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Using recycled organics and manures in grain cropping systems

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Summary

This Primefact examines the use of recycled organics and manures in grain cropping systems. It discusses the characteristics of recycled organics and manures, potential benefits, possible risks associated with their use and economic considerations.

The first task is to identify the production system constraints for which recycled organics or manures may provide an improvement.

Once an opportunity to use recycled organics or manures has been identified, the next step is to understand the physical, chemical and biological characteristics of the product. These will govern the rate at which to apply the products and how effective the amendments may be in providing agronomic and soil conditioning benefits, as well as likely risks. Given recycled organics and manures are derived from a variety of processes, their characteristics are likely to be highly variable.

Depending on the product, benefits may not be apparent until several years after application and users need to account for the costs of purchasing, transporting and applying manures to evaluate cost-effectiveness. However, in the medium to longer term, recycled organics and manures can play a role in improving soil chemical, physical and biological properties and, ultimately, crop productivity.

Introduction

Recycled organics generated from intensive livestock operations, (e.g. cattle feedlots, poultry sheds and piggeries) as well as municipal areas (e.g. biosolids, garden organics) contain nutrients, organic matter and water which can potentially:

- improve soil physical, chemical and biological characteristics;
- increase crop and pasture productivity;
- reduce reliance on inorganic fertilisers.

However, there is uncertainty about the quality and consistency of materials, their agronomic and soil conditioning benefits, and potential environmental and health risks.

This Primefact aims to assist grain growers and their advisors to work through these considerations to make decisions about the use of recycled organics in grain cropping systems. A framework for working through these considerations is presented in Figure 1, with each component discussed in the following sections.

Identifying production constraints and plant nutrition needs

The first step when considering the need for any input to a grain cropping system is to identify the constraints (chemical, physical or biological) to the production system.

For fertiliser inputs, whether organic or inorganic, it is first necessary to assess soil

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nutrient status and identify the nutrient needs of the crop to be grown.

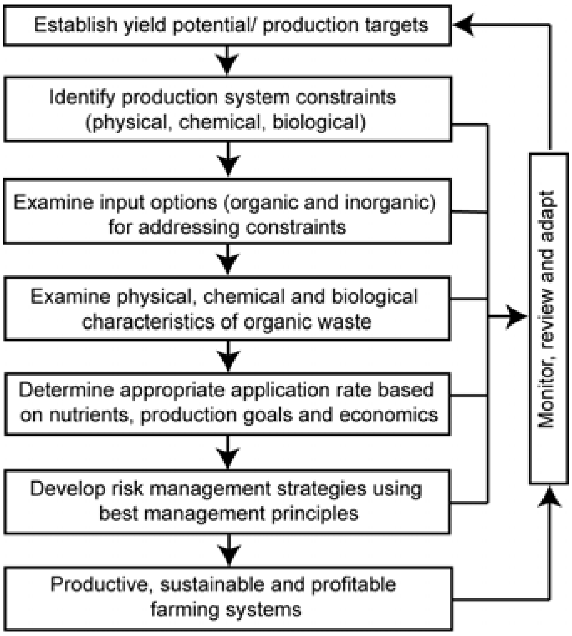

Figure 1. Flowchart for considering the use of manures and recycled organics in grain cropping systems.

The concentration of available nutrient in soil depends on soil properties (e.g. pH, clay content, rooting depth), cropping and fertiliser history and stubble and tillage management. Therefore soil and plant tissue testing is recommended to establish the level of baseline nutrients in the soil and how much are being accessed by plants.

The quantity of nutrients required from fertilisers depends on soil fertility, the crop to be grown and the target yield of the crop. This is illustrated for several grain crops in Table 1. In-season nutrient requirements will be greater than in these examples, but at a minimum, the rates of nutrients applied should be equal to or greater than the rates removed over time so that soil fertility can be maintained.

Other barriers to root growth may include low organic matter, hard setting soils, surface sealing, problems with water infiltration, compaction, sub-soil acidity and other soil health issues.

Physical and chemical properties of manures and recycled organics

The quality of manures can vary considerably (Table 2) and is influenced by a number of factors including:

- product type (plant &/or animal)
- housing and rearing management (e.g. bedding)
- diet
- storage
- treatment and further processing (e.g. composting).

Having individual samples of recycled organics or manures tested or obtaining a 'batch certificate' is essential for determining appropriate application rates and likely nutrient contribution from them.

Make sure sampling procedures include the following principles.

1. Use clean sampling equipment.
2. Take at least 5 sub-samples per 100 tonnes and collect samples from the core of the stockpile.
3. Have the same number of sub-samples in each batch.
4. Mix batch sub-samples thoroughly to make a composite sample for analysis. A composite sample allows the characteristics of a batch to be more accurately estimated.

In lieu of specific standards for manures and other types of recycled organics, samples can be tested using the procedures defined in the Australian Standards for composts, mulches and soil conditioners (AS4454) (Standards Australia, 2003).

Table 1. Typical yields (t/ha) and rates of nitrogen (N), phosphorus (P) and potassium (K) removal (t/kg product; kg/ha) for selected grain crops grown under Australian conditions (adapted from Glendinning 2004).

Crop	Yield	N	P	K	N	P	K
	(t/ha)	---------- (kg/t product) ----------			------------- (kg/ha) -------------		
Wheat	4	21	2.6	3.7	84	10	15
Barley	3.5	19	2.9	4.4	67	10	15
Oats	4	17	3	3.9	68	12	16
Canola	2.8	40	6.5	9.2	112	18	26

Figure 2. Screed solids from feedlot dairy wastewater being transported for application to an adjacent field.

What is the likely nutrient contribution from manures or organic wastes?

The likely nutrient contribution (kg/ha) from manures or organic wastes is a function of:

- moisture content (%)
- density (kg/m^3)
- nutrient concentration (%)
- proportion of total nutrients that is available (%)
- application rate (t/ha).

This is illustrated using the example provided in Table 3.

How much of the nitrogen is likely to be available to the crop?

Not all of the nitrogen in recycled organics or manures will be available to crops for uptake. This is because up to 50% of the nitrogen contained in the manure will be lost from the system as ammonia (NH_3) or nitrogen (N_2) gases during storage or after it is applied to land. In addition, much of the remaining nitrogen will be present in an organic form and needs to be converted to an inorganic form (i.e. mineralised) before it can be utilised by plants. The rate of mineralisation will depend on the characteristics of the organic input used, soil type and climatic conditions. As such only 30 to 70% of the total nitrogen present is likely to be available to plants in the first year after application.

Table 2. Selected chemical characteristics of different types of organic amendments which may be used for broadacre crops and pastures.

Property	Poultry litter	Composted garden organics	De-watered biosolids	Cattle feedlot manure	Piggery solids (Deep litter)
pH	5.8–8.1	6.9	6.7	7	7.3
$EC_{1:5}$ (dS/m)	6.8–16	2.2	0.4	12.4	7.6
Dry matter (%)	64–79	74	12–25	45–80	51
Moisture (%)	21–36	26	82	20–54	49
Carbon (% d.w.)	28–36	24	26–36	11–44	65
Density (m^3/t)	2–2.25		6.2–9		
N (% d.w.)	2.6–5	1	5–7	2.2	1.6
P (% d.w.)	1.2–2.6	0.2	1–4	0.8	0.7
K (% d.w.)	1.0–2.8	0.5	0.3	2.3	1
Cu (mg/kg d.w.)	25–160	57	200–300	40	200
Zn (mg/kg d.w.)	239–580	151	600	323	170

EC = electrical conductivity; d.w. = dry weight

Table 3. Example of how to calculate the loading of carbon (C), nitrogen (N), phosphorus (P) and potassium (K) associated with applying manure with a known nutrient concentration, moisture content, density and application rate.

Property	Formula	C	N	P	K
Concentration (%) (A)		30	2.5	1.8	1.5
[a]Moisture content (%) (B)			30		
Density (kg/m^3) (C)			440		
Application rate (m^3/ha) (D)			15		
Application rate (fresh kg/ha) (E)	C x D		6600		
Application rate (dry kg/ha) (F)	E x (1–B/100)		4620		
Nutrient loading (kg/ha)	A/100 x F	1386	116	83	69

[a]Moisture content (%) = Water/(water + solid) *100

From the example in Table 3:

Total N loading = 116 kg/ha

Total N lost from system = 116 x 0.5 = 58 kg/ha

Total N remaining = 58 kg/ha

Total available for crop in Year 1 (assume 50% of total N) = 58 x 0.5 = 29 kg/ha

Residual N in soil = 58 – 29 = 29 kg/ha

So, an application of 6.6 t/ha of fresh manure would only supply approximately 29 kg/ha of ‘plant-available’ N. This is only a rule of thumb estimate and the actual N contribution will vary from site to site and product to product.

A mass balance approach is useful for calculating whether nutrients applied in recycled organics are greater or less than crop requirements. This is illustrated below:

Crop N removal by wheat (Table 1) = 84 kg/ha

N from manure = 29 kg/ha

Balance = 84–29 = 55 kg N/ha deficit

Therefore, at least an additional 55 kg N/ha will need to be applied to replace the N removed by a 4 t/ha wheat crop. This can be achieved either by increasing the application rate of the product or by using an alternative source of nitrogen, such as inorganic fertiliser.

How much of the phosphorus is likely to be available to the crop?

As with inorganic fertiliser, P in organic wastes can be ‘fixed’ in the soil after application. The rate and strength of P fixation depends on soil properties, including clay content and pH. In addition, P is mostly present in an organic form, so it has to be mineralised before it is available to plants. Therefore, only 10–50% (assume 20%) of the total P applied in manures is likely to be available to the crop.

From the example in Table 3:

Total P loading = 83 kg/ha.

Total P available for crop in Year 1 = 83 x 0.2 = 17 kg/ha.

So, an application of 6.6 t/ha fresh manure would supply approximately 17 kg/ha of effective P, which is 7 kg/ha more than the rate of P removed by a 4 t/ha wheat crop. So, additional P inputs may not be required in this instance.

End-users need to be aware that repeated application of manures and or recycled organics based on their nitrogen content, can lead to the accumulation of phosphorus in the soil and have adverse impacts on water quality. Therefore, in some instances it may be more appropriate to calculate application rates based on phosphorus rather than nitrogen.

Table 4. Estimation of the economic value of nutrients based on current recommended retail prices of granular urea, single superphosphate and muriate of potash (Adapted from Griffiths, 2007).

Nutrient	Average	RRP ($/t incl. GST)	Nutrient concentration (%)	Nutrient value ($/kg)
Nitrogen (N)	Granular urea	600	46	1.30
Phosphorus (P)	Single superphosphate	375	9	4.17
Potassium (K)	Muriate of potash	817	50	1.63

Table 5. Estimate of the economic value of manure based on its nitrogen (N), phosphorus (P) and potassium (K) concentrations (Adapted from Griffiths 2007).

Nutrient	Nutrient concentration (% d.w.)	Nutrient mass (kg/dwt)	Nutrient value ($/kg)	Nutrient value ($/t)	Nutrient value ($/m^3)*
N	2.6	26	1.30	34	15
P	1.8	18	4.17	75	33
K	1	10	1.63	16	7
Total				**125**	**55**

*Assumes a density of 2.26 m^3/t

What are the likely agronomic benefits from applying manures?

The likelihood of an agronomic response to ANY fertiliser (organic or inorganic) depends on:

- inherent soil fertility
- yield potential
- the most overriding constraints (e.g. nutrients, moisture, pests or diseases).

Therefore, end-users need to identify the most limiting factor in the system and use the most appropriate input for overcoming this limitation.

As with the characteristics of organic wastes, their agronomic performance can be variable.

Does the recycled organic or manure alleviate the production constraint? To answer this, growers need to understand product characteristics and assess performance objectively.

What are the other benefits?

The non-fertiliser benefits from recycled organics and manures are all directly or indirectly related to the organic matter and carbon they contain, which may improve soil physical properties, such as structure, infiltration, water holding capacity and porosity.

Recycled organics and manures can also improve soil biological properties. However, as with agronomic benefits, the effects can be variable and will depend on the nature of the amendment and how it is applied. Soil biology is complex and relatively little is understood of the effects of amendments on soil biological processes.

Figure 4. Manures and organic amendments can provide significant grain yield increases, but growers need to identify the most limiting factor in their system and select a product which will address that limitation.

Table 6. Suggested strategies for managing potential risks associated with using manures and recycled organics in grain cropping systems.

Risk	Risk management strategy
Heavy metals	• Regularly monitor manure samples to evaluate heavy metal content. • Limit application rates to ensure maximum in-soil limits, as defined by relevant State guidelines, are not exceeded. • Use soil testing to monitor changes in heavy metal levels over time. • Avoid using products high in metals in soils with high metal content.
Human health risks	• Use composted or pasteurised products where pathogens are of concern. • Establish appropriate withholding periods from treated land. • Exclude stock and people from stockpiles and storage areas. • Provide appropriate personal protective equipment (PPE) and vaccinate workers who are likely to come into contact with raw manures.
Animal health risks	• Do not dump or spread manure in paddocks containing stock. • Only spread manure at recommended rates. • Exclude stock from manure stockpiles. • Avoid close grazing and exclude grazing stock from treated paddocks until sufficient pasture re-growth has occurred. • Other risk management options include vaccinating cattle against botulism and using stabilised products.

Odour, dust and air quality	• Locate storage facilities away from public view and neighbours.
	• Maintain trees and shrubs on property boundaries.
	• Consider the prevailing wind direction and intensity when planning spreading operations.
	• Take a pro-active approach to managing odour issues by:
	  • Engaging all stakeholders (e.g. end-users, neighbours, regulators) to develop acceptable odour management practices.
	  • Developing good communication channels and relationships with neighbours regarding spreading times and dates.
	  • Establishing procedures for verifying and responding to odour complaints.
	• Where odour management is still a problem, even after these strategies have been implemented, consider using stabilised products.

Eutrophication	• Base application rates on P rather than N to avoid accumulation of P in the soil. • Calculate mass balances for nutrients accounting for soil nutrient status, rates of nutrient application, rates of nutrient removal and residual nutrients. • Use soil testing to monitor changes in soil and adjust application rates accordingly. • Maintain vegetated filter strips in riparian areas. • Avoid applying manures within prescribed distances to sensitive areas (e.g. surface waters, bores).
Salinity and sodicity	• Use mass balances to determine loading of Na and K and limit rates to ensure they do not accumulate in the soil over time. • Use soil testing to monitor changes in exchangeable sodium percentages (ESP) and electrical conductivity over time. • Modify management practices where increases in salinity and sodicity are observed.
Weeds	• Ensure all material is exposed to temperatures > 55^{o}C for 3 consecutive days to kill weed seeds and viable plant fragments. • Spray weeds with herbicides or remove mechanically, where necessary.
Phytotoxicity	• Test for potentially toxic elements and organic contaminants prior to application. • Use composted products or allow for sufficient time between application and planting to minimise the potential for phytotoxicity (e.g. nitrogen drawdown or ammonia toxicity).

Are manures cost-effective?

The short-term value can be assessed by evaluating current recommended retail prices for inorganic fertilisers and assigning an economic value per kg of nutrient (Table 4). This information can then be used to derive a 'potential value' of the manure based on its total nitrogen, phosphorus and potassium concentrations (Table 5).

This demonstrates that the product described in Table 3 contains up to $125/t worth of nutrients, without considering longer-term soil conditioning benefits. However, this does not account for differences in nutrient availability and agronomic efficiencies, nor does it include spreading, handling and transport costs, which will vary from site to site and product to product. These should be considered in the final decision regarding use and rates.

Are there any risks?

Manures and recycled organics are waste derived products and may contain contaminants or undesirable elements, which if not considered, may result in adverse outcomes or create a nuisance to neighbours.

The risk of this occurring is a function of:

- Likelihood – how likely is it to happen?
- Consequence – what are the consequences if it does happen?
- Responsibility – who is liable for the consequences?

Risk management frameworks identify and rank risks, develop strategies for managing them and encourage pro-active approaches for managing risks. They also demonstrate a commitment to 'duty of care'. Growers should also be aware that the use of biosolids is regulated in Australia and subject to stringent health and application guidelines (National and State).

The key risks associated with applying recycled organics and manures are: heavy metals; pathogens; odour, dust and air quality; eutrophication; salinity; sodicity; weeds; phytotoxicity; organic chemicals; and physical contaminants such as glass and plastic. Strategies for managing these risks are described below in Table 6.

Conclusions

This publication has aimed to inform end-users in the principles for optimising benefits and minimise the potential for undesirable impacts from using recycled organics and manures as inputs to grain cropping systems.

Growers need to firstly identify the role of the organic input in the system to maximise probability of success. Once this has been established, end-users then need to select the most appropriate input (organic and/or inorganic) for addressing production constraints based on an understanding of the physical, chemical and biological characteristics of the product.

This is critical as product characteristics will govern how effective the amendments are in providing agronomic and soil conditioning benefits, as well as likely risks. Given that recycled organics and manures are derived from a variety of sources and processes, these are likely to be highly variable.

End-users should be aware that benefits may not become apparent until several years after application and that cost-effectiveness will be site specific. However, over time, manures and recycled organics can play a role in improving soil quality and crop productivity.

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