Australian Government
Department of Agriculture

AUSTRALIAN Pork

Demonstrating the Utilisation of Spent Eco-Shelter Bedding in Broadacre Cropping Systems

Final Report
APL Project 2010/1015.338

May 2013

Rural Directions Pty Ltd
Tony Craddock and Brendan Wallis
PO Box 646
Clare SA 5453

Disclaimer: The opinions, advice and information contained in this publication have not been provided at the request of any person but are offered by Australian Pork Limited (APL) solely for informational purposes. While APL has no reason to believe that the information contained in this publication is inaccurate, APL is unable to guarantee the accuracy of the information and, subject to any terms implied by law which cannot be excluded, accepts no responsibility for loss suffered as a result of any party's reliance on the accuracy or currency of the content of this publication. The information contained in this publication should not be relied upon for any purpose, including as a substitute for professional advice. Nothing within the publication constitutes an express or implied warranty, or representation, with respect to the accuracy or currency of the publication, any future matter or as to the value of or demand for any good.

Contents

1. Acknowledgements

This project is supported by funding from Australian Pork Limited and the Department of Agriculture.

The following organisations and individuals are gratefully acknowledged for their contributions to this project:

- Darren Lowe, Robert Bowring, Matthew Starick, Nick and Simon May, and Jock Krause for hosting the demonstration trial sites
- Michael Moore, PIRSA, for providing guidance on the development of the project
- Philip Winchester, LXL Pty Ltd for supplying the pig bedding
- Viterra for conducting grain quality tests

2. Executive Summary

This report details the findings of a two-year project examining and promoting the use of spent pork eco-shelter bedding as an alternative fertiliser and for improving poor fertility soils in broadacre cropping systems.

This work is important because of the emerging and expanding trend towards straw based eco-shelters, which will result in greater volumes of spent bedding being stockpiled on farm.

The findings will benefit broadacre farmers by providing information on utilising spent pig bedding as an alternative crop nutrient source and as a soil improvement agent. The factsheet produced as part of this project will provide a useful reference to support broadacre users.

Pork producers will also benefit from the project by promoting the utilisation of a key by product.

Methods Used

To gain an understanding of the nutrient contents of spent bedding, samples were sourced from commercial pork farms in South Australia and New South Wales. Details on each batch sampled were provided and each batch was tested for macro and micro nutrients as well as heavy metals, carbon and moisture content.

To provide an estimate of the dollar value of the nutrients contained within the spent bedding samples, a purpose built excel-based calculator (*PooCalc*), developed by Rural Directions Pty Ltd was utilised.

Replicated demonstration trials were established on phosphorus responsive and non responsive soils to demonstrate where conventional fertiliser should be applied in conjunction with spent bedding to reduce the risk of crop vigour reductions.

To investigate and promote spent bedding as a soil improvement agent, a replicated demonstration trial was conducted, where high application rates of bedding were applied to a low fertility sand hill, to measure responses in cereal crop performance, grain quality parameters, plant tissue and soil nutrient responses over two years.

An extension program involving presentations at grower and advisor discussion groups, forums and conferences, press and newsletter articles, and demonstration trial field days was conducted to extend research results to broadacre farmers, and pork producers to raise awareness about the product and increase user confidence.

Results/ Key Findings

Product Survey

The product survey indicated that there were useful quantities of macro elements and some trace elements contained in spent bedding from straw-based pig housing, indicating good potential for use as a fertiliser alternative in broadacre cropping systems. Heavy metal contents of the spent bedding were mostly low, however some batches contained moderate copper and zinc levels.

There was a high degree of variation in nutrient and moisture contents between product batches. This highlighted the importance of users and suppliers to obtain an analysis of the product intended for use so that appropriate rates of application can be calculated and to determine product value.

The estimated commercial value of spent bedding based on the nutrient contents (N,P,K, S and Zn) averaged $72/t on a dry weight basis and $37/t on a fresh weight basis delivered to the cropping farm. If the value of potassium was excluded from the valuation (some cropping soils have ample potassium and as such some grain growers are unlikely to value potassium in the product), the average value reduced to $40/t on a dry weight basis and $20/t on a fresh weight basis delivered to the cropping farm. In reality, the price of spent bedding products may need to be discounted further from these estimated values to entice broadacre farmers to utilise them on a broad scale basis given the perceived difficulties associated with using bulky, manure based products.

Improving Poor Soils with Spent Bedding

High rates of straw-based spent pig bedding on a poor producing sandy soil improved cereal crop vigour, grain yields and grain protein for two years following application.

Application of high rates of spent bedding increased plant tissue levels of macro and trace elements for two years following application.

Spent Bedding as a Fertiliser Alternative

Difficulties in identifying highly phosphorus responsive sites are likely to have influenced results at trial sites. On several occasions crop responses (and non responses) indicated phosphorus responsiveness contrary to soil test indications. Elevated plant nitrogen and grain protein levels associated with spent bedding applications indicated that crop responses to nitrogen contained in the bedding may also have influenced results.

As a result, the role of "starter" conventional fertiliser (applying some conventional fertiliser in the seed row when sowing the crop to overcome nutrient availability/accessibility issues) when using spent bedding is difficult to determine from the trial results

There were occasions however, where crop vigour reductions were observed when 5t/ha of spent bedding was applied alone compared to when conventional DAP (NPK 18:20:0) fertiliser was supplied in the seed row. In several instances this transferred into slightly lower grain yields.

The application of higher rates of spent bedding (10t/ha) appeared to negate the need for "starter" conventional fertiliser applications in the seed row, resulting in improved crop vigour and grain yield at several sites.

3. Background to Research

Straw-based housing systems, or "eco-shelters", have been an emerging trend within the pork industry. Associated with this trend is the increased production of spent bedding with potential for environmental issues associated with waste stockpiles, including flies, odour, and contamination of water supplies.

Spent bedding is commonly applied to neighbouring agricultural land with little knowledge of its nutrient content, appropriate application rates, or potentially negative crop effects, with the primary aim to dispose of the product. At the same time, increasing costs of conventional fertilisers have prompted many broadacre cropping farmers to explore alternative nutrient sources to apply to crops.

Recent RIRDC-funded research into spent litter associated with chicken meat production as a fertiliser alternative has established chicken litter as a useful source of crop nutrients and generated information to address frequently asked questions posed by broadacre users. It has also identified a methodology for determining economic value of chicken litter to guide appropriate pricing of litter for sale.

The research has identified appropriate rates of application and use patterns, as well as potential negative effects; the most notable being a reduction in crop vigour under certain circumstances, together with mitigating strategies for overcoming vigour reductions.

This project has generated similar information on the utilisation of spent pig bedding to develop a profile for the product, establish demand and indicate its economic value, and to potentially develop spent bedding as a saleable product.

The project has had a strong extension component aimed at increasing the profile of spent pig bedding as a nutrient source for broadacre crops and to develop markets for the product.

Opportunities have been identified for the use of high rates of spent bedding as a soil conditioner/improver for poor soils, and to integrate improved soil testing techniques to better predict the likelihood of crop vigour reductions and the need to employ mitigating strategies.

4. Objectives of the Research Project

4.1 To Quantify and Communicate the Nutrient Content and Variation in Spent Eco-Shelter Bedding.

4.2 To Demonstrate Grain Crop Responses to the Application of Different Rates of Eco-Shelter Bedding with and without Conventional Fertiliser in Modern No-Till Cropping Systems.

4.3 To Evaluate Improved Soil Testing Technologies as a Predictive Tools to Determine Use Patterns for Eco-Shelter Bedding.

4.4 To Investigate and Demonstrate the Use of High Application Rates of Eco-Shelter Bedding as a Soil Improvement Agent for Poor Soils.

4.5 To Demonstrate the Economic Value of Spent Eco-Shelter Bedding to Aid Pricing of Product by Suppliers and Cost-Effective Decisions on Crop Nutrient Supply by Potential Users.

4.6 To Increase Broadacre Crop Producer Awareness of the Potential for and Practical Aspects of Utilising Spent Eco-Shelter Bedding within Their Farming Systems.

5. Research Methodology, Results and Discussion

5.1 Product Survey

Methodology

To gain an understanding of the nutrient contents of spent bedding, 32 samples of predominantly cereal straw-based beddings were sourced from commercial pork farms in South Australia and New South Wales.

Participating pork farms were asked to supply samples of spent bedding by taking 30 random grab samples from the manure stack/batch, placing them into a bucket and mixing, before removing a representative sub-sample for testing.

The samples were then sent to CSBP laboratories in Western Australia and tested for macro and micro nutrients, heavy metals, carbon and moisture content.

Participants were asked to provide details on each batch sampled including the type of bedding, age of animals housed on bedding, type of feed supplied to the animals, number of batches of pigs housed on bedding and the duration of composting to gain some insight into possible factors influencing the nutrient and heavy metal content of the bedding.

Results & Discussion

Table 1: Moisture, carbon and macro nutrient contents of spent pig bedding samples

	Moisture %	Carbon %	Nitrogen %dwt	Phosphorus %dwt	Potassium %dwt	Sulphur %dwt
Average	48	28	2.93	1.23	2.02	0.6
Range	6.40 - 73.7	17.3 - 35.7	1.73 - 4.54	0.52 - 2.63	0.86 - 3.84	0.35 - 1.0

The results showed that useful quantities of plant nutrients were contained in spent bedding from pig housing, indicating good potential for use as a fertiliser alternative in broadacre cropping systems. On average, macro nutrients nitrogen, phosphorus, potassium and sulphur occurred in quantities comparable to other organic by products (e.g. chicken litter and reclaimed biosolids) currently utilised to supply nutrients to broadacre crops. Micro nutrients zinc, copper and manganese were also contained in spent bedding samples indicating potential to supply these nutrients to broadacre crops.

The survey indicated a high degree of variation in nutrient content between product batches. This has implications for valuation of spent bedding products based on nutrient content, and for calculating appropriate rates of application. It highlights the importance of users to obtain an analysis of the product intended for use, to refine nutrient application decisions.

Moisture contents of bedding samples varied substantially with samples ranging from as low as 6.4% and up to 73.7% moisture, with an average of 48%. This may have been influenced by the wet summer experienced in 2010-11 prior to sampling, resulting in the stockpiles being potentially higher in moisture content than normal.

The implications of this observation is that potential users need to have an understanding of the moisture content of the spent bedding to assess the value of the product and to make informed nutrient application decisions. Nutrient contents of organic by products are generally reported on a dry weight basis, whilst products are applied in tonnes per hectare, on a fresh weight basis. Users of spent bedding will need to calculate the nutrient content of the product on a fresh weight basis, taking into account the moisture content of the product, to determine appropriate rates of application.

Table 2: Average nutrient contents of different types of spent bedding

	No. of samples	Nitrogen %dwt	Phosphorus %dwt	Potassium %dwt	Sulphur %dwt
Cereal Straw + Rice hulls	4	2.27	1.04	1.4	0.4
Cereal straw	27	3.07	1.27	2.13	0.65
Wood chip mix	1	1.85	0.99	1.52	0.35

Cereal straw was the most common bedding base associated with the samples analysed in the survey. Cereal straw-based beddings appeared to contain higher levels of the macro nutrients nitrogen, potassium and sulphur than other bedding bases. However, it should be noted that limited numbers of non-cereal straw-based beddings were analysed.

Table 3: Average macro nutrient content by age of pigs housed on bedding

	No. of samples	Nitrogen %dwt	Phosphorus %dwt	Potassium %dwt	Sulphur %dwt
0-3 months	14	2.97	1.16	2.04	0.59
3-6 months	14	2.90	1.35	2.20	0.62
sows	2	2.91	1.05	1.37	0.55
various	2	2.95	1.11	1.29	0.63

The average macro nutrient levels contained in bedding did not appear to be strongly influenced by the age of pigs housed on the bedding.

Table 4: Average carbon and macro nutrient content by length of composting period

	No. of samples	Carbon %dwt	Nitrogen %dwt	Phosphorus %dwt	Potassium %dwt	Sulphur %dwt
1-6 months	17	30	2.71	1.12	1.88	0.54
6-12 months	7	28	3.56	1.46	2.34	0.78
12 months +	8	25	2.84	1.26	2.04	0.6

The percentage of carbon contained in the samples ranged from 17.3 – 35.7%, with an average of 28%. There was a slight trend towards lower carbon percentages as the composting period increased (see Table 4).

The length of time that the spent bedding was composted appeared to have no influence on macro nutrient levels.

Micro Nutrients

Average micro nutrient levels (on a dry weight basis) in spent beddings are contained in *Tables 5* and *6*.

Table 5: Average and ranges of micro nutrient levels contained in spent bedding

	Zinc mg/kg	Copper mg/kg	Manganese mg/kg
Average	1157	102	370
Range	319 - 4288	<0.05 - 474	191 - 585

Table 6: Average micro nutrient levels by type of bedding

	No. of samples	Zinc mg/kg	Copper mg/kg	Manganese mg/kg
Cereal Straw + Rice hulls	4	1907	167	353
Cereal straw	27	1066	96	376
Wood chip mix	1	614	<0.05	289

Micro nutrients levels differed markedly between samples. Cereal straw and rice hull-based bedding samples appeared to contain higher levels of zinc, however, there were limited samples of alternative bedding types to draw any firm conclusions.

Heavy Metal Content

To gauge levels of heavy metal contamination of spent bedding, the results were compared with the EPA Victoria quality standards (*EPA Victoria, 2004*) for treated biosolids (sewage sludge) products. The standards indicate three quality grades based on the levels of contaminants within the biosolid material; with C1 being the highest quality standard and C3 being the lowest quality standard.

The average and ranges of heavy metals within the spent bedding samples tested are contrasted with EPA Victoria's C1 and C2 standards. Results less than the C1 standard are coloured green. Results exceeding C1 limits but less than C2 limits are coloured orange. Results exceeding the C2 standard are coloured red.

Table 7: Heavy metal levels of spent bedding and chicken litter compared to EPA Victoria Biosolids grade standards

Heavy Metal	Spent Bedding Metal Contents		EPA Vic Biosolids Contaminant Grade Standards		Chicken Litter Metal Contents	
	Average mg/kg	Range mg/kg	Grade C1 mg/kg	Grade C2 mg/kg	Average mg/kg	Range mg/kg
Arsenic	1.2	0.3 - 2.4	20	60	4.3	<2 - 19
Cadmium	0.25	0.05 - 0.6	1	10	0.051	<0.008 - 0.18
Chromium	8.4	1.1 - 23	400	3000	2.6	0.2 - 15
Copper	102	<0.05 - 474	100 (150)	2000	161	78 - 299
Lead	2.8	0.7 - 6.4	300	500	0.8	0.2 - 6.2
Nickel	6.9	2.1 - 14.6	60	270	6.8	3.6 - 15.7
Zinc	1157	319 - 4288	200 (300)	2500	404	160 - 672

Bracketed standards apply to composted biosolids products.

Source: Guidelines for Environmental Management – Biosolids Land Application; EPA Victoria (2004)

Table 8: Average heavy metals by type of bedding

	No. of Samples	Zinc mg/kg	Copper mg/kg	Arsenic mg/kg	Cadmium mg/kg	Chromium mg/kg	Lead mg/kg	Nickel mg/kg
Cereal straw + Rice hulls	4	1907	167	0.4	0.11	2.95	1.78	3.73
Cereal straw	27	1066	96	1.3	0.27	9.38	2.9	7.48
Wood Chip Mix	1	614	<0.05	0.71	0.6	3.65	2.23	4.82

Table 9: Average heavy metals by age of pigs housed on bedding

	No of Samples	Zinc (mg/kg)	Copper (mg/kg)	Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)
0-3 months	14	1511	58	1.2	0.28	7.5	0.25	7.25
3-6 months	14	936	135	1	0.2	8.9	0.3	6.32
sows	2	661	60	1.4	0.19	11.3	0.38	7.86
Various	2	730	211	1.7	0.3	7.7	0.21	7.94

The results indicate that most spent bedding batches contained low levels of heavy metals with respect to arsenic, cadmium, chromium, lead and nickel.

All samples contained moderate levels of zinc with three exceeding Grade C2 biosolids contaminant grade standards. The age of the pigs housed on the bedding appeared to influence the zinc content of samples (Table 9) with levels higher on average in bedding which housed younger pigs. This is likely to be related to the use of higher quantities of zinc oxide as an anti-microbial in the diets of younger pigs.

50% of samples contained moderate levels of copper, whilst the remaining 50% had levels below detection (<0.05ppm). This is likely to be linked to the herd health strategies adopted by individual farms involving the utilisation of copper sulphate in rations as an anti-microbial treatment.

These findings represent an opportunity and a risk in utilising spent bedding in broadacre cropping soils. Zinc and copper, although essential nutrients for broadacre crops and deficient in many cropping soils, are also heavy metals that can accumulate in soils. Farmers in many broadacre cropping zones would regard the zinc and copper content in spent bedding advantageous in building fertility in deficient or depleted soils, rather than a risk. Conversely, soil accumulation of zinc and copper will need to be monitored with long term use and high application rates of spent bedding.

Compared to results from a survey of 123 chicken litter samples in 2009 *(Craddock and Hollitt, 2010)*, average zinc levels in spent bedding from pork farms were higher than those found in chicken litter, whilst levels of other heavy metals were comparable.

5.2 Economic Value Estimation

Methodology

To provide an estimate of the dollar value of the nutrients contained within the spent bedding samples, a purpose built excel-based calculator (*PooCalc*), developed by Rural Directions Pty Ltd was utilised.

The calculator valued the nutrients contained within the spent bedding sample based on the retail price of each nutrient as supplied in commonly used broadacre fertilisers.

The nutrient value per kg of nutrient supplied for the fertiliser products listed in Table 10 was calculated using the following formula:

$$\text{Nutrient Value (\$/kg)} = \frac{\text{Fertiliser Price (\$/t)}}{\text{Nutrient content (\%)} \times 10}$$

The nutrients in the bedding that were used to estimate the value of each product were nitrogen, phosphorus, potassium, sulphur and zinc.

The valuation methodology adopted for phosphorus and nitrogen in the samples was more complex and takes into consideration:

1. *A discounted value of phosphorus* given that the Di-ammonium phosphate (DAP), one of the most common phosphorus-based fertilisers used in broadacre cropping, also contains 18% nitrogen as well as 20% phosphorus. The valuation methodology assumes that the value of the nitrogen contained within DAP (and spent bedding) effectively "cheapens" the per kilogram value of phosphorus. Because spent beddings contain substantial amounts of phosphorus and nitrogen in combination it was considered more realistic to value these nutrients using the value of the nutrients contained in DAP, rather basing the valuation on a phosphorus-only product.

2. *Potential nitrogen losses*. Manure-based products can contain significant amounts of nitrogen in the ammonium. This is likely to be lost as ammonia when applied to the soil surface and not incorporated immediately. Given that most spent beddings applied in broadacre cropping systems will be broadcast onto paddocks and incorporated days, and potentially months later, it was assumed that most of the nitrogen contained in the bedding in the ammonium form would be lost. The amount of nitrogen contained the spent bedding in the ammonium form is likely to vary with the degree of composting, however, to keep the value

of the bedding conservative it was assumed that 50% of the nitrogen contained in the spent bedding would be lost. As a result, 50% of the nitrogen contained in the bedding was valued.

It should be noted that the nutrients considered “of value” by broadacre crop producers will vary depending on the soil type and crop grown.

For example, crop producers situated in the mid north district of South Australia are unlikely to value the potassium contained in spent bedding, as soils within that district contain abundant potassium. Conversely, growers producing crops on sandy soils low in potassium, will value the potassium contained in the product.

Given that potassium is a high value element that may or may not be valued by broadacre users, product values are reported with and without potassium.

Due to the high levels of moisture contained in many of the samples analysed, each bedding sample was valued on a $/tonne dry weight basis. To convert this to a fresh weight value, the reported value needs to be multiplied by its dry matter content.

Compared to most conventional cropping fertilisers, the light and bulky nature of spent bedding requires a specialist, high capacity spreader to evenly spread the product, which incurs additional cost and discounts the value of the bedding. For this reason, the cost of contract spreading (assumed to be $20 per tonne on a dry weight basis) has been deducted from the overall nutrient value of the product to provide a ***net value***.

Note that ***Farm Gate*** values are reported (i.e. the value of the product delivered to the user’s farm). The cost of freighting the spent bedding long distances is considerable given its light and bulky nature. The cost of freighting the product from the pig farm to the cropping farm will further reduce the value of the bedding at the pig farm from the perspective of an individual user. Therefore, the nutrient value reported should be interpreted as the value of the product delivered to the cropping farm (after freighting), not the value at the pig farm. Individual users will need to deduct a freight component from the value to estimate the unfreighted value of the product.

Table 10: Value of Nutrients per kilogram as supplied in commonly used cropping fertilisers

Nutrient	Fertiliser Product	Retail Price* $ per tonne	Nutrient %	Nutrient Value $/kg of nutrient
Nitrogen	Urea	$550	46%	$1.20
Phosphorus	Di-ammonium Phosphate** (DAP) Value of P *(without considering N)*	$800	20% P	$4.00
	(less the value of N contained in DAP)	-$215	18% N	
	Net Value of N in DAP	$585	20%	$2.92
Potassium	Muriate of Potash	$800	50%	$1.60
Zinc	Zinc Sulphate Heptahydrate	$1,000	22.50%	$4.44
Sulphur	Gypsum *(carted and spread)*	$40	16%	$0.25

* *Prices are approximate 2011 retail prices (these will vary over time and between regions)*

*** Also contains 18% Nitrogen*

Table 11: Value per tonne delivered to the cropping farm gate of spent bedding on a dry weight and fresh weight basis

	Value with Potassium $/t dwt	Value with Potassium $/t fwt	Value without Potassium $/t dwt	Value without Potassium $/t fwt
Average	$72	$37	$40	$20
Range	*$44 - $119*	*$12 - $70*	*$17 - $82*	*$5 - $44*

Phosphorus content was a key driver of spent bedding values. The higher the phosphorus content, the higher the value of the product.

Valuation of potassium in addition to other nutrients within the spent bedding products effectively increased the value of the products by 80%.

The calculated values represent the values equivalent to supplying the nutrients via conventional fertilisers. In practice, it is likely that the commercial value of spent bedding products would need to supply nutrients at a discount to conventional fertilisers to entice broadacre farmers to utilise them on a broad scale basis.

There is a “difficulty” factor associated with using a bulky, manure-based product compared to a “convenient”, concentrated nutrient source in the form of a conventional fertiliser which will need to be overcome by supplying the nutrients at a discount to conventional fertilisers.

5.3 Spent Bedding as a Soil Improvement Agent

Methodology

To investigate spent bedding from straw-based pig shelters as a soil improving agent, a simple, replicated demonstration trial was established on a low fertility sandhill near Balaklava in South Australia's Mid North cropping district in 2011. Soil test results from the site are detailed in table 12.

Table 12: Soil Test Results (0-10) from the Balaklava demonstration trial site

Colwell Phosphorus	Phosphorus Buffering Index	DGT Phosphorus	Colwell Potassium	Sulphur	Organic Carbon	pH	Nitrate and Ammonium N
ppm		ug/L	ppm	ppm	%	$CaCl_2$	kg/ha
14	5	193	234	3.83	0.6	6.1	56.7

The trial included rates of 0, 5, 10 and 20 t/ha of spent bedding spread in autumn prior to sowing. Crop yields, grain quality parameters, plant tissue, grain and soil nutrient levels were measured over two years to evaluate the effectiveness, longevity of responses and potential risks associated with this use pattern for chicken litter. The trial was a randomised block design with three replicates of large (4m x 10m) plots.

Partially composted straw-based eco-shelter bedding was sourced from a piggery near Sheaoak Log in South Australia. The partially composted bedding was hand broadcast onto plots on the 21st of April 2011. The manure analysis is detailed in *Table 13*.

Table 13: Moisture and nutrient content of spent bedding used in 2011 demonstration trials

Nitrogen %	Potassium %	Sulphur %	Zinc mg/kg	Manganese %
2.93	2.02	0.6	1157	370

Copper mg/kg	Arsenic %	Phosphorus %	Lead mg/kg	Moisture %
102	1.2	1.23	2.8	48.4

2011

The trial was sown with 85 kg/ha Fleet Barley on the 28th of May 2011 together with 100kg/ha of NPK 24:16:0 fertiliser using a commercial airseeder fitted with 4" shares and finger-tyne harrows.

An additional 80/ha of urea was applied to all plots post emergence (13th July 2011). Plots were also spread with mouse bait due to high mouse numbers which caused some initial damage.

Youngest Emerged Blades (YEB) samples were collected on the 18th of August for plant tissue analysis at CSBP Laboratories in WA. Prior to sampling, plots were visually scored for plant vigour using a 0 to 10 scoring system.

The plots were harvested using a mechanical plot harvester in December 2011. Grain quality parameters were assessed using commercial quality testing equipment at the Keith Viterra receival site.

2012

The trial was sown with 80 kg/ha of Justica CL Plus wheat on the 22nd of May 2012, together with 80kg/ha of NPK 24:16:0 +1% zinc fertilizer. An additional 50kg/ha of urea (NPK 46:0:0) was applied to all plots in July 2012.

Youngest Emerged Blades (YEB) samples were collected on the 7th of August for plant tissue analysis at CSBP Laboratories in WA. Prior to sampling, plots were visually scored for plant vigour using a 0 to 10 scoring system.

The plots were harvested in December 2012. Grain quality parameters were assessed using commercial quality testing equipment at the Bowmans Viterra receival site.

Soil samples from depth of 0-10cm were collected from the plots on the 23rd of January 2013 (21 months after spent bedding application). Soil nutrient analyses were conducted at CSPB Laboratories in WA.

Results and Discussion

Grain yield and quality results are summarised in *Table 14*.

Table 14: Grain Yield and Quality Results 2011 & 2012

Treatment	Grain Protein %	Grain Screenings %	Grain Test Weight kg/hL	Grain Yield t/ha	Vigour 0-10
2011 Barley					
Untreated	11.2 ***b***	1.60	62.2	1.41 ***b***	5
5t/ha	11.4 ***b***	1.53	62.7	1.94 ***ab***	6.3
10t/ha	11.7 ***b***	2.30	61.4	2.21 ***ab***	7.7
20t/ha	13.1 ***a***	2.11	61.93	2.62 ***a***	9
LSD 5%	1.12	n.s.	n.s.	0.94	-
2012 Wheat					
Untreated	11.2 ***ab***	17.97	77.27	0.52 ***c***	6
5t/ha	11.7 ***b***	18.08	76.27	0.71 ***bc***	6
10t/ha	11.6 ***b***	16.60	76.40	0.93 ***ab***	7.7
20t/ha	12.4 ***a***	15.31	76.30	0.96 ***a***	8.5
LSD 5%	0.51	n.s.	n.s.	0.24	-

Letters (i.e. a, b, c) indicate results that were statistically significant from one another

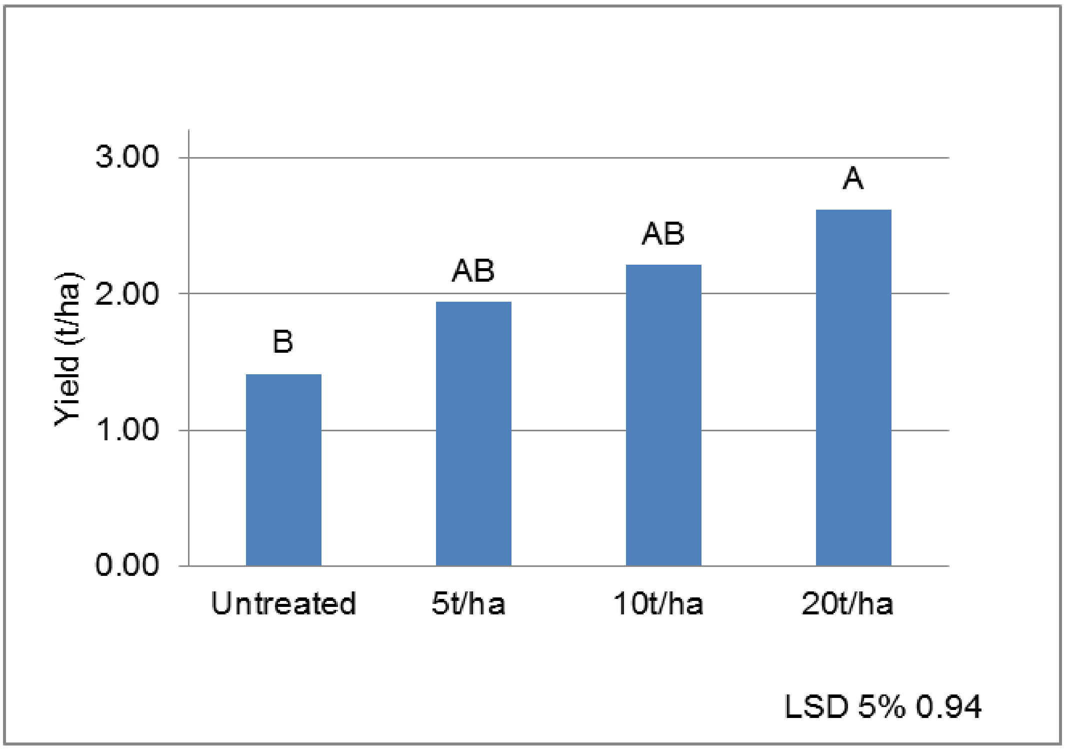

Figure 1: Barley grain yield in response in the year of application of spent pig bedding to a sandhill near Balaklava in 2011

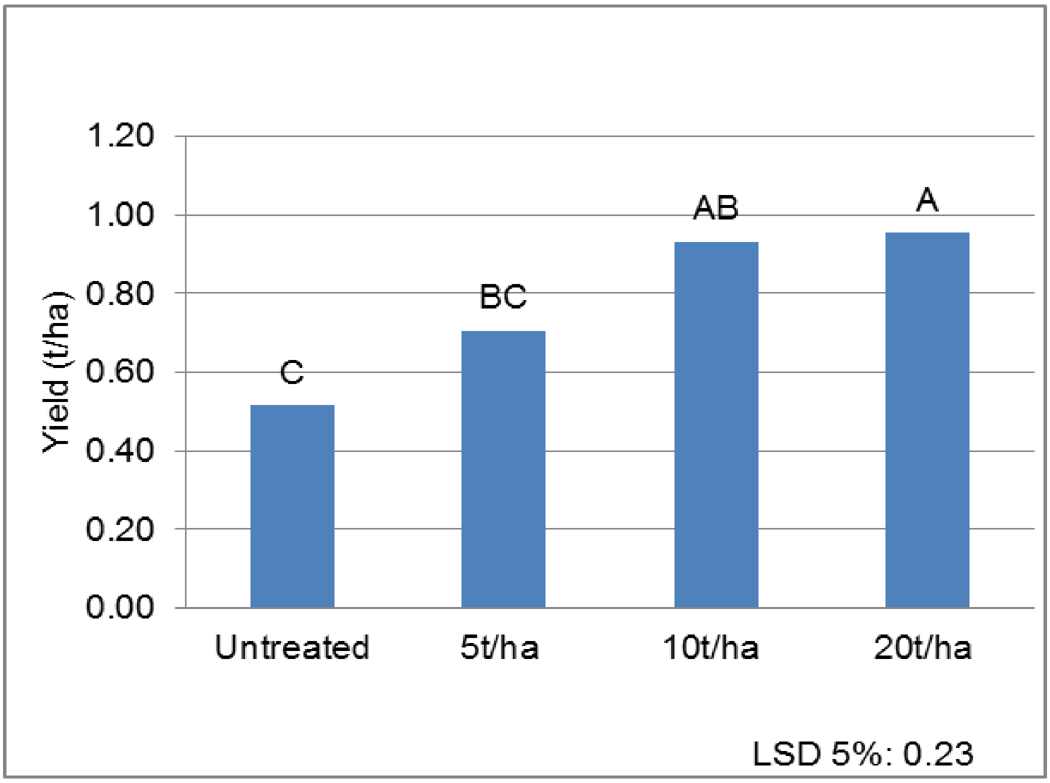

Figure 2: Wheat grain yield in 2012 in response to the application of spent pig bedding in the year prior to a sandhill near Balaklava

Table 15: Plant Tissue Analysis Results (YEB) in response to increasing rates of Spent Eco-shelter bedding on a low fertility sandhill near Balaklava in 2011 and 2012.

	Copper mg/kg	Manganese mg/kg	Phosphorus %	Potassium %	Sulphur %	Nitrogen %	Zinc mg/kg
2011 Barley*							
Untreated	5.26	47.12	0.51	4.53	0.21	4	27.58
5t/ha	5.92	44.21	0.53	4.5	0.32	4.16	30.38
10t/ha	7.15	48.38	0.57	4.61	0.38	4.69	34.36
20t/ha	7.63	51.53	0.63	4.45	0.42	4.95	39.82
*Critical Level***	*1.5*	*15*	*0.27*	*2.5*	*0.2*	*4*	*16*
2012 Wheat							
Untreated	4.66	45.31	0.44 ***a***	3.01	0.25	3.86	46.58
5t/ha	4.91	46.84	0.40 ***b***	2.95	0.24	3.64	52.54
10t/ha	9.69	47.72	0.39 ***b***	3.14	0.3	3.94	54.56
20t/ha	6.86	52.47	0.41 ***ab***	3.16	0.3	4.13	60.7
LSD 5%	n.s.	n.s.	0.031	n.s.	n.s.	n.s.	n.s.
*Critical Level***	*1.5*	*15*	*0.27*	*2.5*	*0.2*	*4*	*16*

Letters (i.e. a, b, c) indicate results that were statistically significant from one another
**Plant tissue sampling was not replicated in 2011*
*** Source: Reuter and Robinson (1997)*

During late winter and spring, in both years visual responses in crop growth and vigour were clearly evident in all treatments where spent eco-shelter bedding was applied. Responses were proportional to the rate of spent bedding applied, with the untreated showing the least visual response and 20t/ha showing the greatest visual response.

Grain yield responses were also measured with increasing rates of eco-shelter bedding. In 2011, barley grain yield increases were measured of up to 1.21t/ha where 20t/ha of spent bedding was applied. Yield responses continued into the 2012 wheat crop with the 20t/ha application rate achieving a 0.44t/ha yield increase over the untreated plots.

The high rates of spent bedding application did not have an adverse affect on grain yield and quality in either year of the trial. This was surprising given the risk of excessive crop growth and subsequent "burning off" associated with high nitrogen application rates.

Grain protein content was significantly increased by the 20t/ha spent bedding application rate in the two years following application (*Table 14*). There were no significant differences recorded in test weight and screenings levels between the various treatments.

It is evident from *Table 15* that there were responses in key plant nutrient levels to increasing spent eco-shelter bedding application rates, but it also needs to be noted that in 2011, composite plant tissue samples were analysed with no replication.

Plant tissue levels of nitrogen, sulphur, zinc, manganese and copper levels were elevated by the application of spent bedding in the year of application.

In the second year following applications, elevated plant tissue levels of copper, manganese, potassium, sulphur, nitrogen and zinc were measured in plots receiving spent bedding applications, however these were not statistically significant.

There was a trend towards elevated plant nitrogen levels in spent bedding treated plots. Although the responses were not statistically significant, a significant difference in grain protein levels associated with 20t/ha application rate of spent bedding occurred in both years following application, indicating longer term nitrogen benefits associated with high application rates of spent bedding.

Table 16: Soil Test Results (0-10cm) in response to increasing eco-shelter bedding applications at Balaklava in February 2013

Treatment	Colwell Phosphorus mg/kg	Colwell Potassium mg/kg	Sulphur mg/kg	Organic Carbon %	Conductivity EC 1:5 dS/m	pH $CaCl_2$
Untreated	36.7	239	5.1	0.45	0.06	6.2
5t/ha	39.3	231	6.3	0.42	0.07	6
10t/ha	36.7	240	5.8	0.44	0.07	6.1
20t/ha	37.7	226	6.9	0.45	0.09	6.5
LSD 5%	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

When soil nutrient levels were analysed 21 months following spent bedding applications, there was a slight trend towards elevated soil levels of sulphur, electrical conductivity and pH in response to spent bedding applications, however the responses were not statistically significant.

5.4 Spent Bedding as a Fertiliser Alternative

Methodology

The aim of the trials was to demonstrate the use of DGT Phosphorus soil testing in determining the appropriate use patterns of spent bedding from straw-based pig shelters, with and without conventional fertiliser, to overcome crop vigour reductions.

The trials were also intended as a visual extension tool for potential users of spent bedding to reinforce the strategy of using starter fertiliser similar to the use of chicken litter, on phosphorus responsive sites (as indicated by DGT testing) to avoid crop vigour issues.

Replicated trials were conducted in 2011 and 2012. The 2011 trials were conducted near Roseworthy in SA's lower north, and the 2012 trials were conducted at Palmer in SA's Murray Plains district. In both years, two identical trials were established in neighboring paddocks; one on a phosphorus responsive soil as indicated by a range of soil tests, the other on a phosphorus non-responsive soil. Test results from a range of soil phosphorus tests conducted by Sean Mason from the University of Adelaide (Colwell P, Phosphorus Buffering Index (PBI) and Diffuse Gradients in Thin Films (DGT)) are summarised below in tables 17 and 20.

2011

Table 17: Soil Phosphorus Test data (0-10cm) for Phosphorus Responsive and Non-Responsive Trial sites at Roseworthy in 2011.

Site	Colwell P (mg/kg)	PBI	*Critical Colwell P (mg/kg)	DGT (ug/L)	DGT Predicted Response (% of maximum)
Phosphorus responsive	28	88	27	49	98
Phosphorus non-responsive	48	51	22	92	88
			Critical DGT value	<50	

*Calculated from Moody et.al. (2007)

Three soil phosphorus testing techniques (Colwell, PBI, and DGT) were conducted prior to site selection in 2011. Colwell + PBI indicated that the P responsive site was non-responsive, whilst the DGT test indicated that the site was marginally phosphorus responsive. All tests indicated that the P non-responsive site was likely to be non-responsive.

The trial design was a randomised block design with three replicates. Wheat was sown with and without conventional Di-Ammonium Phosphate (DAP - NPK 18:20:0) fertiliser in plots treated with spent bedding at varying rates. Combinations of spent bedding and conventional fertiliser treatments are detailed in Table 18.

Table 18: Combinations of spent pig bedding and conventional fertiliser treatments at Roseworthy in 2011

	Eco-shelter Bedding Broadcast Pre-Sowing (t/ha)	DAP Fertiliser Applied in the Seed Row (kg/ha)
Treatment 1	0	0
Treatment 2	5	0
Treatment 3	10	0
Treatment 4	10	30
Treatment 5	0	70

Partially composted, straw-based bedding was sourced from a piggery near Sheaoak Log in South Australia. Analysis of the bedding is detailed in *Table 19*.

Table 19: Analysis of the spent bedding (dry weight basis) applied at the Roseworthy demonstration trial sites in 2011

Nitrogen %	Potassium %	Sulphur %	Zinc mg/kg	Manganese %
2.93	2.02	0.6	1157	370

Copper mg/kg	Arsenic %	Phosphorus %	Lead mg/kg	Moisture %
102	1.2	1.23	2.8	48.4

The spent bedding was hand broadcast on the 24th May 2011 and plots were subsequently direct drilled with 100kg/ha of Mace wheat using a nine row plot seeder equipped with knife points and press-wheels on the 30th of May. An additional 80L/ha of UAN (a mixture of urea plus ammonium nitrate in solution; NPK 42:0:0 w/v) was applied to the P responsive site post emergence. 120L/ha of UAN was applied to the P Non responsive site post emergence. Plots were sampled (youngest emerged blade) for plant tissue analysis on the 20th of September.

Plots were harvested with a small plot harvester to assess grain yield. Grain quality analyses were conducted using Viterra's grain testing equipment at their Keith receival site.

2012

Table 20: Soil Phosphorus Test data (0-10cm) for Phosphorus Responsive and Non-Responsive Trial sites at Palmer in 2012

Site	Colwell P (mg/kg)	PBI	*Critical Colwell P (mg/kg)	DGT (ug/L)	DGT Predicted Response (% of maximum)
Phosphorus responsive	29	46	21	52	90
Phosphorus non-responsive	42	23	16	158	100
			Critical DGT value	<50	

*Calculated from Moody et.al. (2007)

Similar soil tests were conducted prior to site selection as in 2011. Both phosphorus testing techniques (Colwell + PBI and DGT) indicated that the P Non Responsive site was non-responsive.

Colwell + PBI indicated that the P responsive site was non-responsive. The DGT test indicated that this site was marginally P responsive with a predicted response of 90% of maximum yield.

The trial design was a randomised block design with three replicates. Wheat was sown with and without conventional Di-Ammonium Phosphate (DAP – NPK 18:20:0) fertiliser in plots treated with spent bedding at varying rates. Combinations of spent bedding and conventional fertiliser treatments are detailed in table 21.

Table 21: Combinations of spent bedding and conventional fertiliser treatments at Palmer in 2012

	Eco-shelter Bedding Broadcast Pre-Sowing (t/ha)	DAP Fertiliser Applied in the Seed Row (kg/ha)
Treatment 1	0	0
Treatment 2	5	0
Treatment 3	10	0
Treatment 4	5	25
Treatment 5	0	60

Straw-based spent bedding was sourced from a piggery near Mannum in South Australia. Analysis of the bedding is detailed below in Table 22.

Table 22: Spent Eco-shelter bedding analysis (dry weight basis) for the demonstration site at Palmer in 2012

Nitrogen %	Potassium %	Sulphur %	Zinc mg/kg	Manganese %
3.81	2.59	0.81	2240.4	331.54

Copper mg/kg	Calcium %	Phosphorus %	Iron mg/kg	Moisture %
633.52	3.61	2.42	2458.74	40

The spent bedding was hand broadcast on the 7th of May 2012 and plots were direct drilled with 100kg/ha of Kord CL Plus wheat using a nine row plot seeder equipped with knife points and press-wheels on the 8th May 2012. An additional 50L/ha of UAN was applied to both sites at seeding.

Plots were harvested with a small plot harvester to assess grain yield. Grain quality analyses were conducted using Viterra's grain testing equipment at their Bowmans receival site.

Results and Discussion

Plant vigour, leaf tissue tests, grain yield and quality results in response to combinations of spent bedding and conventional DAP fertilisers for the demonstration trials are detailed in *Tables 23* to *30* and summarised in *Figures 3* to *4*.

2011: Roseworthy Site

Table 23: Plant Vigour Scores (1-10) at the Roseworthy demonstration trial sites on 18-8-11

Treatment	P Responsive	P Non-Responsive
Untreated	5.3	5.7
5t/ha eco-shelter bedding	7	6.7
10t/ha eco-shelter bedding	8.3	8.3
10t/ha eco-shelter bedding & 30kg/ha DAP	8.7	9
70kg/ha DAP	8.7	7.7

Grain yield and quality results are summarised in *Tables 24* and *25*.

Table 24: Grain yield and quality results at the Phosphorus Responsive Site, Roseworthy 2011

Treatment	Protein %	Screenings %	Test Weight kg/hL	Yield t/ha
Untreated	10.4	0.64 ***b***	77.2	5.23 ***b***
5t/ha eco-shelter bedding	10.6	0.60 ***b***	76.7	5.68 ***ab***
10t/ha eco-shelter bedding	10.5	0.58 ***b***	76.7	6.27 ***a***
10t/ha eco-shelter bedding & 30kg/ha DAP	10.8	0.94 ***a***	76.5	6.08 ***a***
70kg/ha DAP	10.1	0.71 ***ab***	76.2	6.11 ***a***
LSD 5%	n.s.	0.24	n.s.	0.66

Table 25: Grain yield and quality results at the Phosphorus Non Responsive Site, Roseworthy 2011

Treatment	Protein %	Screenings %	Test Weight kg/hL	Yield t/ha
Untreated	10.2	1.78	77.4 ***b***	4.31 ***c***
5t/ha eco-shelter bedding	10.6	1.55	78.1 ***ab***	4.78 ***b***
10t/ha eco-shelter bedding	10.7	1.92	78.2 ***ab***	4.91 ***ab***
10t/ha eco-shelter bedding & 30kg/ha DAP	10.5	1.49	77.8 ***ab***	4.91 ***ab***
70kg/ha DAP	10.5	1.8	78.7 ***a***	5.05 **a**
LSD 5%	n.s.	n.s.	1.12	0.27

Letters (i.e. a, b, c) indicate results that were statistically significant from one another

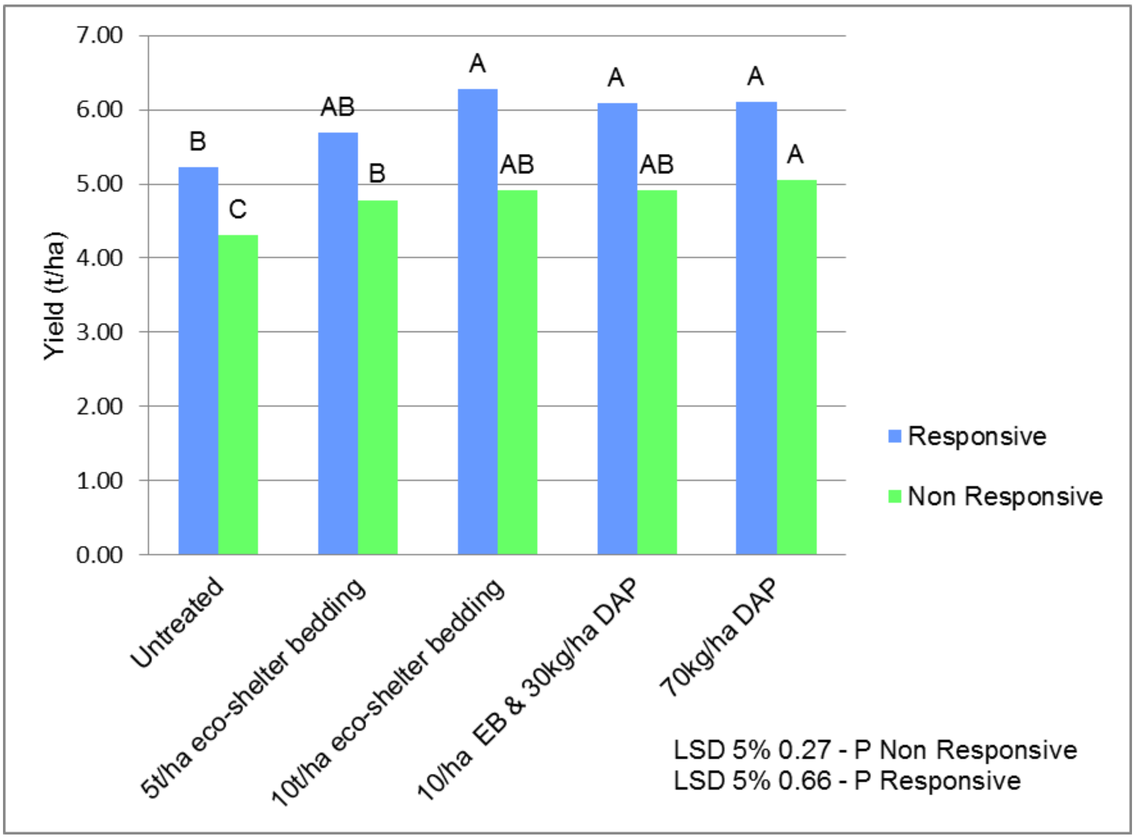

Figure 3: Grain Yield – Phosphorus Responsive and Non Responsive Sites, Roseworthy 2011-

Plant vigour was lowest in untreated plots and those receiving 5t/ha per hectare of spent bedding alone.

Significant grain yield responses were recorded between treatments at the two sites.

At the P responsive site, untreated plots yielded significantly lower than those receiving 10t/ha of spent bedding or DAP fertiliser.

There appeared to be a yield (and vigour) response to increasing the rate of spent bedding applied from 5 to 10t/ha, however it was not statistically significant.

At the P Non-responsive site the untreated plots yielded lower than those receiving spent bedding or conventional fertiliser.

As with the phosphorus responsive site, there appeared to be a yield response to increasing rates of spent bedding from 5 to 10 t/ha, however, this was not statistically significant. 70kg/ha of DAP achieved significantly higher yields than 5t/ha of spent bedding alone. Vigour scores tended to be consistent with the yields recorded for the different treatments with plots treated with 10 t/ha of spent bedding or DAP recording higher vigour scores than untreated plots and those receiving 5t/ha of spent bedding.

Yield responses may be due to the increased phosphorus supplied when spent bedding is applied at rates of 10t/ha or when DAP is applied in the seed row. This is supported by the observation that plant tissue levels of phosphorus tended to be higher where 10t/ha of bedding was applied or DAP was applied in the seed row.

"Starter" DAP fertiliser at 30kg/ha did not result in significantly higher grain yields when 10t/ha of bedding was applied, indicating that application rates of 10t/ha may negate the need for starter fertiliser, perhaps due to the higher rates increasing phosphorus availability or accessibility by the wheat plants. There were no significant differences in grain protein, test weight and screenings in response to different treatments.

Table 26: Plant Tissue Test Levels – Wheat Youngest Emerged blades (YEB's) Roseworthy 2011

	Phosphorus %	Nitrogen %	Zinc mg/kg
Phosphorus Responsive			
Untreated	0.28 ***b***	2.36	17.91 ***ab***
5t/ha eco-shelter bedding	0.30 ***ab***	2.31	17.45 ***ab***
10t/ha eco-shelter bedding	0.35 ***a***	2.34	18.87 ***a***
10t/ha eco-shelter bedding & 30kg/ha DAP	0.36 ***a***	2.28	17.80 ***ab***
70kg/ha DAP	0.31 ***ab***	2.11	15.29 ***b***
LSD 5%	0.057	n.s.	2.87
Phosphorus Non-Responsive			
Untreated	0.25 ***b***	2.08	15.18
5t/ha eco-shelter bedding	0.27 ***b***	2.06	15.99
10t/ha eco-shelter bedding	0.33 **a**	2.20	18.44
10t/ha eco-shelter bedding & 30kg/ha DAP	0.35 ***a***	2.11	18.87
70kg/ha DAP	0.30 ***ab***	1.94	14.68
LSD 5%	0.057	n.s.	n.s

Letters (i.e. a, b, c) indicate results that were statistically significant from one another

Plant tissue test results *(Table 26)* indicate that high rates of spent bedding (10t/ha) result in higher levels of phosphorus in wheat plants. "Starter" DAP fertiliser applied in conjunction with 10t/ha of spent bedding provided no significant increase in phosphorus levels in by wheat plants compared to plots receiving 10t/ha of spent bedding alone, mirroring the yield results. There were no significant differences in the nitrogen levels of the YEB's between treatments.

2012: Palmer Site

Table 27: Plant Vigour Scores (1-10) at the Palmer demonstration trial sites, 15-8-12

Treatment	P Responsive	P Non-Responsive
Untreated	6	6.7
5t/ha eco-shelter bedding	7.3	8
10t/ha eco-shelter bedding	8.3	8.7
5t/ha eco-shelter bedding & 25kg/ha DAP	8.3	8.7
60kg/ha DAP	7.3	7.7

Grain yield and quality results are summarised in *Tables 28* and *29*.

Table 28: Yield and Grain quality results – Phosphorus Responsive Site, Palmer 2012

Treatment	Protein %	Screenings %	Test Weight kg/hL	Yield t/ha
Untreated	10.9	0.93 ***b***	77.3 ***ab***	2.25 ***b***
5t/ha eco-shelter bedding	12.0	1.23 ***b***	76.1 ***b***	2.53 ***a***
10t/ha eco-shelter bedding	12.5	1.87 ***a***	75.5 ***b***	2.29 ***b***
5t/ha eco-shelter bedding & 25kg/ha DAP	11.3	1.03 ***b***	78.9 ***a***	2.27 ***b***
60kg/ha DAP	11.5	0.93 ***b***	77.8 ***ab***	2.21 ***b***
LSD 5%	n.s.	0.01	2.78	0.22

Letters (i.e. a, b, c) indicate results that were statistically significant from one another

Table 29: Yield and Grain quality results – Phosphorus Non-Responsive Site, Palmer 2012

Treatment	Protein %	Screenings %	Test Weight kg/hL	Yield t/ha
Untreated	8.9 ***ab***	0.63	78.9	3.59 ***b***
5t/ha eco-shelter bedding	8.7 ***b***	0.70	78.1	3.97 ***ab***
10t/ha eco-shelter bedding	9.3 ***a***	0.47	79.4	4.67 ***a***
5t/ha eco-shelter bedding & 25kg/ha DAP	8.6 ***b***	0.70	79.2	4.37 ***a***
60kg/ha DAP	8.9 ***ab***	0.43	79.4	3.96 ***ab***
LSD 5%	0.58	n.s.	n.s.	0.72

Letters indicate results that were statistically significant from one another

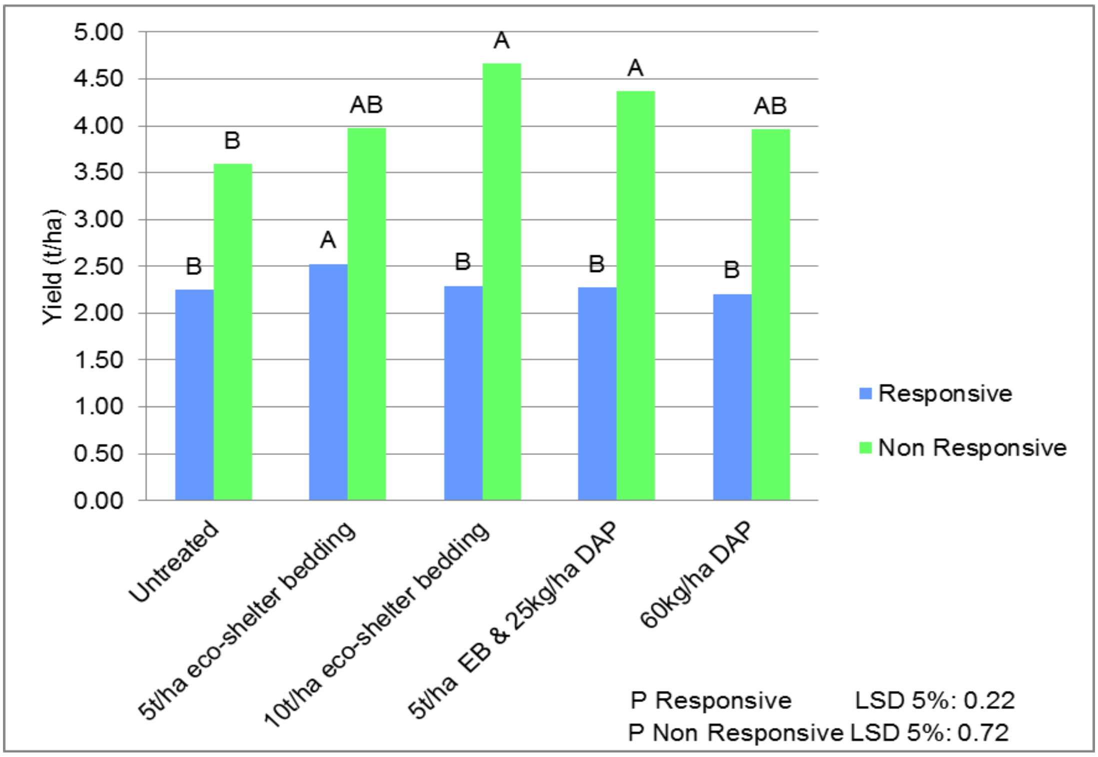

Figure 4: Grain Yield – Phosphorus Responsive and Non Responsive Sites, Palmer 2012

Table 30: Plant Tissue Test Levels – Wheat Youngest Emerged blades (YEB's) Palmer 2012

	Phosphorus %	Nitrogen %	Zinc mg/kg
Phosphorus Responsive			
Untreated	0.34	3.29	43.59
5t/ha eco-shelter bedding	0.39	3.16	43.71
10t/ha eco-shelter bedding	0.40	3.43	59.61
5t/ha eco-shelter bedding & 25kg/ha DAP	0.38	2.79	48.37
60kg/ha DAP	0.35	3.1	50.28
LSD 5%	n.s.	n.s.	n.s.
Phosphorus Non-Responsive			
Untreated	0.34	3.88	29.91 ***bc***
5t/ha eco-shelter bedding	0.38	4.11	38.73 ***ab***
10t/ha eco-shelter bedding	0.38	4.15	43.76 ***a***
5t/ha eco-shelter bedding & 25kg/ha DAP	0.36	3.99	33.66 ***bc***
60kg/ha DAP	0.32	4.07	28.57 ***c***
LSD 5%	n.s.	n.s.	9.48

Letters indicate results that were statistically significant from one another

Vigour scores were higher when spent bedding and/or conventional DAP fertiliser was applied compared to untreated plots. "Starter" conventional fertiliser used in conjunction with 5 t/ha of spent bedding, appeared to improve crop vigour compared to plots where 5t/ha of spent bedding was applied alone.

At the P non-responsive site highest grain yields and protein were achieved where 10t/ha of spent bedding was applied, indicating that potentially the additional nitrogen supplied has promoted crop yields. This is supported by the higher plant nitrogen levels (not significant) as indicated by plant tissue test results associated with the 10t/ha spent bedding treatment (Table 30).

At the P non-responsive site, "starter" fertiliser together with 5t/ha of spent bedding achieved higher yields than plots treated with 5t/ha of spent bedding alone, although differences were not statistically significant. Crop vigour assessments also indicated responses to "starter" fertiliser.

At the P responsive site, 5t/ha of eco-shelter bedding resulted in the highest yields, however, the reasons behind this response is unclear.

Zinc levels, as indicated by the plant tissue tests were highest where 10 t/ha of bedding was applied, with statistically significant differences at the P non-responsive site.

5.5 Extension Program

Methodology

An extension program was conducted to extend the results to broadacre farmers and pork producers across the Australian broadacre farming zones. This was to build awareness of spent bedding from pig shelters as an alternative to chicken litter and bio-solids, as well as to build user confidence.

Presentations on research findings and the use of the economic analysis tool, *PooCalc*, were conducted at farmer and consultant discussion groups and forums, including Agricultural Bureau groups, NRM board forums and Rural Directions Pty Ltd Agronomy client updates.

Presentations on the findings were also made at the 2012 Pan Pacific Pork Expo on the Gold Coast.

Field days at the demonstration site were conducted, targeting broadacre cropping producers and agronomists. Discussion of key findings as well as observations and concepts being explored by the research work into spent bedding utilisation occurred.

Articles were prepared for newsletters, targeting broadacre croppers throughout South Australia. These included Rural Directions Pty Ltd newsletters, Natural Resource Management Board newsletters and the Crop Science Society of SA newsletter.

Press articles publicising the use of spent pig bedding were prepared for farming and regional newspapers in areas with potential for broadacre eco-shelter bedding use in South Australia.

A factsheet with information on spent bedding utilisation in broadacre farming systems was produced. Broadacre user case studies were incorporated into the factsheet.

Results and Discussion
Extension activities delivered in the 2011/12 and 2012/13 seasons as part of the project are detailed in *Tables 31* and *32*.

Table 31: Extension activities delivered in 2011/2012

Activity	Description	Audience	Comments
Demonstration Trial Field Days	3 conducted in September 2011	29 Broadacre farmers, agronomists and researchers attended	
Press Releases	3 press releases were published in regional press publications including the Barossa Leader, the Bunyip and the Stock Journal A press release was distributed nationally via APL networks A column article on spent bedding utilisation was published in the Stock Journal	These publications effectively cover key crop production districts of SA	
Presentations at Interstate Forums and Conferences	2 presentations were delivered at the Pan Pacific Pork Expo conference at the Gold Coast, May 2012	Involved approximately 60 pork producers and industry attendees	Included results from the product survey, demonstration trials and economic valuation of the product.
Presentations at grower forums and	3 presentations/ workshops were delivered	Total of 55 attendees, including broadacre	Included updates on the demonstration

discussion groups	to broadacre grower groups: - Murray Plains crop competition - Mannum/Palmer Understanding Soils workshop - Making Money from Manure workshop	farmers, agronomists and researchers. The Making Money From Manures workshop involved approximately 20 pork producers and industry participants.	trial findings from 2011.
Newsletter Articles	1 article was published in the April 2011 Rural Directions Pty Ltd *InTouch* Newsletter	2000 farming and agribusiness clients	Articles focussed on • valuing manure products (including spent bedding) based on their nutrient content. • trial results on spent bedding utilisation
	1 article was published in March 2012 Rural Directions Pty Ltd *InCrop* agronomic newsletter	200 broad acre farmers across SA and Victoria	
	1 article published in the SA MDB NRM Board Understanding Soils Newsletter in March 2012	25 broadacre farmers in the Murray Plains district	

Table 32: Extension activities delivered as part of the project in 2012/2013

Activity	Description	Audience	Comments
Demonstration Trial Field Days	2 conducted in September/ October 2012	35 Broadacre farmers, agronomists and researchers attended	Included an update on the trial findings from 2011.
Press Releases	2 press releases were published in regional press publications including: -The Plains Producer - Murray Valley Standard	These publications effectively cover key pork production and cropping districts of SA including the Lower-Mid North and Murray Plains	Articles were focussed on publicising the project and extending findings
Presentations at grower forums/discussion groups	3 presentations/ workshops were delivered to broadacre grower groups: - Mallala Ag Bureau - NRM Board Forum, Parilla - Rural Directions Pty Ltd client updates	Total of 71 attendees, including broadacre farmers, agronomists and researches.	Included updates on the trial findings from 2011 and 2012 and economic valuation of the product.
Newsletter Articles	An article was published in the May 2013 SA No-till Farmers Association (SANTFA) Journal	Circulation of over 1000 broadacre farmers, agronomists and researchers	A section on the potential for spent bedding utilisation was included in a wider article on utilising recycled organics
	A article was published in March 2013 Rural Directions Pty Ltd InCrop agronomic newsletter	200 broad acre farmers across SA and Victoria	The article focussed on trial results on Eco-shelter bedding.
	An article was published in the May 2012 Crop Science Society of SA newsletter	550 Crop Science Society Members across SA and interstate	The newsletter article on 2011 trial results was uploaded to the Crop Science Society's website

6. Implications and Recommendations

As a consequence of the research, broadacre users and agronomists have a basis on which to make decisions on application rate, pricing and where spent bedding from pig shelters fits in comparison to other manure-based organic by-products. The research also demonstrates a methodology for valuation of spent bedding product,

One implication of the research, is that even though its nutrient content on a dry weight basis is comparable to other manure-based products, spent pig bedding may not be as attractive to broadacre users compared to other manure-based products (.e chicken litter and biosolids) due to its higher relative moisture contents, lower bulk densities and lumpiness. As a result it will be important that pricing of the product is competitive with other products to ensure demand and subsequent utilisation of the product.

The research also demonstrates the high degree of variability in nutrient and moisture contents between batches of spent bedding product. The implications of these finding is that there an important the need for analysis to help make application rate and pricing decisions.

Group extension work in South Australia's cropping zone has improved knowledge and awareness of the potential for utilisation of spent bedding amongst broadacre cropping farmers. There is potential to further extend the findings in other states with group extension and workshop activities.

One shortcoming of the project is that the need for "starter" conventional fertiliser and the role of DGT soil testing to refine starter fertiliser decisions was not clearly demonstrated in the trial program. This is due phosphorus responsive trial sites being only marginally phosphorus responsive and possible interactions associated with nitrogen supplied in the litter. As a result there is potential for further demonstration trial work to clarify this aspect of spent bedding utilisation.

7. References

Craddock TD and Hollitt JF (2010) Piloting chicken litter usage in broadacre cropping; Setting research directions, RIRDC Final Report

Craddock TD (2010) Chicken Litter as a Fertiliser for Broadacre Grain Crops: A User's Guide; RIRDC/Rural Directions Pty Ltd

Craddock TD (2012) Refining and promoting chicken litter use in broadacre cropping systems, RIRDC Final Report

Reuter, D.J., Robinson, B.J. (ed.)(1997): Plant Analysis: An Interpretation Manual.: CSIRO Publishing, Collingwood, Vic.

Burkitt LL, Moody PW, Gourley CJP and Hannah MC (2007) A simple phosphorus buffering index for Australian soils, Australian Journal of Soil Research 40(3) 497 – 513

Guidelines for Environmental Management – Biosolids Land Application; EPA Victoria (2004)

8. Publications Arising

Craddock, T.D and Wallis, B.A (2013) *Utilising Spent bedding from Pork Farms*; Factsheet Australian Pork Ltd and Rural Directions Pty Ltd.

9. Appendix - Spent Bedding Product Survey Results

Sample	Arsenic	Boron	Cadmium	Calcium	Chromium	Copper	Iron	Lead	Magnesium	Manganese	Nickel	Phosphorus	Potassium	Sodium	Sulfur	Total Nitrogen	Zinc
	µg/Kg	**mg/Kg**	**µg/Kg**	**%**	**µg/Kg**	**mg/Kg**	**mg/Kg**	**µg/Kg**	**%**	**mg/Kg**	**mg/Kg**	**%**	**%**	**%**	**%**	**%**	**mg/Kg**
1	400	13.14	96	2.08	3848	474.18	2031.67	2040	0.66	347.67	3.8	1.06	1	0.19	0.36	2.56	331.96
2	400	12.34	84	1.92	4072	<0.05	1827.35	1592	0.66	347.13	3.98	1.18	0.97	0.21	0.38	2.68	319.55
3	484	21.21	176	1.5	2756	123.29	1184.28	2144	0.49	404.45	4.44	1.28	1.88	0.55	0.48	2.09	4288.94
4	468	18.42	84	0.9	1108	72.52	936.8	1352	0.31	310.88	2.7	0.62	1.76	0.54	0.36	1.73	2688.53
5	1472	18.95	176	3.25	10672	<0.05	9740.05	4328	0.53	448	8.07	1.54	0.86	0.23	0.52	3.03	693.65
6	1312	14.93	144	1.93	8572	422.98	7705	2392	0.52	318.94	7.05	1.01	1.16	0.26	0.41	2.66	503.02
7	348	11.9	52	1.32	2580	394.25	1064.13	1284	0.41	191.17	2.13	1.04	1.82	0.4	0.46	2.62	449.33
8	688	24.01	152	2.4	7584	<0.05	3984.63	2040	0.91	438.65	6.16	1.53	1.71	0.51	0.71	3.84	746.36
9	688	24.69	328	2.46	4116	<0.05	3229.79	1760	0.71	403.36	5.11	1.22	1.49	0.26	0.6	3.56	701.54
10	1492	28.81	200	3.04	12464	91.57	5283.37	4336	0.54	276.53	8.57	0.87	2.4	0.56	0.48	2.67	475.43
11	2220	36.87	248	5.39	15140	102.2	8210.57	5232	0.74	371.07	11.83	1.38	3.07	0.72	0.63	2.76	592.86
12	1156	23.05	144	2.74	5660	<0.05	4688.55	1884	0.65	364.46	11.47	1.58	2.34	0.55	0.73	3.05	696.3
13	1380	18.23	212	3.7	11956	120.91	6091.25	3192	0.58	360.65	7.65	0.56	1.87	0.63	0.57	2.79	628.67
14	1312	28.42	324	2.38	6984	<0.05	5921.22	2696	0.77	451.62	8.7	0.69	2.13	0.67	0.72	3.95	1541.22
15	704	27.12	200	2.28	6468	420.64	3411.67	1360	0.56	207.67	4.06	0.52	1.84	0.79	0.54	2.54	1516.78
16	816	28.9	376	2.7	3136	<0.05	1796.88	1080	0.98	459.48	6.7	1.16	3.07	1.07	1	4.54	2409.42
17	656	27.72	196	2.01	7604	<0.05	3072.93	2032	0.57	358.01	6.3	1.36	1.93	0.63	0.57	3.4	2942.5
18	540	26.26	180	2.44	1804	96.98	1430.46	732	0.51	312.86	3.48	1.35	3.44	0.86	0.77	2.96	529.01
19	1340	24.86	272	3.18	12304	107.55	5035.85	5476	0.67	355.43	7.22	1.34	2.5	0.82	0.67	2.85	976.69
20	840	25.35	224	2.82	6740	132.25	2617.36	1668	0.81	393.65	6.03	1.74	3.84	1	0.77	3.33	1208.94
21	1176	25.02	236	2.87	13296	106.48	4036.71	3296	0.66	341.74	6.42	1.45	2.67	0.83	0.68	3.16	835.8
22	448	21.89	140	2.39	2708	106.56	1532.93	792	0.58	299.14	3.9	1.25	2.38	0.64	0.64	3.06	1022.77
23	1096	42.45	264	5.19	12340	<0.05	5667.86	4144	0.86	584.68	8.24	2.63	1.79	0.76	0.8	3.36	834.65
24	1516	18.43	132	2.93	6496	<0.05	1518.43	2308	0.83	366.33	5.59	1.6	1.61	0.45	0.4	2.9	687.7
25	716	19.38	596	2.28	3648	<0.05	2150.28	2228	0.62	289.34	4.82	0.99	1.52	0.28	0.35	1.85	614.24
26	1244	29.14	192	1.96	2508	<0.05	1481.2	1344	0.59	255.57	3.48	1.07	2.08	0.51	0.52	2.8	742.39
27	2168	29.03	468	2.87	6888	<0.05	5025.5	1992	0.71	521.64	8.82	1.2	1.41	0.46	0.85	3.24	956.01
28	1784	51	448	1.66	10140	<0.05	4647.35	2088	0.72	483.62	14.59	1.02	1.65	0.29	0.79	3.78	883.56
29	2372	53.95	452	2.42	14808	<0.05	5595.9	3132	0.61	432.71	11.48	1.06	1.81	0.41	0.63	3.15	935
30	1684	37.43	468	1.62	18976	125.06	6837.71	6216	0.55	349.34	8.18	1.33	2.14	1.79	0.67	2.13	1521.67
31	2240	36.58	436	1.89	18756	217.75	7851.94	6236	0.66	405.03	11	1.33	2.29	1.5	0.61	2.63	2021.76
32	2120	39.6	520	1.81	22680	133.83	6502.01	6424	0.69	391.79	9.64	1.44	2.17	1.29	0.68	2.14	1740.59
Maximum	2372	53.95	596	5.39	22680	474.18	9740.05	6424	0.98	584.68	14.59	2.63	3.84	1.79	1	4.54	4288.94
Minimum	348	11.9	52	0.9	1108	<0.05	936.8	732	0.31	191.17	2.13	0.52	0.86	0.19	0.35	1.73	319.55
Average	**1165**	**27**	**257**	**2.51**	**8400**	**102**	**4128**	**2776**	**0.65**	**370**	**6.93**	**1.23**	**2.02**	**0.65**	**0.60**	**2.93**	**1157**

Sample	Organic Matter	Moisture %	Carbon	Bulk Density	Bulk Density	Value with K (Dry weight)	Value with K (Fresh weight)	Value without K (Dry weight)	Value without K (Fresh rate)	Type of bedding	Age of pigs housed	Type of feed	Age of bedding (compost period)	Uses for bedding on property	Mutiple batched?	Treated with other products?	Details
	%	%	%	t/m^3	m^3/t	$/t	$/t	$/t	$/t								
1	58.37	66.3	34.3	0.25	4.05	44	15	28	9	Cereal straw + Rice hulls	3-6 months	pellets	1-6 months	fertiliser	no		
2	62.15	62.2	35.2	0.22	4.55	48	18	32	12	Cereal straw + Rice hulls	3-6 months	pellets	1-6 months	fertiliser	no		
3	61.11	68	32.2	0.31	3.18	80	26	50	16	Cereal straw + Rice hulls	0-3 months	pellets	1-6 months	fertiliser	no		
4	64.34	55.5	31	0.24	4.19	49	22	21	9	Cereal straw + Rice hulls	0-3 months	pellets	1-6 months	fertiliser	no		
5	40.88	53.4	24.1	0.42	2.38	61	28	47	22	Cereal straw	sows	crush	1-6 months	fertiliser	no		
6	55.79	73.7	26.2	0.35	2.85	47	12	28	7	Cereal straw	all	crush	1-6 months	fertiliser	no		
7	65.52	55.7	35.7	0.19	5.23	58	26	29	13	Cereal straw	3-6 months	crush	1-6 months	Top-up fertiliser	no		
8	47.81	16.5	31.1	0.13	7.70	80	67	52	43	Cereal straw	3-6 months	crush	6-12 months	Top-up fertiliser	no		
9	62.83	18.1	31.8	0.14	6.99	65	53	41	34	Cereal straw	3-6 months	crush	12 months +	Top-up fertiliser	no		
10	51.51	38.9	29.1	0.26	3.89	63	38	24	15	Cereal straw	0-3 months	crush	1-6 months	Top-up fertiliser	no		
11	43.12	38.4	21.8	0.28	3.53	90	55	41	25	Cereal straw	0-3 months	crush	1-6 months	Top-up fertiliser	no		
12	75.86	18.5	30.7	0.15	6.81	86	70	49	40	Cereal straw	3-6 months	crush	1-6 months	Soil Conditioner	no		
13	54.29	35.3	24.9	0.30	3.28	47	30	17	11	Cereal straw	sows	crush	1-6 months	Soil Conditioner	no	yes	effluent
14	61.76	56.6	28.3	0.30	3.34	66	29	32	14	Cereal straw	0-3 months	crush	6-12 months	Soil Conditioner	no		
15	55.07	71.8	24.1	0.32	3.16	47	13	18	5	Cereal straw	0-3 months	crush	1-6 months	Soil Conditioner	no		
16	64.51	64.9	30.6	0.39	2.55	103	36	54	19	Cereal straw	0-3 months	crush	6-12 months	Soil Conditioner	no		
17	53.1	68	23.9	0.50	1.99	85	27	54	17	Cereal straw	0-3 months	crush	12 months +	Soil Conditioner	no		
18	72.92	51.7	33	0.19	5.17	96	46	41	20	Cereal straw	3-6 months	pellets	1-6 months	All	no		
19	57.99	56.3	27.4	0.31	3.18	82	36	42	18	Cereal straw	3-6 months	pellets	12 months +	All	no	yes	pig carcases
20	61.39	64.3	29.5	0.43	2.35	119	42	58	21	Cereal straw	3-6 months	pellets	6-12 months	All	no		
21	60.42	44.5	21.8	0.38	2.61	89	49	46	26	Cereal straw	3-6 months	pellets	12 months +	All	no		
22	73.84	63.6	33.6	0.24	4.17	79	29	40	15	Cereal straw	3-6 months	pellets	1-6 months	All	no		
23	55.92	54.8	26.7	0.39	2.57	111	50	82	37	Cereal straw	0-3 months	pellets	6-12 months	Soil Conditioner	yes		
24	75.13	8.5	35	0.45	2.24	73	67	48	44	Cereal straw	0-3 months	pellets	1-6 months	Soil Conditioner	no		
25	46.44	6.4	34	0.19	5.20	47	44	23	22	Wood chip mix	0-3 months	pellets	12 months +	Soil Conditioner	no		
26	81.41	8.7	35.3	0.11	8.97	65	59	32	29	Cereal straw	0-3 months	pellets	1-6 months	Soil Conditioner	no		
27	67.28	70.9	30.4	0.40	2.47	63	18	40	12	Cereal straw	all	crush	1-6 months	None	no		
28	62.79	51.1	30.1	0.39	2.55	64	31	38	19	Cereal straw	0-3 months	crush	6-12 months	None	no		
29	49.37	39.5	21.1	0.32	3.17	64	39	35	21	Cereal straw	0-3 months	crush	12 months +	None	no		
30	50.98	53.4	17.3	0.32	3.15	74	34	40	19	Cereal straw	3-6 months		12 months +		no	yes	pig carcases
31	58.94	45.7	19.8	0.34	2.98	81	44	45	24	Cereal straw	3-6 months		12 months +		no	yes	pig carcases
32	39.58	61.5	18	0.48	2.08	79	30	44	17	Cereal straw	3-6 months		6-12 months		no	yes	pig carcases
Maximum	81.41	73.7	35.7	0.50	8.97	119	70	82	44								
Minimum	39.58	6.4	17.3	0.11	1.99	44	12	17	5								
Average	**59**	**48**	**28**	**0.31**	**3.80**	**72**	**37**	**40**	**20**								