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Quantifying the strengthening of soil by commonly used landscape plants and turf.

By Todd Layt and Ian Paananen

Biographical information

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Todd Layt is a well known plant and turf breeder, with tens of millions of his varieties being sold in Australia, USA, Europe, Japan, and New Zealand. He specialises in breeding tough landscape plants, many of which are regularly used to stabilise soils. Prior to founding Ozbreed, he owned and ran a successful turf farm, and a large wholesale nursery that specialised in native grasses, wetland plant, and other revegetation plants. He is a former director of the International Erosion Control Association (Australasia). In the past he consulted on the revegetation of many large restoration projects around Australia, including projects at the Sydney Olympics site, for ACTEW, and various roads departments around Australia. He has presented to many groups of engineers, Landscape Architects, and erosion control professionals, both in Australia, and the USA, including organisations such as Caltrans, and the DOT in Texas.

Todd Layt designed this investigation, supervised the growing of the plants and turf plots for this trial, as well as helping with data collection, and writing this paper. He also made photographic records of this investigation.

Ian Paananen (BSc Agr)

Ian Paananen is a horticultural scientist who consults to various organisations in Australia. He has an Agricultural Science Degree, providing scientific services to many organisations in Australia, Europe and the USA for over twenty years in variety testing, PBR, IPM, plant tissue culture, and nursery production.

Ian Paananen helped with the data collection and conducted the data analysis for this paper. He also reviewed and edited the final version of this paper.

Abstract

Plant roots and rhizomes are known to help strengthen soil, and aid in erosion control. However, until recently very little research has been conducted with regard to which plants strengthen the soil better than others, and the research conducted only focused on a very small sample of plants. The purpose of this investigation is to test the influence 31 different commonly used landscape plants, and three commonly used erosion control turf varieties have on soil shear strength. The varieties were chosen from regularly used erosion control landscape plants and turf types from Australia. However many of these plants and turf types are used in the USA, Europe, and Asia. Many improved varieties were also included, as they are currently widely used in Australia, and it allowed this investigation to test the improved varieties compared to the common forms from the same genus and species.

Ten large sample pots of each variety were grown and tested with a Shear Vane tester, as were samples grown in two different gardens, and replicated turf plots. 29 shear vane tests were taken for each variety from the pots. The results showed all plants strengthened the soil compared to the control samples of unvegetated potting mix and soil. Differences in soil shear strength averages were analysed using an ANOVA test. Statistically significant differences to the unvegetated samples were determined at a 99% confidence level. King Alfred, an improved variety of Dianella caerulea was found to have more than doubled the soil strengthening ability, compared to all other plants, other than Nafray, which was still well below King Alfred. King Alfred strengthened the soil 752%, and in this test had an undrained shear strength of 70 kPa, compared to unvegetated soil of 9 kPa. Many other varieties however, still strengthen the soil greatly. Katrinus Deluxe, a Lomandra longifolia, strengthened the soil by 366%. Some plants that are widely used in the USA and Australia, such as Liriope Evergreen Giant had much lower readings, only strengthening the soil a statistically significant 100%. Varieties improved through breeding all strengthen the soil considerably more than their corresponding common varieties, providing evidence that plant breeding can lead to plants better suited to strengthening soil. Empire Zoysia Turf strengthened the soil significantly, at a rate of 97.9 kPA, considerably more than Couch 68.1 kPa (Bermuda grass) and Kikuyu 72.4 kPa.

This data can help Engineers, Landscape Architects, and Erosion Control professionals choose plants and turf that better strengthen the soil, and enhance erosion control of slopes, batters, stream embankments, roadsides, retaining walls, and shore lines. It will also provide a basis for future plant breeders to develop plants and turf that better strengthen the soil.

Introduction

Plants and turf are regularly used to help reduce or prevent erosion. Often roads departments, or councils plant hundreds of thousands of plants, or lay many thousands of square metres of turf, on batters, slopes, around rivers, dams, gullies, shorelines, roadsides, and retaining walls, to help hold the soil together. Engineers, landscape consultants, councils etc have until now had to guess which plants are best at holding the soil together, unfortunately often spending millions of dollars on infrastructure, only to find the plant selection has not done its job. Designers and consultants need quantitative data as to which are the best plants for holding the soil together. This research provides the first comprehensive quantitative data on which are the best commonly used Australian landscape plants and turf for strengthening the soil, although the research has also including many overseas plants, which will make it relevant for other regions including the USA, Europe, and Asia. We would have liked to include Vetiver grass in the trial, but it is more suited to the tropics, and the winter is too cold in Clarendon NSW for Vetiver to grow correctly. Clarendon, the trial venue, is a temperate climate, with humid summers.

In the past many projects may have simply specified for example; 100000 Dianella caerulea, to strengthen vast areas of soil. With this paper future designers and consultants, will be able to choose which Dianella caerulea varieties strengthen the soil the best, reducing significantly the chance of erosion causing failure to their projects. The results in this paper will show the inadequacy of simply specifying a Genus and species, and not particular cultivars for erosion control.

It is well known that erosion prevention is a major reason for using vegetation. Prior to this paper, there was no major research as to which are the best plants and turf of the commonly used varieties in Australia. However we have purposely included some plants that are popular in the USA as well. This is also the first research to compare specifically bred cultivars to each other, and to common forms with respect to erosion control. This research will aim to show the better varieties bred for vigour and density out perform the common varieties, and the more vigorous rooting plants out perform the less vigorous plants. In the nursery industry it is well known that grasses and strappy leaf plants have more vigorous fibrous root systems than ground covers, trees and shrubs.

Engineering erosion control products often have associated quantitative research which can help civil engineers choose which product would be best for their project. Turf reinforcements for example have regularly been tested, but the actual turf types have rarely been tested in a quantitative manor. This research will help civil engineers, Landscape Architects, councils etc to choose plants and turf for erosion control with more confidence. This coupled with horticultural data of which plants do best in particular regions and conditions will help take the guess work out of plant and turf selection.

Plant Research

Literature Review

In early 2006, a paper was released at the 2006 International Erosion Control Conference in the USA. This excellent ground breaking paper was the catalyst for undertaking this trial. We believed it would be desirable to have access to data like this for commonly used Australian Plants, although we did include many plants that are commonly used in the USA for comparison. Within days of reading this paper we had planted the trials for this Australian paper. The paper 'SOIL STRENGTH REINFORCEMENT BY PLANTS' by *Wendi Goldsmith* President of The Bioengineering Group, Inc. compared the relative strength of various commonly used erosion control plants in the USA. The plants used in that trial were: tussock sedge *(Carex stricta),* switch grass *(Panicum virgatum),* common cottonwood *(Populus deltoides)* and black willow *(Salix nigra).* The results of this paper were claimed to have use for the Erosion control industry. "These conservative root cohesion values can be used in the qualitative or semi-quantitative assessment of the stability of existing vegetated slopes and in the design of vegetated riverbanks, shorelines, embankments, cut slopes, retaining walls, landfill caps, and other reclamation applications where the mechanical contribution of root reinforcement is important to predicting soil behavior." In the USA trial a much smaller test sample was used than this current Australian trial, and a different type of testing apparatus. The apparatus used in the USA trial was a large direct shear apparatus called a box shear tester, which is known to be more accurate than the shear vane tester we used in this test. However, the Box shear tests are very expensive, and only very small numbers of tests can be performed, as opposed to much larger numbers of tests with the shear vane tester. We chose the shear vane tester, with a large number of repetitions, as we believed this would give overall more accurate and statistically correct results. For example we used 29 measurements per plant variety as opposed to 5 from the USA test. This high replication minimised any potential errors from the data collection process. We also chose to use potting mix rather than soil, as the plants could be grown so that they achieve a healthier finished product, and the uniformity of the potting mix could be guaranteed. Plants grown in soil in pots is generally considered to be a bad horticultural practice. We checked these results via soil testing of many of the plants in garden tests. Although having said that, the results of both papers had some common ground. The only similar type of plant in both tests were the Carex varieties. The Carex (Tussock Sedge) tested in both papers are very similar in habit. The USA paper showed that the tussock sedge strengthened the soil 262%, and in the Australian test the Tussock Sedge strengthened the soil 176%. The USA paper had the torque required to shear the soil strengthened by the sedge at 23.9 kPa, whilst this Australian investigation had the sedge at 23.8 kPa. These results were remarkably close, given the spread of results shown in both papers, and considering the very different testing procedures.

The benefits of roots and rhizomes of plants on soil stabilisation and erosion control are well known, and have been frequently documented in many scientific papers, including; Gray and Sotir, 1996; Robbin B. Sotir, 2002; Gray and Leiser, 1989. A very extensive and well written review of literature of how plant roots help stabilise soils can be found in Wendi Goldsmith, 2006.

The top 50mm or so of roots and rhizomes around plants and grasses is a very important part of erosion control prevention. Marc S Theisen, R.G. Carroll Jr, 1990. The surface vegetation, when growing correctly, can provide excellent erosion control. However some plants perform better than others; Wendi Goldsmith, 2006. There is very limited data available on the soil strengthening capabilities comparing frequently used landscape plants in Australia, and a low number of studies available in the rest of the world.

Materials and trial set up.

In early 2006, ten 220mm pots each of 31 commonly used landscape plants were grown using a standard good quality potting mix, plus 10 pots of just potting mix with no plants in them (Bare Soil). The plants were planted from 80mm pots into the 230mm pots. All pots were kept well weeded. The selection of 31 plants represented a good mix of the most commonly used Australian landscape plants, with some commonly used USA, and European landscape plants also included. Some common varieties, and improved bred varieties of a specific genus and species were also chosen, so the erosion control abilities of common and improved plants could be compared. It should be noted that in NSW, Australia, it is more common now for improved varieties to be used in Landscape projects than the common forms, although for bush regeneration this is different. These plants were grown using good horticultural practices, and were all treated in an identical method. Standard potting mix was chosen rather than soil, because soil in pots would have lead to many of the plants becoming sick and weak, possibly resulting in unrepresentative data. It is well known in the nursery industry, that to keep plants healthy in pots for long periods, good drainage and a good potting mix is needed. At the same time, plants were put out in two different gardens of similar construction. One garden was not big enough for all plants. Due to area constraints, not all plants were put in the gardens, but 11 were. The soil type here was of typical sandy loam, with a mixture of fine and medium particle size. These plants were grown for 13 months in both these environments. All plants were planted from 90mm pots.

Testing

In February 2007, all plants were tested. Twenty nine random samples were taken from 8 pots, from the pot trial from 31 different plant types. The worst 2 pots of each variety were discarded. Sixteen random samples were taken from the 5 garden plants of each variety. A ground shear vane tester (Fig. 2) was used to test the strength of the potting mix, and root system, and the soil and roots system of the plants. All soil and potting mix was saturated first, as per the instructions provided by the shear vane tester instruction manual. These devices are regularly used by engineers to test the strength of saturated soil and other bases for construction. To get statistically significant results, and to eliminate the chances of a few unrepresentative readings skewing the results, a larger sample size was used. The ground shear tester was calibrated as per manufacturer's guidelines. The readings were taken from a minimum of 6cm from the centre of the plant, or 2 cm from the vertical plant shoots, or which ever was greater, at a depth of 5cm (Fig. 1). This ensured the reading was outside the 80mm original pot from which the plants were planted, and outside the effect of most of the above ground plant growth. For example, King Alfred is more aggressive, so the distance from the side of the plant was 2cm, which happened to be further than the 6 cm distance from the centre, whilst the shrubs were taken from the 6cm distance. If King Alfred's readings were taken from the 6 cm distance the vertical growth really caught the shear vane tester, and made the readings un-representatively high. The 5cm depth was chosen, because a preliminary test of the pots showed this is where most samples had the strongest reading. The garden plants were tested in the same way. (Fig 3).

Figure 1.

Figure 2.

Figure 3.

Results

The results for the pot trials can be seen in Table 1, and for the garden trials in Table 2 and 3. The aim of the garden trial was to see if the plants were in a similar order to the pot trials, once tested for strength. In general they were. The garden trials acted as a control to see if the data from the pots could be extrapolated to open soil. The answer was generally yes. For example, King Alfred was the best soil strengthening plant in the garden and pot tests, with both results being significant. The soil strengthening in the garden was lower than in the pot, but this would be expected, as there are not barriers in the garden condensing the plant roots, however the soil strengthening ability of King Alfred in the garden was still an impressive (343%), far more then any other plant. The data was also put through a statistical analysis (ANOVA), to ensure the differences were significant. All plants from Liriope Evergreen Giant (100%) strengthening compared to bare soil or higher strengthening rates had a significant difference compared to bare soil. The pots of bare soil and the bare soil in the gardens were also tested. The readings from the plants was compared to the bare soil, giving us results that showed how many times the given plants strengthened the soil. The undrained shear strength (Cu) of the vegetated and unvegetated potting mix was also calculated, and results were reported in kPa. Table 1. We used the classical formula to obtain Cu values from the torque (T);

$Cu = 6T \div [\pi d^2(d + 3h)]$

For a ratio h/d = 2 (height ÷ diameter of the vane blades): $Cu = 6T \div (7\pi d^3)$.

Table 1. Results for plants in 230mm pots.

Trade Names	Botanical names	difference to bare soil	*significant?*	% increase vs bare soil	grouping	Shear Strength kPa
Common Lomandra	Lomandra longifolia	0.43	No	50%	0	13.6
Tanika	Lomandra longifolia 'LM300'ɸ	2.15	YES	250%	2	29.5
Common Caerulea	Dianella caerulea	0.81	No	94%	0	17.9
Little Jess	Dianella caerulea 'DCMP01' ɸ	1.55	YES	181%	2	24.3
Katrinus Deluxe	Lomandra longifolia 'Katrinus Deluxe'	3.15	YES	366%	4	39.6
Breeze	Dianella caerulea 'DCNCO' ɸ	2.56	YES	297%	3	33.2
King Alfred	Dianella caerulea 'John 316' ɸ	6.46	YES	752%	6	70
Nyalla	Lomandra longifolia 'LM400' ɸ	2.82	YES	328%	3	36.1
Melaleuca decora	Melaleuca decora	0.51	No	59%	0	14.5
Carex appressa	Carex appressa	1.52	YES	176%	2	23.8
Microleana	Microlaena stipoides	0.26	No	31%	0	11.9
Eskdale	Poa labillardieri 'Eskdale' ɸ	1.21	YES	141%	1	21.1
Little Rev	Dianella revoluta 'DR5000' ɸ	1.39	YES	161%	2	22.8
Tasred	Dianella tasmanica 'TR20' ɸ	2.15	YES	250%	2	29.6
Revelation	Dianella revoluta 'DRG04' ɸ	1.16	YES	135%	1	20.8
Nafray	Pennisetum alopecuroides' PA300'ɸ	4.08	YES	475%	5	50.3
Katrinus	Lomandra longifolia 'Katrinus' ɸ	1.85	YES	216%	2	26.9
TropicBelle	Lomandra hystrix 'LHCOM' ɸ	1.16	YES	135%	1	20.8
Themeda	Themeda australis	0.47	No	55%	0	14.1
Cassa Blue	Dianella caerulea 'DBB03' ɸ	1.14	YES	132%	1	20.6
EvergreenGiant	Liriope muscari 'Evergreen Giant'	0.86	YES	100%	1	18.1
Hardenbergia	Hardenbergia violacea	0.61	No	71%	0	16.6
Euc.Teritcornis	Eucalyptus tereticornis	0.45	No	52%	0	13.8
Acacia falcata	Acacia falcata	0.31	No	36%	0	12.3
Kennedia rubicunda	Kennedia rubicunda	0.99	YES	115%	1	19.2
Anigozanthos	Anigozanthos flavidus	0.97	YES	113%	1	19.1
Cas.glauca	Casuarina glauca	0.47	No	54%	0	14
Bursaria spinosa	Bursaria spinosa	0.18	No	21%	0	11
Phormium tenex	Phormium tenex	0.22	No	25%	0	11.4
KatieBelles	Lomandra hystrix 'LHBYF' ɸ	2.45	YES	285%	3	32.3
Agapanthus	Agapanthus orientalis	2.43	YES	283%	3	32

groupings:

up to 75%	0
75- 150% increase	1
151-250% increase	2
251-350% increase	3
351-450% increase	4
451-550% increase	5
more than 550% increase	6

Table 1 continued, Anova test for pot trial.

Anova: Single Factor **1% level of testing**

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std dev.*	difference to bare soil	*significant?*
BareSoil	29	24.8	0.86	0.016847	0.1		
Common Lomandra	29	37.4	1.29	0.116675	0.3	0.43	No
Tanika	29	87.4	3.01	0.553374	0.7	2.15	YES
Common Caerulea	29	48.5	1.67	0.323498	0.6	0.81	No
Little Jess	29	70	2.41	0.209803	0.5	1.55	YES
Katrinus Deluxe	29	116.2	4.01	2.156379	1.5	3.15	YES
Breeze	29	99.1	3.42	1.005049	1.0	2.56	YES
King Alfred	29	212.4	7.32	3.826897	2.0	6.46	YES
Nyalla	29	106.8	3.68	0.636478	0.8	2.82	YES
Melaleuca decora	29	39.6	1.37	0.140911	0.4	0.51	No
Carex appressa	29	68.9	2.38	0.210468	0.5	1.52	YES
Microleana	29	32.6	1.12	0.023325	0.2	0.26	No
Poa Esk	29	60.1	2.07	0.49564	0.7	1.21	YES
Little Rev	29	65.2	2.25	0.2833	0.5	1.39	YES
Tasred	29	87.3	3.01	0.527389	0.7	2.15	YES
Revelation	29	58.7	2.02	0.104754	0.3	1.16	YES
Nafray	29	143.4	4.94	0.900419	0.9	4.08	YES
Katrinus	29	78.7	2.71	0.399803	0.6	1.85	YES
TropicBelle	29	58.5	2.02	0.162906	0.4	1.16	YES
Themeda	29	38.6	1.33	0.070074	0.3	0.47	No
Cassa Blue	29	57.9	2.00	0.583916	0.8	1.14	YES
EvergreenGiant	29	50	1.72	0.423325	0.7	0.86	YES
Hardenbergia	29	42.7	1.47	0.153498	0.4	0.61	No
Euc.Teritcornis	29	37.9	1.31	0.150665	0.4	0.45	No
Acacia.Falcata	29	33.9	1.17	0.080788	0.3	0.31	No
Kenedia.ruicunda	29	53.6	1.85	0.541872	0.7	0.99	YES
Aganizanthus	29	53.1	1.83	0.516502	0.7	0.97	YES
Cas.glauca	29	38.5	1.33	0.067069	0.3	0.47	No
Bursaria.spinosa	29	30.2	1.04	0.011084	0.1	0.18	No
Phormium.tenex	29	31.2	1.08	0.019754	0.1	0.22	No
KatieBelles	29	96	3.31	1.072389	1.0	2.45	YES
Agapanthus	29	95.5	3.29	0.579951	0.8	2.43	YES

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1631	31	52.61198	102.8783	2E-270	1.70540204
Within Groups	458.21	896	0.5114			
Total	2089.2	927				

Significant difference present

Least significant difference = 0.82

Table 2 Garden Trial 1.

Anova: Single Factor **1% level of testing**

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std dev.*	difference to bare soil	*significant?*
Bare soil	15	19.9	1.326667	0.143524	0.4		
Revelation	15	34.6	2.306667	0.394952	0.6	0.99	YES
Little Jess	15	38.4	2.56	0.659714	0.8	1.24	YES
Nyalla	15	46.6	3.106667	0.70781	0.8	1.79	YES
Breeze	15	60	4	0.427143	0.7	2.68	YES
Tanika	15	37.7	2.513333	0.271238	0.5	1.19	YES
Katrinus	15	46.9	3.126667	0.494952	0.7	1.81	YES
LittleRev	15	34	2.266667	0.39381	0.6	0.95	YES
Nafray	15	49.7	3.313333	0.12981	0.4	1.99	YES
Eskdale	15	45.7	3.046667	0.695524	0.8	1.73	YES

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	71.76967	9	7.974407	18.46579	5.48E-20	2.536453
Within Groups	60.45867	140	0.431848			
Total	132.2283	149				

Significant difference present

Least significant difference = 0.75

Groups	difference to bare soil	*significant?*	% increase vs bare soil	grouping
Bare soil				
Revelation	0.99	YES	75%	1
Little Jess	1.24	YES	94%	1
Nyalla	1.79	YES	135%	2
Breeze	2.68	YES	203%	3
Tanika	1.19	YES	90%	1
Katrinus	1.81	YES	137%	2
LittleRev	0.95	YES	72%	1
Nafray	1.99	YES	151%	2
Eskdale	1.73	YES	131%	2

groupings:	up to 100% increase	1
	up to 150% increase	2
	up to 200% increase	3

Table 3. Garden trial 2.

Anova: Single Factor **1% level of testing**

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std dev.*	difference to bare soil	*significant?*
Bare soil	15	20.4	1.36	0.105429	0.3		
Katrinus Deluxe	15	58.5	3.9	0.122857	0.4	2.54	YES
King Alfred	15	90.4	6.026667	0.680667	0.8	4.67	YES

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	163.7604	2	81.88022	270.2459	1.04E-24	5.149104
Within Groups	12.72533	42	0.302984			
Total	176.4858	44				

Significant difference present

Least significant difference = 0.63

Groups	difference to bare soil	*significant?*	% increase vs bare soil	grouping
Bare soil				
Katrinus Deluxe	2.54	YES	187%	3
King Alfred	4.67	YES	343%	4

groupings:	up to 100% increase	1
	up to 150% increase	2
	up to 200% increase	3
	more than 200%	4

From the results, it can be seen that in general Dianella and Lomandra and some native grass varieties strengthened the soil more than plants such as native trees and shrubs, or exotic Liriope, or Phormiums etc. However, even amongst the Dianella and Lomandra there were some varieties that performed much better than others. In general, the common forms of the Dianella and Lomandra, did not perform near as good as the better bred varieties. The best Variety of Lomandra longifolia was Lomandra longifolia ‘Katrinus Deluxe’ (366% stronger than bare soil, or it had a saturated shear strength of 39.6 kPa) with another important fact being that it strengthened the soil 3.11 times more than the common form of Lomandra longifolia

(50% stronger then bare soil). The best Variety of Dianella caerulea was KING ALFRED, Dianella caerulea ‘John316’ (752%, 70 kPa) which strengthened the soil 4.37 times more than the common form of Dianella caerulea (94%). Lomandras and Dianellas varied a lot between cultivars. These results make sense, as part of the original selection criteria for breeding better varieties is more dense, vigorous plants, that are more compact and tidier looking, with a more vigorous root system; Inspirations of a Plant Breeder, Garden Gurus Newspaper, Todd Layt, 2007. This data should make engineers consider carefully the implications of just specifying a common plant, by only Genus and species. This investigation has provided evidence that the choice of a cultivar compared to a common form can lead to much better soil strengthening, in the case of King Alfred, 4.37 times better soil strengthening.

As previously stated, one plant stood out far more than all other plants. KING ALFRED, Dianella caerulea ‘John 316’ (752%), strengthened the soil an impressive double the amount to the nearest other Dianella, and 58% more than the closest other plant, which was Nafray, a well known native Pennisetum alopecuroides. In the Garden, King Alfred was also easily the best plant at strengthening the soil at a depth of 50mm. To show how impressive King Alfred was, it only needs to be compared to Common Dianella caerulea. King Alfred strengthened the soil (752%) more than bare soil, whilst, the common Dianella caerulea only strengthened the soil (94%). Although (94%), was still impressive compared to the native shrubs. For example, Acacia falcata only strengthened the soil (36%) and Melaleuca decora achieved only (59%). Other impressive plants included NAFRAY Pennisetum alopecuroides ‘PA300’ (475%,) more strength than bare soil and a saturated shear strength of (50.3 kPa) , Lomandra longifolia ‘Katrinus Deluxe’ (366%, 39.6 kPa), BREEZE Dianella caerulea ‘DCNCO’ (297%, 33.2 kPa), TASRED Dianella tasmanica ‘TR20’ (250%, 29.6 kPa), NYALLA Lomandra longifolia ‘LM400’ (328%, 36.1 kPa) and TANIKA ‘LM300’ (250%, 29.5 kPa). Tanika and Tasred were the shortest growing plants that performed very well. In many projects lower growing plants are needed, and the best performing of the really low growing plants were, LITTLE JESS Dianella caerulea ‘DCMP01’ (181%, 24.3 kPa), and LITTLE REV ‘DR5000’ (161%, 22.8 kPa). These are very good soil strengthening results for such low growing plants, especially when compared to commonly used landscape plants such as Phormium tenax (25%, 11.4 kPa) and the widely used Liriope Evergreen giant (100%, 18.1 kPa). These low growing Dianellas also had much better results than commonly used ground cover plants such as Hardenbergia violacea (71%, 16.6 kPa).

Native grasses were a little surprising. Some had very low soil strengthening results such as Microleana (31%) and Themeda australis (55%) whilst some performed much better; Poa labillardieri cv Eskdale (141%) and the second best performer in the hole study, NAFRAY Pennisetum alopecuroidies ‘PA300’ (475%).

To help analysis, plants were grouped into 7 groups, 0 to 6. O being those that had no significant soil strengthening at the statistical level, 1 having some, up to 6 that strengthened the soil the most. Plants in groups 2 to 6 or higher had 151% or higher soil strengthening ability, which is substantial, as only 13 of the 31 plants made it into these groups in the pot trial. Table 4 lists these plants, and their group; the higher the group number, the higher the soil strengthening ability.

Table 4. Best soil strengthening plants, based on this investigation.

Groups	difference to bare soil	*significant?*	% increase vs bare soil	grouping	Shear Strength kPa
Little Rev	1.39	YES	161%	2	22.8
Carex appressa	1.52	YES	176%	2	23.8
Little Jess	1.55	YES	181%	2	24.3
Katrinus	1.85	YES	216%	2	26.9
Tasred	2.15	YES	250%	2	29.6
Tanika	2.15	YES	250%	2	29.5
Agapanthus	2.43	YES	283%	3	32
KatieBelles	2.45	YES	285%	3	32.3
Breeze	2.56	YES	297%	3	33.2
Nyalla	2.82	YES	328%	3	36.1
Katrinus Deluxe	3.15	YES	366%	4	39.6
Nafray	4.08	YES	475%	5	50.3
King Alfred	6.46	YES	752%	6	70

Conclusion

This study shows that plants that have been through extensive breeding, and selected for better vigour, density, etc, have the potential to have a much better ability to strengthen the soil compared to common forms of the same genus and species. Of these better cultivars, some are much better than others at strengthening the soil. This data can help erosion control professionals and civil engineers choose the best erosion control plants for their projects. It could also be argued that plants with higher soil strengthening abilities, could be used in lower numbers to achieve similar erosion protection, than, a higher quantity of plants that have lower strengthening abilities. When deciding whether a plant is acceptable to help reduce erosion for slope etc, statistical analysis would say that only those that strengthen the soil significantly should be considered, but best practice would suggest using those plants that have higher strengthening characteristics, and that are appropriate for the site. To judge if appropriate, it would first be necessary to chose the right height, then choose plants that work in the conditions and region.

This soil vegetation strengthening data will need to be used in conjunction with good horticultural practices, so the right plant is chosen for the right place, and right region. Eg; periodic flooding then Tropic Belle (135%) or KatieBelles (285%) may be needed as they cope well with wet feet, or for low growing areas, Little Rev (161%) or Little Jess (181%) may be chosen (Little Rev is not good with wet feet), or for slopes with high erosion, some occasional wet feet or dry times, King Alfred (752%) would be the best choice. There is no point planting the best erosion control plant, only to find it dies, because the climate is wrong; too cold, or too humid etc. From this list of plants however, there should be at least a few plants in each category that will work for almost any region. So it is recommended that when Engineers, Landscape Architects, Designers, Councils etc, are using this list that quantifies what are the best plants for erosion control, that they use it in conjunction with plant specification sheets for their region.

Turf Research

Literature review.

Turf has been used for erosion control for many decades, and is a well known effective product at preventing erosion. According to the Turf Producers International, ‘As early at 1986, a U.S. Geologically Survey funded project at The Pennsylvania State University documented that grassed areas established with turfgrass sod are up to 15 times more effective in controlling runoff than seed established grass, even after three years.

More recently, a University of Maryland team of scientists testing the "Runoff and Sediment Losses from Natural and Man-made Erosion Control Materials" found, "Sod offers superior performance when compared with straw in retarding the initiation of runoff, reducing runoff rates and reducing total soil losses. None of the man-made materials effectively extended the time for runoff initiation." ‘

There is little research that quantifies which of the commonly used large area landscape turf type’s best strengthened the soil.

Materials and trial set up

A series of trial plots of 3 types of turf, with 3 replicated plots of each variety were grown at Clarendon NSW Australia, for a period of 10 months. The plots were initially established with instant turf rolls. The soil was an alluvial flood plain silty soil of uniform appearance. Prior to establishing the turf plots, the soil was well rotary hoed, mixed and levelled to ensure uniformity. The plots were fertilised well at establishment phase, and were well watered to begin with. Prior to testing, the plots were somewhat neglected, and mown less frequently, so as to mimic how most erosion control turf is used. The plots were mown when they reached 90mm in height, back to 50mm in height. Turf used in drains, slopes, roadsides, etc are usually treated this way. Only limited irrigation was applied, and no fertiliser for the last 5 months. Another trial at Pitt Town was conducted on very well maintained areas of more cared for lawns, more similar to how sporting ovals are looked after. The turf varieties in both trials were varieties commonly used in Australia for the purpose of erosion control. They were Kikuyu, Greenlees Park Couch (Bremuda Grass), and Empire Zoysia. Buffalo or St Augustine turf varieties were not included in this trial, as they do not have Rhizomes, and are rarely used for erosion control.

Figure 4

Figure 5.

Testing

In 2006, the turf plots were tested to see how much each turf variety strengthened the soil. Each plot was tested using a vane shear tester, at a depth of 50mm. (Figures 4 and 5). The soils were first saturated with water to provide a test more applicable for erosion control, and to comply with recommendations of the manufacture of the shear vane tester. 30 random samples were taken over the three plots of each variety, at each site.

Results

On the Clarendon site, the differences between the Empire turf compared to the other varieties ability to strengthen soil was considerable (Table 5). This could be expected, as Empire turf looked more dense to the human eye. At the Pitt Town site, where all the plots looked dense, due to higher maintenance, the differences were much less (Table 6), and even showed different results from the Clarendon site.

For erosion control, the Clarendon site should be considered to be the most important. The Pitt Town site, is not really relevant for most erosion control purposes, but it is still important to know higher maintenance can change the ability of a turf to strengthen the soil. The Pitt Town site was watered and fertilised more and mowed more frequently at lower mowing heights, and maintained far more than a site typical of turf used for erosion control. Pitt Town turf plots were maintained like a high maintenance sports oval.

At the Clarendon site, Empire Turf strengthened the soil far more than Kikuyu, and Couch. Empire was the only grass to significantly strengthen the soil at Clarendon. Empire strengthened the soil (48%), compared to Couch (3.2%) and Kikuyu (9.7%). Empire had a shear strength of 97.9 kPa. So for sites where the turf receives less than good turf maintenance, which would be most situations for erosion control purposes, Empire is significantly the best turf variety, and Kikuyu is the second best, with Couch being the worst, for strengthening the soil in most situations where erosion control is needed.

At Pitt Town Kikuyu was the best, where couch and Empire were much closer, and not significantly different. Although it would be rare that turf would be looked after this well on roadsides, water channels, on river banks, slopes etc, so these results are not so relevant for the erosion control industry. It does however show that the soil strengthening ability of different turf varieties depends also on how it is maintained. It must be noted, that Kikuyu and Couch lose quality badly if the maintenance is low; Dutschke, Paananen, and Locock, 2007. The research of that paper supports the findings of this paper. The Dutschke paper also showed that Couch and Kikuyu require far more mowing than Empire Turf, another reason why Empire would be better for slopes, embankments etc.

Another test conducted at Clarendon was a test where the RHIZOME and ROOT weights for 900 square centimetres of sod with leaves removed were calculated. The leaves were sheared off first, then a 900 square centre metre section was dug out, the soil was washed off, and the roots and rhizomes were weighed. To reinforce the results of the shear vane tester, the Empire should have a higher root and rhizome mass than the others turf types. The results showed that. Empire weighed 290 grams, the Kikuyu weighed 220 grams, and the Couch weighed 200 grams. The extra roots and rhizomes of Empire Turf explain why it had a better ability to strengthen the soil.

Table 5 Turf shear vane test results and statistics for Clarendon.

Turf Type	Shear strength in kPa	Significant difference to bare soil	% increase to bare soil
Bare Soil	66	N/A	N/A
Couch	68.1	No	3.2%
Kikuyu	72.4	No	9.7%
Empire	97.9	Yes	48%

Anova: Single Factor 5%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std dev*	#
Kikuyu	30	115.1	3.836667	1.303782	1.1	a
Couch	30	107.1	3.57	1.978724	1.4	a
Empire	30	149.3	4.976667	2.380471	1.5	b

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	33.49422	2	16.74711	8.871894	0.000312	3.101292
Within Groups	164.2263	87	1.887659			
Total	197.7206	89				

Significant difference present at 5% level

LSD = 0.85

Anova: Single Factor 1%

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std dev*	#
Kikuyu	30	115.1	3.836667	1.303782	1.1	a
Couch	30	107.1	3.57	1.978724	1.4	a
Empire	30	149.3	4.976667	2.380471	1.5	b

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Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	33.49422	2	16.74711	8.871894	0.000312	4.857782
Within Groups	164.2263	87	1.887659			
Total	197.7206	89				

Significant difference present at 1% level

LSD = 0.85

 # Mean values followed by the same letter are not significantly different

Table 6. Results for Pitt Town.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*Std dev*	#
Kikuyu	30	103.7	3.456667	0.490126	0.7	a
Couch	30	88	2.933333	0.512644	0.7	b
Empire	30	83.6	2.786667	0.466023	0.7	b

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7.471333	3	2.490444	4.32805	0.006247	2.68281
Within Groups	66.74867	116	0.57542			
Total	74.22	119				

Significant difference present at 5% level
LSD = 0.47

\# **Mean values followed by the same letter are not significantly different**

Conclusion

This research shows that of the commonly used erosion control turf types, Empire Turf strengthens the soil the best. Kikuyu is the second best and Couch is the least effective at strengthening the soil, on lower to moderately maintained turf areas. Empire is the best turf for strengthening the soil in areas that are prone to erosion; areas such as water channels, batters, slopes, roadsides, river banks etc. Unless the sites are highly maintained, which is very unlikely on most erosion control sites, Couch (Bermuda) and Kikuyu do not significantly increase soil strength based on the results of this investigation.

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