

Research Updates

Kenaf-based Fiber Mat as a Substrate for Establishing Soilless Sod

K.L. Hensler,¹ B.S. Baldwin,²
and J.M. Goatley, Jr.³

ADDITIONAL INDEX WORDS. washed sod, sod production, sod rooting

SUMMARY. A truly soilless turfgrass sod may be produced on kenaf-based (*Hibiscus cannabinus* L.) fiber mat that offers the integrity of field-cut sod without the use of mineral soil growing medium. This research was conducted to determine the feasibility of producing warm-season turfgrass sod on such a biodegradable organic mat. Seeded turfgrass plots contained 4.9 lb/1000 ft² (24 g·m⁻²) of pure live seed planted on a 66-lb/1000 ft² (325-g·m⁻²) organic fiber mat carrier placed atop either 66- or 132-lb/1000 ft² (325- or 650-g·m⁻²) organic fiber mats. In an experiment using vegetative material, stolons were applied at rates of 16.4 ft³/1000 ft² (0.82 L·m⁻²) over 132- or 198-lb/

1000 ft² (650- or 975-g·m⁻²) organic fiber mats and covered with a rayon scrim. All plots were placed on 6-mil black plastic. Nitrogen was applied at 0.9 lb/1000 ft² (4.4 g·m⁻²) weekly in addition to a monthly micronutrient application. Bermudagrass (*Cynodon dactylon*) had quicker establishment than other grasses in the study, with stolonized and seeded plots achieving ≈100% coverage by 9 weeks in 1995 and 6 weeks in 1996, respectively. By 15 weeks after planting in 1995, the plot coverage ratings for seeded centipedegrass [*Eremochloa ophiuroides* (Munro) Hack. 'Common'] and all stolonized grass plots of centipedegrass, zoysiagrass (*Zoysia japonica* Steud. 'Meyer'), and St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze 'Raleigh'] were 91% or higher. The results were much less favorable in 1996 than 1995 due to a later planting date and an irrigation failure.

Washed sod technology was introduced by Warren's Turf Nursery of Palos Park, Ill., in the 1970s (Turgeon, 1977). Washed sod is the result of a postharvest washing by a patented apparatus consisting of three motorized conveyors passing through two series of high-pressure water jets. The apparatus requires three operators and has a capacity of two 72 × 16.5-inch (183 × 42-cm) sod strips per minute (Turgeon, 1977). Washed sod is expensive to produce, and soil removal can be difficult to accomplish while still maintaining sod integrity. The advantages of washed sod include elimination of layering due to soil differences between sod source and destination, quick rooting establishment, ease of handling, and light weight for shipping. Washed sod has superior water

infiltration rates and rooting characteristics compared to traditional field-cut sods (Casimaty et al., 1993).

In the past, washed sod and soilless sod have been interchangeable terms. In the context of this research, we differentiate between the two terms. Washed sod is defined as field-cut sod that has the soil mechanically removed from the turfgrass plant. Soilless sod is defined as sod grown on an organic fiber mat placed on an impermeable surface.

As an alternative to washed sod, other methods of growing sod over an impervious plastic layer have been investigated, some using soil as a substrate, others using some form of natural or man-made organic fiber. Baron (1982) used two layers of a nonwoven organic fiber mat composed primarily of flax. A cool-season grass mix was seeded between the two layers. Anton (1993) reported growing grass on a nonwoven mat composed of hollow synthetic organic fibers. These hollow fibers can contain water-soluble plant nutrients, pesticides, algicides, or herbicides within their interiors, thereby providing slow release of the chemicals to enhance or protect growing seedlings.

Heard (1988) produced pregrown turf by placing grass seed on a layer of straw deposited on an impervious surface. Chamoulaud (1980) produced sod by applying grass seed to a finely crushed wood bark compost layer. Burns (1980), looking for methods to decrease sod establishment times, grew sprigged 'Tifway' bermudagrass [*Cynodon dactylon* × *transvaalensis* Burt-Davy] on 0.3 inches (8 mm) of wastewater sludge from a secondary treatment plant. All of these methods were successful to some degree in producing turfgrass sod, but there were problems in sod handling characteristics and biodegradation of the mat substrate that limited their acceptability.

Another alternative to washed sod examined here is to grow a truly soilless sod using 100% biodegradable kenaf (organic) fiber mat as a substrate. This eliminates soil removal while using the fiber mat as a component of sod integrity.

The objectives of this research were to 1) determine if turfgrass sod can be produced on a 100% kenaf fiber substrate; 2) compare seeded and vegetatively established planting meth-

Department of Plant and Soil Sciences, Mississippi State University, Mississippi State, MS 39762.

¹Former graduate research assistant.

²Associate professor and agronomist.

³Associate professor and agronomist.

Mississippi Agricultural Forestry Experiment Station journal no. J-9146. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

ods; 3) determine the length of time required to establish a marketable product; and 4) compare rooting characteristics of soilless sod grown on kenaf fiber mat to traditional field-cut sod harvested from a mineral soil.

Materials and methods

Species performance, planting method, and kenaf mat thickness comparisons. Stolons of 'MS Express' bermudagrass (*Cynodon ×magenissii* Hurc.), 'Common' centipedegrass (*Eremochloa ophiuroides*), 'Raleigh' St. Augustinegrass (*Stenotaphrum secundatum*), and 'Meyer' zoysiagrass (*Zoysia japonica*) were harvested from field plots at the Mississippi State Univ. Plant Science Research Center (Starkville, Miss.) with a vertical mower. For the trial established on 31 May 1995, the stolons were scattered at a rate of 16.4 ft³/1000 ft² (0.82 L·m⁻²) over 12.9-ft² (1.2-m²) pieces of commercially available 100% kenaf mat (Mississippi MAT-Line/Agro-Fibers, Inc., Charleston, Miss.). The mat is composed of bast fibers processed kenaf (*Hibiscus cannabinus*). The fibers are processed into a porous mat 5 ft (1.5 m) wide and 0.5 inches (1.27 cm) thick that has very poor water retention. The commercially available mat contained trace amounts of a UV-degradable low melt polyester binding agent and starch polymer at 2 lb/1000 ft² (9.8 g·m⁻²) to improve water retention. Double or triple layers of mat, consisting of 132 or 198 lb/1000 ft² (650 or 975 g·m⁻²) kenaf, respectively, were evaluated in this trial. The study was conducted on a 6-mil-thick sheet of black plastic to prevent roots from penetrating the soil. The underlying soil was slightly crowned (≈0.5% slope) at the midpoint of the plastic barrier to its sides to help move water off the plastic.

Commercially produced mat for the vegetatively established plots was unavailable in 1996 due to temporary mechanical difficulties at the manufacturing facility. Mats for this study were made at the Mississippi State Univ. Plant Science Research Center by floating the appropriate weights of kenaf fiber [66 lb/1000 ft² (325 g·m⁻²) per layer] on water in a wooden frame with a hardware cloth (0.25 in mesh; 6.4 mm) bottom. No polyester binding agent or starch polymer were added. Turfgrass stolons were not sown until 12 July 1996 due to unforeseen mat

production facility difficulties and the time required to acquire raw materials and equipment to produce mats.

For the seeded plots, a commercially available preseeded top mat (Mississippi MAT-Line/Agro-Fibers, Inc.) consisting of 50% kenaf and 50% wood fiber along with a starch polymer was laid over either 66 or 132 lb/1000 ft² (325 or 650 g·m⁻²) of 100% kenaf mat as described previously. Seed of 'AZ Common' bermudagrass [*Cynodon dactylon* (L.) Pers.], 'Common' centipedegrass, 'Raleigh' St. Augustinegrass, and 'Sunrise' Zoysiagrass were applied during mat production at levels of 4.9 lb/1000 ft² (24 g·m⁻²) of pure live seed as recommended by Emmons (1995). The seeded mat trials were established on 31 May 1995 and 4 June 1996, respectively, and commercially available mat was used in both trials.

All plots were fertilized monthly with Slo-Cote slow release 14-14-14 (Bonus Crop Fertilizer, Inc., Bay City, Texas) at 0.9 lb N/1000 ft² (4.4 g·m⁻²) and MicroMax Plus micronutrient mix (The O.M. Scotts Co., Maryville, Ohio) at 23.4 lb/1000 ft² (114.3 g·m⁻²). Supplemental N was applied at 0.9 lb/1000 ft² (4.4 g·m⁻²) weekly. Irrigation was applied as needed with an automatic irrigation system to prevent mat desiccation. The typical irrigation schedule immediately after establishment was for 6-min cycles delivering 0.5 inches³ (8.2 cm³) of water every 2 h beginning just after sunrise and ending 1 h before sunset. As root systems developed, the irrigation schedule was reduced to four 6-min cycles daily scheduled for midmorning, noon, and early and midafternoon to meet the high moisture demands and heat-stress periods during the day. Irrigation frequencies and durations were adjusted to prevent turfgrass and mat desiccation. Plots were mowed at a 1.5-inch (3.8 cm) height weekly. Mowing was initiated after plant height reached 1.5 inches (3.8 cm) to 2 inches (5.1 cm). Each species had different mowing initiation dates based on morphological maturation.

Percent plot coverage was estimated visually at 9 and 15 weeks after establishment in 1995 and at 4, 6, 8, and 10 weeks after establishment in 1996. A 1996 irrigation failure after 8 weeks for the stolonized plots and 10 weeks for the seeded plots resulting in plot desiccation, shortening the study

period compared to 1995. A plot coverage rating of 80% or greater was deemed as marketable sod based on acceptable appearance and sod handling integrity.

A completely randomized factorial design was used for all trials, with four replications per grass species, mat thickness, and establishment method. Means for percent plot coverage for each establishment method (seed versus stolons) were calculated across double or triple mat thicknesses. No statistical comparisons were made between seeded and stolonized bermudagrass and zoysiagrass plots. Different cultivars were used for each planting method due to the unavailability of hybrid bermudagrass and Meyer zoysiagrass seed. Means for percent turfgrass plot coverage were calculated and were compared by Fisher's protected LSD test at $p \leq 0.05$ (SAS, 1989).

TRANSPLANT ROOTING. Once complete coverage of the vegetatively established 'MS-Express' bermudagrass was achieved, studies were conducted to compare rooting characteristics of soilless bermudagrass sod versus traditional field-cut sod. Measurements of transplant rooting were determined using a modified procedure developed by King and Beard (1969). Bare soil was tilled lightly to a depth of <0.5 in (1.3 cm) 1 d before initiation of the study. Fully established 'MS-Express' soilless and field-cut 'MS-Express' bermudagrass sod were cut to 1.0-ft² (0.09-m²) sections. Field-cut sod was harvested at a depth of ≈0.5 in (1.3 cm) with a commercial sod harvester.

Sod sections were placed on 1.0 (0.3 m) × 1.0-ft (0.3-m) expanded metal squares fitted with eye bolts at each corner. The transplanted sod was irrigated during the first week after transplanting as needed to prevent desiccation, with less irrigation toward the end of the 7-d period. At 7, 10, and 14 d after transplanting, vertical force was applied to the metal plates by attaching each of the four corners to a single hook suspended beneath a handheld scale and lifting until the rooted sod separated from the soil. The resulting resistance indicated the relative degree of sod rooting over time.

Sixteen sod sections for soilless (double-thickness mat only) and field-cut sod were established on 11 Aug. 1995. Four replications were lifted at each harvest date. Due to larger-than-

Table 1. Mean percent plot coverage of warm-season turfgrasses at 9 or 15 weeks after establishing on kenaf-fiber mat on 31 May 1995. Ratings are averaged across double- and triple-layer kenaf mat thicknesses.

Species	Weeks after establishment			
	9		15	
	Seeded ^a	Stolons ^b	Seeded	Stolons
	Mean % coverage			
Bermudagrass	90	98	100	99
Centipedegrass	65	81	98	99
St. Augustinegrass	33	69	71	91
Zoysiagrass	59	80	89	96

^aSeeded at rates of 4.9 lb/1000 ft² (24 g·m⁻²) of pure live seed.

^bVegetatively established from stolons at 16.4 ft³/ft² (50 cm³·m⁻²) for all species.

desired variability in root lift values in 1995, 80 sod sections for both types of bermudagrass sod were established on 30 Aug. 1996. Twenty replications of each sod square were lifted at each harvest date. All data were subjected to ANOVA, and mean separation procedures were performed when appropriate using Fishers's protected LSD test at $p \leq 0.05$ (SAS, 1989).

Results and discussion

SPECIES PERFORMANCE. At 9 weeks after planting in 1995, bermudagrass plots established with stolons approached 100% coverage, and in 1996 bermudagrass plots had 96% coverage by 6 weeks after planting (Tables 1 and 2). Quick plot coverage of bermudagrass is a result of a more aggressive lateral growth habit and a larger number of growing points per unit volume of stolons compared to the other grasses (Beard, 1973). In this study, all stolons were applied at 16.4 ft³/1000 ft² (50 cm³·m⁻²). Duple (1989) recommends planting bermudagrass at ≈ 11.8 to 29.5 ft³/ft² (36 to 90 cm³·m⁻²), depending on the rate of coverage required, and using even higher planting rates for quicker establishment. Still, producing soilless sod

in 6 to 9 weeks is markedly superior to the traditional 3- to 12-month sod production period (Hall et al., 1988; John Cobb, Mississippi Grass Nursery, Hattiesburg, personal communication).

Seeded bermudagrass plots had almost total coverage within 9 weeks in 1995, while in 1996 marketable plot coverage of 80% was achieved by 10 weeks. The slightly lower plot coverage values for bermudagrass in 1996 were most likely due to a later establishment date.

Plot coverage ratings for the other grasses were much more variable than for the bermudagrass plots. By 9 weeks after planting the 1995 trial, centipedegrass and zoysiagrass had marketable plot coverage ratings of 80% for the stolonized plots, and by 15 weeks all grasses that were established from stolons had $\geq 90\%$ coverage (Table 1). For the seeded plots in 1995, only St. Augustinegrass did not achieve at least 80% plot coverage by 15 weeks after establishment (Table 1).

In 1996, establishment ratings for all grasses other than bermudagrass were lower than those for 1995. In the seeded plots, only the seeded centipedegrass at 85% coverage at-

tained a marketable rating by 10 weeks after establishment. Percent turf cover ratings for the plots in 1996 were lower than those at comparable evaluation dates for 1995 (Table 1 and 2) because of two major factors: 1) a late initiation of the study due to problems at the kenaf-mat manufacturing facility and 2) an automatic irrigation failure that terminated the vegetative study after 8 weeks and the seeded study after 10 weeks. Higher temperatures and increased watering demands of turf planted in July 1996 than in May 1995 made establishment much more difficult in 1996. Irrigation failure at 8 weeks after vegetative establishment resulted in significant turf loss from desiccation and no further data were collected. A reliable automatic irrigation system is essential to the success of this sod production method, and, while the system worked adequately in 1995, there were constant problems in timing and amounts of irrigation delivered throughout Summer 1996. Therefore, the 1996 results, other than for the more drought-tolerant, rapidly growing bermudagrass, were not as favorable for the other turfgrasses as the 1995 trial.

The data for seeded plots in 1996 are presented only through 10 weeks after establishment (a final rating date of ≈ 20 Sept. 1996). At this point, cooler temperatures and shorter day lengths were not conducive to further warm season turfgrass growth.

Before the irrigation failure, seeded centipedegrass plots had achieved 85% coverage by 10 weeks after establishment in 1996, again meeting our criteria as a marketable sod. Plot coverage ratings for zoysiagrass established from stolons were reduced from the 6- to 8-week period following an application of fenoxaprop $\{(\pm)-2-[4-[(6\text{-chloro-2-}$

Table 2. Mean coverage of warm-season turfgrasses at 4, 6, 8, or 10 weeks after establishment on kenaf mat in 1996. Coverage ratings are averaged across double- and triple-layer kenaf mat thicknesses.

Species	Weeks after establishment							
	4		6		8		10	
	Seeded ^a	Stolons ^b	Seeded	Stolons	Seeded	Stolons	Seeded	Stolons
	Mean % coverage							
Bermudagrass	19	67	64	96	70	100	80	---
Centipedegrass	14	11	69	22	76	40	85	---
St. Augustinegrass	12	19	8	38	8	69	10	---
Zoysiagrass	8	23	23	57	30	26	41	---

^aSeeded at rates of 4.9 lb/1000 ft² (24 g·m⁻²). Study initiated on 4 June 1996.

^bVegetatively established with stolons at 16.4 ft³/ft² (50 cm³·m⁻²) for all species. Study initiated on 12 July 1996.

^cData were not collected due to irrigation failure.

Table 3. Vertical rooting force values of soilless and field-cut 'MS-Express' bermudagrass sod transplanted on 11 Aug. 1995 and 30 Aug. 1996, respectively.

Sod type	Days after transplanting		
	7 ^a	10	14
	Rooting force [lb/ft ² (kg·m ⁻²)]		
	1995		
Soilless	55 (275)	88 (440)	167 (835)
Field-cut	48 (240)	87 (435)	107 (535)
LSD (0.05) ^b	NS	NS	NS
	1996		
Soilless	52 (260)	71 (355)	>202 (1010) ^x
Field-cut	46 (230)	74 (370)	159 (795)
LSD (0.05)	NS	NS	16 (80)

^aMean of plots based on resistance to applied vertical force, with units being expressed in either lb/ft² or kg·m⁻².

^bVertical lift means between soilless and field-cut sod within the same row and year are significantly different according to Fisher's protected LSD test at $p \leq 0.001$. ^{NS}Nonsignificant.

^xMeasuring device was maximized at 202 lb/ft² (1010 kg·m⁻²).

benzoxazolyl)oxy]phenoxy]propanoic acid] at 0.036 lb a.i./acre (41 g·ha⁻¹ a.i.) to control common bermudagrass that had contaminated the plots. While bermudagrass control was achieved, plot density ratings were reduced from 57% to 26% as a result of controlling common bermudagrass. Seeded St. Augustinegrass plots in 1996 never achieved >12% plot coverage through 10 weeks, and stolonized plots had reached 69% coverage by 8 weeks after establishment (Table 2). St. Augustinegrass had consistently lower plot coverage ratings than the other grasses in both years' trials.

PLANTING METHODS. There were few differences in plot coverage between vegetative and seeded plots at the end of the 1995 trial except for St. Augustinegrass, where vegetatively established plots outperformed the seeded plots (Table 1). Statistical comparisons of bermudagrass and zoysiagrass planting materials were deemed inappropriate since different genotypes were used. Establishment using vegetative material requires root, stolon, and rhizome initiation and development at nodal areas, while seeding requires some degree of plant maturation before stolon development occurs. A trend toward superior establishment with vegetative material might therefore be expected. The fact that this trend did not materialize in 1995 may be a factor of plot coverage. Since plot coverage was evaluated by rating the amount of green vegetative cover, and not considering plant morphological development (i.e., tiller, stolon, or rhizome), the data may be misleading as far as sod maturity is

concerned. However, concerns about sod maturity may be irrelevant, since sod without stolons or rhizomes still retains the capability to root, establish, and develop into a mature turf.

At the end of the 1996 study (Table 2), results showed a disparity between coverage for the planting materials, with stolons covering quicker in the bermudagrass and St. Augustinegrass plots and seed covering quicker in centipedegrass plots. However, the previously described problems in the 1996 trial affected the results of this trial, and further research will be necessary to verify these results.

KENAF MAT THICKNESS COMPARISONS. Only centipedegrass coverage was affected by mat thickness. The triple layer mats (198 lb/1000 ft²; 975 g·m⁻²) of centipedegrass at 9 weeks had better coverage than the double layer (132 lb/1000 ft²; 650 g·m⁻²) mats. All other species tested showed no significant differences at both 9 and 15 weeks.

In 1996, bermudagrass, centipedegrass, and zoysiagrass coverage was higher with the triple layer than the double-layer mat at 4 weeks after establishment. After the fourth week, only seeded zoysiagrass was affected by mat thickness. Stolonized plots in 1996 did not favor one substrate thickness over the other. The better early coverage for triple layer mats in the seeded grasses might be attributed to greater moisture retention, thereby decreasing chances for drought stress on hot or windy days.

TRANSPLANT ROOTING. Nearly identical results between 'MS Express' bermudagrass soilless sod and field-

cut sod were observed in 1995 (Table 3). In 1996, at 14 d, the mat had better rooting (as measured by resistance) than field-cut sod (Table 3). The vertical resistance for the soilless sod at 14 d exceeded the capabilities of the measuring device. Data were entered at the maximum 202 lb/ft² (1010 kg·m⁻²) for statistical analysis; however, the actual values were larger.

We observed a greater tendency for the soilless sod to wilt than the field-cut sod during the first week. Beard (1973) reported that thicker, field-cut sod was more tolerant of droughty conditions, but thinner cut sod rooted faster during grow-in situations. The thinner the harvested sod is cut, the greater the stimuli for initiation of a new root system. Growth from existing roots cut during sod harvesting is minimal since the meristematic area of the root is (or was) at its tip. Many new roots must be initiated from the crown and grow through the attached soil layer to replace those damaged or severed in the harvesting process (Madison, 1970).

Conclusions

This research indicates that warm-season turfgrass sod can be grown using kenaf-based organic fiber mat as a growing medium, offering a rapid production method and the potential for faster sod transplant rooting as compared to traditional field-grown sods. In particular, vegetatively propagated bermudagrasses grown on kenaf-based mat could provide a cost-competitive alternative to washed sod for establishing golf and sports turfs on sand-based soils where layering of different textured soils can be a concern. Marketable bermudagrass sod from stolons was produced in ≈6 weeks, while field-grown bermudagrass reportedly takes from 3 to 12 months (Hall et al, 1988; John Cobb, personal communication). Mats from seeded bermudagrasses were also produced within ≈6 weeks. Seeded bermudagrasses, while probably not having the same applications as the vegetatively propagated bermudagrasses, might be marketed for lower maintenance turfs. It is unlikely that soilless bermudagrass sod can be cost-competitive with field-grown sods, although it has advantages as a rapid production method.

For centipedegrass or zoysiagrass, either establishment method (seeding or stolonizing) produced a marketable

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.

Literature cited

- Anton, A. 1993. Fibrous mat for growing plants. U.S. Patent 5 224 292. Date issued: 6 July.
- Baron, G. 1982. Pre-grown turf and manufacturing of pre-grown turf. U.S. Patent 4 364 197. Date issued: 21 Dec.
- Beard, J.B. 1973. Turfgrass: Science and culture. Prentice-Hall, Englewood Cliffs, N.J.
- Burns, R.E. 1980. Techniques for rapid sod production, p. 361–366. In J.B. Beard (ed.). Proc. 3rd Intl. Turfgrass Res. Conf., Munich, Germany. 11–13 July 1977. Intl. Turfgrass Soc., ASA, CSSA, and SSSA, Madison, Wis.
- Casimaty, B.G., J. Neylan, and J.B. Beard. 1993. Effects of removal by post-harvest hydraulic washing on sod transplant rooting of a Kentucky bluegrass-perennial ryegrass polystand and a creeping bentgrass monostand. In: R.N. Carrow, N.E. Christians, and R.C. Shearman (eds.). Intl. Turfgrass Soc. Res. J. 7:850–856.
- Chamoulaud, M.C. 1980. Carpet of vegetable matter. U.S. Patent 4 232 481. Date issued: 11 Nov.
- Duble, R.L. 1989. Southern turfgrasses: Their management and use. TexScape, Inc., College Station, Texas.
- Emmons, R. 1995. Turfgrass science and management. 2nd ed. Delmar Publ., Albany N.Y.
- Hall, C.R., L.G. Kizer, J.V. Krans, T.D. Phillips, and G.E. Coats. 1988. Economic and agronomic analysis of Mississippi turfgrass sod farms. MS Agr. For. Expt. Stat. Agr. Econ. Res. Rpt. 182.
- Heard, R.A. 1988. Pre-grown lawn turf product and method of growing. U.S. Patent 4 716 679. Date issued: 5 January.
- King, J.W. and J.B. Beard. 1969. Measuring rooting of sodded turfs. Agron. J. 61:497–498.
- Madison, J.H. 1970. Rooting from sod by *Poa pratensis* L. and *Agrostis tenuis* Sibth. Crop Sci. 10:718–719.
- SAS Institute. 1989. SAS/STAT user's guide. version 6. 4th ed. SAS Inst., Cary, N.C.
- Turgeon, A.J. 1977. Comparative advantages of soilless sod for Kentucky bluegrass. Rasen Grün-flächen Begrünungen 8(1):13–15.
- Turgeon, A.J. 1991. Turfgrass management. 3rd ed. Regents/Prentice Hall, Englewood Cliffs, N.J.

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

A.A. De Hertogh and
L.B. Gallitano¹

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

¹Department of Horticultural Science, North Carolina State University, Raleigh, NC 27609-7609.

We acknowledge the assistance of C.J. Zonneveld and Sons, Voorhout, The Netherlands, for packing and shipping the bulbs, The Dutch Bulb Exporters Association, Hillegom, The Netherlands for financial support, and Fisons Horticulture Inc., Bellevue, Washington 98004 for providing planting media. We also thank W. Swallow and K. Kalmowitz for their assistance with the statistical analyses. The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Service or criticism of similar ones not mentioned. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.