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Evaluation of impact compaction for reducing recharge from rice

> **In a Nutshell**
> • ***Impact compaction can reduce water infiltration, however, to be economic the effect must be long lasting.***

Impact compaction can reduce water infiltration, however, to be economic the effect must be long lasting.

Impact compaction has the potential to seal highly leaky areas in rice paddocks, and this is a sensible use of this technology.

Furthermore, industry-wide application of impact compaction has the potential to significantly reduce recharge from ponded rice culture.

However, at this stage we do not recommend widespread application due to lack of knowledge of what happens to the soil structure during compaction, whether the changes that occur are reversible, and if so, how to restore the soil to its original state or better and the cost of doing this.

Soil water content at the time of compaction is critical to achieving the desired reduction in infiltration, and our results suggest a minimum of 20g water/100 g soil in the heavy clay soils used for rice culture.

In dry, hard soil conditions, none of the Landpac or Broons machines tested reduced infiltration using an economic number of passes.

At two very high water use sites with marginal soil water content down the profile at the time of compaction, three passes of the Landpac machines reduced infiltration from 16 to 3-4 ML/ha and from 24 to 7-8 ML/ha.

At three low water use sites with higher soil water content, three passes of the Landpac machines reduced infiltration from around 3 ML/ha to less than 1.5 ML/ha.

The Broons machine was not evaluated in moist soil conditions.

Crop growth throughout the season, grain yield and yield components were not impaired by any of the compaction treatments applied.

The effect of compaction on infiltration appeared to last throughout the second rice crop after treatment application, at the one site where this could be tested.

For impact compaction to be economic, the effect needs to last for at least two seasons on highly leaky soils, or for three seasons on soils where the reduction in water use is of the order of 2 ML/ha, at the current cost of treatment (around $330/ha).

Thus the application of impact compaction may require changes in crop rotations to continuous rice cropping, at least until the "payback" period is passed.

The effects of impact compaction on soil structure were transmitted to depths below the soil surface of at least 0.4-0.5 m at some of the experimental sites.

These effects at depth included visual effects of shearing, higher soil strength and possibly reduced hydraulic conductivity.

However, there was no evidence of reduced hydraulic conductivity at a depth of about 1 m. The depth, nature and extent of changes in soil structure as a result of impact compaction are not known.

If the rice industry wishes to consider or condone more widespread adoption of impact compaction beyond sealing small leaky areas within rice paddocks, its effects on soil structure and its reversibility must be investigated.

BACKGROUND

Rising watertables and secondary salinisation are major threats to the sustainability of irrigated agriculture in the rice growing areas of southern NSW, and rice growing contributes about half the accessions to the watertable (Dwyer Leslie 1992).

Therefore farmers are under increasing pressure to reduce recharge from rice. Puddling has the potential to significantly reduce percolation from flooded rice (Humphreys and Muirhead 1996), but adoption has been very poor.

Major constraints to adoption probably include the slowness of the puddling operation (at a busy time), turbidity problems where water management is not optimal (difficult to achieve?), reluctance to operate machinery in the mud and water, and mixed results at the paddock scale.

▶

Pic 1: *Landpac SP3.*
Pic 2: *Broons BH-1300.*
Pic 3: *Landpac SP5.*

◀

Impact or deep lift compaction is a relatively new method of compaction within the Australian civil engineering construction scene, and claims to achieve compaction to depths of 1-2 m.

Impact compacters consist of massive cam-shaped drums which may be 3- ,4- or 5-sided (Photos 1-3).

Pic 1

Some machines are self-propelled and others are trailed, and they are driven across the ground at speeds of 12-16 km/hr.

The cam shape raises the drum(s); then the continued rotation propels a flatter section of the drum downwards, slamming it on the soil surface.

There are currently two companies in Australia with the patented rights to impact compaction machinery - Broons Hire Pty Ltd and Landpac Technologies Pty Ltd.

Impact compaction is used in road construction and to seal dams, channel banks and landfill sites. More recently it has been investigated as a technique for reducing recharge from rice.

Impact compaction has the advantage of being able to be applied well in advance of preparation for rice sowing, whereas puddling is a "last minute" operation.

Preliminary trials conducted by Clark and colleagues during the 1996/7 season showed that impact compaction reduced infiltration from 2.8 ML/ha to 0.1-0.5 ML/ha using the Landpac SP5 (Clark and Humphreys 1997).

Pic 2

Pic 3

Rice establishment and growth appeared to be unaffected in all compaction treatments. Yields of 11.8 and 12.7 t/ha were achieved in the 2 and 3 pass compaction treatments, however there was a large reduction in yield with 4 passes of the machine (9.8 t/ha).

The limitations of the findings of this pilot trial included insufficient replication of treatments and of infiltration measurements, lack of objective crop monitoring throughout the season, and the lack of a control treatment for yield comparisons.

Therefore a more rigorous evaluation of the technique was needed, and for a range of soil types and conditions.

The goal of the research reported here was to further test the results of the pilot experiment - to determine whether impact compaction was worthy of further development and evaluation for use in rice-based farming systems.

It was a 15-month project with four field sites in east Berriquin, and was a joint effort between Robert Clark, CSIRO, Landpac Technologies, NSW Agriculture and co-operating farmers.

Specific objectives included:

1. determination of the effect of impact compaction on infiltration, rice performance and selected soil properties, and

2. evaluation of the economics of impact compaction.

▶

METHODS

Compaction treatments were applied at four sites in commercial rice paddocks as described in Table 1. Photographs of the machines used are shown in Pics 1-3.

In brief, the Broons BH-1300 roller is a 4-sided trailing roller, and the Landpac SP3 and SP5 are self-propelled compacters with two 3- or 5- sided rollers.

Soil water content at each site at the time of compaction is detailed in Figure 1. Treatments were applied using the BH-1300 in dry, hard soil conditions, while the treatments with the Landpac machines were applied over a range of soil water contents.

The three machines have different physical configurations and energy ratings, therefore it should not be assumed that results achieved with one particular machine under one set of soil conditions would automatically be achieved with the other machines.

Table 1

	Paddock A	**Paddock B**		**Paddock C**
	Site 1	**Site 2**	**Site 3**	**Site 4**
Soil	red clay loam topsoil, clay subsoil *Birganbigil clay loam*			self-mulching grey clay
Paddock history	wheat '96 fallow '97	rice '93/94 fallow '95 rice '96/97		wheat '96 fallow '97
Times of compaction	1. April '97 2. September '97	October '96	August '97	August '97
Soil water content at time of compaction	1. April - very dry, hard and cracked 2. September - moist to depth	very moist	very moist to depth	moist at 150-300 mm; dry, hard and cracked below this
Machines	1. Broons BH-1300 (April) 2. Landpac SP3 (April and Sept.)	Landpac SP5	Landpac SP5	1. Landpac SP5 2. Landpac SP3
No. of passes	Broons 0, 2, 4, 6 Landpac 0, 2, 3, 4	0, 2, 3, 4	0, 2, 3, 4	0, 2, 3, 4
EM31 zones in which treatments compared	low	medium	medium	low medium high
Sowing date	13 Oct. '97			24 Oct. '97
Variety	Namaga 136 kg/ha			Namaga 148 kg/ha
Presowing fertilizer	139 kg N/ha as urea	103 kg N/ha as urea		85 kg N/ha as urea
	11 kg P/ha & 15 kg S/ha as superphosphate			
Urea application at PI	85 kg N/ha as urea	71 kg N/ha as urea		57 kg N/ha as urea

Figure 1

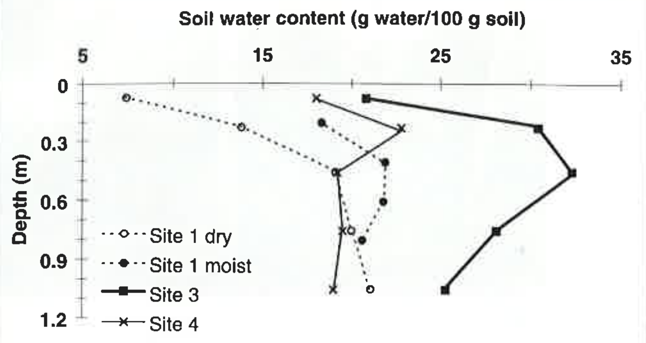


Figure 1: Soil water content at the time of compaction.

RESULTS

A summary of the major findings is presented here. The results are documented in detail in the final report to RIRDC (Humphreys et al 1998a).

1. Effect of compaction on infiltration

Compaction was very effective in moist or very wet soil, but ineffective when the soil was dry and hard

None of the treatments significantly reduced infiltration when applied at Site 1 when the soil was very dry and hard (Fig. 2). In contrast, compaction when the soil was moist reduced total infiltration from 3.8 ML/ha to 1.4 ML/ha with two passes of the SP3, and three and four passes further reduced infiltration to 1 ML/ha.

The soil at Site 3 was similar to the soil at Site 1, but much wetter at the time of treatment (Fig. 1). At site 3 compaction reduced total infiltration from 2.5 ML/ha to 1.5 ML/ha, and two, three and four passes of the SP5 were equally effective.

Figure 2

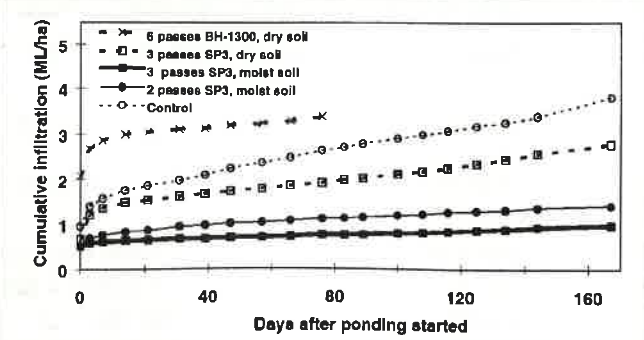


Figure 2: Effect of compaction on infiltration at Site 1, for dry and moist soil at the time of treatment (data points area means of 2-4 determinations).

At Site 4 the soil was moist at the top of the subsoil, but dry and cracked below 0.3 m, at the time of compaction. This was a high water use site, with total infiltration in the controls of 6.7, 16.4 and 24.1 ML/ha at the three EM31 locations where the treatments were monitored.

At the two very high water use locations three passes of either the SP3 or the SP5 reduced infiltration by 67-82% (e.g. Fig. 3). However at the third location the treatments were ineffective. We suspect that these variable results occurred because the soil water content was not high enough in the subsoil at the time of compaction at this site.

The effect of compaction on infiltration lasted for at least two seasons at Site 2.

Compaction reduced infiltration between filling and draining from 1.2 ML/ha to 0.5-0.6 ML/ha during the second season after the treatments were applied at Site 2. In the first season after treatment application, compaction reduced infiltration over this period from 2.8 ML/ha to 0.1-0.5 ML/ha, suggesting that the three and four pass treatments were not quite as effective during the second season.

Figure 3

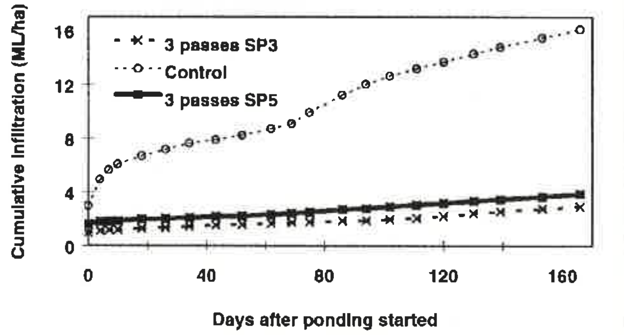


Figure 3: Effect of impact compaction on infiltration at the high EM31 location at Site 4 (data points are means of 3 determinations).

Overall, the effect of compaction on infiltration appears to have lasted reasonably well for two seasons, despite a very dry period of five months after draining the first rice crop.

In contrast, the effect of puddling on infiltration did not carry through to the next season under similar dry post harvest weather conditions (Humphreys and Muirhead 1996).

Compaction reduced infiltration by 40 to 60% on soils that had relatively low water use in the first place, and by 70 to 80% on extremely leaky soils.

Pic 5: This photo at site 3 shows that after four passes of the Landpac 15SP5, obvious movement had occurred in the soil to a depth of about 0.5m. At this site there was a high soil water content to depth.

Pic 4: This photo at site 4 shows that after three passes of the Landpac SP3, obvious movement had occurred in the soil to a depth of about 0.2m. At this site the soil was quite dry except in the region where the movement was detected.

These findings suggest that impact compaction has the potential to "seal" leaky areas in rice paddocks. Puddling has also been shown to reduce infiltration by about 60% on extremely leaky soils (Humphreys and Muirhead 1992). Previous studies have shown that 1 ha of leaky area in a 30 ha rice paddock can double recharge, hence the desirability of sealing these areas, or taking them out of rice production (Humphreys et al 1997).

Secondly, the results suggest that industry-wide application of impact compaction has the potential to significantly reduce recharge from ponded rice culture.

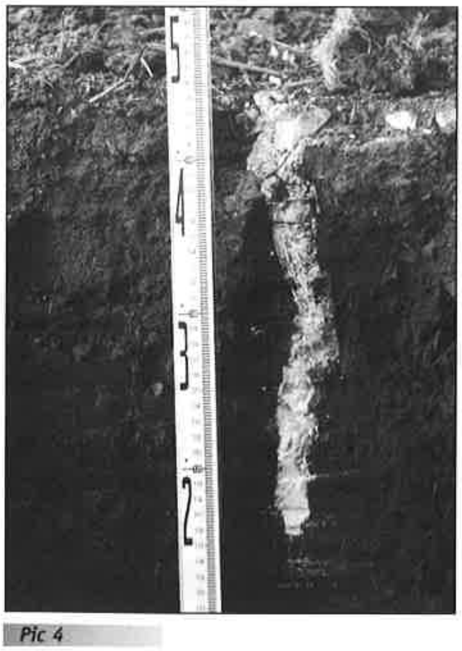
However, at this stage we do not recommend widespread application due to lack of knowledge of what happens to the soil structure during compaction, whether the changes that occur are reversible, and if so, how to restore the soil to its original state or better and the cost of doing this.

2. Effect of compaction on soil structure

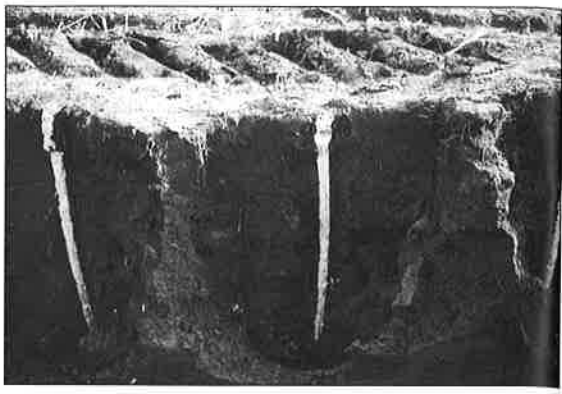
Visual observations

After treatment application on the dry soil at Site 1, the cracks in the subsoil still remained open after several passes of each machine. The Landpac machines started to crumble the tops of the subsoil columns and close the cracks after several passes.

The Broons roller had no visible effect on the subsoil columns, but pulverised the topsoil at these sites into a fine powder. Thus it was not surprising that compaction under these dry soil conditions did not reduce infiltration (Fig. 2).



Pic 4



Pic 5

At Site 4 most of the visible changes (compaction and shearing) were confined to the top of the subsoil, the zone with the highest soil water content at the time of compaction, and which overlay very dry soil to depth (Fig. 1, Pic 4).

Site 3 had a very high soil water content to depth at the time of compaction (Fig. 1), and there was shearing in the soil to a depth of about 0.5 m (Pic 5).

This is clear evidence that impact compaction can cause changes in the soil to a depth of at least 0.5 m, and is a very important finding when considering whether the changes in soil structure are reversible, and methods for achieving this.

Bulk density and soil strength

Site 2 was sampled in 0.15 m layers to a depth of 0.75 m in May 1997 after harvest of the first rice crop.

There was no effect of compaction on bulk density or on soil water content. Thus the term "compaction" is possibly a misnomer under the conditions at this site.

The visual observations above indicate that shearing may have occurred during treatment application, but any compaction effects were too small to be detected after rice harvest.

Penetrometer readings at Site 2 showed that soil strength was much greater in the 4-pass treatment at a depth of 0.2-0.4 m below the soil surface, providing further evidence of considerable change in soil structure to a depth of about 0.4 m (Fig. 4).

The differences were probably greater than the figure indicates as at some locations in the 4 pass treatment the soil was so strong that the penetrometer could not be pushed into it, so no measurement could be made.

Figure 4

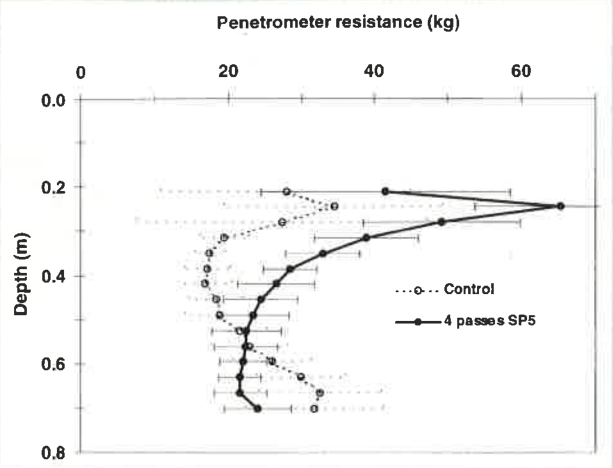


***Figure 4:** Effect of compaction on soil strength after harvest of the first rice crop following treatment application at Site 2 (horizontal bars are standard deviations of the means of 10 measurements).*

Soil hydraulic conductivity down the soil profile

Ponded infiltration at 3 depths in the soil profile was compared in control and compacted treatments at Site 2 at the same time as the above bulk density and penetrometer measurements were made (Pic 6).

Infiltration at 0.2 m was similar in all compaction treatments (0.5-0.8 mm/day, Table 2), whereas penetrometer resistance at this depth was much greater in the 4 pass compaction treatment.

Thus the changes in soil structure which led to an increase in soil strength did not appear to affect soil hydraulic conductivity at this depth.

Infiltration was significantly lower (0.2-0.3 mm/day) at 0.45 m in the compacted treatments compared with at 0.2 m, and these results suggest that hydraulic conductivity below 0.45 m was reduced in both the two and four pass compaction treatments.

However this conclusion is uncertain due to variable infiltration in the control at this depth.

Table 2

Depth (m)	Site	Control	2 passes	3 passes	4 passes
0.2	2	0.7 ± 0.2	0.5 ± 0.1		0.8 ± 0.0
	3	0.7 ± 0.1		0.5 ± 0.1	
0.45	2	0.8 ± 0.6	0.3 ± 0.0		0.2 ± 0.0
	3	0.5 ± 0.1		0.5 ± 0.1	
0.9	2	1.4 ± 0.4	~7[A]		3.5 ± 0.9
	3	1.2 ± 0.5		3.7 ± 1.6	

[A]estimate - one ring used a lot of water (dried out between reading).

***Table 2:** Effect of compaction (SP5) on ponded infiltration (mm/day) at various depths down the soil profile: (1) after harvest of the first rice crop following treatment application at Site 2 (mean infiltration over 60 days), and (2) immediately after treatment application and before sowing at Site 3 (mean infiltration over 18 days) (all data are means of 3).*

Similar investigations were carried out on the adjacent Site 3 immediately after the compaction treatments were applied in August 1997. This time the results suggested a very small but significant decrease in infiltration with compaction at 0.2 m (from 0.66 mm/day in the control to 0.47 mm/day with 3 passes of the SP5), and no effect at 0.45m (Table 2).

A significant and similar finding at both Sites 2 and 3 was that at a depth of about 1m, compaction did not decrease infiltration. In fact the reverse occured - infiltration in the controls at this depth averaged 1.2-1.4 mm/day compared with in excess of 3.5 mm/day in the compaction treatments.

This intriguing result suggests that, if anything, hydraulic conductivity was increased at depth by the compaction treatments. If it is a real effect, then it's cause is not understood at present.

3. Effect of impact compaction on crop performance

Crop establishment, growth and yield were monitored at all four sites. There was no significant effect of any of the compaction treatments on any of the crop parameters measured with one exception.

Compaction with the BH-1300 on the dry soil at Site 1 appeared to significantly reduce plant density, however the plants compensated and there was no effect on total biomass production after tillering commenced, nor on yield components.

Yields of 12.2-13.3 t/ha (14% grain moisture content) were achieved at Sites 1, 2 and 3, while yields at Site 4 were much lower (8.1-9.7 t/ha) (Figs 5a, b, c).

4. Economics of impact compaction

At the time of writing Landpac Technologies Pty Ltd is quoting a price of $330/ha for 2-3 passes using the SP5. Whether 2 or 3 passes are provided will be determined by the apparent effectiveness of the treatment under the prevailing soil conditions.

Broons Hire Pty Ltd is quoting $300/ha for four passes of the BH-1300.

A direct comparison of the cost effectiveness of the Landpac and Broons machines is not possible, as the performace of the BH-1300 in moist or wet soils is unknown.

Assuming that water costs $15/ML and a saving in water use of 1 ML/ha is achieved, then clearly the saving of $15/ha over one season is insignificant against the cost of applying the treatment ($300-330/ha).

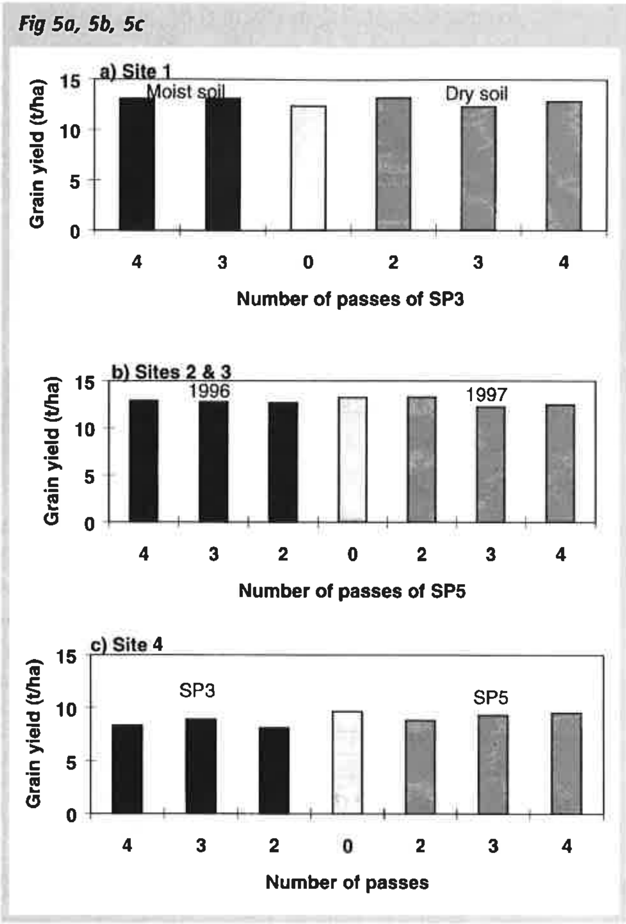


Figure 5: *Effect of impaction compaction on header yield at a) Site 1, b) Sites 2 & 3, and c) Site 4.*

The economic benefits of impact compaction should also be viewed in terms of the additional production possible with the available water that would otherwise be lost to infiltration.

For example, if a 45 ha paddock that uses 15 ML/ha is compacted with a saving in water use of 2 ML/ha, an additional seven hectares could be put into production with the water saved.

Analysed over one season, the cost of the treatment would be $17,160 (52 ha at $330/ha). This would be offset against an increase in gross margin of ($8,315 (7ha x $965 + 52 ha x $30/ha assuming a gross margin of $965/ha with normal soil preparation and water use 15 ML/ha).

Thus it would not be until the third season that the benefit of increased production due to more efficient use of water would out weigh the cost of the treatment.

This analysis assumes that the reduction in infiltration is sustained for three seasons, and that yields are maintained.

Considering the most extreme reduction in infiltration achieved at Site 4 (24 ML/ha to 8 ML/ha), in one season a saving of $240/ha (16 ML/ha x $15/ML) in the cost of water would be achieved.

However, the cost per hectare of treating only small leaky areas is likely to be much higher than the cost of treating whole paddocks, and would include an "establishment cost" (currently estimated to be about $700 by Landpac) plus the normal rate per hectare ($330/ha).

On this basis, it would take over four years to recover the cost of treating one hectare.

However, if the leaky area is to be excluded from rice growing, this would result in a loss of gross margin of $635/ha (assumes a gross margin with a water use of 15 ML/ha is $965/ha, that water costs $15/ML, and that the leaky area uses 37 ML/ha).

In this case, it would only take two seasons to more than recover the cost of treating the very leaky area of 1 ha, provided the effect of the treatment on infiltration continued throughout the second season.

These economic analyses do not account for benefits that would arise due to a reduced rate of watertable rise. Nor do they take into account possible disbenefits such as reduced rice yields due to accumulation of salt if there is insufficient leaching of salt from the rootzone, or reduced productivity of crops grown in rotation with rice due to impaired soil structure for non-rice crops.

Pic 6

Pic 6: *Infiltration rings at different depths in the soil profile.*

DISCUSSION

The results show that soil water content at the time of compaction is critical to achieving the desired reduction in infiltration, and our results suggest a minimum of 20 g water/100 g soil in the heavy clay soils used for rice culture.

In dry, hard soil conditions, none of the Landpac or Broons machines reduced infiltration using an economic number of passes. At two very high water use locations, three passes of the Landpac machines reduced infiltration from 16 to 3-4 ML/ha and from 24 to 7-8 ML/ha.

At a third moderately high water use location in the same paddock, the treatments were ineffective, and we suspect that this was because the soil water content was too low in the subsoil at the time of compaction.

At three low water use sites with higher soil water content, three passes reduced infiltration from around 3 ML/ha to less than 1.5 ML/ha.

Crop growth throughout the season, and yield and yield components were not impaired by any of the compaction treatments applied. This is in contrast with the findings from the pilot study where 4 passes of the SP5 appeared to reduce yield by about 20% (Clark and Humphreys 1997).

In this treatment, infiltration was almost undetectable throughout most of the season, raising the possibility of hostile soil conditions for rice roots due to the fact that the treatment was too effective.

The effect of compaction on infiltration appeared to last throughout the second rice crop after treatment application, at the one site where this could be tested.

For impact compaction to be economic, the effect needs to last for at least two seasons on highly leaky soils, or for three seasons on soils where the reduction in water use is of the order of 2 ML/ha, at the current cost of treatment (around $330/ha).

The effects of impact compaction were transmitted to depths below the soil surface of at least 0.4-0.5 m at some of the experimental sites.

These effects included visual effects of shearing, increasing soil strength and possibly reduced hydraulic conductivity. However, there was no evidence of reduced hydraulic conductivity at a depth of about 1 m - it actually appeared to increase in the compacted treatments, and we are unable to explain this effect.

The depth, nature and extent of changes in soil structure as a result of impact compaction are not known.

If the rice industry wishes to consider or condone more widespread adoption of impact compaction beyond sealing small leaky areas within rice paddocks, its effects on soil structure and its reversibility must be investigated. Such investigations are not currently planned.

ACKNOWLEDGEMENTS

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