Establishment and Management of Salt-Tolerant Amenity Grasses to Reduce Urban Salinity Effect

Dr Rachel Poulter
Department of Employment, Economic Development & Innovation

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TU06006: ***Establishment and Management of Salt-Tolerant Amenity Grasses to Reduce Urban Salinity Effects***

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Purpose of Report: To investigate all aspects of salinity management of amenity areas and to formulate best management practices from scientific results. These guidelines are intended to aid parkland managers maximise turfgrass performance and maintenance efficiency in saline areas.

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1 MEDIA SUMMARY

Salinity has been recognised nationally as a major problem with the main focus on the spread of dryland salinity in agricultural areas. However, salinity has also been recognised as a serious problem in urban areas, affecting both inland towns and coastal areas. Coastal parklands face a high level of use from recreational activities, but their locations present them with a unique set of challenges. Salt spray or tidal inundation can result in areas of unthrifty grass or bare ground.

Maintaining a healthy environment has become a challenging issue in salt-affected urban locations, particularly where tourist-based activities and lifestyle issues are involved.

Salt-tolerant grasses can play a number of positive roles in helping to meet these challenges. While salt tolerant grasses are not a silver bullet for salinity problems, they do buy time for park managers to provide a healthy grass cover in salt affected areas, or areas that are irrigated with water containing appreciable levels of salt. This is especially significant if alternate sources of water are to be used for irrigation. Drought-affected groundwater sources will have relatively high concentrations of salts, as can recycled water, which is in greater use than ever before.

This project looked at finding suitable hard-wearing varieties of turfgrasses for parks and determining the best ways to establish and manage these turfgrasses to ensure locals and visitors could enjoy them.

The project approached the overall problem of poor quality coastal parkland through a step by step process, with detailed investigation into individual issues. These individual issues have been integrated on a larger scale in salt-affected parks as the final stage of proving the technology developed through this and the previous project. A key finding has been that each of the salt tolerant turfgrasses has the potential to establish and maintain good ground coverage if they are well maintained and provided with the necessities of life, food, air and water. Like all plants, they do require these inputs, albeit minimally. Failure to provide any one of these can result in less than satisfactory turfgrass quality.

A key outcome of the project is the development of establishment and management guidelines providing various options from the construction and establishment of new grounds through to remediation of existing parklands. These guidelines, or best management practices, will be readily available to councils.

The research and subsequent guidelines emphasise the importance of viewing the entire system holistically and managing the turfgrass carefully through all aspects of planning, establishment and maintenance.

Through adoption of best management practices identified in this project, councils can be confident in the establishment and management of salt tolerant turfgrasses in amenity areas. The wider advantage is that there will be a flow through effect enhancing consumer confidence in the purchase of premium turfgrass cultivars for specific need situations. These may be home gardens, urban open spaces, sports fields, golf courses, or rehabilitation sites.

The economic benefits to council will be realised through judicious use of funds in planning, establishing and managing such sites. Similarly, the turf production industry stands to benefit through improved consumer confidence. Ultimately the community stands to receive immeasurable benefits through the many health and environmental advantages afforded by healthy parks and gardens.

2 TECHNICAL SUMMARY

Salinity has been recognised nationally as a major problem with the main focus on the spread of dryland salinity in agricultural areas. However, salinity has also been recognised as a serious problem in urban areas, affecting both inland towns and coastal areas. Approximately 85% of Australia's population lives within 50 km of the coast with the greatest population occurring along the coastlines of New South Wales and Queensland (Australian Bureau of Statistics 1998). Maintaining a healthy environment has become a challenging issue in salt-affected urban locations, particularly where tourist-based activities and lifestyle issues are involved. Salt-tolerant grasses can play a number of positive roles in helping to meet these challenges.

However, urban salinity can only be effectively addressed through a holistic approach, in which the adaptation characteristics of the various salt tolerant grasses are understood and integrated into a systems management approach. The ideal outcome would be a patchwork of different species across a landscape, matching levels of tolerance and adaptation to not only levels of salinity, but also waterlogging, high wear and drought and other associated site challenges.

This project built upon the successful outcomes of TU02005 by adding to the database of salt tolerance among warm season turfgrass cultivars, through further hydroponic screening trials. Hydroponic screening trials focussed on new cultivars or cultivars that were not possible to cover in the time available under TU02005, including: 11 new cultivars of *Paspalum vaginatum*; 13 cultivars of *Cynodon dactylon*; six cultivars of *Stenotaphrum secundatum*; one accession of *Cynodon transvaalensis*; 12 *Cynodon dactylon x transvaalensis* hybrids; two cultivars of *Sporobolus virginicus*; five cultivars of *Zoysia japonica*; one cultivar of *Z. macrantha*, one common form of *Z. tenuifolia* and one *Z. japonica x tenuifolia* hybrid.

The relative salinity tolerance of different turfgrasses is quantified in terms of their growth response to increasing levels of salinity, often defined by the salt level that equates to a 50% reduction in shoot yield, or alternatively the threshold salinity.

The most salt tolerant species in these trials were *Sporobolus virginicus* and *Paspalum vaginatum*, consistent with the findings from TU02005 (Loch, Poulter et al. 2006). *Cynodon dactylon* showed the largest range in threshold values with some cultivars highly sensitive to salt, while others were tolerant to levels approaching that of the more halophytic grasses. Coupled with the observational and anecdotal evidence of high drought tolerance, this species and other intermediately tolerant species provide options for site specific situations in which soil salinity is coupled with additional challenges such as shade and high traffic conditions.

By recognising the fact that a salt tolerant grass is not the complete solution to salinity problems this project has been able to further investigate sustainable long-term establishment and management practices that maximise the ability of the selected grass to survive and grow under a particular set of salinity and usage parameters.

Salt-tolerant turf grasses with potential for special use situations were trialled under field conditions at three sites within the Gold Coast City Council, while three sites, established under TU02005 within the Redland City Council boundaries were monitored for continued grass survival. Several randomised block experiments within Gold Coast City were established to compare the health and longevity of seashore paspalum (*Paspalum vaginatum*), Manila grass (*Zoysia matrella*), as well as the more tolerant cultivars of other species like buffalo grass (*Stenotaphrum secundatum*) and green couch (*Cynodon dactylon)*. While scientific results were difficult to achieve under off-site field situations in which conditions cannot be controlled, these trials provided valuable observational evidence of the likely survival of these species.

Four approaches were adopted to investigate the establishment of the selected salt tolerant turfgrasses in order to develop protocols for the better construction or remediation of grassed amenity areas. Alternatives to laying full sod such as sprigging were investigated, and were found to be more appropriate for areas of low traffic as the establishment time is greater. Trials under controlled and protected conditions successfully achieved a full cover of *Paspalum vaginatum* from sprigs in a 10 week time frame.

Salt affected sites are often associated with poor soil structure, due to an imbalance in exchangeable sodium. Such soils can become less permeable to water, oxygen and roots. As soil pores become smaller, blocked or less continuous, water infiltration and drainage decreases, oxygen diffusion decreases and soil strength and surface hardness increase. A segment of the research investigated techniques for the alleviation of soil compaction that compliment salinity management. Various methods of soil de-compaction were investigated on highly compacted heavy clay soil in Redlands City. It was found that the heavy duplex soil of marine clay sediments required the most aggressive of treatments in order to achieve limited short-term effects. Interestingly, a well constructed sports field showed a far greater and longer term response to de-compaction operations, highlighting the importance of appropriate construction in the successful establishment and management of turfgrasses on salt affected sites.

Fertiliser trials in this project determined plant demand for nitrogen (N) (the most substantial element in any turf grass fertiliser program) to species level. This work produced data that can be used as a guide when fertilising, in order to produce optimal growth and quality in the major turf grass species used in public parkland. An experiment commenced during TU02005 and monitored further in this project, investigated six representative warm-season turfgrasses to determine the optimum maintenance requirements for fertiliser N in south-east Queensland. In doing so, we recognised that optimum level is also related to use and intensity of use, with high profile well-used parks requiring higher maintenance N than low profile parks where maintaining botanical composition at a lower level of turf quality might be acceptable. Kikuyu (*Pennisetum clandestinum*) seemed to require the greatest N input (300-400 kg N/ha/year), followed by the green couch (*Cynodon dactylon*) cultivars 'Wintergreen' and 'FLoraTeX' requiring approximately 300 kg N/ha/year for optimal condition and growth. 'Sir Walter' (*Stenotaphrum secundatum*) and 'Sea Isle 1'(*Paspalum vaginatum*) had a moderate requirement of approximately 200 kg N/ha/year. 'Aussiblue' (*Digitaria didactyla*) maintained optimal growth and quality at 100-200 kg N/ha/year.

Turfgrass managers responsible for areas prone to salt accumulation, require a method of monitoring salinity. While laboratory analysis of soil samples, for a range of physical and chemical attributes, is recommended annually, an alternative methodology for soil salinity measurement on a more frequent basis was considered ideal. Two new scientific, portable instruments were investigated to determine their usability for council workers in assessing salinity levels during site inspections. Unfortunately, the variation in readings between sites suggested, that at this stage the units were not satisfactory for use in parks or other amenity spaces where irrigation and soil type were not consistent.

As discussed, this project approached the overall problem of poor quality coastal parkland in a structured step-wise manner. Firstly the detailed work reported in Chapters 4 to 9 describes individual issues that have been assessed, and the management strategies developed for each specific problem. Secondly, these individual strategies were integrated on a larger scale in salt-affected parks as the final stage of proving the technology developed through this and the previous project. A set of guidelines has been prepared to provide various options from the construction and establishment of new grounds through to remediation of existing parklands by supporting the growth of endemic grasses. They describe a best management process through which salt affected sites should be assessed, remediated and managed. These guidelines, or best management practices, will be readily available to councils.

Unfortunately not all aspects of best management could be fully demonstrated due to the drought conditions that persisted throughout the majority of this project. It became council policy to not irrigate amenity areas due to the high level water restrictions imposed by government. This has prevented them employing two of the best management practices for salt-tolerant grasses: frequent irrigation during the establishment phase and regular leaching of salts below the root zone. The consequences limited the ability of this project to fully demonstrate best management practices. However, it has been possible to demonstrate the advantages that best management practices have had on ensuring the sustainability of turfgrass through hostile conditions (high salt levels coupled with inadequate water supply).

Despite the limitations described, this project will deliver valuable outcomes to stakeholders. Through adoption of best management practices identified through segmental research studies, more cost effective (and successful) establishment and management of salt-affected sites will be achieved. Previously, some high salinity sites have been turfed several times over a number of years (and Council budgets) for a 100% failure record. By eliminating this budgetary waste through targeted workable solutions, local authorities will be more amenable to investing appropriate amounts into these areas. In some cases, this will lead to cost savings as well as resulting in better quality turf. In all cases, however, improved turf quality will be of benefit to ratepayers, directly through increased local use of open space in parks and sportsfields and indirectly by attracting tourists and other visitors to the region bringing associated economic benefits. At the same time, environmental degradation and erosion of soil in bare areas will be greatly reduced. These same principles will also be applicable to degradation of public buildings and private dwellings.

By adopting the sound biologically-based principles developed through this project, local councils will also be better equipped to resist (and debunk) ill-considered cost-cutting measures proposed by developers and their supporting “experts’’ (e.g. engineering and environmental consultants). The major and immediate beneficiaries of information and protocols developed through this project will be Redland City and Gold Coast City. Depending on the source of the salinity, some of the detail generated by specific studies under this project will be more applicable to certain local authorities than others (and vice versa at other times).

At the same time, land developers will benefit by knowing clearly what is required of them when preparing an application for submission for planning approval from Council. While some recommended practices may add to the initial costs, this will be more than offset by establishing well grassed parks not in need of the regular and costly remediation required where economic ‘corners’ were previously being cut.

3 BACKGROUND AND GENERAL INTRODUCTION

Salinity is an increasingly important issue facing land and landscape managers throughout Australia. Its recognition as a major national problem, together with the formulation of the National Action Plan (NAP) to tackle salinity and water quality issues, relate primarily to the spread of dryland salinity in agricultural areas, particularly the irrigated lands of the Murray-Darling Basin and dryland cropping areas in south-western Australia. At the same time, salinity is a serious problem in coastal areas, though different underlying factors lead to the accumulation of salt in the soil in each case.

Urban salinity has also been acknowledged as an increasingly serious problem, affecting both inland towns (particularly in southern NSW, Victoria and the WA wheatbelt) and coastal areas where the majority of Australia's population lives, works and spends a major part of their leisure/recreational time. At the community level, maintaining a high integrity of the natural and built environment has become an important issue, particularly where tourist-based activities and lifestyle issues are involved. For affected homeowners, they face the stark reality of their major personal asset - their house - being degraded by rising salt and its economic value reduced. As Nicholson (2003) warned, damage to infrastructure and the built environment in urban areas has the potential to outstrip the cost of salinity in rural environments.

Building in saline landscapes will result in salinity problems emerging in urban areas (just as it will in rural environments) when the water balance through the catchment is disrupted. Water use is increased and water flows changed following urbanisation and the construction of housing developments. This in turn results in drainage problems leading to the development of pockets and whole areas of salinity hazard through an urban community. Landscape factors such as slope, geology, parent material, soils, structural geological controls, and catchment shape are all significant factors in the location and scale of urban salinity development.

In these different salt-affected urban environments, salt-tolerant grasses can play a number of diverse, but positive roles. These include beach protection; grassing of parklands, sportsfields and golf courses; home lawns; and roadside stabilisation and protection (e.g. Loch and Lees (2001)). As with rural salinity, urban salinity can only be effectively addressed through a landscape (ecosystem) based approach in which the needs of discharge and recharge areas can both be addressed (Loch, Barrett-Lennard et al. 2003). The ideal outcome would be a patchwork of different species across a landscape, matching levels of tolerance and adaptation to levels of salinity, waterlogging and associated problems (e.g. wear), all integrated into sustainable systems of management and use. Aggregating these individual options at local, regional and national levels will require not just a salt-tolerant grass but a range of salt-tolerant grasses adapted to different climates and to different roles.

This project built upon the successful outcomes of TU02005. Firstly, the use of halophytic turf grasses was investigated across a wider range of urban salinity hazard areas (southern Queensland) with different climates, different soils, different levels of associated waterlogging, and different uses. Secondly, it recognised the fact that a salt tolerant grass is not a “silver bullet” or easy one-off solution to salinity problems. Rather, it buys time to develop and implement sustainable long-term management practices that will maximise the ability of the selected grass to survive and grow under a particular set of salinity and usage parameters.

A range of halophytic turf grasses was identified in an earlier HAL project (TU02005: Amenity Grasses for Salt Affected Parks in Coastal Australia) completed in 2005. One of these species, seashore paspalum (*Paspalum vaginatum*), was used successfully in wider plantings by Redland City Council (who also contributed financially to TU02005) on salt-affected sites in southern Queensland where numerous earlier attempts to establish conventional (but not highly salt-tolerant) turf grasses had universally failed. As a result of this initial success, Redland City Council, in the following 18 months, invested a further $500,000 (approximately) to establish larger areas of seashore paspalum on what were previously “impossible” high salinity park areas where islands of unthrifty ‘conventional’ turf and weed grasses were interspersed by larger bare soil areas in unsightly saline scalds (Poulter and Loch 2005).

At the same time, there was an on-going need to continue investigations of alternative grass species and cultivars suitable for planting on saline sites. The detailed documentation of salt tolerance in new and existing turf species/cultivars is required so that informed decisions can be made based on the expected salt levels encountered at different sites.

Seashore paspalum was identified as a good basic “workhorse” turf-wise for saline parks and urban use in general, but there are other situations where a more shade and/or wear tolerant grass would be better suited, or where drought or waterlogging tolerance might be required in addition to salt tolerance. For example, trials of seashore paspalum on high use coastal parks by the Gold Coast City Council highlighted the need for more wear-tolerant alternative halophytic species (e.g. *Zoysia matrella*) to be trialled in such areas, the importance of overcoming the associated limitation of soil compaction and poor soil physical properties on plant growth, and the need to correct nutrient imbalances and optimise fertiliser management to ensure the long-term stability and sustainability of the established grass surface. There was also a need to investigate sprigging and seeding (where possible) of suitable grasses to reduce establishment costs, which will enable these to be planted successfully over much larger areas for the same overall cost as laying full sod.

New grasses are continually being developed by breeders and/or imported into Australia: for example, only four seashore paspalum cultivars were available when the initial definitive salt screening studies were done under TU02005. At the commencement of this trial there were another six cultivars available. There were also a number of buffalograss and Cynodon cultivars and other turf species such as Japanese lawngrass (*Zoysia japonica*) that were not included in those initial salt tolerance screening trials; and in some cases there was a need to verify and/or quantify commercial marketing claims and anecdotal evidence via definitive independent research of this kind. Salt tolerance levels critically assessed under this project and the earlier TU02005 using a hydroponic system, currently provide the only source of critical information on the salt tolerance of most turf cultivars used in Australia. Otherwise, relative levels of salt tolerance are based on anecdotal evidence, or derived from similar American studies usually with other cultivars of the species concerned.

However, finding a salt tolerant grass is no “silver bullet” or easy solution to salinity problems. Too often in the past, the construction, establishment and maintenance phases have been considered in virtual isolation of one another. Cheap construction invariably leads to initial cost savings being quickly eroded through higher than necessary maintenance expenses for the indeterminate future. This has been exacerbated by a lack of detailed establishment protocols for park development. By specifying clear guidelines to be followed during the construction of coastal parks, many of the current problems and additional expense in follow-up remediation and management could be minimised and even eliminated in the future.

Laying full turf across large areas of park or sportsfield is expensive, and in some cases can give an inferior result by creating a surface layering effect that reduces depth of rooting and hence drought tolerance. Alternative methods such as sprigging or seeding are attractive to enable councils to reduce establishment costs and increase the area planted from the same budget, provided the reliability of these alternatives can be increased substantially from current levels.

Fertiliser maintenance programs in public open space are often ad hoc, and in some cases virtually non-existent. They tend to be driven by budgetary constraints rather than by plant needs. For turf as with any grass, the main nutritional requirement is nitrogen (N). With regard to their N requirements, however, not all grasses are created equal: some species (e.g. blue couch [*Digitaria didactyla*]) will persist better than others (e.g. green couch) under low soil N. Because of their ready availability commercially, green couch and kikuyu are widely planted as turf grasses, and anecdotal evidence suggests that many of the varieties currently available are ‘high N’ types, and that alternative grasses (principally seashore paspalum at this stage) might come with significantly lower N fertiliser requirements. A long-term replicated split-plot experiment looking at the effect of six fertiliser N treatments (0-400 kg N/ha/year) on six representative turf grasses (kikuyu, seashore paspalum, buffalo grass, blue couch, and two green couches) was initiated under TU02005. With dry matter fortnightly sampling through much of the year, this was a labour-intensive activity that justified trialling at one central site, providing a good guide to the requirements of different turf grasses in other environments where fertilisation practices are already well established for the older industry standards of kikuyu and/or green couch.

Fertiliser trials in this project determined plant demand for nitrogen (N) (the most substantial element in any turf grass fertiliser program) to species level. This work produced data that can be used as a guide when fertilising, in order to produce optimal growth and quality in the major turf grass species used in public parkland. In conducting this trial it was recognised that optimum level is also related to use and intensity of use, with high profile well-used parks requiring higher maintenance N than low profile parks where maintaining botanical composition at a lower level of turf quality might be acceptable, indeed desirable in order to minimise mowing requirements. .

Turfgrass managers responsible for areas prone to salt accumulation, require a method of monitoring salinity. While laboratory analysis of soil samples, for a range of physical and chemical attributes, is recommended annually, an alternative methodology for soil salinity measurement on a more frequent basis would be ideal. A cheaper less time consuming method for site assessment has become available with new technologies leading to the development of portable devices for in situ measurement of soil salinity, allowing park managers to rapidly assess sites in preparation for construction, establishment or remediation of turfgrasses. However, these units had not been assessed for use in such situations prior to commencement of this project.

Construction and maintenance of sporting fields and parklands have often been considered in isolation of one another. The initial cost savings of cheap construction can be quickly eroded by higher maintenance expenses, which recur into the future. This has been exacerbated by a lack of detailed construction protocols for park development. Clear guidelines for the construction of coastal parks, can minimise or even eliminate the additional expense of follow-up remediation and problem management. Rather than a single problem, there are typically a number of issues that contribute to poor, and often patchy, grass growth in salt affected areas—the mark of an unsatisfactory project outcome.

This project has approached the overall problem of poor quality coastal parkland in a structured step-wise manner. Rather than a single problem, there are typically a number of issues that contribute to the overall unsatisfactory outcome of poor, and often patchy, grass growth. Through the detailed work reported in Chapters II to VII, individual issues have been assessed and management strategies developed for each specific problem. These individual strategies have been integrated on a larger scale in salt-affected parks as the final stage of proving the technology developed through this the previous project

Redland City and Gold Coast City Councils in Southeast Queensland encapsulate the wider issues and problems of urban salinity in coastal Australia. Both are rapidly spreading urban areas in high growth regions (among the fastest growing nationally); and both councils are committed to implementing programs aimed at progressively improving the quality of their parks, sportsfields and urban environment in general. Consequently these areas were specifically targeted in this project.

4 Salinity Tolerance.

4.1 Introduction

Like all plants, turfgrasses range from extremely salt sensitive to highly salt tolerant. For turf managers, this provides a variety of ready made options by which different grasses can be matched to a range of 'real life' salinity levels and associated soil and water problems according to differences in their salt tolerance. For plants in general, the establishment and growth of most non-halophytic plants are affected when EC_e values of the soil exceed 12.2 dS/m (Table 4-1).

Table 4-1. Soil salinity EC criteria corresponding to a 10% yield reduction for the plant salt tolerance groupings of Maas and Hoffman (1977) for four ranges of soil clay content, (Shaw 1999).

Plant salt tolerance grouping	Soil salinity rating	EC_e range (dS/m)	Corresponding $EC_{1:5}$ ranges (dS/m) based on:			
			10-20% clay	20-40% clay	40-60% clay	60-80% clay
Sensitive crops	Very low	<0.95	<0.07	<0.09	<0.12	<0.15
Moderately sensitive crops	Low	0.95–1.9	0.07–0.15	0.09–0.19	0.12–0.24	0.15 – 0.30
Moderately tolerant crops	Medium	1.9–4.5	0.15–0.34	0.19–0.45	0.24–0.56	0.30 – 0.70
Tolerant crops	High	4.5–7.7	0.34–0.63	0.45–0.76	0.56–0.96	0.70 – 1.20
Very tolerant crops	Very high	7.7–12.2	0.63–0.93	0.76 – 1.21	0.96– 1.53	1.20 – 1.90
Generally too saline for crops	Extreme	>12.2	>0.93	>1.21	>1.53	>1.90

To assist in the selection and management of turfgrasses for salt-affected parks, a series of four glasshouse screening experiments was conducted to characterise a range of warm-season turfgrasses in terms of their salt tolerance. The results obviously have wider implications (e.g. golf courses, rehabilitation of degraded areas) than the immediate project on salt-affected parks.

Experimentally, the relative salinity tolerance of different turfgrasses (and of other plants) is quantified in terms of their growth response to increasing levels of salinity. This is usually defined by the salt level that equates to a 50% reduction in shoot yield, or alternatively the threshold salinity (the point at which shoot yield starts to decline) together with the rate of yield reduction beyond that point. Because of the uncontrolled variation in salinity levels even over very short distances in the field, critical determinations of salt tolerance are invariably conducted in controlled pot experiments in the glasshouse, and later related to the more variable conditions in the field.

Hydroponic screening experiments focussed on new cultivars or cultivars that were not possible to cover in the time available under TU02005, of species already screened (11 new cultivars of *Paspalum vaginatum*, 13 cultivars of *Cynodon dactylon* and six cultivars of *Stenotaphrum secundatum*) as well as additional species (one accession of *Cynodon transvaalensis*, 12 *Cynodon dactylon x transvaalensis* hybrids, two cultivars of *Sporobolus virginicus,* five cultivars of *Zoysia japonica*, one cultivar of *Z. macrantha*, one common form of *Z. tenuifolia* and one *Z. japonica x tenuifolia* hybrid).

Hybrid couches, both medium-textured types and fine-textured greens grasses, are increasingly being irrigated with recycled water. Understanding the salt tolerance of this set of turf grasses will allow golf course superintendents and open space managers to make informed decisions when faced with using lower quality water for irrigation of putting greens and urban open space.

Experiments were based on the completely randomised design (16 grasses x 6 salinity levels x 6 replications) developed and used successfully in TU02005. As per TU02005, 3 common grasses (as standards) were included in each separate experiment to provide a measure of comparability across experiments. Cultivar names and details are listed in Table 4-2.

Table 4-2 Species and cultivars tested for salinity tolerance in each series

Species	**Cultivar/accession name**	**Screening trial no.**	**Comments**	
Cynodon dactylon	FLoraTeX™	1, 2, 3,4	Standard comparator	US trade mark reg. no. 1854798
Cynodon dactylon[1]	AgRiDark	2		
Cynodon dactylon	Bosker	2		
Cynodon dactylon	Grand Prix⁽ᵇ⁾	2		Australian PBR application no. 2005/291
Cynodon dactylon		2		Selection from Gabba Kevin Mitchell (*pers comm*. 2009)
Cynodon dactylon	MS-Choice	2		US Patent no. PP10332
Cynodon dactylon	MS-Express	2		US Patent no. PP10289
Cynodon dactylon	MS-Pride	2		US Patent no. PP102902
Cynodon dactylon	Oz Tuff⁽ᵇ⁾	2		Australian PBR application no. 2004/035
Cynodon dactylon	Premier	2		US Patent no. PP18247
Cynodon dactylon	Princess	2		
Cynodon dactylon	Riviera	2		
Cynodon dactylon	Tifton 10	2		
Cynodon dactylon	Wintergreen	2		US Patent no. PP6278
Cynodon dactylon x C. transvaalensis	TifSport	1		US Patent no. PP10079
Cynodon dactylon x C. transvaalensis	Tifgreen	1		
Cynodon dactylon x C. transvaalensis	Tifdwarf	1		
Cynodon dactylon x C. transvaalensis	TifEagle	1		US Patent no. PP11163
Cynodon dactylon x C. transvaalensis	MiniVerde	1		US patent and trade mark Serial Number 77694225
Cynodon dactylon x C. transvaalensis	Santa Ana	1		
Cynodon dactylon x C. transvaalensis	Patriot	1		US Patent no. 16801
Cynodon dactylon x C. transvaalensis	Champion Dwarf⁽ᵇ⁾	1		Australian PBR application no. 1996/203 US Patent no. PP9,888
Cynodon dactylon x C.	WS200	1		

[1] This cultivar has since been confirmed to be hybrid *Cynodon dactlyon x C. transvaalensis*

Species	**Cultivar/accession name**	**Screening trial no.**	**Comments**	
transvaalensis				
Cynodon dactylon x C. transvaalensis	Novotek[PBR]	1		Australian PBR application no. 2002/268
Cynodon dactylon x C. transvaalensis	FloraDwarf	1		US Patent no. PP9030
Cynodon dactylon x C. transvaalensis	MS-Supreme	1		US Patent no. PP11781
Cynodon transvaalensis	South African couch	1		Accession collected from Kew Golf Club, Melbourne, Australia (D.E. Aldous, personal communication, 2000)
Digitaria didactyla	Aussiblue[PBR]	1, 2, 3,4	Standard comparator	Australian PBR application no. 1997/181
Paspalum vaginatum	SeaDwarf	4		US Patent no. PP13294 "SDX-1"
Paspalum vaginatum	Neptune	4		
Paspalum vaginatum	Sea Isle Supreme[PBR]	4		Australian PBR application no. 2008/073 US Patent no. PP18869, "SI98"
Paspalum vaginatum	Parrish	4		
Paspalum vaginatum	Sea Spray	4		US Patent no. PP7262341
Paspalum vaginatum	Aloha	4		US Patent and trademark registration no. 3080442
Paspalum vaginatum	Durban Country Club	4		
Paspalum vaginatum	Salam	4		
Paspalum vaginatum	Tropic Shore	4		
Paspalum vaginatum	Spence	4		
Paspalum vaginatum	Sea Isle 2000[PBR]	1, 2, 3,4	Standard comparator	Australian PBR application no. 2002/167 US Patent no. PP12625
Sporobolus virginicus	Salt fine™	4		
Sporobolus virginicus	MR-S2 QLD-Coast[PBR]	4		Australian PBR application no. 2010/038 "QLD-Coast"
Stenotaphrum secundatum	EB-2	3		
Stenotaphrum secundatum	TF-01[PBR]	3		Australian PBR application no. 2007/245
Stenotaphrum secundatum	Kings Pride[PBR] GP-22	3		Australian PBR application no. 2005/341
Stenotaphrum secundatum	Marine[PBR]	3		Australian PBR application no. 2005/033
Stenotaphrum secundatum	Matilda[PBR]	3		Australian PBR application no: 2004/078
Stenotaphrum secundatum	Ned Kelly[PBR]	3		Australian PBR application no: 2005/298
Zoysia japonica	El Toro[PBR]	3		Australian PBR application no: 1992/070

Species	Cultivar/accession name	Screening trial no.	Comments	
Zoysia japonica	Empire	3		US Patent and trademark registration no. 2326735
Zoysia japonica	Palisades(b	3		Australian PBR application no. 2001/199
Zoysia japonica	ZT-11	3		US Patent no. PP 7074
Zoysia japonica	Z-3	3		US Patent no. PP8553
Zoysia japonica hybrid	PristineFlora	3		US Patent and trademark registration no3460323
Zoysia macrantha	Nara™ (MAC-03(b))	4		Australian PBR application no. 2001/199
Zoysia tenuifolia	Common form	3		

4.2 Materials and Methods

The experiments were conducted in a nursery polytunnel at Redlands Research Station, Cleveland, Australia (27°32′S, 153°16′E). The different grass cultivars in each of the experimental runs received complete nutrients in solution (NPK analysis of 14.3:2.3:12.8% w/v, plus trace elements), as well as variable amounts of salt (sodium chloride) to impose six different treatment levels through a flood-and-drain hydroponic system. Each hydroponic system was comprised of a reservoir containing 100 L of solution and a submersible electric pump connected to a growing tray (1000 x 1000 mm square, 180mm deep). Pots were supported by parallel steel rails across the top of the tray. Solution from the reservoir was pumped into the tray around the pots (but not completely submerging them) three times per day for a period of 15 minutes each, such that the grass shoots remained dry during each irrigation cycle. Entries were planted as either vegetative full sod or plugs into pots containing 50 mm of washed sand over 30 mm depth of 5mm gravel.

Each experiment was a completely randomised design with 6 replications. The nutrient + salt solutions for each treatment were replaced monthly. Treatment salinity levels were checked 3 times per week and adjusted as necessary. Each run involved three phases: a ***salt-free settling-in phase*** (4-6 weeks) following planting into 85 mm x 85 mm square pots, 100 mm deep; a ***transitional phase*** of *c*.3 weeks in which the different treatments were gradually applied; and an ***experimental phase*** in which measurements were taken on the grasses in the different salt treatments (12-16 weeks). During the transitional phase, salt was added at a rate to achieve an increase of 2 dS/m per day to avoid the occurrence of “salt shock”. All treatments were flushed weekly with overhead irrigation to minimise salt build up in the pots through capillary rise from evaporation.

Three standards were included in every experimental run to provide a consistent scale against which the results of grasses in the different experimental runs could be assessed. The three standards chosen to cover a range from high to low salt tolerance were *Paspalum vaginatum* ‘Sea Isle 2000’, *Cynodon dactylon* FLoraTeX™ and *Digitaria didactyla* ‘Aussiblue’. In series one dry matter results for Aussiblue were subsequently excluded because the control treatment was severely damaged by an outbreak of sod webworm (*Herpetogramma licarsisalis* Walker) relative to the other treatments.

In series one, two and three, involving less salt-tolerant turfgrasses, the range of salinity covered by the six treatments expressed in terms of electrical conductivity of the irrigation water (EC_W), were 0, 6, 12, 18, 24, and 30 dS/m. The six salt treatments for the more tolerant turfgrasses (series four) were 0, 8, 16, 24, 32, and 40 dS/m covering a range to c.75% of sea water.

All grasses were clipped to a constant height (~5 mm) at the start of the experimental phase. Subsequent fortnightly clippings were collected and oven dried at 65°C for 24 hrs to obtain dry matter production. Percent leaf firing was visually assessed fortnightly. At completion of both the second and third runs, the grasses were removed from pots and crown and root material separated, washed and oven dried at 65°C for 24 hours for dry weight determination.

To facilitate comparisons among the different varieties and species, dry matter production data for each cultivar/accession was standardised by dividing the dry matter production for each salinity treatment by that produced in the corresponding control treatment as represented in Equation 1.

$$DM_{ST} = {DM_T}/{DM_c} \qquad \text{(Equation 1)}$$

where DM_{ST} = Standardised dry matter, DM_T = Treatment dry matter, and DM_C = Control dry matter

All data were analyzed through GenStat® 11th edition, for Windows using standard Analysis of Variance procedures, which also generated Least Significant Differences (LSDs) for comparison of treatment means. Following inspection of the data, relative differences in salinity tolerance were further quantified by regression (linear or third order polynomial, depending on goodness of fit) of standardised clipping DM yields over the final 4 weeks of treatment for each of the cultivars to determine the EC_W value corresponding to 20%, 50% and 80% of the control DM yield (i.e. EC_{50}).

4.3 Results

As illustrated in Figures 4-1 and 4-2 and, during the first 6 weeks (approximately), most genotype x salinity treatment combinations maintained their rate of growth, albeit at somewhat reduced levels where salt was present. Figures 4-1 and 4-2 and show the response over time to salinity for two of the standard entries, FLoraTex and Sea Isle 2000 during series one.

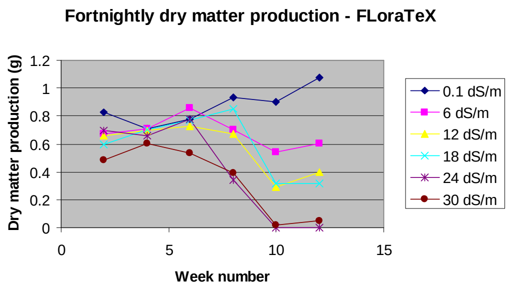


Figure 4-1 Dry matter production of FLoraTeX at each of the six levels of salinity during series 1.

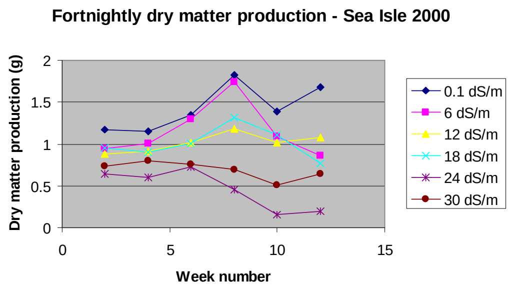


Figure 4-2 Dry matter production of Sea Isle 2000 at each of the six levels of salinity during series 1.

After approximately 6 weeks there were substantial declines in the dry matter yield of clippings over about the next two weeks, the extent of these reductions being positively related to salinity levels, before stabilising again at much lower production levels for the last two harvests representing weeks 8-12. Based on this general pattern of growth response, data from the last 4 weeks of the experiment are the most relevant when assessing relative differences in salinity tolerance over the longer term, hence the data presented here represent the situation prevailing over weeks 8-12. These same data have also been used to determine the threshold EC_W values at 20%, 50% and 80% of the control dry matter yield for each entry discussed below.

In each of the four screening trials, leaf firing increased progressively in response to continuing exposure to salinity. Firing also increased with salinity level, with the more sensitive grasses completely killed (= 100% firing) at the higher levels of salinity applied (Section 16.1 Appendix A-1).

While leaf firing increased with time of exposure to salinity, there was a corresponding decline in dry matter production from the treatments with added salt as each screening trial continued. Relative dry matter production over the final 4 weeks of each experimental series was therefore used to show the response of each cultivar/accession to increasing salinity levels. *Zoysia* species were grouped for comparison within the genus. Due to the large numbers of green couches and hybrid green couches (*Cynodon dactylon* and *Cynodon dactylon x transvaalensis*) investigated, the data were analysed for each species separately, apart from *C. transvaalensis*, which was included with hybrid couches. Data from all remaining entries is presented according to species, as only one species within each genus was investigated.

Standard entries

Figures 4-3 to 4-5 illustrate the growth response to salinity of each of the three standard entries for each screening series. Figure 4-6 illustrates the average of each series for each standard entry.

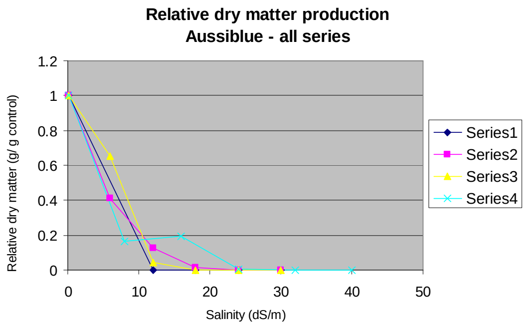


Figure 4-3. Relative dry matter production for Aussiblue in each series.

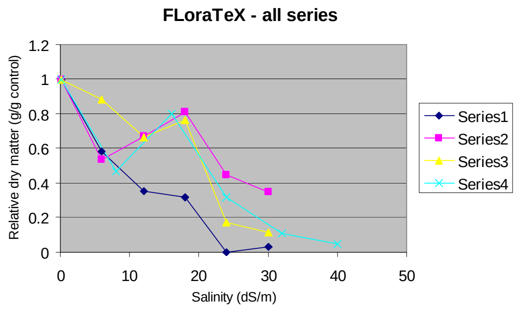


Figure 4-4. Relative dry matter production for FloraTeX in each series.

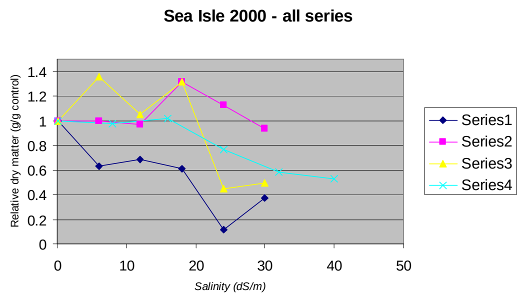


Figure 4-5. Relative dry matter production for Sea Isle 2000 in each series.

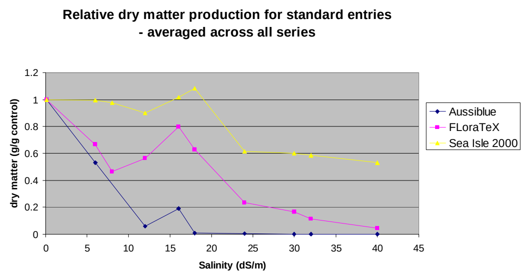


Figure 4-6. Relative dry matter production for all standard entries, averaged across all series.

Cynodon dactylon

Figure 4-7 illustrates the relative growth for weeks 8 to 12, for each of the *Cynodon dactylon* cultivars at each salinity level. Statistical differences are listed in Table 4-3, where different letters for each dry weight figure indicate a statistical difference at 95% confidence.

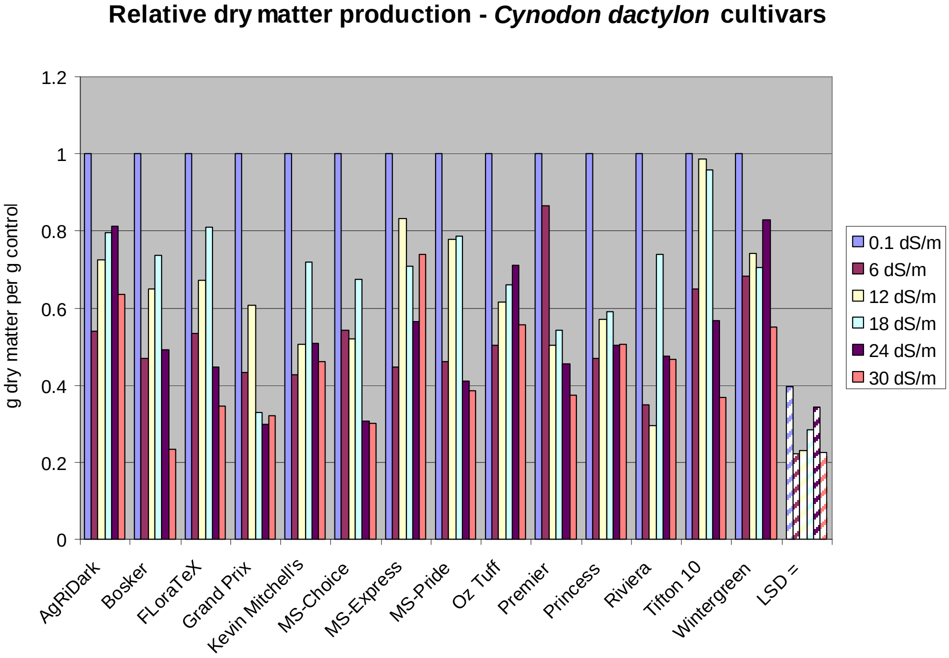


Figure 4-7. Relative dry matter production for each cultivar of *Cynodon dactylon* screened at each of the six salinity levels. LSD values are at 95% confidence interval.

Table 4-3. Relative dry matter production for each cultivar of *Cynodon dactylon* showing statistical significant difference. No letter indicates absence of significant difference within the treatment. Differing letters within a treatment indicate statistical differences at 95% confidence.

Cultivar	Relative dry matter production (as per equation 4-1)					
	0.1 dS/m	**6 dS/m**	**12 dS/m**	**18 dS/m**	**24 dS/m**	**30 dS/m**
AgRiDark	1	0.5385 bcd	0.7252 bcde	0.7961 ab	0.8135	0.636 ab
Bosker	1	0.4707 bcd	0.649 bcde	0.7357 ab	0.4918	0.2325 e
FLoraTeX	1	0.5337 bcd	0.672 bcde	0.8107 ab	0.4476	0.3467 cde
Grand Prix	1	0.4333 cd	0.6083 bcde	0.3298 c	0.2965	0.3191 de
Kevin Mitchell's	1	0.4283 d	0.5047 ef	0.7193 ab	0.51	0.4614 bcd
MS-Choice	1	0.5431 bcd	0.5196 def	0.6734 ab	0.3062	0.3006 de
MS-Express	1	0.4471 cd	0.833 ab	0.709 ab	0.5651	0.7389 a
MS-Pride	1	0.4609 bcd	0.778 abc	0.787 ab	0.4104	0.3839 cde
Oz Tuff	1	0.503 bcd	0.615 bcde	0.6616 b	0.71	0.5578 abc
Premier	1	0.8656 a	0.503 ef	0.5416 bc	0.4546	0.3734 cde
Princess	1	0.4686 bcd	0.5712 cde	0.5904 bc	0.5031	0.506 bcd
Riviera	1	0.3491 d	0.2956 f	0.7379 ab	0.4758	0.466 bcd
Tifton 10	1	0.6505 abc	0.9863 a	0.9583 a	0.5671	0.3677 cde
Wintergreen	1	0.6815 ab	0.743 bcd	0.7041 ab	0.8284	0.5515 abc
LSD =	0	0.2208	0.2302	0.2852	0.3424	0.225

Cyndon dactylon x transvaalensis

Figure 4-8 illustrates the relative growth for weeks 8 to 12, for each of the *Cynodon dactylon x transvaalensis* cultivars at each salinity level. Statistical differences are listed in Table 4-4 where different letters for each dry weight figure indicate a statistical difference at 95% confidence.

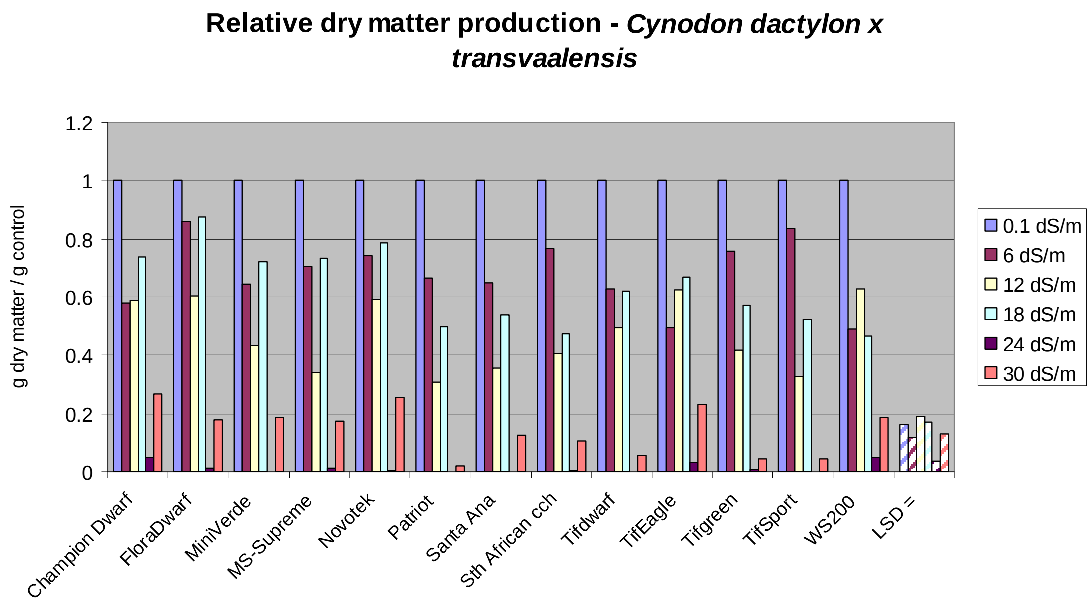


Figure 4-8. Relative dry matter production for each cultivar of *Cynodon dactylon* x *transvaalensis* hybrids screened at each of the six salinity levels. LSD values are at 95% confidence interval.

Table 4-4. Relative dry matter production for each cultivar of *Cynodon dactylon* x *transvaalensis* hybrids showing statistical significant difference. No letter indicates absence of significant difference within the treatment. Differing letters within a treatment indicate statistical differences at 95% confidence.

Cultivar	**0.1 dS/m**	**6 dS/m**	**12 dS/m**	**18 dS/m**	**24 dS/m**	**30 dS/m**
Champion Dwarf	1	0.5807 ef	0.5859 abc	0.736 abc	0.04988 a	0.2667 a
FloraDwarf	1	0.8582 a	0.6034 ab	0.8751 a	0.01023 c	0.1804 abcd
MiniVerde	1	0.6457 cde	0.4323 bcd	0.7214 abc	0 c	0.1861 abc
MS-Supreme	1	0.7049 bcd	0.3419 d	0.7333 abc	0.01387 bc	0.1724 abcde
Novotek	1	0.7433 abcd	0.5921 abc	0.7858 ab	0.00248 c	0.2541 ab
Patriot	1	0.6633 bcde	0.3083 d	0.5 de	0.00157 c	0.022 f
Santa Ana	1	0.6498 bcde	0.3579 d	0.5392 de	0 c	0.1273 bcdef
Sth African cch	1	0.7647 ab	0.4066 cd	0.4726 e	0.00449 c	0.1067 cdef
Tifdwarf	1	0.6296 de	0.4955 abcd	0.6187 bcde	0c	0.0563 def
TifEagle	1	0.4964 f	0.6231 a	0.6701 bcd	0.03238 abc	0.2296 abc
Tifgreen	1	0.7561 abc	0.4159 bcd	0.5715 cde	0.00724 c	0.046 ef
TifSport	1	0.8335 a	0.3286 d	0.5249 de	0 c	0.0428 f
WS200	1	0.4902 f	0.6296 a	0.4666 e	0.04933 ab	0.1865 abc
LSD =	0.1616	0.1158	0.1892	0.172	0.03589	0.1284

Paspalum vaginatum

Figure 4-9 illustrates the relative growth for weeks 8 to 12, for each of the *Paspalum vaginatum* cultivars at each salinity level. Statistical differences are listed in Table 4-5, where different letters for each dry weight figure indicate a statistical difference at 95% confidence.

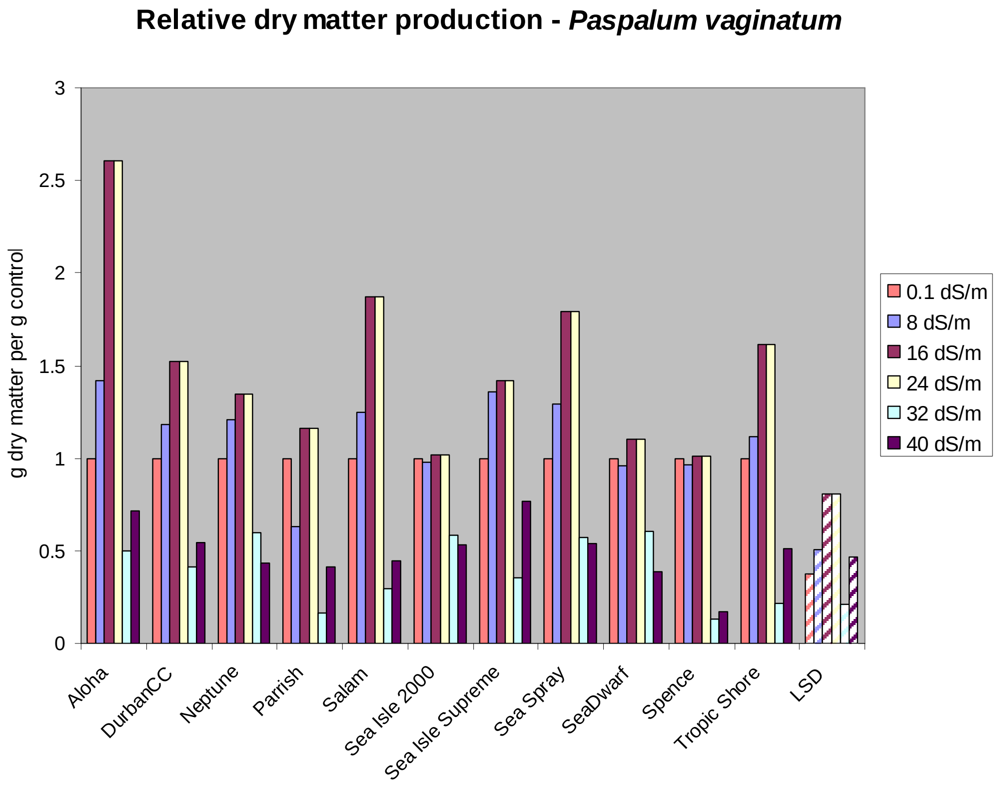


Figure 4-9. Relative dry matter production for each cultivar of *Paspalum vaginatum* screened at each of the six salinity levels. LSD values are at 95% confidence interval.

Table 4-5. Relative dry matter production for each cultivar of *Paspalum vaginatum* showing statistical significant difference. No letter indicates absence of significant difference within the treatment. Differing letters within a treatment indicate statistical differences at 95% confidence.

Cultivar	0.1 dS/m	8 dS/m	16 dS/m	24 dS/m	32 dS/m	40 dS/m
Aloha	1	1.42	2.607 a	0.9136 ab	0.4967 ab	0.7153
DurbanCC	1	1.184	1.524 bc	0.7558 ab	0.4142 abc	0.5437
Neptune	1	1.208	1.345 bc	0.6134 b	0.5948 a	0.4344
Parrish	1	0.63	1.165 bc	0.2892 c	0.1647 de	0.4114
Salam	1	1.247	1.868 ab	0.7949 ab	0.2962 bcde	0.4441
Sea Isle 2000	1	0.978	1.018 c	0.7658 ab	0.5849 a	0.5312
Sea Isle Supreme	1	1.359	1.42 bc	0.9493 a	0.3525 bcd	0.7705
Sea Spray	1	1.296	1.794 bc	0.8304 ab	0.5684 a	0.5358
SeaDwarf	1	0.961	1.105 bc	0.7352 ab	0.606 a	0.3854
Spence	1	0.965	1.009 c	0.3 c	0.1281 e	0.1707
Tropic Shore	1	1.116	1.612 bc	0.1656 c	0.2143 cde	0.5148
LSD	0.3736	0.5081	0.8044	0.3059	0.2079	0.4645

Sporobolus virginicus

Figure 4-10 illustrates the relative growth for weeks 8 to 12, for each of the *Sporobolus virginicus* cultivars at each salinity level. Statistical differences are listed in Table 4-6, where different letters for each dry weight figure indicate a statistical difference at 95% confidence.

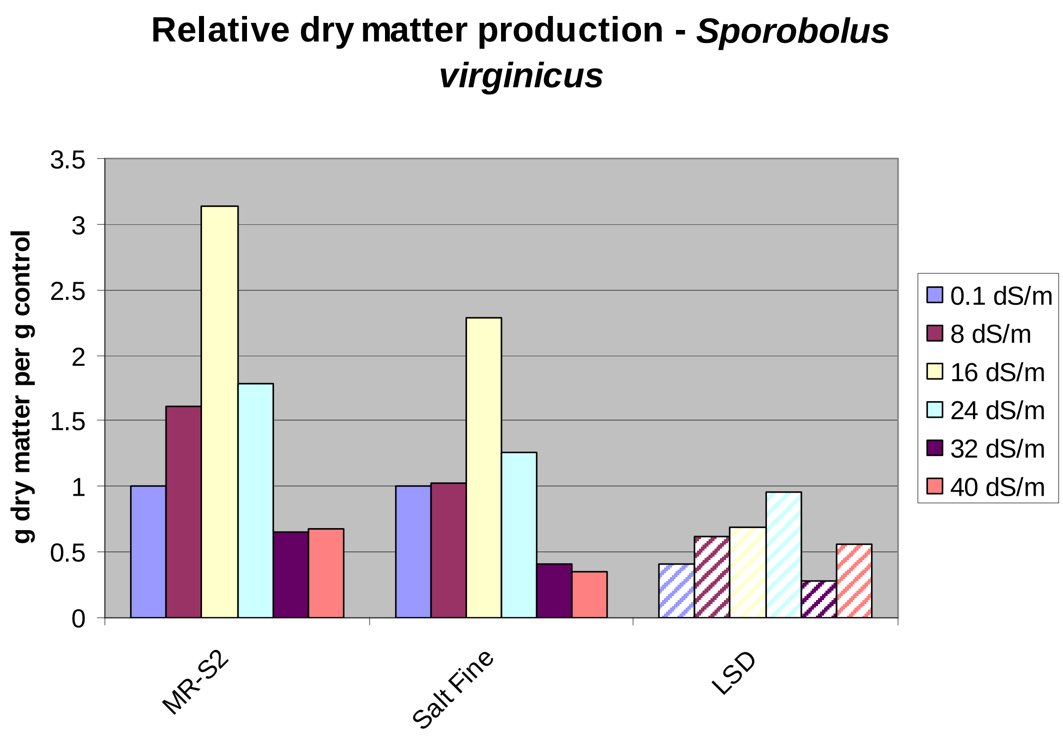


Figure 4-10. Relative dry matter production for each cultivar of *Sporobolus virginicus* screened at each of the six salinity levels. LSD values are at 95% confidence interval.

Table 4-6. Relative dry matter production for each cultivar of *Sporobolus virginicus* showing statistical significant difference. No letter indicates absence of significant difference within the treatment. Differing letters within a treatment indicate statistical differences at 95% confidence.

Cultivar	0.1 dS/m	8 dS/m	16 dS/m	24 dS/m	32 dS/m	40 dS/m
MR-S2	1	1.61	3.134 a	1.79	0.6511	0.677
Salt Fine	1	1.022	2.288 b	1.255	0.4087	0.3494
LSD	0.4097	0.6146	0.6939	0.9609	0.2795	0.5592

***Stenotaphrum secundatum* cultivars**

Figure 4-11 illustrates the relative growth for weeks 8 to 12, for each of the *Stenotaphrum secundatum* cultivars at each salinity level. Statistical differences are listed in Table 4-7, where different letters for each dry weight figure indicate a statistical difference at 95% confidence.

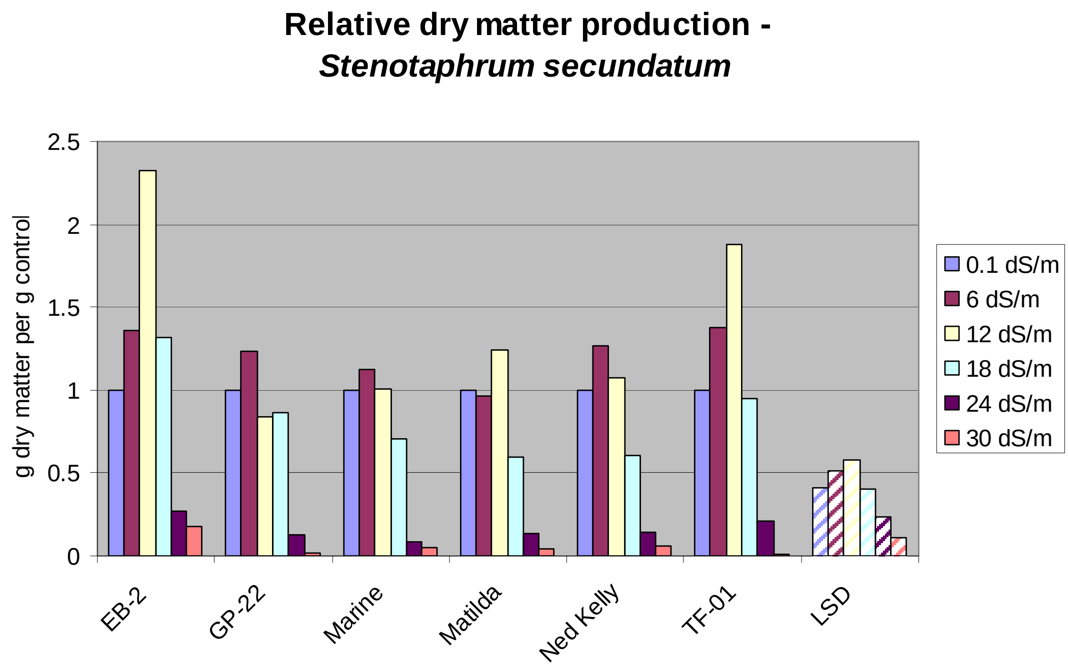


Figure 4-11. Relative dry matter production for each cultivar of *Stenotaphrum secundatum* screened at each of the six salinity levels. LSD values are at 95% confidence interval.

Table 4-7. Relative dry matter production for each cultivar of *Stenotaphrum secundatum* showing statistical significant difference. No letter indicates absence of significant difference within the treatment. Differing letters within a treatment indicate statistical differences at 95% confidence.

Cultivar	0.1 dS/m	6 dS/m	12 dS/m	18 dS/m	24 dS/m	30 dS/m
EB-2	1	1.36	2.326 a	1.3168 a	0.2644	0.17305
GP-22	1	1.235	0.84 b	0.8656 b	0.1259	0.0207
Marine	1	1.12	1.008 b	0.7019 b	0.0861	0.05064
Matilda	1	0.967	1.245 b	0.5968 b	0.1304	0.03992
Ned Kelly	1	1.267	1.071 b	0.6025 b	0.1392	0.05606
TF-01	1	1.373	1.877 a	0.9438 ab	0.2083	0.00995
LSD	0.4102	0.5107	0.5789	0.4053	0.2344	0.1126

***Zoysia* species**

Species from the genus *Zoysia*, have been investigated in three separate series with *Zoysia matrella* being investigated under an earlier project (TU02005). Data from the earlier trial is included graphically for comparison of salinity response in Figure 4-12. This follows a similar pattern to that of most *Zoysia japonica* varieties excluding Zoyboy™, which shows a response more typical of a salt tolerant turfgrass as discussed above. Figure 4-13 illustrates the salinity response of *Z. macrantha*, *Z. tenuifolia*, *Z. japonica* x Z. *tenuifolia* and *Z. japonica*, clearly showing the non-linearity in response of Zoyboy™, PristineFlora™, Nara™ and common *Z.tenuifolia* accession.

Series 3 and 4 of TU06006 were run at two different salinity ranges. However there was sufficient overlap to allow for direct comparison. The results for the standard entries were not significantly different between the two series providing further justification for direct comparison between varieties. The salinity level 24 dS/m was common to both series, therefore used to directly compare relative dry matter as per the above equation. Results for this treatment were analysed using GenStat® 11th edition.

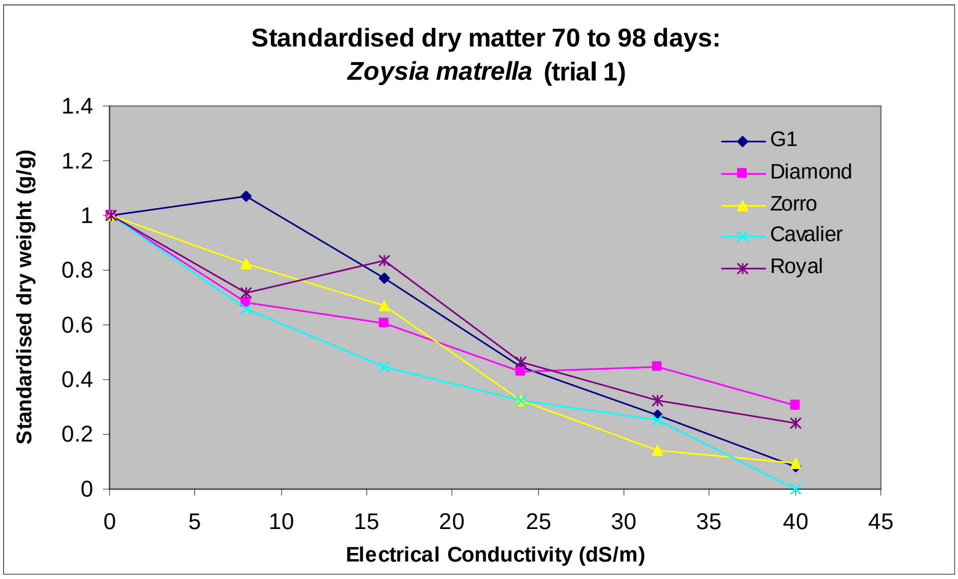


Figure 4-12. Standardised dry matter for the five *Zoysia matrella* cultivars over the final 4 weeks of trial 1, taken from final report TU02005 (Loch et al. 2006). Note: G1 = A-1.

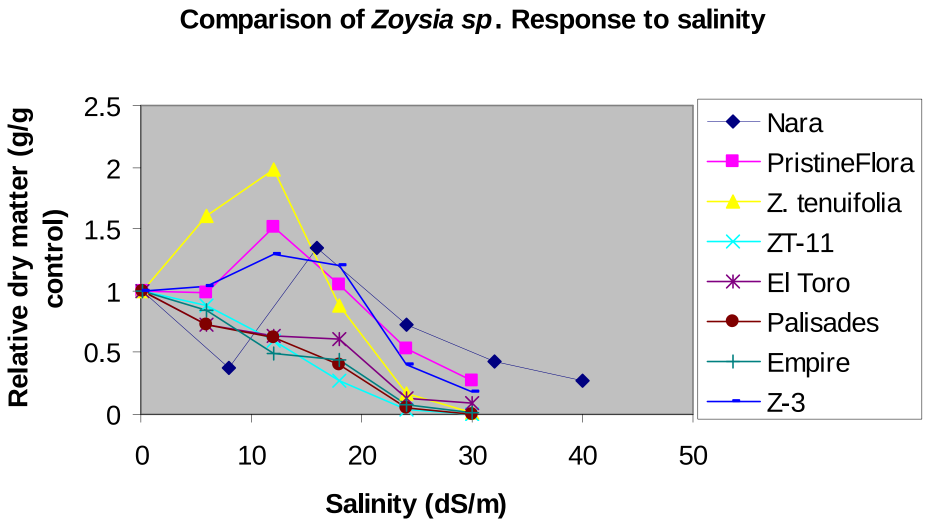


Figure 4-13. Standardised dry matter for the five *Zoysia japonica* cultivars, one hybrid Zoysia, and one *Zoysia macrantha* over the final four weeks of trials 3 and 4 of TU06006. Note: Z-3 = Zoyboy.

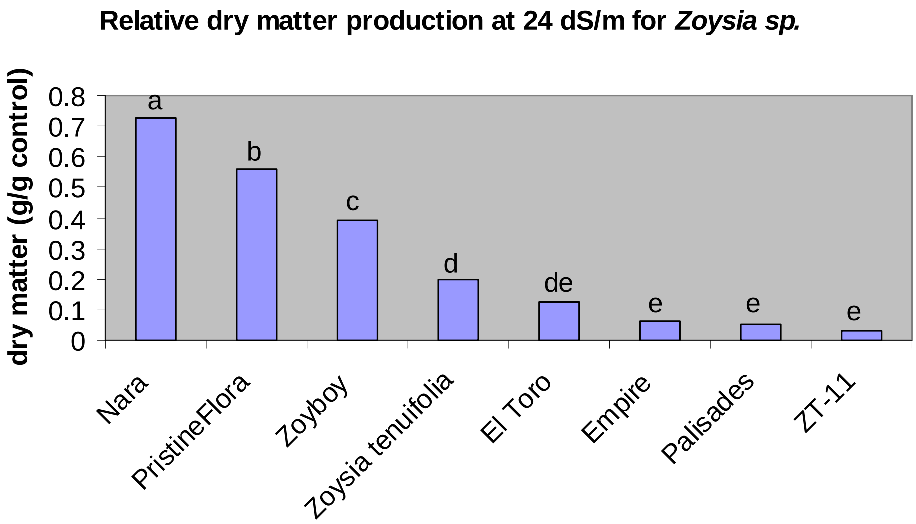


Figure 4-14. Standardised dry matter at 24 dS/m for the five *Zoysia japonica* cultivars, one hybrid Zoysia, and one *Zoysia macrantha* over the final four weeks of trials 3 and 4 of TU06006. Cultivars with a different letter are statistically different at 95% confidence limits (least significant difference = 0.099).

Figure 4-15 illustrates the relative growth for weeks 8 to 12, for each of the *Zoysia* species cultivars included in series 4, at each salinity level. Statistical differences are listed in Table 4-8, where different letters for each dry weight figure indicate a statistical difference at 95% confidence. *Zoysia macrantha* was excluded from this comparison due to the differing treatments between Series three and four.

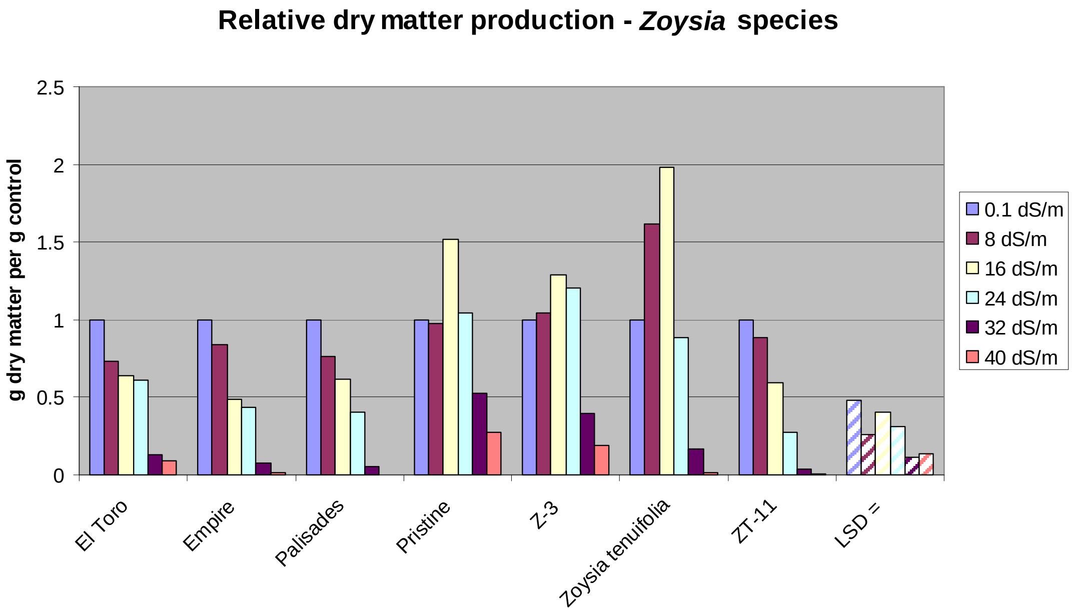


Figure 4-15. Relative dry matter production for each cultivar of *Zoysia* species screened at each of the six salinity levels. LSD values are at 95% confidence interval.

Table 4-8. Relative dry matter production for each cultivar of *Zoysia* species showing statistical significant difference. No letter indicates absence of significant difference within the treatment. Differing letters within a treatment indicate statistical differences at 95% confidence.

Cultivar	0.1 dS/m	8 dS/m	16 dS/m	24 dS/m	32 dS/m	40 dS/m
El Toro	1	0.7311 c	0.64 c	0.6106 cd	0.1307 cd	0.09176 bc
Empire	1	0.8384 bc	0.488 c	0.4374 de	0.0775 cd	0.012 c
Palisades	1	0.764 c	0.618 c	0.402 de	0.0545 cd	0.00363 c
Pristine	1	0.9792 bc	1.515 b	1.0453 ab	0.529 a	0.27191 a
Z-3	1	1.0426 b	1.29 b	1.2006 a	0.3954 b	0.18716 ab
Zoysia tenuifolia	1	1.6121 a	1.984 a	0.8862 bc	0.1664 c	0.01698 c
ZT-11	1	0.885 bc	0.597 c	0.2745 e	0.0382 d	0.005 c
LSD =	0.4833	0.262	0.4048	0.3118	0.118	0.1407

Defining a single parameter by which to assess the relative salt tolerance of the different entries is not possible given the non-linear nature of the growth response. This non-linearity of function was particularly noticeable in the more salt tolerant species where different salt tolerance come into play at different salinity thresholds (R.R. Duncan and R.N. Carrow 2004 , *pers. comm*. 5 October). To address this issue, three points on the growth reduction curve were derived by interpolation for each cultivar/accession: the electrical conductivity at which dry matter production was 80%, 50% and 20% of that occurring in the control. These values are listed in Table 4-9, where "na" indicates that the particular level of growth reduction was not reached in any of the salinity treatments during the experiment.

Table 4-9. Electrical Conductivity (ECw) at which growth was reduced to 80%, 50% and 20% of that occurring in the control treatment (0.1 dS/m).

		EC at 80% DM production:				EC at 50% DM production:				EC at 20% DM production:			
		Trial number				Trial number				Trial number			
Species	**Cultivar/ accession**	**1 (2007-2008)**	**2 (2008)**	**3 (2009)**	**4 (2010)**	**1 (2007-2008)**	**2 (2008)**	**3 (2009)**	**4 (2010)**	**1 (2007-2008)**	**2 (2008)**	**3 (2009)**	**4 (2010)**
Cynodon dactylon	FLoraTeX™	2	3	9	5	11	20	18	18	21	37	28	31
Cynodon dactylon	AgRiDark		19				24				na		
Cynodon dactylon	Bosker		4				21				na		
Cynodon dactylon	Grand Prix[(b)]		7				17				na		
Cynodon dactylon	(Gabba)		9				23				na		
Cynodon dactylon	MS-Choice		2				26				na		
Cynodon dactylon	MS-Express		14				34				na		
Cynodon dactylon	MS-Pride		4				24				na		
Cynodon dactylon	Oz Tuff[(b)]		12				30				na		
Cynodon dactylon	Premier		6				21				na		
Cynodon dactylon	Princess		9				23				na		
Cynodon dactylon	Riviera		9				22				na		
Cynodon dactylon	Tifton 10		12				31				na		
Cynodon dactylon	Wintergreen		14				36				na		
Cynodon dactylon x transvaalensis	TifSport	5				14				23			
Cynodon dactylon x transvaalensis	Tifgreen	5				14				23			
Cynodon dactylon x transvaalensis	Tifdwarf	4				14				24			
Cynodon dactylon x transvaalensis	TifEagle	3				14				30			

		EC at 80% DM production:				EC at 50% DM production:				EC at 20% DM production:			
		Trial number				Trial number				Trial number			
Species	**Cultivar/ accession**	**1 (2007-2008)**	**2 (2008)**	**3 (2009)**	**4 (2010)**	**1 (2007-2008)**	**2 (2008)**	**3 (2009)**	**4 (2010)**	**1 (2007-2008)**	**2 (2008)**	**3 (2009)**	**4 (2010)**
Cynodon dactylon x transvaalensis	MiniVerde	4				15				26			
Cynodon dactylon x transvaalensis	Santa Ana	3				13				23			
Cynodon dactylon x transvaalensis	Patriot	3				12				22			
Cynodon dactylon x transvaalensis	Champion Dwarf$^{(\phi}$	4				16				29			
Cynodon dactylon x transvaalensis	WS200	3				14				25			
Cynodon dactylon x transvaalensis	Novotek$^{(\phi}$	6				17				28			
Cynodon dactylon x transvaalensis	FloraDwarf	8				18				28			
Cynodon dactylon x transvaalensis	MS-Supreme	4				15				26			
Cynodon transvaalensis	South African couch	4.3				14				23			
Digitaria didactyla	Aussiblue$^{(\phi}$	0.3	0.3	0.4	0.3	1	2	2	2	7	9	11	10
Paspalum vaginatum	SeaDwarf				20				39				na
Paspalum vaginatum	Neptune				24				32				na
Paspalum vaginatum	Sea Isle Supreme$^{(\phi}$				20				22				na
Paspalum vaginatum	Parrish				30				31				32
Paspalum vaginatum	Sea Spray				22				26				na
Paspalum vaginatum	Aloha				25				28				na
Paspalum vaginatum	Durban Country Club				22				26				na
Paspalum vaginatum	Salam				20				22				na

		EC at 80% DM production:				EC at 50% DM production:				EC at 20% DM production:			
		Trial number				Trial number				Trial number			
Species	**Cultivar/ accession**	**1 (2007-2008)**	**2 (2008)**	**3 (2009)**	**4 (2010)**	**1 (2007-2008)**	**2 (2008)**	**3 (2009)**	**4 (2010)**	**1 (2007-2008)**	**2 (2008)**	**3 (2009)**	**4 (2010)**
Paspalum vaginatum	Tropic Shore				24				28				29
Paspalum vaginatum	Spence				26				22				28
Paspalum vaginatum	Sea Isle 2000Φ	5	36	21	30	18	39	34	35	31	na	na	na
Sporobolus virginicus	Salt fine™				32				37				na
Sporobolus virginicus	MR-S2 QLD-CoastΦ				38				na				na
Stenotaphrum secundatum	EB-2			20				22				23	
Stenotaphrum secundatum	TF-01Φ			19				22				25	
Stenotaphrum secundatum	Kings PrideΦ GP-22			12				20				27	
Stenotaphrum secundatum	MarineΦ			11				19				27	
Stenotaphrum secundatum	MatildaΦ			21				24				25	
Stenotaphrum secundatum	Ned KellyΦ			12				20				27	
Zoysia tenuifolia	Common form			18				20				22	
Zoysia japonica	Zoyboy™			22				26				30	
Zoysia japonica	ZT-11			6				14				22	
Zoysia japonica	PalisadesΦ			5				14				23	
Zoysia japonica	Empire™			6				14				23	
Zoysia japonica	El ToroΦ			6				16				26	
Zoysia japonica x tenuifolia	PristineFlora™			22				26				30	
Zoysia macrantha	Nara™				19				23				26

Photographs showing the visual effect of increasing salinity levels each variety (including all of the pots in each treatment) at the completion of each screening trial are presented in Section 16.2 (Appendix A-2.).

4.4 Discussion

As Munns (2002) observed, it is difficult to define or quantify differences in salt tolerance among species. Measured reductions in growth are dependant upon the duration in which the plants have been exposed to saline conditions. Salinity affects growth in a number of ways including changed water relations, hormonal balance, or carbon supply. Exacerbating the problem of defining salt tolerance is the fact that the relative importance of each of the listed processes changes through time. The initial effect of salinity is largely an osmotic one, reducing the ability of plants to take up water and inducing effects identical to water stress, often termed a “physiological drought” (Carrow and Duncan 1998). This rapidly causes reductions in growth rate while more salt-specific effects on growth time to develop. Where excessive amounts of salt enter the plant and cannot be compartmentalised in the vacuole, toxic levels eventually develop in the older transpiring leaves. The resultant internal injury reduces the plant’s photosynthetic capacity, which in salt-sensitive genotypes continues to decline.

The results presented here are consistent with Munns’ (1993) concept of a two-phase growth response to salinity as just described. For the first 4-6 weeks of treatment, the response to salinity was apparently dominated by a short-term osmotic effect, which caused only relatively small reductions in the amount of dry matter produced. By the end of this initial period, it is suggested that toxic ions had accumulated in the plants such that growth was greatly reduced and leaf firing increased rapidly as a result of internal injury. For this reason emphasis was placed upon growth occurring in the last four weeks of each trial, where growth appeared to have stabilised at reduced levels and leaf firing at higher levels. To tolerate the second stage where toxic ion effects dominate, grasses must be able to maintain a higher growth rate to survive other stresses of use, such as wear (Duncan and Carrow 2000).

Some of the results for the dry matter production in series two, containing mainly *Cynodon dactylon* cultivars were inconsistent with that reported in TU02005 (Loch et al. 2006) where Wintergreen was a poor performer with respect to salinity tolerance and Oz-E-Green was superior. Closer examination of the data revealed some inexplicable anomalies.

4.5 Conclusion

It is difficult to compare salinity tolerance between species due to the large variations occurring. However the determination of threshold values does allow some degree of comparison to be made. The most salt tolerant species in these trials were *Sporobolus virginicus* and *Paspalum vaginatum,* consistent with the findings from TU02005 (Loch et al. 2006).

Based on the relative dry matter production data collected throughout the four salinity screening trials the *Cynodon dactylon* cultivars or genotypes showing greatest productivity at elevated salinity levels were: MS-Express, Kevin Mitchell’s, Oz-E-Green (now Oz-Tuff), Princess, Riviera and AgriDark although this cultivar has since been confirmed as a hybrid *Cynodon*. Of the other hybrid *Cynodon* genotypes the highest salinity tolerances were observed in FloraDwarf, ChampionDwarf, Novotek and Tifeagle. Within *Paspalum vaginatum* there were no significant differences at 40 dS/m. However, at the next lower level (32 dS/m) the more salt tolerant cultivars included Sea Ilse 2000, Neptune, Sea Spray and Sea Dwarf, which showed significantly greater productivity than all but Aloha and Durban Country Club. There were no significant differences observed within the *Stenotaphrum secundatum* and *Sporobolus virginicus* species. Of all the *Zoysia* species and cultivars, Z-3 (now known as Zoy-Boy) and Pristine were significantly more salt tolerant than Empire, Palisades, *Z.tenuifolia* and ZT-11.

While *Z. tenuifolia* showed a positive response to salinity at the lower levels, the production rapidly declined at 24 dS/m and above.

While it may be tempting to draw species-wide conclusions on salinity tolerance based on the single genotype of *C transvaalensis* screened, this is not possible without screening additional lines to cover adequately the considerable genetic variation within this species. We would also caution against attempting to apply our findings regarding Australian material of the non-proprietary cultivars Santa Ana, Tifdwarf and Tifgreen to the same varieties as constituted in the US or elsewhere. These varieties have been in Australia for at least the past 30-40 years, and almost certainly have diverged from the original varieties in that time through mutation followed by natural selection under different environmental and edaphic conditions.

It was expected from the findings of previous observations that *Zoysia japonica* would be less salt tolerant than the previously investigated cultivars of *Zoysia matrella*. However the EC50 threshold values fall within the same range *as Z. matrella*. Interestingly the EC20 threshold values were slightly less for *Z. japonica* than *Z. matrella*. *Zoysia tenuifolia* and hybrids with this species tended to have a more halophytic type response to increasing salinity levels, with non-linearity of the salinity: dry matter production curve. The same caution applies as regards drawing conclusions on the salinity tolerance of the species *Zoysia tenuifolia*, based on the results obtained from the single form investigated in these trials. However the species does seem to have conferred a level of salinity tolerance to its hybrid cultivars. The anomalous behaviour of Z-3 *Zoysia* grass, following distinctly different response to salinity than the other *Z.japonica* cultivars may well be accounted for by it being a hybrid with *Z.matrella* as suggested but not categorically stated on the US Plant Patent description (Stanton 1994). While *Z.matrella* in general has not shown halophytic type responses to salinity, hybridisation may confer tolerance through various mechanisms such as hybrid vigour.

Cynodon dactylon showed the largest range in threshold values with some cultivars highly sensitive to salt, while others tolerant to levels approaching that of the more halophytic grasses. Coupled with the observational and anecdotal evidence of high drought tolerance, this species provides options for site specific situations.

5 Grass Selection.

5.1 Introduction

Coastal parkland managers must maintain high quality sites a multitude of recreational activities. However, these sites have a unique set of problems. Salt accumulation can result in unthrifty grass or bare ground. Other limitations saline sites present include soil compaction, poor soil physical properties and nutrient imbalances.

Recent trials of seashore paspalum on high use coastal parks by the Gold Coast City Council have highlighted the need for more wear-tolerant alternative halophytic (salt tolerant) species to be trialled in such areas.

This component of the project investigated salt-tolerant grasses with potential for special use situations, such as high wear alongside footpaths and from the footpath to the beach access; high shade under *Allocasuarina, Araucaria* and *Pandanus* species and beside manmade structures; saline areas where low-lying ground intersects a saline water table or as a result of inundation by sea water; sand build-up, which effectively buries the existing turf layer; and layering of the soil profile, either from previous topsoil used or from laying turf grown in clay-based soils, which results in low rates of water infiltration.

The major objective of this study was to identify which turfgrass species are best adapted to a typical salt-affected, amenity area with the additional limitations to growth and survival.

5.2 Methods

Salt-tolerant turf grasses with potential for special use situations (e.g. shade, wear, waterlogging, drought tolerance) in addition to seashore paspalum were trialled more widely than the controlled hydroponic screening tests, under field conditions at three sites within the Gold Coast City Council boundary, while three sites, established under TU02005 within the Redland City Council boundaries were monitored for continued grass survival. Several randomised block experiments within Gold Coast City were established to compare the health and longevity of seashore paspalum (*Paspalum vaginatum*), Manila grass (*Zoysia matrella*), as well as the more tolerant cultivars of other species like buffalo grass (*Stenotaphrum secundatum*) and green couch (*Cynodon dactylon*). Each site is presented here as an individual case study.

5.2.1 Case Study 1 Surfers Paradise Esplanade

5.2.1.1 Site description

Surfers Paradise Beach is a 3 kilometre stretch of beach with high profile foreshore parkland, at location 27°32′S, 153°16′E. The site is regular host to a multitude of visitors, both local and tourist with identifiable periods of very high activity and use, for example V8 supercar racing formally known as Indy 500, and the annual end of year celebrations for school leavers, colloquially known as ‘schoolies week’. Turf establishment and growth is adversely affected by the following problems commonly found on this site, either individually or in combination:

- High wear along foot path and between footpath and beach access
- High shade under *Casuarina sp., Pandanus sp*. and manmade structures.
- Saline areas where low lying ground intersects with saline water table or from sea water inundation.
- Sand inundation burying existing vegetation.

- Layering effect of soil profile resulting in low rates of infiltration and conductivity.

Trials were located on the Esplanade just South of Ocean Avenue. The park improvement strategy involved selection and establishment of well-adapted turfgrass species/varieties that are highly tolerant of wear and also salt tolerant. To achieve the maximum benefit from using better grasses, establishment and maintenance practises were also optimised, as will be discussed under Establishment methods (chapter 6).

5.2.1.2 Trial design

Five replications of five turf varieties were planted adjacent to the pathway between the road and coastal dunes incorporating areas of high shade and wear. A further four replicates were planted across two beach access ways. The trial was a split-split plot design, with turf varieties as the main plot. The first split is topsoil type (sandy loam or compost), and the second split is washed or unwashed sod (to be discussed further under Establishment Methods.).

Turf Varieties:

A: *Cynodon dactylon* Oz-E-Green
B: *Paspalum vaginatum* Sea Isle 1
C: *Paspalum vaginatum* Velvetene
D: *Zoysia matrella* A-1
E: *Zoysia japonica* Empire

1. High shade (*Casuarina sp.*) various wear:

To encompass all levels of shade and wear, strips 3-4 m long and 0.8 m wide were planted from the base of trees in the park through to the pathway. These varietal treatments were replicated in 5 randomised blocks. Full layout is included at Section 16.3 (Appendix B-1)

2. High wear areas near the entrance to beach access points.

Strips of turf 4m long X 0.8 m were planted across beach access approaches with the same five varieties as above. Two blocks were planted at each of two beach entrances (4 in all). Full layout is included at Section 16.4 (Appendix B-2).

Plates 5-1 to 5-6 illustrate the process of site preparation, importing topsoil and establishing full sod of the various turf varieties.

Plate 5-1 April 26, 2007 Site preparation, Surfers Paradise Esplanade showing removal of native soil surface.

Plate 5-2 April 26, 2007 Site preparation, Surfers Paradise Esplanade showing replacement of native soil with split plots of sandy loam or compost.

Plate 5-3 May 2, 2007 Areas of full sod planted along pathway between dune and road blocks 1, 2 and 3. Bare strips were planted with the last turf variety on the following day.

Plate 5-4 May 2, 2007 Areas of full sod planted along pathway between dune and road blocks 4 and 5. Bare strips were planted with the last turf variety on the following day.

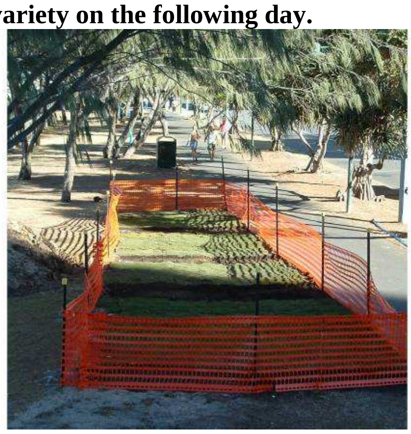


Plate 5-5 May 4, 2007 Strips of full sod planted across beach access ways, blocks 1 and 2.

Plate 5-6 May 4, 2007 Strips of full sod planted across beach access ways, blocks 3 and 4

5.2.1.3 Measurements and observations

58 days after planting core samples were extracted to measure effective rooting depth. On six occasions (days 187; 230; 286; 342; 405; 461) further core samples were collected to measure root dry weights. Average root mass was calculated as an indicator of the healthy functioning of turfgrass in

this environment. Photographic records were kept for the duration of the trial. A set of rating values were estimated by visual observation 187 days after sowing.

The subjective assessment of quality ratings was replaced with a follow up assessment of turf greenness on 11 June 2009 with turf colour readings using a Fieldscout TCM 500 NDVI Turf Colour meter (Spectrum technologies®). This instrument measures reflected light in the infrared (IR) and near infrared (NIR) bands, the ratio of which is the Normalised Difference Vegetation index (NDVI) which is used here as an indication of plant health.

5.2.1.4 Results and discussion

In figures 5-1 and 5-3, the root mass of the five species are compared over time for the pathway blocks and the beach access block respectively. All species followed a similar trend, with root mass peaking in April (day 342). This may be due to a root flush induced by rainfall, just before a relatively dormant state was entered in winter. Figures Figure **5-2** and Figure 5-5 summarise the values of root dry mass for which statistical differences were apparent for each set of turfgrass blocks. At 58 days after planting there was no significant difference in effective rooting depth between the cultivars. 230 days after planting, Empire, a variety of Japanese lawn grass (*Zoysia japonica*) and Oz-E-Green, a variety of green couch (*Cynodon dactylon*) produced significantly less root mass than both *Paspalum vaginatum.* However, this difference was insignificant later in the trial. This suggests conditions were not sufficiently hostile to separate cultivars based on root mass. The later measure of NDVI was hoped to be indicative of differences in sustained health over a longer term. However, there were no statistically significant differences between cultivars with respect to NDVI. Relatively wet winters have prevailed on the Gold Coast for the past 3 years, a situation that may have masked salt tolerance differences, in the absence of a prolonged dry season of salt accumulation.

Finding a parameter by which to separate the health and quality of turfgrass cultivars, grown under conditions of multiple pressures is very difficult. Particulary given that the dominance of each limiting factor varies throughout the growing season. Additional factors such as sand inundation from storm events has also masked any differences that may have been apparent between the turfgrass cultivars.

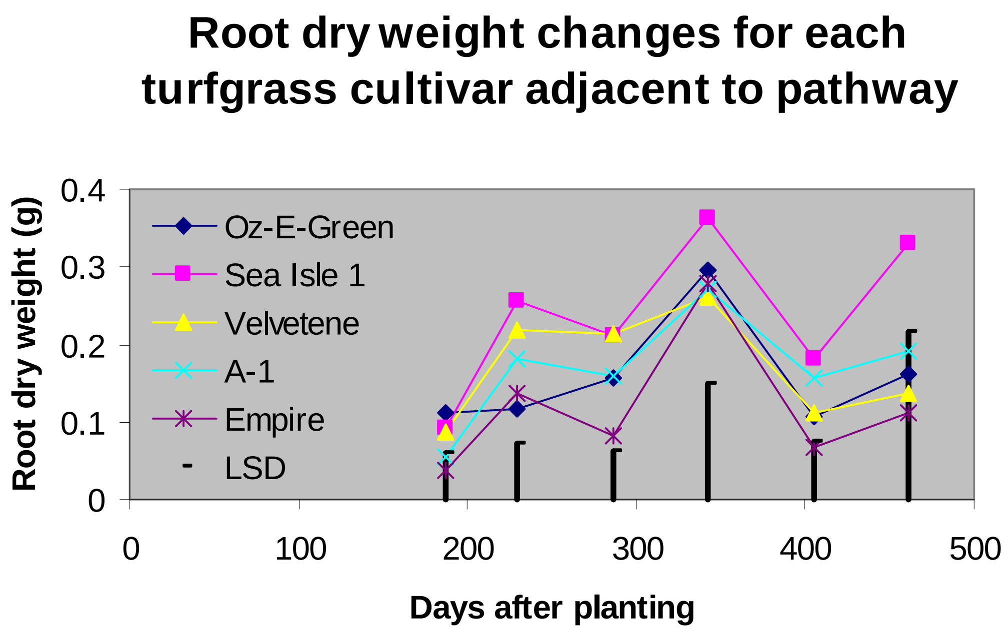


Figure 5-1. Root dry weights at each sampling occasion for each cultivar grown adjacent to the pathway

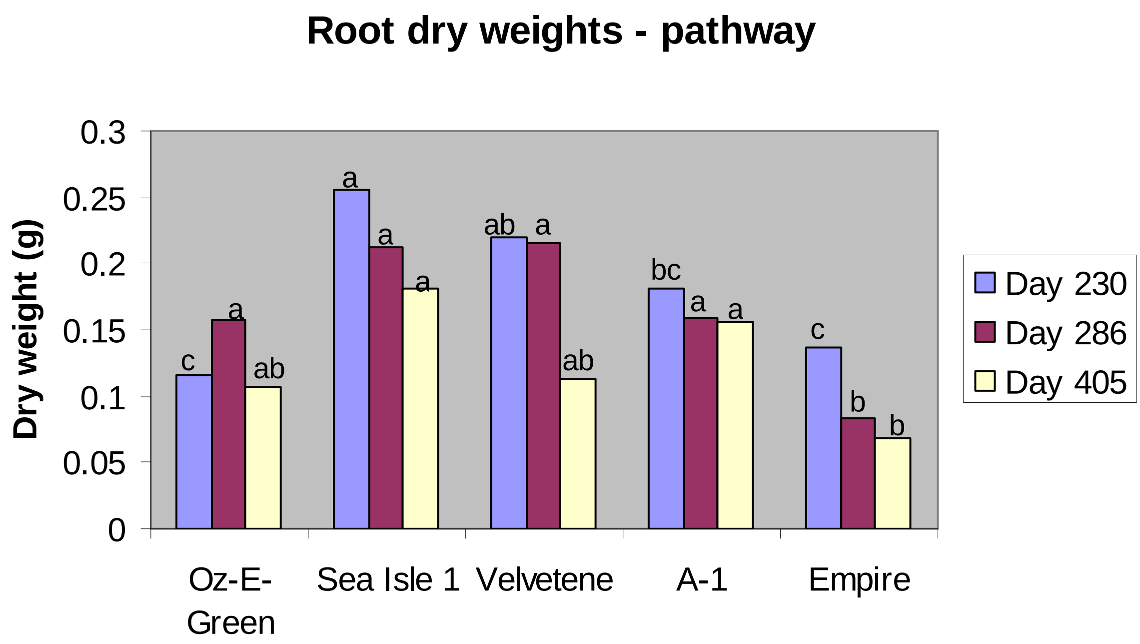


Figure 5-2. Root dry weights for sampling occasions in which statistical differences occurred. Different letters at each sampling day indicate statistical differences at 95% confidence.

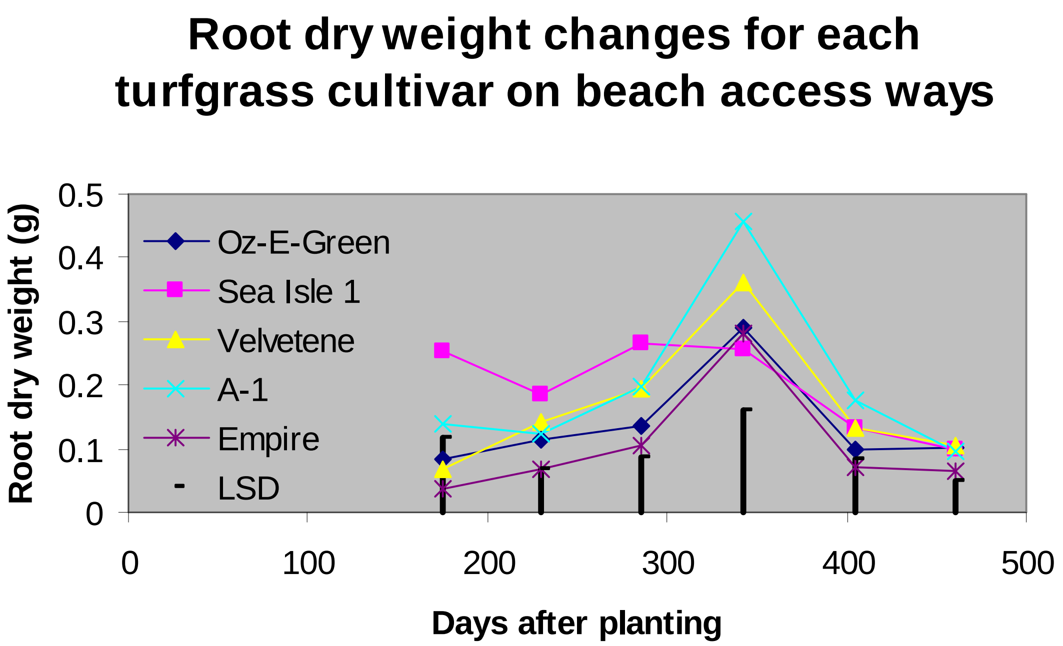


Figure 5-3. Root dry weights at each sampling occasion for each cultivar grown at the beach access ways

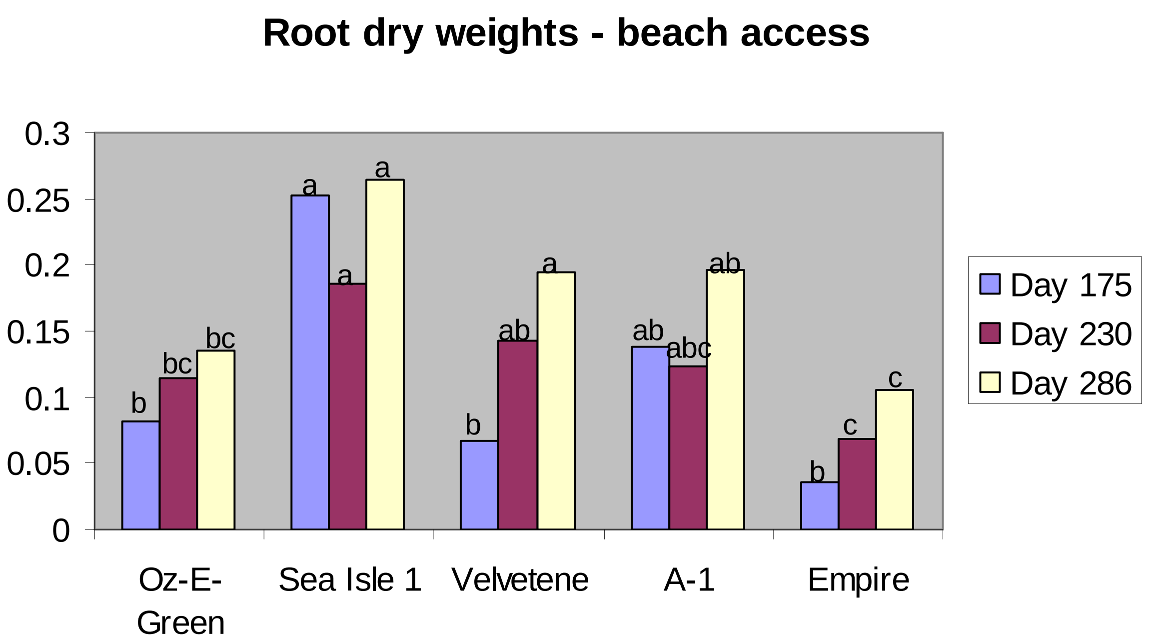


Figure 5-4. Root dry weights for sampling occasions in which statistical differences occurred. Different letters at each sampling day indicate statistical differences at 95% confidence.

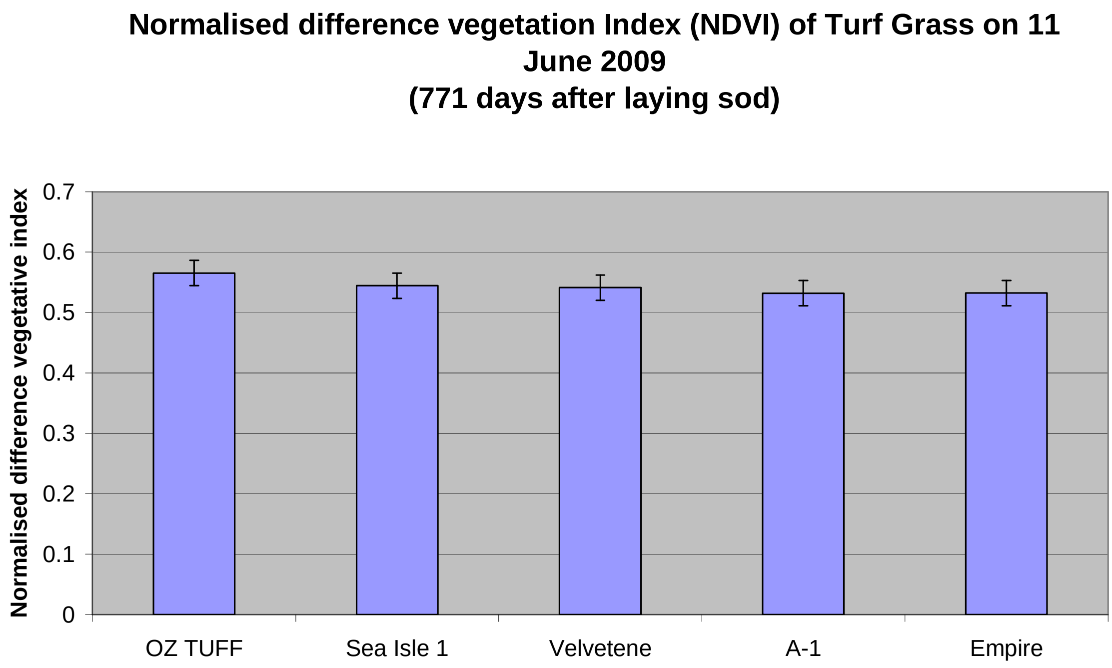


Figure 5-5 The comparative NDVI of 5 turf grasses trialled in a high foot traffic, partially shaded, foreshore amenity area. No significant differences were measured. Bars on the graph indicate L.S.D.s (P=0.05) between cultiivares

The most significant pressure limiting growth at this site, for the duration of this trial was the high level of traffic. As can be seen in
Plate 5-7, where there is a line of healthy growth furthest away from the pathway. All grasses suffered severe damage due to wear, while they all similarly grew well closer to the tree line, suggesting shade was not the major limiting factor at this site.

Plate 5-7. Overview of blocks 1 to 3, taken 28 August 2007. All grasses damaged by high traffic on the right hand side, an healthy growth under shade of the left hand side.

The final inspection of Surfer's Paradise Trial was undertaken on 11 June 2009. The beach access areas had been covered by sand in recent storms, as seen below in plates 5-8 and 5-9. The most striking observations were the invasion of Empire into both A-1 and Sea Isle 1 (Plates 5-10, 5-11 and 5-12). Given that this cultivar was found to be less salt tolerant than each of the other cultivars there was further evidence that salinity was probably not as limiting as wear at this site. Similarly, the healthy growth of Oz-E-Green in localised positions at the site of which Plate 5-7 is an example, suggests that management is equally important as cultivar choice.

Plate 5-8. Southern beach access area, covered by sand

Plate 5-9. Seashore paspalum growing through sand inundating the southern beach access area following a recent storm

Plate 5-10, Empire invading Sea Isle 1 plot

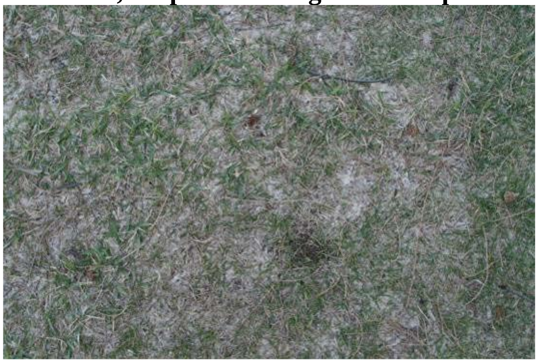


Plate 5-11. Empire invading A-1 plot

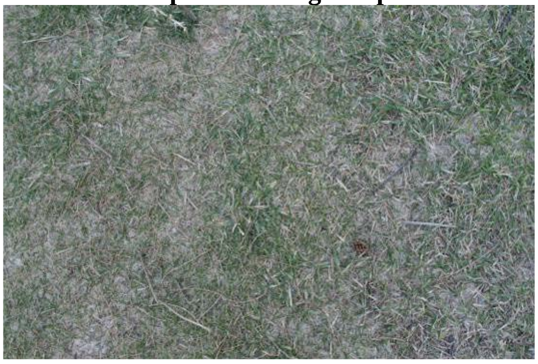


Plate 5-12. Empire moving into a plot of Velvetene on the right

Plate 5-13. Oz-E-Green showing good healthy growth

5.2.2 Case study 2 Budd's Beach

5.2.2.1 Site description

Budd's Beach is a west facing beach opposite Chevron Island at location 27°59′39″ S, 153°25′26″ E.

Turf establishment and growth is adversely affected by the following problems commonly found on this site, either individually or in combination:

- High wear close to large fig tree
- Saline areas close to beach front.
- High traffic

5.2.2.2 Trial design

Four observational trials were established to investigate turfgrass performance under each of the stresses listed above, with the fourth trial incorporating a combination of adverse conditions. A map of the field site is shown at Section 16.5 (Appendix B-3).

The included turf varieties were:

- *Cynodon dactylon* Oz-E-Green
- *Paspalum vaginatum* Sea Isle 1
- *Zoysia matrella* A-1

At the site incorporating combined pressures a fourth species was included as it is well adapted to low-light conditions and was observed growing endemically:

- *Dactyloctenium australe* sweet smother grass

Wear Tolerance

Three species were planted adjacent to a concrete slab of the observation deck (the northern most block). Turf rolls were planted perpendicular to the slab, with plots approximately 200mm x 2000mm with spaces left between plots. This block was situated in constant, full sunlight.

Shade tolerance and salinity tolerance / beach stabilisation
The same three cultivars were planted adjacent to the large fig tree. The plots were approximately 500mm x 2000mm with spaces of 500mm between plots.

Combined Pressures limiting Turfgrass Growth

The southern most plots included the same three cultivars with the addition of Sweet smother grass. The turf was laid to ensure consistent traffic, shade and salinity across plots. The plots were approximately 500mm x 2000mm with spaces of 500mm between plots.

5.2.2.3 Methods

Each trial did not include replication due to lack of space, which therefore precluded statistical analysis. Existing topsoil and grass cover was removed prior to planting. A good quality sandy loam to a depth of 100mm was used to replace that which was removed. Turf sod was laid on 23 April 2009 and fertilised with quick release, balanced fertiliser at 5 gN/m^2 (NPK ratio: 18-10-9).

5.2.2.4 Measurements

Turf colour readings, using a Fieldscout TCM 500 NDVI Turf Colour meter (Spectrum technologies®), were recorded on 27 May, 9 June and 4 August, 2009 as an indication of plant health. Photographic records were taken on 4 August and 20 October 2009, at which point the trial was terminated due to damage.

5.2.2.5 Results and discussion

As stated above, this trial was terminated on 30 October 2009, partially due to inundation from storm events, but also due to failure of the irrigation system. A prolonged dry period meant that all grasses were unable to survive dehydration. Results presented below must be considered to represent the defined stressed environments with the additional pressure of severe water deficits.

Figure 5-6 illustrates the change in NDVI readings with time for the site considered to represent a high wear environment. All grasses show an improvement in NDVI from 27 May to 9 June, followed by a rapid decline in NDVI which would be indicative of the onset of moisture deficit stress. Oz-E-Green (a cultivar of *Cynodon dactylon*) seems to show a higher NDVI on the last reading, suggesting it survived for longer during the moisture deficit period. Figure 5-7 illustrates the same NDVI relationship for conditions of low light intensity. Again the *Cynodon dactylon* cultivar has maintained a higher level of greenness for the later readings. Figure 5-8 shows the pattern of NDVI for the combined stress site. Here the *Paspalum vaginatum* cultivar Sea Isle 1 has maintained a higher level of greenness by the latter date. At this site, it appears the water deficit stress may be of lesser significance than salinity, traffic and shade, in which case the more salt tolerant species has maintained dominance. Interestingly, this pattern is not fully repeated in the data from the saline site. Figure 5-9 represents NDVI data for the three species in the saline position, where all species show a similar response.

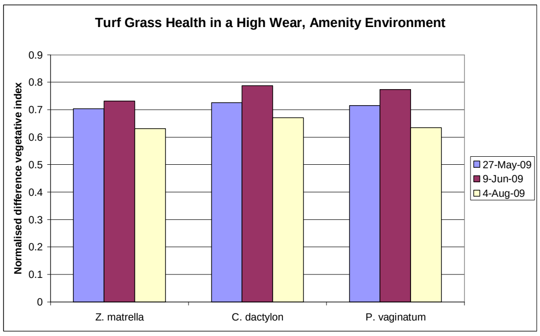


Figure 5-6 The comparative NDVI for 3 amenity turf grasses, grown in an area subject to high levels of foot traffic.

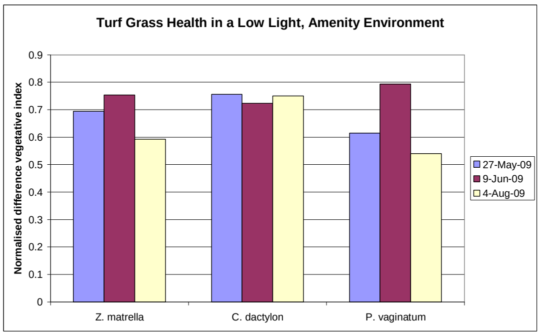


Figure 5-7 The comparative NDVI for 3 amenity turf grasses, grown in an area shaded by adjacent trees for the majority of each day.

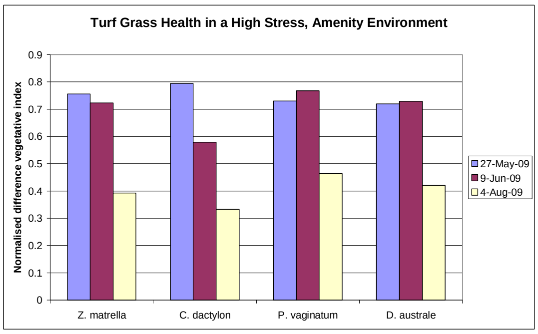


Figure 5-8 The comparative NDVI for 3 amenity turf grasses, grown adjacent to beach dunes and potentially exposed to high levels of salinity.

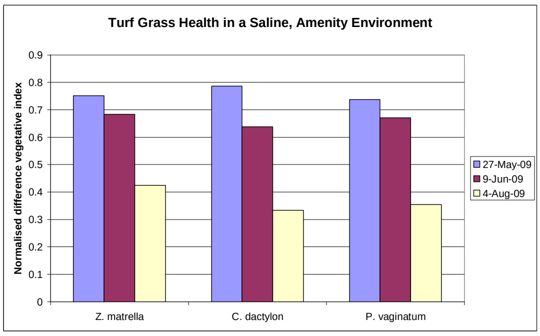


Figure 5-9 The comparative NDVI for 4 amenity turf grasses, grown in an area exerting wear, shade and salinity stress through proximity to foot traffic, tree canopies and beach dunes.

5.2.3 Case study 3 Hollindale Park

5.2.3.1 Site description

Hollindale Park is located south of the Sheraton Hotel, on Sea World drive and MacArthur Parade on Main Beach at the Gold Coast at location 27°58′28″ S, 153°25′43″ E.

On 12 March 2008 preliminary soil tests indicated that the site had a bulk density of 1.35, pH was 6.8 and salinity was 374 µS/m with a volumetric moisture content of 4.6%.

The most significant limitation to turf growth at this site was considered to be shading from surrounding trees, as can be seen in Plates 5-14 and 5-15.

Plate 5-14

Plate 5-15

5.2.3.2 Trial design

One replicated trial was established on a high shaded area and a further two sites were established adjacent to individual trees as demonstration sites with larger plots. Trial layout for the trial and demonstration sites is included in Section 16.6 (Appendix B-4).

5.2.3.3 Methods

One replicated trial was established on a high shaded area on the 23/04/2008, but was relocated to a similar site on 21/05/2008 due to road construction. A further two sites were established adjacent to individual trees as demonstration sites with larger plots. Cultivars included were: Sea Isle 1, Oz-E-Green and A-1 Zoysia. The turfgrasses were fertilised with CK88 at 5 gN/m^2 on 30 May 2008.

5.2.3.4 Measurements

Visual observations of % cover (0-100), colour (1-9), % leaf firing (0-100) and overall quality (1-9) on three occasions, 21 May 2008, 10 June 2008 and 5 August 2008, with a final inspection of the trial conducted on 11 June 2009.

5.2.3.5 Results

The figures below represent the estimated ratings for the four categories of: vigour; % cover; colour and overall quality. Sea Isle 1 shows lower coverage, colour and overall quality at each of the assessment dates (Figure 5-11, 23 and 24). All three cultivars showed declining colour at each assessment apart from Oz-E-Green which maintained good colour throughout June and July 2008.

This site, as with all other sites relied upon rainfall to supply 100% of the plant water requirements after the establishment phase, during which time the irrigation water source was recycled water. The superior performance of Oz-E-Green may well be due to a greater drought tolerance, rather than tolerance to high shade *per se.*

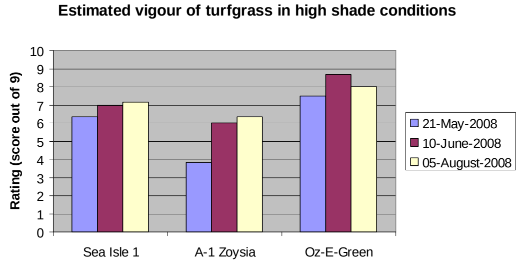


Figure 5-10. Visual rating of turfgrasses vigour under high shade.

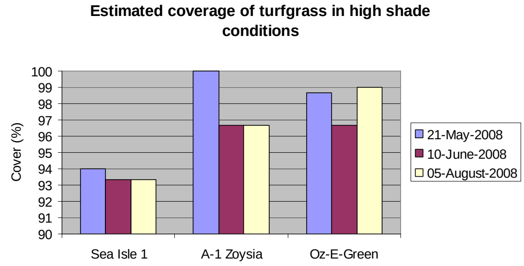


Figure 5-11. Visual estimation of percentage turfgrass cover under high shade.

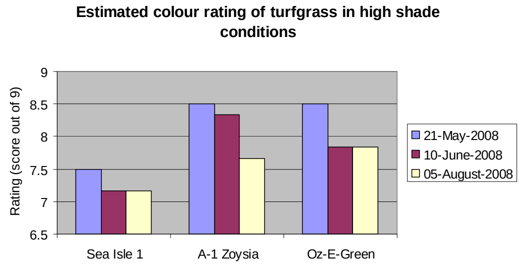


Figure 5-12. Visual rating of turfgrass colour under high shade.

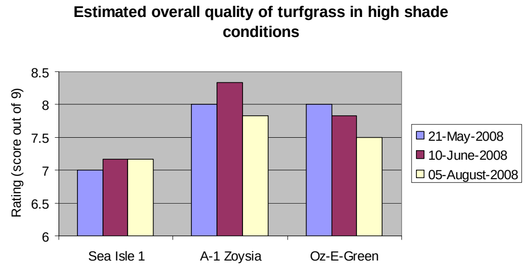


Figure 5-13. Visual estimation of turfgrass quality under high shade.

A final inspection of the trial on 11 June 2009 revealed all plots were dominated by Oz-E-Green, as illustrated below in Plate 5-16 andPlate 5-17.

Plate 5-16 Close up of main trial in which Oz-E-Green has become the dominant cultivar as of 11 June 2009

Plate 5-17 Close up of Oz-E-Green 11 June 2009

Plates 5-18 and 5-19 show the demonstration trial at the southern tree before establishment and at the conclusion of the trial. Plates 5-20, 5-21, and 5-22 are close up photographs of the three cultivars at this same demonstration site.

Plate 5-18 Site preparation – Northern tree viewed from north west.

Plate 5-19 Southern tree viewed from North West at conclusion of trial. Grasses are from left to right, Sea Isle 1, Oz-E-Green and A-1 Zoysia

Plate 5-20 Close up of Sea Isle 1 at southern tree

Plate 5-21 Close up of Oz-E-Green at southern tree

Plate 5-22 Close up of A-1 Zoysia at southern tree

5.3 Conclusions

While there has been a lack of evidence to support one tested cultivar over another, a general pattern has emerged in which different species, and cultivars have shown superior performance under different stress conditions, supporting the notion first introduced in TU02005 (Loch et al. 2006) that a patchwork of different turfgrass species across a landscape would be ideal, matching levels of tolerance and adaptation to levels of salinity, waterlogging, wear and tear and drought all integrated into sustainable systems of management and use.

Scientific results are difficult to achieve under off-site field situations in which conditions cannot be controlled. Similarly, finding a parameter by which to separate the health and quality of turfgrass cultivars, grown under conditions of multiple pressures is very difficult. While root growth provided important information as to the rate of establishment under various stress conditions, it did not translate into an indicator of the longer term survival of individual cultivars. At the Surfers Paradise site, Empire showed consistently slower root growth in terms of root dry matter production from sampled soil cores. However, at the final inspection of this site, Empire appeared to show the greatest survival in the longer term. Conversely Sea Isle 1, under a combination of moderate wear and high shade had the highest root growth rates. However, in the beach access ways this difference was no longer apparent, suggesting the higher wear at that position limited this cultivar's advantage.

These trials have provided valuable observational evidence of the likely survival of these species. It is noteworthy that each of the introduced, more salt tolerant grasses included in trials, grew and invaded surrounding areas where inferior or endemic grasses were struggling to maintain any degree of cover. There was some evidence that some do better in shade, but if water became limiting the ability to tolerate drought overrode this difference. At the Budd's Beach site, severe water stress was the primary limitation to turfgrass growth, leading to failure of all turfgrasses in the longer term. However, Oz-E-Green's superior drought tolerance ensured it survived for the longest period. At the same site, under conditions of low light intensity and subsequently less severe water stress, the salt tolerance of Sea Isle 1 allowed this cultivar to demonstrate superior performance. Similarly at the Hollindale Park site, severe water deficit prevailed as a limitation to turfgrass growth in which Oz-E-Green again showed superior performance. Sea Isle 1 appeared to not be as drought tolerant as Oz-E-Green. In the shaded situation at Hollindale Park, despite Oz-E-Green becoming dominant there were also areas in which the A-1 zoysia maintained a good dense coverage, it which case species choices may come down to personal opinions, preferences or availabilty.

Saline conditions do not seem to be the most important limiting factor on the Gold Coast – wear, shade and water availability appear to be factors of equal, if not greater importance in limiting turfgrass growth and survival.

All the grasses tested are premium grasses. Such an investment warrants good establishment and maintenance protocols. Most important of which is irrigation during prolonged periods of water deficit. The key outcome here is that accurate identification of the major limitations to turgrass growth at each site is essential in selecting the right species and cultivar. The key is not selection of the right turfgrass as an isolated component. Rather the key to success is the selection of the right species and cultivar for each situation combined with establishing and maintaining those turfgrasses in the right way. It is important to find strategies to ensure good establishment, and to irrigate when needed, so that the chosen cultivars have a greater ability to stand up to the pressures imposed on them.

6 Establishment Methods.

6.1 Introduction

As discussed above, turfgrasses range from extremely salt sensitive to highly salt tolerant, as do plants in general. However, finding a salt tolerant grass is no “silver bullet” or easy solution to salinity problems. Too often in the past, the construction, establishment and maintenance phases have been considered in virtual isolation of one another. Cheap construction invariably leads to initial cost savings being quickly eroded through higher than necessary maintenance expenses for the indeterminate future. This has been exacerbated by a lack of detailed establishment protocols for park development. By specifying clear guidelines to be followed during the construction of coastal parks, many of the current problems and additional expense in follow-up remediation and management could be minimised and even eliminated in the future.

Laying full turf across large areas of park or sportsfield is expensive, and in some cases can give an inferior result by creating a surface layering effect that reduces depth of rooting and hence drought tolerance. Alternative methods such as sprigging or seeding are attractive to enable councils to reduce establishment costs and increase the area planted from the same budget, provided the reliability of these alternatives can be increased substantially from current levels.

Maximum return from the investment into good quality grass cultivars was shown above to be limited by establishment and management protocols, or lack thereof. Improvements to these protocols were the focus of this section. Four approaches were adopted to investigate establishment. The components to the research included development of protocols for the better establishment from full sod as observational investigation of sprigging, a scientific investigation of sprigging under controlled conditions, and finally, continued observation of trial sites established under TU02005 in which plugs of turfgrasses were used to remediate saline scalds in coastal parks within the Redland City Council boundaries.

6.2 Investigations

6.2.1 Topsoil and sod preparation

6.2.1.1 Methods

The first step in improving turf performance in Surfers Paradise Beach park (Case study 1, section 5) was to develop a good growing profile below the turf by incorporating organic matter (<5% by volume) into the well-drained but depauperate beach sands.

It appeared from observations on 6 December 2006, that the topsoil (red-brown earth) brought to the site on the existing turf sod was contributing to the problem of stratification within the soil profile, inhibiting water infiltration and root growth. The likely presence of sodium salts at this site would further exacerbate the problem by altering the physical properties of this soil. To prevent the occurrence of soil profile layering it was suggested that all further sod introduced to the site be washed, at an approximate cost of $1.50 /m2. A layer of sandy loam topsoil was then suggested to enhance establishment of turfgrass and also reduce surface hardness through the area. Many of the topsoils on the market need critical evaluation for their suitability as a turf underlay.

While the main plots at the Surfers Paradise site were each of the cultivars, as discussed in the preceding section, the trial was actually designed as a split-split plot, with the first split being topsoil material and the second split being washed and unwashed sod. The two topsoil materials under comparison as turf underlay were 100% compost and sandy clay topsoil, each applied above the sand profile to a depth of 10 cm. (Trial layout included as Appendix B-1).

Turf was laid as washed or unwashed full sod, and protected (as far as practicable) from wear for the first two weeks using temporary fencing (illustrated above in Plate 5-1 to Plate 5-6). Turf was laid on 10 cm deep compost or sandy loam topsoil containing no more than 25% organic matter. Turf was watered daily for the first 14 days. After the first fortnight, irrigation intervals were extended until turf was surviving on 100% rainfall. The turf was then managed according to regular mowing and maintenance schedule for the site. Blanket dressings of fertiliser were applied in accordance with existing fertiliser program.

Data collected as per the protocols listed in section 5.2.1 were analysed such that comparisons could not only be made between cultivars, but also between topsoil materials (sandy clay versus compost) and sod preparation (washed versus unwashed). Statistical analysis was conducted using GenStat 11th Edition.

6.2.1.2 Results and discussion

As discussed above, the first samples did not show any statistical differences between cultivars, or between washed and unwashed roots (Figure 5-1 and 6-1). However, the root growth in sandy loam was significantly higher than in compost (Figure 6-2). As can be seen by later figures this difference was temporary, with the compost profile showing significantly greater root production than the topsoil (Figure 6-3). The superior root growth translated to improved quality at the final inspection, with the turfgrass grown on compost showing a higher NDVI (Figure 6-4). This could be explained either through higher water holding capacity of the compost underlay or better nutrient retention, although neither were assessed during this trial. Using compost, rather than a clay loam, beneath turf rolls at establishment, leads to significantly higher NDVI, regardless of whether full sod or bare-rooted turf grass is used.

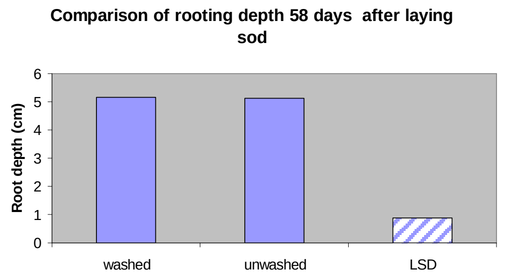


Figure 6-1. Measured root depth of washed and unwashed sod 58 days after planting.

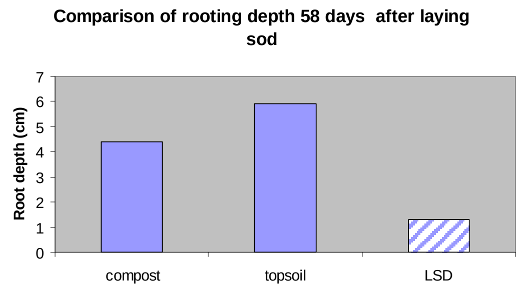


Figure 6-2. Measured root depth of sod having and underlay of compost as compared to that with an imported topsoil underlay.

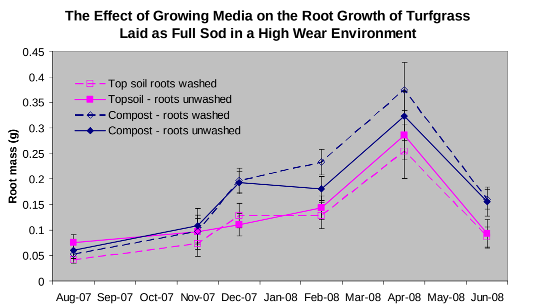


Figure 6-3. Root dry matter production on different turf underlays, with and without root washing prior to planting.

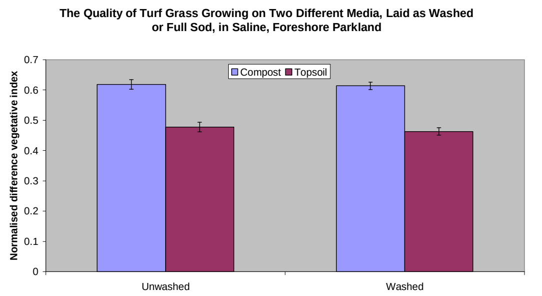
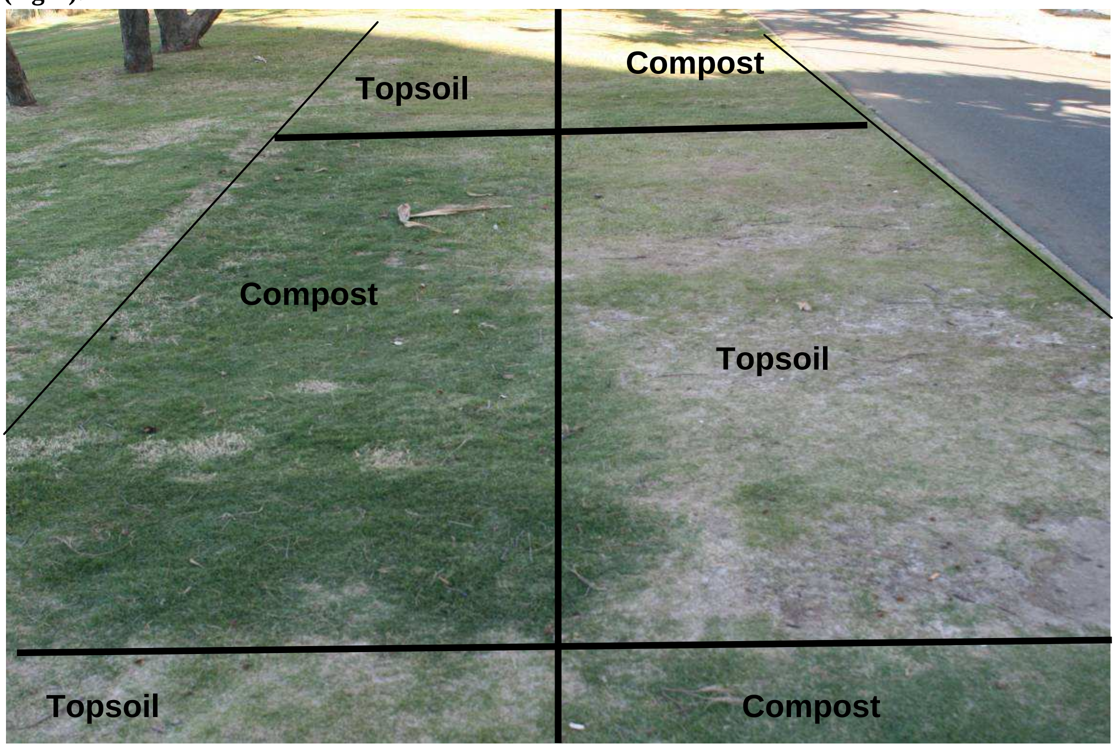


Figure 6-4. NDVI of turfgrasses on different underlays, with and without root washing.

Plate 6-1 Turf grass plots displaying healthy growth and colour when growing on composted organic material (left) compared to sparse cover over a clay loam (right).



6.2.2 Alternative planting method – large, low wear areas

6.2.2.1 Methods

Sprigging or stolonising a cheaper alternative to laying full turf was investigated as a viable technique for establishing turf over larger areas. Three large areas of the coastal parkland at Surfers Paradise were planted with sprigs of *Paspalum vaginatum* VelveteneTM and large plugs (10 cm diameter) of *Stenotaphrum secundatum* SaphireTM were planted under trees.
The planting of turfgrass plugs was investigated as an alternative to more costly establishment methods. Plugs of *Paspalum vaginatum*, *Zoysia matrella* and *Sporobolus virginicus* had previously been planted at Masthead Drive, Raby Bay. These sites were monitored for the duration of this trial.

Plate 6-2. June 14 2007 Sprigging machine

Plate 6-3. Loading sod of Velvetene (*Paspalum vaginatum*) ready for sprigging.

Plate 6-4. Sprigging foreshore areas with Velvetene (*Paspalum vaginatum*)

Plate 6-5 June 14, 2007 areas of foreshore sown to sprigs of Velvetene (*Paspalum vaginatum*)

6.2.2.2 Results and discussion

This method is more appropriate for areas of low traffic as the establishment time is greater. Sprigs of Velvetene have shown limited success in the coastal situation, due mostly to limited access to water. Timing of planting was also not conducive to rapid establishment due to cooler temperatures limiting growth of this warm season turfgrass. Use of the site for Indy 500 required that planting occur prior to

the event in the hope that the grasses would establish in preparation for schoolies. Such limitations highlight the difficulties faced by park managers in high use areas.
The following plates illustrate the time required to establish 100% grass cover from sprigging, under suboptimal conditions of irrigation and traffic. Clearly 10 weeks is an insufficient time period. However extension of this period is impractical given the usage demands for the site.

Plate 6-6 28 August 2007 Sprigs starting to spread between rows, 10 weeks after planting

Plate 6-7. 28 August 2007 Velvetene sprigs spreading over sand which inundated the site following storm events (10 weeks after planting)

Plate 6-8. 9 November 2007, turfgrasses under imposed shade and traffic during Indy 500.

Plate 6-9. 9 November 2007, harsh conditions limiting full establishment from sprigs of Velvetene 20 weeks after planting.

Plate 6-10 14 January 2008 Sprigs of Velvetene not yet providing 100% coverage

Plate 6-11 14 January 2008, individual plant of Velvetene showing limited density due to harsh conditions.

6.2.3 Controlled investigation of sprigging using good quality compost growing media

A concurrent trial was conducted under controlled conditions at Redlands research station to investigate the potential to expedite the process of establishment from sprigs. Seashore paspalum (*Paspalum vaginatum*) turf growth in a 5 cm layer of compost growing medium. Whilst this trial was primarily focussed on the value of a commercial growing media, the results have application for any sites in which a minimum timeframe is required for establishment, where full sod is unachievable due to budgetary constraints.

6.2.3.1 Methods

A level site was selected on Redlands Research Station, Cleveland (27º32′S, 153º15′E) within a 10 x 10 m area irrigated by 4 x 90° pop-up sprinklers with head-to-head coverage. This was bounded by 5 cm thick planks and heavy-duty black plastic was laid on the ground surface within the growing area to allow easy removal of full sod at completion of the trial. Compost mixed with c. 10% sand to improve internal drainage was laid to a depth of approximately 5 cm within the surrounding planks.

On 16 February 2007, sprigs of the seashore paspalum variety SeaDwarf were spread on the surface and held in place by shade cloth fastened over the top (standard greenkeeping practice when laying a new bowls green). Programmed daily watering commenced to replace evapotranspiration losses (based on 80% of average pan evaporation), and continued through to maturity of the new sod. The shade cloth was removed on 2 March, from which time onwards a sequence of weekly or fortnightly photographs were taken to follow the grow-in of the SeaDwarf sod. Urea (at a rate of 50kg N/ha) was hand broadcast over the area after 5 weeks and again after a further 4 weeks to replace nitrogen lost through leaching.

6.2.3.2 Results and discussion

The sprigs took well and grew rapidly, achieving full sod cover by 10 weeks after planting. By this stage, extensive root and rhizome development had taken place throughout the growing medium. The short time taken to produce mature sod looks very promising, as this process, in a field situation was shown to take 4-6 months for a similar cultivar of the same species. On the down side, some broadleaf weeds and sedges also developed, but in future weed problems should be easily avoided by applying oxidiazon (Ronstar®) at planting to prevent any seed germination taking place.

Plates 6-12 to 6-29 are a photographic time sequence showing development of full sod from sprigs of SeaDwarf paspalum during the first 11 weeks following planting (*Left* – general plot view*; Right* – close-up of turf).

This method has proven successful for rapid establishment of Seashore paspalum. This method ensured the growing media with a regular water supply and fertiliser regime kept the sprigs in optimal growing conditions. Protection from traffic was also paramount to the successful establishment of a healthy grass sward.

Plate 6-12. 2 March 2007 (2 weeks)

Plate 6-13. 2 March 2007 close-up of turf

Plate 6-14. 9 March 2007 (3 weeks)

Plate 6-15. 9 March 2007 close-up of turf

Plate 6-16. 16 March 2007 (4 weeks)

Plate 6-17. 16 March 2007 close-up of turf

Plate 6-18. 23 March 2007 (5 weeks)

Plate 6-19. 23 March 2007 close-up of turf

Plate 6-20. 29 March 2007 (6 weeks)

Plate 6-21. 29 March 2007 close-up of turf

Plate 6-22. 4 April 2007 (7 weeks)

Plate 6-23. 4 April 2007 close-up of turf

Plate 6-24. 20 April 2007 (9 weeks)

Plate 6-25. 20 April 2007 close-up of turf

Plate 6-26. 26 April 2007 (10 weeks)

Plate 6-27. 26 April 2007 close-up of turf

Plate 6-28. 5 May 2007 (11 weeks)

Plate 6-29 . 5 May 2007close-up of turf

6.2.4 Monitoring of long term establishment trials with Redlands City Council

Plugs of *Paspalum vaginatum*, *Zoysia matrella* and *Sporobolus virginicus* were planted at Masthead Drive, Raby Bay with mixed results. Due to the drought conditions that persisted throughout the majority of this project, it became council policy to not irrigate amenity areas due to the high level water restrictions imposed by government. This has limited the survival of many species within coastal parkland areas. However, the overall longevity of turfgrasses in this parkland has been surprisingly good, with some areas displaying growth that has connected plugs to form a continuous and healthy verdure. Grass cover remains sparse, however, in some low tracts of ground where high salt accumulation is evident. It is suspected that concentrations of salt in discrete areas of this unirrigated land, developed from marine mud, are not conducive to establishment from plugs. The partial success observed in this area, however, suggests that the planting of plugs of salt-tolerant cultivars may be an option for establishment where soil quality is better and/or salt leaching is possible.

Plates 6-30 and 6-31 are a side by side comparison of the same area of parkland photographed in January 2004 (a) prior to laying full sod of salt tolerant turfgrass (*Paspalum vaginatum*) and again in March 2010 (b). In February 2004, Redland City Council established seashore paspalum (*Paspalum vaginatum*). The site was underlain by compacted marine mud, and was both strongly acid (pH 3.3-4.7 surface, 2.9-4.4 subsoil) and saline (ECe 2.8-41.1 dS/m surface, 4.2-46.7 dS/m subsoil). While the aspect is slightly altered it is still clear that grass cover has improved significantly, despite extended drought during the interim period. Plate 6-31 was taken after a prolonged rainfall period, when grasses are in the recovery phase.

Similarly, Plates 6-32 through to 6-35 demonstrate the successful establishment and persistence of plugs of salt tolerant grasses. These plugs were planted into a layer of good quality topsoil which has provided a suitable medium for the grasses to establish. Salt tolerance has then allowed continued survival in hostile conditions.

Plate 6-30 January 2004 Queens Esplanade Birkdale (looking west).

Plate 6-31 March 2010 Queens Esplanade Birkdale (looking west).

Plate 6-32 plugs of *Sporobolus virginicus* planted in 2004

Plate 6-33 plugs of *Sporobolus virginicus* providing good cover and persisting despite extended drought.

Plate 6-34 Overview of Masthead Park in February 2007 following planting of salt tolerant plugs

Plate 6-35 Overview of Masthead Park in March 2010, showing not only persistence of grass species but a marked improvement in grass cover due to better species choices.

6.3 Conclusions

The most beneficial management practice identified is the addition of composted organic material to the media used beneath turf laid as full sod. Turf grass has been found to benefit from such amendment whether sod is washed bare or containing soil. Washing turf sod alone has not been found to affect turf grass health.

Compost was found to be superior to the selected topsoil, as defined by root production, with significant differences detected on two of the sampling dates. When roots were washed free of soil, prior to laying the differences between the effects of the two media were augmented. These results support the evidence that suggests that layers, formed in the soil profile, limit the vertical movement of water, oxygen and roots. This restriction of soil function ultimately leads to reduced turfgrass health and quality. Such layers are formed when two media of very different texture are interfaced. Another reason that washed sod may have an advantage in a salt-affected park is that in the absence of clay particles, sodium ions are not able to be retained in the root zone for extended periods. Conversely, if sodium builds up by adhering to clay platelets, soil structure may be compromised and concentrations that are toxic to turfgrass may even be attained.

Composted material could benefit a deep sand profile by raising the cation exchange capacity, nutrient retention, water holding capacity and organic cycling of nutrients, as a pure sand lacks these properties.

The possible use of the new seeded seashore paspalum variety 'Sea Spray' (becoming available commercially in the USA), especially for large scale plantings or patch-up work, was to be investigated, depending on seed availability and possible restrictions imposed by the IP owners. A structured and designed experiment, planned for a site on the Gold Coast to compare seeding and sprigging was cancelled due to lack of irrigation.

Alternative methods have been shown to be successful in controlled situations. The fragile nature of grass sprigs makes irrigation essential as they rapidly dehydrate. It is important not to be reliant upon incident rainfall, although water and energy savings will be made if rainfall does occur in sufficient quantities. Also, the area must be protected from traffic for a minimum of 10 weeks. Regular applications of fertiliser are important to ensure growth rates are at a maximum, giving the plant opportunity to establish a healthy root system in the time allocated. This method may be possible in low use parks or discreet areas that can be fenced, or on sporting fields that can be closed for the duration. It is not appropriate in high use sites with limited water supply. Pre-emergent herbicides are also required if sprigging under optimal conditions is chosen as the establishment method. The optimal conditions for grass establishment will also support the germination and growth of weeds from the latent seed store in the soil.

This chapter and the preceding chapter have highlighted the importance of viewing turfgrass establishment and management from a holistic viewpoint. As shown, it is not a simple matter of selecting a cultivar, planting and forgetting. The cultivars investigated, while showing superior performance in sub-optimal conditions, do have limitations. They are living plants that do require necessities of life – water, nutrient, light and some protection. The high water needs required to establish the turfgrass sward, will be a valuable investment in the long term as it will allow the plant to perform many benefits to the environment, as well as the social and health benefits that living plants provide (Gullone 2000; Maller, Townsend et al. 2006; Kaczynski and Henderson 2007).

7 Soil de-compaction.

7.1 Introduction

Soil salinity is sometimes associated with high concentrations of soil sodium (Na) (sodicity) since sodium ions account for a number of the cations resulting from dissolution of salts. Sodium status is often defined by the exchangeable sodium percentage (ESP) – a measure of the sodium available for exchange or to increase sodium concentration in soil solution, relative to all the exchangeable cations on exchange sites within the soil. Exchangeable sodium and cation exchange capacity (CEC) are measured in units of centimoles of positive charge per kilogram (cmol(+)/kg).

$$ESP = \frac{Exchangeable \cdot Na \times 100}{CEC}$$

Since the dominance of sodium relative to other cations, particularly calcium and magnesium, is important for understanding physical soil structure, the sodium absorption ratio (SAR) is also used to quantify sodium. Classification of soils, based on salinity and sodicity, is given in Table 1.

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)} \div 2}$$

Table 7-1. The Australian classification of soils based on the effective electrical conductivity (ECe) and SAR measured from a 1:5 (soil:water) mixture (Naidu and Sumner 1995)

Class	Total Soluble Salt Status	Sodium Status
	Approx. EC_e	1:5 Extract SAR
Saline	≥4	<3
Sodic	<4	≥3
Saline-sodic	≥4	≥3

Considerations of sodium content in soil are critical, as an excessive amount will lead to poor soil structure and properties that are not conducive to optimal turfgrass growth. More specifically, soil can become less permeable to water, oxygen and roots. As soil pores become smaller, blocked or less continuous, water infiltration and drainage decreases, oxygen diffusion decreases and soil strength and surface hardness increase.

As sodium ions replace others on the CEC sites on clay particles, compaction becomes more prevalent. This is due to the difference between Na+ (monovalent) and cations with a positive charge of 2 or more (e.g. Ca+2) (polyvalent). Clay is negatively charged and polyvalent cations are able to attract at least 2 microscopic fragments of clay, bringing them together in the beginnings of flocculation (building soil into structurally stable units called aggregates).

When sodium builds up and becomes the dominant cation, it is less efficient at overcoming the negative charge of soil, relative to polyvalent ions. This means that most clay platelets will retain a net negative charge, causing repulsion of each other and a loss of soil structure.

Because sodicity can be a problem in saline soils, this segment of the research aims to investigate techniques for the alleviation of soil compaction that compliment salinity management. Initially, cultivation of the soil with 2 different machines as well as topdressing was examined. As no significant improvements were recorded, a second phase was implemented, utilising a number of settings on a deep tine aerator (DTA), arguably the best, easily-accessed machine for intense soil aeration where soil disturbance is not permitted (Shim and Carrow 1997).

Although this work evaluates the ability of machinery to change the physical properties of an extremely compacted, marine mud, a decompaction programme should holistically address all aspects of the problem. The physical and chemical nature of the soil, as well as the irrigation, drainage and topdressing practices should all be included in any plans to maximise soil aeration.

7.2 Methodology

Parkland situated on the Birkdale foreshore (S 27° 26' 46.0832", E 153° 19' 55.4224") in Redland City Council, Queensland, was constructed using marine mud from nearby offshore locations. The ECe of the profile varies but samples taken from saline scalds produced values of 109.41 and 115.54 mS/cm. These take conversion factors into account, based on the percentage clay in the soil (Slavich and Petterson 1993).

These same samples yielded 5.2 and 23.2% ESP, indicating a sodic soil. Although the former value is reasonably low, in comparison to 15% which is traditionally used to indicate sodicity, the high content and type of clay in the profile suggests increased sensitivity to Na+ (Carrow and Duncan 1998). The park construction resulted in marine clay sediment, capped by a red, volcanic Ferrosol.

7.2.1 Phase One

Phase one of the experiment consisted of a randomised, split-plot trial design with five treatments (including the control) and four replications (Table 7-2). The plot dimensions were 5 x 10 m with 5 x 5 m sub-plots. The primary treatments were the application of cultivation machinery at various settings with each plot split into the secondary treatments of topdressed or not topdressed.

Table 7-2 Treatments applied in phase one of the decompaction study.

Primary Treatment		Secondary Treatment
Machinery	**Working Depth**	
Control	N. A.	Topdressed
		Not topdressed
Terra Combi deep spiker	70-100 mm	Topdressed
		Not topdressed
Verti Drain® deep tine aerator	80 mm	Topdressed
		Not topdressed
Verti Drain® deep tine aerator	120 mm	Topdressed
		Not topdressed
Verti Drain® deep tine aerator	170 mm	Topdressed
		Not topdressed

The Terra Combi unit, equipped with a heaving rotor and knives for deep spiking, consists of four blades spaced equally around a rotating shaft, with each set of blades offset to the adjacent set (Plate 7-1). Each knife follows a twisting path as it extends outwards from the shaft, allowing the soil to be slit and then have a lateral force exerted through the profile, creating fissures that result in increased aeration. The blades are 200 mm in length and fixed at a 90° angle to the rotating shaft. The spacing between sets of blades is 200 mm and the working width of the machine is 1.6 m.

Plate 7-1 The Terra Combi with deep spiking tools

Plate 7-2 Verti Drain deep tine aerator

The DTA utilises tines, held in pairs by tine holders (Plate 7-2). In this investigation, solid tines, 300 mm long and with a 19 mm diameter, were used. The principal benefit of using a DTA is the subsurface fracturing of the soil, which takes place due to the orientation of the tines upon exiting the soil. The tines enter the profile at approximately 90° to the surface. The machine then travels forward, levering the distal end of the tine (and the soil behind it) rearwards, before the tine is lifted from the soil. This creates a fracturing of compacted soils, as well as increasing the subsoil spaces for the movement of oxygen, water and roots.

In this trial the DTA was set to pivot the tines through 80° before retraction. The ground penetration spacing was 150 x 150 mm and this particular model had a working width of 2.4 m. The DTA treatments were distinguished by their different working depths (see Table 7-2). The deep spiking and DTA treatments were applied on 16 April 08 and six days after treatment approximately 7 mm of sand was topdressed, in the relevant plots, using a belt spreader with two spinning discs.

Prior to execution of treatments (31 March 08) all plots were assessed for surface hardness, penetration resistance, soil bulk density, soil moisture content and soil moisture infiltration. The latter was also assessed on 6 June 08 and 27 August 08. All other types of assessment, measurements resumed on 1 May 08 and were repeated at 14 day intervals until the conclusion of phase one (4 October 08).

Soil water infiltration was ascertained using twin infiltration rings with external diameters of 90 and 250 mm. These were made of sections of dense, polymer, irrigation pipe, 140 mm in length with graduations of 10 mm marked along the height of the inner surface. The bottom edge of each ring was sharpened with an electric grinder to enable the rings to be driven into the soil, approximately 10-20 mm, with the smaller inside the larger, in a concentric arrangement. Water was then poured into both tubes and kept topped up throughout the measurement process. As the water being poured reached the top graduation on the inside of the smaller ring, a stopwatch was started and the time taken to move between each mark was recorded. When the time taken for infiltration of 10 mm was consistent, this was taken as an indication of the steady state infiltration rate of the soil. Seconds per 10 mm were converted to mm per hour.

Surface hardness was assessed using a Clegg hammer, which allows a 2.25 kg weight to be dropped from a height of 45 cm, with deceleration of the weight recorded as it impacts on the soil surface (Clegg 1976). A hard surface will be associated with a higher deceleration value, than a soft surface. The use protocol entails dropping the weight four times in the one spot and referencing the fourth measurement as the Clegg impact value (CIV) for that location. Australian standards for surfaces used for sport state that CIVs of 7-9 are desirable with 12 constituting the upper ceiling of acceptable (Chivers and Aldous 2003). A CIV of 20 or higher indicates that a head injury sustained on such a surface is twice as likely to result in a serious brain trauma compared to those incurred on playing fields with desirable CIVs.

Penetration resistance is measured using a penetrometer, which gives some indication of soil compaction. A 1 kg mass is dropped from a height of 1 m, sliding down a metal rod and driving a 1 cm^2 flat steel tip into the ground. The depth of penetration is observed in centimetres. The weight is dropped 3 times in randomly assigned, different spots within a sub-plot and the average of these measurements is taken as the penetration resistance value for that particular treatment and replicate. The penetrometer is designed so that the force required for the steel rod to move through the profile is related to the ability of oxygen, moisture and roots to pervade the soil.

The greater the compaction of a sodic soil, the greater the soil bulk density. This relates to the reduction of soil macro- and micropores that accompanies compaction of soils with excessive sodium content. Bulk density of the soil at Birkdale was determined using plugs of soil, taken from the ground using a soil sampler. As the plugs were cylindrical with a diameter of 4.8 cm and a length of 15 cm, the volume was calculated as 271.54 cm^3 (volume of a cylinder = π x $radius^2$ x length). All core samples were dried in an oven at 65°C for 24 hours. The dry weight, expressed in grams was then used to calculate the bulk density (dry weight ÷ volume).

The recording of soil moisture over time was important for the interpretation of data. It is a variable that is dependent on treatments (aeration changes moisture holding capacity through the improvement of both moisture infiltration and drainage). It is also, however, an independent variable, since this field experiment was exposed to the elements. Monitoring moisture changes associated with rainfall events allowed other measurements to indicate the impact of applied moisture on soil hardness and other parameters of compaction.

As core samples were being utilised for bulk density calculations, soil moisture was determined gravimetrically, making use of the same soil samples. Fresh weight (FW) was measured for all samples before drying and this was compared to the dry weight (DW) to establish gravimetric soil moisture (%), using the formula: ((FW – DW) / DW) x 100.

7.2.2 Phase Two

A more aggressive approach to soil aeration was taken in the second phase of the research. Concentrating on the capabilities of the mechanical aerator shown in other studies to relieve compaction most effectively (Shim and Carrow 1997), the DTA was tested at various depth and subsoil rotation settings as well as for frequency of application (see Table 7-3). A randomised complete block design was employed, using five treatments plus a control, with four replicates. The plot dimensions were 10 x 5 m.

Table 7-3 Treatments included in phase two of the decompaction study.

Treatment	**Depth**	**Sub-Soil Rotation**	**No. of Applications**
1	Control		
2	80 mm	5°	1
3	120 mm	5°	1
4	120 mm	15°	1
5	200 mm	15°	1
6	200 mm	15°	2

The tine length, diameter and spacing were the same as that used in phase one. All treatments were imposed on the relevant plots on 15 June 09. Treatment 6 consisted of a second application, which was administered 7 days later. The second application was carried out in the same direction as the first due to plot size limitations. Results were measured every day, for 5 days, commencing on 16 June 09. After this, weekly assessments were made, for 4 weeks, followed by continued data collection at 6 week intervals.

Surface hardness (using a Clegg hammer), penetration resistance (using a penetrometer), and soil moisture infiltration (using infiltration rings) were used, as in phase one. Volumetric soil moisture content was measured with frequency domain reflectometry using a ThetaProbe from Delta-T

Devices, a probe that consists of 4 rods with sharp ends for insertion into test media. A 100 MHz signal is sent through the steel rods and impedance is measured to calculate moisture percent, by volume, which is displayed on the attached logger. For all types of assessment, with the exception of moisture infiltration, sub-plot replication was introduced by taking 3 readings at random locations within each plot.

7.2.3 Phase One

There is little significant difference between treatments for all parameters investigated in phase one (figures 7-1 to 7-10). In Figure 7-1 and 7-2 , soil bulk density is highly variable, with a general trend of higher peak values when topdressed. This is in accordance with higher specific gravity data for sand (1.602 g/cm^3) than for clay (1.073 g/cm^3). All bulk densities observed (predominately < 1.5 g/cm^3) are considered typical for a soil of this type.

There is also considerable fluctuation in the readings taken by the Clegg hammer over time (Figures 7-3 and 7-4). They range from less than 5 CIV (desirable) to 17 CIV (unacceptable, with respect to safe play of sport). Significant improvement to surface hardness, relative to the control, can be seen on 8 October 08. Only minor differences between topdressed and non-topdressed sub-plots are apparent. In figures 7-5 and 7-6 soil moisture content in this unirrigated park appears to be unrelated to cultivation treatments or topdressing. The peak values recorded through winter are closely aligned with the relatively high rainfall experienced in June (118 mm) and July (121.6 mm). Some of the data collection during this period occurred directly after significant rainfall events. Figure 7-5 and 7-6 show a range of soil moisture content with minimum values that approximate wilting point for a clay loam (12-15 %) and with maximum readings roughly indicative of field capacity for this soil type (approximately 38 %).

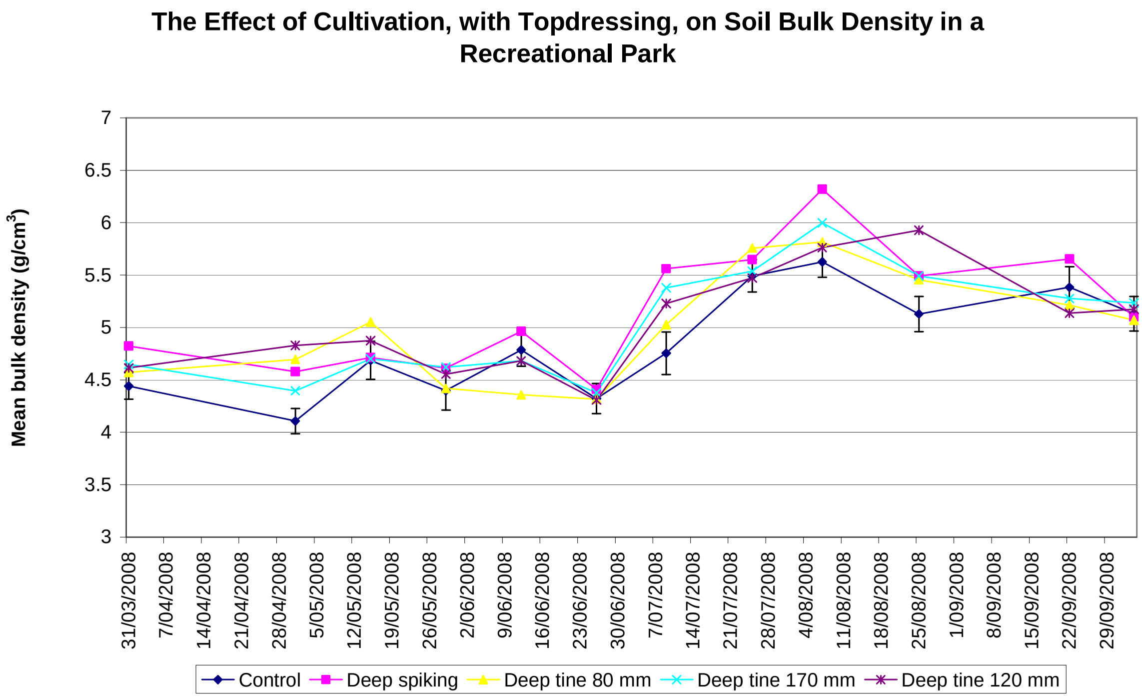


Figure 7-1. The effect of cultivation with topdressing on soil bulk density.

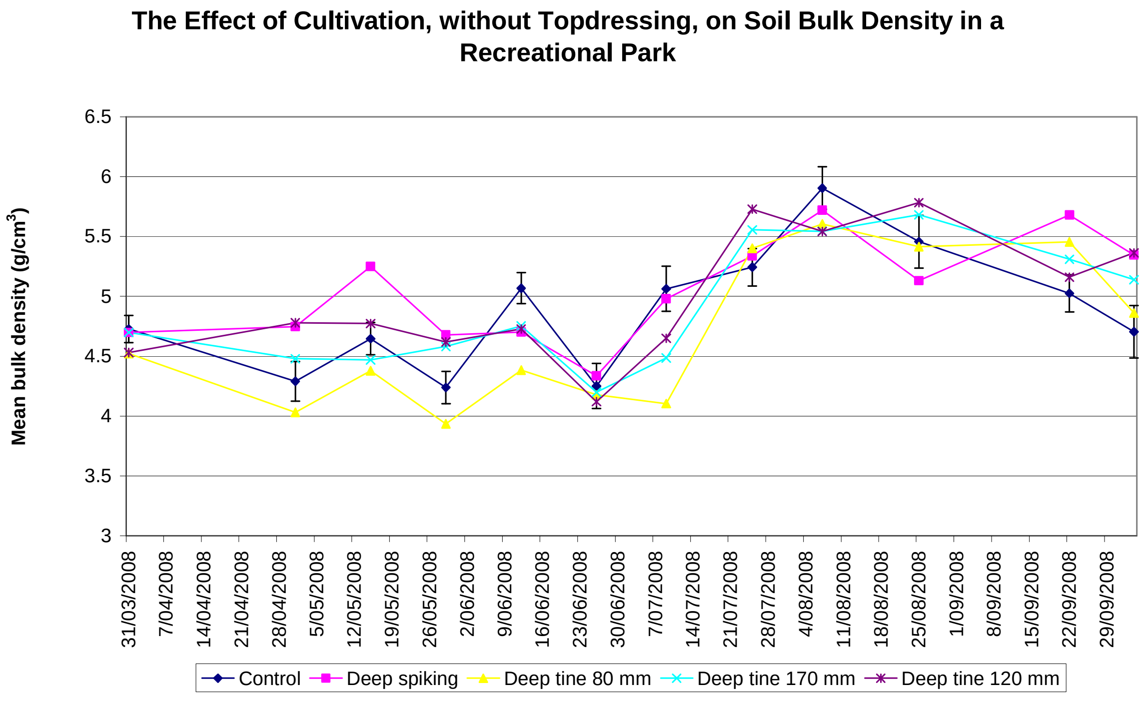


Figure 7-2. The effect of cultivation without topdressing on soil bulk density.

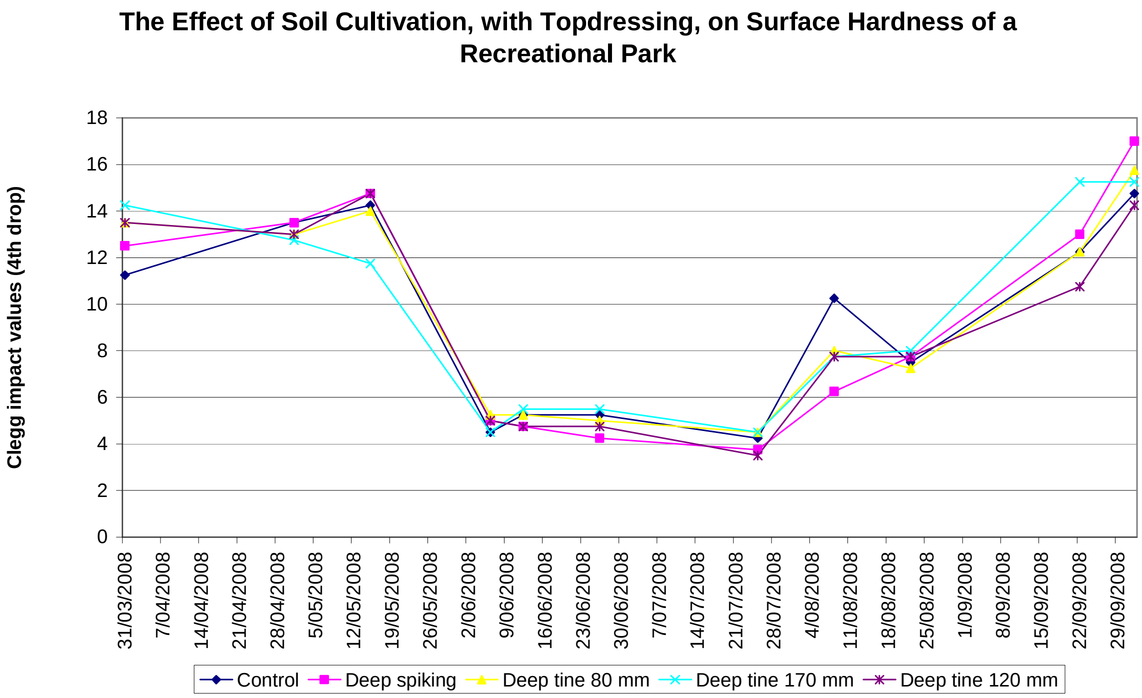


Figure 7-3. The effect of cultivation with topdressing on soil surface hardness.

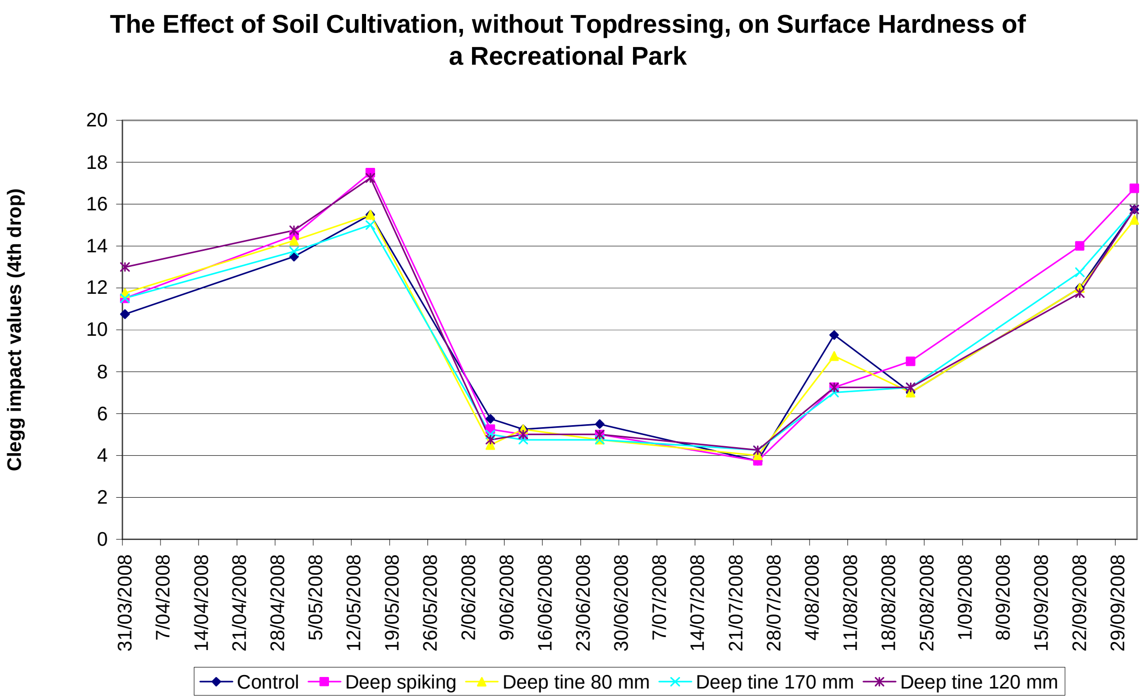


Figure 7-4. The effect of cultivation without topdressing on soil surface hardness.

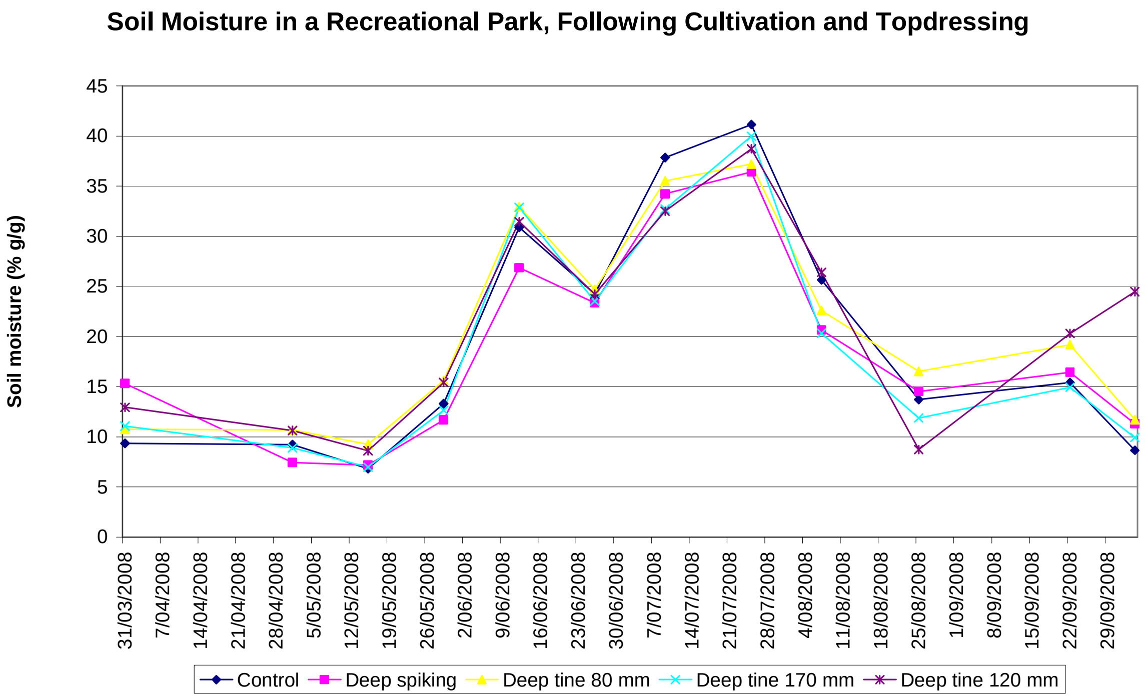


Figure 7-5 The effect of cultivation with topdressing on soil moisture content.

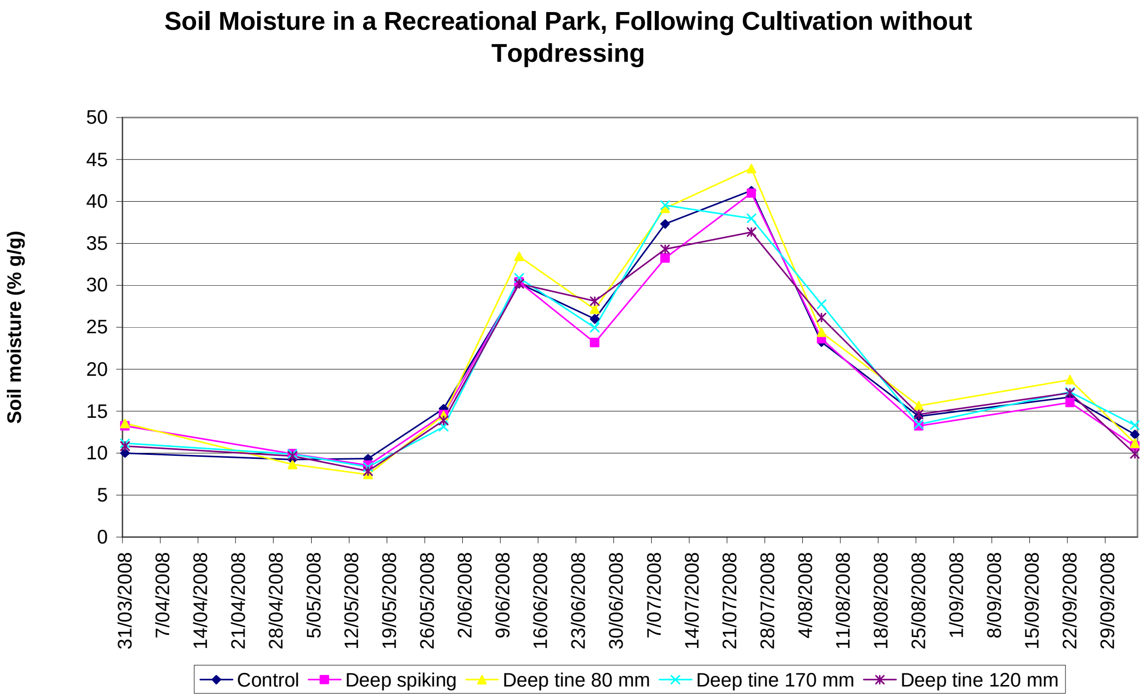


Figure 7-6 The effect of cultivation without topdressing on soil moisture content.

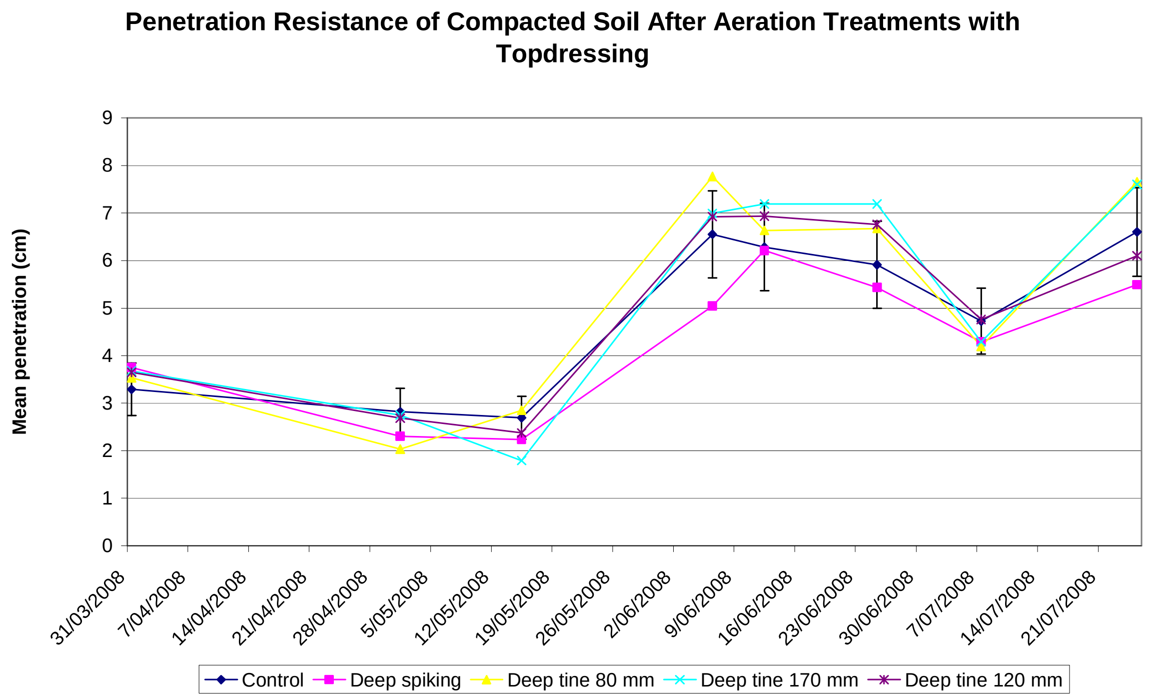


Figure 7-7 The effect of cultivation with topdressing on soil penetration resistance.

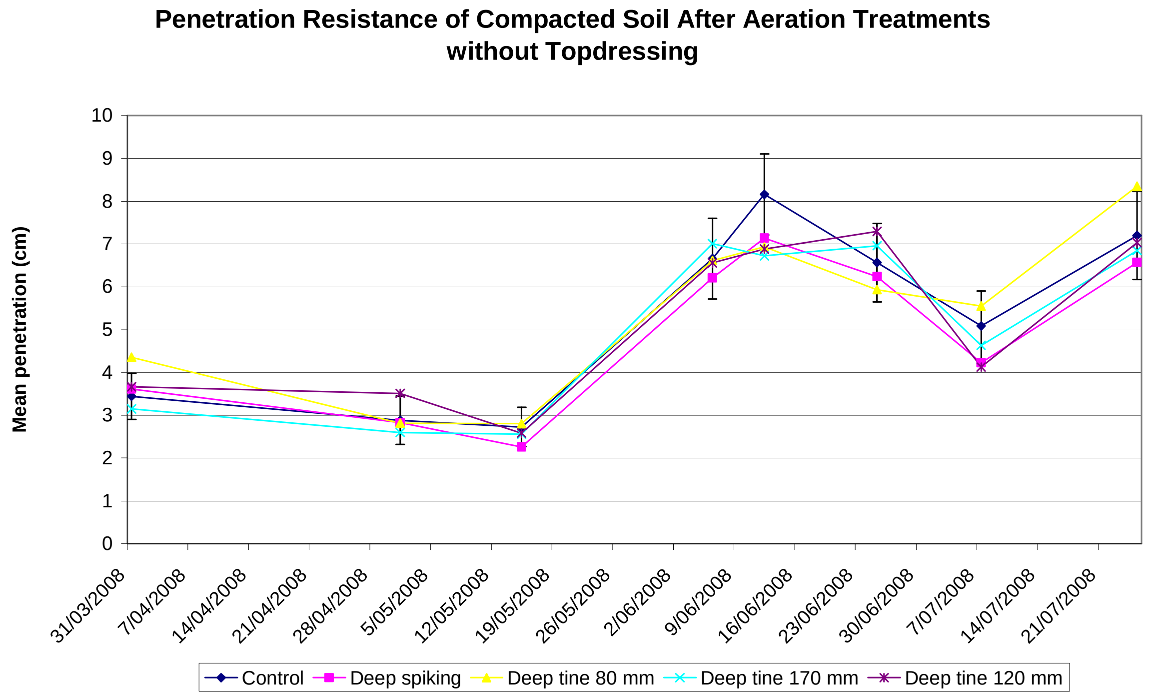


Figure 7-8 The effect of cultivation without topdressing on soil penetration resistance.

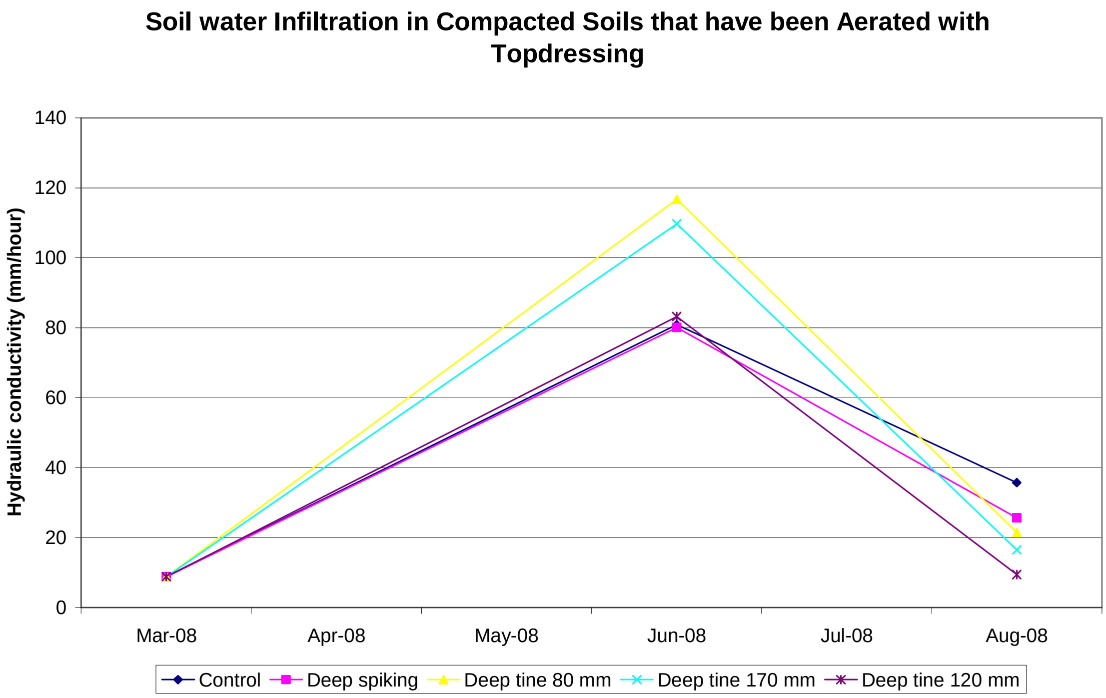


Figure 7-9. The effect of cultivation with topdressing on soil water infiltration.

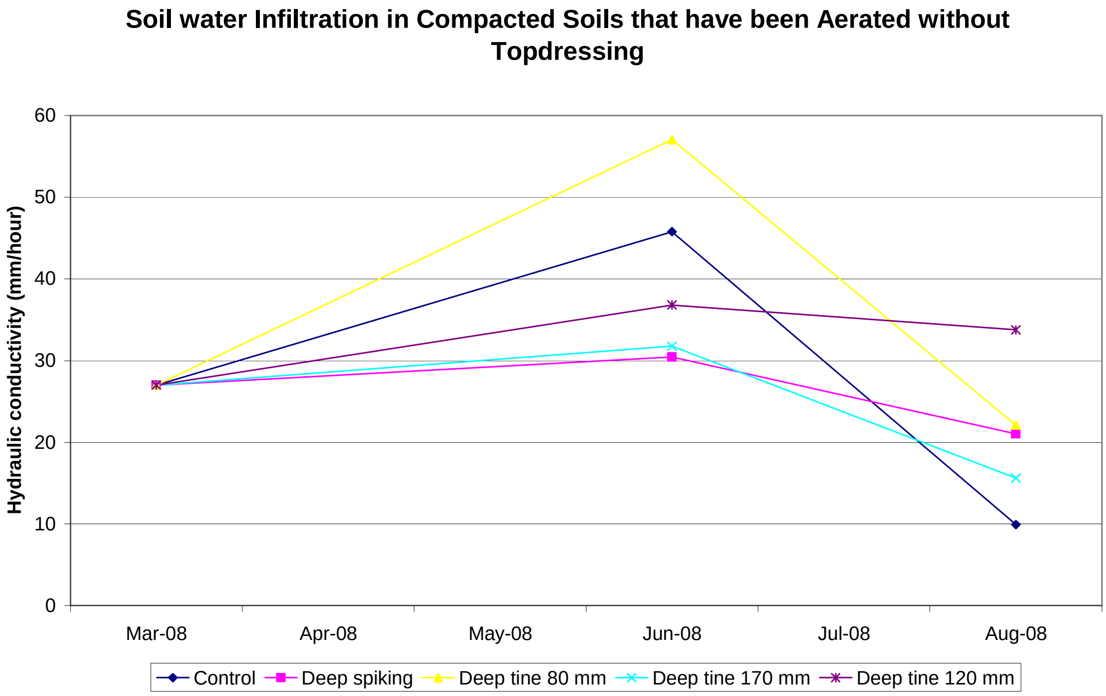


Figure 7-10. The effect of cultivation with topdressing on soil water infiltration.

Soil penetration (Figures 7-7 and 7-8) was generally shallow in the early assessments with peaks in the latter half of the trial, from the 6th to the 25th of June and also on the 25th of July. Data from both topdressed and non-topdressed treatments produced similar trends. Results span approximately 2 cm to 8 cm penetration, representing a spectrum of compacted to well aerated soil condition.

Figures 7-9 and 7-10 illustrate treatment effects on soil water infiltration. Significant differences between cultivation and the control were only detected almost five months after treatment. Moisture infiltration reached a maximum on 6 June 08 across all treatments, although topdressing resulted in higher values on this date.

7.2.4 Phase Two

Early assessments (up until 10 July 09) of soil surface hardness reveal significantly lower Clegg impact for some DTA treated soil than for control plots (Figure 7-11). The DTA setting that reduced surface hardness most consistently during this period was a working depth of 200 mm and subsurface leverage of 15°. This treatment kept the CIV below 8 throughout these early stages.

Soil moisture (Figure 7-12) was relatively high during late June and early July (30.2-37 %) before dropping to a minimum for the trial duration in late August (10-13.4 %). Final readings in late October increased to 18.8-21.6 %. This temporal trend for all treatments is related to local precipitation. Reasonably high rainfall was experienced in June (122 mm) followed by a much drier July (7 mm) and August (8.8 mm). Soil moisture then increased with increasing rainfall, through September (23.9 mm) and October (57.7 mm).

Throughout the first four assessments the treatment involving two passes with the DTA rendered soil moisture results that were significantly lower than the control. On the third and fourth measurements, depth settings of 200 mm and 120 mm respectively (both at the maximum heave setting of 15°) were associated with significantly higher moisture than the control. No other differences were significant with the exception of an increased soil moisture level facilitated by cultivation at 200 mm with 15° heave on 26 August 09.

The penetration resistance (Figure 7-13) follows a similar qualitative trend to that of soil moisture, over time. Penetration that is significantly different to that of the control can be observed in the initial stages of the trial in late June and early July. Apart from the effect (measured on 18 June 09) of applying the DTA at 200 mm with 15° heave twice, all significant results are associated with increased penetration.

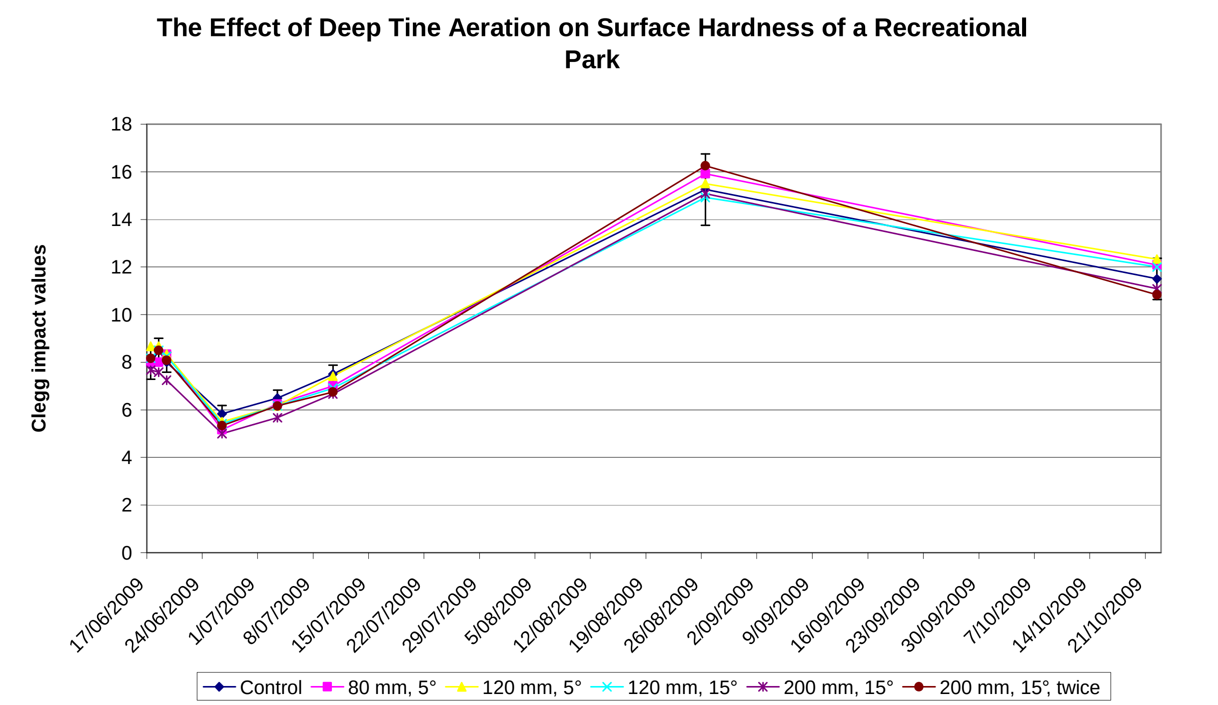


Figure 7-11 The effect of deep tine aeration on soil surface hardness

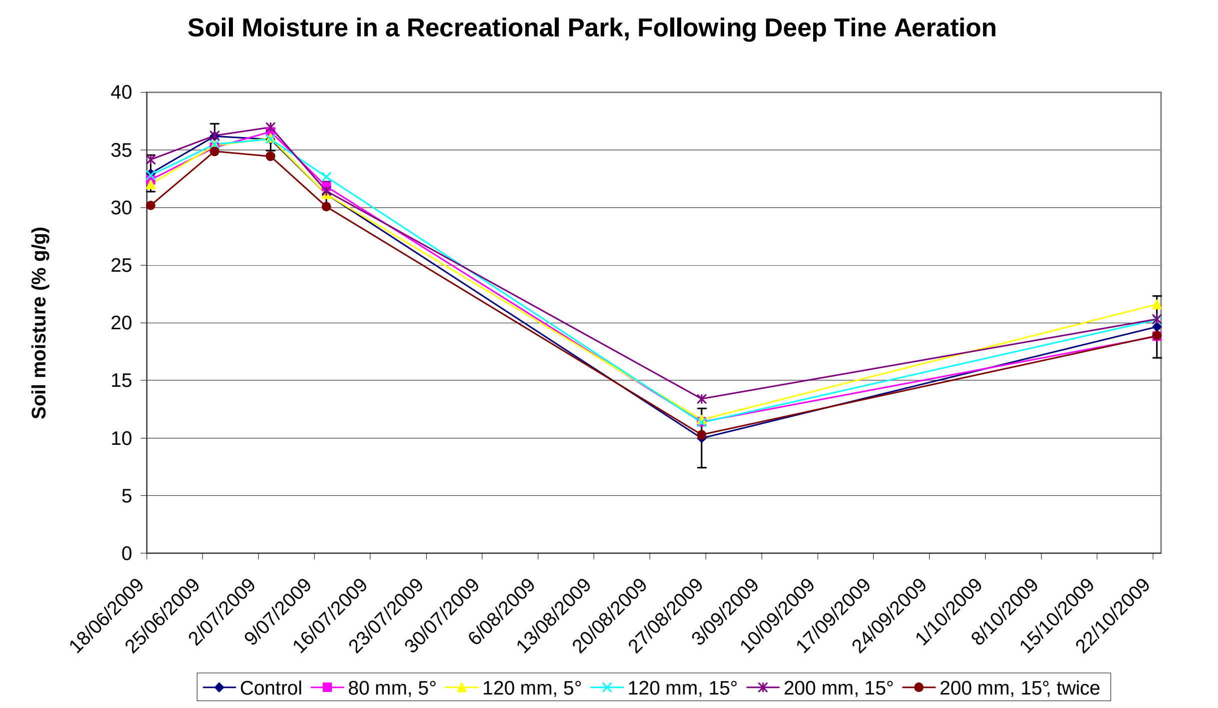


Figure 7-12 The effect of deep tine aeration on soil moisture.

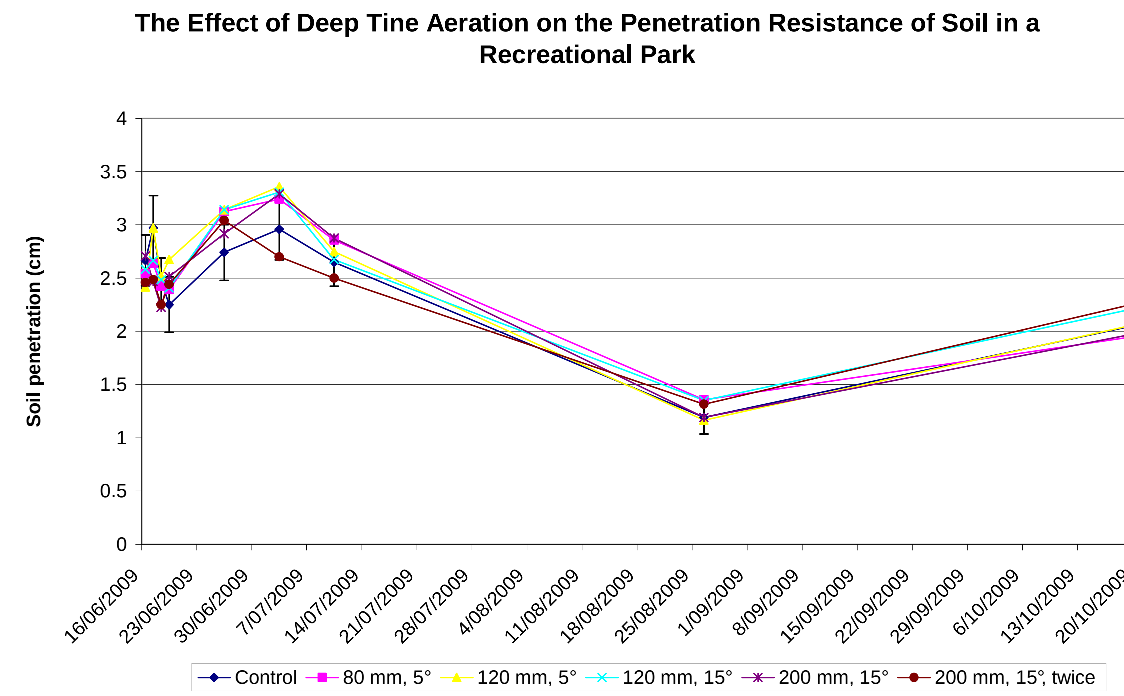


Figure 7-13 The effect of deep tine aeration on soil penetration resistance

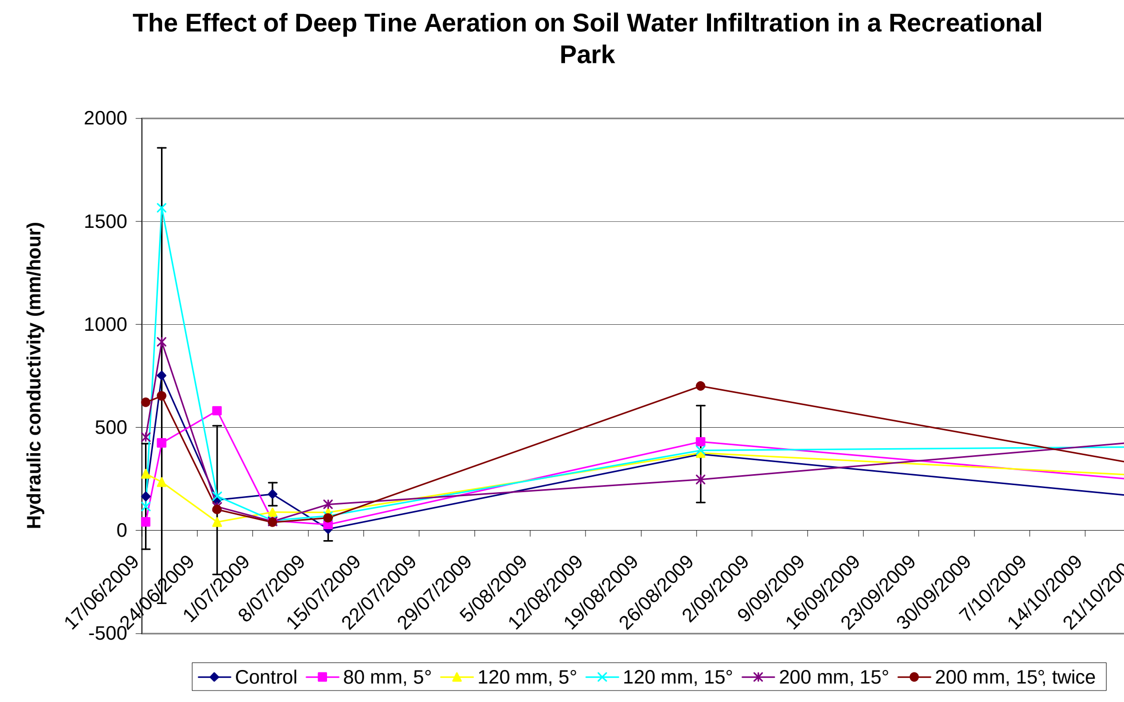


Figure 7-14 The effect of deep tine aeration on soil hydraulic conductivity

DTA at 120 mm and 5° heave resulted in improved soil penetration on the 19th and 26th of June as well as the 3rd of July. Increases can also be seen as a result of DTA application to a depth of 80 mm with 5° subsoil rotation and to a depth of 200 mm with 15° heave (26 June 09). With a soil working depth of 120 mm and 15° heave, improved penetration was made possible on 26 June 09 and 03 July 09. With a maximum value of 3.4 cm reached, penetration resistance was considerably higher throughout phase two than in phase one.

With the exception of data recorded on 03 July 09, all results that were significantly different from the control constituted an improvement to soil moisture infiltration. Such increased infiltration included the most extreme treatment, two passes with a DTA set to 200 mm and 15° (17 June 09 and 26 August 09). A single pass with the same settings of 200 mm and 15° also generated significant improvements, on the 17 June 09, 10 July 09 and 22 October 09. Other settings which resulted in positive, significant outcomes were 120 mm, 15° (22 October 09), 120 mm, 5° (10 July 09) and 80 mm, 5° (26 June 09). Data obtained for phase two infiltration is extremely variable, particularly in the early stages, when high levels of rainfall were recorded. The maximum value is 1566.2 mm/hour while the minimum is just 6.8 mm/hour.

7.3 Discussion

Throughout the experiment there was little significant difference between the control and any given treatment. Only the most aggressive practices applied during phase two appeared to facilitate some short-term decrease in the soil compaction. Given the adequate documentation of DTA in improving aeration in a range of soils, exposed to a number of different compaction pressures (Shim and Carrow 1997; Aldous, James et al. 2001) it would appear that the soil examined in this research is not responsive to DTA.

The duplex soil of marine clay sediments, capped with a red Ferrosol, is sodic and highly saline. Soil structure and drainage problems exacerbate sodium build up and exposure of turfgrass roots to high concentrations of salts. The defiance of this soil type to compaction alleviation highlights the need for construction of a profile that functions well with respect to moisture infiltration and drainage as well as oxygen transport and optimal root growth. Where endemic soils do not posses these attributes, suitable media should be imported. Although adherence to these guidelines may be costly at the time of construction, it will enable efficient maintenance, high performance of turfgrass and ornamental plants and sustainable amenity spaces that are cost-effective in the long term.

As a means of contrasting the construction of the trial site and a more deliberate construction of a playing field, consider field one of Redlands United soccer club which was undergoing renovation during the course of this experiment. As for many turfgrass areas devoted to sporting activities, construction was with a sand profile, which has many advantages for a moderately intensively managed playing surface (Lodge and Baker 1993; Gibbs, Liu et al. 2001).

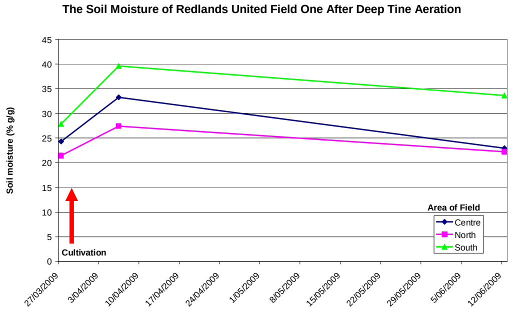


Figure 7-15 The effect of DTA on soil moisture of a soccer playing field.

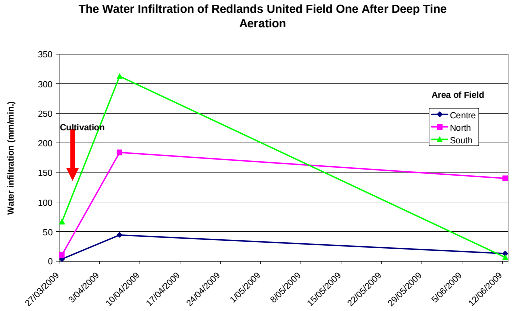


Figure 7-16 The effect of DTA on soil water infiltration of a soccer playing field. Observational data only

The entire field was treated on 30 March 09 with a DTA fitted with 275 mm long solid tines and set to heave through an arc of 8° after insertion into the soil and before retraction. Tines with a diameter of 12 mm were used with 65 mm spacing. The field was assessed for soil moisture and moisture infiltration three days prior to treatment and then again at seven days and seventy-four days after treatment. The results (Figures 7-15 and 7-16) were not derived from a scientifically designed trial and are strictly observational; however they illustrate the response to DTA that can be expected from a well constructed profile.

Different areas of the field displayed differing reactions, possibly due to the uneven nature of wear and compaction, conveyed through game play and training drills. All areas, however, presented an increased moisture holding capacity and infiltration rate of soil, seven days after cultivation. The data collected suggests that ideally, such a field would be renovated every three months with a DTA. Due to considerations of budget and pragmatism, this interval may be longer in practice. Even with a commercially viable frequency of application, the DTA can usually ensure that most of the time, most of the field contains soil that is well aerated.

In addition to the magnitude of the soil structural problems, the data suggests that the soil monitored during the trial is highly variable. The inconsistent nature of values expressed over time and the erratic relationship with those of other treatments concurs with a high degree of variation between samples and between sampling dates. This potentially explains suggestions that may seem erroneous, such as a decrease in soil aeration, following cultivation. The number of samples per plot, used in this study, would need to be greater to accommodate a highly variable soil (Dunkerley 2002).

Although there was little significant difference between treatments, especially in phase one, clear trends can be observed in the data, implying dependence on an extrinsic variable. Given the relationship between precipitation events and the peaks and troughs of certain parameters assessed, it would seem plausible that rainfall is driving variation in some of the relevant factors.

In phase one, soil moisture is displayed graphically as a bimodal peak (Figures 7-5 and 7-6) over the winter months, which correlates well with winter rainfall. No relationship is apparent between bulk density (Figures 7-1 and 7-2) and soil moisture. Soil surface hardness (Figures 7-3 and 7-4) however, is minimal during maximum soil moisture and the penetration peak (Figures 7-7 and 7-8) coincides with the maximal soil moisture value. This suggests that a softening of the ground, during wet conditions, reduces Clegg impact and allows a penetrometer to spear deeper into the soil. Figures 7-9 and 7-10 (soil water infiltration) also seem to align with the soil moisture graphs, although this is rather simplistic, owing to limited data points. Any correlation between these two variables could possibly be related to soil hydrophobicity, restricting infiltration when the profile is dry. This condition could be alleviated by sufficient soaking rain, such as that experienced in the winter of 2008.

Results for phase two seem related to soil moisture in a similar way. Surface hardness (Figure 7-11) is almost a mirror image of soil moisture (Figure 7-12**)**. and penetration resistance (Figure 7-13) follows the soil moisture trend. It is difficult to compare soil water infiltration (Figure 7-14) and soil moisture, although the two appear inversely related, qualitatively speaking. The magnitude of infiltration data is not as important as the variation between treatments, since infiltration is dependent on so many factors (Dunkerley 2002). Low infiltration during periods of high soil moisture might be explained by the large percentage of pores that are filled with water and impede further infiltration. Low internal saturated hydraulic conductivity can limit the rate at which further water is able to enter and move through the soil.

There is some indication that topdressing after cultivation will aid aeration. Of all the aspects of soil physical properties measured in phase one, only bulk density and water infiltration showed some sign that topdressing made a difference. In the case of bulk density (Figures 7-1 and 7-2), the significantly higher peak value in early August, in response to topdressing, may be an artefact of specific gravity of the media, greater for sand than for clay. In Figures 7-9 and 7-10, a notable increase in infiltration rate can be seen (06 June 08) through topdressing.

While phase one failed to divulge meaningful trends that illustrate DTA effects, some significant treatment differences can be observed in phase two. These differences are generally seen within the first 25 days after treatment with improvements relative to the control. After this initial stage there are less significant differences and soil moisture becomes the underlying influence on all treatments. Soil surface hardness ascends to CIV as high as 16.25 as the profile dries out, reflecting a soil state that is deemed unacceptable regarding the safe playing of sport.

The treatment most evident in significantly improving soil structure was cultivation at 200 mm with 15° of heave. This application, the deepest with the greatest arc of subsoil tine movement, compared to all other treatments in both phase one and two, was only able to elicit relatively minor changes relative to the control. This is testament to the difficulty in managing this soil type. The treatment designed to be the most aggressive (depth of 200 mm with 15° of heave and two passes) appears to mainly have a negative impact on soil aeration, where it is significantly different from the control. It is possible that driving over the plots with a tractor and cultivation implement significantly affects compaction and the effect of two passes is counterproductive to aeration.

As discussed, the longevity of any benefits derived from the treatments does not exceed 25 days. Theoretically, a program of monthly DTA applications would be needed to sustain ideal soil condition. Apart from economic and time consumption disadvantages, overly frequent DTA treatment can contribute to decline of fine root mass and health, particularly in heavy soils (Aldous et al. 2001). Due to the limited gain afforded by the DTA in this parkland, currently administered annually, the overall advantage of the exercise should be questioned.

The importance of a well considered construction has been emphasised. For existing amenity areas with poor soil structure, reconstruction may be an option. Although such extremes may seem cost prohibitive, the initial expenditure must be compared to ongoing costs, with an acknowledgement of both tangible expenses (e.g. maintenance costs) and esoteric yet important considerations (e.g. the value of health, happiness and lifestyle).

Soil amendments that contain exchangeable calcium (e.g. gypsum) are another means of alleviating compaction. Calcium can replace sodium in the profile and improve soil structure. The importance of soil moisture has also been highlighted as an influence of soil strength and infiltration. Irrigation is another option for such sites where the ability to flush salts below the root zone is important.

8 Soil Fertility.

8.1 Introduction

Fertiliser maintenance programs in public open space are often ad hoc, and in some cases virtually non-existent. They tend to be driven by budgetary constraints rather than by plant needs. For turf as with any grass, the main nutritional requirement is nitrogen (N). With regard to their N requirements, however, not all grasses are created equal: some species (e.g. blue couch [*Digitaria didactyla*]) will persist better than others (e.g. green couch) under low soil N. Because of their ready availability commercially, green couch and kikuyu are widely planted as turf grasses, and anecdotal evidence suggests that many of the varieties currently available are 'high N' types, and that alternative grasses (principally seashore paspalum at this stage) might come with significantly lower N fertiliser requirements. A long-term replicated split-plot experiment looking at the effect of six fertiliser N treatments (0-400 kg N/ha/year) on six representative turf grasses (kikuyu, seashore paspalum, buffalo grass, blue couch, and two green couches) was initiated under TU02005. With dry matter sampled fortnightly through much of the year, this was a labour-intensive activity that justified trialling at one central site, providing a good guide to the requirements of different turf grasses in other environments where fertilisation practices are already well established for the older industry standards of kikuyu and/or green couch.

Fertiliser trials in this project determined plant demand for nitrogen (N) (the most substantial element in any turf grass fertiliser program) to species level. This work produced data that can be used as a guide when fertilising, in order to produce optimal growth and quality in the major turf grass species used in public parkland. In conducting this trial it was recognised that optimum level is also related to use and intensity of use, with high profile well-used parks requiring higher maintenance N than low profile parks where maintaining botanical composition at a lower level of turf quality might be acceptable, indeed desirable in order to minimise mowing requirements. .

As green couch (*Cynodon dactylon*) constitutes the most widely used amenity turf grass and because the species comprises significant physiological diversity, two cultivars from this taxon were examined. 'Wintergreen' was used to represent one of the most commonly utilised green couches and 'FLoraTeX' was included due to reports that it is adapted to growth with lower inputs than many other green couches(Dudeck 1994). The objective of the study was not only to provide guidelines for fertiliser applications but also to aid selection of turf grasses by highlighting those with comparatively lower nutrient demand, which are more cost-effective, with regards to fertilisation.

8.2 Methods

The experiment, initiated under TU02005 at Redlands was monitored for a further 8 months to document the continuing rundown in turf quality and weed ingress in sub-optimal fertiliser treatments. The experiment took place on Redlands Research Station, Cleveland, (27°32'S, 153°15'E), Queensland, on an infertile yellow Kurosol, which commonly supports turf grass growth in south-east Queensland. The commencement (planting) of the trial was in June 2003, during previous project TU02005 "Amenity Grasses for Salt-Affected Parks in Coastal Australia". The early initiation of this work ensured that long-term effects could be measured and reported in the current project.

A split-plot trial design was employed with 6 main plots representing the species / cultivar factor. The two previously-mentioned *Cynodon dactylon* cultivars were included along with 'Aussiblue' (*Digitaria didactyla*), 'Sea Isle 1' (*Paspalum vaginatum*), the male-sterile common type of kikuyu (*Pennisetum clandestinum*) and 'Sir Walter' (*Stenotaphrum secundatum*).

The sub-plots contained the 6 N treatments (rates of 0, 50, 100, 200, 300 and 400 kg N/ha/year) administered as urea as 5 split treatments of equal amounts, applied at the beginning of September, November, January, March and May. Other required amendments, such as lime and industry-standard quantities and timing of phosphorus and potassium, were also applied, along with pesticides, irrigation, mowing and cultural practices conducive to turf grass growth typical of an amenity space. All treatment combinations were replicated four times.

Initially, a 25 kg N/ha/yr treatment was included, but after 6 months it was apparent that this rate was going to contribute little if any useful information at the lower end of the scale and so was changed on 5 January 2006 to 300 kg N/ha/yr (as listed above) to provide more detail on optimum N requirements towards the upper end of the scale of N rates used.

The grass plots were planted from rooted sprigs on 2 June 2003 with oxidiazon (Ronstar®) applied at 150 kg/ha, and allowed to grow in as full swards during 2003/04. The original Sea Isle 1 plots were removed by turf cutter on 8 January 2004 because of contamination by *Cynodon dactylon*, and were replaced with full sod of the same variety. Other plots were hand-weeded, spot-sprayed with glyphosate, or sprayed with atrazine (Kikuyu), DSMA (FLoraTeX, Wintergreen) or fluazifop (Aussiblue) to remove less serious contamination by other grass species to give uniform weed-free plots by January 2005.

Fertiliser N treatments were imposed on 25 January 2005 and experimental methodology and management trialled before commencing to take and record dry matter samples on 5 July 2005. Maintenance P was applied annually in September at 250 kg/ha of superphosphate, and K (150 kg/ha/yr) applied twice a year at 75 kg/ha of potassium chloride in September and March. Lime was applied annually (based on soil test results) to maintain soil pH at 6.0-6.5. Soil samples were taken across the experimental area on 10 September 2004 and from each N treatment on 30 August 2005. The experiment was irrigated as required to avoid moisture stress. Commencing on 17 January 2006, temperatures were recorded at hourly intervals with Thermocron Temperature Loggers located 1.5 m above ground and 10 cm below the ground surface.

Plots were mown with a standard domestic rotary mower at either 60 mm (Kikuyu, Sir Walter), or 30 mm (FLoraTeX, Wintergreen, Aussiblue, Sea Isle 1). Mowing frequency was weekly from September to March, reducing to fortnightly mowing from April to August.

Before every second mowing, clippings were collected from a 1.0 m^2 area of each sub-plot using the same mower set at the same height. Ratings are also made of turf quality, density and colour on a 0-9 scale (0=bare soil, 9=best), and per cent weed cover in each sub-plot. The samples of clippings are dried at about 70°C and weighed to determine dry matter production. Dry matter production for each sub-plot was calculated through removal of leaf clippings, using a mower over a unit area, on a regular basis, with subsequent drying of leaf material at 65°C for 24 hours and then weighing. Sub-plots were also rated for quality parameters routinely. Data were analysed using Genstat (11th Edition).

Following a recommendation from TU02005, a further investigation was carried out in collaboration with HAL project TU04013, in which uneven fertiliser applications were compared to equal amounts, applied at two monthly intervals to 12 buffalo grass cultivars (*Stenotaphrum secundatum*). The full methodology and results for this project have been reported (Duff, Loch et al. 2009); however, reference is made to the results in the discussion.

8.3 Results and discussion

Data for turf quality; density; colour ratings; per cent weed cover; weekly dry matter production and finally, annual dry matter production are presented for Aussiblue in Figures 8-1 to 8-6, with each cultivar investigated grouped accordingly in the subsequent figures. This data is tabularised in Section 16.7 (Appendix C-1).

During the growing season, quality, density and colour ratings and dry matter production tended to rise after each fertiliser N application, and then decline towards the end of the two month period approaching the next fertiliser application date (November application highlighted for reference in the graphs). Fluctuations in the quality, density and colour of the control treatment follow a similar pattern, indicating a seasonal effect operating in addition to nitrogen availability. This is particularly noticeable for FLoraTeX (Figures 8-7, 8-8 and 8-9) and Sea Isle 2000 (Figures 8-19, 8-20 and 8-21), while Sir Walter shows more stable quality, density and colour ratings for the control treatment of 0 Kg N/Ha (Figures 8-25, 8-26 and 8-27). The quality, density and colour responses of both Kikuyu and Wintergreen to seasonal influences, in the absence of nitrogen, are intermediate (Figures 8-13 to 8-15 and 8-31 to 8-33 respectively).

The dry matter production from each weekly or fortnightly mowing also rose from about late September through to April, although there were apparent troughs through midsummer. This reflects the rise and fall of temperatures during the growing season, with seasonal peaks in spring and autumn, more often seen in cool season turfgrasses (Millar and Frank 2006). The trough through mid summer was more pronounced for all treatments of Sir Walter (Figure 8-29). However, considering only the control treatment, the other turfgrass cultivars showed growth patterns typical of warm season grasses with a midsummer peak (Millar and Frank 2006), albeit lower than those receiving nitrogen applications. The summer decline following the September and March peaks suggests the availability of nitrogen was declining through the peak growing season, limiting dry matter production during this period. Kikuyu displayed less contrast between the peak of vegetative growth in spring/summer and the dormancy of winter, relative to the other warm-season grasses examined. This is associated with better growth rates in early spring and autumn (Cook and Mulder 1984) which is reflective of the species' origin in the mild tropical highlands of eastern and central Africa.

Increased growth at higher N rates during spring is reflected in differences in the proportions of total annual dry matter produced from July through to December as opposed to the following 6 month period (Figure 8-6, 8-12, 8-18, 8-24, 8-30 and 8-36). For example, the control treatment (0 kg N/Ha) for Aussiblue produced 74% of its total annual production in the period from Jan to July while the highest N treatment only produced 45% of its annual dry matter production during the same period (Figure 8-6). This difference was also apparent for Kikuyu and Sea Isle 2000 but was less clearly defined in Sir Walter, Wintergreen and FLoraTeX.

The concept of increased nitrogen requirement for the spring growth flush was investigated as a component of TU04013, although results presented in the final report (Duff, Loch et al. 2009) were inconclusive. Some cultivars of *Stenotaphrum secundatum* were shown to benefit from higher rates of N in spring and lower rates going into the winter dormancy, while others continued to show the same seasonal growth pattern as displayed here irrespective of the N regime.

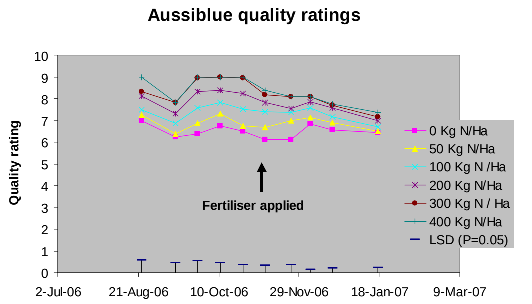


Figure 8-1. Quality ratings for Aussiblue under varying nitrogen application rates.

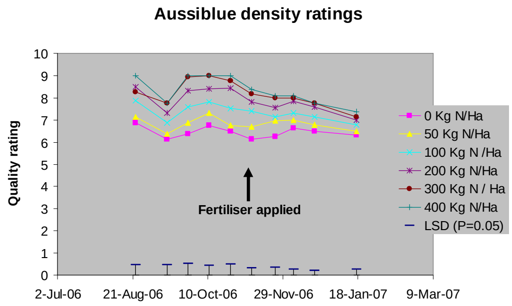


Figure 8-2. Density ratings for Aussiblue under varying nitrogen application rates.

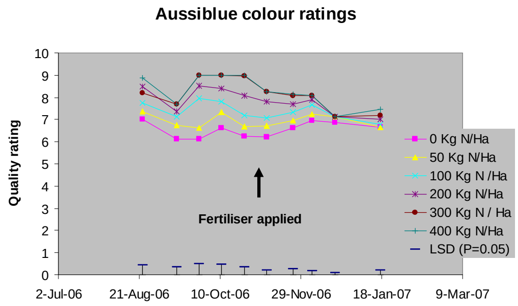


Figure 8-3. Colour ratings for Aussiblue under varying nitrogen application rates.

No weed invasion into Aussiblue observed for duration of trial

Figure 8-4. Estimated percentage cover of weeds in plots of Aussiblue under varying nitrogen application rates.

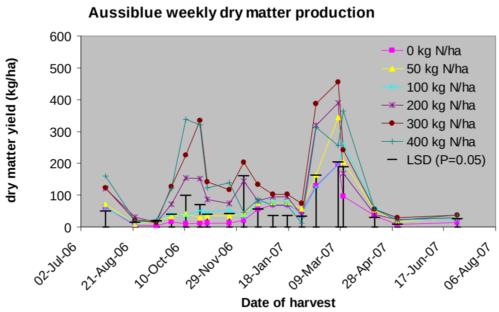


Figure 8-5. Weekly growth (dry matter production) of Aussiblue under varying nitrogen application rates.

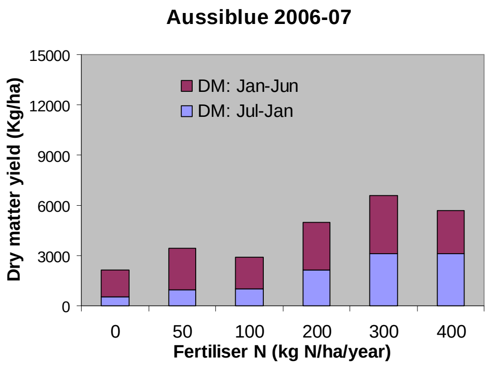


Figure 8-6. Annual dry matter production of Aussiblue grown under varying nitrogen application rates.

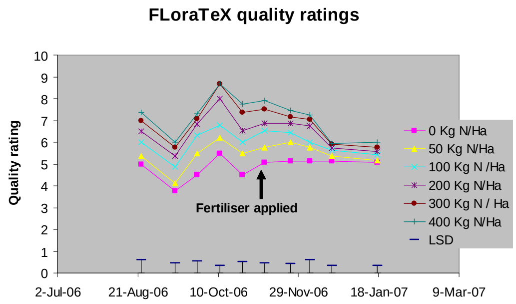


Figure 8-7. Quality ratings for FLoraTeX under varying nitrogen application rates.

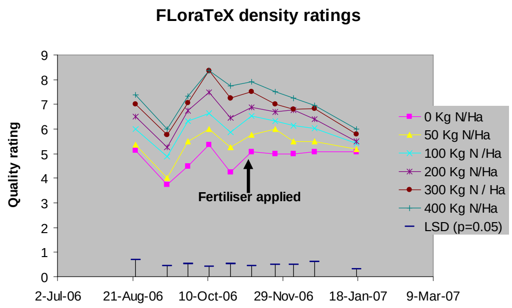


Figure 8-8. Density ratings for FLoraTeX under varying nitrogen application rates.

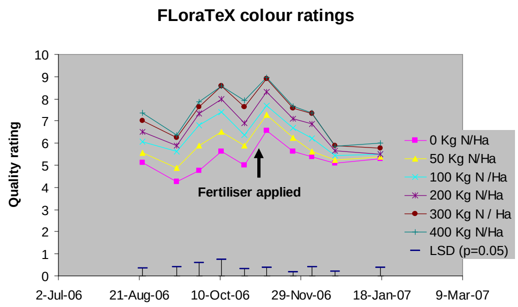


Figure 8-9. Colour ratings for FLoraTeX under varying nitrogen application rates.

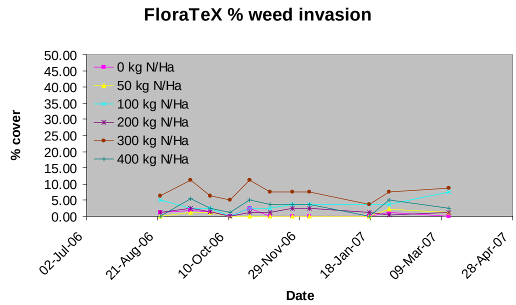


Figure 8-10. Estimated percentage cover of weeds in plots of FLoraTeX under varying nitrogen application rates.

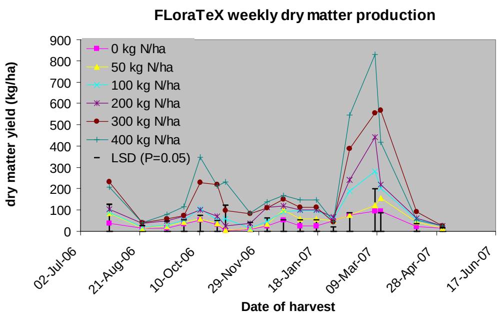


Figure 8-11. Weekly growth (dry matter production) of FLoraTeX under varying nitrogen application rates.

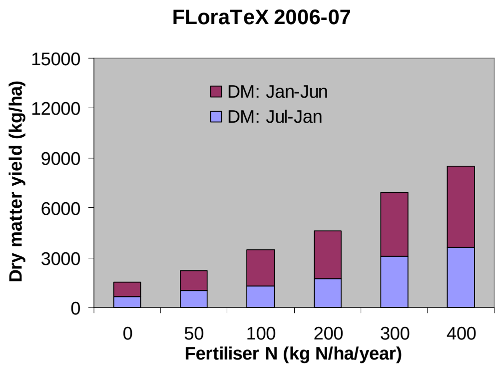


Figure 8-12. Annual dry matter production of FLoraTeX grown under varying nitrogen application rates.

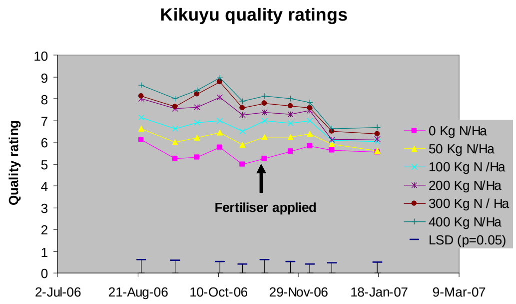


Figure 8-13. Quality ratings for Kikuyu under varying nitrogen application rates.

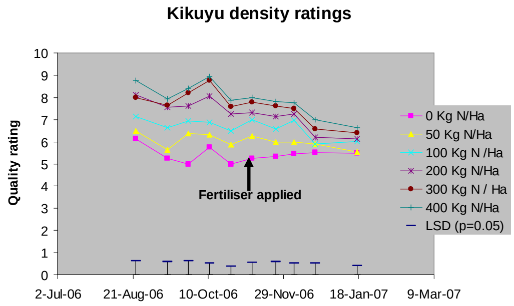


Figure 8-14. Density ratings for Kikuyu under varying nitrogen application rates.

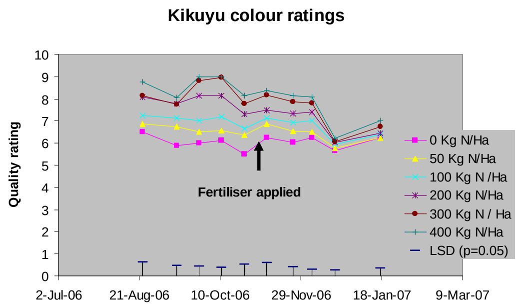


Figure 8-15. Colour ratings for Kikuyu under varying nitrogen application rates.

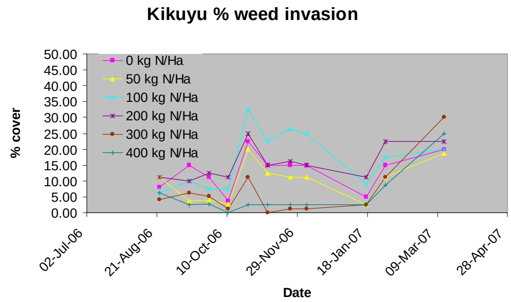


Figure 8-16. Estimated percentage cover of weeds in plots of Kikuyu under varying nitrogen application rates.

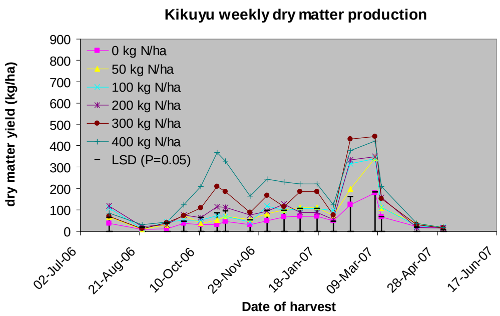


Figure 8-17. Weekly growth (dry matter production) of Kikuyu under varying nitrogen application rates.

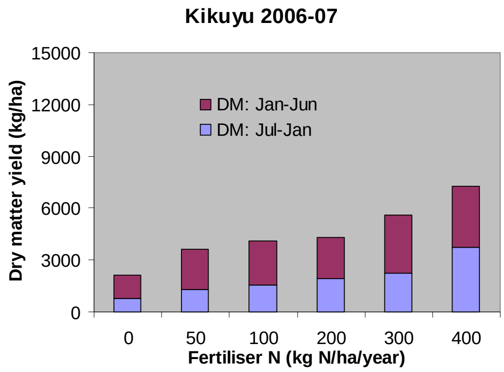


Figure 8-18. Annual dry matter production of Kikuyu grown under varying nitrogen application rates.

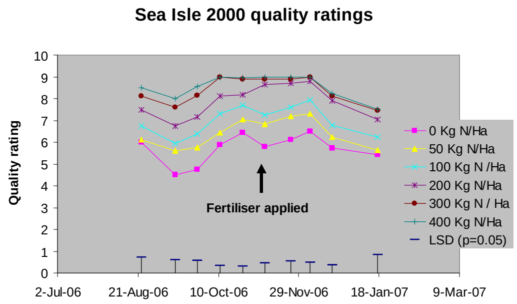


Figure 8-19. Quality ratings for Sea Isle 2000 under varying nitrogen application rates.

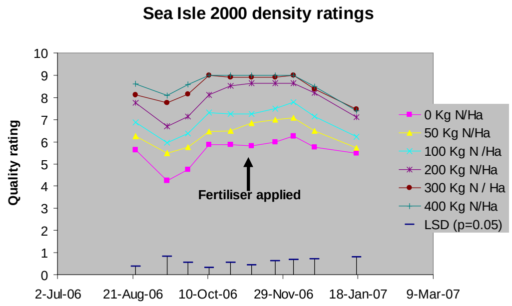


Figure 8-20. Density ratings for Sea Isle 2000 under varying nitrogen application rates.

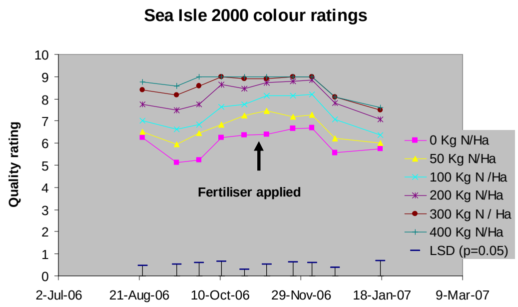


Figure 8-21. Colour ratings for Sea Isle 2000 under varying nitrogen application rates.

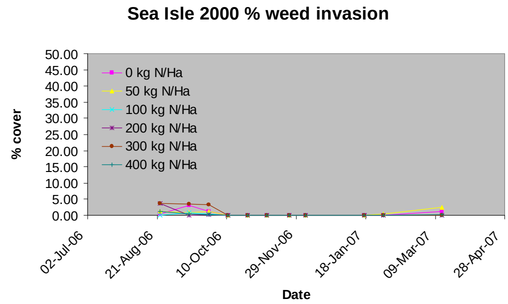


Figure 8-22. Estimated percentage cover of weeds in plots of Sea Isle 2000 under varying nitrogen application rates.

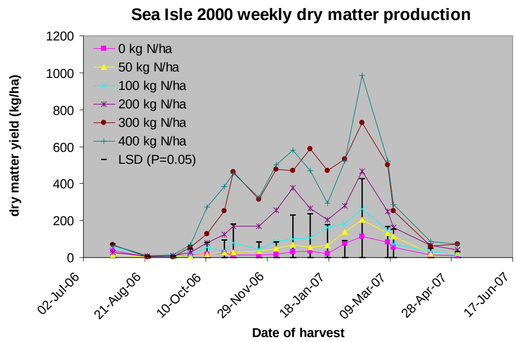


Figure 8-23. Weekly growth (dry matter production) of Sea Isle 2000 under varying nitrogen application rates.

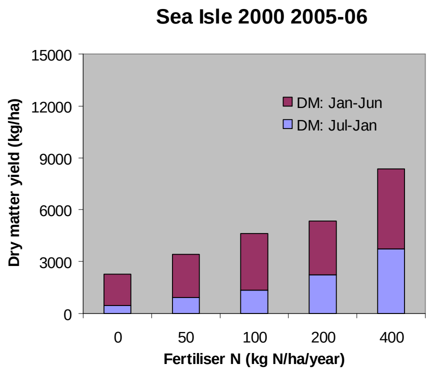


Figure 8-24. Annual dry matter production of Sea Isle 2000 grown under varying nitrogen application rates.

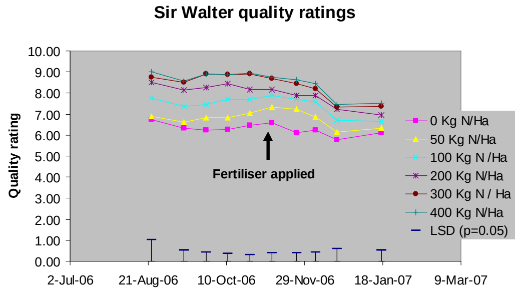


Figure 8-25. Quality ratings for Sir Walter under varying nitrogen application rates.

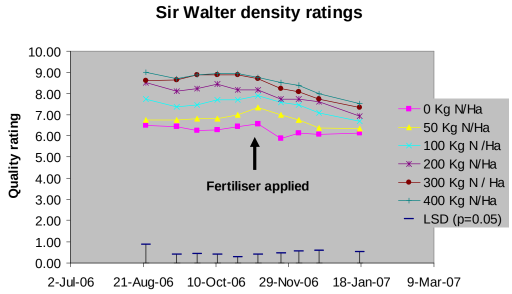


Figure 8-26. Density ratings for Sir Walter under varying nitrogen application rates.

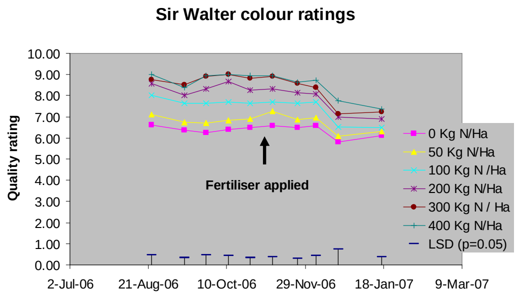


Figure 8-27. Colour ratings for Sir Walter under varying nitrogen application rates.

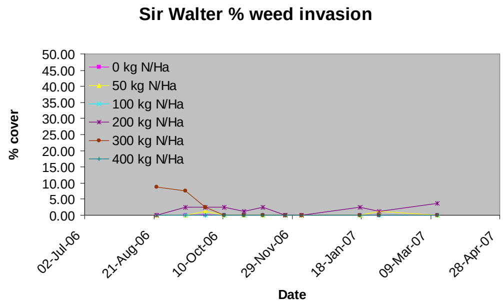


Figure 8-28. Estimated percentage cover of weeds in plots of Sir Walter under varying nitrogen application rates.

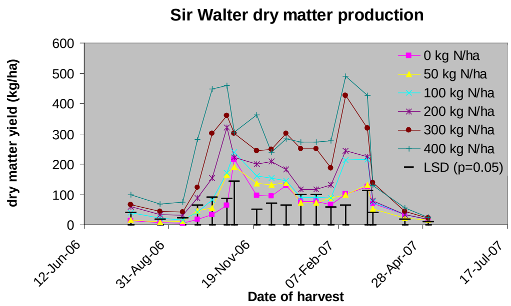


Figure 8-29. Weekly growth (dry matter production) of Sir Walter under varying nitrogen application rates.

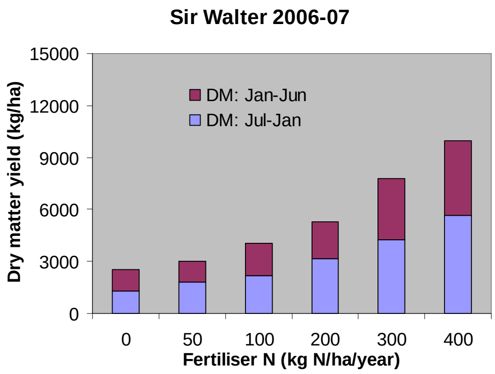


Figure 8-30. Annual dry matter production of Sir Walter grown under varying nitrogen application rates.

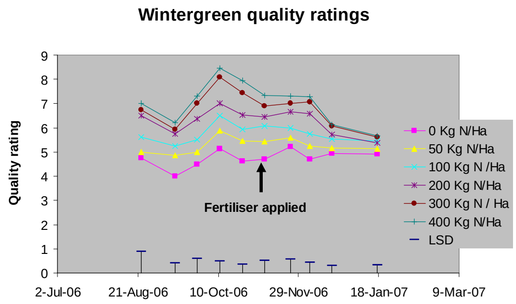


Figure 8-31. Quality ratings for Wintergreen under varying nitrogen application rates.

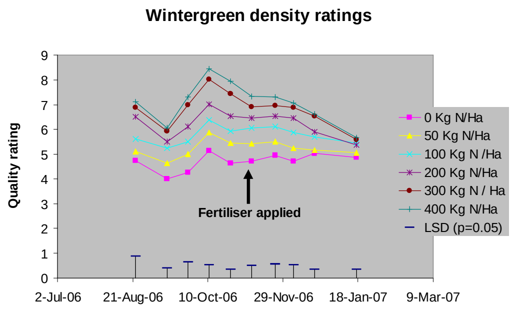


Figure 8-32. Density ratings for Wintergreen under varying nitrogen application rates.

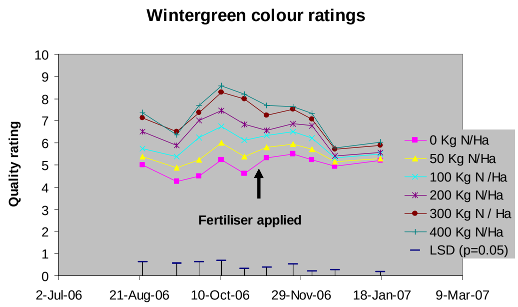


Figure 8-33. Colour ratings for Wintergreen under varying nitrogen application rates.

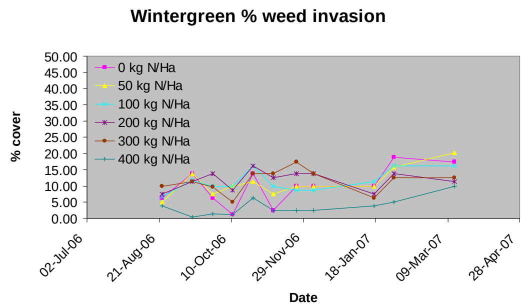


Figure 8-34. Estimated percentage cover of weeds in plots of Wintergreen under varying nitrogen application rates.

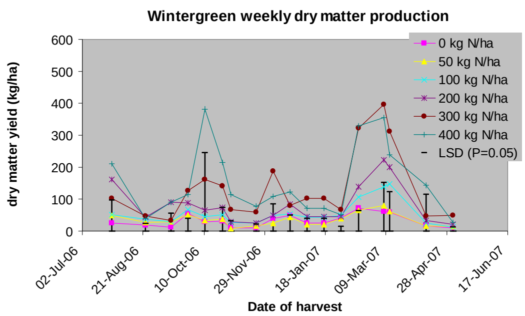


Figure 8-35. Weekly growth (dry matter production) of Wintergreen under varying nitrogen application rates.

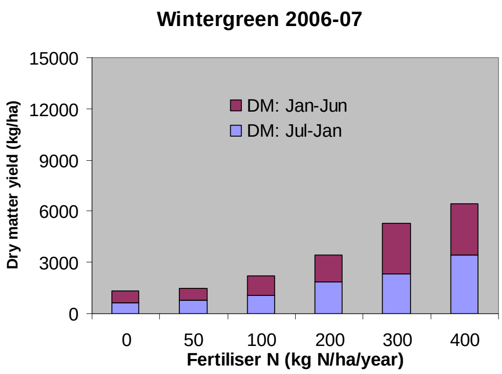


Figure 8-36. Annual dry matter production of Wintergreen grown under varying nitrogen application rates.

8.4 Conclusion

Kikuyu seemed to required the greatest N input (300-400 kg N/ha/year), which may be related to its natural distribution, as it is often found on fertile, volcanic soils. The green couch cultivars were found to be the next most demanding, in terms of N use. Although a range of N requirements for *Cynodon dactylon* have been discussed in the literature, both ‘Wintergreen’ and ‘FLoraTeX’ were found to display a similar growth response to N, requiring approximately 300 kg N/ha/year for optimal condition and growth.

‘Sir Walter’ and ‘Sea Isle 1’ can be considered moderately responsive to N applications, benefitting from approximately 200 kg N/ha/year. ‘Aussiblue’, although responsive to higher rates of N application, maintained optimal growth and quality at 100-200 kg N/ha/year.

Although this experiment aimed to determine the N requirement of parkland in south east Queensland, subject to high profile use and with the objective of minimising mowing operations, it must be recognised that other factors will influence ideal N application, such as local climate, soil type, type and intensity of use as well as management practices. It appears that N requirements are cultivar specific suggesting that values presented here should be used as a guide only, with further fine tuning determined through site specific experiences.

As a guide for fertilising turf grass that is often found in saline, coastal areas or on parkland utilising recycled water, this information will be combined with results from other aspects of the project to produce a holistic document to designate best management practices (BMPs) for salt-affected amenity areas.

9 Salinity Measurement.

9.1 Introduction

Turfgrass managers responsible for areas prone to salt accumulation, require a method of monitoring salinity. While laboratory analysis of soil samples, for a range of physical and chemical attributes, is recommended annually, an alternative methodology for soil salinity measurement on a more frequent basis would be ideal.

The usual practice of sampling a number of times, with a pattern that represents the “average soil” is a useful technique for pragmatic administration of a reasonably large area. However, this does not allow for more intensive management of smaller areas that warrant individual treatment (e.g. a low-lying area that has higher water content than its surrounds or a tract of sandy soil that drains freely). The cost of such soil testing often limits its use. This limitation can be compounded by a lack of understanding of the potential return on investment. The sample collection process can be relatively time and labour intensive and the turnaround time for some laboratories is not conducive to precision management that seeks to rectify problems as they arise.

The objective of this study was to ascertain whether scientific instruments could offer instant, precise measurement of soil salinity in the field. Such an instrument should be usable for assessment at a single point or over a larger expanse through averaging a number of readings. A device that is easy to use with only a single purchase cost could enable a range of different turfgrass managers to make well-informed decisions regarding salinity management. Apart from routine evaluations, more specific tasks could be executed, such as checking salinity after irrigation with recycled water and measuring soil salt content before and after a flushing irrigation.

Ultimately, equipment has been appraised for its ability to enhance the best management practices of those responsible for the care of saline amenity spaces.

9.2 Methodology

Two devices that are distributed by reputable scientific instrument companies were chosen. The HI98331 direct soil conductivity and temperature meter was purchased from Hanna Instruments and the 2265FS FieldScout direct soil EC meter was purchased from Spectrum Technologies, Incorporated. Both meters were calibrated with a 2760 µS/cm standard solution.

The Hanna meter consists of a plastic housing, 163 mm long. It features a liquid crystal display (LCD) that presents conductivity within the range of 0 to 4.00 mS/cm with a resolution of 0.01 mS/cm. It requires the HI73331 direct soil conductivity penetration probe (150 mm long) to be attached and pushed into soil (or any growing medium) in order to take measurements.

The FieldScout unit is 125 mm long with a larger LCD, which displays conductivity and temperature data simultaneously. Its EC range is 0-19.99 mS/cm with a resolution of 0.01 mS/cm. The meter is supplied with a probe (200 mm long) that is attached to the meter by a cable.

Four locations were chosen for measuring EC, representing a range of soil types. Birkdale contains the heaviest soil, a clay loam. Raby Bay’s and Jacob’s Well’s soils are both sandy clay loams and the profile at Surfer’s Paradise is a sand. Salinity was measured with each probe being inserted 60 mm into the soil and as close to each other as possible. A soil sampling probe with an internal diameter of 50 mm was then used to extract a core sample that removed the soil tested by both devices, to the same depth. This procedure (Plate 9-1) was performed 40 times at each of the sites, using the same pattern of sampling across the field, to obtain a set of data that is representative of each soil.

Plate 9-1. Hanna probe being inserted into the soil prior to salinity measurement.

Plate 9-2. FieldScout probe being inserted into the soil prior to salinity measurement.

Plate 9-3. Collecting soil core sample for laboratory measurement of soil salinity.

Plate 9-4. Soil core ready for transport to laboratory for analysis

All soil samples were taken to a laboratory for further processing. After crushing to fine powder with a mortar and pestle and then sieving through a 2.36 mm mesh screen, each sample was mixed with distilled water in a 1:5 soil:water ratio, by weight, agitated for 30 seconds and then left for a period of at least one hour for equilibration of the salts throughout the solution. This technique is a widely-recognised means of determining soil salinity using a prepared solution EC (Rayment and Higginson 1992). The solutions were shaken vigorously for two seconds before insertion of a TPS temperature and conductivity sensor (part number 122230) and determination of the soil salinity with a TPS smartCHEM-LAB laboratory analyser (part number 126124).

EC values obtained in the laboratory could then be compared to those given by each of the salinity meters. Graphic correlations were produced using simple linear regression with coefficients of determination (R^2) used to comment on the accuracy of both instruments, relative to standard laboratory verification.

9.3 Results

Overall, both meters produced data that correlated poorly with the laboratory results (Figures 9-1 and 9-2) when measurements from all sites were included. The coefficients of determination were 0.5754 and 0.6255 for the Hanna and FieldScout equipment, respectively.

When individual sites were considered in isolation, however, different results were obtained (Figures 9-3 to 9-10). The best fit to a linear equation in matching laboratory data was with FieldScout measurements taken at Birkdale. This was followed by the Hanna readings taken at the same location. A summary of R2 values, by location, is given in Table 9-1.

Table 9-1. Coefficients of determination (R^2 values) for correlations between salinity measurements derived from soil solution assessment and from salinity meters used in the field. Data is listed by location.

Location	Salinity Meter	R^2
Birkdale	Hanna	0.8099
	FieldScout	0.8440
Jacob's Well	Hanna	0.0460
	FieldScout	0.3922
Raby Bay	Hanna	0.4034
	FieldScout	0.5637
Surfer's Paradise	Hanna	0.2388
	FieldScout	0.1879

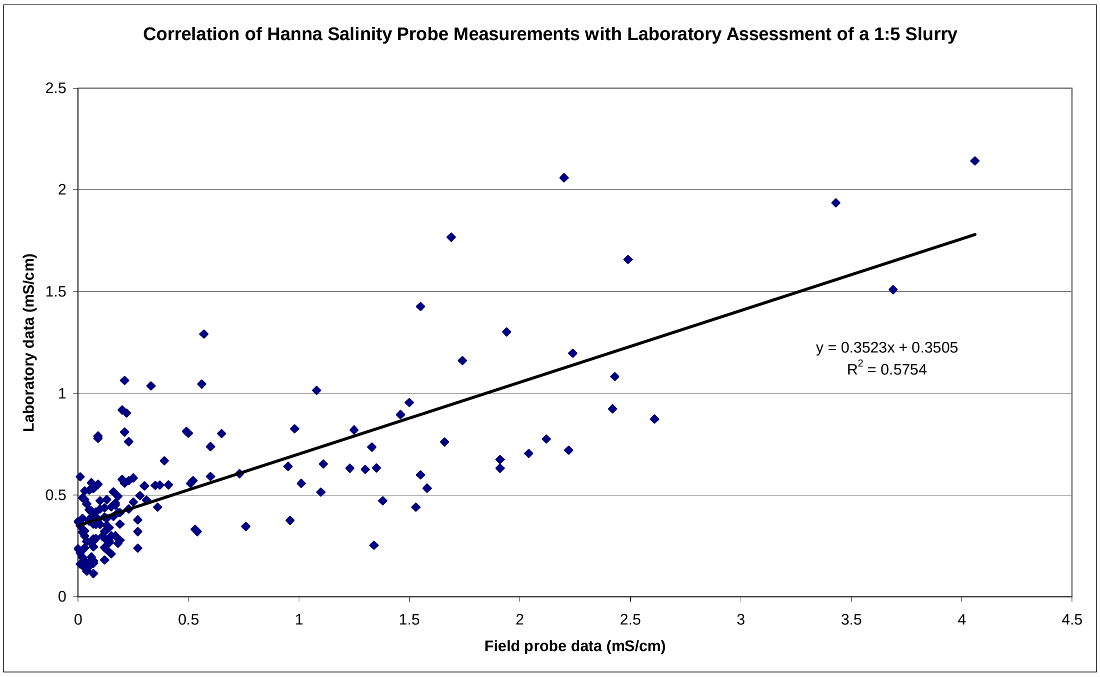


Figure 9-1 Overall linear regression using data from the Hanna meter paired with laboratory data.

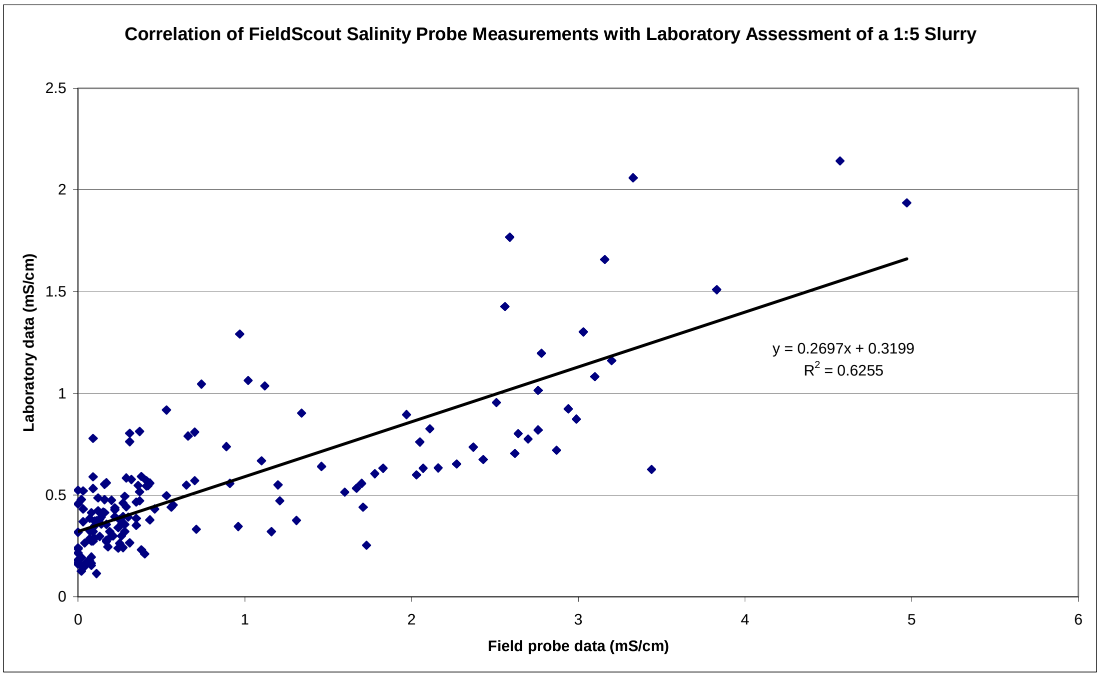


Figure 9-2 Overall linear regression using data from the FieldScout meter paired with laboratory data.

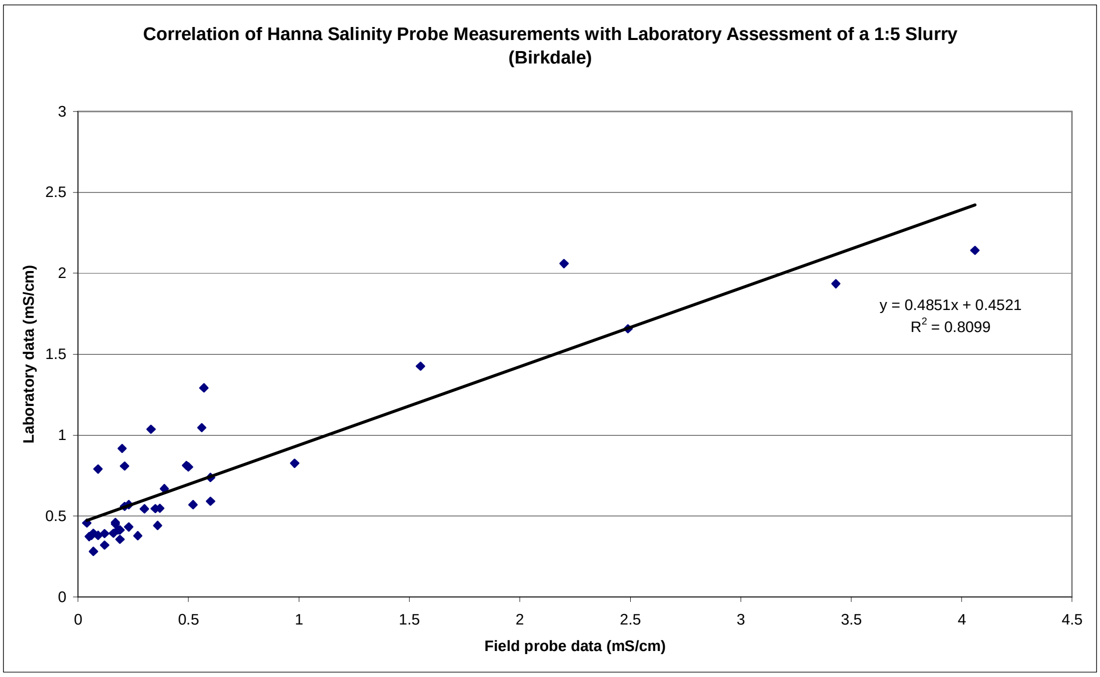


Figure 9-3. Correlation between laboratory-determined salinity of Birkdale soil and that derived from the Hanna meter and probe.

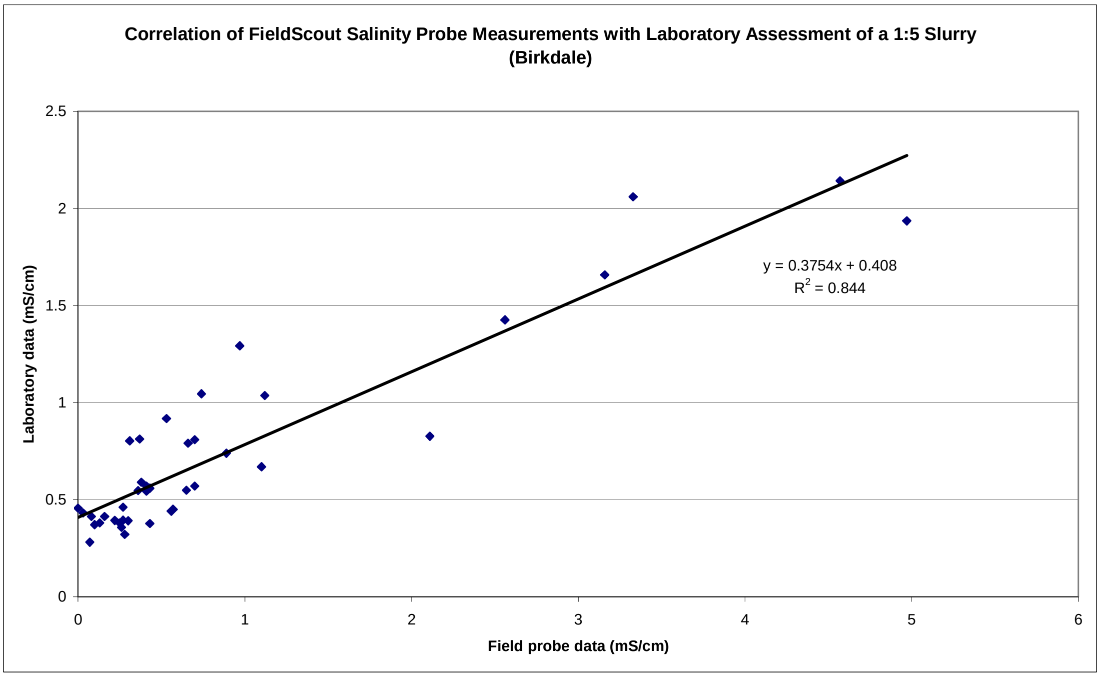


Figure 9-4. Correlation between laboratory-determined salinity of Birkdale soil and that derived from the FieldScout meter and probe.

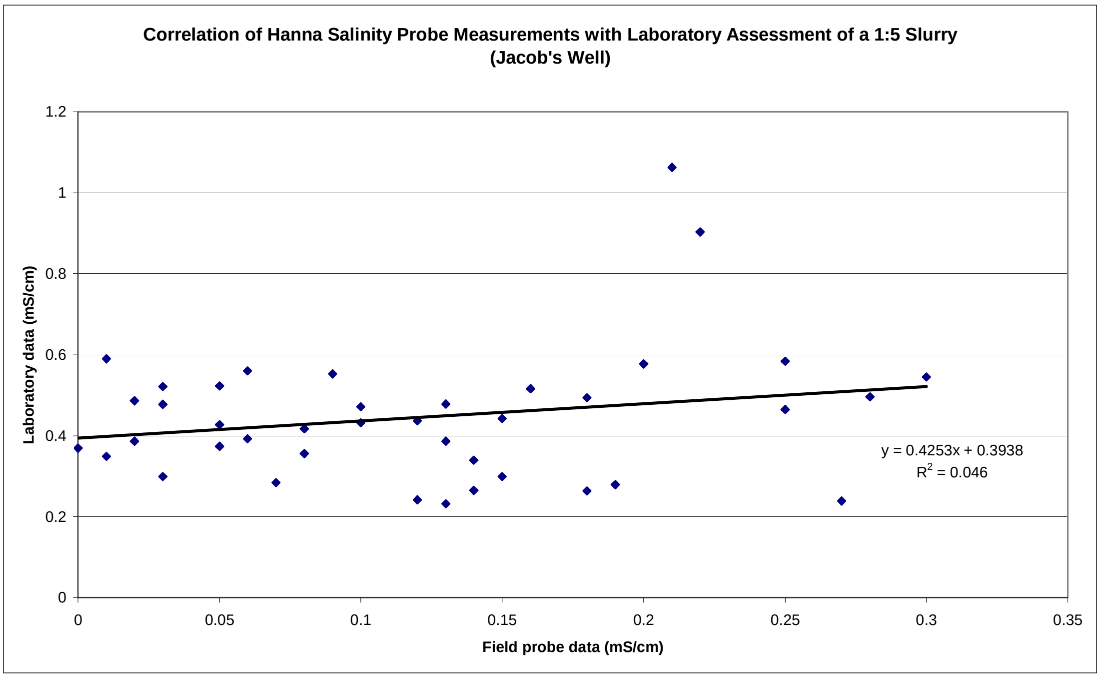


Figure 9-5. Correlation between laboratory-determined salinity of Jacob's Well soil and that derived from the Hanna meter and probe.

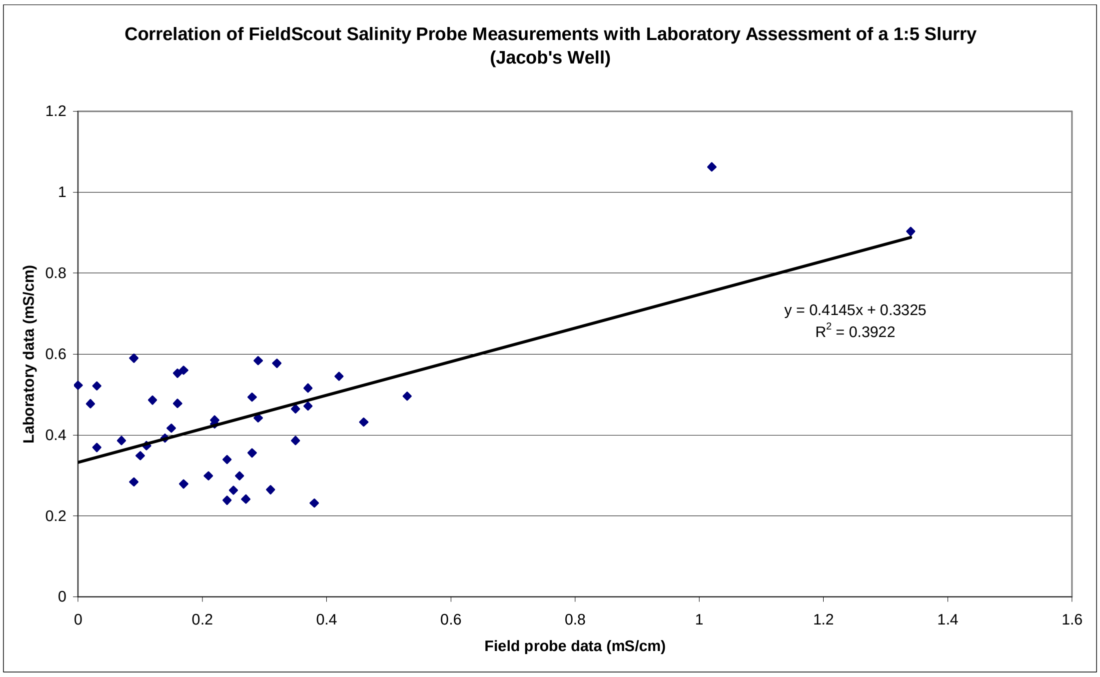


Figure 9-6. Correlation between laboratory-determined salinity of Jacob's Well soil and that derived from the FieldScout meter and probe.

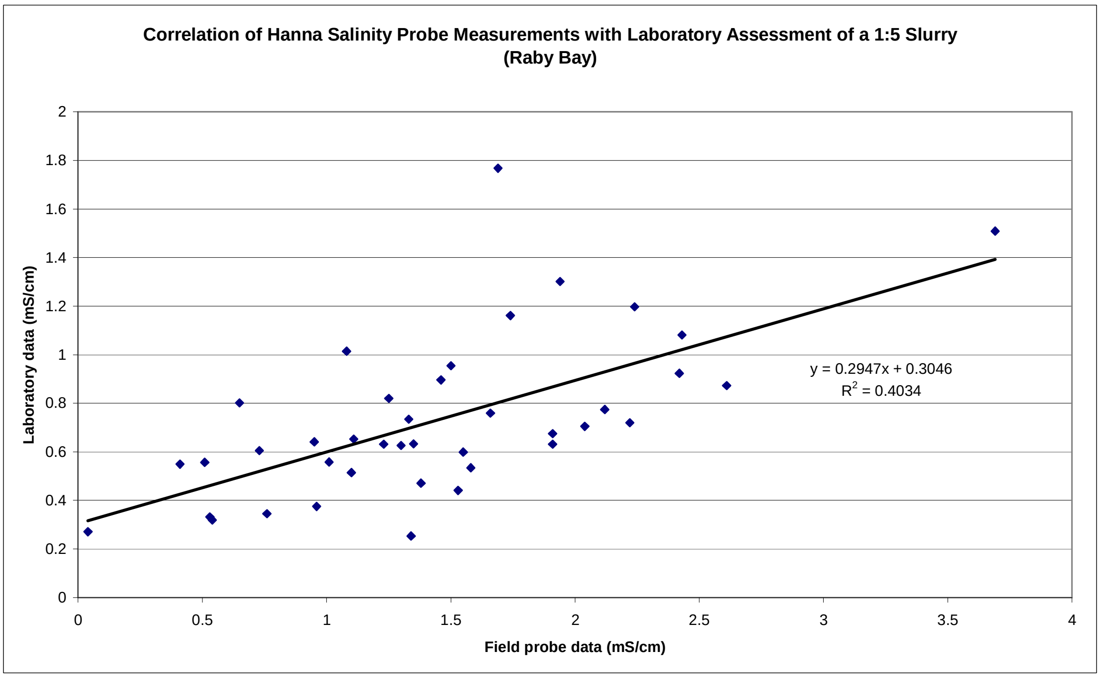


Figure 9-7 Correlation between laboratory-determined salinity of Raby Bay soil and that derived from the Hanna meter and probe

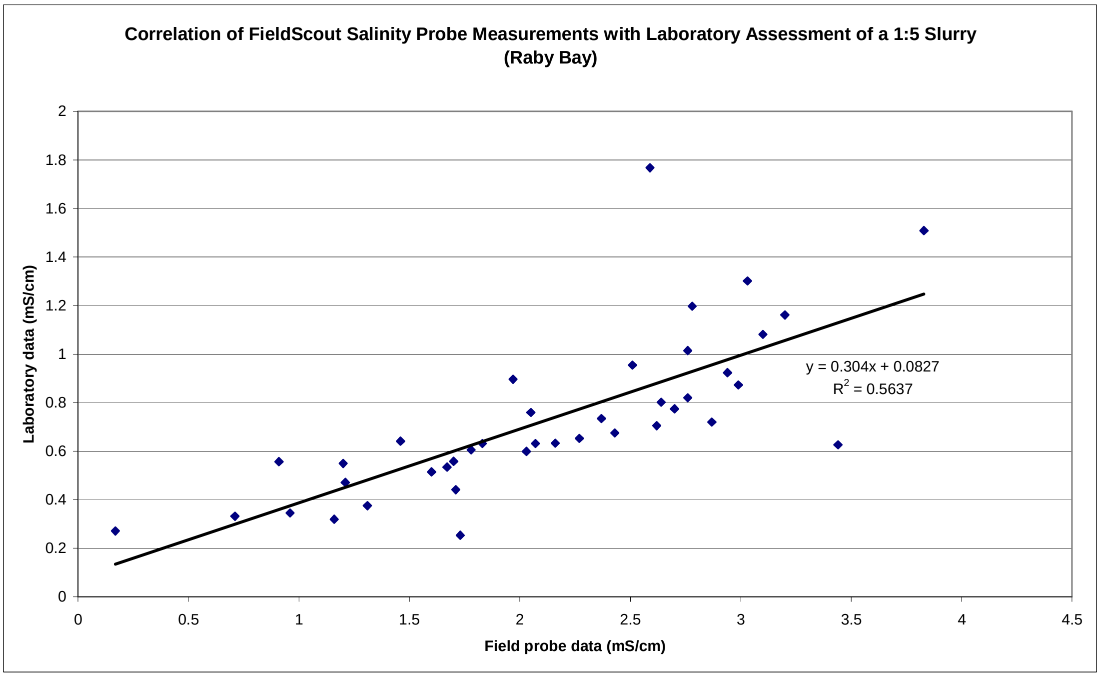


Figure 9-8. Correlation between laboratory-determined salinity of Raby Bay soil and that derived from the FieldScout meter and probe.

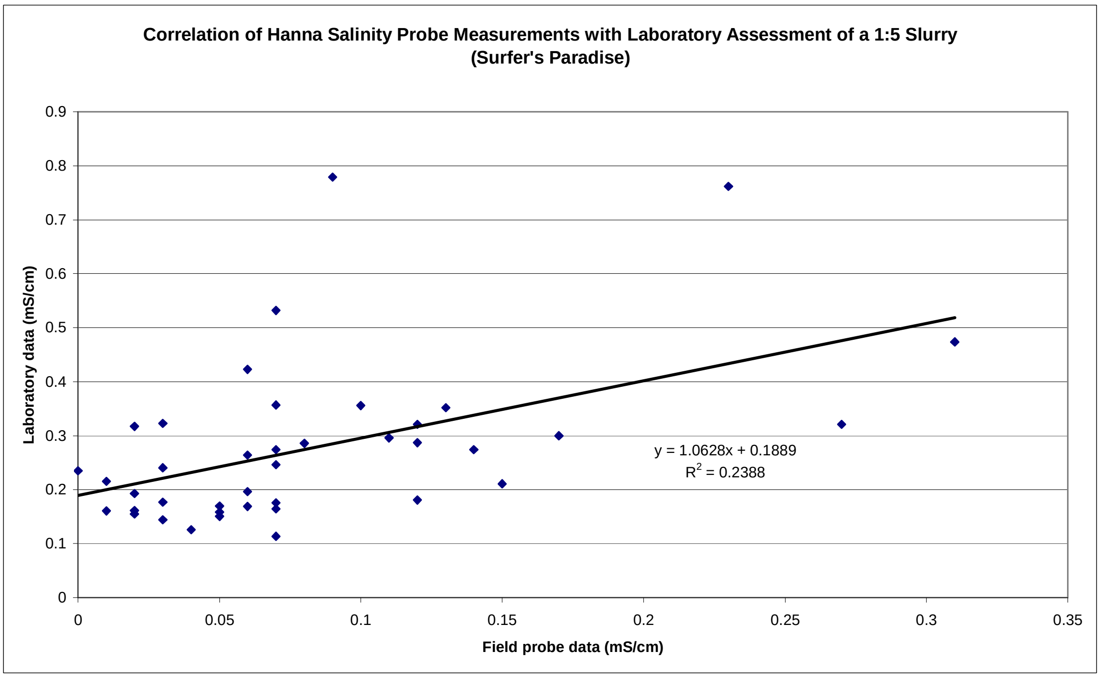


Figure 9-9. Correlation between laboratory-determined salinity of Surfer's Paradise soil and that derived from the Hanna meter and probe.

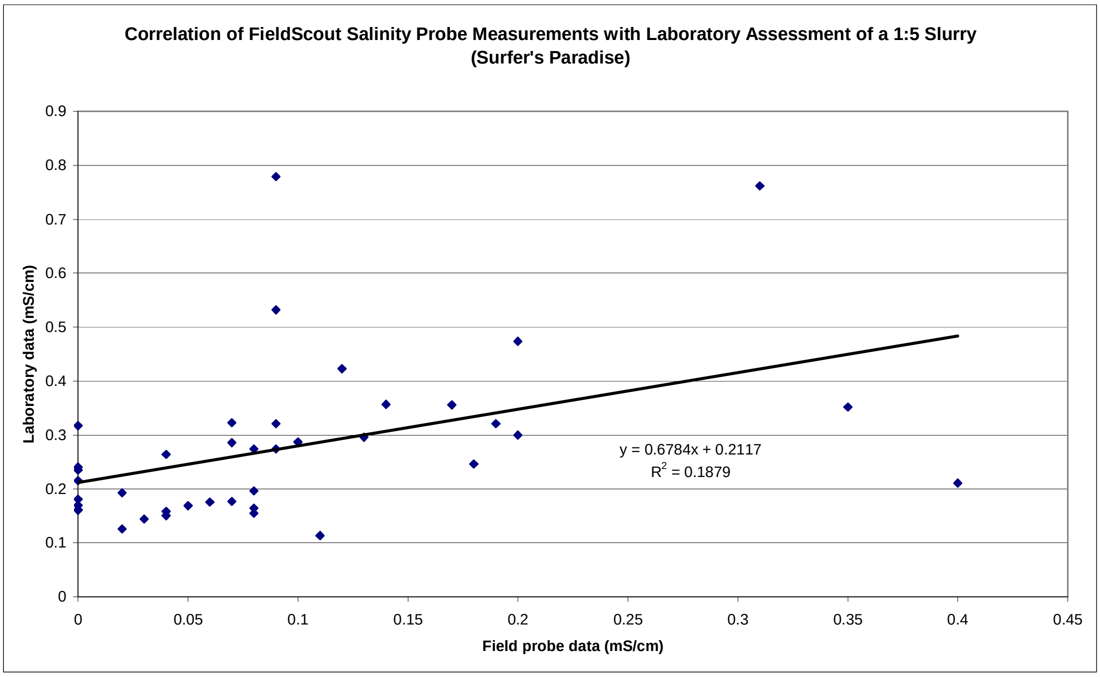


Figure 9-10 Correlation between laboratory-determined salinity of Surfer's Paradise soil and that derived from the FieldScout meter and probe.

9.4 Discussion

Overall correlation between field data and the values obtained through proven laboratory methodology for salinity determination was less than ideal (Figures 9-1 and 9-2). Upon inspection of results by location (Figures 9-3 to 9-10), it would appear that certain factors, which vary between sites, influence the accuracy of both meters. The soil with the highest clay content (Birkdale, Figures 9-3 and 9-4) afforded the best correlation with laboratory results. This may be due to any number of soil attributes associated with soil type, such as calcium content, magnesium content, soil moisture and depth to underlying clay (Hartsock, Mueller et al. 2000).

Moisture content, with a potentially high variation between sites, is hypothesised to be responsible for a large proportion of varying accuracy of salinity meters. Manufacturers of the FieldScout unit even stipulate that soil moisture content should not differ between readings and suggest that measurements are always taken 30-60 minutes after an irrigation event. This limits the use of this technology, especially for managers of unirrigated green space.

The general summary of this investigation is that neither meter tested is satisfactory for use in parks or other amenity spaces where irrigation and soil type are not consistent. Although such equipment may coarsely indicate trends of increasing or decreasing salinity, they do not necessarily give an accurate account of EC, which is needed for comparison to guideline values. Such instruments need to work reliably, independently of soil type. Poor performance in sandy profiles, such as that at Surfer's Paradise (Figures 9-9 and 9-10) is concerning, considering that soil profiles constructed specifically for turfgrass growth often utilise a sand or sand mixture medium.

In every case, except for measurements taken at Surfer's Paradise, the FieldScout meter generated data that matched laboratory values more closely than the Hanna unit's output. This information is somewhat academic, however, given that the soil type effect was considerably larger than meter type effect.

To fit the available suite of turfgrasses (each with different levels of salt tolerance and other attributes) into different sites according to their capabilities, turf managers need simple, yet relatively cheap, instrumentation to be able to reach immediate decisions on-site without first having to send soil samples away to a dedicated soil analytical laboratory.

The range of inexpensive salinity measuring devices is increasing. The aim is to determine their effectiveness and accuracy (by correlating measurements with those by known accurate standard instruments) as possible field aids, in particular, to Council staff unsure as to whether field problems on a particular site are related to salinity or to other soil parameters.

10 Integration and Demonstration of Best Management Practices (BMPs).

10.1 Introduction

Construction and maintenance of sporting fields and parklands have often been considered in isolation of one another. The initial cost savings of cheap construction can be quickly eroded by higher maintenance expenses, which recur into the future. This has been exacerbated by a lack of detailed construction protocols for park development. Clear guidelines for the construction of coastal parks, can minimise or even eliminate the additional expense of follow-up remediation and problem management. Rather than a single problem, there are typically a number of issues that contribute to poor, and often patchy, grass growth in salt affected areas—the mark of an unsatisfactory project outcome.

This project has approached the overall problem of poor quality coastal parkland in a structured step-wise manner. Rather than a single problem, there are typically a number of issues that contribute to the overall unsatisfactory outcome of poor, and often patchy, grass growth. Through the detailed work reported in Chapters II to VII, individual issues have been assessed and management strategies developed for each specific problem. These individual strategies have been integrated on a larger scale in salt-affected parks as the final stage of proving the technology developed through this the previous project

A set of guidelines has been prepared to provide various options from the construction and establishment of new grounds through to remediation of existing parklands by supporting the growth of endemic grasses. They are also mindful of budgetary constraints. They describe a best management process through which salt affected sites should be assessed, remediated and managed. These guidelines will be readily available to councils (included in draft format here at Appendix D-1). The overall theme is a holistic approach to turfgrass establishment and management, including the following process steps:

A. Site assessment: visual assessment and soil testing.

B. Site preparation: provision of irrigation; subsoil remediation and/or amendment (physical and/or chemical); ensuring good quality and quantity of topsoil as underlay and if needed provision made for leaching of salts on a regular basis.

C. Choice of establishment method: full sod versus sprigging taking into account time frames for use of the site.

D. On going maintenance

The results of the individual segmental experimental studies were integrated through a systems approach in which turf was established, managed and remediated on larger demonstration areas based on best management practices (BMP's). As such this chapter is not based upon scientific trial work with statistical analysis of treatment differences. Rather, it is presented, again as a series of case studies.

10.1.1 Case Study 1: Queens Esplanade Birkdale.

10.1.1.1 Introduction

A 0.2 ha demonstration planting of *Paspalum vaginatum* as full sod was made on part of the Queen's Esplanade Park at Birkdale in February 2004, under TU02005. This site was continually monitored for the duration of this project, and was used to assess maintenance operations such as de-compaction, as discussed previously.

10.1.1.2 Best management practices

A. Site assessment and description

Queens Esplanade, Birkdale (27° 28′ 57″ S, 153° 12′ 40″ E) is a site that was previously investigated under TU02005. This site is a coastal park fronting Waterloo Bay, bordered by Mangroves, endemic halophytic grasses, succulents and mangroves (for example, *Sporobolus virginicus, Crithmum maritimum, Avicennia marina and, Aeyiceras cornicultum*). The site is underlain by compacted marine mud and was both strongly acid (pH 3.3-4.7 surface, 2.9-4.4 subsoil) and saline (EC_e 2.8-41.1 dS/m surface, 4.2-46.7 dS/m subsoil). The soil profile is considered man-made in that the marine sediments were deposited during canal development. By current Australian Soil Classification this soil is considered to be a 'Dredgic Anthroposol' which comprises soils formed or forming on mineral materials dredged by human action from the sea or other waterways, or deposited as slurry from mining operations. The dredged materials commonly occur as a lithologically distinctive unit overlying buried soil surfaces, and are frequently found in urban coastal areas (Isbell 2002).

Existing site problems were identified to be:

- Challenging soil conditions (especially high salinity and/or sodicity, compaction, poor internal and surface drainage, acid sulphate);
- Poor choice of turfgrass species/cultivars (e.g. for highly or moderately saline areas, sections subjected to heavy wear from foot traffic);
- Difficult establishment (e.g. into a compacted high clay profile, particularly in man-made profiles, without amendment or subsurface cultivation); and
- Inadequate management and maintenance procedures (lack of fertiliser, irrigation, weed control)

B. Site preparation

The major site preparation focussed on improving the soil fertility and structure, through both physical processes and chemical amendments. Prior to rolling out full sod, the ground was sliced to relieve compaction, gypsum applied to improve soil structure and Ca status, and sandy loam laid (up to 5 cm deep) to provide a level surface for laying the turf. Regular leaching irrigation was applied to flush salts below the root zone. The maintenance program included annual slicing, soil amendment and topdressing, plus regular fertiliser applications.

C. Establishment

Full sod of *Paspalum vaginatum* (Sea Isle 1) was planted to a 0.2 hectare area in February 2004. In December 2004, a further 0.8 ha of *P. vaginatum* sod was laid to extend this initial planting. Irrigation difficulties slowed the establishment process with the *P. vaginatum* sod taking approximately 2-3 months to develop a strong rhizome and root system into the soil below before becoming properly established. This was longer than would normally be expected from *C. dactylon* or *D. didactyla*, and needs to be factored into establishment protocols for *P. vaginatum* sod. A seeding trial also conducted under TU02005 at this site (December 2004) gave only a patchy and inadequate strike (Loch et al. 2006).

The species *Paspalum vaginatum* was identified as a halophytic turfgrass, capable of growing and thriving on much higher levels of salt approaching or equalling that of seawater (Loch and Lees 2001). The cultivar Sea Isle 1 was released from Australian quarantine in mid-2001 and has been commercially available in Australia since 2002/03. Preference was given to Sea Isle 1 due to the lower rate of inflorescence (flower) production, than alternate cultivars of the same species, Velvetene and Saltene (Loch et al. 2006).

D. Maintenance

The Redland City Council adheres to an annual program of cultivation, amendment addition, top-dressing, fertilisation and weed-management, as per the best management practices derived through TU02005. De-compaction is typically achieved with solid tine coring using a tine diameter of 25mm and a depth of 75-150mm, depending on soil physical properties. Soil testing is carried out annually on sports fields and biennially on parks and forms the basis for determining the annual requirements for gypsum, lime, fertiliser and organic material.

Gypsum is applied at 1-2 t/ha and organic matter is supplied in the form of manure fines with a relatively low odour, suitable for residential areas. Sand is top-dressed to a depth of 7mm. Broadleaf weeds (mainly clover) are controlled, at selected sites only, with a mixture of dicamba and MCPA herbicides and wire grass is eradicated using glyphosate, administered through a wick wiper unit. This herbicide regime is not included in the maintenance schedule at Queens Esplanade, Birkdale, as preference is given to maintaining cover, regardless of species. The use of insecticides is not feasible, due to the broad and continuous usage of the park environment.

Water restrictions were implemented across the city (and south-east Queensland) in October 2005 preventing Redland City Council from using water on parkland. This prevented them employing two of the best management practices for salt-tolerant grasses: frequent irrigation during the establishment phase and regular leaching of salts below the root zone. Despite these problems, the previously established grasses were sufficiently well advanced for them to survive with limited applications of recycled water from a water truck and good November rains.

10.1.1.3 Monitoring

Visual monitoring, in addition to that reported in the final report for TU02005 (Loch et al. 2006) was carried out on 29 February 2008, 27 March 2009 and 25 March 2010. In addition to visual assessments, the site was assessed for greenness and hardness, using the turf colour meter and the Clegg impact hammer respectively, on 27 March 2009. The turf colour meter measured red light and near infra-red light reflected from plant tissue, the ratio of which is termed the normalised difference vegetative index (NDVI). This value, between 0 and 1, correlates with visual rating systems that estimate turfgrass colour and is considered an indication of plant health. Surface hardness, measured with the Clegg impact hammer is an attribute related to the safety of an open park space for amenity activities.

10.1.1.4 Results and discussion

A stable, complete grass cover has now been established, despite several prolonged periods without significant rain over the past 6 years. Plates 10-1 to 10-6. illustrate chronologically the establishment and on-going condition of this site over the last six years. This site remained unirrigated from the first introduction of water restrictions in 2005, and now relies solely upon incident rainfall. During the prolonged drought (up until 2009), the general condition of grass cover in all areas suffered due to low soil moisture as can be seen in plate 10-5. The turf colour meter, revealed a persisting contrast (figures 10-1 and 10-2) between BMP areas and the park in general. This is further demonstrated in plate 10-7.

in which the area remediated with Sea Isle 1 is in the background showing good turf coverage and quality, and the untreated area is in the foreground showing lower quality and clear patchiness.

Surface hardness follows a decreasing trend as measurement moves from areas of traditional park management to those holistically managed for sustained growth with salinity (Figure 10-2). This trend, however, was not found to be significant, possibly due to elevated soil moisture following an acute rain period that occurred prior to measurement. Figure 10-1 illustrates that no significant difference could be detected in NDVI between general park areas and the BMP demonstration site at Birkdale.

While demonstration areas were constructed to BMP specifications using the very salt-tolerant seashore paspalum (*Paspalum vaginatum*) cultivar ‘SeaIsle 1’, the remaining areas are comprised of mixed turfgrass species, mainly green couch (*Cynodon dactylon*) of irregular density, some endemic grasses, a variety of weeds and scalds of bare earth where salt levels inhibit the growth of all but halophytic plants.

At Birkdale, there are also significant areas of weed encroachment, where turfgrass growth is limited, in the areas outside of the demonstration site. The weed health at this location, however, is quite strong, possibly explaining the relatively high NDVI value and misleading comparison between the BMP site and the surrounds.

Plate 10-1. January 2004 Queens Esplanade Birkdale (looking west).

Plate 10-2. 27 April 2004 Queens Esplanade Birkdale (looking west).

Plate 10-3 25 June 2004

Plate 10-4 29 February 2008

Plate 10-5. 27 March 2009

Plate 10-6. 25 March 2010

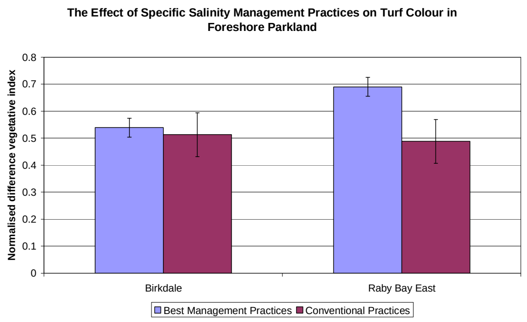


Figure 10-1. NDVI of turfgrasses maintained according to best management practices as compared to those under conventional management.

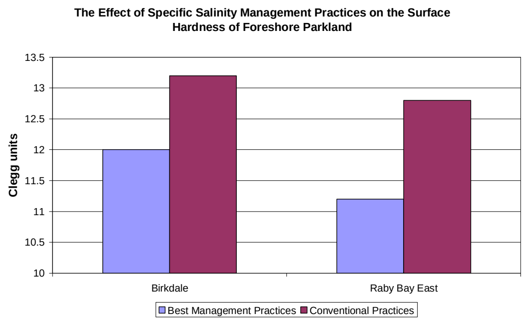
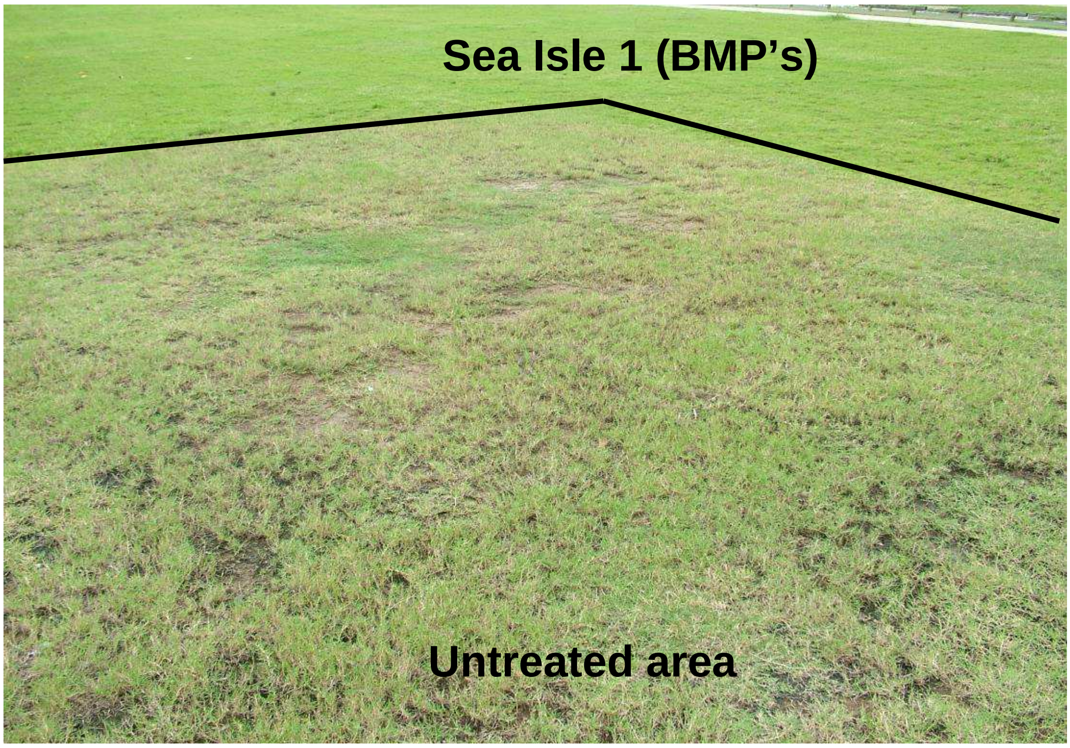


Figure 10-2. Surface hardness of turfgrasses maintained according to best management practices as compared to those under conventional management.

Plate 10-7. 29 February 2008



10.1.2 Case Study 2: Raby Bay Boulevard, Raby Bay.

10.1.2.1 Introduction

This case study represents another site established under TU02005. In the current project this site was monitored for survival and quality of the different turfgrasses that had been previously established with varying depths of topsoil.

10.1.2.2 Best management practices

A. Site assessment and description

The site was located at Raby Bay Boulevard, Raby Bay (27° 30′ 57″ S, 153° 17′ 5″ E) again, on the coastal fringe. Much of the endemic vegetation, such as mangroves, has been removed in order to construct a rock breakwater.

Soil assessment was conducted under TU02005 with core samples collected to a depth of 1 metre. Each 1 m deep core was divided into 4 samples from depths of 0-10, 10-30, 30-60, and 60-90 cm. Soil chemical analysis determined pH, Electrical Conductivity (EC) and chloride from 1:5 suspensions of soil:water. Analyses of surface soil from scalded areas across the four parks confirmed one sample to be sodic with an exchangeable sodium percentage (ESP) greater than 15. Four others were approaching sodic levels (ESP = 12-15), and all were highly saline ($EC_e \geq 30$) and ranged from strongly acid (pH 3.9) to alkaline (pH 7.9). [Soil analysis results are included in the final report for TU02005 (Loch et al. 2006)].

Overall, the results from soil sampling and analysis indicated that the major factors limiting the successful establishment and growth of "normal" turfgrasses on this site were the high levels of salinity and sodicity present in the soil profile. Layering was a problem in the Boulevard, where red volcanic subsoil from a local commercial building site had been spread over most of the park to a depth of approximately 3-4 cm. This surface layer was easily compacted and hard setting, greatly reducing the rate of water infiltration into the soil below.

B. Site preparation

Prior to planting, the soil profile was amended by removing the surface soil and adding 10 cm of sandy loam topsoil.

C. Establishment

A trial was established on 19 July 2002 to compare the four *Paspalum vaginatum* cultivars Saltene^{TM}, Velvetene^{TM}, 'Sea Isle 1' and 'Sea Isle 2000' planted with rooted plugs of the designated variety on a 25 cm grid; a 0.5 m buffer was left bare between adjacent plots. Additional unreplicated observation plots of other turfgrasses with potential for parks use and various degrees of salt tolerance were subsequently added to the side the replicated experiment: *Zoysia japonica* 'El Toro', 'De Anza', 'Victoria' and 'ZT-11'(planted 6 September 2002); *Zoysia macrantha* forms from South Australia and northern NSW (6 September 2002); *Cynodon dactylon* 'Windsor Green' (15 September 2002) ; two forms of *Sporobolus virginicus* (21 November 2002); and *Digitaria didactyla* 'Tropika' (17 January 2003). The two seeded grasses, Blue Dawn and Sydney, were sown at $1g/m^2$. However, these failed to establish, which effectively reduced the number of grass treatments to the nine vegetatively propagated entries. The latter were planted as rooted plugs c. 15 cm apart on a diamond pattern, giving a final planting density of 40 per m2. Blended fertiliser (N:P:K = 12:5:14) was applied at planting to give 50 kg N/ha. Ammonium nitrate was applied on 16 January 2004 at a rate of 100 kg N/ha.

Another salt-tolerant grass, Japanese lawn grass (*Zoysia japonica*) was trialled in an area of high wear. This species, although not as halophytic as seashore paspalum, is known to have a higher resistance to wear. Full sod of Japanese lawn grass was laid around a barbeque, where bare earth had previously been exposed.

D. Maintenance

Blended fertiliser with an N:P:K ratio of 12:5:14 was applied on 31 July 2002 and again on 10 October 2002 and 7 February 2003 to give 50 kg N/ha at each application. Due to dry conditions during the latter half of 2002, the establishing grass plots were irrigated as required. Nutrient-rich compost from wool scouring waste was applied to half of each seashore paspalum plot on 31 October 2002. As with case study 1, irrigation was ceased in all Redland City Council Parks in 2005. Following completion of TU02005, maintenance reverted to standard council practices as described for the Birkdale site, above.

10.1.2.3 Monitoring

During the dry period from planting through to February 2003, the soil profile proved very difficult to wet up and infiltration into the compacted subsoil was very slow. The movement of salt in the profile followed the pattern typical of saline soils: downward during significant irrigation and rainfall events, then upward by capillary action as the soil dried. As the salt was pushed downward, growth of the less salt-tolerant grasses (*C. dactylon, D. didactyla, Z. japonica*) improved, but then suffered from leaf firing and stolon death as the salt zone again rose to the soil surface.

During the intervening dry periods, all grasses were susceptible to salt-induced physiological drought (with premature wilting exacerbated by the shallow root zone in the compacted profile), but the more salt-tolerant species (*P. vaginatum, S. virginicus, Z. macrantha*) showed little or no firing of the top growth. *P. vaginatum* and *S. virginicus* showed the greatest promise for long-term park use on salt-affected sites, with *S. virginicus* appearing to be the more drought-tolerant species but *P. vaginatum* currently having the better turf types available. Work here and in other projects indicates that the native *Z. macrantha*, while salt tolerant, is not well adapted to the compacted heavy clay soils.

Following salt damage to many of the plots, the experiment was abandoned but the surviving plots re-assessed on 25 May 2006 (Loch et al. 2006). Further assessment was carried out on 27 March 2009 to determine turf colour (NDVI) and surface hardness (Clegg hammer). Visual assessment and photographic records were also collected on 29 February 2008 and 27 March 2009.

10.1.2.4 Results and discussion

From regular observations on the grow-in of each turfgrass, the two most salt-tolerant halophytic grasses (*S. virginicus* and *P. vaginatum*) grew better with approximately 2-3 cm of topsoil covering the heavy compacted clay below than with greater depths of topsoil, as might be expected from grasses that occur naturally in, and grow better on, marine mud than on well-drained sands. In contrast, the best growth of the less salt-tolerant *C. dactylon, D. didactyla, P clandestinum* and *Z. japonica* was observed where there was a minimum of 10 cm of topsoil. In addition, substantial sections of *P clandestinum* and the two *D. didactyla* cultivars were affected by salt in surface and sub-surface water flows through the area in March 2004, showing very severe leaf firing and loss of affected plants in the most heavily saline areas.

After a two year period, the area of *Z. japonica* had persisted as a full covering over the barbeque surrounds. As a demonstration site, this shows how a selection of halophytic grasses can be used in a salt-affected area. By understanding the various tolerances of different species, the best grass can be selected to serve a specific function in a specific area. On 29 February 2008 there was still evidence that the *Z. japonica,* in front of one BBQ, was coping better with the high traffic while the seashore paspalum was worn bare or invaded by clover (Plate 10-8).

In 2005 it was observed and reported that the grass was greener over pipes where cultivation had loosened the soil. This enhanced growth was still evident on the 29 February 2008. Maintenance practices were also observed to enhance turfgrass growth at this site. Plate 10-10 shows healthy, three year old Sea Isle 1 that has been maintained with coring and topdressing, despite drought conditions during the majority of that time. Similarly, Sea Isle 1 has performed well on path edges, where it was able to receive rainfall run-off, and store that moisture in a deeper soil profile. In the adjacent low area however, salt accumulation is high. The salinity combined with the wear creates a bare patch (Plate 10-11). Soil cores extracted from a treated area and a non-treated area on 27 March 2009 were different in terms of structure, with the cored and topdressed area showing better root growth due to the more friable nature of the soil in the rootzone (Plate 10-13).

Results from the surface hardness test and turf colour meter are presented in Figure 10-1 and Figure 10-2. At Raby Bay East, a 40% improvement to NDVI was obtained through the employment of BMPs. (as discussed, the cause of this differential site performance may be related to weed composition.). The major weed at this site was wire grass (*Polygonum acivulare*), prolific in areas experiencing soil compaction. The weeds in this location had stems and leaves that were at various stages of necrosis, appearing yellow to white. The lower NDVI achieved here, relative to that attained in the BMP site, is a reflection of the absence of healthy turfgrass cover.

Plate 10-8. 29 February 2008, *Paspalum vaginatum* invaded with clover in high wear areas.

Plate 10-9. 29 February 2008, greener cover of Paspalum vaginatum above irrigation pipes (left), where soil was loosened.

Plate 10-10. 29 February 2008, three year old Sea Isle 1 that has been successfully maintained with coring and topdressing.

Plate 10-11 29 February 2008, Sea Isle 1 surviving well on a deeper soil profile capturing water from the pathway.

Plate 10-12. 27 March 2009 SeaIsle 1 treated with BMP in foreground with untreated area, in background, with visible bare patches and weed infestation (mainly wire weed - sprayed out).

Plate 10-13. 27 March 2009, Cores showing friable soil and root growth in BMP area (left) and compaction in non-BMP area (right).

10.1.3 Case study 3: Masthead drive, Raby Bay

10.1.3.1 Introduction

Again, continued monitoring of a site in which trials were established under TU02005 has allowed assessment of the longterm survival and quality of turfgrasses in a salt affected environment.

10.1.3.2 Best management practices

A. Site assessment and description

The park at Masthead drive, Raby Bay is located at 27° 31′ 12″ S, 153° 16′ 3″ E. The original trial site comprised the furthermost Eastern section of Masthead Drive.

Soil samples were collected and analysed as per the site at Raby Bay Boulevard (Case study 2). The surface soil was the imported red volcanic soil with clay contents approximately 25%. The subsoil was found to be neutral to acidic, with pH ranging from 4.8 to 7.9. Salinity ranged from 0.87 to 7.6 dS/m for 1:5 soil water extracts. The exchangeable sodium percentage was 14.8%.

Overall, the results from soil sampling and analysis indicated that this site was also subject to the hostile conditions imposed by the “Dregic anthroposol” soil type with high levels of salinity and sodicity present in the soil profile. The imported red volcanic soil also induced layering problems to a similar state to that of Raby Bay Boulevard (Case study 2).

B. Site preparation

Organic compost was applied to approximately one-third of the Masthead Drive park in August 2003 with the aim of improving soil fertility and building better soil structure through the organic components. This followed slicing, gypsum amendment and topdressing to 1-2 cm with sand as part of developing protocols for relieving soil compaction.

On Monday 29 March 2004, screened top soil and sandy loam was applied to scalded areas of ground in preparation for discreet plantings of sprigs and plugs of various cultivars for an observational trial of establishment and survival.

C. Establishment

Different cultivars of turf were planted on 29-30 March 2004, including large sprigs of Sea Isle 1; plugs of Sea Isle 2000, *Zoysia Matrella* G1 (now refered to as A-1$^{(b)}$), and *Sporobolous virginicus*. All were irrigated by hand and from the existing irrigation system. On Tuesday 27th April 2004 small plugs of *Sporobolus virginicus* were planted into further scalded areas. A light application (50 –100N) of Lesco Sports Turf Starter Fertiliser (N:P:K ratio 14:10:9) was applied to the scalded areas which were then irrigated via fixed sprinklers and by hand.

D. Maintenance

The maintenance at this site followed standard council protocols with annual de-compaction using an aerovator with solid tines (1 inch diameter) coring to a depth of 75 - 150 mm deep (Plate 10-14) and topdressing with a light sandy loam to a depth of 7 mm (Plate 10-15). Gypsum was applied at 1-2 t/ha and a low-odour manure fines product was used as organic matter. Fertiliser applications were based upon soil test results with a low P fertiliser generally recommended.

Plate 10-14. Solid tine aerovator as used in regular park maintenance, Redland City Council

Plate 10-15. Application of light topdressing as a component of regular park maintenance, Redland City Council.

10.1.3.3 Monitoring

Site inspections were carried out during TU02005, with further inspections occurring on 29 February 2008 and 11 March 2010.

10.1.3.4 Results and discussion

Initial applications of compost material enabled stolons of *C. dactylon* to grow across bare scalded patches without incurring the usual firing and dieback due to high salinity.

In the long term, planting of plugs at Masthead Drive, Raby Bay has greatly improved the grass cover of this parkland. Improvements can be observed to the overall coverage at this site through the use of more salt tolerant turfgrasses. Plate 10-16, while newly planted with new turfgrasses, provides an indication as to the extent of scalding which previously existed at this site. Plate 10-17 shows a closer view of the same location, with halophytic and drought tolerant species (*Sporobolus virginicus* and *Zoysia matrella*) predominating in the previously scaled area. Plates 10-18 to Plate 10-21 illustrate similar persistence of *Sporobolus virginicus* from establishment in 2004, through a drought period to revival following good rainfalls in 2010.

However, some exposure of bare earth remained in low-lying areas of high salt accumulation. Plate 10-22 and Plate 10-23 illustrate the same area of parkland. It is apparent at that all turfgrasses were unable to survive extended periods without water with the added complication of increased salinity due to evaporative concentration. There is some ambiguity as to whether the planting technique or unfavourable conditions are responsible for the compromised grass cover in this park. Without the ability to irrigate and leach salts, the full potential of a remediation program cannot be reached.

The best management practice of annual decompaction has contributed to improved health of turfgrass at this site. Plate 10-24 is a clear illustration of the value of carrying out regular aeration where turfgrass greenness is enhance along the line through which the tines have loosened the soil, allowing greater infiltration of incident rainfall. Similarly, the choice of halophytic grasses, some endemic to the area has allowed surface cover to remain intact during trying conditions of drought and salt accumulation. Plate 10-25 has an area in the centre in which *Sporobolus virginicus* has persisted in what would otherwise have been bare ground, due to its tolerance to increasing levels of salinity.

Plate 10-16. 2 April 2004, saline scald topdressed with plugs of new grasses planted.

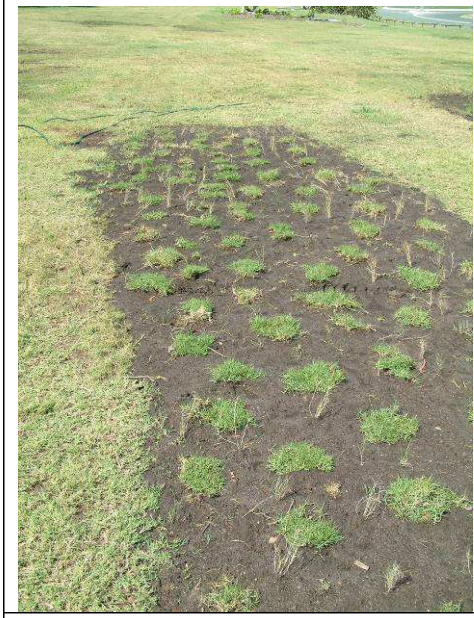


Plate 10-17. 29 February 2008, minimal bare ground despite extended drought since new grasses were established. The surviving species are mainly *Zoysia matrella* and *Sporobolus virginicus*.

Plate 10-18 plugs of *Sporobolus virginicus* planted in 2004.

Plate 10-19. 11 March 2010, *Sporobolus virginicus* providing good cover and persisting despite extended drought.

Plate 10-20. 29 February 2008

Plate 10-21. 11 March 2010

Plate 10-22. 29 February 2008,

Plate 10-23 11 March 2010

Plate 10-24. 11 March 2010 turfgrasses showing healthy growth along lines of de-compaction

Plate 10-25. 11 March 2010, *Sporobolus virginicus* persisting on a previously bare patch with high salinity levels.

10.1.4 Case study 4: Jacobs Well

10.1.4.1 Introduction

The site at Jacobs Well is beach front parkland adjacent to boat launching facilities. It suffers from high wear and tear and also salt accumulation from either high tides or from bathers dripping water from the beach onto the grassed area. It is a high profile site, often used for weddings or other social functions.

10.1.4.2 Best management practices

A. Site assessment and description

The site was on the Esplanade, Jacobs Well at location 27° 46′ 49″ S, 153° 22′ 2″ E. The condition of the turfgrass before renovation was poor, consisting of a sparse covering of an unknown cultivar of green couch (*Cynodon dactylon*). The site clearly had high levels of compaction through a combination of soil type and high wear and tear. Soil samples were collected on 5 June 2008 and sent for laboratory analysis. The soil was suggested to be a sandy loam with a low cation exchange capacity of 7.17 meq/100g, indicative of poor moisture and nutrient holding capacity. Nitrogen and potassium were considered likely to leach readily. The pH (1:5 water) was 6.04 and the electrical conductivity was found to be within acceptable limits (103 µS/cm). Despite the low electrical conductivity in the collected samples, salt accumulation, through inundation and evaporative concentration, could not be ruled out as a limiting factor at this site, due to proximity to the Broad Water. In this example, salt accumulation and high wear were assumed to be the main obstacles to sustained, healthy turfgrass growth.

B. Site preparation

Site preparation commenced on 17 March 2009. The soil surface was removed (Plate 10-26) and the subsoil cored with hollow tine cores (plates 10-27 and 10-28) to relieve compaction and enhance mixing in of the imported topsoil. This was the only compromised practice, with respect to what was considered optimal for this site, as a solid-tine aerator was considered ideal in this situation. However, the machinery available was limited, due to the confined nature of the site.

The existing grass and topsoil were removed to a depth of 150mm and a weed-free topsoil, rich in organic material (a sandy loam mixed with mill mud) was spread and levelled to the depth of the previous soil (Plate 10-29). Eco 88, a fertiliser with composted manure and an N-P-K analysis suitable for turf (15-4-11), was spread at approximately 30g/m^2 and then lightly incorporated into the topsoil.

Plate 10-26. 17 March 2009, removing existing soil surface.

Plate 10-27. 17 March 2009, coring the Jacobs Well site.

Plate 10-28. Close up view of hollow tine coring machine.

Plate 10-29. Spreading sandy loam / mill mud mix in preparation for laying full sod of Zoysia matrella (foreground).

C. Establishment

Zoysia matrella was chosen due to its combination of wear tolerance and halophytic properties (reasonable tolerance to salinity and wear). Cultivar A-1$^{\Phi}$ was chosen due to its commercial production and availability. Strips of turf sod were laid, on 17 March 2009, in a staggered pattern (Plate 10-30) before being rolled to enhance sod-topsoil contact (Plate 10-31). Fertiliser Eco 88 was applied at approximately 300 kg/ha. Temporary fencing was erected for protection during the initial establishment phase. The area was hand irrigated twice daily with recycled water for a period of three weeks.

<table>
<tr>
<td>Plate 10-30. 17 March 2009, Zoysia matrella sod being layed
</td>
<td>Plate 10-31. 17 March 2009, rolling and irrigating newly layed Zoysia matrella sod.
</td>
</tr>
</table>

D. Maintenance

Maintenance was carried out by the project collaborator (Gold Coast City Council) as per regular council guidelines with irrigation ceasing on approximately 7 April 2009 (the allocated three week establishment period), leaving turfgrass reliant upon incident rainfall.

10.1.4.3 Monitoring

The site was visually inspected on 1, 13 18 May 2009, 30 October 2009 and 11 March 2010. The rainfall and reference evapotranspiration (Australian Government Bureau of Meteorology 2010) for the interceding periods is summarised in Table 10-1.

Table 10-1

	Total Rainfall	Rainfall - daily average	Reference evapotranspiration - daily average
7 April 2009 to 1 May 2009	70	3.02	4.43
1 May 2009 to 13 May 2009	19	1.42	3.6
13 May 2009 to 18 May 2009	0	0.00	4.2
18 May 2009 to 30 October 2009	472	2.86	4.03
30 October 2009 to 11 May 2010	571	2.96	5.46

10.1.4.4 Results and Discussion

Photographs from site inspections are presented below in chronological order (plates 10-32 to 10-41). There was a clear decline in turfgrass cover and quality due to insufficient rainfall to meet plant demands, and lack of management budget to supply irrigation (recycled water) beyond the nominal three week establishment phase, which as shown in chapter 6 was insufficient to ensure adequate root growth into the subsoil.

The area adjacent to the retaining wall, being constructed with back fill would most likely drain more readily than that closer to the carparks. This is also the first point of contact with saltwater inundation which would require heavy leaching irrigation to prevent salt accumulation. Clearly irrigation was insufficient to achieve this, indeed rainfall at this site, for the duration of the study was well below that which was required to meet reference evapotranspiration (Table 10-1). Plate 10-32 showed clear evidence of inefficient handwatering, with an arc nearest to the carpark growing well while the extremities were suffering from dehydration. Plate 10-37 illustrates the persistence of this problem upon inspection on 18 May 2009. Plate 10-36 is evidence of the technique used to irrigate the turfgrass, with the arc of healthy growth clearly mirrored in the irrigators application arc.

This site clearly has a high need for water to ensure grass survival, either providing leaching of salts, or to replace moisture loss from the high evaporation caused through regular windy conditions. Due to budgetary constraints, council decided to replace some of the area with green couch sod. Plate 10-41 illustrates the level of dehydration occurring at this site, with this new sod showing clear signs of moisture stress even after a 2 week period of regular rain. On the other hand, *Zoysia matrella*, which had previously declined, is now showing signs of recovery following the rainfall (Plate 10-40).

Plate 10-32. 1 May 2009

Plate 10-33 1 May 2009

Plate 10-34. 13 May 2009

Plate 10-35. 18 May 2009

Plate 10-36. Initial watering of turfgrass with recycled water. Although out of sequence (taken on 17 March 2009) the area or arc likely to receive higher irrigation is clearly evident.

Plate 10-37. 18 May 2009 well irrigated turfgrass in foreground, with areas suffering dehydration at the back (closest to the beach).

Plate 10-38. 30 October 2009, turfgrass suffering severe water stress.

Plate 10-39. 11 March 2010, turfgrass showing signs of recovery following heavy rainfall events.

Plate 10-40. 11 March 2010 *Zoysia matrella* at the Jacob's Well site showing signs of recovery following rainfall. 	Plate 10-41 11 March 2010 Green couch sod showing clear dehydration due to failure to provide adequate irrigation. 

10.2 Conclusion

Leaching is widely acknowledged as the most important management practice on salt-affected sites, because without control of soil salt levels through leaching other management practices may not be able to compensate for the salt stress imposed on badly salt-affected sites. The implementation of effective leaching protocols was therefore an important consideration in setting up long-term sustainable management of salt-affected parks in Redland City. However, the prolonged drought through the duration of this project limited the ability of this project to achieve full success in demonstrating best management practices.

For effective leaching (and also successful establishment of new turf areas), a prerequisite is a well-designed and well-maintained irrigation system capable of distributing water uniformly and as required. In particular, pulse irrigation is required (i.e. little and often, rather than a single large application) to allow infiltration of the first pulse before applying the second.

Unfortunately not all aspects of best management could not be fully demonstrated due to the drought conditions that persisted throughout the majority of this project. It became council policy to not irrigate amenity areas due to the high level water restrictions imposed by government. This has prevented them employing two of the best management practices for salt-tolerant grasses: frequent irrigation during the establishment phase and regular leaching of salts below the root zone. The consequences limited the ability of this project to fully demonstrate best management practices. However, it has been possible to demonstrate the advantages that best management practices have had on ensuring the sustainability of turfgrass through hostile conditions (high salt levels coupled with inadequate water supply).

It is an understanding of the specialised management of halophytic grasses in salt-affected soils that has led to the implementation of best management practices, carried out with the appropriate frequency on foreshore parkland. The condition of the turf in these areas is testament to the appropriate selection of salt-tolerant species, establishment techniques and cultural practices, despite the previously discussed water deficits.

Particularly in the Redlands City Council area, the overall long-term grass cover has been significantly improved with some areas displaying growth that has connected plugs to form a continuous and healthy verdure. Visual appearance, surface hardness, soil structure, turfgrass rooting and colour and overall colour; confirm that BMPs for salt-affected sites continue to facilitate turfgrass growth and quality that is superior to that of areas managed with generic park maintenance programs.

As discussed under case study 2, core samples reveal that BMPs with an affinity for salinity management also benefit soil structure. Improved soil structure was observed within the best management practice demonstration areas, which appeared to allow deeper root penetration and assisted with drainage and flushing of salts through the profile.

Seashore paspalum (*Paspalum vaginatum*) was the major salt-tolerant turfgrass used to improve foreshore parkland. Large plantings of full sod in parks adjacent to Queens Esplanade, Birkdale and Raby Bay Boulevard, Raby Bay, have sustained strong growth and favourable colour in areas that were previously occupied by a mixture of unhealthy grasses – predominately green couch (*Cynodon dactylon*). In areas of very high salt accumulation the couch had receded to display unsightly bare ground, however the current stands of paspalum in these parks has persisted as a complete ground cover.

Although there are benefits to laying full sod when constructing a new area or completely replacing a species, it is a relatively expensive means of establishing a stand of turfgrass, compared to other means such as plugging, sprigging, stolonizing and seeding. Plugging with *Sporobolus virginicus* and *Zoysia matrella* also proved successful as mixed plantings in discreet problematic areas of Redland City Council. These methods are potentially efficient means for remediation of salt-affected areas, especially where only patches of bare ground need to be addressed within an existing cover of turf. The success of these techniques will be dependant upon adequate supply of irrigation to both meet the plant requirements and to leach salts from the rootzone, as well as the ability to provide some degree of physical protection from traffic.

Unfortunately the best management practice sites established on the Gold Coast have not been as successful as in the Redlands due to the extreme wear and tear combined with a similar lack of irrigation and/or rainfall. The site at Jacob’s Well aimed to further assess the efficacy of grass selection, establishment and maintenance. The lesson learned from this was that drought tolerant and salt tolerant grasses are not ‘silver bullets’. Indeed, the sporadic “failings” observed throughout this project were valuable in highlighting the importance of considering the management of these sites, and indeed all turfgrass management, from a holistic viewpoint. The entire system must be established and maintained according to a holistic set of best management practices. In effect, it has been demonstrated that failure to undertake any single aspect results in less than adequate turfgrass cover. However, in a saline environment the salt tolerant species are more likely to persist, and sites should be managed carefully to maximise this potential.

The best management practice areas investigated within this project, while not providing turfgrass that would meet the standards of a fastidious green keeper, did provide improvements to turfgrass cover despite severe water deficits. With the aim of bringing together research findings from various aspects of the project, the multiple best management practice demonstration sites remain successful in highlighting the long-term success of the model for management of salt-affected amenity sites.

Best management practices, confirmed through larger-scale development studies have been incorporated into draft establishment and management protocols for adoption by Redland City Council and Gold Coast City Councils to provide clear guidelines for their staff, land developers and any other practitioners involved in the development and management of urban open space areas. A document targeting such stakeholders will focus on the soil-plant-water continuum from a practical point of view, such that existing problems associated with salt-affected sites are not exacerbated, rather established and managed by the best possible means. These guidelines will be presented to councils at a pending workshop planned for early 2011.

11 CONCLUSIONS

This project, initially focussing on individual factors of turfgrass establishment and management in saline environments, has taken a holistic approach in viewing the outcomes from segmental studies as parts of an integrated system. The importance of taking this view point has been highlighted at every step. A number of species, down to cultivar level, have been assessed for salinity tolerance under controlled conditions. These cultivars have been tested under various and numerous limitations, to determine the best way to establish and manage these turfgrasses under the condtions imposed upon them in saline, coastal parkland.

The most salt tolerant species *Sporobolus virginicus* and *Paspalum vaginatum,*while showing distinct advantages in areas in which high salt levels are the primary limitation to growth, have been out performed under conditions in which other factors outweigh salinity levels. Species with moderate salinity tolerance such as *Zoysia japonica* and *Zoysia matrella* have performed well at specific locations in which high wear was the predominant limitation to growth. The higher salt tolerant cultivar within the low to moderately tolerant species of *Cynodon dactylon* (Oz-E-Green) has shown superior performance under conditions of severe water stress and high wear. Collectively, these species and cultivars provide a range of options for turfgrass managers on salt-affected sites, because each is adapted to different environments.

With respect to grass selection *per se,* there has been a lack of evidence to support one tested cultivar over another. However, as described above a general pattern has emerged in which different species, and cultivars have shown superior performance under different stress conditions, supporting the notion first introduced in TU02005 (Loch et al. 2006) that a patchwork of different turfgrass species across a landscape would ideal, matching levels of tolerance to various factors identified through detailed site assessments.

The turfgrass choices available to managers, as tested in this project, are all premium turfgrasses, and as such are a significant financial investment. Such an investment warrants good establishment and maintenance protocols. One of the most beneficial establishment practices identified in this project is the addition of composted organic material to the media used beneath turf laid as full sod, particularly on denuded sands with little or no nutrient and moisture holding capacity.

Alternative methods of establishment were shown to be successful in controlled situations. The fragile nature of grass sprigs makes irrigation essential as they rapidly dehydrate. It has also been shown that protection of the area from traffic for a minimum of 10 weeks is required for successful establishment from sprigs, making it a viable method in low use parks or discreet areas that can be fenced, or on sporting fields that can be closed for the duration. Fertiliser is important to ensure growth rates are at a maximum, giving the plant opportunity to establish a healthy root system in the time allocated. The water required to establish the turfgrass sward will be a valuable investment in the long term as it will allow the plant to perform many benefits to the environment, as well as the social and health benefits that living plants provide (Gullone 2000; Maller et al. 2006; Kaczynski and Henderson 2007).

A number of management practices were investigated on existing turfgrass swards both in extremely compacted soils in parklands under field conditions to determine appropriate de-compaction techniques, and as controlled experimentation to determine turfgrass nitrogen requirements. The site investigated for de-compaction, as discussed was an example of the most extreme case of poor soil structure, being a duplex soil of marine clay sediments showing signs of the physical properties brought about through sodicity along with chemical problems associated with elevated salinity. Only the most aggressive practices applied appeared to facilitate some short-term decrease in the soil compaction. The defiance of this soil type to compaction alleviation highlighted the need for construction of a profile that functions well with respect to moisture infiltration and drainage as well as oxygen transport and optimal root growth. Here we have a clear example in which the system as a whole must be managed rather than individual segments. This site exemplifies poor initial construction limiting the ability of post-establishment management operations to succeed, and thus the turfgrass system as a whole has failed to thrive. This was further supported with examples from a site in which construction was carried out in accordance with best management practices. De-compaction operations on a well constructed sportsfield were found to improve the physical conditions within the rootzone for an extended period of up to three months. There was also an indication that topdressing after cultivation improved soil structure in the rootzone, with notable increases in the rate of water infiltration following application of a light topdressing. The treatment most evident in significantly improving soil structure was cultivation at 200 mm with 15° of heave, applied with a single pass.

Soil amendments that contain exchangeable calcium (e.g. gypsum) are further means of alleviating compaction. Calcium can replace sodium in the profile and improve soil structure. The importance of soil moisture has also been highlighted as an influence of soil strength and infiltration. Irrigation is another option for such sites where the ability to flush salts below the root zone is important.

Providing the turfgrass plant with the three major necessities of life (air, water and nutrition) has been pointed out repeatedly throughout this project, with a chapter devoted to further understanding the nitrogen requirements of these turfgrasses. Under the hostile conditions imposed by saline sites, maintaining a good supply of nutrient is essential to ensure the turfgrass has the ability to repair itself during periods of reduced stress and store assimilates in preparation for high stress periods, such as elevated salt levels, or high wear and tear. It was found that N requirements are cultivar specific suggesting that the values presented here should be used as a guide only, with further fine tuning determined through site specific experiences.

Leaching is widely acknowledged as the most important management practice on salt-affected sites, because without control of soil salt levels through leaching other management practices may not be able to compensate for the salt stress imposed on badly salt-affected sites. The implementation of effective leaching protocols was therefore an important consideration in setting up long-term sustainable management of salt-affected parks in Redland City. However, the prolonged drought through the duration of this project limited the ability of this project to achieve full success in demonstrating best management practices.

For effective leaching (and also successful establishment of new turf areas), a prerequisite is a well-designed and well-maintained irrigation system capable of distributing water uniformly and as required. In particular, pulse irrigation is required (i.e. little and often, rather than a single large application) to allow infiltration of the first pulse before applying the second.

Integration of each of the segmental research studies presented here has lead to the development of a set of best management practices presented in Section 16.8 (Appendix D-1). Emphasis is given to the importance of adequate planning. These guidelines will be of most benefit if they are fully understood before embarking on a parkland development /remediation project, enabling all aspects of the protocol to be included in the proposed budget. Despite extended drought for the duration of this project, it has been possible to demonstrate the advantages that best management practices have had on ensuring the sustainability of turfgrass through hostile conditions (high salt levels coupled with inadequate water supply). It has been demonstrated that failure to undertake any single aspect results in less than adequate turfgrass cover. However in a saline environment the salt tolerant species are more likely to persist, and sites should be managed carefully to maximise this potential.

As stated earlier, the key outcome here is that accurate identification of the major limitations to turgrass growth at each site is essential in selecting the right species and cultivar. Species and indeed cultivar selection should not be considered as an isolated decision but as a factor in an integrated system of turfgrass establishment and management. The key to success, then is the selection of the right species and cultivar for each situation combined with establishing and maintaining those turfgrasses in the right way, ensuring an adequate supply of the necessities of plant growth and survival: water; air and nutrition. Thus ensuring successful and sustainable turfgrass cover and the many benefits this brings about environmentally, socially and economically.

12 TECHNOLOGY TRANSFER

Refereed Paper:

Bauer, B. K., R. E. Poulter, A. D. Troughton and D. S. Loch (2009). "Salinity tolerance of twelve hybrid Bermudagrass [Cynodon dactylon (L.) pers. x c. transvaalensis burtt davy] genotypes." International Turfgrass Society Research Journal 11: 313-326.

Conference presentations and posters:

Loch, D.S and Poulter, R.E. Establishment & management of salt-tolerant turfgrasses on salt affected parkland – paper presentation at UrbanSalt, 2007 Sydney 22nd & 23rd May 2007

Poulter, R.E and Loch D.S. Identifying salt-tolerant turfgrasses for use on salt affected parkland – poster presentation at UrbanSalt 2007, Sydney22nd & 23rd May

Magazine articles:

Poulter, R. (2008) Turf grasses for salt affected parklands – phase 2 research commences Turfcraft International Issue 118 (Jan-Feb 2008) page 28

Bauer, B. (2008) Aeration of Soils Experiencing Chronic Compaction Turfcraft International Issue 123 (Nov-Dec 2008) pages 19-22

Bauer, B. (2009) Screening Hybrid Green Couch Cultivars for Salinity Tolerance. Australian Turfgrass Management Volume 11.4 (July –Aug 2009) page 62

Media Release:

Hargraves, K. Queensland Government Department of Employment, Economic Development and Innovation Media Release 27 August 2009 ‘Tough grass no big ask of turf researchers’

Informal communications:

Liaison with the relevant contacts within the Gold Coast City and Redland City Councils has been sustained, providing a two-way flow of information regarding the best practice management of their salt-affected foreshores.

Interim results from grass selection and salt-tolerance trials has also been shared with these stakeholders.

Pending communications:

Workshop: Successful establishment and management of salt affected parklands, for Council management and maintenance staff. To be held early 2011

13 RECOMMENDATIONS

The key to successful establishment and management will be extension of the information provided in this report. The Guideline document will require professional design layout and printing for widespread distribution to councils in Queensland initially, followed by National distribution.

Workshops, locally and regionally, will be required to ensure councils are supported through the process of adopting best management practices.

Future research needs to focus on the wear tolerance, under controlled conditions, of some of the cultivars investigated in this project. Ideal protocols for research would mirror that of TU08018 “Traffic Tolerance of Warm-Season Turfgrasses under Community Sportsfield Conditions”.

Given that a key factor underpinning the success or failure of turfgrasses in salt affected areas, mentioned throughout this report, is the ready supply of water for irrigation, it is important to gain a full understanding of the water requirements of these grasses, to ensure they receive enough to survive and/or recover from high wear whilst maintaining a healthy sward, without wasting any of this precious recourse through over irrigation. Recommendations made in TU09033 “Status Assessment of Water Use research in turf growth and maintenance” would be invaluable in addressing some of the irrigation issues faced by local councils.

14 ACKNOWLEDGMENTS

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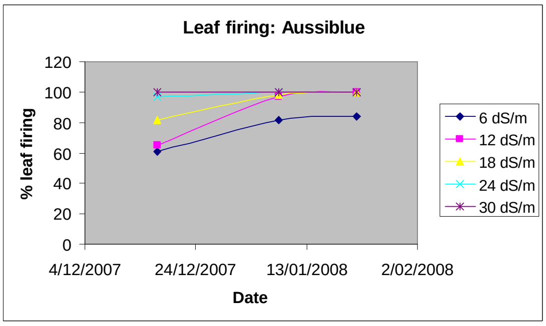
16 Appendices

16.1 APPENDIX A-1: Leaf firing in response to rootzone salinity level

a



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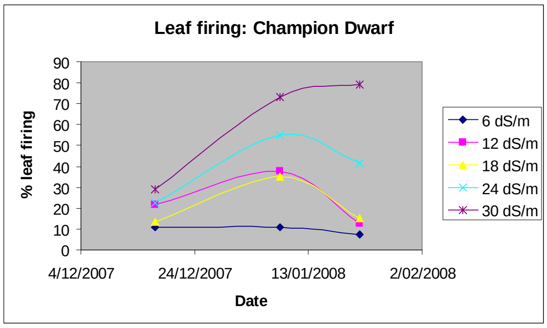

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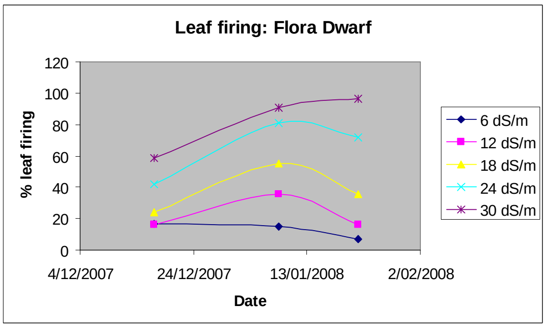

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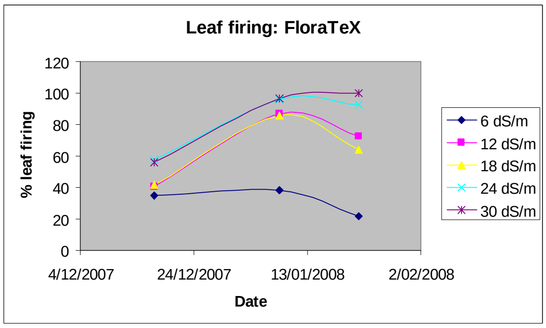

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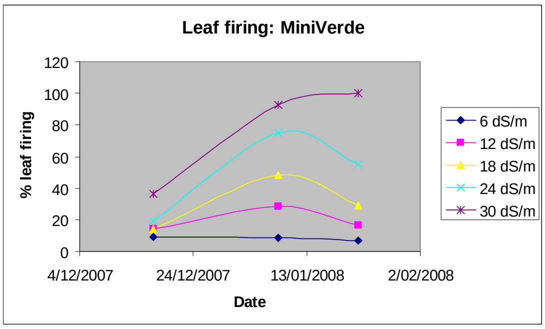
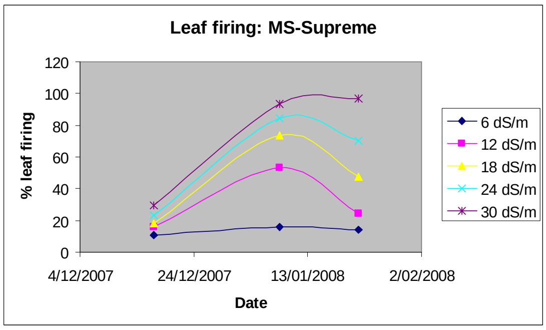
f





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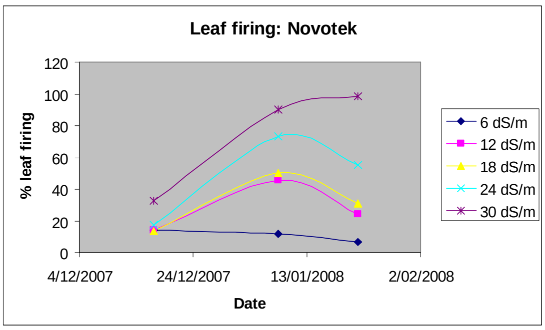
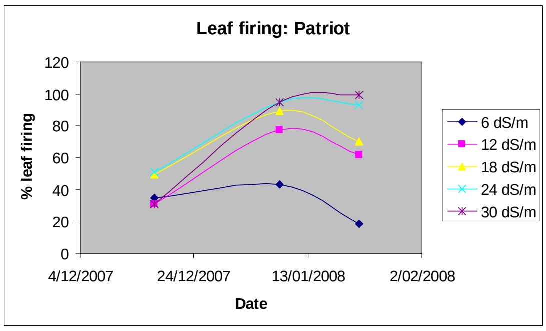


i



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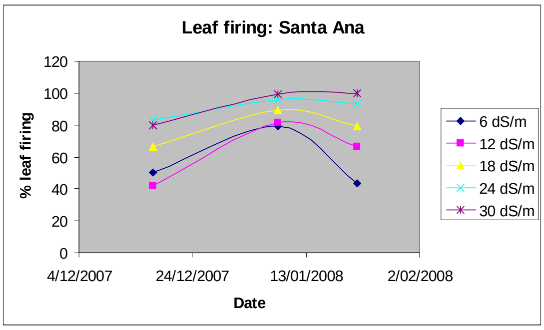
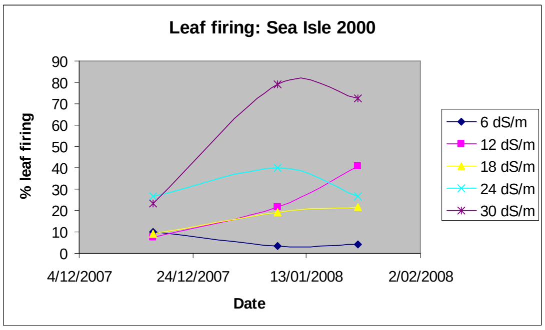
k


Leaf firing: Santa Ana
% leaf firing
Date
6 dS/m
12 dS/m
18 dS/m
24 dS/m
30 dS/m


Leaf firing: Sea Isle 2000
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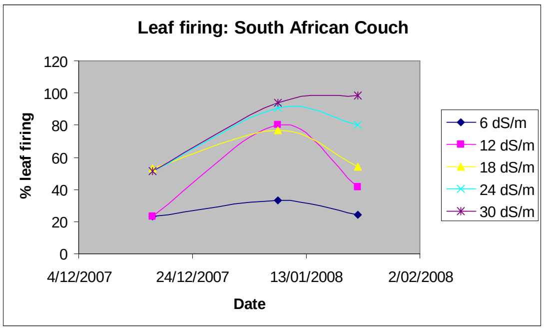
18 dS/m
24 dS/m
30 dS/m

l

m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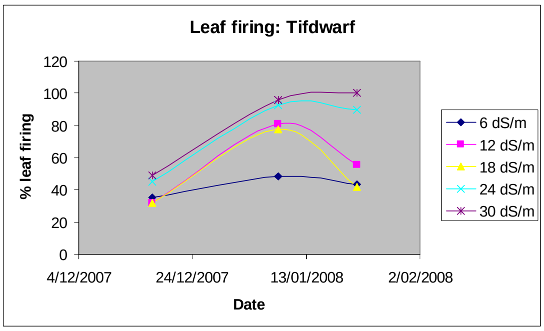
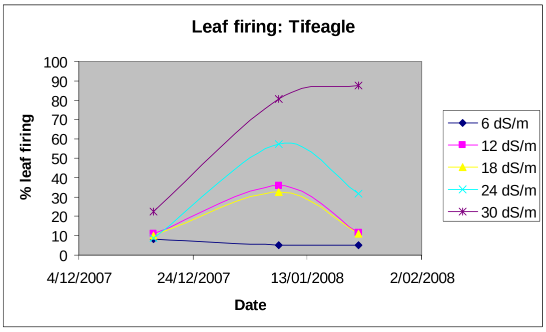
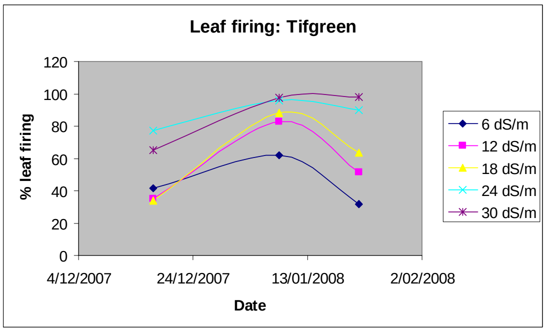
24 dS/m
30 dS/m


Leaf firing: Tifdwarf
% leaf firing
Date
6 dS/m
12 dS/m
18 dS/m
24 dS/m
30 dS/m

n

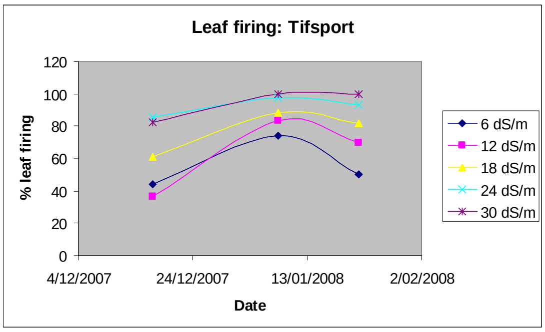
o


Leaf firing: Tifeagle
% leaf firing
Date
6 dS/m
12 dS/m
18 dS/m
24 dS/m
30 dS/m


Leaf firing: Tifgreen
% leaf firing
Date
6 dS/m
12 dS/m
18 dS/m
24 dS/m
30 dS/m

p

q


Leaf firing: Tifsport
% leaf firing
Date
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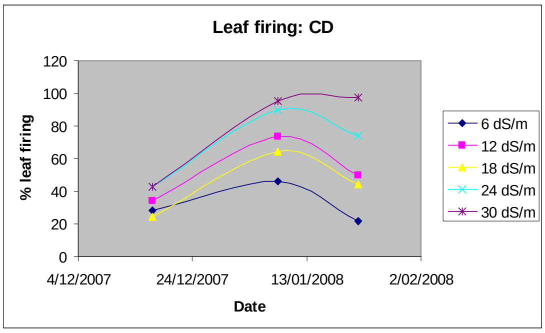
12 dS/m
18 dS/m
24 dS/m
30 dS/m


Leaf firing: CD
% leaf firing
Date
6 dS/m
12 dS/m
18 dS/m
24 dS/m
30 dS/m

16.2 APPENDIX A-2 – Photographic records of visual quality in response to rootzone salinity level.

Cynodon dactylon

[Salinity levels from left to right are: 0.1; 6; 12; 18; 24 and 30 dS/m]

Plate 16-1. FLoraTeX Series one

Plate 16-2. FLoraTeX Series two

Plate 16-3. FLorTeX Series three

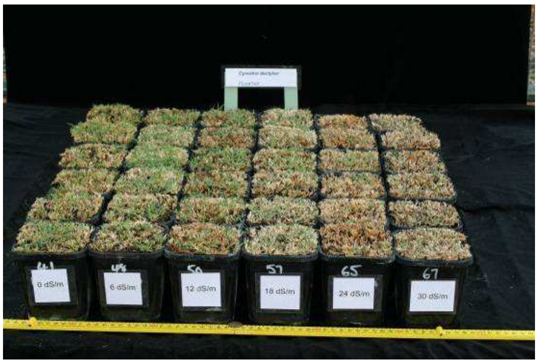


Plate 16-4 FLoraTeX Series four

Plate 16-5. Bosker Series two

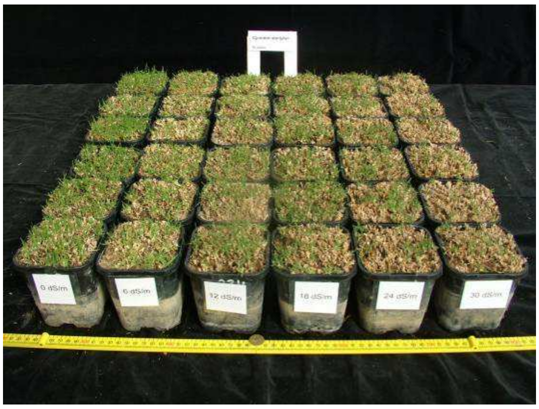


Plate 16-6 Grand Prix Series two

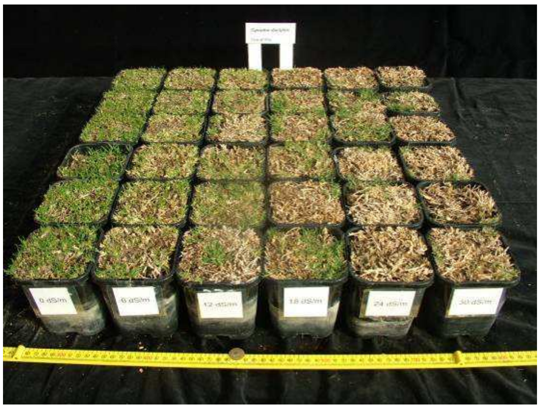


Plate 16-7 Kevin Mitchell's Series two

Plate 16-8 MS Choice Series two

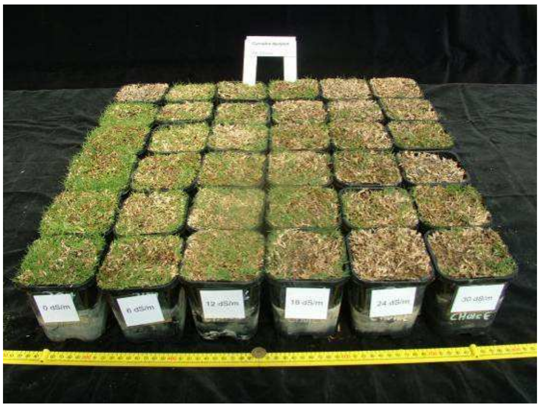


Plate 16-9. MS Express Series two

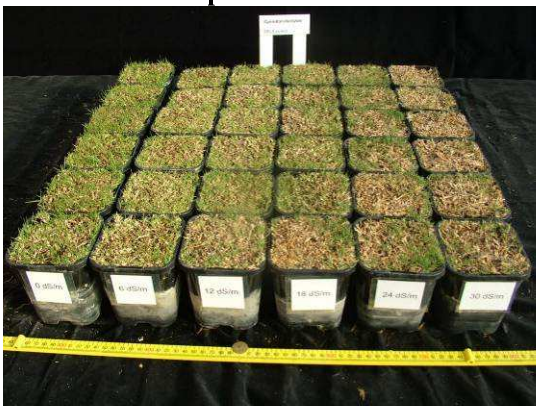


Plate 16-10. MS Pride Series two

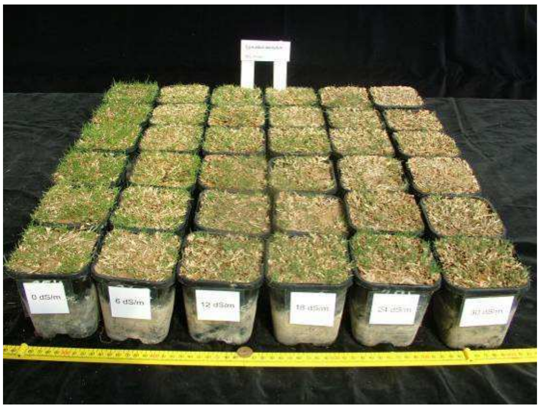


Plate 16-11 Oz-E-Green

Plate 16-12. Premier Series two

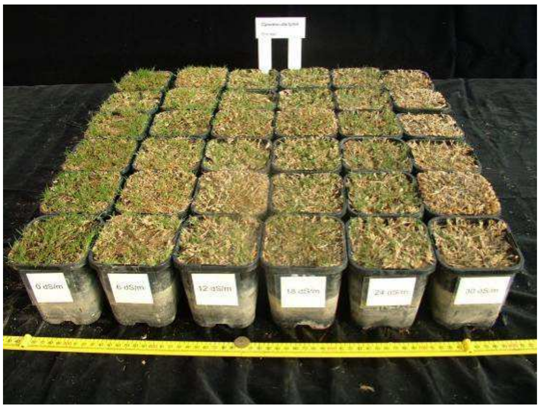


Plate 16-13. Princess

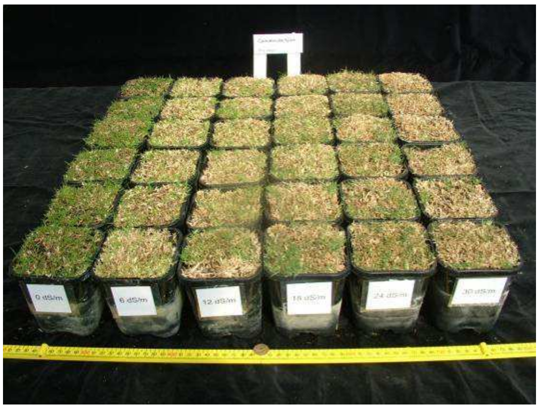


Plate 16-14. Riviera

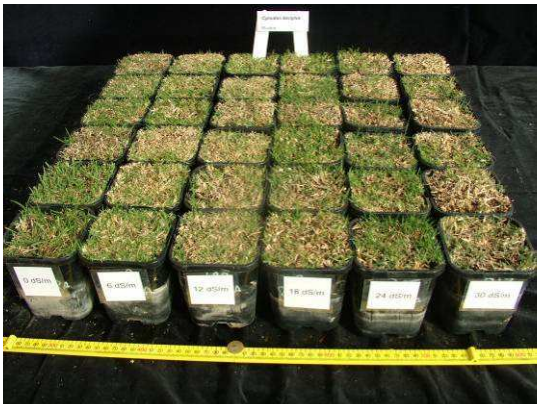


Plate 16-15. Tifton 10 Series two

Plate 16-16. Wintergreen Series two

Cynodon dactylon x transvaalensis
[Salinity levels, from left to right are: 0.; 8; 16; 24; 32 and 40 dS/m]

Plate 16-17. Tifsport Series one

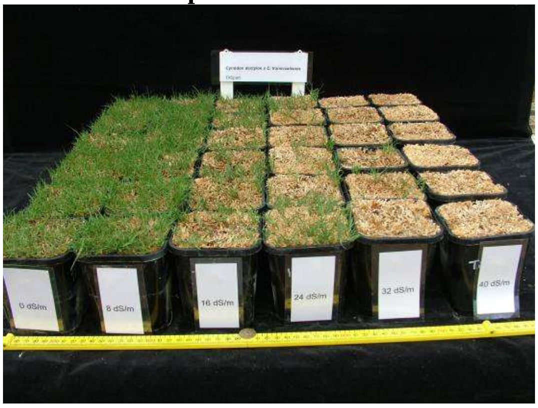


Plate 16-18. Tifgreen Series one

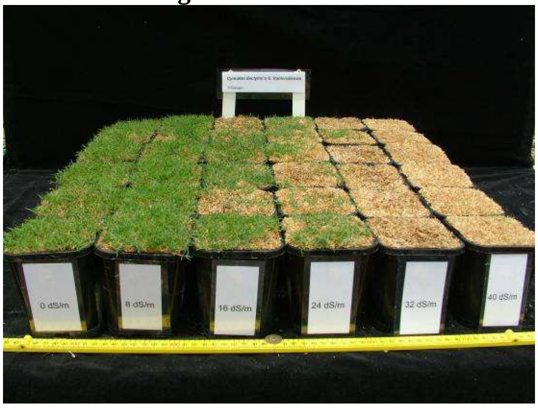


Plate 16-19. Tifdwarf Series one

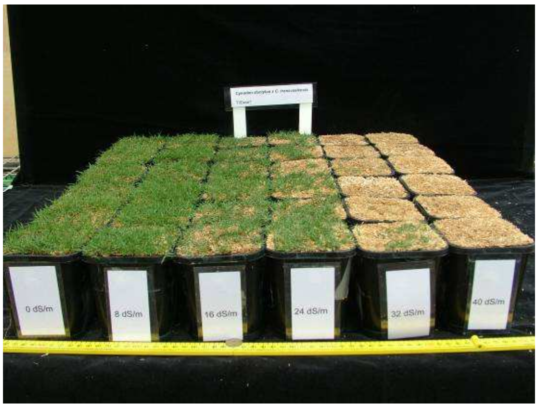


Plate 16-20. TifEagle Series one

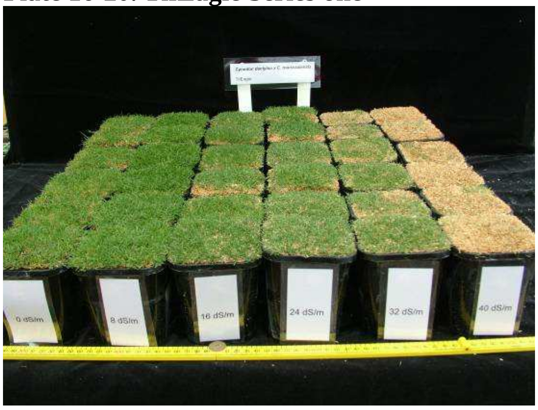


Plate 16-21. MiniVerde Series one

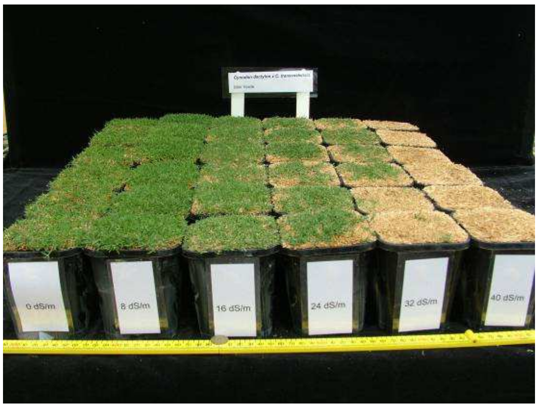


Plate 16-22. Santa Ana Series one

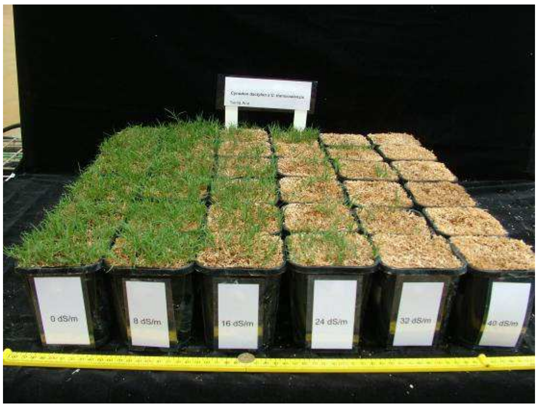


Plate 16-23. Patriot Series one

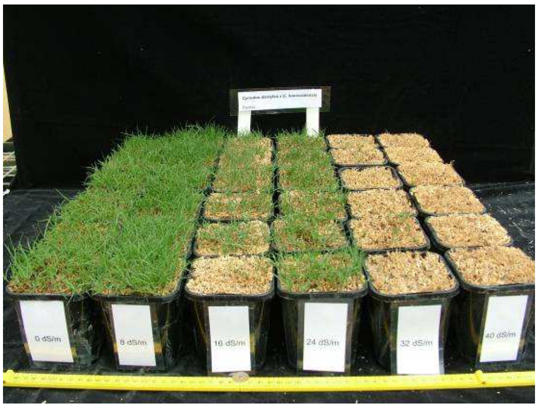


Plate 16-24. Champion Dwarf Series one

Plate 16-25. WS200 Series one

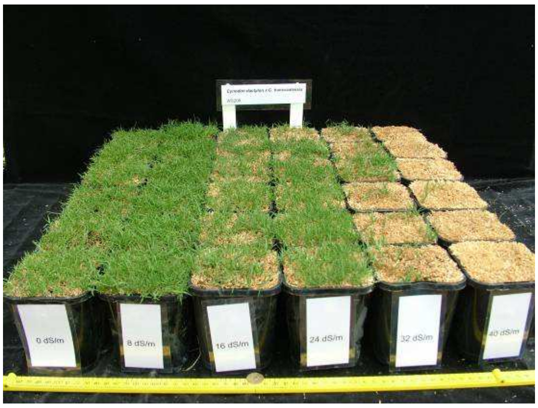


Plate 16-26. Novotek Series one

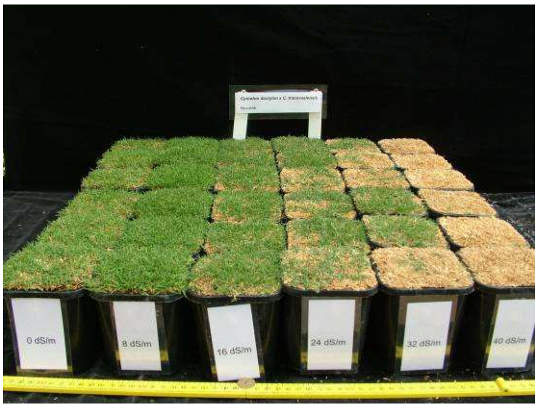


Plate 16-27. FloraDwarf Series one

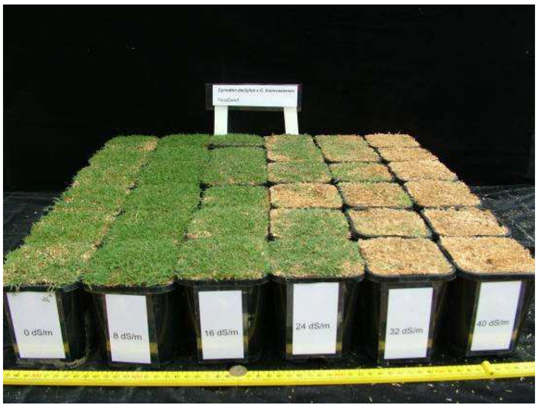


Plate 16-28. MS-Supreme Series one

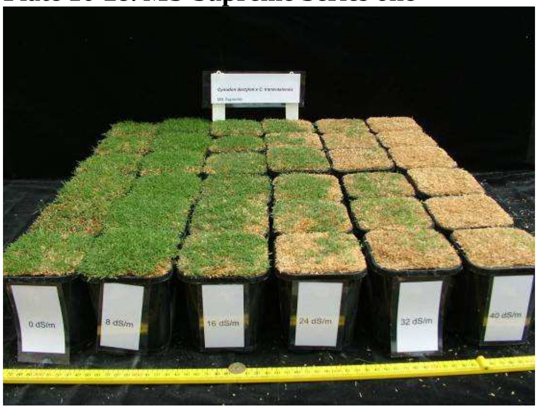
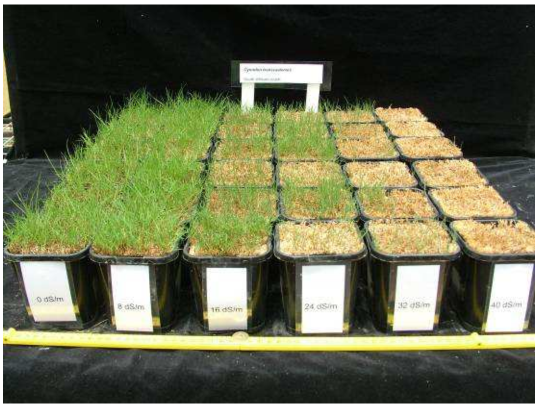


Plate 16-29. AgRiDark Series two

Cynodon transvaalensis

Salinity levels, from left to right are: 0.; 8; 16; 24; 32 and 40 dS/m

Plate 16-30 South African couch



Digitaria didactyla

[Salinity levels from left to right are: 0.1; 6; 12; 18; 24 and 30 dS/m]

Plate 16-31. Aussiblue Series one

Plate 16-32. Aussiblue series two

Plate 16-33 Aussiblue Series three

Plate 16-34. Aussiblue Series four

Paspalum vaginatum:

[Salinity levels, from left to right are: 0.; 8; 16; 24; 32 and 40 dS/m]

Plate 16-35 Sea Isle 2000 Series one

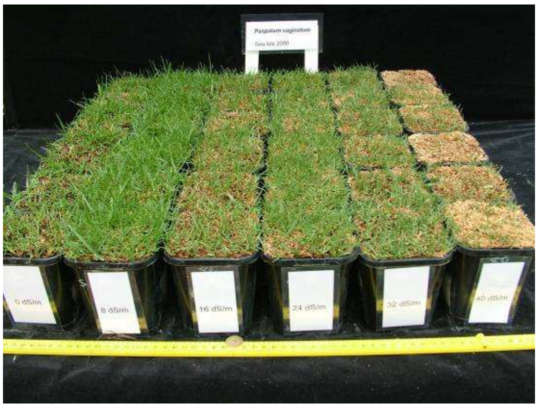


Plate 16-36 Sea Isle 2000 Series two

Plate 16-37. Sea Isle 2000 series three

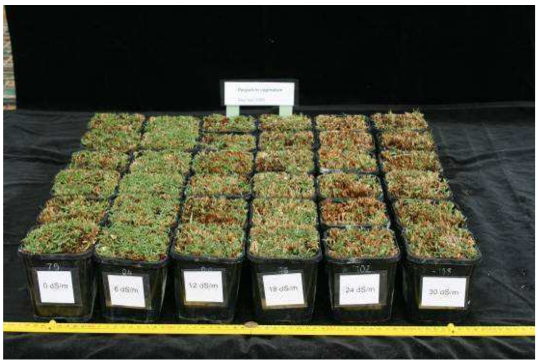


Plate 16-38 Sea Isle 2000 Series four

Plate 16-39 SeaDwarf Series four

Plate 16-40. Neptune Series four

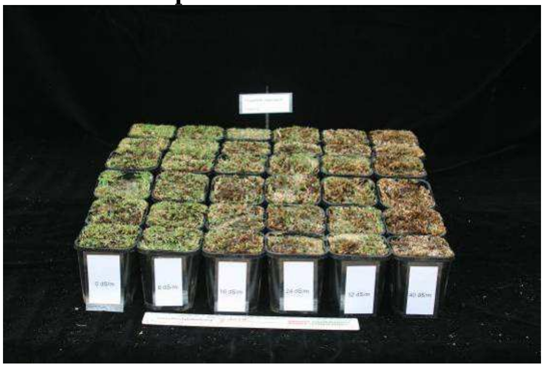


Plate 16-41 Sea Isle Supreme Series four

Plate 16-42. Parrish Series four

Plate 16-43. Sea Spray Series four

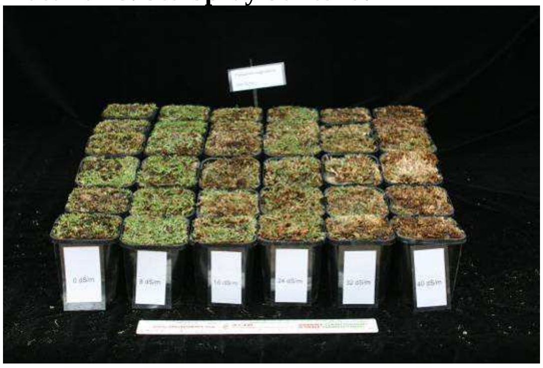


Plate 16-44. Aloha Series four

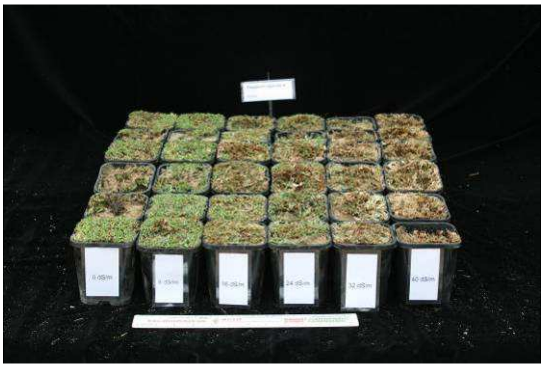


Plate 16-45. Durban Country Club Series four

Plate 16-46. Salam Series four

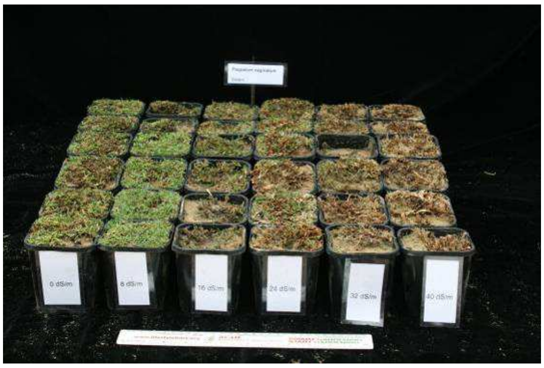


Plate 16-47. Tropic Shore Series four

Plate 16-48. Spence Series four

Sporobolus virginicus:

[Salinity levels, from left to right are: 0.; 8; 16; 24; 32 and 40 dS/m]

Plate 16-49 QLD-Coast Series four

Plate 16-50. Salt fine Series four.

Stenotaphrum secundatum:

[Salinity levels from left to right are: 0.1; 6; 12; 18; 24 and 30 dS/m]

Plate 16-51. EB-2 Series three

Plate 16-52 TF-01. Series three

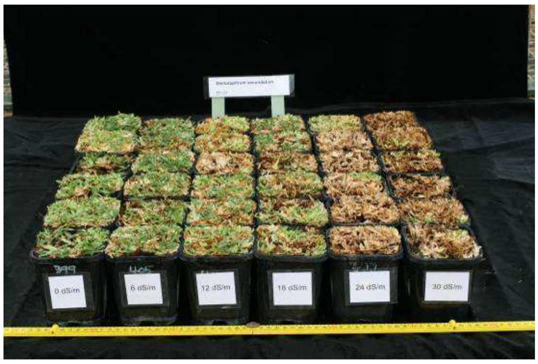


Plate 16-53. Kings Pride Series three.

Plate 16-54. Marine series three.

Plate 16-55. Matilda Series three.

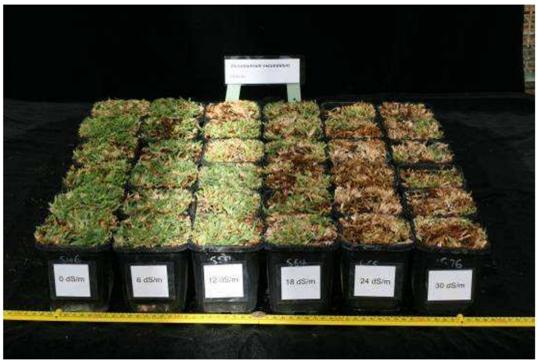


Plate 16-56. Ned Kelly Series three.

Zoysia japonica:

[Salinity levels from left to right are: 0.1; 6; 12; 18; 24 and 30 dS/m]

Plate 16-57. El Toro Series three.

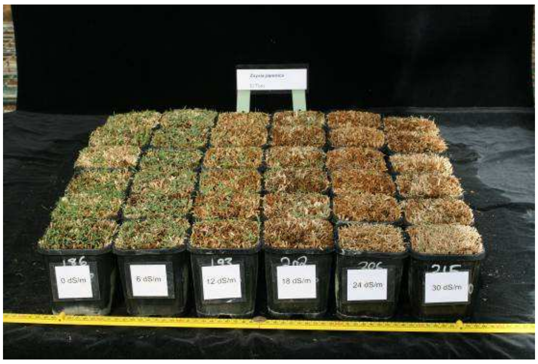


Plate 16-58. Empire Series three.

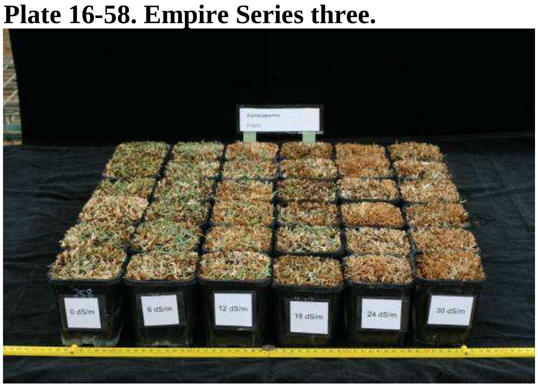
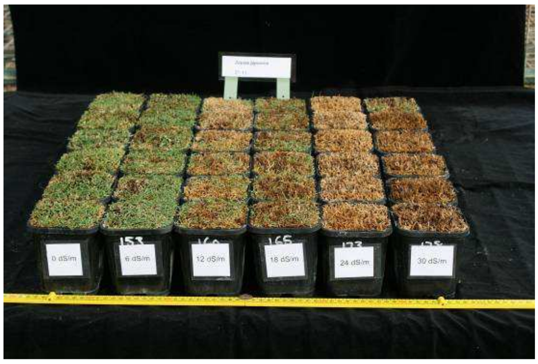


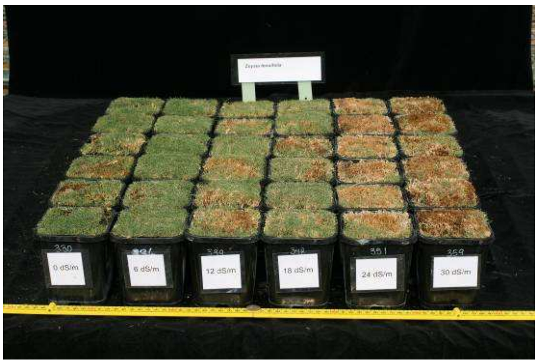
Plate 16-59. Palisades Series three

Plate 16-60. ZT-11 Series three



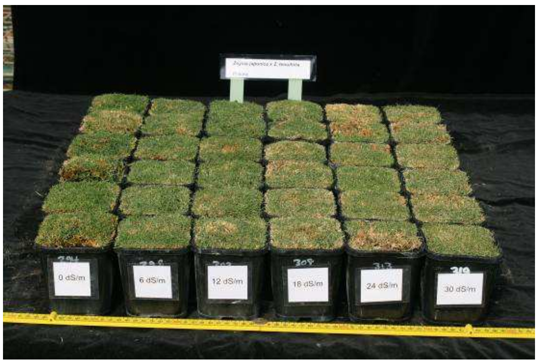
Zoysia tenuifolia:

Plate 16-61. South African couch Series three



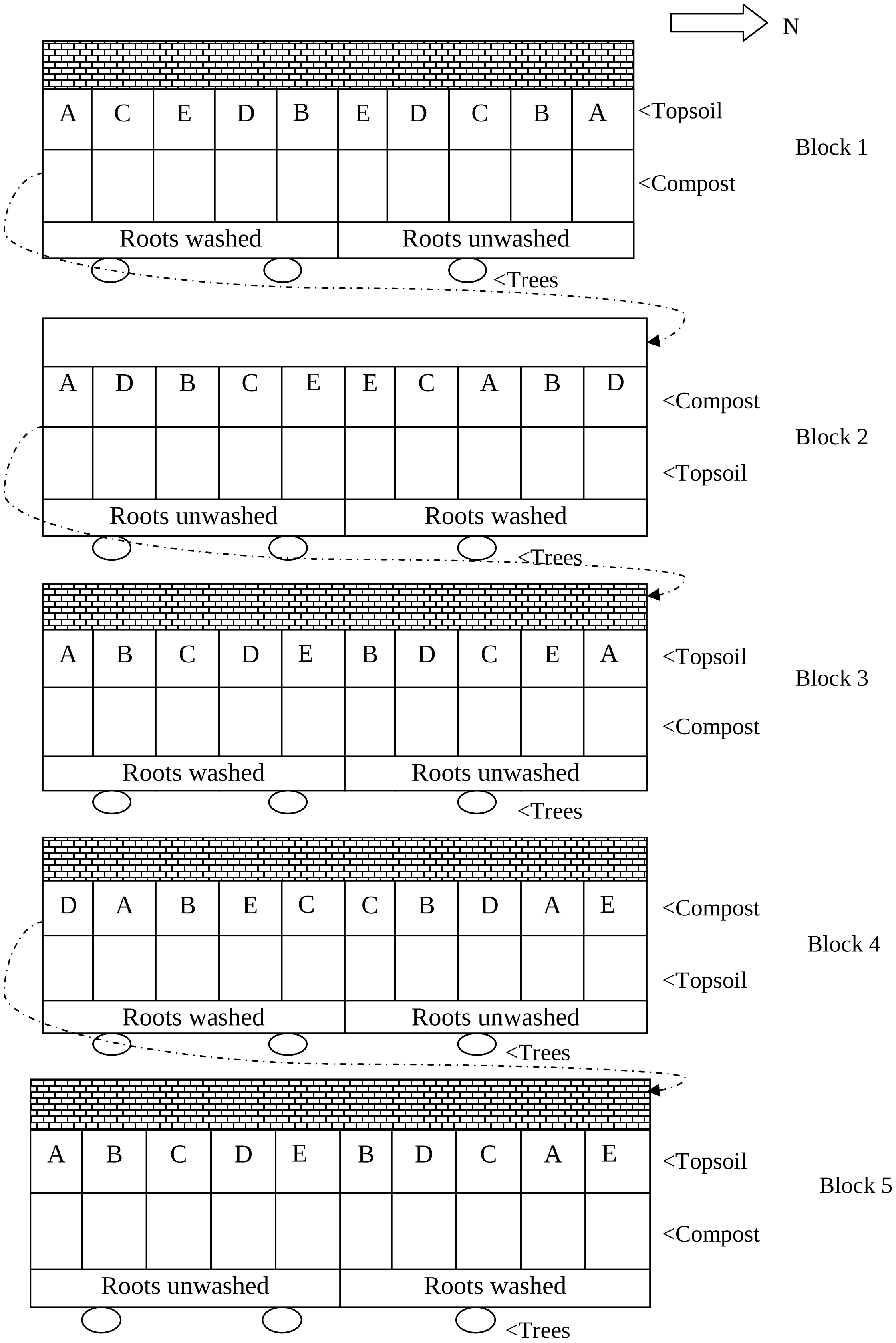
Zoysia japonica x tenuifolia:

Plate 16-62. PristineFlora Series three

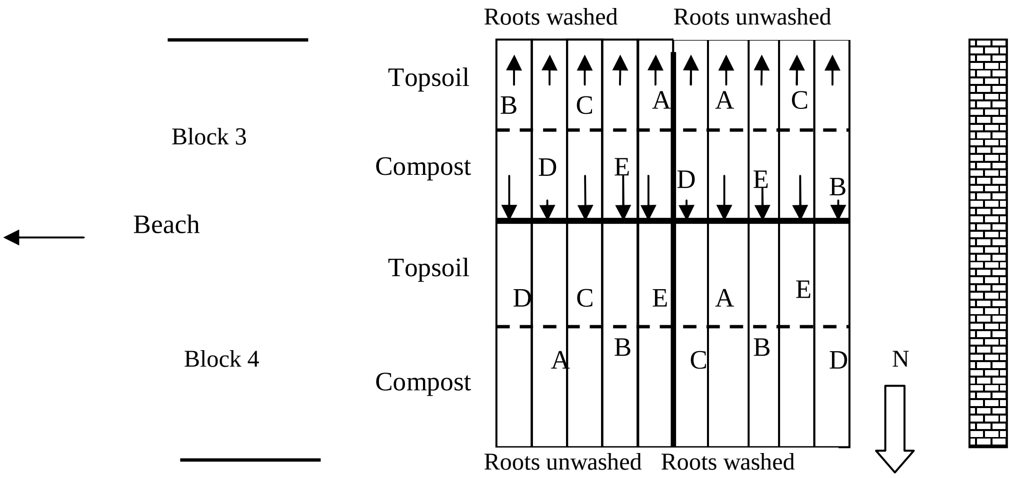


Note: No photographs available for hybrid Zoysia Z-3, and *Z. macrantha* Nara™.

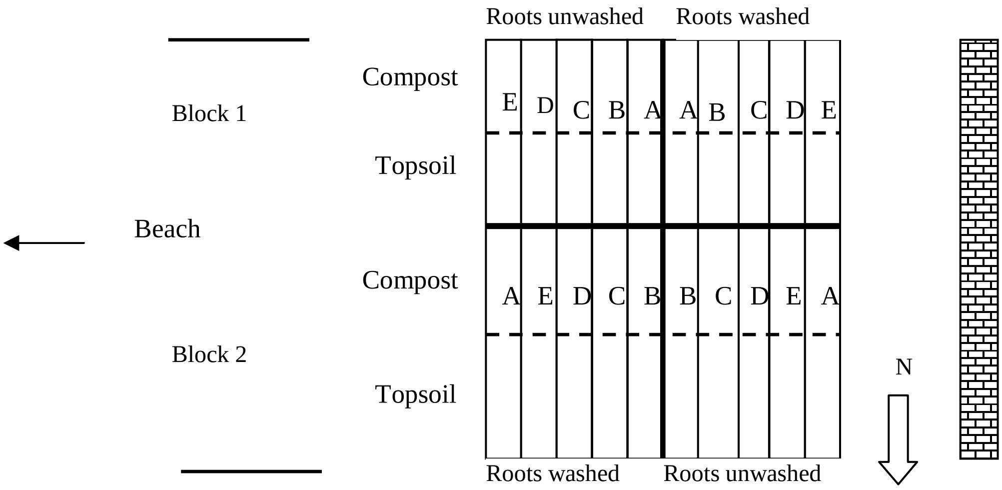
16.3 Appendix B-1 Layout of Gold Coast grass selection trial - pathway



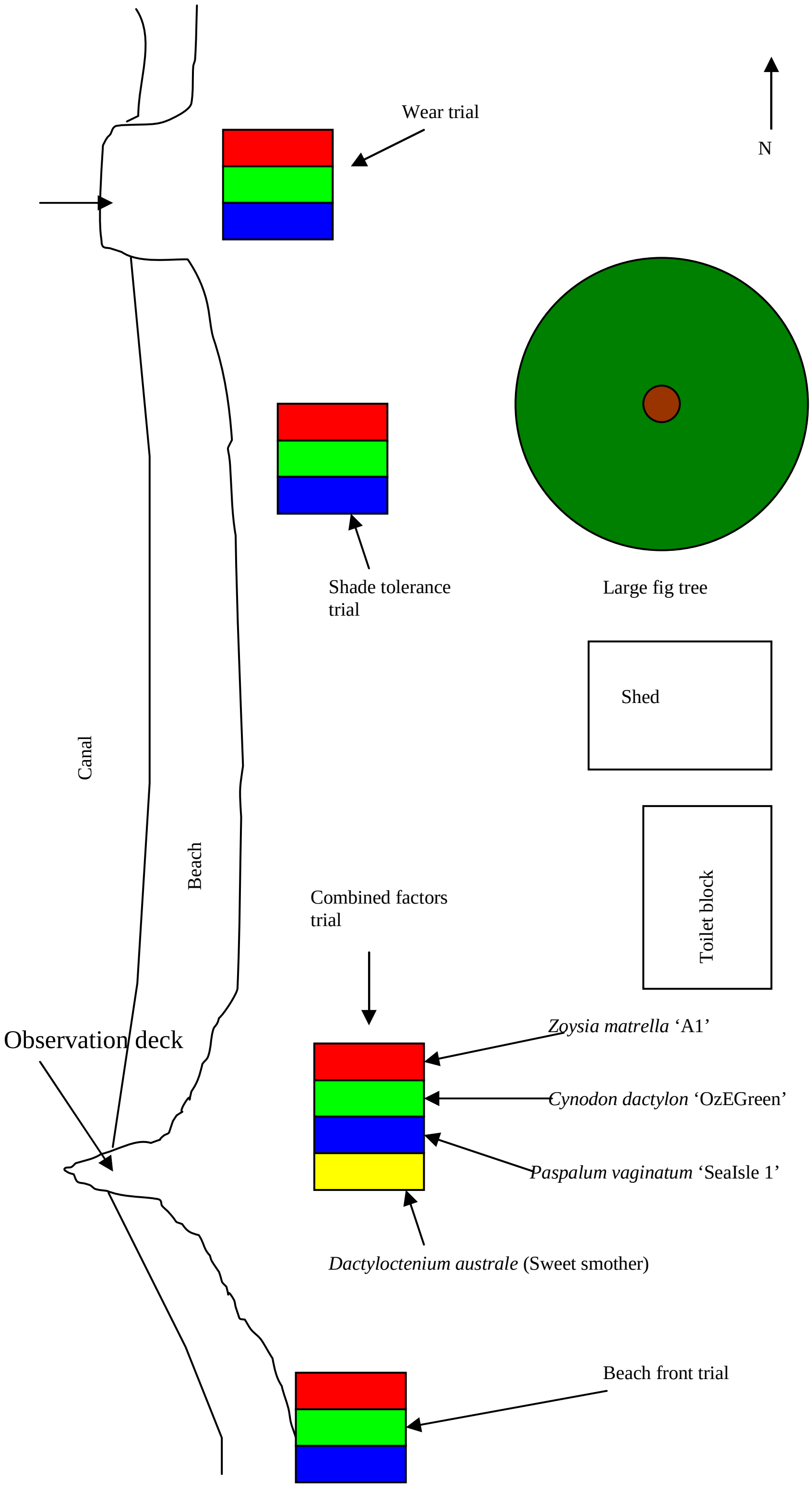
16.4 Appendix B-2 Layout of Gold Coast grass selection trial – beach access



A=Oz-E-Green
B= Sea Isle 1
C=Velvetene
D=*Zoysia matrella*
E=Empire



16.5 Appendix B-3 Layout of Gold Coast grass selection trial – Budd's Beach



16.6 Appendix B-4 Layout of Gold Coast grass selection trial – Hollindale Park

Trial Area: Elevated with high shade

← N

Sea Isle 1	A-1 Zoysia	Oz-E-Green	A-1 Zoysia	Oz-E-Green	Sea Isle 1	Sea Isle 1	A-1 Zoysia	Oz-E-Green
Block 1			Block 2			Block 3		

Demonstration area 1 – Northern tree

Oz-E-Green	A-1 Zoysia	Sea Isle 1

Demonstration area 2 – Southern tree

Sea Isle 1	Oz-E-Green	A-1 Zoysia

16.7 Appendix C-1 Turfgrass ratings – fertility trial

Table 16-1 Effect of fertiliser N rate on turf quality ratings on irrigated swards of six warm-season turfgrasses grown on a yellow Kurosol soil at Cleveland, Queensland.

Date	Turfgrass	Kg N/Ha/year						LSD
		0	50	100	200	300	400	
23-Aug-06	Aussiblue	7.00	7.25	7.50	8.13	8.33	9.00	0.56
	FLoraTeX	5.00	5.38	6.00	6.50	7.00	7.38	0.61
	Kikuyu	6.13	6.63	7.13	8.00	8.13	8.63	0.59
	Sea Isle 1	6.00	6.13	6.75	7.50	8.13	8.50	0.71
	Sir Walter	6.75	6.88	7.75	8.50	8.75	9.00	1.04
	Wintergreen	4.75	5.00	5.62	6.50	6.75	7.00	0.89
13-Sep-06	Aussiblue	6.25	6.38	6.88	7.33	7.83	7.83	0.45
	FLoraTeX	3.75	4.13	4.88	5.38	5.75	6.00	0.44
	Kikuyu	5.25	6.00	6.63	7.55	7.65	8.00	0.57
	Sea Isle 1	4.50	5.63	5.95	6.75	7.63	8.00	0.59
	Sir Walter	6.33	6.63	7.38	8.13	8.50	8.58	0.53
	Wintergreen	4.00	4.88	5.25	5.75	5.93	6.20	0.39
27-Sep-06	Aussiblue	6.38	6.88	7.58	8.33	8.95	9.00	0.52
	FLoraTeX	4.50	5.50	6.33	6.83	7.08	7.33	0.53
	Kikuyu	5.30	6.2	6.90	7.60	8.20	8.40	0.50
	Sea Isle 1	4.75	5.75	6.38	7.15	8.15	8.58	0.56
	Sir Walter	6.25	6.83	7.45	8.25	8.90	8.90	0.43
	Wintergreen	4.50	5.00	5.50	6.38	7.00	7.30	0.59
11-Oct-06	Aussiblue	6.75	7.33	7.83	8.40	9.00	9.00	0.45
	FLoraTeX	5.50	6.20	6.78	8.00	8.70	8.70	0.32
	Kikuyu	5.75	6.45	7.00	8.05	8.78	8.95	0.51
	Sea Isle 1	5.88	6.45	7.33	8.13	9.00	9.00	0.34
	Sir Walter	6.28	6.83	7.70	8.45	8.88	8.88	0.36
	Wintergreen	5.13	5.88	6.50	7.03	8.08	8.45	0.49
25-Oct-06	Aussiblue	6.50	6.75	7.53	8.25	8.95	9.00	0.35
	FLoraTeX	4.50	5.50	6.00	6.53	7.38	7.75	0.52
	Kikuyu	5.00	5.88	6.50	7.25	7.58	7.88	0.38
	Sea Isle 1	6.45	7.05	7.70	8.18	8.90	8.95	0.31
	Sir Walter	6.45	7.05	7.70	8.18	8.90	8.95	0.31
	Wintergreen	4.63	5.45	5.93	6.53	7.45	7.95	0.34
8-Nov-06	Aussiblue	6.13	6.70	7.40	7.83	8.18	8.38	0.32
	FLoraTeX	5.08	5.75	6.53	6.88	7.53	7.90	0.45
	Kikuyu	5.25	6.25	7.00	7.38	7.80	8.13	0.61
	Sea Isle 1	5.80	6.85	7.25	8.65	8.90	9.00	0.43

Date	Turfgrass	Kg N/Ha/year						LSD
		0	50	100	200	300	400	
	Sir Walter	6.58	7.33	7.90	8.18	8.70	8.75	0.41
	Wintergreen	4.70	5.43	6.08	6.45	6.90	7.33	0.51
24-Nov-06	Aussiblue	6.13	7.00	7.38	7.55	8.08	8.08	0.36
	FLoraTeX	5.13	6.00	6.45	6.88	7.18	7.45	0.42
	Kikuyu	5.58	6.25	6.88	7.28	7.68	8.00	0.52
	Sea Isle 1	6.13	7.20	7.63	8.73	8.90	9.00	0.53
	Sir Walter	6.13	7.25	7.70	7.88	8.45	8.63	0.41
	Wintergreen	5.20	5.58	6.00	6.65	7.00	7.30	0.56
6-Dec-06	Aussiblue	6.83	7.13	7.58	7.85	8.08	8.08	0.15
	FLoraTeX	5.13	5.75	6.00	6.75	7.05	7.25	0.61
	Kikuyu	5.83	6.38	7.00	7.45	7.58	7.83	0.38
	Sea Isle 1	6.50	7.33	7.95	8.80	9.00	9.00	0.48
	Sir Walter	6.25	6.88	7.58	7.88	8.20	8.45	0.42
	Wintergreen	4.70	5.25	5.75	6.58	7.08	7.28	0.44
20-Dec-06	Aussiblue	6.58	6.90	7.15	7.58	7.70	7.75	0.20
	FLoraTeX	5.13	5.38	5.65	5.73	5.90	5.95	0.32
	Kikuyu	5.65	5.90	6.08	6.13	6.50	6.63	0.46
	Sea Isle 1	5.73	6.25	6.78	7.90	8.13	8.25	0.37
	Sir Walter	5.78	6.15	6.70	7.25	7.33	7.45	0.60
	Wintergreen	4.95	5.15	5.53	5.73	6.08	6.13	0.29
17-Jan-07	Aussiblue	6.45	6.50	6.73	7.00	7.15	7.38	0.25
	FLoraTeX	5.08	5.18	5.43	5.58	5.78	6.00	0.32
	Kikuyu	5.55	5.63	6.03	6.15	6.40	6.68	0.47
	Sea Isle 1	5.43	5.65	6.23	7.03	7.45	7.53	0.83
	Sir Walter	6.13	6.35	6.65	6.95	7.35	7.53	0.53
	Wintergreen	4.93	5.13	5.45	5.38	5.63	5.68	0.31

Table 16-2. Effect of fertiliser N rate on turf density ratings on irrigated swards of six warm-season turfgrasses grown on a yellow Kurosol soil at Cleveland, Queensland.

Date	Turfgrass	Kg N/Ha/year						LSD
		0	50	100	200	300	400	
23-Aug-06	Aussiblue	6.88	7.13	7.88	8.50	8.25	9.00	0.47
	FLoraTeX	5.13	5.38	6.00	6.50	7.00	7.38	0.68
	Kikuyu	6.13	6.50	7.13	8.13	8.00	8.75	0.61
	Sea Isle 1	5.63	6.25	6.88	7.75	8.13	8.63	0.40
	Sir Walter	6.50	6.75	7.75	8.50	8.62	9.00	0.86
	Wintergreen	4.75	5.12	5.62	6.50	6.88	7.12	0.86
13-Sep-06	Aussiblue	6.13	6.38	6.88	7.33	7.75	7.75	0.48
	FLoraTeX	3.75	4.00	4.88	5.25	5.75	6.00	0.46

Date	Turfgrass	Kg N/Ha/year						LSD
		0	50	100	200	300	400	
	Kikuyu	5.25	5.63	6.63	7.55	7.65	7.93	0.60
	Sea Isle 1	4.25	5.50	5.95	6.70	7.75	8.07	0.81
	Sir Walter	6.45	6.75	7.38	8.13	8.63	8.70	0.41
	Wintergreen	4.00	4.63	5.25	5.50	5.93	6.08	0.41
27-Sep-06	Aussiblue	6.38	6.88	7.58	8.33	8.95	9.00	0.52
	FLoraTeX	4.50	5.50	6.33	6.75	7.08	7.33	0.54
	Kikuyu	5.00	6.38	6.93	7.63	8.20	8.40	0.63
	Sea Isle 1	4.75	5.75	6.38	7.15	8.15	8.58	0.56
	Sir Walter	6.25	6.83	7.45	8.25	8.90	8.90	0.43
	Wintergreen	4.25	5.00	5.50	6.13	7.00	7.30	0.63
11-Oct-06	Aussiblue	6.75	7.33	7.83	8.40	9.00	9.00	0.45
	FLoraTeX	5.38	6.00	6.65	7.50	8.38	8.38	0.43
	Kikuyu	5.75	6.33	6.88	8.05	8.78	8.95	0.53
	Sea Isle 1	5.88	6.45	7.33	8.13	9.00	9.00	0.34
	Sir Walter	6.28	6.83	7.70	8.45	8.88	8.95	0.39
	Wintergreen	5.13	5.88	6.38	7.03	8.03	8.45	0.52
25-Oct-06	Aussiblue	6.50	6.75	7.53	8.45	8.75	9.00	0.50
	FLoraTeX	4.25	5.25	5.88	6.45	7.25	7.75	0.54
	Kikuyu	5.00	5.88	6.50	7.25	7.58	7.88	0.38
	Sea Isle 1	5.88	6.50	7.25	8.53	8.90	9.00	0.57
	Sir Walter	6.45	7.00	7.70	8.18	8.90	8.95	0.29
	Wintergreen	4.63	5.45	5.93	6.53	7.45	7.95	0.34
8-Nov-06	Aussiblue	6.13	6.70	7.40	7.83	8.18	8.38	0.32
	FLoraTeX	5.08	5.75	6.53	6.88	7.53	7.90	0.45
	Kikuyu	5.25	6.25	7.00	7.33	7.80	8.00	0.55
	Sea Isle 1	5.80	6.85	7.25	8.65	8.90	9.00	0.43
	Sir Walter	6.58	7.33	7.90	8.18	8.70	8.75	0.41
	Wintergreen	4.70	5.43	6.08	6.45	6.90	7.33	0.51
24-Nov-06	Aussiblue	6.25	6.95	7.13	7.55	8.00	8.08	0.37
	FLoraTeX	5.00	6.00	6.33	6.70	7.00	7.53	0.51
	Kikuyu	5.33	6.00	6.58	7.13	7.63	7.83	0.59
	Sea Isle 1	6.00	7.00	7.50	8.65	8.90	9.00	0.61
	Sir Walter	5.88	7.00	7.58	7.75	8.25	8.50	0.45
	Wintergreen	4.95	5.50	6.13	6.53	6.95	7.30	0.57
6-Dec-06	Aussiblue	6.63	7.00	7.33	7.85	8.00	8.08	0.28
	FLoraTeX	5.00	5.50	6.13	6.78	6.80	7.25	0.51
	Kikuyu	5.45	6.00	6.95	7.25	7.50	7.75	0.53
	Sea Isle 1	6.25	7.08	7.78	8.65	9.00	9.00	0.68

Date	Turfgrass	Kg N/Ha/year						LSD
		0	50	100	200	300	400	
	Sir Walter	6.13	6.75	7.45	7.75	8.08	8.38	0.55
	Wintergreen	4.70	5.25	5.88	6.45	6.88	7.08	0.53
20-Dec-06	Aussiblue	6.50	6.78	7.15	7.58	7.75	7.75	0.22
	FLoraTeX	5.08	5.50	6.03	6.40	6.83	6.95	0.61
	Kikuyu	5.53	5.90	5.90	6.20	6.58	7.00	0.52
	Sea Isle 1	5.75	6.50	7.13	8.20	8.38	8.50	0.70
	Sir Walter	6.08	6.38	7.08	7.63	7.75	8.00	0.58
	Wintergreen	5.03	5.15	5.70	5.90	6.53	6.63	0.34
17-Jan-07	Aussiblue	6.33	6.50	6.78	7.00	7.15	7.38	0.27
	FLoraTeX	5.08	5.18	5.43	5.50	5.78	6.00	0.31
	Kikuyu	5.48	5.55	6.03	6.15	6.40	6.63	0.41
	Sea Isle 1	5.48	5.73	6.23	7.10	7.45	7.40	0.81
	Sir Walter	6.13	6.35	6.70	6.95	7.35	7.53	0.54
	Wintergreen	4.88	5.05	5.45	5.38	5.58	5.68	0.35

Table 16-3. Effect of fertiliser N rate on turf colour ratings on irrigated swards of six warm-season turfgrasses grown on a yellow Kurosol soil at Cleveland, Queensland.

Date	Turfgrass	Kg N/Ha/year						LSD
		0	50	100	200	300	400	
23-Aug-06	Aussiblue	7.00	7.38	7.75	8.50	8.20	8.88	0.45
	FLoraTeX	5.13	5.58	6.08	6.50	7.00	7.38	0.36
	Kikuyu	6.50	6.88	7.25	8.08	8.13	8.75	0.63
	Sea Isle 1	6.25	6.50	7.00	7.75	8.40	8.75	0.47
	Sir Walter	6.63	7.13	8.00	8.58	8.75	9.00	0.47
	Wintergreen	5.00	5.38	5.75	6.50	7.13	7.38	0.62
13-Sep-06	Aussiblue	6.13	6.75	7.13	7.38	7.70	7.70	0.35
	FLoraTeX	4.25	4.88	5.63	5.88	6.25	6.38	0.43
	Kikuyu	5.88	6.75	7.13	7.78	7.75	8.05	0.47
	Sea Isle 1	5.13	5.95	6.63	7.50	8.18	8.58	0.55
	Sir Walter	6.38	6.75	7.63	8.00	8.50	8.38	0.34
	Wintergreen	4.25	4.88	5.38	5.88	6.50	6.38	0.57
27-Sep-06	Aussiblue	6.13	6.63	7.95	8.53	9.00	9.00	0.51
	FLoraTeX	4.75	5.88	6.80	7.35	7.63	7.88	0.59
	Kikuyu	6.00	6.50	7.00	8.13	8.83	9.00	0.43
	Sea Isle 1	5.25	6.45	6.83	7.75	8.58	9.00	0.60
	Sir Walter	6.25	6.70	7.65	8.33	8.90	8.95	0.45
	Wintergreen	4.50	5.25	6.25	7.00	7.38	7.70	0.63
11-Oct-06	Aussiblue	6.63	7.33	7.83	8.40	9.00	9.00	0.48
	FLoraTeX	5.63	6.50	7.40	8.00	8.58	8.58	0.73

Date	Turfgrass	Kg N/Ha/year						LSD
		0	50	100	200	300	400	
	Kikuyu	6.13	6.58	7.20	8.13	8.95	9.00	0.39
	Sea Isle 1	6.25	6.83	7.63	8.63	9.00	9.00	0.65
	Sir Walter	6.40	6.83	7.70	8.65	9.00	9.00	0.44
	Wintergreen	5.25	6.00	6.75	7.45	8.28	8.58	0.69
25-Oct-06	Aussiblue	6.25	6.68	7.20	8.08	8.95	9.00	0.35
	FLoraTeX	5.00	5.88	6.38	6.90	7.63	7.93	0.34
	Kikuyu	5.50	6.38	6.65	7.30	7.78	8.13	0.52
	Sea Isle 1	6.38	7.25	7.75	8.45	8.90	9.00	0.30
	Sir Walter	6.50	6.90	7.63	8.25	8.83	8.95	0.34
	Wintergreen	4.63	5.38	6.13	6.83	8.00	8.20	0.33
8-Nov-06	Aussiblue	6.20	6.73	7.08	7.83	8.25	8.25	0.21
	FLoraTeX	6.58	7.28	7.70	8.33	8.90	8.95	0.38
	Kikuyu	6.25	6.88	7.13	7.50	8.18	8.38	0.59
	Sea Isle 1	6.40	7.45	8.13	8.73	8.90	9.00	0.53
	Sir Walter	6.58	7.28	7.70	8.33	8.90	8.95	0.38
	Wintergreen	5.33	5.80	6.33	6.58	7.25	7.70	0.39
24-Nov-06	Aussiblue	6.63	6.95	7.33	7.70	8.08	8.13	0.26
	FLoraTeX	5.63	6.25	6.70	7.10	7.58	7.65	0.17
	Kikuyu	6.03	6.55	6.93	7.33	7.88	8.13	0.41
	Sea Isle 1	6.65	7.20	8.13	8.80	9.00	9.00	0.62
	Sir Walter	6.50	6.88	7.63	8.13	8.58	8.63	0.31
	Wintergreen	5.50	5.95	6.50	6.85	7.53	7.63	0.54
6-Dec-06	Aussiblue	6.95	7.25	7.65	7.90	8.08	8.08	0.17
	FLoraTeX	5.38	5.63	6.20	6.88	7.33	7.38	0.42
	Kikuyu	6.25	6.50	7.03	7.40	7.83	8.08	0.30
	Sea Isle 1	6.70	7.28	8.20	8.85	9.00	9.00	0.58
	Sir Walter	6.58	6.95	7.70	8.08	8.38	8.73	0.43
	Wintergreen	5.25	5.70	6.20	6.78	7.08	7.33	0.22
20-Dec-06	Aussiblue	6.85	7.13	7.13	7.13	7.13	7.13	0.09
	FLoraTeX	5.10	5.23	5.45	5.65	5.90	5.85	0.20
	Kikuyu	5.65	5.78	5.95	6.03	6.08	6.20	0.25
	Sea Isle 1	5.58	6.20	7.08	7.83	8.08	8.08	0.38
	Sir Walter	5.80	6.10	6.53	7.00	7.13	7.75	0.76
	Wintergreen	4.95	5.15	5.33	5.40	5.70	5.78	0.26
17-Jan-07	Aussiblue	6.65	6.65	6.78	7.00	7.18	7.45	0.19
	FLoraTeX	5.30	5.38	5.50	5.50	5.78	6.00	0.38
	Kikuyu	6.25	6.25	6.40	6.45	6.75	7.03	0.35
	Sea Isle 1	5.73	6.00	6.35	7.08	7.48	7.60	0.69

Date	Turfgrass	Kg N/Ha/year						LSD
		0	50	100	200	300	400	
	Sir Walter	6.13	6.30	6.50	6.90	7.23	7.38	0.36
	Wintergreen	5.20	5.30	5.50	5.55	5.88	6.03	0.16

Table 16-4. Effect of fertiliser N rate on percentage weed invasion in irrigated swards of six warm-season turfgrasses grown on a yellow Kurosol soil at Cleveland, Queensland.

Date	Turfgrass	Kg N/Ha/year						LSD
		0	50	100	200	300	400	
23-Aug-06	Aussiblue	0.00	0.00	0.00	0.00	0.00	0.00	*
	FLoraTeX	1.25	0.00	5.00	1.25	6.25	0.00	6.81
	Kikuyu	8.00	11.25	6.25	11.25	4.25	6.25	10.11
	Sea Isle 1	0.50	1.25	0.00	3.75	3.75	1.25	4.81
	Sir Walter	0.00	0.00	0.00	0.00	8.75	0.00	10.77
	Wintergreen	6.25	5.00	6.75	7.50	10.00	3.75	12.48
13-Sep-06	Aussiblue	0.00	0.00	0.00	0.00	0.00	0.00	*
	FLoraTeX	1.75	1.25	2.50	2.50	11.25	5.50	7.41
	Kikuyu	15.00	3.75	10.00	10.00	6.25	2.50	11.94
	Sea Isle 1	3.00	0.75	0.75	0.00	3.50	0.50	3.40
	Sir Walter	0.00	0.00	0.00	2.50	7.50	0.00	9.92
	Wintergreen	13.75	13.75	11.75	11.25	11.25	0.50	20.53
27-Sep-06	Aussiblue	0.00	0.00	0.00	0.00	0.00	0.00	*
	FLoraTeX	1.50	1.25	2.50	1.50	6.25	2.50	6.10
	Kikuyu	11.25	4.00	7.50	12.50	5.25	2.75	11.74
	Sea Isle 1	1.25	1.25	0.50	0.25	3.25	0.25	2.72
	Sir Walter	0.25	1.25	0.00	2.50	2.50	0.00	4.65
	Wintergreen	6.25	7.50	10.00	13.75	9.75	1.50	16.08
11-Oct-06	Aussiblue	0.00	0.00	0.00	0.00	0.00	0.00	*
	FLoraTeX	0.00	0.00	0.00	0.00	5.00	1.25	3.71
	Kikuyu	3.75	2.75	7.50	11.25	1.25	0.00	6.73
	Sea Isle 1	0.00	0.00	0.00	0.00	0.00	0.00	*
	Sir Walter	0.00	0.00	0.00	2.50	0.00	0.00	3.08
	Wintergreen	1.25	10.00	10.00	8.75	5.00	1.25	17.38
25-Oct-06	Aussiblue	0.00	0.00	0.00	0.00	0.00	0.00	*
	FLoraTeX	2.50	0.00	2.50	1.25	11.25	5.00	10.05
	Kikuyu	22.50	20.00	32.50	25.00	11.25	2.50	19.32
	Sea Isle 1	0.00	0.00	0.00	0.00	0.00	0.00	*
	Sir Walter	0.00	0.00	0.00	1.25	0.00	0.00	1.54
	Wintergreen	13.75	11.25	16.25	16.25	13.75	6.25	24.74
8-Nov-06	Aussiblue	0.00	0.00	0.00	0.00	0.00	0.00	*
	FLoraTeX	0.00	0.00	2.50	1.25	7.50	3.75	6.20

Date	Turfgrass	Kg N/Ha/year						LSD
		0	50	100	200	300	400	
	Kikuyu	15.00	12.50	22.50	15.00	0.00	2.50	14.45
	Sea Isle 1	0.00	0.00	0.00	0.00	0.00	0.00	*
	Sir Walter	0.00	0.00	0.00	2.50	0.00	0.00	3.08
	Wintergreen	2.50	7.50	10.00	12.50	13.75	2.50	17.76
24-Nov-06	Aussiblue	0.00	0.00	0.00	0.00	0.00	0.00	*
	FLoraTeX	0.00	0.00	3.75	2.50	7.50	3.75	6.93
	Kikuyu	15.00	11.25	26.25	16.25	1.25	2.50	14.23
	Sea Isle 1	0.00	0.00	0.00	0.00	0.00	0.00	*
	Sir Walter	0.00	0.00	0.00	0.00	0.00	0.00	*
	Wintergreen	10.00	10.00	8.75	13.75	17.50	2.50	19.84
6-Dec-06	Aussiblue	0.00	0.00	0.00	0.00	0.00	0.00	*
	FLoraTeX	0.00	0.00	3.75	2.50	7.50	3.75	6.93
	Kikuyu	15.00	11.25	25.00	15.00	1.25	2.50	14.97
	Sea Isle 1	0.00	0.00	0.00	0.00	0.00	0.00	*
	Sir Walter	0.00	0.00	0.00	0.00	0.00	0.00	*
	Wintergreen	10.00	10.00	8.75	13.75	13.75	2.50	20.79
17-Jan-07	Aussiblue	0.00	0.00	0.00	0.00	0.00	0.00	*
	FLoraTeX	0.00	0.00	3.75	1.25	3.75	0.00	7.65
	Kikuyu	5.00	2.50	9.00	11.25	2.50	2.50	9.05
	Sea Isle 1	0.00	0.00	0.00	0.00	0.00	0.00	*
	Sir Walter	0.00	0.00	0.00	2.50	0.00	0.00	1.95
	Wintergreen	10.00	10.00	11.25	7.50	6.25	3.75	16.14
31-Jan-07	Aussiblue	0.00	0.00	0.00	0.00	0.00	0.00	*
	FLoraTeX	1.25	2.25	3.75	0.50	7.50	5.00	5.84
	Kikuyu	15.00	11.25	17.50	22.50	11.25	8.75	16.83
	Sea Isle 1	0.00	0.50	0.00	0.00	0.00	0.00	0.62
	Sir Walter	0.00	1.25	0.00	1.25	0.00	0.00	4.62
	Wintergreen	18.75	15.75	16.25	13.75	12.50	5.00	27.14
14-March-07	Aussiblue	0.00	0.00	0.00	0.00	0.00	0.00	*
	FLoraTeX	0.00	1.25	7.50	1.25	8.75	2.50	10.01
	Kikuyu	20.00	18.75	20.00	22.50	30.00	25.00	19.45
	Sea Isle 1	1.25	2.50	0.00	0.00	0.00	0.25	2.28
	Sir Walter	0.00	0.00	0.00	3.75	0.00	0.00	5.33
	Wintergreen	17.50	20.25	16.25	11.25	12.50	10.00	27.94

16.8 Appendix D-1 Draft Guidelines for the successful establishment and management of salt affected parklands

Introduction

Construction and maintenance of sporting fields and parklands have often been considered in isolation of one another. The initial cost savings of cheap construction can be quickly eroded by higher maintenance expenses, which recur into the future. This has been exacerbated by a lack of detailed construction protocols for park development. Clear guidelines for the construction of parks, can minimise or even eliminate the additional expense of follow-up remediation and problem management. Rather than a single problem, there are typically a number of issues that contribute to poor, and often patchy, grass growth in salt affected areas—the mark of an unsatisfactory project outcome.

These guidelines provide various options from the construction and establishment of new grounds through to remediation of existing parklands by supporting the growth of endemic grasses. They are also mindful of budgetary constraints. They describe a best management process through which salt affected sites should be assessed, remediated and managed.

Successful project outcomes can only be achieved through adequate planning. These guidelines will be of most benefit if they are fully understood before embarking on a parkland development/remediation project. This will enable all aspects of the protocol to be included in the proposed budget.

The management of turfgrass is “systems management”, with the soil, atmosphere and human factors all influencing plant growth. The turf manager needs to understand the importance of individual components within the context of the whole system.

Planning

Planning is the key. Planning parkland development should commence as soon as a site is identified. Initial site assessment will determine the extent of site preparation required. Similarly constraints to growth can be identified early so that species selection can be planned in advance.

Often, managers are presented with a “pre-prepared” area of ground and a small budget to establish and maintain top quality turfgrass cover. This can quickly set a project up for failure or, at the least site maintenance problems.

Two scenarios are common:

1. The prepared ground is often overly compacted. Much of the budget is quickly expended, trying to remedy the problem.

2. The site may well be saline, have high traffic or be under significant shade, all factors that need to be addressed through the careful choice of turf species.

Often the areas are extensive, requiring a large amount sod to cover it. Unfortunately the more salt tolerant species or the more wear resistant species are often specialised grasses, which are in short supply and often higher cost. Due to budgetary constraints, cheaper alternatives are selected so that the park can be constructed within budget.

The development of small individual, high profile areas could be considered if a complete re-construction is beyond the budget. This could be implemented over a period of time. If it is apparent that tolerant varieties of turf will be required, it is essential to contact suppliers early to ensure they will have adequate material available at the time of planting. This may require significant advanced notice (up to 12 months in some cases).

Alternatively, if there are existing dominant grasses, it may be possible to renovate the site to encourage their growth at a lower cost. These decisions can be used form appropriate budget estimates and develop a project structure. Guidelines for establishing new turf are discussed, as is the renovation of existing grasses.

New developments

Site assessment

Visual observations

This information is vital in selecting the most appropriate grass species or cultivar. Simple observations such as the number of people currently using the site through to the level of shade either from trees or buildings, should all be documented on site plans. Proposed usage of a site will also determine what pressures will be placed upon the turf. For example, areas around play equipment, barbeques and adjacent to pathways will all receive a high level of traffic, so the chosen species or cultivar will need a degree of traffic tolerance, while areas under trees or on the southern side of picnic shelters will have a significant level of shade, requiring more shade tolerant varieties.

In most cases, it is likely that a number of different grasses will be appropriate for one site. Refer to Chapter 5 of final report TU06006 to identify appropriate species or cultivars for each situation.

Look for signs of soil structural problems such as compaction. A simple indication is the rate at which water enters the soil (infiltration). A simple test can be done to see how long it takes for a volume of water to seep into the soil. This can be done by pushing a tin can (open at both ends) into the soil approximately 25 mm and filling it with water. Observe how long it takes for the water level to drop 25mm (one inch). A sandy soil should take 1 to 5 minutes, a loam or gravely soil may take up to 60 minutes and a clay soil can take significantly longer than 60 minutes. If the water takes longer than 30 minutes to soak into the soil, significant de-compaction operations will be required and should be factored into the proposed budget.

Soil sampling and testing

Testing the electrical conductivity (EC) of the soil will confirm the level of salinity, which in turn narrows the species selection. Similarly testing the acidity or alkalinity (pH) will clarify any amendments that may be required during the site preparation phase. Both parameters (EC, and pH) can be measured with reasonable accuracy using portable units ranging in price from $100 to $200 each. Further analysis for nutrient availability can be carried out by accredited laboratories.

It is recommended that samples be sent for testing at the planning stage, particularly if either EC or pH falls outside the recommended ranges. Not only will this information support species choices, but will also provide guidelines as to the type and amount of fertiliser required.

For meaningful results from soil testing, it is important that the sample is representative of the site given that samples sent for analysis are a fraction of the volume of soil in situ (generally about 1 part in 3 million!). An appropriate technique would be to take one soil core every square metre and mix it into a bulk sample. Soil cores should be taken to a depth of 10 cm. although, where obvious changes in soil type or texture occur within this zone, it is best to keep the depth increments as separate samples, bulked for each layer. Similarly, where obvious differences in topography occur, it is best to sample these areas separately.

When choosing a laboratory, look for accreditation from the Australasian Soil and Plant Analysis Council (ASPAC), as they run proficiency testing programs among member laboratories to ensure quality standards are met. Analytical methods, and indeed the interpretation of results, can vary significantly between laboratories. Most laboratories will provide an interpretation of results and recommendations for fertiliser requirements, however, advice from an independent agronomist is recommended.

Site preparation – start from the ground up.

Where possible, level the area, taking out surplus existing soil if necessary.

De-compaction:

De-compaction is generally not needed where the subsoil is sandy and has been disturbed and/or translocated. However, if the soil or subsoil has obvious compaction problems it will be necessary to alleviate this through cultivation. For mild compaction simply slicing to a depth of approximately 20 cm will be sufficient.

On compacted sites, such as parks based on marine mud, subsurface cultivation is needed to improve infiltration and internal soil drainage. Cultivation creates new macropores and channels for percolation, as well as air movement and root growth. In these situations a deeper, more aggressive cultivation is recommended. Soils with high clay content may benefit from an application of gypsum at the same time as subsurface cultivation is carried out. This will enhance soil structure and further improve internal drainage, with the added advantage of improving the effectiveness of the removal of salts from the root zone by rainfall and irrigation.

In an earlier project, slicing the subsoil to relieve compaction and applying gypsum amendment (to improve soil structure), followed by a sand topdressing, enabled stolons of green couch (*Cynodon dactylon*) to grow across bare scalded patches without incurring the usual browning off and dieback due to high salinity (Loch, Poulter et al. 2006).

Leaching

Leaching is widely acknowledged as the most important management practice on salt-affected sites. Without the ability to control soil salt levels through leaching, other management practices may be rendered ineffective over time.

For effective leaching, and also successful establishment of new turf areas, a well designed irrigation system is required. In particular, pulse irrigation is a useful technique. This works by applying a little water often, rather than in a single large application. The process allows the first pulse to infiltrate into the rootzone, where salts have time to be dissolved before a second, larger pulse flushes them from the rootzone.

Chemical amendments and fertilisers

Use the soil test results as a basis for determining the base rate of complete fertiliser to be mixed into the turf underlay or top dressed. Adjust pH to be within the range 5.5 to 7.0. If acid, add lime. If neutral or alkaline, add gypsum.

Many rootzone amendments which improve soil moisture relations are available on the market today, some with questionable value. Trial work indicates that most products are of limited use when the existing soil already has good water holding capacity. Decisions about using these products, as opposed to organic materials, come down to availability and economics. Take care in choosing these products. Adhere to the application rates on the label, as mistakes tend to have drastic consequences.

Topsoil

Spread a minimum of 5 cm of quality topsoil. Use turf underlay or straight sandy loam. In the case of a dune site where turf will be growing in loose sand, it is best to incorporate well composted organic material to a depth of 10-20 cm rather than applying a separate layer of topsoil. Many turf managers shy away from the inclusion of organic materials into turf underlay. However, if the materials are well composted, meeting the specifications of the Australian Standard and in the correct proportion with the mineral soil components, they will provide substantial benefits. Nutrient-rich organic composts have been shown to boost the growth of the previously unfertilised grass and this improvement lasted at least twice as long as the effect of inorganic nitrogen fertiliser. Trials on Queensland's Gold Coast have also shown improved root growth of new sod, over compost as opposed to mineral soil.

A good discussion of soil health and structure is provided in "Healthy soils for great turf"(Carson 2006).

Irrigation

It has previously been stated that a prerequisite for any turf establishment is a well-designed and well-maintained irrigation system capable of distributing water uniformly and as required (Loch et al. 2006). Water availability has been a limiting factor for turf growth in the past, and with permanent water restrictions it is unlikely that parklands will ever have unlimited water supplies.

One option is the consideration of alternate water sources. During the establishment phase, it is essential to have a regular supply of water. Access to water or consistent rainfall is vital when establishing from seed, as seedling root systems are particularly vulnerable to drying out. This may require the transport of recycled water to a site—an item which must be factored into the planning budget. If sufficient rainfall occurs during this time, the allocated money can be considered as a cost saving, but should not be relied upon. It is vital to know the quality of recycled water being used and its likely effects on plants and soils.

Do not order turf unless provision has been made for some form of irrigation during the establishment and post-establishment phase.

Grasses are living plants and even the most drought tolerant types require some water for survival. During periods of drought, it is argued that this is an inappropriate use of water. There are many benefits provided from living turf and other vegetation—to the environment, and to our health and well being. All these factors should be considered before turning off the tap.

Only when the site is fully prepared as per above steps, is it appropriate to have the sprigs, seeds or turf delivered.

Laying Turf as full sod

During the planning phase, select a quality turfgrass that is suitable for the site (as identified in your initial site assessment). Ensure that the correct quantity is available for the proposed planting time. Organise labour for laying turf to ensure the job can be completed in the shortest timeframe possible. Laying sod can be contracted out to the sod supplier or other industry professional.

Some simple procedures to follow are:

- Lay freshly cut turf as soon as possible after delivery
- Lay turf across the direction of surface water flow,
- Ensure that mats/rolls are laid systematically across the site and that the edges are butted up closely against each other, preventing gaps,
- Do not stretch or overlap rolls or slabs.

- Irrigate newly laid turf twice a day in cooler weather and three times a day in summer for at least two weeks. If water restrictions prohibit this, provision must be made for the use of alternate water sources.

Plugs or sprigs

Laying full vegetative turf works well but can be expensive. In areas with only patchy areas of bare salty ground, a much cheaper option is to re-plant just the problem areas with plugs of salt tolerant grasses—leaving untouched the areas already grassed. Success will depend on regular irrigation, and protection from heavy traffic for a minimum of 10 to 12 weeks.

Seeding

Seeding is now an option following the release of the seeded *P. vaginatum* cultivar 'Sea Spray'. Seed of Sea Spray, however, is very expensive (>US$40 per kg) and supplier recommendations are to sow 45 kg/ha. At this point in time seeds of this variety have not been available in Australia in large enough quantities for trial work to establish the effectiveness of this method of establishment. Once available, further work will be required in particular to maintain better moisture around the seed (e.g. hydroseeding).

Care of New Turf

Rope off the area to discourage traffic in the first few weeks if possible.

New turf requires a properly set up and uniform sprinkler irrigation system. All sprinkler heads must be checked to ensure that they are in good working order. The system must deliver a uniform volume of water across all parts of the site. Applied water should not be high in salts, particularly on clay-based sites. Recycled water is generally acceptable but monitoring water quality is essential. The quantity of water applied should exceed the evapotranspiration rate of the grass by around 10%, with the aim to leaching salts down the profile and away from the root zone. Water daily to encourage root growth in the first 14 days. For the slower growing *Zoysia* species this should be extended to 21 days.

After three to four weeks, irrigation intervals may be extended, dependant upon visual inspection. A slightly higher volume of water can be applied to encourage the development of a deep root system. Continue with irrigation for 2-3 months to ensure full establishment and deep root development. Routinely check that the irrigation system is operating effectively (e.g. check the alignment of the system and for nozzle wear).

Spot-spray grass weeds with registered herbicide for the chosen turfgrass.

Fertilize with 50 kg N/ha of quick release nitrogen every three months in the first year (giving a total of 200 kg N/ha/year). Roll after the grass is established (several months). Topdress to level if required.

Monitor the site closely for signs of compaction. This can be alleviated by routine Verti-draining or the use of other decompaction devices.

Monitor the site regularly for signs of salt build up. If salt levels appear to increase, apply irrigation to remove salts from the root zone (similar to when the site was being prepared).

If grass shows signs of wear stress, where possible, rope off the area, ensure irrigation is adequate and apply fertiliser with an N:P:K ratio of 3:1:2.

References and further reading

Loch, D. S., R. E. Poulter, et al. (2006). Amenity Grasses for Salt-Affected Parks in Coastal Australia, Department of Primary Industries & Fisheries, Queensland, Redland Shire Council, and Horticulture Australia Ltd. HAL project number: TU02005.

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Carson, C., (Editor) (2006). Healthy soils for great turf, Cleveland, Queensland, Queensland Department of Primary Industries.