MANAGEMENT OF BASAL ROT – THE NARCISSUS DISEASE

Gordon Hanks and John Carder of Horticulture Research International (HRI) describe the methods being used to manage basal rot, the main fungal disease of this important ornamental crop

Narcissus crops

Narcissus (daffodil) bulbs have been grown in the Netherlands and the British Isles for several centuries, becoming an important floricultural crop in the late-nineteenth century. The long-held fondness for these quintessential spring flowers continues today (Figure 1). However, the strict quality and competitive pricing requirements for export sales and the multiple retailer sector now place tough demands on bulb and flower growers – including freedom from pests and diseases – despite stringent restrictions on pesticide use.

Currently the world area of commercial field-grown narcissus is over 7000 ha, with 4400, 1800 and 400 ha in the UK, the Netherlands and the USA, respectively (Hanks, 2002). These figures may be a little deceptive, as in the UK narcissus are grown as two-year-down crops, lifting half the acreage each year, a system which is economic of land and labour but which restricts bulb yield compared with traditional crops that are planted and lifted one year later. In practice, the UK and the Netherlands produce a saleable yield (after taking out bulbs for re-planting) of around 30,000 tonnes each.

UK growing centres on standard cultivars of traditional, large yellow daffodils (‘Golden Harvest’ and ‘Carlton’), whereas the Dutch produce a diversity of types including the dwarf ‘Tête-à-Tête’. Traditionally, growers specialised in either bulb or flower production, but many crops are now dual-purpose. The current relative demand for bulbs or flowers is an important consideration. Large numbers of bulbs are also ‘forced’ in glasshouses to produce cut-flowers over an extended season. In recent years, significant amounts of UK bulbs have been processed for the extraction of galanthamine, used in the treatment of Alzheimer’s disease.

In the UK particularly, large-scale mechanised narcissus growing and bulk handling fit in well with potato and onion production, sharing some of the equipment and facilities required for those crops. The high percentage of UK-grown narcissus bulbs and flowers exported is a tribute to the skills of the growers.

Narcissus diseases and constraints on their control

‘Basal rot’, caused by *Fusarium oxysporum* f.sp. *narcissi*, is a topic often on the minds of UK narcissus growers (Figure 2). Cultivars ‘Golden Harvest’ and ‘Carlton’ are both susceptible to the disease. Tackling this problem is constrained by some management practices in modern narcissus growing, particularly leaving crops in the ground for two or more years (rather than annual lifting) and using high planting densities, together with bulk handling and storage (all favouring spread of disease). Although bulb growers have known about basal rot for many years, modern concerns about it began in the 1970s, and this is likely to have been due to changing crop management, rather than climate change.

‘Neck rot’ has symptoms similar to basal rot, but it starts at the top of the bulb rather than the bottom (Price and Linfield, 1981). A number of fungi have been considered as

Figure 1. **General view of a commercial daffodil crop.**

Figure 2. **Basal rot symptoms – half bulb views.**

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potential causes of neck rot, including *Botrytis narcissicola* (the cause of 'smoulder', see below), *Penicillium* species (common colonisers of decaying plant tissues) and *Stagonospora curtisii* (the cause of narcissus 'leaf scorch'), as well as *F. oxysporum*. Recent research at HRI-Wellesbourne has shown that, although all of these fungi can be isolated from neck rots, only *F. oxysporum* reproduced the characteristic neck rot symptoms when inoculated onto wounded bulb necks.

Several other fungal diseases affect narcissus foliage, predominantly smoulder (*B. narcissicola*) and white mould (*Ramularia vallisumbrosae*) in UK crops, and fire (*Sclerotinia polyblastis*) in Dutch crops (Moore *et al*., 1979; Hanks, 1993). Smoulder is a widespread disease, generally unspectacular but probably causing a 10 per cent loss in bulb and flower yield. White mould is largely confined to Cornwall, the second largest of the narcissus growing regions of the UK after the eastern counties. These foliar diseases are treated by fungicide spray programmes in the field, which do not appear to have any controlling effects on basal rot. Recently, predictive disease models have been formulated by Roy Kennedy at HRI-Wellesbourne for both smoulder and white mould, leading to better targeted but fewer sprays being applied.

The control of pests and diseases in narcissus – as in all 'minor' crops – is hindered by the loss of pesticides, withdrawn for environmental or economic reasons. But bulb growers are fortunate in that they can use the period from lifting to re-planting for pest and disease control measures that involve non-chemical methods such as drying, storage, inspection and hot-water treatment (HWT), as well as utilising pesticides. In combination with the sensible use of proven, safe pesticides, physical, cultural and plant breeding solutions are being used to provide an integrated approach to managing basal rot. Biological control, in the form of fungal species naturally antagonistic to *F. oxysporum*, has been demonstrated in small-scale experiments (Beale and Pitt, 1990), but has not been used successfully in the field.

Hot-water treatment (HWT)

Because of its distinctive importance in narcissus growing, HWT merits description at this point (Gratwick and Southey, 1986). Potentially the most destructive pest of narcissus is the stem nematode, *Ditylenchus dipsaci*, which can devastate crops and leave a reservoir of infection that can survive for years under appropriate conditions. HWT has been known as a means of controlling nematodes for a hundred years or so. The method relies on immersing plant material in hot water at a temperature and for a duration that will kill the target pests yet not cause significant heat damage to the plants (Figure 3). In practice, it is necessary to add a disinfectant, formaldehyde, to the tank to control more heat-tolerant forms of the nematode. Used properly, it is very effective in controlling stem nematode in narcissus bulbs, and its use is routine in commercial bulb growing. HWT incidentally controls other narcissus pests, and diseases.

Many growers utilise the HWT procedure to add fungicides (and sometimes an insecticide to control large narcissus fly) to the treatment tank. When using HWT, it is essential to follow recommendations rigorously to achieve control without crop damage. The timing, temperature and duration of HWT are all critical. Standard UK recommendations advise a 3-hour immersion period at 44.4°C in late-July to early-August, with formaldehyde, fungicide and a wetter.

Figure 3. **Hot-water treatment tanks: Bulk bins of bulbs are loaded into the tanks by a fork-lift truck, the door is secured and pre-heated water is pumped into the treatment tank from a holding tank.**

Fusarium bulb rots: chemical control

Basal rot is controlled, with variable degrees of success, by HWT with formaldehyde. This treatment, used to control nematodes, is theoretically adequate to kill propagules of the basal rot pathogen. But, despite this, basal rot is not always successfully controlled by HWT, and a number of variants may be utilised:

- a fungicide, often an MBC (*e.g.* thiabendazole), may be added to the HWT tank
- HWT (with or without a fungicide) may be carried out soon after bulb lifting, instead of at the usual time, giving better disease control but more crop damage
- immediately after lifting, bulbs may be given either a 'cold dip' in formaldehyde, or (on-line from the yard to the store) a fungicide spray (thiabendazole).

In some cases, a double treatment of fungicide is given – after lifting *and* in HWT. The method used will depend on costs or on practicalities at the farm, and will be influenced by the level of disease present and the susceptibility of the cultivar. In extreme cases, growers may be advised to return to 'one-year-down' growing, so that their stocks can have HWT every year, but this is unlikely to be adopted when bulb prices, notoriously cyclical, are low.

Cultural and physical methods of control

Success in controlling basal rot varies considerably between individual farms. Why? It is likely that greater or lesser adherence to recommendations (*e.g.* maintaining correct chemical concentrations) is one factor. Secondly, deficiencies in cultural or physical control methods may simply overwhelm the usual effectiveness of HWT. Thirdly, overall farm hygiene may be a factor: strictly, all movements of bulbs should be arranged to avoid the contamination of ‘clean’ (hot-water treated) bulbs by untreated bulbs, dust and other possibly infective debris. Achieving this degree of hygiene on a farm is very difficult.

The basal rot pathogen grows fastest at temperatures between 20 and 30°C, so many cultural controls for basal rot aim to keep the bulbs cool. Thus, warm planting sites should be avoided, bulbs should be planted deep, and bulbs should be lifted early (June) and planted late (September) to reduce the time in warm soil. Most growers favour early bulb lifting, enabling their bulbs to reach markets early, but they also prefer prompt re-planting, in August immediately after HWT, which reduces handling and storage costs. Early lifting may result in problems associated with incomplete leaf senescence, such as reduced yield, increased damage to bulb necks and higher risk of neck rot. Using mulch or weed cover has been suggested for reducing soil temperatures, and certainly the former is appealing for water conservation and reduced herbicide use. Excessive nitrogen concentrations in the soil have been shown to favour basal rot infestations. Other recommended cultural practices include using a long (>8 years) crop rotation, since the thick-walled spores of *F. oxysporum* can persist for many years under certain conditions.

Physical methods of control

The physical control of basal rot relates to how bulbs are handled between lifting and re-planting. Rapid drying, with high rates of air-flow, is important in creating unfavourable conditions for germination of fungal spores and invasion of wounds immediately after lifting. Drying should take place either below 20°C or at 35°C, to minimise pathogen growth. Drying at 35°C (‘high temperature drying’) has the additional advantage that the rapid drying and shrinking of the bulb skins renders them easily removed in cleaning, producing a more attractive product for retail sales in ‘pre-packs’. Once the bulbs are surface dry, further drying should involve a reduced, but still adequate, air-flow, preferably below 20°C. Bulb drying is most effectively carried out in 1 tonne bulk bins placed on a ‘letter box drying wall’ system (Figure 4).

Figure 4. **Letter box drying wall. Bulbs in one-tonne bulk bins (left) are placed against the drying wall (right background) which houses powerful fans. Air (at 35°C) is blown through the ‘letter-box’ openings into the pallet bases of the bins, and up through the bins to dry the bulbs in 2–3 days.**

Bulb storage should be carried out in controlled temperature (CT) facilities, ideally 17–18°C (cooler temperatures retard internal bulb development). In the UK summer, ‘ambient’ storage is inappropriate, often taking bulb temperatures to the low or middle twenties, ideal for *Fusarium* growth. Common-sense is also needed, for example not allowing bulb boxes to stand between treatments in sunshine in the yard. Trials at HRI-Kirton clearly demonstrated the reduction in basal rot incidence that is obtained, even in heavily infected stocks, by initiating a programme of rapid drying, CT storage and precise HWT, even in the absence of a fungicide treatment. Adding an effective fungicide speeds up this process (Hanks, 1996).

Once lifted, bulbs have to be cleaned, inspected (removing damaged and diseased bulbs and splitting up bulb clusters) and graded. At all stages, bulbs should be handled carefully to minimise damage that could result in wounds that allow fungal infection. One outcome of recent basal rot research at HRI-Wellesbourne was the realisation that large quantities of diseased bulbs are being planted back into fields because it is impossible to identify all diseased bulbs by manual inspection. Flotation of bulbs has been tested as a possible means of segregation, but has limitations since some but not all diseased bulbs float. Development of automated detection for internally rotted bulbs is one current aim.

A further factor is that even the best fungicide treatments currently available may not cure basal rot if it is already present deep within the bulb. Thiabendazole in bulb dips or HWT does not move far into the bulb, so its fungicidal activity can operate only against fungi on or close to the bulb surface. Furthermore, thiabendazole is degraded by soil microbial activity and will only offer protection for a few months after planting.

Studies on the basal rot pathogen

Large numbers of isolates of *F. oxysporum* f. sp. *narcissi* collected from bulbs displaying neck rot and basal rot have been examined at HRI-Wellesbourne. DNA fingerprinting has shown that all isolates from either type of rot are almost identical, indicating a common cause for both diseases. Some variation in virulence has been seen, expressed as differences in the rate at which bulb tissue is invaded, although all isolates are ultimately lethal. The widespread occurrence of increasing numbers of strains that can tolerate up to 100 ppm thiabendazole – most strains are inhibited by <5 ppm – is of concern to the bulb industry. Fortunately, all such isolates found are sensitive to low concentrations of an alternative fungicide, prochloraz. Hence, two or more fungicides should be alternated in HWT to minimise the risk of fungicide tolerance. A rapid, sensitive and specific molecular detection system has been developed and successfully tested on infected bulb samples. Hopefully, it can

Figure 5. **Two narcissus cultivars important in breeding – 'St Keverne' (LEFT) (with field resistance to basal rot) and 'Golden Harvest' (RIGHT) (highly susceptible).**

Figure 6. ***Narcissus jonquilla* (LEFT) and *N. viridiflorus* (RIGHT), basal rot-resistant species being exploited in narcissus breeding.**

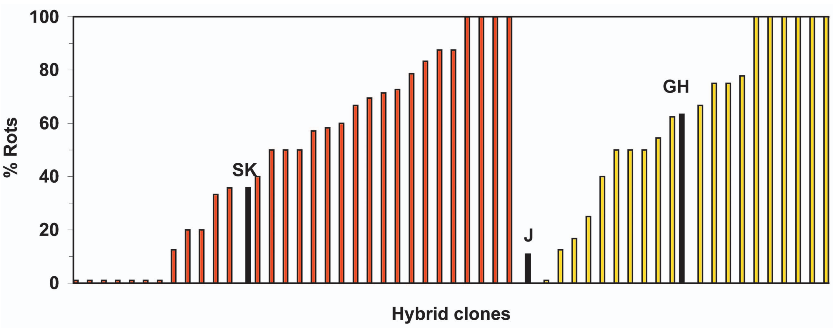

Figure 7. **Disease resistance of *jonquilla* × hybrid crosses. Basal rot in daffodil 'St Keverne' (SK), 'Golden Harvest' (GH) and *N. jonquilla* (J), and in 51 hybrids between *N. jonquilla* and SK (red bars) and *N. jonquilla* and GH (yellow bars)**

ultimately be extended to quantify the pathogen in field soils and predict the risk of bulb-rot. This might permit shorter periods of crop rotation to be used in place of the eight-year minimum currently suggested.

Breeding for resistance to basal rot

A project designed to study the genetics of basal rot resistance in narcissus started in the 1980s at the Glasshouse Crops Research Institute, later moving to HRI-Wellesbourne. It can take up to 7 years to produce a bulb of flowering-size from a seedling, and, as no reliable method of assessing disease-resistance in juvenile bulbs has been perfected, breeding for disease resistance in narcissus is a lengthy process. Crosses were made between commercial daffodil cultivars, using conventional plant breeding methods and the good field resistance of cultivar 'St Keverne' (Figure 5) Juvenile bulbs were planted in pathogen-infested soils. Only 15% of the many thousands of resultant progeny survived this exposure, and these were afforded a lengthy period of multiplication and agronomic assessment. Fifty of the most commercially-promising selections are currently being evaluated under contract on commercial farms. The resistance status of these will have to be tested before their wider release.

Resistance to *F. oxysporum* in the cultivar hybrids was shown to be almost certainly due to not one, but several, genes. Thirty-three *Narcissus* species have been examined at HRI-Wellesbourne to determine their resistance (Linfield, 1992). Several were shown to be unaffected by the fungus (Figure 6), and one of these, *Narcissus jonquilla*, was selected as a pollen parent for crosses with 'Golden Harvest' and 'St Keverne'. Hybrids from these crosses displayed a complete spectrum of resistance, preventing the expression of the resistance gene or genes present in *N. jonquilla* in these triploid offspring (Carder and Grant, 2001) (Figure 7). A similar hybridisation experiment has now been carried out using the tetraploid resistant species *N. viridiflorus*, to see whether a double complement of species chromosomes in the hybrids will confer resistance to all the F1 generation. If new cultivars with even higher resistance than 'St Keverne' and the same desirable agronomic characters as 'Golden Harvest' could be bred, this would lift many of the restrictions imposed on narcissus growers because of the need to control basal rot. A considerable reduction in production costs, and benefits to the environment, would result.

Conclusions

- Narcissus is an important floricultural crop in western Europe and North America. Narcissus suffer from a number of pests and diseases, but none has proved as difficult to control reliably as basal rot. This is probably related to modern ways of growing the crop.
- Chemical control of basal rot is largely through applying thiabendazole or prochloraz fungicides, usually by

addition to the hot-water treatment with formaldehyde routinely used to control nematodes.

- Despite using appropriate fungicides, the control of basal rot often breaks down. Physical controls – correct drying and storage of the bulbs, and avoidance of re-infection – are very important.
- Cultural controls for basal rot include early bulb lifting and late re-planting, to avoid bulbs being in warm soil during the summer, which favours growth of the pathogen.
- Biological methods of controlling basal rot are as yet insufficiently developed.
- Recent research has led to an understanding of the basal rot pathogen, leading to new approaches to managing the disease.
- Progress has also been made in understanding the genetic nature of resistance to basal rot in narcissus cultivars and species, and disease-resistant lines are being developed.
- Combined with the use of cultural and physical means of disease control, the introduction of disease-resistant cultivars will lead to a lowered dependence on fungicides.

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MORE GM NEWS

Canadian canola GM patent case
The future of GM crops in North America is in the hands of a 73-year-old Canadian canola farmer Percy Schmeiser, who already has lost two court cases dealing with his use of seed designed by Monsanto, but he and his supporters have made it to the Supreme Court of Canada with a new argument: Monsanto's patent is invalid.

The case, to be heard in January 2004, will be binding only in Canada. But the outcome will have an unofficial ripple effect throughout the United States and the rest of the continent, where Monsanto has sued more than 500 farmers for infringing on its GM seed patents.

The arguments revolve around the validity of patenting higher life forms.

EFSA gives opinions on new GM maize
The European Food Safety Authority's (EFSA) Scientific Panel on Genetically Modified Organisms has published two opinions on GM maize NK603. The Panel has concluded that the herbicide-tolerant GM maize NK 603 is as safe as conventional maize and therefore that its placing on the market – for import for processing and food or feed use – is unlikely to have an adverse effect on human or animal health, or in this context, on the environment.

GM crops benefit the environment
Using a life-cycle analysis approach, Richard Phipps and Richard Bennett of the School of Agriculture at the University of Reading, UK, concluded in findings presented to ACRE, that modified sugar beet is far more environmentally friendly than conventional beet.

Phipps and Bennett gathered data from published literature, farmers and real field experiments on GM and conventional beet. They measured various parameters including: toxicity to aquatic life, contribution to global warming, damage to the ozone layer, energy used in making herbicide, and the amount of diesel used by tractors spraying it.

They argue that their analysis gives a broader picture than the farm-scale evaluations, which simply examined effects on wildlife.