Evaluation of Seashore Paspalum in Southeastern Virginia

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Abstract

Seashore paspalum *(Paspalum vaginatum* Sw.) has been successfully grown in warm, humid environments in both the United States and southeastern Asia. In the U.S., seashore paspalum has been planted in parts of North Carolina south to Florida, Texas, California and Hawaii. Very tolerant of low mowing heights, this species has been used primarily for golf courses, but also has applicability as a turf for lawns. High salt tolerance makes it a promising turf for areas near the Chesapeake Bay and the Atlantic Ocean. Research and testing of seashore paspalum in the U.S. has been conducted primarily in Georgia and Florida. Virginia Tech has not conducted any research on this potential new turf species for Virginia. For this project, I have evaluated the adaptability of nine vegetative and three seeded cultivars of seashore paspalum in southeastern Virginia in comparison to bermudagrass (*Cynodon dactylon* L.*)* as an industry standard for comparison. Evaluations of turf cover were made weekly during establishment and at time of spring green-up. Weed competition significantly reduced establishment, with only the vegetative cultivars 'Sea Star' and 'Sea Isle Supreme' seashore paspalum achieving greater than 65% cover during the first growing season. No cultivar planted by seed successfully established due to weed competition. All seashore paspalum cultivars planted vegetatively survived the winter; however, only Sea Isle Supreme and Sea Star had exceeded 75% turf cover by June 19, 2014, approximately 75 days after breaking dormancy. 'Yukon' bermudagrass achieved an 85% turf cover in the same time frame.

Acknowledgements

I would like to thank my advisor, Jeff Derr, for all of his insight and guidance with this project. His assistance was needed and definitely appreciated from start to finish of my trial. Being an off-campus student can sometimes feel like being alone on a desert island. Jeff was always there for me, to lead me through the University infrastructure and intervene when necessary to keep me on track. Without his help, this project would not have come to fruition. It is my hope that Jeff and his team at the Hampton Roads AREC continue my research on seashore paspalum as there is still much left to discover.

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Introduction

Potable water is essential for human survival. With the progression of climate change and unpredictable weather conditions, the United States has experienced significant areas of drought over the last decade (Schiavon et al. 2013). As turfgrass on lawns, golf courses and athletic fields is a major user of water for irrigation, minimizing that use is of great importance in an effort to conserve water resources. Seashore paspalum (*Paspalum vaginatum* Sw.) is a warm-season species of turfgrass that once established can be irrigated with brackish water. Its use could augment water conservation efforts in drought prone parts of the country and minimize potable water use in other areas. It is for that reason that I have undertaken this research project.

In order to determine the viability of seashore paspalum in southeastern Virginia, multiple questions needed to be answered. Three seeded cultivars and six vegetative cultivars of seashore paspalum were obtained for testing. The seeded cultivars were also propagated in the Virginia Tech Hampton Roads Agricultural Research Center (AREC) greenhouse so that they could be planted vegetatively. The cultivars were compared for rates of establishment, color and percent turf cover at time of spring greening.

The objectives of this research were to determine 1) if there is any difference in establishment of the seeded or vegetative cultivars of seashore paspalum, 2) if there are any differences among cultivars in winter survival, 3) if any differences in turf cover would be apparent at time of spring green-up, 4) if there are any differences in response of seeded and transplanted seashore paspalum to broadleaf and grass weed competition, 5) and are there any differences among cultivars in disease incidence, particularly with dollar spot. One cultivar of bermudagrass was included for comparison.

Would any of the tested cultivars of seashore paspalum survive low temperatures below -7 C (20 F)? This issue was our biggest concern. As seashore paspalum had not previously been tested in

Virginia there was no data available for a climate this cold. While the summer temperatures in the southeastern part of the state are comparable with summer temperatures in Georgia and the semi-tropical humidity found in more Mediterranean climates, only laboratory testing using acclimation chambers had been done simulating temperatures below -7 C (20 F) (Cardona, Duncan, and Lindstrom 1997). We could find no record of field testing in winters this cold.

The project was based on the following five hypotheses:

I. H_0: There is no difference in the color, texture or percent turf cover in spring characteristics of the seashore paspalum cultivars that were propagated in the AREC greenhouse.

H_a: There is a difference in the color, texture or percent turf cover in spring characteristics of the seashore paspalum cultivars that were propagated in the AREC greenhouse.

II. H_0: None of the tested seashore paspalum cultivars will survive low temperatures below -7 C (20 F).

H_a: Some of the tested seashore paspalum cultivars will survive low temperatures below -7 C (20 F).

III. H_0: There is no difference in establishment rate of seashore paspalum from seed or vegetative parts.

H_a: There is a difference in establishment rate of seashore paspalum from seed or vegetative parts.

IV. H_0: Establishment of seashore paspalum will not be affected by the presence of actively growing broadleaf and grass weeds.

H_a: Establishment of seashore paspalum will be affected by the presence of actively growing broadleaf and grass weeds.

V. H_0: The disease dollar spot will not affect the growth of any of the seashore paspalum cultivars during establishment and grow in of this study.

H_a: The disease dollar spot will affect the growth of some of the seashore paspalum cultivars during the establishment and grow in of this study.

Literature Review

Native to Africa and Latin America, seashore paspalum is found throughout the tropics. With its saline water tolerance as a central focus, funding was obtained from the United States Golf Association (USGA) for research and development at the University of Georgia (UGA) beginning in 1993 (Duncan 2000). It was at UGA's Griffin Experiment Station that most commercially available cultivars of seashore paspalum were developed by Dr. Ronny R. Duncan and Dr. Paul D. Raymer of the University's Crop and Soil Science Department and their research is a large part of most existing literature on seashore paspalum.

Initial emphasis for breeding was focused on golf course use and the appropriateness of the turf for specific parts of the course – the tee, the fairway, the green or the rough. The first three commercially available cultivars, 'Sea Isle 1', 'Sea Isle 2000' and 'Sea Isle Supreme' were classified by those uses (Raymer et al. 2007). Sea Isle 1 and Sea Isle 2000, both released in 2000, were deemed appropriate for use on golf courses from tee to green with Sea Isle 1 also considered useful as a sports turf. Sea Isle Supreme, released in 2005, is a semi-dwarf cultivar with a vigorous spreading growth habit ideal for quicker establishment. Since Sea Isle Supreme tolerates a variety of mowing heights, it is ideal for all parts of a golf course and was also determined to be even more salt tolerant than the initial two cultivars. Sea Isle Supreme was also considered useful as a sport turf. A true dwarf cultivar of seashore paspalum, 'Seadwarf', was subsequently introduced by UGA. It tolerates the widest range of mowing heights (0.25 to 10 cm) but due to its dwarf nature rarely grows taller than 5 cm. Seadwarf was considered an excellent surface for putting greens and fairways. All four are fine-bladed cultivars propagated from rhizomes and stolons.

Another USGA grant was awarded to the University of Florida researchers who evaluated color, quality and density of several seashore paspalum cultivars at both putting greens-height and fairway-height, as well as compared leaf texture and incidence of dollar spot (*Sclerotinia homoeocarpa* F. T. Bennett*)* (Unruh and Brecke 2004). While some of the cultivars included in the 2004 tests are no longer commercially available, of all cultivars evaluated Seadwarf exhibited the best color, quality and density at greens-height and the lowest incidence of dollar spot in the Florida trial. There were no significant differences in color, quality and density among the seashore paspalum selections at fairway-height.

Additional work at the University of Florida evaluated the use of potable water for irrigation of seashore paspalum under putting green and fairway conditions (Unruh, Brecke, & Partridge, 2007). The best performing cultivars at greens-height were Seadwarf and Sea Isle 2000, and the best performing cultivars at fairway-height were 'Seaway' and 'Aloha'. Additional tests were for dollar spot and thatch depth. Sea Isle Supreme showed the highest incidence of dollar spot on greens-height turf (51.1% of the plot area infected) whereas Seadwarf showed the lowest incidence (7.8% of the plot area infected). Aloha developed the least thatch of cultivars evaluated in the fairway trial, while there were no differences in thatch depth between cultivars maintained at greens-height. Thatch can be controlled by reducing nitrogen fertilization (Unruh et al. 2007).

Dr. Micah Woods has researched seashore paspalum extensively in Asia and the Far East (Woods 2013). He recommended seashore paspalum for golf courses due to its beautiful appearance and its ability to be mowed at many heights allowing it to be used on the entire course. In the Far East, seashore paspalum grows wild in saturated conditions at waters' edge.

Seashore paspalum does not tolerate drought conditions as well as bermudagrass (Woods 2013). The primary disease has been from dollar spot, usually in slow growth/cool temperature conditions. This problem can be alleviated by application of nitrogen fertilizer to encourage turf growth. Weed competition in the region that Dr. Woods has studied has been primarily from bermudagrass. Since bermudagrass outcompeted seashore paspalum in a golf course in Thailand, and since eradication is costly and not 100% effective, it is important to treat as soon as it is identified. Granular sodium chloride and irrigation were his recommended treatments. Dr. Woods concluded that in soil with more water, more salt and less air seashore paspalum will outperform other warm season turfgrasses.

Researchers at the University of Hawaii at Mãnoa compared multiple cultivars of seashore paspalum with bermudagrass (Brosnan and Deputy 2008). Seashore paspalum produced a higher quality, darker green turf that tolerated reduced light conditions (but not tree shade), a wider range of soil pH, and required fewer applications of nitrogen fertilization

Aloha was a top performing cultivar when maintained at fairway-height while Sea Isle 2000 performed best at greens-height, demonstrating limited dollar spot susceptibility (Brosnan and Deputy 2008). The seeded cultivar Sea Spray, while slow to establish, was appropriate for use on golf course tees, greens, fairways and roughs. Sea Spray also had good applicability for athletic fields and landscapes. Seadwarf was also appropriate for use in golf courses, athletic fields and landscapes, and demonstrated less susceptibility to dollar spot than any other cultivar. Of the cultivars tested, Sea Isle 1 had the highest drought tolerance but was more prone to dollar spot than the other cultivars tested in Hawaii.

All seashore paspalum cultivars included in the Hawaii trial (Aloha, 'Salam', Seadwarf, Sea Isle 1, Sea Isle 2000, Sea Spray, 'Neptune', Sea Isle Supreme, Seaway and 'Seagreen') were irrigated with ocean water once established (Brosnan and Deputy 2008). While this was acceptable as long as the soil was amended with sulfur plus lime or gypsum to keep salts from accumulating, the turf quality was not as high as when irrigated with potable water. However, the salinity helped to control weeds. Many weeds have a low tolerance for salt and irrigation with saline water controlled the weeds without harming the turf. This was particularly important as weeds were a problem in Hawaii and seashore paspalum is sensitive to many herbicides.

An additional trial from Hawaii evaluated the traffic tolerance of Sea Isle 1, Seadwarf, Sea Isle 2000 and Salam seashore paspalum as compared to 'Tifway' bermudagrass (Brosnan and Deputy 2009). Traffic was simulated with a Cady Traffic Simulator (CTS) performing a total of 90 passes over a four week period of time on half the plots, while the other half were used as a control group with no traffic. Percentage turfgrass cover was evaluated periodically during and after completion of the test. Sea Isle 1 had 90.8% cover and Seadwarf had 80.8% cover at the completion of the 90 pass test while the bermudagrass had only 29.6%. Sea Isle 2000 responded poorly to the traffic passes with a cover at completion of only 13.1%.

In 2010, a National Turfgrass Evaluation Program report on cold tolerance of seashore paspalum was submitted from a testing location in Fayetteville AR (Richardson et al. 2011). While there was little winter kill in 2008 and 2009, the seashore paspalum plots exhibited up to 98% winterkill in the spring of 2010, with less than 10% survival of Sea Spray and less than 5% survival of Sea Isle 1. The researchers concluded that seashore paspalum was not well-adapted to northern Arkansas and that none of the cultivars tested have enough cold tolerance to consistently survive winters there.

Georgia researchers tested the potential for cold acclimation to influence the survivability of the turf to freezing temperatures (Cardona et al. 1997). Three seashore paspalum cultivars ('Adalayd', 'PI

299042' and 'HI-1') were used for the test with 'Midiron' bermudagrass for comparison. Bermudagrass was more cold hardy than all three seashore paspalum cultivars, with a 58% spring recovery compared to 32% for seashore paspalum when using an electrolyte leakage testing method. Both turfgrass species recovered better when cold acclimated.

Seashore paspalum has demonstrated sensitivity to multiple herbicides and many products available for use on bermudagrass are not labeled for seashore paspalum (Johnson and Duncan 1998a; Patton, Trappe, Richardson, and Nelson 2009). In a 1996 to 1997 study in Georgia seven commercially available herbicides were tested on eight seashore paspalum cultivars following sprigging (Johnson and Duncan 1998A). The herbicides were selected based on specific weeds controlled and were applied at two different rates (label recommended and 3x label recommended levels) and were applied on the day of planting. Turf growth and percent of injury were evaluated at 2, 4 and 6 week intervals after application for both years. The herbicides halosulfuron and oxadiazon applied at time of planting did not injure the seashore paspalum cultivars regardless of rate applied. Dicamba was safely applied at the recommended rate but slight (≤ 11%) injury occurred at the 3x rate. Quinclorac, dithiopyr and pendimethalin were safely applied in 1996 but caused unacceptable injury (≥ 16%) in 1997. This led to the conclusion that selected herbicides can be safely applied to newly-sprigged seashore paspalum without reducing turf growth.

Care must also be taken when applying herbicides for the postemergence control of crabgrass (*Digitaria* spp.), goosegrass (*Eleusine indica* L.), nutsedge (*Cyperus* spp.) and broadleaf weeds. While most of the herbicides tested in this trial did not result in significant seashore paspalum injury, diclofop use resulted in an unacceptable 42% injury at the lower rate and up to 62% injury at the 3x rate (Johnson and Duncan 1998A). All other herbicides tested produced less injury in 1996 when the mean high air temperature was 30 C (85 F) for 4 weeks after planting compared to 24 C (76 F) in 1997.

A study conducted in 2007 and 2008 in Arkansas evaluated herbicide tolerance on Sea Spray seedlings (Patton et al. 2009). Twenty-one herbicides and salt water were applied to the seedlings two weeks after emergence. Not all of these were labeled for use in established seashore paspalum and only one, quinclorac, was labeled for use on seashore paspalum seedlings. The herbicides halosulfuron, clopyralid, carfentrazone, metsulfuron and quinclorac, as well as salt water, did not cause significant injury (11 to 30%). The other herbicides studied (including pendimethalin, pronamide, oxadiazon, prodiamine, sulfentrazone, sulfosulfuron, fluroxypyr, dithiopyr, imazaquin, MSMA, ethofumesate, siduron, triclopyr, and fluazifop) caused unacceptable levels of injury and reduced turf coverage. It should be noted that the combination products tested, 2,4-D plus MCPP plus dicamba plus carfentrazone and 2,4-D plus MCPP plus dicamba, caused more injury on seashore paspalum seedlings than is expected for established turf. Herbicides such as fluazifop, triclopyr, siduron and ethofumesate, used to control bermudagrass growing as a weed in seashore paspalum, all caused severe injury to the seashore paspalum seedlings.

Studies conducted in 2009 and 2011 in Georgia investigated seashore paspalum tolerance to pronamide for postemergence control of annual bluegrass on Sea Isle 1 (McCullough, Yu, and Barreda, 2012). This research concluded that pronamide was both safe and effective for use on seashore paspalum at all growth stages.

Due to seashore paspalum's salt tolerance, sodium chloride has been studied for weed control. In Hawaii during 2007 and 2008 sodium chloride was evaluated for post-emergence control of goosegrass in the Salam cultivar with limited effectiveness (≤ 58%) (Brosnan et al. 2009). In that study, the herbicides MSMA, MSMA plus metribuzin, and foramsulfuron did not control goosegrass without unacceptable injury to the seashore paspalum turf. A study conducted in Georgia in 2009 and 2010 concluded that there was potential for using sodium chloride for control of smooth crabgrass in Sea Isle 1 seashore paspalum (McCullough and Raymer 2011).

Studies conducted in Arkansas and Louisiana concluded that newly-sprigged Aloha seashore paspalum had some tolerance of sulfonylurea herbicides (Patton et al. 2010). Two of the herbicides tested (trifloxysulfuron and foramsulfuron) reduced establishment and caused unacceptable injury to the Aloha turf (≥ 23%); however, injury from metsulfuron and sulfosulfuron was considered acceptable (≤ 4%). There was no injury to seashore paspalum from halosulfuron.

Because of seashore paspalum's intolerance of herbicides, Korean researchers, in conjunction with Dr. Raymer, examined the potential for breeding a herbicide-resistant cultivar of seashore paspalum (Kim et al. 2009). Their research utilized seeded seashore paspalum and the herbicide glufosinate and concluded that a *bar* gene with resistance to glufosinate could be isolated in some seashore paspalum plants. This demonstrated a possible use for biotechnology in future seashore paspalum breeding.

An issue with warm season turfgrasses is their period of winter dormancy. A 1 ½ year study was conducted in Italy examining nitrogen fertilization schedules and the effect on fall color retention and spring green-up of seashore paspalum and bermudagrass (Rim et al.2013). The results indicated that shifting of the nitrogen application did not result in any loss of cold hardiness and that the result of dividing the nitrogen applications into five treatments instead of three resulted in a few days earlier spring green-up for both the bermudagrass cultivars tested and Sea Spray seashore paspalum.

Materials and Methods

Greenhouse Propagation

Sea Spray seashore paspalum seed was received from Hancock Seed Company (Dade City, FL) on March 1, 2013. The seed was stored under refrigeration until propagation began on March 6th at which time the seed was planted in two 21.7 cm by 30.5 cm by 6.4 cm flats filled with commercial potting media and placed in the Hampton Roads AREC greenhouse. Seeding was at the rate of 0.33 g/661.8 cm^2

and each flat was fertilized with 6 g of Osmocote 14-14-14 slow release granular fertilizer. The temperature in the greenhouse at the time of planting was 13 C (56 F) and both flats were placed on a heating pad. One flat was covered with clear plastic for comparison to potentially aid germination. Germination did not begin until March 28th, 3 weeks after planting. The greenhouse temperature had been over 21 C (70 F) for most of that time. There was still little germination in the plastic covered flat so the covering was removed on March 28, 2013.

Two other seeded cultivars were received the following week, neither of which was commercially available. Hybrid #2 was received directly from the University of Georgia and the cultivar 952 was supplied by Landmark Turf (Spokane, WA). One flat of each was planted in the HR AREC greenhouse at the rate of 0.33 g/661.8 cm^2 and fertilized with 6 g of Osmocote 14-14-14 granular slow release fertilizer. The temperature in the greenhouse on the day of planting was 24 C (76 F). Germination of both cultivars began within 2 weeks.

Four cultivars of vegetative material were received from the University of Georgia at the same time. These were Sea Isle 1, Sea Isle 2000, Sea Isle Supreme and Sea Star. The planting material was divided and Sea Isle 1 and Sea Star were planted in 4 flats each while Sea Isle 2000 and Sea Isle Supreme were placed in 5 flats each. All were fertilized with 6 g of Osmocote 14-14-14 slow release granulated fertilizer. This planting also was done on March 14, 2013. The Sea Isle 2000 began to show new growth after 1 week. All four cultivars had new growth by March 28th with the Sea Isle Supreme almost filling its flats.

Yukon bermudagrass was used for comparative purposes. Four flats were planted in the greenhouse in early April with the same seeding and fertilization rates as had been used for the seashore paspalum cultivars. Two vegetative cultivars, Seadwarf and Aloha, had still not been received.

All greenhouse flats were regularly irrigated and the shoots hand trimmed as they grew. Osmocote fertilization as previously described was applied on a monthly basis. When stolons exceeded the capacity of the flat, they were cut and used to propagate additional flats. By late May there were 8 flats of Sea Isle Supreme, 7 of Sea Isle 2000 and 6 each of the other vegetative cultivars.

On May 12th two large flats of Seadwarf were received from American Sod Farms (Escondido, CA). They were placed in the greenhouse and fertilized with Osmocote. Aloha was not received until after the field trial had begun.

All greenhouse propagation had been done to develop material to plant in the field. Both the seeded and vegetative trials would be replicated four times requiring that additional planting material be propagated.

Field Trials

During May 2013, the field area that would be used for planting was sprayed with glyphosate and then tilled. Two plot plans were generated: one for a seeded trial and one for a vegetative trial. Plots were 1.2 m by 1.2 m each with a 15.2 cm buffer between them. A randomized complete block design with 4 replications was used for both trials.

Planting was done on May 29, 2013.

For the vegetative trial, one flat measuring 661.8 cm^2 was used for each plot. The flat was cut into 12 plugs for planting in a 4 by 3 grid. The flats that had been started from seed had not grown enough to fill four plots each. For Sea Spray, two plots were completely filled, one was planted with 8 plugs and one was left empty. For Hybrid #2, one plot was completely filled, one was planted with 8 plugs and two were left empty. For 952, one plot was completely filled, one was planted with 8 plugs and two were left empty. As Aloha had not been received yet, all four plots designated for Aloha were left empty.

After planting, 454 g of nitrogen/93 m^2 was applied from 14-20-14 starter fertilizer with 30% polymer-coated urea to all plots and granular oxadiazon was applied at a rate of 2.24 kg ai/ha on the vegetative trial section for preemergence weed control. Overhead irrigation was initiated and applied as needed during the growing season. Fertilization was repeated at the rate of 454 g of nitrogen/93 m^2 on June 29th, August 15th, and September 17th using 32-0-8 fertilizer with 27% polymer-coated urea.

Aloha sod was received on June 7, 2013 from Pike Creek Turf Farm (Adel, GA) and the Aloha plots were planted on June 9th. As only 0.2 m^2 of turf was received, the plantings were limited to eight plugs per plot.

For the seeded trial, all seed was spread by hand. As Sea Spray and Yukon were both coated seed, they were planted at a rate of 907 g/93 m^2. Hybrid #2 and 952 were not coated and were planted at a rate of 454 g/93 m^2 to give an equivalent seed count. The ground for the seeded seashore paspalum trial had been prepared the same way as for the vegetative trial and was also planted on May 29, 2013. However the plots in the seeded trial received no herbicide application.

As weed growth began almost immediately, all plots in both trials were sprayed with quinclorac at the labeled rate of 0.84 kg ai/ha plus sulfentrazone at a rate of 0.28 kg ai/ha on June 26th. Spraying of sulfentrazone at a rate of 0.28 kg ai/ha was repeated on July 2nd.

By early July, enough growth occurred of the two cultivars that had been propagated from seed in the greenhouse to plug into the empty plots. On July 9th, two plots were hand weeded and then planted with Hybrid #2. The remaining two empty plots were sprayed for weeds with glyphosate on July 17th and the last flat of Sea Spray and 952 were planted on July 30th.

Turf coverage was evaluated visually on July 18, 2013 and continued every 7 to 14 days until November. For the initial observations, percentage cover of turf, weeds and bare ground were recorded. At later ratings, only visually estimated turf cover was recorded. Additionally, a color evaluation was made on November 14, 2013 using the NTEP 1-9 rating scale, where 1 = completely brown turf, 5 = minimally acceptable, and 9 = dark green. All observations were discontinued mid-November with complete dormancy observed on November 30, 2013.

Shade Trial

In late July, seven plots in the shade area at the Hampton Roads AREC were sprayed with glyphosate and made available for a seashore paspalum trial. Four were in semi-shade and one plot each was planted with Seadwarf, Sea Isle 1, Sea Isle Supreme and Sea Star. Three were in full shade and one plot each was planted with Seadwarf, Sea Isle Supreme and Aloha. These plantings were done between July 30 and August 2, 2013. They were hand fertilized with Osmocote at the time of planting and were hand irrigated. Beginning one month after planting, these plots were observed at two week intervals to determine if seashore paspalum would establish in shade. Observations were discontinued in November as dormancy ensued.

Spring Green-up

At the beginning of March 2014 in anticipation of spring green-up, granular oxadiazon was applied at the rate of 3.36 kg ai/ha to both the seeded and vegetative seashore paspalum trials for preemergence control of grass weeds. On March 29th, dicamba, mecoprop-p, 2,4-D and carfentrazone-ethyl were applied at the rate of 1.4 L product/3.54 ha to the same trials for control of broadleaf weeds. Spray volume was delivered at a rate of 930 L/ha.

On April 4, 2014, the seashore paspalum vegetative trial plots began emerging from dormancy. Observations were begun on April 14, 2014 and recorded 3 times during the month of April and again on June 3 and June 19, 2014. Both the seeded and shade trials were also visually observed by this researcher. As no spring recovery was observed in the shade trial, no observations were recorded.

Results and Discussion

Greenhouse Propagation

All three seeded cultivars germinated slowly, with no signs of growth until the greenhouse temperatures had exceeded 21 C (70 F) for three weeks (data not shown). When additional seeded flats were planted after the field trial had begun, it took Hybrid #2 and 952 more than a month to cover 80% of the 21.6 cm by 30.5 cm flats even though it was quite warm in the greenhouse by then. Sea Spray took even longer, requiring an additional week of development before there was enough to transplant into a field plot.

Growth habit for Hybrid #2 and 952 differed from Sea Spray and the vegetative cultivars. Not only was there vertical growth from the shoots, but the stolons grew vertically as well. This made it difficult to trim the vertical growth to promote lateral spread and it caused the lateral spread to progress slower.

The growth pattern for Seadwarf was slightly different in that the shoots never grew very tall. As Seadwarf was the only dwarf cultivar in the trial, and the only dwarf cultivar of seashore paspalum, that wasn't surprising. Seed heads formed when the shoots were less than 5 cm and were snipped off.

Other than trimming excess vertical growth, the flats were almost maintenance free. A few weeds appeared and were immediately removed. There was no indication of the complications that would develop in the field.

Field Vegetative Trial Establishment

As the planting area had been sprayed with glyphosate and tilled, the ground was free of visible weeds at planting. At establishment, daily highs were approximately 29.4 C (85 F) and it seemed to be an excellent time for the seashore paspalum cultivars that had developed so well in the greenhouse to follow that same pattern in the ground. Unfortunately, those temperatures were also conducive to germination of southern crabgrass (*Digitaria ciliaris* Retz.*)*, goosegrass, dallisgrass (*Paspalum dilatatum* Poir.*)* and summer broadleaf weeds. Oxadiazon had been applied to the vegetative trial at planting time, but as the literature indicated seashore paspalum sensitivity to herbicides (Johnson and Duncan, 1998B; Patton et al. 2009), it was applied at a low rate of 2.24 kg ai/ha. The tilling prior to planting brought many weed seeds to the soil surface, leading to their rapid germination, and seashore paspalum establishment was greatly reduced due to the competition. The rate of establishment in the field was much less than that in the greenhouse, with high variability among plots of the same cultivar. Weed competition was far greater and more detrimental to establishment and overall performance than expected. Disease problems were non-existent at that time.

The data collected on weed coverage in summer proved very significant when evaluating turf cover in November (Table 1). There was a significant negative correlation between initial weed cover ratings in July and turf cover ratings in November for all seashore paspalum cultivars, ranging from -0.58 for Sea Spray to -0.99 for Hybrid #2. In contrast, Yukon bermudagrass had a negative correlation coefficient of only -0.10. It became clear that seashore paspalum does not compete well with grass or broadleaf weeds.

The Hybrid #2 plots that were planted in hand weeded plots the first week in July did not encounter weed competition due to lack of seasonal weed germination at the time of planting. Hybrid #2 established slowly and achieved a mean cover of 45% by mid-September and a 60% cover before dormancy. The Sea Spray and 952 plots which were planted on July 30th did not establish well due to weed competition from smartweed (*Polygonum* spp.) and doveweed *(Murdannia nudiflora* L.). Evaluation of this information resulted in a rejection of Null Hypotheses IV.

Color and Texture

Turf color was much more consistent from plot to plot of a cultivar than percent cover. In the current study, the seashore paspalum had a lighter color than Yukon bermudagrass. This is contrary to that noted in previous studies (Brosnan and Deputy 2008; Woods 2013). Using the NTEP color rating scale previously described, Yukon bermudagrass had a mean of 8.1, while Sea Isle 2000 achieved the highest rating of the seashore paspalum cultivars with a mean of 7.8. Aloha and Sea Star were evaluated as the lightest green with a mean of 6.8 (Table 2). These ratings were similar to an observation recorded in early October (data not shown). At that time I had also noted that Aloha was the lightest of the seashore paspalum cultivars. I found the texture of all the seashore paspalum cultivars to be fine or very fine.

When color was observed during spring green-up, the Yukon bermudagrass was again the darkest (data not shown). Comparative color evaluations of the seashore paspalum cultivars were not made at that time.

Field Seeded Trial

With no preemergence herbicide applied, the seeded seashore paspalum cultivars struggled from the outset. Grass weeds developed immediately and quinclorac could not be applied until three weeks after seeding. By that time the weed competition was so severe that seashore paspalum did not successfully establish. Yukon bermudagrass achieved 14% fill. The highest fill for any of the seashore paspalum cultivars was 2% (Table 3). The seeded seashore paspalum cultivars had not successfully established and at this point Null Hypothesis II was rejected. There was a definite difference in establishment of seashore paspalum from seed versus vegetative propagation.

This is very similar to the percent cover at time of spring green-up. The seeded seashore paspalum cultivars achieved a maximum of 8% fill when observed on June 19, 2014 while Yukon bermudagrass achieved a mean cover of 49% (Table 3). Consistent with information in the literature reviewed (Woods 2013), Yukon had spread to the adjacent seashore paspalum plots.

Shade Trial

One month after planting, all four cultivars planted in semi-shade had grown vertically but Sea Isle Supreme had not produced new lateral growth and weeds were invading these plots 9data not shown). Seadwarf appeared robust in color and had lateral growth of stolons, Sea Star was spreading out in the plot and Sea Isle 1 looked best with the most fill of any shaded variety. The three cultivars planted in deep shade appeared healthy and were growing vertically but not spreading laterally in the plots. Aloha had an unusual growth pattern that looked as if it was growing vertically, like a bunch grass. There weren't thick stolons as had been noted with the seeded cultivars in the greenhouse, but there were branched vertical shoots in Aloha.

There was no irrigation in the shade area and all watering was done by hand. In mid-September after a period of little rain, all plots were very dry. Only the Seadwarf plot in semi-shade appeared to have spread since the previous observation. The last observation of these plots was recorded on October 15, 2013 after a span of rainy days. Again, only the Seadwarf plot in semi-shade appeared to have spread, with an additional 10% cover. The other 3 cultivars in semi-shade were tall since they had not been mowed, but were not spreading laterally. The 3 plots in deep shade were becoming leaf covered. The plants had grown vertically but with no lateral spread. As there was no replication for the shade trial no data is shown in this report.

Dormancy

Air temperature was being tracked using the data from the Norfolk Airport station (Weather Underground 2014). The seashore paspalum plots at HRAREC became dormant on November 29, 2013 after a -2.2 C (28 F) night.

During the winter months of December, January and February, the air temperature was below -1.1 C (30 F) on 35 days and below -6.7 C (20 F) on 9, reaching a low of -14.4 C (6 F) on January 30, 2014. Soil temperatures are tracked on an hourly basis at HRAREC. While they remained between 2 C and 10

C (35 F and 50 F) for most of the winter, the soil temperature at a depth of 5 cm never went below 0.1 C (32.18 F), recorded on February 12 and February 13, 2014. The soil temperature on January 30, 2014, the day with the coldest air temperature, was 0.2 C (32.36 F) at 2:00 PM. On April 4, 2014 when a general observation of seashore paspalum greening-up was first noted, the soil temperature at HRAREC was only 7.2 C (45 F).

The literature reviewed earlier in this paper addressed seashore paspalum turf injury related to air temperature. While low air temperature duration and degree play an important part in warm season turfgrass survival, soil temperature must also be considered. Based on the soil temperature data at HRAREC during the winter of 2013-2014, the ground never froze. While some degree of winter kill may have occurred, the soil temperature remaining warmer than the air temperature undoubtedly contributed to the survival of the seashore paspalum cultivars.

Spring Green-up

Although the polar vortex caused a much colder than normal winter, all cultivars in the seashore paspalum vegetative trial survived the winter. However, as of June 19, 2014 there was tremendous variation in the percent turf cover between cultivars (Figure 1).

The Yukon bermudagrass had filled in the most with a mean percent cover of 85%. Of the seashore paspalum cultivars, Sea Isle Supreme and Sea Star had a mean percent cover of 78% and Sea Isle 1 had a mean percent cover of 68%. While Aloha had the lowest percent turf cover (29%), the three cultivars whose vegetative plantings had been started from seed also had not filled in well with Hybrid #2 at a mean cover of 56%, Sea Spray at 50% and 952 at 49%. When you compared the percent turf cover on June 19th with the amount of weed cover on April 30th there was a definite negative correlation. As the common chickweed (*Stellaria media* L.) died and took up less space in the plot, the seashore paspalum shoots emerged. Dallisgrass and nimblewill (*Muhlenbergia schreberi* J.F. Gmel) also emerged, providing competition for the seashore paspalum cultivars and, once again, seashore paspalum had difficulty competing with weeds.

All of the seashore paspalum cultivars greened-up more slowly than Yukon bermudagrass (Table 2). Yukon had a cover percent of 68 on April 30, 2014, while the highest achieving seashore paspalum cultivars, Sea Isle Supreme and Sea Star had covers of only 13% and 21% respectively on that date. When comparing numbers between percent cover before dormancy and cover after green-up there are also similarities (Table 2). During establishment, the best performing seashore paspalum cultivars were Sea Star with a percent cover on November 1, 2013 of 70% and Sea Isle Supreme with a 68% cover. The mean cover for Yukon bermudagrass was 54%, lower than four of the seashore paspalum cultivars, and below the 65% cover deemed as acceptable for this trial.

A small amount of green-up was noted in the seeded trial on June 19, 2014 (Table 3). Yukon bermudagrass achieved a mean green-up of 49%; however, the three seashore paspalum cultivars had a mean of only 5% turf cover (Table 3) and a high weed presence. There was no green-up in the shade trial areas when observed on April 30, 2014 (data not shown).

With these green-up results we can now reject Null Hypothesis II. Seashore paspalum cultivars survived temperatures below -7 C (20 F). As there was really no disease development during the initial grow in and spring green-up we can accept Null Hypothesis V. Dollar spot had no effect on seashore paspalum during the 14 month study.

Significant Differences

The last analytical data to review is that of the differences in means for the vegetative trial (Table 2). In all cases the Yukon bermudagrass and the seashore paspalum cultivars fell into three groups. While there was a difference in establishment percent, in color, and in percent turf cover at spring green-up, using a P value = 0.05, the differences weren't significant enough to separate into more than three groups. On November 1, 2013 Yukon bermudagrass had f 54% cover while Sea Star had 70% cover, Sea Isle Supreme had 68% cover, Sea Isle 1 had 63% cover and Hybrid #2 had f 60% cover. However, Yukon bermudagrass established quicker, resumed spring growth earlier, and had a darker color throughout the trial period. As discussed earlier, Aloha was always the poorest performer, with results considerably below that of the other seashore paspalum cultivars.

Was there a difference in characteristics between the seashore paspalum cultivars? In quantifiable aspects there was not a significant difference between every cultivar, though there was between some cultivars.   Therefore, we can reject Null Hypothesis I. There is a difference in the characteristics of the seashore paspalum cultivars.

Conclusion

Seashore paspalum could be a viable warm season turfgrass species for southeastern Virginia. While there are many good qualities such as the ability to be irrigated with saline water, the tolerance to low mowing heights, an attractive appearance and texture, and no apparent disease during the first year after planting, it is not a maintenance-free turf. This trial demonstrated that weed competition is a major concern during establishment. As weed presence is also a concern at time of spring green-up, preemergence control is a must.

This was a short, fourteen month trial that only encompassed one growing season. Subsequent data after a second summer of growth for these trials when the weed competition is anticipated and can be handled more appropriately should prove interesting.

Table 1. Correlations between initial visual weed coverage percentages and final seasonal percent turf cover ratings during the establishment of the vegetative seashore paspalum cultivars and Yukon bermudagrass at the Hampton Roads Agriculture Research & Extension Center in 2013.

	Rating Date		
	July-18-2013 Weeds	Nov-1-2013 Turf	Correlation
Cultivar Name			
Sea Isle 2000	45	43	-0.78
Sea Isle Supreme	41	68	-0.68
Sea Isle 1	35	63	-0.86
Sea Spray[a]	63	48	-0.58
Seadwarf	78	33	-0.78
Sea Star	38	70	0.0
952[a]	49	44	-0.59
Hybrid #2[a]	18	60	-0.99
Aloha	80	19	-0.75
Yukon[a]	54	54	-0.10

[a] These cultivars were started from seed in the greenhouse for vegetative planting.

Table 2. Means for visual estimates of establishment turf cover, turfgrass color, and percent spring green-up turf cover for the vegetative seashore paspalum trial at the Hampton Roads Agriculture Research & Extension Center planted on May 29, 2013.

	Rating Date				
	Nov-1-2013	Nov-14-2013	Apr-30-2014	Jun-3-2014	Jun-19-2014
Cultivar Name	% cover	Color[b]	% cover	% cover	% cover
Sea Isle 2000	43	7.8	30	48	63
Sea Isle Supreme	68	6.9	13	58	78
Sea Isle 1	63	7.3	14	60	68
Sea Spray[a]	48	7.0	36	33	50
Seadwarf	33	7.6	34	35	61
Sea Star	70	6.8	21	59	78
952[a]	44	7.4	8	33	49
Hybrid # 2[a]	60	7.0	13	28	56
Aloha	19	6.8	25	21	29
Yukon[a]	54	8.1	68	65	85
LSD (P=0.05)	28	1.1	29	26	27

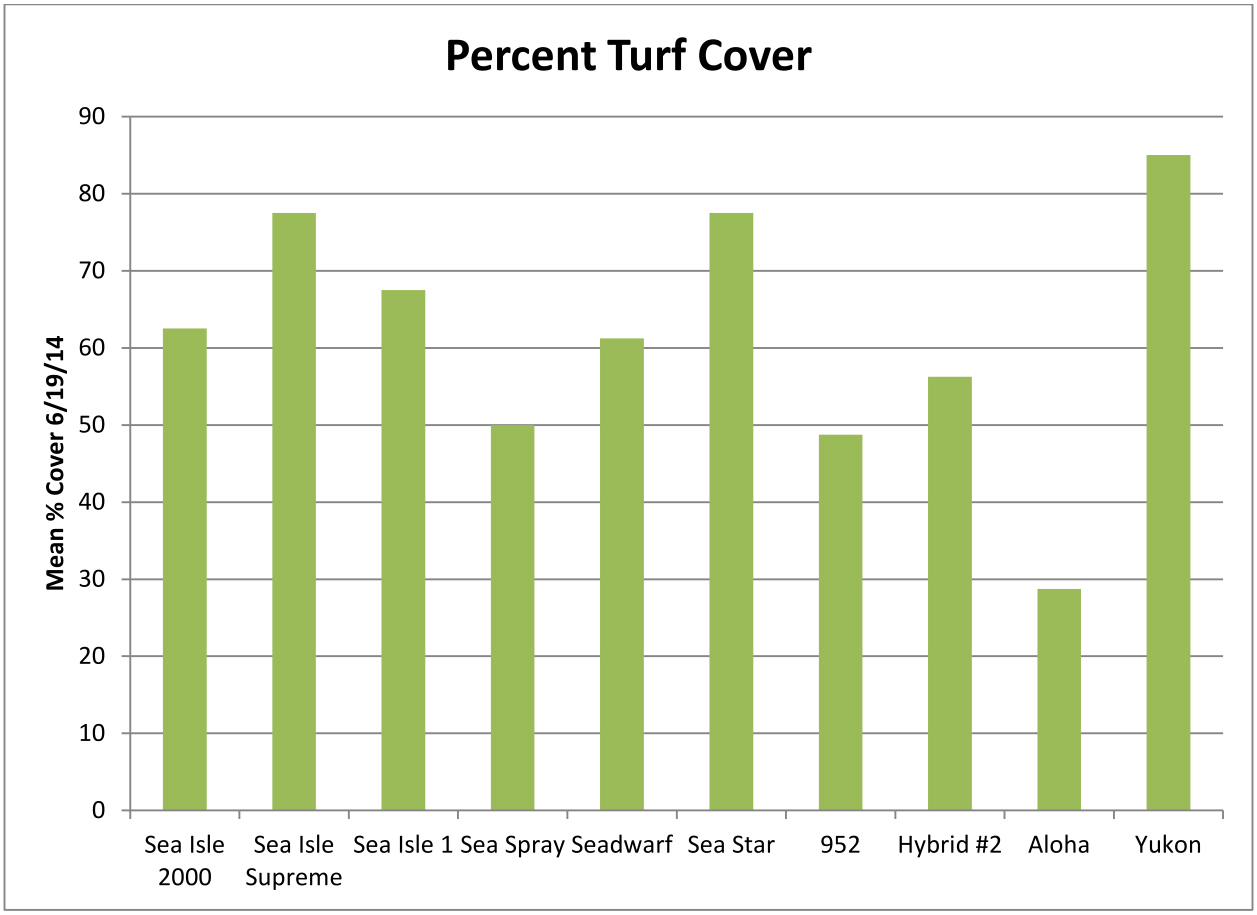
[a] These cultivars were started from seed in the greenhouse for vegetative planting.

[b] Color ratings based on NTEP scale of 1 to 9, with 9 representing ideal, dark green turf and 1 representing tan or brown turf.

Table 3. Means for visual estimates of establishment turf cover and percent spring green-up turf cover for the seeded seashore paspalum trial at the Hampton Roads Agriculture Research & Extension Center planted on May 29, 2013.

	Rating Date	
	Nov-1-2013	Jun-19-2014
Cultivar Name	% cover	% cover
Sea Spray	1	8
952	1	3
Hybrid # 2	2	4
Yukon	14	49
LSD (P=0.05)	14	16

Figure 1. Means for percent turf cover on June 19, 2014 of the vegetative seashore paspalum trial at the Hampton Roads Agriculture Research & Extension Center, approximately one year after planting.



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