Carbon and Sustainability: A demonstration on vegetable properties across Australia

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Project Number: VG09190

VG09190

This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for the vegetables industry.

The research contained in this report was funded by the Department of Agriculture, Fisheries and Forestry.

ISBN 0 7341 3092 9

Published and distributed by:
Horticulture Australia Ltd
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179 Elizabeth Street
Sydney NSW 2000
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Horticulture Australia

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A demonstration on vegetable properties across Australia

A Project Conducted under the DAFF Climate Change Research Program (CCRP)

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This project is supported by funding from the Australian Government under its climate change research program

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Project Brief: A two year study was conducted to demonstrate reduced GHG emissions management techniques on vegetable farms in Australia. On farm demonstration of activities leading to reduced GHG emissions were packaged into case studies and informational products to provide the industry with an understanding of the importance of carbon and GHG emissions in the vegetable supply chain.

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1. Plain English Summary

Project title:	Carbon and Sustainability – A demonstration on vegetable properties across Australia
Lead organisation:	Horticulture Australia Limited
Consortium member organisations:	Victorian Department of Primary Industries Queensland Department of Agriculture, Fisheries and Forestry Growcom
Objectives	This demonstration project focussed on three key objectives to increase the understanding by the vegetable supply chain of the market requirements for carbon/ sustainability, and provide information to industry to be able to address these market requirements. These three objectives were: • Identify how Carbon is an important part of the overall sustainability picture for the Australian vegetable industry. • Understand greenhouse gas (GHG) emissions and demonstrate their management in the vegetable supply and marketing chain. • Develop information products, which can be utilised by the vegetable farming community in helping vegetable growers manage GHG emissions. These objectives were achieved by: • trialling and demonstrating the implementation of emissions management practices within vegetable production. • demonstrating the benefit of on-farm emissions management to the vegetable industry, including improvements in profitability across a range of emissions sources including fuel, electricity and fertiliser. • producing case studies based on the demonstration sites that outline the business case, including benefits and risks of implementing the demonstrated cropping systems and management techniques; and • consultation with retailers on carbon and sustainability issues.
Location	Melbourne Region, Victoria Granite Belt, Queensland Lockyer Valley, Queensland

Key activities	• Demonstration trial sites: Report on the spatio-temporal variation of carbon and nitrous oxides emissions across different cropping systems and management practices. • Report/case studies/fact sheets from each of the demonstration sites to assist vegetable growers to apply the vegetable industries' carbon footprinting tool on-farm, understand their emissions for different organic and inorganic treatments and present the business case for applying appropriate management practices on-farm that can mitigate emissions. • consultation with retailers on carbon and sustainability issues and report to industry.
Outcomes	This project was an awareness raising project aimed at identifying and benchmarking GHG emissions on vegetable farms. Techniques to reduce GHG emissions from on-farm vegetable production fertiliser management were measured and a list is provided below: • Nitrification inhibitors • Reduced fertiliser rates – inorganic and organic • Manure management – incorporation of manure into the soil These practices however cannot be considered in isolation from crop productivity, and other production activities. The interaction between fertiliser types, soil type, irrigation method, crop type and crop length all need to be considered before recommendations for the vegetable industry can be made.
Implications	The research findings have, for the first time, quantified GHG emissions for the Australian vegetable industry. This provides a baseline of information for industry, government, greenhouse gas accounts, and service providers wishing to further this research.
Publications	• 6 case studies from the project, which are posted on the website: ○ www.carboninhorticulture.com.au • Retailer report • Draft scientific paper

2. Executive Summary

Five demonstration sites were established on four vegetable production farms on the east coast of Australia. These sites were used to trial and implement greenhouse gas (GHG) emission reduction techniques to increase the ability of the vegetable industry to manage their emissions and improve their productivity. On farm demonstration and communication of the business case were used as drivers for the uptake of these practices to reduce GHG emissions. The project also aimed to provide information for vegetable producers to supply produce that meets consumers growing demand for food that is grown in sustainable and low emissions production systems.

Farm demonstrations focussed primarily on reducing GHG emissions from the application of fertilisers. While potential exists to reduce GHG emissions from energy use and fuel use on farm, the most immediate opportunity to reduce emisisons without significant capital investment, or changing any other practices, came from changed fertiliser practices.

This project has clearly demonstrated that nitrification inhibitors can very effectively reduce nitrous oxide (N_2O) emissions in vegetable crop production. Further research is required however to understand which type of inhibitor fits best with what crop. In these trials the potential of a nitrification inhibitor to reduce GHG emissions (N_2O emissions) was heavily dependent on the type of inhibitor/fertiliser combination, and whether organic amendments were also added to the production system.

The effect of inhibitors on GHG emissions could not be considered alone within this demonstration study. Trials have also shown another major benefit of nitrification inhibitors i.e. improved nitrogen (N) use efficiency. This has the potential to reduce nitrate leaching, reducing pollution of groundwater and offer great potential to reduce the number of applications of high analysis fertilisers, particularly calcium nitrate ($CaNO_3$), treatments to vegetable crops without reductions in yield. The results in trials in Victoria in 2012 indicated that at least one fertiliser application could be dropped due to improved N efficiency. This saves fertiliser costs, fuel costs and labour costs estimated at over $500/ha. It indirectly also allows reduced fertiliser application rates for crop production which will further lower N_2O emissions. Therefore a key finding from this research is the need to understand the effect of inhibitors on the total nitrogen budget of the vegetable production system.

Manures were found to emit GHG's at rates of up to 20 times higher than inorganic fertilisers in this project. Given this result and the frequent use of manures in vegetable production systems, there is great potential to reduce GHG emissions through better manure management. Trials conducted in Victoria demonstrated a 19% reduction in GHG emissions from the application of nitrification inhibitors on manure on the surface, and a 60% reduction on manure treated with inhibitors and incorporated into the soil. This result is significant and practice change as a result of this work can be immediate. The added benefit of inhibitors on manure was the increased yield response seen across the trials (in the absence of the $CaNO_3$ side dressing).

This project has identified areas for improved emissions management on vegetable farms. However, the demonstration focus in the two year period has only just scratched the surface in terms of answering some of the complex questions related to reducing GHG emissions on farm. Further work is needed to understand the complexity of emissions reduction across such a diverse industry and the integrated supply chain. This being said, this project has provided the vegetable industry with enough information to make more informed management decisions on farm to reduce GHG emissions.

3. Introduction

Agriculture is estimated to have contributed 87.9 $MtCO_{2-e}$ in 2005, of which horticulture and the vegetable industry are estimated to have contributed approximately 1 $MtCO_2$-e (1.1%) and 0.6 $MtCO_{2}$-e (0.7%) respectively (Rab, et al., 2008). Therefore, the vegetable industry contributes approximately 55% of greenhouse gas (GHG) emissions attributed to the Australian horticulture industry. Deurer et al. (2008) stated that the contribution of horticulture to the GHG footprint of agriculture is small, primarily because of its smaller area of land use. However on a per hectare basis, horticulture and vegetable production in particular, has a higher impact than other agricultural sectors primarily through more intensive practices and higher fertiliser use. However, given the greater sophistication of vegetable production practices there are strong opportunities to reduce GHG emissions and thus improve the carbon footprint of the Australian vegetable industry.

Both the quantity of direct on-farm emissions and opportunities to reduce them vary by farm, location, climate, crops grown, inputs and markets where the vegetable products are sold. With such diversity in the industry the most suitable approach to first measure and understand the source and quantity of GHG emissions from any one farm was to conduct a series of demonstration studies across some of the major growing regions in Australia.

This demonstration project focussed on three key objectives to increase the understanding by the vegetable supply chain of the market requirements for carbon/ sustainability, and provide information to industry to be able to address these market requirements. These three objectives were:

- Identify how Carbon is an important part of the overall sustainability picture for the Australian vegetable industry.
- Understand (GHG) emissions and demonstrate their management in the vegetable supply and marketing chain.
- Develop information products, which can be utilised by the vegetable farming community in helping vegetable growers manage GHG emissions.

These objectives were achieved by:

- trialling and demonstrating the implementation of emissions management practices within vegetable production.
- demonstrating the benefit of on-farm emissions management to the vegetable industry, including improvements in profitability across a range of emissions sources including fuel, electricity and fertiliser.
- producing case studies based on the demonstration sites that outline the business case, including benefits and risks of implementing the demonstrated cropping systems and management techniques.
- consultation with retailers on carbon and sustainability issues.

Five demonstration sites were established on vegetable production farms on the east coast of Australia. These sites were used to trial and implement emissions reductions techniques to increase the ability of the vegetable industry to manage their emissions and improve their productivity. On farm demonstration and communication of the business case were used as drivers for the uptake of these practices to adopt methods to reduce GHG emissions. The project also aimed to provide information for vegetable producers to supply produce that meets consumers growing demand for food that is grown in sustainable and low emissions production systems.

4. Background

4.1 Vegetable Industry in Australia

The Australian vegetable industry is a multifacetted and diverse industry which is represented across every state and territory in Australia. The geographical spread and range of crops grown present unique opportunities and challenges to the industry, and its close relationship with the domestic and overseas markets require careful consideration of the supply chain to provide a clean and fresh product.

According to the vegetable industry's peak industry body Ausveg, the vegetable industry consists of approximately 5800 vegetable businesses. The industry was estimated by ABARES to have a gross value of production of $3.6 billion in 2011/12, some 7 % increase in growth from previous years. The total land area in vegetable production is estimated to be approximately 120-130,000 ha with around 62% of growers operating their business on farms less than 50 ha in size (Ausveg 2011).

The needs of the vegetable industry are complex, from regional issues, crops grown, position in the supply chain, farm size, business model, strategic outlook, and skill base. In addition, the vegetable industry is very closely integrated with the whole supply chain, perhaps more than other agricultural industries. Supply chain partners such as packers, processors, marketers, wholesalers, agents, providors, retailers and food service companies all influence the supply of quality vegetables to the consumer.

Whilst needs of the industry may be complex on one level, there are issues and opportunities that are common to the majority of the industry. These include climate change, long term sustainablity of natural resources and productivity, consumer demand, workforce issues and input costs.

Some of these issues remain out of the hands of individual growers, however there are some direct actions that growers can take on farm to ensure that the production remains resilient over the long term for a productive and sustainable future. Combatting the impacts of climate chage is a good example, and vegetable growers are required to consider the long term implications of climate change on their business and develop ways to mitigate and adapt to climate change. Some of the key vegetable farming practices that will be pivotal to mitigate climate change are recorded below, and are recorded as a background to this report to provide a snapshot of current industry practice.

4.2 Maintaining soil health and soil carbon for production

The majority of vegetables in Australia are produced under field growing conditions; therefore the function and 'health' of the soil is pivotal to long term crop productivity.

Soil health declines worldwide have been attributed to land clearing largely for agricultural purposes, with soil physical and chemical factors such as erosion, acidity and salinity being the main documented effects. Soil biological factors that relate to soil health have been given less attention, mainly because they are comparatively poorly understood. This is despite the scientific understanding that the biological, physical and chemical attributes of soil are closely intertwined and that soil function is largely dependent on interactions between the three. In recent years, a holistic or "ecosystems" approach to soil health management has been evolving, but understanding of the biological component of the trilogy is still far behind the understanding of soil physical and chemical factors (Porter *et al.* 2007).

Good soil health is largely driven by the amount of carbon in the soil, which provides both the food for soil organisms (good and bad) and helps build the good soil structure required for root growth and water storage. Cropping practices within the vegetable industry, especially tillage, tend to reduce soil carbon levels. The greater the intensity of cultivation, the greater the loss of soil carbon. Within raised bed vegetable production systems in Australia, soils are typically cultivated many times prior to planting. As a consequence, soil organic matter levels are typically low; often around 1-2% (Rogers *et al.* 2012).

Efforts in recent years to address the declining soil carbon levels have taken place both deliberately, and by default. Industry practice to utilise low cost organic inputs and strive toward innovative cultural advancements with crop rotations have resulted in more of a focus toward long term soil health and maintenance of soil carbon levels.

4.3 Fertiliser Practice in the Vegetable Industry

While horticulture only represents a small proportion of land used for agriculture in Australia (vegetable = 0.034 per cent, horticulture = 0.13 per cent), horticulture accounts for approximately 12 per cent of nitrogen fertiliser use in Australian agriculture, exemplifying the high rates of nitrogen fertiliser used in the horticultural industry (O'Halloran *et al*. 2008).

Nitrogen is not only the most important nutrient to crop production, it is also an integral component for the generation of the greenhouse gas nitrous oxide (N_2O).

Nitrogen (N) exists in two forms in the soil, organic and inorganic nitrogen. While organic nitrogen is not directly available to plants it can account for the majority of all nitrogen occurring in soil. The decomposition of organic matter in the soil occurs via a number of microorganisms, resulting in a process called mineralisation, where organic nitrogen is converted to inorganic nitrogen forms. The inorganic plant available forms of nitrogen include ammonium and nitrate.

As organic material decomposes, plant residues or soil microbes can tie up inorganic nitrogen in the soil, making it unavailable to plants, a process known as immobilisation. Nitrogen, particularly in the nitrate form can also be lost from the soil through leaching during irrigation and heavy rainfall events and denitrification, or the conversion of nitrates into gaseous nitrogen and nitrous oxides, in water saturated soils.

4.3.1 Current fertiliser practices

Current fertliliser practice in vegetable production varies significantly, dependent largely on the crop being grown, the region or location the crops are grown, soil type, availability of fertilisers, and the individual management of a crop. Growers usually consider what to apply and how much to apply via careful consideration of the fertiliser price, fertiliser type (e.g. granular, liquid), elemental concentrations required in the product, previous success with the product, season, and previous paddock history. With this being said many growers within the industry tend to stick to a set "recipe" of fertiliser type and quantity for any given crop. This makes sense when previous crop yields and crop performance provide growers with the knowldege and confidence to successfully produce crops into the future.

4.3.2 Granular applications of nitrogen

Granulated nitrogenous fertilisers include urea, compound forms of nitrates (e.g. ammonium nitrate), and compound forms of ammonia (ammonium sulphate). Granulated nitrogenous fertilisers are usually applied to vegetables around planting time, with additional applications of nitrogen applied as a side dressing throughout the growing season. Nitrogen applied at planting usually represents a minimum 50% of the total nitrogen to ensure that the young plants have ample supply of available nutrients to the small root zone throughout the first few weeks of growth.

Current recommendations from publications in the public domain suggest that most vegetable crops require approximately 150 kg N/ha. This can vary depending on the crop type, length of the crop, soil type, planting configuration, current nitrogen concentration in the soil and irrigation management. In some instances, nitrogen fertiliser rates have been observed above 200 kg/N/ha for maximising yield.

4.3.3 Organic fertilisers

Organic soil amendments are used extensively in the production of vegetables. Products or bi-products derived from crop residues, green waste or animal waste form the majority of organic amendments. Of the available amendments, chicken manure, cow manure and composted green waste are utilised most in the industry as both fertiliser and soil conditioning amendments.

Organic amendments have typically been used by the industry for 2 reasons:

- Relatively cheap and locally sourced supply of nutrients
- Soil conditioner - improve soil physical, chemical and biological properties.

Many vegetable growing regions flank major cities in Australia, and the ongoing use of organic amendments is dictated by the continuous supply of consistent quality products at a low cost. Given that transport costs usually make up a significant component of the costs for the delivery of organic amendments to the farm gate, most products are sourced from within a growing region.

For this reason most of the major vegetable growing regions of Australia use chicken manure more than any other organic fertiliser. The manure is available in good supply, and typically has high rates of nitrogen, phosphorous and potassium in forms that are readily available for plant uptake. The percentage of N/P/K is typically 2.5/1/1, higher than that seen in any other animal manure.

Chicken (or fowl) manure is sourced from the intensive broiler production, where chickens are produced within controlled environments. After the chickens are harvested the manure is collected from within the growing sheds, and the manure is usually combined with sawdust or fine wood shavings, the bedding material first placed in the shed during the broiler production period. Composting of the manure varies, with fresh manure described as "hot" manure, which can be toxic to plant growth.

4.3.4 Managing nitrogen through the system

Managing nitrogen in an intensive crop production system requires continual analysis and monitoring of the yield and quality of each crop, together with the consideration of the soil type and local environment. Nitrogen can be highly mobile through the soil, particularly in irrigated crops such as vegetables. Leaching of nitrogen into the groundwater, and runoff, can cause long term environmental impacts. It is in the grower and vegetable industry's interests to make every effort to ensure that nitrogen is retained within the root zone for plant growth, as environmental consequences for nitrogen loss may be high.

This being said, one of the fundamental requirements for commercial vegetable production is yields must be maximized for every unit of land farmed together with every unit of nitrogen applied to remain cost effective and profitable in production. The yield potential curve tapers away toward the upper rate of fertiliser application, demonstrating that additional fertiliser will not generate a proportionate increase in yield. For intensive vegetable production this trade-off between maximizing yield without oversupplying fertiliser requires constant monitoring and evaluation for each crop. Temperature, rainfall, and length of time the crop is in the ground all have an impact on fertiliser decisions made by growers.

Given the statement above, fertiliser inputs within intensive production is the critical key to successfully maximizing yield within the relatively small production areas used. Therefore fertiliser could be considered as insurance, or a risk management tool that growers maintain total control of the input. Consider then that fertiliser is used as a risk management tool, with growers usually preferring to supply, or slightly oversupply nitrogenous fertilisers in order to maximize yield at the other end of the crop. Or put this in another light, where the cost of fertiliser is relatively cheap, a 10-20% reduction in fertiliser application may result in a 2-5% loss in yield, resulting in a much lower gross margin due to the yield penalties and relative costs of the commodity when compared to the fertiliser input cost.

This scenario fundamentally underpins the focus of this research study, where the potential for improved nitrogen management within the Australian vegetable industry not only aims to validate current nitrogen management practices, but also to drive best management practice, where nitrogen use efficiency is improved to reduce losses through leaching and volatilization, whilst maintaining or improving productivity.

4.4 Tillage Practices in Production

The intensive production of vegetables, combined with relative short production times for each crop requires ongoing cultural management of the soil profile to maximise plant growth. The majority of the vegetable farms in Australia grow vegetables in prepared beds; with the shape, height and width of the beds being dictated by the soil type, crop grown, irrigation infrastrucutre and plant machinery. The reasoning for prepared raised beds in production are numerous, with irrigation and the control of water usually being the primary focus.

Up to 3-4 vegetable crops can be planted per unit area annually. After one crop is harvested a significat amount of biomass is usually left behind with the harvestable component sometimes only being a small part of the plants biomass e.g. broccoli. This residual biomass (including roots) in conventional vegetable production is typically turned back into the soil after harvest and left to fallow for a period to allow the breakdown of the biomass.

Biomass turned back into the soil provides a source of organic matter and carbon to the soil. The organic matter from most vegetable residue is not fibrous or woody and has the potential, given the right conditions, to be broken down very quickly in the soil by soil micro-organsims.

Vegetable producers practicing conventional production will fallow land after harvest and till crop residues back into the soil. During the fallow period producers will typically maintain weed control via herbicide sprays. Given the relatively short turnaround time in production, producers will typically operate to a program to ensure theres an ongoing supply of crops in the ground and going to market, whilst ensuring that costs are minimised.

Cultivation requires a lot of energy, but it also increases loss of soil carbon because of increased soil aeration and exposure soil organic matter otherwise physically protected by soil structure. Numerous studies have demonstrated increased losses of carbon relating to tillage, however losses vary depending on soil type and type of tillage used (O'Halloran 2008). With intensive cropping like vegetable production, farms practicing conventional tillage often have low soil carbon content, even with the addition of soil amendments and crop residues.

A trend toward minimum tillage and controlled traffic farming in broadacre cropping across Australia has occurred over the last 30 years. One of the key drivers of this cultural shift was soil health and better water retention in the soil. The vegetable industry has invested signifcant funds into the research and development of these minimum tillage cultural practices. While there has not been widespread adoption of these practices at this time, there is an ongoing shift toward farming with long term soil health and sustainability now considered in farming decisions. The use of permanent beds, cover crops and minimum tillage all have high potential, but need to be further researched to provide the industry and individual producers with confidence that a change to the cultural farming practice will work in their situation. Some barriers to adoption so far are listed below:

- Crops in rotation require different bed shapes and widths
- Machinery is specialised for each crop in rotation
- Soil disease incidence
- Taking land out of production to grow cover crops
- A lack of information to assist growers identify and implement appropriate practices

4.5 Managing Greenhouse Gas Emissions on Farm

The identification of agriculture's contribution to greenhouse gas production in Australia led the horticulture indstry to invest in research and development projects to identify where the emissions are coming from in production, and methods to minimise greenhouse gases from production.

Dick *et al* (2008) divided farm emissions into three groups: 1) indirect emissions associated with goods and services imported onto the farm 2) Direct farm emissions (e.g. fuel emissions from tractor and other farm machinery, crop residue decomposition or burning, soil organic matter decomposition, manure storage, changes in carbon storage in soil and vegetation); and 3) carbon sequestered in products exported from the farm (e.g. grain, silage, beef). Initial scoping studies on horticulture properties found that energy use, fuel use and fertliser use were the 3 major sources of on-farm greenhouse gases. With this in mind, Horticulture Australia Limited funded the development of the "vegie carbon tool" to provide vegetable growers the opportunity to measure and benchmark their greenhouse gas emissions from on-farm activities (www.vegiecarbontool.com.au).

Energy use, fuel use and fertilisers represent some of the most significat costs to production. Efforts to measure and minimise the GHG emissions from these sources will actually drive efficiencies and innovation that will reduce these costs, in addition to reducing greenhouse gas emissions from on-farm activities.

The vegetable industry is not a very large emitter of greenhouse gases. However, given the information presented above, there is such potential to look at current vegetable production processes and find improvements that will result in more efficient use of fertilisers, higher potential to sequester carbon in the soil, and reduce energy and fuel consumption.

With the context of the Background provided in this report, and the current industry practice, five demonstration field sites were selected for reduced emissions reduction techniques and are detailed below.

5. Victorian Demonstration Trial Sites

General Metholodology

The treatments applied at the demonstration sites were consistent with current best practice and included the main inputs (fertilisers and manures) that contribute to N_2O and CO_2 emissions. In particular these included the impact of high analysis nitrogen fertilisers compared with stabilised nitrogen fertilisers, organic manures (chicken manures, green waste organics, silage) and other carbon treatments, (e.g. lignite). At all sites the standard grower practice was used to compare with the potentially more environmentally sustainable and 'lower emissive' practice. Also, where possible, effects on crop productivity, disease and profitability of each practice were calculated (but this was constrained by funding and labour).

From this information charts showing the difference in emissions between different production practices have been presented to enable growers to compare practices. A simple benefit/cost model was used to calculate profit gains from the yield obtained from use of stabilised fertilisers and manures. The impacts on soil carbon are also discussed briefly.

Table 1. Site characteristics for demonstration sites at Werribee and Boneo in 2011 and 2012.

Year	**2011**	**2012**	**2011**		**2012**	
Demonstration Site	**Werribee 1**	**Werribee 2**	**Boneo 1**	**Boneo 2**	**Boneo 3**	**Boneo 4 & 5**
Host Crop	**Broccoli**	**Lettuce**	**Broccoli**	**Broccoli**	**Broccoli**	**Broccoli**
Soil classification	Red sodosol		Tenosol (Bleached – orthic)			
Soil texture	Fine sandy loamy clay		Loamy sand			
Soil temp. (mean)	18.3	22.4	19.2	19.2	25.4	25.4
Soil moisture (Est. range)		27-55			8.3 - 13.5	
Cropping period	Mar - May	Dec - Jan	Mar - Jun	Mar - Jun	Feb - Apr	

Table 2. Treatment and fertiliser schedule for demonstration trials at Werribee and Boneo in 2011 and 2012.

Trial	Pre-plant	Fertiliser Applications				Harvest Dates		
		At Transplant	Top-dress	Base Boneo 2	Budding N application	H1	H2	H 3
Werribee 1	1/03/2011	2/03/2011	15/03/2011		20/04/2011	4/05/2011	7/05/2011	12/05/2011
Boneo 1		16/03/2011	6/04/2011		13/05/2011	27/05/2011	2/06/2011	
Boneo 2	8/03/2011	16/03/2011	18/03/2011	8/04/2011	13/05/2011	27/05/2011	2/06/2011	
Werribee 2#		6/12/2011	21/12/2011			24/01/2012		
Boneo 3	14/02/2012	21/02/2012	none		19/04/2012	26/04/2012	1/05/2012	4/05/2012
Boneo 4 & 5		21/02/2012	none		19/04/2012	26/04/2012	1/05/2012	4/05/2012

N applied at routine intervals

Table 3a. Nitrification inhibitor products used

Product/abbreviation	**Chemical name**
ENTEC® (DMPP)	3,4-dimethyl pyrazole phosphate
DCD	dicyandiamide
Triazole	1 H-1,2,4- triazole
3-MP	3-methylpyrazole
Piadin®	1 H-1,2,4- triazole, 3-methylpyrazole

Table 3b. Fertiliser products used in Victorian Trials

Product	N : P : K	Manufacturer	Nitrogen form	Nitrification inhibitor
Nitrophoska Special®	12 : 5.2 : 14.1	Incitec Pivot	Ammonium/nitrate	None
ENTEC Nitrophoska Blue®	12 : 5.2 : 14.1	Incitec Pivot	Ammonium/nitrate	DMPP
ENTEC Urea[1]	46 : 0 : 0	-	Urea	DMPP
Alzon® 46	46 : 0 : 0	SKW Piesteritz	Urea	DCD, triazole
Perlka®	19.8 : 0 : 0	Alz chem	Cyanamide	DCD
N-Sure®	26 : 0 : 0	Incitec Pivot	Ammonium/nitrate	None
AAMO[2]	12 : 5 : 14	Dongbu	Ammonium/urea	None
Nitrabor®	15.4 : 0 : 0	Yara	Nitrate	None
Calcium nitrate	15.5 : 0 : 0	Incitec Pivot	Nitrate	None

[1] Not a commercial product

[2] Australian Agricultural Marketing Organization

Irrigation

At all sites plots were irrigated by overhead sprinklers either daily or every second day or as required by the crop. Generally the grower irrigated to fit in with gas sampling for before and after irrigation samples if required. This meant irrigation between 12.00 hr till 14.00 hr. Gas sampling always took place within 1.5 to 2 hours after irrigation.

Measurement of Greenhouse Gasses:

Measurements of on-farm greenhouse gas (GHG) emissions were made using manual (static) chambers. Gas samples were collected at regular intervals (every 24 hrs for 5 days and then weekly or fortnightly until harvest) after fertilisation or treatment with organic products. At each site up to 88 chambers were used. The carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) concentration was determined by gas chromatography at the Queensland University of Technology. Soil temperature and moisture were measured at the same time as gas collection during the one hour time period during which gasses were measured.

Economic Assessment:

At each site, a preliminary economic assessment of proposed and actual changes to farming practices, including the cost-effectiveness of reducing GHG emissions and/or energy inputs, was conducted. The economic assessment looked at the variable costs between treatments which included the difference in treatment costs, the cost of labour for harvests, machinery and fuel between the different treatments.

Trial design:

All trials were set up as randomized block designs using simple factorial designs. Each treatment was replicated at least 4 times.

Statistical Analyses:

Yield and related trial data were analysed using Anova (Genstat Version 14).

5.1 Werribee, Victoria

5.1.1 Demonstration Site 1, Werribee, Broccoli, (Fine sandy loamy clay) 2011.

Figure 1. Application of treatments at the Werribee field site in 2011.

Key Aim

To determine the effect of different stabilised (i.e. with nitrification inhibitors) fertiliser treatments (i.e. ENTEC Nitrophoska, ENTEC urea, Alzon, Perlka), with and without chicken manure, compared to the standard grower practice on greenhouse gas emissions, productivity and profit. In addition, a half dose fertiliser treatment was evaluated to determine if similar yields could be achieved with stabilised fertilisers using lower fertiliser rates.

Method

Broccoli (cv. Viper) was planted in two rows at a density of 30,000 plants/ha in raised beds of 1.62 m width. The fertiliser treatments applied are shown in Table 4. Treatments were applied in bands over the transplant rows by hand. Pre-plant treatments (chicken manure, chicken manure with the Piadin inhibitor, and Perlka) were applied the day before planting to the surface of plots and immediately incorporated across the full bed using a rotary hoe. Treatments were applied to trial plots of 9.1 m length. Each treatment was replicated four times in a randomized block design. All treatments received a broadcast application of N-Sure (Incitec Pivot) (26 % N) at budding (20/4/11) seven weeks after transplanting at a rate of 39 kg/ha nitrogen.

Treatments

Table 4. Treatments used in the fertiliser trial on broccoli at Werribee (Trial 1). Numbers in brackets following a fertiliser refer to the amount of N applied in kg/ha.

No.	Treatment	Pre-plant (1/3/11)	Base (2/3/11)	Top dress (15/3/11)	Broadcast (20/4/11)	TOTAL Applied N kg/Ha
1	Control - Budding treatment only	-	-	-	39	39
2	Nitrophoska (base only)	-	Nitrophoska (48)	-	39	87
3	ENTEC Nitrophoska (base only)	-	ENTEC Nitrophoska (48).	-	39	87
4	$CaNO_3$ (top dress only)	-	-	$CaNO_3$ (39)	39	78
5	Standard grower Nitrophoska + $CaNO_3$	-	Nitrophoska (48)	$CaNO_3$ (39)	39	126
6	ENTEC Nitrophoska + $CaNO_3$	-	ENTEC Nitrophoska.(48)	$CaNO_3$ (39)	39	126
7	Manure incorporated	Manure (175)	-	-	39	213
8	Nitrophoska + $CaNO_3$+Manure	Manure (175)	Nitrophoska (48)	$CaNO_3$ (39)	39	300
9	ENTEC Nitrophoska + ENTEC Urea +Manure	Manure (175)	ENTEC Nitrophoska.(48)	ENTEC Urea (37)	39	298
10	Urea (top dress only)	-	-	Urea (37)	39	76
11	ENTEC Urea (top dress only)	-	-	ENTEC Urea (37)	39	76
12	ENTEC Nitrophoska + ENTEC Urea	-	ENTEC Nitrophoska (48)	ENTEC Urea (37)	39	124
13	1/2 rate standard grower	-	1/2 Nitrophoska.(24)	1/2 $CaNO_3$ (19.4)	39	82
14	1/2 rate ENTEC programme	-	1/2 ENTEC Nitrophoska (24)	1/2 ENTEC Urea (18.4)	39	81
15	Manure Incorp. + Piadin	Manure + Piadin (175)			39	213
16	Alzon + $CaNO_3$	-	Alzon (48)	$CaNO_3$ (39)	39	125
17	Alzon full rate	-	Alzon (87)	-	39	126
18	ENTEC NP (full rate)	-	ENTEC Nitrophoska 987)	-	39	126
19	Nitrophoska (full rate)	-	Nitrophoska (87)	-	39	126
20	Perlka	Perlka (87)		-	39	126

Results and Discussion

Greenhouse Gas Emissions - Werribee Trial 1

N_2O emissions (i.e. flux rates) were reduced by at least 50% at most sampling points during the period of peak emissions (up to approximately 350 hrs) by two products containing nitrification inhibitors (i.e. ENTEC Nitrophoska Blue and Perlka) relative to the standard practice of using Nitrophoska Special® and $CaNO_3$ (Fig. 2 and 3). In contrast, Alzon which contains different inhibitors to ENTEC had a higher emission rate than Nitrophoska during the period 180 to 450 hrs after application. Emissions were very low for Perlka fertiliser treatment up until 240 hrs when sampling ended for this product.

The addition of Piadin® (i.e. a mixture of two nitrification inhibitors, 3-Methylpyrazole and 1,2,4-triazole) to chicken manure reduced the N_2O flux rate by more than 75% relative to uninhibited manure over the period of peak emissions (up to approximately 460 hrs) (Fig 4). A similar level of N_2O emission reduction was observed when ENTEC Nitrophoska + Urea were added to the manure (Figs 5 and 6).

The N_2O emissions from chicken manures were much greater than those from fertilisers (Fig. 4, 5 and 6) and therefore greater potential for reduction of emissions would appear to come from management of emissions from chicken manure, and possibly other high nitrogen manures.

Top dressings of $CaNO_3$ at 15 days and at budding at 50 days contributed little to N_2O emissions (i.e. less than 5-10%) compared to the base fertiliser applications (Fig. 2, 3 and 4).

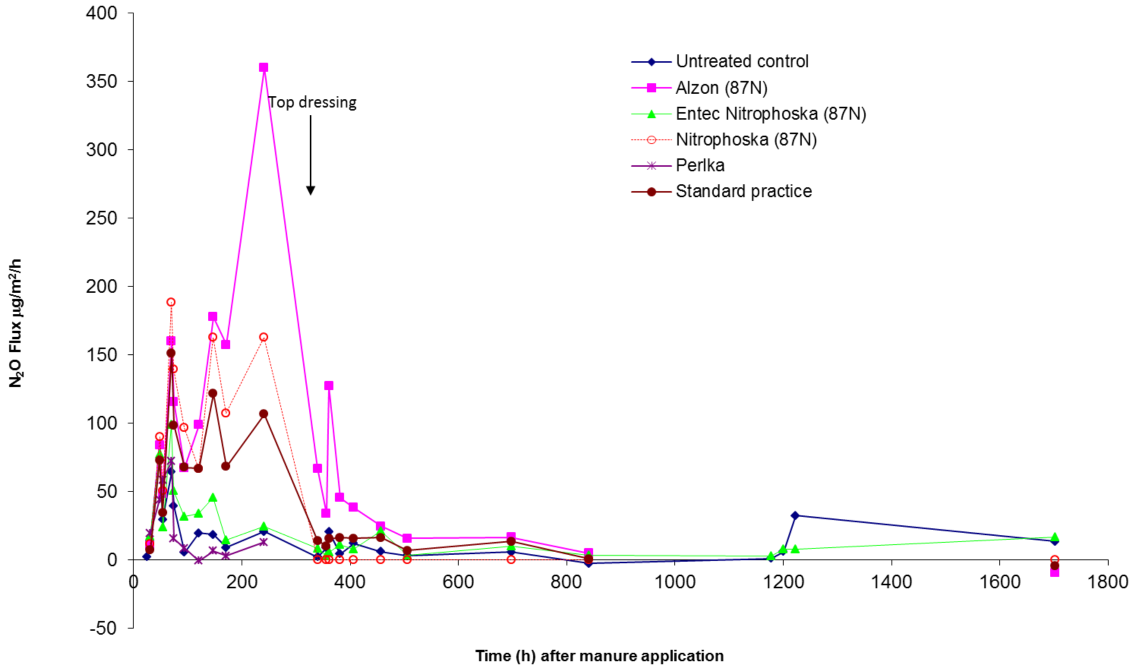

Figure 2. The effect of different fertilisers, including inhibitors on fertilisers, on N_2O emissions from the 2011 Werribee broccoli trial. (Fertilizer readings commenced 1 day after manure readings – no manure was added to the treatments, untreated plots had no fertiliser added until the CaNO3 application at budding - approx. 1200 hours).

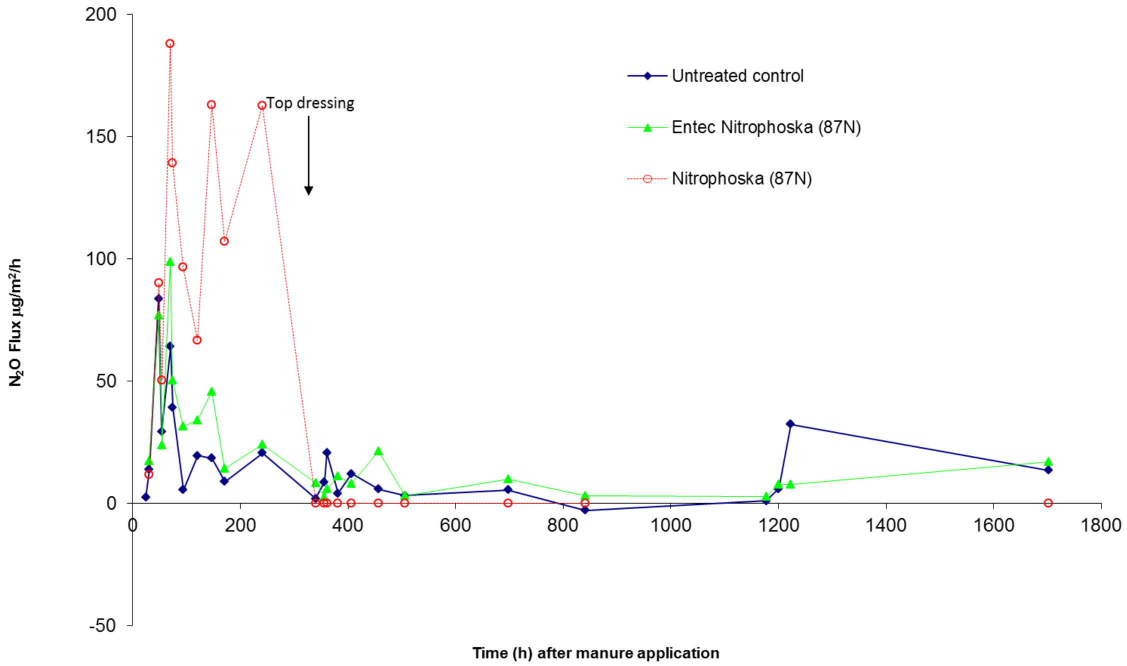

Figure 3. The comparison of N_2O emissions from the base Nitrophoska (87N) fertiliser, ENTEC (87N) Nitrophoska base fertiliser in a broccoli trial in Werribee in 2011. (Fertilizer readings commenced 1 day after manure readings – no manure was added to the treatments shown, untreated plots had no fertiliser added until the CaNO3 application at budding - approx. 1200 hours).

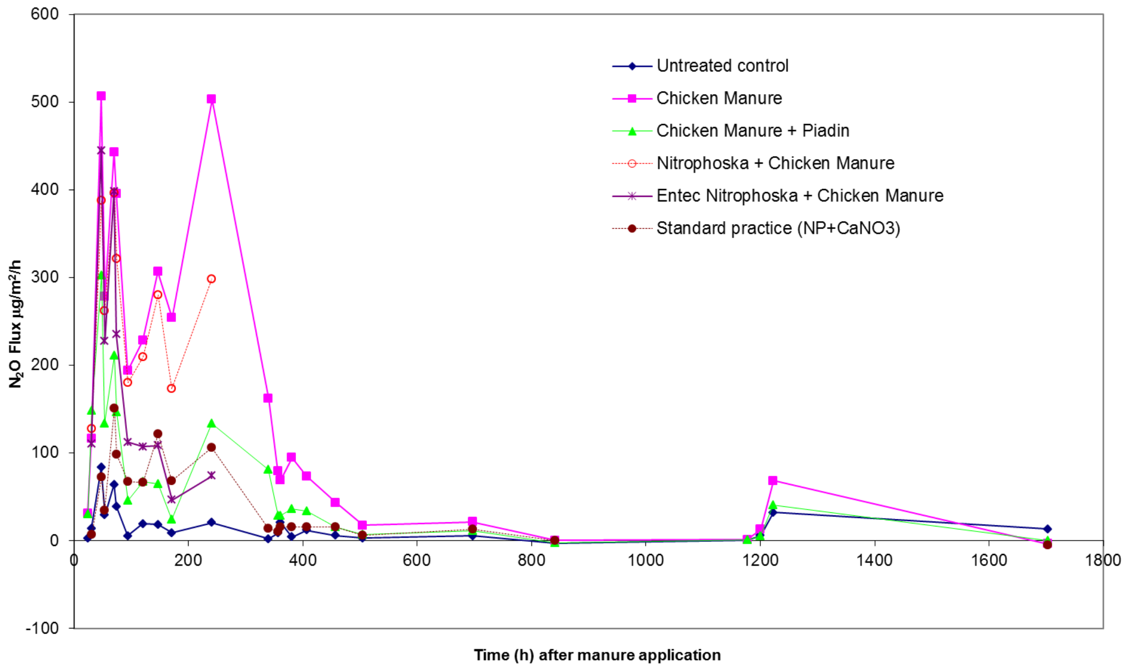

Figure 4. The effect of nitrification inhibitors on N_2O emissions from incorporated manure treatments from the 2011 Werribee broccoli trial. (Untreated control plots had no fertiliser added until budding).

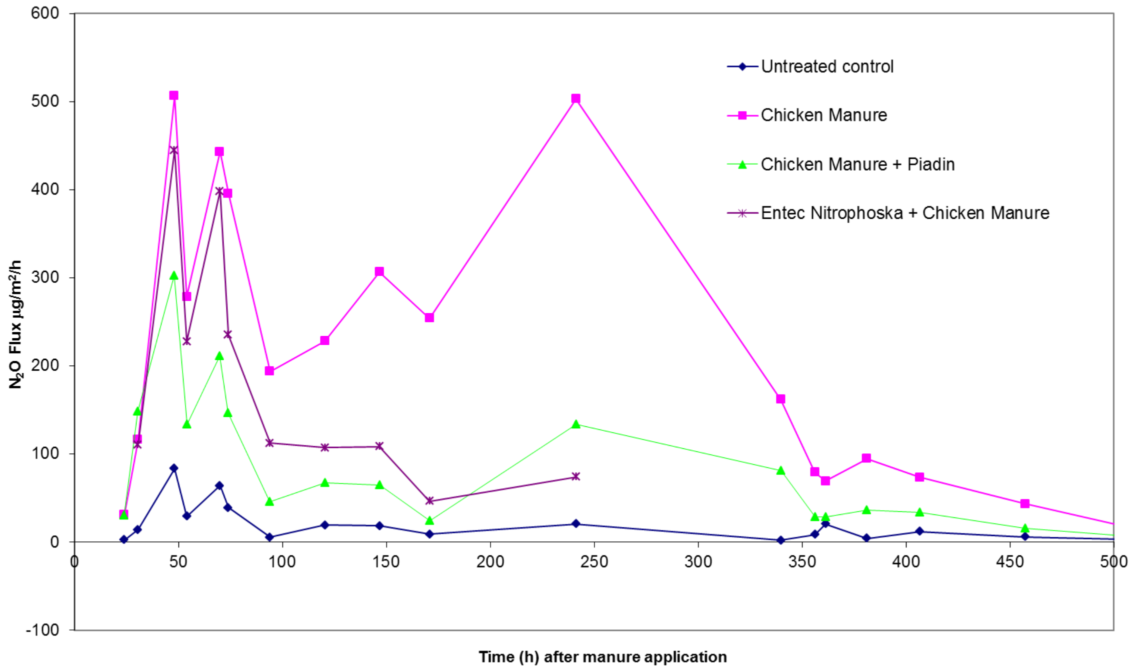

Figure 5. The effect of nitrification inhibitors on N_2O emissions from incorporated manure treatments from the 2011 Werribee broccoli trial (500 hours only).

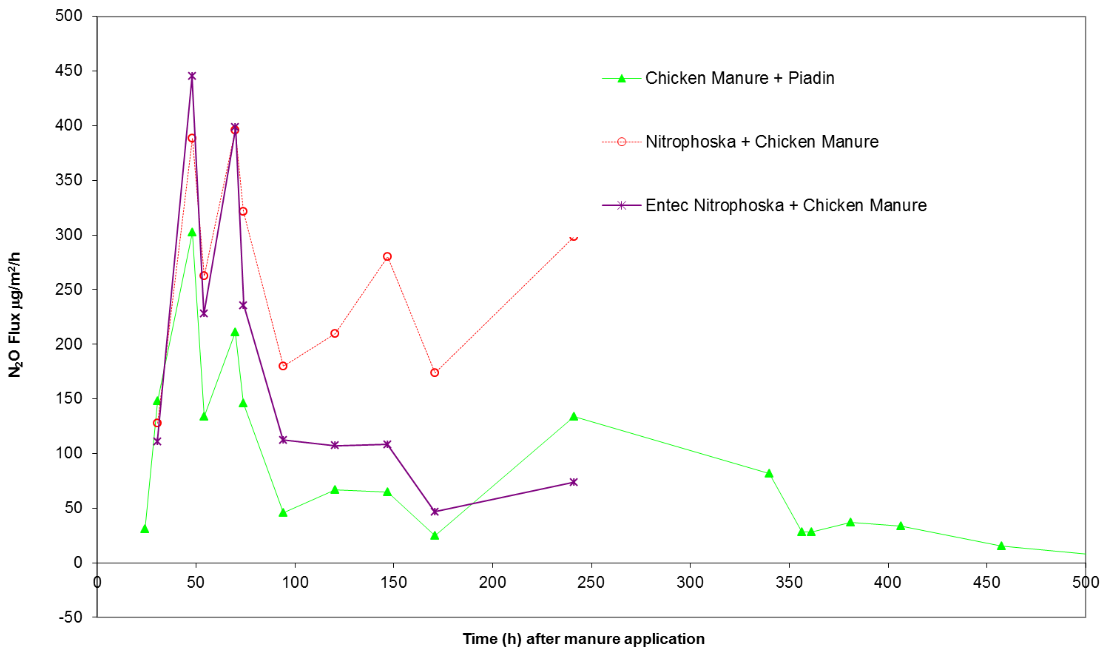

Figure 6. The effect of nitrification inhibitors applied to the manure (Piadin) or the fertiliser (ENTEC) on N_2O emissions from chicken manure incorporated into soil from the 2011 Werribee broccoli trial (500 hours only).

Yield and Average Head Weights - Werribee Trial 1

The highest broccoli yields and average head weights were obtained when manure (chicken) was added to both the standard grower program (Nitrophoska and $CaNO_3$) and the ENTEC Nitrophoska and $CaNO_3$ treatment (Table 5 Section A). These treatments yielded 51% higher than the non-fertilised controls.

Using the ENTEC stabilised Nitrophoska, whether it was applied to soils which had been amended with manure or without manure, did not affect broccoli yields compared to the standard grower practice with Nitrophoska (Table 5 Section B, Fig. 7).

There was no yield advantage when top dressings ($CaNO_3$ or ENTEC Urea) were added to the base ENTEC Nitrophoska (48N) (Table 5 Sections B and C).

Application of the ENTEC base at a lower rate of N (48N) alone without the N side dressings yielded the same as the best treatments in the trial where much greater amounts of N were applied (85-261 N) (Table 5 Section C).

The yields obtained with other programs using the stabilised fertilisers, Perlka and Alzon showed no statistical difference to the standard grower or ENTEC programs at the same N rates (Table 5 Section D).

The side dressing with $CaNO_3$ at approximately two weeks after planting did not significantly increase yields (P=0.05) although when combined with Nitrophoska there was a tendency for larger yields (Table 6).

This was anticipated as the common practice is to add a $CaNO_3$ side dressing within a few weeks after transplanting to increase yields. The $CaNO_3$ application was not effective when applied with the ENTEC base fertiliser as it was not required due to the higher levels of soil N as NH_4 at two weeks (Table 6, Fig. 8, 9 and 10). This was attributed to the inhibitor product in ENTEC Nitrophoska retaining ammonium in the soil instead of nitrate, reducing the potential for leaching and denitrification (Fig. 9 and 10).

ENTEC fertiliser reduces the need for a side dressing application of $CaNO_3$.

Table 5. Broccoli yield tables from the Werribee field trial in 2011 (Trial 1).

Treatment	Total N applied at harvest (kg/ha)	Yield (kg/5m)	% Change to SGP
A.			
ENTEC Nitrophoska + ENTEC Urea + manure	298	8.38 a	8.5
Nitrophoska + $CaNO_3$ + manure	300	7.88 a	2.1
B.			
Nitrophoska + $CaNO_3$ (Standard Grower Practice, SGP)	126	7.72 ad	
ENTEC Nitrophoska+ $CaNO_3$	126	7.32 bd	-5.2
ENTEC Nitrophoska + ENTEC Urea	124	7.43 bd	-3.8
C.			
Nitrophoska (base)	87	7.09 bd	-8.2
ENTEC Nitrophoska (base)	87	7.63 ad	-1.2
1/2 rate Nitrophoska + $CaNO_3$	82	7.39 bd	-4.3
1/2 rate ENTEC Nitrophoska + ENTEC Urea	81	7.31 bd	-5.3
Nitrophoska (base and side) - 87N	126	7.15 bd	-7.4
ENTEC Nitrophoska (base and side) - 87N	126	6.63 b	-14.1
D.			
Perlka	126	7.17 bd	-7.1
Alzon 48N + $CaNO_3$	125	7.06 bd	-8.5
Alzon 87N	126	6.66 b	-13.7
Untreated Control	39	5.56 c	-28.0
P value		<0.001	
LSD (5%)		0.841	

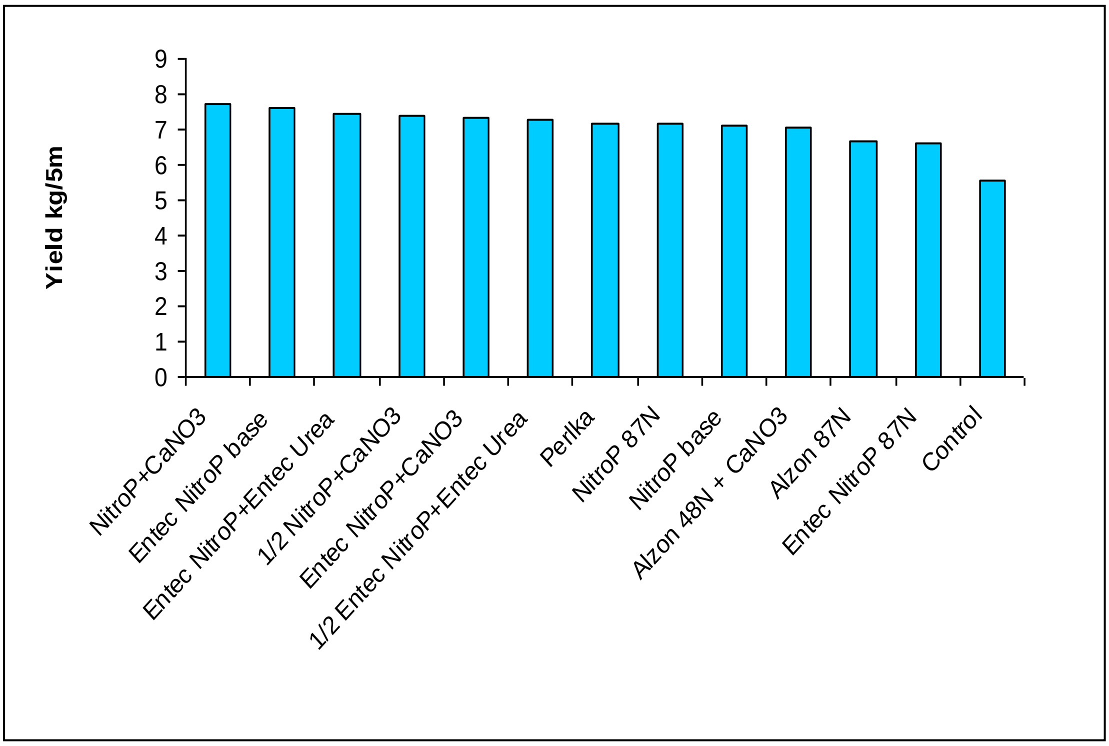

Figure 7. Broccoli yield in Werribee field trial. NitroP=Nitrophoska. (Note treatments with manures which are shown in Table 5 have not been included. The table only shows fertilizer comparisons).

Table 6. Effect of base fertiliser and top dressing main effects on broccoli yield (kg/5m) at Werribee in 2011.

Base fertiliser	Top dressing				
	Nil	**$CaNO_3$**	Mean	P value	LSD
Nil	5.56	6.79	6.18	0.002	0.688
NitroP	7.09	7.72	7.40		
ENTEC NitroP	7.63	7.32	7.47		
Mean	6.76	7.28			
P value	0.068				
LSD (5%)	NS				

NS – Non significant

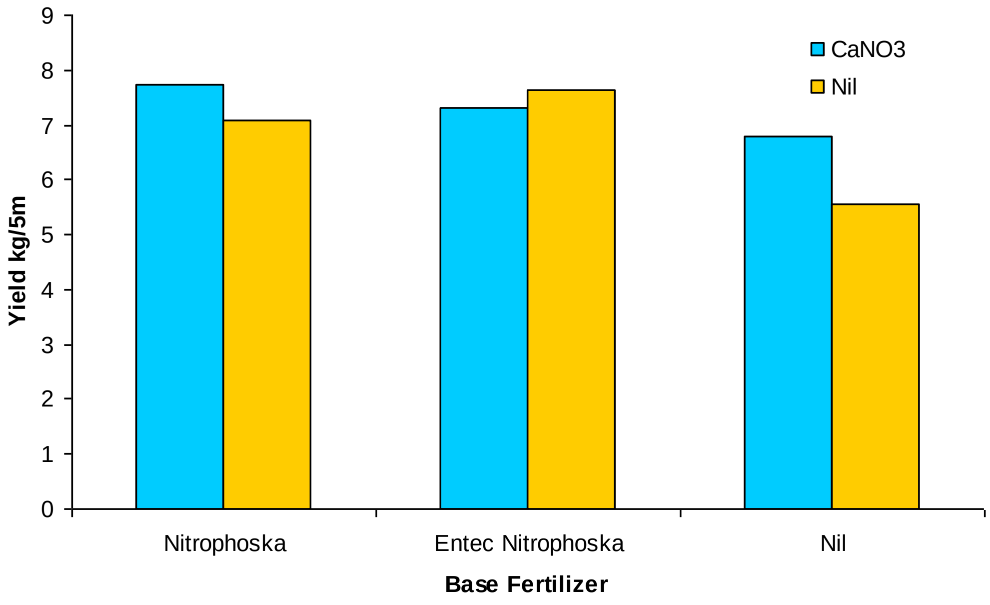

Figure 8. Effect of top dressing fertiliser applications (Nil and $CaNO_3$) on broccoli yield at Werribee in 2011.

Soil chemistry - Werribee Trial 1

The Alzon treatment (87N) and untreated control had much lower soil nitrate levels than the Nitrophoska and ENTEC Nitrophoska treatments 2 days after planting (Fig. 9). Nitrate levels increased in the Alzon treatment by 14 days to similar levels observed in the other fertiliser treatments. Ammonium levels in soil were similar for all fertiliser treatments 2 days after planting. However, the ENTEC Nitrophoska 87 N treatment had higher ammonium than all other treatments 14 days after planting (Fig. 10).

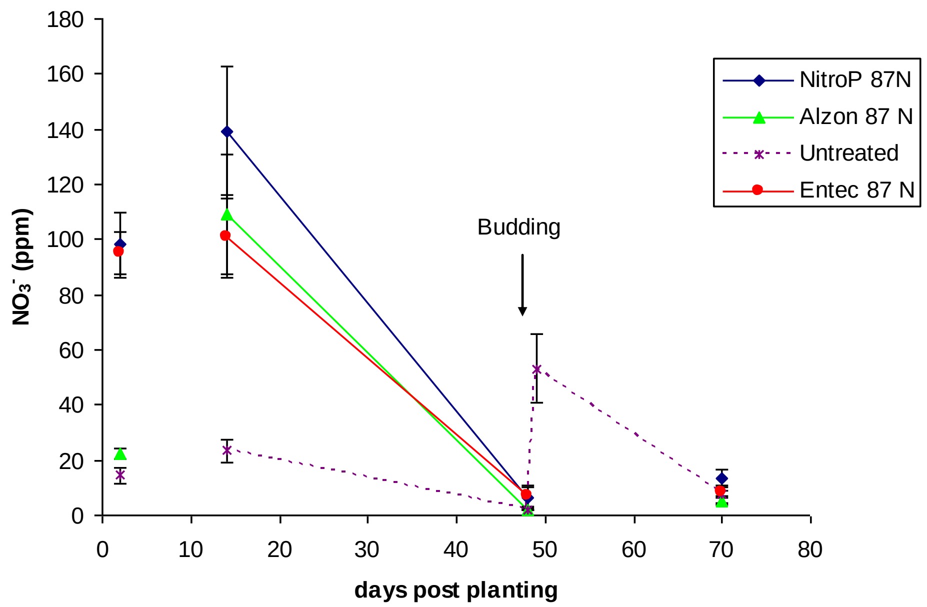

Figure 9. Soil nitrate concentration in the 2011 Werribee broccoli trial. Error bars=standard error of the mean. Nitrogen (N-Sure) was applied at budding.

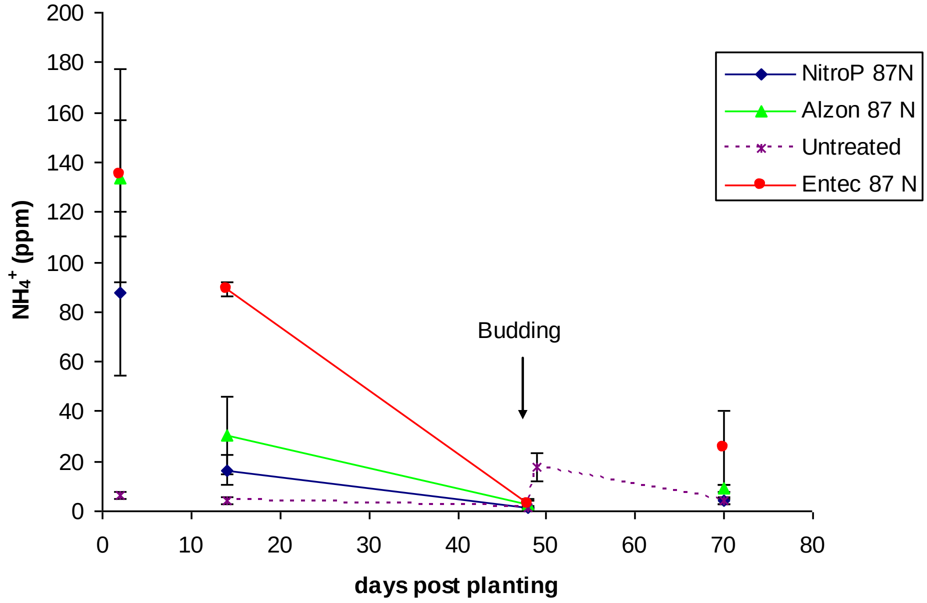

Figure 10. Soil ammonium concentration in the 2011 Werribee broccoli trial. Error bars=standard error of the mean. Nitrogen (N-Sure) was applied at budding.

5.1.2 Demonstration Site 2, Werribee, Lettuce, (Fine sandy loamy clay) 2012.

Figure 11. Photos taken at the Werribee Field site 2012.

Key Aim

To determine the effect of two inhibitors (ENTEC and DCD - dicyandiamide) and stabilised fertiliser treatments (i.e. ENTEC Nitrophoska, ENTEC urea, Alzon, Perlka), compared to the standard grower practice (Nitrophoska) on greenhouse gas emissions and productivity.

Method

Lettuce (cv. Avatar) was planted in four rows at a density of 40,000 plants/ha in raised beds of 1.62 m width. The fertiliser treatments were applied on the day of planting (6/12/2011) using a drop spreader along the transplant row (Table 7). Base fertilisers were applied at rates of 720 kg/ha and 400 kg/ha for Nitrophoska based (12% N) and Urea based (22.2%N) products respectively. Treatments were applied to trial plots of 9.1 m length. Each treatment was replicated three times in a randomized block design. All treatments received side dressing applications of (100kg/ha) of NPK Hydrocomplex (Yara Australia), fertigation with a nitrogen fertiliser + trace elements (100kg/ha) (Campbells Diamond White) and then $CaNO_3$ (100kg/ha) on the dates specified below (Table 7). Yields were determined on a 5m length from the centre of each plot on two replicates only as the grower needed lettuce for market earlier than main trial.

Treatments

Table 7. Treatments used in Werribee lettuce trial in 2012.

No.	Treatment	Units of N applied (kg/Ha)				
		Base N (6/12/11)	Side (21/12/11)	Fertigation (14/1/12)	Fertigation (20/4/11)	Total
1	No base fertiliser	-	12	15	16	43
2	Nitrophoska (SGP)*	87	12	15	16	130
3	ENTEC Nitrophoska	87	12	15	16	130
4	DCD Nitrophoska	87	12	15	16	130
5	AAMO+Alzon	89	12	15	16	132
6	AAMO+ENTEC Urea	89	12	15	16	132
7	AAMO+Urea	89	12	15	16	132

*- SGP = Standard Grower Practice

Results and Discussion

Greenhouse Gas Emissions - Werribee Trial 2

Fertiliser emissions of N_2O were only evident for the first 500 hrs (21 days) of the trial irrespective of whether N-stabilised products were used or not (Fig. 12 and 13). N_2O emissions were greater from the base fertiliser applications than the $CaNO_3$ side dressings (Fig. 14). Stabilisation of fertiliser products with ENTEC resulted in N_2O emission reductions of approximately 60% when applied to Nitrophoska or urea (Fig. 12 and 13). Reductions were the greatest during the first 200 hrs after application of the fertilisers although effects were still observed after 400 hrs (Fig. 12 to 15). Adding DCD to Nitrophoska was less effective at reducing N_2O emissions with reductions of less than 20% when used with Nitrophoska or urea (Alzon) relative to the same base fertiliser without inhibitor (Fig. 14 and 15). Urea fertiliser produced higher emissions, approximately 30% higher than ammonium and nitrate based fertiliser (Nitrophoska) when applied at the same rate of N (Fig. 12 and 13).

The greatest contribution to GWP (Global Warming Potential) from greenhouse gas emissions from vegetable production came from N_2O emissions as expected. Methane emissions had a negligible contribution to GWP and were generally not different between treatments. CO_2 emissions were often relatively high, especially for organic amendment treatments, however their contribution to GWP is often discounted as even though they have higher emissions they could still be sequestering more carbon (Grace, Pers comm.).

Plotting the total CO_2 equivalents for all 3 gases shows the relative contribution made by fertilisers in general and the reductions by using two different inhibitors.

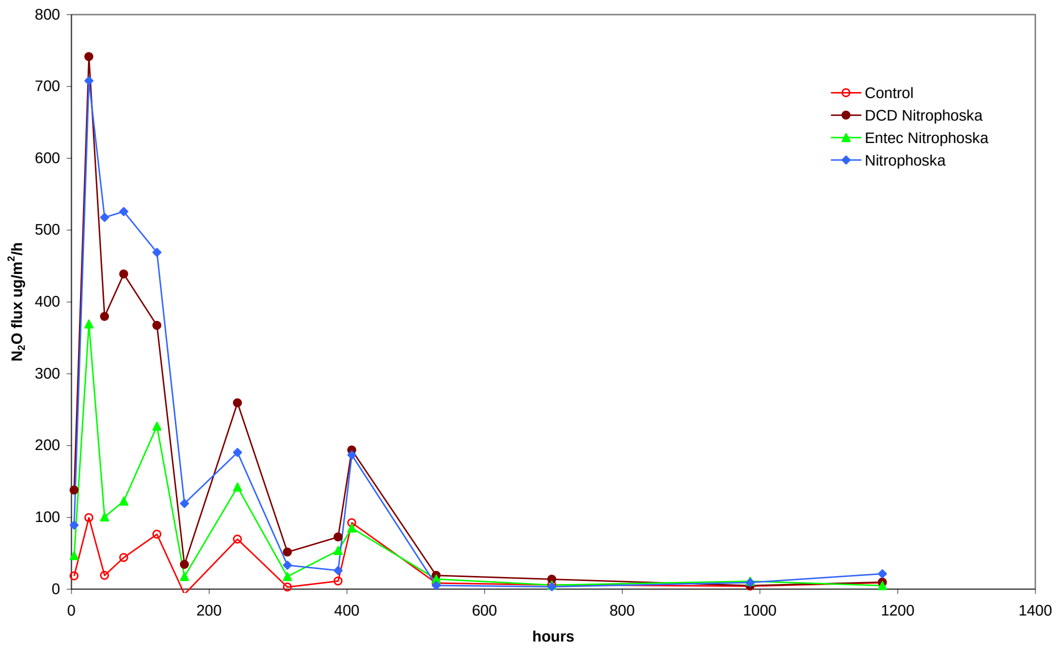

Figure 12. Effect of stabilisers added to Nitrophoska base fertilisers on N_20 emissions at a lettuce trial in Werribee in 2012.

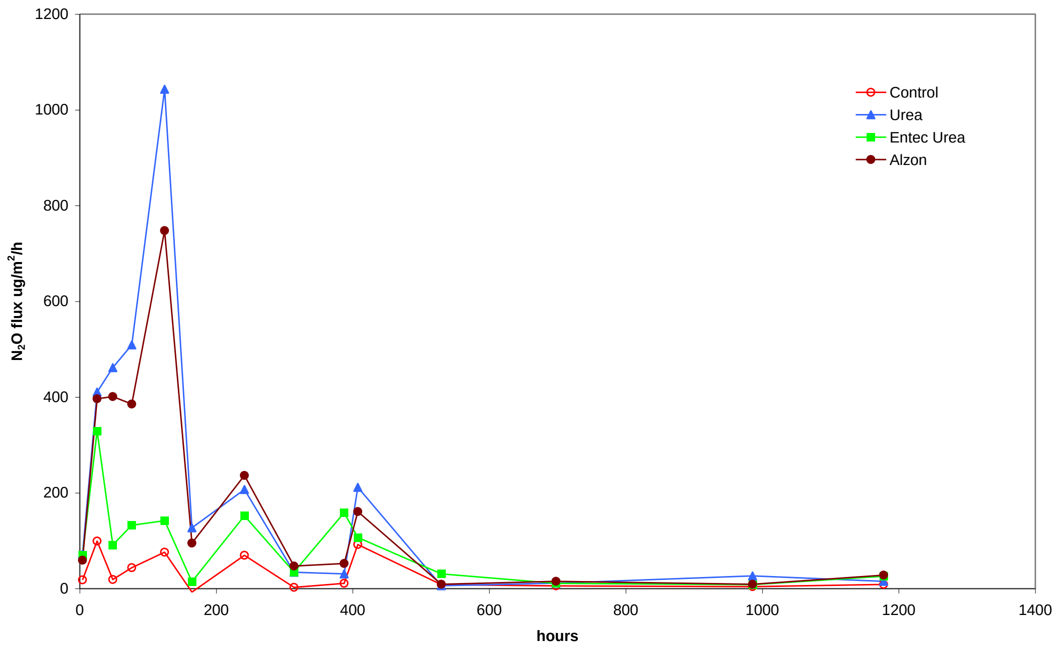

Figure 13. Effect of stabilisers added to urea base fertiliser on N_20 emissions at a lettuce trial in Werribee in 2012.

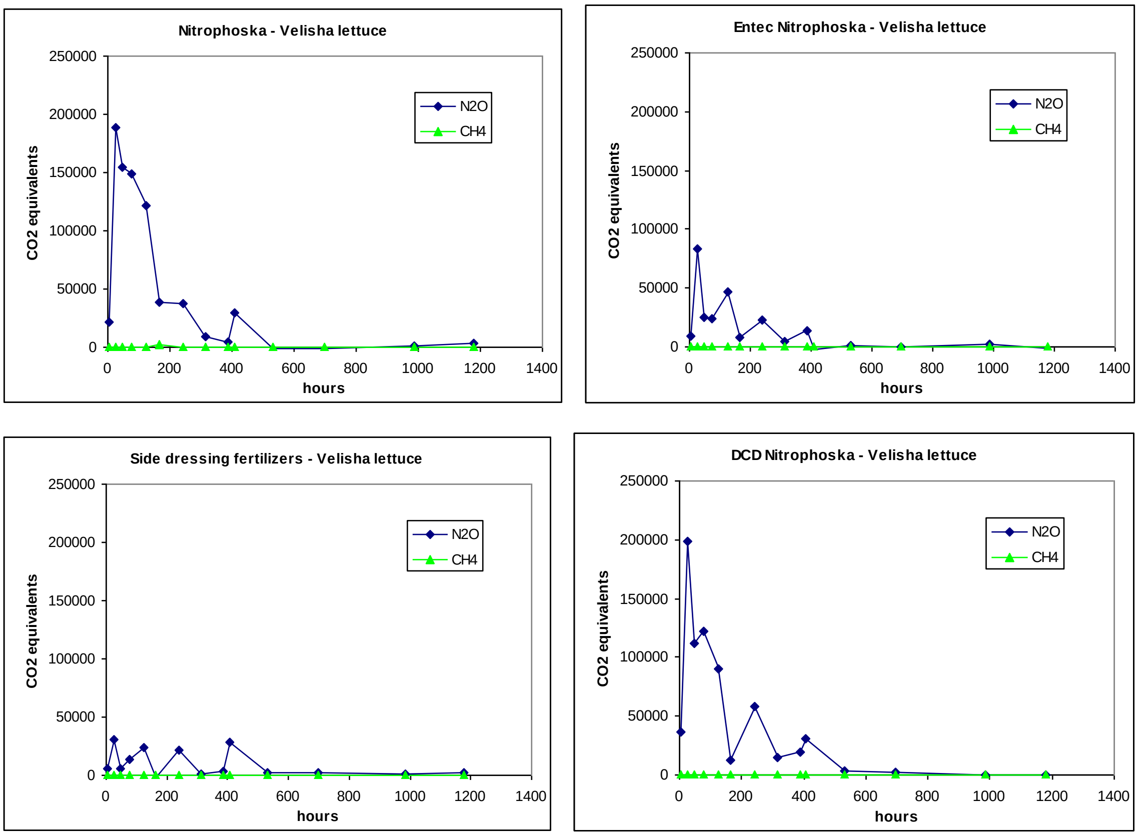

Figure 14. Effect of individual stabilisers added to Nitrophoska based fertiliser on CO_2 equivalents from emissions of N_20 and CH_4 at a lettuce trial in Werribee in 2012.

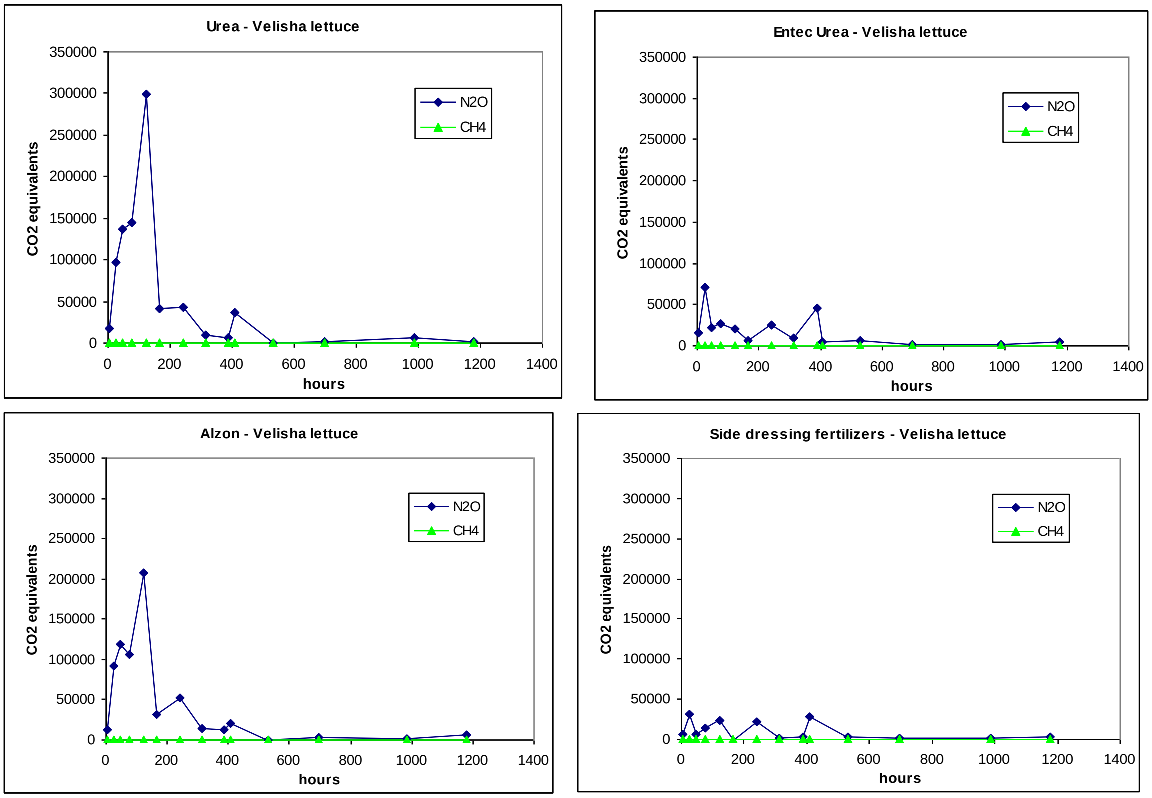

Figure 15. Effect of individual stabilisers added to urea based fertiliser on CO_2 equivalents from emissions of N_20 and CH_4 at a lettuce trial in Werribee in 2012.

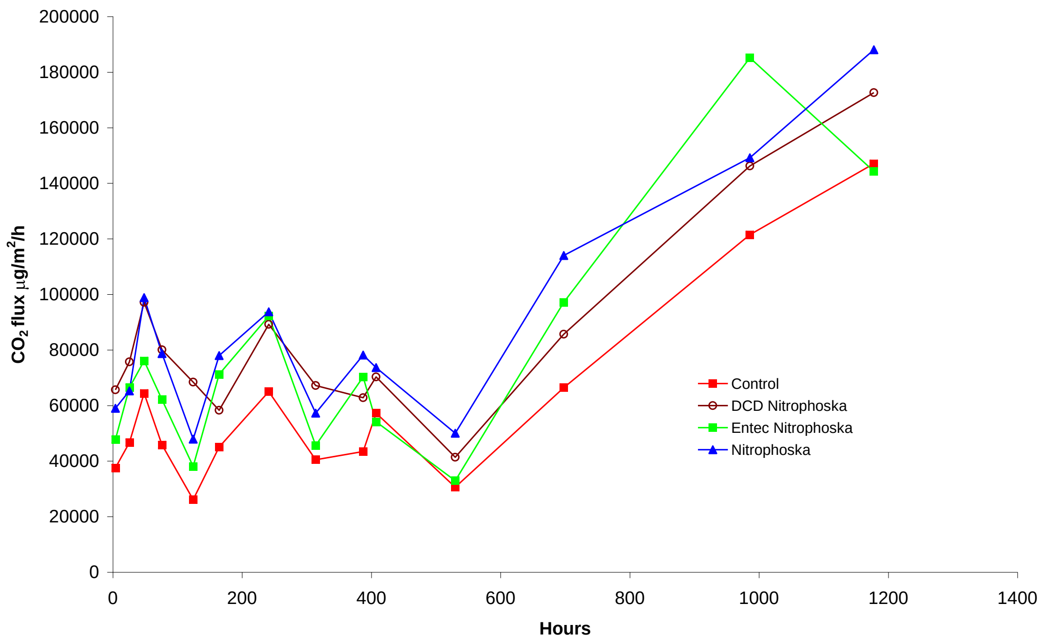

Figure 16. Comparison of the total CO_2 equivalent emissions (N_2O, CH_4, CO_2) for two inhibitors applied to Nitrophoska base fertiliser at Werribee in 2011. (Note: The control treatment contained no base fertiliser treatments but did receive the side dressings which were considered to have minimal contribution to CO2 equivalents in this trial). The increase in CO_2 after 500 hours was probably due to plant root respiration as roots had proliferated the soil in the chambers).

Yield Assessment - Werribee Trial 2

Even though only two blocks from the trial could be harvested trends in results showed useful outcomes for future trials (Table 8).

The inhibitor, DCD, when used on Nitrophoska showed similar yields of lettuce compared to the standard grower practice, whereas ENTEC Nitrophoska reduced yields. Observations of the leaves at harvest suggested that the lettuce grown in plots treated with stabilised fertilisers had too much nitrogen and it is suggested future trials consider lowering dosage rates and eliminating at least one side dressing. These lettuces tended to have large leaves and extended mid ribs and were slightly misshapen. The urea based fertilisers (urea, ENTEC urea, Alzon) also tended to reduce yields compared to the standard grower practice (SGP).

Table 8. Lettuce yields from a field trial at Werribee in 2012.

Treatment	Ave Yield (kg/5m plot)	% Below SGP
Untreated (no base fertiliser)	4.46	-37.1
Nitrophoska (SGP)*	7.09	
ENTEC Nitrophoska	5.65	-20.3
NPK + Urea	6.00	-15.4
NPK + Alzon	6.23	-12.1
NPK + ENTEC Urea	6.30	-11.1
DCD Nitrophoska	6.71	-5.4
P value	NA	
LSD (5%)		

*SGP = Standard Grower Practice: NA – Only two of the three replicates were harvested as the grower needed the lettuce prior to full maturity

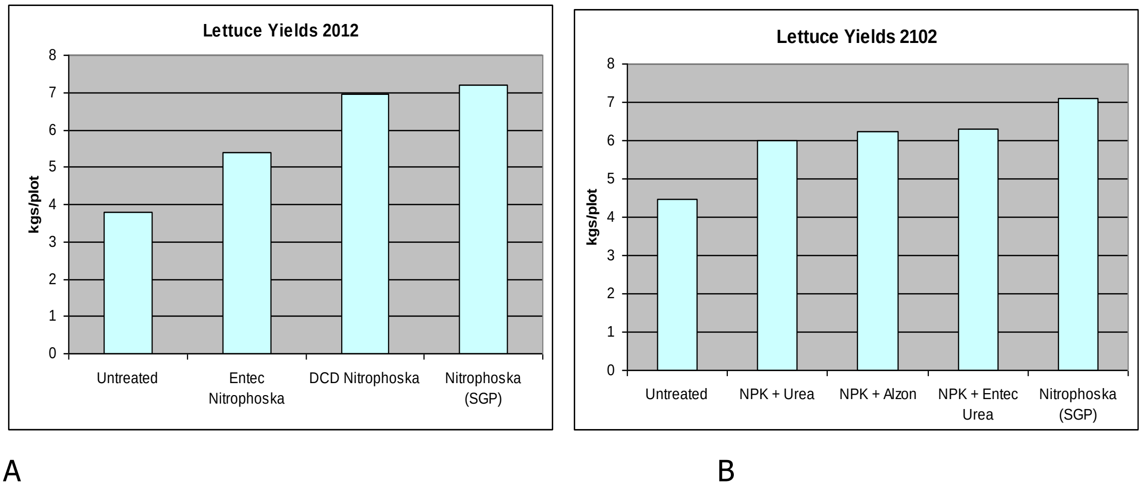

Figure 17. Lettuce Yields for Nitrophoska based fertilisers (A) and urea based fertilisers (B) at Werribee in 2012.

5.2 Demonstration Trials at Boneo, Victoria

5.2.1 Demonstration Site 1, Boneo, Broccoli, (Loamy sand), 2011

Figure 18. The Boneo demonstration site 2011.

Key Aims

To determine the effect of different stabilised (i.e. with nitrification inhibitors) fertiliser treatments (i.e. ENTEC, ENTEC urea, Alzon, Perlka), with and without chicken manure, compared to the standard grower practice on greenhouse gas emissions, productivity and profit. In addition, a half dose fertiliser treatment was evaluated to determine if similar yields could be achieved with lower rates of stabilised fertilisers.

Method

Broccoli (cv. Viper) was planted in two rows at a density of 30,000 plants/ha in raised beds of 1.62 m width. Base fertilisers were applied on the day of planting. Treatments were applied to trial plots of 10.6 m length (Table 9). Each treatment was replicated four times in a randomized block design. All treatments received a side-dress application of Nitrabor (Yara, Australia) ($CaNO_3$ + Boron) at budding (13/5/11) at the rate of 39 kg/ha N.

Table 9. Treatments applied in the fertiliser trial on broccoli at Boneo (Trial 1). Numbers in brackets following a fertiliser refer to the amount of N applied in kg/ha.

Code	Treatment	Base (17/3/11)	Top dress (6/4/11)	Budding (13/5/11)	Total N kg/ha
A1	No fertiliser	-	-	39	39
A2	$CaNO_3$ only	-	$CaNO_3$ (39)	39	78
B1	Nitrophoska (base only)	Nitrophoska (48)	-	39	87
B2	Nitrophoska+ $CaNO_3$ (SGP[1])	Nitrophoska (48)	$CaNO_3$ (39)	39	126
C	ENTEC Nitrophoska+ENTEC Urea	ENTEC Nitrophoska (48)	ENTEC Urea (34)	39	120
D	Alzon 87N	Alzon (87)	-	39	126
E	1/2 rate ENTEC Nitrophoska+ENTEC Urea	ENTEC Nitrophoska (24)	ENTEC Urea (34)	39	80
F	1/2 rate Alzon	Alzon (43.5)	-	39	82
I	Perlka	-	Perlka[2] (87)	39	126

[1] Standard grower practice

[2] Perlka was applied as 2 split applications

Results and Discussion

Greenhouse Gas Emissions - Boneo Trial 1

There were no clear reductions in greenhouse gas emissions observed for any of the inhibited fertiliser treatments relative to non-inhibited standard practice treatment (Fig. 19). Alzon tended to slow the rate of N_2O emission for the first 150 hours. After 150 hrs, N_2O emissions from the Alzon treatment were similar to the ENTEC and standard fertiliser programs at the same rate of N applied (126N), and at some time-points, were higher. Similar trends have been observed in other trials (Demonstration Trial 2, Werribee). Emissions from the ENTEC program were similar to the standard grower program (Nitrophoska + $CaNO_3$) and this was unexpected.

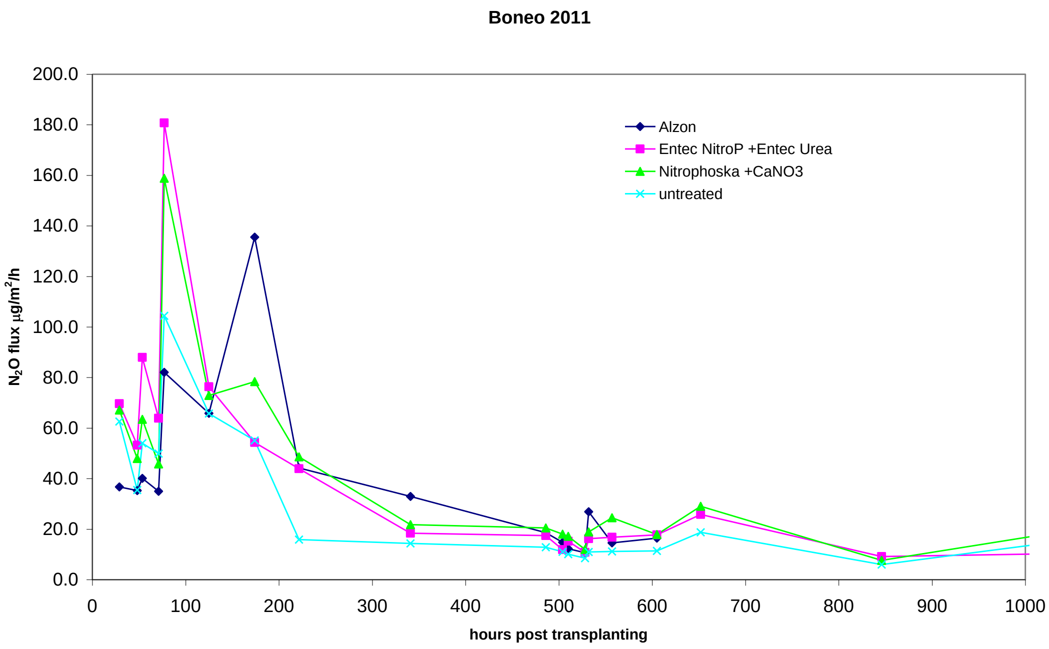

Figure 19. N_2O emissions from fertiliser treatments applied to a broccoli crop from Boneo Trial 1 in 2011.

Yield Assessment - Boneo Trial 1

The half rate ENTEC program (80 N) together with a budding application of $CaNO_3$ yielded similarly to the standard grower program of Nitrophoska and $CaNO_3$ applications (126 N) (Table 10). While not significantly lower, the full rate ENTEC program tended to produce lower yields than the half rate program. The reduced yield for the Alzon 87 N program was due to some seedling mortality following transplanting and appeared to be associated with Rhizoctonia infection. The head weights however were as large as the other treatments. When adjusted for plant number the yield was similar to the half rate ENTEC program (i.e. 9.04 kg/5 m).

Table 10. Broccoli yield in fertiliser Trial 1 at Boneo in 2011.

Treatment*	N applied kg/ha	Yield kg/5m	% Below the SGP
NitroP+$CaNO_3$ (SGP) (87N)	126	9.22 a	
NitroP (87N)	126	8.77 a	-4.9
ENTEC NitroP+ENTEC Urea (81N)	120	8.12 a	-7.0
1/2 rate ENTEC program (40N)	80	9.01 a	-2.3
Alzon (87N)	126	7.89 (9.04[#]) a	-2.0
1/2 rate Alzon (43N)	82	8.29 a	-9.0
Perlka (87N)	126	8.51 a	-7.7
$CaNO_3$ (39N)	78	6.89 b	-25.3
Untreated	39	6.44 b	-30.2
P value		0.017	
LSD (5%)		1.47	

* Numbers in brackets refer to amount of N applied prior to budding (kg/ha). All plots received the same $CaNO_3$ application at budding
[#] adjusted for missing plants

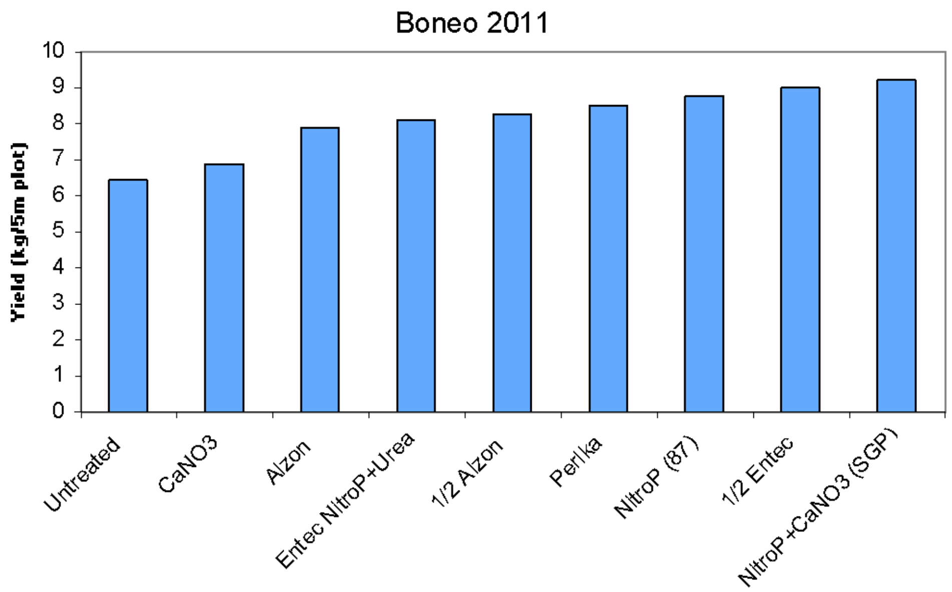

Figure 20. Effect of stabilised fertilisers and standard fertiliser practice on broccoli yield (kg/5m of two rows/plot) in Trial 1 at Boneo in 2011. NitroP=Nitrophoska.

Soil chemistry – Boneo Trial 1.

There was a spike in soil nitrate in the standard grower treatment measured at day 22 (1 day after the top dress application of $CaNO_3$) (Fig. 21). The Alzon and ENTEC treatments had increased soil ammonium levels relative to the standard grower treatment up until approximately 49 days after transplanting (Fig. 22).

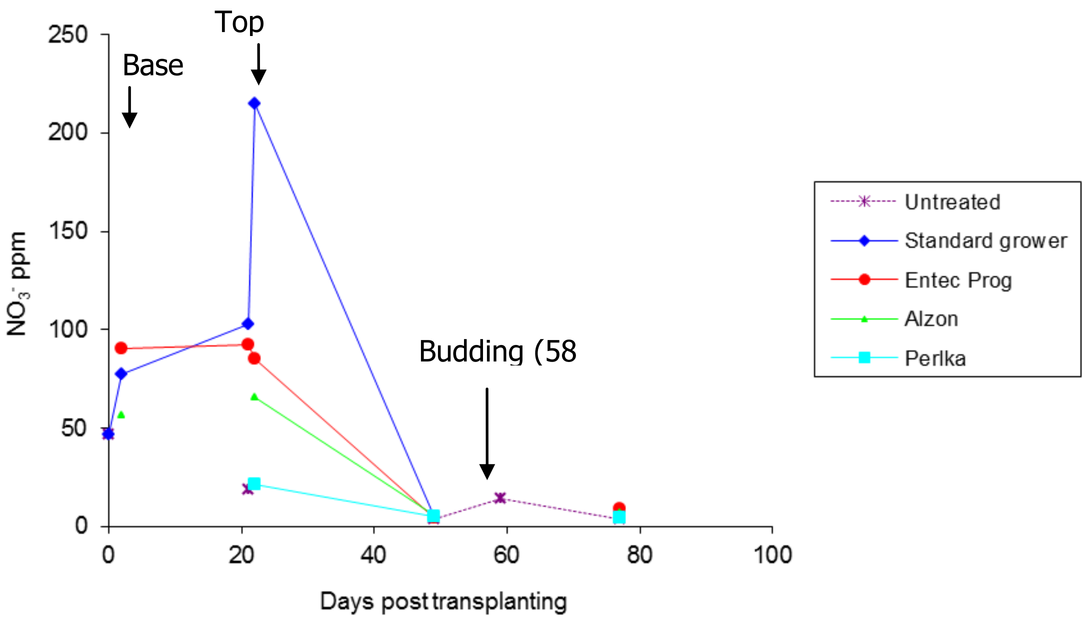

Figure 21. Soil nitrate levels in the 2011 Boneo broccoli trial

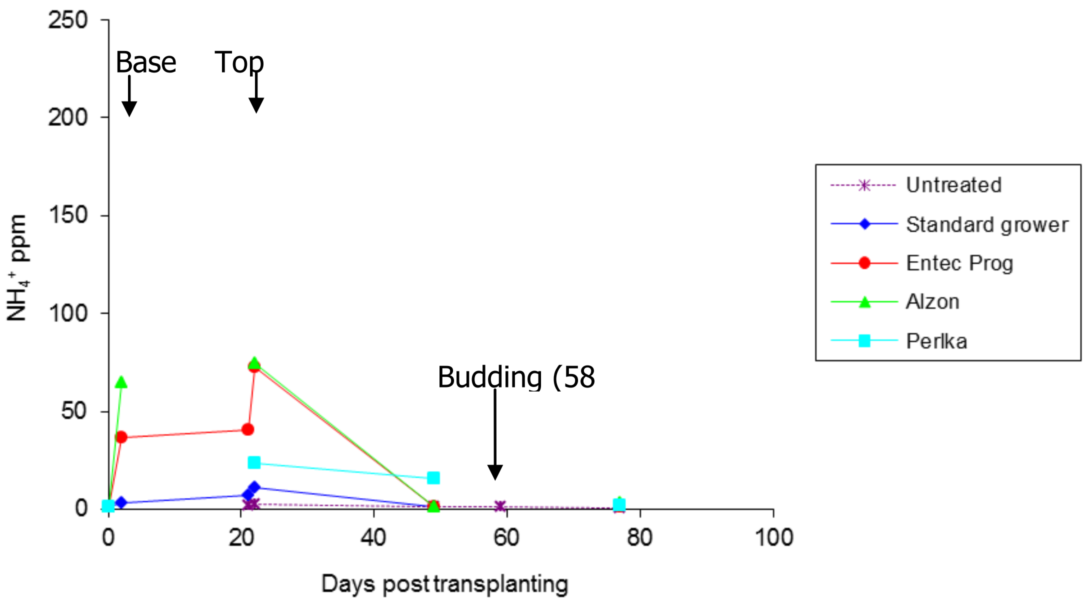

Figure 22. Soil ammonium levels in the 2011 Boneo broccoli trial.

5.2.2 Demonstration Site 2, Boneo, Broccoli, (Loamy sand) - 2011

Key Aim

This trial assessed the effect of different organic amendments applied at 5 t carbon/ha on broccoli yield, soil carbon content, and N_2O emissions (Table 11). Chicken manure was applied with and without the nitrification inhibitor product, Piadin. In addition, N_2O emissions were measured from plots where chicken manure was applied at 1.6 t carbon/ha with and without nitrification inhibitors, and then either incorporated into soil or left on the surface. In this latter case, surface applied chicken manure was applied at a lower rate than when incorporated in trials which was consistent with the commercial grower practice (5.2 t manure/ha).

Method

Organic treatments were broadcast onto the surface of hilled plots (1.64 m x 10.6 m length) seven days before transplanting and immediately incorporated by a rotavator and bed formed. Prior to the incorporation of some chicken manure plots, the inhibitor Piadin at 7.5 ml/plot (0.43 ml/m^2) in 9 L water per plot was applied by watering can to the manure and the treated manure either left on the surface or incorporated by rotovator.

Broccoli (cv. Viper) was planted in two rows at a density of 30,000 plants/ha in raised beds of 1.62 m width. Nitrabor® ($CaNO_3$ + Boron, Yara Australia) was applied one day after planting. Base fertiliser, Rustica Plus® (Campbells Australia) was applied 3 weeks after transplanting. Each treatment was replicated four times in a randomized block design. All treatments received an additional side-dress application of Nitrabor at budding (13/5/11) at the rate of 39 kg/ha N. Yields were determined on 5m of row per plot.

Treatments

Table 11. Treatments applied to broccoli in the Boneo Trial 2 in 2011.

Code	Fresh weight of material equivalent to 5 t carbon added to plots#	Total N^A from organics	Base (Rustica) (400 kg/ha)	Nitrabor side (247 kg/ha)	Nitrabor budding (247 kg/ha)	Total N
A	Standard practice (Rustica and $CaNO_3$) - SGP	-	48	39	39	126
C	SGP and Compost (26.5 t/ha)	329	48	39	39	455
D	SGP and Chicken Manure (16.4 t/ha)	289	48	39	39	415
DI	SGP and Chicken (16.4 t/ha) Manure+Piadin	289	48	39	39	415
DII	SGP and Chicken Manure (5.2 t/ha)	Only emission studies conducted				
DIII	SGP and Chicken Manure (5.2 t/ha)+Piadin	Only emission studies conducted				
E	SGP and Silage (20 t/ha)	160	48	39	39	286
F	SGP and Lignite – High rate (16.4 t/ha)	112	48	39	39	238
F1	SGP and Lignite – Low rate (4.1 t/ha)	28	48	39	39	154

Organic products were added at a rate equivalent to approximately 5 t C/ha; ^{A} -All organic amendments released N slowly and at different rates

Results and Discussion

Greenhouse Gas Emissions - Boneo Trial 2

Emissions of N_2O were much higher (up to 10 fold) for treatments that included chicken manure at the higher rate (16.4 t/ha) relative to the standard grower treatment (Rustica + $CaNO_3$) (Fig. 23). Chicken manure applied at the high rate had a N_2O flux which was 3 times that of the other organic treatments (Fig. 23).

The addition of the liquid nitrification inhibitor product (Piadin) to chicken manure at the lower rates appeared to delay rather than reduce total N_2O emissions relative to the manure without inhibitor. The inhibitor product, Piadin, halved the rate of emissions during the first 200 hours, but then it appeared to lose its effect and emissions fluxes were double that of standard manure for the next 100 hours (Fig. 24). This appears to indicate that the Piadin locks up N as ammonium and is preventing conversion to nitrate early after manuring, but then it releases nitrate more rapidly from around 10 to 18 days. Trials in 2012 confirm this effect. Surface applied chicken manure at 5.2 t/ha emitted similar levels of N_2O to the incorporated manure applied at 3 times the rate (16.4 t/ha) indicating that burial of manure can dramatically reduce emissions. Piadin applied to surface manure reduced N_2O emission flux for a short period only (100 to 200 hrs) and then seemed to continue to produce emissions for a longer period later in the season (Fig. 25). This delay of emissions was observed to increase yields in some trials (i.e. Boneo 2012).

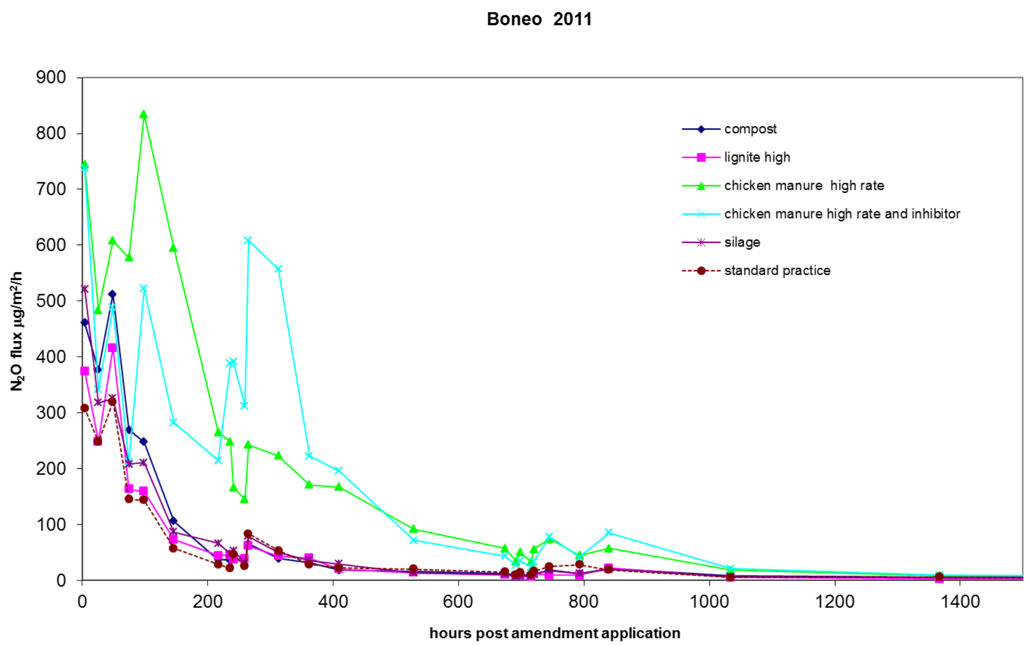

Figure 23. N_2O emissions from organic matter treatments (silage, compost, lignite and chicken manure high rate) treatments from the 2011 Boneo broccoli trial.

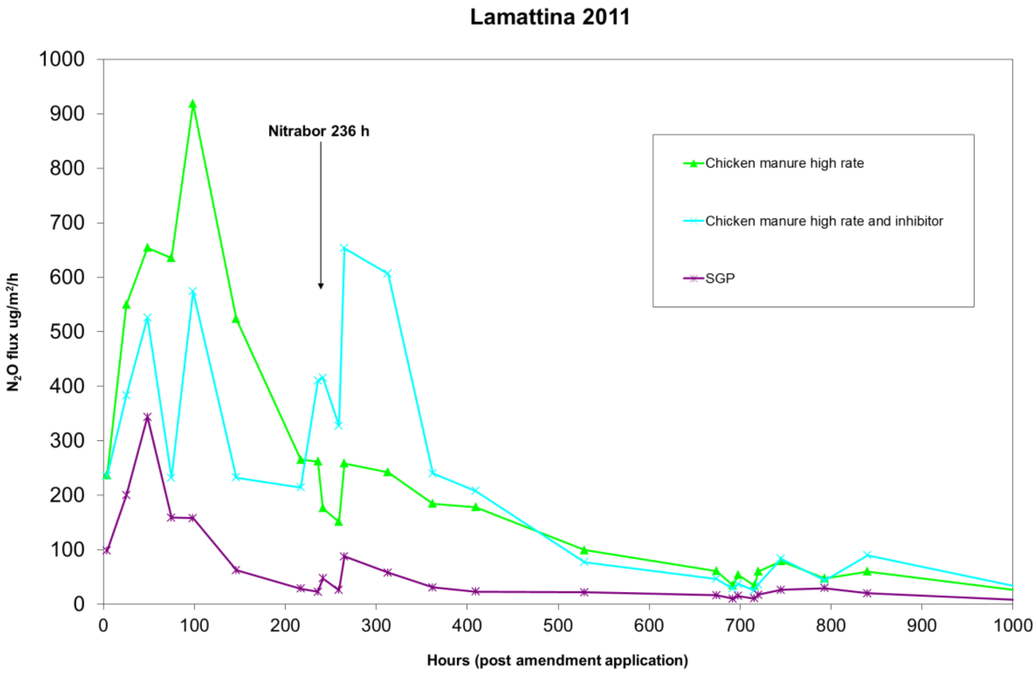

Figure 24. Effect of Piadin inhibitor on N_2O emissions from chicken manure (at 16.4 t/ha) incorporated into soil at Boneo in 2011. SGP = Standard Grower Practice

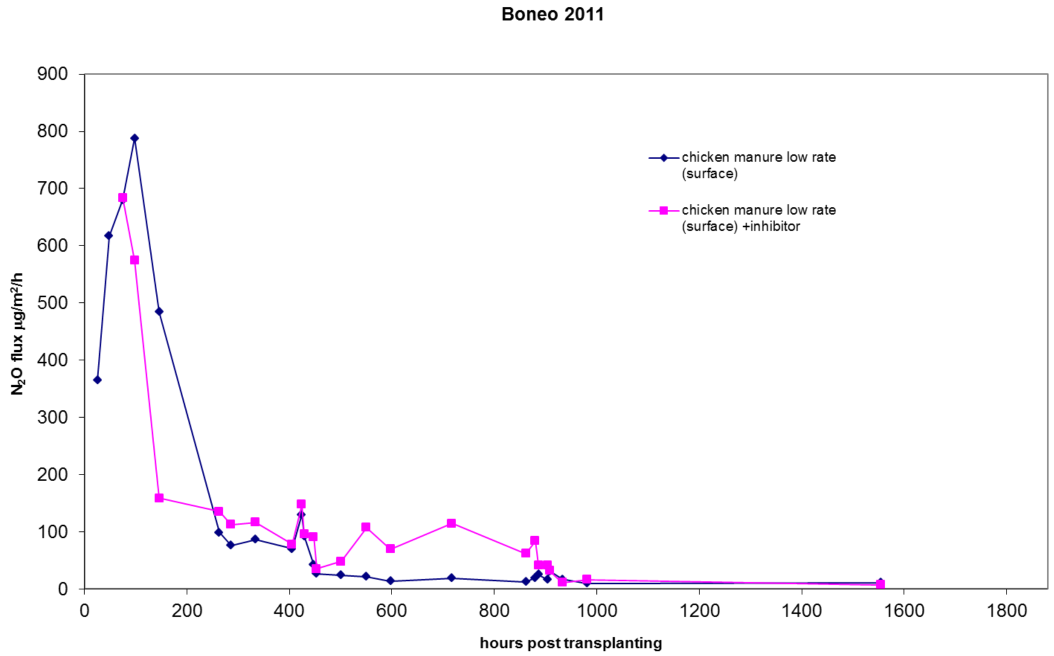

Figure 25. Effect of Piadin inhibitor applied to chicken manure (5.2 t/ha) applied on the surface of soil on N_2O emissions at Boneo in 2011

Yield Assessment - Boneo Trial 2

Both the chicken manure alone and with Piadin incorporated into soil at 16.4 t/ha increased yields significantly relative to standard practice (Table 12). Yield increases for these treatments were 18-23 % relative to the standard practice treatment. While there was a trend for higher yields with the other organic treatments, differences were not statistically significant. Lignite promoted the disease clubroot, and although severity was generally low, this may have affected yields slightly (not shown). In previous seasons, clubroot had been shown to increase in plots treated with most of the organic amendments and was worst in lignite treated plots.

Table 12. Effect of long term organic treatments on yields of broccoli at Boneo in 2011.

Organic Treatments equiv to 5 t carbon per ha)#	**Yield kg/5m**	**% Increase above SGP**
No organics (SGP) *	8.93 a	
Lignite Low Rate (i.e. 1.25 t/C/ha)#	9.24 a	3.5
Lignite	9.53 a	6.7
Silage	9.61 ab	7.6
Green waste compost	9.74 ab	9.1
Chicken (16. t/ha)+ Piadin inhibitor	10.49 bc	17.5
Chicken manure (16.4 t/ha)	10.96 c	22.7
P value	<0.001	
LSD (5%)	0.8902	

* Standard grower practice (no organic amendments); # Lignite was also applied at 25% of the standard rate owing to signs of phytotoxicity in earlier trials (2010).

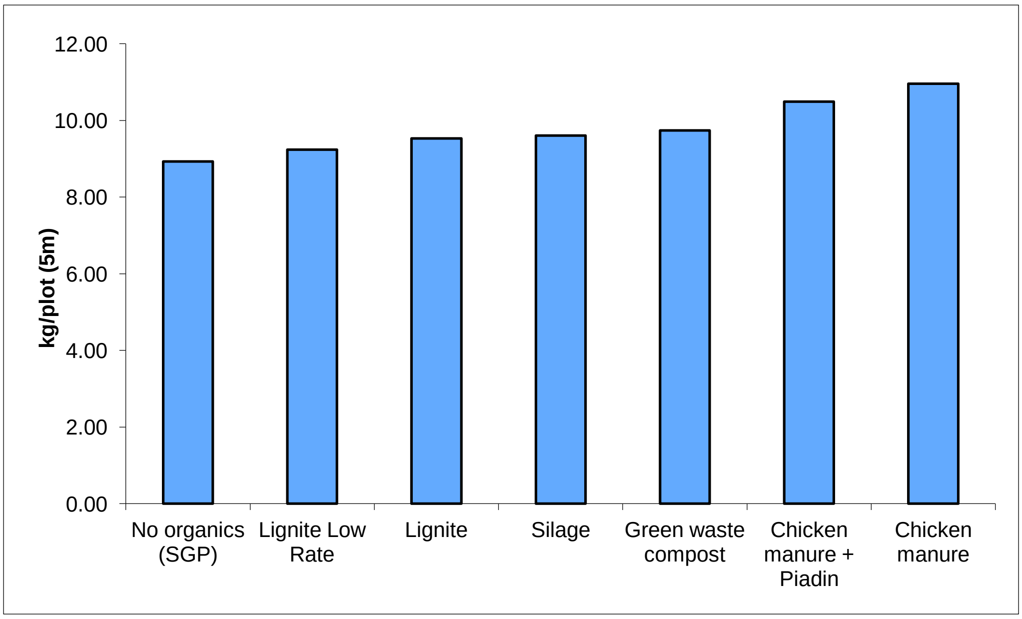

Figure 26. Effect of organic treatments on broccoli yield at Boneo in 2011.

5.2.3 Demonstration Site 3, Boneo, Broccoli, (Loamy sand) 2012.

Figure 27. Demonstration site 3 at Boneo in 2012.

Key Aim

This trial was set up to assess whether different N-stabilised fertilisers could improve the nitrogen use efficiency as well as GHG emissions and yield for both urea and the standard commercial NPK base fertiliser. The N in urea is converted to ammonium when applied to soil while Nitrophoska contains N as both ammonium and nitrate. The trials balanced the N units to enable direct comparisons of the GHG emissions. If it worked then it was predicted to offset the yield reduction caused by removal of the $CaNO_3$ side dressing applied two weeks after transplanting.

Method

Broccoli (cv. Viper) was planted in two rows at a density of 30,000 plants/ha in raised beds of 1.62 m width. The treatments applied are shown in Table 13. Base fertilisers were applied on the day of planting. Treatments were applied to trial plots of 10.6 m length. Each treatment was replicated four times in a randomized block design. All treatments received a side-dress application of Nitrabor ($CaNO_3$ + Boron) at budding (13/5/11) at the rate of 39 kg/ha N. No early side dressing fertiliser treatments (within 2-3 weeks after transplanting) were applied in this trial in contrast to the previous trials.

Table 13. Treatments applied to soil for broccoli production in the Boneo Trial 3 in 2012.

Code	Base fertiliser Treatments	Units of N applied (kg/ha)		
		Base (21/2/12)	$CaNO_3$ at Budding 16/4/12	Total
1	No fertiliser	-	39	39
2	Full Nitrophoska (600 kg/ha)	72	39	111
3	Reduced Nitrophoska (400 kg/ha) – SGP[1]	48	39	87
4	Full ENTEC Nitrophoska (600 kg/ha)	72	39	111
5	Reduced ENTEC Nitrophoska (400 kg/ha)	48	39	87
6	1/2 rate ENTEC Nitrophoska (200 kg/ha)	24	39	63
7	Full Urea[2] (325 kg/ha)	72	39	82
8	Reduced Urea[2] (216 kg/ha)	48	39	87
9	ENTEC Urea[2] (325 kg/ha)	72	39	87
10	Half ENTEC Urea[2] (216 kg/ha)	24	39	87
11	Alzon[2] (216 kg/ha)	48	39	87

[1] SGP - Standard commercial base fertiliser application

[2] Blend of NPK base fertiliser with urea product (urea, ENTEC urea or Alzon 46)

Results and Discussion

Greenhouse Gas Emissions - Boneo Trial 3

N_2O emissions from ENTEC Nitrophoska were almost 70% lower than those of Nitrophoska (Figure 28). Urea based fertiliser showed larger emissions than all other fertiliser treatments especially from 100 to 200 hrs after application. N_2O emissions from Alzon from day 10 (240 h) onwards were three times the emissions of all other treatments indicating a possible breakdown in the Piadin inhibition.

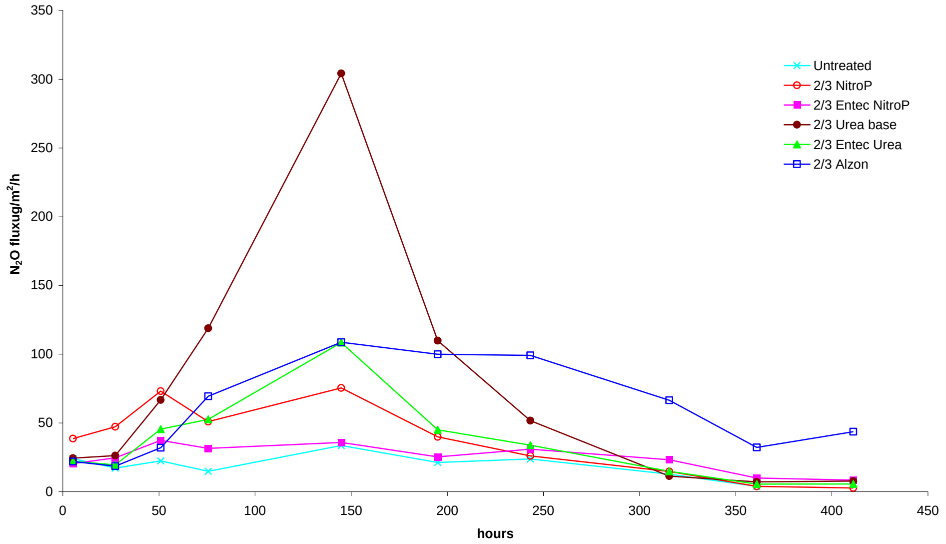

Figure 28. N_2O Emissions from fertiliser treatments applied to soil for broccoli production at Boneo 2012 (Trial 3).

Yield - Boneo Trial 3

The full ENTEC Nitrophoska treatment (600 kg/ha) yielded 77 % higher than the equivalent rate of Nitrophoska without ENTEC (Table 14). Note that the early $CaNO_3$ application was excluded from all treatments in this trial in order to examine the nitrogen use efficiency of the base fertiliser treatments. ENTEC Nitrophoska applied at a rate of 400 kg/ha yielded 59% greater than 600 kg/ha Nitrophoska.

For Nitrophoska base fertiliser application rates of 400 kg/ha or greater, the crop reached maturity more consistently and earlier for the ENTEC Nitrophoska treatments, with 90% of the crop harvested in the first 2 cuts, compared to approximately 67% for Nitrophoska without ENTEC (Fig. 29).

The urea based programs yielded between 2-26% lower than the Nitrophoska (ammonium+nitrate) based programs at the same N application rate without nitrification inhibitors. The addition of nitrification inhibitors to the urea based programs (ENTEC urea and Alzon) resulted in yield increases of 49-66% relative to the same rate N without inhibitor. The urea programs with nitrification inhibitors resulted in small (11-23%), but non-significant, yield increases relative to the 400 kg/ha Nitrophoska treatment.

Table 14. Effect of inhibitors on fertilisers applied at standard and reduced dosage rates at Boneo in 2012. (Note the standard $CaNO_3$ side dressing was excluded from all treatments two weeks after transplanting).

Treatment	Rate Product Applied	Rate N Applied	Yield (kg/5m)	% Increase above SGP*
No fertiliser	-	-	0.66	
Full Nitrophoska Base	600	72	3.14	
2/3 Reduced Nitrophoska Base (SGP)	400	48	3.23	-
Full ENTEC Nitrophoska	600	72	5.55	76.8
2/3 Reduced ENTEC Nitrophoska	400	48	4.98	58.6
1/2 ENTEC Nitrophoska	200	24	3.63	15.6
Full Urea	325	72	3.07	-23.2
2/3 Reduced Urea	216	48	2.39	-23.9
Full ENTEC Urea	325	72	3.97	26.8
Alzon	216	48	3.57	14.0
P value			<0.001	
LSD (5%)			1.29	

* SGP - the standard grower practice in this trial excluded the first $CaNO_3$ side dressing so that the ENTEC program could be evaluated

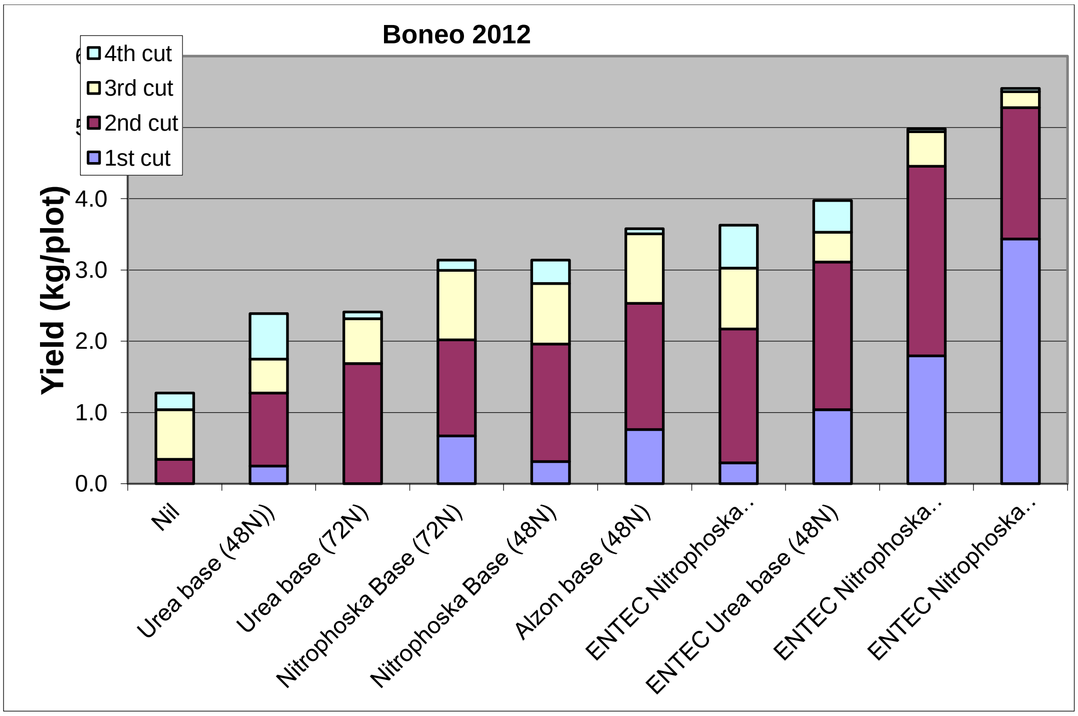

Figure 29. Effect of nitrification inhibitors applied to base fertilisers used at different dosage rates on the number of cuts and yield of broccoli at Boneo in 2012.

5.2.4 Demonstration Site 4, Boneo, Broccoli, (Loamy sand) 2012

Key Aim

This trial continued to assess the long term effect of different organic amendments on broccoli production, including the effect on building soil carbon. In addition, the effect of nitrification inhibitors added to chicken manure on N_2O emissions was compared to chicken manure without the nitrification inhibitors.

Method

Organic treatments (Table 15) were broadcast onto the surface of plots (1.64m x 10.6 m length) seven days before transplanting and immediately incorporated. The inhibitor product Piadin was applied to the manure at 7.5 ml/plot (0.43 ml/m^2) in 9 L of water per plot by watering can prior to being left on the surface or being incorporated.

Broccoli (cv. Viper) was planted in two rows at a density of 30,000 plants/ha in raised beds of 1.62 m width. Base fertiliser (Nitrophoska) was applied on the day of planting. Each treatment was replicated four times in a randomized block design. All treatments received an additional side-dress application of Nitrabor ($CaNO_3$ + Boron) at budding (20/4/12) at the rate of 39 kg/ha N.

Table 15. Treatments incorporated into soil for broccoli production at Boneo (Trial 4) in 2012.

Code	Treatment#	Organic Amendment N	Base (Nitrophoska) (400 kg/ha)	Nitrabor (247 kg/ha)	Total N
-	No base fertiliser	-	-	39	39
A	Standard practice	-	48	39	72
C	Compost (26.5 t/ha)	329	48	39	416
D1	Chicken Manure (16.4 t/ha) alone	289	-	39	328
D2	Chicken Manure + Nitrophoska	289	48	39	376
D3	Chicken Manure + ENTEC Nitrophoska	289	48	39	376
D4	Chicken Manure+Piadin + Nitrophoska	289	48	39	376
E	Silage (20 t/ha) + Nitrophoska	160	48	39	247
F	Lignite – High rate (16.4 t/ha) + Nitrophoska	112	48	39	199
F1	Lignite – Low rate (4.1 t/ha) + Nitrophoska	28	48	39	115

Organic products were added at a rate equivalent to approximately 5 t C/ha, All treatments had Nitrophoska base fertiliser applied except D2 which had ENTEC Nitrophoska applied.

Results

Greenhouse Gas Emissions - Boneo Trial 4

Chicken manure emitted three times the rate of N_2O compared to any other organic product (silage, green waste compost, lignite) (Fig. 30). ENTEC Nitrophoska approximately halved N_2O emissions from manure compared to manure with Nitrophoska indicating that the inhibitor can still affect manure in soil even when applied on fertilisers rather than directly on the manure (Fig. 31). The N_2O emission reductions were greater when ENTEC Nitrophoska was used relative to applying Piadin to the manure. Piadin applied to the manure resulted in emission reductions up until approximately 300 h after which emissions were slightly higher than untreated manure.

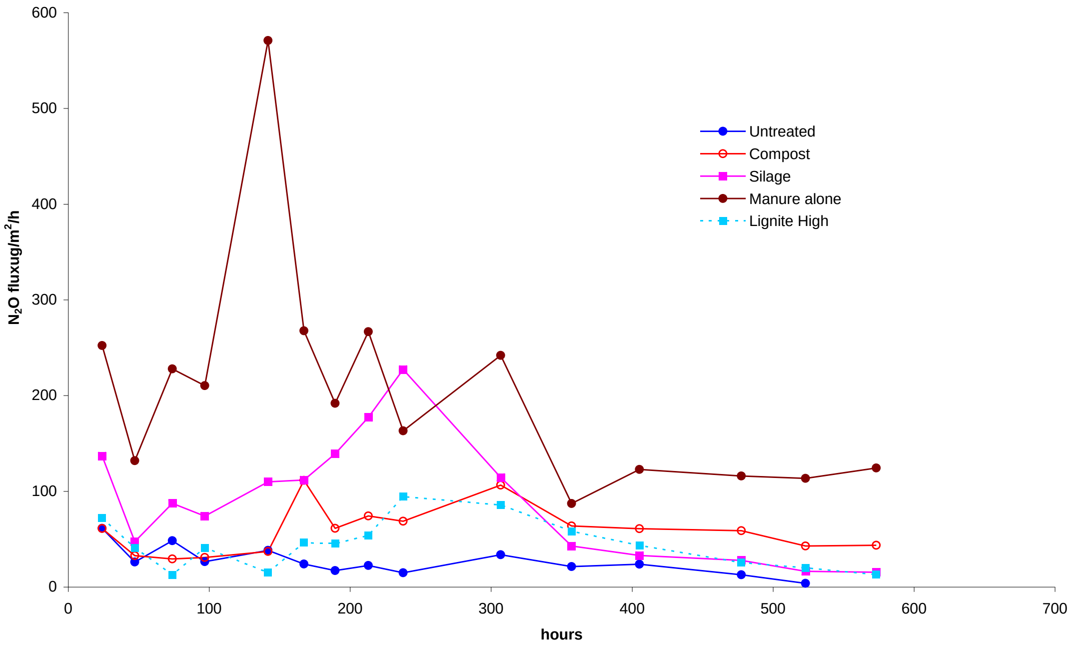

Figure 30. N_2O emissions from different organic treatments applied to soil at Boneo in 2012.

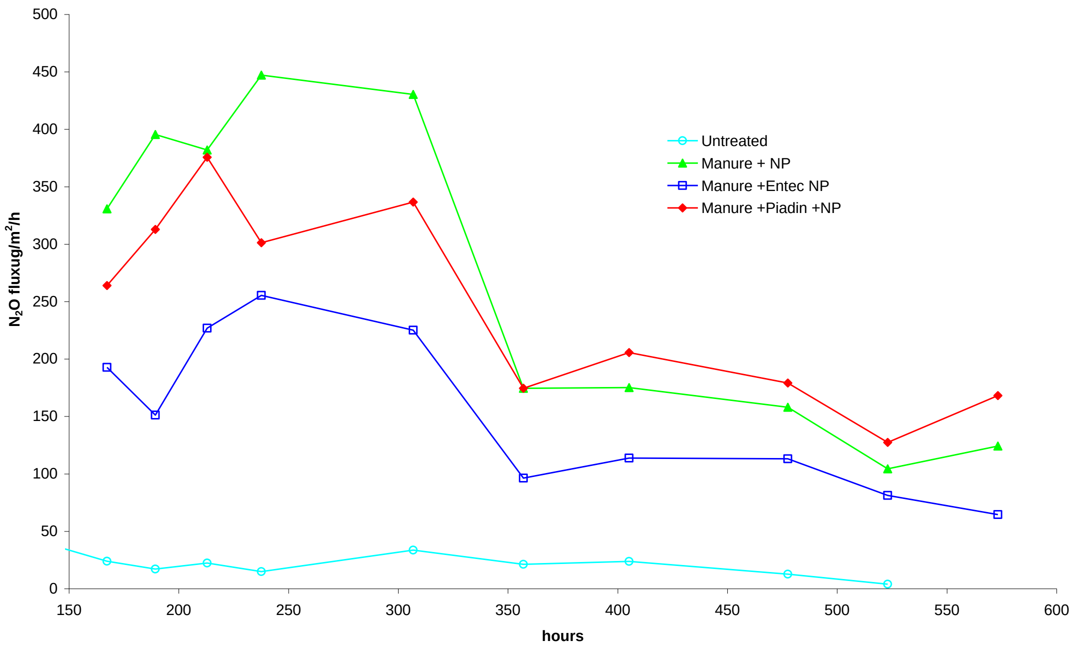

Figure 31. Effect of nitrification inhibitors on N_2O emissions from chicken manure (16.4 t/ha) and fertiliser applied to soil at Boneo in 2012

Yield Assessment - Boneo Trial 4

When chicken manure was either combined with ENTEC Nitrophoska or treated with Piadin and applied in combination with Nitrophoska, yields were increased by 19% and 39% respectively relative to chicken manure applied with Nitrophoska alone (Table 16, Fig. 32). Incorporation of silage gave the biggest yield response (89% increase) of all organic amendments without nitrification inhibitors compared to fertiliser applied alone. As with all organic products, this was the 4th application of silage to the same land over the past 4 years. The addition of chicken manure and fertiliser gave a slightly smaller yield response than silage addition.

The addition of ENTEC Nitrophoska to manure treated plots or Piadin to manure followed by the addition of Nitrophoska resulted in earlier maturity of the crop compared to Nitrophoska and chicken manure applied alone (Fig. 33).

Table 16. Effect of stabilised fertilisers combined with long term organic treatment of soils on the yield of broccoli at the Boneo, Victoria.

Treatment	Yield (kg/plot)	% Increase compared to standard practice*	% Increase compared to the chicken manure and Nitrophoska treatment
No base fertiliser	0.87 a		
Standard practice* (Nitrophoska)	3.23 b		
Chicken manure alone	3.66 b	16.6	
Lignite high + Nitrophoska	3.73 b	17.8	
Compost + Nitrophoska	4.38 bc	51.3	
Chicken manure + Nitrophoska	5.35 cd	68.8	-
Silage + Nitrophoska	6.20 de	88.9	
Chicken manure + ENTEC Nitrophoska	6.35 de	102.5	18.7
Piadin on chicken manure + Nitrophoska	7.46 e	137.6	39.4
P value	<0.001		
LSD (5%)	1.4		

* The standard grower practice in this trial excluded the first $CaNO_3$ side dressing so the effect of inhibitor programs on N use efficiency could be evaluated.

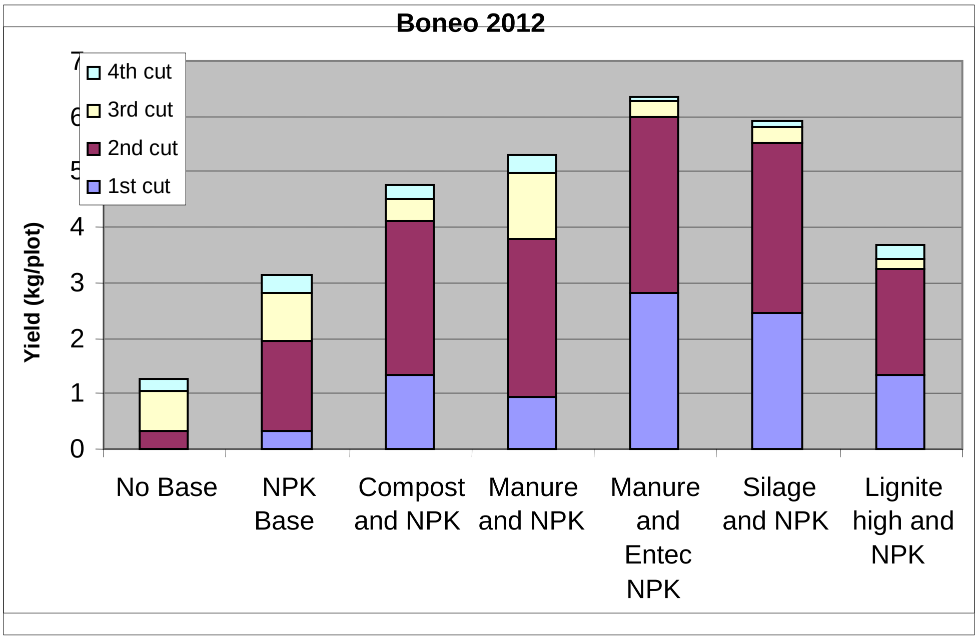

Figure 32. Effect of the long term addition of organic amendments on the yield of broccoli at the Boneo, Victoria in 2012 (Trial 4).

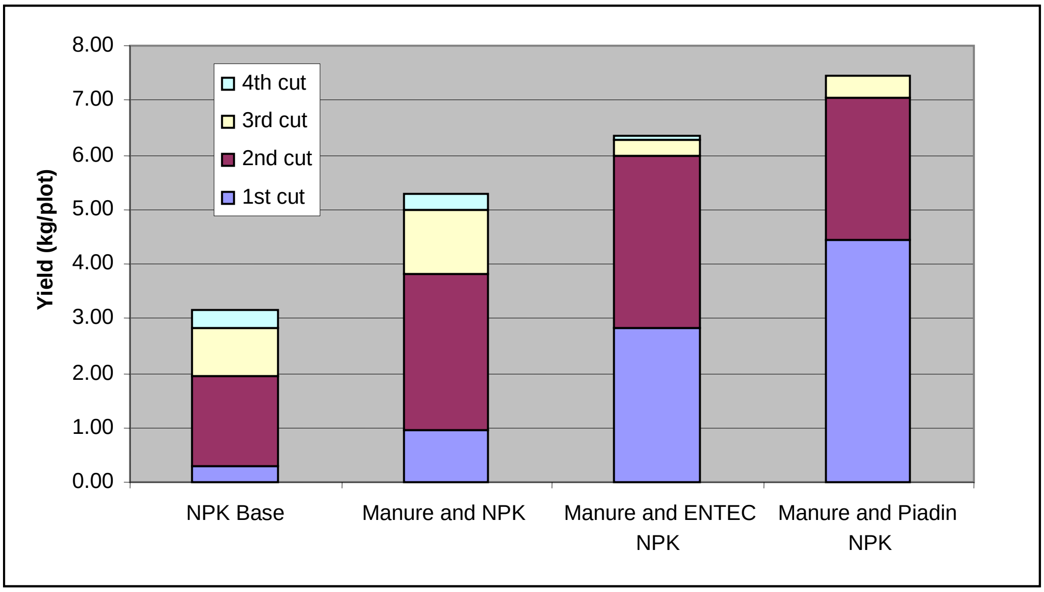

Figure 33. Effect of ENTEC and Piadin inhibitors applied to fertiliser or manure respectively on broccoli yields from chicken manure plots at Boneo, in 2012 (Trial 4).

5.2.5 Demonstration Site 5, Boneo, Broccoli, (Loamy sand) - 2012

Key Aim

This trial examined the effects of adding nitrification inhibitors to chicken manure, applied at the standard grower rate of 5.2 t manure/ha, on GHG emissions and broccoli production when either surface applied or immediately incorporated. Applying chicken manure to the surface is a standard practice used by many growers in Victoria.

Method

Chicken manure was applied to plots and was either left untreated, or was treated with liquid nitrification inhibitors. Piadin and liquid ENTEC inhibitor (supplied by Incitec Pivot) were applied to the manure at rates of 7.5 ml/plot and 5.5 ml/plot respectively in 9 L of water per plot by watering can. Manure was then either left on the surface of plots or incorporated into soil (Table 17). All treatments had a base fertiliser application of Nitrophoska at 400 kg/ha. At budding, Nitrabor was applied at 247 kg/ha to all treatments.

Table 17. Treatments applied to the surface or incorporated for broccoli production at Boneo (Trial 5) in 2012.

Code	Treatment	Units of N applied (kg/ha)			
		Organic amendment	Base (Nitrophoska 400 kg/ha)	Budding Nitrabor (247 kg/ha)	Total
M	Chicken manure on surface (grower rate)	82	48	39	169
N	Chicken manure on surface and Piadin	82	48	39	169
O	Chicken manure on surface and ENTEC	82	48	39	169
P	Chicken manure incorporated (grower rate)	82	48	39	169
Q	Chicken manure incorporated with Piadin	82	48	39	169
R	Chicken manure incorporated with liquid ENTEC	82	48	39	169

Results

Greenhouse Gas Emissions - Boneo Trial 5

In general the inhibitors reduced N_2O emissions by approximately 20% (Figs. 34 and 35). However, the emission reductions at these lower rates of manure application were lower than observed when manures were used at higher rates in other trials. Although overall reductions in N_2O emissions were not large when averaged across the season (max 15-20 %), application of nitrification inhibitors to surface and incorporated manures changed the dynamics of N_2O emissions during the growing season. Application of nitrification inhibitors to incorporated manure only reduced N_2O emissions early in the crop cycle (24-97 hours) and late in the crop cycle 740-909 hours (data not shown). Application of nitrification inhibitors to the manure on the surface of plots reduced N_2O emissions at most time-points sampled with the exception of first 50 hours and the 167 hour sample

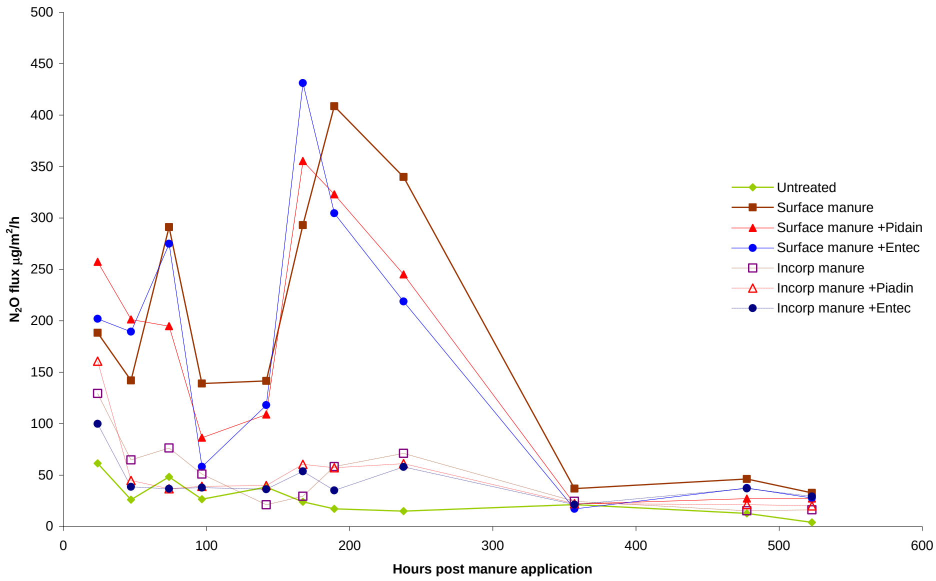

Figure 34. N_2O Emissions from chicken manure (5.2 t/ha) treated with inhibitors (ENTEC and Piadin) either left on the surface or incorporated into soil at Boneo 2012.

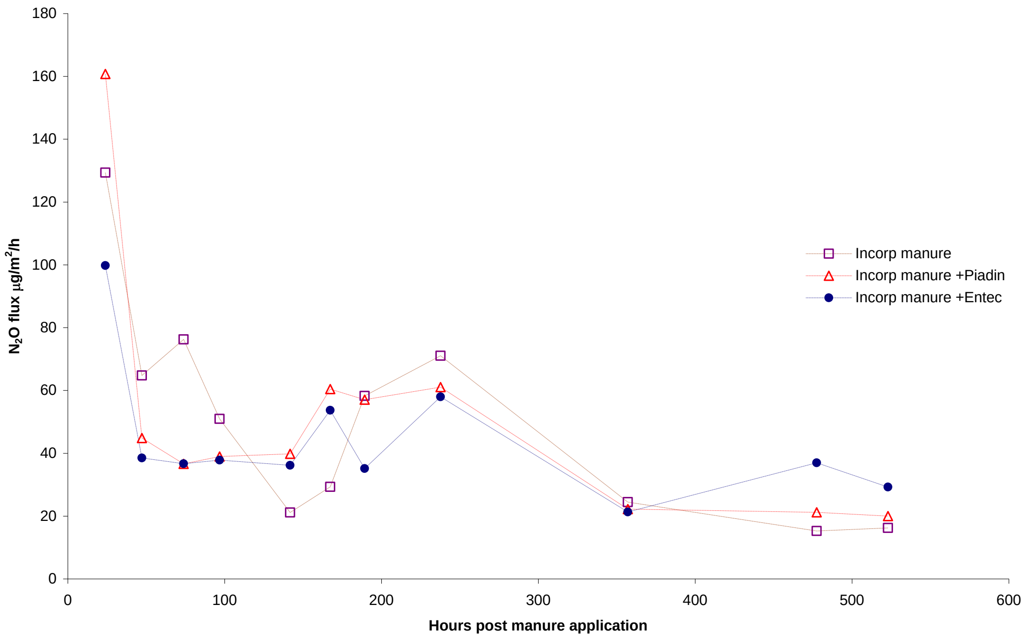

Figure 35. N_2O Emissions from chicken manure (5.2 t/ha) treated with inhibitors (ENTEC and Piadin) incorporated into soil at Boneo 2012.

Yield Assessment - Boneo Trial 5

Adding inhibitors to the chicken manure on the surface increased yields by approximately 60% for both inhibitors (ENTEC and Piadin) compared to surface manure alone (Table 18). The crop matured earlier (more heads picked in the first two cuts), for both inhibitor treatments (Fig. 36) which saves machinery and labour costs. The same treatments had less effect on yield when the manure was incorporated into soil although yield increases of

49% were obtained with ENTEC and 14% with Piadin. Piadin again was less effective than ENTEC when incorporated into soil.

In general, yield responses were greater than might be expected on the basis of the relatively small reductions in N_2O emissions, suggesting that the inhibitors dramatically improved nitrogen use efficiency, especially when the inhibited was applied to the manures left on the surface. There is potential that these treatments may also have dramatically decreased nitrate leaching.

Table 18. Effect of stabilised fertilisers and nitrification inhibitors combined with chicken manure on the yield of broccoli at the Boneo, Victoria.

Treatment	Total yield (kg/5m)	% Increase compared to the SGP*#
Nitrophoska Base (48N)	3.23	
Manure on surface+ Nitrophoska (SGP)	3.86	-
Manure on surface and Piadin+ Nitrophoska	6.19	60.4
Manure on surface and ENTEC Nitrophoska	6.17	59.8
Manure incorporated+ Nitrophoska	3.96	2.5
Manure incorporated with Piadin+ Nitrophoska	4.52	17.0
Manure incorporated with ENTEC+ENTEC Nitrophoska	5.91	53.1
P value	<0.001	
LSD (5%)	1.352	

NPK base was applied to all treatments; * SGP - The standard grower practice in this trial excluded the first $CaNO_3$ side dressing so the effect of inhibitor programs could be evaluated fairly

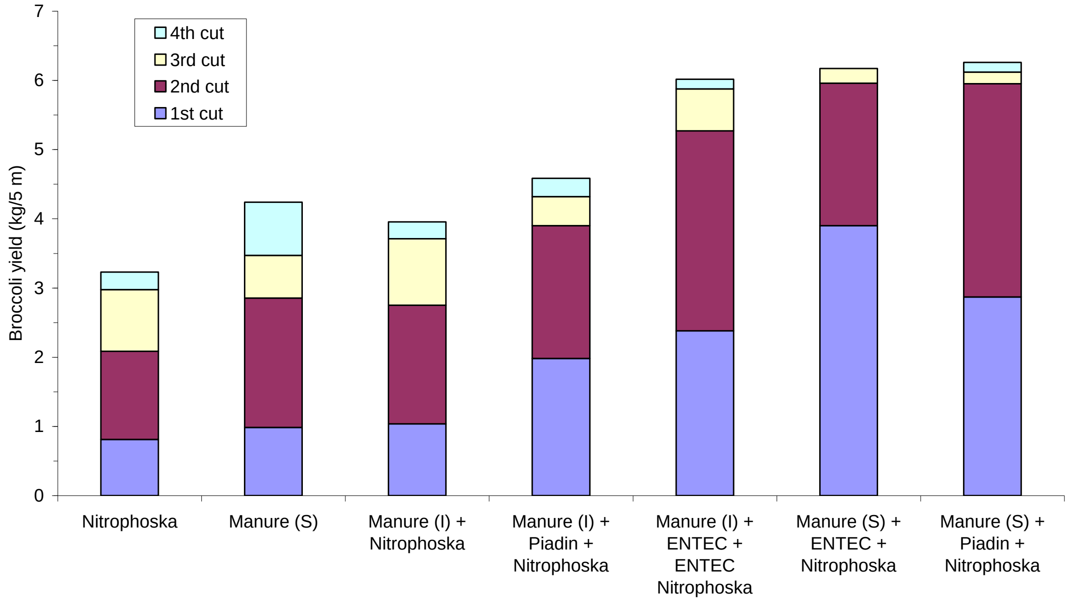

Figure 36. Effect of stabilised fertilisers and nitrification inhibitors combined with surface applied chicken manure (5.2 t) either left on the surface (S) or incorporated (I) on the yield of broccoli at the Boneo, Victoria.

5.2.6 Effect of irrigation on N_2O flux at Boneo in 2012

The N_2O flux from soil which had been recently irrigated was up to 262% greater for the different fertiliser treatments compared to non-recently irrigated soil.

Emissions in moist soils treated with ENTEC Nitrophoska and ENTEC urea were 25 - 60% lower than the respective base treatments (Nitrophoska and urea). (The figures shown are for a sampling period 66 hours after surface application of the fertiliser).

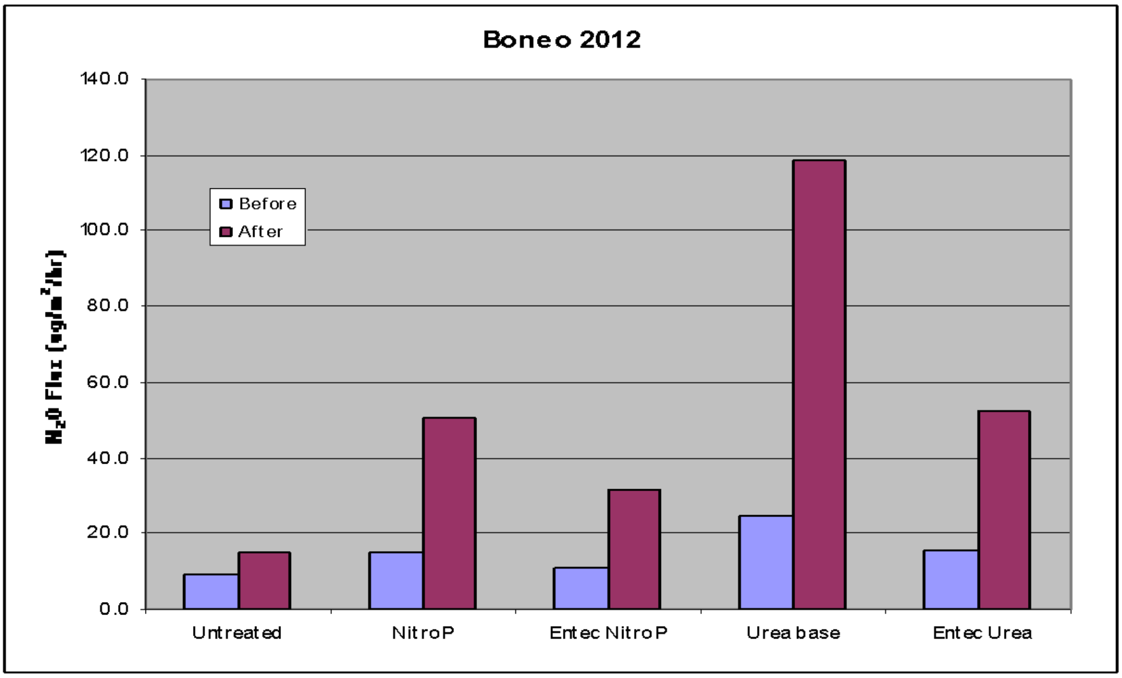

Figure 37. Effect of irrigation 1 hour prior to emission measurements on N_2O flux measurements (µg/m^2/h) from fertilisers applied at Boneo in 2012

The N_2O flux from soil which had been recently irrigated was up to 120% greater for soils which had been amended with organic products compared to the non-recently irrigated soils.

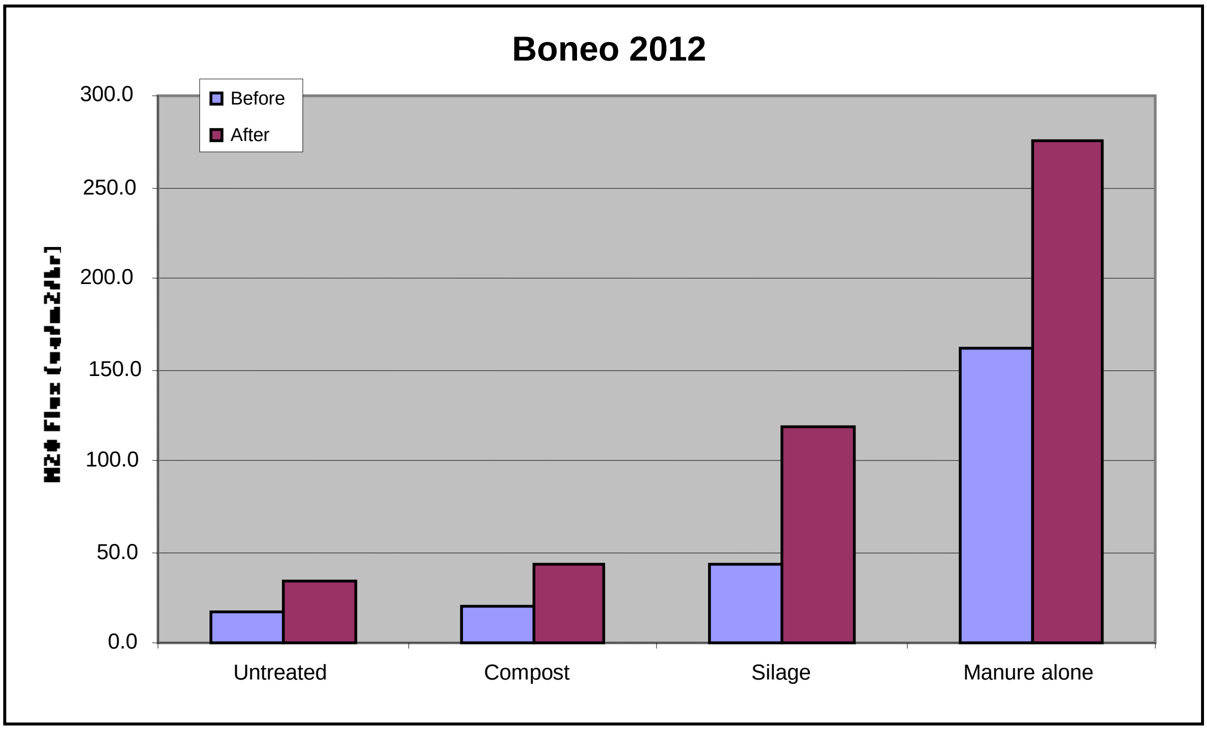

Figure 38. Effect of irrigation on N_2O flux measurements (μg/m^2/h) from untreated soil or those treated with organic amendments at Boneo in 2012

5.2.7 Effect of organic treatments on soil carbon levels at Boneo 2012

This trial was the 4th consecutive year that organic amendments had been applied to the same plots. All plots received applications of the various organic products at 5t C/ha to attempt to increase carbon levels in soil. However, previous years' soil data have shown that carbon levels have not increased over time which has been attributed to the high number of tillage treatments applied in southern Victorian vegetable production. To date, only the lignite treatment has increased the carbon content in soils (Fig. 39).

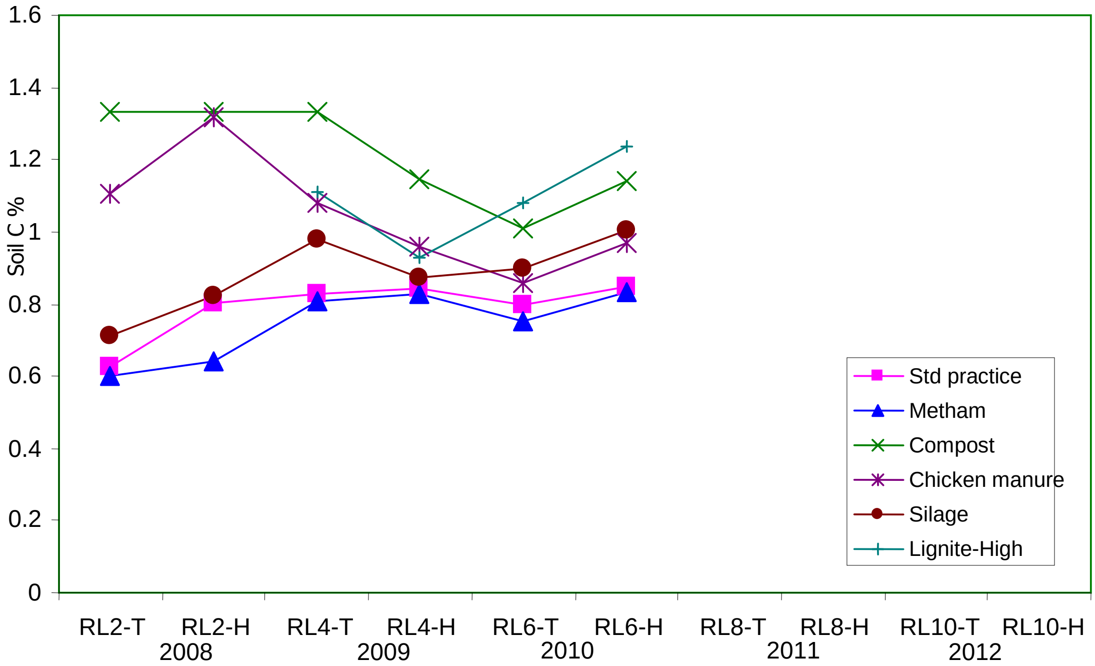

Figure 39. Impact of repeat applications (5t C/ha) of organic treatments 7 days before transplanting on soil carbon content (%). RL = Boneo field trial number; T= At transplanting; H = At harvest. (2011 and 2012 data is not shown as it is being reanalysed)

5.2.8 General Victorian Results

The following tables in this section present a summary of findings from the experiments conducted at Werribee and Boneo in Section 5 of this report. The summaries show the key site details, greenhouse gas (GHG) emission data and yield responses to different treatments used to reduce emissions. Summary results from seven trials are reported, two from Werribee and five from Boneo and allow for quick interpretation of the results from the corresponding field trials for similar treatments.

Table 19. Site characteristics for demonstration sites at Werribee and Boneo in 2011 and 2012.

Year	**2011**	**2012**	**2011**		**2012**	
Demonstration Site	**Werribee1**	**Werribee 2**	**Boneo 1**	**Boneo 2**	**Boneo 3**	**Boneo 4&5**
Host Crop	**Broccoli**	**Lettuce**	**Broccoli**	**Broccoli**	**Broccoli**	**Broccoli**
Soil classification	Red sodosol		Tenosol (Bleached – orthic)			
Soil texture	Fine sandy loamy clay		Loamy sand			
Cropping period	March - May	Dec - Jan	March - June	March - June	Feb - April	Feb - April
Soil temperature (mean)	18.3	22.4	19.2	19.2	25.4	25.4
Moisture (Est. range)		27-55			8.3 - 13.5	

Table 20. Estimated Emission factors* from fertiliser and organic amendments used in Victorian trials.

Treatment	Estimated Emission Factor*	
	Werribee	Boneo
Fertilisers		
Nitrophoska	0.21 - 0.86	0.11 - 0.14
Stabilised Nitrophoska (ENTEC)	0.02 - 0.27	0 - 0.15
Stabilised Nitrophoska (DCD)	0.80	-
Perlka - Stabilised NPK	-0.01	-
Urea	0.74	-
Stabilised urea (ENTEC)	0.28	-
Stabilised urea (Alzon)	0.40 - 0.74	0.02
Organic Products		
Chicken manure (16.4 t/ha incorporated)	0.58	0.20 - 0.30
Stabilised chicken manure (Piadin) (16.4 t/ha incorporated)	0.20	0.08 - 0.30
Chicken manure (5.2 t/ha on surface)	-	0.25 - 0.35
Stabilised chicken manure (Piadin) (5.2 t/ha on surface)	-	0.25 - 0.28

* Emission factor was calculated as (N_2O - N emission treatment– N_2O - N emission untreated)/N applied x 100 during the emissive period, measured maximum rate of emission so real emission factors over the life of the crop would likely be lower

Table 21. Summary of the greenhouse gas emission data from the vegetable industry demonstration sites in southern Victoria in 2011 and 2012.

	Ave. N_2O flux ($\mu g/m^2/hr$)		CO2 equivalents# (kg/ha/yr)	
	Fine sandy loamy clay	**Loamy sand**	**Fine sandy loamy clay**	**Loamy sand**
1. Base fertilisers N	400 -600 kg/ha	400 kg/ha	400 kg/ha	400 kg/ha
Unfertilised	19 - 32	29 - 43	-	-
Standard practice - NPK (48N)	48	50 - 59	774	418 - 570
Stabilised NPK (ENTEC) (48N)	26	27 - 59	185	0 - 420
Standard practice - NPK (87N)	126*- 207	-	2891- 4749	
Stabilised NPK (ENTEC) (87N)	87	-	1480	
2A. Incorporated chicken manure (5.2 - 6 t/ha)- 92 N				
Unstabilised - standard	199		4899	
Stabilised (Piadin)	80		1651	
2B. Incorporated chicken manure (16.4 t/ha) - 289N				
Unstabilised - standard		228 - 363		5399 - 8674
Stabilised (Piadin)		104 - 360		2042 - 8584
3. Surface Applied Chicken Manure (5.2 t/ha) - 92N				
Unstabilised - standard		121 - 208		3286 - 5651
Stabilised (Piadin)		124 - 174		3370 - 4733

Table 22. Average N_2O emission flux (μg/m^2/hr) during a crop season (10-12 weeks for broccoli, 8 weeks for lettuce) in trials conducted in Victoria during 2011/2012.

Year	**2011**	**2012**	**2011**		**2012**	
Demonstration Site	**Werribee1**	**Werribee 2**	**Boneo 1**	**Boneo 2**	**Boneo 3**	**Boneo 4&5**
Host Crop	**Broccoli**	**Lettuce**	**Broccoli**	**Broccoli**	**Broccoli**	**Broccoli**
1. Base fertilisers (400 - 600 kg/ha)	**48N**	**87N**	**48N**	**48N**	**48N**	**48N**
Unfertilised	19.0	32.4	43.4		29.1	
Standard practice - NPK	47.5	207.3	58.8		50.1	
Stabilised NPK (ENTEC)	25.8	86.9	58.5		27.0	
2. Incorporated chicken manure#	**6.0 t/ha – (88N)**			**16.4 t/ha – (289 N)**		**16.4 t/ha – (289 N)**
Unstabilised - standard	199.4			362.8		227.9
Stabilised (Piadin)	79.8			359.5		104.3
3. Surface Applied Chicken Manure#				**5.2 t/ha – (92 N)**		**5.2 t/ha – (92 N)**
Unstabilised - standard				121.0		208.1
Stabilised (Piadin)				124.1		174.3

- Chicken manure contains organic N which releases more slowly than inorganic N in fertilisers; [A] – Trials may have included extra side dressing applications

Table 23. Average adjusted N_2O emission flux (treatment – no treatment) and emission reduction in trials conducted in Victoria during 2011 and 2012 ($\mu g/m^2/hr$).

Trial	Treatment	Inhibitor	Base N (kg/ha)	Adjusted N_2O flux $\mu g/m^2/h$ (flux treatment-flux no fertiliser)		Emission reduction (%)
				No inhibitor	Inhibitor treated	
Werribee 1	NPK	ENTEC	48	29	7	76
Werribee 2	NPK	ENTEC	87	175	55	69
Werribee 2	NPK	DCD	87	175	162.1	13
Boneo 1	NPK	ENTEC	48	15.4	15.1	0.02
Boneo 3	NPK	ENTEC	48	21	-2	100
Werribee 1	Incorporated manure (6 t/ha)	Piadin	88	61	180	66
Boneo 2	Incorporated manure (16 t/ha)	Piadin	289	319	316	0.01
Boneo 4	Incorporated manure (16 t/ha)	Piadin	289	199	75	62
Boneo 2	Surface manure (5.2 t/ha)	Piadin	92	121	124	0
Boneo 4+5	Surface manure (5.2 t/ha)	Piadin	92	208	174	19

Table 24. Average yields (t/ha) of broccoli or lettuce in trials conducted in Victoria during 2011 and 2012.

Year	2011	2012	2011		2012	
Demonstration Site	**Werribee1**	**Werribee 2**	**Boneo 1**	**Boneo 2**	**Boneo 3**	**Boneo 4&5**
Host Crop	**Broccoli**	**Lettuce**	**Broccoli**	**Broccoli**	**Broccoli**	**Broccoli**
1. Base fertilisers N	400 kg/ha 48N	600 kg/ha 87N	400 kg/ha 48N	400 kg/ha 48N	400 kg/ha 48N	
Unfertilised	5.56 (-28.0%)	4.46 (-37.1%)	6.44 (-30.2%)		1.27	
Standard practice - NPK	7.72	7.09	9.22	8.93	3.14	
Stabilised NPK (ENTEC)	7.63 (-1.2%)	5.65 (-20.3%)	8.12 (-7.0%)		5.55 (76.8%)	
Stabilised urea NPK (ENTEC)		6.30 (-11.1%)			3.98 (26.8%)	
Stabilised NPK (Piadin)		6.71 (-5.4%)				
Alzon	6.66 (-13.7%)		9.04 (-2.0%)			
Perlka	7.17 (-7.1%)		8.51 (-7.7%)			

Table 24 (continued)

2. Incorporated chicken manure#	**6.0 t/ha – (88 N)**			**16.0 t/ha (289 N)**	**16.0 t/ha (289 N)**	**5 t/ha (92N)**
Manure, side dressing and NPK base (‘CON’)	7.88			10.96		
Manure and NPK base (‘CON’)					5.30	3.63
Manure and ENTEC NPK base	8.38 (6%)				6.36 (20%)	5.91 (63%)
Manure and Piadin NPK base					7.46 (41%)	4.52 (25%)
Piadin inhibitor on manure and NPK base				10.49 (- 0.4%)		
3. Surface Applied Chicken Manure#						**5.2 t/ha (92 N)**
Unstabilised - standard						3.63
Stabilised (Piadin)						6.44 (77.4%)
Stabilised (ENTEC)						6.17 (70.0%)

CON = comparative control for determining yield differences; # - Chicken manure contains organic N which releases more slowly than inorganic N in fertilisers; Inhibited manure treatments and NPK were compared to the manure and NPK standard as the SGP.

5.3 Amiens, Queensland

General Metholodology

This section provides a description of the methods for sampling and analysis used at all of the trials undertaken at Amiens, Queensland and the Lockyer Valley, Queensland. The sampling of greenhouse gas emissions was performed using static chambers (Fig. 40). The experimental treatments varied for each trial and are described in the relevant sections.

Gas Sampling

The field gas sampling was conducted by Growcom using manual (static) chambers with the assistance of Queensland Department of Agriculture, Fisheries and Forestry. The cylindrical chambers had an internal diameter of 240mm and were located on rows over bare soil (Fig. 40) at least 20m apart along each trial row. The chambers remained in place for the duration of each measurement period. The chambers were inserted to a soil depth that provided an effective seal, and head space volumes varied between approx. 5000 and 8000ml. The chambers were sealed with a rubber o-ring and lid. The total number of chambers deployed varied among the trials and will be described in later sections.

For each measurement session, gas sampling commenced on the first morning after planting and/or fertiliser application. The first chamber was sealed at 9:00am on each day of sampling, and the remaining chambers were sealed in sequence. Depending on the trial, sealing all chambers took between 20 and 50 minutes.

Samples were extracted from each chamber via a sampling tube fitted with a 3-way stopcock using a needle and 25ml syringe, and were then transferred to 12ml evacuated vials (exetainer, Labco Ltd, United Kingdom). The sample from the first chamber was extracted 60 minutes (10:00am) after the chamber was sealed. Remaining chambers were sampled in the same order they were sealed.

On each day of sampling, soil temperature was measured to a depth of 10cm using a digital probe thermometer both inside and outside the first chamber, when the chamber was sealed and again when the sample was extracted. Six clear air samples for calibration were collected adjacent to the field after the chambers were sealed and prior to the extraction of samples. Similar to method used to extract samples from the chambers, these air samples were collected using a needle and syringe and then transferred to evacuated tubes. Samples were stored at ambient temperature prior to analysis.

Figure 40. A measurement chamber deployed on-site in a crop of mini cos lettuce, first measurement campaign, September 2010, Granite Belt. The sampling tube and stopcock are clearly visible.

GHG Analysis

The analyses of the gas samples were performed by the Land and Vegetation Science Group in the Queensland Department of Environment and Resource Management (DERM). The concentration of N_2O, CH_4 and CO_2 were determined using gas chromatography (GC). Gas samples were analysed as soon as possible after collection by gas chromatography as described by Allen et al. (2007), using commercial standards (BOC Gases, Australia) with 1% or better calibration accuracy to calculate sample gas concentrations. Standards were injected every 10 samples to monitor instrument precision. N_2O gas fluxes were calculated using linear increase over time, with values of $R^2 > 0.95$ accepted (Allen et al., 2007). In calculating the rate of emissions for each sample, the analysis considered the head space volume in each chamber and the duration for which the chamber was sealed prior to the extraction of the sample.

Data analysis was performed using R (version 2.14.0; The R Foundation for Statistical Computing, http://cran.r-project.org/). All graphs illustrating emissions measurements are based on cumulative results over the full sampling period.

The treatments applied at the demonstration sites were consistent with current best practice and included the main inputs (fertilizers and manures) that contribute to N_2O and CO_2 emissions. In particular these included the impact of high analysis nitrogen fertilizers compared with stabilized nitrogen fertilizers, organic manures (chicken manures, green waste organics, silage) and other carbon treatments, (e.g. lignite). At all sites the standard grower practice was used to compare with the potentially more environmentally sustainable and 'lower emissive' practice. Also, where possible, effects on crop productivity, disease and profitability of each practice were calculated (but this was constrained by funding and labour).

From this information charts showing the difference in emissions between different production practices have been presented to enable growers to compare practices. A simple benefit/cost model was used to calculate profit gains from the yield obtained from use of stabilized fertilizers and manures. The impacts on soil carbon are also discussed briefly.

At each site, a preliminary economic assessment of proposed and actual changes to farming practices, including the cost-effectiveness of reducing GHG emissions and/or energy inputs, was conducted.

Key Aim

To determine the effect of different stabilised (i.e. with nitrification inhibitors) fertiliser treatments (i.e. ENTEC, Nitrophoska), with and without other agronomic practices, when compared to the standard grower practice on greenhouse gas emissions, productivity and profit.

Rationale for the Selected Treatments

The work program for the Queensland component of the project was designed as a demonstration, as well as confining the focus of the work on nitrification inhibitors in the main. In consultation with team members and the grower co-operator, a number of potential changes to standard grower practice were considered. These included less tillage, changes to the cover cropping regime and changes to fertilizer programs and fertilizer types.

Because of the need to make minimal farming system changes in a Demonstration Project such as this, so that the results can be more easily interpreted and utilized by growers in their own businesses, the decision was made to concentrate on the effects of different stabilised fertilizer treatments, as fertiliser use is something that an individual grower can have immediate impact on for relatively small changes to the production system. In the first Trial, a number of these more complex farming system changes were included. They were not continued into the remaining three (3) trials because of the complexity of the treatments which do not suit a Demonstration Project as well as a more Research oriented approach.

The treatments which were applied in each of the Demonstrations are listed in each of the four (4) Trials conducted at Amiens over the duration of this project.

The Farming System

The farm for the demonstration site is located at Amiens, in the Granite Belt of S.E.-Queensland.

It is operated by Harslett's Enterprise and is considered a medium to large vegetable production enterprise for Queensland. Approximately 135 Ha are farmed annually with 100% of production irrigated by overhead sprinklers.

The main crops produced are leafy vegetables, primarily celery, Chinese cabbage, lettuce and cos lettuce. The production season is spring, summer and autumn, winter being too cold for the types of vegetables grown by this enterprise.

A key feature of these crops is their high perishability and thus the importance of rapidly removing field heat and maintaining the cold chain to point of sale.

Most produce is marketed through central markets, with some value adding carried out on the eastern seaboard of Australia.

The soil is described as a Pozieres and is classified as a tenosol under the Australian classification system. Soil tests and historical application rates were used to determine fertiliser treatments and application timing.

5.3.1 Demonstration Site, Amiens, Qld - Trial 1

The first measurement campaign was conducted on a mini cos lettuce crop planted on the demonstration site at Harsletts farm at Amiens in the Granite Belt of Queensland.

Mini cos lettuce is produced on the farm for a contract price. After harvest it is pre-cooled on-farm before transport to Gatton for retail packing. Yield is determined by the number of mini cos harvested per hectare. Plants must meet a minimum specification for harvest, with the major quality parameter being head size.

The first measurement campaign was set out in discussion with farm management and the project team at DAFF Queensland and Growcom. Nine treatments were selected to compare and determine GHG emissions from the mini cos lettuce crop and associated economics from the use of grower custom blend fertiliser formulations, fertigation, biochar, manure and minimum till.

Harslett farms in recent years have shifted to the use of a custom blend fertiliser for basal and side-dress applications. This was compared to the traditional practice of a standard basal product and a series of fertigations (fertiliser applied through overhead irrigation during normal irrigation applications). Permanent overhead irrigation is standard practice in the Granite Belt, where production occurs on shallow sandy soils over a generally mild summer season.

Feedlot cattle manure is traditionally applied pre-plant at 25t/Ha annually in late winter, and its use was compared with and without manure across the custom blend and fertigation applications and a biochar product being trialled on the farm. No details were available or provided on the packaging of nutrient content or other products contained in the biochar.

Method

The custom blend fertiliser is custom made for the farm and is marked as controlled release fertiliser, however does not contain a nitrogen inhibitor.

A minimum till treatment whereby two ground working applications prior to planting were removed was also included in the trial.

The final treatments[1] are outlined below:[2]

1 – Fertigation (12kg N/ha, applied weekly for 4 weeks 48kg/ha total N)

2 - Fertigation, manure (25T/ha) & biochar 2.5T/ha)

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[1] Nitrogen was applied in the fertigation process as Ammonium sulphate tech with analysis of Nitrogen at 20.5%, four applications of 60kgHa were applied. Additional quantity of fertiliser was applied to match the N rates of treatments with manure applied.

[2] controlled release fertiliser was a custom blend containing N12%

3 - Fertigation & biochar

4 - Fertigation & manure

5 - Minimum till, controlled release & manure

6 - Controlled release (400kg/ha 48kg/ha total N)

7 - Controlled release, manure & biochar

8 - Controlled release & biochar

9 - Controlled release & manure

The applications rates were adjusted to ensure the same level of nitrogen from each treatment method.

The crop was planted on the 14th of September 2010 with basal treatments applied and incorporated in the bed forming process immediately prior to planting.

Greenhouse Gas Emissions - Amiens, Qld - Trial 1

Simple analyses suggested that the fertiliser and manure treatments affected the emissions of the three greenhouse gases to some degree, while biochar appeared to have little effect.

The controlled release fertiliser program had higher emissions than the fertigation program (Fig. 41). This was most likely because the nitrogen applications via fertigation supplied the plant requirements, resulting in significantly reduced denitrification. Manure significantly increased emissions (Fig. 42), this being caused by the concentration of manure applied (25T/ha) containing large quantities of nitrogen, carbon and microorganisms.

A multivariate analysis of variance (MANOVA) using carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) as the multiple responses confirms this result – there are statistically significant effects of both fertiliser and manure treatments but no effect of biochar. This analysis also revealed a significant interaction between fertiliser and manure application (Fig. 43).

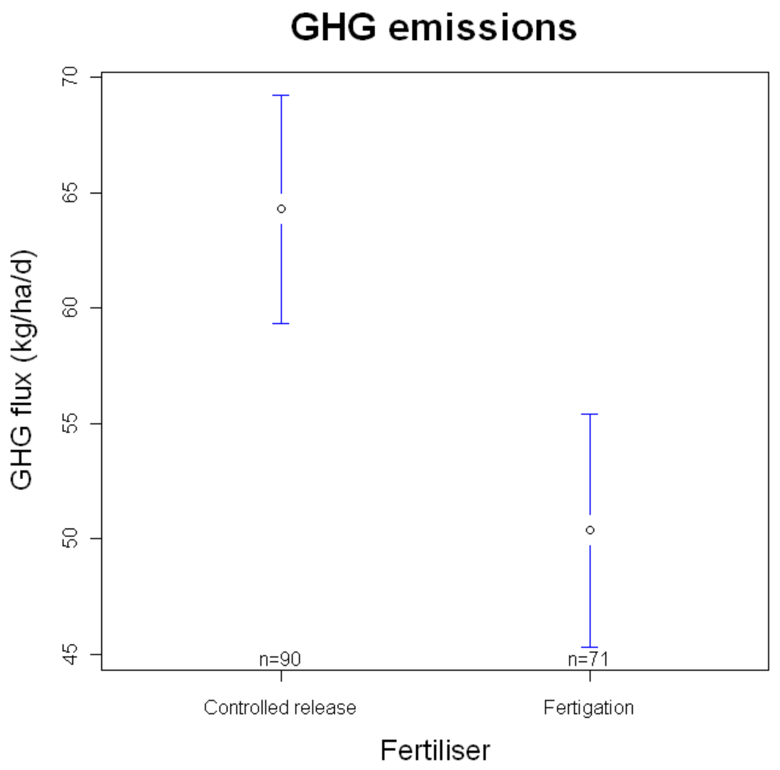

Figure 41. Results of total emissions under controlled release and Fertigation, mini cos lettuce, first measurement campaign, September 2010, Granite Belt, Qld.

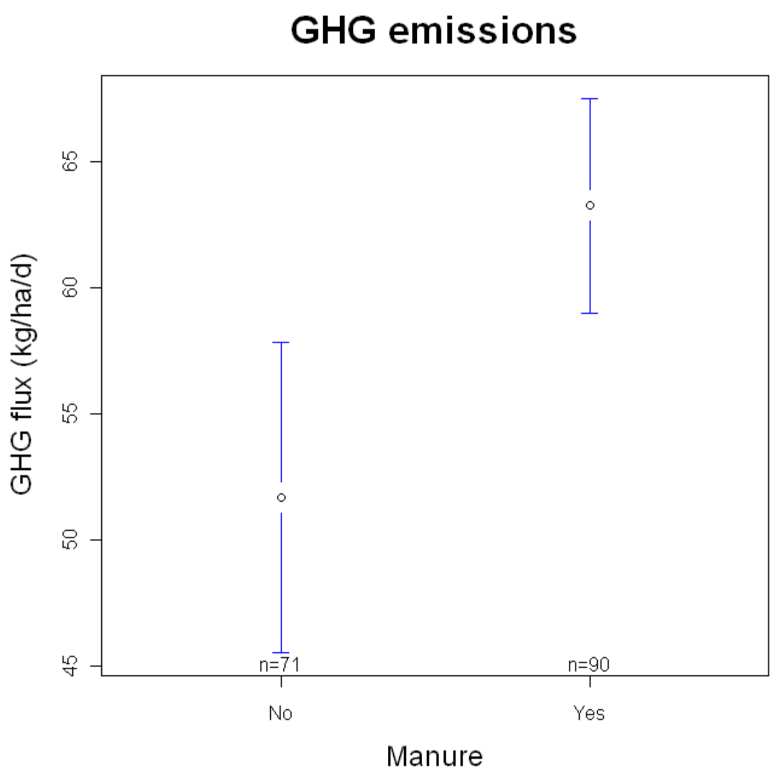

Figure 42. The effect of manure on total GHG emissions (kg CO_2-e/ha/day), mini cos lettuce, first measurement campaign, September 2010, Granite Belt, Qld.

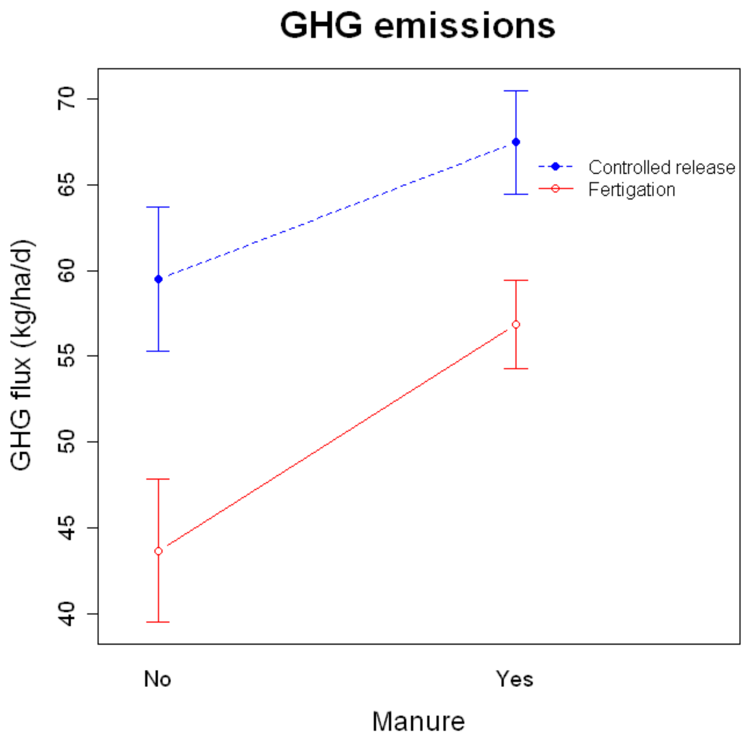

Figure 43. An illustration of the combined effects of fertiliser method and manure application on the total greenhouse gas (GHG) emissions (kg CO_2-e/ha/day; means ± standard errors), mini cos lettuce, first measurement campaign, September 2010, Granite Belt.

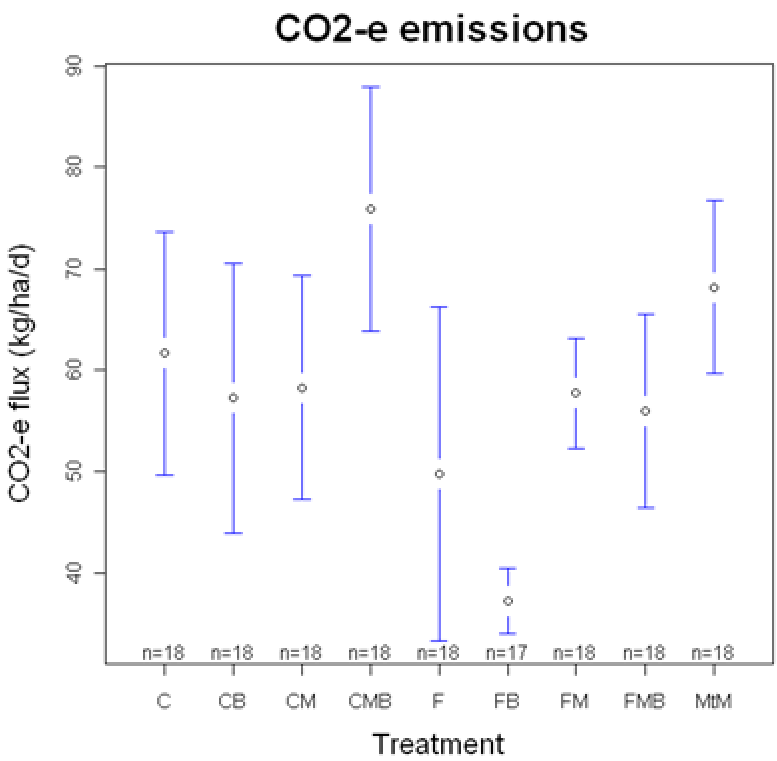

Figure 44. Overall GHG emissions (kg/ha/d) from the nine different treatments at Demonstration Site 3, Amiens, Qld – Trial 1.

Yield Assessment – Amiens, Qld - Trial 1

The potential yield was assessed prior to harvest with growers as part of a field day, and again during and after harvest. The trial crop prior to harvest can be seen in Plate 1.

During the field walk, participants were asked to look at each treatment and identify which treatment produced the highest yield. The general consensus amongst the group of growers was that there was no significant variation between treatments. This was confirmed with farm management and harvest and post harvest assessments which showed insignificant variation between treatments.

Therefore treatments had no significant effect on crop yield and harvest maturity.

Plate 1 - Trial 1- Minicos lettuce prior to harvest.

Economics Assessment – Amiens, Qld - Trial 1

Gross margins from each treatment were calculated after the harvest data was collected and results are outlined in Table 25 below. Detailed gross margins and key assumptions for the treatments can be seen in Appendix 14.3.

The treatment that gave the best results economically was Treatment 6, controlled release fertiliser only, with a gross margin of $5629.80/Ha. Treatment 2 produced the lowest gross margin of $1997.40/Ha. This treatment was a combination of fertigation, manure and biochar.

Yield and income were very similar for each of the treatments, so variations were due to fertiliser and application costs.

It must also be noted that the minimum till treatment resulted in a poor efficiency with the automatic transplanter used on the farm. The planters require a clean bed with minimum plant residue. As this could not be assured in future reduced till activities, it was decided not to continue with this option for future trials.

Table 25. Gross Income, total costs and Gross Margins $/Ha for Trial 1 treatments in a mini cos lettuce crop at Amiens 2010.

Treatment	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Gross Income ($/Ha)	22400	22400	22400	22400	22400	22400	22400	22400	22400
Total Costs ($/Ha)	16845.40	20402.60	19402.60	17867.40	17763.60	16770.20	20320.80	19287.40	18294.20
Gross Margin ($/Ha)	5554.60	**1997.40**	2997.40	4352.60	4636.40	**5629.80**	2079.20	3112.60	4105.80

Discussion and recommendation for future demonstrations

The custom blend (slow release) fertiliser increased GHG emissions when compared to traditional non slow release fertigation and basal applications. This was not expected prior to the trial or by suggestions from the young grower group.

Manure significantly increased emissions and had no effect on crop yield and thus contributed negatively in an economic sense to farm production. The effects on emissions was constant with the project team, farm management and the young grower group, however the effects on yield was unexpected.

Discussion also occurred relating to other benefits manure provided to the farm production system including improving soil health attributes such as improved water holding capacity, less soil crusting and improved water infiltration.

Therefore it was also recommended to repeat the scenarios with the next trial to confirm these results.

Although biochar had minimal effects on emissions and contributed significantly to poorer economics it was also suggested to include it again in the next trial to confirm these results.

It might also be noted that best case treatment for reduced emissions was Treatment 1, fertigation only, which had the second best overall gross margin of $554.60/Ha which was only $75.20 less than the highest gross margin in Treatment 6, controlled release only.

Thus from discussions with growers and the project team, and results from Demonstration Trial 1 the treatments for the next trial were determined. These treatments were aimed at comparing different types of custom blend fertilisers, a standard fertiliser or fertigation treatment, and continue with manure and biochar applications on emissions and associated economics.

5.3.2 Demonstration Site, Amiens, Qld - Trial 2

The second measurement session at the Granite Belt site was completed in February 2011, followed by a second on-site field day in April 2011.

Demonstration trial 2 aimed to investigate the use of different types of fertilisers, including nitrogen inhibitors and repeat the manure and biochar trials from trial 1.

Research has indicated that nitrification inhibitors may have a place in this vegetable production system. A commercially available fertiliser could be sourced locally containing an inhibitor - ENTEC Nitrophoska. An equivalent fertiliser, without an inhibitor, Nitrophoska Blue Special was also available as a comparison. Their nutrient analysis was also suitable for this crop. A detailed nutrient analysis can be seen in Appendix 14.2 for these products.

The growers own custom blend fertiliser used in Trial 1 was also included for reference.

Method

Celery was planted on the 2nd of February 2011 as per normal practice on farm with an automatic transplanter. Celery is harvested, packed and cooled onsite before being sent to central markets on the Australian eastern seaboard for distribution to retail markets. Harvest generally occurs when the majority of celery meets a saleable size. Yield is determined by the number and size of cartons harvested per hectare.

Celery is a relatively long crop to grow and requires a further side dressing or fertigation application of nutrients to reach maturity. This was applied at the same rate across treatments and wasn't included in the emissions measurements. Emissions were measured using static chambers for the first 7 days after planting only.

Nine treatments were applied to the celery crop consisting of combinations of fertiliser application (with or without N Inhibitor) overlapped onto previous applications of manure (with and without) and biochar (with and without), and a treatment containing the farms own custom blend formulation.

All fertiliser treatments were banded along the top of the bed and incorporated into bed immediately prior to planting.[3]

1 - Nil Inhibitor (Nitrophoska Blue Special) (500kg/Ha)

2 - Nil Inhibitor (500kg/Ha), manure & biochar

3 - Nil Inhibitor (500kg/Ha) & biochar

4 - Nil Inhibitor (500kg/Ha) & manure

5 – Growers standard slow release fertiliser (own blend) (500kg/Ha) & manure

6 – N Inhibitor (ENTEC Nitrophoska) (500kg/Ha)

7 - N Inhibitor (500kg/Ha) , manure & biochar

8 - N Inhibitor (500kg/Ha) & biochar

9 - N Inhibitor (500kg/Ha) & manure

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[3] Basal fertilisers all had a N analysis of 12% providing 60kg/Ha N at basal application

Plate 2 - Trial 2 - Celery prior to field day and harvest - April 2011.

Greenhouse Gas Emissions – Amiens, Qld - Trial 2

The second trial produced very promising results showing that nitrification inhibitors may be an effective method to reduce GHG emissions. Both the nitrification inhibitor (Fig. 45 and Fig. 46) and manure (Fig. 47) had significant effects on the overall GHG emissions expressed in carbon dioxide equivalent (CO_2-e), and there is also a significant interaction between the inhibitor and manure (Fig. 48).

This result makes sense for two reasons. Firstly, the inhibitors should not be expected to have an effect on CO_2 emissions which were greatly elevated with manure in this trial. Also, given that the inhibitor is applied with the fertiliser, it is likely to be less successful at suppressing the conversion of nitrogen from other sources.

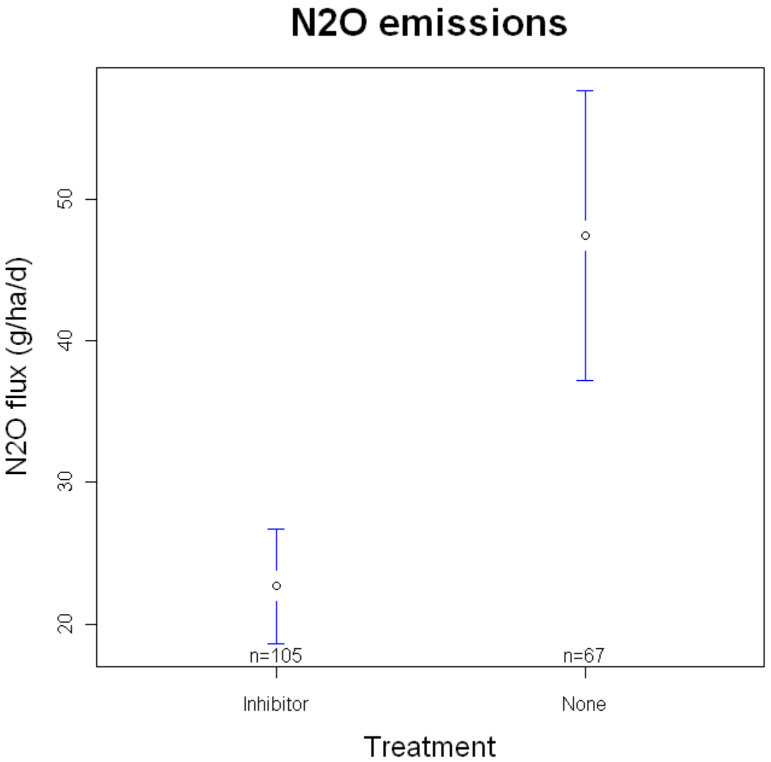

Figure 45. N_2O emissions in relation to nitrification inhibitor in a Celery crop, Amiens, Qld, February 2011. Measurements taken for the first seven days after fertiliser application only.

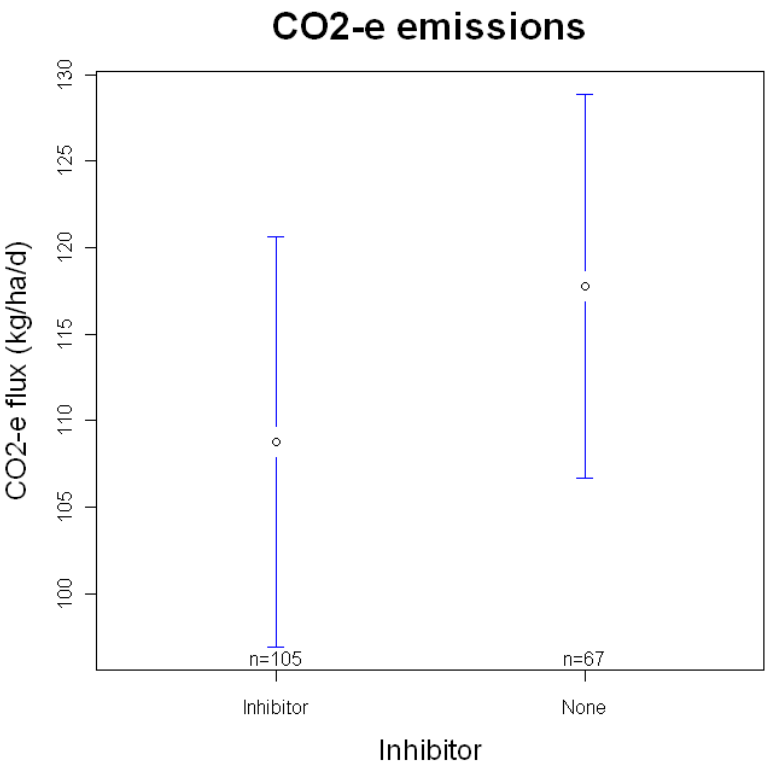

Figure 46. CO_2-e emissions in relation to nitrification inhibitor in a Celery crop, Amiens, Qld, February 2011. Measurements taken for the first seven days after fertiliser application only.

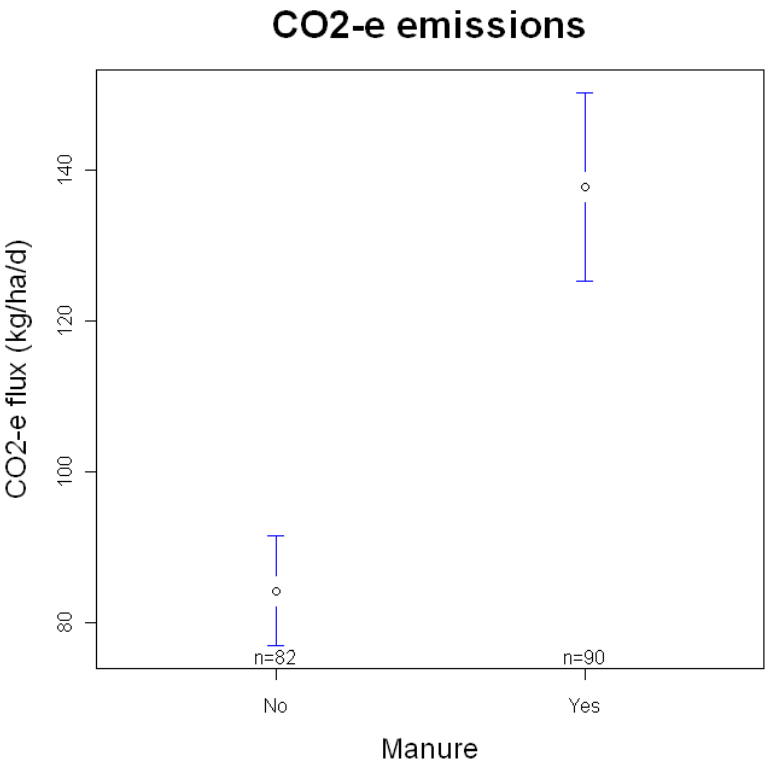

Figure 47. CO_2-e emissions in relation to manure in a Celery crop, Amiens, Qld, February 2011. Measurements taken for the first seven days after fertiliser application only.

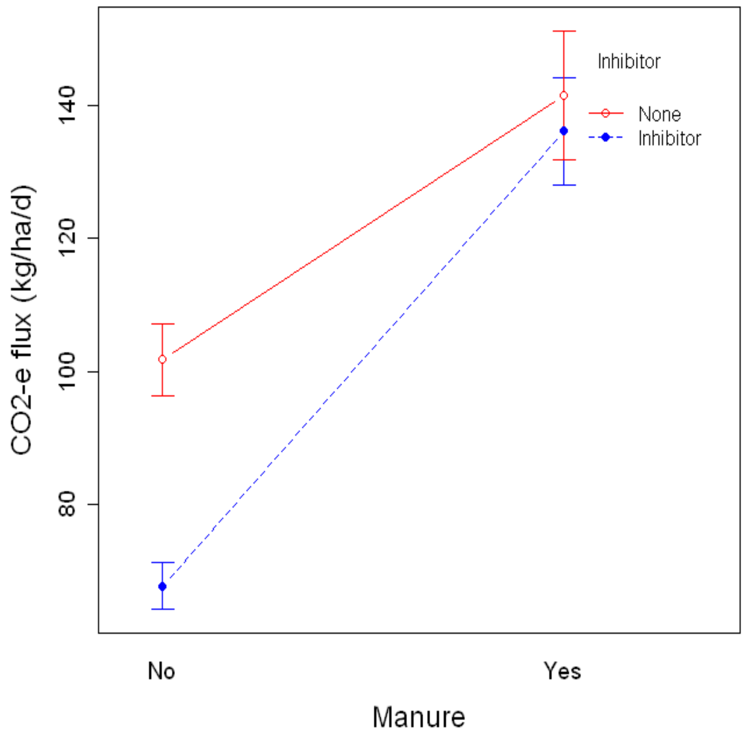

Figure 48. The combined effects of the nitrification inhibitor and manure application on the total greenhouse gas (GHG) emissions (kg CO_2-e/ha/day; means ± standard errors) in a Celery crop, Amiens, Qld, February 2011. Measurements taken for the first 7 days after fertiliser application only.

Yield Assessment – Amiens, Qld - Trial 2

The potential yield was assessed prior to harvest with growers as part of a field day and also during and after harvest. The trial crop prior to harvest can be seen in Plate 3.

During the field walk participants were asked to look at each treatment and identify which treatment had the highest yield. Plants from a metre of bed of each treatment were placed at the end of treatments for growers to assess and weights taken. The general consensus amongst the group of growers determined that there was no significant variation between treatments which was confirmed from actual plot weights.

Unfortunately harvest data could not be used to accurately determine treatment yields as poor market prices and low market demand resulted in a long delay between harvest dates for the treatments and some plots were ploughed out due to potential low economic returns and poor quality due to over maturity of the crop. These returns and over maturity were not due to fertiliser or trial treatments but rather prevailing market conditions.

Therefore yields for each trial were assumed at 2500 cartons/Ha which was the pack out for the first block harvested.

Economic Assessment – Amiens, Qld - Trial 2

Due to poor market conditions resulting in destruction and non harvest of a section of the trial crop, the economic analysis presumed a standard price received for celery as that of the first day of harvest of the trial crop. This assumption can be made because there were no differences in maturity between the treatments.

Yield and income were considered equal for each of the treatments, so economic variations were due to fertiliser and application costs. The cost of the inhibitor fertiliser was $120/tonne, therefore ENTEC Nitrophoska was $1178/tonne compared to $1058/tonne for Nitrophoska Blue Special.

The treatment that gave the best results economically was Treatment 1, no inhibitor only, with a gross margin of $2313.20/Ha. Treatment 7 produced the lowest gross margin of -$1364.00/Ha, this treatment was a combination of inhibitor, manure and biochar.

Table 26. Gross margin analysis for treatments in demonstration trial 2, Amiens.

Treatment	1	2	3	4	5	6	7	8	9
Gross Income ($/Ha)	25000	25000	25000	25000	25000	25000	25000	25000	25000
Total Costs ($/Ha)	22686.80	26244.00	25222.00	23722.00	24164.00	22806.80	26364.00	25342.00	23842.00
Gross Margin ($/Ha)	**2313.20**	-1244.00	- 222.00	1278.00	836	2193.20	**-1364.00**	-342.00	1158.00

Discussion and recommendation for future demonstrations

Trial 2 confirmed the results from Trial 1, in that manure did not affect yield and increased GHG gas emissions, and thus was not beneficial to the production system in both environmental and economic terms.

Discussions with participants at the field day and farm management on what the implications of this would be to the farm, indicated manure may have other benefits such as increased water holding capacity and improved soil structure that may not appear in the short term. It was agreed that yields should be monitored in the future if manure rates were reduced or not used at all.

Biochar again had no impacts on GHG emissions, yields and contributed negatively to economics. Again it may bring long term benefits to the farm however these cannot be determined at this stage.

The use of an inhibitor definitely reduced emissions and did not have any difference in yield; however the cost of using the inhibitor resulted in a reduced return of $120 for every tonne of fertiliser used. Therefore at this stage its use could not be justified economically.

This led to discussions amongst field day participants about the possibility of the inhibitor to maintain yields at a reduced rate and thus becoming cost neutral. This would lead to part of the program for Trial 3.

5.3.3 Demonstration Site, Amiens, Qld - Trial 3

Given the results of earlier trials that provided interesting results for the use of nitrification inhibitors, this session focussed on the use of nitrification inhibitors and the effects of fertiliser application.

The third measurement campaign was conducted on a Chinese cabbage crop planted on the demonstration site in October 2011. Chinese cabbage is planted on the farm for spring, summer and autumn production. Chinese cabbage is planted at approximately 40000 plants per Ha using an automatic transplanter using seedlings produced in the nursery on farm. Fertiliser is banded along planting beds and incorporated immediately prior to planting.

Harvest occurs approximately 8 - 10 weeks after transplanting.

At harvest, Chinese cabbage is packaged into cartons in the field before being taken back to cool room for cooling before transport to Queensland and interstate markets.

This demonstration focussed on the effects of reduced fertiliser application rates and the use of nitrification inhibitors.

There were six treatments using three different fertilisers (the grower's custom blend, Nitrophoska, and ENTEC Nitrophoska with inhibitor) at two application rates, standard practice of 750kg/Ha and a reduced rate of 500kg/Ha[4]. These treatments were:

1. Harslett's custom blend 500kg/ha
2. Harslett's custom blend 750kg/ha
3. Nitrophoska Blue Special 500kg/ha (No inhibitor)
4. Nitrophoska Blue Special 750kg/ha (No inhibitor)
5. ENTEC Nitrophoska 500kg/ha (inhibitor)
6. ENTEC Nitrophoska 750kg/ha (inhibitor)

The trial crop of Chinese cabbage prior to harvest can be seen in Plate 3.

[4] All basal fertilisers contained 12% N giving basal N applications of 60kg/Ha N for 500kg/Ha basal fertiliser treatments and 90kg/Ha N with the 750kg/Ha basal fertiliser treatments.

Plate 3 - Demonstration trial 3, Amiens Qld - Chinese cabbage - November 2011.

Greenhouse Gas Emissions – Amiens, Qld - Trial 3

The third trial focused on the use of nitrification inhibitors and reduced application rates to manage emissions of N_2O. Emissions were lower under the reduced application rate (500kg/ha compared to 750kg/ha) (Fig. 49). The results showed that the treatment with inhibitor had the lowest levels of N_2O emissions; this was significant in comparison with the customer blend. However, when comparing the two Nitrophoska products, with and without inhibitor, only a very small difference was found in this system (Fig. 50).

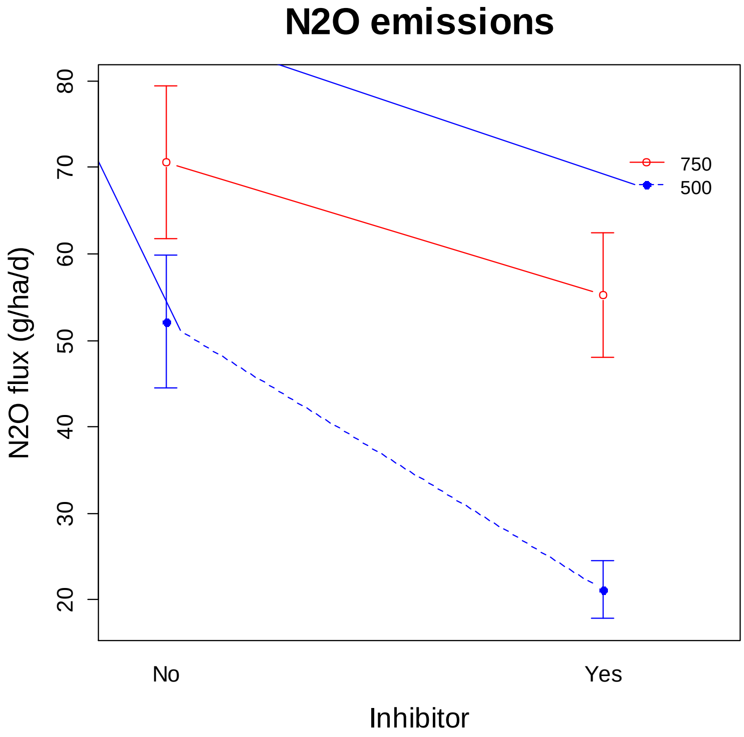

Figure 49: The combined effects of the nitrification inhibitor and fertiliser application rate on nitrous oxide (N_2O) emissions (g/ha/day; means ± standard errors), Chinese cabbage crop, Amiens, Qld, February 2011. Measurements taken for the first 7 days after fertiliser application only.

For both Nitrophoska and ENTEC Nitrophoska, lower application rates led to lower N_2O emissions levels. However, for the grower custom blend the two applications rates lead to no significant difference in emissions (Fig. 50).

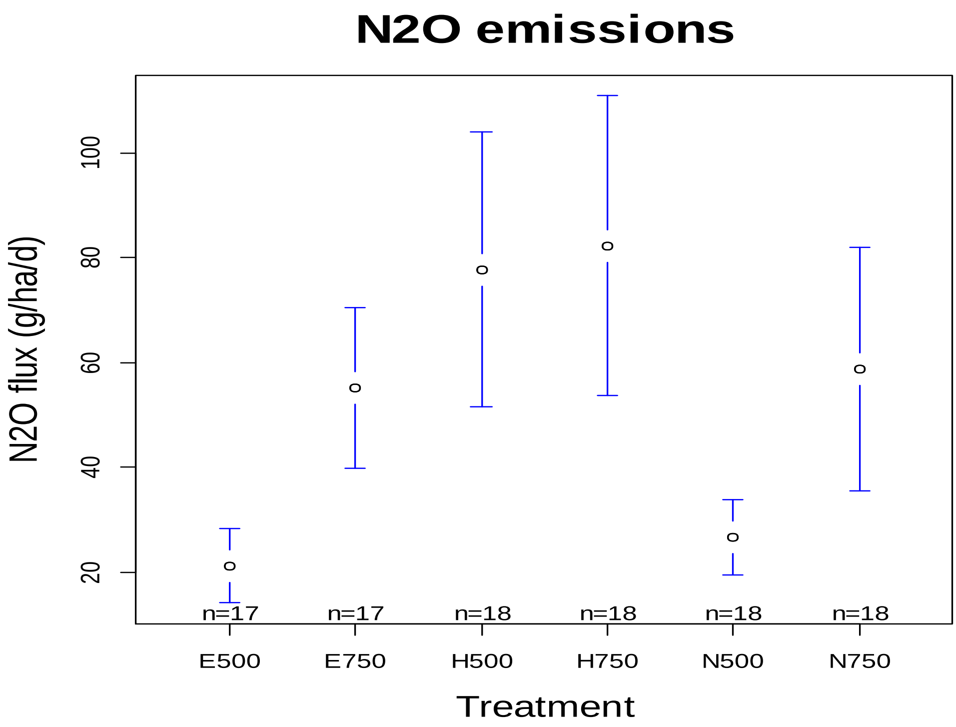

Figure 50: Nitrous oxide (N2O) emissions, E: ENTEC Nitrophoska, H: Grower custom blend, N: Nitrophoska, Application rate 500 kg/ha, 750 kg/ha, Chinese cabbage crop at Amiens, Qld, February 2011. Measurements taken for the first 7 days after fertiliser application only.

Yield assessment – Amiens, Qld - Trial 3

A yield assessment was performed on the Chinese cabbage crop at harvest. The number of cartons harvested were counted for 1/10th of a Hectare for each treatment and extrapolated to give a Hectare yield.

The yields are outlined in Figure 51.

The highest yielding treatment was with E750 or the standard fertiliser rate with an inhibitor. The lowest yield was the standard rate of Nitrophoska Blue Special (750 kg/ha).

Reduced yields were seen with the farmer's custom blend and the ENTEC Nitrophoska when the reduced fertiliser rate was used, however this did not occur with Nitrophoska Blue (no inhibitor) product.

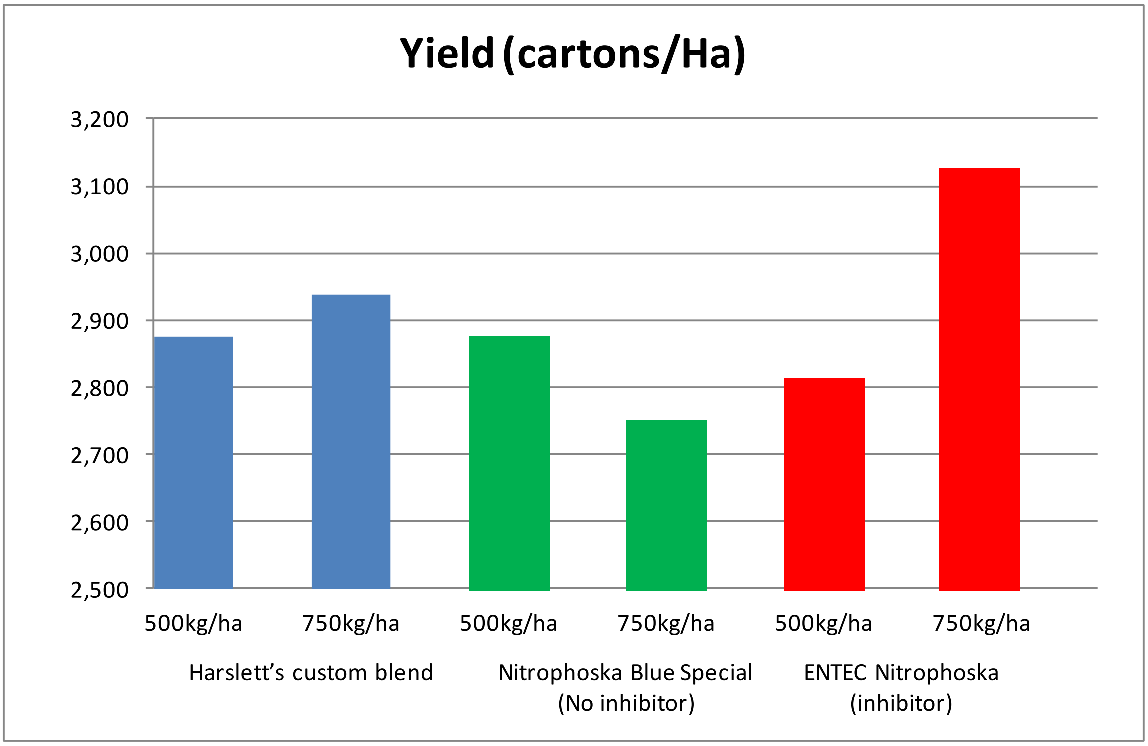

Figure 51: Yields cartons/Ha for treatments in demonstration trial 4 - Chinese cabbage - November 2011, Amiens Qld.

A yield assessment was carried out on the Chinese cabbage to estimate the differences in crop income compared to the different fertiliser types and rates. The assessment was made on one hectare and the monetary figures in the graph show the income potential after fertiliser costs have been extracted (Fig. 52). The assessment showed insignificant variations in costs and total yield. However, the figures do not consider crop size and the fact that larger crops are easier to sell.

Economic Assessment – Amiens, Qld Trial 3

Gross margins for the inhibitor and non inhibitor treatments and the reduced rate treatments of these fertilisers were calculated after the harvest data was collected and results are outlined in Table 27 below. Detailed gross margins for the treatments can be seen in Appendix 14.3.

The treatment that gave the best results economically was E750, with a gross margin of $8541/Ha. E500 or the reduced rate of fertiliser using an inhibitor resulted in the lowest gross margin of $6942/Ha.

Reducing the fertiliser rate with the ENTEC product by 250 kg/Ha would save the farm $294/Ha in fertiliser costs. However a decreased yield with this treatment of 312 cartons per hectare resulted in the farmer being worse off financially by $1579 per hectare.

The opposite occurred with the non inhibitor Nitrophoska product whereby reducing fertiliser rate increased the yield from the trial and therefore resulted in a more positive economic return of $258/Ha.

Table 27. Gross margin analysis for demonstration trial 3 - Chinese cabbage – Amiens Qld November 2011.

	ENTEC 500 kg/ha	Nitrophoska Blue @ 500kg/ha	ENTEC 750 kg/ha	Nitrophoska Blue @ 750kg/ha
Crop	Chinese Cabbage			
Season	Summer			
Yield Cartons/ha	2813	2875	3125	2750
Price $/t	$688.90	$706.52	$690.00	$721.59
Average price $/t	$701.75	$701.75	$701.75	$701.75
Gross income $/ ha	$31,006	$32,500	$34,500	$31,750
Gross income (Av price) $/ ha	$31,584	$32,281	$35,088	$30,877
Total of variable costs $/ha	24063.65	24321.77	25959.01	23830.4
(Excluding machinery FORM)				
Gross margin (actual prices) $/ ha	$6,942	$8,178	$8,541	$7,920

Nb: No gross margin analysis was conducted for the Custom Blend treatment

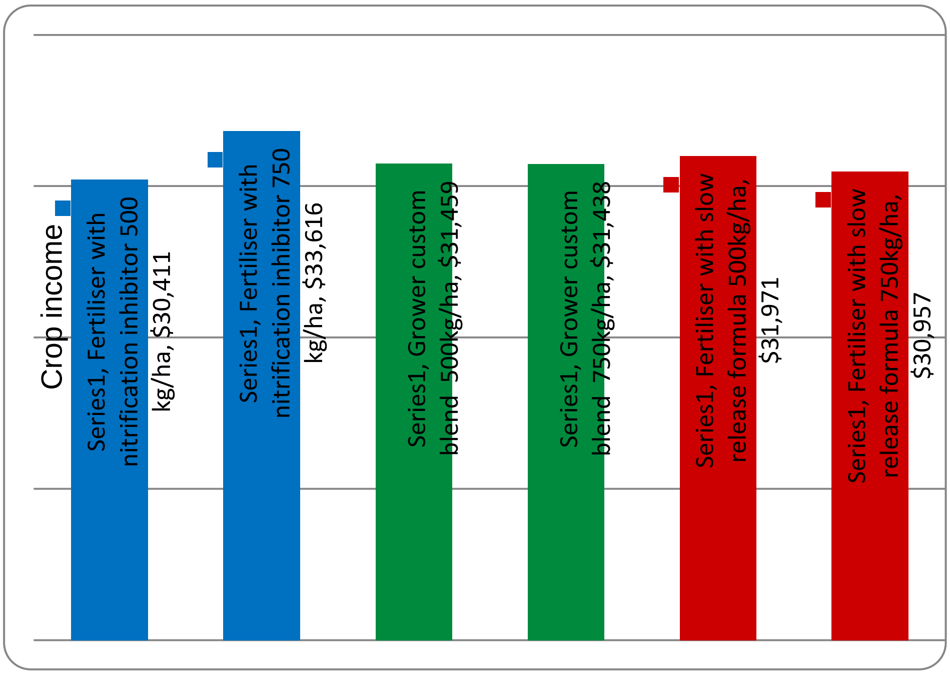

Figure 52: Result of yield assessment, Chinese cabbage, third measurement campaign, October 2011, Granite Belt.

Similarly, an assessment of the yields from the celery crop (trial 4) revealed no obvious differences among the treatments, with an average yield of 2,500 cartons per hectare (Table 27 & Fig 52).

5.3.4 Demonstration Site, Amiens, Qld - Trial 4

Demonstration trial four aimed to determine if GHG emissions were reduced when inhibitors were used in the side dressing of the celery crop. The crop was planted in February and harvested in late May 2012.

Side dressing involves spreading fertiliser along the surface of the crop during different growth stages and incorporating with irrigation or mechanical devices.

A fourth round of measurements was undertaken with a focus on three different types of fertiliser, one with and two without nitrification inhibitor in a celery crop. These treatments were:-

1. Grower's custom blend (nil inhibitor)
2. Nitrophoska Blue Special (nil inhibitor)
3. ENTEC Nitrophoska (inhibitor)

Fertiliser was applied at a rate of 350kg/Ha, providing 42kg/ha Nitrogen, on top of the bed and incorporated using irrigation and light cultivation. The timing of application was 6 weeks after transplanting which is normal application time for this farm.

The demonstration trial 4 celery crop prior to harvest can be seen in Plate 4.

Plate 4 - Demonstration trial 4 - Celery - May 2012, Amiens Qld

Greenhouse Gas Emissions – Amiens Qld - Trial 4

The results reveal significantly lower N_2O emissions from fertiliser with inhibitor compared to the grower custom blend. Interestingly, the N_2O emissions from Nitrophoska are similar to those of ENTEC Nitrophoska. This indicates that the slow release Nitrophoska formula may have an equivalent effect on the release of nitrogen from the soil as the inhibitor in ENTEC Nitrophoska, at least in this system (Fig. 53).

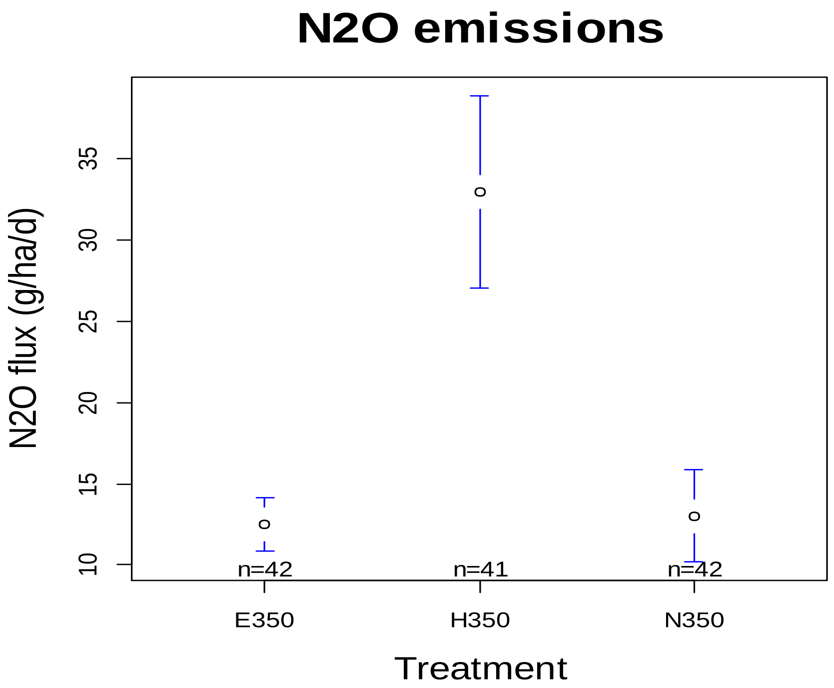

Figure 53: Nitrous oxide (N_2O) emissions g/ha/day, E: ENTEC Nitrophoska, H: Grower custom blend, N: Nitrophoska, Application rate 350kg/ha, celery crop at Amiens Qld, March 2012. Measurements taken for the first 7 days after fertiliser application only.

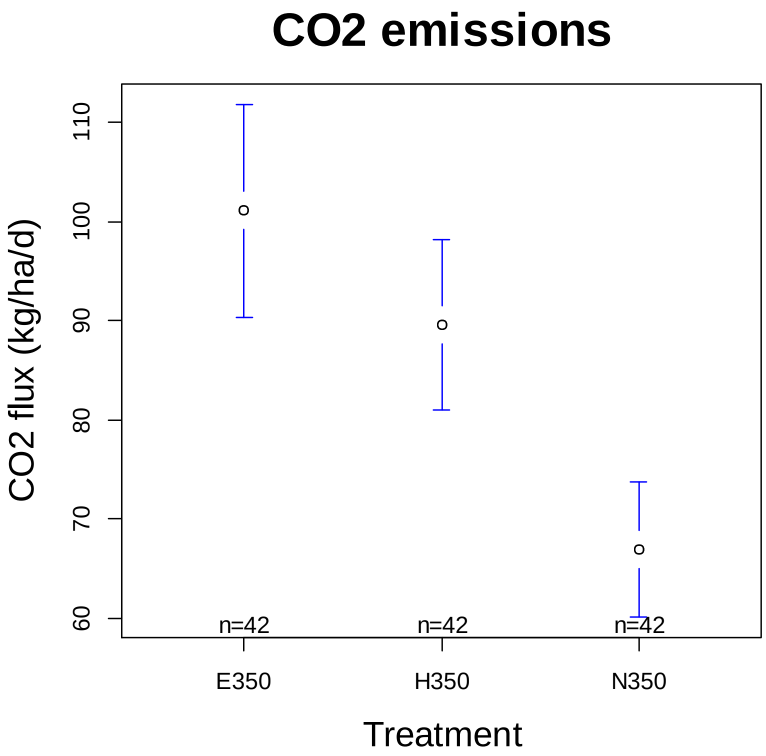

Figure 54: CO_2 emissions g/h/d, E: ENTEC Nitrophoska, H: Grower custom blend, N: Nitrophoska, Application rate 350kg/ha, celery crop at Amiens Qld, March 2012. Measurements taken for the first seven days after fertiliser application only.

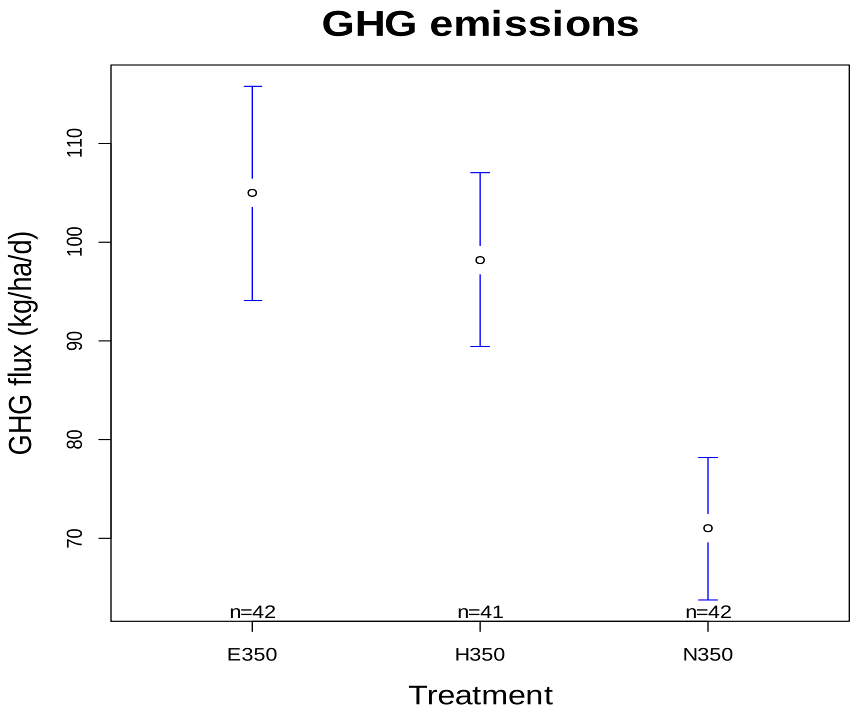

Figure 55: Greenhouse gas (GHG) emissions kg/ha/day, E: ENTEC Nitrophoska, H: Grower custom blend, N: Nitrophoska, Application rate 350kg/ha, celery crop at Amiens Qld, March 2012. Measurements taken for the first 7 days after fertiliser application only.

CO_2 emissions are so high (Fig. 54) that they influence the overall GHG emissions, and high levels of total emissions were recorded for rows treated with the ENTEC inhibitor (Fig. 55) even though N_2O emissions were significantly lower (Fig. 53).

The highly variable relationship between nitrification inhibitors and emissions of the three main GHGs illustrates the complexities involved in managing GHG emissions in farming systems.

Yield assessments – Amiens Qld - Trial 4

Similarly to trial 3, an assessment of the yields from the celery crop revealed no obvious differences among the treatments, with an average yield of 2,500 cartons per hectare.

Economic Assessment – Amiens Qld Trial 4

As yield was not affected the only economic differences between treatments related to fertiliser costs, thus the fertiliser with the lowest cost, standard Nitrophoska Blue special, was the most economically successful. Gross margins for each treatment can be seen in Table 28.

Table 28. Gross margin analysis for demonstration Trial 4 - Celery - May 2012, Amiens Qld

Treatment	Gross margin $/Ha
Harslett custom blend	6666.50
ENTEC Nitrophoska 350kg/Ha	6779.20
Nitrophoska Blue Special 350kg/Ha	6821.90

5.3.5 General Results - Amiens, Queensland

In the first demonstration, harvest and post harvest assessments showed insignificant differences between treatments, whereas the manure treatments had higher emissions than using standard fertilizer applications.

The second demonstration showed that nitrification inhibitors can be an effective method to reduce greenhouse gas emissions. Both the nitrification inhibitor and manure had significant effects on the overall GHG emissions, and there is also a significant interaction between the inhibitor and manure.

This result makes sense for two reasons. Firstly, the inhibitors should not be expected to have an effect on CO_2 emissions, which were greatly elevated with manure in this trial. Also, given that the inhibitor is applied with the fertiliser, it is likely to be less successful at suppressing the conversion of nitrogen from other sources.

The third Demonstration focussed on the effects of reduced fertiliser application rates and the use of nitrification inhibitors, where emissions were lower under the reduced application rate, and were further reduced with the use of nitrification inhibitors. The effects on yield were as follows. The highest yielding treatment was with the standard fertiliser rate containing the nitrification inhibitor. This also produced the best economic return as well. The lowest yield was the standard fertilizer rate with no nitrification inhibitor. Reduced yields occurred for the farmer's custom blend and the nitrification inhibitor at the reduced fertiliser rate.

Reducing the fertilizer rate will reduce emissions and fertilizer costs, but these are negated by reduced yields and subsequent reduced economic returns.

In the fourth Demonstration, no yield differences were measured. The only economic differences between treatments related to fertiliser costs, thus the fertiliser with the lowest cost, standard fertilizer with no inhibitor, was the most economically successful, and the emissions from the fertilizer with a nitrification inhibitor were the same as those without the inhibitor.

5.3.6 Carbon footprint of the farm at Amiens Qld

The Vegetable Carbon Calculator was developed specifically for Australian vegetable growers and can be found at http://www.vegiecarbontool.com.au.

This tool was used to estimate a carbon footprint for the farm of this trial demonstration site for the first year of the project. Data was collected from;

- Electricity bills/meter records
- Fuel bills/receipts
- Records of waste processed on-farm
- Records of fertiliser usage for the reporting year
- Service documents for on-site cold rooms.

A resulting estimate of the farms carbon footprint can be seen in Table 29 and Figure 56.

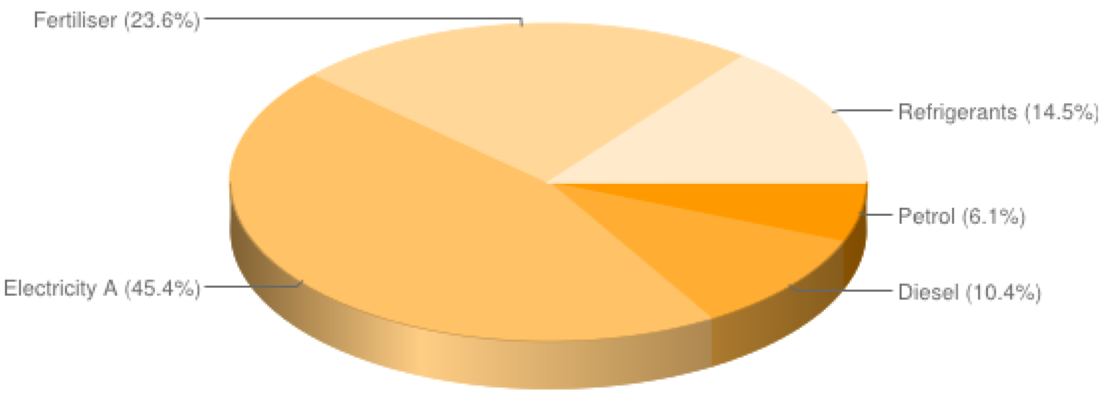

Figure 56: Carbon footprint for Harslett Farms Amiens Qld 2010 prior to commencement of project

Table 29. Greenhouse Gas Emissions - Harslett Farms Amiens Qld 2010 prior to commencement of project.

Source of GHG's	Tonnes CO_{2-e}	% of Total Emissions
Electricity	437.40	45.4
Diesel	99.71	10.4
Petrol	58.45	6.1
Fertiliser	226.99	23.6
Refrigerants	140.00	14.5
TOTAL	982.54	100

The largest emissions of GHG's are from electricity (47.1%). When discussed with the farm owner, the largest component of electricity use is attributed to cold storage and cooling of farm produce.

Due to the nature of the crops produced (leafy green vegetables) and limitations on existing cold room technology, no obvious opportunities to demonstrate emissions reductions from electricity could be identified.

The next largest emissions of GHG was nitrogen fertiliser use, and various methods were available that could potentially mitigate these emissions. It was therefore determined that fertiliser use was where potential mitigation strategies could be best demonstrated on farm.

Potential strategies include fertiliser application rates, fertiliser types and fertiliser application methods. A series of trials were set up on farm to demonstrate these strategies.

The use of Nitrification inhibitors is considered to be a technology which can potentially reduce N_2O emissions (DCCEE, 2012, Edmeades, 2004, Chen, et.al, 1994, Chen, et.al, 2010 & Pfab, et.al, 2012).

After the conclusion of our demonstration trials the farmer has decided to reduce the application of manure from 25t/Ha to 8t/Ha. The grower has decided to also trial stabilised fertilisers (nitrification inhibitors) on farm but this was not included for the purposes of this footprint audit.

A new carbon footprint of the farm was conducted and results can be seen in Table 30 and Figure 57. Compared to the footprint with farm practices prior to our demonstration project a decrease in the total emissions of 47.3 tonnes of CO2 equivalents per year has occurred for the farm. This equates to the percentage of emissions from fertiliser on the farm reducing from 23.6% of total emissions to 19.6% for the farm.

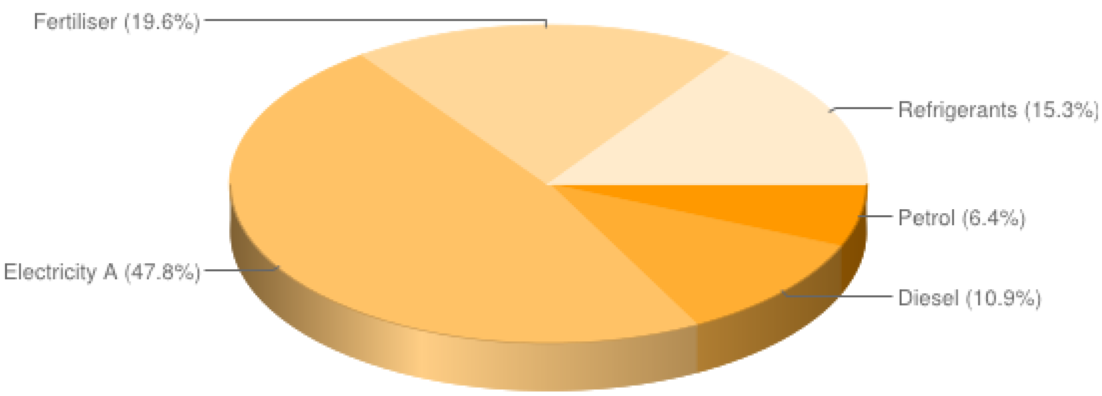

Figure 57: Carbon footprint of Harslett farms Amiens Qld, post demonstration trial, 2012

Table 30. Carbon footprint of Harslett farms Amiens Qld, post demonstration trial, 2012

Source of GHG's	Tonnes $CO_{2\text{-}e}$	% of Total Emissions
Electricity	437.40	47.8
Diesel	99.71	10.9
Petrol	58.45	6.4
Fertiliser	179.64	19.6
Refrigerants	140.00	15.3
TOTAL	915.20	100

5.4 Lockyer Valley, Queensland

Measurement campaigns 2012

The second Queensland demonstration site was established at Forest Hill in the Lockyer Valley. Constant changes in planting schedules, mostly driven by weather events, led to delays in initiating the trials at this site and also placed restrictions on the trial design.

The trials were undertaken in March and April 2012 on paddocks planted with mung beans, the beans were planted on the 12th of March and the 16th of April. Based on the results from earlier trials in the Granite Belt, this demonstration was based around a simple design investigating the effectiveness of nitrification inhibitors. Two types of fertiliser were tested in these sessions:

1. Urea (the grower's normal practice)
2. Urea with the ENTEC nitrification inhibitor

Both types of fertilisers were applied in sub-surface bands with a rate of 250kg/ha in both trials; the main focus was to examine the difference in emissions between fertilisers with and without a nitrification inhibitor. In the first round of trials, 16 chambers were set up in four rows, two rows for each fertiliser type. In the second round 12 chambers were used, again with two rows on each fertiliser type.

Plate 5. Chambers at demonstration site in the Lockyer Valley, mung beans, March 2012

Results – Lockyer Valley Trial 5+6

In both trials, emissions of N_2O (g/ha/d) were significantly lower for rows treated with inhibitors in comparison to those using standard nitrogen fertilisers.
The results from these trials provide a clear demonstration of the potential reductions in N_2O emissions through the use of nitrification inhibitors (Fig. 58 & 59).

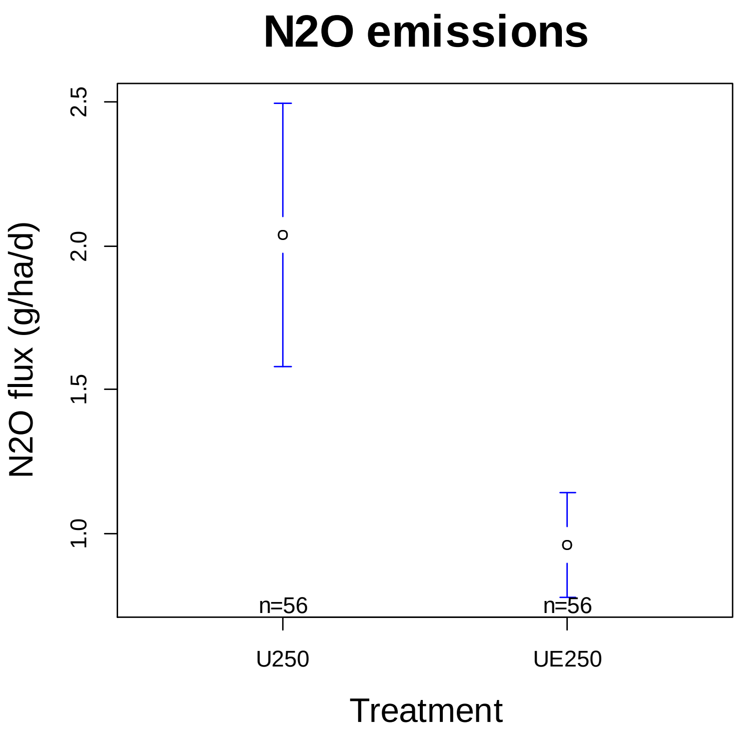

Figure 58. Nitrous oxide (N_2O) emissions g/ha/day, U250: Urea 250 kg/ha, UE250: Urea with inhibitor 250 kg/ha, mung beans, March 2012, Lockyer Valley. Measurements taken for the first seven days after fertiliser application only.

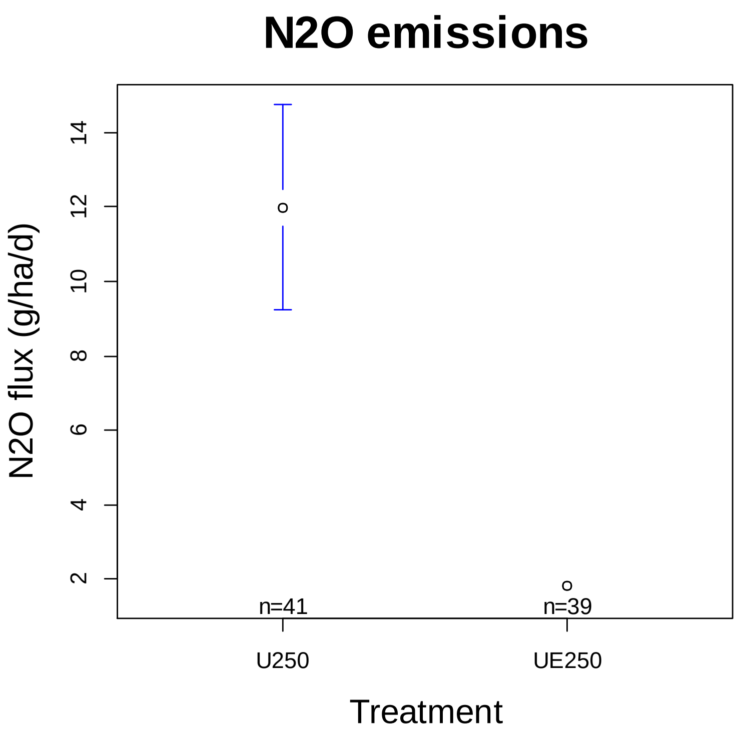

Figure 59. Nitrous oxide (N_2O) emissions g/ha/day, U250: Urea 250 kg/ha, UE250: Urea with inhibitor 250 kg/ha, mung beans, April 2012, Lockyer Valley. Measurements taken for the first seven days after fertiliser application only.

However, there were no clear relationship between the amount of CO_2 emissions and the type of fertiliser in the two trials. Despite N_2O being 310 times more potent than CO_2, the much higher level of CO_2 emissions, relative to N_2O, influenced the overall GHG emissions expressed in CO_2-e (Fig. 60 and 61).

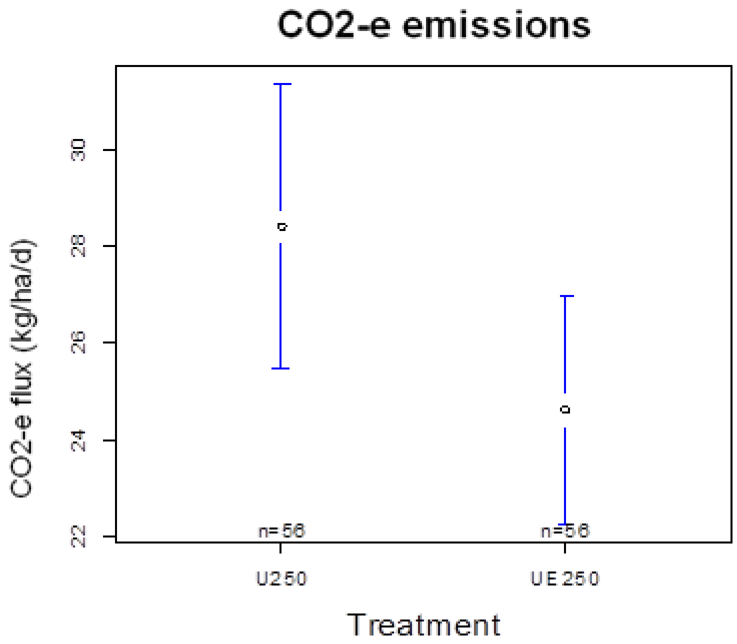

Figure 60. Greenhouse gas (GHG) emissions kg CO_2-e/ha/day, U250: Urea 250 kg/ha, E250: Urea with inhibitor 250 kg/ha, mung beans, March 2012, Lockyer Valley. Measurements taken for the first seven days after fertiliser application only.

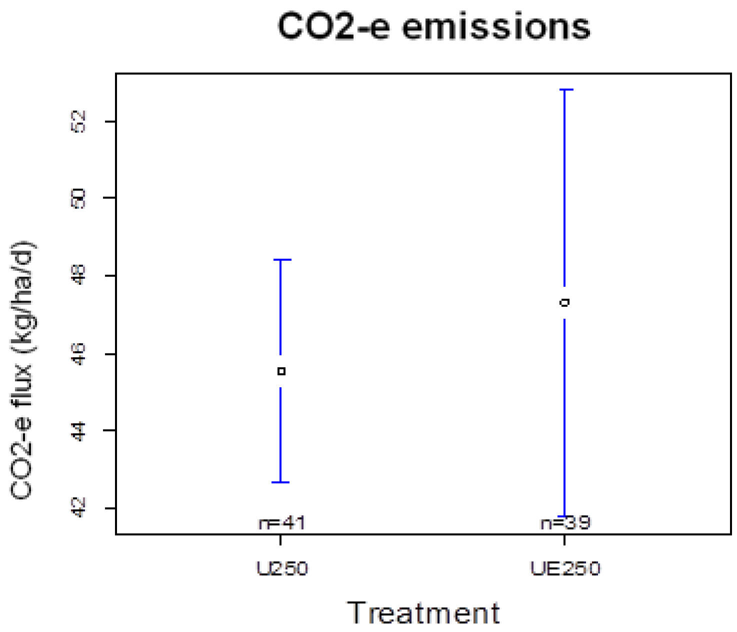

Figure 61. Greenhouse gas (GHG) emissions kg CO_2-e/ha/day, U250: Urea 250 kg/ha, UE250: Urea with inhibitor 250 kg/ha, mung beans, April 2012, Lockyer Valley. Measurements taken for the first seven days after fertiliser application only.

Yield assessment – Lockyer Valley Trial 2

The yield assessment was carried out by harvesting all bean pods in two meter sections in four places of the rows. The pods were harvested by cutting single pods or hands of pods from the plant. All 16 sections were individually packed and weighted. The average of the eight sections for each treatment type is shown below (Fig. 62)

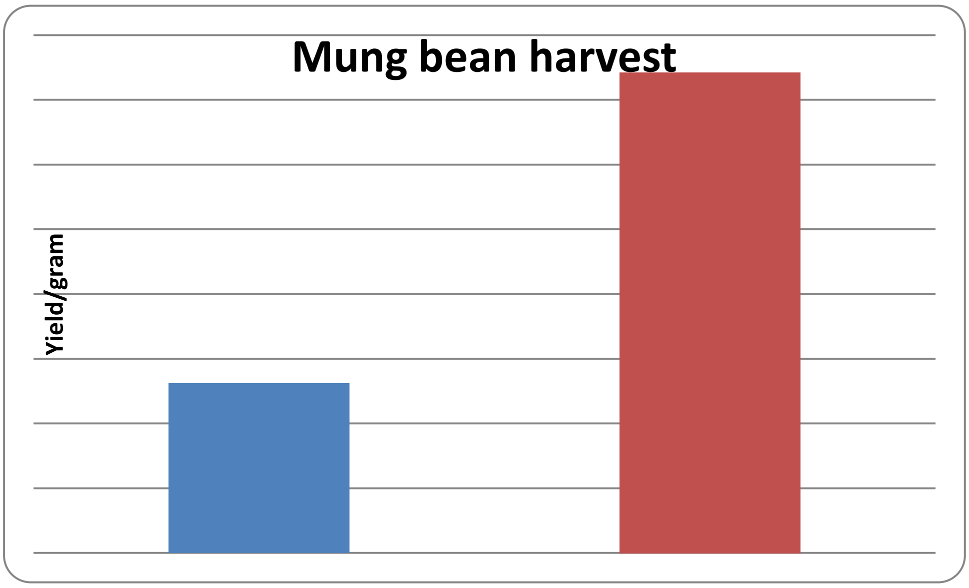

Figure 62. Result of mung bean yield assessment Trial 6, April 2012, Lockyer Valley.

6. Field days

6.1 Victoria

In each year at each demonstration site a field day was held with industry to discuss the results. In total, around 100 growers and industry representatives attended the sites including the President and members of the Executive of the Victorian Grower's Association.

In addition, talks have been presented at the AusVeg national conference in 2011 and at the DPIs Horticultural Showcase with national industry leaders in July 2011. The National Conference in 2011 was attended by almost 1000 industry representatives and a large majority attended the presentations.

At each of the field days, presentations were given by DPI staff, Incitec Pivot and the Australian Marketing Company, who the key companies providing inhibitor products. Formulations of products, their benefits and yield samples from field trials were discussed.

As a follow up to recent field days, the two growers who have conducted the trials have obtained large quantities of stabilised fertilisers for use across their own farms. Both growers changed fertiliser practices based on the results and other growers have shown a key interest in the results but are waiting for further work to sort out for which crops and times of year maximum benefits can be obtained in yield and profit by use of the stabilised formulations.


vegetables victoria

CIO Sub-program

HAL Horticulture Australia

State Government Victoria

Horticulture Industry Network

"Looking after your soil"- Field day on the Mornington Peninsula

Slobodan Vujovic – IDO East

Recently, the Victorian Department of Primary Industries, in conjunction with VGA IDO East Slobodan Vujovic, organised a field day for vegetable growers.

The field day focused on carbon and nitrogen and how they can be managed to increase profits and sustainability on farms. The event at Russell Lamattina's Farm (Lamattina Group) at Boneo was held on Thursday 26 May, 2011.

Program leader Dr Ian Porter opened the field day and presented background information on the project and thanked our host Russell Lamattina and the DAFF Climate Change Research Program for funding the project.

The group then followed Dr Porter through a field tour of long-term trials in broccoli crops grown with different manures, fertilisers and pesticide inputs. Tom Schreurs, was assisting Dr Porter in the visual assessment of the trial. Mr Schreurs said there was a clear difference between treatments in plant frame and head size.

David Riches, DPI VIC Project Officer, demonstrated how the team measured nitrogen emissions into the atmosphere. By that time the rain became more persistent forcing the crowd to go under cover.

The group then heard about a computer tool called 'C-Calc' that estimates the carbon contribution added to soil from rotations or organic amendments. The group also heard about stabilised nitrogen fertilisers – how they work and the advantages and disadvantages of using them.

Dr Porter said: "What you saw there on the field is the result of three-years of field work with a range of soil amendments with different soil health impacts. Encouragingly, most of them resulted in a positive financial return for growers. Particularly, slow release ammonium fertilisers increased broccoli yields by 15% above standard grower practice. Organic amendments also had positive effects, but due to the slower breakdown of these products, positive profits occur more slowly."

"Slow release ammonium fertilisers increased broccoli yields by 15% above standard grower practice. Organic amendments also had positive effects, but due to the slower breakdown of these products, positive profits occur more slowly."

Andrew Fragapane and Rob Nave travelled from Werribee South to attend field day, and both said it was time well spent. Mr Fragapane said: "I'd like to thank Russell for hosting the field day and his warm welcome to all growers and the DPI and VGA for organising the event."

6. THE JOURNAL OF THE VEGETABLE GROWERS' ASSOCIATION OF VICTORIA (INC)


In The Field

News for Victorian Vegetable Growers

22 May 2012

Fertiliser Stabiliser Trials

A recent Field Day at **A & G Lamattina's** farm at Boneo was organised by DPI Victoria to demonstrate the results of a 4-year trial of the use of Nitrogen stabilisers on brassica crops.

The field day was very well attended by growers who were able to view first-hand the effect of new stabilisers on fertilisers and manures to improve carbon and nitrogen use efficiency.

The trials showed how to save money by reducing nitrogen losses

Stabilisers applied to the soil keep nitrogen where the plants can use it and reduce leaching and emission losses in sandy soils.

The trials showed that plant nutrition needs can be better matched with fewer fertiliser application, by using nitrogen stabilisers.

Another major benefit from these trials was the substantial reduction in potential greenhouse gases released to the atmosphere.

Dr Ian Porter explains the findings of the Nitrogen stabiliser trials

This "coal face" research undertaken by Ian Porter and his team, clearly demonstrates how sound well-funded research can deliver practical benefits to growers.

It is now up to individual growers to consider applying these findings to improve their crops and their bottom line.

This project is a joint initiative of the Federal Department of Agriculture, Fisheries and Forestry and the Victorian Department of Primary Industries.

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"In The Field" is published by VGA-Victoria
(Vegetable Growers' Association of Victoria Inc.)
Mail Box 111, Melbourne Markets
542 Footscray Road, West Melbourne, Vic, 3003
Jointly funded by VGA-Victoria, DPI Victoria and Horticulture Australia Limited

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6.2 Amiens / Lockyer Valley Queensland

A field day was held at the demonstration site on October 26th 2010 as part of the regular Stanthorpe young vegetable growers group activities.

Growers were impressed with the quality and expected yields for all treatments.

Presentations given to the growers at the field day provided the growers with a greater understanding of GHG emissions in vegetable production and potential implications to vegetable growers. Growers in the group indicated that they were aware of GHG emissions however, had little awareness and knowledge of what the likely implications were for their farms.

Significant discussion took place amongst the grower group about fertiliser rates and the use of manure, as was the use of different custom blend fertilisers and the number of products on the market, including nitrification inhibitors. This contributed to future trial decisions on the site.

Plate 6 - Results of demonstration trial 1 were discussed at a young vegetable growers field day - October 2010

In April 2011 a field day for vegetable growers was held at the demonstration site. Approximately 20 growers and industry representatives attended.

At the field day growers were able to view treatments and anticipated yields as well as hear a series of presentations relating to carbon and vegetable farms.

Topics presented included;

- Traditional vegetable production practices in the region – Clinton McGrath, Agri-Science Queensland, Department of Agriculture, Fisheries and Forestry
- Carbon and Emissions in Fruit and vegetable farms – Simon Redpath, Department of Agriculture, Fisheries and Forestry
- Outcomes of this trial and where to next – David Putland, Growcom and Mary Firrell, Department of Agriculture, Fisheries and Forestry
- Implications of the carbon price and horticulture – David Putland, Growcom.

Much discussion related to the use of manures, the effects and results associated with reduced rates and the rates of manure application.

Plate 7 - Field day and associated presentations from demonstration trial 2 - April 2011

Field Walk – December 2011

Local growers and agronomists were invited to participate in a field walk to observe the trial in December 2011. Four local crop advisors and seven vegetable growers took advantage of this walk and spent considerable time discussing the trial. Most growers, and especially other Chinese cabbage growers, were impressed with the results of the trial and indicated an immediate desire to trial the inhibitor fertiliser and vary their own rates of application.

Plate 8 - Local advisors inspect trial prior to harvest - December 2011

Field Walk – May 2012

Local growers and agronomists were invited to participate in a field walk to observe the trial in May 2012. Two local agronomists and 3 leafy vegetable growers took advantage of this walk and spent considerable time discussing the trial. General consensus amongst participants is that using an inhibitor as a side dress fertiliser has no physical or nutritional barriers, however if it is more expensive than the non inhibitor product there is no immediate incentive to use it in a program.

7. Case Studies

Case studies were produced from each demonstration trial site, and one from the retailer perspective. The six case studies are attached as Appendices to this report.

8. Discussion and Conclusions

This project has provided the Australian vegetable industry with the first ever measurement of GHG emissions in different crops across a number of growing regions of Australia. The baseline measurement of GHG emissions has allowed the project team to implement different management techniques to further understand where opportunities may lie in reducing on-farm GHG emissions.

On farm activities that give rise to GHG emissions are usually related to three sources:

1. Energy use – cool rooms, irrigation pumps
2. Fuel use
3. Fertiliser use – N_2O emissions

When the project team considered which areas to focus emissions reduction techniques, energy and fuel use incentives were more difficult to implement, given the capital investment in energy and fuel using equipment used on farm. Generally growers had invested heavily in specialised capital equipment required for specialist intensive vegetable production, and could not make sudden changes or adjustments within their production system. A good example of this was specialist transplant machinery that was recently purchased by one grower. When cover crops were trialled on the farm the transplanter could not handle planting into the trash. Fertiliser use however is something that an individual grower can have immediate impact on for relatively small changes to the production system.

8.1 Victoria

Trials at Boneo in 2012 showed yield increase from the addition of nitrification inhibitors, particularly by applying them on chicken manure, a product widely utilised by the vegetable industry in Victoria. It is thought that inhibitors reduced losses of nitrate N from the manures, and probably preventing major leaching losses, especially from the sandy soils which support a major portion of Australia's vegetable production.

The process by which inhibitors improve the nitrogen efficiency in manures is explained below. The mineral nitrogen in manures consists of ammonium. It is converted into nitrate within a few weeks by the *Nitromonas* and *Nitrobacter* bacteria in soil. Horticultural crops absorb some but not all applied nitrate and a large quantity may be leached especially in sandy soils. ENTEC and Piadin inhibit the development of the *Nitromonas* bacterium and this ensures that the conversion into nitrate is delayed considerably and that more nitrogen will remain available for the crop. As explained above, demonstration trials in this study showed an additional yield in broccoli of up to 100% when side dressings were deliberately removed from the standard cropping practice. This demonstrates a major improvement in N use efficiency.

Results also show that the inhibitors work very differently in different environments and that care must be taken to match the inhibitor with the cropping system. ENTEC proved to be a very durable inhibitor, whilst Piadin (and the commercial fertiliser Alzon) appeared to work for a shorter duration after which increased N_2O emissions were sometimes observed. Future studies are required to match inhibitors to the correct crop and soil type, otherwise yield reductions are possible.

The following presents specific findings from the Victorian field trials.

Impact of Nitrification Inhibitors Applied to Fertilisers or Manures on Greenhouse Gas Emissions

- The greatest contribution to GWP (Global Warming Potential) from GHG emissions from vegetable production came from N_2O emissions as expected. CH_4 emissions had a negligible contribution to GWP and were generally not different between treatments. CO_2 emissions were often relatively high, especially for organic amendment treatments, although their contribution to GWP is not used in accounting methodologies as the net change in soil carbon is the preferred option.
- Studies in Victoria have shown that the range in estimated emissions for different fertiliser and manure treatments varied greatly from 26 to 363 $\mu g/m^2/hr$. The application rates of manures used in these trials emitted up to 20 times more N_2O than the fertilisers.
- As the N_2O emissions from chicken manures were much greater than those from fertilisers, greater potential for reduction of emissions would appear to come from management of emissions from chicken manure, and possibly other high N manures.
- The emission factors for fertiliser was 0.21 - 0.86 and 0.2 - 0.27 for the stabilised forms containing the inhibitor ENTEC. A similar emission factor was measured for manures in this study (i.e. 0.20 - 0.58) however the application rates were 10 times those of the fertiliser treatments and this led to the higher N_2O emissions.
- Side dressings of $CaNO_3$ contributed little to N_2O emissions (i.e. less than 5-10%) compared to the base fertiliser applications as the rate of $CaNO_3$ applied and the increased uptake of N in more mature plants reduces the impact of N_2O emissions.
- In three out of the four field trials, the stabiliser fertiliser ENTEC Nitrophoska reduced the average N_2O emission flux by 69 to 100%. Piadin was not applied to fertiliser.
- In three out of the four field trials, the stabilizer Piadin applied to manure and incorporated into the soil reduced the average N_2O emission flux by up to 66%.
- In two trials, the stabiliser Piadin was less effective when applied to manure which was left on the surface compared to manure which was incorporated, however it still reduced N_2O emissions by 10-20%.
- Although Piadin was usually effective at reducing emissions from manures, it was generally less effective (or worked for a shorter period) than the ENTEC inhibitor.
- Adding the DCD inhibitor to Nitrophoska was less effective at reducing N_2O emissions with reductions of 20 % or less when used with either Nitrophoska or urea (i.e. as Alzon) relative to the same base fertiliser without inhibitor.
- In one study, Perlka emitted the least N_2O of all the commercial fertilisers evaluated. Emissions were similar to the baseline untreated soils.
- At Werribee in 2012, emissions from the standard practice fertiliser programs were 4 times those from the other trials. This may have been due to the high moisture levels at the site and the warmer conditions compared to the winter trials at the same site.
- Nitrification inhibitors gave consistent results in the fine sandy clay loam at Werribee, but inconsistent results in the loamy sand at Boneo. In 2011, the inhibitors may have failed at Boneo due to the lower soil and air temperatures.
- N_2O emissions were higher from urea than from the other nitrogen fertilisers.

Impact of Nitrification Inhibitors Applied to Fertilisers or Manures on Yields

- The use of nitrification inhibitors applied to standard base fertilisers (i.e. Nitrophoska) gave yield responses between 8 and 77% in situations where supplementary side dressings were not applied. Although these yield gains can also be achieved by the use of side dressings by the grower, this result shows that growers can improve the nitrogen use efficiency of the base fertiliser products for yield and gain additional benefit of reduced GHG emissions.
- Results suggest that the nitrification inhibitors can offset the need for additional nitrogen side dressings at and soon after transplanting, and that this saves the grower costs for fertiliser, labour and machinery.
- Results also suggest that fertiliser application rates can be reduced and this will save additional costs and consequent environmental impact of inorganic fertilisers i.e. reduce the amount of nitrate leaching
- The use of nitrification inhibitors applied to incorporated chicken manure gave yield responses of between 20 to 63% in situations where supplementary fertiliser side dressings were not applied and 0.4 to 6% when supplementary side dressings were applied.
- The reduction in N_2O emissions did not correlate well with yield responses and results suggest that the benefits of use of inhibitors may be mainly due to an improvement in N use efficiency by reduction in nitrate leaching from soils and other mechanisms. This requires studies on full nitrogen budgets.
- Liquid formulations of nitrification inhibitors (ENTEC and Piadin) applied to chicken manure on the soil surface increased broccoli yields by 70 - 77% when supplementary fertiliser side dressings were omitted.

Key implications and limitations:

- The nitrification inhibitors used in these trials usually resulted in substantial reductions in N_2O emissions but this did not always lead to a yield response in the crop. Care must be taken not to compare the yield responses from treatments across trials and years as grower side dressings influence interpretation. Although these had little effect on N_2O emissions they had a big effect on yields. In 2011, trials were designed to mirror grower practices as much as possible and yield differences by treatments were reduced by grower side dressings. In 2012 at Boneo, the trials were designed to reduce grower fertilisers where possible and this led to greater yield differences between treatments.
- Care should be taken suggesting nitrification inhibitors be used for all crops as this may impact negatively on yields. Although ENTEC reduced emissions more effectively than either DCD or Alzon, it did not always lead to the best yield response. At Werribee in lettuce in 2012, it decreased yields and this may have been due to the slow release rate of nitrate from the product in the short term lettuce crop. For the longer term broccoli crop, ENTEC gave good yield responses and appeared to be more suited. Further studies are required to match the right inhibitor with the crop, soil type and climatic conditions.
- Alzon did not have a marked effect on reducing N_2O emissions during a season, as it often delayed but did not reduce emissions. This seemed to be associated with a positive effect on yield. It is possible that it caused a slow release effect which broke down rapidly after a few weeks. On the other hand, ENTEC appeared to reduce

emissions for the whole crop period suggesting that nitrogen was held as ammonium for longer. The variability of results suggests that in some cases the release rate may have been well matched with the crop and in others not well matched for the crop.

- Large yield responses were observed when ENTEC and Piadin were applied to chicken manure on the soil surface relative to chicken manure alone but N_2O emissions were only reduced marginally. Further studies are required on the mechanisms leading to improvement in N use efficiency.
- The addition of ENTEC to the base fertiliser enabled at least one early season $CaNO_3$ side dressing to be dropped from the fertiliser program without any impact on yield.
- Soil type and seasonal conditions had a big impact on emissions of N_2O and yield responses.

8.2 Conclusions from Amiens & Lockyer Valley, Queensland

The second and third trial in this demonstration project showed that nitrification inhibitors may be an effective method to reduce GHG emissions. Nitrification inhibitors were found to have significant positive effect on emissions of N_2O, whereas manures had a significant negative effect on N_2O emissions. A significant interaction was also found between the inhibitor and manure in these trials.

This result makes sense for two reasons. Firstly, inhibitors don't affect CO_2 emissions which were greatly elevated with manure application in this trial. Also, given that the inhibitor is applied with the fertiliser, it would be less likely to suppress the denitrification of nitrogen from other sources such as the manure.

This confirmed the results from the first trial which revealed a significant interaction between fertiliser and manure application, suggesting that fertiliser and manure treatments affected the emissions of the three GHG's to some degree.

In the third trial, emissions were lower under the reduced nitrogen application rates compared to the standard rate, and were further reduced with the use of nitrification inhibitors. The fourth trial confirmed that significantly lower N_2O emissions can be achieved from fertiliser with inhibitor compared to the grower's standard fertiliser.

Economically, Trial 3 proved that the use of inhibitors resulted in an improved economic performance for the Chinese cabbage crop. This being said, when rates of fertiliser containing an inhibitor were reduced, the emissions were also reduced and this treatment performed poorly in an economic sense.

When rates of the non inhibitor fertiliser were increased yields were increased and economic performance improved along with reduction of emissions. As this was a demonstration trial and with one crop, further research is required before accurate conclusions can be made regarding yield and economic results with reduced fertiliser rates.

Key Findings

- Significantly lower N_2O emissions can be achieved from the use of fertilisers containing a nitrification inhibitor compared with standard fertiliser.
- Nitrification inhibitors don't affect CO_2 emissions which can be greatly elevated when animal manures are utilised.

- Economically there appears to be little incentive for farmers to use nitrification inhibitors.

9. Retailer and supply chain: Interests in carbon emissions in the downstream supply chain

9.1 Introduction

To provide a broader picture of the drivers of carbon emissions management and sustainable vegetable production, the research has incorporated a brief review of international market trends, an overview of Australia's carbon emissions policy and legislative framework, and an investigation into domestic fresh produce retailers' interests regarding carbon emissions management.

An understanding of the interests, directions and strategies of fresh produce retailers may assist vegetable producers to prepare for future requirements or position themselves to be able to collaborate on new initiatives or take advantage of emerging market opportunities.

In turn, this information needs to be understood in the context of the policy and regulatory environment in which all members of the supply chain operate.

This chapter outlines the results and analysis of the research into retailers' interests and the policy/regulatory environment and suggests implications for vegetable producers and possible management responses.

9.2 Methodology

Supermarkets have a 65% share of the retail market for fruit and vegetable sales in Australia (Spencer and Kneebone 2012), so this research has primarily focussed on consultation with the major fresh produce retailers. Information was obtained from three retailers in the study - Woolworths, Coles, Metcash/IGA. ALDI declined to be interviewed.

The research process included a mix of desktop reviews of publically available information, matched together with semi-structured interviews with key personnel from three of the major retailers.

The desktop research component included a review of key Australian Government climate change policies and legislation and public-record documents from the corporate sector, such as corporate policy statements, sustainability strategies and annual reports.

Key contacts were identified for each of the target companies, generally fresh produce or quality managers, though in some cases, more senior managers were engaged. Researchers contacted the key personnel to provide background to the research project and seek their involvement. The semi-structured interviews were conducted either through face-to-face meetings or via telephone.

Interviews were held with personnel from Metcash/IGA, Coles and Woolworths. A representative from ALDI was approached to participate in the research; however, our request for an interview was declined.

The questions and discussion points used in the semi-structured interview are provided in Appendix 14.1.

9.3 Results

9.3.1 Australian policy and regulatory environment

The Australian Government has introduced a suite of policies and legislation that seek to monitor GHG emissions, reduce greenhouse gas emissions through the introduction of a price on carbon, improve energy efficiency, increase the availability of energy from renewable sources, and encourage land managers to generate carbon offsets (Commonwealth of Australia 2011).

The key pieces of legislation are the National Greenhouse and Energy Reporting Act 2007 (NGER Act) and the Clean Energy Act 2011.

Under the NGER Act, companies who meet certain thresholds for greenhouse gas emissions, energy production or energy consumption have been required, since July 2008, to report on these matters annually to the Clean Energy Regulator. Major fresh produce retailers meet the thresholds for energy consumption and greenhouse gas emissions levels and are therefore required to register and submit annual reports. Participating companies are required to follow strict procedures for collecting data and generating estimates. The data provided through the reporting process contributes to the preparation of Australia's National Greenhouse Accounts, which is the key mechanism for domestic and international reporting. All components of the measuring and reporting system must conform to international guidelines outlined through the Kyoto Protocol.

The *Clean Energy Act 2011* was legislated in November 2011 and will commence on 1 July 2012. It is the Government's primary mechanism to reduce the emissions intensity of the Australian economy and incorporates four key elements: a carbon price implemented through an emissions trading scheme, a renewable energy target, energy efficiency measures, and the Carbon Farming Initiative.

While the major retailers will not be required to participate in the emissions trading scheme, their businesses will be impacted by the increases in the costs of electricity, fuel and other inputs that will flow on from the introduction of the carbon price mechanism.

The Carbon Farming Initiative (CFI) commenced in December 2011. It is a legislated offsets scheme that allows farmers and land managers to earn carbon credits by storing carbon or reducing greenhouse gas emissions on the land. Credits generated under the CFI that are recognised as part of Australia's obligations under the Kyoto Protocol can be sold to companies with liabilities under the carbon price mechanism. This includes credits earned from activities such as reforestation, savanna fire management and reductions in emissions from livestock and fertiliser use. The CFI non-Kyoto Carbon Fund provides incentives for other activities, including revegetation and soil carbon projects.

Australia's current policy and legislative framework provides clear drivers for managing greenhouse gas emissions and seeking energy efficiencies at all points along the vegetable supply chain.

9.3.2 International Market Trends

In international markets, retailers have responded to strong consumer interests in carbon issues, largely through the introduction of "carbon impact" labels on products.

Carbon labelling schemes were established in a number of countries from around 2006, including "The Carbon Trust" in the United Kingdom, "Carbon Counted" in Canada, "Climatop" in Switzerland and government-based initiatives in Japan.

United Kingdom supermarket chain, Tesco, took a strong market leadership role, introducing carbon labels to many of its own-brand products and announcing in 2008 plans to roll out carbon labelling across its full product range. By late 2011, more than 1000 products had been researched with 500 certified and labelled (including potatoes and orange juice). Early in 2012, however, the company announced that the labelling initiative would be discontinued as the background research was too time consuming and costly and because labelling had not been embraced by other retailers (Quinn 2012).

In recent years, carbon labelling of supermarket products has been increasingly criticised as an expensive, difficult, ineffective or potentially confusing mechanism for communicating with consumers (Hogan and Thorpe 2009, Upham et al 2011).

Food manufacturers and retailers are currently exploring options for a more holistic approach to eco-labelling, incorporating a broader suite of sustainability indicators such as energy efficiency, carbon emissions, water use efficiency, waste, and other environmental considerations.

A major coordinator of these efforts is The Sustainability Consortium, a United States-based organisation initiated by Walmart, whose members include retailers such as Tesco; multi-national food manufacturing companies such as Nestle, Unilever, Coca-Cola, PepsiCo, MARS, Kellogg's and Campbell's; food service companies including McDonalds; and non-government organisations such as the World Wide Fund for Nature (http://www.sustainabilityconsortium.org/who-we-are/).

The Consortium facilitates collaboration amongst its members and aims to "drive a new generation of innovative products and supply networks that address environmental, social, and economic imperatives". Its mission is to "design and implement credible, transparent and scalable science-based measurement and reporting systems accessible for all producers, retailers, and users of consumer products". The Consortium's analysis tools and reporting standards are intended to inform and support improved decision-making for product sustainability through the entire product lifecycle and enhance the ability to understand and address environmental, social and economic implications of products.

The Consortium notes a number of significant drivers (http://www.sustainabilityconsortium.org/why-we-formed/). For consumers these include:

- Desire for product transparency and increasing demand for responsible products
- Confusion on what constitutes a sustainable product and the proliferation of single attribute eco-labels and increase in green claims and green washing
- Calls for help in making informed decisions
- Supply chains drivers include:
- No set standard for suppliers to measure the sustainability of products throughout the life cycle
- No set standard for suppliers to report measurements to their customers
- Lack of data and traceability of system inputs and outputs and their implications
- Shifts in resource pools and resource usability
- Unrealised potential in efficiency and economic value.

9.3.3 Directions for Australian fresh produce retailers

The following results are based on the analysis of the desktop reviews and interviews. Where information is presented from a public record document, the individual companies are named. Perspectives or information garnered through interviews have been de-identified.

9.4 Overarching position on, and commitments to sustainability

All of the retailers involved in the study had a policy statement and/or strategic plan regarding sustainability. Most noted the need for their company to act in socially and environmentally responsible ways, recognising their size and influence in the Australian economy and community.

Woolworths has developed a comprehensive strategic plan with clearly defined targets to drive its sustainability efforts. Wesfarmers/Coles tracks progress towards its sustainability policies by reporting annually against core sustainability indicators. Metcash's sustainability policies and strategy are delivered through an Environmental Management System. ALDI appears not to have a sustainability strategy but instead pursues a number of sustainability projects. Woolworths, Coles and Metcash have made a number of documents available to the public through their websites, for example:

Woolworths: http://www.woolworths.com.au/wps/wcm/connect/Website/Woolworths/About+Us/Our+Planet/

Coles: http://media.corporate-ir.net/media_files/IROL/14/144042/RBA003_6854_site/index.html

Metcash: http://www.metcash.com/index.cfm?objectid=74F7E470-4DB0-11DF-8FA50019BB28FF60

In Woolworths' *Sustainability Strategy 2007-2015*, climate change (and its potential impact on fresh food production) is identified as "the most critical environmental issue" facing the company. Management of carbon emissions is placed as central to the company's sustainability efforts. In its strategy, Woolworths states that there is a "compelling business case" for seeking to minimise its carbon footprint and the company appears to have deeply integrated carbon emissions management strategies into its day to day activities. Woolworths also notes the significant influence of its stakeholders to drive a strong focus on environmental sustainability; the risk to its corporate reputation if it is not seen to be addressing carbon emissions; and the increasing public scrutiny of corporate environmental performance. Woolworths states that it aims to move to a leadership position in Australia and New Zealand on sustainability.

Coles' Sustainability Report notes a range of various actions to improve energy efficiency and reduce greenhouse gas emissions and that one of the company's areas of focus is to achieve sustainable supply chains. A Coles spokesperson indicated that this is driving a greater emphasis on measurement of environmental indicators.

Metcash reports that it has a strong commitment to sustainability and that the principle of "people – profit - planet" underpins all corporate decision-making.

Some retailers specifically outlined how their sustainability policies and an improved understanding of environmental issues provide a sound structure for risk management. Through assessing the needs of consumers, suppliers, and their own business, risks to the business (such as negative media coverage or increased costs due to the introduction of the carbon price) can be better managed or minimised.

9.5 Implications of carbon reporting and pricing regulations

Woolworths, Coles and Metcash/IGA all noted the regulatory requirement for annual public reporting of their carbon emissions and their participation in voluntary reporting initiatives.

One spokesperson stated that emissions reporting requirements added to the complexity of regulatory requirements and to the company's compliance costs and that the introduction of the carbon price mechanism would add a significant additional cost to the business that would drive efforts to find greater efficiencies across the whole business.

Another spokesperson indicated that the policy and regulatory framework has placed carbon emissions issues squarely on the agenda for retailers.

The introduction of regulations requiring the reporting of emissions and energy use and the imminent introduction of the carbon price has encouraged retail businesses to take a proactive approach to seeking efficiency improvements across the whole retail chain.

9.6 Carbon accounting and reporting

Woolworths, Coles and Metcash indicated that carbon accounting and reporting is now an established company procedure, both to meet regulatory requirements under the NGER Act and as a means of demonstrating corporate stewardship. Some retailers are voluntarily contributing to processes such as the global reporting initiative, the Carbon Disclosure Project (CDP)[5].

Currently, under the NGER Act, retailers are required to report only on scope one and two emissions - that is, emissions resulting from activities within the company's boundary plus those associated with the generation of electricity used by the company. Companies may also chose to voluntarily report on scope three emissions (those generated by the company's operations but that occur outside the site of the company's operations such as waste disposal, purchased fuels, or air travel) and some retailers are doing this. All of the retailers interviewed believed that, in future, they would be required to expand the scope of their emissions estimates to include the emissions of their suppliers. All noted the difficulties of extending accounting requirements to fresh produce suppliers – due to the number of suppliers, the diverse locations of production, the diversity of production systems and the challenges of estimating emissions from natural systems.

At a company-wide scale, retailers are seeking efficient ways to capture the necessary data to generate estimates and also aiming to ensure that data and estimation methods are consistent and accurate across all retailers.

One retailer stated that their company is actively looking for improved sources of data to feed into life cycle assessments and emissions estimates.

[5] The CDP is coordinated through an independent international not-for-profit organization working to drive greenhouse gas emissions reduction and sustainable water use by business and cities.

Another retailer indicated that it will initially work with a few of its larger or more progressive fresh produce suppliers to develop estimates of on-farm emissions and that this data may then be scaled up to develop broader industry estimates.

A number of the major retailers along with the Australian Food and Grocery Council have formed a forum with a focus on developing a common approach to methodologies and a central "data format" system. In time, this may support further efforts to establish industry standards and display rules for "environmental labelling" initiatives. The forum would seek endorsement from the ACCC for any arrangements that emerged, and agreed processes would operate through a formal, transparent corporate structure.

To track international trends and approaches, the Australian forum is also closely monitoring the activities of The Sustainability Consortium.

9.7 Carbon emissions management

Woolworths (2007a) state that a "business as usual approach to energy use is not an option". Their first priority is to address their immediate and direct impacts, taking action on matters direction under their control such as refrigeration, lighting, electricity use, freight. Minimising the company's carbon footprint is considered to be integral to business growth and to improve their capacity to deliver increased financial returns.

Coles is implementing energy efficiency measures through improvements to in-store refrigeration systems and store lighting.

During interviews, retailers noted significant opportunities to address emissions in the fresh produce supply chain post farm-gate particularly through finding efficiencies in freight and distribution systems. Specific strategies identified included conducting distribution efficiency assessments, avoiding movement of empty trucks and having a smaller number of larger suppliers.

9.8 Working with suppliers

The Woolworths Sustainability Strategy states that the company has a responsibility to address matters within its own direct control before seeking to influence the environmental performance of its suppliers. The company does indicate, however, that in the future they will seek to work with their suppliers on emissions issues.

Woolworths (2007a) notes the following likely approaches:

- Sourcing policies – a policy of preference to source products that can be demonstrated to be sustainable.
- Use and ongoing development of carbon footprint calculators – have already invested in the development of an on-line calculator tool with Houston Farms.
- May make available grants for suppliers for projects aimed at addressing greenhouse gas emissions.
- Support for key suppliers in projects aimed at the development of new varieties, improved farming techniques or product innovation.
- Retailers noted that in terms of on-farm emissions, in-field emissions from electricity and diesel use are probably about equal with emissions generated in packing sheds (particularly from refrigeration).

Regarding carbon emissions accounting or estimates, Woolworths (2007a) notes the limitations of available data and a poor capacity to accurately measure or estimate emissions. Expanding the scope of their emissions accounting to include the emissions of fresh produce suppliers will not be feasible until data and methodology issues are resolved. Another retailer commented that their company recognises that "the data underpinning greenhouse gas accounting systems is inadequate and significant further research is required to improve the accuracy and sophistication of estimation methodologies and conversion rates". This retailer expressed a strong interest in contributing to efforts to advocate for research that delivers high quality, credible, verifiable and locally-relevant data.

Some retailers indicated strong approval for suppliers using footprint calculators or life cycle assessment (LCA) tools, though one retailer commented that greenhouse gas emissions estimates and management records are in the "nice to have" category but not essential.

Woolworths has directly invested in the development of an on-line carbon footprint calculator for use by vegetable producers – the "vegie carbon tool" (www.vegiecarbontool.com.au), and other retailers indicated that if the rigour of carbon footprinting calculators available to the vegetable industry can be verified, they would be pleased to promote the use of them to their suppliers. One retailer further indicated that, if there was wide industry adoption of carbon footprinting, it may consider incorporating a carbon footprinting tool in future into its approved supplier requirements.

One retailer noted their preference to work with suppliers who had a good handle on costs and inputs and ideas for where efficiencies or quality improvements could be achieved. This retailer had a strongly positive attitude to suppliers who use more sophisticated business management tools as this was considered necessary to reduce risk and provide greater traceability of products.

All noted that good farm practices contribute to emissions control/reduction. Most of the retailers suggested that progressive suppliers understand that profitability and competitiveness are best achieved through seeking to manage the costs of inputs and to achieve optimal efficiency from inputs such as fertilisers. Accordingly, the retailers believe that an interest in carbon foot prints and opportunities to minimise emissions is consistent with efforts to optimise efficiency and profitability.

One retailer indicated that fertiliser practices may be incorporated as a requirement in approved supplier accreditation processes in the future or one of the criteria used to select major suppliers.

Retailers are supportive of growers' efforts to improve farm practices, particularly focussed on fertiliser management and efficiency, soil health and irrigation efficiency. Some provide financial support to projects aimed at optimising sustainable farm practices. Improved product quality and reduced environmental impacts were cited as twin outcomes of and drivers for improved fertiliser management and farm practices.

9.9 Interests in certification, labelling or other means communicating carbon information to customers

All companies acknowledge the difficulties of measuring/estimating, reporting and communicating emissions from production systems based in the natural environment.

From the interviews, it is clear that retailers are also grappling with the challenge of finding a meaningful way to communicate carbon emissions information about food products to consumers.

Consumer attitudes research mechanisms provide evidence of growing interest in environmental matters, including Woolworth's "Green shopper survey" of 1000 shoppers which found that 84% of participants were concerned about the impacts of their shopping decisions on the environment (Woolworths 2010) and Coles' "Mothers Panel" of 2000 mothers. Retailers indicate, however, that it appears that consumers do not make a strong connection between horticultural produce and climate change. Issues that appear to be of higher priority to consumers include food safety, the provenance of food, and "getting rid of nasties from food".

One retailer commented on evidence from schemes in the United Kingdom that publishing an 'emissions/unit' figure on a product can be meaningless to customers as they are unable to determine its significance or compare the result to other products.

One retailer, in particular, noted that because it is "very early days" in carbon pricing and emissions management, "no hard and fast rules or approaches have been implemented" and that "it is difficult to predict what the landscape will be like in five years time".

All retailers indicated an open mind to footprinting schemes and/or product labelling in the future, but that this would rely on the resolution of a number of constraints and barriers. A greater body of information, data and estimation methodologies is required. As one spokesperson said, "Our current capacity to accurately measure/estimate emissions is not adequate to support a labelling initiative".

Some retailers believed that a standard may be introduced for emissions reporting by suppliers or for environmental labelling of products in future– when all players have had sufficient time and support to move towards it.

One retailer commented that any future certification or labelling scheme would be more likely to focus on demonstrating management improvement over time rather than a specific emissions impact result.

Another retailer commented that the aim would be to design a thoroughly researched, credible, robust eco-labelling system based on validated data supplied to all retailers by food manufacturers. This retailer did not expect such a system to be implemented for a number of years and that labelling of fresh produce would be "quite a long way off".

Some of the retailers also noted that they closely monitor international trends in certification and labelling, particularly through The Sustainability Consortium. Regarding labelling or other techniques for communicating "carbon impact" information, Australian retailers acknowledge that contemporary food chains are global in scale, so initiatives need to be consistent with international trends or approaches.

A Woolworths spokesperson indicated that their current strategy, in partnership with Landcare Australia, is to establish a website that their customers can use to access detailed background information on the "behind the scenes" aspects of food, including quality assurance, food safety measures and environmental management. Woolworths suggested there could be opportunities for the vegetable industry to contribute information to the website about its research and development outcomes or environmental initiatives. In general though, their view was that the horticulture industry should make a greater effort to directly communicate its sustainability efforts to the public.

Another communication option that was mentioned by retailers was a greater use of QR codes.

Factors identified by retailers that would drive more rapid action on certification or labelling included:

- If there was a significant increase in incentives available to support major advances in on-farm management and accounting.
- If one retailer introduced emissions reporting requirements into its approved supplier scheme, the others would quickly follow.
- If customers began to demand or request greater disclosure of the carbon emissions information about products on shelves, there would be a more rapid move to life cycle assessment (LCA) labelling or reporting of footprint results.

9.10 Implications for vegetable growers and the vegetable industry

The results demonstrate that retailers have a positive view of suppliers who are committed to continually improving farm practices, particularly energy, fertiliser and water use efficiency, and who make use of tools that generate management information and support risk assessment and decision-making. Retailers perceive that these growers will be more capable of delivering a consistent, high quality product with strong sustainability credentials and are likely to have a good handle on their costs of production and opportunities for innovations or savings.

From the results it is also clear that the major fresh produce retailers have a strong interest in carbon emissions for a number of reasons, including:

- Corporate commitments to sustainability
- Desire to protect their corporate reputation
- Corporate strategies or targets to reduce emissions and drive cost savings
- Introduction of the carbon price
- Regulatory requirements for mandatory annual reporting of energy use and greenhouse gas emissions.
- The establishment of regulatory and corporate requirements for energy use and greenhouse gas emissions accounting and reporting has direct implications for vegetable producers.

While there is no immediate requirement for suppliers to contribute to retailers' energy use and emissions reports, retailers are clearly anticipating the need to gather emissions data from all of their suppliers in the future. To prepare for this, retailers are actively considering the issues associated with developing emissions estimates from fresh produce suppliers.

Accordingly, retailers had a favourable view of the development and use of carbon footprinting calculators or tools that provide vegetable growers with a simple method of producing a preliminary assessment of the greenhouse gas emissions generated within farming enterprises. Such tools were seen to provide a number of benefits: a reasonably valid estimate of emissions at the farm scale, a useful tool that supports information-driven management, and an opportunity to identify efficiencies and areas where costs of production could be reduced. Retailers indicated that they would value working with suppliers who were making use of such tools.

Retailers further noted that significant work is required to boost the capacity to more accurately assess emissions from agricultural production and that this will involve generating improved baseline data, developing more accurate conversion rates for Australian conditions and further refining estimation methodologies. They suggested that greater government and industry investment in research and development is needed in this area; some retailers stated their willingness to assist in advocating for this.

Another clear theme that emerges from the results is that retailers have identified that poor data, inadequate estimation methodologies and a lack of appropriate data capture and management systems are a significant barrier to incorporating emissions information from fresh produce suppliers into their accounting and reporting processes.

Retailers are collaboratively working on addressing this challenge. Through their sustainability forum, retailers are seeking to develop improved data sources, consistent analysis tools and common data systems in order to progress an agreed, rigorous and consistent standard for emissions reporting requirements for their suppliers.

The establishment of such a standard provides the basis for incorporation of emissions reporting requirements into approved supplier programs or produce certification schemes. This, in turn, provides a foundation for communication of sustainability or emissions information to consumers.

There is currently no clear indication on the format that may be used for communicating environmental information to consumers. Retailers have not ruled out the development of a labelling scheme, and have indicated that if this mechanism is implemented it is more likely to incorporate a suite of sustainability indicators and may emphasise management processes rather than outcomes. Retailers, however, appear to be considering a range of alternatives to labelling, particularly web-based or smart-phone based options.

From the results, a potential timeframe for progressing these issues can be estimated.

In the short term (the next two years), the vegetable industry is likely to best align with the direction of retailers through a focus on:

- On-going efforts to address negative environmental impacts from horticultural production, particularly in the areas of optimising water use efficiency, boosting soil health and improving fertiliser practices in order to minimise greenhouse gas emissions and avoid water quality impacts.
- Encouraging broader uptake of carbon footprinting calculators to contribute towards the development of preliminary estimates of emissions arising from horticultural production.
- Continuing to refine emissions estimation methodologies and tools.

In the medium term (two to five years), retailers are likely to:

- Develop common approaches to data capture and analysis and common frameworks for emissions accounting and reporting.
- Develop an emissions accounting and report standard for suppliers.
- Request that suppliers contribute data towards the retailers' corporate and regulatory reports on energy use and emissions.

In the longer term (five to ten years), retailers may:

- Incorporate emissions reporting into approved supplier programs or certification schemes.
- Introduce some form of labelling or communication initiative to share emissions or sustainability information about products with their customers (though fresh produce may not be included in the early phases of such an initiative).

So what does this mean for growers and the vegetable industry?

Clearly, it is timely that the vegetable industry invests in projects aimed at improving its understanding of emissions issues and management options and projects that may contribute to the development of improved emissions estimation methods.

Vegetable growers who utilise carbon footprinting calculators, maintain records of their emissions estimates over time and use footprinting results in management processes are likely to be well placed to identify efficiencies or opportunities to reduce costs of production, to identify risks, and to contribute to efforts along the supply chain to reduce emissions or energy use. Information from carbon footprinting assessments may also support the development of stronger collaborative relationships between retailers and suppliers. Vegetable growers, however, may wish to progress with caution regarding the sharing of emissions information with retailers as the data does provide them with a means to estimate a growers' likely costs of production which could influence their negotiations on prices with a number of suppliers.

There is a strong case for the vegetable industry to take a proactive approach to working through these risks and opportunities through on-going discussions with retailers, regulators and other stakeholders.

9.11 Conclusions and recommendations

Australia's major fresh produce retailers have indicated a clear interest in greenhouse gas emissions management, accounting and reporting.

In response to strong regulatory and corporate responsibility drivers, major retailers are actively collecting and reporting data regarding their energy use and greenhouse gas emissions and implementing measures within their business to achieve energy efficiencies and cut their carbon emissions.

Retailers are also collaborating through a sustainability forum to find more efficient and consistent means of data collection and analysis.

Retailers do not currently require their suppliers to maintain emissions accounting systems or to report their greenhouse gas emissions. There are no immediate plans to introduce emissions accounting or reporting into approved supplier arrangements or certification schemes.

Labelling of food products, particularly fresh produce, is very unlikely even in the medium term (2 - 5 years). Retailers, however, are investigating the feasibility of footprinting initiatives and believe that some form of certification or labelling system may be developed and implemented in the longer term.

Instead, it is more likely in the medium term that retailers will be required include in their mandatory reports estimates of the greenhouse gas emissions of their suppliers – including vegetable suppliers.

Accordingly, retailers are likely to appreciate a cooperative approach with their suppliers towards developing robust methods of estimating greenhouse gas emissions arising from vegetable production. Retailers have a positive view of vegetable suppliers who are proactively utilising carbon footprinting tools and seeking efficiencies in their energy and fertiliser use. Retailers are also strongly supportive of growers' efforts to continually improve the sustainability of their farming practices.

Based on these findings, the following recommendations are made.

Vegetable growers should be encouraged to:

- Continue efforts to improve the environmental sustainability of farming practices, particularly in the areas of fertiliser efficiency, irrigation efficiency and soil health.

- Identify opportunities to improve energy efficiency and/or seek alternative, renewable energy sources.

- Collect/collate and analyse data on electricity, fuel and fertiliser use and record this data in business management systems.

- Complete annual carbon footprints with industry developed calculators and maintain records of results.

- Regularly review carbon footprint results to identify efficiency opportunities and to drive adaptive management.

- Direct suppliers or contract growers should maintain good communication with retailers and other supply chain partners to track trends, identify efficiency opportunities and develop collaborative approaches.

It is further recommended that the vegetable industry as a whole should:

- Continue to invest in R&D that supports and drives environmentally sustainable vegetable production, in particular, improved energy and fertiliser efficiency.

- Further invest in improving the capacity of vegetable growers to monitor and measure their greenhouse gas emissions through the ongoing development of carbon footprinting calculators and other accounting tools.

- Consider investment in collaborative research with supply chain partners to identify efficiency opportunities in the cool chain, freight and distribution system for vegetables.

- Advocate for, and seek increased investment in, research into the greenhouse gas emissions associated with vegetable production including more accurate and locally-relevant baseline data and more robust estimation methodologies.

- Maintain strong communication channels with major fresh produce retailers, food processors, food services industries and other stakeholders to monitor trends and identify opportunities for collaboration.

- Develop and implement a communication strategy to publicly promote the efforts and achievements of the Australian vegetable industry regarding carbon emissions management and sustainable production.

- Invest in market research to track community and consumer interests in product labelling and communication of the environmental and carbon emissions impacts of fresh produce.

10. Industry Adoption and Evaluation

Up until recently GHG emissions in Australian horticulture have been poorly understood with little effort or incentive to measure and find alternate ways to reduce the GHG emissions from on-farm activities. Qualifying the source and quantity of GHG emissions from on-farm vegetable production activities now provides the industry with baseline information to build a knowledge base for action. If you couple the current policy environment and attention to GHG emissions with the efforts of this project, the Australian vegetable industry now has a better understanding of the emissions reduction techniques that can be employed on-farm.

One of the obstacles to adoption of low emissions practices in the vegetable industry stems from the diversity of the industry, with over 80 crops grown in varying rotations across different growing regions right across Australia. With this in mind a deliberate effort was made in this project to choose crops and production systems that represent the major crops within the major growing regions to reach as many growers as possible. Crops used in this research, such as lettuce and broccoli, are grown across these major growing regions, so results are more easily extrapolated to growers outside of the growing regions where trials were conducted.

From 2010 to 2012 regular field days were conducted at each of the field sites, with a total of over 200 growers and industry personnel attending. Field day presentations focussed on the results of the field work, but discussion also took place on the wider topic of the role of carbon and GHG emissions in vegetable production. Field days and field walks were held in the crop when possible, and growers were often asked to assess the crop and different treatments if possible. Firstly this involved growers in the process, and secondly it enabled the opportunity for growers to engage with the objectives being demonstrated as part of this project. At Amiens vegetable growers were asked to rate plots for biomass differences and in some cases yield potential to draw them into the scientific process at hand.

The field days were attended by key influential growers, for example, the Chair and Executive of the Victorian Growers Association in Victoria. In addition to influential growers, private agronomists, consultants and fertiliser representatives also attended, demonstrating the variety of stakeholders interested in this topic of research and development. Private agronomists (Elders, Landmark etc) and consultants often consult with 20-30 local growers, so delivery of the outcomes to these professionals was highly valuable for dissemination. The intensive nature of vegetable growing makes it very hard for vegetable growers to leave the farm for industry events, so these issues were taken into consideration when inviting attendees with an influence over growers in the region.

The growers used for the demonstration sites were selected for their forward thinking and their standing amongst the vegetable producing community. Each of the growers involved in the project were typically well respected in the region and were well connected to their peers.

Each of the vegetable growers involved in the trial have changed their fertiliser practices as a result of the research conducted on their farms. These changes include:

Victoria –

- Both growers have introduced nitrification inhibitor products on farm.
- One grower has reduced synthetic and organic fertiliser inputs by 25% as a result of the trial work. Early indications from the grower suggest that there have been no yield penalties from the reduced fertiliser applications.
- One grower is about to trial inhibitors on surface applied manures
- Both growers consider fuel and energy costs to production, as well as long term soil health initiatives conducive to long term productivity.

Queensland

- One Queensland grower has reduced the rate of manure application to 1/3 of past applications as a result of the trial work. The grower is now also trialling nitrification inhibitors on farm, and a manure/compost mix to keep carbon and nitrogen in the soil for longer periods during crop production

The young grower group based in Amiens monitored the activities on the demonstration farm throughout the project and provided input to the project team on key objectives they would like trialled at each measurement campaign. This inclusive approach by engaging with industry throughout the project has resulted in changes in practice in the region. Anecdotal evidence from the District Horticulturist and local fertiliser salesman suggest that many are using nitrification inhibitors on farm given the volume of inhibitors sold in the area over the last 12 months. Tomato and capsicum growers in the region report success with the use of the ENTEC inhibitor. This practice change occurred while results of the demonstration farm were still being generated, indicating that progressive farmers are quick to adopt new practices if a driver is present. It should also be added that the grower at the demonstration site is a young grower and through his own networks would have provided information to others in the group in addition to results generated from the project team.

While inhibitors provide a potential reduction in GHG emissions, another driver just as likely to be driving this uptake is the slowed release of nitrogen provided with inhibitors, and there is a very good potential fit with these products into some annual vegetable crops. Vegetable growers typically apply a side dressing of fertiliser during the growth of a vegetable crop, this is obviously time consuming and adds additional costs to production, approximately $500/ha. Vegetable growers seek a fertiliser that slowly releases nitrogen to a crop as the crop requires it, minimising N losses in the system.

Industry adoption of GHG emissions reductions techniques has therefore happened both formally via this project, and organically amongst growers throughout the course of this project. Now that two years of data has been obtained from the demonstration site some clear trends have emerged that has been packaged as messages for the vegetable industry. The project team are still mindful that these messages are based on demonstration trials and clearly further replicated research is required before solid recommendations could be made to an industry as diverse as the vegetable industry.

The adoption strategy to deliver messages to the vegetable industry has been centred on the generation of 6 case studies, a dedicated website, and road shows to growers in states where this demonstration study was not conducted.

The case studies capture packaged information to provoke thinking amongst growers to look at how reduced emissions management techniques may be adopted on their own farming business. These case studies will be available through the website, and have been produced in high and low resolution for web format or for high quality print at any point in the future.

The dedicated website for this project was designed with two simple and unique functions in mind:

1. Simple for the reader to navigate to relevant information
2. Provide a site for all future GHG emissions research to be added to the site

The website will go live once approval of this report and case studies from DAFF is complete. The website has been designed with the ability to monitor web traffic visiting the site, and a function for enquiries to be made to continue the dissemination of results of this project (enquiries directed to project leader - HAL). The website will remain online for a minimum of two years upon completion of this project, however it is anticipated that the website will developed into a comprehensive 'go to' information portal for GHG emissions information in horticulture.

The vegetable industry's own online vegetable carbon calculator that was used for parts of this project will remain a close link to the outputs and continued communication of this project. The online calculator allows growers, or even general members of the public, the opportunity to calculate total emissions from on-farm activities. This tool provides growers with knowledge of their own carbon footprint, but also provides them with a function to theoretically manipulate certain carbon intense inputs and monitor what the effect on the footprint may be. The ongoing improvement of emissions calculations via published research will be required to continually improve the accuracy of the carbon calculator over time. The current calculator relies on many assumptions that should be further refined as more information comes to hand.

Formal information sessions have already taken place, with the first promotion of this project via Dr Ian Porter's presentation at the 2011 AusVeg convention in May with over 1000 delegates in attendance. Peter Melville presented to over 20 growers at Devonport in Tasmania at an Ausveg (Peak Industry Body) growers meeting.

Planned events at the end of August/September will take place at three vegetable growing regions in WA (Waneroo, Perth, Carnavon), and to growers in the Sydney basin.

Continued efforts will be made by HAL to promote the results of this research to the vegetable industry and other horticultural member industries beyond the completion of this project. Other horticultural industries are very interested in this research and multiple requests have been made regarding this research in the vegetable industry.

A 'Communication Plan' and 'Monitoring and Evaluation Plan' were drawn up for this project and the broader objectives of these plans have been realised.

11. Conclusions

This project has clearly demonstrated that nitrification inhibitors can very effectively reduce N_2O emissions in vegetable crop production. Further research is required however to understand which type of inhibitor fits with what crop. In this trial the potential of a nitrification inhibitor to reduce GHG emissions (N_2O emissions) was heavily dependent on the type of inhibitor/fertiliser combination, and whether organic amendments were also added to the production system.

The effect of inhibitors on GHG emissions could not be considered alone within this demonstration study. Trials have also shown another major benefit of nitrification inhibitors i.e. improved nitrogen use efficiency. This has the potential to reduce nitrate leaching, reducing pollution of groundwater and offer great potential to reduce the number of applications of high analysis fertilisers, particularly $CaNO_3$, treatments to vegetable crops without reductions in yield. The results in trials in Victoria in 2012 indicated that at least one fertiliser application could be dropped due to improved N efficiency. This saves fertiliser costs, fuel costs and labour costs estimated at over $500/ha. This indirectly also allows reduced fertiliser application rates for crop production which will further lower N_2O emissions. Therefore a key finding from this research is the need to understand the effect of inhibitors on the total nitrogen budget of the vegetable production system.

Manures were found in this project to emit GHG's up to 20 times that of fertilisers. Given this result and the frequent use of manures in the vegetable production system, there is great potential to reduce GHG emissions through better manure management. Trials conducted in Victoria demonstrated a 16% reduction in GHG emissions from the application of nitrification inhibitors on manure on the surface, and a 60% reduction on manure treated with inhibitors and incorporated into the soil. This result is significant and practice change as a result of this work can be immediate. The added benefit of inhibitors on manure was the increased yield response seen across the trials (in the absence of the $CaNO_3$ side dressing).

Vegetable production by its very nature is very intensive, often with increased fertiliser inputs resulting in increased yield responses. Results from this demonstration project were no different with yields generally increasing as a result of increased nitrogen application. Given this relationship between fertiliser and yield response, there is some difficulty suggesting to growers to reduce fertiliser inputs, particularly when a grower is operating to efficient N practices. This then begs the question whether we should be considering GHG emissions and fertiliser input per unit of commodity produced. For example, two growers were to apply a given quantity of nitrogenous fertiliser, and one produces a crop with a yield 20% greater than the other even though GHG emissions were the same. The grower producing the higher yield per unit of nitrogen will utilise nitrogen more efficiently and produce less GHG emissions per unit of product.

This project has identified areas for improved emissions management on vegetable farms, however the focus on demonstration in the two year period has only just scratched the surface in terms of answering some of the complex questions to reducing GHG emissions on farm. Further work is needed to understand the complexity of emissions reduction across such a diverse industry. This being said, this project has provided the vegetable industry with enough information to make more informed management decisions on farm to reduce GHG emissions.

12. Recommendations

This demonstration project has focussed primarily on emissions reduction techniques focussed around fertiliser inputs. While energy and fuel emissions reduction techniques can be achieved, the timeframe and demonstration focus of this project lent itself to practice change that could be achieved in the short timeframe.

Recommendations listed below provide a clear outline of the research and development required to continue to drive the adoption of on-farm emissions reduction techniques.

1. A number of nitrification inhibitors now exist on the market. Whilst many were used in this project, the mode of action, effect on crop, and seasonal differences will all have an effect on the GHG emissions reduction and crop productivity. Future work should focus on replicated research with key inhibitors in the key vegetable crops to understand which inhibitors will work best in which situations. This could easily be made into a decision support tool for growers, supported of course by the economics behind such decisions.

2. Manures will continue to be used in the vegetable industry as they provide a good cheap source of carbon and nitrogen to production. Results from this project indicate that the incorporation of manures and/or the addition of inhibitors onto the manure can reduce GHG emissions and reduce nitrate leaching from the manure. This research should be continued to provide industry with a decision support tool, supported by replicated research and economic analysis.

3. Efforts need to be made to increase carbon in the soil, and avoid the 'burnoff' of applied carbon through manures, cover crops etc. By maintaining soil carbon levels, nitrogen management and use efficiency can also be improved. This effort needs to consider the value to current crops and future crops, and the values of continuous improvement in production.

4. The intensive production of vegetables requires high volumes of inputs to maximise yield. By simply recommending reduced fertiliser inputs or manures without considering the implications to productivity may not act as a driver for adoption. The more efficient use of nitrogen in the production system should become the focus of the research. If more nitrogen is made available to plants for productivity gains then the potential for nitrogen losses from volatilisation or leaching will be reduced. This research has found that some fertilisers may not reduce GHG emissions, but when the yield or reduced leaching potential is considered, the GHG emissions per kg of crop will offset the GHG's emissions.

5. Further validation of GHG emissions must be conducted with replicated research using automated chambers so an understanding of daily fluctuations in GHG emissions can be measured. Static chambers may not measure peak emissions.

6. Most vegetable crops are irrigated regularly, and the role of irrigation in reducing GHG emissions needs to be considered when designing future research programs.

7. Further research is required on the combination effect of inhibitors on synthetic fertilisers and manures applied. There is potential to reduce rates of application of both for the same yield responses.

8. The vegetable industry need to collaborate with the supply chain on continued GHG emissions efficiency gains to provide stakeholders with a responsibility toward long term sustainability.

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14. Appendices

14.1 Discussion points for semi-structured interviews with retailer personnel

General

1. What is your company's overarching policy regarding environmental sustainability? How does the company's interest in sustainability flow through to its suppliers (for example, vegetable suppliers)?
2. What has been your company's corporate response to the introduction of carbon pricing and carbon emissions trading?
3. What international trends are having an influence on Australian markets and retailing practices?
4. Does your company have specific policies / interests regarding carbon emissions? Are there direct drivers? What pressures are retailers facing?
   Where is interest likely to lie in short term: In-house? Freight system? Cool chain? On-farm?
5. Does the "Carbon and sustainability in the vegetable industry" project research agenda sound consistent / complementary with your company's direction?
6. What is the fit of environmental attributes with other marketing considerations for fresh produce?
7. To what extent does your company see public concern about environmental issues reflected in consumer behaviour / sales trends – can you provide any specific examples? Do shoppers make much connection between any concerns they may have about the environmental impacts of farming and the purchase of fresh produce?
8. Has consumer research been conducted on attitudes to / concerns regarding / interest in greenhouse gas emissions/impacts of grocery or fresh produce items?
9. What are the current requirements for: direct suppliers (fresh produce / vegetables); category champions / major suppliers; suppliers via wholesale?
10. What do you anticipate future requirements may be in each of these categories?

Regarding specific issues for fresh vegetable suppliers (over 2-5 years and 5-10 years horizons):

11. Are greenhouse gas emissions likely to be added to the agenda of matters which fresh produce suppliers are asked to address / consider? If so, would retailers be likely to seek to drive the management of the issues or support industry initiatives?

12. What points of the chain are likely to be of most interest / concern for retailers? In-field, packing, freight, cool chain, DC, in-store?

13. In what ways are retailers likely to pursue the issue? Accounting / recording keeping / reporting requirements? Incorporation into established certification systems? Life cycle assessments (LCA)?

14. Is the focus likely to be on management practices, management processes, or management outcomes?

15. What alternate options might your company be considering? E.g. direct carbon labelling requirements? Sustainability index ratings? LCA?

16. Are there likely to be different strategies/approaches/requirements for different kinds of suppliers (e.g. major supplier in a category? Suppliers of private brand product? Suppliers of controlled brand product? Smaller scale suppliers? Indirect suppliers?)

17. Is there any interest in differentiating / labelling/marketing low emission / sustainably grown fresh produce?

18. Can you give a ball park time horizon for any possible new requirements? What factors could fast track that timeline?

19. In what ways might retailers partner with / support / collaborate with the vegetable industry in carbon / sustainability management issues?

14.2 Nutrient analysis for ENTEC Nitrophoska and Nitrophoska Blue Special

ENTEC Nitrophoska

http://www.pivot.com.au/zone_files/PDF_Products/IPL1028ENTECNitrophosBlueFlyer.pdf

ENTEC Nitrophoska Blue contains the nitrification inhibitor 3,4-dimethylpyrazolephosphate (DMPP), also known by the product name ENTEC. ENTEC stabilises ammonium nitrogen in the soil by delaying the activity of the *Nitrosomonas* bacteria.

Analysis:

Primary Nutrients

12.0% Nitrogen (N)

→ 6.8% Ammonium (NH4) Nitrogen

→ 5.2% Nitrate (NO3) Nitrogen

5.2% Phosphorus (P)

→ 2.6% P water soluble

14.1% Potassium (K) as potassium sulfate,

water soluble

Secondary Nutrients

4.3% Calcium (Ca)

1.2% Magnesium (Mg)

6.0% Sulfur (S)

0.02% Boron (B)

0.01% Zinc (Zn)

Nitrophoska Blue Special

http://www.incitecpivot.com.au/zone_files/pdf_products/ipl2827nitroblue.pdf

Analysis:

Primary Nutrients

12.0% Nitrogen

5.2% Phosphorous

14.1% Potassium

Secondary Elements:

4.3% Ca

1.2% Mg

6.0% Sulfur

0.01% Zinc

0.02% Boron

14.3 Gross Margins Analysis – Amiens Queensland

Gross margins for each treatment in the Amiens demonstration trials are outlined below.

Key Assumptions

Harslett Custom Blend Fertiliser $1500/tonne

Nitrophoska Blue Special $1056/tonne

ENTEC Nitrophoska $1178/tonne

Spreading of manure takes 1hour/Ha

Spreading Biochar takes 1hour/Ha

Spreading fertiliser takes 1 hour/Ha

All other tractor operations (spraying, harvest) were the same for all treatments.

Comparison ReportTrial 1

Name of Scenario	Trial 1 mini cos Treatment 1 Fertig		Trial 1 mini cos Treatment 2 Fertig		Trial 1 mini cos Treatment 3 Fertig		Trial 1 mini cos Treatment 4 Fertig		Trial 1 mini cos Treatment 5 Minim	
Crop	Lettuce		Lettuce		Lettuce		Lettuce		Lettuce	
Season	Spring		Spring		Spring		Spring		Spring	
Water Requirement	2 ML per Ha		2 ML per Ha		2 ML per Ha		ML per Ha		2 ML per Ha	
Your Area Unit	1 Hectare		1 Hectare		1 Hectare		Hectare		1 Hectare	
Your Harvest Unit	Head (of 0.2 kg)		Head (of 0.2 kg)		Head (of 0.2 kg)		Head (of 0.2 kg)		Head (of 0.2 kg)	
Yield	56,000.00 Heads 56,000.00 Heads/Hectare 11.20 Tonnes/Hectare		56,000.00 Heads 56,000.00 Heads/Hectare 11.20 Tonnes/Hectare		56,000.00 Heads 56,000.00 Heads/Hectare 11.20 Tonnes/Hectare		56,000.00 Heads 56,000.00 Heads/Hectare 11.20 Tonnes/Hectare		56,000.00 Heads 56,000.00 Heads/Hectare 11.20 Tonnes/Hectare	
Average Price	$2,000.00 per Tonne $2.00 per Kilogram $0.40 per Head		$2,000.00 per Tonne $2.00 per Kilogram $0.40 per Head		$2,000.00 per Tonne $2.00 per Kilogram $0.40 per Head		$2,000.00 per Tonne $2.00 per Kilogram $0.40 per Head		$2,000.00 per Tonne $2.00 per Kilogram $0.40 per Head	
	$/Area Unit	**$/Hectare**	**$/Area Unit**	**$/Hectare**	**$/Area Unit**	**$/Hectare**	**$/Area Unit**	**$/Hectare**	**$/Area Unit**	**$/Hectare**
Gross Income	22,400.00	22,400.00	22,400.00	22,400.00	22,400.00	22,400.00	22,400.00	22,400.00	22,400.00	22,400.00
Operating Costs										
Seed & Plants	4,620.00	4,620.00	4,620.00	4,620.00	4,620.00	4,620.00	4,620.00	4,620.00	4,620.00	4,620.00
Fertiliser	1,280.00	1,280.00	4,780.00	4,780.00	3,780.00	3,780.00	2,280.00	2,280.00	2,200.00	2,200.00
Fuel	370.80	370.80	384.00	384.00	384.00	384.00	370.80	370.80	369.00	369.00
Chemicals	900.00	900.00	900.00	900.00	900.00	900.00	900.00	900.00	900.00	900.00
Water	129.60	129.60	129.60	129.60	129.60	129.60	129.60	129.60	129.60	129.60
Labour	5,346.00	5,346.00	5,390.00	5,390.00	5,390.00	5,390.00	5,368.00	5,368.00	5,346.00	5,346.00
Electricity/Gas	340.00	340.00	340.00	340.00	340.00	340.00	340.00	340.00	340.00	340.00
Packaging	330.00	330.00	330.00	330.00	330.00	330.00	330.00	330.00	330.00	330.00
Freight/Transport	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00
Other Operating Costs	169.00	169.00	169.00	169.00	169.00	169.00	169.00	169.00	169.00	169.00
Total Costs	16,845.40	16,845.40	20,402.60	20,402.60	19,402.60	19,402.60	17,867.40	17,867.40	17,763.60	17,763.60
Gross Margin	5,554.60	5,554.60	1,997.40	1,997.40	2,997.40	2,997.40	4,532.60	4,532.60	4,636.40	4,636.40
Gross Margin per ML Water	2,777.30		998.70		1,498.70		2,266.30		2,318.20	
Weeks from Planting to Final Harvest	7.00		7.00		7.00		7.00		7.00	

Comparison Report 11-Jun-2012

Name of Scenario	Trial 1 mini cos Treatment 6 Contr		Trial 1 mini cos Treatment 7 Contr		Trial 1 mini cos Treatment 8 Contr		Trial 1 mini cos Trement 9 Contr	
Crop	Lettuce		Lettuce		Lettuce		Lettuce	
Season	Spring		Spring		Spring		Spring	
Water Requirement	2 ML per Ha		2 ML per Ha		2 ML per Ha		2 ML per H	
Your Area Unit	1 Hectare		1 Hectare		1 Hectare		1 Hectare	
Your Harvest Unit	Head (of 0.2 kg)		Head (of 0.2 kg)		Head (of 0.2 kg)		Head (of 0.2 kg)	
Yield	56,000.00 Heads 56,000.00 Heads/Hectare 11.20 Tonnes/Hectare		56,000.00 Heads 56,000.00 Heads/Hectare 11.20 Tonnes/Hectare		56,000.00 Heads 56,000.00 Heads/Hectare 11.20 Tonnes/Hectare		56,000.00 56,000.00	ds ds/Hectare nes/Hectare
Average Price	$2,000.00 per Tonne $2.00 per Kilogram $0.40 per Head		$2,000.00 per Tonne $2.00 per Kilogram $0.40 per Head		$2,000.00 per Tonne $2.00 per Kilogram $0.40 per Head		$2,000.00	Tonne Kilogram Head
	$/Area Unit	$/Hectare	$/Area Unit	$/Hectare	$/Area Unit	$/Hectare	$/Area Unit	$/Hectare
Gross Income	22,400.00	22,400.00	22,400.00	22,400.00	22,400.00	22,400.00	22,400.00	22,400.00
Operating Costs								
Seed & Plants	4,620.00	4,620.00	4,620.00	4,620.00	4,620.00	4,620.00	4,620.00	4,620.00
Fertiliser	1,200.00	1,200.00	4,700.00	4,700.00	3,700.00	3,700.00	2,680.00	2,680.00
Fuel	375.60	375.60	382.20	382.20	370.80	370.80	375.60	375.60
Chemicals	900.00	900.00	900.00	900.00	900.00	900.00	900.00	900.00
Water	129.60	129.60	129.60	129.60	129.60	129.60	129.60	129.60
Labour	5,346.00	5,346.00	5,390.00	5,390.00	5,368.00	5,368.00	5,390.00	5,390.00
Electricity/Gas	340.00	340.00	340.00	340.00	340.00	340.00	340.00	340.00
Packaging	330.00	330.00	330.00	330.00	330.00	330.00	330.00	330.00
Freight/Transport	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00
Other Operating Costs	169.00	169.00	169.00	169.00	169.00	169.00	169.00	169.00
Total Costs	16,770.20	16,770.20	20,320.80	20,320.80	19,287.40	19,287.40	18,294.20	18,294.20
Gross Margin	5,629.80	5,629.80	2,079.20	2,079.20	3,112.60	3,112.60	4,105.80	4,105.80
Gross Margin per ML Water	2,814.90		1,039.60		1,556.30		2,052.90	
Weeks from Planting to Final Harvest	7.00		7.00		7.00			

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Trial 2 celery treatments 1 - 5

Name of Scenario	Trial 2 celery Treatment 1 Nil inhib		Trial 2 celery Treatment 2 nil inhib		Trial 2 celery Treatment 3 Nil inhibi		Trial 2 celery celery Treatment 4 Nil inhibi		Trial 2 celery Treatment 5 growers	
Crop	Celery		Celery		Celery		Celery		Celery	
Season	Summer		Summer		Summer		Summer		Summer	
Water Requirement										
Your Area Unit	1 Hectare		1 Hectare		1 Hectare		1 He Hectare		1 Hectare	
Your Harvest Unit	Carton (of 12 kg)		Carton (of 12 kg)		Carton (of 12 kg)		Carton (of 12 k(of 12 kg)		Carton (of 12 kg)	
Yield	2,500.00 Cartons 2,500.00 Cartons/Hectare 30.00 Tonnes/Hectare		2,500.00 Cartons 2,500.00 Cartons/Hectare 30.00 Tonnes/Hectare		2,500.00 Cartons 2,500.00 Cartons/Hectare 30.00 Tonnes/Hectare		2,500. 2,500.00 Cartons 2,500. 2,500.00 Cartons/Hectare 30.00 Tonnes/Hectare		2,500.00 Cartons 2,500.00 Cartons/Hectare 30.00 Tonnes/Hectare	
Average Price	$833.33 per Tonne $0.83 per Kilogram $10.00 per Carton		$833.33 per Tonne $0.83 per Kilogram $10.00 per Carton		$833.33 per Tonne $0.83 per Kilogram $10.00 per Carton		$833. $833.33 per Tonne $0.83 per Kilogram $10. $10.00 per Carton		$833.33 per Tonne $0.83 per Kilogram $10.00 per Carton	
	$/Area Unit	**$/Hectare**	**$/Area Unit**	**$/Hectare**	**$/Area Unit**	**$/Hectare**	**$/Area UArea Unit**	**$/Hectare**	**$/Area Unit**	**$/Hectare**
Gross Income	25,000.00	25,000.00	25,000.00	25,000.00	25,000.00	25,000.00	25,000 25,000.00	25,000.00	25,000.00	25,000.00
Operating Costs										
Seed & Plants	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00	3,360. 3,360.00	3,360.00	3,360.00	3,360.00
Fertiliser	1,058.00	1,058.00	4,558.00	4,558.00	3,558.00	3,558.00	2,058. 2,058.00	2,058.00	2,500.00	2,500.00
Fuel	343.80	343.80	357.00	357.00	357.00	357.00	357. 357.00	357.00	357.00	357.00
Chemicals	800.00	800.00	800.00	800.00	800.00	800.00	800. 800.00	800.00	800.00	800.00
Water	340.00	340.00	340.00	340.00	340.00	340.00	340. 340.00	340.00	340.00	340.00
Labour	6,710.00	6,710.00	6,754.00	6,754.00	6,732.00	6,732.00	6,732. 6,732.00	6,732.00	6,732.00	6,732.00
Electricity/Gas	1,325.00	1,325.00	1,325.00	1,325.00	1,325.00	1,325.00	1,325. 1,325.00	1,325.00	1,325.00	1,325.00
Packaging	6,250.00	6,250.00	6,250.00	6,250.00	6,250.00	6,250.00	6,250. 6,250.00	6,250.00	6,250.00	6,250.00
Freight/Transport	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500. 2,500.00	2,500.00	2,500.00	2,500.00
Other Operating Costs										
Total Costs	22,686.80	22,686.80	26,244.00	26,244.00	25,222.00	25,222.00	23,722 23,722.00	23,722.00	24,164.00	24,164.00
Gross Margin	2,313.20	2,313.20	-1,244.00	-1,244.00	-222.00	-222.00	1,278. 1,278.00	1,278.00	836.00	836.00
Gross Margin per ML Water										
Weeks from Planting to Final Harvest	12.00		12.00		12.00		12.00		12.00	

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*WARNING Some operating cost fields do not have a value. Interpret results with caution.

Comparison Report 11-Jun-2012

Name of Scenario	Trial 2 celery Treatment 6 Inhibitor		Trial 2 celery, Treatment 8 Inhibitor		Trial 2 celery Treatment 7 Inhibitor,		Trial 2 celery Treatment 9 Inhibitor	
Crop	Celery		Celery		Celery		Celery	
Season	Summer		Summer		Summer		Summe	
Water Requirement								
Your Area Unit	1 Hectare		1 Hectare		1 Hectare		Hectare	
Your Harvest Unit	Carton (of 12 kg)		Carton (of 12 kg)		Carton (of 12 kg)		Carton (of 12 kg)	
Yield	2,500.00 Cartons 2,500.00 Cartons/Hectare 30.00 Tonnes/Hectare		2,500.00 Cartons 2,500.00 Cartons/Hectare 30.00 Tonnes/Hectare		2,500.00 Cartons 2,500.00 Cartons/Hectare 30.00 Tonnes/Hectare		2,500.00 Cartons 2,500.00 Cartons/Hectare 30.00 Tonnes/Hectare	
Average Price	$833.33 per Tonne $0.83 per Kilogram $10.00 per Carton		$833.33 per Tonne $0.83 per Kilogram $10.00 per Carton		$833.33 per Tonne $0.83 per Kilogram $10.00 per Carton		$833.33 per Tonne $0.83 per Kilogram $10.00 per Carton	
	$/Area Unit	**$/Hectare**	**$/Area Unit**	**$/Hectare**	**$/Area Unit**	**$/Hectare**	**$/Area Unit**	**$/Hectare**
Gross Income	25,000.00	25,000.00	25,000.00	25,000.00	25,000.00	25,000.00	25,000.00	25,000.00
Operating Costs								
Seed & Plants	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00
Fertiliser	1,178.00	1,178.00	3,678.00	3,678.00	4,678.00	4,678.00	2,178.00	2,178.00
Fuel	343.80	343.80	357.00	357.00	357.00	357.00	357.00	357.00
Chemicals	800.00	800.00	800.00	800.00	800.00	800.00	800.00	800.00
Water	340.00	340.00	340.00	340.00	340.00	340.00	340.00	340.00
Labour	6,710.00	6,710.00	6,732.00	6,732.00	6,754.00	6,754.00	6,732.00	6,732.00
Electricity/Gas	1,325.00	1,325.00	1,325.00	1,325.00	1,325.00	1,325.00	1,325.00	1,325.00
Packaging	6,250.00	6,250.00	6,250.00	6,250.00	6,250.00	6,250.00	6,250.00	6,250.00
Freight/Transport	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00
Other Operating Costs								
Total Costs	22,806.80	22,806.80	25,342.00	25,342.00	26,364.00	26,364.00	23,842.00	23,842.00
Gross Margin	2,193.20	2,193.20	-342.00	-342.00	-1,364.00	-1,364.00	1,158.00	1,158.00
Gross Margin per ML Water								
Weeks from Planting to Final Harvest	12.00		12.00		12.00		12.00	

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*WARNING Some operating cost fields do not have a value. Interpret results with caution.

Trial 3 DAFF Demo

Name of Scenario	Entec 500kg/Ha		Entec 750 kg/Ha		Nitrophoska Blue Special 500kg/H		Nitrohoska Blue Special 750kg/Ha	
Crop	Chinese Cabbage		Chinese Cabbage		Chinese Cabbage		Chinee Cabbage	
Season	Summer		Summer		Summer		Sumn	
Water Requirement	4 ML per Ha		4 ML per Ha		4 ML per Ha		ML per Ha	
Your Area Unit	1 Hectare		1 Hectare		1 Hectare		Hectare	
Your Harvest Unit	Carton (of 16 kg)		Carton (of 16 kg)		Carton (of 16 kg)		Carto(of 16 kg)	
Yield	2,813.00 Cartons 2,813.00 Cartons/Hectare 45.01 Tonnes/Hectare		3,125.00 Cartons 3,125.00 Cartons/Hectare 50.00 Tonnes/Hectare		2,875.00 Cartons 2,875.00 Cartons/Hectare 46.00 Tonnes/Hectare		2,750.00 Cartons 2,750.00 Cartons/Hectare 44.00 Tonnes/Hectare	
Average Price	$688.90 per Tonne $0.69 per Kilogram $11.02 per Carton		$690.00 per Tonne $0.69 per Kilogram $11.04 per Carton		$706.52 per Tonne $0.71 per Kilogram $11.30 per Carton		$721.59 per Tonne $0.72 per Kilogram $11.55 per Carton	
	$/Area Unit	**$/Hectare**	**$/Area Unit**	**$/Hectare**	**$/Area Unit**	**$/Hectare**	**'Area Unit**	**$/Hectare**
Gross Income	31,006.00	31,006.00	34,500.00	34,500.00	32,500.00	32,500.00	31,750.00	31,750.00
Operating Costs								
Seed & Plants	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00	2,100.00
Fertiliser	1,284.00	1,284.00	1,578.50	1,578.50	1,224.00	1,224.00	1,224.00	1,224.00
Fuel	249.72	249.72	249.72	249.72	249.72	249.72	249.72	249.72
Chemicals	1,200.00	1,200.00	1,200.00	1,200.00	1,200.00	1,200.00	1,200.00	1,200.00
Water	266.00	266.00	266.00	266.00	266.00	266.00	266.00	266.00
Labour	3,696.00	3,696.00	3,696.00	3,696.00	3,696.00	3,696.00	3,696.00	3,696.00
Electricity/Gas	834.56	834.56	834.56	834.56	834.56	834.56	834.56	834.56
Packaging	7,735.75	7,735.75	8,593.75	8,593.75	7,906.25	7,906.25	7,562.50	7,562.50
Freight/Transport	6,697.62	6,697.62	7,440.48	7,440.48	6,845.24	6,845.24	6,697.62	6,697.62
Other Operating Costs								
Total Costs	24,063.65	24,063.65	25,959.01	25,959.01	24,321.77	24,321.77	23,830.40	23,830.40
Gross Margin	6,942.35	6,942.35	8,540.99	8,540.99	8,178.23	8,178.23	7,919.60	7,919.60
Gross Margin per ML Water	1,735.59		2,135.25		2,044.56		1,979.90	
Weeks from Planting to Final Harvest	8.00		8.00		8.00		8.00	

Total Gross Margin 31,581.17

*WARNING Some operating cost fields do not have a value. Interpret results with caution.

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Trial 4 comparison

Name of Scenario	Trial 4 Harslett Custom Blend side		Trial 4 Entec sidedress 350kg/Ha		Trial 4 Nitrophoska blue sidedress	
Crop	Celery		Celery		Celery	
Season	Summer		Summer		Summer	
Water Requirement						
Your Area Unit	1 Hectare		1 Hectare		1 Hectare	
Your Harvest Unit	Carton (of 12 kg)		Carton (of 12 kg)		Carton (of 12 kg)	
Yield	2,500.00 Cartons 2,500.00 Cartons/Hectare 30.00 Tonnes/Hectare		2,500.00 Cartons 2,500.00 Cartons/Hectare 30.00 Tonnes/Hectare		2,500.00 Cartons 2,500.00 Cartons/Hectare 30.00 Tonnes/Hectare	
Average Price	$1,000.00 per Tonne $1.00 per Kilogram $12.00 per Carton		$1,000.00 per Tonne $1.00 per Kilogram $12.00 per Carton		$1,000.00 per Tonne $1.00 per Kilogram $12.00 per Carton	
	$/Area Unit	**$/Hectare**	**$/Area Unit**	**$/Hectare**	**$/Area Unit**	**$/Hectare**
Gross Income	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00
Operating Costs						
Seed & Plants	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00	3,360.00
Fertiliser	1,704.70	1,704.70	1,592.00	1,592.00	1,549.30	1,549.30
Fuel	343.80	343.80	343.80	343.80	343.80	343.80
Chemicals	800.00	800.00	800.00	800.00	800.00	800.00
Water	340.00	340.00	340.00	340.00	340.00	340.00
Labour	6,710.00	6,710.00	6,710.00	6,710.00	6,710.00	6,710.00
Electricity/Gas	1,325.00	1,325.00	1,325.00	1,325.00	1,325.00	1,325.00
Packaging	6,250.00	6,250.00	6,250.00	6,250.00	6,250.00	6,250.00
Freight/Transport	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00
Other Operating Costs						
Total Costs	23,333.50	23,333.50	23,220.80	23,220.80	23,178.10	23,178.10
Gross Margin	6,666.50	6,666.50	6,779.20	6,779.20	6,821.90	6,821.90
Gross Margin per ML Water						
Weeks from Planting to Final Harvest	12.00		12.00		12.00	

*WARNING Some operating cost fields do not have a value. Interpret results with caution.

14.4 Carbon & Sustainability Case Studies (6 in total)