Ryegrass transitioning in couch turf

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An investigation into ryegrass transitioning in a warm-season turf environment

Final Report

Compiled by K. McAuliffe
Sports Turf Institute Aust.

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Final Report Submitted to Horticulture Australia Limited: April 2010

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Purpose of the report:

The project set out to improve the understanding of ryegrass over-seeding (transitioning) in sports turf; a common practice in Australia, especially at the elite sports stadium level.

Acknowledgement of funding and in-kind support:

This project has been funded by HAL using voluntary contribution from Sports Turf Institute, PGG Wrightsons, Stadiums Queensland and Bayer Environmental Science, with matching funds from the Australian Government. We are also grateful to the NZ Sports Turf Institute and Auckland Council for help with the Auckland trial site, Peter Cronin, David Teale, Michael Finch, Tony Gander and Brett Austin with the set up and maintenance of local trial sites.

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Media Summary

Turf transitioning, or the over-seeding of a warm-season (C4) grass with perennial ryegrass, is a common practice in Australia, especially at high profile sports stadia, on top end golf courses and race tracks. Although over-seeding with ryegrass can enhance winter performance and appearance, the process can be both expensive (venues can use up to 2-Tonne of seed per field over a season) and, more importantly, damaging to the performance of the warm season grass in the long term.

The research project sought to identify current transitioning practice in Australia and elsewhere, as well as provide new information to assist Turf Managers in planning a transitioning program. The project involved four components, namely: a survey of our leading grounds, a comprehensive literature search, field trials involving 5 different sites in 3 separate geographic locations and development of a model for predicting timing of transitioning.

The primary reasons cited for over-seeding are to provide for improved winter recovery after wear, to improve surface stability and to produce a more aesthetically pleasing surface. For the turf production industry over-seeding is seen as a means of enhancing the visual appeal of warm-season turf to the customer, and as such it may offer a marketing edge.

Dealing with a transitional (over-seeded) grass program is without doubt challenging, and we consider that Turf Managers seeking to provide year-round green, high-quality playing conditions are on a “hiding to nothing”. Although the benefits of over-seeding couch or kikuyu with perennial ryegrass are evident, the research clearly illustrates that failure to transition out the ryegrass early can severely damage the underlying couch and in turn cause long term problems.

Getting ryegrass seed established within a couch or kikuyu sward in autumn appears to be relatively straight-forward, provided appropriate timing and sufficient spelling is allocated before field re-use. Our research indicates that a surface ideally needs at least 3 weeks for the ryegrass seedling to mature and handle limited wear. Variables such as timing, the weather conditions (temperature in the main) and usage tend to be more significant to ryegrass establishment than the type of ryegrass used.

Turfgrass managers need an effective and reliable way to transition perennial ryegrass out of over-seeded couch. Recent research suggests that cultural methods of ryegrass removal can work well, but are unreliable and weather dependent. This is particularly apparent in a cooler zone (such as Melbourne or Auckland) and where a wet, cool spring is encountered. Chemical removal methods seem to be the most reliable and effective way to promote a smooth transition in the spring and early summer, albeit will result in discoloured turf for several weeks after treatment.

The research supports past observations that couch is a very poor competitor for light, and that shading from ryegrass in spring/early summer can cause rapid decline in couch rhizome health and ultimately couch recovery. Turf Managers are advised to monitor the condition of couch rhizomes throughout the spring-early summer period.

This study has identified key variables determining the success or otherwise of a transitioning program. We consider that further research is required on several of the key variables, in particular the impact of leaving ryegrass in the sward for an extended period going in to summer.

Technical Summary

Over-seeding C4 grass (couch and kikuyu) sports turf facilities with ryegrass (*Lolium perenne*) is a common practice in Australia, especially at high profile sports stadia, on top end golf courses, race courses and recreational areas. Over-seeding, and the processes of removing the ryegrass post-winter, can be a costly operation (some venues are using greater than 2000kg of ryegrass seed per ha per annum in over-seeding). However, there is minimal research information to assist our curators and others make decisions on the need for and the process associated with over-seeding C4 grasses with ryegrass.

The primary reasons cited for over-seeding sports fields are to provide for improved recovery after wear, to improve surface stability and to produce a more aesthetically pleasing surface. On the down side, ryegrass over-seeding into sports fields can suppress, rather than enhance, the long term performance of the couch or kikuyu. For the turf production industry over-seeding is seen as a means of enhancing the visual appeal of warm-season turf to the customer, and as such it may offer a marketing edge.

Dealing with a transitional (over-seeded) turf management program definitely adds to the complexity of turf management. In fact our research indicates that it is impractical to maintain year-round green, high performance turf in a transitional management situation. Turf Managers at our high profile multi-use venues are on a “hiding to nothing” if a sufficient renovation/transitioning period is not allocated.

Our research concludes that:

- Transitioning programs need to be customised for the local conditions, in particular climate and usage program.
- Climatic modeling can be a useful tool in planning transitioning and in particular identifying dates when the C4 grasses will be actively growing.
- Establishing ryegrass in a C4 grass in autumn is seen as relatively straight-forward, provided a sufficient window of opportunity (research data suggests 3 weeks) is allowed between seeding and re-use.
- Relying on mechanical or natural methods of ryegrass removal from the mixed sward in spring is unpredictable and unreliable. Chemical control measures, albeit discoloring the turf for several weeks, reduce the risks of poor transitioning out of ryegrass.
- Failure to remove ryegrass over late spring/early summer can cause significant longer term damage to the C4 grass. Couch, for example, is a very poor competitor for light, and any shading from ryegrass in spring will result in the energy reserves of couch being depleted and in turn death of the couch plant.
- Operating a dual grass system creates new challenges and problems that we currently have limited knowledge on, such as determining the impact of ryegrass competition on the couch viability in spring and early summer.
- Turf Managers are advised to routinely monitor the health and viability of the C4 grass rhizome system in order to understand the sward dynamics and to help plan transitioning.

It is recommended that further research on ryegrass over-seeding into couch be carried out, to look at the costs and benefits of over-seeding, to further our knowledge on what practices work best and to derive a set of best practice guidelines for over-seeding.

This study represents an important start on what is undoubtedly a complex issue, especially given the numerous variables to be accounted for.

1. Introduction

Over-seeding warm season (C4) sports turf facilities with perennial ryegrass (*Lolium perenne*) is a common practice in Australia, especially at high profile sports stadia, on top end golf courses and recreational areas in commonly C3 dominant growing regions. Over-seeding, and the processes of removing the ryegrass post-winter, can be a costly operation (some venues are using greater than 2 tonne of ryegrass seed per ha per annum in over-seeding). However, there is minimal research, or even professionally prepared recommendations, to assist curators and others make decisions on the need for and the process associated with over-seeding couch with ryegrass.

The primary reasons cited for over-seeding are to provide for improved recovery after wear, to improve surface stability and to produce a more aesthetically pleasing surface. On the down side, ryegrass over-seeding can suppress, rather than enhance, the performance of the couch. For the turf production industry over-seeding is seen as a means of enhancing the visual appeal of warm-season turf to the customer, and as such it may offer a marketing edge.

Dealing with a transitional (over-seeded) turf management program definitely adds to the complexity of turf management. When assessing current practice it would be fair to say that:

- transitioning programs need to be customised for specific site conditions (especially local climate and usage program);
- there is limited scientific information available to guide curators in planning transitioning. elements of transitioning currently seem to be more of an art than a science; and
- operating a dual grass system creates new challenges and problems (that we currently have limited knowledge on e.g. determining the impact of ryegrass competition on the couch rhizome and stolon system).

This HAL-funded study sought to investigate and report on over-seeding (e.g. assistance with the use of a growth regulator) and removal techniques (e.g. chemical and mechanical) of ryegrass in a series of replicated studies. Our overall objective of this research program was to derive a set of best practice guidelines for transitioning, that could be used by practitioners throughout Australia.

Plates 1 & 2. Illustration of damage done to couch cover at two major sports stadiums as a result of shading and competition from ryegrass over early summer.

2. Materials and Methods

2.1 General

The project involved four distinct components:

The initial component was to identify current practice in Australia with respect to ryegrass over-seeding and associated transitioning. To achieve this goal a survey involving leading stadium managers from around Australia was conducted.

The second step in the process was to find out what previous research has been carried out on cool season grass transitioning in a warm season grass. Most of the relevant research stems from the USA, where over-seeding of dormant bermudagrass (couch) golf fairways is common.

The third, and most important, component in our research was to set up trial sites to evaluate some of the critical variables involved in transitioning – both the ryegrass establishment phase and the removal of ryegrass phase. A total of 5 trial sites were used, with 3 sites in Queensland, 1 in Sydney and 1 in Auckland, New Zealand.

A final part of the research was to derive climatic models to help turf managers/curators in planning when to transition. Five different climatic zones were investigated.

2.2 Survey

The survey involved interviewing turf managers from 13 leading sports facilities around Australia, plus 1 facility from Hong Kong.

The venues involved and location were:

Venue	Queensland	NSW	Victoria	Hong Kong
1	GABBA	Sydney Football Stadium	Etihad Stadium	Hong Kong Stadium
2	Suncorp Stadium	ANZ Stadium		
3	Skilled Park	Redfern Oval		
4	Ballymore	North Sydney Oval		
5	QSAC	Newcastle main sports field		
6	Stockland Park			

Detail on the survey questionnaire is provided in Appendix 1.

2.3 Literature review

A comprehensive literature review of work related to transitioning of warm season grasses was carried out. The bulk of research on transitioning has come out of the United States, where over-seeding of dormant Bermuda grass (couch) golf fairways is standard practice in some regions.

Detailed information on the literature review is provided in Appendix 2.

2.4 Trial Sites

Five trial sites were established at (i) Queensland Sports and Athletics Centre (QSAC), Mt Gravatt, Brisbane, QLD; (ii) Redlands United Soccer & Sporting Club (Redlands United), Cleveland, Redland City, QLD; (iii) Moore Park sports complex (Moore Park), Moore Park, Sydney, NSW; (iv) Silverdale Rugby Club, Auckland, New Zealand; (v) DEEDI's Redlands Research Station (RRS), Cleveland, QLD.

Originally a wear trial was to be run at QSAC, trialling multiple treatments (e.g. ryegrass varieties and utilising growth regulators). Plots were established 6th May 2010. However, heavy fleet used the trial area as a thoroughfare to conduct major works on the stadium grandstand resulting in significant damage to two of the four replications (Plate 3). Consequently, the trial was terminated immediately due to the irreversible damage.

Plate 3. The original wear trial, established at QSAC 6th May 2010, incurred damage from heavy traffic over the trial area (photo taken 19th May 2011).

2.4.1 Turf Varieties Used

The existing turf surface at QSAC was 'Wintergreen' (C84-135) a variety of green couch (*Cynodon dactylon*); Redlands United was TifSport™ (Tift 94), a hybrid couch (*C. dactylon* x *C. transvaalensis*); Moore Park was a variety of kikuyu (*Pennisetum clandestinum*), Silverdale was Legend™ couch, and RRS utilised 'AGRD' a hybrid couch as the foundation for the application of ryegrass.

The ryegrass (*Lolium perenne*) varieties trialled within the establishment and removal trials conducted at QSAC, Redlands United and Moore Park were 'Colosseum', 'Fiesta 4', and 'T3'. For the RRS wear experiment a blend of 'Colosseum' and 'Fiesta 4' was used. Ryegrass was supplied by PGG Wrightsons Turf who was a voluntary contributor (VC) to the HAL-funded project.

2.4.2 Experimental Design

Application and removal of ryegrass studies

A completely randomised block design containing 4 replications was adopted for the QSAC (Figure 1), Redlands United (Figure 2) and Moore Park (Figure 3) studies. The blocks were established in a strip, sub-plot design, with individual plots measuring 1.2 x 2.0 m. The total area for each site encompassed 403.2m². A total of 7 application treatments and 6 removal techniques were trialled[1] at each of the 3 sites. They included:

Ryegrass application techniques:

- Control (no ryegrass, no Primo Maxx®) (Control)
- Ryegrass *Colosseum* with Primo Maxx® (A1)
- Ryegrass *Colosseum* without Primo Maxx® (A2)
- Ryegrass *Fiesta 4* with Primo Maxx® (A3)
- Ryegrass *Fiesta 4* without Primo Maxx® (A4)
- Ryegrass *T3* with Primo Maxx® (A5)
- Ryegrass *T3* without Primo Maxx® (A6)

Ryegrass removal techniques carried out at approximately monthly intervals:

- Control (no mechanical removal, no chemical removal) (Control)
- Mechanical removal (lowering of HOC and/or grooming/light scarification) (Mechanical)
- Herbicide removal around the month of August[1] (Chem 1)
- Herbicide removal around the month of September[1] (Chem 2)
- Herbicide removal around the month of October[1] (Chem 3)
- Herbicide removal around the month of November[1] (Chem 4)

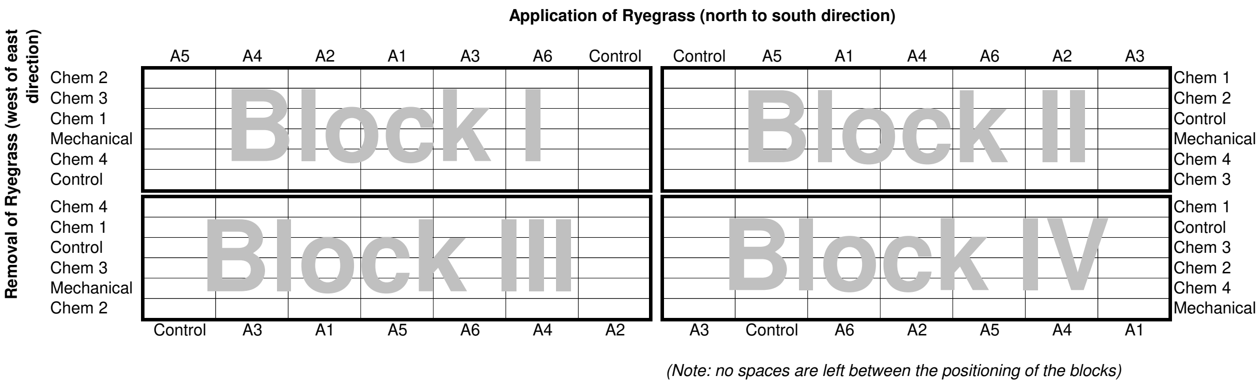
  Note: The months listed above are a guide only with some adjustment made to suit inclement weather and field usage programs. More precise time frames are listed hereafter.

[1] Application dates (months) varied because of inclement weather and unexpected bookings of facilities being. Not all removal techniques were incorporated.

2.4.3 QSAC trial

Plots were marked out and Primo Maxx® (active constituent: 120 g/L trinexapac-ethyl) treatment applied at 1.05 L/ha on 6th May 2011, 3 days prior to seeding. Ryegrass varieties were over-seeded at 7kg/100m² using a Scotts SS-1 Professional Drop Spreader (Plate 7) on 9th May 2011. The trial area was irrigated immediately after the sowing of the rye.

Figure 1. Plot design and layout of the QSAC ryegrass establishment and removal trial.



Application Treatments

- Control (no ryegrass, no Primo Maxx®) (C)
- Ryegrass *Colosseum* with Primo Maxx® (A1)
- Ryegrass *Colosseum* without Primo Maxx® (A2)
- Ryegrass *Fiesta 4* with Primo Maxx® (A3)
- Ryegrass *Fiesta 4* without Primo Maxx® (A4)
- Ryegrass *T3* with Primo Maxx® (A5)
- Ryegrass *T3* without Primo Maxx® (A6)

Removal Treatments

- Control (no mechanical removal, no chemical removal) (C)
- Mechanical removal (lowering of HOC and/or grooming/light scarification) (M)
- Herbicide removal in August (Chem 1)
- Herbicide removal in September (Chem 2)
- Herbicide removal in October (Chem 3)
- Herbicide removal in November (Chem 4)

Application of Treatments

The treatments trialled for the ryegrass removal at the QSAC trial site were as follows:

- Control: No mechanical or chemical removal application for the duration of the study.
- Mechanical: Mechanical removal using a Graden® GS04 verticutter (3mm blades, 25mm spacings) (Plate 8), set to a depth of 15 mm was used on 30th August 2011.
- Chem 1: no herbicide application was applied due to on- going field usage at QSAC.
- Chem 2: Tribute® (active constituent: 22.5 g/L Foramsulfuron) at 1.5L/ha was applied 28th September 2011.
- Chem 3: Tribute® as per above was applied 11th November 2011.
- Chem 4: Application withheld because of the lack of ryegrass remaining.

Assessments

Subjective quality [0 (= worst) to 9 (= best); 6 (= acceptable)] was assessed in the field, whereas ryegrass cover (%), and turf cover (% green vegetative colour) were assessed in the laboratory using SigmaScan Pro Software (v. 5.0, SPSS, Inc., Chicago, IL 60611). This was done by assessing individual digital photos taken of each sub- plot on the day of testing. To determine the test area to analyse, a 0.25m² quadrat (Plate 4) was randomly positioned within each sub-plot when assessments were taken in the field or where a digital photo was to be taken.

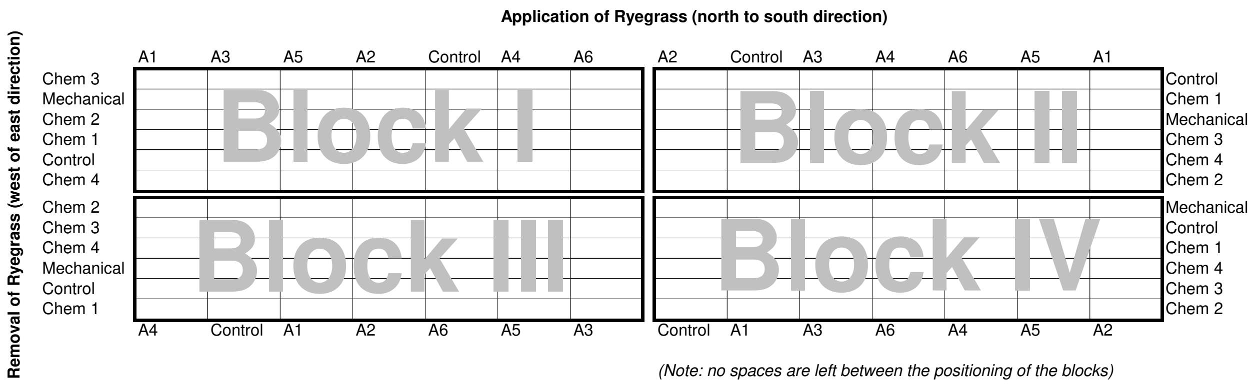
Plate 4. A 0.25m² quadrat used to identify the composition of each plot/subplot.

Assessments at the QSAC site were undertaken on 8th June, 19th August (Blocks 1 and 2 only, because of tents and activities from a sports carnival being located on Blocks 3 and 4), 30th August (before the mechanical treatment), 28th September, 11th November and 21st December 2011.

2.4.4 Redlands United trial

A higher rate of Primo Maxx®, 2 L/ha, was applied to the growth regulator treatment plots on 29th April 2011. On the 11th May 2011 the trial site was scarified using a Ryan® Mataway® slicer/dethatcher machine (Plate 8) prior to seeding. Three ryegrass varieties were sown into the turf using a Scotts SS-1 Professional Drop Spreader. The application rate for all three varieties was approximately 6kg/100m². The trial area was irrigated immediately after the sowing of the rye.

Figure 2. Plot design and layout of the Redlands United trial.



Application Treatments

- Control (no ryegrass, no Primo Maxx®) (C)
- Ryegrass *Colosseum* with Primo Maxx® (A1)
- Ryegrass *Colosseum* without Primo Maxx® (A2)
- Ryegrass *Fiesta 4* with Primo Maxx® (A3)
- Ryegrass *Fiesta 4* without Primo Maxx® (A4)
- Ryegrass *T3* with Primo Maxx® (A5)
- Ryegrass *T3* without Primo Maxx® (A6)

Removal Treatments

- Control (no mechanical removal, no chemical removal) (C)
- Mechanical removal (lowering of HOC and/or grooming/light scarification) (M)
- Herbicide removal in August (Chem 1)
- Herbicide removal in September (Chem 2)
- Herbicide removal in October (Chem 3)
- Herbicide removal in November (Chem 4)

Application of Treatments

The treatments for ryegrass removal used at the Redlands United trial site were as follows:

- No mechanical or chemical removal application for the duration of the study.
- Mechanical: Mechanical removal using a Graden® GS04 verticutter (3mm blades, 25mm spacings), set to a depth of 15 mm was used on 29 August 2011.
- Chem 1: no herbicide application was applied for this treatment.
- Chem 2: Tribute® at the rate of 1.5 L/ha was applied 30 September 2011.
- Chem 3: Tribute® as per above was applied 2 November 2011.
- Chem 4: Tribute® as per above was applied 20 December 2011.

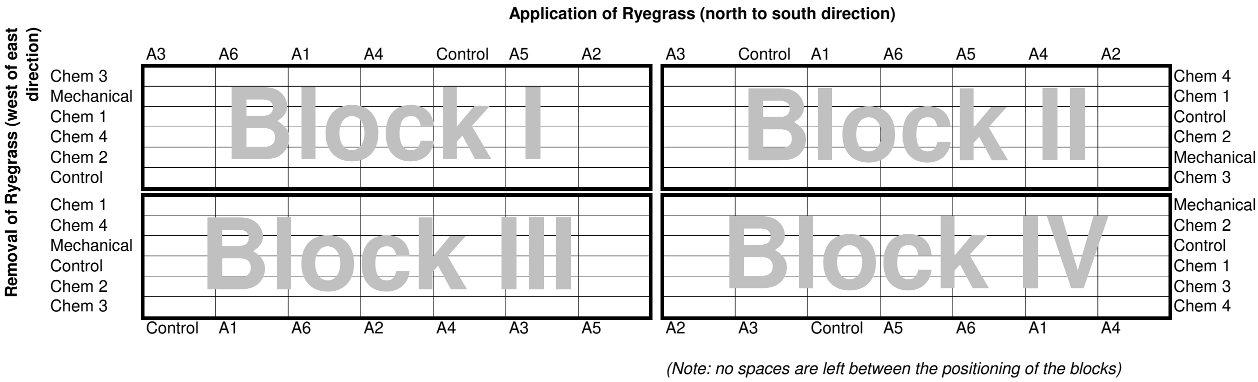
Assessment

Turf quality and percentage ryegrass cover was measured using the same methodology as QSAC, with measurements undertaken on 8th June, 12th August, 29th August (before the mechanical treatment), 28th September, 28th October, 8th December 2011 and 3rd February 2012.

2.4.5 Moore Park trial

Plots were marked out and Primo Maxx® at 1.05 L/ha was applied to the growth regulator treatment plots on 11th April 2011. The following day a light scarification was carried out using a hitched scarification unit (Plate 15) with vegetative material swept up by an Amazone® Groundkeeper (Plate 16). The three ryegrass varieties were hand-sown at a rate of 6kg/100m². The trial area was irrigated immediately after the sowing of the rye.

Figure 3. Plot design and layout of the Moore Park trial.



Application Treatments
- Control (no ryegrass, no Primo Maxx®) (C)
- Ryegrass *Colosseum* with Primo Maxx® (A1)
- Ryegrass *Colosseum* without Primo Maxx® (A2)
- Ryegrass *Fiesta 4* with Primo Maxx® (A3)
- Ryegrass *Fiesta 4* without Primo Maxx® (A4)
- Ryegrass *T3* with Primo Maxx® (A5)
- Ryegrass *T3* without Primo Maxx® (A6)

Removal Treatments
- Control (no mechanical removal, no chemical removal) (C)
- Mechanical removal (lowering of HOC and/or grooming/light scarification) (M)
- Herbicide removal in August (Chem 1)
- Herbicide removal in September (Chem 2)
- Herbicide removal in October (Chem 3)
- Herbicide removal in November (Chem 4)

Application of Treatments

The treatments trialled for ryegrass removal at the Moore Park trial site were as follows:

- Control: No mechanical or chemical removal application for the duration of the study.
- Mechanical: Mechanical removal using a verticutter and Amazone® Groundkeeper on 21 October 2011.
- Chem 1: no herbicide application was applied for this treatment.
- Chem 2: Destiny® (active constituent: 100 g/kg Iodosulfuron-Methyl-Sodium) at 150g/ha with Hasten 1% v/v and a water rate of 395L/ha was applied 14 October 2011.
- Chem 3: Destiny® as per above was applied 2 November 2011.
- Chem 4: Destiny® as per above was applied 8 December 2011.

Assessment

Turf grass quality and percentage ryegrass cover was measured using the same methodology as QSAC and Redlands United. Testing was done on 18th May, 24th June, 1st August, 29th September, 27th October, 6th December 2011 and 8th February 2012.

2.4.6 Silverdale Rugby Club, Auckland Trial site

The trial involved setting up 36 plots within the dead ball area of the number 1 rugby ground. Layout and treatment application commenced soon after the Rugby World Cup, which saw the ground used as a training venue.
The trial incorporated 3 treatments and 4 replicates, with the treatments being to methods of ryegrass removal (chemical and mechanical), plus a control (no ryegrass removal. Mechanical control involved a combination of scarifying and close-mowing. Chemical control involved using Hussar (iodosulfuron) product at label rate.
Three ryegrass removal dates were scheduled, namely: early November, end of November and early January.

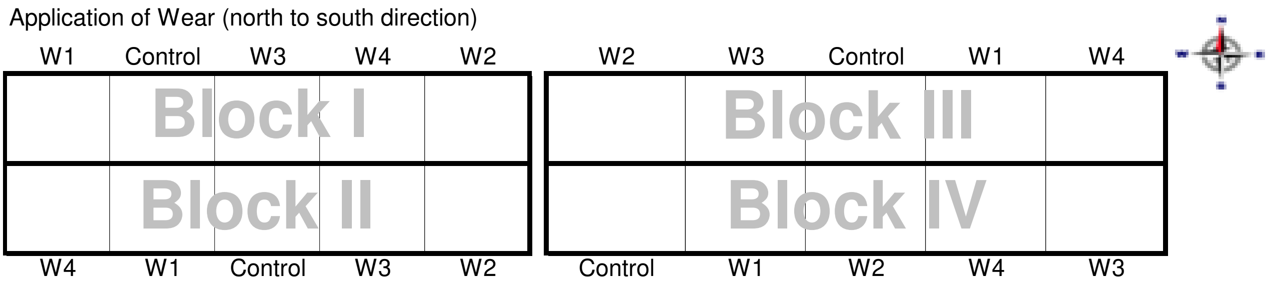
Assessments
Performance of the plots was determined by quadrat measurement of botanical composition and by scoring the overall performance (appearance, quality, etc) of the plot using a scale of 1 to 5.

Plate 5. The Silverdale trial site.

2.4.7 Wear study – Redlands Research Station

A completely randomised block design with 4 replications was marked out on an already established turf (cv. 'AGRD') growing on a sand carpet (70 mm USGA spec. sand on top of krasnozem red clay) at RRS. Each plot measured 1.2 x 5 m with the total trial area covering 180m² (Figure 4). A ryegrass mixture of 1.25 kg 'Colosseum' and 2.5 kg 'Fiesta 4' per 100m² was applied on 27th May 2011 using a Scotts SS-1 Professional Drop Spreader. The plots were irrigated immediately after the application of ryegrass.

Figure 4. Plot design and layout of the RRS wear trial.



Application of treatments

Wear treatments were applied at weekly intervals using the DEEDI Redlands Traffic Simulator (Plate 3) commencing 7 days after sowing the ryegrass. A total of 6 runs of the Redlands Traffic Simulator as per Roche et al. 2009 were applied during each wear application. This amount roughly equates to twelve games of touch football. Wear treatments as listed below only had one application of wear applied throughout the duration of the study:

- Control (W0) – no wear;
- Wear applied one week post sowing of ryegrass (W1) – 3rd June 2011;
- Wear applied two weeks post sowing of ryegrass (W2) – 10th June 2011;
- Wear applied three weeks post sowing of ryegrass (W3) – 17th June 2011; and
- Wear applied four weeks post sowing of ryegrass (W4) – 24th June 2011.

Plate 6. DEEDI Redlands Traffic Simulator used to impose wear to the ryegrass.

Assessment

Assessments including subjective quality [0 (= worst) to 9 (= best); 6 = acceptable], subjective ryegrass cover (%), and quantitative ryegrass and turf cover (i.e. % green vegetative colour) using SigmaScan Pro Software (v. 5.0, SPSS, Inc., Chicago, IL 60611) were taken on 6th , 13th , 20th and 27th June 2011. The latter testing dates were 3 days after the application of wear treatments W1, W2, W3 and W4 respectively. A quadrat was randomly positioned within each plot on each testing date to determine the measurable area which encompassed $0.25 m^2$.

Data Analysis

Quantitative ryegrass and turf cover was measured using SigmaScan Pro for Windows Version 5.0 (SPSS, Inc., Chicago, IL 60611). The latter and remaining data (e.g. percentage ryegrass cover and subjective turfgrass quality) was then analysed via the standard Analysis of Variance (ANOVA) using GenStat for Windows Version 14.2 (VSN International Ltd, UK). Comparisons of means were made using Fischer's protected Least Significant Difference at a 5% (P=0.05) probability level. Line graphs were constructed using Microsoft Office Excel for Windows Version 2003.

2.4.8 Turf Maintenance

QSAC turfgrass was routinely mown at a 20 mm height of cut by the Turf Manager, David Teale. Maintenance of the Moore Park surface was coordinated by Tony Gander, Coordinator Centennial Park and Moore Park Trust, Sydney. The Redlands United fields were maintained by Brett Austin, who is the turf manager and Club President at Redlands United Soccer. The Silverdale trial was maintained by Dave Ball from Citycare Services. At RRS the wear trial was maintained by Jon Penberthy, DEEDI Experimentalist. All sites had irrigation and fertiliser applied based on their routine management practices.

Plate 7. Scotts SS-1 Professional Drop Spreader used to apply the ryegrass to the turf at the QSAC, Redlands United and RRS trials.

Plate 8. Graden® GS04 verticutter used to impose mechanical treatments at QSAC and Redlands United. Insert showing the style of tungsten carbide tip blade used with the Graden® verticutter..

2.5 Climate modelling for transitioning

Climate modelling in relation to couch growth was undertaken in order to derive information that could aid Turf Managers plan a transitioning calendar. Two different couch growth models were derived, namely:

- **Model A** - Based on research information from the USA that proposes couch growth (green up) occurs when minimum diurnal temperature remains above 60° F (approx 15°C) for several days in the spring. The model proposes that significant couch growth is promoted when the daily minimum exceeds 15° C for 5 consecutive days. At the other end of the season, it is assumed couch growth is limited when temperature falls below 15°C for 5 consecutive days.
- **Model B** - Based on feedback from local stadium managers (pers. comm. Mal Caddies), that observable couch growth occurs when the combined maximum daily and minimum daily temperature exceeds 40°C. The model sums the recorded maximum and minimum daily temperatures, and assumes significant couch growth occur when the sum exceeds 40°C for 5 or more consecutive days. Conversely, when the combined temperature falls below 40°C growth will be inhibited.

To test the models the last 11 years of temperature data from five locations (Brisbane, Gosford, Sydney, Melbourne and Auckland City) was evaluated.
In addition to the desktop analysis of data stadium managers in the respective regions were asked if their observations supported the model. Information from the initial transitioning survey was also referred to.

This survey was backed up by a study of the couch-ryegrass dynamics over the spring-early summer at a major sports field venue in Brisbane. This work involved monitoring the health of couch rhizomes and stolons over the spring/early summer period in order to better understand the spring transition from ryegrass to couch and to match change to climatic data.
Fifteen plugs (3 plugs from 5 different locations) were collected fortnightly from the start of September to mid-December in order to check on botanical composition and rhizome health.

3. Results

3.1 Survey of transitioning practice at major stadiums

Information provided from the survey (see Appendix 1), showed that there is a wide range in views and current practice for transitioning among stadium curators. Some of the more relevant points from the survey include:

- Given the multi-use requirement of most venues, there is limited time and opportunity available to get ryegrass established in the autumn and for couch to recover in the spring. Typically no more than two weeks is available in autumn between ryegrass seeding and re re-use.
- Although more time is generally available for spring transitioning (3 weeks on average), the majority of curators consider that a greater time window is needed in spring to achieve satisfactory couch re-establishment (estimated to be an average of eight weeks for recovery from the start of transitioning).
- Stadiums are using high seeding rates to get ryegrass established, with an average of 500 kg per hectare of seed used.
- The use of growth regulators to help with ryegrass establishment was mixed, with one third of grounds using a growth regulator prior to over-seeding.
- The use of chemicals to remove ryegrass in the spring time was also varied, with just under 50% of venues using a selective herbicide to remove ryegrass.
- The majority of curators rated the success of the 2011 transitioning program as average to poor, citing unpredictable weather conditions as the major challenge.
- A variety of different ryegrass cultivars are used for over-seeding, with curators having their own reasons for selecting a specific cultivar.

As an overall assessment of the survey returns, it is apparent that stadium managers are currently relying heavily on hearsay information or “gut feel” for planning transitioning programs. It is also apparent that stadium managers come under considerable pressure with scheduling transitioning, given the common requirement to maintain a year-round green, high performing surface.
There would appear to be a definite need for quality, independent research information to help guide curators in this important management operation.

3.2 Literature review

The bulk of research on transitioning has come out of the United States, where over-seeding of dormant Bermuda grass (couch) golf fairways is standard practice in some regions.
The following outlines key points gleaned from the literature review. For more detailed information refer to Appendix 2.

What is transitioning, where is it carried out and for what reasons?

Transitioning refers to the seeding, and later removal, of one grass into and from another grass, generally a cool season grass is over-seeded into a warm season (C4) grass species.
Transitioning is practiced around the world, particularly in areas with a Mediterranean climate, including Southern USA, parts of Southern Europe, South America, South Africa, Central Asia and Australasia. Over-seeding is done into both kikuyu and couch sports fields in Australia and New

Zealand. In addition to sports fields, transitioning is done on (kikuyu) race tracks, and golf course fairways. Some turf producers over-seed in order to provide a more attractive, green sod for winter or early spring plantings.

There are mixed reports on the benefits afforded by transitioning. The main benefit of over-seeding is deemed to be improved appearance of the turf over the cooler months, when the couch or kikuyu moves into a dormant, off-colour condition. Whereas some research shows minimal if any improvement in wear tolerance with over-seeding, other research indicates over-seeding can significantly increase the amount of traffic while maintaining acceptable turf cover. There is a general opinion among sports field managers in Australia that over-seeded couch is more wear-tolerant than dormant couch alone. Whether this is the case or not over-seeding is most likely to help winter divot recovery.

Timing of seeding

The optimum time for over-seeding is late autumn when the C4 grass growth has slowed due to lower temperatures, but early enough that temperature is still favorable for germination of the ryegrass. Seeding too early can see the ryegrass struggle to compete against the couch, and will increase the risk of disease (pythium and brown patch). Seeding too late and cold weather can inhibit ryegrass establishment. Of course a key factor in seeding date is the availability of any window in the sporting program. Mainly for this reason many of our sports stadiums are over-seeded earlier than would be deemed desirable.

Over-seeding too early can have a negative impact on the health of the over-wintering couch. Couch accumulates energy reserves over the growing season, and sufficient time (100 days of active growth advised) is needed to build up sufficient reserves to carry couch through the winter/spring.

Seeding methods and rates

When over-seeding it is considered important to provide the ryegrass seed with soil contact and to reduce early competition. Generally this is aided by close mowing and verticutting. In denser couch swards more intensive treatments may be required. Specialist seed drills are considered to help achieve good seed-soil contact.

Over-seeding rates used around the world can be surprisingly high, with rates in excess of 600 kg/ha common. Some practitioners adopt sequential over-seeding throughout the autumn/winter sports season (often sowing after each match).

Early management of over-sown turf is critical. Recommended practice includes using a starter fertiliser at sowing, maintaining consistent root zone moisture, monitoring for disease and leaving a window preferably of at least 3 weeks prior to play.

Turf species and cultivars used to over-sow

Annual ryegrasses were traditionally used for over-seeding, but are generally considered too coarse and upright for high quality turf. Perennial ryegrass is the main species now over-sown on sports fields. Turf Managers are faced with choosing between winter-active cultivars, summer-active cultivars, high or low endophyte cultivars and perennial or annual cultivars.

Researchers have noted that cultivars with less tiller density and a more upright growth habit transition out better than the newer heat-, disease-, and drought-tolerant varieties of perennial ryegrass The newer varieties tend to survive later into spring or summer which, while good on one hand, creates additional challenges with spring transitioning back to couch.

Spring transitioning, mechanisms of dormancy break and conditions needed for couch recovery

For couch to break dormancy and begin budding it requires temperature (air and soil) to be above a minimum value (various figures have been cited, with a day minimum temperature of around 15°C being regarded as a threshold). Depending on the temperature, complete green-up may take in the order of 6 weeks.

Spring green-up of couch is accompanied by a rapid dieback of old stolons and rhizomes and production of new roots and shoots. Couch is vulnerable to low temperatures, herbicides and competition from winter grasses during the transition period. Shade (either from structures or the over-seeded grass) has a major impact on spring transitioning of couch by weakening the plant (reducing energy reserves) and by limiting soil warming.

Spring transitioning practice – what choices?

It is an important and well-known fact that over-seeded ryegrass aggressively competes with the couch for resources in the spring (especially light). As such couch health can be badly compromised by ryegrass persevering in spring.

The choices for spring transitioning are to use cultural practices (scarifying/close mowing), use chemicals, or a combination of both. A gradual transition back to couch would be ideal if it could be achieved, especially for our heavily-used stadiums where there is no window to take out the ryegrass and no tolerance of a discolored surface. However experience has demonstrated that to achieve natural or cultural transitioning is challenging and unpredictable, given the vagaries of weather.

Cultural transitioning is generally achieved via:

- Reducing mowing height,
- Avoiding spring fertilization until 2 to 3 weeks after spring green-up.
- Holding back on moisture
- Verticutting

Research points to a need for chemical application for effective transitioning. Chemical application offers the most predictable means of controlling the process and minimizing any damage. There are several chemicals that can selectively remove ryegrass without affecting the health of the couch. These products include slow transitioning chemicals such as Kerb, and faster transitioning products such as the sulfonylureas, (trade names include Revolver, Monument and Tribute).

Summary

Ryegrass over-seeding into couch or kikuyu swards is carried out largely to improve aesthetics of the playing surface. This is particularly significant with major stadiums in NSW and Southern Queensland.

There is no doubt that over-seeding can have a negative effect on the health of the warm season grass. Failure to acknowledge this fact and to take an appropriate program is likely to result in loss of couch cover and an ever-increasing reliance on ryegrass to provide cover.

3.3 Ryegrass trials

3.3.1 QSAC Site

The 'Colosseum' treatments (A1 and A2) were first to establish of the three ryegrass cultivars trialled (Plate 9a). However, no difference was observed between the two growth regulator treatments (with or without Primo Maxx®). Throughout the duration of the trial the Colosseum plots had a better density, whereas Fiesta 4 (A3 and A4) produced a darker green colour.

The percentage green values recorded throughout the duration of the study varied considerably, largely in accordance with the moisture availability to the turf (Figure 5). The minimum percentage green recorded was 54.1% in August 2011, the mean value was 82.8% and the maximum value of 98.7% was observed on 8 June 2011 in the control plot.

Initially a good strike of ryegrass was observed within the trial, and rye growth continued under favourable conditions until early winter (Plate 9b). Percentage ryegrass significantly declined throughout the duration of the trial, but this decline was attributed to a combination of high wear (sports field usage and foot traffic e.g. Plate 9c) and lack of irrigation, more so than the imposed ryegrass removal treatments.

The mean minimum, average and maximum percentage ryegrass cover observed throughout the study for the control plots of 'Colosseum', 'Fiesta 4' and 'T3' were 7.1% (28th September 2011), 47.0% and 70.1% (30th August 2011) respectively (Figure 6). Only two ryegrass removal treatments were used with the QSAC study, namely 'Mechanical' and 'Chem 2' treatments applied on 30th August and 28th September 2011, respectively. Following the Mechanical treatment the percentage ryegrass cover decreased by 38.0% in September, but then recovered by a further 13.5% in November to represent 19.7% of the turf sward. However, between August and September, when irrigation to the trial site and surrounding area was switched off at QSAC, ryegrass cover of the control plots decreased by a staggering 63.1%. The application of 'Chem 2' (Tribute®) visually looked to have done a good job at removing the bulk of the ryegrass following an inspection on 11th November 2011 (Plate 10). However, prior to the herbicide application on 28th September 2011, the mean percentage ryegrass present within the 'Chem 2' plots was only 3.5%. During the November inspection the 'Chem 2' plots contained a mean percentage ryegrass cover of only 2.6%. Results show that no recovery of ryegrass occurred in the chemically-treated plots, unlike the other untreated plots, which had an average increase in ryegrass cover of 12.1% (Table 1).

Subjective turf grass quality ratings undertaken throughout the QSAC study saw on average a minimum turf quality rating of 4.4, a mean rating of 6.1 and maximum rating of 7.5 (Figure 7). Between June and September 2011 the turf grass quality of all plots gradually declined. It took until November before all plots were rated as acceptable.

The decline in turf grass quality, like that of percentage ryegrass cover, could be directly linked to field usage and the lack of irrigation. While assessing the trial on 11th November 2011, ryegrass cover was just below 20% and turf quality was around 6 (acceptable).

Figure 5. Percentage green cover of application treatments A1 to A6 vs. control of the QSAC trial as observed on 8th Jun., 19th Aug., 30th Aug., 28th Sep. and 11th Nov. 2011. (LSD (P=0.05)).

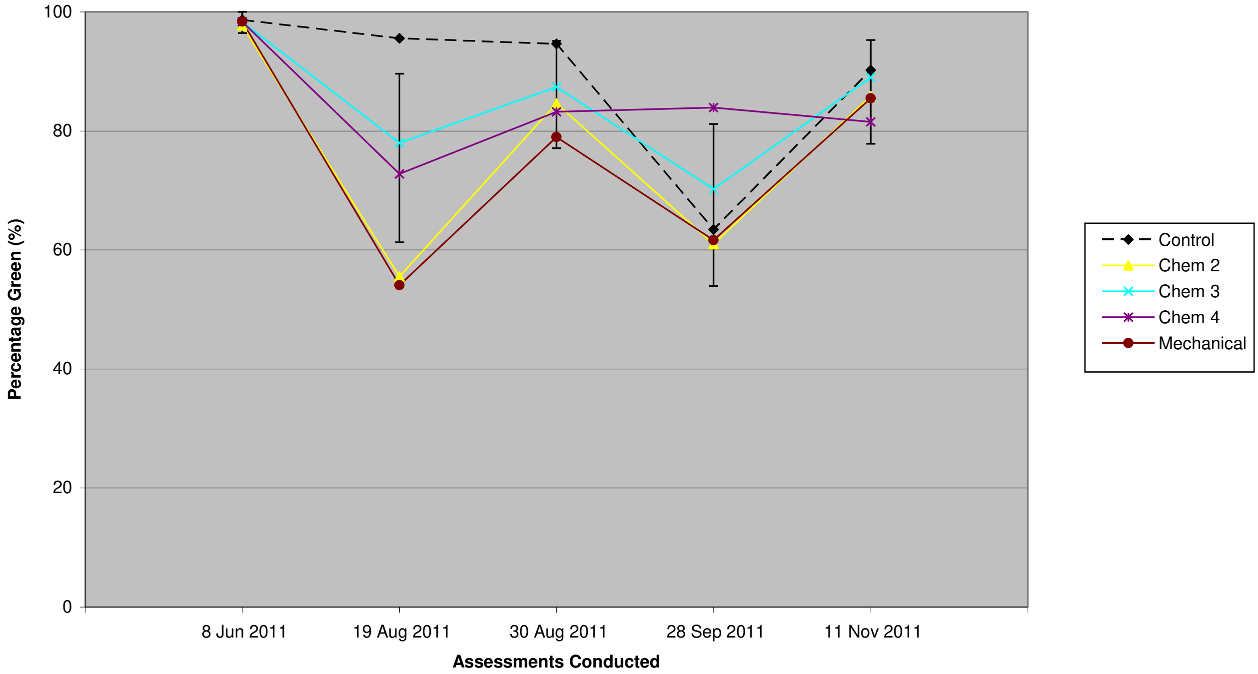


Figure 6. Percentage ryegrass cover of application treatments A1 to A6 vs. control of the QSAC trial as observed on 8th Jun., 19th Aug., 30th Aug., 28th Sep. and 11th Nov. 2011. (LSD (P=0.05)).

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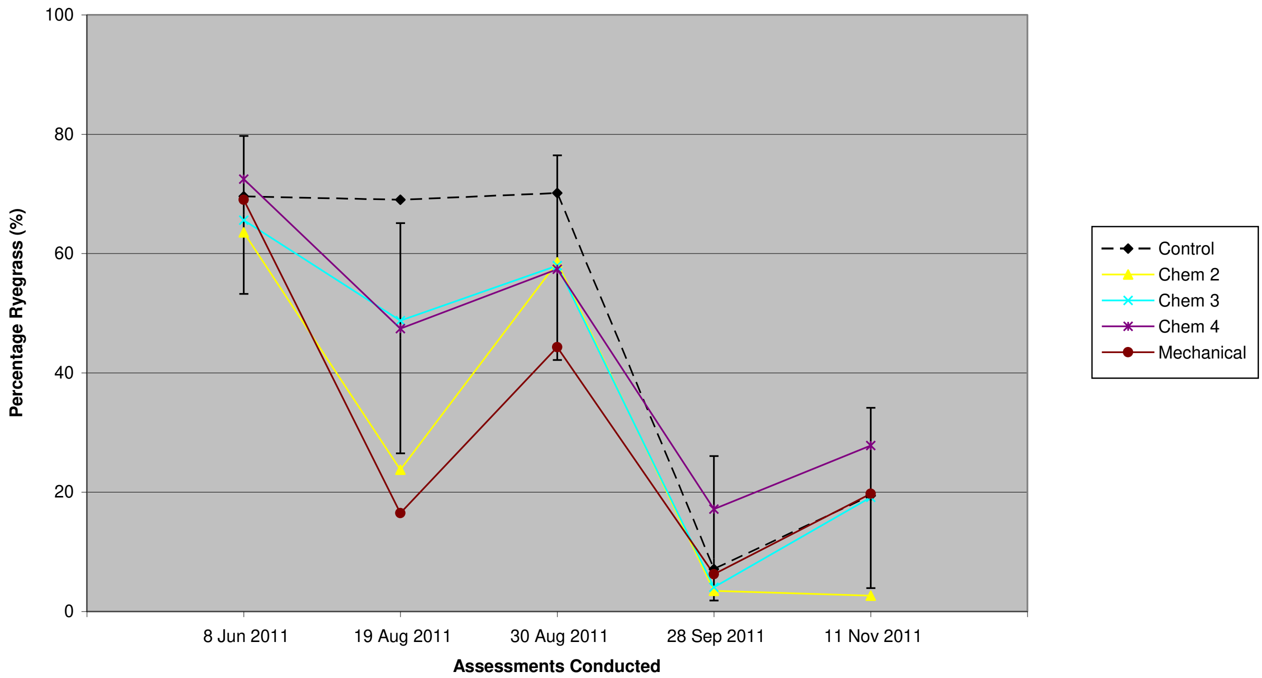


Figure 7. Turfgrass quality ratings [0 (= worst) to 9 (= best); 6 = acceptable] of application treatments A1 to A6 vs. Control of the QSAC trial as observed on 8th Jun., 19th Aug., 30th Aug., 28th Sep. and 11th Nov. 2011. (LSD (P=0.05)).

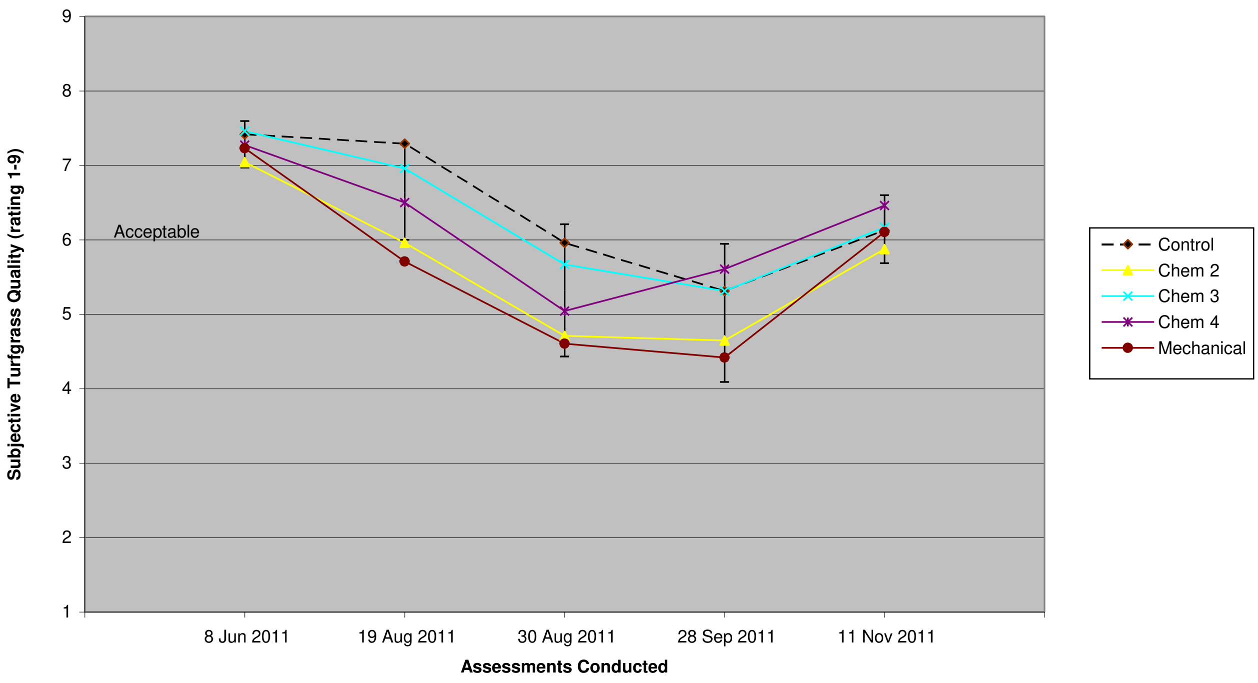


Table 1. Summary of % green, % ryegrass and turfgrass quality collected from the QSAC trial site on 8th June to 11th November 2011. Further detail is provided in Appendix 3.

		SigmaScan Data - Percentage Green (%)					Subjective Assessment - Percentage Ryegrass (%)					Subjective Assessment - Turfgrass Quality (1-9)				
		8 Jun 2011	19 Aug 2011	30 Aug 2011	28 Sep 2011	11 Nov 2011	8 Jun 2011	19 Aug 2011	30 Aug 2011	28 Sep 2011	11 Nov 2011	8 Jun 2011	19 Aug 2011	30 Aug 2011	28 Sep 2011	11 Nov 2011
A1	Control	99.8	98.5	97.7	70.9	90.4	90.0	96.5	95.7	16.3	37.0	7.6	7.8	7.0	6.0	6.4
	Chem 1	98.7	97.8	85.0	65.5	85.0	78.2	95.0	75.0	19.5	38.0	7.3	7.8	6.3	4.8	6.0
	Chem 2	98.2	60.6	87.0	66.2	80.7	78.0	47.5	80.7	7.0	0.0	7.1	6.3	5.1	4.4	5.5
	Chem 3	99.2	92.9	85.6	70.4	86.0	68.0	90.0	57.0	7.5	42.5	7.4	7.0	5.6	5.5	6.3
	Chem 4	99.2	89.8	83.9	89.1	81.0	95.8	72.5	64.2	40.0	36.3	7.5	7.3	5.4	5.8	6.5
	Mechanical	99.4	85.4	78.5	62.7	88.9	83.3	47.5	59.5	21.3	23.8	7.5	6.3	5.4	4.8	6.0
A2	Control	99.4	94.9	96.5	54.4	91.9	93.7	87.5	85.8	1.3	16.3	7.9	7.3	6.3	5.1	6.1
	Chem 1	98.7	99.2	88.6	61.4	91.4	94.7	97.5	74.5	26.3	35.0	8.1	7.8	6.3	4.8	6.3
	Chem 2	98.1	50.3	85.9	60.2	86.1	92.0	22.5	66.2	1.3	10.0	7.6	6.0	4.9	4.5	5.9
	Chem 3	99.3	52.8	84.4	70.3	86.3	88.7	45.0	64.5	0.5	8.3	7.9	7.3	5.6	5.1	6.3
	Chem 4	99.3	72.0	84.8	79.7	74.4	89.2	50.0	65.0	15.0	30.0	7.9	6.8	5.1	5.8	6.4
	Mechanical	99.5	38.2	79.8	64.6	77.5	93.2	2.5	61.3	2.5	35.8	8.0	5.3	4.3	4.3	6.3
A3	Control	98.9	98.3	96.2	61.2	91.9	50.0	52.5	66.0	2.5	26.2	7.1	7.0	6.1	5.3	6.0
	Chem 1	98.0	98.3	90.7	66.9	96.5	27.5	40.0	62.5	6.3	27.8	7.1	7.3	6.1	4.6	6.4
	Chem 2	97.5	46.5	89.8	64.6	83.5	52.5	10.0	60.0	10.0	2.8	7.0	5.5	5.5	4.9	6.1
	Chem 3	98.4	91.9	95.1	63.0	94.5	62.0	50.0	65.0	2.5	12.8	7.4	6.5	6.4	5.4	6.4
	Chem 4	98.0	61.3	79.9	79.0	80.2	53.8	10.0	47.5	15.0	17.5	7.0	6.0	5.1	5.8	6.0
	Mechanical	97.8	47.3	82.2	57.3	84.6	53.8	20.0	39.2	1.3	5.5	6.8	6.0	4.9	4.6	6.0
A4	Control	98.3	91.9	95.7	63.2	95.0	43.8	35.0	63.8	6.3	21.2	7.5	7.3	5.9	5.3	6.5
	Chem 1	98.1	96.7	85.0	66.1	82.9	46.2	45.0	57.5	5.0	11.7	7.3	7.5	5.5	4.9	6.1
	Chem 2	97.9	60.7	81.9	55.7	89.5	42.5	10.0	43.8	1.3	2.5	7.1	6.0	4.5	4.6	5.9
	Chem 3	98.1	74.2	86.8	69.3	92.4	47.5	30.0	47.5	10.0	23.7	7.6	7.3	5.6	4.9	6.1
	Chem 4	97.7	78.8	89.7	88.3	97.9	63.8	52.5	56.2	11.3	33.0	7.4	6.8	5.8	5.9	7.0
	Mechanical	98.6	48.9	81.3	63.9	94.0	51.2	7.5	42.5	5.0	16.7	7.5	5.8	4.6	4.3	6.1
A5	Control	97.8	94.4	91.4	76.8	86.5	71.2	77.5	57.5	13.8	11.2	7.3	7.3	5.8	5.5	6.3
	Chem 1	97.5	94.9	88.1	64.8	78.2	51.2	89.0	62.5	21.3	27.5	6.9	7.3	5.6	5.0	6.1
	Chem 2	96.2	58.5	75.6	57.2	81.5	48.8	30.0	38.0	1.3	0.0	6.5	6.0	3.5	4.6	5.9
	Chem 3	96.6	75.6	87.7	73.2	85.2	56.2	25.0	63.0	2.5	12.5	7.1	7.0	5.4	5.6	6.0
	Chem 4	97.6	68.2	83.2	84.8	77.0	70.0	50.0	53.8	16.8	37.5	6.9	6.0	4.5	5.5	6.8
	Mechanical	97.4	45.4	79.0	60.8	81.7	61.2	17.5	41.2	6.3	27.0	7.0	5.5	4.4	4.3	6.1
A6	Control	97.9	95.3	90.2	54.1	85.6	68.8	65.0	52.0	2.5	4.5	7.1	7.3	4.8	4.8	5.5
	Chem 1	97.0	94.0	90.0	66.0	89.1	53.8	50.0	73.5	11.8	12.5	7.0	7.0	5.9	4.9	5.9
	Chem 2	98.3	56.7	87.6	61.9	93.7	67.5	22.5	62.5	0.0	0.5	6.9	6.0	4.8	4.9	6.0
	Chem 3	98.2	80.5	84.8	75.1	89.6	71.2	52.5	50.8	1.3	15.0	7.4	6.8	5.4	5.4	6.0
	Chem 4	98.5	66.6	77.6	82.5	78.7	62.2	49.5	57.5	5.0	12.5	7.0	6.3	4.4	5.0	6.1
	Mechanical	97.5	59.3	72.9	60.5	86.0	71.3	4.0	22.0	1.3	9.5	6.6	5.5	4.1	4.4	6.1
Control	Control	90.7	85.5	77.3	68.1	91.1	0.0	0.0	0.0	0.0	0.0	6.3	6.0	4.4	5.1	5.8
	Chem 1	87.9	82.4	78.6	79.2	79.2	0.0	0.0	0.0	0.0	0.0	6.4	6.3	5.1	5.6	6.3
	Chem 2	80.3	40.9	80.6	65.8	89.2	0.0	0.0	0.0	0.0	0.0	5.8	5.3	4.4	5.3	6.3
	Chem 3	88.1	59.0	82.0	60.9	92.0	0.0	0.0	0.0	0.0	0.0	6.0	5.3	4.9	4.9	5.8
	Chem 4	90.4	57.2	74.7	81.9	90.9	0.0	0.0	0.0	0.0	0.0	6.1	5.3	4.1	5.0	6.0
	Mechanical	83.6	46.7	77.0	67.3	92.6	0.0	0.0	0.0	0.0	0.0	5.8	5.8	4.5	4.8	6.1
LSD (0.05)		*3.6*	*28.3*	*18.0*	*27.2*	*17.4*	*26.5*	*38.6*	*34.3*	*24.2*	*30.2*	*0.6*	*1.3*	*1.8*	*1.9*	*0.9*

Plates 9 a-d. Photos taken at the QSAC trial site on (a) 19th May 2011 showing the 'Colosseum' plots (A1 and A2) with better early establishment, (b) 8th June 2011 the ryegrass plots all growing well, (c) 30th August 2011 the quality of the turf and ryegrass declining following high wear, divoting (shot put) and foot traffic, and (d) 28th September 2011 showing little to no ryegrass present due to the irrigation having to be shut off to undertake major works on the surrounding grandstands.

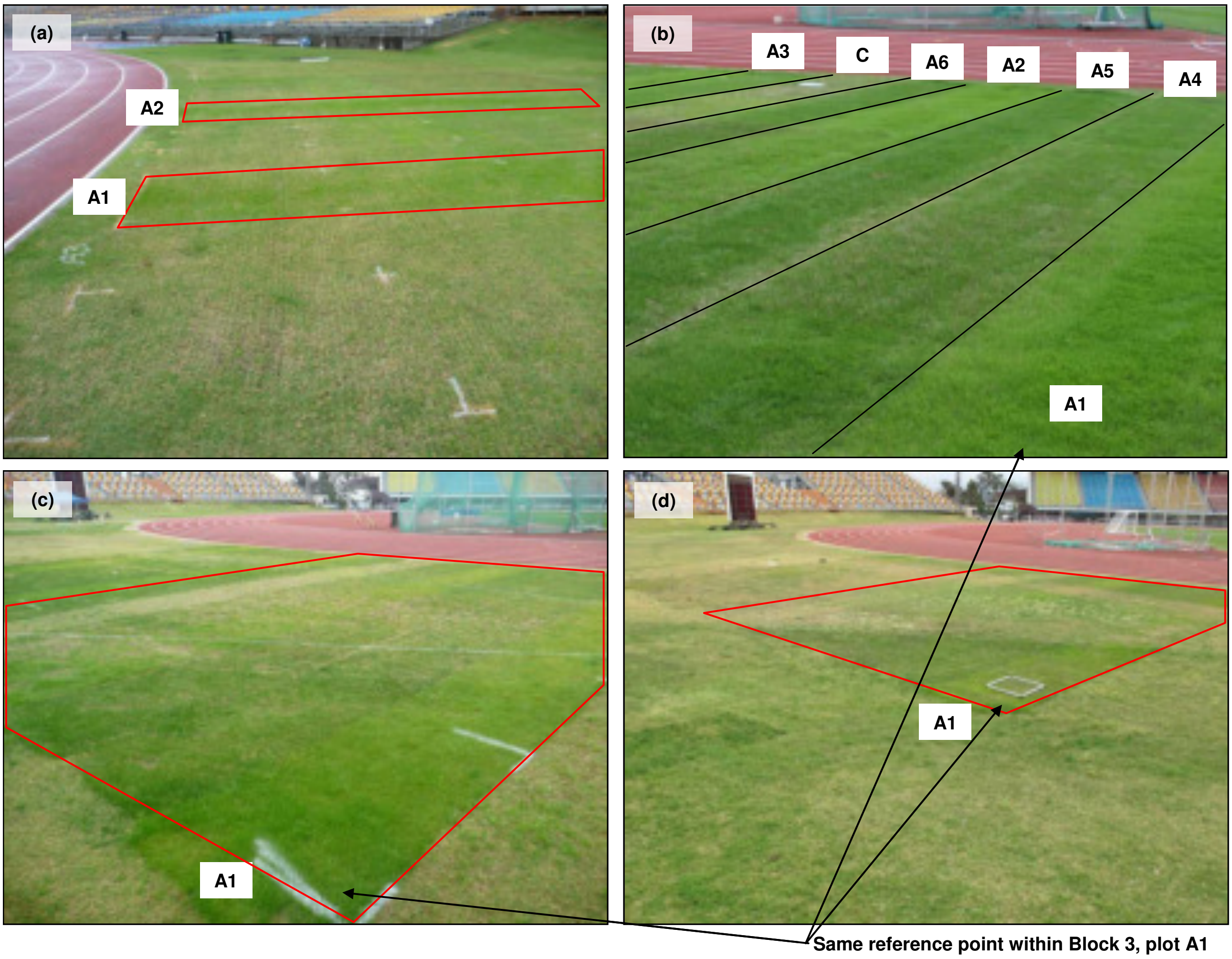
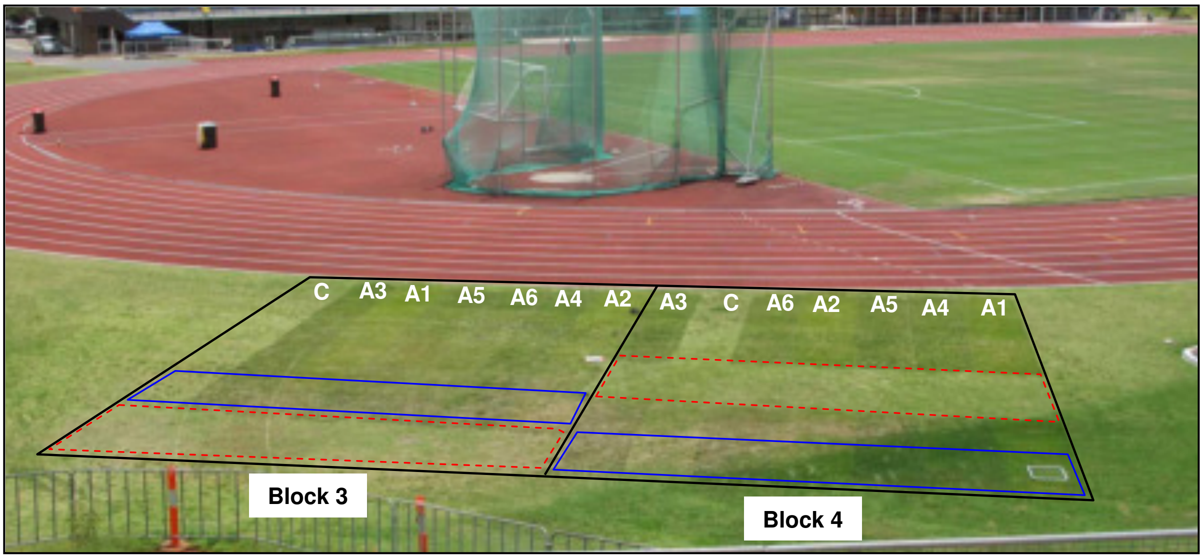


Plate 10. Photo taken of Blocks 3 and 4 at the QSAC trial site 11th November 2011, showing the condition of the ryegrass after 'Mechanical' (blue solid line) and 'Chem 2' (red dotted line) treatments on 30th August and 28th September 2011 respectively.



3.3.2 Redlands United trial

The first evaluation of the turf plots was conducted on 29th April 2011, one week post-application of the Primo Maxx® treatments, to observe how the turf handled the higher application rate of growth regulator (2 L/ha used). Upon inspection it was observed that slight “browning off” of the TifSport™ hybrid green couch had occurred and a phytotoxicity rating of 1 (after Australian Weeds Committee 1979) was recorded. This rating indicates that “negligible damage (discolouration, distortion and/or stunting barely seen) was observed. Within 2-3 weeks of application of Primo Maxx® the “browning off” damage was gone.

The ryegrass sown into the TifSport™ hybrid couch grass struck well, and within two weeks produced a consistent cover across all plots excluding the control plots where no ryegrass was seeded. The trial site was initially roped off with no traffic (Plate 11). However, on 30th May 2011 football training activities resumed, resulting in extensive wear to the ryegrass, but not the couch surface (e.g. Plate 12). This damage reflected the relative susceptibility to wear of young ryegrass. This damage to the ryegrass proved to be irreversible, with limited re-growth in the worn corridors for the remainder of the trial (Plate 13).

Percentage green values observed from the Redlands United trial produced on average a minimum value of 69.3%, a mean of 87.9% and a maximum value of 98.8% (Figure 8). The results were consistent throughout the study, and only in August 2011 did all treatments produce a percentage green value less than 80%.

With regard to the ryegrass removal treatments, the ‘Mechanical’, ‘Chem 2’, ‘Chem 3’, and ‘Chem 4’ treatments were imposed to the Redlands United trial site. The ‘Mechanical’ treatment, which incorporated the use of the Graden verticutter (3mm blades, 25mm spacings) set to a depth of 15 mm, removed approximately 90 g/m² (oven dried) of vegetative material from the field on 29th August 2011. Prior to treatment the mean percentage ryegrass cover of the ‘Chem 2’ plots was 71.7%. By 28th September 2011 the average ryegrass cover for the same plots had been reduced by 22.5%.
The application of Tribute® as treatment ‘Chem 2’ on 30th September 2011 had no discernible effect within the initial 7 days after treatment (DAT). By 12 DAT a slight yellowing of the ryegrass was observed and by 18 DAT the ryegrass had started to die. Nearly one month after the herbicide application, on the 28th October 2011, it was observed that only 3.1% of ryegrass remained on average across the ‘Chem 2’ plots (Figure 9). By December, no ryegrass remained within the ‘Chem 2’ plots. However, it must be noted that by December there was also only 1.9% ryegrass remaining in the control plots, and it was evident heat and moisture stress had severely checked ryegrass activity.

No conclusions can be drawn following the application of the ‘Chem 3’ or ‘Chem 4’ treatments made on 2nd November and 20th December 2011 because of the “natural” decline in ryegrass from heat and moisture stress. By February 2012 no ryegrass had survived in any of the plots (Table 2).

Turfgrass quality throughout the duration of the Redlands United study remained almost entirely above acceptable (>6) (Figure 10). Only once (in early December 2011) did turf grass quality fall narrowly short of being considered adequate, recording an average value of 5.5 within the ‘Chem 4’ plots. Herbicide damage was not a contributing factor in this instance since the ‘Chem 4’ application of Tribute® did not occur until 20 December 2011. At no stage did any of the chemical treatments Tribute® damage the TifSport™ couch grass.

Figure 8. Percentage green cover of application treatments A1 to A6 vs. control of the Redlands United trial as observed on 8th Jun., 12th Aug., 29th Aug., 28th Sept., 28th Oct., 8th Dec. 2011 and 3rd Feb. 2012. (LSD (P=0.05)).

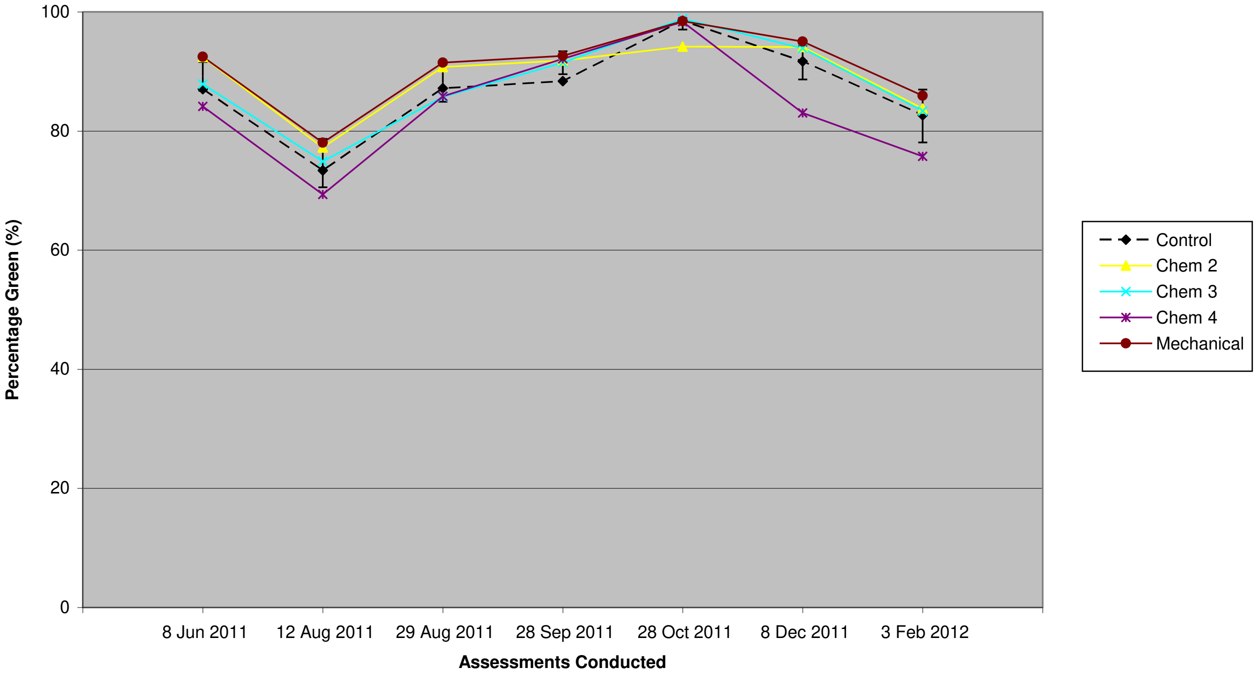


Figure 9. Percentage ryegrass cover of application treatments A1 to A6 vs. control at the Redlands United trial as observed on 8th Jun., 12th Aug., 29th Aug., 28th Sept., 28th Oct., 8th Dec. 2011 and 3rd Feb. 2012. (LSD (P=0.05)).

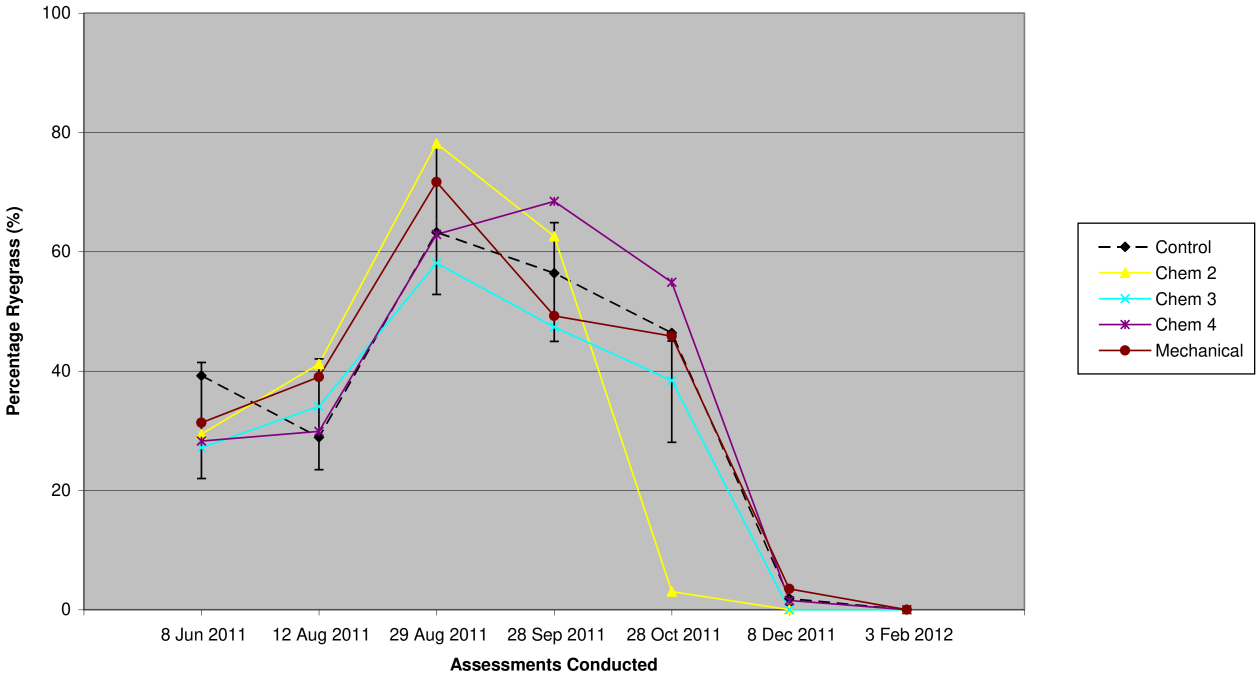


Figure 10. Subjective turf grass quality ratings [0 (= worst) to 9 (= best); 6 = acceptable] of application treatments A1 to A6 vs. Control of the Redlands United trial as observed 8th Jun., 12th Aug., 29th Aug., 28th Sep., 28th Oct., 8th Dec. 2011 and 3rd Feb. 2012. (LSD (P=0.05)).

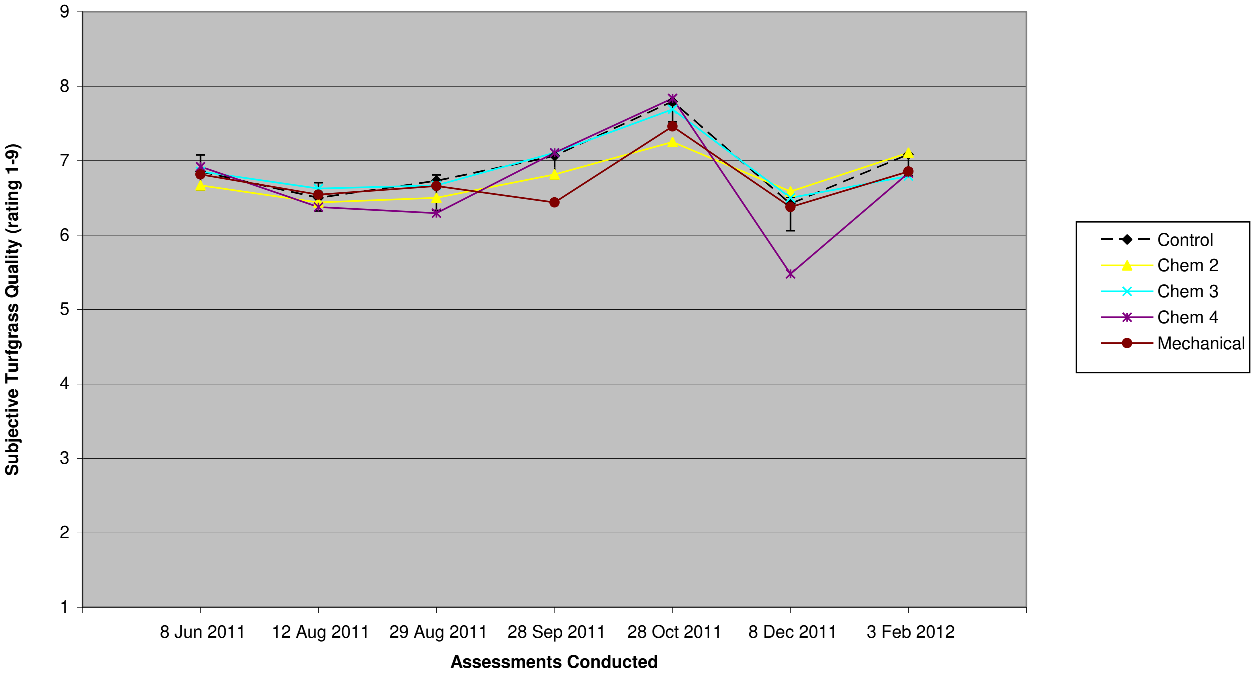


Table 2. Summary of percentage green, percentage ryegrass and turfgrass quality collected from the Redlands United trial site on 8th June 2011 to 3rdFebruary 2012. Further detail is provided in Appendix 3.

		SigmaScan Data - Percentage Green (%)						
		8 Jun 2011	12 Aug 2011	29 Aug 2011	28 Sep 2011	28 Oct 2011	8 Dec 2011	3 Feb 2012
A1	Control	83.9	74.7	90.3	86.5	98.5	92.6	84.6
	Chem 1	93.0	74.9	90.4	92.4	98.1	91.5	90.4
	Chem 2	92.1	81.3	94.6	92.4	91.3	89.6	85.4
	Chem 3	87.1	76.0	93.5	94.6	98.2	93.1	86.2
	Chem 4	82.1	71.2	84.9	93.6	98.1	75.3	72.8
	Mechanical	90.7	78.7	95.1	95.8	97.0	91.2	83.9
A2	Control	89.7	67.3	92.0	91.4	99.3	93.1	87.7
	Chem 1	90.9	75.2	88.1	95.4	98.8	92.6	87.2
	Chem 2	93.9	79.6	94.0	92.3	94.9	91.7	83.7
	Chem 3	89.2	72.8	87.2	91.8	98.5	89.8	74.8
	Chem 4	84.0	66.3	87.4	92.8	98.6	83.8	72.8
	Mechanical	89.1	81.4	93.7	94.2	98.3	93.9	88.8
A3	Control	84.4	79.0	87.6	84.9	98.0	89.9	80.5
	Chem 1	92.3	79.8	88.9	87.5	98.7	82.5	86.0
	Chem 2	93.6	77.4	90.6	90.7	91.7	93.3	85.0
	Chem 3	89.2	78.2	83.8	89.8	99.4	94.8	85.8
	Chem 4	85.8	68.9	87.7	91.4	97.4	86.2	77.3
	Mechanical	95.8	79.3	91.6	89.8	97.8	94.0	83.4
A4	Control	89.2	73.7	88.5	86.6	98.9	92.6	80.6
	Chem 1	93.3	74.2	84.9	92.6	98.6	91.8	78.0
	Chem 2	94.1	77.7	89.9	92.6	94.8	95.7	83.2
	Chem 3	88.5	76.5	83.7	92.3	98.5	95.7	82.6
	Chem 4	86.5	73.3	90.0	92.0	98.5	78.8	71.0
	Mechanical	94.3	75.3	91.0	91.1	99.5	96.3	85.8
A5	Control	84.6	75.8	84.4	90.8	98.2	90.4	82.3
	Chem 1	86.3	68.5	87.5	91.4	99.1	95.1	80.5
	Chem 2	88.1	76.1	88.1	91.1	95.5	96.6	85.3
	Chem 3	84.9	75.7	81.8	88.8	99.2	94.7	86.8
	Chem 4	80.4	71.9	83.3	91.8	98.9	85.6	82.8
	Mechanical	92.4	77.2	89.9	92.9	99.2	98.2	86.0
A6	Control	90.4	69.9	80.2	90.1	98.1	91.6	80.1
	Chem 1	90.6	75.5	85.0	94.6	98.9	94.5	79.5
	Chem 2	92.9	71.4	87.3	92.1	96.8	97.8	80.2
	Chem 3	88.4	70.2	84.4	91.7	99.3	95.3	83.7
	Chem 4	85.9	64.4	81.7	91.1	98.6	88.5	77.8
	Mechanical	92.5	76.4	87.7	91.7	99.0	96.6	87.6
Control	Control	83.1	69.3	78.6	87.7	96.9	98.2	84.2
	Chem 1	87.0	68.7	77.4	93.4	98.4	97.9	84.7
	Chem 2	89.1	67.8	79.4	92.7	98.4	98.4	78.7
	Chem 3	82.8	66.8	83.9	91.7	99.4	98.7	85.5
	Chem 4	79.8	63.1	77.5	91.4	97.2	97.0	77.6
	Mechanical	89.0	70.0	82.7	92.3	97.9	97.4	90.5
LSD (0.05)		*9.7*	*16.3*	*12.6*	*7.7*	*3.2*	*11.4*	*17.8*

		Subjective Assessment - Percentage Ryegrass (%)						
		8 Jun 2011	12 Aug 2011	29 Aug 2011	28 Sep 2011	28 Oct 2011	8 Dec 2011	3 Feb 2012
A1	Control	52.5	46.5	73.5	61.3	52.5	2.0	0.0
	Chem 1	47.5	31.5	69.2	60.0	42.3	3.3	0.0
	Chem 2	45.5	60.5	91.7	81.3	2.5	0.0	0.0
	Chem 3	38.0	48.8	73.0	54.3	47.5	0.0	0.0
	Chem 4	30.8	49.2	48.2	86.0	63.7	2.3	0.0
	Mechanical	40.5	49.2	90.8	48.5	73.0	4.5	0.0
A2	Control	42.5	29.2	74.5	70.0	57.7	4.0	0.0
	Chem 1	41.7	32.0	60.5	65.0	54.5	4.3	0.0
	Chem 2	24.7	57.2	82.8	75.8	0.8	0.0	0.0
	Chem 3	29.0	42.2	59.3	52.8	46.0	0.0	0.0
	Chem 4	31.7	20.5	60.3	67.5	91.2	2.5	0.0
	Mechanical	48.0	55.7	76.3	71.8	74.2	5.3	0.0
A3	Control	49.0	45.7	76.5	75.0	57.5	1.8	0.0
	Chem 1	49.3	28.7	73.0	52.5	28.8	0.8	0.0
	Chem 2	47.5	30.5	90.5	63.8	2.0	0.0	0.0
	Chem 3	39.0	24.2	60.7	48.5	45.0	0.0	0.0
	Chem 4	48.8	30.7	83.0	78.5	42.0	0.5	0.0
	Mechanical	35.8	60.2	91.5	66.3	38.2	1.8	0.0
A4	Control	54.5	18.2	73.8	59.0	45.8	1.5	0.0
	Chem 1	47.5	25.5	68.0	49.8	23.8	0.0	0.0
	Chem 2	37.5	43.8	85.0	71.8	5.0	0.0	0.0
	Chem 3	27.2	40.5	65.0	60.0	37.0	0.0	0.0
	Chem 4	31.2	32.2	86.8	78.8	36.2	0.0	0.0
	Mechanical	38.7	30.5	86.8	65.8	44.8	3.3	0.0
A5	Control	25.0	21.2	47.0	44.8	42.2	1.3	0.0
	Chem 1	11.5	13.5	42.2	28.5	24.8	0.8	0.0
	Chem 2	11.2	31.0	60.0	40.5	2.0	0.0	0.0
	Chem 3	16.2	32.5	47.0	33.3	30.0	0.0	0.0
	Chem 4	18.0	27.5	57.0	53.0	57.0	2.3	0.0
	Mechanical	8.0	28.2	40.8	24.0	22.5	3.0	0.0
A6	Control	11.7	12.7	34.2	28.3	22.5	0.8	0.0
	Chem 1	11.7	9.5	30.0	17.3	10.3	0.8	0.0
	Chem 2	10.2	24.2	58.8	42.3	6.0	0.0	0.0
	Chem 3	13.7	16.2	43.5	35.3	25.0	0.0	0.0
	Chem 4	9.2	19.2	42.2	46.8	39.2	1.8	0.0
	Mechanical	17.0	10.2	44.0	19.0	22.5	3.3	0.0
Control	Control	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Chem 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Chem 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Chem 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Chem 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mechanical	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LSD (0.05)		*39.0*	*37.2*	*49.4*	*39.8*	*33.9*	*2.8*	*

		Subjective Assessment - Turfgrass Quality (1-9)						
		8 Jun 2011	12 Aug 2011	29 Aug 2011	28 Sep 2011	28 Oct 2011	8 Dec 2011	3 Feb 2012
A1	Control	6.8	6.5	7.1	7.3	7.6	6.1	7.4
	Chem 1	7.0	6.6	6.8	7.3	7.9	6.3	7.4
	Chem 2	6.6	6.8	7.1	6.9	7.1	6.3	7.0
	Chem 3	7.0	6.5	6.8	7.3	7.6	6.6	7.0
	Chem 4	6.9	6.5	6.4	7.3	7.9	5.1	6.9
	Mechanical	6.9	6.4	7.0	6.5	7.4	6.0	7.0
A2	Control	7.0	6.3	6.9	6.9	7.6	6.5	7.4
	Chem 1	6.8	6.5	7.0	7.0	7.9	6.3	7.0
	Chem 2	6.6	6.4	6.4	7.0	6.9	6.3	7.1
	Chem 3	6.9	6.8	6.8	7.3	7.9	6.4	6.6
	Chem 4	6.9	6.4	6.3	7.0	7.9	5.0	6.9
	Mechanical	7.1	6.6	7.0	6.5	7.4	6.1	6.9
A3	Control	6.9	6.8	7.4	7.5	8.1	6.3	7.0
	Chem 1	7.3	6.9	6.6	7.3	7.9	5.6	6.6
	Chem 2	6.8	6.5	7.0	6.9	7.3	6.3	7.1
	Chem 3	7.1	6.6	6.9	7.0	7.6	6.6	6.9
	Chem 4	7.0	6.6	6.3	7.4	7.9	5.5	7.0
	Mechanical	6.9	6.8	7.1	6.3	7.4	6.3	7.0
A4	Control	7.0	6.6	6.6	7.0	7.8	6.4	7.1
	Chem 1	7.1	6.8	6.6	6.9	7.6	6.6	6.9
	Chem 2	6.8	6.5	6.3	6.9	7.4	6.8	7.3
	Chem 3	7.0	6.8	6.5	7.1	7.6	6.4	6.9
	Chem 4	7.4	6.4	6.5	7.3	8.0	5.5	6.6
	Mechanical	6.9	6.5	6.4	6.6	7.6	6.6	6.9
A5	Control	6.6	6.5	6.3	7.0	7.9	6.5	6.9
	Chem 1	6.5	6.5	6.3	6.5	7.8	6.6	6.9
	Chem 2	6.3	6.1	6.1	6.6	7.4	7.0	7.1
	Chem 3	6.5	6.6	6.6	7.1	7.8	6.6	6.6
	Chem 4	6.6	6.3	6.1	6.8	7.8	5.9	6.8
	Mechanical	6.4	6.4	6.5	6.4	7.5	6.6	6.8
A6	Control	6.9	6.4	6.1	6.8	7.8	6.8	6.8
	Chem 1	7.0	6.4	6.1	6.6	7.8	6.8	6.8
	Chem 2	7.0	6.4	6.1	6.6	7.5	7.0	7.0
	Chem 3	6.6	6.5	6.5	6.9	7.6	6.4	6.8
	Chem 4	6.8	6.1	6.3	7.0	7.6	5.9	6.9
	Mechanical	6.8	6.6	6.0	6.4	7.5	6.6	6.6
Control	Control	6.8	6.6	5.9	7.0	7.6	7.3	7.0
	Chem 1	6.8	6.6	5.9	6.9	7.6	7.1	6.9
	Chem 2	6.5	6.5	5.9	7.0	7.8	7.3	7.0
	Chem 3	6.9	6.8	6.0	7.1	7.8	7.1	6.8
	Chem 4	7.0	6.5	5.8	7.0	7.5	6.3	6.9
	Mechanical	6.9	6.6	5.8	6.6	7.4	6.9	6.9
LSD (0.05)		*0.9*	*0.8*	*1.0*	*0.6*	*0.5*	*0.9*	*0.5*

Plate 11. A good strike of the ryegrass plots observed on 25th May 2011, two weeks after sowing. The control plot of Block 4 is shown in the centre of the photo.

Plate 12. Wear damage to ryegrass at the Redlands United trial site as seen on 8th June 2011 following intensive training commencing 30th May 2011.

Plate 13. Wear damage of the ryegrass was still evident 3 months after the wear damage occurred. Photo was taken 29th August 2011, prior to any removal treatments being imposed.

Plate 14. During an inspection of the Redlands United trial site on 3rd February 2012 no ryegrass was observed in the trial area, not even the control plots.

3.3.3 Moore Park

An excellent strike rate and rapid development of the ryegrass was achieved at the Moore Park trial site one month after sowing (Plate 17). However, by late June 2011 the ryegrass content reverted to an average of 37% (Figure 12). The decline in ryegrass cover and lack of overall turf growth was largely due to insufficient soil fertility, preventing the ryegrass growing to the second-, third and fourth-leaf stage of development (Figure 14). On the 24th June 2011 fertiliser was applied to the trial and plant recovery was observed shortly after. By August the ryegrass cover had reached on average 47% and by late September was at 74% cover.

An inspection of the trial site on 29th September 2011 revealed that the park was being set up for a concert to be held over the subsequent weekend. Although protective flooring was set up across some of the plots (Plate 20), it was apparent that noticeable damage was done to the ryegrass (Plate 21).

Ryegrass removal treatments included: 'Chem 2' (14th October), 'Mechanical' (21st October), 'Chem 3' (2nd November) and 'Chem 4' (8th December 2011). 'Chem 1' was not applied to the trial.

Throughout the duration of the trial the percentage green cover remained consistent and high within the kikuyu and ryegrass combined surface. The mean figures collected through the course of the trial were a minimum percentage green cover of 85%, an average value of 95% and a maximum value of 99.5% (Figure 11). Ryegrass cover was highest on the 29th September 2011. On average there was 74% ryegrass cover, whereas the control plots had 73.1% and 'Chem 2' plots had 79.6% cover.

The 'Chem 2' application of Destiny® was applied on 14th October 2011, 13 days before the next scheduled rating. During this period the percentage ryegrass cover of the 'Chem 2' plots decreased from 79.6% to 0.6% (Figure 12). However, the control plot also decreased by 51.2% during the same period, as a result of intensive "foot traffic" during the concert held on the weekend of the 1st October 2011.

The 'Chem 3' treatment of Destiny® applied on 2nd November 2011 saw the ryegrass cover decrease by 21.4%. The control plots decreased by 5.9% within the same time period.

It is not possible to draw conclusions from the implementation of the 'Mechanical' treatment on 21st October 2011, nor the 'Chem 4' herbicide treatment applied on 8th December 2011, because the percentage ryegrass cover over the latter period did not exceed 22% within the control plots.

Average turf grass quality at the Moore Park trial site remained above acceptable (>6) for the duration of the trial (Figure 13). The average figure was 6.9 and the maximum figure obtained during September, prior to the concert, was 7.9.

Figure 11. Percentage green cover of application treatments A1 to A6 vs. control of the Moore Park trial as observed during on 18th May, 24th Jun., 1st Aug., 29th Sep., 27th Dec. 2011 and 8th Feb. 2012. (LSD (P=0.05)).

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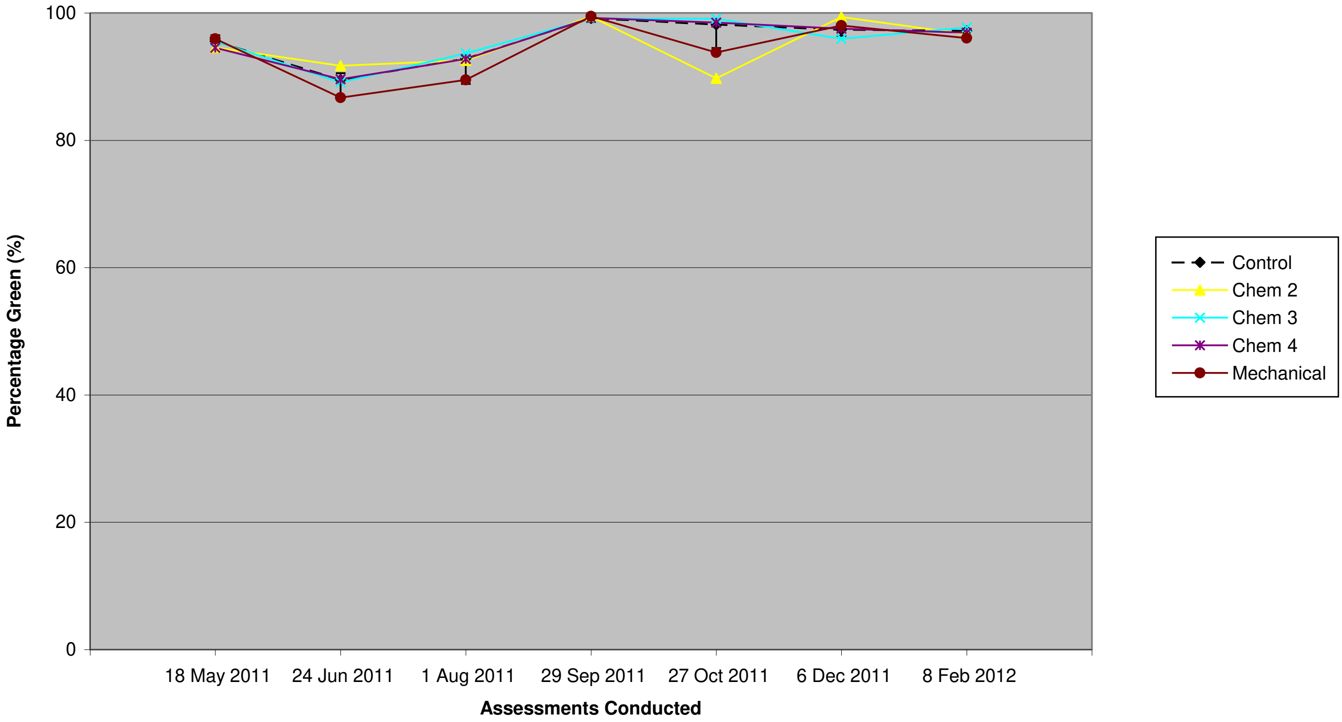


Figure 12. Subjective percentage ryegrass cover of application treatments A1 to A6 vs. control of the Moore Park trial as observed on 18th May, 24th Jun., 1st Aug., 29th Sep., 27th Oct., 6th Dec. 2011 and 8th Feb. 2012. (LSD (P=0.05)).

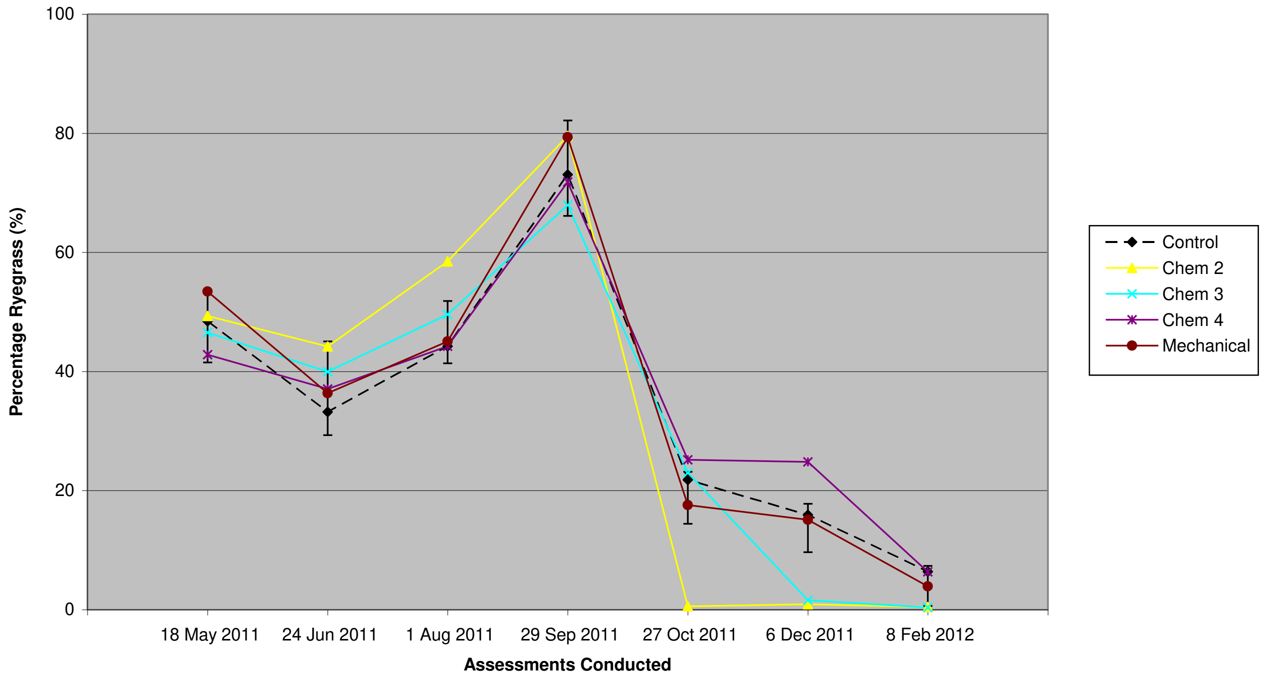


Figure 13. Subjective turf grass quality ratings [0 (= worst) to 9 (= best); 6 = acceptable] of application treatments A1 to A6 vs. control of the Moore Park trial as observed on 18th May, 24th Jun., 1st Aug., 29th Sep., 27th Oct., 6th Dec. 2011 and 8th Feb. 2012. (LSD (P=0.05)).

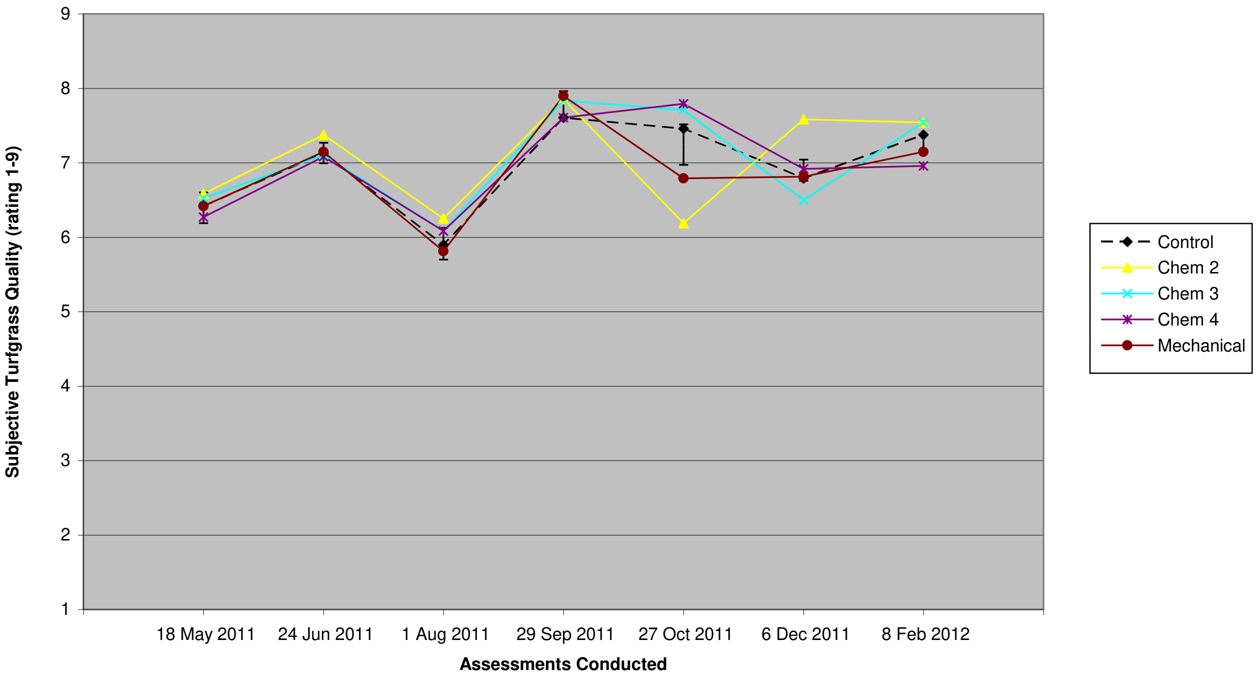


Table 3. Summary of percentage green, percentage ryegrass and turf grass quality collected from the Moore Park trial site 18th May 2011 to 8th February 2012. More detail is presented in Appendix 3.

		SigmaScan Data - Percentage Green (%)						
		18 May 2011	24 Jun 2011	1 Aug 2011	29 Sep 2011	27 Oct 2011	6 Dec 2011	8 Feb 2012
A1	Control	96.4	86.1	93.8	99.5	98.7	96.7	98.6
	Chem 1	96.8	83.9	84.1	99.3	98.8	98.2	96.8
	Chem 2	95.6	91.1	93.7	99.6	90.7	99.4	97.3
	Chem 3	96.1	86.4	95.0	99.7	99.4	96.4	97.5
	Chem 4	93.5	90.2	92.2	98.2	98.9	96.2	97.0
	Mechanical	95.4	89.2	93.5	99.8	96.1	99.0	96.7
A2	Control	95.8	90.9	94.1	99.3	96.7	96.5	97.8
	Chem 1	96.7	86.0	87.1	99.0	96.5	97.9	97.3
	Chem 2	95.5	93.6	93.7	99.7	80.6	99.3	95.5
	Chem 3	97.1	92.7	96.8	98.7	99.4	95.2	98.9
	Chem 4	96.1	90.6	95.0	99.5	95.1	97.4	97.5
	Mechanical	97.6	84.6	88.6	99.7	92.0	98.7	96.6
A3	Control	94.2	90.7	92.0	99.1	98.3	98.0	96.8
	Chem 1	94.5	86.0	83.9	98.8	97.6	96.8	95.8
	Chem 2	92.9	90.6	88.9	99.5	83.7	99.3	96.4
	Chem 3	96.3	89.2	94.4	99.2	97.9	94.3	96.1
	Chem 4	95.8	89.4	92.6	99.0	99.0	98.3	97.5
	Mechanical	95.4	84.8	85.3	99.0	87.8	95.7	95.2
A4	Control	96.1	87.3	90.3	99.6	99.2	97.8	97.4
	Chem 1	96.2	82.1	84.0	99.3	99.4	98.3	96.8
	Chem 2	94.5	92.5	91.9	99.3	98.2	99.6	96.8
	Chem 3	95.9	85.1	86.9	99.4	99.3	96.2	97.5
	Chem 4	95.6	88.1	91.7	99.6	99.4	98.4	95.7
	Mechanical	96.0	86.0	90.4	99.4	97.2	98.4	97.1
A5	Control	95.7	91.6	93.6	98.3	97.8	98.6	95.9
	Chem 1	94.9	85.2	87.2	99.2	98.1	98.3	96.6
	Chem 2	94.2	91.0	95.7	99.1	94.9	99.6	96.6
	Chem 3	92.7	91.8	95.5	98.9	99.1	97.4	98.6
	Chem 4	90.9	89.9	94.5	99.5	99.3	98.1	97.0
	Mechanical	94.9	89.6	89.1	99.5	94.4	97.7	94.9
A6	Control	95.2	90.4	93.2	99.0	98.3	96.4	96.6
	Chem 1	90.3	87.2	84.8	99.1	97.8	97.2	96.9
	Chem 2	94.6	91.5	91.5	99.5	90.2	99.2	97.4
	Chem 3	95.5	89.4	93.5	98.9	99.4	96.2	97.8
	Chem 4	95.2	89.4	90.6	99.4	99.1	96.8	96.6
	Mechanical	96.4	86.0	90.0	99.4	95.1	98.6	95.8
Control	Control	89.0	79.9	82.4	98.2	99.1	98.8	98.0
	Chem 1	90.5	78.9	83.5	97.8	99.1	99.0	97.2
	Chem 2	87.6	82.1	83.9	98.1	99.3	99.1	95.3
	Chem 3	92.4	81.9	83.0	99.1	99.6	99.7	97.2
	Chem 4	89.9	84.7	88.8	98.7	99.1	99.2	98.1
	Mechanical	87.7	76.5	81.1	98.4	95.3	99.0	97.0
LSD (0.05)		*5.3*	*7.8*	*9.0*	*1.4*	*6.9*	*2.7*	*2.6*

		Subjective Assessment - Percentage Ryegrass (%)						
		18 May 2011	24 Jun 2011	1 Aug 2011	29 Sep 2011	27 Oct 2011	6 Dec 2011	8 Feb 2012
A1	Control	85.8	51.3	45.5	94.0	28.8	33.8	17.5
	Chem 1	60.0	45.0	35.0	95.5	24.3	37.0	2.5
	Chem 2	75.5	67.0	78.5	99.0	0.0	1.3	0.0
	Chem 3	58.3	53.8	69.0	93.2	14.8	0.0	1.0
	Chem 4	61.8	44.0	45.0	98.0	22.0	34.5	2.5
	Mechanical	70.5	44.3	56.3	92.8	11.8	13.3	2.0
A2	Control	47.3	46.0	45.5	83.0	13.0	6.8	4.5
	Chem 1	42.0	49.5	45.5	83.5	19.3	14.0	2.5
	Chem 2	50.0	58.8	58.3	98.5	0.0	0.0	0.0
	Chem 3	46.3	51.8	60.0	89.3	21.3	0.0	0.0
	Chem 4	48.8	66.8	52.8	87.0	13.5	23.0	0.0
	Mechanical	61.3	65.5	51.5	99.0	6.8	5.3	0.0
A3	Control	47.5	17.3	43.8	51.5	18.3	12.8	7.5
	Chem 1	50.0	32.2	32.5	43.8	25.0	26.3	14.8
	Chem 2	44.3	16.8	42.5	49.0	0.5	2.5	1.0
	Chem 3	61.5	22.8	36.8	49.3	30.0	8.8	1.3
	Chem 4	37.0	27.5	42.5	54.0	26.3	18.0	6.3
	Mechanical	46.8	27.0	45.8	57.5	16.0	23.5	11.8
A4	Control	27.0	21.5	44.5	55.8	37.5	13.0	4.5
	Chem 1	34.5	16.0	32.8	53.8	35.8	24.3	7.5
	Chem 2	33.8	30.0	52.5	58.0	1.8	0.0	0.0
	Chem 3	31.3	45.0	32.0	49.2	25.0	0.0	0.0
	Chem 4	30.0	31.2	37.8	49.5	31.5	24.3	0.0
	Mechanical	40.0	19.5	31.8	72.0	28.0	18.0	2.5
A5	Control	53.8	42.0	53.8	79.3	15.0	10.0	0.0
	Chem 1	43.8	28.0	43.3	92.8	23.8	22.5	0.0
	Chem 2	57.5	45.8	68.0	87.5	0.0	0.0	1.8
	Chem 3	47.0	30.8	52.0	69.5	26.5	0.0	0.0
	Chem 4	40.8	35.5	49.5	85.3	29.3	23.5	25.0
	Mechanical	60.0	34.8	41.3	78.8	20.5	9.8	0.0
A6	Control	29.5	21.2	32.5	74.8	18.5	19.3	4.5
	Chem 1	33.8	23.0	39.3	69.0	19.3	20.0	11.0
	Chem 2	35.0	46.8	51.3	85.3	1.3	1.8	0.0
	Chem 3	35.0	35.5	47.8	57.0	20.5	0.8	0.0
	Chem 4	38.8	17.3	38.0	57.2	28.5	25.8	4.5
	Mechanical	42.0	27.0	43.8	76.0	22.5	20.8	7.3
Control	Control	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Chem 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Chem 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Chem 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Chem 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mechanical	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LSD (0.05)		*23.7*	*31.4*	*20.9*	*32.0*	*17.5*	*16.3*	*13.4*

		Subjective Assessment - Turfgrass Quality (1-9)						
		18 May 2011	24 Jun 2011	1 Aug 2011	29 Sep 2011	27 Oct 2011	6 Dec 2011	8 Feb 2012
A1	Control	6.6	7.0	5.8	7.6	7.8	6.6	7.4
	Chem 1	6.4	6.9	5.1	8.0	8.0	7.0	7.0
	Chem 2	6.9	7.5	6.6	8.0	6.0	7.4	7.6
	Chem 3	6.6	7.3	6.5	7.9	7.8	6.4	7.5
	Chem 4	6.5	7.3	6.4	7.6	8.0	7.0	6.8
	Mechanical	6.8	7.4	6.1	7.9	6.9	7.0	7.4
A2	Control	6.4	7.1	5.5	7.9	6.4	6.5	7.4
	Chem 1	6.4	7.1	5.5	7.8	6.9	6.5	7.1
	Chem 2	6.8	7.5	6.0	7.9	5.5	7.8	7.5
	Chem 3	6.6	7.3	6.1	7.9	7.5	6.5	7.6
	Chem 4	6.3	7.3	5.8	7.8	7.0	6.9	7.3
	Mechanical	6.6	7.1	5.6	8.0	5.9	6.8	6.9
A3	Control	6.3	7.1	6.4	7.4	7.4	7.0	7.3
	Chem 1	5.9	6.9	5.3	7.9	7.4	6.6	6.9
	Chem 2	6.0	7.0	5.8	7.8	6.0	7.4	7.4
	Chem 3	6.8	7.0	6.1	7.9	7.1	6.3	7.4
	Chem 4	6.1	6.8	6.3	7.8	7.8	6.9	7.1
	Mechanical	6.3	6.9	5.9	7.8	6.5	6.5	7.0
A4	Control	6.1	7.0	5.9	7.4	7.9	6.8	7.4
	Chem 1	6.0	6.8	5.1	7.6	7.9	6.9	6.9
	Chem 2	6.5	7.3	6.4	7.8	6.8	7.6	7.4
	Chem 3	6.1	6.8	5.5	7.5	8.1	6.8	7.8
	Chem 4	6.1	7.0	6.0	7.3	8.1	6.8	6.8
	Mechanical	6.1	7.3	5.6	7.8	7.6	6.8	7.1
A5	Control	6.5	7.3	6.1	7.5	7.8	7.1	7.5
	Chem 1	6.0	7.1	5.5	8.1	7.1	6.9	7.1
	Chem 2	6.5	7.4	6.5	7.9	6.3	7.8	7.6
	Chem 3	6.6	7.0	6.1	7.9	7.8	6.6	7.5
	Chem 4	6.3	7.3	6.0	7.8	7.9	7.0	7.1
	Mechanical	6.5	7.0	5.5	7.9	7.0	6.8	7.3
A6	Control	6.6	7.3	5.8	7.9	7.6	6.8	7.4
	Chem 1	6.4	7.0	5.6	7.9	7.9	6.9	7.1
	Chem 2	6.9	7.6	6.3	7.9	6.6	7.6	7.8
	Chem 3	6.4	7.4	6.1	8.0	8.0	6.5	7.5
	Chem 4	6.4	7.0	6.1	7.5	8.0	7.0	6.8
	Mechanical	6.3	7.3	6.1	8.1	6.9	7.1	7.3
Control	Control	6.0	6.6	5.8	7.1	7.9	7.4	7.6
	Chem 1	5.3	6.3	5.6	7.4	8.1	7.4	7.5
	Chem 2	5.9	6.9	5.8	7.5	7.6	7.8	7.9
	Chem 3	5.9	6.4	5.8	7.1	7.9	7.4	7.4
	Chem 4	5.9	6.8	5.9	6.9	8.1	7.8	7.6
	Mechanical	5.5	6.4	5.5	7.4	7.4	7.5	7.5
LSD (0.05)		*0.8*	*0.5*	*0.9*	*0.7*	*1.1*	*0.6*	*0.5*

Plate 15. All plots at the Moore Park being verti-cut prior to seeding on 12th April 2011.

Plate 16. Cleanup of vegetative material following scarification at Moore Park using a Amazone® Groundkeeper on 12th April 2011.

Plate 17. Excellent strike rate of the ryegrass as observed 16th May 2011. Photo taken by Tony Gander, Contracts Coordinator, Centennial Park and Moore Park Trust.

Plate 18. Moore Park trial site 3rd August 2011. The turf, in particular the ryegrass, was nutrient deficient. Refer to Figure 14 and Plate 19 for additional information.

Figure 14. Leaf re-growth of a ryegrass tiller following defoliation. Source: Dairy Australia.

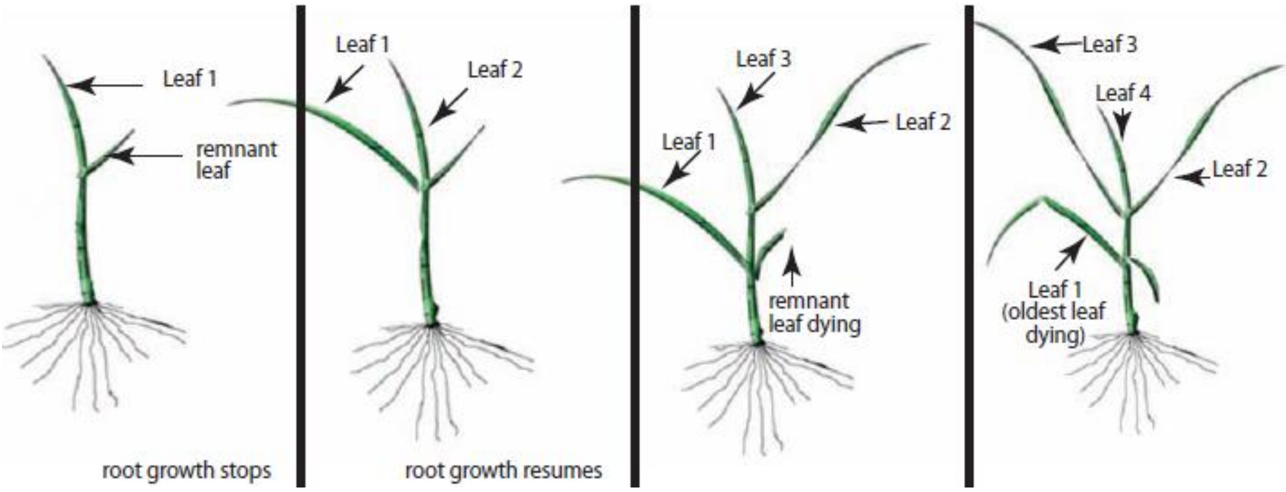


Plate 19. A closer look at the ryegrass within the Moore Park trial site on 3 August 2011 showing a delayed development. The ryegrass was primarily in first-leaf development stage (see Figure 14).

Plate 20. Protective flooring set up across several plots within the trial site prior to a concert at Moore Park. Part of the trial area can be seen in the highlighted red area.

Plate 21. Damage within the Moore Park trial site following foot traffic from the concert. The photo was taken 3rd October 2011 by Tony Gander, Contracts Coordinator, Centennial Park and Moore Park Trust.

Plate 22. Photo taken on 27th October 2011 at the Moore Park trial site showing approximately 19% ryegrass remained across the entire plots.

Plate 23. Photo taken 8th February 2012 at the Moore Park trial site, showing only 4% ryegrass remaining across the entire plots.

3.3.4 Silverdale trial

Treatments to control ryegrass (spray or mechanical) were applied on three separate occasions (end October, end November and end December). Botanical composition results and the overall score for each plot on each sample date are presented in Tables 4, 5 & 6.

Where no control measures were applied the ryegrass remained the dominant grass over the entire summer, with the couch cover progressively declining in the control plots. There was less than 4% couch cover remaining in control plots by the end of the monitoring period (mid-Feb).

The decline in couch stolon and rhizome viability over time, if ryegrass wasn't removed, is illustrated by the reduced couch content at the start of removal treatments 2 and 3, relative to treatment 1.

Removal of ryegrass reduced the overall turf quality, at least in the short term (late spring/early summer) period. The fact that the ryegrass persisted over the entire summer meant that control plots consistently gave best overall scores (Table 5). The quality of the ryegrass removal treatment plots had not caught up with the ryegrass plots by the end of the monitoring period.

Differences between chemical and mechanical ryegrass control treatments are difficult to interpret. It appears that chemical control offered a more reliable and predictable control method than physical treatment. However it also appears that chemical control resulted in poor turf quality for a significant period after spraying, given that the ryegrass is discoloured as it dies out.

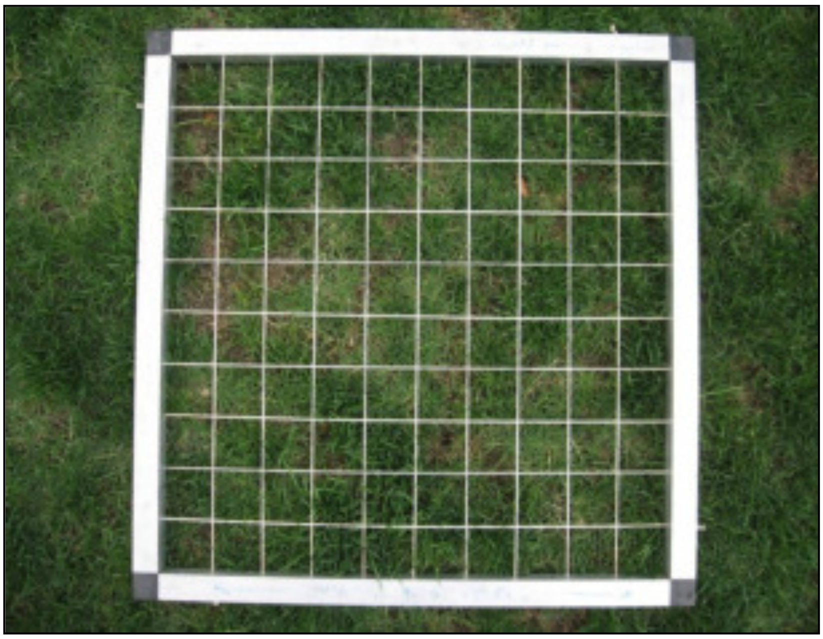
It must be noted that the summer of 2011/12 in Auckland was relatively wetter and cooler than normal. Different results could be expected in a hotter, drier year.

Table 4 . Summary of data from the Silverdale trial. Highlighted data is the mean of 4 replicates.

1st treatment	**Early November**															
2nd Dec		Control					Spray					Mechanical				
						Mean					Mean					Mean
	Bare ground%	9	3	14	35	15.3	75	80	83	95	83.3	55	37	22	35	37.3
	Ryegrass %	79	87	72	30	67.0	0	0	0	0	0.0	16	31	35	31	28.3
	Couch %	12	10	14	35	17.8	25	20	17	5	16.8	29	32	43	34	34.5
	Score	3	2	2.5	2	2.4	1	1	1	1	1.0	1	1	1	2	1.3
11th Dec		Control					Spray					Mechanical				
	Bare ground%	1	1	3	9	3.5	35	44	76	70	56.3	11	2	3	6	5.5
	Ryegrass %	98	98	95	88	94.8	2	1	4	10	4.3	46	50	87	45	57.0
	Couch %	1	1	2	3	1.8	63	55	20	20	39.5	43	48	10	49	37.5
	Score	1	1	2	3	1.8	2	2	1	1	1.5	2	3	2	2	2.3
23rd Jan																
	Couch%					0					92					
	Score					4					2.6					2.6
2nd treatment	**end Nov**															
11th Dec		Control					Spray					Mechanical				
	Bare ground%	2	1	4	7	4	8	3	4	10	6.3	40	30	29	25	31
	Ryegrass %	96	96	93	90	94	30	1	3	2	9.0	25	40	47	35	36.8
	Couch %	2	3	3	3	3	61	94	93	88	84.0	35	30	24	40	32.3
	Score	4	4	4	3	4	1	3	2	2.5	2.1	1	1	1.5	2	1.4
7th Feb		Control					Spray					Mechanical				
	Bare ground%	0	0	1	2	1	10	50	3	45	27.0	3	5	6	10	6
	Ryegrass %	100	99	99	98	99	0	0	0	0	0.0	25	25	20	20	22.5
	Couch %	0	0	0	0	0	90	50	97	55	73.0	72	70	74	70	71.5
	Score	5	5	4	4	5	2	1	1	1	1.3	3	3	3	3	3
3rd treatment	**end Jan**															
23rd Jan		Control					Spray					Mechanical				
	Bare ground%	0	5	1	2	2	25	10	12	10	14.3	80	80	77	14	62.8
	Ryegrass %	60	70	94	83	77	35	49	68	64	54.0	13	18	15	80	31.5
	Couch %	40	25	5	15	21	40	40	20	26	31.5	7	2	8	6	5.75
	Score	4	4	4	4	4	2	3	2	2	2.3	1	1	1	1	1
12th Feb.		Control					Spray					Mechanical				
	Bare ground%	0	1	0	1	1	60	65	45	88	64.5	10	4	20	25	14.8
	Ryegrass %	100	7	95	97	75	10	10	25	2	11.8	30	60	60	65	53.8
	Couch %	0	3	5	2	3	30	25	30	10	23.8	60	36	20	10	31.5
	Score	5	5	4	5	5	2	2	2	2	2.0	3	3	3	3	3

Plates 24 & 25. Silverdale trial site showing control plots (above) and chemical treatment plots (below).

Plates 26, 27 and 28. Photos taken 19th Dec. 2011 showing botanical composition of plots. Control plot (100% ryegrass) - top; Mechanical treatment (mix of ryegrass and couch) – centre; Chemical control plot (zero ryegrass) – bottom.



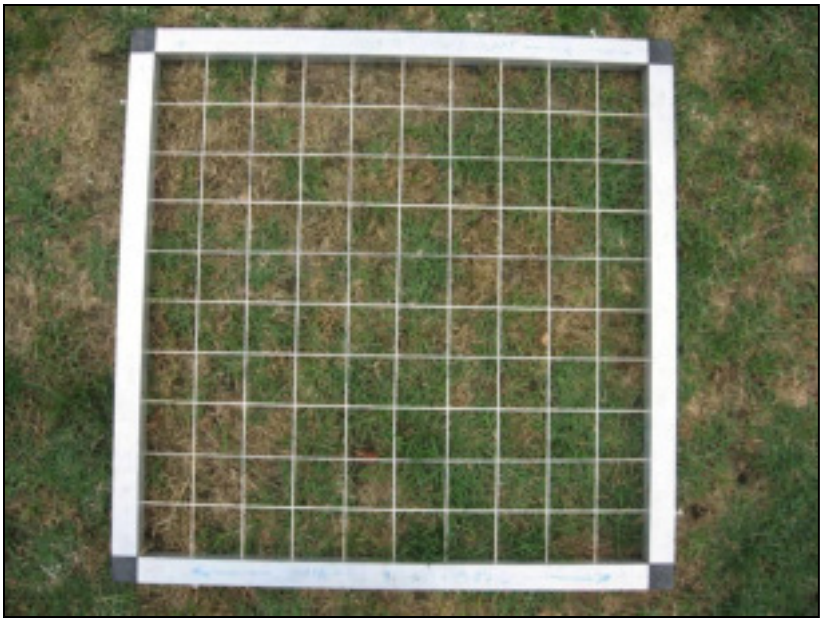


Table 5. Summary of overall mean quality score from the Silverdale trial site for each sampling date (1 = very poor; 5 = excellent).

Summary of overall scores				
Treatment number	Test date	Control plots	Spray plots	Mechanical plots
1	2nd Dec	2.4	1	1.3
	11th Jan	1.8	1.5	2.3
	23rd Jan	4	2.6	2.6
2	11th Dec	4	2.1	1.4
	7th Feb	5	1.3	3
3	23rd Jan	4	2.3	1
	12th Feb	5	2	3

Table 6. Summary of mean couch cover (%) for the Silverdale site on each sampling date.

Summary of %couch cover				
Treatment number	Test date	Control plots	Spray plots	Mechanical plots
1	2nd Dec	18	17	34
	11th Jan	2	40	38
	23rd Jan	0	92	90
2	11th Dec	3	84	32
	7th Feb	0	73	71
3	23rd Jan	21	31	6
	12th Feb	3	24	31

3.3.5 Wear Study – Redlands Research Site

The W1 wear treatment was applied on the 3rd June 2011, 1 week after ryegrass seeding. Three days later the W1 plots had no visible ryegrass cover, while the unworn plots had on average 17.2% rye cover (Table 7 and Figure 15).

Wear applied two weeks after sowing (W2) resulted in 13.8% rye cover remaining, whereas the control plots had 45% ryegrass cover.

The W3 application of wear resulted in reducing the rye cover to 31.2%, compared with the control plots with 96.8% ryegrass cover. The W1 and W2 plots had shown some recovery over the fortnight, and had reached approximately 40% ryegrass cover by 20th June.

The W4 application saw the ryegrass cover diminish from 98.2% to 47.5% following wear, although it must be noted that the ryegrass content in the control plots had also reduced by 53%, due to climatic conditions. This decline in ryegrass (percentage cover) illustrates the unpredictability of establishing new turf from seed.

Results illustrate that where significant wear was applied to establishing ryegrass one, two and even three weeks after sowing there was noticeable damage incurred (trial results showed that only 7.5-8.7% rye coverage remained by the 4th week). Where ryegrass was left to establish for a period of four weeks or longer there was no statistical difference between the wear and no wear plots.

Table 7. Ryegrass and turf (green) cover (%) [0 (= worst) to 9 (= best); 6 (= acceptable)] of control and trafficked plots at Redlands Research Station following implementation of wear on 3rd June, 10th June, 17th June and 24th June 2011.

		Treatment					
		Control	Week 1 (W1)	Week 2 (W2)	Week 3 (W3)	Week 4 (W4)	LSD (P=0.05)
6th Jun 11 (3 days after W1)	Quantitative Cover (green)	68.9	82.2	80.2	80.7	77.4	24.5
	Subjective Rye Present	17.2	0.0	8.5	11.2	16.2	15.0
	Subjective Turf Quality	5.8	4.0	5.6	5.8	6.1	0.5
13th Jun 11 (3 days after W2)	Quantitative Cover (green)	74.5	89.0	82.6	86.3	71.0	23.0
	Subjective Rye Present	45.0	3.8	13.8	56.2	52.5	24.9
	Subjective Turf Quality	6.4	5.3	5.1	6.4	6.4	0.4
20th Jun 11 (3 days after W3)	Quantitative Cover (green)	81.6	90.3	82.7	89.1	69.8	20.6
	Subjective Rye Present	96.8	38.8	40.0	31.2	98.2	21.2
	Subjective Turf Quality	7.9	5.9	6.0	5.9	8.0	0.6
27th Jun 11 (3 days after W4)	Quantitative Cover (green)	80.8	91.3	90.6	91.6	76.3	14.6
	Subjective Rye Present	43.8	7.5	8.2	8.7	47.5	18.4
	Subjective Turf Quality	7.6	5.6	6.0	6.1	6.6	0.6

Figure 15. Assessed ryegrass cover (%) of trafficked plots vs. control plots at Redlands Research Station following wear on 3rd June, 10th June, 17th June and 24th June 2011 (LSD (P=0.05)).

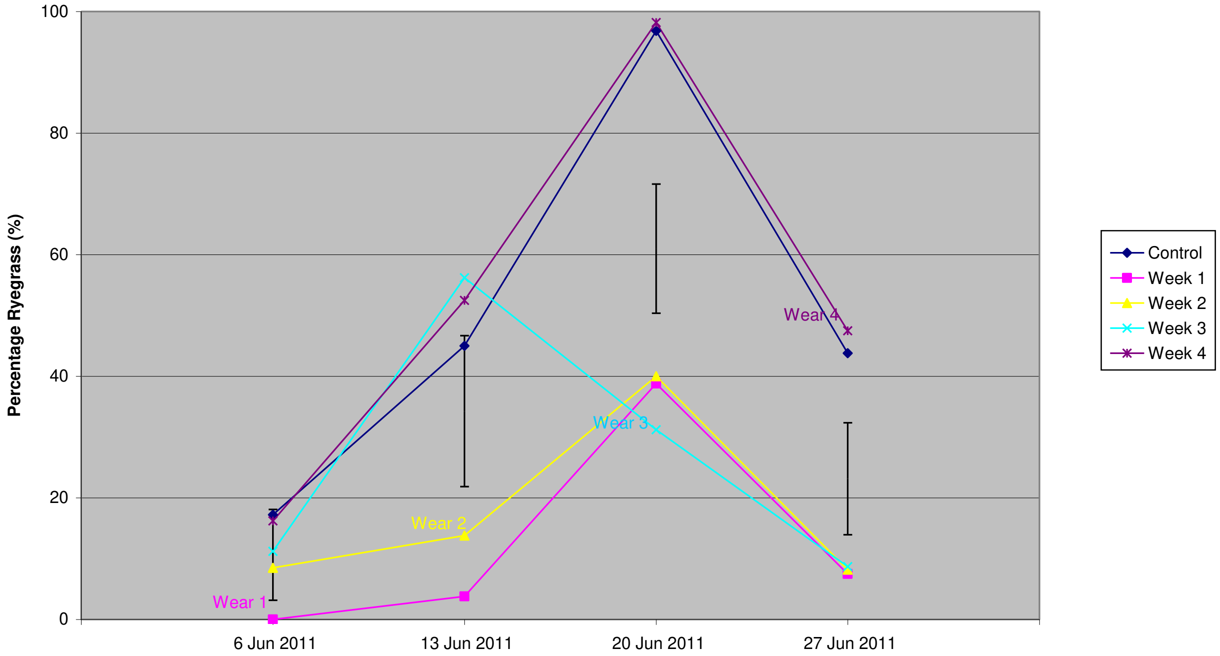
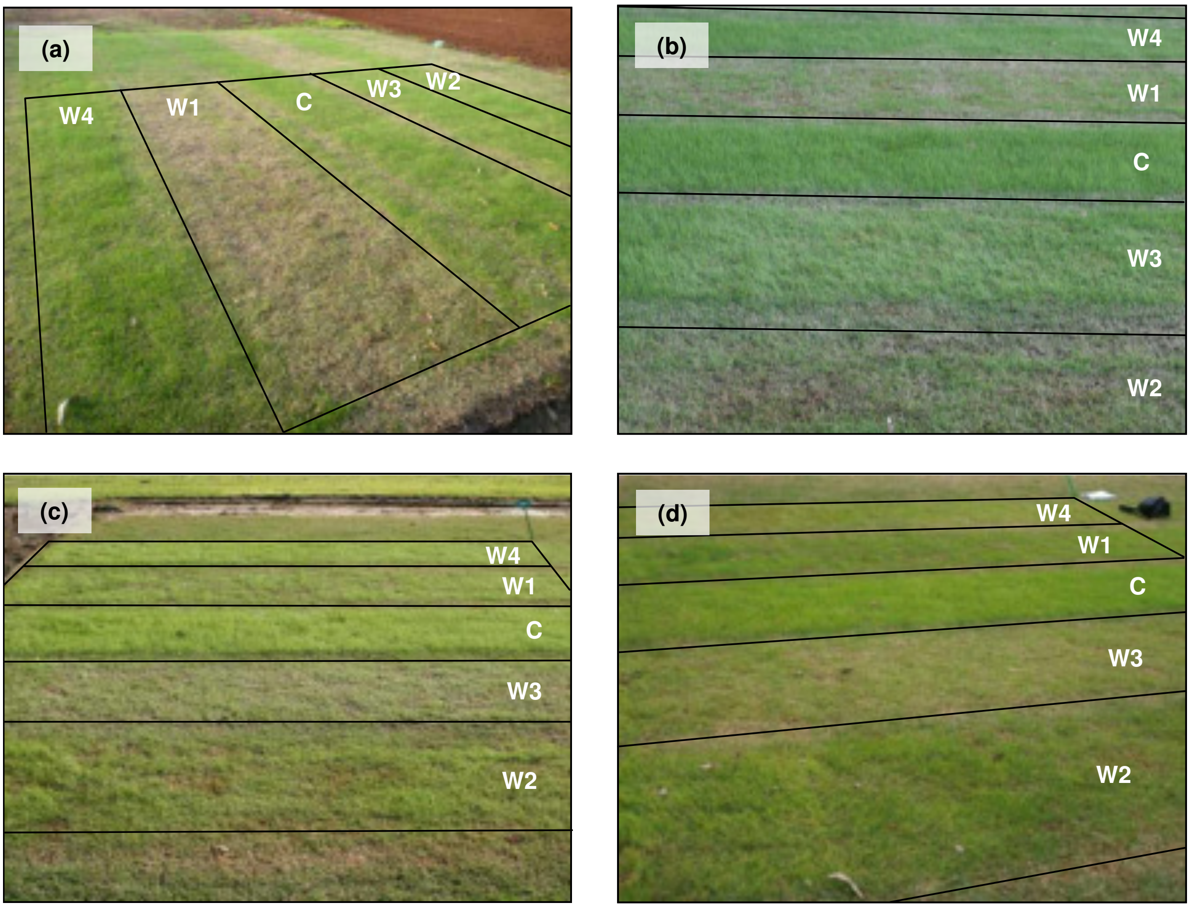


Plate 29 (a-d). Control (C) and trafficked (week 1 (W1), week 2 (W2), week 3 (W3) and week 4 (W4)) plots on 6th June (a), 13th June (b), 20th June (c) and 27th June 2011 (d).



3.4 Climate modelling for transitioning

Two different climate models for couch growth were evaluated:

Model A proposes that significant couch growth results when the daily minimum exceeds 15° C for 5 consecutive days. At the other end of the season, it is assumed couch growth slows when temperature falls below 15°C for 5 consecutive days.

Model B sums the recorded maximum and minimum daily temperatures, and proposes that significant couch growth occur when the sum exceeds 40°C for 5 or more consecutive days. Conversely, when the combined temperature falls below 40°C growth is inhibited.

Temperature data for the past 10 years was evaluated with each of the two models, using five locations: Brisbane, Gosford, Sydney, Melbourne and Auckland City. Stadium Managers in the respective regions were asked if the model supported their observations.

3.4.1 Climatic analysis for Brisbane using the 15°C model

Results using the15°C model are shown in Table 8.

Table 8. Dates over an 11 year period for Brisbane when temperature falls below 15°C for 5 consecutive days, and when temperature exceeds 15°C for 5 consecutive days.

Year	Date when temp falls below 15° C	Date when temp rises above 15° C
2000	May 10	Sept 26
2001	May 7	Oct 25
2002	May 11	Sept 25
2003	May 3	Sept 22
2004	May 1	Sept 25
2005	May 14	Sept 27
2006	April 23	Oct 15
2007	April 30	Sept 27
2008	April 23	Oct 30
2009	April 27	Oct 21
2010	May 7	Sept 22
2011	May 1	Oct 12

The model proposes that significant couch growth slow-down commences between 23rd April and 14th May; quite a narrow time scale (within a week or so either side of May 1st), which suggests there is a relatively high degree of predictability with the autumn slow down in couch growth.
Significant couch recovery is deemed to commence between 22nd Sept and 30th Oct; (7 out of 11 readings between 21st and 27th Sept).
Note that in a significant percentage of years (2000; 2001; 2002; 2003; 2007; 2008; 2009 and 2010) there was a subsequent cold snap during the 1st or 2nd week Oct. which would slow down couch recovery.
Results would suggest that optimal conditions for over-seeding in Brisbane would be around end of April, and for removing the ryegrass around end of September through to end of October.

3.4.2 Results for the combined 40°C model

Data for each of the 11 years for Brisbane was also analysed using the combined 40° C model (Table 9). Comparing the data sets it is apparent that there is a good agreement between the two models, with the "critical" estimated dates for couch growth within a week of each other.

Table 9. The combined 40° C model for Brisbane in 2011 (green represents dates when good couch growth can be expected).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1st	50.1	53.9	55.1	45.4	41.8	31.1	33	31.8	36.7	39.4	43	50.2
2nd	52.3	56.8	51.3	46.8	41.7	36.5	33.4	33	36.9	34.9	46.1	41.6
3rd	55	55.6	56.9	43.9	41.3	37.3	33.2	32.6	33.9	35.9	45.3	42.9
4th	52.9	56.2	47.6	44.8	40.1	34.8	34.1	31	34.2	35.3	47.3	44.3
5th	51	57.2	48.1	43.4	39.8	33.9	33.4	32	35.9	34.8	43.8	45
6th	45.3	57.2	46.6	42.4	39.2	36.4	28.6	33	35.7	35.6	42.6	41.5
7th	46.1	54.6	46	42.6	37.3	32.8	28.3	38.7	37.9	42.2	42.8	36.7
8th	48.4	48.1	45.1	40.7	36.6	31.4	27.3	36.8	37.9	40.2	45.6	42.7
9th	49.8	50	45.5	42.9	35.1	24.8	29	27.4	37.9	41.8	46.4	44.4
10th	49.6	50.4	47.3	43	35.7	27.2	26	28.4	30.3	40.6	48	45.6
11th	52.4	49.5	49.9	45.4	31.8	25	31.9	30.7	29.9	41.9	50.9	48.9
12th	51.5	50.9	50.1	44.8	33.5	30.9	28.3	31.9	30.4	43.3	49.6	54.2
13th	50.5	51.5	49.2	44.1	30.8	35	29.1	31.6	33.6	45.8	49	49.5
14th	48.3	53.2	48.9	46.6	31.2	29.7	9.3	33.4	35.9	44	52	47.6
15th	49	51.1	49.8	46	34.7	28.5	33	32	37.9	46.9	51.8	43.1
16th	49.2	49.1	51.7	41.4	34.2	29.7	28.4	34.1	39.7	44.5	52.3	45.3
17th	53	50.6	51.2	42.1	36.1	29.7	34	33.2	42.8	42.2	50.7	44.4
18th	58.1	52.3	50.5	38.7	35.9	28.8	33.5	35.6	46.2	40.7	49.3	42.3
19th	54.6	54	46.2	42.6	37	27.8	27.9	27.4	44.5	39.1	47.3	44.6
20th	50.4	57.4	47.5	46.4	38.3	26.8	28	30.9	39.9	39.3	48.6	48.2
21st	49.2	58.9	53.3	47.4	37.3	28.9	34	33.6	40.9	41.7	49.4	49.6
22nd	48.3	50.3	57.6	47.8	41.5	26.7	35.9	33.6	38.9	40.8	48.7	47.2
23rd	48.6	45.8	52	45.5	39	26.5	33.5	35.5	38	40.4	53.3	48.2
24th	48.5	46.5	51.6	44.5	36.7	30.8	29.7	35.7	41.2	40.8	45.2	48
25th	50.6	47.6	46.2	44.3	31.1	34.8	29.9	37.2	43.6	44.5	50.3	48.3
26th	52	49.8	47.8	42.1	33.2	35.7	31.6	35.3	37.3	47.7	52.3	50.2
27th	51.6	53.5	46.4	38.4	33.3	35.1	31.7	36.4	36.4	42.5	54.8	53.9
28th	53.3	54.1	44.9	38.5	33.2	34.4	28.7	40.3	35	43.2	53.1	47.4
29th	52.8		45.8	41.7	37.5	33.1	32.6	39.1	39	46.2	51.3	47.8
30th	50.8		43	41.2	37.1	33.1	31.5	38.4	36.2	46	49.8	48.6
31st	52.2		46.9		30.3		31.4	36.7		45.9		44.7

3.4.3 Regional comparisons

Locations evaluated using the two models were:

Brisbane – Brisbane 040913 Lat: 27.48° S Lon: 153.04° E

Sydney - Sydney Airport AMO, station no 066037 Lat: 33.95° S Lon: 151.17° E

Gosford – Station No 61087 Narara Research Station Lat: 33.39° S Lon: 151.33° E

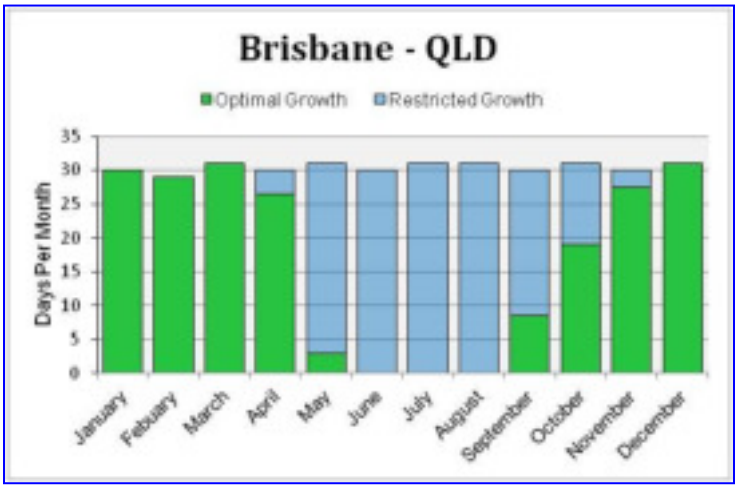
Auckland - No. 1962 Auckland Aero -37.00813 174.78873

Melbourne - Avalon Airport No 087113 Lat: 38.03° S Lon: 144.48° E

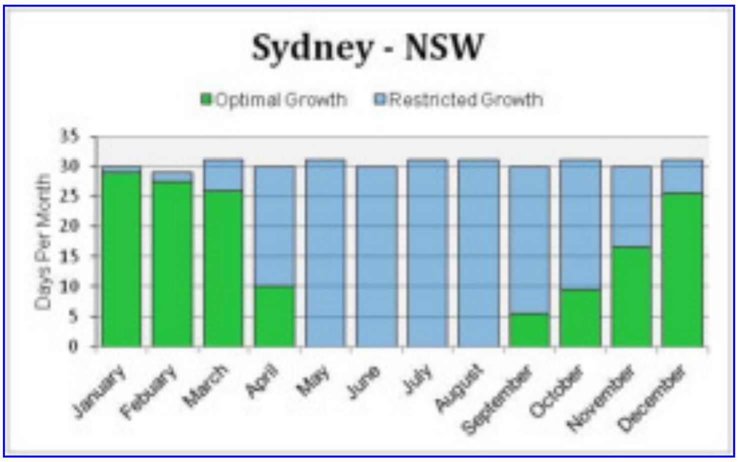
A summary of averaged data from the past 11 years is presented in Fig 16 (a-e). Green represents periods when optimal couch growth is expected.

Figure 16 (a-e). Time of the year when the temperature (as determined using the combined 40°C model) is deemed optimum for couch growth.

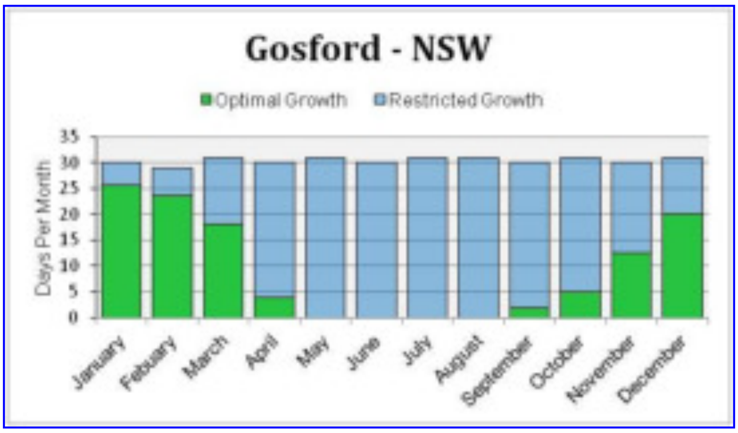
(a)



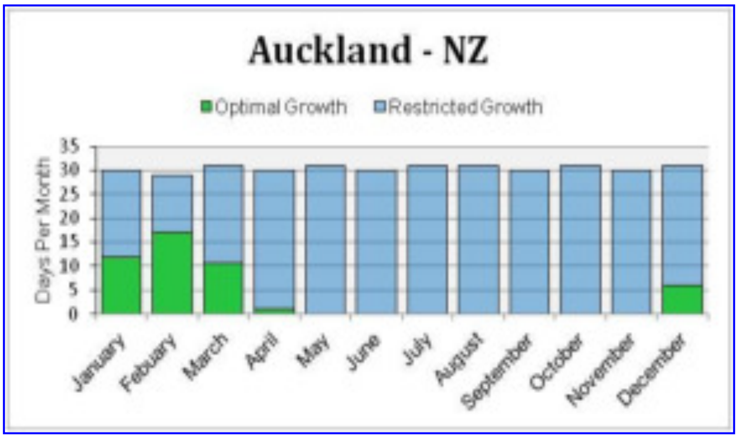
(b)



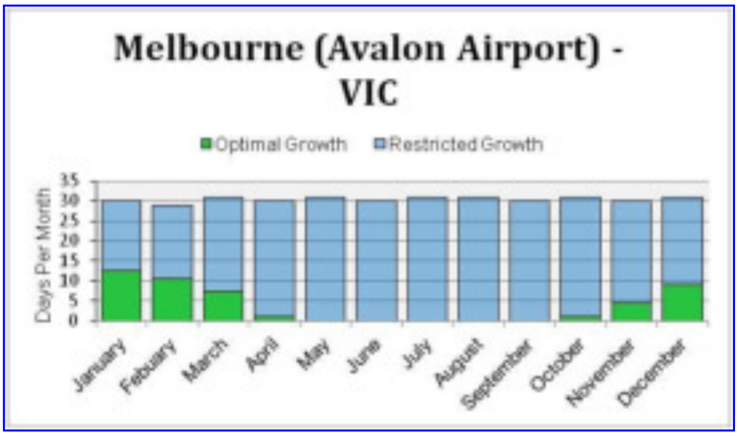
(c)



(d)



(e)



The data, not surprisingly, shows that there is a big difference in couch growing seasons between regions. Whereas Brisbane has at least 7 months of conditions ideal for couch growth, (Sydney is also well-placed), zones further south or even further inland (such as Gosford) have a restricted couch growth season. The model and comparative regional information could be useful to councils and others considering whether or not to use couch as the primary turf cover.

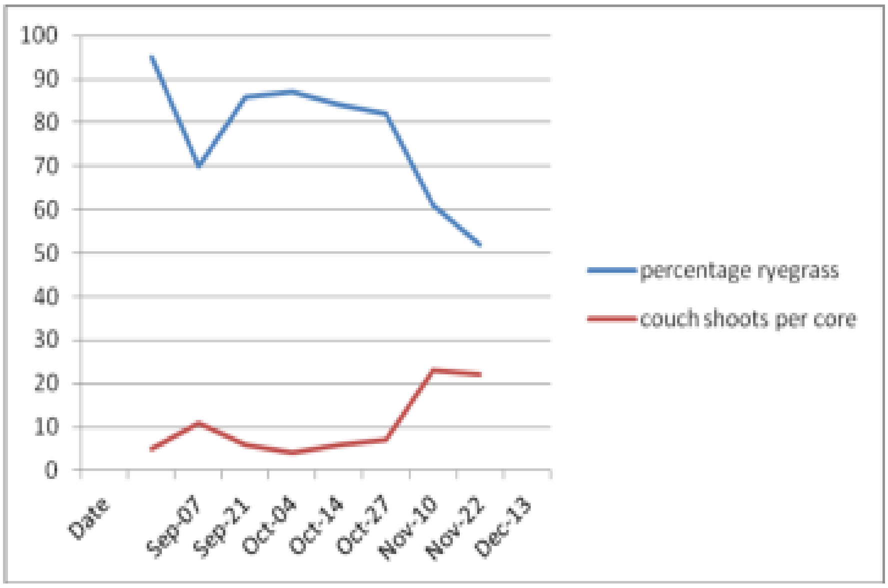
3.4.4 Monitoring the dynamics of a transitional turf grass environment

The health of couch rhizomes and stolons was monitored fortnightly at a major stadium in Brisbane over the spring/early summer period of 2011 in order to better understand the dynamics associated with spring transitioning from ryegrass to couch and to match this to the climatic data. The percentage of ryegrass and number of active couch shoots in the sports field on each sampling date are shown in Figure 17.

Results showed that the ryegrass percentage of the sward initially declined (in response to a warm "green-up" spell end of August), but then increased over what was a very cool and cloudy September. It wasn't until the end of October that a further significant decline in ryegrass percentage was evident. By early January the ryegrass had died out completely.

The couch health and active bud number remained relatively consistent throughout the period of sampling, and it was only from mid-late November on that a significant increase in the couch bud count was noted.

Figure 17. The change in ryegrass percentage and the number of active couch shoots per 50mm Ø core over the period September to mid-December, 2011, along with minimum daily temperature data (yellow denotes dates when good couch growth is expected).



Temperature data for Brisbane 2011

	Aug	Sept	Oct	Nov	Dec
Graph					
1st	8.8	12.8	12	18.1	21.9
2nd	9.8	13.1	12.4	18.1	16.7
3rd	9.7	11.8	13.3	17.1	15.8
4th	9.1	12.6	10.6	20.4	16.4
5th	10.3	13.4	12.2	18.6	19.4
6th	9.5	12.2	14.3	16.1	17.9
7th	13.9	12.6	15.9	15.8	16.8
8th	12.9	12.7	15.5	18	17.3
9th	5.3	15.2	12.7	18	16.9
10th	5.6	10.7	14.8	18.1	18.7
11th	9.7	7	14.2	21.6	18.5
12th	9.2	8.8	15.7	21.4	21.3
13th	9.1	11.4	18.5	20.5	18.4
14th	11	9.7	17.1	22.1	19.2
15th	9.5	10.2	19.4	19.4	18.5
16th	10.5	10.3	15.2	21.9	19.6
17th	11.4	11.2	19.7	21.8	17.3
18th	13.8	13.9	16.9	20.8	16.8
19th	6	13.9	15.9	18.7	17.6
20th	8.7	13.6	15.3	19	19.1
21st	12.1	15.8	16.1	19.5	21.7
22nd	12.4	14.2	15.6	19.7	19
23rd	13.9	12.3	15.3	22.4	20.6
24th	13.4	14.8	14.4	20.4	20.4
25th	14.2	17.5	16.2	20.7	19.4
26th	13.2	13.5	20.3	22.8	18.7
27th	16.1	13.1	16.8	20.9	21.4
28th	15.4	12.4	19.3	21.5	18.5
29th	13.7	16.9	19.8	21.5	19.7
30th	15.9	9.9	18.2	20.8	20.2
31st	12.5		20.3		18

4. Discussion

4.1 Survey and literature review

Transitioning, or ryegrass over-seeding into a warm season or C4 grass, is seen as an essential practice at many of our high profile sports stadiums and other turf areas. It is apparent that there is limited local information available to assist our stadium managers and others in planning and monitoring a transitioning program. The majority of our major stadiums that adopt transitioning practices have incurred major problems at times.

It is very apparent that turf managers, especially those at major multi-use stadiums, are "caught between a rock and a hard place" with transitioning. Most are aware that the ryegrass will compete strongly with the C4 grass for light and end up limiting the recovery of the C4 grass in spring/summer (this has been clearly highlighted with our research). Yet they are also aware of the pressure to prepare a quality, green-looking playing surface year-round. As such the temptation is to over-sow as early as possible (when a window of opportunity for seeding establishment is presented), to use very heavy seeding rates, often with repeats throughout the season, and to hold off removing the ryegrass until nature (hot weather) takes control. Turf managers having to prepare a year-round surface are very much at the mercy of weather in conjunction with the allocated usage program.

4.2 Field trials

All three cultivars of ryegrass ('Colosseum', 'Fiesta 4' and 'T3') established well at the four trial sites (3 sites in Queensland and 1 in NSW) regardless of the sowing method. Colosseum showed through as the quickest to germinate and to establish.

Researchers had success using the drop seeder and with applying the seed by hand as in the case with the application of seed to the NSW trial site. All sites were scarified or verticut prior to seeding, which was deemed to have aided ryegrass development. It was apparent to us through the research and site visits that scarifying is of value in ryegrass establishment where the couch mat is dense and where there is a need to get good seed/soil contact.

We were surprised that the field trials didn't show up any benefit of applying a growth regulator prior to seeding; we have seen benefits in other field situations. One possible reason for the nil response could be the lateness in the season (end April/early May) of our over-seeding, coupled with relatively low fertility and growth levels of the trial sites. It is expected that a growth regulator such as Primo will likely benefit ryegrass seedling establishment in other situations where the couch is actively growing and competing.

Results from our trials, in particular the Redlands Research Centre site, illustrate how vulnerable newly-established turf (in this case over-seeded ryegrass) is to wear and other stresses.
The RRC trial illustrated that significant damage was done to the ryegrass for up to 3 weeks after sowing, and beyond that the ryegrass was able to withstand the imposed wear. This has relevance for our major stadiums, who often struggle to find a 3+ week window following autumn over-seeding. Results from our other trial sites illustrate that even relatively mature ryegrass will

have inhibited growth if stresses are imposed (high wear at the Redlands Football club site, moisture stress at the QSAC trial site and nutrient stress at the Moore Park site).

Damage done to recently germinated ryegrass was found to be long-lasting, with poor recovery of the damaged ryegrass plants. It is understandable why some turf managers are required to repeat over-seeding throughout the season in order to maintain a uniform cover of ryegrass.

Our field trials illustrate the critical significance of climate on the transitioning out of ryegrass. Where stresses, in particular low moisture and high temperature, were imposed there was rapid reduction in the ryegrass percentage. Both the QSAC and Redlands Football sites were subjected to moisture stress, which had an over-riding impact on the ryegrass percentage and overall turf appearance. However, it was apparent from the trials that climatic stresses are unpredictable and unreliable. The Silverdale trial site for example resulted in full ryegrass cover remaining throughout the entire summer in the absence of artificially imposed (mechanical or chemical) stresses. Consequently the control plots were invariably of higher visual quality than the ryegrass control plots. In a different year, with less rain and more heat, a different response would be expected.

Using mechanical equipment (in particular verticutting and close mowing) was found to be effective at controlling ryegrass, provided there was subsequent hot, dry conditions. However, mechanical methods alone have an element of risk associated, and may not achieve complete removal of ryegrass, especially in a cool, wet summer. This was apparent to us on at least two of our trial sites. A combination approach using verticutting, a reduction in height of cut, in conjunction with the application of a selective herbicide (e.g. Tribute® or Destiny® depending on the genus of turf) would seem to be a less risky transitioning strategy.

International literature, supported by our research, indicates that ryegrass can be safely and efficiently removed from couch and kikuyu using selective herbicides. We are aware of and sympathetic to, cases where the turf manager are required to retain a year-round green surface and can't afford to have dead or discoloured turf for more than say a fortnight or so. Our trials showed that the use of chemicals, albeit resulting in relatively slow death and removal of ryegrass, resulted in discoloured turf for several weeks after treatment. Having turf of poor appearance for several weeks after transitioning is something that will be hard to avoid. Use of colorants is one possible alternative to mask discoloration.

A challenging feature of the sites selected (QSAC, Redlands United and Moore Park trial sites) was that they were subjected to actual and intense wear. Although this allowed us to observe "real world" situations, it made it more difficult to derive statistically significant differences between treatments. It is recommended that future trials be set up in areas where traffic can be controlled.

4. 3 Climatic modelling

The transitioning information derived from observing a local stadium in Brisbane, along with the climatic modeling information, represents interesting and useful data to help understand the dynamics of the turf environment. Data indicates that the decline in ryegrass content without chemical interference will depend on the season, with a wet, cool spring prolonging ryegrass persistence. Although this might seem useful in order to bring about a more consistent and less disruptive transitioning, it is also risky in that it is likely to inhibit couch recovery, and could even cause permanent damage to the couch stolons and rhizomes.

We were surprised that the health of the couch rhizomes and stolons at the venue monitored did not deteriorate badly over the late spring, despite the competition from ryegrass in October and early November. Observations in previous years from the same ground, and from other local venues, indicate that couch rhizome vigor can rapidly decline in spring/early summer as a result of ryegrass shading. Results from 2011 could reflect climatic differences, or the fact that the couch over-wintered in a stronger condition.

It is apparent that management of an over-seeded, couch-based sports field in a cooler environment, such as Auckland or Melbourne, presents added challenges. Leaving the ryegrass in over spring/early summer will undoubtedly set the couch back, yet removing ryegrass early will detract from the quality (appearance and potentially performance) over the late spring/early summer period. We are left with the view that it is not practical in such locations to have year-round green, high quality turf if using a transitional turf management strategy.

5. Recommendations

Every site (ground) will have specific requirements for transitioning. Timing and transitioning procedure will need to account for key variables such as fluctuations in climate, usage program and health of the warm season grass.

When over-seeding ryegrass into a couch or kikuyu sward it is important to ensure there is good seed to soil contact. Where the couch or kikuyu cover is dense it is recommended to scarify in order to open up a seed bed.

Given the vulnerability of young ryegrass plants to stresses, every opportunity should be given to get ryegrass seedlings well-established before re-use. A minimum of 3 weeks grow-in is advised. Ideally this spelling should be a consideration for sports administrators and venue managers when scheduling events.

Use of selective herbicides to transition out ryegrass is recommended, given the uncertainty of our climate. Mechanical and cultural transitioning treatments can work well, but are unreliable.

Retaining ryegrass cover beyond the point where couch starts budding represents a risk, in that couch is extremely sensitive to competition from shade, with a resulting deterioration in the condition of the couch rhizome health. Ideally ryegrass should be removed as soon as the couch starts sending out shoots. The longer transitioning is delayed beyond this point the greater the likely impact on couch turf cover and quality when the ryegrass is finally removed.

Spring transitioning back to a full couch or kikuyu sward is challenging. It must be expected that the turf cover will look and perform poorly for a significant period following transitioning. Again this should be considered by administrators when scheduling fixtures.

The point in spring at which couch rhizome vigor deteriorates to a dangerous level is something that definitely needs further investigation. As a practical guide stadium curators should regularly core sample and evaluate the health of the couch stolons and rhizomes throughout the spring/early summer. If health is seen to be rapidly deteriorating then early removal of ryegrass is advised.

In order for couch or kikuyu to build up sufficient reserves to over-winter it is important to ensure the plant is given adequate time to recover and photosynthesize. Research suggests at least 100 days of uninterrupted growth is required, which means turf managers need to be aware of the risks of over-seeding too early. The mechanisms associated with how couch builds up reserves is another area that warrants further investigation.

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Extension

Presentations included:

- A TU10015 project update by DEEDI members Jon Penberthy and Cynthia Carson was given at the 'Show Me the Green Stuff' field day hosted by Parks and Leisure Australia and Redlands City Council, Cleveland, 26 Oct. 2011 at the Redlands United Football Club. Plots inspections were also carried out by delegates at the Redlands United trial site.

- Formal paper presentation on ryegrass over-seeding into couch at the 2011 NZ Turf Conference (July 2011)
- Presentation to combined Sports Turf Association/Turf Queensland field day (March 2011).

Further presentations planned include:

- Turf Managers seminar for Sports Turf Association, NSW at Ryde TAFE on 17 April 012.
- Presentation to Gosford City Council and local stadium officials, 16 April 2012.
- Major Stadium Symposium, Brisbane, 7-9 August 2012.

Related articles that have been compiled to date include:

- McAuliffe, K.W. 2011. Ryegrass transitioning in warm season grasses. NZ Turf Management Journal. 26(3):17-18.
- McAuliffe, K.W. 2011. Couch in Queensland. Pitchcare Oceania, August 28th, 2011.
- McAuliffe, K.W. 2011. Ryegrass transitioning in warm season grasses. Pitchcare Oceania, 19th Sept, 2011.
- McAuliffe, K.W. 2011. Ryegrass transitioning in warm season grasses. Proceedings NZ Turf Conference and Trade Show 2011:51-53.

Appendix 1 Survey results summary

Turf Managers at thirteen leading Australian and 1 major off-shore sports venues that undertake ryegrass over-seeding into a couch or kikuyu turf surface were interviewed. Venues (and Curators) interviewed included:

- Gabba (Kevin Mitchell) – Queensland
- Suncorp Mal Caddies) – Queensland
- Skilled Park – (Phil Burke) - Queensland
- Bally more Oval (- Scott Wallis) - Queensland
- Stockland Park (Brian Perrin)- Queensland
- QSAC (Peter Cronin) – Queensland
- Sydney Football Stadium (Michel Finch) – NSW
- ANZ Stadium (Graeme Logan) – NSW
- Sydney Football Stadium (Tom Parker) - NSW
- Etihad Stadium (Gavin Darby) – Vic (limited transitioning done)
- Newcastle Main field - Greg Askew
- Redfern Oval – Matt Sommerville
- North Sydney Oval – Peter Devlin
- Hong Kong Stadium (Yuen Hing-keung) – Hong Kong

Summary of survey returns

Question	Mode	Range	Comments
Window available after autumn over-seeding before re-use (in weeks)?	2	0-4	Damage to young ryegrass in first couple of weeks is unknown
Window available after spring transitioning before re-use (weeks)	3	1-15	Major multi-use venues have minimal resting interval due to overlapping seasons
Estimated time needed after sowing before re-use (weeks)	4	2-7	Needs research to identify and quantify
Seeding rate (kg/ha)	500	300 - 6000	Multiple applications made at some venues.
Does the curator have any input to fixture scheduling?	Mix		Yes = 6; No = 8
Assessed success rating for 2010 overseeding	Average to low		50% rated success as average only
Use of growth regulator in autumn over seeding?	1/3 use		Yes = 5; No = 9
Use of chemicals to take out ryegrass in spring?			Yes = 6; No = 8
Chemical used (if used)?			Monument 225mls/ha; Coliseum 100mls /ha; Destiny (for kikuyu)
Success rating for spring removal of ryegrass?	Average		50% indicated only average success; Cool wet conditions in spring were cited as affecting ryegrass die-out.
Estimated time for full couch recovery after removing ryegrass in spring? (weeks)	8	5-12	The time period to achieve recovery of the couch exceeds the window of rest available

Q. Planned oversowing date in 2011

Timing varied depending largely on latitude of the venue.

- Central Queensland – As late as end May
- SE Queensland – early to late April
- NSW – early to mid-march
- Hong Kong – Nov/Dec (equivalent of May/June in Australia)

Q. Methods of overseeding

All grounds used a specialist seed drill as part of the overseeding (various makes and models; Blec machine common); broadcasting before match play was also carried out.

Q. Ryegrass type used for over-seeding

All grounds used specialist- bred sports turf perennial ryegrass cultivars
A variety of ryegrass cultivars were used for oversowing, including: Arena 2; Colosseum; Caravelle; Pennant and Fiesta 4, Striker Gold. Preference was for a winter-active ryegrass, although most used a mix of grasses. It was reported that little difference was noted between cultivar types.

Q. Transitioning method

The majority (8 out 14) grounds used cultural stress (rather than chemicals) as a means of controlling ryegrass in spring. This included: inducing moisture stress, lowering mowing height; applying biostimulants; scarifying and traffic/concert stress.

Q. Date for spring transitioning

Venues in Queensland started transitioning in September; 5 grounds in Queensland in early October; NSW transitioning started mid Sept to mid October; Hong Kong starts in late May (late November equivalent).

Q. Estimated date when couch breaks dormancy

Most venues in Queensland cited mid- to late September as the date for notable couch re-growth. Sydney venues noted mid Sept to mid to late October, and in Hong Kong early April (early Oct equivalent).

Q. Ideal date for spring transitioning

Timing depended largely on latitude.

- Central Queensland –Sept
- SE Queensland – Oct
- NSW – mid Sept to early Nov
- Hong Kong – May (equivalent to Nov in Australia)

Q. Other points noted

- Transitioning timetables will depend on (and must fit around) usage schedules
- Concern of poor appearance/performance in spring if using chemicals to remove ryegrass
- Also some concern about damage done to couch by chemicals
- Each venue will have a different need/timing and methodology
- Most venues do not have enough spelling for successful transitioning
- Important to ensure couch gets chance to build up energy reserves in autumn if it is to effectively transition in the spring.

Appendix 2 Literature review on ryegrass transitioning with warm season grasses

Where is transitioning carried out and for what reasons?

Transitioning refers to the overseeding, and later removal, of one grass into and from another grass, generally a cool season grass overseeded into a warm season grass. Most overseeding, (and most related research) is based on the overseeding of couch fairways in the southern states of the USA.

Overseeding is done around the world, particularly those areas with a Mediterranean climate, including parts of southern Europe, South America, South Africa, Central Asia and Australasia.

Next to the USA, Australia has done more research on the subject. Overseeding in Australia occurs along the eastern seaboard from Melbourne through to Townsville. Overseeding is done with both kikuyu and couch sports fields (Cooper, 1994).

In addition to sports fields, transitioning is done on (kikuyu) race tracks, and some golf course fairways.

There are mixed reports on the benefits afforded by transitioning. There is no doubt that the main benefit of overseeding is improved appearance over the cooler months, when the couch or kikuyu is in a dormant condition. Overseeded ryegrass can continue to grow and remain green over winter months. Furthermore ryegrass can stripe up and produce a high quality appearance.

Powell noted that there is limited evidence to show that overseeding improves anything except color and appearance. He argues that it may be better to put up with a few weeks of brown turf than to have the hassles created by overseeding. In contrast , research at the University of Tennessee (Thoms et al.) demonstrated that couch sports field that were overseeded could tolerate up to twice the amount of traffic as non-overseeded couch, while maintaining 90% turf cover.

There is a general agreement among sports field managers in Australia that overseeded couch is more wear tolerant than dormant couch alone, and that new ryegrass seedlings can help with divot recovery.

As the level of wear increases, non-overseeded couch is considered to take a longer time to break dormancy so repair slows even more. Stewart et al.demonstrated that late winter or early spring traffic on dormant couch on a sports field delayed spring green-up significantly.

Timing of seeding

The optimum time for over-seeding is late autumn when the warm season grass growth has slowed by lower temperatures but early enough that temperature is still favourable for germination of the ryegrass.

Powell notes that the best overseeding date is approximately 2-3 weeks prior to the expected first killing frost. Seeding too early will have the ryegrass struggle to compete against the couch, and will increase the risk of disease (pythium and brown patch). Fungicide- treated seed would be suggested for early sowings. Seeding too late and cold weather may prevent sufficient establishment.

Whitlark endeavored to model couch transitioning in Phoenix Arizona using climatic data. He suggested that couch growth may be best predicted by using heat units, rather than day or night temperatures. Using 1900 heat units as the benchmark Whitlark estimated couch growth would slow down in Phoenix on June 11th on average, with timing ranging from June 4th to June 20th.

Peart recommended that the best time to oversow in Australia is when the soil temperature at 100 mm depth is between 22-26°C. He pointed out that timing is best determined from historic temperature records. Spencer suggests the ideal temperature for overseeding is when day temperature is between 21-29C and night time temperature around 13°C.

Overseeding too early can have a negative impact on the health of the over-wintering couch. Duble points out that couch energy reserves show a definite cyclic pattern. During summer months, energy reserves accumulate very little since they are repeatedly used for re-growth following mowing. Significant energy reserve accumulation occurs in autumn when photosynthetic activity is high and shoot growth is reduced. Energy reserves, principally starch, will be gradually depleted during winter months, and rapidly depleted during the spring green-up and root dieback period.

In Australia most ryegrass overseeding is carried out in March through to April, largely depending on latitude and program (McAuliffe).

Seeding methods and rates

In regard to method of seeding, methodology will depend to some degree on the density of the couch. It is considered important to open up a dense couch canopy in order to enable the ryegrass seed to have soil contact, and to reduce early competition (Peart). Grady advised to close-mow and verticut a couch sward before seeding to enhance success.

Thoms et al demonstrated optimal benefits of overseeding occurred at high seeding rates of perennial ryegrass (up to 900 kg/ha).

Some practitioners adopt sequential overseeding throughout the autumn/winter season. Rossi investigated weekly overseeding with either perennial ryegrass or tall fescue at 300kg/ha. He observed that ryegrass was able to maintain 90% density throughout the season when overseeded weekly. There was no difference between a 300 and 500kg per ha rate of application.

Bornino et al. looked at seeding rates with overseeded couch athletic fields in the northern transition zone of the USA. They found a seeding strategy of 25/25/25/25 (10 days apart) consistently produced the best coverage, and that coverage rarely increased at seeding rates higher than 2440 kg/ha/year. Their recommendation for the region was to sow a total of 2440 kg/ha/year in four equal applications ten days apart.

Survey information from leading curators around Australia (McAuliffe) provide the following summary points for a successful autumn over seeding:

- Target good seed / soil contact through the removal of thatch (but at a time that will allow recovery of the warm season turf prior to overseeding).
- Lower mowing height at time of sowing.

- Use a growth regulator product such as Primo Maxx to reduce competition.
- Time the sowing to coincide with night temperatures of 12 to 17C.
- Use a starter fertiliser at sowing or at the first signs of seedling emergence.
- Monitor young seedlings for disease; an application of a fungicide prior to oversowing is advisable.
- A window of at least a minimum 3 weeks without play is advisable to allow for good establishment.
- Sow ryegrass should be sown at the rate of 3 to 5kg / 100m2, with additional top ups as and when needed.
- Maintain consistent moisture levels up to and immediately following seedling emergence.

Use of plant growth regulators in transitioning

Researchers and practitioners have found that ryegrass establishment into a couch sward can be enhanced by using plant growth regulators (Delgado). This effect is the result of reduced competition from the couch. McCarty found that foliar-absorbed PGRs such as Primo have little residual soil activity, and as such allow overseeding soon after the PGR application with minimum effect upon seed germination.

Growth regulators are currently only used in Australia at a small proportion of venues (McAuliffe).

Ryegrass cultivars

There is limited documented information on what species and cultivars perform best in overseeding. Annual ryegrasses have been used for overseeding in the past, but are generally considered too coarse and upright for high-quality turf. Perennial ryegrass appears to be the superior species to use (Fontanier & Steinke). With respect to ryegrass cultivars, the seed companies go to length to highlight differences in the temperature sensitivity of different grasses. Curators are faced with choosing between winter-active cultivars, summer active cultivars, high or low endophyte cultivars and perennial or annual cultivars.

Researchers have noted that the newer heat-, disease-, and drought-tolerant varieties of perennial ryegrass used for overseeding tend to survive later into spring or summer than older cultivars. Thus, while these newer ryegrass varieties provide more attractive turf during winter months, they also create challenges with spring transition (Horgan & Yalverton, 1999a). Fontainier and Steinke noted that perennial ryegrass inhibited spring green up of couch more so than annual ryegrass. This trend was also noted by Nelson, who commented that transitioning out of perennial ryegrass in Overton Texas occurred about 1 month later and took place over a longer time frame than for annual ryegrass.
Morris outlined the findings of a major cultivar evaluation trial conducted by the USGA, NTEP and GCSAA in the USA. He noted that many perennial ryegrasses performed well in the trials and there was no statistical difference among the entries.

Post-seeding management

Observation demonstrates that young seedlings cannot take abuse. If the surface is trafficked during the germination period damage to seedlings can be expected. There is no research of note that has been done to demonstrate how much damage is done when newly-sown ryegrass is trafficked, although general opinion among Australian curators indicates a minimum of 3 weeks spelling is required (McAuliffe).

Spring transitioning - Mechanisms of dormancy break and conditions needed for couch growth/recovery

Literature cites the following conditions are needed for couch to break dormancy and begin budding (kikuyu will recover at a lower temperature).

- Night time air temperature (or day time minimum) of around 16 C;
- Feedback from Queensland indicates that some cultivars of couch may require temperatures of 17 or 18C before budding (Pers. Comm., P. Cronin).
- Soil temperature above 10C (Murphy)
- The minimum soil temperature for sowing couch seed is 18C (Dossey)

Duble noted that couch green-up and recovery begins when night time temperatures remain above 60° F for several days in the spring and soil temperature reaches 65° F (15.5 °C) at the 100mm depth. In contrast Whitlark cites a soil temperature at 100 mm of 55° F (13 C), as the start of spring green-up.
When these conditions occur lateral buds at the nodes of couch stolons and rhizomes break dormancy, carbohydrate reserves are converted to soluble sugars and the first new leaves appear. About this time some of the old roots begin to deteriorate and new roots are produced at the node.

If the temperature remains favorable during the transition period, couch recovery will progress until complete green-up of the turf occurs. Depending on the temperature, complete green-up may require 2 to 6 weeks (the higher the temperature, the faster the process is completed).

It is also recognized by researchers in the USA that couch needs at least 100 days of good growth, without competition from ryegrass (Miller).

Duble reported that early spring green-up of couch is accompanied by a rapid dieback of old roots and production of new roots. This accounts for the vulnerability of the grass to low temperatures, herbicides and competition from winter grasses during the transition period. A significant change in temperature, untimely applications of fertilizers or herbicides or competition from cool season grasses could result in a significant loss of couch during the spring transition period.

Shade (either from buildings or overseeded grass) has a major impact on spring transition of couch by weakening the plant (reducing energy reserves) and by limiting soil warming. Couch growing in partial shade accumulates less energy reserves as that growing in full sunlight, and as such is slower to recover in the spring and more susceptible to environmental stress during this period.

Spring Transitioning practice

It is an important and well-known fact that perennial ryegrass aggressively competes with the couch for resources in the spring (especially light). This competition can have a significant after effect. In addition to light competition, there is some evidence that ryegrass provides an allelopathic/inhibitory effect on couch (McCauley et. al). If this does occur however it is likely to be of secondary importance to the light competition effect. Regardless of the mechanism, the fact that couch health is badly compromised by ryegrass persevering in spring shouldn't be overlooked. Observations from both the USA and Australia highlight that in just one or two years of overseeding, couch fields often convert to ryegrass and the couch is predominantly lost (Powell). Perennial ryegrass transitioning has been made more difficult by the development of heat-tolerant cultivars that persist longer (Teuton et al,).

The choices for spring transitioning are to use cultural means, use chemicals, or a combination of both.

From research conducted at North Carolina State University Horgan and Yelverton (1999a) noted that the use of cultural methods to remove perennial ryegrass at higher heights of cut was not effective. They noted that plots receiving the cultural treatments transitioned the ryegrass out at about the same time as the untreated plots, indicating that it was the climatic conditions, especially temperature and relative humidity that dictated the speed of transition.

Natural/cultural removal of ryegrass?

A gradual transition back to couch would be nice if it could be achieved, especially for our heavily-used stadiums where there is no window to take out the ryegrass and no tolerance of a discoloured surface. However experience has demonstrated that to achieve natural transitioning is challenging (McIroy,). First up climate is unpredictable, and it becomes somewhat of a lottery to know if the climate will enable stress to be imposed on the ryegrass. Also, it is often noted that some ryegrass plants hold on longer, given a clumpy, unsightly appearance to the field.

Cultural transitioning

With cultural transitioning in North Carolina Horgan and Yelverton (1999a) offered the following advice :

- Reduce mowing height, if possible, several weeks before expected spring green-up of couch in order to reduce shading, warm the soil and set back the overseeded ryegrass.
- Avoid spring fertilization until 2 to 3 weeks after spring green-up.
- Maintain good soil moisture for the new set of roots being produced by couch.
- Initiate light, frequent verticutting

McAfee pointed out that along with proper timing, seedbed preparation is an important step in achieving a successful stand of cool-season turfgrass on sports fields.
A key goal with spring transitioning is to reduce shading impact on the couch. Duble noted that high rates of soluble nitrogen applied too early can be detrimental to spring recovery of couch and that application of fertilizer should be made once the green-up process in well under way.

Vertical mowing and topdressing have shown to inhibit couch grass transition in the spring (Horgan and Yelverton, 1999b).

The most common cultural practices for removal of ryegrass in Australia include: inducing moisture stress, close mowing and scarifying (McAuliffe).

Chemical Removal of ryegrass – why needed?

Breedon et al. advised that turf managers who decide to overseed in the fall should be committed to chemically removing the overseeded perennial ryegrass in spring with a transitioning herbicide. They argue the cost of chemical removal is minor in relation to the damage that can be done by leaving the ryegrass in for too long.

Despite advice from the USA turf industry, only around 50% of Australian curators chemically transition out ryegrass in spring (McAuliffe). The main reasons for this are the risk of chemicals causing damage to the turf (couch) and having an unsightly appearance and poor performance of the turf as the ryegrass dies out. This latter view is understandable, in that many of our major stadiums are used year-round, with no more than a couple of weeks window between seasons. This differs from the majority of football/baseball stadiums in the USA that have a decent window for renovation post-season.

What chemicals to use for transitioning?

There are several chemicals that can selectively remove ryegrass without affecting the health of the couch. These products (trade names listed) include slow transitioning chemicals such as Kerb, and faster transitioning products such as the sulfonylureas, such as foramsulfuron (Revolver), rimsulfuron (Tranxit), trifloxysulfron (Monument) and metsulfuron (Manor). A slower response does not mean that these herbicides are less effective. McElroy notes that rate of application will hinge on the maturity of the ryegrass, with higher rates needed for strong, individual clumpy ryegrass. He observed that the best results were achieved after lowering mowing height to 12mm, and applying 0.005 kg ai ha-1 mid-May of trifloxysulfuron (Monument). Teuton et al. conducted a major study of the different chemicals used to transition out ryegrass from couch. They compared foramsulfuron, trifloxysulfuron, metsulfuron, rimsulfuron, diclofop-methyl and natural (non-chemical) transition. It was found that all herbicides provided > 90% ryegrass control except diclofop-methyl and foramsulfuron by three weeks after initial application. There was no couch injury observed except for sequential applications of rimsulfuron.
Another major study of chemical use for transitioning was conducted by Callahan et. al. They found the most effective herbicides on ryegrass removal were: metsulfuron at 0.02 kg ai/ha, and sulfometuron at 0.034 kg/ha. The most phytotoxic herbicide to the couch was sulfometuron.

Nickson compiled a review of chemicals that have historically been used in Australia for controlling cool season grasses in couch. Since this review (in 2002) new chemicals have entered the market. The two most popular chemicals for ryegrass removal in Australia at present are Monument and Coliseum.

When to apply chemical?

In Tennessee, USA, McElroy recommended applying chemicals beginning in mid-April through mid-May (bear in mind this is the northern hemisphere). In South East Queensland climatic information and practice would suggest end of September is an appropriate time for treatment (pers comm. Malcolm Caddies). In general, warmer temperatures usually increase the speed of transitioning.

Callahan et al. found that an April 1st application date was best when using chemicals to remove ryegrass from couch in Tenessee, USA. They also noted that the couch could experience more than one break of dormancy in the spring.

With regard to the guideline rule of thumb that couch needs 100days of growth without competition from ryegrass, Whitlark advised that ryegrass in Phoenix needs to be completely removed by end of June. Given chemicals will take time to kick in it was advised to spray mid-June.

Summary

Ryegrass overseeding into couch or kikuyu swards is seen by many as a luxury, to improve aesthetics of the playing surface, rather than performance. However there is no doubt that for some venues, in particular major stadiums in northern NSW and south east Queensland, ryegrass overseeding is seen as an essential practice in order to meet user group requirements.

There is no doubt that overseeding a cool season grass has a negative effect on the health of the warm season grass. Failure to acknowledge this fact and to take appropriate measures will inevitable result in loss of couch cover and an ever-increasing reliance on ryegrass to provide cover.

Appendix 3 Raw data from QSAC, Redlands Football and Moore Park trial sites

Table 10. Summary of percentage green, percentage ryegrass and turfgrass quality collected from the QSAC trial site 8 June to 11 November 2011.

		SigmaScan Data - Percentage Green (%)					Subjective Assessment - Percentage Ryegrass (%)					Subjective Assessment - Turfgrass Quality (1-9)				
		8 Jun 2011	19 Aug 2011	30 Aug 2011	28 Sep 2011	11 Nov 2011	8 Jun 2011	19 Aug 2011	30 Aug 2011	28 Sep 2011	11 Nov 2011	8 Jun 2011	19 Aug 2011	30 Aug 2011	28 Sep 2011	11 Nov 2011
A1	Control	99.8	98.5	97.7	70.9	90.4	90.0	96.5	95.7	16.3	37.0	7.6	7.8	7.0	6.0	6.4
	Chem 1	98.7	97.8	85.0	65.5	85.0	78.2	95.0	75.0	19.5	38.0	7.3	7.8	6.3	4.8	6.0
	Chem 2	98.2	60.6	87.0	66.2	80.7	78.0	47.5	80.7	7.0	0.0	7.1	6.3	5.1	4.4	5.5
	Chem 3	99.2	92.9	85.6	70.4	86.0	68.0	90.0	57.0	7.5	42.5	7.4	7.0	5.6	5.5	6.3
	Chem 4	99.2	89.8	83.9	89.1	81.0	95.8	72.5	64.2	40.0	36.3	7.5	7.3	5.4	5.8	6.5
	Mechanical	99.4	85.4	78.5	62.7	88.9	83.3	47.5	59.5	21.3	23.8	7.5	6.3	5.4	4.8	6.0
A2	Control	99.4	94.9	96.5	54.4	91.9	93.7	87.5	85.8	1.3	16.3	7.9	7.3	6.3	5.1	6.1
	Chem 1	98.7	99.2	88.6	61.4	91.4	94.7	97.5	74.5	26.3	35.0	8.1	7.8	6.3	4.8	6.3
	Chem 2	98.1	50.3	85.9	60.2	86.1	92.0	22.5	66.2	1.3	10.0	7.6	6.0	4.9	4.5	5.9
	Chem 3	99.3	52.8	84.4	70.3	86.3	88.7	45.0	64.5	0.5	8.3	7.9	7.3	5.6	5.1	6.3
	Chem 4	99.3	72.0	84.8	79.7	74.4	89.2	50.0	65.0	15.0	30.0	7.9	6.8	5.1	5.8	6.4
	Mechanical	99.5	38.2	79.8	64.6	77.5	93.2	2.5	61.3	2.5	35.8	8.0	5.3	4.3	4.3	6.3
A3	Control	98.9	98.3	96.2	61.2	91.9	50.0	52.5	66.0	2.5	26.2	7.1	7.0	6.1	5.3	6.0
	Chem 1	98.0	98.3	90.7	66.9	96.5	27.5	40.0	62.5	6.3	27.8	7.1	7.3	6.1	4.6	6.4
	Chem 2	97.5	46.5	89.8	64.6	83.5	52.5	10.0	60.0	10.0	2.8	7.0	5.5	5.5	4.9	6.1
	Chem 3	98.4	91.9	95.1	63.0	94.5	62.0	50.0	65.0	2.5	12.8	7.4	6.5	6.4	5.4	6.4
	Chem 4	98.0	61.3	79.9	79.0	80.2	53.8	10.0	47.5	15.0	17.5	7.0	6.0	5.1	5.8	6.0
	Mechanical	97.8	47.3	82.2	57.3	84.6	53.8	20.0	39.2	1.3	5.5	6.8	6.0	4.9	4.6	6.0
A4	Control	98.3	91.9	95.7	63.2	95.0	43.8	35.0	63.8	6.3	21.2	7.5	7.3	5.9	5.3	6.5
	Chem 1	98.1	96.7	85.0	66.1	82.9	46.2	45.0	57.5	5.0	11.7	7.3	7.5	5.5	4.9	6.1
	Chem 2	97.9	60.7	81.9	55.7	89.5	42.5	10.0	43.8	1.3	2.5	7.1	6.0	4.5	4.6	5.9
	Chem 3	98.1	74.2	86.8	69.3	92.4	47.5	30.0	47.5	10.0	23.7	7.6	7.3	5.6	4.9	6.1
	Chem 4	97.7	78.8	89.7	88.3	97.9	63.8	52.5	56.2	11.3	33.0	7.4	6.8	5.8	5.9	7.0
	Mechanical	98.6	48.9	81.3	63.9	94.0	51.2	7.5	42.5	5.0	16.7	7.5	5.8	4.6	4.3	6.1
A5	Control	97.8	94.4	91.4	76.8	86.5	71.2	77.5	57.5	13.8	11.2	7.3	7.3	5.8	5.5	6.3
	Chem 1	97.5	94.9	88.1	64.8	78.2	51.2	89.0	62.5	21.3	27.5	6.9	7.3	5.6	5.0	6.1
	Chem 2	96.2	58.5	75.6	57.2	81.5	48.8	30.0	38.0	1.3	0.0	6.5	6.0	3.5	4.6	5.9
	Chem 3	96.6	75.6	87.7	73.2	85.2	56.2	25.0	63.0	2.5	12.5	7.1	7.0	5.4	5.6	6.0
	Chem 4	97.6	68.2	83.2	84.8	77.0	70.0	50.0	53.8	16.8	37.5	6.9	6.0	4.5	5.5	6.8
	Mechanical	97.4	45.4	79.0	60.8	81.7	61.2	17.5	41.2	6.3	27.0	7.0	5.5	4.4	4.3	6.1
A6	Control	97.9	95.3	90.2	54.1	85.6	68.8	65.0	52.0	2.5	4.5	7.1	7.3	4.8	4.8	5.5
	Chem 1	97.0	94.0	90.0	66.0	89.1	53.8	50.0	73.5	11.8	12.5	7.0	7.0	5.9	4.9	5.9
	Chem 2	98.3	56.7	87.6	61.9	93.7	67.5	22.5	62.5	0.0	0.5	6.9	6.0	4.8	4.9	6.0
	Chem 3	98.2	80.5	84.8	75.1	89.6	71.2	52.5	50.8	1.3	15.0	7.4	6.8	5.4	5.4	6.0
	Chem 4	98.5	66.6	77.6	82.5	78.7	62.2	49.5	57.5	5.0	12.5	7.0	6.3	4.4	5.0	6.1
	Mechanical	97.5	59.3	72.9	60.5	86.0	71.3	4.0	22.0	1.3	9.5	6.6	5.5	4.1	4.4	6.1
Control	Control	90.7	85.5	77.3	68.1	91.1	0.0	0.0	0.0	0.0	0.0	6.3	6.0	4.4	5.1	5.8
	Chem 1	87.9	82.4	78.6	79.2	79.2	0.0	0.0	0.0	0.0	0.0	6.4	6.3	5.1	5.6	6.3
	Chem 2	80.3	40.9	80.6	65.8	89.2	0.0	0.0	0.0	0.0	0.0	5.8	5.3	4.4	5.3	6.3
	Chem 3	88.1	59.0	82.0	60.9	92.0	0.0	0.0	0.0	0.0	0.0	6.0	5.3	4.9	4.9	5.8
	Chem 4	90.4	57.2	74.7	81.9	90.9	0.0	0.0	0.0	0.0	0.0	6.1	5.3	4.1	5.0	6.0
	Mechanical	83.6	46.7	77.0	67.3	92.6	0.0	0.0	0.0	0.0	0.0	5.8	5.8	4.5	4.8	6.1
LSD (0.05)		*3.6*	*28.3*	*18.0*	*27.2*	*17.4*	*26.5*	*38.6*	*34.3*	*24.2*	*30.2*	*0.6*	*1.3*	*1.8*	*1.9*	*0.9*

Table 11. Summary of percentage green, percentage ryegrass and turfgrass quality collected from the Redlands United trial site 8 June 2011 to 3 February 2012.

		SigmaScan Data - Percentage Green (%)							Subjective Assessment - Percentage Ryegrass (%)							Subjective Assessment - Turfgrass Quality (1-9)						
		8 Jun 2011	12 Aug 2011	29 Aug 2011	28 Sep 2011	28 Oct 2011	8 Dec 2011	3 Feb 2012	8 Jun 2011	12 Aug 2011	29 Aug 2011	28 Sep 2011	28 Oct 2011	8 Dec 2011	3 Feb 2012	8 Jun 2011	12 Aug 2011	29 Aug 2011	28 Sep 2011	28 Oct 2011	8 Dec 2011	3 Feb 2012
A1	Control	83.9	74.7	90.3	86.5	98.5	92.6	84.6	52.5	46.5	73.5	61.3	52.5	2.0	0.0	6.8	6.5	7.1	7.3	7.6	6.1	7.4
	Chem 1	93.0	74.9	90.4	92.4	98.1	91.5	90.4	47.5	31.5	69.2	60.0	42.3	3.3	0.0	7.0	6.6	6.8	7.3	7.9	6.3	7.4
	Chem 2	92.1	81.3	94.6	92.4	91.3	89.6	85.4	45.5	60.5	91.7	81.3	2.5	0.0	0.0	6.6	6.8	7.1	6.9	7.1	6.3	7.0
	Chem 3	87.1	76.0	93.5	94.6	98.2	93.1	86.2	38.0	48.8	73.0	54.3	47.5	0.0	0.0	7.0	6.5	6.8	7.3	7.6	6.6	7.0
	Chem 4	82.1	71.2	84.9	93.6	98.1	75.3	72.8	30.8	49.2	48.2	86.0	63.7	2.3	0.0	6.9	6.5	6.4	7.3	7.9	5.1	6.9
	Mechanical	90.7	78.7	95.1	95.8	97.0	91.2	83.9	40.5	49.2	90.8	48.5	73.0	4.5	0.0	6.9	6.4	7.0	6.5	7.4	6.0	7.0
A2	Control	89.7	67.3	92.0	91.4	99.3	93.1	87.7	42.5	29.2	74.5	70.0	57.7	4.0	0.0	7.0	6.3	6.9	6.9	7.6	6.5	7.4
	Chem 1	90.9	75.2	88.1	95.4	98.8	92.6	87.2	41.7	32.0	60.5	65.0	54.5	4.3	0.0	6.8	6.5	7.0	7.0	7.9	6.3	7.0
	Chem 2	93.9	79.6	94.0	92.3	94.9	91.7	83.7	24.7	57.2	82.8	75.8	0.8	0.0	0.0	6.6	6.4	6.4	7.0	6.9	6.3	7.1
	Chem 3	89.2	72.8	87.2	91.8	98.5	89.8	74.8	29.0	42.2	59.3	52.8	46.0	0.0	0.0	6.9	6.8	6.8	7.3	7.9	6.4	6.6
	Chem 4	84.0	66.3	87.4	92.8	98.6	83.8	72.8	31.7	20.5	60.3	67.5	91.2	2.5	0.0	6.9	6.4	6.3	7.0	7.9	5.0	6.9
	Mechanical	89.1	81.4	93.7	94.2	98.3	93.9	88.8	48.0	55.7	76.3	71.8	74.2	5.3	0.0	7.1	6.6	7.0	6.5	7.4	6.1	6.9
A3	Control	84.4	79.0	87.6	84.9	98.0	89.9	80.5	49.0	45.7	76.5	75.0	57.5	1.8	0.0	6.9	6.8	7.4	7.5	8.1	6.3	7.0
	Chem 1	92.3	79.8	88.9	87.5	98.7	82.5	86.0	49.3	28.7	73.0	52.5	28.8	0.8	0.0	7.3	6.9	6.6	7.3	7.9	5.6	6.6
	Chem 2	93.6	77.4	90.6	90.7	91.7	93.3	85.0	47.5	30.5	90.5	63.8	2.0	0.0	0.0	6.8	6.5	7.0	6.9	7.3	6.3	7.1
	Chem 3	89.2	78.2	83.8	89.8	99.4	94.8	85.8	39.0	24.2	60.7	48.5	45.0	0.0	0.0	7.1	6.6	6.9	7.0	7.6	6.6	6.9
	Chem 4	85.8	68.9	87.7	91.4	97.4	86.2	77.3	48.8	30.7	83.0	78.5	42.0	0.5	0.0	7.0	6.6	6.3	7.4	7.9	5.5	7.0
	Mechanical	95.8	79.3	91.6	89.8	97.8	94.0	83.4	35.8	60.2	91.5	66.3	38.2	1.8	0.0	6.9	6.8	7.1	6.3	7.4	6.3	7.0
A4	Control	89.2	73.7	88.5	86.6	98.9	92.6	80.6	54.5	18.2	73.8	59.0	45.8	1.5	0.0	7.0	6.6	6.6	7.0	7.8	6.4	7.1
	Chem 1	93.3	74.2	84.9	92.6	98.6	91.8	78.0	47.5	25.5	68.0	49.8	23.8	0.0	0.0	7.1	6.8	6.6	6.9	7.6	6.6	6.9
	Chem 2	94.1	77.7	89.9	92.6	94.8	95.7	83.2	37.5	43.8	85.0	71.8	5.0	0.0	0.0	6.8	6.5	6.3	6.9	7.4	6.8	7.3
	Chem 3	88.5	76.5	83.7	92.3	98.5	95.7	82.6	27.2	40.5	65.0	60.0	37.0	0.0	0.0	7.0	6.8	6.5	7.1	7.6	6.4	6.9
	Chem 4	86.5	73.3	90.0	92.0	98.5	78.8	71.0	31.2	32.2	86.8	78.8	36.2	0.0	0.0	7.4	6.4	6.5	7.3	8.0	5.5	6.6
	Mechanical	94.3	75.3	91.0	91.1	99.5	96.3	85.8	38.7	30.5	86.8	65.8	44.8	3.3	0.0	6.9	6.5	6.4	6.6	7.6	6.6	6.9
A5	Control	84.6	75.8	84.4	90.8	98.2	90.4	82.3	25.0	21.2	47.0	44.8	42.2	1.3	0.0	6.6	6.5	6.3	7.0	7.9	6.5	6.9
	Chem 1	86.3	68.5	87.5	91.4	99.1	95.1	80.5	11.5	13.5	42.2	28.5	24.8	0.8	0.0	6.5	6.5	6.3	6.5	7.8	6.6	6.9
	Chem 2	88.1	76.1	88.1	91.1	95.5	96.6	85.3	11.2	31.0	60.0	40.5	2.0	0.0	0.0	6.3	6.1	6.1	6.6	7.4	7.0	7.1
	Chem 3	84.9	75.7	81.8	88.8	99.2	94.7	86.8	16.2	32.5	47.0	33.3	30.0	0.0	0.0	6.5	6.6	6.6	7.1	7.8	6.6	6.6
	Chem 4	80.4	71.9	83.3	91.8	98.9	85.6	82.8	18.0	27.5	57.0	53.0	57.0	2.3	0.0	6.6	6.3	6.1	6.8	7.8	5.9	6.8
	Mechanical	92.4	77.2	89.9	92.9	99.2	98.2	86.0	8.0	28.2	40.8	24.0	22.5	3.0	0.0	6.4	6.4	6.5	6.4	7.5	6.6	6.8
A6	Control	90.4	69.9	80.2	90.1	98.1	91.6	80.1	11.7	12.7	34.2	28.3	22.5	0.8	0.0	6.9	6.4	6.1	6.8	7.8	6.8	6.8
	Chem 1	90.6	75.5	85.0	94.6	98.9	94.5	79.5	11.7	9.5	30.0	17.3	10.3	0.8	0.0	7.0	6.4	6.1	6.6	7.8	6.8	6.8
	Chem 2	92.9	71.4	87.3	92.1	96.8	97.8	80.2	10.2	24.2	58.8	42.3	6.0	0.0	0.0	7.0	6.4	6.1	6.6	7.5	7.0	7.0
	Chem 3	88.4	70.2	84.4	91.7	99.3	95.3	83.7	13.7	16.2	43.5	35.3	25.0	0.0	0.0	6.6	6.5	6.5	6.9	7.6	6.4	6.8
	Chem 4	85.9	64.4	81.7	91.1	98.6	88.5	77.8	9.2	19.2	42.2	46.8	39.2	1.8	0.0	6.8	6.1	6.3	7.0	7.6	5.9	6.9
	Mechanical	92.5	76.4	87.7	91.7	99.0	96.6	87.6	17.0	10.2	44.0	19.0	22.5	3.3	0.0	6.8	6.6	6.0	6.4	7.5	6.6	6.6
Control	Control	83.1	69.3	78.6	87.7	96.9	98.2	84.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	6.6	5.9	7.0	7.6	7.3	7.0
	Chem 1	87.0	68.7	77.4	93.4	98.4	97.9	84.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	6.6	5.9	6.9	7.6	7.1	6.9
	Chem 2	89.1	67.8	79.4	92.7	98.4	98.4	78.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	6.5	5.9	7.0	7.8	7.3	7.0
	Chem 3	82.8	66.8	83.9	91.7	99.4	98.7	85.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.9	6.8	6.0	7.1	7.8	7.1	6.8
	Chem 4	79.8	63.1	77.5	91.4	97.2	97.0	77.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	6.5	5.8	7.0	7.5	6.3	6.9
	Mechanical	89.0	70.0	82.7	92.3	97.9	97.4	90.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.9	6.6	5.8	6.6	7.4	6.9	6.9
LSD (0.05)		*9.7*	*16.3*	*12.6*	*7.7*	*3.2*	*11.4*	*17.8*	*39.0*	*37.2*	*49.4*	*39.8*	*33.9*	*2.8*	***	*0.9*	*0.8*	*1.0*	*0.6*	*0.5*	*0.9*	*0.5*

Table 12. Summary of percentage green, percentage ryegrass and turfgrass quality collected from the Moore Park trial site 18 May 2011 to 8 February 2012.

		SigmaScan Data - Percentage Green (%)							Subjective Assessment - Percentage Ryegrass (%)							Subjective Assessment - Turfgrass Quality (1-9)						
		18 May 2011	24 Jun 2011	1 Aug 2011	29 Sep 2011	27 Oct 2011	6 Dec 2011	8 Feb 2012	18 May 2011	24 Jun 2011	1 Aug 2011	29 Sep 2011	27 Oct 2011	6 Dec 2011	8 Feb 2012	18 May 2011	24 Jun 2011	1 Aug 2011	29 Sep 2011	27 Oct 2011	6 Dec 2011	8 Feb 2012
A1	Control	96.4	86.1	93.8	99.5	98.7	96.7	98.6	85.8	51.3	45.5	94.0	28.8	33.8	17.5	6.6	7.0	5.8	7.6	7.8	6.6	7.4
	Chem 1	96.8	83.9	84.1	99.3	98.8	98.2	96.8	60.0	45.0	35.0	95.5	24.3	37.0	2.5	6.4	6.9	5.1	8.0	8.0	7.0	7.0
	Chem 2	95.6	91.1	93.7	99.6	90.7	99.4	97.3	75.5	67.0	78.5	99.0	0.0	1.3	0.0	6.9	7.5	6.6	8.0	6.0	7.4	7.6
	Chem 3	96.1	86.4	95.0	99.7	99.4	96.4	97.5	58.3	53.8	69.0	93.2	14.8	0.0	1.0	6.6	7.3	6.5	7.9	7.8	6.4	7.5
	Chem 4	93.5	90.2	92.2	98.2	98.9	96.2	97.0	61.8	44.0	45.0	98.0	22.0	34.5	2.5	6.5	7.3	6.4	7.6	8.0	7.0	6.8
	Mechanical	95.4	89.2	93.5	99.8	96.1	99.0	96.7	70.5	44.3	56.3	92.8	11.8	13.3	2.0	6.8	7.4	6.1	7.9	6.9	7.0	7.4
A2	Control	95.8	90.9	94.1	99.3	96.7	96.5	97.8	47.3	46.0	45.5	83.0	13.0	6.8	4.5	6.4	7.1	5.5	7.9	6.4	6.5	7.4
	Chem 1	96.7	86.0	87.1	99.0	96.5	97.9	97.3	42.0	49.5	45.5	83.5	19.3	14.0	2.5	6.4	7.1	5.5	7.8	6.9	6.5	7.1
	Chem 2	95.5	93.6	93.7	99.7	80.6	99.3	95.5	50.0	58.8	58.3	98.5	0.0	0.0	0.0	6.8	7.5	6.0	7.9	5.5	7.8	7.5
	Chem 3	97.1	92.7	96.8	98.7	99.4	95.2	98.9	46.3	51.8	60.0	89.3	21.3	0.0	0.0	6.6	7.3	6.1	7.9	7.5	6.5	7.6
	Chem 4	96.1	90.6	95.0	99.5	95.1	97.4	97.5	48.8	66.8	52.8	87.0	13.5	23.0	0.0	6.3	7.3	5.8	7.8	7.0	6.9	7.3
	Mechanical	97.6	84.6	88.6	99.7	92.0	98.7	96.6	61.3	65.5	51.5	99.0	6.8	5.3	0.0	6.6	7.1	5.6	8.0	5.9	6.8	6.9
A3	Control	94.2	90.7	92.0	99.1	98.3	98.0	96.8	47.5	17.3	43.8	51.5	18.3	12.8	7.5	6.3	7.1	6.4	7.4	7.4	7.0	7.3
	Chem 1	94.5	86.0	83.9	98.8	97.6	96.8	95.8	50.0	32.2	32.5	43.8	25.0	26.3	14.8	5.9	6.9	5.3	7.9	7.4	6.6	6.9
	Chem 2	92.9	90.6	88.9	99.5	83.7	99.3	96.4	44.3	16.8	42.5	49.0	0.5	2.5	1.0	6.0	7.0	5.8	7.8	6.0	7.4	7.4
	Chem 3	96.3	89.2	94.4	99.2	97.9	94.3	96.1	61.5	22.8	36.8	49.3	30.0	8.8	1.3	6.8	7.0	6.1	7.9	7.1	6.3	7.4
	Chem 4	95.8	89.4	92.6	99.0	99.0	98.3	97.5	37.0	27.5	42.5	54.0	26.3	18.0	6.3	6.1	6.8	6.3	7.8	7.8	6.9	7.1
	Mechanical	95.4	84.8	85.3	99.0	87.8	95.7	95.2	46.8	27.0	45.8	57.5	16.0	23.5	11.8	6.3	6.9	5.9	7.8	6.5	6.5	7.0
A4	Control	96.1	87.3	90.3	99.6	99.2	97.8	97.4	27.0	21.5	44.5	55.8	37.5	13.0	4.5	6.1	7.0	5.9	7.4	7.9	6.8	7.4
	Chem 1	96.2	82.1	84.0	99.3	99.4	98.3	96.8	34.5	16.0	32.8	53.8	35.8	24.3	7.5	6.0	6.8	5.1	7.6	7.9	6.9	6.9
	Chem 2	94.5	92.5	91.9	99.3	98.2	99.6	96.8	33.8	30.0	52.5	58.0	1.8	0.0	0.0	6.5	7.3	6.4	7.8	6.8	7.6	7.4
	Chem 3	95.9	85.1	86.9	99.4	99.3	96.2	97.5	31.3	45.0	32.0	49.2	25.0	0.0	0.0	6.1	6.8	5.5	7.5	8.1	6.8	7.8
	Chem 4	95.6	88.1	91.7	99.6	99.4	98.4	95.7	30.0	31.2	37.8	49.5	31.5	24.3	0.0	6.1	7.0	6.0	7.3	8.1	6.8	6.8
	Mechanical	96.0	86.0	90.4	99.4	97.2	98.4	97.1	40.0	19.5	31.8	72.0	28.0	18.0	2.5	6.1	7.3	5.6	7.8	7.6	6.8	7.1
A5	Control	95.7	91.6	93.6	98.3	97.8	98.6	95.9	53.8	42.0	53.8	79.3	15.0	10.0	0.0	6.5	7.3	6.1	7.5	7.8	7.1	7.5
	Chem 1	94.9	85.2	87.2	99.2	98.1	98.3	96.6	43.8	28.0	43.3	92.8	23.8	22.5	0.0	6.0	7.1	5.5	8.1	7.1	6.9	7.1
	Chem 2	94.2	91.0	95.7	99.1	94.9	99.6	96.6	57.5	45.8	68.0	87.5	0.0	0.0	1.8	6.5	7.4	6.5	7.9	6.3	7.8	7.6
	Chem 3	92.7	91.8	95.5	98.9	99.1	97.4	98.6	47.0	30.8	52.0	69.5	26.5	0.0	0.0	6.6	7.0	6.1	7.9	7.8	6.6	7.5
	Chem 4	90.9	89.9	94.5	99.5	99.3	98.1	97.0	40.8	35.5	49.5	85.3	29.3	23.5	25.0	6.3	7.3	6.0	7.8	7.9	7.0	7.1
	Mechanical	94.9	89.6	89.1	99.5	94.4	97.7	94.9	60.0	34.8	41.3	78.8	20.5	9.8	0.0	6.5	7.0	5.5	7.9	7.0	6.8	7.3
A6	Control	95.2	90.4	93.2	99.0	98.3	96.4	96.6	29.5	21.2	32.5	74.8	18.5	19.3	4.5	6.6	7.3	5.8	7.9	7.6	6.8	7.4
	Chem 1	90.3	87.2	84.8	99.1	97.8	97.2	96.9	33.8	23.0	39.3	69.0	19.3	20.0	11.0	6.4	7.0	5.6	7.9	7.9	6.9	7.1
	Chem 2	94.6	91.5	91.5	99.5	90.2	99.2	97.4	35.0	46.8	51.3	85.3	1.3	1.8	0.0	6.9	7.6	6.3	7.9	6.6	7.6	7.8
	Chem 3	95.5	89.4	93.5	98.9	99.4	96.2	97.8	35.0	35.5	47.8	57.0	20.5	0.8	0.0	6.4	7.4	6.1	8.0	8.0	6.5	7.5
	Chem 4	95.2	89.4	90.6	99.4	99.1	96.8	96.6	38.8	17.3	38.0	57.2	28.5	25.8	4.5	6.4	7.0	6.1	7.5	8.0	7.0	6.8
	Mechanical	96.4	86.0	90.0	99.4	95.1	98.6	95.8	42.0	27.0	43.8	76.0	22.5	20.8	7.3	6.3	7.3	6.1	8.1	6.9	7.1	7.3
Control	Control	89.0	79.9	82.4	98.2	99.1	98.8	98.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	6.6	5.8	7.1	7.9	7.4	7.6
	Chem 1	90.5	78.9	83.5	97.8	99.1	99.0	97.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	6.3	5.6	7.4	8.1	7.4	7.5
	Chem 2	87.6	82.1	83.9	98.1	99.3	99.1	95.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	6.9	5.8	7.5	7.6	7.8	7.9
	Chem 3	92.4	81.9	83.0	99.1	99.6	99.7	97.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	6.4	5.8	7.1	7.9	7.4	7.4
	Chem 4	89.9	84.7	88.8	98.7	99.1	99.2	98.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	6.8	5.9	6.9	8.1	7.8	7.6
	Mechanical	87.7	76.5	81.1	98.4	95.3	99.0	97.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	6.4	5.5	7.4	7.4	7.5	7.5
LSD (0.05)		*5.3*	*7.8*	*9.0*	*1.4*	*6.9*	*2.7*	*2.6*	*23.7*	*31.4*	*20.9*	*32.0*	*17.5*	*16.3*	*13.4*	*0.8*	*0.5*	*0.9*	*0.7*	*1.1*	*0.6*	*0.5*