soilless sod within 15 weeks in 1995, but only seeded centipedegrass plots produced marketable sod after 10 weeks in 1996. St. Augustinegrass establishment on kenaf-based mat was the least successful. Field-grown centipedegrass and St. Augustinegrass typically take ≈12 to 15 months to produce a harvestable crop, and zoysiagrass takes 12 to 18 months (Hall et al., 1988; John Cobb, personal communication). These grasses grown on kenaf-based mats will not have the same specialty market that soilless bermudagrass sod could have for golf and sports turf and would have to compete with traditional field-grown sods in the market.

Fertilization and irrigation management of this system require further study. Fertilization programs must be developed that can maximize turf performance while minimizing fertilizer inputs. Kenaf mat as a growing medium is essentially a nutrient-free environment with a pH of 5.5 to 6.0. Since most warm-season grass species are fairly well adapted to acid soil conditions (Turgeon, 1991), pH is not a concern, but all essential plant nutrients must be supplied. A reliable watering system must be available throughout the production period. Further research into irrigation methods and strategies is needed, including possible ways to recycle the applied water and any nutrients that have been carried away in the runoff stream. Additional work is also needed to determine 1) optimum fertility and stolonizing rates for individual species; 2) rates of mat degradation and any resulting effects of the mat on the physical and chemical properties of the soil; and 3) winter survival characteristics of turfgrass sods grown on plastic.

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Influence of Bulb Packing Systems on Forcing of Dutch-grown *Hippeastrum* (*Amaryllis*) as Flowering Potted Plants in North America

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Additional index words. hout-wol (excelsior), finn-peat, polyethylene packaging, root growth, wood shavings, postharvest physiology, storage, Amaryllidaceae

Summary. Dutch-grown *Hippeastrum* bulbs ('Apple Blossom' and 'Red Lion') were packed in five readily available and economical packing systems and after transport and storage were evaluated as flowering potted plants. After being harvested and graded, bulbs were specially packed and placed in perforated cardboard boxes, shipped by boat to Raleigh, N.C., and stored in the original packing materials for 84 days at 48 °F (9 °C). At planting time, the best old basal root system and lowest disease incidence for both cultivars was obtained when bulbs were packed with hout-wol, a type of excelsior, in perforated polyethylene bags and placed in perforated cardboard boxes. Plants from bulbs with this system and those packed loose in polyethylene bags flowered the earliest. At full flower, the

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longest leaves were obtained with the hout-wol, box only, and wood chip systems. There were no significant effects of the five packing systems on floral stalk length, number of flowers produced per stalk, flower diameter, strength of the first floral stalk or leaves, or overall plant quality. After flowering, the root systems were harvested. The hout-wol packing system significantly increased the fresh weights of the old basal roots retained, secondary roots produced, and total weight of the root system. There were significant differences between cultivars. 'Apple Blossom' produced fewer roots and lower quality plants (shorter leaves and taller floral stalks) than 'Red Lion'. Other significant cultivar differences, e.g., days to flower, were attributed to genetic variation. Based on the most desirable forcing characteristics, the superior packing system for shipping and storing Dutch-grown *Hippeastrum* bulbs was hout-wol combined with perforated polyethylene bags.

Hippeastrum Herb. (Amaryllidaceae) are primarily indigenous to South America (Liberty Hyde Bailey Hortorium, 1976; Okubo, 1993). Commercially, however, they are usually referred to as amaryllis (Okubo, 1993; Vijverberg, 1980, 1981). They have been extensively bred in The Netherlands and South Africa and many cultivars are available (Zandbergen, 1980). They are a specialty bulb, with <10 million bulbs exported annually from The Netherlands (Okubo, 1993). North American plant quarantine regulations (De Hertogh and Le Nard, 1993) require that flower bulbs imported from foreign countries be free of soil. Usually, this requires that the bulbs be thoroughly washed immediately after harvest. Before being replanted for forcing, *Hippeastrum* bulbs must be stored at 48 to 55 °F (9 to 13 °C) for at least 8 to 10 weeks to promote optimum growth of the leaves and floral stalks (Okubo, 1993). For use in North America, bulbs are transported during this storage period. De Hertogh and Tilley (1991) investigated the effects of planting media on forcing of Dutch-grown *Hippeastrum* and observed variation in the root systems retained. Bulbs for that study were shipped without special packing in 62-L perforated cardboard boxes. Although special packing materials are often used for flower bulbs either to prevent desiccation or development of serious diseases (De Hertogh and Le Nard, 1993; Langeslag, 1989), we are unaware of data on packing materials for *Hippeastrum*. Manley (1954) has indicated that aeration is required and that the packing materials should absorb moisture. The objective of this study was to evaluate the effects of readily available and economical packing systems on 1) the characteristics of Dutch-grown *Hippeastrum* bulbs as flowering potted plants and 2) growth of the root system, which can promote reflowering of the bulbs.

Materials and methods

A preliminary trial conducted in the 1991–92 forcing season demonstrated obvious differences in plant growth due to the packing systems used. A replicated trial was conducted during the 1992–93 forcing season using Dutch-grown *Hippeastrum* 'Apple Blossom' and 'Red Lion' produced in greenhouses (Vijverberg, 1980, 1981). Bulbs were harvested in early October and, after being washed, bulbs 28 to 30 cm in circumference were packed immediately in each of the five systems (Table 1). All bulbs were shipped by boat, the normal transportation system for *Hippeastrum*, on 6 Oct. 1992, and they arrived in Raleigh, N.C., on 21 Oct. 1992. Subsequently, they were stored for 84 d at 48 °F (9 °C) until they were planted on 13 Jan. 1993. For each cultivar, 150 bulbs were used, with five bulbs packed per bag (replication) and six bags per treatment. The fresh root weight (Table 2) of bulbs from one bag per treatment was determined at planting. In addition, moisture content of the packing material was determined by recording the initial weight and then drying it at 109 °F (43 °C) for 7 d.

One bulb was planted per 6-inch (15-cm) diameter, standard depth plastic pot [0.5 gal (1.8 L)] with one-third of the bulb above the surface of the medium. Sunshine mix no. 4 (a mixture of coarse peat and perlite) was used as the planting medium (Fisons Horticulture Inc., Bellevue, Wash.). After a thorough initial watering, the medium was kept slightly moist at all times. All pots were placed in a double-layer polyethylene-covered greenhouse using electrically controlled heating mats to maintain the planting medium at 73 ± 5 °F (23 ± 2 °C). Plants were not fertilized and were forced under prevailing light conditions (8.1 to 14.8 $MJ \cdot d^{-1}$ from January to March). A completely randomized design was used with five replications (blocks) and five observations (pots) per treatment. Data were analyzed as a split plot, with cultivar as the main plot and treatment as the subplot. Mean separation was by Duncan's new multiple range test. For packing treatment comparisons, cultivar data were combined when there was no significant interaction.

The date of the marketing stage and leaf length were recorded when the first floral stalk reached 30 cm (12 in) above the shoulder of the bulb (Fig. 1). All other data were recorded when the first flower of the first stalk opened fully. This included 1) date of flowering, 2) leaf length, and 3) plant quality rating. Plant quality rating (4 = excellent, 1 = poor) was subjective and included many other parameters that are genetically controlled, e.g., total plant height (measured from the shoulder of bulb to the uppermost petal of the first open flower),

Table 1. Description of packing systems used.

Packing system	Materials used
Box only	Bulbs without special packing materials and placed in 62 liter perforated cardboard boxes with 2-cm holes 10 or 20 cm apart (24 holes/box).
Peat	Bulbs in Finn-peat packed in perforated (1-cm holes ≈10 cm apart), low density, 1.2-mil polyethylene bags and placed in perforated cardboard boxes.
Wood chips	Bulbs in wood chips packed in the perforated polyethylene bags and placed in perforated cardboard boxes.
Poly bag	Bulbs packed in the perforated polyethylene bags and placed in perforated cardboard boxes.
Hout-wol	Bulbs in hout-wol (an excelsior), packed in the perforated polyethylene bags and placed in perforated cardboard boxes.

Table 2. Condition of *Hippeastrum* bulbs, basal root fresh weight, and percent moisture of the packing systems on the date of planting.

Packing system	Cultivar[z]	Bulb condition	Root fresh mass (g)	Moisture[y] (%)
Box only	AB	All bulbs were normal	4.4	NA
	RL	*Stagonospora* on scales of three bulbs	4.6	NA
Peat	AB	*Stagonospora* on scales of one bulb	6.1	59
	RL	*Stagonospora* on scales of all bulbs	6.5	60
Wood chips	AB	All bulbs were normal	10.9	22
	RL	*Stagonospora* on scales of all bulbs	6.6	24
Poly bag	AB	A white mold on all old root systems *Stagonospora* on scales of all bulbs	10.4	NA
	RL	A white mold on all old root systems	5.5	NA
Hout-wol	AB	*Stagonospora* on three bulbs A white mold on old root systems of 3 bulbs	18.6	38
	RL	*Stagonospora* on scales of all bulbs	12.2	23

[z]AB = 'Apple Blossom'; RL = 'Red Lion'.
[y]NA = not applicable.

number of flowers per first stalk, flower diameter of the first flower when fully open, and upright strength of first floral stalk and leaves. The presence of a second floral stalk and diseases, e.g., *Stagonospora curtisii,* were also considered in the plant quality rating.

The *Hippeastrum* root system consists of thickened contractile basal roots that produce secondary roots (De Hertogh and Tilley, 1991). The growth and development of the root systems were determined after the last plant of each cultivar flowered. This was 25 Mar. 1993 for 'Apple Blossom' and 1 Apr. 1993 for 'Red Lion'. Each root system, was recovered by carefully washing it in tap water until it was free of the planting medium. The basal plate was removed with roots attached, the old and new basal roots and secondary roots were carefully separated and blotted dry with paper towels, and fresh weight was determined to the nearest 10 mg.

Results and discussion

The major use for *Hippeastrum* in North America is as a flowering potted plant (De Hertogh, 1996). Although some bulbs are forced commercially, most are grown by homeowners and the plants are usually retained for flowering in subsequent years. Thus, on arrival in North America, bulbs should not only have an excellent old root system but also be free from diseases such as *Stagonospora* and *Fusarium* (Okubo, 1993). Bulbs with these basic characteristics will promote growth of an excellent root system and produce high-quality flowering plants in the initial forcing season. Normally, these growth responses are carried over into subsequent seasons.

No significant interactions were obtained between cultivars and treatments for any parameter measured (Tables 3 and 4). There were, however, significant differences between cultivars and the major parameters will be discussed.

'Apple Blossom' reached the market and flowering stages of development ≈10 d earlier than 'Red Lion' (Table 3). This agrees with flowering data for these cultivars reported by De Hertogh and Tilley (1991). Although there were no statistical differences between packing systems in the number of days to the market stage, bulbs from the hout-wol and poly-bag packing systems flowered significantly earlier than other treatments. Although the acceleration was only 3 to 4 d, this is important since earliness of flowering is a desirable trait for most forced bulbs.

Plants from the hout-wol and wood chip systems produced significantly longer leaves at market stage (Table 3), but the wood chip system was not significantly different than plants from the box only treatment. These differences could have been due to an early regrowth of roots retained by these two packing systems (Table 2). At flowering, neither system had leaves significantly longer than plants from bulbs that were packed loose in boxes only. Long leaves at market and flower stages of development are desired for flowering potted *Hippeastrum* (De Hertogh, 1996). They contribute to the aesthetic value of the forced potted plant and to photosynthesis, which is necessary for satisfactory reflowering of the bulb.

All other parameters measured were not significantly affected by the packing systems used. There were, however, significant differences between cultivars that affected plant quality ratings (Table 3). For example, 'Red Lion' was shorter than 'Apple Blossom' and had more flowers. These parameters are controlled genetically (Vijverberg, 1980, 1981) and data are similar to those obtained for these cultivars in the planting media study (De Hertogh and Tilley, 1991).

At planting, the hout-wol packing system had the highest amount of roots retained (Table 2). This may have been due to the increased aeration of this packing system, which Manley (1954) indicated is desired for *Hippeastrum.* After the bulbs had flowered, plants from this packing system retained the greatest fresh weight of old roots and also produced significantly greater fresh weights of secondary roots and total

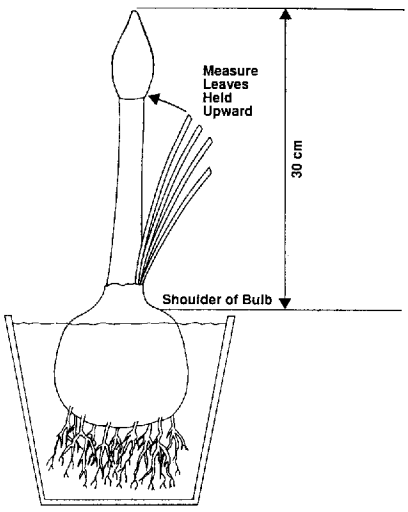

Fig. 1. Diagram showing the market stage measurements for *Hippeastrum* as a flowering potted plant.

Table 3. Effects of packing systems on days to market stage, days to first flower opening, total leaf length, and plant quality of Dutch-grown 'Apple Blossom' (AB) and 'Red Lion' (RL) *Hippeastrum*.

	Days to			Leaf length (cm)		Plant	
	Market stage		Flowering	Market stage	Flowering	quality	
Packing system	AB	RL	AB + RL	AB + RL	AB + RL	AB	RL
Box only	42.0	51.2	64.9 a	30.9 bc	37.7 ab	2.5	3.2
Peat	41.8	48.0	64.0 ab	28.5 c	35.8 bc	2.4	3.3
Wood chips	41.0	52.8	65.3 a	32.8 ab	39.3 a	2.5	3.1
Poly bag	41.3	49.5	60.6 c	29.3 c	34.8 c	2.3	3.4
Hout-wol	39.6	51.2	61.4 bc	34.8 a	40.0 a	2.6	3.4
Cultivar mean	41.1	50.5	58.4/68.1	28.1/34.4	33.0/42.1	2.5	3.2
Significance							
Cultivar	**		**	**	**	**	
PS[z]	NS		**	**	**	NS	
Cultivar × PS	NS		NS	NS	NS	NS	

[z]PS = packing system.
NS,*,**Nonsignificant or significant at $P = 0.05$ or 0.01, respectively. Mean separation in columns is by Duncan's multiple range test and was performed on combined cultivar data when the PS was not significant.

roots (Table 4). This ability for root regrowth was apparently influenced by the hout-wol and also the perforated polyethylene bags. These bags were selected because some aeration was needed to prevent a buildup of excess moisture, which can cause bulb diseases. Prince et al. (1987) demonstrated that nonperforated bags can increase the incidence of diseases with tulip bulbs. In contrast, Maqbool and Cameron (1994) studied storage of 15 bare-rooted herbaceous perennials and found that most bare-rooted plants could be stored for up to 6 months without affecting regrowth performance when stored at proper temperatures in a nonperforated polyethylene liner and wooden crates. They noted, however, that mold growth increased with time, but it did not affect regrowth potential. We also had some white mold on the roots of some bulbs at planting time (Table 2), but it did not affect root growth or flowering. 'Red Lion' produced significantly more roots than 'Apple Blossom' (Table 4), which agrees with the results of De Hertogh and Tilley (1991).

Conclusions

Our goal was to identify a readily available, economical, and lightweight packing system for Dutch-grown *Hippeastrum* bulbs that would help produce high-quality plants from imported bulbs. Therefore, when all parameters (Tables 2–4) are considered, hout-wol (excelsior) combined with perforated polyethylene bags was superior to the other packing systems for the cultivars used. Hout-wol retained and promoted regrowth of the old basal roots, increased secondary root growth, and produced early flowering plants with long leaves. It appears that this system equilibrates the moisture from the bulbs and roots after they have been washed for export. Since hout-wol and polyethylene are lightweight, they do not add greatly to the overall shipping weight. Also, these materials are clean, economical, and easy to handle by bulb exporters, wholesalers, and consumers. By combining the hout-wol packing system, proper bulb programming, and the use of an optimum planting medium, homeowners and commercial forcers should be able to force high-quality plants from Dutch-grown *Hippeastrum* bulbs.

Table 4. Effect of packing systems on root growth of Dutch-grown 'Apple Blossom' (AB) and 'Red Lion' (RL) *Hippeastrum*.

	Root fresh mass (g)/bulb				
	Basal roots				
	Old	New		Secondary roots	Total roots
Packing system	AB + RL	AB	RL	AB + RL	AB + RL
Box only	8.1 b	13.9	21.0	7.3 b	32.8 bc
Peat	8.1 b	11.0	23.0	8.3 b	32.1 c
Wood chips	10.2 b	11.9	25.6	8.7 b	37.6 b
Poly Bag	9.1 b	13.0	26.4	8.0 b	36.7 bc
Hout wol	14.1 a	9.8	24.1	13.3 a	41.2 a
Cultivar mean	9.6/10.2	11.9	24.0	9.5/8.7	30.9/42.5
Significance					
Cultivar	NS	**		NS	**
PS[z]	**	NS		**	**
Cultivar × PS	NS	NS		NS	NS

[z]PS = packing system.
NS,*,**Nonsignificant or significant at $P = 0.05$ or 0.01, respectively. Mean separation in columns is by Duncan's multiple range test and was performed on combined cultivar data.

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Establishment of Tetranychid Mites in vitro

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Additional index words. *Tetranychus urticae*, somaclonal variation, surface disinfestation, tissue culture, axenic cultures

Summary. **Procedures were developed to determine if live, adult two-spotted spidermites (*Tetranychus urticae* Koch) could be surface disinfested before being introduced into in vitro cultures of torenia (*Torenia fournieri* L.). Three time periods (5, 10, and 15 minutes) and five levels of sodium hypochlorite (0.05% to 0.25%) were evaluated. Surface disinfestation was accomplished by agitating 2 × 3 cm pieces of infested bean leaves in sodium hypochlorite solutions and then drying in a mite drier apparatus. All sodium hypochlorite concentrations disinfested the mites completely, however high concentration levels were lethal to the mites. Exposure periods of 10 and 15 minutes also significantly increased mortality. For optimum disinfestation of two-spotted spidermites with minimum mortality, a concentration of 0.05% sodium hypochlorite and 0.05% Tween-20 for 5 minutes should be used.**

For either the study of plant processes or of a plant's relationship to its environment, the plant should be free of microorganisms. Axenic cultures are necessary because microorganisms can influence plant nutrition, physiology, and health. The need for asepsis while working with plant tissue culture requires that all culture vessels, instruments, and media be sterile. A variety of wet and dry heat treatments, such as radiation, filtration, gas, and chemical agents, are available for sterilization (Klein and Klein, 1970). In addition, simple precautions, such as maintaining a high level of cleanliness, will reduce the risk of widespread contamination (Kreider, 1968). The disinfestation of plant tissue culture media and apparati is usually accomplished by autoclaving.

Several chemical agents are used for to surface disinfest plant material, including sodium hypochlorite, calcium hypochlorite, mercuric chloride, hydrogen peroxide, silver nitrate, and bromine water. The choice of chemical and the time of exposure depends on the sensitivity of the material to be disinfested. Overzealous disinfestation may not only remove all microorganisms, but it may also be lethal to the plant tissue. Therefore, optimum conditions have to be determined for each tissue or situation.

The chemical agent should be easily removed after application because the retention of noxious chemicals seriously affects the establishment of cultures. Repeated rinses with distilled water will wash most chemical agents away, whereas others degrade to less-toxic chemicals that can be washed away. For example, sodium hypochlorite breaks down to chlorine, its active agent, and sodium hydroxide; the latter is removed during rinsing. Hydrogen peroxide decomposes and evaporates. Silver nitrate can be inactivated by the addition of sodium chloride (NaCl) to render the sterilizing agent harmless to the tissue. Dilute mercuric chloride is a satisfactory sterilizing agent, but difficult to remove.

Studies on the surface disinfestation of insects or arthropods for introduction into in vitro cultures have not been reported; however, techniques exist to evaluate the effects of acaricides on spidermites. Methods to evaluate the resistance of spidermite populations to acaricides should be simple, provide reproducible results, and simulate, as closely as possible, the conditions under which the acaricide will be used for mite control. The slip-dip method, as described by Voss (1961), fulfills the first two criteria; however, it measures only topical toxicity and is difficult to use with acaricides that are effective against adult female mites. Furthermore, it is

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