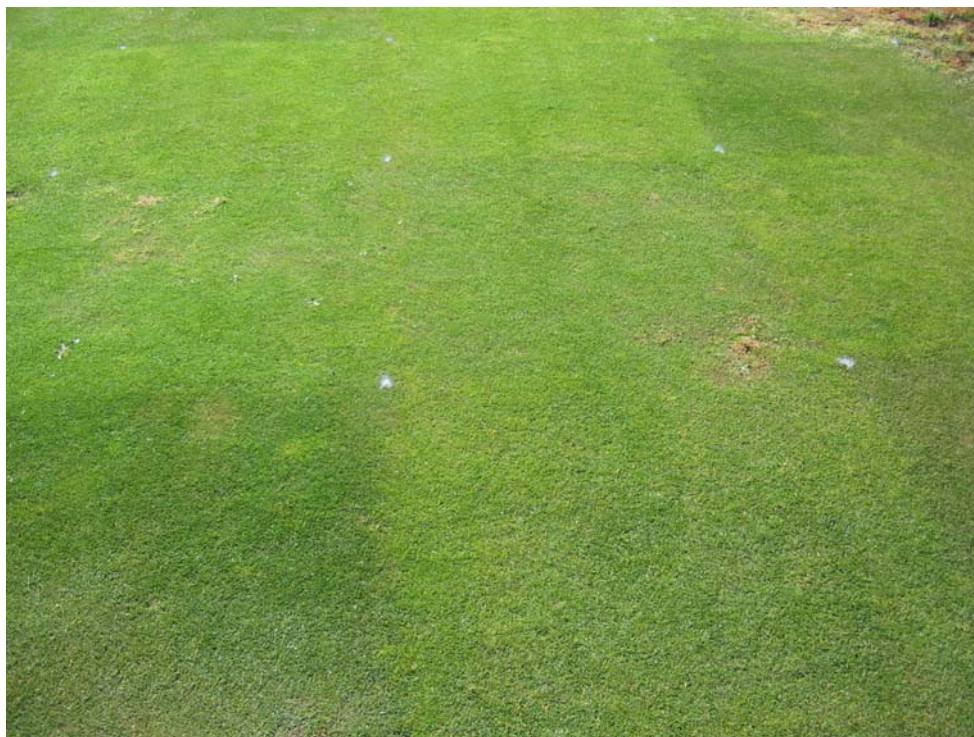


**HAL PROJECT TU06001 (MAY 2009)
EVALUATION OF SELECTED BENTGRASS ECOTYPES FOR SALINITY
TOLERANCE AND SOD PRODUCTION**



Andrew Peart
(Senior Agronomist, AGCSA)

John Neylan
(General Manager, AGCSA)

AUSTRALIAN GOLF COURSE SUPERINTENDENTS ASSOCIATION (AGCSA)



**Australian Golf Course
Superintendents Association**



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**HAL PROJECT TU06001
EVALUATION OF SELECTED BENTGRASS ECOTYPES FOR SALINITY
TOLERANCE AND SOD PRODUCTION
MAY 2009**

PROJECT LEADER

John Neylan
General Manager
Australian Golf Course Superintendents' Association Ltd.
Suite 1
752 Blackburn Road, Clayton VIC 3168
Phone: (03) 9548 8600 Fax: (03) 9548 8622
Email: john@agcsa.com.au

OTHER RESEARCHERS

Mr. Andrew Peart (Senior Agronomist, AGCSA)
Mr. Bruce Macphee (Lecturer, Chisholm TAFE, Rosebud)

PURPOSE OF THE REPORT

The purpose of this report was to explore the potential of the bentgrass (*Agrostis* sp.) ecotypes that were collected under the research program, project TU01001. With over 450 ecotypes collected from around Australia, several were identified as having superior salinity tolerance.

Several of the ecotypes that provided a superior playing surface provided very few seedheads and propagation by seed is not an option. In this project vegetative propagation through sod production techniques were explored as an option compared to traditional seed production methods.

The best performing ecotypes have been subjected to further salinity tolerance testing in both a greenhouse and field situation and their ability to form a playing surface from vegetative means has also been investigated.

ACKNOWLEDGEMENTS

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Mr. Richard Forsyth, former course superintendent at Metropolitan Golf Club for the use of their pedestrian scarifer for the harvesting of sprigs in the recovery of bentgrass trial.

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MEDIA SUMMARY

PROJECT TU06001

EVALUATION OF SELECTED BENTGRASS ECOTYPES FOR SALINITY TOLERANCE AND SOD PRODUCTION

There were over 450 ecotypes of bentgrasses, primarily creeping bentgrass (*Agrostis stolonifera* L.; syn = *Agrostis palustris* Huds.), collected from around Australia in project TU01001 where several had been identified as potentially having superior salinity tolerance. Some of the ecotypes collected come from established saline zones and have been subjected to high salinity conditions for many years.

Varying researchers have observed significant differences for salinity tolerance among creeping bentgrass cultivars grown in solution cultures. These cultivars have included some of the earlier vegetative selections from the 'C-series' bentgrasses in the 1920's through to the modern day seeded varieties.

The 27 Australian ecotypes trialed in this project generally had a better turfgrass quality than the commercially available bentgrass cultivars at the salinity regimes of 4 and 8dS/m, however, Penn G2 and Mariner cultivars were comparable to the better performing Australian ecotypes at the high salinity regimes of 12 and 16 dS/m.

The best performing ecotype in the salt screening trials was ecotype B22 which was a creeping bentgrass collected from Royal Adelaide Golf Club in South Australia. As well as performing very well in the salt screening trial it also had excellent turf quality in the initial planting out of the one hundred best ecotypes at Chisholm TAFE as part of Project TU01001.

Ecotype B22 was included as one of the twenty best ecotypes and then subsequently chosen as one of the 5 ecotypes to be assessed in the turf production trial. The turf production trial assessed the ability of the five ecotypes to produce a complete turfgrass cover using vegetative propagation at two different planting rates ($0.28\text{m}^3/100\text{m}^2$ and $0.42\text{m}^3/100\text{m}^2$). Initially the higher rate had better turf coverage than the lower rate but at three months after planting, or at about 50-60% coverage, there was no significant difference between any of the ecotypes or their planting rate.

After assessing the grasses for a period of five months ecotype B22 exhibited excellent colour and turf density and provided a high quality surface and was the standout ecotype by the end of the trial.

Throughout the trial ecotype B22 has performed very well both in terms of its salinity tolerance, even up to 16dS/m, and its ability to form a turf of excellent quality when grown from vegetative sprigs. Subsequently it has been included in the most recent research project TU08002 to assess its performance against the latest high quality bred seeded creeping bentgrass cultivars.

TECHNICAL SUMMARY

PROJECT TU06001

EVALUATION OF SELECTED BENTGRASS ECOTYPES FOR SALINITY TOLERANCE AND SOD PRODUCTION

Nature of the problem

Bentgrass is the preferred species for golf putting greens on golf courses in New South Wales, Victoria, South Australia and southern Western Australia and with all states facing issues of increasing salinity, new locally adapted ecotypes would improve its long term sustainability. With increasing pressure on the availability of low salinity potable water for turf use there is greater use of reclaimed effluent water, stormwater and bore water, most of which are high in salinity, sodium and chloride. This has led to the need to select for more saline tolerant turf species/cultivars, along with other approaches to become more efficient, effective and strategic with the limited water supplies.

The long term sustainability of the turf industry and in particular golf courses is dependent on being able to utilise these lower quality (i.e. high salinity) water sources with little or no detrimental effects on turf quality.

Research conducted by Lunt et al., (1961), Harivandi et al., (1992) and Marcum (2000) indicate that creeping bentgrass is considered moderately sensitive (3-8 dSm⁻¹) to salinity, with grasses such as the colonial bentgrass (*Agrostis tenuis*) and velvet bentgrass (*Agrostis canina* L.) considered very sensitive to salinity.

To date there has been only limited progress in developing new cultivars with improved salt tolerance from vegetative sources in Australia.

Methodology

Thirty six bentgrass ecotypes were initially tested for salinity tolerance by growing them in a saline solution. Thirty one grasses were selected to undergo further salinity testing by propagating them in a medium sand typical of a greens construction and then when they were mature they were irrigated with foliar applied saline solutions.

The individual ecotypes were established by planting 10mm diameter cores into 100mm square pots filled with a sandy soil type. The pots were irrigated with potable water (non-saline) until they had achieved a complete turf cover across the top of the entire pot.

Pots were then watered using a watering can with a known salinity concentration. They were watered three times per week with an equivalent of 5-10mm of irrigation per application. There were three salinity treatments with the bentgrass ecotypes being replicated four times within each treatment. The initial salinity concentrations were 0, 4 and 8dS/m and these levels were obtained by increasing the salinity by 2dS/m on a weekly basis until the desired salinity was attained. By the conclusion of the trial the salinity concentrations has been increased to 12 and 16dS/m. There was also a subsequent field salinity trial conducted which commenced after establishment data had been collected for the turf production trial.

As well as assessing the Australian collected ecotypes for salinity tolerance the five best performing bentgrass ecotypes selected from the twenty best ecotypes in the putting greens trial as part as project TU01001, were sprigged into a replicated turf production trial. This involved two planting rates; 0.28m³/100m² and 0.42m³/100m² with three replicates.

Lastly, four of these ecotypes were assessed for their ability to recover after harvesting the sprigs with a scarifier, replicating a commercial vegetative operation. This trial was established in the same way as the turf production trial and the scarifying occurred at two rates once a full mature sward had been established.

Research findings and Industry outcomes

The 27 Australian ecotypes tested in the second of the salt screening trials generally had a greater turfgrass quality than the commercially available bentgrass cultivars at the salinity regimes of 4 and 8dS/m. However, Penn G2 and Mariner were comparable to the better performing Australian ecotypes at the 12 and 16dS/m regimes.

The ecotype B22 was the standout variety in the second salt screening trial as well as performing very well in the greens trial at Chisholm TAFE (project TU01001) and for this reason it was included in the turf production trial at Evergreen Turf. As well as B22, ecotype B200 also had very good salinity tolerance at 4 and 8dS/m. The other two ecotypes in the turf production trial, B85 and B161, while they showed excellent turf grass quality attributes in the field their salinity tolerance was less than the other two based on results of the greenhouse trial.

The turf production trial demonstrated that those ecotypes established at the higher planting rate ($0.42\text{m}^3/100\text{m}^2$) initially had better turf coverage than when planted at the lower rate ($0.28\text{m}^3/100\text{m}^2$) and in some cases this was significantly greater. However, at three months after planting, or at about 50-60% coverage, there was no significant difference in the percent cover between any of the ecotypes or their planting rate.

The field salinity trial indicated that there were some significant differences observed between ecotypes with ecotype B22 providing a significantly darker green colour, greater turfgrass density and quality compared to the other four ecotypes.

Recommendations to industry

The project has clearly demonstrated that a quality creeping bentgrass sward can be established from vegetative propagation. It has also shown that many of the Australian ecotypes exhibit a greater tolerance to saline conditions than commercially available seeded bentgrasses.

The recovery after harvesting trial demonstrated that a mature bentgrass sward can quickly recover from a single scarification pass. However during the project it could not be clearly demonstrated that this form of commercial operation would be profitable due to the extended period of time required to initially establish enough clonal material.

New technology and future work

The superior Australian ecotype identified during this project has been the ecotype B22 which exhibited excellent salinity tolerance at all four salt concentrations in the greenhouse study as well as producing a turf of high quality in the field trial. Subsequently, this ecotype has been planted into a new replicated seeded bentgrass trial (Project TU08002) that will assess its attributes as a putting green surface compared to the next generation of commercially available seeded creeping bentgrass varieties. This trial will occur in Victoria, South Australia and New South Wales.

HAL PROJECT TU06001

EVALUATION OF SELECTED BENTGRASS ECOTYPES FOR SALINITY TOLERANCE AND SOD PRODUCTION

May 2009

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HAL PROJECT TU06001

EVALUATION OF SELECTED BENTGRASS ECOTYPES FOR SALINITY TOLERANCE AND SOD PRODUCTION

1. INTRODUCTION

1.1 Salinity Tolerance

Bentgrass is the preferred species for golf putting greens on golf courses in New South Wales, Victoria, South Australia and southern Western Australia and with all states facing issues of increasing salinity, new locally adapted ecotypes would improve the long term sustainability of its use. With increasing pressure on the availability of low salinity potable water for turf use there is greater use of reclaimed effluent water, stormwater and bore water, most of which are high in salinity, sodium and chloride. This has led to the need to select more salinity tolerant turf species/cultivars, along with other approaches to become more efficient, effective and strategic with the limited water supplies.

The long term sustainability of the turf industry and in particular golf courses is dependent on being able to utilise these lower quality water sources with little or no detrimental effects on turf quality.

Research conducted by Lunt et al., (1961), Harivandi et al., (1992) and Marcum (2000) indicates that creeping bentgrass (*A. stolonifera*) is considered moderately sensitive (3-8 dSm⁻¹) to salinity, with *Agrostis* species such as colonial bentgrass (*A. tenuis*) and velvet bentgrass (*A. canina* L.) are considered very sensitive to salinity.

Younger et. al. (1967) observed significant differences for salinity tolerance among creeping bentgrass cultivars grown in solution cultures. These varieties were some of the original vegetative selections from the 'C-series' bentgrasses namely; 'Congressional', 'Cohansey' and 'Old Orchard' compared to the newer seeded cultivar 'Penncross'. In this trial 'Penncross' had the poorest clipping yield compared with the other cultivars trialed.

To date there has been only limited progress in developing new cultivars with improved salt tolerance from vegetative sources in Australia. Marcum (2000) found a considerable range in the salinity tolerance creeping bentgrass cultivars, with cv. 'Mariner', 'Grand Prix', 'Seaside', and 'Seaside II' being salt-tolerant, 'L-93', 'Penn G2', '18th Green', and 'Syn 96-1' being moderately salt tolerant, and 'Avalon', 'Ambrosia', 'R1119', 'Regent', 'Putter', 'Penncross', and 'Penn G6' being salt sensitive.

1.2 Turf Production

Producing turf from vegetative planting has been a common practice for establishing warm season grasses for decades. Vegetative propagation has been seldomly used to establish creeping bentgrass since the mid-1900's due to the availability of improved quality creeping bentgrass seed. However, the high quality of surface provided by several of the Australian ecotypes collected, indicates a high potential for vegetative propagation rather than traditional seed propagation methods.

The term 'vegetative' was invented to distinguish this method of planting from seeding as the stem, which is a vegetative part of the plant, is planted to produce a new plant. Carrier (1924), states that creeping bentgrass has the ability to take root whenever the stems come into contact with moist ground.

The early improved bentgrass cultivars were clonal selections from greens originally established to the south German mixed bentgrass. Reese (2000), states that south German mixed bentgrass consisted of 75-80% colonial bentgrass, 10-20% velvet bentgrass and 1-5% creeping bentgrass. Many hundreds of clones were eventually selected from this grass of which the better performing ones were used for vegetative establishment of bentgrasses and were known as the 'C-series'. These included cultivars such as 'Toronto', 'Cohansey', 'Washington', 'Arlington', 'Congressional' and 'Old Orchard', each of which was well adapted to specific regions of the United States (Warnke, 2003). This was considered a standard method of bentgrass establishment until the 1950's when the first improved seeded cultivars were released.

Although a seeded variety 'Seaside' was available from the 1920's, it was considered to be inferior in turf quality compared to the vegetatively propagated 'C-series' bentgrasses. It was not until Penncross was released by Dr. H.B. Musser in 1955 from Pennsylvania State University that it established a new level of excellence for seeded bentgrasses and ever since then the primary focus for bentgrass establishment has been using seeded cultivars.

Traditional turfgrass breeding is often a compromise between turf quality and density and producing commercial quantities of seed. Consequently, it may mean that some of the plants with the very best turf characteristics are either left out or play a minor role in the final multi-parent clone.

Because several of the bentgrass ecotypes collected as part of Project TU01001 fit into this category of excellent turf characteristics and low seed head production it has been decided to undertake trials to examine the feasibility of vegetative propagation as a means of utilising these grasses.

Trials have been previously undertaken to build up the amount of plant material for further trials in harvesting and large scale propagation.

The objectives of this research are as follows;

- To evaluate the turfgrass quality of the Australian collected ecotypes compared with the known salt tolerant commercially available bentgrass cultivars at differing salinity regimes.
- To assess the ability of the Australian ecotypes to form a high quality turf from vegetative propagation techniques.
- To assess the ability of the Australian ecotypes to recover after stolon harvesting in a commercial operation.

2. METHODOLOGY

2.1 Salinity tolerance

2.1.1 Salinity screening trial 1

The objective of this study was to compare plant growth and turfgrass quality of a number of vegetatively grown sources of creeping bentgrass across a range of salinity levels that were collected as part of project TU01001.

Thirty-two creeping bentgrass (*Agrostis palustris* Huds), ecotypes from saline and non-saline sites in Victoria and South Australia and four commercially available seeded cultivars were vegetatively propagated, into RLC-4 Pine cells the base of which was fitted with cotton wool and filled with coarse (inert, neutral pH) sand. Pots were placed in RL-200 racks which were suspended into tubs containing constantly aerated Hoagland's no 1 solution. Tube bottoms allowed the roots to grow into the solutions. Plants were grown in 25°C day/18°C night greenhouse, with light levels supplemented for 2h during early morning and late afternoon with high-pressure sodium lamps. To ensure complete establishment, plants were grown for 2 months prior to initiation of salinity treatments.

Experimental design was a randomized complete block with four replications, each solution tub containing all 36 vegetative selections. Salinity levels were increased daily by 1 dS/m in treatment tubs (control tubs received no salt) using a salt mix of 75% NaCl: 25% CaCl₂ (w/w), until the required concentration was reached; at this point data collection began. Grasses were held at 4, 8, 12 and 16 dS/m for 10 weeks to determine tolerance to chronic salinity stress. Solutions were monitored daily for salinity levels, adjusted every 10-days to ensure minimal changes in nutrient ion concentrations. Throughout the experiment, grasses were clipped twice a week at 5-mm height.

At each harvest the relative dry weight of leaf clippings (RLW) and plant quality were recorded. At the termination of the study shoot and root rates were harvested, washed and dried at 80°C in an oven for 24 hours. Visual quality of turfgrass quality, assessing colour, shoot density, and uniformity were determined prior to each harvest. Turfgrass quality was rated on a 1-9 scale with 9=best turfgrass quality. Unacceptable turfgrass quality was deemed at being less than 7.0 on the scale.

Table 1 lists the 36 ecotypes/cultivars that were screened for their salinity tolerance.

2.1.2 Salinity screening trial 2

This trial was established in a greenhouse at Chisholm TAFE, Rosebud Campus in Victoria. There were 31 ecotypes/cultivars assessed with 27 being Australian bentgrass ecotypes, three were commercially available bentgrass cultivars ('Mariner', 'Seaside II' and 'Penn G2') as well as one variety that is a blend of *Poa annua* var. *reptans* selections from Penn State University. The cultivars 'Mariner' and 'Seaside II' were included as salt tolerant selections. The last four cultivars were all included in a trial conducted at Barwon Heads Golf Club in 2003-2004 which compared the effects of potable water versus saline effluent used for irrigating bentgrass and *Poa annua* (TU01003).

The various ecotypes/cultivars were established by planting 10mm diameter cores into 100mm square pots filled with a sandy soil type. The pots were irrigated with potable water until they had achieved a complete turf cover across the top of the entire pot. The grasses were established over a six month period before the salinity treatments were first imposed.

Table 1: Bentgrass ecotypes and cultivars screened for their salinity tolerance in the salinity tolerance trial 1.

No.	Origin	No.	Origin
	Penn A1 – commercial cultivar	B167	4 th green, Flinders Golf Club, Vic
	Penn A4 – commercial cultivar	B203	Avondale Golf Club, NSW
	Penn G2 – commercial cultivar	B467	Gawler Golf Club, SA
	Penncross – commercial cultivar	B468	Gawler Golf Club, SA
B2	12 th green, Thurgoona Golf Club, NSW	B469	Gawler Golf Club, SA
B10	4 th green, Royal Adelaide Golf Club, SA	B471	Gawler Golf Club, SA
B18	8 th green, Royal Adelaide Golf Club, SA	B472	Gawler Golf Club, SA
B22	11 th green, Royal Adelaide Golf Club, SA	B473	Gawler Golf Club, SA
B24	11 th green, Royal Adelaide Golf Club, SA	B474	Gawler Golf Club, SA
B34	1 st green, Riverside Golf Club, SA	B475	Gawler Golf Club, SA
B39	5 th E green, The Grange Golf Club, SA	B476	Gawler Golf Club, SA
B41	6 th E green, The Grange Golf Club, SA	B477	Gawler Golf Club, SA
B67	Lawn, Frankston, Vic	B478	Gawler Golf Club, SA
B133	1 st green, Corowa Golf Club, NSW	B479	Gawler Golf Club, SA
B145	Prac. fwy, Waverley Private Golf Club, Vic	B480	Gawler Golf Club, SA
B148	Prac. fwy, Waverley Private Golf Club, Vic	B481	Gawler Golf Club, SA
B155	Prac. fwy, Waverley Private Golf Club, Vic	B483	Gawler Golf Club, SA
B159	4 th green, Flinders Golf Club, Vic	B483A	Gawler Golf Club, SA

The grasses were watered using a watering can with a known salinity concentration. They were watered three times per week with an equivalent of 5-10mm of irrigation per application. There were three salinity treatments, with the bentgrass ecotypes being replicated four times within each treatment. The salinity treatments were 0, 4 and 8dS/m and these levels were obtained by increasing the salinity by 2dS/m weekly until the required salinity was achieved.

The first salinity ratings were not taken until the highest concentration was reached.

After 13 weeks of assessment it was decided to increase the salinity regime to 8 and 12dS/m so the pots that had been watered with the 4dS/m salinity were increased to 12dS/m while those at 8dS/m remained. For the final six weeks of the trial those pots being watered with 8dS/m were then watered with 16dS/m.

Sea water was used as the bare source of saline water and diluted to achieve the specific salinity. The analysis of the seawater is as follows;

Table 2: Typical analysis of seawater

Parameter Tested	Level
Electrical conductivity (dS/m)	54
Salinity (ppm)	34,442
Sodium (ppm)	10,556
Chloride (ppm)	18,980
Calcium (ppm)	400
Magnesium (ppm)	1272
Potassium (ppm)	380

The total exposure of the ecotypes to the salinity regimes over the 35 week duration of the trial can be summarised as follows;

- 0 dS/m for 35 weeks
- 4dS/m for 13 weeks
- 8 dS/m for 29 weeks
- 12 dS/m for 22 weeks
- 16 dS/m for 6 weeks

Assessments for visual turf quality were undertaken generally 2 - 3 times per week.

Table 3 details the origins of the bentgrass ecotypes used in this salinity screening trial.

Table 3: Bentgrass ecotypes and cultivars screened in the salinity tolerance trial 2.

No.	Origin	No.	Origin
	Mariner – commercial cultivar	B89	5 th green W, Cool-Tweed GC, NSW
	Penn G2 – commercial cultivar	B100	4 th green W, Cool-Tweed GC, NSW
	Seaside II – commercial cultivar	B106	1 st green W, Cool-Tweed GC, NSW
	PSU Poa – Penn State University selection	B111	1 st green W, Cool-Tweed GC, NSW
B10	4 th green, Royal Adelaide Golf Club, SA	B122	13 th green Werribee Park GC, Vic
B20	10 th green, Royal Adelaide Golf Club, SA	B123	13 th green Werribee Park GC, Vic
B22	11 th green, Royal Adelaide Golf Club, SA	B158	Flinders Golf Club, Vic
B26	11 th green, Royal Adelaide Golf Club, SA	B161	4 th green, Flinders Golf Club, Vic
B34	1 st green, Riverside Golf Club, SA	B200	Avondale Golf Club, NSW
B36	17 th green, Riverside Golf Club, SA	B467	Gawler Golf Club, SA
B41	6 th E green, The Grange Golf Club, SA	B470	Gawler Golf Club, SA
B50	9 th green, Cheltenham Golf Club, Vic	B472	Gawler Golf Club, SA
B51	9 th green, Cheltenham Golf Club, Vic	B473	Gawler Golf Club, SA
B54	5 th green Lakes, Joondoolup Golf Club, WA	B479	Gawler Golf Club, SA
B76	8 th green, Corowa Golf Club, NSW	B480	Gawler Golf Club, SA
B85	4 th green, Royal Aust. Engineers GC, NSW		

2.2 Turf Production

2.2.1 Selection of bentgrass ecotypes for turf production trials.

Twenty of the best performing bentgrass selections that were planted in a greens nursery at Chisholm TAFE, Rosebud in May 2003 were transplanted into plots measuring 2m x 1m at Evergreen Turf, Pakenham in October 2005.

As well as these 20 individual selections, five blends were also created from a mix of three selections from these 20 individuals. Each blend contained a range of different textured selections i.e.: dense type, aggressive space filler and an intermediate type.

The combinations are to provide genetic diversity, which is typically found in multi-parent clones. The combinations are based on the observations of Daryl Sellar where in his studies he noted that there were three broad categories of bentgrasses; a very fine dense type with minimal lateral extension, a coarser textured type that exhibit vigorous lateral extension and an intermediate type. The three types play various roles in a mixed sward that responds to changing conditions throughout the year but in combination provides a consistent playing surface.

Table 4 details the origins of the bentgrasses used.

Table 4: Origins of the bentgrasses used for the selection of the bentgrass ecotypes for turf production trial.

No.	Origin	No.	Origin
B22	11 th green, Royal Adelaide Golf Club, SA	B158	Flinders Golf Club, Vic
B54	5 th green Lakes, Joondoolup Golf Club, WA	B200	Avondale Golf Club, NSW
B161	4 th green, Flinders Golf Club, Vic	B36	17 th green, Riverside Golf Club, SA
B20	10 th green, Royal Adelaide Golf Club, SA	B89	5 th green W, Cool-Tweed GC, NSW
B122	13 th green Werribee Park GC, Vic	B111	1 st green W, Cool-Tweed GC, NSW
B26	11 th green, Royal Adelaide Golf Club, SA	B85	4 th grn, Royal Aust. Engin.GC, NSW
B50	9 th green, Cheltenham Golf Club, Vic	B123	13 th green Werribee Park GC, Vic
B51	9 th green, Cheltenham Golf Club, Vic	M1	Blend B20, B50 & B200
B106	1 st green W, Cool-Tweed GC, NSW	M2	Blend B22, B100 & B10
B34	1 st green, Riverside Golf Club, SA	M3	Blend B54, B36 & B111
B100	4 th green W, Cool-Tweed GC, NSW	M4	Blend B26, B36 & B85
B76	8 th green, Corowa Golf Club, NSW	M5	Blend B51, B34 & B76
B10	4 th green, Royal Adelaide Golf Club, SA		

The selections, once established, were assessed on a fortnightly basis for turfgrass quality using a 0 – 9 scale with 0 = very poor and 9 = excellent. The best performing selections at the end of autumn were then chosen to be included in the turf production trial.

2.2.2 Turf production trial

The five best performing bentgrass selections (4 individual ecotypes and one blend) (see table 5) were sprigged and established in the following manner;

- Solid turf rolls of each ecotype were shredded using a pedestrian scarifier to create sprigs (vegetative plant material)
- Planted at two planting rates (0.28 cubic metres and 0.42 cubic metres per 100 square metres)
- Three replicates of each variety
- Plot size 1.0m x 1.0m
- The trial was planted in a replicated block design

Table 5: Origin of bentgrass ecotypes used in the turf production trial

No.	Origin
B22	11 th green, Royal Adelaide Golf Club, SA
B161	4 th green, Flinders Golf Club, Vic
B200	Avondale Golf Club, NSW
B85	4 th green, Royal Australian Engineers Golf Club, NSW
M1	Blend of no. B20 - 10 th green, Royal Adelaide GC, SA B50 - 9 th green, Cheltenham GC, Vic B200 - Avondale GC, NSW

The plots were established by broadcasting the stolons over the prepared surface followed by a light topdressing of sand to ensure good plant and soil contact. After rolling the surface it was covered with a growth cloth to protect the stolons from wind and water erosion and to conserve moisture.

The plots were evaluated for;

- % ground cover
- characteristics of bentgrasses
- time to produce a mowable surface
- once a complete surface was established they were assessed for;
 - turf quality (rating 0 - 9. 0 = worst and 9 = best)
 - turf density (rating 0 - 9. 0 = worst and 9 = best)
 - presence of pests and disease (% area affected)

2.3 Recovery of bentgrass after harvesting

In a commercial operation the bentgrass would be harvested by scarifying the turf and collecting the resultant plant material. In a commercial operation it is important that the bentgrass recovers to form a complete sward before being able to be harvested again. This trial was set up in the following manner;

- Four grasses were used to initiate this trial. Ecotype B22 was not used as additional plant material was required to establish before it could be included in project TU08002
- The ecotypes used were selections B85, B161, B200 and the blend (M1) that was grown on as part of the sod production trial.
- Solid turf rolls of each ecotype were shredded using a pedestrian scarifier to create sprigs (vegetative plant material).
- Sprigs were planted at a rate of 0.42 cubic metres per 100 square metres.
- Three replicates of each ecotype were planted in a replicated block design.
- Plot size was 3.0m x 1.0m.

The plots were established in late October 2008 by broadcasting the stolons over the prepared surface followed by a light topdressing of sand to ensure good plant and soil contact. After rolling the surface it was covered with a growth cloth to protect the stolons from wind and water erosion as well as to conserve moisture. By early summer there was a complete turf cover, however, due to the hot weather conditions and limited water availability the scarification of the plots did not occur until early autumn 2009.

The plots were scarified at two rates;

- a single pass
- four passes taking the cover back to near bare ground

The plots were then assessed for the rate of recovery by using a 1 square metre grid, consisting of 100 squares and determining the amount of green leaf present, expressed as a percentage of the plot area.

3. RESULTS

3.1 Salinity tolerance

3.1.1. Salinity screening trial 1

There was a significant variation in turfgrass quality ratings (table 6) between the bentgrass ecotypes at all salinity levels. The industry standards, the bentgrass cultivars Penn A1 and Penn G2, were about mid-range while Penncross exhibited the highest tolerance along with two of the selected ecotypes from saline sites.

Dry shoot weight (table 7) was also significantly affected by salinity with many Australian collected ecotypes having significantly greater amounts of shoots, after clipping yields were collected and dried, than the better performing commercially available cultivars Penn A4 and Penn A1

3.1.2 Salinity screening trial 2

In tables 8 – 13 the data for turfgrass quality is detailed for each level of salinity.

The turfgrass quality of the bentgrass ecotypes irrigated with non saline water declined over the last month of the trial due to heat stress in the greenhouse environment.

When the bentgrass ecotypes were subjected to a salinity regime of 4dS/m for a 13 week period there were 5 Australian collected ecotypes that had significantly greater turfgrass quality than the best performing commercially available cultivar, 'Seaside II'. Three of the four worst performing grasses at that salinity regime were commercially available cultivars, which included the *Poa annua* from Penn State University (PSU *Poa*).

At the end of the 29 week period with the grasses being subjected to 8dS/m there were 3 Australian collected ecotypes that had significantly greater turfgrass quality than the best performing commercially available bentgrass cultivar, 'Mariner'. The PSU *Poa annua* had a significantly lower turfgrass quality than any other commercial cultivar or ecotype.

After 22 weeks at 12dS/m there was no significant difference in turfgrass quality between the best performing commercially available bentgrass cultivar 'Penn G2' and the best performing Australian ecotypes. Table 13 shows a similar result after 6 weeks exposure to a salinity regime of 16dS/m with four Australian ecotypes and 'Penn G2' not being significantly different in turfgrass quality.

Table 6: Results of turfgrass quality after the initial salt screening work undertaken at differing salinities (0 = poor quality, 9 = best turfgrass quality).

Ecotype/Cultivar	4 dS/m	8dS/m	12dS/m	16dS/m
Penncross	8.3	7.9	7.8	8.0
B483A	8.0	6.6	6.8	8.0
B477	8.0	7.4	7.0	8.0
B472	8.0	7.6	7.8	7.8
B41	7.8	8.0	8.0	7.8
B474	5.8	6.4	7.0	7.5
B203	7.8	7.0	7.4	7.3
B481	8.0	7.8	7.4	7.0
B480	6.8	7.1	6.0	7.0
B469	7.5	7.0	6.8	7.0
Penn G2	8.0	6.9	6.4	6.8
Penn A1	7.8	7.0	6.0	6.5
B24	8.0	7.3	7.1	6.5
B167	7.5	6.3	7.0	6.5
B155	7.5	6.5	6.0	6.5
B475	8.0	7.1	6.0	6.0
B22	8.0	6.5	7.1	6.0
B159	8.0	7.3	7.8	6.0
B483	6.5	7.6	6.0	5.9
B479	8.0	7.4	5.0	5.5
B10	4.6	4.0	4.5	5.3
Penn A4	8.0	4.0	4.3	5.0
B67	8.0	7.0	6.0	5.0
B478	7.4	6.5	5.5	5.0
B473	7.5	6.8	6.8	5.0
B34	8.0	4.8	4.0	5.0
B2	5.0	4.0	6.0	5.0
B133	7.8	6.5	5.0	5.0
B39	6.0	4.8	3.5	4.8
B471	6.4	6.1	5.5	4.3
B145	6.5	3.5	3.5	4.3
B467	7.3	7.3	7.1	4.0
B18	6.9	6.5	5.0	4.0
B148	7.0	4.0	3.5	4.0
B476	6.8	7.0	4.5	2.0
B468	8.0	7.6	7.8	
LSD (P<0.05)	0.9	0.7	1.0	1.4

Figure 1: Results of the tolerance of the bentgrass ecotypes to two different salinity regimes.

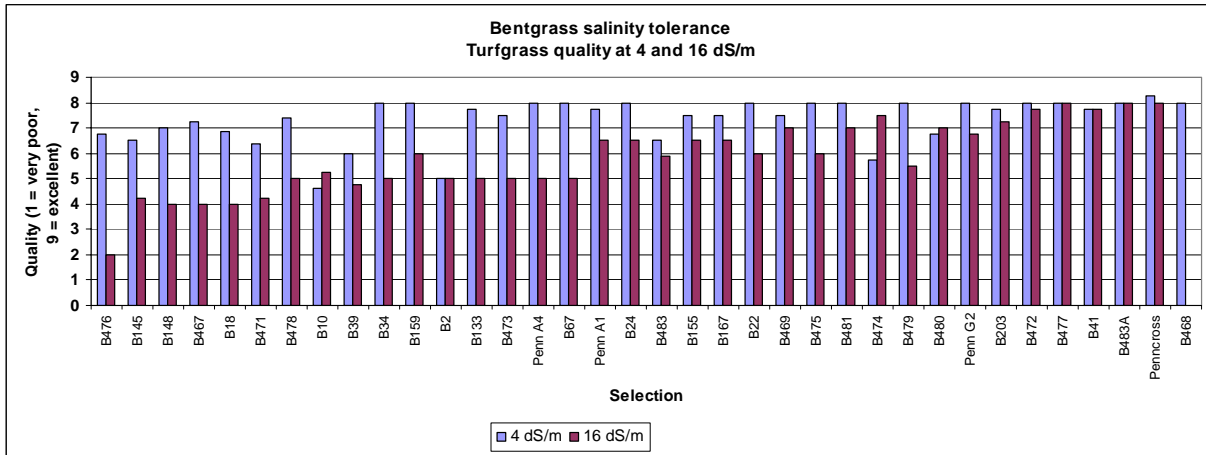


Figure 2: Turfgrass quality of three ecotype selections compared to three commercially available cultivars.

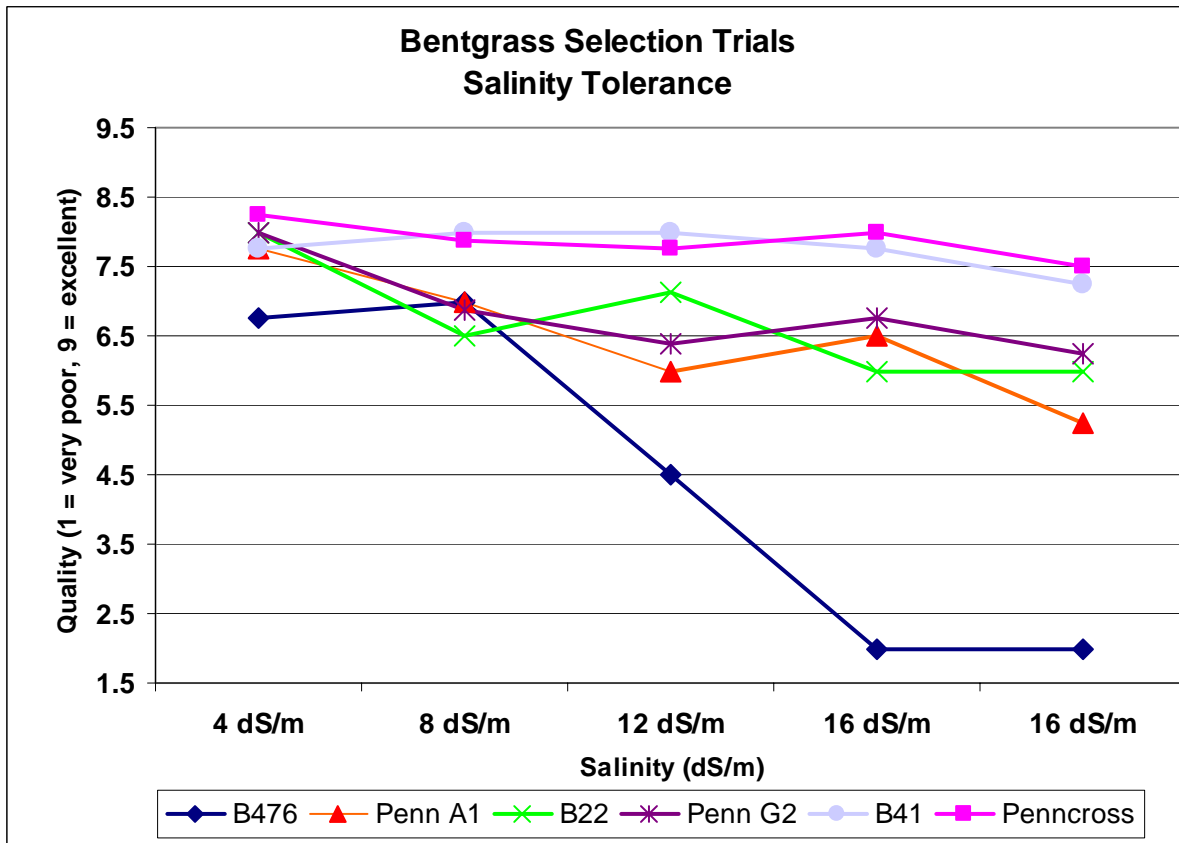


Table 7: Results of the dry shoot weight (g) of each cultivar after the initial salt screening trial undertaken at differing salinities.

Ecotype/cultivar	4 dS/m	8 dS/m	12 dS/m	16 dS/m
B203	0.22	1.55	*	0.05
B481	0.29	1.26	1.01	0.30
B167	0.17	1.07	0.93	0.05
B41	0.05	1.38	0.91	0.19
B479	0.24	1.51	0.91	0.46
B474	0.27	1.88	0.89	0.16
B475	0.52	0.92	0.74	0.01
B468	0.12	0.80	0.61	0.45
B148	0.33	0.77	0.55	0.05
B467	0.23	0.95	0.51	0.04
B22	0.33	2.53	0.51	0.04
B483	0.21	1.01	0.39	0.04
Penn A4	0.14	0.45	0.34	0.05
B480	0.15	1.37	0.33	0.03
B2	0.28	0.59	0.27	0.03
B477	0.21	1.01	0.24	0.09
B133	0.15	0.41	0.24	0.03
Penn A1	0.11	0.41	0.20	0.33
Penncross	0.34	1.28	0.20	0.02
B18	0.12	1.06	0.19	0.03
Penn G2	0.36	1.41	0.19	0.06
B472	0.22	1.21	0.17	0.17
B24	0.34	1.03	0.16	0.08
B473	0.65	1.28	0.15	0.14
B471	0.46	1.06	0.14	0.04
B10	0.25	0.94	0.14	0.06
B483A	0.50	1.19	0.14	0.12
B469	0.11	0.89	0.07	0.07
B155	0.45	1.18	0.07	0.05
B159	0.14	0.81	0.06	0.04
B478	0.22	2.62	0.05	0.04
B34	0.21	2.28	0.04	0.03
B67	0.17	0.96	0.03	0.02
B145	0.17	1.54	0.03	0.02
B39	0.12	0.64	0.03	0.02
B476	0.19	0.94	0.01	0.02
LSD (P<0.05)	0.94	0.66	0.10	0.03

Table 8: Average turfgrass quality of bentgrass ecotypes irrigated with potable water.

Ecotype/Cultivar	Wk 1	Wk 5	Wk 9	Wk 13	Wk 17	Wk 21	Wk 25	Wk 29	Wk 33
B22	8.3	8.8	8.5	8.8	8.3	8.0	8.3	8.0	7.3
B111	7.8	8.3	8.0	8.3	7.8	7.8	7.8	7.3	6.0
B50	7.5	7.8	7.3	7.5	7.8	7.5	7.5	7.3	5.8
B26	8.0	7.5	7.5	7.0	6.3	6.5	6.3	6.0	5.8
B200	8.0	8.0	8.0	7.8	8.0	7.5	7.3	7.8	5.8
B51	7.8	8.3	7.3	6.8	6.5	6.8	6.8	7.0	5.3
B4	7.8	6.8	6.5	6.3	6.5	6.8	6.8	6.8	5.3
B76	7.5	7.5	5.8	5.5	5.3	6.3	6.5	6.3	5.0
Penn G2	7.8	7.5	6.5	6.5	6.0	5.3	5.8	5.3	4.8
B20	8.0	8.0	7.3	7.0	6.5	6.8	6.8	6.8	4.8
B89	8.0	7.5	5.8	4.5	4.0	4.5	4.5	4.8	4.5
B54	8.0	8.3	7.8	7.3	7.5	7.0	7.0	6.8	4.5
B123	8.0	7.5	7.3	6.8	6.3	6.3	6.8	6.5	4.5
B10	8.0	7.8	5.8	5.3	5.5	5.3	5.8	5.8	4.5
B85	7.8	7.3	5.3	6.8	7.3	7.3	7.0	7.0	4.3
B479	8.0	7.0	6.5	6.0	5.8	5.8	5.3	5.3	4.3
B122	8.0	6.5	5.0	4.3	5.3	5.0	5.3	5.3	4.3
B472	8.0	7.3	6.5	5.5	5.8	6.0	6.5	5.8	4.0
B106	7.5	8.0	6.3	7.5	7.8	7.5	7.5	7.3	4.0
B470	7.5	7.5	5.3	6.8	7.3	7.3	6.8	6.3	3.8
B34	8.0	7.8	7.8	7.8	7.0	6.3	6.3	6.0	3.8
B100	7.8	6.0	5.5	5.5	6.0	6.3	5.8	5.5	3.8
B158	8.0	6.8	5.3	6.5	6.0	6.0	5.5	5.3	3.5
Seaside II	8.0	6.5	5.8	4.3	5.5	5.3	5.3	5.3	3.3
B467	8.0	8.0	7.5	5.5	5.5	5.5	5.8	6.0	3.3
B41	8.0	7.8	7.3	6.8	6.3	6.8	6.3	6.3	3.3
B473	7.5	4.8	4.0	4.3	4.3	4.0	3.8	3.3	2.8
B161	7.8	5.8	4.3	3.8	3.8	4.0	4.5	4.0	2.8
Mariner	7.5	7.0	6.3	4.8	5.0	5.3	4.5	4.5	2.0
B36	8.0	8.0	6.5	5.8	6.0	7.0	7.0	6.8	2.0
PSU Poa	6.8	6.8	4.8	4.0	3.5	2.8	1.8	1.5	1.0
LSD (P<0.05)	0.4	1.4	2.1	2	1.9	1.9	1.9	1.7	1.8

Table 9: Average turfgrass quality of bentgrass ecotypes irrigated with water at 4dS/m salinity.

Ecotype/Cultivar	Wk 1	Wk 3	Wk 5	Wk 7	Wk 9	Wk 11	Wk 13
B50	8.0	8.3	8.3	8.0	7.3	6.5	6.8
B200	8.0	7.8	8.0	8.0	7.3	7.0	6.8
B22	8.0	8.0	8.0	7.8	7.3	7.0	6.5
B111	8.0	8.3	8.0	7.5	7.5	7.8	6.5
B34	7.8	8.0	8.3	8.0	7.5	6.3	6.0
B51	8.0	7.8	7.5	7.3	7.0	6.3	5.8
B158	8.0	7.8	7.5	7.5	6.8	6.5	5.8
B479	8.0	7.8	7.5	7.5	7.3	6.0	5.5
B472	7.5	7.5	7.8	7.5	7.0	6.3	5.5
B470	7.0	7.5	7.3	7.3	6.5	6.3	5.5
B26	7.3	8.3	7.5	7.3	7.5	6.3	5.5
B161	8.0	8.0	7.3	7.3	6.8	6.3	5.5
B123	7.8	8.3	8.3	8.0	7.0	6.0	5.5
B85	7.3	7.3	7.5	7.5	6.5	6.0	5.3
B100	8.0	7.8	7.5	7.5	7.0	6.0	5.3
B54	7.8	7.5	7.3	7.0	6.5	5.3	5.0
B4	7.8	7.8	7.5	7.5	7.0	5.8	5.0
B36	7.8	7.5	7.5	7.3	6.0	5.5	5.0
B106	8.0	7.8	7.5	7.3	6.5	6.0	5.0
B10	8.0	8.0	7.8	7.8	6.5	6.0	5.0
Seaside II	7.5	7.5	7.5	7.5	6.3	5.5	4.8
B89	8.0	7.5	7.3	7.3	7.0	5.8	4.8
B76	7.8	7.3	7.0	6.5	6.5	5.8	4.8
B473	7.8	7.5	7.5	7.3	6.5	5.8	4.8
B467	7.5	7.3	7.3	7.3	7.0	6.5	4.8
B41	7.5	7.5	7.3	6.8	6.3	6.0	4.8
B20	7.5	7.5	7.3	7.3	5.8	5.5	4.8
Penn G2	7.8	7.8	7.8	7.5	7.0	5.8	4.5
B122	7.8	8.3	8.0	8.0	7.0	5.8	4.5
Mariner	7.3	7.5	6.3	6.0	5.3	4.3	3.8
PSU Poa	7.8	7.3	5.5	4.5	3.5	2.8	2.3
LSD (P<0.05)	ns	ns	0.9	0.9	0.9	0.9	1.0

Table 10: Average turfgrass quality of bentgrass ecotypes irrigated with water at 8dS/m salinity.

Ecotype/Cultivar	Wk 1	Wk 5	Wk 9	Wk 13	Wk 17	Wk 21	Wk 25	Wk 29
B111	7.8	7.3	7.0	6.5	6.3	6.5	6.5	6.3
B22	9.0	8.8	8.3	7.0	6.8	6.3	7.0	6.0
B200	8.0	8.0	7.3	6.8	6.3	5.8	5.8	5.8
B50	8.0	6.8	6.3	5.8	5.8	5.8	6.0	5.3
B4	7.5	7.3	6.5	5.0	5.3	5.3	5.8	5.3
B161	7.3	7.0	6.3	5.3	5.5	5.5	5.5	5.0
B89	7.5	6.8	6.3	4.5	4.8	4.5	5.0	4.8
B85	7.0	7.5	6.3	5.0	4.8	4.8	5.3	4.8
B51	7.3	7.5	6.3	5.0	5.5	4.8	5.3	4.8
B41	7.8	7.0	6.0	5.0	5.3	5.0	5.8	4.8
B26	7.3	7.0	6.3	5.0	4.5	4.3	4.8	4.8
B100	8.0	7.8	6.8	5.3	5.8	5.5	5.5	4.8
B10	7.0	7.0	6.3	4.3	4.0	4.5	5.0	4.8
Mariner	7.3	6.8	6.0	4.8	4.3	4.8	5.0	4.5
B479	7.8	6.8	5.5	5.0	5.3	4.0	4.5	4.5
B34	7.3	6.8	5.8	5.5	5.8	5.3	5.8	4.5
B158	7.3	6.8	5.8	5.0	5.3	5.0	5.3	4.5
B106	7.8	7.3	6.5	5.0	5.0	5.3	4.8	4.5
B54	7.0	6.5	5.0	4.5	4.8	5.3	4.8	4.3
B123	7.8	7.0	6.3	5.0	5.3	5.0	5.0	4.3
B122	6.8	6.8	5.8	4.8	4.3	4.3	4.8	4.3
B473	7.0	6.5	5.8	5.0	5.0	4.8	5.0	4.0
B36	7.8	6.8	5.3	4.8	4.5	4.3	4.5	4.0
B470	6.8	6.8	5.8	4.5	4.3	4.3	4.0	3.8
Seaside II	6.8	6.8	5.5	4.0	3.3	3.8	4.8	3.5
Penn G2	7.0	7.3	6.5	4.8	4.3	3.5	4.0	3.5
B472	7.3	7.0	6.0	4.3	4.5	4.0	4.5	3.5
B76	8.0	6.5	6.0	4.5	4.8	3.8	4.0	3.3
B20	7.3	7.3	5.8	4.5	4.0	3.8	4.0	3.3
B467	7.0	7.0	6.3	4.8	4.3	4.0	4.3	3.0
PSU Poa	5.8	5.3	2.8	1.3	1.3	1.0	1.0	0.8
LSD (P<0.05)	0.5	0.6	0.8	0.8	1.0	1.0	1.1	1.1

Table 11: Average turfgrass quality of bentgrass ecotypes irrigated with water at differing salinity regimes 13 weeks after the trial commenced.

Ecotype/Cultivar	0dS/m	4dS/m	8dS/m
B22	8.8	6.5	7.0
B200	7.8	6.8	6.8
B111	8.3	6.5	6.5
B50	7.5	6.8	5.8
B34	7.8	6.0	5.5
B161	3.8	5.5	5.3
B100	5.5	5.3	5.3
B85	6.8	5.3	5.0
B51	6.8	5.8	5.0
B479	6.0	5.5	5.0
B473	4.3	4.8	5.0
B470	6.8	5.5	5.0
B41	6.8	4.8	5.0
B4	6.3	5.0	5.0
B26	7.0	5.5	5.0
B158	6.5	5.8	5.0
B106	7.5	5.0	5.0
Penn G2	6.5	4.5	4.8
Mariner	4.8	3.8	4.8
B467	5.5	4.8	4.8
B36	5.8	5.0	4.8
B122	4.3	4.5	4.8
B89	4.5	4.8	4.5
B76	5.5	4.8	4.5
B54	7.3	5.0	4.5
B20	7.0	4.8	4.5
B123	6.8	5.5	4.5
B472	5.5	5.5	4.3
B10	5.3	5.0	4.3
Seaside II	4.3	4.8	4.0
PSU Poa	4.0	2.3	1.3
LSD (P<0.05)	2.0	1.0	0.8

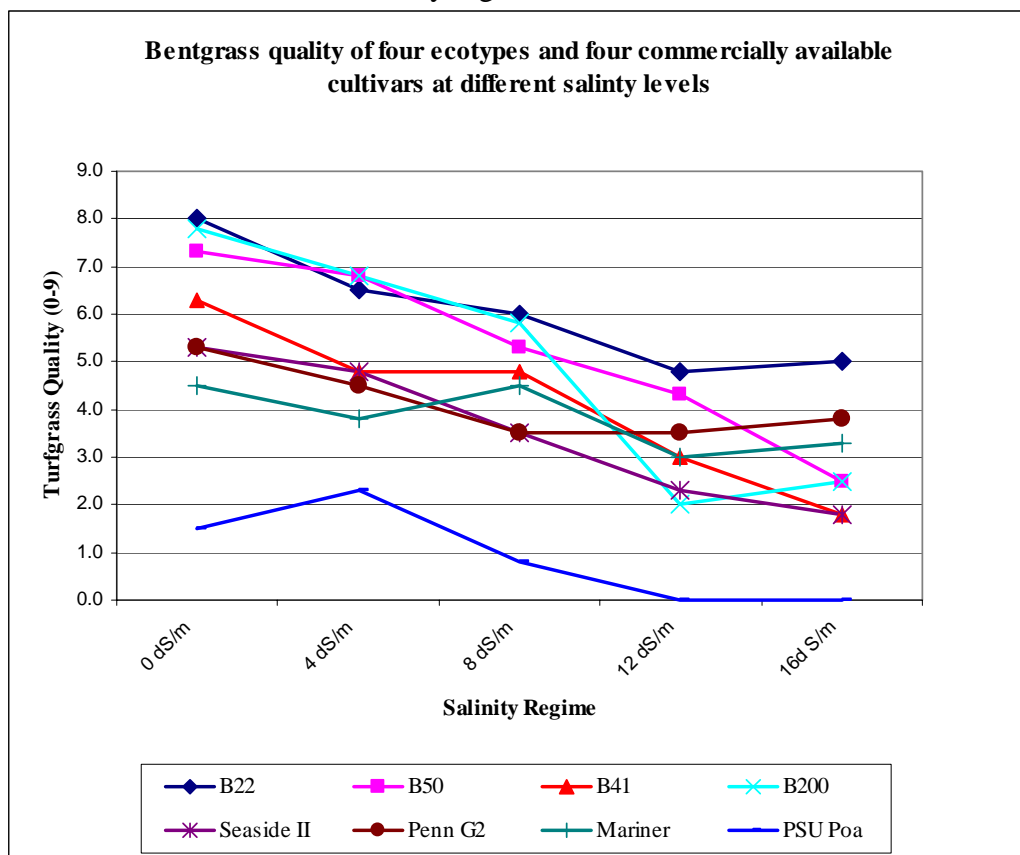
Table 12: Average turfgrass quality of bentgrass ecotypes irrigated with water at 12dS/m salinity.

Ecotype/Cultivar	Wk 3	Wk 7	Wk 11	Wk 15	Wk 19	Wk 22
B22	7.0	6.3	6.3	5.0	4.8	4.8
B50	5.3	5.5	6.3	5.3	4.8	4.3
B158	5.3	4.5	4.8	5.3	4.0	3.8
Penn G2	4.5	4.3	3.3	3.5	3.5	3.5
B89	4.3	4.3	4.5	4.0	3.8	3.3
B106	4.8	5.0	5.3	4.8	3.8	3.3
Mariner	3.3	3.5	3.5	4.0	3.0	3.0
B54	5.8	4.5	4.3	3.8	3.8	3.0
B479	4.8	4.3	4.3	4.0	3.0	3.0
B41	4.8	4.5	4.5	4.8	3.3	3.0
B26	4.8	4.3	4.0	4.3	3.5	3.0
B161	5.3	4.8	4.5	4.0	3.3	3.0
B122	5.0	4.0	4.3	3.8	3.0	3.0
B100	4.5	4.0	4.0	4.3	3.3	3.0
B51	4.8	4.5	4.3	3.5	3.0	2.8
B472	5.8	5.3	4.5	3.8	3.0	2.8
B123	5.0	4.5	4.3	4.0	3.5	2.8
B470	5.0	4.3	4.3	4.5	3.3	2.5
B4	5.5	4.5	4.5	3.3	2.8	2.5
Seaside II	3.8	4.0	4.3	3.8	2.8	2.3
B111	5.5	5.5	6.0	4.8	3.0	2.3
B85	5.3	4.5	3.8	3.0	1.8	2.0
B473	4.0	3.5	3.3	3.0	2.5	2.0
B467	4.3	4.3	3.8	3.3	2.3	2.0
B200	6.0	5.3	5.0	4.3	3.0	2.0
B20	4.3	3.8	3.8	3.8	3.0	2.0
B10	4.5	4.0	3.5	3.3	2.8	2.0
B76	4.3	4.0	4.0	3.0	2.0	1.8
B36	4.0	3.8	3.3	2.3	1.8	1.8
B34	5.8	5.8	6.3	4.8	2.0	1.0
PSU Poa	0.8	0.0	0.0	0.0	0.0	0.0
LSD (P<0.05)	0.9	0.9	1.3	1.3	1.1	1.3

Table 13: Average turfgrass quality of bentgrass ecotypes irrigated with water at 16dS/m salinity.

Ecotype/Cultivar	Wk 2	Wk 4	Wk 6
B22	5.5	5.0	5.0
B51	4.5	4.5	4.8
B10	4.5	4.3	4.5
B89	4.3	4.0	4.3
Penn G2	3.5	3.5	3.8
B26	4.5	4.0	3.8
B100	4.3	4.0	3.8
B85	4.5	3.8	3.5
B4	4.8	4.0	3.5
B111	5.5	4.3	3.5
Mariner	3.8	3.3	3.3
B479	4.3	4.3	3.3
B106	4.8	3.8	3.3
B122	4.3	3.3	3.0
B470	3.3	3.0	2.8
B158	3.8	3.3	2.8
B123	3.8	3.3	2.8
B54	3.8	3.0	2.5
B50	4.5	3.8	2.5
B472	3.3	2.8	2.5
B34	4.0	3.0	2.5
B200	5.5	4.5	2.5
B161	4.8	4.0	2.5
B473	3.3	2.8	2.3
B467	2.5	2.3	2.3
B36	3.5	2.5	2.3
B20	2.5	2.5	2.3
B76	3.0	2.5	2.0
Seaside II	3.0	2.3	1.8
B41	4.5	3.5	1.8
PSU Poa	0.8	0.3	0.0
LSD (P<0.05)	1.2	1.2	1.3

Figure 3: Turfgrass quality of four ecotype selections and four commercially available cultivars at the end of each salinity regime.



3.2 Turf production

3.2.1 Selection of bentgrass ecotypes for turf production trials

In table 14 the results of the assessments for turfgrass quality are detailed. The best performing ecotypes for the turf production trial were chosen based on their overall performance and their appearance at the time of the last assessment.

After assessing the grasses for a period of five months some significant differences were noted in the quality of the various ecotypes and blends. B22 exhibited excellent colour and density and was the standout ecotype by the end of the trial. B85 and B161 had shown the most consistent turfgrass quality throughout the trial period. B200 was also a very good performer with the exception of a loss in quality over the summer months however was equal to any other ecotype at the conclusion of the trial. A selection of ecotypes (M1) was chosen to assess whether the mix of 3 ecotypes would provide any additional benefits in terms of sod production.

Table 14: Turfgrass quality ratings for bentgrass ecotypes (0 = poor, 9 = excellent).

Variety	Wk 1	Wk 3	Wk 5	Wk 7	Wk 9	Wk 11	Wk 13	Wk 15	Wk 17	Wk 19	Ave
B22	5	4	6	6	6	7	7	9	9	9	6.8
B54	6	6	7	6	5	5	6	6	6	6	5.9
B161	7	7	8	7	7	7	7	8	8	8	7.4
B20	6	6	7	6	6	7	6	7	7	7	6.5
B122	5	5	6	5	5	6	5	7	7	7	5.8
B26	6	7	7	6	5	5	6	6	6	6	6.0
B50	7	7	7	6	5	5	6	6	6	6	6.1
B51	7	7	8	6	6	8	7	7	7	7	7.0
B106	6	6	7	6	5	5	6	6	6	6	5.9
B34	5	6	6	5	5	6	6	6	6.5	7	5.9
B100	7	7	8	6	6	6	6	6	6	7	6.5
B76	7	6	7	6	6	6	6	6	7	7	6.4
B10	5	5	6	5	5	7	7	7	7	7	6.1
B158	5	5	5	4	5	6	6	6	7	7	5.6
B200	8	7	8	7	6	6	7	7	7	8	7.1
B36	6	6	5	6	6	7	6	7	7	7	6.3
B89	7	6	6	5	6	5	6	6	6	7	6.0
B111	8	8	7	7	5	5	6	5	5	5	6.1
B85	8	8	7	8	8	8	8	8	7	7	7.7
B123	7	7	6	7	7	8	6	7	7	8	7.0
M1	7	7	6	6	6	7	7	7	8	8	6.9
M2	5	6	6	6	5	7	6	7	7	7	6.2
M3	6	7	7	6	7	7	7	8	7	7	6.9
M4	6	6	6	6	6	7	6	7	7	6	6.3
M5	6	6	6	6	6	6	6	6	7	7	6.2

3.2.2 Turf production trial

The results for turfgrass establishment at the two sprigging rates are detailed in table 15.

Ecotype

There was a significant cultivar effect on one occasion at 3 weeks after planting. Ecotype B22 had a significantly greater area cover compared to B200. At all other assessment dates there was no significant difference between ecotypes

Sprigging Rate

There was a significant effect on percentage area cover between sprigging rates on the first four assessment dates, up to 14 weeks after planting, where the higher sprigging rate had a greater percentage cover.

Interaction

There was a significant cultivar/sprigging rate interaction on one date (3 weeks after planting) where B22 at the higher sprigging rate had a significantly greater percentage cover compared to all other treatments except for B85 at the lower sprigging rate. B85 at the lower rate had a significantly greater percentage cover compared to B200 at both sprigging rates and M1 at the lower sprigging rate.

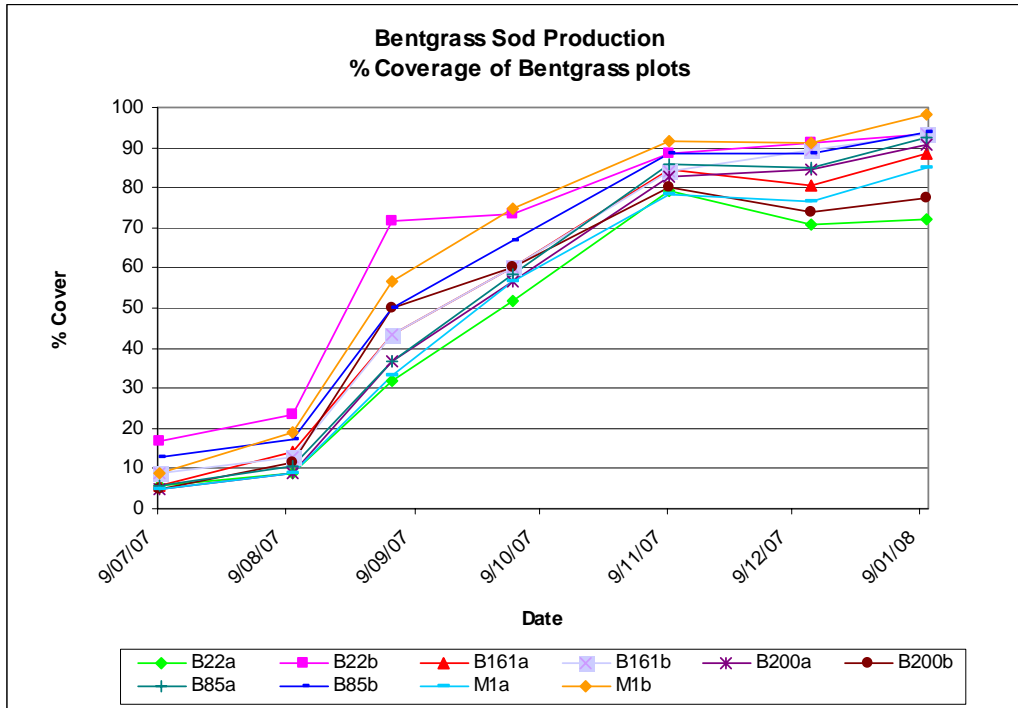
Table 15: Results of the replicated establishment trial based on two different sprigging rates

Cultivar effect	3 WAP	7 WAP	10 WAP	14 WAP	19 WAP	23 WAP	27 WAP
B22	11.2	16.2	51.7	62.5	83.8	80.8	82.8
B161	7.3	13.5	43.3	60.0	84.3	85.0	90.8
B200	5.0	10.2	43.3	58.3	81.3	79.2	84.0
B85	9.2	14.0	43.3	62.5	87.0	86.8	93.2
M1	7.0	14.0	45.0	65.8	85.0	83.8	91.7
LSD (P<0.05)	4.9	ns	ns	ns	ns	ns	ns
Sprigging rate							
S1	5.4	10.3	36.3	56.7	82.1	79.4	85.7
S2	10.5	16.8	54.3	67.0	86.5	86.8	91.3
LSD (P<0.05)	SD	SD	SD	SD	ns	ns	ns
Cultivar x sprigging rate interaction							
B22							
S1	5.7	9.0	31.7	51.7	79.3	70.7	72.3
S2	16.7	23.3	71.7	73.3	88.3	91.0	93.3
B161							
S1	5.7	14.0	43.3	60.0	84.7	80.7	88.3
S2	9.0	13.0	43.3	60.0	84.0	89.3	93.3
B200							
S1	5.0	9.0	36.7	56.7	82.7	84.3	90.7
S2	5.0	11.3	50.0	60.0	80.0	74.0	77.3
B85							
S1	12.7	10.7	36.7	58.3	85.7	85.0	92.3
S2	5.7	17.3	50.0	66.7	88.3	88.7	94.0
M1							
S1	5.0	9.0	33.3	56.7	78.3	76.7	85.0
S2	9.0	19.0	56.7	75.0	91.7	91.0	98.3
LSD (P<0.05)	7.0	ns	ns	ns	ns	ns	ns

S1 = sprigging rate at 0.28m³/100m²

S2 = sprigging rate at 0.42m³/100m²

Figure 4: Rate of coverage of plots when sprigged at two different planting rates



a = sprigging rate at 0.28m³/100m²
 b = sprigging rate at 0.42m³/100m²

Table 16 illustrates the difference in the growth habits of the four ecotypes and one blend based on the degree of stoloniferous growth. Ecotype B161 had significantly greater amount of stolons present at 15 weeks after planting compared with any other ecotype or blend.

Table 16: A visual assessment of the growth habit (0 = no stolons, 5= extensive stolons) of the four ecotypes and one blend.

Plot	15 WAP
B22	2.3
B161	4.7
B200	3.0
B85	2.2
M1	1.7
LSD (P<0.05)	1.4

Table 17 showed that ecotype B22 had a significantly darker green colour than any of the other four ecotypes on four of the assessment dates (7-Mar through to 20-Jun), and a significantly darker green colour than ecotypes B85 and M1 on the assessment date of 31-Jul.

Table 17: Turfgrass colour ratings (0 - 9) of the bentgrass selections planted in the replicated trial.

Ecotype	10-Jan	11-Feb	7-Mar	7-Apr	2-May	20-Jun	31-Jul	27-Aug
B22	7.2	6.1	7.3	7.6	7.5	7.2	6.4	6.4
B161	7.1	6.0	6.3	6.3	6.1	6.2	6.0	6.3
B200	7.0	6.0	6.1	6.3	6.3	6.4	6.1	6.2
B85	7.0	6.0	5.7	6.1	6.3	5.9	5.8	6.0
M1	7.0	6.0	5.7	6.3	6.3	6.3	5.9	5.8
LSD (P<0.05)	ns	ns	0.9	0.7	0.6	0.6	0.4	ns

The results for turfgrass density are detailed in table 18.

Ecotype effect

There was a significant difference between ecotypes in turfgrass density on seven assessment dates;

10/1/08 – M1 had significantly greater turfgrass density compared with B85 and B200.

11/2/08 – B22 had significantly greater turfgrass density compared with B85 and B200.

7/4/08 – B22 had significantly greater turfgrass density compared with B85.

2/5/08 – B22 had significantly greater turfgrass density compared with all other ecotypes.

20/6/08 – B22 had significantly greater turfgrass density compared with B85 and B161.

31/7/08 – B22 had significantly greater turfgrass density compared with B85 and B200.

27/8/08 – B22 had significantly greater turfgrass density compared with all other ecotypes.

Sprigging Rate

There was a significant difference between sprigging rate on turfgrass density on two assessment dates. On 10/1/08 and 2/5/08 the higher sprigging rate had a significantly greater density.

Interaction

There were no significant interactions on any of the assessment dates.

The results for turfgrass quality are detailed in table 19.

Ecotype effect

There was a significant difference between ecotypes in turfgrass quality on seven assessment dates;

10/1/08 – M1 had significantly greater turfgrass quality compared with all other ecotypes except for B22.

11/2/08 – B22 had significantly greater turfgrass quality compared with B85 and B200.

7/4/08 – B22 had significantly greater turfgrass quality compared with B85.

2/5/08 – B22 had significantly greater turfgrass quality compared with all other ecotypes.

20/6/08 – B22 had significantly greater turfgrass quality compared with B85 and B200.

31/7/08 – B22 had significantly greater turfgrass quality compared with B85 and B200.

27/8/08 – B22 had significantly greater turfgrass quality compared with all other ecotypes.

Sprigging Rate

There was a significant difference in turf quality between the two sprigging rates on two assessment dates. On 10/1/08 and 2/5/08 the higher sprigging rate had a significantly greater turf quality compared with the lower rate.

Interaction

There were no significant interactions on any of the assessment dates.

Table 18: Turfgrass density ratings (0 - 9) of the bentgrass selections planted in the replicated trial.

Ecotype effect	10-Jan	11-Feb	7-Mar	7-Apr	2-May	20-Jun	31-Jul	27-Aug
B22	6.5	7.2	6.8	7.5	7.5	7.3	7.3	7.4
B161	6.5	6.5	5.8	6.6	6.5	6.1	6.3	5.9
B200	6.3	6.0	6.1	6.6	6.4	6.3	5.8	4.9
B85	6.1	6.1	5.5	6.0	6.3	6.0	5.7	5.3
M1	7.2	6.8	6.0	6.6	6.8	6.3	6.6	6.1
LSD (P<0.05)	0.7	0.8	ns	1.1	0.6	1.0	1.1	1.1

Sprigging rate

S1	6.3	6.4	5.6	6.6	6.5	6.3	6.2	5.8
S2	6.8	6.6	6.4	6.7	6.9	6.5	6.4	6.1
LSD (P<0.05)	SD	ns	ns	ns	SD	ns	ns	ns

Ecotype x sprigging rate interaction

B22

S1	6.2	6.8	6.2	7.3	7.3	7.3	7.0	7.2
S2	6.8	7.5	7.5	7.7	7.7	7.3	7.5	7.7

B161

S1	6.2	6.5	5.2	6.5	6.3	5.8	6.0	5.8
S2	6.8	6.5	6.3	6.7	6.7	6.3	6.5	6.0

B200

S1	6.3	6.0	6.0	6.8	6.5	6.5	6.2	5.2
S2	6.3	6.0	6.2	6.3	6.3	6.2	5.3	4.7

B85

S1	6.0	6.0	5.3	6.0	6.2	5.7	5.5	5.3
S2	6.2	6.2	5.7	6.0	6.5	6.3	5.8	5.3

M1

S1	6.7	6.7	5.5	6.2	6.3	6.2	6.2	5.3
S2	7.7	6.8	6.5	7.0	7.2	6.3	7.0	6.8

LSD (P<0.05)	ns	ns	ns	ns	ns	ns	ns	ns
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S1 = sprigging rate at 0.28m³/100m²

S2 = sprigging rate at 0.42m³/100m²

Table 19: Turfgrass quality ratings (0 - 9) of the bentgrass selections planted in the replicated trial.

Ecotype effect	10-Jan	11-Feb	7-Mar	7-Apr	2-May	20-Jun	31-Jul	27-Aug
B22	6.6	7.2	6.5	7.6	7.5	7.2	7.3	7.4
B161	6.3	6.5	5.8	6.6	6.5	6.1	6.3	5.9
B200	6.3	6.0	5.8	6.3	6.5	6.0	5.8	4.9
B85	6.1	6.1	5.0	6.0	6.3	6.0	5.7	5.0
M1	6.9	6.5	5.8	6.6	6.7	6.3	6.6	6.1
LSD P<0.05	0.5	0.8	ns	1.3	0.6	1.1	1.1	1.0
Sprigging rate								
S1	6.2	6.3	5.5	6.6	6.5	6.2	6.2	5.6
S2	6.7	6.6	6.1	6.6	6.9	6.3	6.4	6.1
LSD P<0.05	SD	ns	ns	ns	SD	ns	ns	ns
Ecotype x sprigging rate interaction								
B22								
S1	6.2	6.8	6.0	7.3	7.3	7.0	7.0	7.2
S2	7.0	7.5	7.0	7.8	7.7	7.3	7.5	7.7
B161								
S1	6.2	6.7	5.3	6.5	6.3	5.8	6.0	5.8
S2	6.5	6.3	6.3	6.7	6.7	6.3	6.5	6.0
B200								
S1	6.3	6.0	6.0	6.8	6.5	6.5	6.2	5.2
S2	6.3	6.0	5.5	5.7	6.5	5.5	5.3	4.7
B85								
S1	6.0	6.0	4.7	6.0	6.2	5.7	5.5	4.7
S2	6.2	6.2	5.3	6.0	6.5	6.3	5.8	5.3
M1								
S1	6.5	6.2	5.3	6.2	6.2	6.2	6.2	5.3
S2	7.3	6.8	6.2	7.0	7.2	6.3	7.0	6.8
LSD P<0.05	ns	ns	ns	ns	ns	ns	ns	ns

S1 = sprigging rate at 0.28m³/100m²

S2 = sprigging rate at 0.42m³/100m²

3.3 Recovery of bentgrass after harvesting

The results in table 20 detail the effect of the two different scarification rates on the recovery rate of the bentgrass.

Ecotype effect

There was no significant ecotype effect on any of the assessment dates.

Sprigging Rate

There was a significant difference between scarifying rates on the recovery of the bentgrass on all assessment dates following the scarifying operation.

Interaction

There were no significant interactions on any of the assessment dates.

Table 20: Percent area cover of the bentgrass following scarifying.

Ecotype effect	8-Apr Pre	8-Apr Post	20-Apr	29-Apr	7-May	14-May	20-May
B161	93.0	50.8	55.0	62.2	73.3	78.0	83.8
B200	93.3	57.5	61.7	68.3	76.3	81.7	85.8
B85	96.0	50.0	52.5	63.3	77.3	80.8	84.3
M1	96.7	55.8	59.2	62.5	68.0	75.8	84.2
LSD P<0.05	ns	ns	ns	ns	ns	ns	ns

Scarifying rate

Sc1	96.6	76.7	77.9	82.8	89.2	93.2	95.8
Sc2	96.6	30.4	36.3	45.4	58.3	65.0	73.3
LSD P<0.05	ns	SD	SD	SD	SD	SD	SD

Ecotype x scarifying rate interaction

B85

Sc1	93.0	71.7	73.3	79.3	88.3	91.0	94.3
Sc2	93.0	30.0	36.7	45.0	58.3	65.0	73.3

B200

Sc1	93.3	76.7	78.3	83.3	87.7	93.3	95.0
Sc2	93.3	38.3	45.0	53.3	65.0	70.0	76.7

B161

Sc1	96.0	78.3	78.3	85.0	94.7	96.7	98.7
Sc2	96.0	21.7	26.7	41.7	60.0	65.0	70.0

M1

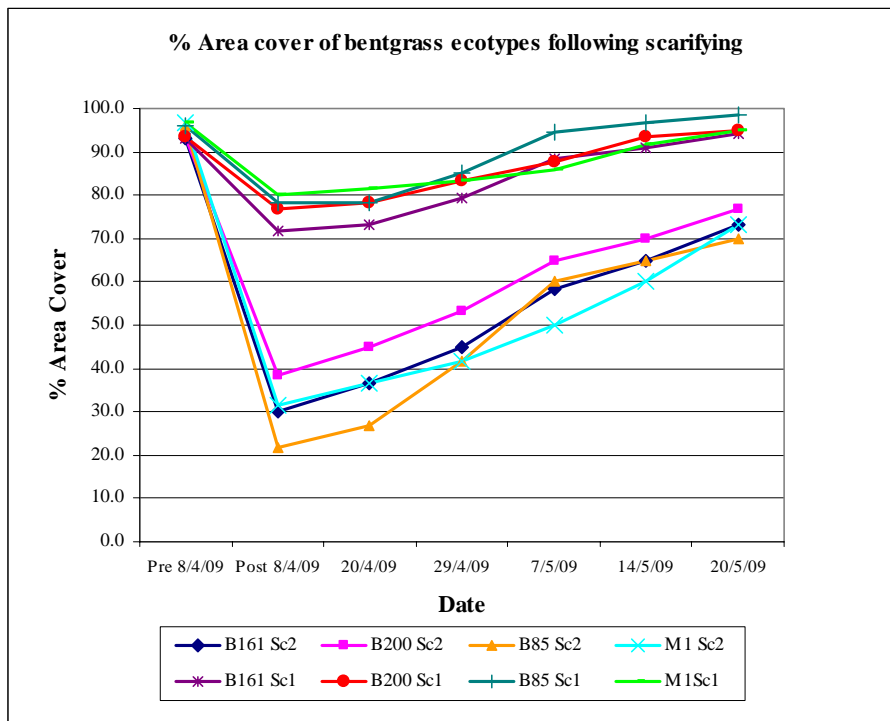
Sc1	96.7	80.0	81.7	83.3	86.0	91.7	95.0
Sc2	96.7	31.7	36.7	41.7	50.0	60.0	73.3

LSD P<0.05	ns	ns	ns	ns	ns	ns	ns
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Sc1 = Single scarification

Sc2 = 4 passes with scarifier

Figure 5: Results of the two different scarification rates on the recovery of the bentgrasses.



4. DISCUSSION

4.1 Salinity tolerance

There was a significant variation in turfgrass quality ratings between the bentgrass ecotypes at all salinity levels in salinity screening trial 1. Further salinity trials were conducted with the treatments applied as a foliar application.

In the second salinity screening trial the 27 Australian bentgrass ecotypes generally had a greater turfgrass quality than the commercially available bentgrass cultivars at the lower salinity regimes of 4 and 8dS/m, however 'Penn G2' and 'Mariner' were comparable to the better performing Australian ecotypes at the higher salinity regimes.

The selection B22 was the standout bentgrass in the second salt screening trial and as well as performing very well in the first of the salt screening trials.

Marcum (2000) compared the salt tolerance of 35 bentgrass cultivars and demonstrated that the cultivars 'Mariner' and 'Seaside II' were the two best performing cultivars in terms of salinity tolerance when assessing per cent green leaf and were also in the top group for clipping weight and root depth.

The greenhouse salinity tolerance trials undertaken as part of this project have demonstrated there are several Australian bentgrass ecotypes that have superior turfgrass quality compared to 'Mariner' and 'Seaside II'.

In January 2008 the quality of the effluent irrigation water increased in salinity and it was decided that this trial area would serve as the salinity field trial due to the high level of salinity in the irrigation water, 2.0dS/m. The trial was irrigated with this quality water until mid April 2008.

In terms of overall turfgrass quality ecotype B22 was again the best performing grass being of a significantly better quality than any other grass. It was for this reason that the ecotype B22 has been incorporated into Project TU08002 to assess its performance against two industry standards 'Penn A1' and 'Penn G2' as well as thirteen new seeded bentgrass cultivars.

4.2 Turf Production

Although it took 5 months to achieve a full coverage (>90%) in this trial, the planting time was not ideal. It would be expected that this time could be diminished if the planting had occurred in early September or even later, rather than early July when conditions were much cooler and there was far less sunlight. This is supported by the findings when plots were established at a planting rate of 0.42m³/100m² in mid October 2008 for the recovery of bentgrass after harvesting trial when a full cover was established in three months.

Three months is generally the time required for establishment of bentgrass putting surfaces from seed if sown during the growing months. For vegetative propagation to be accepted as an alternative establishment process this time frame would need to be similar. This trial has shown that the planting rate of 0.42m³ per 100 m² would be the preferred planting rate over the lower rate of 0.28m³ per 100m² due to the increased coverage within those first three months.

During the grow in period a visual assessment was undertaken of the stoloniferous nature of the ecotypes. Generally turf that exhibits more stolons will generally be able to form a

complete cover more quickly than those grasses with fewer stolons. In October 2007 (15 WAP) when the assessment was made, B161 had significantly more visual surface stolons than any of the other three ecotypes or the blend. However the results for percent cover during the establishment trial does not support this theory indicating that the planting rate provided enough plant material that stolon growth was not primarily required to achieve a full turf cover.

4.3 Recovery of bentgrass after harvesting

The heavier scarification rate (Sc2) severely reduced the turf cover or percentage of green leaf present. After six weeks the grass had not fully recovered and it would be expected that at least another four weeks would be required to obtain a full turfgrass cover, irrespective of ecotype or blend.

Although, there was about three times the quantity of material harvested from the four passes opposed to one, it took a lot longer for the more heavily scarified areas to recover. The other issue with the heavier scarification rate is the damage to the turf is far greater and therefore the likelihood of disease incidence or abiotic damage is also increased.

While it has been proved in this project that it is possible to achieve an excellent cover of bentgrass through vegetative propagation the time to produce enough material of a specific ecotype is probably a limiting factor for a commercial operation. However, once a viable area was established the results have shown that the bentgrass will recover from scarification events relatively quickly if done in a controlled manner.

The best way to achieve a large bentgrass turf nursery would be to sod cut small areas of mature turf. Then the resultant sod is shredded to produce enough plant material to establish an area 5 times as large as the initial harvested area within 3 months. This was demonstrated in the establishment of the recovery of bentgrass after harvesting trial.

In theory, with adequate irrigation and not allowing for any growth over winter, an area 125 times greater than an initial area should be able to be established in a year. Therefore, if you started with 1 square metre of a vegetative ecotype it would take between no more than 2 years to generate a nursery large enough (1000m²) to scarify enough plant material to establish an area of an average golf green. Once the nursery area was established however it would provide a reliable source of sprigs for many years.

The amount of material generated from a single pass with the scarifier was calculated to be in the vicinity of 0.1m³ per 40 square metres of mature bentgrass. Therefore to establish an area of 100 square metres from scarifyings (vegetative material) would require an area of 168 square metres of mature bentgrass using a planting rate of 0.42m³ per 100 square metres.

The cost to establish a green of 600 square metres from seed would be about \$200, as bentgrass seed sells for about \$60 per kg and is normally sown at a seeding rate of 5-6g per square metre. To establish this area from vegetative material at the preferred planting rate of 0.42m³/100m² would require the scarification of an area of 1008 square metres of bentgrass in a single direction.

The benefits of vegetative propagation is the ability to utilise bentgrass of superior turf quality and once the nursery area is established have a reliable source of a quality bentgrass that is ready for further harvesting again within a six week period.

5. EXTENSION ACTIVITIES

Over the life of this project there has been an extension program running which has involved; seminars, conference presentations, field days and articles in conference proceedings and the Australian Turfgrass Management Journal.

The following is a list of activities and publications;

AGCSA Research Update in: *Proceedings Australian Turfgrass Conference, Cairns, July 2007.*

AGCSA Research Update in: *Proceedings Australian Turfgrass Conference, Hobart, July 2009.*

Australian Turfgrass Management Journal – 2005 AGCSATech Update: *Bentgrass Trials* ATM 7.6

Australian Turfgrass Management Journal – 2007 AGCSATech Update: *Bentgrass Vegetative Propagation Project* ATM 9.5.

Australian Turfgrass Management Journal – 2009 AGCSATech Update: *Local ecotypes perform in bentgrass salinity trials* ATM 11.1.

Website: All articles on the trials are uploaded onto the website. New HAL/Research link created.

A field day was undertaken at Evergreen Turf in July 2008 with local golf course superintendents in attendance to discuss field results and show some of the bentgrass ecotypes that were involved in the salinity greenhouse trial that were brought up from Chisholm TAFE.

Data has also been presented at the Bonville Golf Club in northern NSW in June 2008 as part of their two day seminar and field day which was attended by more than 80 superintendents and trade representatives. Salinity results were also presented at the South Australian Golf Course Superintendents annual general meeting in June 2008.

6. RECOMMENDATIONS

The superior Australian ecotype identified during this project has been the ecotype B22 which exhibited excellent salinity tolerance at all four salt concentrations in the greenhouse study as well as producing a turf of high quality in the field trial. Subsequently, this ecotype has been planted into a new replicated seeded bentgrass trial (Project TU08002) that will assess its attributes as a putting green surface compared to the current and next generation seeded creeping bentgrass cultivars. This trial is being conducted in Victoria, South Australia and New South Wales.

The AGCSA has also planted a nursery area of 32 square metres of this ecotype at the Victorian site of Project TU08002.

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