AUSTRALIAN NUFFIELD FARMING SCHOLARS ASSOCIATION

2001 SCHOLARSHIP

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By

Trevor Caithness

PO Box 1185
BAIRNSDALE VIC 3875
Tel: 03 5157 7669
Mobile: 0419 543 801
Email: caithness@dodo.com.au

Topic: ALTERNATIVE SOURCES OF NUTRIENT FOR PASTURE AND CROPPING

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Executive Summary

My private Nuffield studies were based around the subject of finding by-products from other industries that could be used as cost effective sources of nutrient for pasture and cropping. My study very quickly narrowed to the utilization of poultry litter for this purpose, as it is readily available within our area. I found that, although very easy to calculate, the NPK value of poultry litter and many other factors needed to be looked at before achieving a true understanding of how maximum value can be obtained from its use. The following are some generalized observations of my studies.

◊ Poultry litter is not a complete or balanced fertilizer and productivity of crops or pasture will be limited by the most limiting factor ie pH, N/P or K;

◊ Poultry litter is a slower releasing source of NPK than traditional inorganic fertilizers;

◊ Bedding material type can have a large bearing on mineral/trace element composition of poultry litter;

◊ Poultry litter is a rich source of organic matter;

◊ Soil microbal activity can be greatly enhanced with the inclusion of poultry litter to a fertilizer program;

◊ There can be health risks associated with the use of poultry litter;

◊ Poultry litter is a potential pollutant if used or stored inappropriately;

◊ Poultry litter can be a very cost effective source of NPK depending on cost ex shed, transportation and spreading costs;

From my experience, the greatest challenge travelling on my Nuffield studies was to absorb the constant new ideas and information I was confronted with, sometimes from industries totally distant from our own, but somehow always having something in common with our respective industries.

Acknowledgments

I would like to thank Wesfarmers for their sponsorship of the Nuffield Farming Scholarships who made it possible for me to travel and undertake my core study.

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David Debenham Pty Ltd

Special thanks to my wife, parents, brother and loyal staff members who provided me with the freedom to spend time away pursuing my Nuffield studies.

Aims\Objectives\Study Goals

Objectives

The Nuffield Farming Scholarship provided an opportunity to study how poultry manure, a by-product of the poultry industry in Europe and North America, is utilized by the agricultural industry to improve soil qualities and increase productivity.

The poultry industry in Australia also produces large amounts of manure as a by-product. Poultry sheds in this country produce on average 150 cubic metres of manure. Sheds are emptied up to five times per year.

While the benefits of poultry manure are understood to some extent, I wanted to undertake a more comprehensive study into how industries in other countries make use of this material, and how manure can be converted into cost-effective input into our production systems.

The objectives of the study were to:

1) Determine the short and long term effects of the use of poultry manure on key soil properties by observation and discussion:
   a) Macronutrients; Nitrogen (N), Phosphorus (P) and Potassium (K).
   b) micro nutrients; Copper, Zinc
   c) soil acidity (pH).
   d) soil structure
   e) biological activity
2) Understand the environmental issues associated with the use of poultry manure.
3) Collect information about the use of composted versus fresh poultry manure.
4) Look at poultry manure quality and quantity issues.
5) Determine the disease risks to livestock from the application of poultry manure on pastures.
6) Conduct a cost comparison between the use of poultry manures and conventional NPK fertilisers.

The Group Tour

My Nuffield Farming study tour commenced in February 2002 with attendance at the 52nd Farm Management Course at Wye Imperial College, Kent, England. During the three week course I gained some understanding of the complexities and frustrations arising from the effect of the European Union on agriculture in the United Kingdom.

In June 2002, the next stage of the tour was to obtain an overview of some agricultural systems in south-east Asia. This was facilitated by a number of government and industry people in Singapore, Indonesia, Hong Kong and the Philippines who kindly offered their time and shared their knowledge and experience with us. We were able to look over a number of operations and institutions, including wholesale produce markets, an abattoir, an agricultural college, and cattle & pig feedlots etc.

The opportunity to compare and contrast our industry, our culture and our economy to those in south-east Asia was certainly worthwhile. The sheer size of the population in this region, and the proportion of people engaged in either commercial or subsistence farming are staggering. There are some real extremes in this region, namely between the poor and the rich. Add to this the juxtaposition of traditional and modern practices made this part of the tour something that will not be forgotten.

There were a number of very intriguing facts obtained from this section of our tour:

1. 100,000 young people travel from this region to Australia each year to undertake some form of tertiary study. Many more travel to other countries for the same purpose.
2. In Indonesia, poor take up of modern techniques, as well as corruption between industry and government people has resulted in this country only achieving a faction of its potential in agricultural production.
3. Agricultural workers in Indonesia are paid just US$1.00 per day (men) and 60 cents per day if you are a woman. In fact in Indonesia more than 64 million people earn no more than US$2.00 per day.
4. The agricultural sector is responsible for 50% of fresh water consumption in Asia.
5. In the Philippines, population is 90 million and estimated to double in the next twenty five years.

The next stage of the tour was in the United States of America. In the USA we had the opportunity of looking at a number of different agricultural operations, including dairy farms, cattle feedlots, grazing, cropping, processing and horticultural enterprises. The proprietors & managers of these operations were all keen to share their personal views and experiences on their industry, and the difficulties they face in their world. A common thread through these enterprises is concern over the cost of labour.

Late June 2002 we met Bryce Lumburg, who runs a family operation, producing and milling organic rice. The Lumburgs use poultry litter as their primary source of fertilizer for their rice crops. Interestingly, we found that the US has a law prohibiting the use of fresh fowl manure on crops harvested within 60 days of sowing. Composted fowl manure may be used as fertilizer for crops harvested longer than 60 days.

From California we stopped over briefly in Dallas, Texas, then flew up to Canada to continue our study tour, getting an overview of several more livestock and cropping operations and more of an insight into agricultural industries in that part of the world.

In August 2002 after six weeks to catch up with my family and our own operation back home I returned to England. A highlight was the visit to JSR Farming Group East Yorkshire, which is now the largest privately owned farming operation in the UK. We spent time with officers from the NFU, discussing the rural subsidy system, the outlook for various commodities and the future viability of farming in their country given the impact of the entry of the UK into the E.U. and the expansion of the E.U. into Eastern Europe.

From England we moved on to Brussels to obtain an understanding of the workings of the EU and then returned to London. From London, commencing my private study, I flew out to the USA then back up into Canada. At this point in my tour I spent some time with the Rigby's in Canada who gave me many contacts within their local area that had much experience with composting various animal manures. They shared their knowledge about the techniques of composting; carbon/nitrogen ratios, optimal temperatures and turning rates. I was also able to make some interesting comparisons between different materials used as the base for the manure, that is, wood bases versus rice hull bases. It was also this leg of the tour where I learnt about mushroom compost used as an accelerant for composting animal manure.

Discussions were had with people who spread animal manure and the effect on soil pH and nitrogen and phosphorus levels. It was also interesting finding out the cost effectiveness of

inorganic, commercially available sources of NPK versus the cost of NPK in found animal manure.

From Canada back to Tennessee, USA, I met some people who have integrated the use of animal manure as a core component of their fertilizer program.

There seems to be a mix of operators who spread animal manure simply to get rid of what is seen as an non disposable by-product, to people who have a good understanding of the benefits of animal manure in their fertilizer program and use it to good effect.

In late September I moved onto Arkansas. People from the University of Arkansas, as well as a Washington Country Judge were quite helpful in sharing their knowledge and experiences in the use of poultry manure. Some extremely useful information was obtained in this leg of the tour towards the subject of my Nuffield Study Tour.

Introduction

The very nature of traditional farming is to produce a valuable commodity, which in some way is derived from the soil. The soil is our livelihood.

It is accepted that farming practices are not sustainable without putting back in what we take out.

Soil science tells us that we need to have an understanding of the chemical and structural properties of the soil profile. It tells us that without the right quantity and balance of key soil quality components and indicators, our soil will have a limited productive life. Running down our soil is not only bad science, it is bad management, and bad stewardship of a precious, finite, resource.

The rising cost of farming inputs forces us to look at all sources for the inputs we require to continue our operation. As in all business enterprises, farming inputs must be cost-effective.

Of particular interest to me was sourcing economically important soil nutrients that may be seen as by-products from other industries and there for available at a lower cost per unit of NPK than through traditional sources.

Australia has a large poultry meat industry. Around the country are hundreds of poultry meat producing farms. On these farms are one or more large sheds up to 160m in length, each housing approximately 20,000 meat birds, all running around on a bed of rice hulls or wood shavings or some other type of absorbent, hygienic material. When the birds have matured and are removed for slaughter, the bedding material is scraped out and removed from the farm. By the time the bedding material is removed, tonnes of poultry manure has been mixed in with the raw bedding material. This happens on every farm, up to five times per year. Each time the shed is cleaned out, up to 150 cubic metres of bedding material is removed.

To the poultry industry it is seen as a by-product, but to animal and crop producers, it can be a cost effective means of improving soil nutrient levels and structural qualities.

While the qualities of animal manure in improving the soil are already well known, this study sought to gain a better understanding of its short and long term effects on various aspects of soil qualities, namely:

- Nitrogen, Phosphorus and Potassium levels
- pH levels
- Effect on organic matter levels and soil structure.

It was also important to look at:

- Effects on pasture growth and crop yields.
- Effects on long term balance in soil nutrients and soil structure.
- Techniques and cost effectiveness in sourcing the material and spreading it.

The study also found issues related to the effects on the environment and neighbourhood amenity.

With this information it was then possible to compare sources of soil nutrients on a dollar for dollar basis.

This report discusses the what, whys, hows, effects and costs of the use of poultry manure as an alternate or supplementary source of soil nutrients in pasture and cropping systems. It was evident from observations and discussions with operators, particularly in North America who use large quantities of animal manure as a substitute or supplement to traditional fertilizers, that its long term effects are simply not well understood. This is also the case in this country. Manure is applied in some cases simply to get rid of a material that otherwise has to be stockpiled at great cost.

The scope of this study was not to identify commercial outlets for a by-product of the poultry industry, but to understand its efficacy in pastoral and cropping agriculture in an attempt to rationalize the costs of inputs.

Poultry Litter - What's In It?

The mainstream poultry meat industry in Australia is predominantly an intensive farming system. A shed up to 160m long housing thousands of birds needs a floor material that is both low cost yet effective in providing a means of absorbing wastes. This is important for disease and environmental control within the shed.

The most common bedding material used for poultry sheds are cereal straws, rice hulls and wood shavings. These are in themselves a by-product of other industries. After the birds have been through the production cycle the birds are removed for processing. Left behind is a bedding material, which is a much different material to what it was before the birds went in. *Poultry Litter* is the term applied to the combination of the accumulated manure, bedding material, spilt feed and water.

The nutrient analysis in poultry litter varies widely depending on shed management, as well as the bedding material, the number of batches which have been through the shed before clean out, feed rations, and climate.

The following nutrient analysis however, is typical for poultry litter:

Property	**Average Analysis**	**Range**
Nitrogen (N)	2.6 % (of dry matter)	1.4% - 8.4%
Phosphorus (P)	1.8 % (of dry matter)	1.2% - 2.8 %
Potassium (K)	1.0 % (of dry matter)	0.9% to 2.0 %
Sulphur (S)	0.6% (of dry matter)	0.45%-0.75%
Calcium (Ca)	2.5% (of dry matter)	1.7%-3.7%
Magnesium (Mg)	0.5% (of dry matter)	0.35%-0.8%
Sodium (Na)	0.3% (of dry matter)	0.25%-0.45%
Carbon (C)	36% (of dry matter)	28%-40%
Dry Matter	75%	40% - 90%
pH	8.1	6.0 - 8.8
Weight/m^3	550 kg	500 – 650

Table 1, Typical Nutrient Analysis of Poultry Manure
Source: NSW Agriculture Agnote. DPI-212 1998. Neil Griffith.

Poultry litter also contains trace elements, including Manganese Copper, Zinc and Boron.

Table 2, taken from a guide to the use of livestock manures published by the Ministry of Farming & Fisheries in the UK, puts values, in kilograms per tonne, on the total nutrient content in livestock litter. This is an interesting comparison between solid manure from different animals.

Solid Manure Type	**Dry Matter %**	**Nitrogen (N) kg/t**	**Phosphorus (P_2O_5) kg/t**	**Potash (K_2O) kg/t**	**Sulphur (SO_3) kg/t**	**Magnesium (MgO) kg/t**
Cattle	25	6.0	3.5	8.0	1.8	0.7
Pig	25	7.0	7.0	5.0	1.8	0.7
Layer	30	16	13	9	3.8	2.2
Poultry	60	30	25	18	8.3	4.2

Table 2: Typical total nutrient content of livestock manures

Source: Making Better use of livestock manures on Arable Land. Chambers *et al*

Clearly, on a fresh weight basis, poultry litter outstrips other solid manure types in terms of its NPK content.

Phosphorus

It is widely recognised that manure, including poultry litter, results in a gradual accumulation of phosphorus in the soil, about 13% (range 6%-30%) of phosphorus in poultry litter is immediately available for plant uptake. As the organic component of the litter applied to the soil gradually decomposes, more phosphorus is released into the soil profile. This is a process performed by soil microorganisms.

Nitrogen

Nitrogen present in poultry manure is basically in two forms, ammonium nitrate and organic nitrate. Poultry manure normally consists of approximately one third ammonium nitrate, which will be immediately available to the plant and also at risk of volatilisation, if not incorporated into the soil or watered in via rainfall or irrigation. However, organic nitrate will

be broken down slowly over approximately a 12 month period by microbal activity within the soil structure and therefore becomes a very slow release source of nitrogen.

The loss of N into the air or into waterways and sub-surface water are issues important both to the farmer spreading the litter, as well as authorities and governments who are interested in the environmental and neighbourhood implications of the use of animal manures on pasture and crops.

Potassium K

Poultry litter contains minimal quantities of Potassium and therefore normally needed to be added from other sources especially in situations where hay/silage forage is being removed.

Organic Matter and the Carbon Nitrogen Ratio (C/N)

Improvements in soil qualities, and therefore crop and pasture production, are achieved by maintaining good levels of organic matter. Soils rich in organic matter:

- are more structurally stable and less prone to erosion. Carbon binds the soil particles together making a stable aggregate.
- Are easier to cultivate,
- Have greater biological activity within them,
- Have greater amounts of nutrients available to plants

The presence of organic matter in the soil is essential for successful plant growth. Organic Matter levels are an indicator of soil fertility.

The high organic matter levels present in poultry manure is a major benefit from utilizing this material to maintain and improve soil qualities.

The C/N ratio in poultry manure is an important consideration. The C/N ratio is simply the ratio of organic C to the weight of total N in the material. The C/N ratio affects the biological activity in the soil.

A C/N ratio of 30:1 will have too little N to allow for rapid decomposition, therefore the microorganisms in the soil will take N out of the soil to fuel the decomposition. This depletes the soil of N. A lower C/N ratio of about 15:1 to 25:1 is preferable. This allows sufficient N in the manure to be taken up by the microorganisms, instead of from the soil.

While in Canada I met with some farmers running a mixed cropping and intensive animal production operation. They try to achieve a C/N ratio of 15:1 with their manure composting operations using the compost and spreading it onto their fallow cropping land, as well as selling in bags as a lawn repairer and also in bulk to other local district farmers.

Acidity

Poultry litter, while testing alkaline as shown in Table 1, is not as effective in neutralising soil pH. Continued use over extremely long periods of time will show a slight rise in pH but this could not be seen as an effective way of combating soil acidity.

Trace Elements

While poultry manure does contain a huge assortment of trace elements they are not considered to be of a quantity worth placing any substantial value on and do vary considerably according to the feed diet. It was noted that in some parts of the USA copper is used in considerable quantities in the feed ration as an appetite stimulant which would create a poultry manure with considerably higher copper levels than generally seen.

It was noted by several farmers that I had spoken with that molybdenum levels within pastures and crops where poultry manure had been used over sustained periods had risen quite dramatically thus causing copper deficiencies mainly showing up as animal livestock health issues.

From some as yet unpublished work undertaken by one of the major Canadian Universities it appears as though these high molybdenum levels are in direct relationship to the bedding material used within the poultry unit. It appears as though poultry manure coming from sheds bedded with either rice hulls or straw will have substantially higher Mo levels than sheds bedded with wood shavings. It was also noted that sheds bedded with wood shavings appeared to have substantially higher copper levels in comparison to rice hull/straw. Once this work is clarified it could be used as a tool by farmers to address particular needs within their soil type.

Water

The water content in poultry litter varies widely. It is better to buy poultry litter by volume (m^3) rather than by weight (tonnes). Refer back to Table 1. It is also important to consider the moisture content when calculating your nutrient budget, as this will affect NPK per ha available.

While in Tennessee I heard that it was common for poultry producers to sell their litter at the farm gate by the tonne. This is good business if you can get it. The amount of water being sold with the litter did not seem to be an issue.

Why Use Poultry Litter?

As we know, poultry litter is a by-product of the poultry industry. It is available directly from the shed door, or from commercial operators who clean out sheds, and/or stockpile and compost the litter for bulk and/or value-added sales.

It is used as a cost effective alternative to traditional commercial fertilizers to maintain and improve the chemical, structural and biological qualities of the soil. It is not in my opinion however a replacement for traditional commercial fertilizers which are formulated and applied to the exact needs for plant requirements. This must be made clear. The make-up of poultry manure is far too variable and unreliable to ever be considered in this context.

Discussions with an agronomist in Ontario, Canada were interesting. Poultry farmers establish cropping enterprises just to get rid of their poultry litter. This is a common practice. In many cases farmers have absolutely no idea how much NPK, and in what ratios, is being applied to the soil. They just know that the NPK is present, and the crops or pastures grow. Soil tests conducted on a property where there was a 20 year history of spreading poultry litter, showed a ten fold increase in Olsen P levels of more than 200 ppm.

There is good evidence that the ever growing North American poultry industry is producing more poultry litter than can be sold or even given away. This has resulted in a number of industry and University studies into on and off-farm means of disposing of the material, for example, using poultry manure as a fuel for incineration type power stations. This is currently taking place at several sites in the UK and has interestingly pushed the price of poultry manure beyond the reaches of what several farmers believed they could justify.

The decision to use poultry litter will depend on a number of factors:

1. Source/Availability.
2. Transportation costs.
3. Availability and cost of owning versus contracting spreading equipment,
4. Existing soil structure and fertility.
5. Nature of existing cropping and pasture based enterprises.
6. Comparative cost of traditional alternatives.
7. Proximity of ground water in the soil profile.
8. How well you get on with your neighbours (is their house upwind or downwind of your spreading activities?)

HOW is Poultry Litter Used?

Experiences from the US state of Arkansas was extremely useful in the study tour. Poultry is this state's biggest farm commodity, and is the largest broiler producing state in the USA. Arkansas is also one the biggest turkey and egg producing states in the USA.

I was astounded to be told that many poultry enterprises were established in Arkansas in the 1950 and 1960's on a break-even basis for the bird production. The only profit from the enterprise was from selling the litter.

The University of Arkansas, and Winrock International of Morrilton, Arkansas, have put much work into profitable and not-for-profit outlets for poultry litter. It is a subject which has generated many ideas, and much debate for some time.

Uses on Crops and Pastures

Poultry litter can be applied to crops or pastures in three forms.

1. Fresh

   Fresh poultry litter has the highest levels of N (least amount of N lost into the atmosphere) and the least amount of decomposition of organic matter compared to other forms of poultry litter. Most of the litter generated on farm tends to be used on farm soon after sheds are cleaned out.

2. Stockpiled

   Stockpiling of poultry litter occurs on farm where there is simply too much litter to be spread out after shed clean out, or it is stored to be applied to match plant nutrient requirements. Stockpiling is also conducted by clean-out contractors and/or commercial outfits who stockpile litter for re-sale in its raw form or for value-added sales.

   Stockpiling does not encourage proper composting, which is a more carefully managed process.

   Stockpiling poultry litter brings with it a number of safety, environmental and neighborhood amenity issues if not stored properly.

   If not stored well, the heap can overheat and catch fire, and nutrients can leach out of the pile into watercourses and ground water.

3. Composted

   Composting is a controlled biological decomposition process that converts organic matter to a stable, humus like product.

   It is made possible by the activity of microorganisms found in poultry litter. The organisms use decomposable organic waste as an energy and food source. The process, if carried out correctly under the right conditions, reduces the unpleasant odors, removes unwanted pathogens and kills weed seeds. Pathogens are killed off from the heat generated during the composting process.

   The weight and volume of the raw material is reduced because of the actions of the organisms producing carbon dioxide and water vapour, which is lost into the atmosphere. This reduces transport and spreading costs.

Composting is successfully achieved under aerobic conditions. If too much water is present in the raw material, anaerobic processes take over which reduces the quality of the end product.

Management of the process involves maintaining proper temperatures and oxygen levels and ideally a carbon:nitrogen ratio of approximately 15:1. This is best achieved by placing manure in windrows or through the more capital intensive indoor batching type operations where compost is put in long concrete bunkers, sometimes up to 50 metres long, 4 metres wide and 1.5 metres deep. Proper composting is achieved with the aid of a rotary compost turner, which turns the windrows periodically to maintain temperature and oxygen levels. Organisms needed for composting best operate at temperatures between 43 and 65 degrees Celsius. Optimum temperatures are between 55 and 60 degrees C.

A drawback of composting is the potential loss of valuable nitrogen to the atmosphere. The nitrogen phosphorus ratio in litter is already lower than what most crops require. The loss of further nitrogen worsens the situation. By paying attention to the C/N ratio, this problem can be alleviated to some extent. Organisms use 25 times as much carbon as nitrogen by weight, thus the carbon in lower C/N ratio litters will be used up well before the nitrogen. Mixing a cereal straw during the composting process assists in conserving N otherwise lost into the atmosphere. This is achieved by increasing the C/N ratio to a more optimal level.

Most windrows are 1 to 2 metres high, and 3 to 6 metres wide. If windrows are too large, temperatures can get too high and oxygen can be depleted, particularly at the center of the pile.

The result is a finer textured material, which enables easier spreading and is less offensive in odour.

There was some time during the study tour spent on discussions and observations of composting and attempts at composting poultry litter, mainly in North America. The major issues associated with composting were:

1. Costs of equipment and infrastructure
2. Social and regulatory issues, associated with environmental concerns from long term storage of litter.

In North America there have been several unsuccessful attempts at commercial composting enterprises instigated by local governments with some form of federal environmental funding.

Rol-land Farms Ltd in Ontario Canada, was a good example of how a poultry industry by-product can be used to make a profit at more than one level. Raw turkey shed litter, as well as straw is used for growing mushrooms. When the mushrooms are harvested, the litter from the mushroom sheds are composted and used as a source of NPK for their cropping operation. I heard that mushroom compost, if used as an additive in the composting of poultry litter, would create an environment that will actually accelerate the rate of composting. There appears to be several microbial families found within mushroom spores that have the ability to break down straw at a much faster rate than normally seen. If these could be identified and used within the Australian minimal till cereal cropping industries we may see a much quicker straw decomposition within our paddocks.

Many farmers I met, such as the Vanetta family of Tennessee, are using poultry litter as their main source of fertility in their cropping organizations. Their standard practice consisted of 5 cubic metres per hectare of manure being cultivated into their land pre sowing of their corn crops followed by nitrogen/urea being applied through the growing season as required. Once the corn was harvested "Round Up Ready" Soya Beans were direct drilled with no poultry litter or conventional fertilizer being applied. The following season the cycle starts again with poultry manure and corn. This seemed to be a fairly common practice for many that were using poultry litter.

Other Uses

Poultry litter is known to be used as a high protein supplement in cattle rations in the US. In the UK it has been used as a source of fuel for the production of electricity.

Whilst in North America I visited several farms using poultry manure as the composting agent for their dead farm livestock. This is due to laws prohibiting the burying of dead animals and the unavailability of knackeries to collect these animals. It was interesting to note that it took 5 – 6 months to completely compost (skeleton included) a fully grown cow or other large animal. I was told these compost heaps were being turned probably around 3 – 4 times during that period.

Handling

Most poultry litter seems to be handled with telehandlers as this enables the loading into very high sided trucks. Whilst in Arkansas I did see several contractors using long conveyor systems which were conveying the material up into the back of trucks, thus allowing a very small front end loader to be used to load the conveyor. This was effective but seemed very slow and the conveyors must have been quite cumbersome to shift between sheds.

Transportation

Whilst tipping bodies such as truck and trailer combinations and semi tippers are very common throughout much of the poultry litter industry that I saw most operators who have been updating equipment in recent years are now preferring to move to walking floor trailers which operate with a series of aluminium slats on the floor moving in a back and forth motion. This quite effectively moves the loaded material out the rear of the trailer. These trailers have great advantages as they eliminate the risk of tipping trailers rolling onto their sides whilst fully extended.

Poultry litter being a very bulky product to handle, transport and spread creates it own challenges that need to be overcome in a cost effective and efficient manner.

Spreading

There are basically two types of spreaders used to spread solid litter.

1. The first is a side discharge spreader, which has a cylindrical body, and a pto driven shaft fitted with flails running along the centre of the cylinder. As the rotor spins, the flails throw the litter out to the side.

2. The second is a bin or trailer fitted with a moving conveyor type floor, which delivers litter to the rear of the bin, arriving at two discs, which catch the material and throw it out to the rear.

Application rates vary widely. Through some parts of North America rates of up to 50 m3 per ha were observed however my personal experience is much less than that. Based on the nutrient analysis in Table 1, the following quantities of the macro nutrients would be spread per cubic metre per hectare.

Nitrogen (N)	10.6 kg
Phosphorus (P)	7.4 kg
Potassium (K)	4.1 kg

Table 3: Macro nutrients spread in poultry litter per cubic meter per hectare

The EFFECTS of using Poultry Litter on Crop & Pastures

Observations made during my study tour were such that it is universally accepted that the application of poultry litter does result in long term benefits to the soil and improvements in crop and pasture production. Care is required however to reduce the impact on the environment, and interestingly, to reduce the *appearance* of the impact on the environment as well.

I was very fortunate to meet H L Goodwin from the Poultry Division of the University of Arkansas who was of great assistance. The poultry industry in Arkansas, which is the largest agricultural commodity in that state, has gone to great lengths to research and promote the benefits in an attempt to create an outlet for a valued by-product of that industry and is particularly positive about the future. The work of Winrock International is worth mentioning at this point. Their groundbreaking work which led to the establishment of a poultry litter distribution network has been a great benefit to growers attempting to find a market for what is well regarded as a valuable by-product of their industry. Beneficiaries of this marketing system have been the cropping farmers in the Delta region of east Arkansas who have cut away top soil in levelling operations for water management purposes, and, predictably, suffered declines in yields as a result. Being able to source poultry litter through the distribution and marketing system set up by Winrock Intl has resulted in some significant yield responses when spread on freshly laser-levelled fields.

Figure 1 presents the yield responses in a trial conducted at Dunklin Farm in the delta region of east Arkansas in 1993.

George Dunklin, owner of Dunklin Farms, gave the University of Arkansas 15 acres (approx 6ha) for a 3 year trial on the effects of using poultry litter on rice fields, which were cut from 6 inches (15cm) to 3 feet (91cm). The response to the application of poultry litter was obvious to George Dunklin in a very short time. As a result. Mr Dunklin now applies approximately half a ton per acre (0.6t/ha) annually to maintain the productivity of the rice fields.

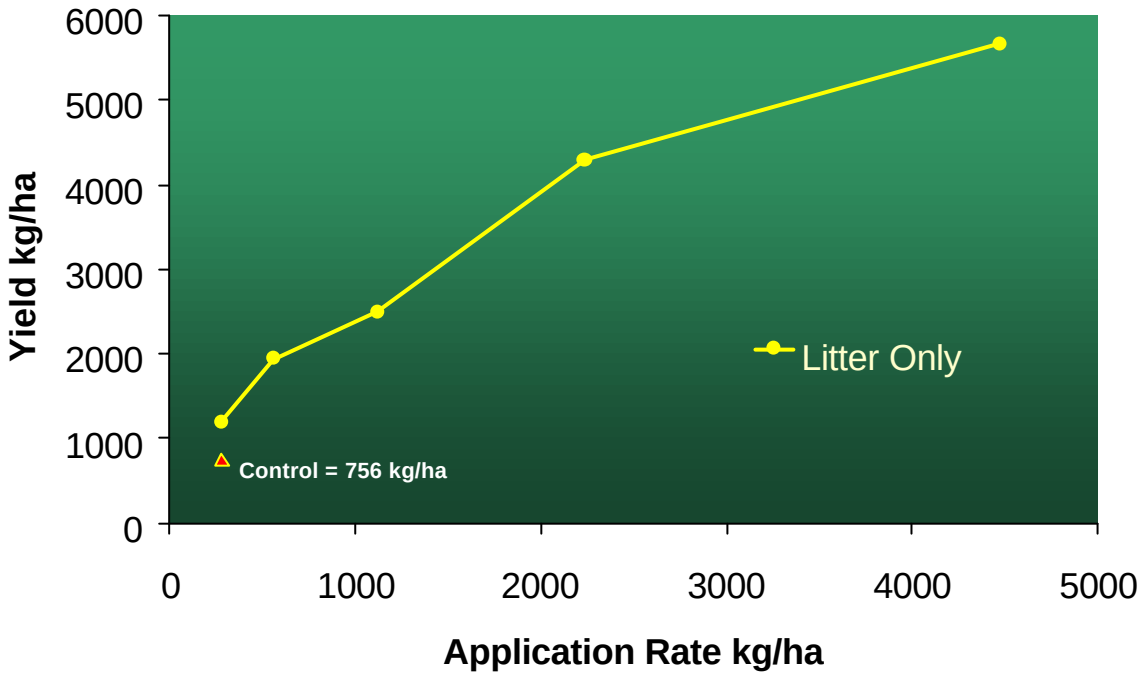

Figure 1: Rice Grain Yield Trial - Application of Poultry Litter

Dunklin Farm, Arkansas, U.S.A 1993

(Laser levelled field, deep cut)

The University of Arkansas Cooperative Extension Service regards poultry litter as a "valuable, natural soil amendment that adds nutrients and organic matter to increase soil fertility" but follows on with the statement "It is also a potential pollutant of surface and groundwater if mishandled."

A study conducted by Kingery *et al* (1994) presented some interesting data on the long term effects of the use of poultry litter in north western Alabama, USA. They took soil samples from a range of sites throughout the region, which had a 28 year history of litter application, and compared the results to samples from sites where no litter had been applied.

This research concluded that the long term application of poultry litter had changed the characteristics of the soil in the region they studied. They cite greater levels of organic matter, which has resulted in increased porosity in the soil, along with an abundant supply of macro and micro nutrients, including a substantial pool of mineralizable N - a result of the low C/N ratio.

The study also confirmed that which was long suspected by growers met during the study who apply poultry litter, that levels of soil NO_3-N, P, and K are present at greater levels than that required by pastures. This then leads to a situation where the excess amounts of nutrients can leach out into ground water with deleterious environmental consequences, which is the subject for the next topic in this report.

Environmental Concerns

The agricultural industry in the EU and north America is facing increasing regulatory and social pressures to better manage the use of manure based soil amendments.

As the environmentalist's voice gets louder, it is inevitable that it will be more difficult for producers to make the best use (on and off farm) of poultry litter.

The poultry litter project managed by Winrock International for the Arkansas poultry industry in the 1990's however, demonstrated however that a shift towards environmentally positive solutions to the litter problem actually produced some excellent, market driven results.

The main environmental concerns with the application of poultry litter are the application of nutrients in excess of plant requirements, that is, spreading quantities of litter without having prepared a nutrient budget for present and future crops and pastures. This is clearly the case from discussions with agronomists in Canada. Litter is spread simply as a means of disposal with some limited knowledge of crop and pasture nutrient requirements.

The spin-off from this practice, the world over, is the leaching-out of nutrients into the soil profile, beyond the root zone or run-off from heavy downpours of rain which then make their way into ground water, which ends up in water-ways and catchments.

The effect of excess nutrients in waterways and catchments are well documented. Effects from this include:

- algal blooms, resulting in reduction of oxygen, losses in fish stocks, poisoning of livestock drinking water, and restrictions in the use of water bodies for public recreational activities;
- nitrate contamination of water sources for human consumption.

Similar concerns arise from the storage/stockpiling of poultry litter. Nutrients from litter stored without adequate protection can wash out into waterways and water storage, or leach into the ground water. It is strongly felt that all stockpiled litter will have to be stored under cover according to forthcoming government legislation throughout the UK and America.

There are also concerns about the spread of disease due to the use of fresh poultry litter on crops. In California, it was heard how an Almond grower had caused an outbreak of Salmonella due to the spreading of raw poultry litter around the base of trees, which was then drawn into vacuum harvesting equipment. The litter spread in this case was not composted. I believe US law now prohibits the use of litter on crops harvested within 60 days of application ie, almonds.

The COSTS of Poultry Litter

Experiences in Europe and north America with the costs of poultry litter at the shed door were reasonably similar. (AUS)$10-15 per tonne appears to be the going price. Referring back to Table 1, this works out to be about $6.00/$m^3$.

The most important considerations with regards to costs are:

- purchase price of raw, stockpiled or composted litter
- transportation,
- spreading.

The actual cost-effectiveness of spreading poultry litter in Australia depends mainly on the costs of commercial fertilizers. In the USA, the cost of commercial NPK fertilizers are substantially less than in Australia. This has created a number of challenges for the poultry industry in that country in promoting poultry litter as a commercially attractive alternative to traditional commercial fertilizers.

Conclusions

- Poultry litter can be a cost effective source of NPK, however its effect in the soil profile and to the environment must be understood.
- Widely used amongst arable farmers that own and operate poultry units;
- Environmental regulations with regards to nitrate zones and application restrictions are very much becoming the norm throughout much of America and the UK;
- There is a microbal value with poultry litter but is yet to be fully documented;
- The poorer the soil type and structure the more magnified the benefits from using poultry litter;
- Although poultry litter contains most major nutrients and trace elements it cannot be seen as a complete and balanced fertilizer as the ratios of most are out of proportion to most plant requirements.

Recommendations

- Bedding type material of poultry litter be clarified as to its trace element/mineral composition;
- Microbal families found within mushroom compost be identified and isolated as they could be useful within minimum till agriculture as an accelerator of straw decomposition.

Non-related Observations

Whilst travelling on my Nuffield studies I developed a great interest in the production of cereal crops in high rainfall areas such as ours in southern Victoria. I found myself spending time looking at tiled drainage systems and gaining an understanding of drainage systems to remove excess water from such cereal crops. Upon my return home, with an understanding that we could not economically put tiled drains under a large area of our properties, we decided to put some wheat, triticale and canola on 1.8 metre raised beds. At this stage it is much more cost effective and appears to be giving us the desired result with quick removal of excess moisture.

Whilst in the UK I observed quite a trend towards lower seeding rates of cereal crops in an endeavour to allow more tillering of individual plants. We have cut our seeding rates by one third and have found this to be very effective at promoting tillering within the plants and at this stage with no loss in production.

A concerning conclusion I came to whilst travelling throughout the world was that Australia is going to have severe problems sourcing labour for relatively unskilled manual activities within agriculture and general industry. If you are an American company and you require labour that is of relatively low skilled requirements you have the ability to source seasonable labour from countries such as Mexico where they are paid a minimum US wage which the workers see as a very attractive package. If you are an English company you have the ability to do the same with eastern European workers. This allows these developed countries to obtain a workforce that is prepared to work and do the duties required. This is certainly not the case for Australia and to enable us to have the ability to compete in an open world market we need the opportunity to be able to source seasonal workers from other countries within our region at a basic minimum Australian wage.

My time away certainly reinforced the value of family, friends and the ability to enjoy life to its fullest. In circumstances where this is not the case my Nuffield studies have certainly given me the ability to make the necessary changes to achieve this.

A favourite saying picked up from a very successful elderly farmer in Tennessee with whom I spent a couple of hours doing over the world's problems:-

"Young man, by the time you get to my age you'll have worked out that if you die with any more than a buck in your pocket you've mismanaged your finances ….."

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