Comparison of Recycled Organic Compost Blankets with Hydromulch in Controlling Soil Erosion Under Simulated Rainfall

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Executive Summary

A trial to compare the effectiveness of recycled organic (RO) compost blankets against conventional hydroseeding mulch in reducing runoff and soil erosion was conducted using soils typically used in roadside verge landscaping applications in Western Sydney. Soil profiles were constructed in plastic recycling bins (surface area 0.19 m^2) using a 120 mm clay sub-soil typical of shale soils from Western Sydney, and a 50 mm sandy loam topsoil. The soil profiles were prepared to simulate specifications in RTA QA 49. Four soil cover treatments were compared:

1: RO compost blanket with binder;

2: RO compost blanket without binder;

3: hydromulch; and

4: bare soil.

Other factors in the experimental design included two angles of slope (low = 20°, high = 45°) and two levels of soil compaction (uncompacted; compacted). Soil cover treatments were applied to the bins by commercial contractors used for field applications, with the RO compost blankets installed at 25 mm depth, and the hydromulch to 5 mm (maximum) depth. Hydromulch was applied as specified in RTA 178. Japanese millet seed was supplied in soil cover treatments at conventional rates (20 kg/ha). After treatment, bins were kept in a glasshouse at the required angle, and watered twice weekly for five weeks (March–May 2006). Bins were then subjected to simulated rainfall for 30 minutes, at an average intensity equivalent to 92 mm/h (equivalent to 1 in 75 year event for Sydney). Runoff and suspended sediment were collected; variables measured included total runoff, runoff over time (hydrograph), steady state runoff at 30 mins, soil loss, total suspended solids, total N and P in the runoff, plant density and shoot biomass.

Runoff, both total and steady state, was greatest from bare soil, and was significantly reduced by all the soil covers. Hydromulch reduced total runoff by 14% compared to bare soil, and steady state runoff by 23%. The RO compost blankets gave even greater, and statistically significant reductions in both total and steady state runoff. RO compost blankets reduced total runoff by 46–49%, and steady state runoff by 49–53%, compared to bare soil, indicating that more infiltration occurred under the RO compost blankets. Soil compaction significantly increased both total and steady state runoff; total runoff was greater at the steeper slope.

Soil loss was greatest for bare soil at the steepest slope. Soil cover treatments significantly reduced soil loss compared to bare soil, by 98% for hydromulch and 99.5% to 99.6% for the RO compost blankets (treatment averages). At the steep slope, soil loss compared to bare soil was reduced by 91% under hydromulch, but by 99.8 to 99.9% under the RO compost blanket.

Total suspended solids (TSS) were greatest in runoff from bare soil; soil cover significantly reduced TSS, with the greatest reduction achieved by hydromulch (98.5%) followed by the RO compost blankets (96 to 97.3%). Total N was lowest in runoff from bare soil and hydromulch (0.8–1 mg/L), and significantly higher in runoff from the RO compost blankets (1.25–1.35 mg/L). Total P was lowest in runoff from hydromulch (0.3 mg/L), and higher from bare soil (0.7 mg/L); total P in runoff from RO compost blankets ranged between 0.3–0.7 mg/L, with lower values associated with non-compacted soil.

Thus RO compost blankets gave the greatest reductions in runoff and soil loss; hydromulching gave the greatest reductions in TSS, total N and total P.

Plant densities ranged from 2,000–5,000 m^{-2} and were significantly reduced by soil compaction, and the RO compost blanket + binder treatment. Shoot biomass was only affected by soil compaction, which reduced it.

The two RO compost blanket treatments had very similar values for runoff, soil loss, and nutrient concentration in runoff, and were statistically indistinguishable from each other. The only significant difference between them was in plant density, where the presence of binder reduced density by one-third.

1.0 Introduction

Any human activity that removes vegetative cover and litter from large areas of soil and leaves the bare soil exposed for periods of time is liable to result in soil erosion. This problem occurs in agriculture, and in engineering works associated with building and infrastructure construction. Additional problems such as soil compaction by machinery and steep slopes often compound soil erosion on sites such as road verges. Devising adequate measures to protect bare soil and minimise soil loss is an important environmental priority.

In Australia, the organic fraction of the urban waste stream is diverted from landfill; products generated from composted recycled organic waste have been used overseas in soil protection, with considerable success (see Literature Review). There has been no scientific trial of these products under Australian conditions in this specific application, though a number of demonstration trials have been established. This report describes the results of a scientific trial, conducted using constructed soil profiles.

1.1 Literature Review

A number of studies, mainly from the USA, have compared RO compost blankets with conventional practice such as hydromulching. The Environment Protection Agency of the USA now lists compost blankets on their website as best management practice (BMP) for erosion control, replacing previous BMP's such as geotextile blankets (http://cfub.epa.gov/npdes/stormwater/menuofbmps/index.cfm). A number of the studies reviewed below are cited in the BMP fact sheet to support this recommendation.

Faucette et al. (2005) reported a field evaluation of four RO composted blankets and two hydroseed treatments (one with a silt fence at the bottom of the slope, one with a berm at the top of the slope). The RO composted blankets were spread to 37.5 mm depth over a sandy clay loam at a site in Georgia, USA, and were subjected to simulated rainfall (77 mm/h) immediately after installation, at three months and at twelve months.

While any soil cover reduced runoff, a consistent pattern of greater reduction by the RO composted blankets than by hydroseeding emerged. Total runoff was lower under RO composted blankets than hydroseed treatments, the difference being significant at the three months sampling. Total cumulative runoff (compared to bare soil) at the one year mark was reduced by 55% under RO composted blankets, and by 30% under hydroseed. More water infiltrated into the soil (compared to bare soil) under the RO composted blankets (range 31– 51% at first rain event) than under the two hydroseed treatments (range 20 -24% at first rain event). By the final rain event, infiltration percentages were 61–65% for the RO composted blankets and 43–47% for the hydroseed treatments. Average cumulative time to first runoff was 24 minutes for the RO composted blankets, 9 minutes for the hydroseed, and less again for bare soil. Cumulative peak runoff rates were 60% lower for RO composted blankets compared to bare soil, and 34% lower for the hydroseed treatments.

Soil loss was reduced under both types of soil cover, but the greatest reductions were observed under RO composted blankets. Total solid loads compared to bare soil were 4–5% immediately after sampling under hydroseed treatments, and 1.6–3% under RO composted blankets. By three months, the comparisons were 1.4–4% under hydroseed and 0.1–0.3% under RO composted blankets.

Total nitrogen loss changed with time, from being initially greatest under RO composted blanket and hydroseed treatments, to being significantly less under all soil treatments after one year (all soil covers had vegetation establish after seeding). Total nitrogen (and nitrate) losses were least from two of the RO composted blankets (municipal solid waste compost and yard waste compost). Total phosphorus mass load over the one year of the study was highest from the two hydroseed treatments, and half to one-tenth or more under the RO composted blankets, or bare soil.

A range of RO composted blankets (consisting of compost and woody mulch materials) were compared using constructed soil flats by Faucette et al. (2004). RO composted blankets included three types of poultry litter and four types of composted organic mulches; these were compared to three types of wood mulch and bare soil. A 50 mm soil depth was overlain with 50 mm of each soil cover in stainless steel flats, and subjected to 160 mm/h rainfall for up to 60 minutes after runoff commenced. Soil covers reduced total runoff (with the exception of one of the poultry mulches, which was hydrophobic), the greatest reduction being a 50% reduction of total runoff under one of the wood mulches and one of the composted organic mulches; the average reduction under all mulches was 20%. Total solids loss from bare soil was significantly higher than all but one of the soil covers (one of the poultry litter treatments), and was lower under the woodchip mulches than under the composted organics (difference was slight, and not significant).Nutrient losses were highest from the poultry litter and composted biosolids compost treatments, and generally higher for the other composted mulches than either woodchip or bare soil (the simulation represented a very severe rainfall event immediately after mulch application). Treatments with lower respiration rates, nitrate-nitrogen, soluble salt, potassium and sodium concentrations tended to have less erosion and transport of solids.

A field trial of three types of RO composted blankets (biosolids, yardwaste and bio-industrial byproducts) in comparison with a compacted subsoil (control) or control + 150 mm of topsoil, was conducted by Persyn et al. (2004). RO composted blankets were applied at two depths (50 mm or 100 mm) to replicate plots on a 3:1 highway embankment in Iowa, and subjected to simulated rainfall (95 mm/h) for up to 60 minutes after runoff began. All three compost covers reduced runoff; steady-state runoff rates were reduced by 64–94% compared to the control, under the RO composted blankets. Steady-state interrill erosion under the three composts was reduced by 0.1–30% compared to either the control, or topsoil treatments. The largest reductions in erosion occurred under the RO composted blanket with coarse mulch (yard waste compost). Soil under yard waste showed the greatest resistance to rill formation (Persyn et al. 2005). Time to first runoff was 30 minutes or longer under the compost media, and was 8 minutes or less for the soil treatments. Depth of the RO composted blanket only affected the runoff rate on unvegetated treatments, with more runoff recorded from the shallower depth of application.

Runoff from the mulched plots was assessed for nutrient and pollutant loads, and compared to runoff from embankments treated with two conventional erosion control methods (light tillage and seeding of native embankment soil, or application of 150 mm of topsoil followed by seeding) (Glanville et al. 2004). The applied composts contained much greater concentrations of pollutants than the soils used. Runoff from the organic mulch plots contained significantly greater concentrations of of soluble and absorbed zinc, phosphorus and potassium, and absorbed copper and chromium. However, mulched plots had significantly higher infiltration capacity than the soils, and required substantially more rain to produce 1 hour of runoff. Thus the pollutants exported by equal amounts of rainfall (30 minutes, equivalent to a 1 in 25 year event at that rainfall intensity) was used for comparison of the treatments. Total masses of individual quantifiable soluble and absorbed contaminants in runoff from conventional areas were 5 and 33 times respectively, those in runoff from compost-treated areas.

A comparison of a range of soil erosion controls was compared on two soil types over a range of slopes (30–70%) in the Lake Tahoe basin, California, by Grismer and Hogan (2005). Simulated rainfall (60 mm/h) was applied to field plots. Sediment yield from bare soils increased with slope, and were higher on one soil type (fine volcanic) than the other (coarse granitic). Revegetation with native grasses or pine needle mulch dramatically reduced sediment loss on both soils. Mulch (pine needle) alone reduced sediment yield by 30% compared to bare soil on granitic soil, but sediment loss still exceeded that of undisturbed native soils. Full soil treatments that included incorporation of woodchips, or used tillage, compost or biosolid amendments and mulch covers together with plant seeding resulted in little or no runoff and sediment yield from both soils.

In a further series of studies, the performance of RO composted blankets was compared with other products in field trials, and runoff from natural rain events was collected and analysed. Ettlin and Stewart (1993) set up a trial in Portland, Oregon, using two compost products (medium and coarse grade), leaf mulch, two conventional erosion measures (hydromulching, sediment fence), and a bare soil control. Replicate plots were established at two sites with different slopes (34% and 42%); runoff samples were collected after five storm events and analysed. Soil loss under composts was less than that from sediment fences, and similar to that from hydromulched plots. Losses of settleable solids were 9% of the bare soil value under hyromulching, and 2–9% under the RO compost blankets. Losses of total suspended solids from hydromulched plots were 2.4% of the bare soil value, and 0.9–4% from RO compost blanket plots. Composts reduced heavy metal runoff from soils high in heavy metals, and humic acids in yard debris compost removed chemical pollutants such as oil, grease, petrol and pesticides from runoff.

Denmars and Long (1998) compared the performance of five types of RO compost blankets, with a hay / seed conventional method (i.e. hydromulching), and bare soil, in (unreplicated) test cells at 26° slope over a silty sand on a roadside verge in Conneticut. Natural runoff was collected in buckets at the base of each cell, from natural storm events (range 6 – 110 mm) over a nine month period. The concentration of total suspended solids was highest in runoff from bare soil, and reduced to 10% or less of the bare soil value by the RO composted blankets. Concentration of soluble salts in runoff from all cells was low, and concentrations of metals were well below the published limits for these elements.

Ros et al. (2001) compared unstabilized municipal waste, compost, sewage sludge and bare soil in field plots on a 15% slope located in SE Spain. Runoff from natural rainfall events was collected over a two year period. All soil covers significantly reduced soil erosion compared to bare soil. The most effective treatment was compost, which reduced soil loss by 94% and runoff by 54%, compared to bare soil.

1.2 Aim

The aim of the trial was to compare the performance of two RO composted blankets (one with, and one without added binder), with a conventional erosion control methods (hydromulching), and bare soil, in reducing runoff and soil erosion from constructed soil profiles. Soil compaction and angle of slope were also varied, to determine the effect of these two factors on results.

2.0 Methods

2.1 Experimental design

The experimental design for the trial included the following factors:

1: **soil cover** – three types of soil cover were compared with bare soil (control). The soil covers were

- bare soil
- hydromulch
- RO composted blanket with binder (RO + binder)
- RO composted blanket without binder (RO – binder)

2: **soil compaction** – the topsoil surface was either compacted, or not compacted

3: **angle of slope** – bins were kept at either a low or high angle of slope (low = 20°, high = 45°)

Replicate bins (n = 4) were prepared for each soil cover x compaction x angle combination, to give a total of 64 bins in the trial.

2.2 Construction of soil profiles

Soil profiles were constructed in black plastic 36 L recycling containers with solid sides and a mesh base, which allowed free drainage. Bins (internal dimensions 553 x 355 mm, 190 mm depth; surface area = 0.1925 m^2), were filled to 120 mm depth with a heavy clay subsoil from the Rouse Hill area, typical of subsoils overlying Bringelly Shales or Hawkesbury Sandstone found under road works in Western Sydney. The subsoil was wetted up (RTA QA Specification R49) and allowed to drain (Fig. 2.1). Over the subsoil 50 mm of sandy loam topsoil was laid (soils supplied by Hills Landscaping).

(a) (b)

Fig. 2.1. *Heavy clay subsoil in situ in the bins (a) at wet-up; (b) after draining.*

2.3 Soil Compaction

Bins in the compaction treatment were watered after application of the topsoil, and left to dry; this treatment resulted in a compacted soil surface compared to the uncompacted treatment (Fig. 2.2; this method was adopted after trials of alternative methods, such as mechanical compaction, proved impractical). Tests on the soil surface of 12 bins in the compaction treatment with a hand held soil penetrometer showed that a mean pressure of 3.7 kg/cm^2 was required to break the surface crust after the compaction treatment; zero pressure was required to break the soil surface of uncompacted bins.

(a)

(b)

Fig. 2.2. *Topsoil in situ in the bins (a) close-up of compacted treatment; (b) overview of uncompacted treatment.*

2.4 Application of soil covers

RO composted blankets were applied to 25 mm depth by The Hills Bark Blower using commercial pneumatic blowing equipment (Fig. 2.3(a)). RO composted blanket in the + binder treatment had a degradable organic glue added. Hydromulching to RTA specification R178 was applied using commercial equipment by The Daracon Group (Fig. 2.3(b)). The hydromulch consisted of wood pulp applied in water at a rate equivalent to 2.5 tonnes/ha, with fertiliser (Dynamic Lifter Agripellets), polymer binder (3 kg/ha) and wetting agent (50 kg/ha) added. Maximum depth of the hydromulch layer was 5 mm. Japanese millet seed was added to all soil covers at a rate equivalent to 20 kg/ha.

(a)

(b)

Fig. 2.3. *Application of the (a) RO compost blanket, and (b) hydromulch covers to bins.*

2.5 Slope angle and establishment period

Bins were placed in the glasshouse in a randomised replicated block arrangement. Plastic pipe was cut to length and arranged under the southern end of each bin to achieve the required slope. Bins with soil cover treatments were watered after soil covers were applied, and then twice weekly (which approximated the frequency of rainfall in western Sydney during September: 8 rainy days in the month on average at the Richmond weather station *(www.bom.gov.au/)*. Japanese millet germinated readily in all soil cover treatments. A period of approximately 4 weeks was allowed for plants to establish before rainfall simulation trials began.

Table 2.1 *Time-line for the soil erosion trial.*

Event	Time period
Soil profile established, compaction applied	20 March–7 April
Soil covers applied	10–13 April
Establishment period	13 April–10 May
Rainfall simulations	11–17 May

Fig. 2.4. *Tubs in position in the glasshouse during the 4-week establishment phase. Glasshouse benches were inverted to help stabilise tubs.*

(b)

Fig. 2.5 *(a) holes cut to collect runoff; (b) rainfall simulator at work.*

2.6 Rainfall simulation

Rainfall was simulated using a portable rainfall simulator (Fig. 2.5) (Loch et al. 2001). The original intention was to apply simulated rainfall at an intensity of 67 mm/h for 30 minutes (1 in 10 year event for Sydney). Due to problems with the calibration of the simulator, the actual rainfall intensity averaged 92 mm/h (± 2.1 mm/h 95% CL; equivalent to a 1 in 75 year event for Sydney region). Prior to the simulations, two outlet pipes were installed along the lower leading edge of each bin, to allow runoff to be collected. Bins were moved outside the glasshouse and positioned under the rainfall simulator. Two replicates of each treatment were included in each simulation.

(a)

2.7 Data collection

Runoff was collected from the outlet holes (Fig. 2.5(a)) for each 5 minute period during the simulation, and the volume measured. Runoff was quantified by calculating total runoff over the 30 minutes of the simulation, and by plotting runoff per 5 minutes against time (the runoff hydrograph). To quantify soil loss, each runoff sample was allowed to stand for a further 30 minutes so that suspended sediment would settle out. Collected sediment was pooled, dried at 105°C for 24 hours, and weighed.

Two 50 mL sub-samples of the pooled total runoff were kept and frozen for analysis.

2.8 Laboratory Analysis

Runoff samples were analysed for total suspended solids, total nitrogen, and total phosphorus. Total nitrogen and total phosphorus were determined after an autoclave digestion of subsamples in acid persulphate; flow injection analysis was used to determine values. Total suspended solids were determined gravimetrically on a subsample which had been passed through a glass fibre filter and dried at 105°C for 1 hour (Rayment and Higginson 1992).

2.9 Data Analysis

Data were analysed using a Three-Way Analysis of Variance (ANOVA) with soil treatment, compaction, and angle of slope as fixed factors. The analysis tested whether each of the factors varied in the experiment affected the results in its own right (factor significant as a main effect), or, whether the factors interacted with each other (interactions significant). Data were the mean of the two replicates per treatment per simulation (soil and water data) or the tub value (plant data). Homogeneity of variances was tested for using Cochran's test; if variances were not homogeneous, data were transformed as appropriate to satisfy the assumptions of the test. Interactions were examined first, and if not significant, the main effect of factors were tested for significance.

If factors in the experiment were significant as main effects, the means of each level of the factor were compared. For soil compaction and angle of slope, each with only two levels, the interpretation of a significant result was straightforward. If soil cover treatment was significant as a main effect, this required comparison across four means ie. the means for bare soil, hydromulching, RO compost blanket – binder and RO compost blanket + binder (pooled across compaction and slopes). Where soil treatment was significant in the analysis, the four means were compared using a series of planned comparisons (Sokal and Rohlf 1995):

1: bare soil vs. all soil covers pooled;

2: hydromulch vs. RO compost blanket covers, and

3: – binder vs. + binder for the RO compost blankets.

These three planned comparisons asked the following questions:

1: Did soil cover affect the variable in question?

2: Did hydromulch differ significantly from the two RO compost blanket covers?

3: Did the presence or absence of binder affect the performance of the two RO compost blanket covers?

Planned comparisons were used because they are more powerful (able to pick up differences) than post hoc comparisons (Sokal and Rohlf 1995). This approach was taken for total and steady-state runoff, and total suspended solids and total N. For interaction means, and soil cover means for total N and plant density, the Student Newman-Kuels (SNK) test was used for post-hoc comparison.

3.0 Results

3.1 Total runoff

Total runoff is shown for all treatments in Fig. 3.1, and ranged from 1 – 4 L per tub during the 30 minutes of simulated rainfall (equivalent to 5–20 L/m^2), depending on the combination of treatments. The factors that significantly affected total runoff were the soil cover treatments, and soil compaction (significant as main effects Table 3.1(a)); angle of slope, and interactions not significant). Total runoff was highest for bare soil; all soil cover treatments significantly reduced total runoff (Table 3.1(b)). Hydromulching reduced total runoff by 14% (Table 3.2(a)), and the RO compost blankets gave a significant further reduction compared to hydromulch (Table 3.1(b)), the reduction being 46% of the bare soil value (– binder) or 49% (+ binder; Table 3.2(a)). Soil compaction significantly increased total runoff (Table 3.2(b)). Whilst more total runoff occurred at the higher slope (33% increase on low slope mean, Table 3.2(c)), the difference was not statistically significant (Table 3.1).

Fig 3.1	*Total runoff per tub from the surface of each treatment at (a) low angle of slope; (b) high angle of slope. Bars = SE.*

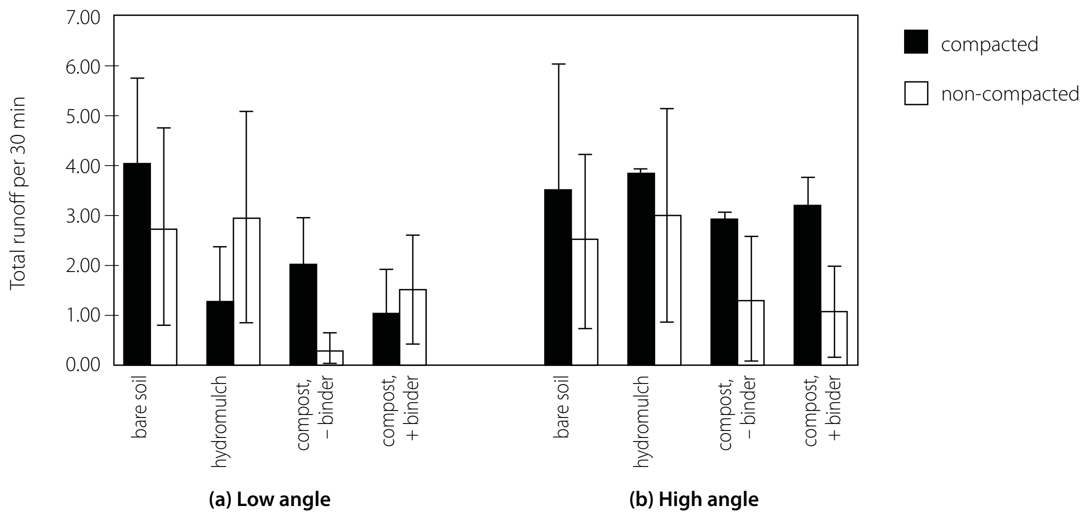


Table 3.1 (a)	*Three-Way ANOVA of total runoff from the surface during the experiment. Variances homogeneous (Cochran's test NS).*				
Dependent Variable: total runoff					
Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
angle	3,563,448.8	1	3,563,448.82	3.417	0.083
compaction	5,323,176.6	1	5,323,176.63	5.104	**0.038**
treatment	14,747,402.1	3	4,915,800.70	4.714	**0.015**
angle * compaction	2,882,100.4	1	2,882,100.38	2.764	0.116
angle * treatment	3,383,241.1	3	1,127,747.05	1.081	0.385
compaction * treatment	4,840,470.8	3	1,613,490.28	1.547	0.241
angle * compaction * treatment	3,808,916.5	3	1,269,638.82	1.217	0.336
Error	16,686,419.9	16	1,042,901.24		
Corrected Total	**55,235,176.2**	**31**			

Table 3.1 (b)	*Planned comparisons of soil cover treatments.*				
Source	**SS**	**df**	**MS**	**F1,31**	**P**
1. bare vs covers	8303442.9	1	8,303,442.9	7.96	**<0.01**
2. hydro vs composts	6422570.1	1	6,422,570.1	6.16	**<0.025**
3. + vs – binder	21389.1	1	21,389.1	0.02	>0.75
sum	**14,747,402.09**	**3**			

Table 3.2	*Comparison of mean total runoff by (a) soil cover treatment; (b) soil compaction and (c) angle of slope. Means followed by the same letter are not significantly different at P = 0.05. Relative change shown in last column.*		
(a) Treatment	**mean (L)**	**SE**	**% change**
bare soil	3.24 a	0.36	100%
hydromulch	2.80 b	0.36	-14%
RO – binder	1.66 c	0.36	-46%
RO + binder	1.73 c	0.36	-49%
(b) Compaction	**mean (L)**	**SE**	**% change**
non-compacted	1.95 a	0.25	100%
compacted	2.77 b	0.25	+42%
(c) Angle	**mean (L)**	**SE**	**% change**
low	2.02 a	0.25	100%
high	2.69 a	0.25	+33%

3.2 Steady state runoff

Fig 3.2 (a)	*Runoff over time (hydrograph) for soil cover and compaction treatments at (a) low angle of slope. Data for RO compost blanket + and – binder treatments pooled.*

(a) Runoff vs. time at low angle

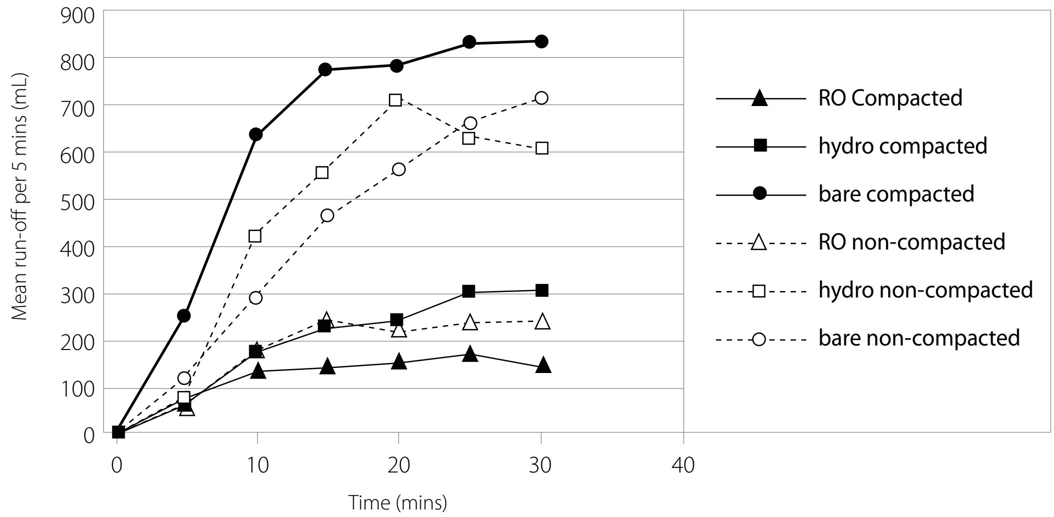
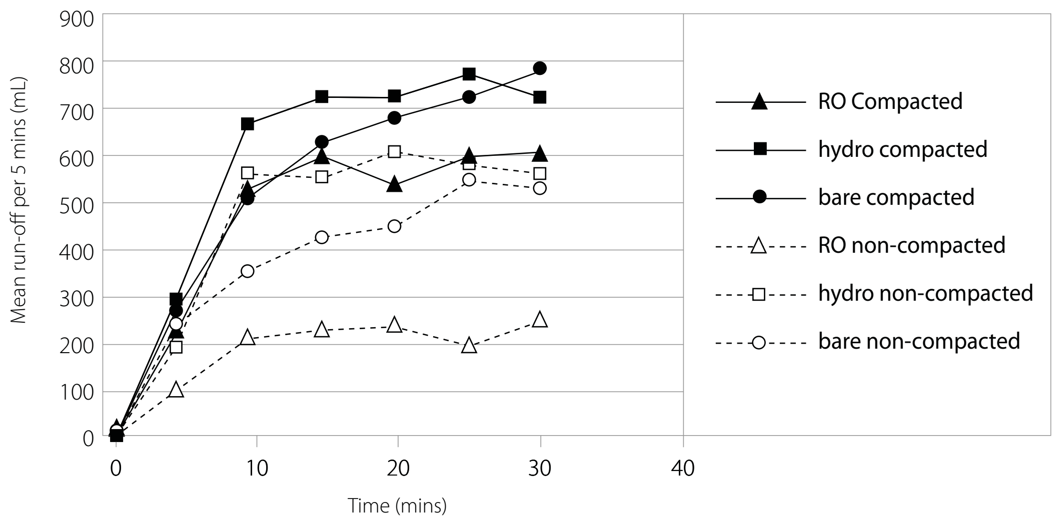


Fig 3.2 (b)	*Runoff over time (hydrograph) for soil cover and compaction treatments at (b) high angle of slope. Data for RO compost blanket + and – binder treatments pooled.*

(a) Runoff vs. time at high angle



Runoff over time became approximately constant by 10–20 minutes in most treatments (Fig. 3.2), indicating that infiltration had become constant, and the surplus was appearing as a steady state runoff per time interval. At the low angle of slope, this runoff was approximately 700–800 mL per time period for bare soil (compacted or not), and 600 mL for the hydromulch on non-compacted soil (Fig. 3.2(a)). Runoff was 100–300 mL per time period for the RO compost blanket treatments (irrespective of soil compaction), and for the hydromulch on compacted soil (Fig. 3.2(a)). Thus infiltration was highest under these latter treatments.

At the high angle of slope, steady-state runoff remained low only for the RO compost blanket soil cover on non-compacted soil (200 mL per 5 mins; Fig. 3.2(b)), indicating a high rate of infiltration for this treatment. Steady-state runoff approximated 500–600 mL for three treatments (RO compost blanket on compacted soil, hydromulch on non-compacted soil, and bare non-compacted soil; Fig. 3(b)), and 700–800 mL for bare soil and hydromulch on compacted soil (Fig. 3(b)).

Analysis of steady-state runoff (at 30 minute mark) showed that soil cover treatment, and compaction, were both significant as main effects (Table 3.3); angle of slope, and interactions between factors, were not significant. Comparison of soil treatment means showed that over both angles of slope and compaction treatments, the reductions in steady state runoff (compared to bare soil) by soil cover treatments were significant (Table 3.3(b)). The reduction compared to the bare soil value was 23% for hydromulch (Table 3.4). The RO compost blankets significantly reduced steady-state runoff compared to hydromulching (Table 3.3(b); 3.4), the reductions (compared to bare soil) being 49 to 54% for the RO compost blankets (Table 3.4).

Table 3.3 (a) *Three-Way ANOVA of steady-state runoff from the surface at 30 minutes. Terms in model not significant at P = 0.25 have been pooled into the error term. Variances homogeneous (Cochran's test NS).*

Dependent Variable: steady state runoff					
Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
angle	68,565.7	1	68,565.7	1.65	>0.25
treatment	766,186.1	3	255,395.4	6.16	**<0.005**
compaction	182,445.8	1	182,445.8	4.40	**<0.05**
angle * compaction	138,305.1	1	138,305.1	3.34	<0.10
treatment * compaction	218,673.2	3	72,891.1	1.76	0.1<P<0.25
Error	912,299.1	22	41,468.1		
Corrected Total	**2,286,474.95**	**31**			

Table 3.3 (b) *Planned Comparisons of soil cover treatments.*

Source	*SS*	*df*	*MS*	*F*	*P*
1. bare vs rest	535696.1	1	535,696.1	12.92	**<0.005**
2. hydro vs comp	225502.1	1	225,502.1	5.44	**<0.05**
3. + vs – binder	4987.9	1	4,987.9	0.120	>0.50
sum	**766,186.08**	**3**			

Table 3.4	*Soil cover treatment means for steady-state runoff at 30 minutes (means pooled across slopes and compaction).*		
Treatment	**Mean (mL/5 mins)**	**SE**	**% reduction**
bare	711 a	72	100%
hydromulch	549 b	72	-23%
compost – binder	361 c	72	-49%
compost + binder	326 c	72	-54%

3.3 Soil loss

Soil loss from treatments during the rainfall simulation is shown in Table 3.5, and was greatest from bare soil, ranging from 200–300 g at the high slope to 40–50 g at the low slope (highest rate equivalent to 1.5 kg soil/m^2; Table 3.5). Analysis showed that all soil covers reduced this loss, and angle of slope increased it (main effects significant; Table 3.6; soil compaction and interactions not significant). Comparing soil loss under the three soil covers, there was no significant difference in this reduction; however the lowest values for soil loss occurred under the RO compost blanket treatments (Table 3.7).

When soil loss data were pooled across compaction treatments; reductions in soil loss were greater than 99% under all soil covers at the low angle of slope (Table 3.8). At the high angle of slope, reduction in soil loss was only 90% of the bare soil value under hydromulch, but 99% under the RO compost blankets (Table 3.8).

Table 3.5: *Mean soil loss (g dry weight per tub) from treatments during the rainfall simulation.*

	Low angle		**High angle**	
Soil cover	**compacted**	**non-compacted**	**compacted**	**non-compacted**
bare soil	39.42	49.34	295.79	217.62
hydromulch	0.20	0.10	0.40	47.13
compost, – binder	0.70	0.00	0.91	0.05
compost, + binder	0.43	0.05	0.53	0.21

Table 3.6 (a)	*Three-Way ANOVA of soil loss from surface during the experiment. Data transformed to log(x + 1). Variances heterogeneous: Cochran's test significant 0.01 < P < 0.05.*				
Dependent Variable: log total soil loss					
Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
angle	1.508	1	1.508	7.104	**0.017**
soil cover treatment	16.484	3	5.495	25.885	**2.23×10^{-6}**
compaction	0.121	1	0.121	0.571	0.461
angle * treatment	1.474	3	0.491	2.314	0.115
angle * compaction	0.018	1	0.018	0.085	0.774
treatment * compaction	0.701	3	0.234	1.101	0.378
angle * treatment * compaction	0.818	3	0.273	1.284	0.314
Error	**3.396**	**16**	**0.212**		
Total	**24.520**	**31**			

Table 3.6 (b)	*Planned comparisons of soil cover treatments.*				
Source	**SS**	**df**	**MS**	**F**	**P**
1. bare vs rest	16.145	1	16.145	76.06	**<0.005**
2. hydro vs comp	0.338	1	0.338	1.59	<0.25
3. + vs – binder	0.0012	1	0.0012	0.01	>0.50
sum	**16.48**	**3**			

Table 3.7	*Comparison of soil cover treatment means for soil loss (transformed and back-transformed means shown; data pooled across angle and compaction treatments). Means followed by the same letter are not significantly different.*		
Treatment	**mean (log scale)**	**Mean (back-transformed)**	**Percentage change (back transformed)**
bare	1.835 a	67.4	100%
hydro	0.362 b	1.30	-98%
RO – binder	0.119 b	0.31	-99.5%
RO + binder	0.102 b	0.26	-99.6%

Table 3.8	*Mean soil loss (g/tub) for each soil cover treatment at low and high angle of slope. Data pooled across compaction treatments. SE in brackets after each mean.*			
	low angle	**high angle**	**% change low angle**	**% change high angle**
bare soil	44.4 (32)	256.7 (92)	100%	100.0%
hydromulch	0.15 (0.1)	23.8 (23)	-99.7%	-90.7%
compost, – binder	0.35 (0.3)	0.48 (0.3)	-99.2%	-99.8%
compost, + binder	0.24 (0.1)	0.37 (0.4)	-99.5%	-99.9%

3.4 Total suspended solids

Mean total suspended solids (TSS) in the runoff from bare soil ranged up to 2,400 mg/L at the low angle of slope, and up to 4,600 mg/L at the high angle (Table 3.9). All soil cover treatments significantly reduced TSS, by 95 to 98% of the bare soil value (soil cover significant as main effect; Table 3.10; angle, soil compaction and interactions not significant), with TSS being lowest under the hydromulch treatment (Table 3.11). TSS levels under the RO compost blankets were higher than the values observed under hydromulch, the difference being significant (Table 3.10(b); 3.11).

Table 3.9	*Mean total suspended solids (TSS; mg/L) for each treatment.*			
	Low angle		**High angle**	
Soil cover	**compacted**	**non-compacted**	**compacted**	**non-compacted**
bare soil	1267.1	2415.3	3953.1	4683.8
hydromulch	30.5	84.3	31.1	62.8
compost, – binder	115.8	66.9	91.1	55.3
compost, + binder	518.8	117.8	69.8	81.3

Table 3.10 (a)	*Three-Way ANOVA of (log) total suspended solids in runoff from soil erosion trial. Variances homogeneous by Cochran's test.*				
Dependent Variable: log TSS					
Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
angle	0.008	1	0.008	0.072	0.792
soil cover treatment	15.884	3	5.295	50.522	**0.000**
compaction	0.020	1	0.020	0.188	0.671
angle * treatment	0.555	3	0.185	1.764	0.195
angle * compaction	0.004	1	0.004	0.038	0.848
treatment * compaction	0.375	3	0.125	1.192	0.344
angle * treatment * compaction	0.138	3	0.046	0.439	0.728
Error	1.677	16	0.105		
Total	**18.660**	**31**			

Table 3.10 (b)	*Planned comparisons of soil treatments.*				
Source	**SS**	**df**	**MS**	**F**	**P**
1. bare vs rest	15.16	1	15.158	144.63	**<0.001**
2. hydro vs comp	0.58	1	0.575	5.49	**<0.05**
3. + vs – binder	0.15	1	0.1514	1.44	<0.25
sum	**15.88**	**3**			

Table 3.11	*Comparison soil cover treatment means for total suspended solids (back-transformed means; data pooled across angle and compaction treatments). Means followed by the same letter are not significantly different.*	
Treatment	**Mean (mg/L)**	**% change**
bare soil	2666 a	100%
hydro	41 c	-98.5%
RO – binder	71 b	-97.3%
RO + binder	110 b	-95.9%

3.5 Total N

Mean total nitrogen in runoff from each treatment is shown for each treatment in Fig. 3.3, and differed significantly with soil cover treatment only (Table 3.12). Total nitrogen levels in runoff from the bare soil and hydromulch treatments did not differ significantly and were in the range 0.8–1 mg/L; values in the two RO compost blanket treatments were significantly higher than the previous two treatments (1.25–1.35 mg/L), and did not differ significantly from each other (Fig. 3.4).

Fig 3.3	*Total nitrogen in runoff from the surface of each treatment at (a) low angle of slope;(b) high angle of slope. Bars = SE.*

Total phosphorus

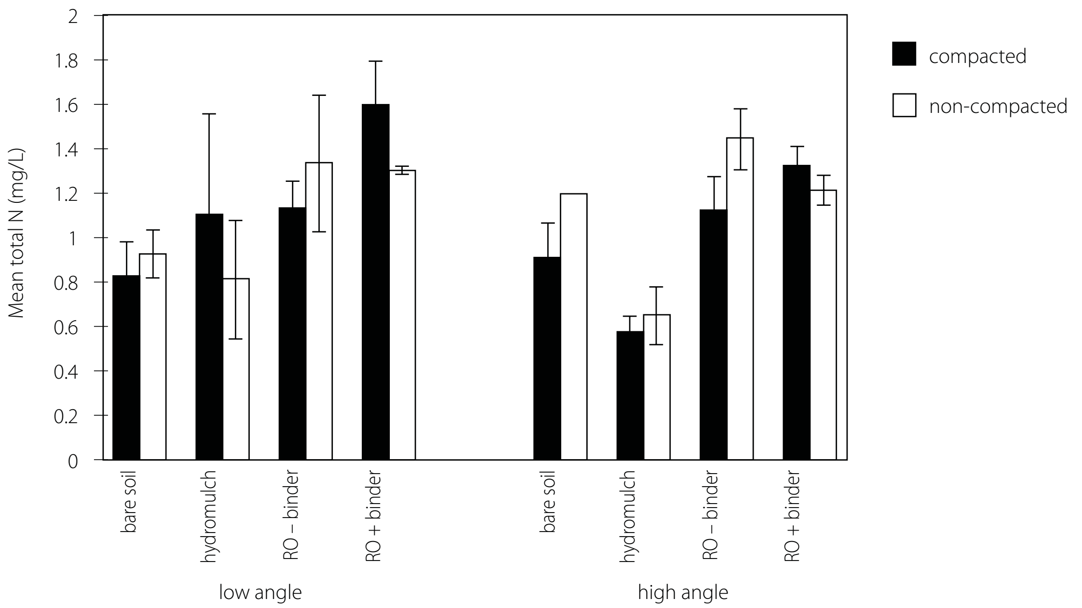


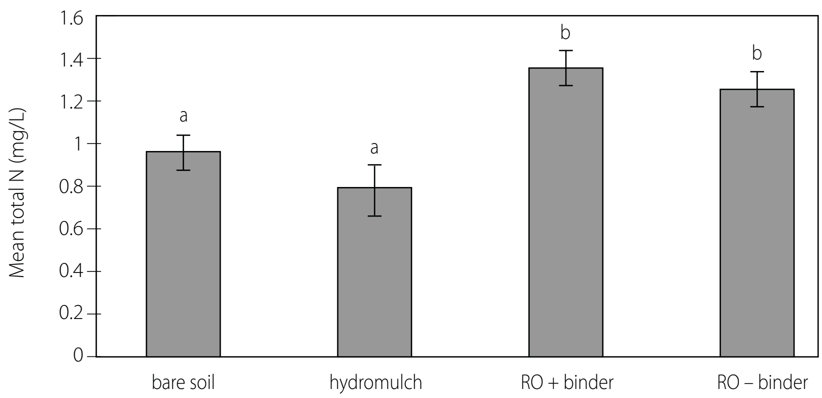
Table 3.12 *Three-Way ANOVA of total N in runoff from soil erosion trial. Variances homogeneous by Cochran's test.*

Dependent Variable: Total N

Source	SS	df	Mean Square	F	Sig.
angle	0.045	1	0.045	0.631	0.439
soil cover treatment	1.671	3	0.557	7.749	**0.002**
compaction	0.013	1	0.013	0.180	0.677
angle * treatment	0.324	3	0.108	1.503	0.252
angle * compaction	0.091	1	0.091	1.262	0.278
treatment * compaction	0.305	3	0.102	1.413	0.275
angle * treatment * compaction	0.016	3	0.005	0.076	0.972
Error	**1.150**	**16**	**0.072**		
Total	**3.615217**	**31**			

Fig 3.4 *Mean total nitrogen in runoff from soil cover treatments. Data pooled across slope and compaction treatments. Means with the same letter not significantly different at P = 0.05 (SNK test).*

Total N: treatment means



3.6 Total P

Mean total phosphorus in runoff from each treatment is shown for each treatment in Fig. 3.5, and differed significantly with soil cover treatment, depending on soil compaction (soil cover x compaction significant, Table 3.13). Total phosphorus in runoff was lowest from the hydromulch treatment (0.3 mg/L), and generally highest from bare soil (0.7 mg/L), irrespective of soil compaction (Fig. 3.6); in the RO compost blanket treatments, phosphorus in runoff was comparable to that from hydromulch for non-compacted soil, but rose significantly to 0.7 mg/L under compacted soil (Fig. 3.6).

Fig 3.5	*Total phosphorus in runoff from the surface of each treatment at low and high angle of slope. Bars = SE.*

Total phosphorus

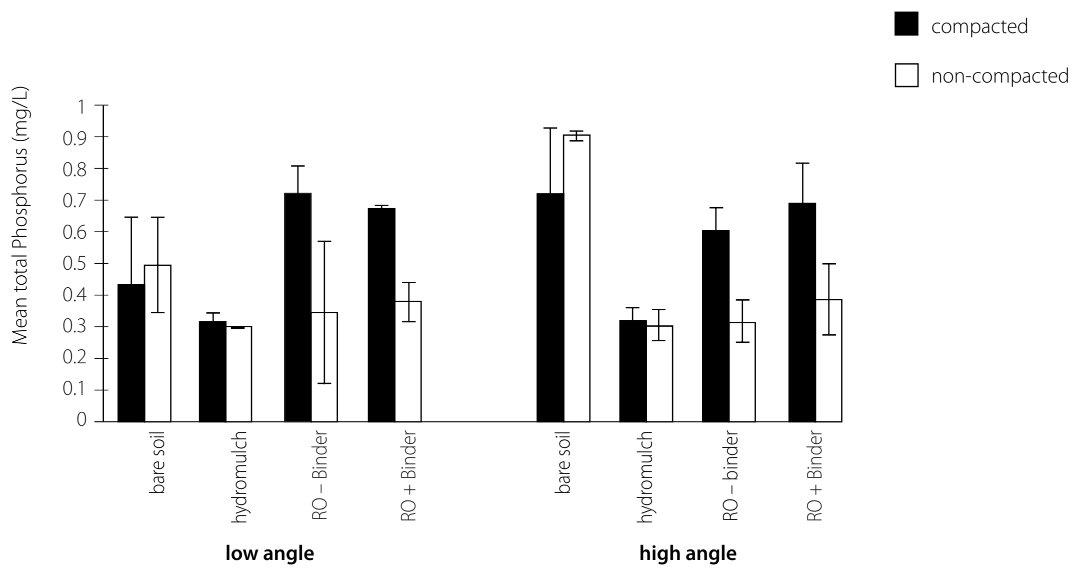
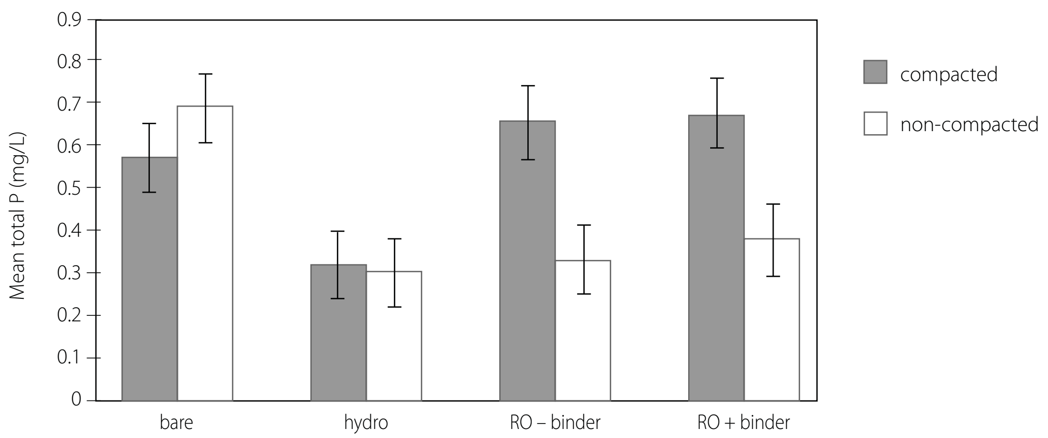


Table 3.13	*Three-Way ANOVA of total P in runoff from soil erosion trial. Variances homogeneous by Cochran's test.*				
Dependent Variable: Total P					
Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
angle	0.044	1	0.044	1.627	0.220
soil cover treatment	0.450	3	0.150	5.493	0.009
compaction	0.138	1	0.138	5.057	0.039
angle * treatment	0.208	3	0.069	2.543	0.093
angle * compaction	0.005	1	0.005	0.192	0.667
treatment * compaction	0.291	3	0.097	3.554	**0.038**
angle * treatment * compaction	0.007	3	0.002	0.081	0.969
Error	0.437	16	0.027		
Total	**1.582**	**31**			

Fig. 3.6 *Mean total phosphorus in runoff from soil erosion trial: data pooled over angle of slope.*

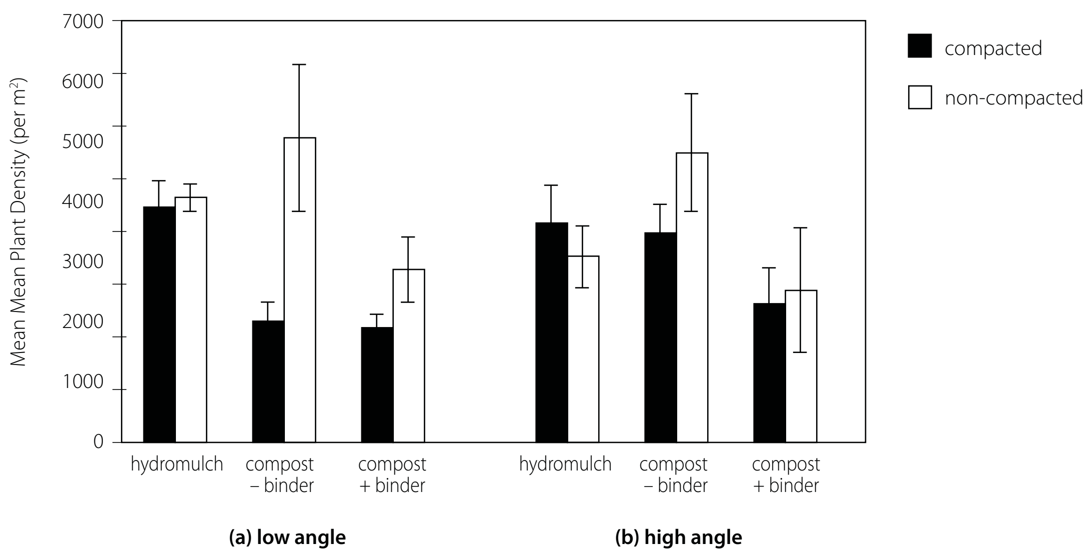


Comparison of means: soil cover treatments within
> compacted treatment: hydromulch < (bare = RO compost blanket – binder = RO compost blanket + binder)
> non-compacted treatment: bare > (hydromulch = RO compost blanket – binder = RO compost blanket + binder)
Compaction treatments with soil cover treatments:
> bare, hydromulch NS;
> RO compost blanket –/+ binder, compacted > non-compacted.

3.7 Plant density

Fig 3.7	*Plant density of each treatment at (a) low angle of slope; (b) high angle of slope. Bars = SE.*

Plant Density



The cover crop of Japanese millet established at densities in the range 2,000–5,000 per m^2 (Fig. 3.7). Plant density was significantly affected by soil compaction, and soil cover treatment (significant as main effects, Table 3.14). Density was lower on compacted soil (Table 3.15); comparison of soil cover means showed that density was comparable on hydromulch and RO compost blanket without binder treatments, but was significantly less (36% less than other two densities) on the RO compost blanket with binder treatment (Table 3.15).

Table 3.14	*Three-Way ANOVA of density from the 3 treatments where Japanese millet was sown. Variances homogeneous (Cochrans Test not significant).*

Dependent Variable: density

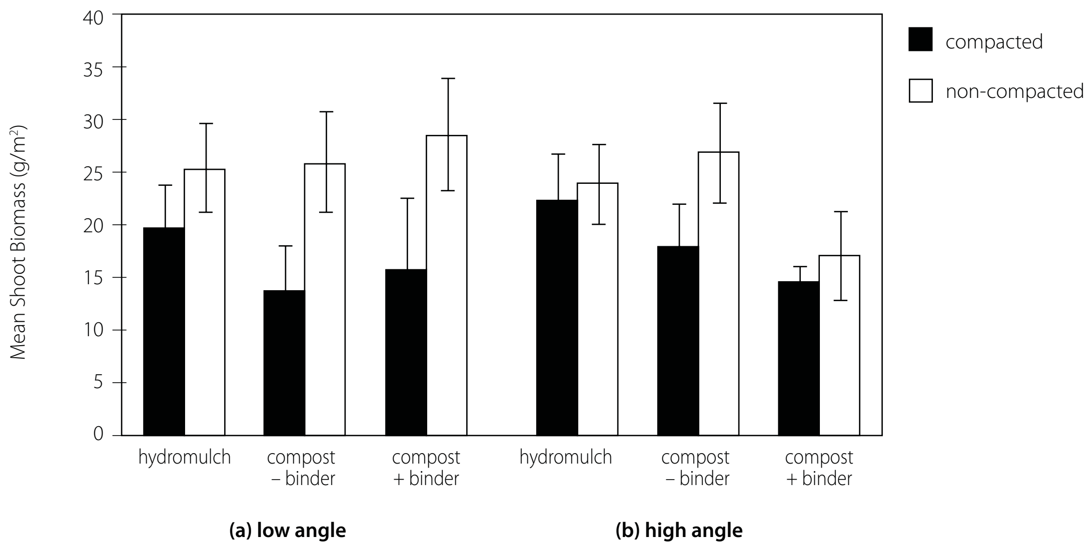
Source	Sum of Squares	df	Mean Square	F	Sig.
Compaction	34884.08333	1	34884.08333	4.924	**0.033**
angle	0.083333333	1	0.083333333	0.000	0.997
Treatment	77208.29167	2	38604.14583	5.449	**0.009**
Compaction * angle	13068	1	13068	1.845	0.183
Compaction * treat	46119.29167	2	23059.64583	3.255	0.050
angle * treat	11644.79167	2	5822.395833	0.822	0.448
Compaction * angle * treat	2491.125	2	1245.5625	0.176	0.839
Error	255029	36	7084.138889		
Total	**440444.6667**	**47**			

Table 3.15	*Comparison of plant density (per m²) for soil cover treatment means.*	
Treatment	**mean**	**SE**
hydromulch	3661 a	337
compost – binder	3823 a	337
compost + binder	2388 b	337
compacted	2859 a	275
noncompacted	3291 b	275

3.8 Shoot Biomass

Fig. 3.8 *Shoot biomass (dry weight) of Japanese millet at low and high angle of slope. Bars = SE.*

Shoot Biomass



Shoot biomass after 4 weeks of growth averaged 15–30 g/m^2 of dry weight over the 12 treatments where Japanese millet was sown. Analysis showed that the only factor to significantly affected shoot biomass was soil compaction (Table 3.16); shoot biomass was less on the compacted soil (Fig. 3.8).

Table 3.16	*Three-Way ANOVA of shoot biomass.*				
Dependent Variable: shoot biomass					
Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Compaction	2.565	1	2.565	8.014	**0.008**
angle	0.056	1	0.056	0.176	0.677
treat	0.460	2	0.230	0.719	0.494
Compaction * angle	0.420	1	0.420	1.313	0.259
Compaction * treat	0.393	2	0.197	0.614	0.547
angle * treat	0.701	2	0.351	1.096	0.345
Compaction * angle * treat	0.120	2	0.060	0.188	0.830
Error	11.524	36	0.320		
Total	**16.242**	**47**			

4.0 Discussion

The results obtained from the trial, conducted on constructed soil profiles under glasshouse conditions, were comparable to overseas studies under field conditions, for the rank order of soil cover treatments in reducing runoff and soil loss, and increasing infiltration. For each of these three indicators of the extent of soil protection afforded by soil covers where RO compost blankets and hydromulching have been compared in field trials, RO compost blankets have consistently performed at least as well as hydromulching; usually the best measures of soil protection have been recorded under RO compost blankets (Faucette et al. 2005; Ettlin and Stewart 1993).

This pattern was repeated in the trial reported here; in reducing runoff and steady-state flow, the improved performance of the two RO compost blankets compared to hydromulching was large enough to be statistically significant. Lowest values for soil loss were recorded under the RO compost blanket products in the trial, in line with overseas field studies. Faucette et al. (2005) observed a ten-fold decrease in soil loss under RO compost blankets compared to hydromuching (at the three month mark of their study); the reduction in soil loss under RO compost blankets compared to hydromulching in the trial was ten-fold, at the high angle of slope.

Hydromulching significantly outperformed RO compost blanket products for total suspended solids, total N, and total P (on uncompacted soils) in the trial. However, the values for these parameters from RO compost were still low. The finding of Glanville et al. (2004) about nutrient and pollutant loads from soil covers is relevant: that total load to the environment is the product of concentration x runoff. Whilst the RO compost blanket products had higher concentrations of total N and P in their runoff, they also had the lowest runoff. Thus total load to the environment in field trials may well be less from the compost soil covers (Glanville et al. 2004).

The presence or absence of binder in the RO compost blankets made very little difference to runoff (total, and steady state), soil loss, total suspended solids and nutrient concentrations. Means for these parameters for the two products were very similar, and statistically indistinguishable for these parameters. The only significant effect detected for the presence of binder was a reduction in plant density (but not plant growth) for the + binder treatment. The reason for this reduction in density was not clear. Plant establishment on the RO compost blanket with binder was still adequate, but about two-thirds the density on the other two treatments.

Soil compaction and angle of slope significantly affected results for a number of parameters, in ways that would be expected from the literature eg Persyn et al. (2004). Compaction increased runoff (total, and steady state), and reduced plant density and growth. A higher angle of slope increased total runoff, and soil loss.

5.0 Acknowledgements

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