ORGANIC NUTRIENT SOURCES

- Finding new ways to fertilise

Potatoes are a hungry crop. Maximising yield requires good plant nutrition. However, skyrocketing fertiliser costs have seen many growers search for ways to use inputs more efficiently. Another potential strategy is to supplement the potato plant diet with organic nutrient sources such as composts, green waste and manures. However, while these can provide benefits above and beyond nutrition, they are not without their own risks. Dr Jenny Ekman investigates.

RECYCLED ORGANICS AND COMPOST

What is compost anyway?

In the broadest sense, compost is any mixture of different organic materials that has been broken down by naturally occurring organisms. These include bacteria and fungi as well as larger organisms such as mites and worms.

However, there is much debate about the various terms used to describe composted materials. Recycled organics, green waste, FOGO and compost can all be used to refer to slightly different mixtures and processing methods.

Recycled organics

Recycled organics (RO) can include a wide range of different materials, such as commercial green waste from landscaping, grass clippings, wood residues and sometimes the contents of kerbside collection bins. However, RO products generally do **not** include manure, other animal products, or food waste. This means they can be used freely without affecting certification to food safety programs such as Freshcare and HARPS.

The materials used to make RO products are usually shredded, mixed, stockpiled for up to six months and finally screened to remove contaminants before use. Recycled organics are often very high (>60%) in carbon, which means they are an excellent way to improve soil health. They are also usually cheap, with councils frequently keen to dispose of green waste this way (Figure 1).

There is no requirement for RO products to be high temperature pasteurised (heated through) as they are unlikely to contain human pathogens. While this makes them simple to produce, it means that weed seeds and other plant propagules may not be destroyed during the ageing process. There have also been issues with RO products containing physical contaminants, such as fragments of glass and plastic – especially if the raw materials include kerbside collections (Figure 2).

If the material has a high carbon:nitrogen (C:N) ratio (>30:1) this

Figure 1. Delivery and spreading of recycled organics at a vegetable farm in Cowra, NSW.

Figure 2. Any delivery of RO or compost must be checked to ensure it is free of contaminants such as plastic and glass.

can increase drawdown of nitrogen from the soil. This is most likely if the RO is immature (still breaking down). The C:N ratio will depend on the materials in the mix (Table 1).

Compost

Compost can include all of these ingredients, plus manures and other materials of animal origin (e.g. blood, bone and carcasses).

The high nutrient content of manures increases activity of microbes, so composting occurs more rapidly. Some high intensity 'in vessel' systems can turn organic materials into compost in only a few days. However composting more often takes several weeks or months.

Composts may also contain food wastes: some councils have introduced collection of food organics and garden organics (FOGO) within the same bin. Unfortunately, contamination rates in this material are relatively high; a 2020 study found that 8 to 32% of FOGO bins contained contaminants such as plastics, glass

Food safety programs allow compost to be used freely *IF* it is certified to Australian Standard (AS) 4454. This standard is not just about microbial food safety, but includes details about particle size, levels of contaminants, biological stability and nutrient content.

It also prescribes a minimum of five turns and at least 15 days above 55°C for mixtures containing materials of animal origin (Figures 3, 4). This is to ensure human pathogens and weed seeds are destroyed. If the mixture does NOT include any materials of animal origin, this is reduced to three turns and 9 days above 55°C.

Products which contain products of animal origin but have not been, or cannot be, certified against AS4454, are considered to be the same as untreated manures under most food standard codes. This means exclusion periods may apply between application and harvest.

Compost has higher nutrient values than recycled organics / green waste

Table 1. The C:N values of some common compost ingredients. An ideal ratio for composting is approximately 30:1.

Material	C:N
Wood chips	>600:1
Sawdust	500:1
Paper and cardboard	200:1
Straw	90:1
Corn stalks	50:1
Nut shells	35:1
Garden waste	30:1
Fruit and vegetable wastes	25 to 40:1
Grass clippings	15 to 20:1
Seaweed	20:1
Weeds	20:1
Cattle manure	20:1
Chicken litter (broiler)	10 to 20:1
Chicken manure	7:1

(Table 2) and generally contains around 40 to 50% organic matter.

The cost of compost is commonly $50 to $80 per cubic metre, although larger volumes are likely to attract a discount. Freight costs are clearly location dependant, while the cost of spreading is in the order of $140/ha.

Application rates are usually 20 – 30m^3/ha, although some intensive vegetable producers apply up to 50m^3/ha. High rates are particularly beneficial in sandy soils, as the organic material stabilises the soil, helping raised beds retain their structure.

Figure 3. . To be considered truly compost, the material needs to be turned regularly (left and centre, Images J. Ekman and V Brunton) and heat to at least 55°C in between turning events (right, Image: Rodale Institute).

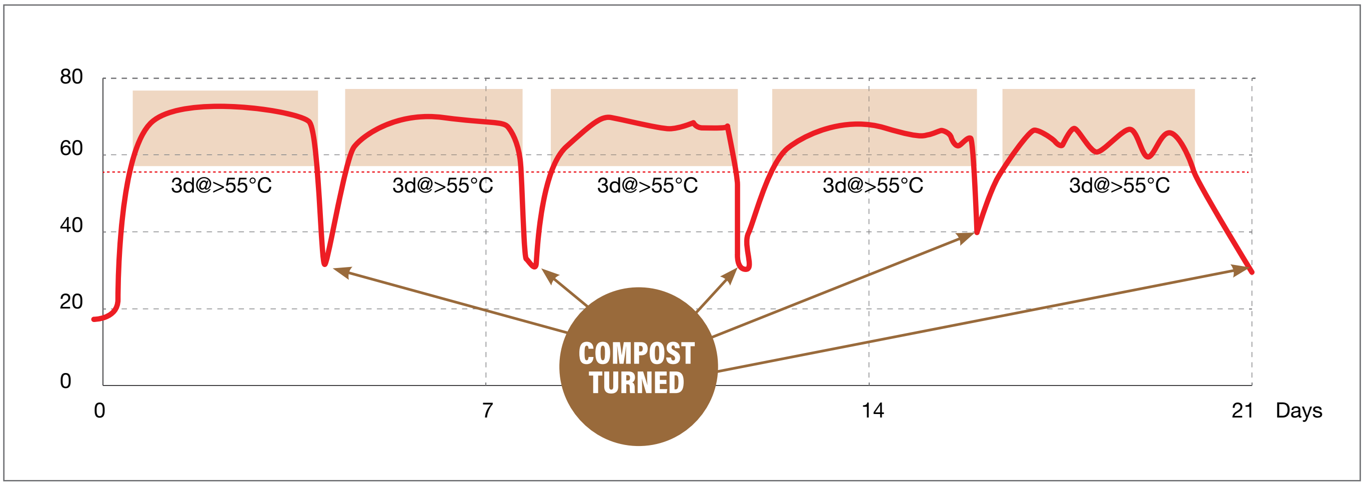

Figure 4. Temperatures inside a compost pile containing manure. The core temperature needs to exceed 55°C for three consecutive days on five occasions, with the pile being turned after each heating event, for it to be considered properly composted in accordance with AS4454.

Other costs and benefits of compost / recycled organics

In addition to nutrients (Table 2), the key benefits of adding either recycled organics or compost to soil include:

- Increased organic matter, and therefore improved soil structure and soil health
- Improved water infiltration and soil water holding capacity
- Increased soil biological activity
- Potential reduction in some soil-borne diseases.

POULTRY LITTER - MORE THAN JUST A NITROGEN SOURCE

Poultry litter is surely proof that one person's waste is another's windfall. Poultry litter is a relatively compact and cost-effective source of nitrogen. It also provides other nutrients, organic matter and carbohydrates that can improve plant and soil health.

Poultry litter sourced from broiler sheds is not just manure, but contains bedding material, feathers, blood, and potentially dirt or other materials. Litter from barn-based egg production and turkey manure can provide bulk organic material, but tends to be lower in nitrogen than litter from broiler sheds (G. Martin pers. com.).

	Green waste compost	Conventional compost
Organic matter	65 – 75%	30 – 50%
pH	6.8 – 7.7	6.0 – 7.6
C:N ratio	25:1 – 35:1	15:1 – 20:1
Nitrogen	1.2 – 1.6%	1.5 – 2.0%
Phosphorus	0.2%	0.6%
Potassium	1.0%	1.0 – 1.4%
Sulphur	2 – 3 kg/tonne	4 – 5 kg/tonne
Calcium	3.0 – 4.0%	3.0 – 4.0%
Magnesium	0.6%	0.6%

Table 2. Typical analysis of a recycled organic product (green waste) and a conventional compost. All values by dry weight. N.B. compost commonly contains 25-35% moisture. Data summarised from multiple sources.

What goes in affects what comes out

Modern broiler chickens are incredibly efficient converters of feed to body mass – approximately 1.5kg of food produces 1kg of chicken. High feed use efficiency equals less waste, especially of the carbohydrates which could potentially nourish soil microbes.

Despite this efficiency, feed still accounts for up to 70% of the cost of raising chickens. The type of feed used is clearly going to affect the attributes of the manure. For example, broiler chickens were once fed mixtures of maize, soya, meat meals, offal, feather meal and tallow. However, modern mixes are predominantly grains plus vegetable proteins and oils. This predominantly vegetarian diet affects the nutrient balance within the litter.

Moreover, the life of a broiler chicken may be as little as six weeks, compared to 10 weeks a few decades ago. This factor, combined with dietary changes, has reduced average nitrogen levels in manure from 5.7% to approximately 3.5%. Modern litter also has 30% less phosphorus, lower levels of fats, carbohydrates, uric acid and enzymes than it once did[1].

Bedding materials matter

Chicken litter consists of both manure and bedding, at a ratio of about 55:45. The type of bedding material used

Figure 5. Adding compost to soils low in organic matter can increase root growth, as shown in these sweet corn seedlings grown with (left) and without (right) compost.

FOOD SAFETY AND MANURES

Manures have been used to improve agricultural soil since the very start of human civilisation. As well as nutrients, manures add organic matter, increase soil bulk density, enhance structure, improve water holding capacity and stimulate soil biodiversity.

Unfortunately, manures can also contain human pathogens such as *Escherichia coli* (*E. coli*), *Salmonella* spp., *Listeria monocytogenes* and others. Products grown in manure amended soil can be contaminated by these bacteria, potentially causing severe illness or even death.

Fortunately, potatoes are always eaten cooked. This process kills any bacteria that may be on the skin or even inside the tuber flesh. As a result, potatoes are usually considered **low risk** with regard to potential contamination by human pathogens.

Human pathogens such as *E. coli* and *Salmonella* spp. are relatively poorly adapted to the soil environment. As a result, their populations in manure amended soil usually die-off over a matter of days or weeks, especially if temperature and UV intensity are high[5]. To take advantage of this decline most, if not all, food standards mandate an exclusion period between application of untreated manures and harvest of fresh produce, including ware potatoes.

Recently released Food Safety Guidelines by the Fresh Produce Safety Centre (fpsc-anz.com) recommend exclusion periods based on maximum air temperature. If the mean maximum (monthly) temperature during the growing period is above 20°C, then 45 days must elapse between application of manure and harvest. If the mean maximum temperature is below 20°C, then this exclusion period doubles to 90 days.

However, other standards are more restrictive. For example, GLOBALG.A.P. stipulates 60 days between application of manure and planting for all vegetable crops.

It is therefore important that before applying manures, or other amendments containing animal products, check the requirements of your food safety certification body, as well as local regulations.

It is also important to practise good hygiene when handling or spreading litter. This is to protect the health of workers and ensure it does not accidentally contaminate neighbouring crops or waterways.

Figure 6. Chicken litter from broiler sheds is not just manure, but includes feathers, bedding, blood, feed and other organic materials.

is likely to significantly alter the C:N balance and nutrient levels in the waste product. For example, litter from wood shavings has lower nitrogen content than that from rice hulls (G. Martin, pers. com.).

Another change is the more frequent recycling of the litter by re-use, layering or mixing. In the past, about 70% of Australian broiler chickens were grown on new bedding, with the remaining farms practicing partial re-use[2].

In the US, litter may be re-used for up to 2 years before the sheds are fully cleared out. The bedding is windrowed inside the shed, allowing it to partially compost, before re-spreading for the next batch of birds[3].

Australian growers appear to be recycling litter more frequently, altering both the volume and composition of material available (Table 3).

Availability of nutrients

In addition to nitrogen, poultry litter contains phosphorus, potassium and micronutrients such as sulphur, calcium, magnesium, manganese, zinc and copper.

About 25% of the nitrogen (N) contained in litter is ammonium, which is readily plant available. The rest is uric acid, protein and urea. In the months following application an additional 25-35% of the nitrogen in the litter is converted to ammonium, making it available to plants.

Importantly, poultry litter needs to be incorporated into soil as soon as possible in order to preserve nitrogen held in the manure. Ideally, manure should be incorporated within 12 to 24 hours after spreading (Figure 9).

It is also essential to keep litter moist; piles should be kept covered to prevent drying out and protect the material from UV light, both of which increase volatilisation of ammonia.

If litter is not incorporated, either mechanically or with irrigation, then a significant portion of the available ammonium will be lost to the air. This may be up to 50%, especially if the soil is dry and/or the weather is warm.

Phosphorus (P) is relatively immobile in the soil, so it needs to be placed where crops need it. Surface application may not make P available in the plant root zone. Between 30-80% of the P in chicken manure is inorganic, which also limits its availability; the phosphorus in chicken litter may be more tightly bound than in chemical fertilisers (e.g. DAP), reducing availability during early crop growth.

In contrast, potassium (K) in litter is readily available and mobile in soil. As a result, 90% of the K in poultry litter is available to plants, compared to 30 to 80% of P.

How much litter is good litter?

Chicken litter is usually sold and applied by the cubic metre. However, nutrient analysis is reported as % dry weight, so it is important to know moisture content. At typical levels of 20-30% moisture, a tonne of litter will weigh approximately 2.5m^3.

This allows calculation of the nutrients in a m^3 of litter, and comparison with synthetic fertiliser.

For example, a cubic metre of litter that is 4% N, 1.3% P, 2% K, 26% moisture and weighs 400kg/m^3 will contain:

0.04 (N) x 0.74 x 400kg = 11.84kg N

Using this same calculation, it will also contain 3.85kg P and 5.92 kg K.

The trace elements in litter, as well the organic matter it contains, are useful as well, but harder to value monetarily. Note that 50% of N may be lost if the material is not used promptly.

According to Wiedemann (2015), an application of 2.5m^3 chicken litter is roughly equivalent to a 50kg/ha application of DAP (di-ammonium phosphate) or 70kg/ha application of CK 66 fertiliser, in terms of N and P supplied.

Once nutrient content has been estimated, application rates per hectare can be calculated. While spreaders can distribute down to about 2m^3/ha, it is difficult to apply evenly. Rates of 4-5 m^3/ha allow for better distribution.

Figure 7. The food that chickens eat affects the nutrient mix of their manure. (Image: Australian Chicken Meat Association).

Figure 8. Broiler chicken litter is generally piled up for a day or two, allowing some composting of the material even before it is removed from the shed (left, Image: Australian Chicken Meat Association), after which it is delivered to the farm for spreading (right).

Table 3. Typical nutrient values in chicken litter with different bedding materials. Values by dry weight. From Wiedemann, 2015* and Griffiths, 2011**.

	Chicken litter single use			Chicken litter multi-use*	Turkey litter**	Layer manure**
	Straw*	Sawdust*	Wood shavings*			
Moisture (%)	20	25	26	21	32	41
Total carbon	30 to 40%, lower in multi-use litter				39	33
Total nitrogen	4.0	3.8	3.9	4.0	3.8	5.8
Total phosphorus	1.1	1.2	1.3	1.7	1.7	2.2
Potassium	2.2	1.8	1.9	2.4	1.9	1.7
Magnesium	0.43	0.44	0.44	ND	0.46	0.49
Sulphur	0.63	0.5	0.5	0.6	0.49	0.45

Litter contains low levels of chloride and sodium. A high application of 10m³/ha will add around 12 kg sodium, which will not influence salinity. However, repeated high applications can start to have negative impacts – as has been observed on some vegetable farms.

FEEDLOT FERTILISER

Growers located close to feedlots may be able to access feedlot manure. Compared to poultry litter, fresh livestock manure is somewhat lower in nutrients, containing around 2.4% N (compared to 4% in poultry litter) and 0.75% P. It also contains approximately 0.5% sulphur and 0.02% zinc.

However, it is relatively high in potassium (K). Feedlot manure (semi-dry) contains approximately 2.6% K, which is similar to the levels found in chicken litter. Moreover, it remains stable during ageing and composting.

Potato plants need huge amounts of potassium, taking up over 4 kg/ha/day during tuber bulking. While this is the period of greatest demand, it is also essential to have ample potassium present during stolon growth and tuber initiation. Feedlot manure added before planting can therefore be a good source of potassium for potato crops.

Release of ammonia and nitrous oxide (NO) is much less from livestock manure compared to chicken manure. Despite this, as with chicken litter, it is important to incorporate the manure into the soil as soon as possible to maximise avoid losing N to the air.

Most of the N in feedlot manure is in an organic form, but it is released more slowly than from poultry litter. According to a report by P. Wylie (2008) approximately 30-50% of N in feedlot manure becomes available to the plant over the first 12 months of application. This extended release may be useful for potato crops.

Distribution of feedlot manure is more difficult than poultry litter because of its lumpiness. It is collected by yard scrapers which lift manure compacted by many hooves and dried in the sun (Figure 10). The manure may therefore need to be aged and screened in order to be evenly distributed, especially if it is applied at relatively low rates e.g. 6 t/ha.

Feedlot manure has a C:N ratio of around 10:1, suggesting it is significantly lower than manure from free ranging, grass fed animals. As a result, it breaks down relatively rapidly. For comparison, chicken litter may be as high as 20:1. However, this also means it is a good source of organic matter, being rapidly absorbed into the soil.

Like chicken litter, cattle manure is a potential source of human pathogens.

Figure 9. Chicken litter should be kept moist and both spread (left) and incorporated (right) as soon as possible after delivery in order to minimise loss of nitrogen to the atmosphere (Images: L. Southam-Rogers).

It should be considered that the bacteria *Listeria monocytogenes* has occasionally been found in feedlot manure. *L. monocytogenes* is a natural soil dwelling organism, so is more persistent in soil than *E. coli* and *Salmonella* spp.[ii]. Risk of persistence can be minimised by composting the manure then incorporating thoroughly into the soil. *L. monocytogenes* populations decline most quickly in sandy soils at temperatures over 21°C[4].

PIGGERY SLURRY – *NOT FOR POTATOES*

Piggeries produce effluent, manure and used bedding materials. Unlike poultry litter and feedlot manure, most piggery wastes are collected and transported as either liquid effluent or sludge.

Piggery slurry is NOT RECOMMENDED for application to land used for horticulture. As it is liquid, it runs off more easily than solid wastes, potentially contaminating other crops and water sources. It can contain higher populations of human pathogens than other manures, as well as parasitic viruses and cysts, both of which can survive for extended periods in the environment. Slurry is also a poor carbon source, typically being only 4 to 5% dry matter.

Piggeries also periodically dispose of bedding materials, including sawdust, rice hulls, barley straw or wheat straw. These materials can add organic matter, but are generally low in nutrients.

Figure 10. Feedlot manure can be hard to distribute as it has been hard-packed by hooves (left). The material is scraped and mounded before removal from the pen (right) (Images: Meat and Livestock Australia).

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