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Final Report

Fields 800 Sand Trial

for

McCallum Brothers Ltd

Palmerston North, New Zealand

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Author	A Mitchell
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Contact Details	New Zealand Sports Turf Institute Head Office PO Box 347 Palmerston North NEW ZEALAND Phone: +64 6 356 8090 Fax: +64 6 354 0081 Email: amitchell@nzsti.org.nz

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CONTENTS

TABLES

INTRODUCTION

At the request of McCallum Brothers Ltd, NZ Sports Turf Institute have undertaken a trial to test the suitability of a marine sourced sand (Fields 800) for use in the construction of sand based sports fields, compared to a commercially available sand (control). The trial was established in January 2007 and ran for 24 months. Three turf grass varieties were grown including, *Cynodon*, kikuyu and ryegrass.

Fields 800 sand contains approximately 5 percent biogenic shell material, and has an elevated $pH_{(water)}$ and high concentration of available (exchangeable) calcium. The concern was that elevated pH will promote worm activity thereby, increasing the rate of contamination if used in a sand carpet sports field. In addition, high concentration of available calcium may induce foliar deficiencies of other nutrients, mainly magnesium and potassium.

The Fields 800 sand used in the trial had a particle size distribution which sits within accepted limits for sports field applications. Calcium carbonate content was found to be approximately 5 percent. Tests on other samples of Fields 800 sand have shown the hydraulic conductivity to be approximately 600mm/hr. This was considerably greater than the accepted minimum of 300mm/hr for sports field applications.

MATERIALS AND METHODS

Site details

Location:	NZSTI, Palmerston North
Soil type:	Tokomaru silt loam, pipe drained
Mean annual rainfall:	995 mm
Mean relative humidity:	74% (Dec-Feb), 81% (Mar-May), 84% (Jun-Aug), 75% (Sep-Nov)
Mean monthly temperature:	17°C (Dec-Feb), 13.7°C (Mar-May), 8.5°C (Jun-Aug), 12.4°C (Sep-Nov)
Trial design:	Randomised block design consisting of three main plots (blocks) of each sand. Each main sand plot was further divided into three sub-plots with the grass species randomly allocated to the sub-plots.
Main plot size:	3 m by 3 m
Sub plot size:	3 m by 1 m

Grass variety details

Species:	Perennial ryegrass (*Lolium perenne*), *Cynodon dactylon* Kikuyu (*Pennisetum clandestinum*)

Trial establishment and maintenance

Seeding/stolonising date: 24 January 2007

Seeding/stolonising rate: Ryegrass at 4 kg/100m^2
Cynodon at approximately 20 kg/100m^2
Kikuyu at approximately 15 kg/100m^2

Mowing: Up to weekly during spring and summer, as required during autumn and winter, clippings returned,

Height of cut: Ryegrass and Kikuyu at 40 mm
Cynodon at 15 mm

Irrigation: No regular irrigation applied.

Weed control: Broadleaf and grass weeds were controlled during the first winter (2007) by brushing target weeds with glyphosate

Pest control: None.

Disease: No fungicides were used to control disease. The only significant disease has been minor patches of red thread, rust and slim mould.

Fertiliser:

Date	Fertiliser	Rate (kgN/ha)
2007		
Jan	Scotts High Maintenance Slow Release (31-1-8)	86
Feb	Bio-boast (6-3-0)	61
Feb	DAP (18-20-0)	29
Mar	Ammonium sulphate (20.5-0-0)	20.5
Apr	Ammonium sulphate (20.5-0-0)	20.5
May*	Ammonium sulphate (20.5-0-0)	20.5
July	Ammonium sulphate (20.5-0-0)	20.5
Aug	Ammonium sulphate (20.5-0-0)	20.5
Sep	Ammonium sulphate (20.5-0-0)	20.5
Nov	Urea (46-0-0)	23
Dec	Ammonium sulphate (20.5-0-0)	20.5
2008		
Jan	Yara Mila Complex (12-5-15)	24
Apr	Yara Mila Complex (12-5-15)	24
Jun	Urea	23
Aug	Ammonium sulphate (20.5-0-0)	20.5
Sep	Ammonium sulphate (20.5-0-0)	20.5
Oct	Yara Mila Complex (12-5-15)	24
Dec	Ammonium sulphate (20.5-0-0)	20.5
Jan	Ammonium sulphate (20.5-0-0)	20.5

* Ryegrass plots only fertilised

Assessments

Early sward establishment density: Plots were scored for early establishment density using a 1-9 scale visual assessment of how quickly the plants were growing and establishing with 1 being bare ground and 9 being very dense, complete ground cover.

Sward density: Plots were scored using a 1-9 scale visual assessment of the density and uniformity of plants per unit area, with 1 being bare ground and 9 being very dense complete ground cover.

Percent weed cover: Visual assessment of percentage weed cover for each plot was made using a 1m x 1m grid.

Sward Colour: Plots colour was described once during each season using the following descriptions; thorny brown, yellow, light green, mid green and dark green.

Worm surface casting: Worm activity was assessed during cooler and wetter months by counting the number of surface casts present on the surface of each plot.

Sand contamination severity index (CSI): The degree of contamination of the sand carpet resulting from earthworm activity was determined using a settlement test from three 50mm soil cores taken at random from each plot.

Foliar nutrient analysis: Foliar nutrients were assessed periodically to determine whether the high exchangeable calcium concentrations in the Fields 800 sand were promoting any deficiencies of other nutrients. Foliar samples were collected by taking grab sample of mower clippings from each sub-plot and combining to give a single sample of each grass variety for each sand type (6 samples in total). Foliar samples were sent to R J Hills Laboratories Ltd, Hamilton for analysis for nitrogen, phosphorus, calcium, magnesium, potassium, sodium and trace elements. Only the results for the major elements are detailed in this report.

Sand and soil nutrient analysis: Changes in chemistry of the sand carpet and underlying soil were assessed at establishment of the trial and periodically during the trial by taking five 20mm soil cores at 0-50mm and 50–100mm depths from each sub–plot and combining to give a single sample of each grass variety for each sand type (6 sand and 6 soil samples in total). Sand and soil samples were sent to R J Hills Laboratories Ltd, Hamilton for analysis of $pH_{(water)}$, exchangeable calcium, exchangeable magnesium, exchangeable potassium and exchangeable sodium and Olsen phosphorus.

Data collection, processing and statistical analysis

Season	Early sward est. density	Sward density	Percent weed cover	Sward colour	Earthworm surface casts	CSI	Foliage nutrient analysis	Sand/soil nutrient analysis
Autumn 2007	9/03/07 26/03/07 5/04/07	20/04/07 8/05/07 18/05/07	20/04/07	20/04/07			20/03/07	15/05/07
Winter 2007		22/06/07 27/07/07 27/08/07	5/07/07	5/07/07	23/07/07 15/08/07 28/08/07			
Spring 2007		27/09/07 9/11/07	27/09/07	27/09/07	27/09/07 9/11/07			12/11/07
Summer 2007		10/12/07 18/01/08 22/02/08	22/02/08	22/02/08			10/01/08	
Autumn 2008		30/03/08 24/04/08 16/05/08	16/05/08	16/05/08	16/05/08			
Winter 2008		20/06/08 25/07/08 21/08/08	20/06/08 28/07/08 25/08/08	28/07/08	20/06/08 28/07/08			21/08/08
Spring 2008		26/09/08 24/10/08 14/11/08	24/10/08	24/10/08	26/09/08			
Summer 2008		19/12/08 26/01/09 23/02/09	19/12/09 23/02/09	23/02/09		18/02/09	22/12/08	18/02/09

Results were grouped and means calculated for each seasonal period where appropriate.

Results were statistically analysed using multiple factor analysis of variance function of Statgraphics Centurion XV version 15.0.10 with the least significant difference (LSD) used to determine differences between the Fields 800 and control sands at the 5% probability level. Note: ns = Not Significant.

Figure 1: Trial six weeks after establishment

RESULTS

Early sward establishment density

Plots were scored for early establishment density at approximately fortnightly intervals from weeks six to ten after establishment (Figure 1). By 10 weeks after establishment, early establishment density scores were all in the range 5.7 to 9 (Table1, Figure 2). There were no significant differences in the establishment densities of the grasses between the two sands. The *Cynodon* plots were slowest to establish and had not reached full cover by 10 weeks.

Table 1: Early sward establishment density

Sand	Species	Sward density 10 weeks after sowing
Fields 800	*Cynodon*	6.7
Control	*Cynodon*	5.7
Fields 800	Kikuyu	7.3
Control	Kikuyu	7.3
Fields 800	Ryegrass	9.0
Control	Ryegrass	8.3
Significance		ns

Figure 2: Trial ten weeks after establishment

Sward density

Sward density was scored at approximately fortnightly intervals from weeks 10 to 18 after establishment and then at monthly intervals. Sward density scores were grouped on a seasonal basis and only seasonal mean scores are reported here. No significant differences were recorded in sward density for the individual grasses between the Fields 800 and control sands except for the summer 2008 measurements (Table 2a and 2b). In summer 2008 sward density of the ryegrass in the Fields 800 plots was significantly greater than those in the control plots.

Generally, sward densities for the *Cynodon* and kikuyu declined over the winter periods, whereas the ryegrass plots tended to be at their lowest densities during the drier summer periods.

Table 2a: Sward density 2007

		Sward density			
Sand	**Species**	**Autumn 07**	**Winter 07**	**Spring 07**	**Summer 07**
Fields 800	*Cynodon*	7.4	8.9	6.5	6.3
Control	*Cynodon*	7.1	8.8	6.8	6.9
Fields 800	Kikuyu	8.3	8.6	7.7	8.2
Control	Kikuyu	8.1	9.0	8.3	8.4
Fields 800	Ryegrass	9.0	9.0	8.8	8.0
Control	Ryegrass	9.0	9.0	8.7	7.9
Significance		ns	ns	ns	ns

Table 2b: Sward density 2008

		Sward density			
Sand	**Species**	**Autumn 08**	**Winter 08**	**Spring 08**	**Summer 08**
Fields 800	*Cynodon*	9.0	8.6	8.1	9.0
Control	*Cynodon*	9.0	8.7	8.3	9.0
Fields 800	Kikuyu	9.0	7.9	7.7	9.0
Control	Kikuyu	9.0	8.2	7.9	9.0
Fields 800	Ryegrass	8.7	8.0	8.0	8.7
Control	Ryegrass	8.7	8.0	8.2	8.2
Significance		ns	ns	ns	$p<0.05$
CV%					3.53
LSD 5% level					0.15

Percent weed cover

The percentage weed cover per plot was assessed at least once per season. There were no significant differences in the amount of weed infestation between the Fields 800 and control sands (Table 3a and 3b). Due to the slow grow-in of the *Cynodon* plots they suffered from a considerable infestation of weeds in the first autumn and winter. Similarly, the kikuyu plots also suffered from infestation of weeds in the spring following the period of winter dormancy.

Table 3a: *Percent weed cover 2007*

Sand	Species	Weed cover			
		Autumn 07	Winter 07	Spring 07	Summer 07
Fields 800	*Cynodon*	62.3	51.3	8.7	5.3
Control	*Cynodon*	58.7	52.3	8.7	12.3
Fields 800	Kikuyu	17.7	17.0	56.7	3.0
Control	Kikuyu	16.0	14.7	27.0	4.7
Fields 800	Ryegrass	0.7	0.0	0.0	9.0
Control	Ryegrass	1.3	0.0	12.7	10.0
Significance		ns	ns	ns	ns

Table 3b: Percent weed cover 2008

Sand	Species	Weed cover			
		Autumn 08	Winter 08	Spring 08	Summer 08
Fields 800	*Cynodon*	14.3	22.1	25.3	13.8
Control	*Cynodon*	11.0	16.4	36.7	18.0
Fields 800	Kikuyu	5.3	9.3	26.3	40.5
Control	Kikuyu	12.3	13.7	29	27.8
Fields 800	Ryegrass	8.3	13.6	19.3	35.8
Control	Ryegrass	6.0	8.8	19.7	37.2
Significance		ns	ns	ns	ns

Sward colour

There were no differences in the sward colour descriptions between the Fields 800 and control sands for any of the grass species used in the trial (Table 4a and 4b). The ryegrass was a mid green colour with some thorny brown colourings in older growth in the summer of 2008. *Cynodon* colour when actively growing (summer) was a dark green. During periods of cooler weather thorny brown colouring became evident in the *Cynodon* particularly during winter dormancy period. The kikuyu when actively growing was a light green colour. During the cooler months of late autumn, winter and early spring yellow and thorny brown colourings became evident.

Table 4a: Sward colour 2007

Sand	Species	Colour			
		Autumn 07	Winter 07	Spring 07	Summer 07
Fields 800	*Cynodon*	Dg/Tb[1]	Tb	Tb/Dg[2]	Dg
Control	*Cynodon*	Dg/Tb[1]	Tb	Tb/Dg[2]	Dg
Fields 800	Kikuyu	Lg/Y	Y	Tb/Lg[3]	Lg
Control	Kikuyu	Lg/Y	Y	Tb/Lg[3]	Lg
Fields 800	Ryegrass	Mg	Mg	Mg	Mg
Control	Ryegrass	Mg	Mg	Mg	Mg

Table 4b: Sward colour 2008

Sand	Species	Colour			
		Autumn 08	Winter 08	Spring 08	Summer 08
Fields 800	*Cynodon*	Dg	Tb/Dg[2]	Dg	Dg
Control	*Cynodon*	Dg	Tb/Dg[2]	Dg	Dg
Fields 800	Kikuyu	Lg	Y/Tb[4]	Lg	Lg
Control	Kikuyu	Lg	Y/Tb[4]	Lg	Lg
Fields 800	Ryegrass	Mg	Mg	Mg	Mg/Tb[1]
Control	Ryegrass	Mg	Mg	Mg	Mg/Tb[1]

Key:
Lg – Light green
Mg – Mid green
Dg – Dark green
Y – Yellow
Tb – Thorny brown

[1] – Older growth thorny brown
[2] – Shoot tips dark green
[3] – Shoot tips light green
[4] – Thorny brown leaf tips

Worm surface casting and sand contamination severity

Counts of earthworm surface casts showed no significant differences in the level of activity between the Fields 800 and control sands (Table 5a). Generally, more surface cast were observed on the surface of the ryegrass plots compared to the *Cynodon* and kikuyu plots.

There was no significant difference in the contamination severity index between the Fields 800 and control sands (Table 5a). The level of contamination can be interpreted as relatively clean for *Cynodon* plots across both sands (Table 5b). In the kikuyu and ryegrass plots the contamination severity index in the control sand can be interpreted as relatively clean and slightly contaminated in the Fields 800 sand.

The results from worm cast counts and contamination severity index indicate that growth habit of *Cynodon* with its tightly packed stolons and fibrous root system discourages earth worm activity compared to the results for the other two species grown in this trial. The results of the contamination severity index for the kikuyu plots indicates that the earthworms were able to deposit a portion of their casts within the layers of stolons rather than coming completely to the surface as was observed in the ryegrass plots.

Table 5a: Worm surface casting and sand contamination severity index (CSI)

		Worm casts				CSI
Sand	**Species**	**Winter 07**	**Spring 07**	**Winter 08**	**Spring 07**	**(%)**
Fields 800	*Cynodon*	21	14	13	13	16
Control	*Cynodon*	20	8	5	6	15
Fields 800	Kikuyu	20	14	12	17	25
Control	Kikuyu	18	10	6	8	21
Fields 800	Ryegrass	63	25	50	20	24
Control	Ryegrass	42	15	41	17	19
Significance		ns	ns	ns	ns	ns

Table 5b: Interpretation of sand contamination severity index

CSI (%)	Interpretation
< 20	Sand carpet is relatively clean
20-25	Sand carpet is slightly contaminated
25-30	Sand carpet is moderately contaminated
30-40	Sand carpet is heavily contaminated
> 40	Sand carpet has reverted to soil-based field

Foliar nutrient analysis

Foliar samples were collected in autumn and summer 2007, and summer 2008 for nutrient analysis. In the autumn 2007 samples, only nitrogen was below desirable levels for adequate grass growth and this was common to both sands at both times of sampling (Table 6a). Concentrations of foliar phosphorus in the samples collected were significantly higher (averaged across all grass types) in the grasses grown in the control sand, compared to the grasses in the Fields 800. Concentrations of foliar calcium were significantly higher in the grasses grown in the Fields 800 sand, compared to the grasses grown in the control sand.

By summer 2007 no significant differences were recorded in foliar concentrations of nutrients analysed (Table 6b). Concentration of foliar nitrogen remained below desirable levels for adequate grass growth. Between the sampling in autumn and summer 2007, there was a decline in concentrations of foliar nitrogen, phosphorus and potassium, particularly for the ryegrass. This decline was common to both sands.

In the summer 2008 no significant differences were found in foliar concentrations of nutrients analysed (Table 6c). There was a general increase in concentrations of foliar nitrogen, phosphorus and potassium between the sampling in summer 2007 and summer 2008 probably reflecting the application of a balanced fertiliser (Yara Mila Complex) at various times during this period. However, concentrations of foliar nitrogen in the ryegrass plots remained below desirable levels for adequate grass growth.

The high concentrations of available calcium in the Fields 800 sand have not induced any foliar deficiencies of other nutrients.

Table 6a: *Foliar analysis autumn 2007*

Sand	Species	N	P	K	S	Ca	Mg
		(%)					
Fields 800	*Cynodon*	3.6	0.49	1.6	0.34	0.80	0.27
Control	*Cynodon*	3.3	0.51	1.5	0.33	0.58	0.20
Fields 800	Kikuyu	3.1	0.40	1.8	0.25	0.85	0.28
Control	Kikuyu	3.2	0.60	2.8	0.25	0.32	0.27
Fields 800	Ryegrass	4.0	0.63	2.6	0.34	0.67	0.23
Control	Ryegrass	3.6	0.78	2.3	0.30	0.43	0.25
Significance		ns	0.002	ns	ns	0.0001	ns
CV%			23.4			35.5	
LSD 5% level			0.07			0.13	

Table 6b: *Foliar analysis summer 2007*

Sand	Grass species	N	P	K	S	Ca	Mg
		(%)					
Fields 800	*Cynodon*	1.8	0.22	1.1	0.29	0.93	0.13
Control	*Cynodon*	2.0	0.26	1.3	0.34	0.34	0.12
Fields 800	Kikuyu	2.3	0.31	2.1	0.20	0.41	0.16
Control	Kikuyu	2.3	0.32	2.0	0.20	0.36	0.17
Fields 800	Ryegrass	2.6	0.29	1.8	0.32	0.88	0.21
Control	Ryegrass	2.4	0.25	1.6	0.32	0.59	0.19
Significance		ns	ns	ns	ns	ns	ns

Table 6c: *Foliar analysis summer 2008*

Sand	Grass species	N	P	K	S	Ca	Mg
		(%)					
Fields 800	*Cynodon*	2.7	0.31	1.5	0.33	0.74	0.16
Control	*Cynodon*	2.5	0.32	1.7	0.32	0.57	0.16
Fields 800	Kikuyu	3.2	0.35	2.1	0.23	0.99	0.21
Control	Kikuyu	2.5	0.29	1.7	0.19	0.50	0.17
Fields 800	Ryegrass	3.1	0.36	2.2	0.32	1.04	0.21
Control	Ryegrass	2.7	0.39	2.1	0.37	0.81	0.22
Significance		ns	ns	ns	ns	ns	ns

Sand nutrient analysis

Comparing results from analysis of sand samples collected at 24 months with those collected at the start of the trial, mean pH in the Fields 800 plots decreased from pH 8.6 to 7.2 (Figure 3). In sand samples from the control plots, pH has also decreased from pH 7 to 5.5. The pH of the Fields 800 sand was significantly higher than the pH in the control sand at each sampling time after establishment.

Olsen phosphorus concentrations had increased in the first samples collected in May 2007 reflecting the application of fertiliser during establishment of the trial (Figure 4). Over the term of the trial Olsen phosphorus concentrations have remained generally uniform. There were no significant differences in Olsen phosphorus concentrations between the Fields 800 and control sands.

Mean exchangeable potassium concentrations of the sand in the Fields 800 plots decreased from 0.4 to 0.28 $cmol_{(+)}kg$ (Figure 5). By contrast, there were no changes in mean concentrations of exchangeable K in sand samples collected from the control plots. There were general increases in the concentrations of exchangeable potassium between the samples collected in winter (day 580) and summer 2008 (day 761) reflecting the application of a balanced fertiliser over this period.

Mean exchangeable calcium concentrations of the sand in the Fields 800 plots increased from 10.5 to 12.7 $cmol_{(+)}kg$, indicating some decomposition of the shell material (Figure 6). By contrast, there were no changes in mean concentrations of exchangeable calcium in sand samples collected from the control plots. Exchangeable calcium concentrations were significantly higher in the Field 800 sand compared to the control sand at each sampling time after establishment.

In the Fields 800 plots mean exchangeable magnesium of the sand decreased from 1.06 to 0.49 $cmol_{(+)}kg$ and exchangeable sodium has decreased from 2.12 to 0.12 $cmol_{(+)}kg$ (Figures 7 and 8). Similarly, in the control plots mean exchangeable magnesium of the sand has decreased from 0.48 to 0.29 $cmol_{(+)}kg$ and mean exchangeable sodium has decreased from 0.16 to 0.08 $cmol_{(+)}kg$. Exchangeable magnesium concentrations in the Fields 800 plots were significantly higher compared to the control sand at each sampling time after establishment.

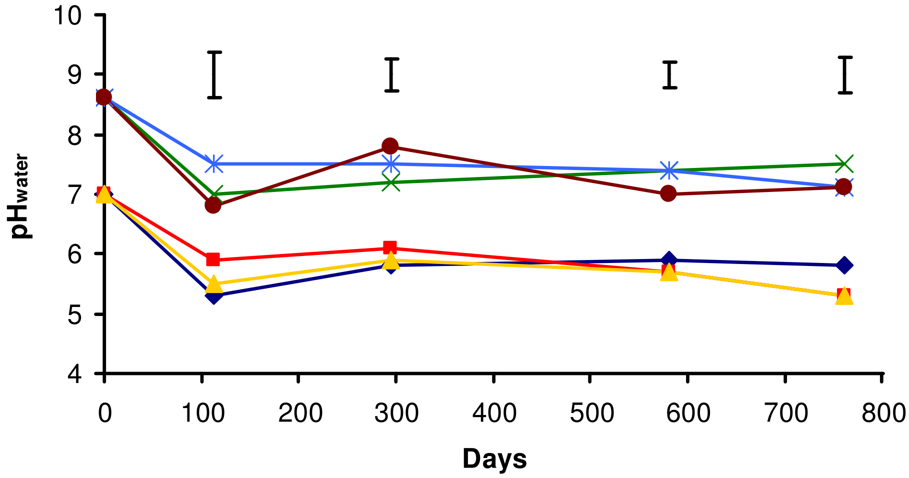

***Figure 3*:** Changes in pH over time in Fields 800 and control sands (0-50mm) for each grass species: **x** :Fields 800 Ryegrass, ● :Fields 800 *Cynodon*, ✳ :Fields 800 Kikuyu, ♦ :Control Ryegrass, ▲ : Control *Cynodon*, ■ :Control Kikuyu; Vertical bars indicate l.s.d. (*P = 0.05*)

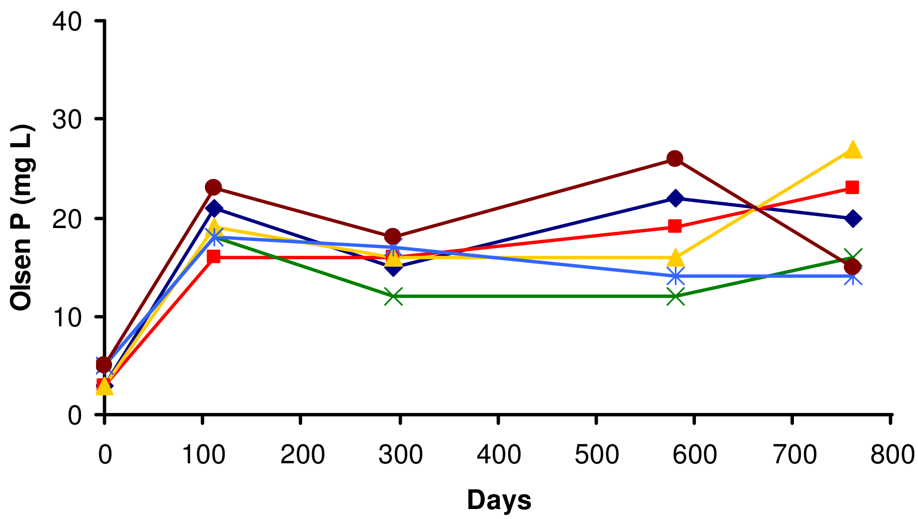

***Figure 4*:** Changes in concentrations of Olsen phosphorus over time in Fields 800 and control sands (0-50mm) for each grass species: **x** :Fields 800 Ryegrass, ● :Fields 800 *Cynodon*, ✳ :Fields 800 Kikuyu, ♦ :Control Ryegrass, ▲ : Control *Cynodon*, ■ :Control Kikuyu

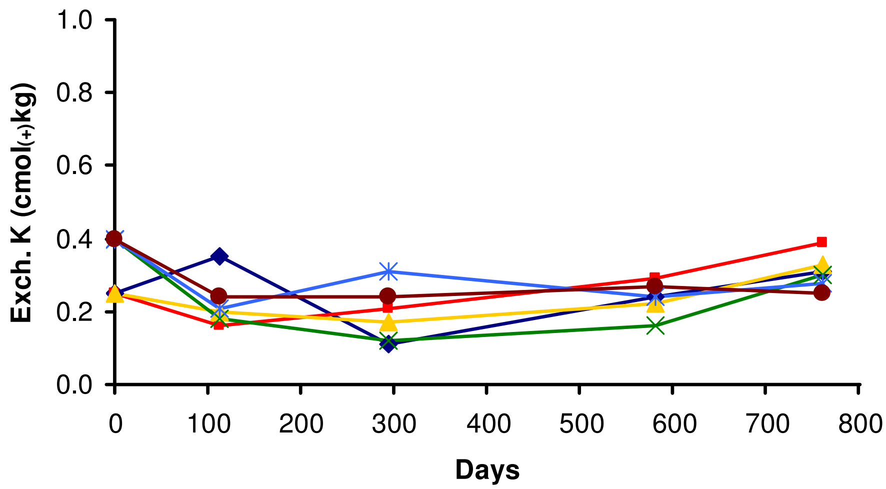

Figure 5: Changes in concentrations of exchangeable potassium over time in Fields 800 and control sands (0-50mm) for each grass species: **x** :Fields 800 Ryegrass, ● :Fields 800 *Cynodon*, ✳ :Fields 800 Kikuyu, ♦ :Control Ryegrass, ▲ : Control *Cynodon*, ■ :Control Kikuyu

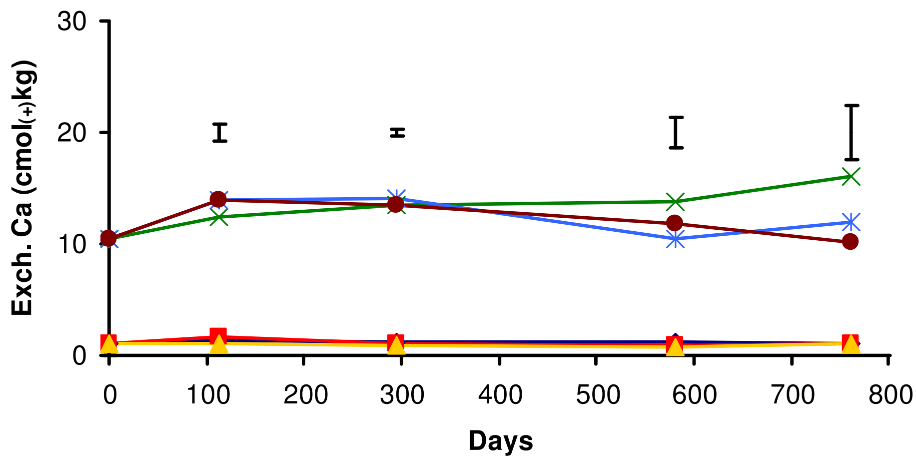

Figure 6: Changes in concentrations of exchangeable calcium over time in Fields 800 and control sands (0-50mm) for each grass species: **x** :Fields 800 Ryegrass, ● :Fields 800 *Cynodon*, ✳ :Fields 800 Kikuyu, ♦ :Control Ryegrass, ▲ : Control *Cynodon*, ■ :Control Kikuyu; Vertical bars indicate l.s.d. ($P = 0.05$)

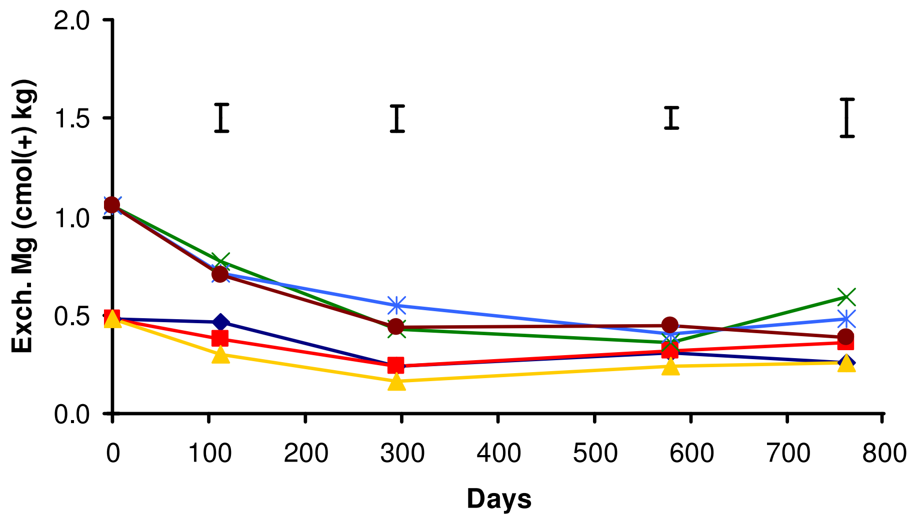

***Figure 7*:** Changes in concentrations of exchangeable magnesium over time in Fields 800 and control sands (0-50mm) for each grass species: **x** :Fields 800 Ryegrass, ● :Fields 800 *Cynodon*, ∗ :Fields 800 Kikuyu, ♦ :Control Ryegrass, ▲ : Control *Cynodon*, ■ :Control Kikuyu; Vertical bars indicate l.s.d. (*P = 0.05*)

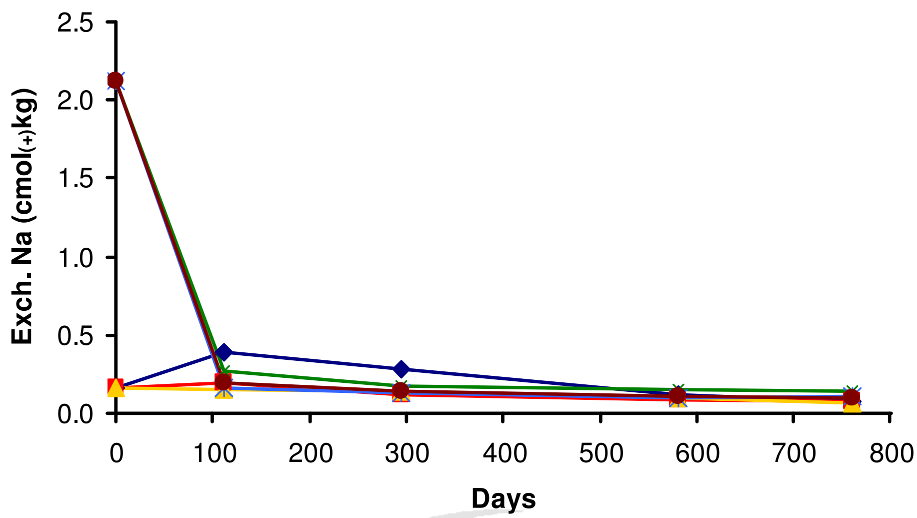

***Figure 8*:** Changes in concentrations of exchangeable sodium over time in the Fields 800 and control sands (0-50mm) for each grass species: **x** :Fields 800 Ryegrass, ● :Fields 800 *Cynodon*, ∗ :Fields 800 Kikuyu, ♦ :Control Ryegrass, ▲ : Control *Cynodon*, ■ :Control Kikuyu

Subsoil nutrient analysis

Comparing results from analysis of subsoil (50-100mm) samples collected in summer 2008 with those collected at the start of the trial, mean subsoil pH in the Fields 800 plots increased from pH 5.3 to 7.0 (Figure 9). In the control plots subsoil pH generally remained the same. The subsoil pH values of the Fields 800 plots were significantly higher than the subsoil pH of the control plots at each sampling time after establishment.

Olsen phosphorus concentrations generally remained uniform over the period of the trial (Figure 10). There were no significant differences in Olsen phosphorus concentrations in the sub-soils between the Fields 800 and control sands.

Similarly, mean exchangeable potassium concentrations remained uniform over the period of the trial (Figure 11). There were no significant differences in exchangeable potassium concentrations in the sub-soils between the Fields 800 and control sands.

Mean exchangeable calcium concentrations in the subsoil of the Fields 800 plots increased from 4.6 to 9.7 $cmol_{(+)}kg$ (Figure 12). By contrast mean exchangeable calcium concentrations in the subsoil of the control plots generally remained the same. Exchangeable calcium concentrations were significantly higher under the Fields 800 sand compared to those recorded under the control sand plots at each sampling time after establishment.

Mean concentrations of exchangeable magnesium in the subsoil of the Fields 800 plots increased from 0.99 to 1.09 $cmol_{(+)}kg$ (Figure 13). In the control plots mean exchangeable magnesium in the subsoil has generally remained the same. As with exchangeable calcium, concentrations of exchangeable magnesium in the subsoil of the Fields 800 plots were significantly higher compared to the control plots at each sampling time since establishment up to an including samples collected near the end of winter 2008 (day 580).

Mean concentrations of exchangeable sodium have increased from 0.11 to 0.14 $cmol_{(+)}kg$ in the subsoils of the Fields 800 and from 0.11 to 0.16 $cmol_{(+)}kg$ in the subsoils of the control plots (Figure 14). There was also a significant flush of exchangeable sodium in the subsoil of the Fields 800 subsoil compared to the control plots, in samples collected in autumn 2007 and spring 2007.

These results indicate that leaching of cations, particularly calcium, from the Field 800 sand, has taken place. It should be noted that the trial has largely been fertilised with acidifying nitrogen fertilisers.

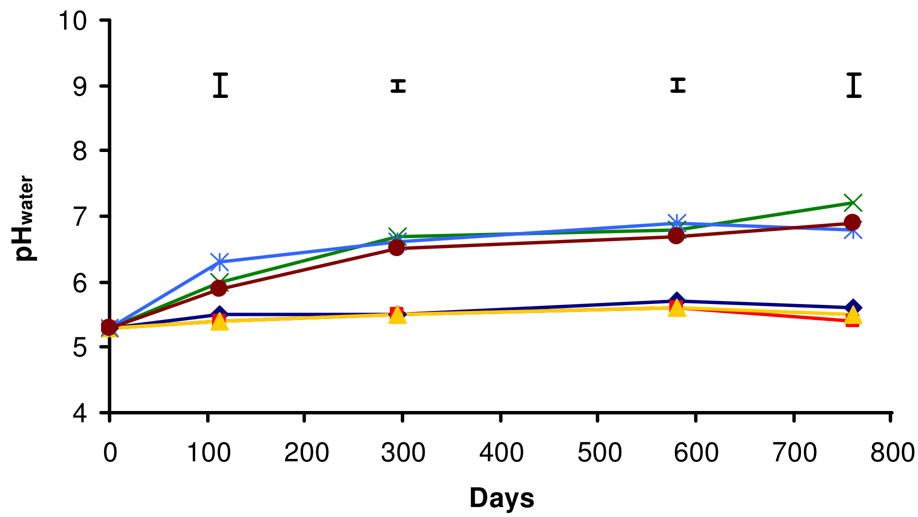

Figure 9: Changes in soil pH over time in the subsoil (50-100mm) under Fields 800 and control sands for each grass species: x :Fields 800 Ryegrass, ● :Fields 800 *Cynodon*, ✳ :Fields 800 Kikuyu, ♦ :Control Ryegrass, ▲ : Control *Cynodon*, ■ :Control Kikuyu; Vertical bars indicate l.s.d. (*P = 0.05*)

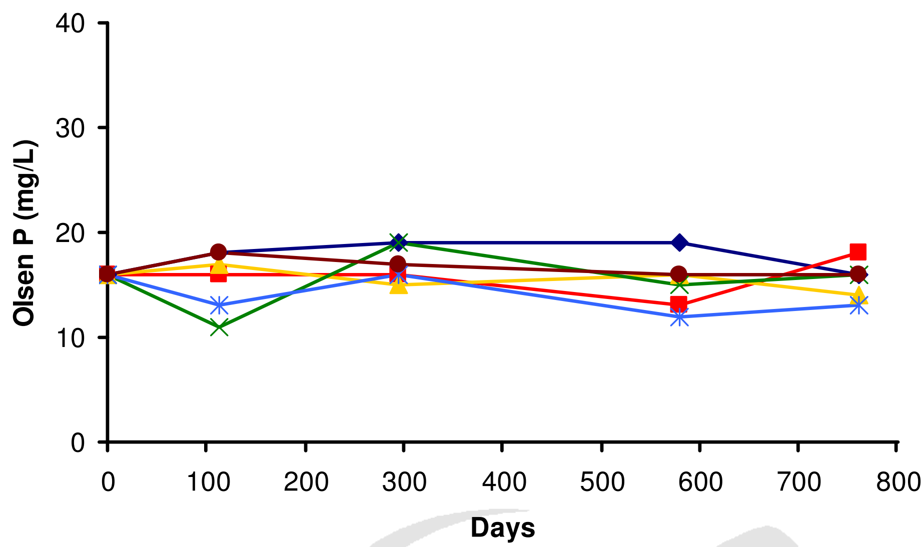

Figure 10: Changes in concentrations of Olsen phosphorus over time in the subsoil (50-100mm) under Fields 800 and control sands for each grass species: x :Fields 800 Ryegrass, ● :Fields 800 *Cynodon*, ✳ :Fields 800 Kikuyu, ♦ :Control Ryegrass, ▲ : Control *Cynodon*, ■ :Control Kikuyu

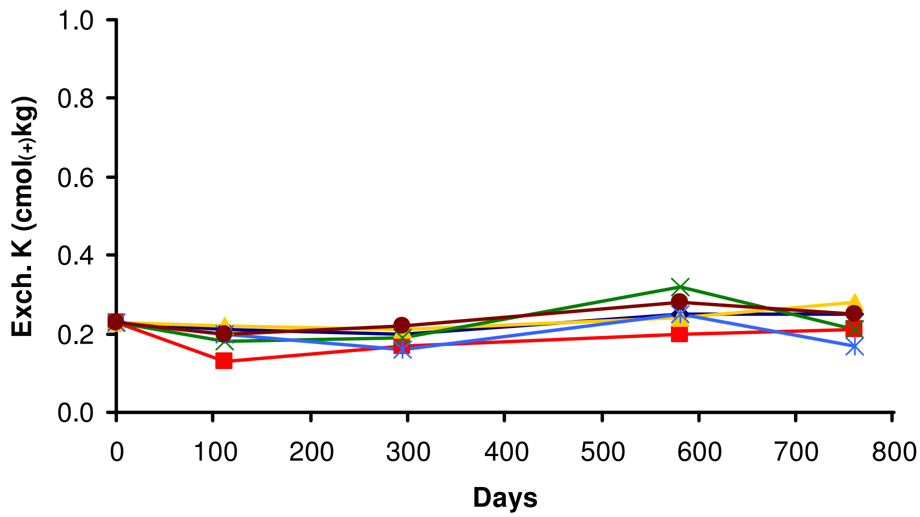

Figure 11: Changes in concentrations of exchangeable potassium over time in the subsoil (50-100mm) under Fields 800 and control sands for each grass species: **x** :Fields 800 Ryegrass, ● :Fields 800 *Cynodon*, ✳ :Fields 800 Kikuyu, ♦ :Control Ryegrass, ▲ : Control *Cynodon*, ■ :Control Kikuyu

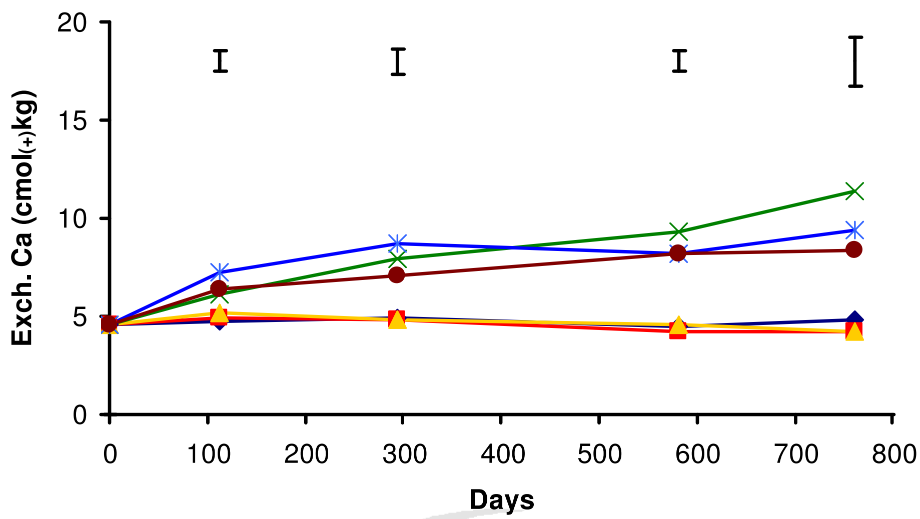

Figure 12: Changes in concentrations of exchangeable calcium over time in the subsoil (50-100mm) under Fields 800 and control sands for each grass species: **x** :Fields 800 Ryegrass, ● :Fields 800 *Cynodon*, ✳ :Fields 800 Kikuyu, ♦ :Control Ryegrass, ▲ : Control *Cynodon*, ■ :Control Kikuyu; Vertical bars indicate l.s.d. ($P = 0.05$)

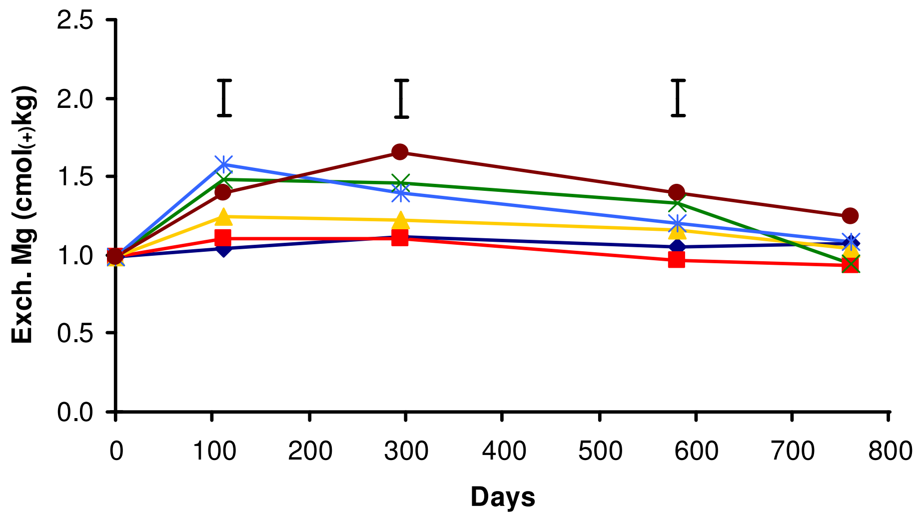

Figure 13: Changes in concentrations of exchangeable magnesium over time in the subsoil (50-100mm) under Fields 800 and control sands for each grass species: **x** :Fields 800 Ryegrass, ● :Fields 800 *Cynodon*, ✳ :Fields 800 Kikuyu, ♦ :Control Ryegrass, ▲ : Control *Cynodon*, ■ :Control Kikuyu; Vertical bars indicate l.s.d. (*P = 0.05*)

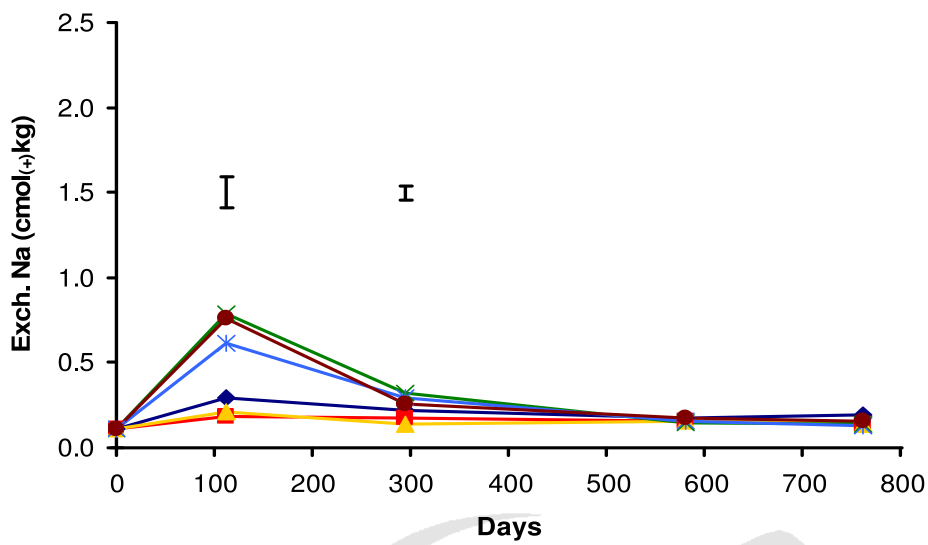

Figure 14: Changes in concentrations of exchangeable sodium over time in the subsoil (50-100mm) under Fields 800 and control sands for each grass species: **x** :Fields 800 Ryegrass, ● :Fields 800 *Cynodon*, ✳ :Fields 800 Kikuyu, ♦ :Control Ryegrass, ▲ : Control *Cynodon*, ■ :Control Kikuyu; Vertical bars indicate l.s.d. (*P = 0.05*)

CONCLUSION

In the 24 months since establishment there have been no significant differences in the growth characteristics in any of the three grasses between the two sands used in the trial. The elevated concentrations of exchangeable calcium in the Fields 800 sand have not resulted in any induced deficiencies of other nutrients. Elevated soil pH has not resulted in any significant increases in earthworm surface casting or contamination of the sand by fine soil material.

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