissue between the veins decays entirely. In the field, this fungus is characterised by irregular emergence. A severely infected plant will ultimately Shoot of iris showing symptoms of Sclerotium rolfsii Rhizoctonia

symptoms: tunics of a new corm Roots with brown rot, a symptom of Pythium. Rhizoctonia symptoms: underground leaf parts.

Bacteria

The field of human medicine deals with many bacteria, but far fewer are encountered as diseases affecting the plant kingdom. Control measures are usually confined to removing infected plants or corms. Fungicides are not effective in controlling bacterial infections.

Fasciation (*Rhodococcus fascians*)

Bacteria are spread by means of infected planting material and infected soil. There are indications that bacteria can be spread by machines, containers used for planting material and harvested products and water used to leach the soil. The results are usually limited and remain confined to a smaller stand of individual plants. The corm's normally brown tunics can become more roughly creased and have

longitudinal ribs. Warty growths protruding from the root crown can appear. Cauliflower-like fasciation appears on the neck and part of the stem just above it. Developing on top of these are many buds, sometimes bluish-red in colour, that often form weak, thin shoots. Depending on the degree of infection, the corms produce few if any roots and a shoot that is not as heavy as it should be.

Scab (*Burkholderia gladioli*)

Scab develops following damage caused by soil insects, slugs/snails or bulb mites feeding on the plant. Water-soaked spots develop in the corm tissue and later expand into crater-shaped cavities that are dark brown at the lowest points and raised around the margins. The slimy mass that forms inside these cavities turns reddish as it dries and forms a hard, shiny coating. Elongated brown to

reddish-brown leaf spots develop on the margins of the leaf. Plants that emerge from diseased corms are often deformed and exhibit dwarfed growth.

Measures for prevention and control:

Follow a good crop rotation programme.

Gladiolus Rust (*Uromyces transversalis*)

This fungus, *Uromyces transversalis*, occurs mainly in the tropics and subtropics (during the summer months), and easily spreads over large areas. The orange-yellow spores are responsible for the spread of the disease during the growing season. Raised yellowish spots develop on both sides of the leaf; after a while, the tissue bursts open to reveal an orange-yellow mass of spores. These spots start out being round in shape but grow wider across the surface of the leaf so that they eventually elongate in this direction. The infection is sometimes so severe that the plants turn a rusty-brown colour. The corms and roots are not infected.

Measures for prevention and control:

- Conduct a programme of weekly spraying with an approved fungicide that is effective at controlling this fungus. Begin this programme before emergence or as soon as the symptoms are observed. Symptoms of Septoria fungus infection on leaves : Plants exhibiting fasciation Leaf showing symptoms of Gladiolus Rust, Corm with scab.

Thrips (*Taeniothrips simplex*)

Thrips are a very common insect. At higher temperatures, they are extremely active and reproduce rapidly. They can cause severe damage to the leaves and flowers of gladioli by feeding on them. Dark brown spots, often forming rings that clearly define where the tunic is attached, appear on the corm tissue beneath the tunics. The areas exhibiting these symptoms feel tacky. Silvery-white spots are distributed over the leaves. In a severe infestation, these spots will coalesce into large greyish to light brown areas with small black specks of thrip faeces. These spots appear first on places where the leaves overlap one another and between the sepals in the spike. The flowers can also be infested and will show definite visible spots. These flowers will usually open with difficulty.

- During the warm storage treatment, treat the corms with a storage insecticide.
- Store corms at temperatures below 5 °C.

The first symptom of infection is the appearance of very small, reddish-brown raised spots at the base of the leaf. These spots become larger and coalesce to form elongated spots or stripes. Large brown spots will form on the leaves under damp weather conditions accompanied by a high RH. Next, the stem just at or beneath the soil surface will completely decay.

Measures for prevention and control:

- Spray the crop once every two weeks during production with an approved insecticide effective against this pest.



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Burkholderia gladioli

This disease can become a problem particularly during a warm year with high rainfall levels. Infection then results in major crop damage, particularly among high-density plantings. This disease is particularly associated with the cultivar 'Amsterdam' but can also occur in other gladiolus cultivars. Identification in the field The leaves suddenly turn grey and the outer leaf layer separates from the leaf tissue beneath. This makes the leaf tear open easily in a lengthwise direction. When the plants wither and die, this causes failure of flower development or adversely affects corm production. The disease develops above the soil level and can quickly spread to healthy surrounding plants. Measures for prevention and control: These bacteria are impossible to control during production in the field. Giving the cormels a hot-water treatment, however, will kill the bacteria.

Xanthomonas campestris

This disease can become a problem particularly in a year with high rainfall levels. Infection results in widespread crop damage, particularly among high-density plantings. Identification in the field Distributed over the leaves are small, water-soaked spots that expand and coalesce into square or rectangular dark green spots. These dark green leaf spots later turn brown to black with yellow margins. The entire leaf can turn brown. Infected leaf tissue exudes a syrupy, viscous substance.

Measures for prevention and control:

- These bacteria cannot be controlled during production in the field. Keep the leaves dry. Avoid working in a wet crop. Grey spots on leaf with a bacterial infection Leaf spots cause by Xanthomonas Corm exhibiting damage made by thrips along with yellow thrip larvae and black adult thrips Leaf infestation showing adult black thrips Flower infestation.

Red spider mites can be controlled chemically by spraying with an approved acaricide that is effective at controlling this pest or by biological means using natural predators such as predatory mites and predatory bugs.

Caterpillars and corn borers

The larvae of various moths and butterflies can feed on gladiolus plants. Besides damaging the plant, their faeces can also be a source of food for fungi. In addition to insecticides, biological products (bacterial suspensions) are available. Once emerged from their eggs, the larvae of *Pyrausta nubilalis* (synonym: *Ostrinia nubilalis*) or European Corn Borer) eat their way into the central part of the stem. Fully developed larvae pupate inside the stem of the gladiolus and can survive the winter there. The innermost leaves turn yellow. These leaves and the flower stem then wither and die. The first symptom in a crop that has reached a later stage of development is that the spikes start to droop. Commonly found in these cases is a hole eaten into the plant half-way down the stem.

Aphids

Various species of aphids can be encountered on gladiolus where they pierce the surfaces of leaves and extract the sap. Their rapid reproduction rates produce colonies of wingless aphids on the leaves. The honeydew excreted by the aphids serves as a source of food for fungi that make the leaves smudgy-looking and tacky to the touch. Winged aphids can also transmit plant viruses from plant to plant. The spreading of viruses can also take place from weeds to gladiolus plants. Young leaves curl and become deformed. Aphids colonise mainly young parts of the plant and are often found on the undersides of the leaves. Flower buds and florets become deformed and open poorly. The florets of light-coloured varieties display green speckles.

Measures for prevention and control:

- Prevent the growth of weeds.
- Check the crop periodically for local aphid infestations. Conduct control measures periodically in relation to the life cycle of the aphids (which depends on the temperature). Systemic insecticides are available that can be used as a dip prior to planting. Fogging insecticides that leave no residues are sometimes available as well for use in the greenhouse. Various biological control insects (gall midges, hover flies, ichneumon wasps) can also be released.

Whitefly

Whitefly is a pest occurring in the greenhouse or in warm regions. Both the Greenhouse Whitefly (*Trialeurodes vaporariorum*) and the Silverleaf Whitefly (*Bemisia argentifolii*) damage leaves and can transmit virus. Identification in the field Whiteflies feed on the undersides of the leaf and damage leaves by puncturing their surfaces. In large numbers, whiteflies can kill a plant. They excrete honeydew that encourages the growth of fungi that make the leaves sooty-looking and tacky. Measures for prevention and control Various insecticides are available to control whitefly; they must be applied in three consecutive applications at intervals of 7 to 10 days. Various biological control insects (ichneumon wasps, predatory bugs) can also be released.

Red Spider Mites (*Tetranychus urticae*)

Red Spider Mites occur primarily under warm, dry conditions. At 20°C, the total life cycle from egg to adult takes about 17 days and at 30°C only 7 days. Development ceases at temperatures of 12°C or less. A whitish-yellow mottling appears on the upper side of the leaf. The mites themselves live on the underside of the leaf where they suck the sap from their host. The leaf ultimately turns light yellow and the plant takes on an unhealthy appearance. In most cases, the leaves show evidence of webbing that contains large numbers of young visible as tiny yellow to orange 'spiders'. Leaf tips with a severe infestation of red spider mites.

Plant infested by European Corn Borer larvae

Take a soil sample before planting so that it can be examined for the presence of soil insects. If they are encountered, either plant in another field or disinfect the soil according to current recommendations using a soil insecticide.

Nematodes

Root-knot Nematode (*Meloidogyne incognita*) The Root-knot Nematode (*Meloidogyne incognita*) is native to regions with hot climates and thus requires warmth to thrive.

Bean Seed Fly (*Delia platura*)

The Bean Seed Fly lays its eggs on freshly cultivated soil that is not necessarily near its host plants. Maggots of the Bean Seed Fly can cause damage to gladioli by feeding on the parts of the plant beneath the soil surface. In some areas, plants will emerge later than in others areas. In these plants, the white underground leaf sheaths can exhibit decayed spots and evidence of feeding that can continue downward to the basal plate of the corm. The shoot can be entirely destroyed by feeding damage so that the next bud often emerges. This shoot, however, will usually not be damaged. If the damage is limited to the outer leaf sheaths, the emergence of the shoot will be delayed. Measures for prevention and control: Plant the corms immediately after the soil has been worked and made ready for planting and then firm the soil after planting or cover with plastic sheeting. When planting the corms later in the season, it would be advisable to follow current recommendations in using an insecticide applied as a row treatment.

Soil insects

Soil insects can cause major damage to gladioli grown in the field. Larvae of the Click Beetle (wireworms), the June Beetle (white grubs), the Crane Fly (leatherjackets) and the larvae of Owl. Butterflies (cutworms) can be present in the soil before planting. These larvae living in the soil can damage emerging plants and root systems. The plants will grow poorly or even die. Many soil insect larvae occur in fields, particularly former grasslands. These soil insects are rarely

In addition to gladiolus, it infests many other plants (tomatoes, cucumbers and various weeds). An infestation causes root-knot galls to form on the roots. Above ground, plants in some areas will display stunted growth. During hot weather, the leaves will quickly droop and then turn yellow. These symptoms are similar to a *Fusarium* infection but unlike a *Fusarium* infection, the corms remain firm. Measures for prevention and control Follow a crop rotation programme that does not include other host plants. Sterilise the soil well in advance of planting. This is especially necessary if these nematodes were identified in a previous crop (even if the crop was not gladiolus).

Measures for prevention and control:

- Do not plant any gladioli near maize fields if flower harvesting is planned for autumn.
- Check periodically for the presence of eggs and symptoms of an infestation; as required, apply an approved insecticide that is effective at controlling this pest. Repeat treatment weekly for as long as eggs and/or larvae are encountered.

a problem in greenhouses. Cutworm infestation Shoot with Bean Seed Fly larvae. The base of the corm becomes corky. A brown discolouration radiates upward into the corm. Large light brown, vaguely defined spots are found on the exterior of the corm. These spots are not sunken. The diseased tissue is dry and not granular in structure. Diseased corms shrivel during storage. Infested plants turn yellow and then die. Measures for prevention and control: Follow a crop rotation programme that does not include host plants of these nematodes (*D. destructor*).

Viruses

Notched Leaf, Tobacco Rattle Virus (TRV). Notched Leaf is transmitted and spread by trichodorids (Trichodorus nematodes) that are found predominantly in sandy and loamy soils. TRV occurs in several bulbous plants as well as in various weeds. A viral infection can originate in the soil (primary infection) or in a batch of gladioli corms (secondary infection). Plant growth is stunted. Brown or white stripes appear on the leaves and later become decayed. The name 'Notched Leaf' comes from a common symptom: the leaf margins often become notched. Primary infections always show up as patches in the field; secondary infections show up distributed over the field wherever corms from that particular batch of infected corms were planted.

Measures for prevention and control:

- Consider the possibility of the presence of trichodorids when planting in light soils. Have the soil analysed in advance for the presence of these nematodes. Follow a crop rotation programme that includes Oil Radish, or disinfect the soil to control nematodes.

Cucumber Mosaic, White Break Virus (CMV)

This virus occurs in a very wide range of plants including weeds, vegetable crops and flower bulbs. It is transmitted by aphids. This virus is not seen that often in gladioli grown in the Netherlands.

Columbia Root-knot Nematode (*Meloidogyne chitwoodi*) and False Columbia Root-knot Nematode (*Meloidogyne fallax*)

These root-knot nematodes appear to be becoming more common, particularly in sandy soil, reclaimed peat soil and

lighter clay soils. The spread of these nematodes can have major economic consequences for growers of starting material because infested material may not be sold. Once a field is infested, the risk that *M. chitwoodi* and *M. fallax* will survive and spread is extremely high, because these nematodes have a very wide range of host plants and can produce 1 to 3 generations within a single growing season. *Meloidogyne chitwoodi* has reached a quarantine status. Severely infested corms exhibit knotty swellings around the root crown. *Meloidogyne chitwoodi* and *Meloidogyne fallax* display the same symptoms. In general, an infestation of either species results in small to tiny knobs ('knots') on the roots of the plant. The corm and/or contractile roots is/are infested as well; this is usually the result of the second and third generations of nematodes. The symptoms are knobs on the corms and roughened tunics. Taking a cross-section of the corms will enable the identification of female nematodes in the form of brown spots. Sometimes, the symptoms are not always clear. Infested gladioli exhibit bulges at the base of the corms as well as on the sides of the corms.

Measures for prevention and control:

- Performing a biological soil sterilisation procedure, in combination with a year in which the land is left fallow, with a follow-up planting of nematode-resistant Oil Radish as a trap crop, is often effective.
- The use of chemical soil sterilisation and ploughing in chitinous materials can considerably reduce a population of root-knot nematodes.
- In the greenhouse, soil sterilisation is an option.

Destructor Nematode (*Ditylenchus destructor*)

Ditylenchus destructor infests only the underground parts of the plant and results in damage to the surface of the corms. This nematode is found only in small-flowering gladioli. Its symptoms are sometimes confused with those of *Fusarium*. Corm showing symptoms of infestation by Potato Rot Nematodes Tobacco Rattle Virus infestation in the field plants will not develop into normal flowering specimens. In a healthy crop, when clean corms are planted, leafhoppers can transmit phytoplasmas during production. In an early infection the inner leaves of these plants will then turn yellow and die prematurely whilst the outer leaves remain green. If infected early in production, the plants will produce no flowers; if infected later, the flower will usually be deformed. Measures for prevention and control: Control leafhoppers by means of approved insecticides that are effective against these insects.

Snails and slugs

The way to differentiate the holes eaten by snail/slug damage from caterpillar damage is the presence of slime trails. The rest of the symptoms are the same.

Preventive/control measures:

- In addition to insecticides (granules/pellets), there are also biological products (bacterial suspensions) available.

Rodents, deer, etc.

Localised damage can result from mice, hares, rabbits and deer feeding on the plants. Deer damage is usually limited to the perimeter of the field. If the population is causing a great deal of damage, the only effective control is to hunt and destroy these animals. Attempting to scare them off with noise like exploding devices is usually only a temporary solution.

Iron

When the plant is deficient in iron, the chlorophyll between the veins turns yellow-green whilst the veins often retain their green colour. The symptom is first visible among the youngest leaves. This deficiency occurs mainly among rapidly growing plants. This occurs more commonly on lighter soils with a higher pH that are more susceptible to silting up, at locations that can be flooded and at higher temperatures. The cause is not so much the lack of iron in the soil but its inaccessibility by the plant. Ensure proper drainage and a suitable pH (6 - 7). Adjust the quantity of fertilisers containing iron to the current pH regime. The corms are usually deformed and knobbly.

Aster Yellows (Phytoplasma)

Phytoplasmas are pathogens transmitted by leafhoppers. In cross-section, newly formed corms exhibit a water-soaked brown discolouration in the centre. The vascular tissue in the surrounding tissue is visible as brown spots and radial stripes. During further storage, it can be seen that the root primordials are poorly developed, if at all. Abnormally deep cavities sometimes develop at the base of the corm. The remnants of the mother corm are often still present (and are not removed by mechanical peeling), and the cavities are often filled up with these remnants. Corms with a red colour are pale and spotty. Plants with various small shoots ('bushy plants' is the Dutch term) are produced from corms infected by recently infected plants. These Brown or red-rimmed spots in the corm by CMV infestation 'Bushy plants' an infection of aster yellows An early infection of aster yellows; inner leaves turn yellow and the outer leaves remain green Plants with a phosphorus (P) deficiency are somewhat smaller and have dull pale green leaves. The older leaves have reddish-brown tips. Correcting a deficiency of this element during cultivation is not easy, so make sure that the soil contains enough of this element at the beginning of production.

Potassium (K)

Smaller, more slowly growing plants with a rather stiff appearance are often suffering from a potassium (K) deficiency. The younger leaves are dull yellow-green with a brown discolouration except for the leaf tips. Small white necrotic spots are found over the entire leaf surface. The last part of the leaves to wilt will be the tips.

Magnesium (Mg)

Signs of a magnesium (Mg) deficiency can crop up fairly suddenly. The plants remain stunted. The leaves become light green and start to curl. Brownish-white spots sometimes appear over the length of the leaf. The oldest leaves display the most obvious symptoms.

Manganese (Mn)

Signs of a manganese (Mn) deficiency are often not that

Brown sunken spots are found on the surface of the corm. In cross-section, the corm displays brown or red-rimmed spots. Starting among the lowest part of the plant, yellow-green to silvery-grey spots appear all over the leaves. Another symptom is colour breaking in the flowers. This is often invisible in the white, cream or yellow-flowering varieties. Plant growth is stunted and flowers of good quality are not produced. Measures for prevention and control: Remove all plants that display symptoms of this virus. Monitor the crop periodically and control pests such as aphids that are vectors.

clear and has no obvious effect on growth. The youngest leaves are lighter in colour. Leaf tips turn yellowish to light brown.

Boron (B)

Boron (B) deficiency can develop if the only source of water is Nitrogen rainwater. Leaves of a plant deficient in nitrogen turn yellowish all over. This can occur at any time during production up until flowering. The general condition of the plants (often in localised areas) appears only average: leaves are often narrower, flower stems are lighter in weight and have fewer florets. These symptoms are caused by an insufficient absorption of nitrogen. During warm weather, providing extra water leaches out a portion of the nitrogen in the upper levels of the soil into deeper levels. Provide regular applications of nitrogen fertilisers (the quantity preferably based on an analysis of a soil sample) throughout cultivation. Quick-release nitrogen fertilisers can correct these symptoms.

Other elements: Ca, P, K, Mg, Mn, B

Deficiencies of trace elements can often be corrected during cultivation by the prompt application of the proper corrective fertilisers. Soil analyses often provide an indication of already existing lower levels of such elements.

Calcium (Ca)

Plants deficient in calcium (Ca) will not grow as tall as they should. Their leaves are light to pale green. Leaf tips droop and can suffer leaf tip burn. Extremely pale leaves can sometimes display white spots. Root development is poor. Yellowing caused by iron deficiency Boron deficiency symptoms.

Heat damage

Heat treatments can also damage corms. In this case, the central part of the corm turns brown. The corm softens and then hardens during storage.

'Little horns'

'Little horns' are small bulging growths found on the floret that can keep the flower stem from developing into a product worth harvesting. Several flower buds on the spike will be irregularly shaped. The cause of this disorder is unknown.

Nutrient toxicities: F, Mn, B, Ca, Excesses of potassium, magnesium, iron, copper (Cu) and molybdenum (Mo) in the plant are difficult to detect.

Fluorine (F)

Gladiolus can be damaged by an excess of fluorine (F). Fluorine accumulates in the leaf tips and cannot be easily redistributed. Rapid transpiration removes water from the plant and increases the concentration of fluorine that results in leaf tip burn. Large parts of the leaf, starting at the tip, can turn brown and die.

Manganese (Mn)

The sign of manganese (Mn) toxicity is the appearance of purple discolouration on the veins in the leaves that begins as small purplish-red speckles at the tips of older leaves. This phenomenon is common among plants grown in soil that has been sterilised with steam and is exacerbated by a low pH.

Boron (B)

The symptom of boron (B) toxicity is the appearance of white (sometimes brown) spots on the tips of all the leaves even though these spots are most obvious on the outer leaves. If a soil analysis indicates that the soil contains enough boron, use fertilisers that do not contain boron.

Calcium (Ca)

High calcium levels make it difficult for the plant to absorb iron, phosphate and magnesium. This can lead to the plant's deficiency in these elements.

Frost damage

Corms that have been exposed to cold temperatures for too long will exhibit blisters on the surface of the corm that can later become flakes. In severe cases, the corm turns brown and the corm tissue becomes less opaque and softens. Corm with blisters Shoots with dead leaf tips and deformed growth.