workload. However, the results proved very variable and these plants are currently produced from softwood cuttings. Rooting percentages and crop quality are good but when production first changed to softwood cuttings for this crop there were occasional failures. For example, the leaves often turned black, even when cuttings were collected when cool, put into the cold store (at 3 to 4°C) quickly, not stored for excessive periods, prepared when cool, misted regularly at the bench, and bedded down promptly.

Three changes radically improved results. Firstly cuttings are collected in trays rather than directly into black bags. The trays are then carefully put into bags. This avoids bruising. Secondly, the cold store is turned off. It appears that sudden change in temperature is one of the main factors in blackening the foliage. Thirdly, the propagators don't hold excessive numbers in their hands; it is amazing how much damage can be done by squeezing cuttings.

These principles also work for *Weigela* and *Buddleja*, both of which exhibit the same symptoms—the link seems to be that none have waxy foliage.

A Review of Developments in *Narcissus* Propagation©

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INTRODUCTION

Commercial daffodil (*Narcissus*) production currently accounts for some 7500 ha of field-grown crops worldwide, mainly in the UK (4400 ha), the Netherlands (1800 ha) and north-western USA (400 ha) (Hanks, 2002). Typically, growers plant the bulbs at a rate of 15 to 20 tonnes ha^{-1}, there being some 20,000 bulbs per tonne. Well-grown narcissus plants would be expected to double in bulb numbers and weight each year through bulb splitting and offset production.

Compared with sexual plant propagation, this multiplication rate is low, imposing a severe restraint on the introduction of new cultivars or elite stocks, a situation amplified by the long juvenile phase of several years before bulbs are large enough to flower (Rees, 1972). With natural vegetative propagation it takes 16 years to produce 1000 bulbs from one original bulb (Rees, 1969). It can take 20 to 25 years to produce commercial-scale stocks—a few tonnes of bulbs—of a new narcissus. Thus, new commercial cultivars from a breeding programme at Rosewarne Experimental Horticulture Station (EHS), started in 1963, were released starting in 1981 (Pollock, 1985) and only came on-stream in reasonable amounts in the 1990s.

A scheme, begun in the 1970s, to replace existing narcissus stocks with virus-tested (VT) stocks (Brunt, 1985) ran into difficulties largely because of the years of commitment required to bulk stocks. The predominant UK commercial narcissus cultivars, 'Carlton' and 'Golden Harvest', were introduced in the 1920s. Not surprisingly, then, the cultivar choice of UK narcissus growers may seem staid, in marked contrast to the rapid changes in cultivars seen in Dutch lily and tulip growing, where active breeding and propagation programmes have been developed.

SCOOPING AND SCALING

Simple propagation methods used on bulbs rely on the removal of the apical dominance exerted by the main growing point, allowing adventitious bulbs to form (Rees, 1972). It is known that many bulblets can be produced naturally on a narcissus bulb when the growing point is damaged ("grassiness"). In lily scaling, the loosely attached bulb scales are separated and placed in a suitable medium under suitable conditions, when new bulblets form. In hyacinth, scooping or cross-cutting are the techniques used. Either the base plate of the bulb is scooped out using a special tool, or the base of the bulb is cut across in a star or cross pattern and, following storage in suitable conditions, many new bulblets are formed on the cut surfaces. These methods are relatively ineffective when used on narcissus (Stone, 1973; Alkema, 1975). Leaf cuttings were unsuccessful with narcissus (G.R. Hanks, unpublished data).

TWIN-SCALING AND CHIPPING

Narcissus propagation has concentrated on methods known as twin-scaling and chipping. These were developed from a method of "stem cuttage" described by Traub (1935) for other amaryllid bulbs such as *Hippeastrum*. Bulbs are divided into a number of vertical segments (like cutting a cake) that are subdivided by cutting through the base plate. The pieces are planted in compost, with new bulblets being formed near the base of the bulb scales. The technique appears to have been "rediscovered" in the 1960s, perhaps via the *American Gardener's Book of Bulbs* (Everett, 1954), as a means of propagating newly developed nuclear stocks of VT narcissus derived from meristem-tip culture or by virus indexing (Stone, 1973). At about the same time, bulb propagation was being researched for several genera in the Netherlands (Alkema, 1971).

Twin-scaling developed from these investigations (Flint and Hanks, 1982). After the bulb was cut into a number of segments (between 6 and 16 segments, depending on size), scales were removed in pairs from the segments by cutting down through the bulb's base plate. The twin-scale so produced, weighing about a gram, consists of two adjacent scale pieces with a conjoining piece of base plate. The twin-scales are dipped in a fungicide, mixed with a damp medium (such as vermiculite), and incubated in polythene bags or trays for 12 weeks at 20°C. During this time, bulblets are formed, and should grow to around 10 mm long. Most twin-scales give rise to one or two new bulblets, usually at the base of the abaxial surface of the inner scale. After incubation, the propagules are planted in the field and flower in 3 or 4 years. This method was used successfully in Scotland to multiply VT narcissus (Mowat et al., 1986). Since 60 to 100 twin-scales could be cut from a flowering-sized narcissus bulb, there was potential for a high multiplication rate (Flint, 1982). This led to claims that could not be substantiated in practice.

While twin-scaling can be an effective method of multiplying small quantities of bulbs, it has its problems. The quest for higher multiplication rates resulted in more and smaller propagules being cut, and the resultant very small bulbs are delicate and take several years to reach flowering size or a size that can be propagated again (Hanks and Rees, 1978). Twin-scaling is labour-intensive, and, although it is not a difficult process, it has to be done carefully by committed staff. Because of the tissue damage caused by twin-scaling, and the need to incubate the segments in a damp medium, fungal infections can cause serious losses. Immersing twin-scales for 30 minutes in captafol fungicide at 2% a.i., as formerly recommended, was a highly effective treatment, perhaps partly due to the high rate. The problems with twin-scaling were exacerbated when captafol was withdrawn in 1989, leaving only less effective fungicides.

There was little possibility for mechanising twin-scaling, and an alternative approach was needed to make the method a more practical one. This came about by reverting to larger, less divided propagules known as “chips”. Chips were simply the eight, 12 or 16 vertical segments into which a bulb was cut, with no further division. The potential rates of multiplication were revised downwards, Hanks and Rees (1979) considering a rate yielding 1000 bulbs from one bulb in 5 to 6 years as realistic (the years to grow into flowering-sized bulbs have to be added). Chipping required less labour, generally produced robust propagules and bulblets, and was amenable to mechanisation.

OPTIMISING CHIPPING

Mechanisation. At Kirton Experimental Horticulture Station (as it was then known), after attempts based on cutters fixed to a vertical drill stand, a chipping machine was developed (Flint et al., 1984). Initially, the bulb was dropped or pushed down into a vertical tube through an array of 15 circular saw blades chain-driven first from a foot pedal and later from an electric motor. Later, the machine was split into two modules linked by a conveyer belt. In the first module, bulbs were placed vertically between two rubber belts, on which they were conveyed through two circular saw blades (one above and one below the belts) to be split into two vertical halves. Falling onto the conveyer belt, the halves were inspected for freedom from disease and placed cut-side down along a further belt. This took the halves into the second module, in which an array of circular saw blades cut the half-bulbs into eight segments (later changed to four segments, giving more accurate cutting and more robust propagules). Although, it is understood, some simplified versions were produced to order, the machine did not progress beyond a prototype.

Both static and moving-belt chipping machines were developed in the Netherlands. A machine produced by the Akerboom company (at Hillegom, the Netherlands) became widely used. It consists of a pneumatically operated plunger fitted with a radiating array of blades that is propelled downwards onto a bulb held vertically on a pin. The machine is simple in concept, effective and cheap, but can cause compression to the bulbs at high cutting rates (Hanks, 1993). With the advent of machines, chipping was developed and used in the Netherlands, especially for the narcissus cultivar ‘Tête-à-Tête’ which is in demand as a naturally dwarf, pot-grown narcissus and is now by far the most widely grown narcissus in Holland. In the UK, chipping appears to have been used more sporadically to multiply specialist stocks and cultivars.

Cultivation Methods. Twin-scaling and chipping have been the subject of much applied research, aimed at optimising the procedure, in both the Netherlands and the UK (see review in Hanks, 1993). Much of this work involved evaluating incubation temperatures, fungicides, growth regulators, etc. In the UK, the more recent trials were focused on simplifying the methodology, for example, by direct-planting chips (rather than incubating) and using bulk incubation (in fan-ventilated, 0.5-tonne, bulk bins filled with chips and vermiculite) (G.R. Hanks, unpublished data).

Chipping and twin-scaling are successful with a number of other bulbs, such as *Hippeastrum* (syn. *Amaryllis*), *Galanthus*, *Nerine*, and *Iris*.

MICROPROPAGATION

Several groups have studied the micropropagation of *Narcissus*. Seabrook et al. (1976) were able to produce shoots, roots, and callus on various explants, especially on the bases of young leaves from cold-treated bulbs. Two leaf sections produced 2,620 shoots after subculturing for 5 months, but transfer of the rooted shoots to the soil was difficult. Hussey (1975) found that plantlets could be regenerated on double scale segments ('mini-twin-scales') from the basal meristem. The shoots eventually formed dormant bulblets, whose dormancy could be broken by giving a cold treatment prior to planting out, transfer to soil being easy (Hussey, 1982). Five hundred to 2000 bulblets could be generated from one bulb in 18 months, with flowering in 3 or 4 years. Squires and Langton (1990) carried out a commercial evaluation of Hussey's (1982) method, confirming these rates. *Narcissus* micropropagation was extensively studied by Selby and co-workers (Harvey and Selby, 1997). A high degree of genetic stability is expected in these methods, the bulblets having an origin similar to natural increase.

Sage et al. (2000) were able to produce somatic embryos from various explants, especially stem explants. Leaf explants taken from shoot cultures produced somatic embryos and converted to plantlets efficiently on a suitable medium after a cold treatment, transferring to ex vitro conditions readily. Somatic embryogenesis in liquid media could provide a means of rapid, automated plant production via bioreactors and at reduced cost.

CONCLUSIONS

The author shares the view expressed by Ticknor (1974) that chipping can be "an adventure". A couple of *Narcissus* bulbs chipped into two handfuls of damp vermiculite in polythene bags is a fun way of introducing bulb propagation to the new gardener. On the other hand, several tonnes of chips rife with aggressive *Penicillium* is not conducive to the propagator's good mental health. Despite its problems, there is scope to use mechanised chipping as an efficient step between the micropropagation and normal field growing phases.

Up to now, micropropagation has been used only to a limited extent for narcissus, mainly with new, basal-rot-resistant cultivars, but as experience is gained its use is likely to increase. In turn the availability of effective micropropagation should stimulate the introduction of improved cultivars, through conventional breeding and genetic transformation. It could also lead to new growing systems whereby a high health status stock is maintained under protected conditions and fed out to provide bulbs for commercial production.

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