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**COMPOST USE IN AGRICULTURE
CONSOLIDATED REPORT**



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The project was funded with landfill tax credits through the *shanks first fund* with third party funding from the British Potato Council.

The project was managed by Enviros Consulting Ltd with Envirofield carrying out the field trials management. Research was conducted by the University of Reading and Rothamsted Research. The farmer survey, economics and dissemination were carried out by Fieldfare Associates.



The University of Reading



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ABBREVIATIONS

C, CO ₂	carbon, carbon dioxide
cfu	colony forming units
cm	centimetre
DM	dry matter
FS	farm standard
g	gram
h	hour
ha	hectare
HCl	hydrochloric acid
K, K ₂ O	potassium, potash
kg	kilogram
l	litre
LSD	least significant difference
Mg, MgO	magnesium, magnesium oxide
mg	milligram
ml	millilitre
mm	millimetre
m/m	mass/mass
N, NH ₄ , NO ₃	nitrogen, ammonium-N, nitrate-N
NaOH	sodium hydroxide
O	oxygen
OSR	oilseed rape
P, P ₂ O ₅	phosphorus, phosphate
S, SO ₃	sulphur, sulphur trioxide
SMN	soil mineral nitrogen
t	tonnes
Trt	treatment
µm	micrometre
µS	microSiemens
VS	volatile solids
WHC	water holding capacity
yr	year



EXECUTIVE SUMMARY

Background

A three year project investigating the use of green waste derived compost in agriculture was funded with landfill tax credits through the *shanks first fund* with third party funding from the British Potato Council.

The project was managed by Enviros Consulting Ltd with field work carried out by Envirofield Ltd, microbiological aspects conducted by The University of Reading and Enviros, soil structure effects and a literature review carried out by Rothamsted Research, and communications and dissemination, including a farmer survey, undertaken by Fieldfare Associates Ltd.

The trials

Seven sites were established in Eastern England on varying soil types. Fully replicated trials were laid out with eight treatments and four replicates, as follows:

- 1 Untreated
- 2 Farm Standard (FS) fertilizer
- 3 50 Tonnes compost/ha + FS nitrogen
- 4 100 Tonnes compost/ha + FS nitrogen
- 5 50 Tonnes compost /ha
- 6 100 Tonnes compost/ha
- 7 50 Tonnes compost /ha + Low N
- 8 100 Tonnes compost/ha + Low N

Farm standard fertilizer was mainly nitrogen on each site with phosphorus and potassium as required in treatment 2. The low N treatments (7 and 8) were designed to observe the effects of saving nitrogen inputs and costs.

Compost was applied annually for the 50 t/ha treatments, and every two years for the 100 t/ha treatments, to follow the Soil Code.

The sites, soil textures and crops grown were:

Table A1 Sites, soils and crops grown

	Location	Soil texture	Cropping		
			Year 1	Year 2	Year 3
1	Suffolk	sandy loam	winter barley	potatoes	winter barley
2	Suffolk	clay loam	sugar beet	potatoes	spring barley
3	Suffolk	sandy loam	sugar beet	potatoes	spring barley
4	Suffolk	sandy clay loam	potatoes	winter barley	sugar beet
5	Essex	clay loam	potatoes	winter wheat	winter OSR
6	Lincolnshire	sandy silt loam	spring wheat	winter feed cereal	potatoes
7	Lincolnshire	sandy clay loam	carrots	potatoes	leeks

Various soils and sites were used for experiments carried out by the University of Reading and Rothamsted Research.

Results

The trials showed that the soil properties could be improved over time. Soil organic matter and plant available nutrients were raised by using compost. Potassium levels in composts derived from green wastes are high and this was reflected in the soil measurements on compost addition over time. Soil pH was also stabilised by the use of compost in conjunction with inorganic nitrogen fertilizers, which tend to acidify soil. The mineral nitrogen in the soil in winter did not accumulate after compost addition indicating that little nitrogen would leach into the groundwater. Compost nitrogen mineralisation rates were also demonstrated to be low as yields from compost alone were often no much greater than untreated control plots.

A review of the literature on the effects of adding organic matter to soils indicated that soil aggregation and structure should be improved by adding compost. Practical laboratory work demonstrated improved water holding capacity, raised microbial biomass, and increased enzyme activity and associated nitrogen and carbon mineralisation. Positive interactions between compost and inorganic nitrogen fertilizers were found, i.e. nitrogen fertilizers could be enhanced by the addition of compost giving yield increases. Alternatively fertilizer rates could be reduced without loss of yield. Major and minor nutrients, apart from nitrogen, could be completely provided by compost when applied at 30 t/ha or more.

Standards for compost, such the BSI PAS 100, are being established and improved upon to provide end users with confidence in composted products. Trials were carried out on plant pathogen kill through the composting process. Certain common pathogens were readily eradicated, such as *Rhizoconia solani*, whereas tests on *Erwinia carotovora* were less consistent. Research carried out by Horticultural Research Institute (HRI) funded by WRAP have since provided clear evidence that the composting process does kill pathogens if time, moisture and temperature parameters are met.

Plant disease suppression by compost was not, itself, assessed but composts were tested for the presence of *Trichoderma*, a plant disease suppressive

microorganism. It was found in more stable and mature compost. Chitinase enzyme activity was also found to be enhanced by compost addition to soil and this is also associated with increase disease suppressivity.

A summary of yield effects is shown from all and selected trials for all crops and for potatoes in Tables A2 and A3. Some of the trials were affected by adverse ground and climatic conditions such as erosion, flooding and uneven irrigation (caused by variable wind direction during the hot, dry summer in 2003). Those affected are shown in grey cells in Table A3 for potatoes.

Table A2 Yields as a percentage of control – all crops

	Treatment	All Average	Selected Average
1	UNTREATED	100	100
2	FARM STANDARD (FS)	150	159
3	50 T/HA COMPOST + FS	154	158
4	100 T/HA COMPOST + FS	159	163
5	50 T/HA COMPOST	120	112
6	100 T/HA COMPOST	121	116
7	50 T/HA COMPOST + LOW N	152	156
8	100 T/HA COMPOST + LOW N	159	157

Taking all sites in all years, yields were slightly increased by compost application alone (20%) indicating a small release of nitrogen from the organic matter. Interactions were seen between fertilizer and compost leading to potential savings of inorganic fertilizers or, in some cases, valuable yield increases.

Selecting out sites where adverse conditions were thought to have compromised results still showed that the compost alone was able to raise yields slightly (12-16%). Reduced N treatments with compost almost achieved the same yields as farm standard and the greatest yields were found from farm standard plus the highest rate of compost.

These effects are probably as would be expected. It takes time to build up soil properties from compost due to the low application rates that are allowed to be applied according to the Soil Code and Nitrate Vulnerable Zone regulations.

Table A3 Yields for potatoes t/ha

Site	1	2	3	4	5	6	7	All Average	Selected Average
Trt									
1	39.79	42.20	53.24	22.44	44.74	51.51	46.76	43.0	41.0
2	50.97	41.39	52.83	35.62	51.23	71.57	63.63	52.5	54.6
3	51.33	50.60	59.90	30.40	48.67	74.86	63.97	54.2	53.8
4	55.46	42.59	53.48	39.38	48.75	82.59	62.36	54.9	57.7
5	31.49	48.89	54.17	27.12	47.73	55.28	44.11	44.1	41.1
6	41.68	50.79	53.93	25.10	49.86	58.38	44.84	46.4	44.0
7	53.59	43.39	61.54	35.14	51.65	72.18	63.59	54.4	55.2
8	62.40	56.27	63.56	34.02	47.30	76.16	64.07	57.7	56.8

It can be seen that the effect from 50 t/ha compost is small but at 100 t compost/ha in alternate years that yields can be increased by 2 to 3 t/ha of potatoes. What is also shown is that artificial nitrogen fertilizer can be reduced when compost is used at 100 t/ha. This may be due to the increased supply of potassium, and nutrient interactions, as well as compost possibly moderating nitrogen supply over the growing season. The effects of organic matter and increased microbial activity may also play a part in nutrient cycling and nutrient uptake through improvements in root development.

The value of compost was assessed. Compost has a nutrient component, a liming effect and a beneficial effect on soil physical and biological properties. However, compost costs more to transport and spread than artificial fertilizers. The total nutrient replacement value is approximately £5 per tonne but because much of the nitrogen is not readily available the available nutrients are estimated to be worth £2.50/t (£75/ha applied at 30 t/ha). The lime equivalent value is for that of 2 tonnes of chalk delivered and spread (£33/ha) and savings in irrigation are estimated at £144/ha. This is £8.40 per tonne of compost. However, there are associated costs of haulage and spreading which can either be done with farm units or by contractor, and are affected by distance from the composting site. Typical costs are £120/ha for haulage and £55.50/ha for spreading with farm equipment, or a total of £5.85/t at 30 t/ha. Compost therefore has a net value delivered and spread of £2.55 per tonne in this case. Where yields can be increased with high value irrigated crops such as potatoes the worth of compost could be higher than this.

Dissemination

Considerable effort was put into disseminating results during the course of the project including presentations at the Composting Association and other conferences, a presence at the Royal Show in 2003 and 2004, and the production of a 'Compost use in Agriculture' information sheet which was widely distributed.

The annual technical reports are available from the author to advisors and researchers.

1. OBJECTIVES

The aims of the project were to demonstrate the benefits, value and safety of green compost to the farming industry in order to secure farmland as an end market place for composts from plant wastes.

To achieve these aims, the objectives were:

- ◆ to assess the effects of the application of composted green waste to arable land through replicated field trials on seven sites in Eastern England over three years;
- ◆ to analyse composts used, and soils and crops on each site every year;
- ◆ to carry out a literature review and practical work on the effects of compost on soil structure;
- ◆ to assess the effects on soil microbiology;
- ◆ to carry out trials to assess the effects of composting on plant pathogens;
- ◆ to assess the economic benefits of using compost;
- ◆ to survey the farming industry on their perception of compost; and
- ◆ to disseminate the information to the farming and composting industries.

2. FIELD TRIALS

The following treatments were applied to all of the seven sites:

- ◆ Untreated
- ◆ Farm Standard (FS)
- ◆ 50 Tonnes/ha annually + FS nitrogen
- ◆ 100 Tonnes compost/ha biannually + FS nitrogen
- ◆ 50 Tonnes/ha annually
- ◆ 100 Tonnes compost/ha biannually
- ◆ 50 Tonnes/ha annually + Low N
- ◆ 100 Tonnes compost/ha biannually + Low N

In year 1 the same treatments as shown above were applied. However, in year 2 the 100 t/ha compost treatments were omitted in accordance with the Soil Code. The 50 t/ha compost applications were made every year. The compost used was analysed each year (Table 1) and results converted into nutrients per tonne of compost (Table 2). This is compared with data based on samples from around the UK (WRAP Compost Information Package 1) which has 35% moisture and is recommended to be applied at 30 t/ha moist weight.

Table 1 Compost analysis results

		Year 1	Year 2	Year 3	Average
Bulk density	g/litre	480	464	438	460
Moisture	% m/m	43.3	49.5	46.6	46.5
Organic matter	% m/m	44.4	48.7	39.5	44.2
pH	units	8.8	8.5	8.5	8.6
Electrical conductivity	uS/cm	700	480	500	560
Nitrogen (N)	% dry matter	1.24	1.31	1.29	1.28
Phosphorus (P)	% dry matter	0.246	0.275	0.211	0.244
Potassium (K)	% dry matter	0.797	1.077	0.963	0.946
Magnesium (Mg)	% dry matter	0.183	0.225	0.217	0.208
Sulphur (S)	% dry matter	0.166	0.183	0.160	0.170

Table 2 Total nutrients in compost

	Used in trials	National data	
	Nutrient content	Nutrient content	Nutrients applied @ 30/t/ha
	kg/t	kg/t	total kg/ha
N	6.8	8.1	250
P₂O₅	3.0	3.3	100
K₂O	6.1	6.6	200
MgO	1.85	3.3	100
SO₃	2.3	2.5	75
Organic matter	236	200	6,200

Note: P x 2.29 = P₂O₅, K x 1.2 = K₂O, Mg x 1.66 = MgO, S x 2.5 = SO₃

Based on the compost analysis results, as used in the trials, the addition of the compost gave the equivalent nutrient addition as follows:

	<u>50 t/ha</u>	<u>100 t/ha</u>
	340 kg N	680 kg N
	150 kg P ₂ O ₅	300 kg P ₂ O ₅
	310 kg K ₂ O	620 kg K ₂ O
	93 kg MgO	186 kg MgO
	115 kg SO ₃	230 kg SO ₃
	11.8 t organic matter	23.6 t organic matter

The nitrogen loading was slightly above that normally recommended but it was expected that the nitrogen would be slow release and so not cause any environmental problems, especially when applied in small plots. It was also hoped that the rates of compost applied would aid soil physical enhancements so that they could be detected within the three year time frame for the project.

The trials, with four replicates of each treatment, were of randomised block design and statistically analysed accordingly. The sites were soil sampled and analysed pre-treatment for available nutrients, pH, organic matter (as loss on ignition 105°C-450°C) and texture, and in the spring for soil mineral nitrogen.

The crops were assessed for colour and vigour during growth and crop samples taken in spring for nutrient content. At harvest, the yield of the crops was measured and the material analysed for nutrient content. Diseases were assessed as seen.

Full reports by year giving detailed results are available. This report provides the main findings from the field trials coupled with the research carried out in the laboratories.

2.1 Sites and soil analysis

The details of the seven sites are shown in Table 3 along with the cropping regime, originally designed so that potatoes were grown on at least two sites every year. However, in year 2, potatoes were grown on four sites and therefore only on one site in year 3. Site 1 had been used in Levington Agriculture trials for compost work and the same plots were continued with the same treatment applications to give one site with as long a history of compost use as possible.

Table 3 The seven sites

	Location	Soil texture	Cropping		
			Year 1	Year 2	Year 3
1	Suffolk	sandy loam	winter barley	potatoes	winter barley
2	Suffolk	clay loam	sugar beet	potatoes	spring barley
3	Suffolk	sandy loam	sugar beet	potatoes	spring barley
4	Suffolk	sandy clay loam	potatoes	winter barley	sugar beet
5	Essex	clay loam	potatoes	winter wheat	winter OSR
6	Lincolnshire	sandy silt loam	spring wheat	winter feed cereal	potatoes
7	Lincolnshire	sandy clay loam	carrots	potatoes	leeks

2.1.1 Soil measurements

Soil available nitrogen (SMN)

There were no discernable differences in soil mineral nitrogen between treatments but there were differences between sites, the very sandy soils having a lower average SMN than the heavier textured soils with greater organic matter content (see Table 4).

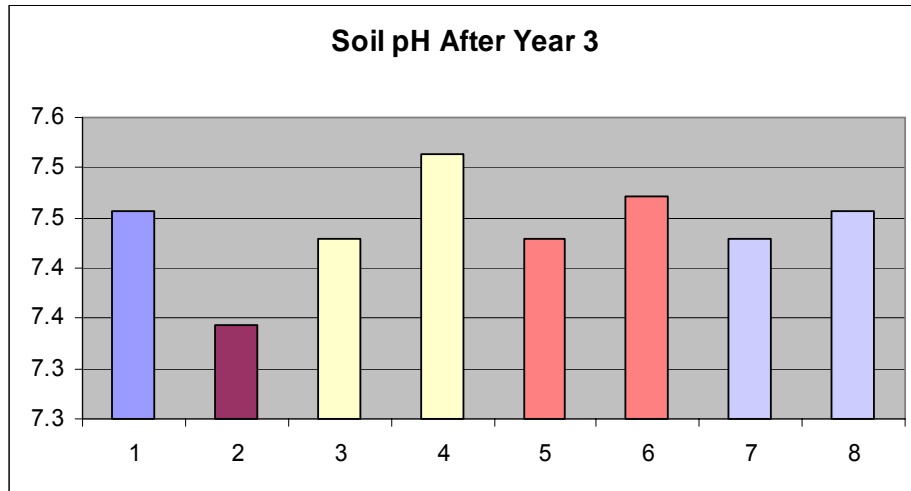
Table 4 Soil mineral nitrogen (SMN) kg/ha by site and average after year 2

Treatment	Site:	1	2	3	4	5	6	7	Ave
1. Untreated		126	93	47	156	67	100	138	104
2. Farm Standard (FS)		128	65	41	80	66	78	125	83
3. 50 Tonnes/Ha + FS		80	104	42	61	109	131	146	96
4. 100 Tonnes/Ha + FS		102	81	42	61	107	125	193	101
5. 50 Tonnes/Ha		72	70	44	66	86	114	148	86
6. 100 Tonnes/Ha		109	76	52	66	85	112	116	88
7. 50 Tonnes/Ha + Low N		89	93	134	67	116	90	153	106
8. 100 Tonnes/Ha + Low N		113	62	41	82	102	70	166	91
Averages:		102	80	55	80	92	103	148	
Textures:		SL	CL	SL	SCL	CL	SZL	SCL	
Average % organic matter after year 2		2.3	3.5	1.4	1.8	4.9	4.0	3.4	

pH

Inorganic fertilizers tend to acidify the soil, especially on light land. Compost has a small neutralising value which was able to counteract the acidifying effect and so stabilize soil pH in the trials (Graph 1).

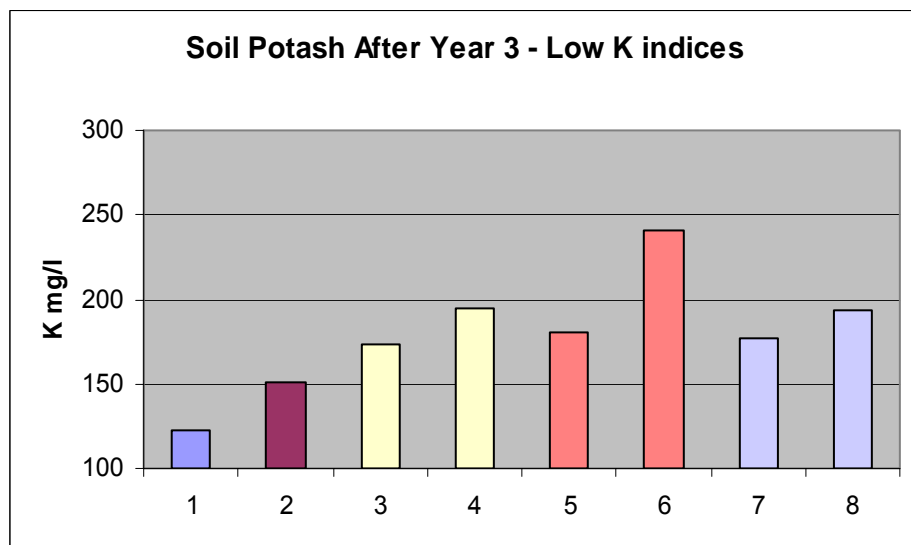
Graph 1 Soil pH after three years



Available nutrients

Over the course of three years, the soil available phosphate levels were marginally raised by all treatments compared with untreated. Soil available potash on the low K index soils (index 2 and below) was raised by the application of compost (Graph 2). Soil available magnesium levels were not greatly affected by the addition of compost although the indication was that the levels were raised.

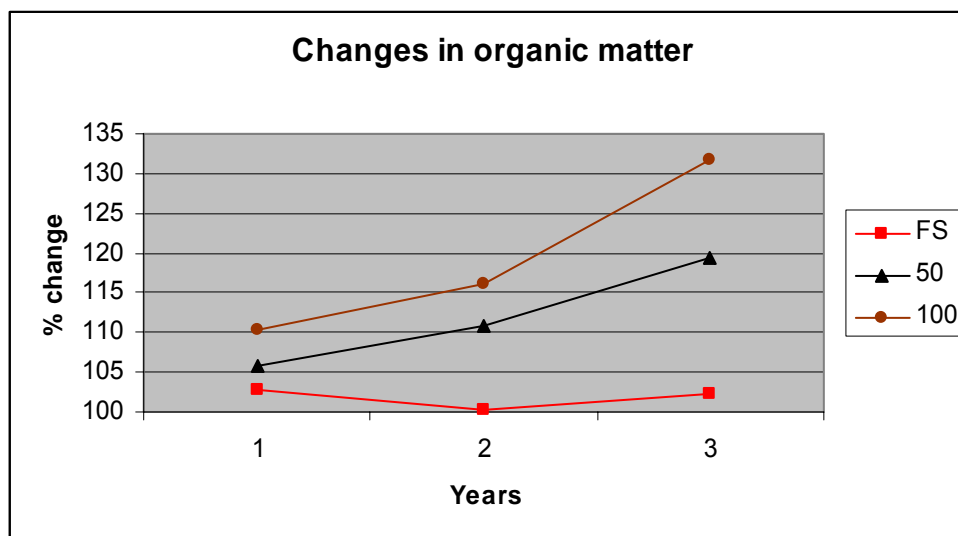
Graph 2 Soil potash after three years on low index soils



Organic matter

Soil organic matter levels increased over three years where compost had been applied, up from 3.0% on untreated plots (fertilizer standard alone (FS) was 3.1 %) to 3.6 at 50 t/ha compost and 4.0 % at 100 t/ha compost. These changes are shown as a percentage of untreated control (in Graph 3) over the three years.

Graph 3 Changes in organic matter over three years



2.1.2 Fertilizers applied

Farm standard fertilizers were applied as a fertilized control (treatment 2) against a completely untreated control (treatment 1). Farm standard fertilizers were calculated according to RB209, Fertilizer recommendations for agricultural and horticultural crops (MAFF 2000), according to the crop being grown. The same nitrogen as in this treatment was applied along with compost in treatments 3 and 4. Treatments 5 and 6 had compost alone at the two rates, and treatments 7 and 8 had the rate of inorganic fertilizer reduced to assess the release of nitrogen from the compost applied at the two rates.

It was generally found that the nitrogen rate could be cut by up to 25 kg nitrogen/ha where compost had been applied, without yields being reduced.

2.2 Site responses

The principal characteristics at the start of the project of each site can be summarised, as shown in Table 5. These are the characteristics that compost might be expected to influence over time.

Table 5 Potential site responsiveness at project commencement

	Location	Soil texture	pH	P index	K index	Mg index	Organic matter %	Drought resistance
1	Suffolk	sandy loam	7.7	4	1	2	1.0	Low
2	Suffolk	clay loam	8.0	2	2	2	2.0	Moderate
3	Suffolk	sandy loam	7.4	4	1	2	1.0	Low
4	Suffolk	sandy clay loam	7.3	4	0	2	1.3	Low
5	Essex	clay loam	7.9	4	3	2	2.6	High
6	Lincolnshire	sandy silt loam	6.0	4	2	2	2.8	Moderate
7	Lincolnshire	sandy clay loam	7.7	6	4	2	2.6	Low

Sites 1, 3, 4 (low potash) and 6 (acid) would be expected to respond the most due to combinations of low pH, low available potassium and organic matter contents, and low drought resistance (based on clay content). Site 5 would be expected to be the least responsive site as it had a relative high nutrient status, organic matter content and clay loam soil.

2.2.1 Site 1 responses

Soil characteristics

This site had had compost applied in the same treatments and plots in 1999 and 2001. By the end of 2004, the soil pH was stabilised where compost was applied and available potassium and organic matter raised, see Table 6.

Table 6 Site 1 Soil analysis post harvest 2004

Trt	pH	Phosphorus (P)		Potassium (K)		Magnesium (Mg)		Organic Matter %
		mg/l	Index	mg/l	Index	mg/l	Index	
1	7.4	29	3	76	1	41	1	2.2
2	7.2	32	3	111	1	40	1	1.9
3	7.5	34	3	158	2	50	1	2.8
4	7.7	33	3	150	2	56	2	3.3
5	7.7	36	3	152	2	48	1	2.6
6	7.6	35	3	210	2	62	2	3.3
7	7.5	33	3	159	2	52	2	2.7
8	7.6	38	3	200	2	57	2	2.9

Yields

In year 1, barley grain yield was significantly increased by 100 t/ha compost alone but not 50 t/ha alone, above untreated control. Where a low amount of nitrogen was added with the compost, yields were found to be equivalent to the farm standard treatment saving 45 kg N/ha. Compost applied at 100 t/ha plus farm standard fertilizer resulted in the greatest yields, significantly above farm standard on its own.

In year 2, potatoes were grown. The valuable larger sized potatoes were found to a greater amount where the combination of compost plus nitrogen had been applied, especially at the lower rate of N saving 25 kg N/ha as well as 50 kg phosphate and 200 kg potash per hectare.

In the third year winter barley was grown and good residual effects from the compost were seen. Lower nitrogen (by 50 kg N/ha) with compost was almost equivalent to farm standard fertilizers, but the greatest yields were found from full nitrogen plus 100 t/ha compost.

Overall, yields were increased and fertilizer savings could be made from compost application. The greatest benefits were found from the interactions of fertilizers with compost.

2.2.2 Site 2 responses

Soil characteristics

Soil pH and available potassium were raised by compost addition, and organic matter levels also increased with compost application.

Table 7 Site 2 Soil analysis post harvest 2004

Trt	pH	Phosphorus (P)		Potassium (K)		Magnesium (Mg)		Organic Matter
		mg/l	Index	mg/l	Index	mg/l	Index	%
1	7.9	17	2	240	2	123	3	3.4
2	8.0	26	3	278	3	113	3	3.4
3	8.1	18	2	264	3	123	3	4.1
4	8.1	21	2	274	3	116	3	4.9
5	8.1	20	2	299	3	120	3	4.1
6	8.1	20	2	362	3	126	3	3.9
7	8.1	19	2	241	3	112	3	4.1
8	8.1	25	2	386	3	140	3	4.9

Yields

Sugar beet was grown in year one with only small yield effects from compost seen. Savings of 24 kg N/ha were made up by 100 t/ha compost. In the second year, potatoes were grown but the irrigation was affected by coastal sea breezes in this hot dry year and no yield differences were found from the treatments.

In year 3, spring barley responded to the applied compost with interactions with the fertilizers. 30 kg N/ha could be saved where compost was applied.

2.2.3 Site 3 responses

Soil characteristics

On this sandy soil, available phosphorus was maintained by compost and potassium and magnesium increased. Organic matter was raised by compost addition.

Table 8 Site 3 Soil analysis post harvest 2004

Trt	pH	Phosphorus (P)		Potassium (K)		Magnesium (Mg)		Organic Matter
		mg/l	Index	mg/l	Index	mg/l	Index	%
1	7.6	47	4	123	2	80	2	1.7
2	7.5	37	3	106	1	75	2	1.5
3	7.4	45	3	166	2	88	2	2.2
4	7.5	47	4	218	2	88	2	2.7
5	7.3	47	4	150	2	73	2	2.0
6	7.5	47	4	298	3	105	3	3.1
7	7.4	45	3	163	2	96	2	2.3
8	7.5	50	4	217	2	96	2	2.8

Yields

In year 1, the establishment of the sugar beet was affected by wind blow on this very sandy soil giving variable and non- significant yield effects. The potato crop in year 2 was affected by an internal headland and possible uneven irrigation application. The spring barley in the third year did not show significant differences between treatments although where compost had been applied, yields tended to be greater than the untreated and farm standard controls.

2.2.4 Site 4 responses

Soil characteristics

On this light soil, potassium levels were raised by the compost, and organic matter levels marginally improved relative to the controls.

Table 9 Site 4 Soil analysis post harvest 2004

Trt	pH	Phosphorus (P)		Potassium (K)		Magnesium (Mg)		Organic Matter
		mg/l	Index	mg/l	Index	mg/l	Index	%
1	7.4	35	3	58	0	64	2	1.6
2	7.2	35	3	113	1	68	2	1.8
3	7.3	37	3	90	1	74	2	1.9
4	7.5	43	3	70	1	70	2	2.2
5	7.3	36	3	110	1	69	2	2.0
6	7.4	37	3	126	2	73	2	2.1
7	7.2	36	3	95	1	64	2	1.7
8	7.4	36	3	122	2	71	2	2.3

Yields

In the first year, potato yields were significantly increased by the fertilizer treatments and low N fertilizer plus compost was as effective as the farm standard treatment, saving 25 kg N/ha as well as P and K.

An important quality effect was seen in the tuber dry matter contents. The threshold for processing potatoes is 19.5% dry matter (DM). Farm standard fertilizer reduced the DM which is a result of the effects of added nitrogen. Where compost was applied in addition to farm standard, the DM increased despite nitrogen being available from the compost. Where compost alone was applied, the DMs were higher reflecting the low N available in the compost. Low N plus compost depressed the DM compared with control but with the higher rate of compost application this was partly alleviated. There may be effects on nitrogen use efficiency from compost e.g. nitrogen transport within the plant as a result of the extra potassium present or available sulphur affecting protein formation.

In year 2, winter barley yields were slightly but not significantly lower where the lower rate of N had been applied with compost in treatments 7 and 8 compared with Farm Standard saving 25 kg N/ha. Compost alone at 50 t/ha gave a slight increase in yield above untreated control but there was little residual effect from 100 t/ha the previous year. Compost with farm standard fertilizer tended to give the better yields.

The sugar beet yield in year 3 did not show additional benefits from compost application although the beet population was lower where farm standard fertilizers had been applied, possibly an effect of seedling scorch which appeared to be alleviated by the addition of compost.

2.2.5 Site 5 responses**Soil characteristics**

Organic matter levels were increased at this site even though the initial site organic matter was relatively good, possibly due to interactions with the clay content of the soil. There were also indications of improved available potassium levels from the use of compost.

Table 10 Site 5 Soil analysis post harvest 2004

Trt	pH	Phosphorus (P)		Potassium (K)		Magnesium (Mg)		Organic Matter
		mg/l	Index	mg/l	Index	mg/l	Index	%
1	8.0	35	3	397	3	100	2	4.9
2	8.1	47	4	494	4	76	2	6.1
3	8.0	35	3	494	4	106	3	6.5
4	8.1	33	3	491	4	92	2	6.4
5	8.0	51	4	496	4	85	2	6.7
6	8.0	36	3	498	4	96	2	7.3
7	8.1	28	3	389	3	85	2	6.8
8	8.0	44	3	408	4	95	2	7.2

Yields

The potatoes grown in year one did not show any additional effects from compost application over and above that from fertilizer alone. Also in year 2, the winter wheat did not show effects from the compost although the compost plus low N treatments did not differ in yield significantly from farm standard alone, indicating a possible saving of 25 kg N/ha.

In year three, oil seed rape was grown. With low N plus compost, yields were not significantly lower than from farm standard fertilizers alone. However, contract spread fertilizer probably resulted in over fertilization on the site masking effects.

2.2.6 Site 6 responses

Soil characteristics

pH at this more acid site was maintained by compost compared with artificial fertilizers and available potassium increased. Organic matter levels increased where compost had been applied.

Table 11 Site 6 Soil analysis post harvest 2004

Trt	pH	Phosphorus (P)		Potassium (K)		Magnesium (Mg)		Organic Matter
		mg/l	Index	mg/l	Index	mg/l	Index	%
1	6.0	28	3	156	2	58	2	3.6
2	5.8	28	3	172	2	61	2	3.6
3	6.1	30	3	194	2	64	2	4.3
4	6.2	43	3	282	3	69	2	4.5
5	6.0	30	3	233	2	67	2	4.4
6	6.2	29	3	248	3	67	2	4.3
7	6.1	29	3	211	2	65	2	3.6
8	6.0	25	2	209	2	57	2	3.9

Yields

The spring wheat in year 1 indicated that low N plus compost could achieve the same yields as farm standard fertilizer, saving 25 kg N/ha. In year 2 a poor yield was obtained from a feed cereal crop with no clear differences between treatments apart from all being greater than the untreated control.

In year 3, a good crop of potatoes was grown. Fertilizing with nitrogen decreased the weight of small tubers < 45 mm in size. There were no significant differences in the 45-65 mm size grade due to treatments. Compost alone did not raise yields in the 65-85 mm grade or overall.

Yields were raised in the valuable 65-85 mm grade by fertilizer but particularly by farm standard (and to a lesser extent by low N) in conjunction with the 100 t/ha compost rate. This reflects a lowering of the 45-65 mm size and a general increase in tuber weight /ha due to high rates of compost.

Compost raised yields from 71.57 t/ha with farm standard alone to 76.16 t/ha with low N + 100 t/ha compost, and further still to 82.59 t/ha from farm standard N + 100 t/ha compost.

These effects may well be due to the extra potassium provided by the compost and a supply of slowly released nitrogen.

2.2.7 Site 7 responses

Soil characteristics

No major changes in soil properties were seen at this site with only a small increase in available potassium relative to the untreated control.

Table 12 Site 7 Soil analysis post harvest 2004

Trt	pH	Phosphorus (P)		Potassium (K)		Magnesium (Mg)		Organic Matter
		mg/l	Index	mg/l	Index	mg/l	Index	%
1	7.9	53	4	200	2	63	2	3.6
2	7.6	55	4	253	3	55	2	3.2
3	7.6	63	4	258	3	67	2	3.5
4	7.5	66	4	255	3	64	2	3.7
5	7.6	58	4	260	3	65	2	3.4
6	7.5	57	4	320	3	67	2	3.6
7	7.6	63	4	257	3	66	2	3.5
8	7.6	63	4	222	2	68	2	3.7

Yields

In year 1, the carrots did not respond significantly to the treatments, possibly due to residual mineral nitrogen at this site which was higher than for the other sites that year. Potatoes were grown in the second year and yield increases were found from the fertilizers but no additional yield was gained from the compost. The low N treatments with compost did yield the same as farm standard saving 25 kg N/ha as well as 275 kg potash/ha. Leeks were grown in year three but yields were lost due to floods.

2.3 Conclusions from field trials**2.3.1 All sites and crops**

The yield responses are shown in the following tables as a percentage of control. Averages are shown for all sites as well as those for sites not affected by outside agencies i.e. variable irrigation, erosion or floods. Those affected are shown in grey cells.

Table 13 Year 1 yield responses

Site	1	2	3	4	5	6	7	All Average	Average 1,2,4,5,6
Trt									
1	100	100	100	100	100	100	100	100	100
2	136	160	99	159	115	121	96	127	138
3	140	170	91	135	109	119	103	124	135
4	156	159	118	175	109	121	105	135	144
5	96	109	99	121	107	103	94	104	107
6	122	119	94	112	111	107	93	108	114
7	132	150	120	157	115	126	93	128	136
8	141	157	138	152	106	125	97	131	136

Table 14 Year 2 yield responses

Site	1	2	3	4	5	6	7	All Average	Average 1,4,5,7
Trt									
1	100	100	100	100	100	100	100	100	100
2	128	98	99	235	198	228	136	160	174
3	129	120	113	241	189	289	137	174	174
4	139	101	100	239	189	307	133	173	175
5	79	116	102	128	151	306	94	139	113
6	105	120	101	116	150	267	96	136	117
7	135	103	116	223	188	274	136	168	171
8	157	133	119	225	186	340	137	185	176

Table 15 Year 3 yield responses

Site	1	2	3	4	5	6	7	All Average
Trt								
1	100	100	100	100	100	100		100
2	173	120	102	165	291	139		165
3	167	131	114	148	290	145		166
4	186	129	110	142	304	160		172
5	114	106	112	101	154	107		116
6	134	112	116	98	123	113		116
7	160	126	124	141	283	140		162
8	160	129	114	143	277	148		162

Table 16 All years yield responses

	Treatment	All Average	Selected Average
1	UNTREATED	100	100
2	FARM STANDARD (FS)	150	159
3	50 T/HA COMPOST + FS	154	158
4	100 T/HA COMPOST + FS	159	163
5	50 T/HA COMPOST	120	112
6	100 T/HA COMPOST	121	116
7	50 T/HA COMPOST + LOW N	152	156
8	100 T/HA COMPOST + LOW N	159	157

The soil properties in terms of soil organic matter and, especially, available potash were raised by the addition of compost.

Taking all sites in all years, yields were slightly increased by compost application alone (20%) indicating a small release of nitrogen from the organic matter. Interactions were seen between fertilizer and compost leading to potential savings of inorganic fertilizers or, in some cases, valuable yield increases.

Selecting out sites where adverse conditions were thought to have compromised results still showed that the compost alone was able to raise yields slightly (12-16%). Reduced N treatments with compost almost achieved the same yields as farm standard and the greatest yields were found from farm standard plus the highest rate of compost.

These effects are probably as would be expected. It takes time to build up soil properties from compost due to the low application rates that are allowed to be applied according to the Soil Code and Nitrate Vulnerable Zone regulations.

2.3.2 Potatoes

The yield responses for potatoes are shown in the following tables as tonnes per hectare. Averages are shown for all potato sites as well as those for sites not affected by outside agencies i.e. variable irrigation. Those affected are shown in grey cells.

Table 17 Potato yield responses

Site	1	2	3	4	5	6	7	All Average	Selected Average
Trt									
1	39.79	42.20	53.24	22.44	44.74	51.51	46.76	43.0	41.0
2	50.97	41.39	52.83	35.62	51.23	71.57	63.63	52.5	54.6
3	51.33	50.60	59.90	30.40	48.67	74.86	63.97	54.2	53.8
4	55.46	42.59	53.48	39.38	48.75	82.59	62.36	54.9	57.7
5	31.49	48.89	54.17	27.12	47.73	55.28	44.11	44.1	41.1
6	41.68	50.79	53.93	25.10	49.86	58.38	44.84	46.4	44.0
7	53.59	43.39	61.54	35.14	51.65	72.18	63.59	54.4	55.2
8	62.40	56.27	63.56	34.02	47.30	76.16	64.07	57.7	56.8

It can be seen that the effect from 50 t/ha compost alone is small but at 100 t/ha in alternate years that yields can be increased by 2 to 3 t/ha of potatoes. What is also shown is that artificial nitrogen fertilizer can be reduced when compost is used at 50 or 100 t/ha. This may be due to the increased supply of potassium, and nutrient interactions, as well as compost possibly moderating nitrogen supply over the growing season. The effects of organic matter and increased microbial activity may also play a part in nutrient cycling and nutrient uptake through improvements in root development.

3. SOIL STRUCTURE

3.1 Literature review

A literature review was carried out by Rothamsted Research entitled 'Soil organic carbon forms responsible for structure aggregation'.

The influence of soil carbon on soil aggregates is the result of both biological and physicochemical processes. Soil aggregates follow a hierarchical principle based on organic components and clay minerals. The organic component is based on a dynamic process that is largely dependent on the input of organic debris into soil where the action of bacteria and fungi result in the organic compounds on which aggregate formation is based. Plant root exudates also play an important, but lesser, role in aggregate formation.

The hierarchical system of aggregate separation is based on the size and stages of aggregation. Practically, this is largely dependent on the physical methods used for aggregate separation, but the most general assumption follows:

$$<0.2\mu\text{m} \rightarrow 0.02\text{-}2\mu\text{m} \rightarrow 2\text{-}20\mu\text{m} \rightarrow 20\text{-}250\mu\text{m}$$

Microaggregates are designated as $<250\mu\text{m}$ and macroaggregates as greater.

For macroaggregates the organic binding agents are mainly (a) temporary, roots and fungal hyphae (light fraction $<1.6 \text{ g cm}^3$) and (b) transient polysaccharides. These are also involved with microaggregates to a varying degree, but, the influence of more persistent aromatic humic components and polymers, both strongly sorbed to clay mineral surfaces, generally increases as microaggregate size decreases.

The decomposition of the organic components of aggregates by microbial synthesis, results in progressively resistant plant residue components as aggregates decrease in size. As a result, the proportion of alkyl, carbonyl and aromatic carbon increases with decreasing aggregate size, this is associated with an increase in humic substances (fulvic and humic acids) and resistant particulate organic matter derived from plant materials. As aggregates increase in size they generally have a greater proportion of O-alkyl and carbohydrate carbon, predominantly derived from microbial exudates.

Humic substances appear to coat the surfaces of clay particles, having the greatest influence in clay dominated microaggregates $<50\mu\text{m}$, the formation of polyvalent cation bridges is believed to be the dominant bonding process between the organic and inorganic phases. Polysaccharides (carbohydrates) are also involved in binding clay particles throughout the aggregate range, but they increase in importance as aggregates increase in size, such that they dominate the formation of larger aggregates. The proportion of plant associated polysaccharide (root exudates and cellulose synthesis) increases with increased aggregate size.

The application of organic manure or compost enhances the formation of soil aggregates by increasing the physical and chemical substrate for microbial and fungal activity. As a result, it increases the soil content of the basic organic chemical building blocks required for aggregate formation.

3.2 Practical studies

3.2.1 Site and sampling

The information contained within this report is based on data collected from Site 1 used in this project in Suffolk, which is a sandy loam. At the time of sampling, a crop of potatoes (cultivar Estima), was still in the field. Dutch augers were used to remove soil samples from the top 23 cm of the selected plots, (the plough layer).

The eight treatments were:

- 1 Control (no treatments)
- 2 Inorganic fertiliser
- 3 50 t compost ha⁻¹ + fertiliser
- 4 100 t compost ha⁻¹ + fertiliser
- 5 50 t compost ha⁻¹
- 6 100 t compost ha⁻¹
- 7 50 t compost ha⁻¹ +* Low N Fertiliser
- 8 100 t compost ha⁻¹ + Low N Fertiliser

Although there were 8 treatments at the site, only treatments 1-6 were sampled. Using the augers, large polybags, each containing about 6-7kg of soil were filled from the 24 sampled plots (4 replicates of treatments 1-6 inclusive). The soil was taken from the raised rows within the crop, from which the potatoes were growing and from the centre of each treatment to minimise edge effects. These were then taken to Rothamsted Research and stored at 4 °C prior to analysis.

The soil samples were removed from cold storage to allow for the removal of all obvious fresh organic matter. This was achieved by spreading the soils individually on large plastic sheets, and then picking out the organic matter by hand. This mostly consisted of pieces of potato, but also included; roots, leaves and small invertebrates.

The manual removal of organic matter was carried out in order to prepare the soils for sieving. The soil samples were sieved by hand using a 2mm sieve. This ensured that the soils all have a similar workable consistency for future analysis.

3.2.2 Methods

20 gram samples of each soil, (two replicates of each), were oven dried overnight at 105 °C to determine soil moisture.

Soil water holding capacities (WHC) were assessed by the standard method (volumetric) taken from the Laboratory Manual of the Soil Biomass at Rothamsted and is briefly as follows. Each sample was replicated in duplicate and a mean value calculated.

Moist soil of about 50 g fresh weight, was placed into funnels, each plugged with glass-wool and sealed at the base. 50 ml water was gently added to the surface of the soils and the funnels allowed to stand for 30 minutes. Controls of water only

were prepared at the same time. The funnels were then opened and the water allowed to drain freely into flasks for a further 30 minutes. The drained water was then measured and the WHC calculated as: ml water retained 100 g⁻¹ oven-dry soil.

For gravimetric water content the soil samples were first sieved (< 2 mm) before being air-dried. Buchner funnels and burettes (Haynes apparatuses) were first saturated using de-ionised water and checked for air leaks. A filter paper was placed on the burette and the water level in the burette drawn down to 20 cm below the funnel. Soil samples were placed (in a ring 2 cm diameter by 1 cm deep) on the filter paper allowing the soil to wet from below. The burette stopcock was closed and water carefully added around the ring until the soil was saturated. The funnel was covered to prevent evaporation and allowed to stand for 1 hour.

The burette stopcock was opened and water allowed to flow out into the burette. The water level was lowered to 10 cm below the centre of the sample until flow ceased. The sample was then placed in a clean, pre-weighed container (w1) and re-weighed (w2) before being placed in an oven at 105 °C overnight. The dry soil and container were then reweighed (w3).

Gravimetric water content was then determined $(w2-w3)/(w3-w1)$

For the soil total carbon and nitrogen analyses, oven dried samples of soil were ground < 160 µm diameter in a Fritsch Agate Ball Mill for total C and N determination using a LECO CNS analyser

Soil pH was determined using oven dried soil in a 1:5 ratio with pure water, (5g soil to 25ml water) and measured using a TitraLab 850 (pH_w) pH meter.

For microbial biomass carbon and nitrogen mineralization measurements the sieved soils were adjusted to 40% of total water holding capacity by spraying with the required volumes of water. They were then covered with plastic sheeting, left overnight at room temperature to equilibrate, then gently but thoroughly mixed. The soils were then given a pre-incubation at 25°C, in air tight drums containing water and soda-lime (to absorb excess CO₂), under aerobic conditions for 7 days, before microbial biomass or CO₂ measurements were performed.

Microbial biomass carbon (biomass C) was measured using the fumigation extraction method. Briefly, soil samples (moist soil containing 50 g soil on an oven-dry soil basis) were fumigated in desiccators with ethanol-free chloroform (CHCl₃) for 24 hours at 25 °C. The CHCl₃ was then removed by repeated vacuum evacuation and the fumigated soil then extracted with 100 ml 0.5 M K₂SO₄ (1:4 soil: solution basis) for 30 minutes on an end-to-end shaker. Non-fumigated control soils were extracted similarly at the time fumigation commenced. The soil extracts were then filtered through Whatman No 42 filter papers. These were then frozen before being analysed for organic carbon using a TOC 200 carbon analyser.

Soil microbial biomass C (B_c) was calculated from:

$B_c = 2.22E_c$, where $E_c = [(organic\ C\ extracted\ from\ fumigated\ soil) - (organic\ C\ extracted\ from\ non-fumigated\ soil)]$.

The factor 2.22 is a proportionality constant to account for the fact that about 45 % of the C in the biomass is extracted by K₂SO₄ following fumigation.

The unfumigated extracts were also used to measure nitrogen mineralization (NO₃⁻, NH₄⁺) using the Skaler Continuous Segmented Colourimetric Analyser (San^{plus} System).

Carbon mineralization was measured on soils at 40% WHC. 50 g soil on an oven-dry weight basis were incubated for 100 days in the dark in large sealed brown glass jars. Each jar contained a vial with 25 ml 1.0 M NaOH to trap CO₂ evolved from the soil and 10ml of water to keep the soils at 40% WHC. Appropriate controls using jars containing only the NaOH and water were also made. After 25 days the NaOH was replaced and again after each further 25 days. The CO₂ was then measured by titrating the NaOH against standardised HCl (0.5 M) using the TIM 850 Autotitrator.

3.2.3 Results and Discussion

Soil pH and WHC

The pH ranged from 6.86 in treatment two, to pH 7.8 for treatments five and six (Table 18). Addition of fertiliser alone significantly reduced the pH due to the replacement of nutrient ions with hydrogen ions. However, when fertiliser was used in conjunction with compost, the soil appeared to be buffered against pH changes. The addition of compost alone caused a slight rise in the pH.

Water holding capacity increased due to the addition of compost, this was augmented by the addition of fertiliser and compost together but decreased when fertiliser was added alone.

Table 18 Soil properties

Soil No.	Treatment	pH _w	^a WHC	%N	%C	C/N ratio
1	control	7.61a	31.7	0.08a	0.84a	10.49
2	inorganic fertiliser	6.86	29.3	0.08a	0.86a	10.20
3	50t ha ⁻¹ compost + fertiliser	7.24	34.2	0.11b	1.15	10.83
4	100t ha ⁻¹ compost + fertiliser	7.61a	34.9	0.12	1.40b	11.27
5	50t ha ⁻¹ compost	7.78b	32.2	0.09	1.02	11.24
6	100t ha ⁻¹ compost	7.82b	32.3	0.11b	1.28b	11.85

Means in each column followed by the same letter do not differ significantly (t test $P \leq 0.05$).

^a – ml water held 100 g⁻¹ oven dry soil

Soil C and soil N

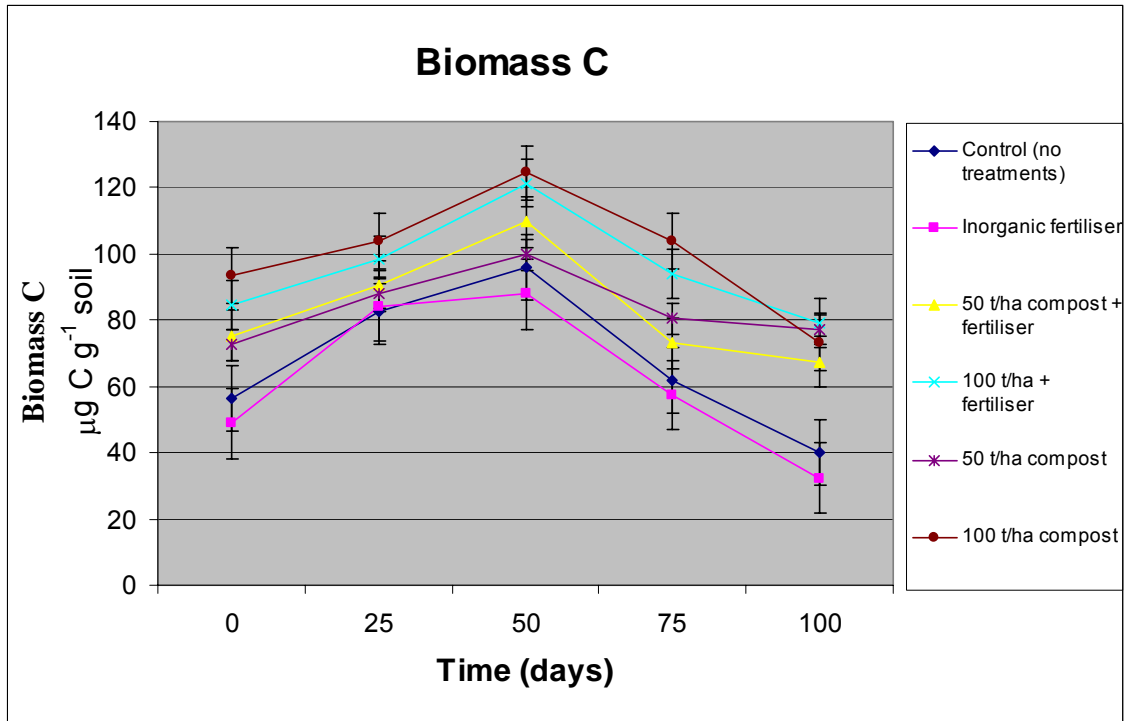
Both soil C and N were increased significantly by the addition of compost (Table 18), as was the soil C/N ratio which showed an increase relative to the amount of compost added. As the compost was very stable (thermogravimetric data), it can be deduced that the carbon added to the soil in the form of stable organic matter will have a very long residence time. This is because the soil microbes will preferentially use the more labile organic fractions, which have more energy than the recalcitrant humified material.

Microbial Biomass C

The soil microbial biomass (defined as the combined mass of all soil micro-organisms <500 µm diameter) can be considered as the living fraction of soil organic matter. Because it is alive, it is much more labile than most other soil organic matter fractions, some of which may have a half-life of more than 100 years. The biomass thus serves as an important pool of potentially labile plant nutrients, especially C, N, P and S which are released to plants during the process of biomass turnover. It also serves as an 'early warning' of changing soil conditions, indicating the direction of change of soil organic matter concentration long before it can be measured by classical chemical analysis.

The microbial biomass C increased with all treatments until day 50, (Graph 4), whereupon it began to decline. With respect to the control only treatment 6 (100 t compost ha⁻¹) differed significantly, and in respect to treatment two, fertiliser alone, both treatments giving 100t ha⁻¹ compost were significantly larger. This aside, there were no significant differences in the microbial biomass as measured by fumigation-extraction. The compost had previously been found to be very stable with very little labile organic C. It would therefore provide very little extra C to the majority of the soil microbes. A less degraded compost may have increased the microbial population more significantly. However, at the end of the 100 day incubation, the biomass in the soils given compost was still significantly larger than in soils where it was not applied.

Graph 4 Changes in microbial biomass during long-term incubations of soils with and without compost

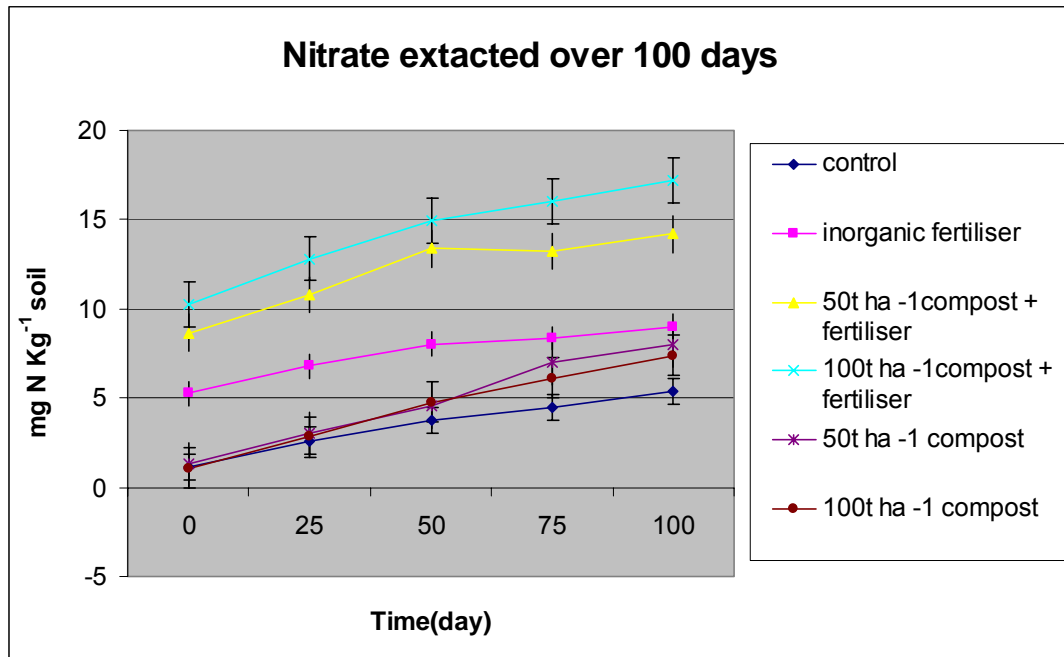


Nitrogen Mineralization

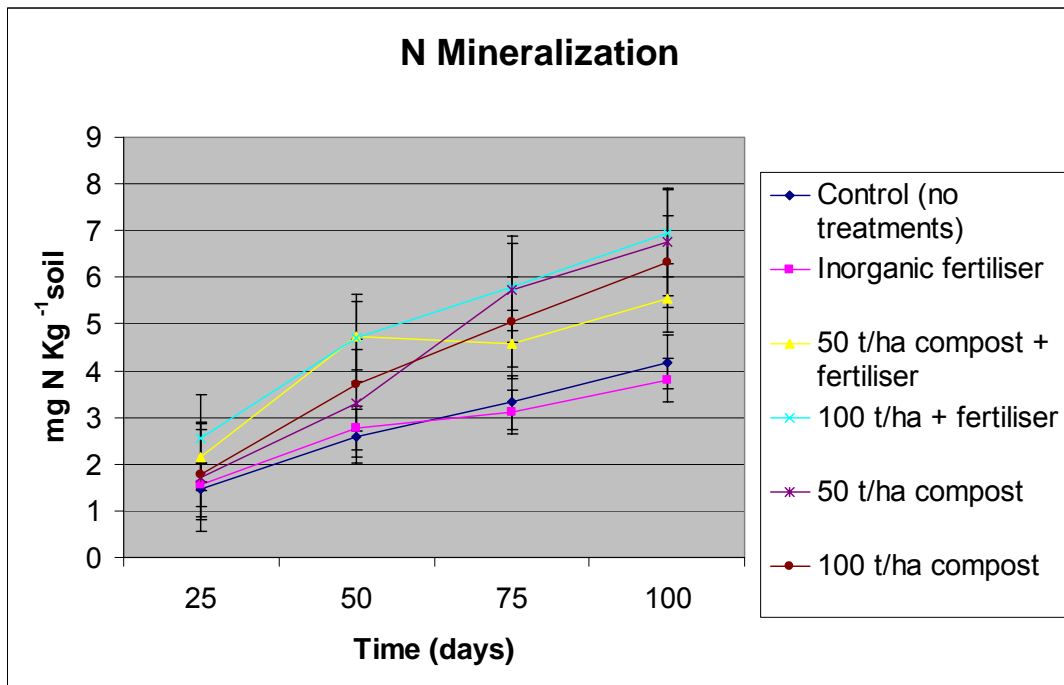
From Graph 5, it can be seen that there are two distinct populations, comprising the soils that have had both compost and fertiliser, treatments 3 and 4 and the second group of those that have had either or neither.

However, Graph 6 shows that, once the initial nitrogen mineralization at zero time has been removed, the groups change. The group with the higher mineralization contains the four treatments that have had compost added whilst the second group comprising the control and treatment with inorganic fertiliser show a much lower rate of mineralization. Clearly, the addition of organic matter appears to have a direct and measurable effect on the rate of mineralization of nitrogen, and the most likely source of this extra N is the compost itself, which can be regarded as a pool of very slowly available plant-N. Presumably, if soils are given repeated annual compost dressings this slowly available N pool will accumulate, so lessening the need for the application of additional N as inorganic fertilizer

Graph 5 Nitrate extracted over 100 days



Graph 6 N mineralization

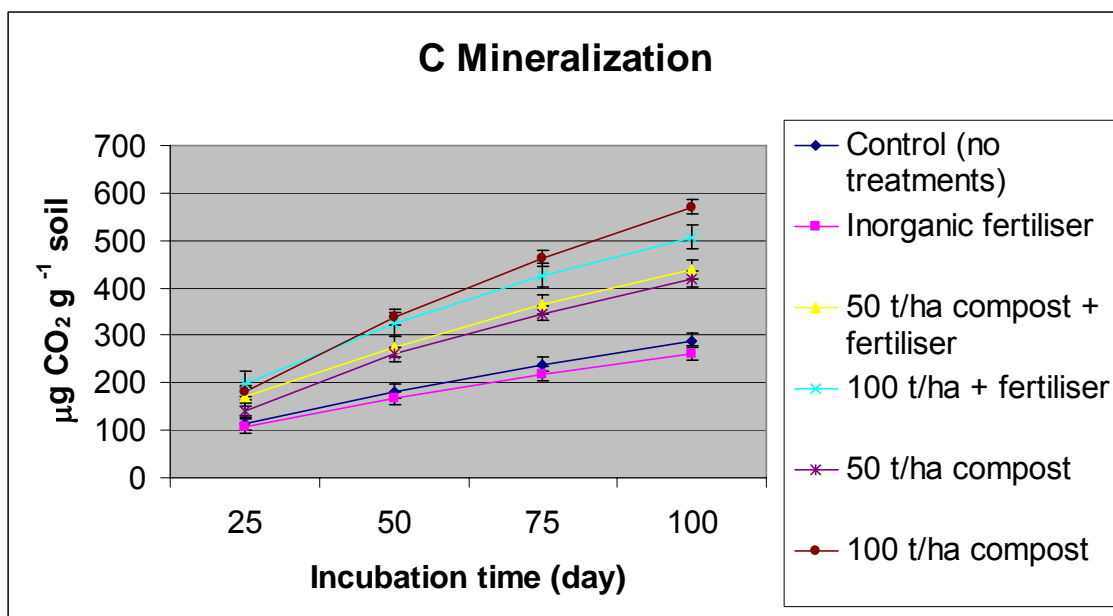


Carbon Mineralization

Carbon mineralization, as measured by CO₂ evolved, shows the same pattern as nitrogen mineralization with two distinct groups (Graph 7). The rate of mineralization was significantly higher in those soils that had been given compost when compared to the control and to fertiliser addition alone, with treatment six mineralizing as much as treatments one and two combined. This may be due to the

extra carbon supplied as organic matter within the compost or may be due to a priming effect of the organic matter on the soil microbes.

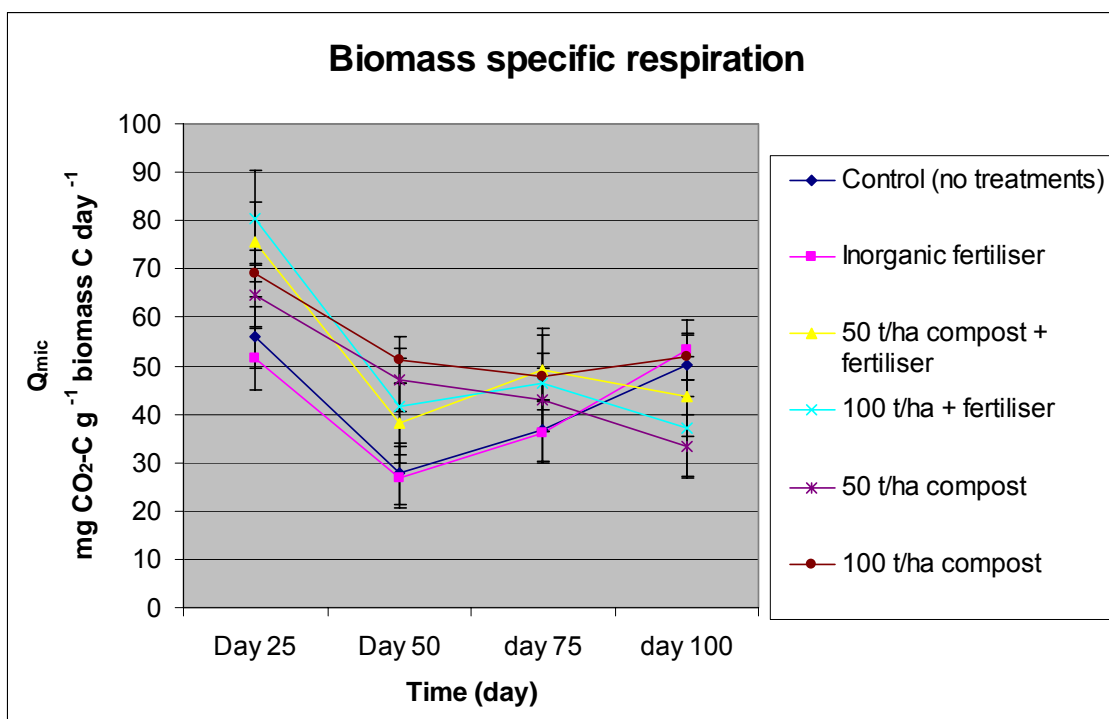
Graph 7 C mineralization



Biomass specific respiration

Biomass specific respiration or metabolic quotient (Q_{mic}), is a sensitive indicator of changing soil conditions for the soil microbes. Q_{mic} values for the six treatments were very similar, with no significant differences between the treatments (graph 8). This may have been a reflection of the nature of the organic C available. There is evidence that Q_{mic} in the control soil and soil given inorganic fertilizer only have different dynamics than soils given compost. However, the system appears highly complex and further speculation would not be useful.

Graph 8 Biomass specific respiration



3.2.4 Conclusions

Soil organic matter, C and N concentrations increased as a result of compost incorporation, as did the C to N ratio. These are considered to be excellent indicators of overall soil health and quality.

Soil water holding capacity increased due to the addition of compost. The ability of a soil to retain water has many implications for the modern farmer. Increased ability to retain water can reduce the amount of water needed for irrigation, reduce the soils susceptibility to erosion, reduce the leaching of nutrients and help to protect against salinization.

Soil microbial biomass is increased by the addition of compost which can lead to a more closed nutrient cycling system, preventing leaching of nutrients and allowing nutrients to become available over a longer period of time rather than in one large burst.

C and N mineralization, driven by the soils microbial community are increased by the addition of compost. N mineralization supplies NO_3^- and NH_4^+ which are then available to crops.

Although the site used for this study had had compost applied for three years in the treatments mentioned, the benefits of compost application can take many years to be fully apparent and it is the cumulative benefits over a much longer time span which are likely to show the most benefits.

Compost addition can probably benefit most soils, however, the effects will be most notable on more degraded soils, particularly soils where there is a very low organic matter content or in areas where yields have begun to decrease or no further increases are made even with the addition of extra fertiliser.



Compost, when used correctly, can be a useful tool in modern farming practices. It has many varied properties and uses which make it excellent as both a soil conditioner and a potential supply of nutrients.

4. SOIL MICROBIOLOGY

4.1 Introduction

One of the major benefits from adding an organic material such as compost to soil is the increase in soil biological activity which leads, amongst other things, to an increase in nutrient cycling. Other benefits include improvements in soil physical conditions, and a soil population which is better able to suppress disease-causing organisms. Biological activity can be estimated by the rate of respiration, and a number of techniques are available for measuring this, ranging from simple test kits such as the Solvita test kit, to sophisticated field and laboratory tests. Respiration measurements can also be used to assess the biological activity of organic materials through a composting system. Following a period of intense biological activity during the thermophilic phase, the transformation of active material to mature compost is associated with a decrease in respiration. Immature compost with high biological activity can cause problems due to the associated high demand for oxygen. The rate of respiration of a compost sample can therefore be used to assess its suitability for use as a soil amendment. Successful management of compost use in agriculture therefore requires a balance to be struck between increasing the biological activity in soil to an optimum level which maximises the supply of nutrients from organic matter, but which is not so high that the demand for oxygen deprives the plants of their supply.

The work carried out by The University of Reading focussed on two main aims:

- ◆ to test respiration measurements for assessing the stability of compost,
- ◆ to quantify the impact of field application of compost on soil biological activity.

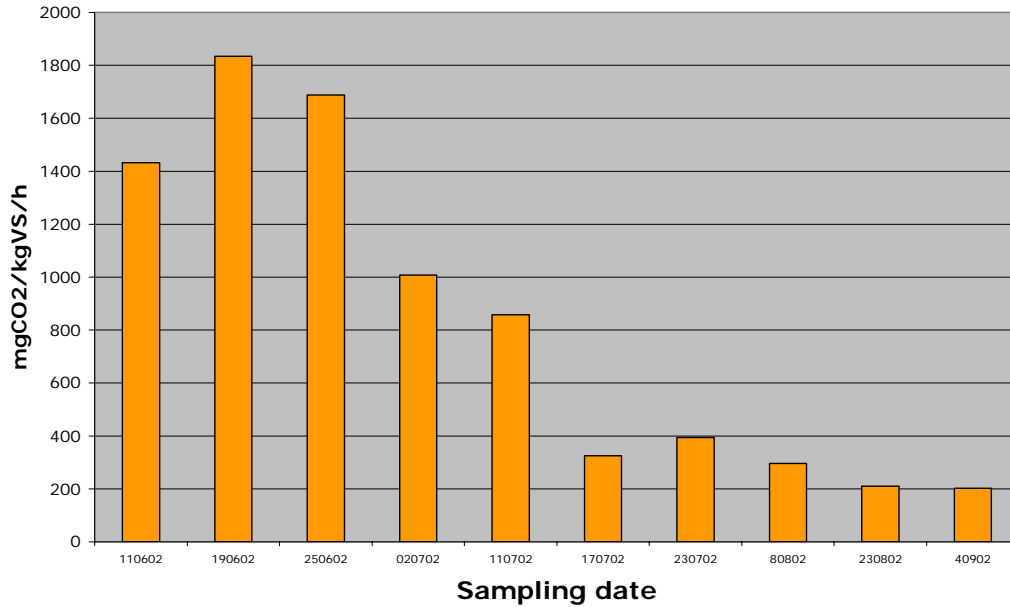
4.2 Stability of compost

Samples of green waste compost were supplied by Enviro Consulting Ltd. Subsamples were taken from a bulked sample and analysed for water content, volatile solids and respiration (CO₂ production). Water content was measured by drying the samples at 105° C overnight, and volatile solids by heating dried samples to 500 °C for 24 hours. Respiration was measured by placing duplicate 50 g samples in a CES combined respirometer which measures O₂ uptake by manometry and CO₂ production by absorption in alkali. O₂ is replenished as used, and measurements were made every 15 min for 20 h at 26°C. All values are the mean of 2 replicate analyses.

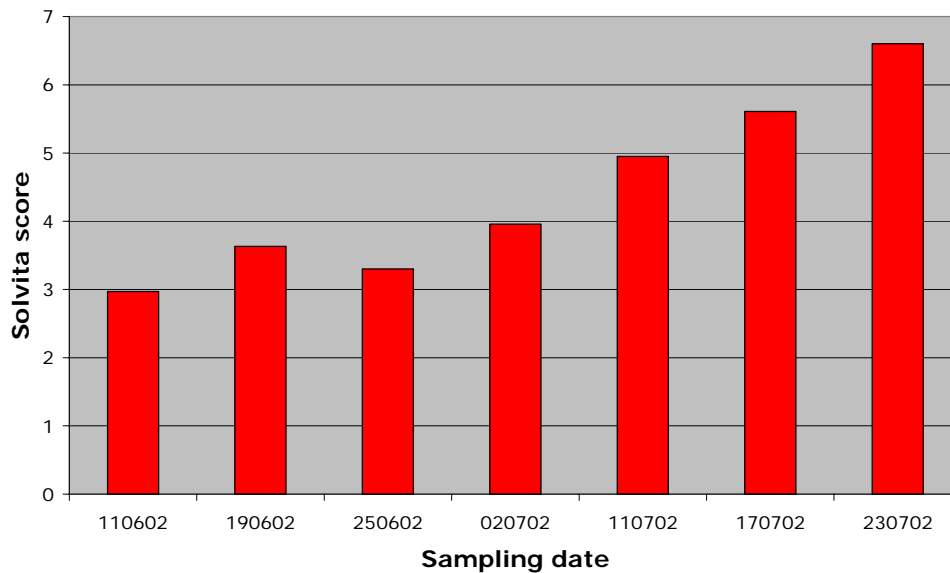
Solvita™ test kits (www.solvita.co.uk) were used to measure CO₂ production over a period of 4 hours at room temperature from a sample of approximately 100 ml compost. All respiration measurements were made on field-moist samples, which were judged to be adequate according to the Solvita instruction manual.

In 2002 analyses were carried out on samples taken at regular intervals from a windrow. In 2003 analyses by respirometer were carried out on compost samples from windrows provided by Organic Recycling Ltd (OR) aged between 4 and 52 weeks.

Graph 9 Changes in CO₂ production by green waste during 10 weeks composting in a open windrow as measured using a laboratory respirometer.



Graph 10 Changes in CO₂ production by green waste during 10 weeks composting in a open windrow as measured using Solvita test kits (Solvita score of 1-8 relates to increasing stability from fresh material, score of 1, to mature compost, score of 8).



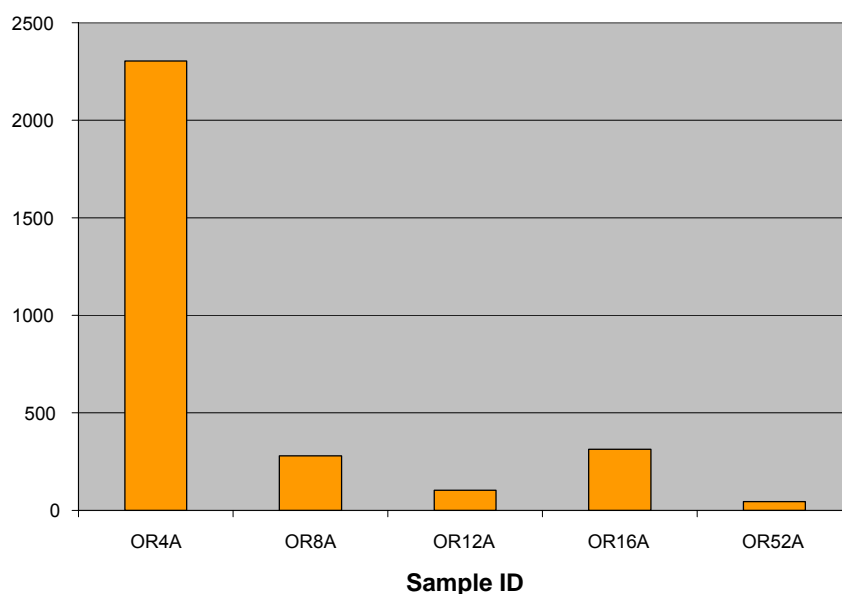
The data (Graph 9) show that as the 10 weeks composting process progressed the rate of CO₂ production by the green waste decreased by a factor of almost 10. The most rapid change occurred during the first 5 weeks of composting, and thereafter a very slow decrease in activity was observed.

The decrease in measured CO₂ production was associated with an increase in the Solvita score from 3 to 6.5 (Graph 10), indicating an increasing stability/maturity with time. The Solvita test kit is based on CO₂ production from the compost,

therefore it is re-assuring that the data agree with the laboratory respirometer. A 50% decrease in CO₂ production from around 2000 mg CO₂/kgVS/h to 1000 mg CO₂/kgVS/h was associated with an increase in Solvita score from 3 to 4. A further 50% decrease in CO₂ production from around 1000 mg CO₂/kgVS/h to 400 mg CO₂/kgVS/h was associated with an increase in Solvita score from 4 to 5, and to 200 mg CO₂/kgVS/h was associated with an increase in Solvita score from 5 to 6. This indicates a logarithmic relationship between Solvita score and CO₂ production rate, and confirms that the Solvita test is most sensitive in distinguishing between different degrees of stability/maturity rather than different degrees of initial activity.

The changes in CO₂ production were also associated with a decrease in moisture content in the samples from 55 g/100g fresh weight to 30 g/100g fresh weight. This was considered not to be a major influence on the CO₂ production rates for two reasons. First, it was demonstrated that it was necessary to dry the material to a moisture content of approximately 25 g/100 fresh weight to cause a major reduction in the respiration rate. Second, samples with moisture contents of around 40 g/100g fresh weight showed very low respiration rates associated with stable compost materials. Furthermore, re-wetting of dried compost material did not cause a flush of CO₂ production, but rather a return to the approximately the same rate of CO₂ production prior to drying the sample.

Graph 11 Changes in CO₂ production by green waste at different stages over 52 weeks as measured using a laboratory respirometer.



A second set of samples taken over a longer period of composting (Graph 11) showed similar trends in CO₂ production to those shown in Graph 9. At 8 weeks (OR8A) the rate of CO₂ production had decreased from >2000 mg CO₂/kgVS/h to well below 500 mg CO₂/kgVS/h (equal to < 12 mg CO₂/g VS/day).

These data indicate that CO₂ production provides consistent information on the biological activity and hence stability/maturity of green waste compost, and that there is good agreement between data obtained using a laboratory respirometer and a simple test kit.

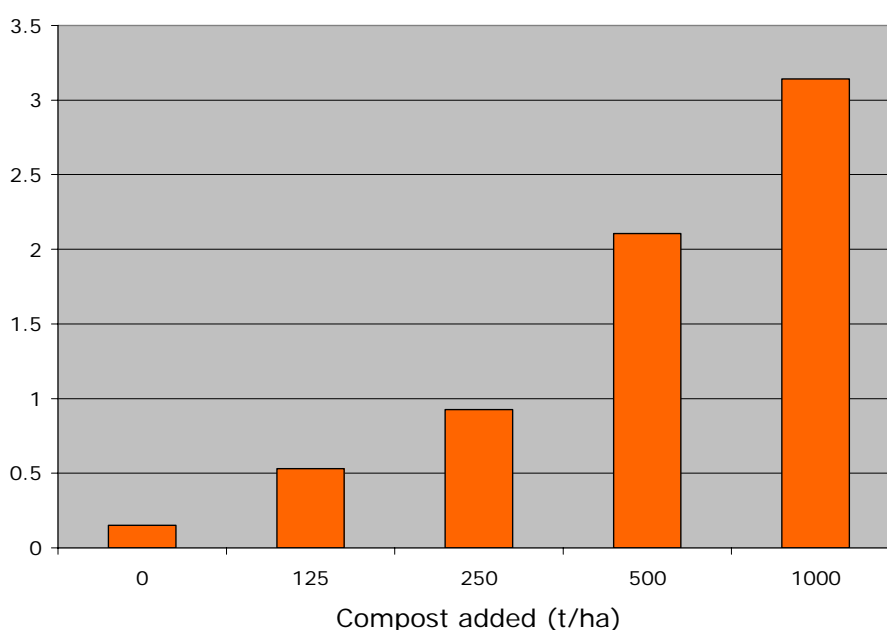
4.3 Effect of compost on soil biological activity

Measurements were made in the laboratory and in the field at site 1. Samples of green waste compost were added to 200 g amounts of Rowland series soil (loamy sand) at rates equivalent to field application of 0, 125, 250, 500 or 1000 t ha⁻¹. Soils were incubated at approximately 70% of water holding capacity and 26°C. After 20 days the samples were analysed for respiration (as described in 4.2) and for hydrolytic enzyme activity. The activity of leucine peptidase, N-acetyl glucosaminidase was measured by the rate of production of fluorescence from amino methyl coumarin (AMC) and methyl umbelliferone (MUB) respectively liberated from their respective conjugates. Leucine peptidase was chosen as an example of a common peptidase involved in N mineralization, and N-acetyl glucosaminidase was selected as an example of an enzyme involved in C and N cycling (a chitinase).

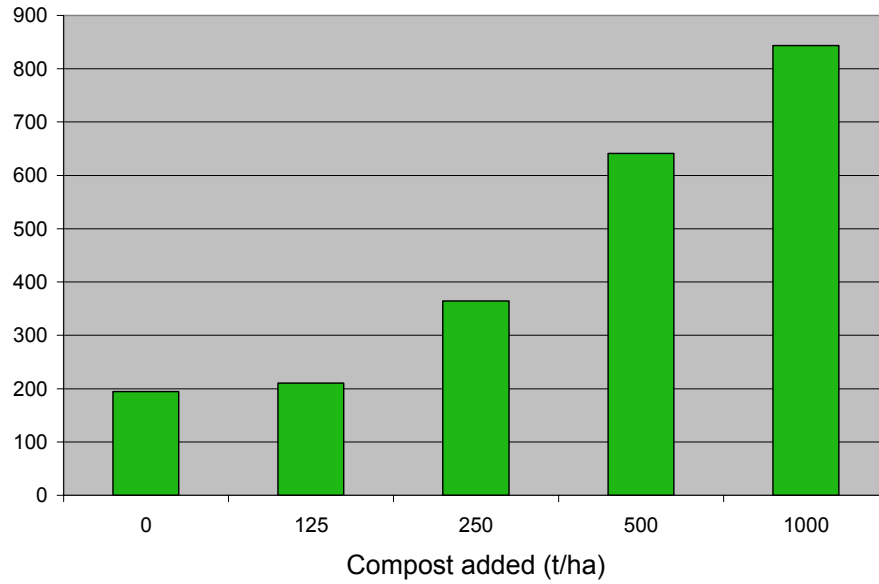
Measurements were also made on the compost trial plots at Site 1 in 2003. Field measurements were made of CO₂ production on all four replicate plots of the treatments receiving either no composts (or other fertilizer) or 50 t/ha compost every year (no additional fertilizer). A LICOR 6400 CO₂ flux chamber was used to make measurements at four locations in each plot at four times during a day. Soil temperature was measured using thermistors and soil moisture content was measured using a Theta probe.

The addition of compost to the loamy sand soil in the laboratory caused an increase in respiration as measured by CO₂ production (Graph 12), and this increase was directly proportional to the amount of compost added. The increased biological activity in the compost treated soil was associated with an increase in activity of both hydrolytic enzymes leucine peptidase (Graph 13), and N acetyl glucosaminidase (Graph 14). This increase in enzyme activity was directly proportional to the amount of compost added.

Graph 12 Effect of green waste compost on biological activity in a loamy sand soil as measured by CO₂ production in the laboratory.



Graph 13 Effect of green waste compost on activity of leucine peptidase in a loamy sand soil (relative units of enzyme activity).



Graph 14 Effect of green waste compost on activity of N acetyl glucosaminidase in a loamy sand soil (relative units of enzyme activity).

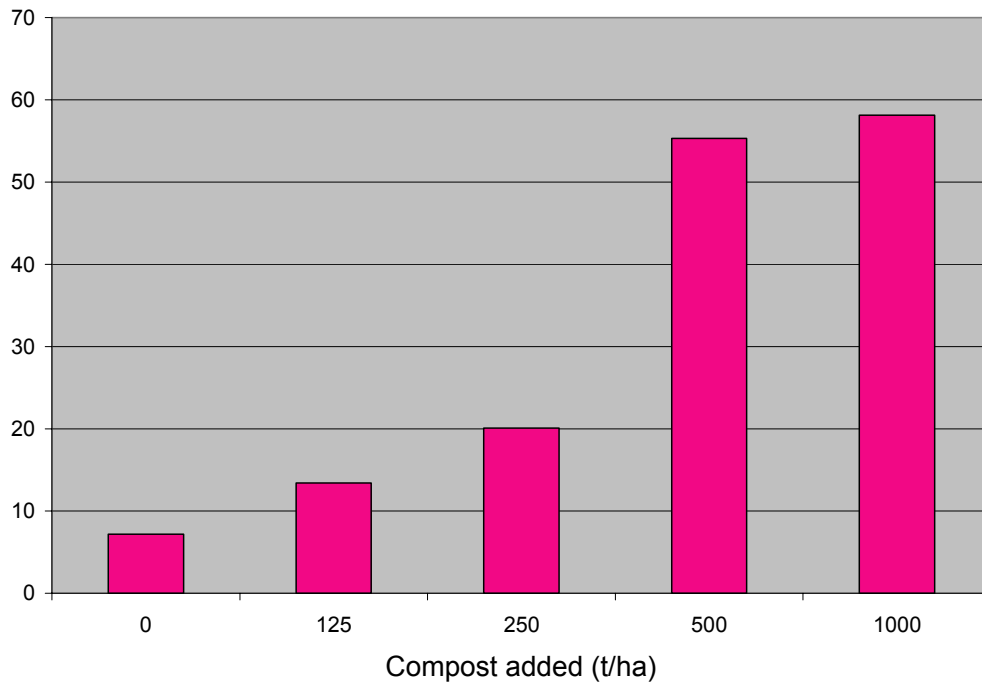


Table 19 Effect of compost at Site 1 on soil biological activity as measured by respiration and activity of two hydrolytic enzymes (figures in parenthesis are standard error of means).

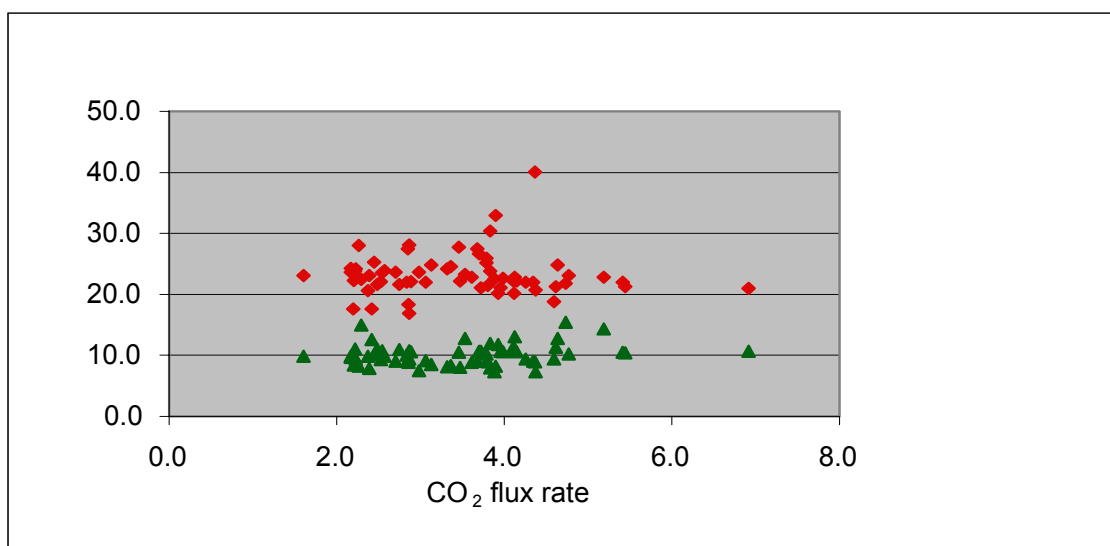
Measurement	No compost	50 t/ha compost
Field respiration	3.46	4.79
($\mu\text{mol}/\text{m}^2/\text{s}$)	(0.126)	(0.116)
N acetyl glucosaminidase	0.88	1.38
(relative units)		
Leucine peptidase	10.22	9.90
(relative units)		

The plots treated with compost at Site 1 showed a higher rate of CO_2 production than the control plots. This increase in soil respiration due to the addition of compost was due to a higher level of biological activity in the compost-treated soil. The plots treated with compost also showed a higher level of activity of the enzyme N acetyl glucosaminidase (chitinase). Compost addition to the field plots had no effect on the activity of the enzyme leucine peptidase.

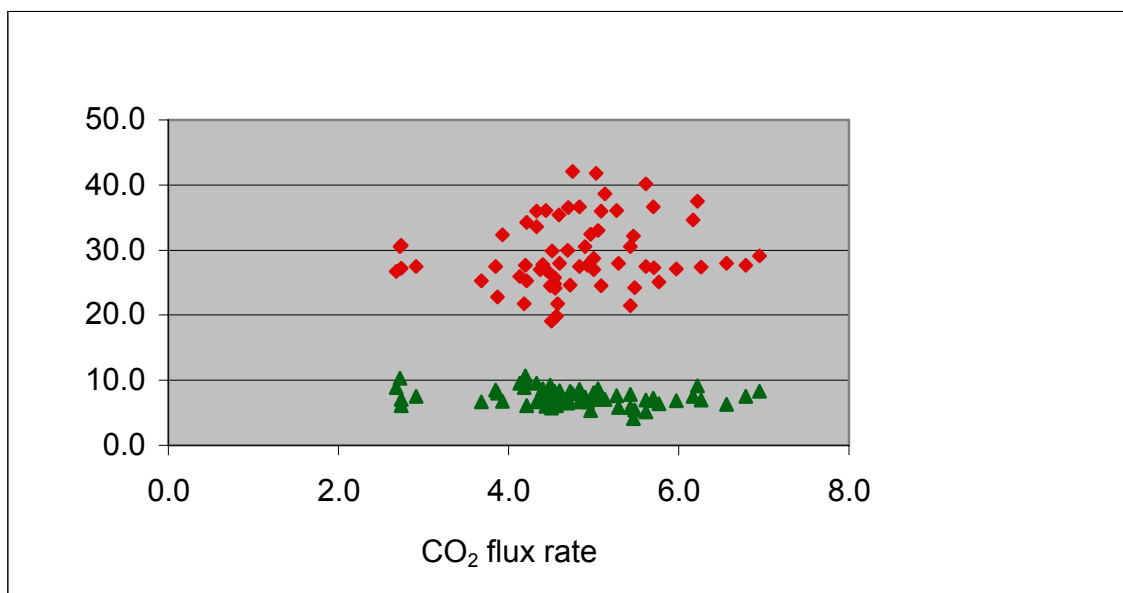
The soil respiration data for the Site 1 field plots were analysed further. The coefficient of variation soil respiration data for the control plots was 29.2% compared to a coefficient of variation of the compost treated plots of 19.3%. This indicates that the addition of compost had reduced the variability in soil respiration (as well as increasing the rate of respiration overall).

Finally, the possible effect of soil temperature and moisture content on the measured rates of soil respiration was investigated by in the scatter plots shown in Graphs 15 and 16. There was no evidence for a significant role of these environmental variables in influencing the rate of CO_2 production in the control plots or the compost treated plots.

Graph 15 Correlation between CO_2 flux rate ($\mu\text{mol}/\text{m}^2/\text{s}$) and soil temperature (ν) and soil volumetric water content (σ) for CO_2 flux measurements at the Site 1 trial in the control plots without compost. Measurements made from 0930 h to 1700 h on 11th June 2003.



Graph 16 Correlation between CO₂ flux rate ($\mu\text{mol}/\text{m}^2/\text{s}$) and soil temperature (ν) and soil volumetric water content (σ) for CO₂ flux measurements at the Site 1 trial in the plots treated with compost. Measurements made from 0900 h to 1430 h on 13th June 2003.



4.4 Conclusions

During a 10 week composting trial, the rate of CO₂ production by the green waste material decreased by a factor of almost 10 as measured using a laboratory respirometer. The most rapid change CO₂ production occurred during the first 5 weeks of composting, and thereafter a very slow decrease in production was observed.

The Solvita test kit, which is based on a simple method for measuring CO₂ production, gave data that was in agreement with the laboratory respirometer. The Solvita test was most sensitive in distinguishing between different degrees of stability/maturity rather than different degrees of initial activity.

A decrease in moisture content in the samples from 55 g/100g fresh weight to 30 g/100g fresh weight did not appear to be a major influence on the CO₂ production rates.

CO₂ production provided consistent information on the biological activity and hence stability/maturity of green waste compost.

The addition of compost to a loamy sand soil in the laboratory caused an increase in CO₂ production (soil respiration) as measured using a laboratory respirometer, and this increase was directly proportional to the amount of compost added.

Increased biological activity in the compost treated soil was associated with an increase in activity of both hydrolytic enzymes leucine peptidase, and N acetyl glucosaminidase. This increase in enzyme activity was directly proportional to the amount of compost added.

The plots treated with compost at Site 1 (50 t/ha/year for 5 years) showed a higher rate of CO₂ production than the control plots. This increase in soil respiration due

to the addition of compost was due to a higher level of biological activity in the compost-treated soil. The addition of compost also reduced the variability in soil respiration compared to the untreated plots.

The plots treated with compost also showed a higher level of activity of the enzyme N acetyl glucosaminidase (chitinase). Compost addition to the field plots had no effect on the activity of the enzyme leucine peptidase.

The increased activity of chitinase may be associated with an increase in the ability of the soil microbial population to suppress disease-causing organisms.

There was no evidence for a significant role of soil temperature and soil moisture in influencing the rate of CO₂ production in the control plots or the compost treated plots.

It is concluded that the increased rate of respiration in the compost treated plots is due mainly to the increased supply of substrates and microorganisms in the compost.

5. COMPOSTING AND PLANT PATHOGENS

5.1 Introduction

Composting biodegradable municipal solid wastes is becoming a key waste treatment option for local authorities trying to meet ever increasing recycling/composting and landfill diversion targets. Much of past and current activity consists of processing of green waste collected from local civic amenity sites, but kerbside collection of household kitchen and garden waste is increasing to meet the high waste diversion targets required. The changing nature of these wastes has come under close scrutiny in the form of the Animal By-products Regulations following a Risk Assessment commissioned by DEFRA. The risk assessment was originally designed to address only the risks of animal pathogens contained in meat that may enter these waste streams. WRAP has funded the HRI for work to include plant pathogens.

During the composting process, routine temperatures of 60-70°C are normally sufficient to achieve the destruction of most pathogens and/or weed seeds (sanitisation). However, concern and mistrust is expressed by potential end-users of waste derived composted products. The potential of failure to fully sanitise the composted material could lead to the composts spreading plant pathogens to commercial crops, with serious economic implications.

Little scientific research has been carried out on the survival of plant pathogens during composting, with much emphasis being placed on potential human and animal pathogens such as *E. coli* and *Salmonella*. Research has shown that these pathogens are rapidly killed at temperatures $\geq 55^{\circ}\text{C}$.

Some studies into the destruction of plant pathogens have shown they are able to survive such thermophilic temperatures by forming resistant spores. It is difficult for composts to be tested for such pathogens using traditional plating and colony forming unit (cfu) counts, and therefore difficult to be sure composts are truly free of plant pathogens.

The work reported here set out to explore the destruction of specific plant pathogens during in-vessel composting of controlled waste types likely to act as potential vectors for disease of, in particular, potatoes, a high value crop. It also highlights the advantages and disadvantages between traditional and innovative detection techniques using specific disease antibodies. Furthermore, the colonisation of composts with potentially disease suppressing microorganisms (*Trichoderma* spp.) was also explored during traditional windrow composting of green wastes.

Aims:

The occurrence of potato pathogens on potato waste, and effectiveness of in-vessel composting to destroy a number of specific potato pathogens.

Monitor the colonisation of green waste by *Trichoderma* spp., a known fungal predator of disease organisms, during the windrow composting.

5.2 Results and discussion

Although not conclusive this investigation has shown some interesting results. It appears that *R. solani*, a commercially important pathogen of potatoes can be destroyed rapidly (within 24 hours) during thermophilic composting. Other species such as *Erwinia carotovora* subsp. *Atroseptica* appeared more difficult to kill even during high temperatures (>60°C to 70°C). Although numbers of this pathogen were reduced over prolonged composting, large numbers still persisted.

Analysis of fresh samples of potato peelings showed large variations in colony forming units of pathogens, showing that waste types very similar in appearance can give very different results. Results suggested that possible variations arising from cross contamination from green waste were unlikely.

Levels of *Rhizoctonia*, *Fusarium*, *Helminthosporium*, and *Colletotrichum* were generally below detectable limits in the fresh potato peelings (<20 colony forming units) using traditional detection methods, although *R. solani* was detected using more sensitive methods developed by Eco-Diagnostics. Spore counts of some of these pathogens were detected even when cfu were not, highlighting the possibility that infected material may be considered 'pathogen free' if cfu counts are used alone.

Initially, the colonisation of *Trichoderma* spp. during green waste composting in an urban environment was not detected, although high levels of compost stabilisation had been achieved. Further investigation was used to monitor conditions that may be required to encourage colonisation of composts by this species, known to be a beneficial antagonist to plant pathogens. A second trial using vegetable waste composting in a rural environment, revealed the emergence of *Trichoderma* spp. in 12 week old compost. The occurrence of *Trichoderma* in this material was possibly due to the compost being inoculated by spores from the surrounding (rural) environment, and the particularly high level of stability (low microbial activity) observed in the compost.

In conclusion, the seeding technique used during these trials revealed some interesting results, but was subject to high levels of variation – making interpretation of results difficult. It is the suggestion of this author that continued research is required in this field to unravel some of the complexity surrounding pathogen destruction during composting. It is also suggested that more sensitive and more numerous tests for plant pathogens are required to ensure composts that go into commercial applications are pathogen free and safe for use by commercial growers.

This study has also shown that the 'natural' infection by plant disease suppressing organisms, such as *Trichoderma* spp., is possible but only if specific conditions in the composted material are met. Although these conditions have not been fully determined, it is likely that a high level of compost stability is required.

6. CONCLUSIONS FROM RESEARCH WORK

A literature review by Rothamsted Research on organic matter and soil structure discussed the enhancement of soil aggregation through increased physical and chemical substrate availability for microbial and fungal activity from compost application. Practical measurements on soil samples showed an increase in organic matter and total nitrogen due to compost coupled with an increase in microbial biomass. Plant available nitrogen was shown to be slowly released from the compost with a positive interaction in the presence of inorganic nitrogen. Nutrients were cycled more efficiently where compost was applied and made available over time rather than all remaining in water soluble and leachable forms.

Laboratory work by The University of Reading showed that composted products are relatively stable but that they can increase soil biological activity and enzyme activity. Compost addition can also reduce the variability of soil microbial activity within the field. This may be important to aid the suppression of soil borne plant diseases, coupled with the increased activity of the chitinase enzyme.

The concerns from farmers about the potential transmission of plant diseases through the use of green waste based composts was investigated. Composting trials showed that *Rhizoctonia solani* could be successfully destroyed by composting. Trials on *Erwinia carotovora* were less consistent. However, trials since conducted by other projects (funded by WRAP) have provided clear time, moisture and temperature regimes for the eradication of plant diseases that might arise in green wastes, including clubroot. Tests in this project have showed that disease suppressive microorganisms such as *Trichoderma* can re-inoculate composts when they are suitably stabilised and mature.

The field research and soil measurements have shown that soil organic matter and plant available nutrients can be raised through the addition of compost. Soil pH was shown to be stabilised and interesting interactions between compost and applied nitrogen fertilizer were seen. Nitrogen fertilizers were able to be reduced by approximately 25 kg N/ha where compost was applied without yield loss. In addition, with some crops including potatoes in some situations, this led to increased yields possibly as a result of improved nutrient cycling and availability over the growing season. When compost is applied all other nutrients, apart from nitrogen, can probably be omitted from the fertilizer programme.

Crop yields were generally highest when compost was applied with the full nitrogen fertilizer rate. However, with potatoes a high rate of compost coupled with a lower rate of nitrogen fertilizer (compared with standard recommendations) gave the best yields. These results should encourage farmers to apply compost immediately before high value, irrigated crops such as potatoes. Farmers do not use animal manures too soon before potatoes because of the unpredictable nature of nitrogen release. Compost releases only a small amount of nitrogen and appears to make applied inorganic nitrogen more efficiently used by the crop.

Soil water holding capacity was demonstrated to be raised through the addition of compost but actual measurements on savings in irrigation in the field were not measured. Further work on nitrogen release over time from compost amended soils is recommended, coupled with measurements on plant available water and water usage. The potential for disease suppression from raised soil fertility (increased organic matter, nutrient turnover and microbial activity) is also of great potential benefit to farmers and needs to be investigated in more detail.

7. FARMING AND COMPOST USE

7.1 Perception of compost

Fieldfare Associates Ltd compiled the Compost in Agriculture farmer survey with the assistance of the British Potato Council. The questionnaire was sent to 300 BPC members of whom 23 replied with some very helpful comments.

Are you aware of waste-derived composts being used on farm?

*If yes, a) were the results good?
b) what benefits did you notice?*

41% replied yes, 59% no. One individual stated a 25% increase in yield of potatoes with increased workability and drainage. Two individuals are currently involved in using compost within this cropping year and are awaiting results. The first farmer has applied compost, produced on farm, to 10 acres of wheat sown September 2002. The second farmer is part owner of a composting business processing 30,000 tonnes per annum of green waste and is currently involved in trial work. A further individual stated short-term nutrient benefits had been seen.

We are researching six specific areas, farmers were asked to rate these areas according to their importance to them with 1 as not important and 5 as highly important.

- a) nutrient supply to arable rotations*
- b) effects on soil physical characteristics*
- c) effects on crop yields, quality & disease*
- d) effects of compost on pests & diseases in the soil*
- e) compost quality in terms of pests & diseases*
- f) costs of production from domestic organic and potato waste on-farm*

The results to this section are represented graphically in Graph 17. All of the topic areas were considered to be very important to them.

Where would you like to incorporate the compost in your rotation?

A variety of answers were given for this section. Many farmers would like to use the compost prior to potatoes and root crops or vegetables, or where sugar beet is grown after cereals. One farmer would like to apply to spring cropping on light land. It would seem that convenience and value to the crop were the main considerations as would be expected. One farmer raised the point that he would apply prior to potatoes providing Assured Produce Scheme approval was given, another mentioned a time period of 12 months before potatoes.

How much would you be prepared to pay for the compost if it was good quality, delivered?

Many farmers required more information on the nutrient value and proposed application rate for the compost before answering this question. Of those who provided an answer, 6 farmers would expect the material free of charge, 9 would pay £1-5 per tonne and one farmer £6-10 per tonne

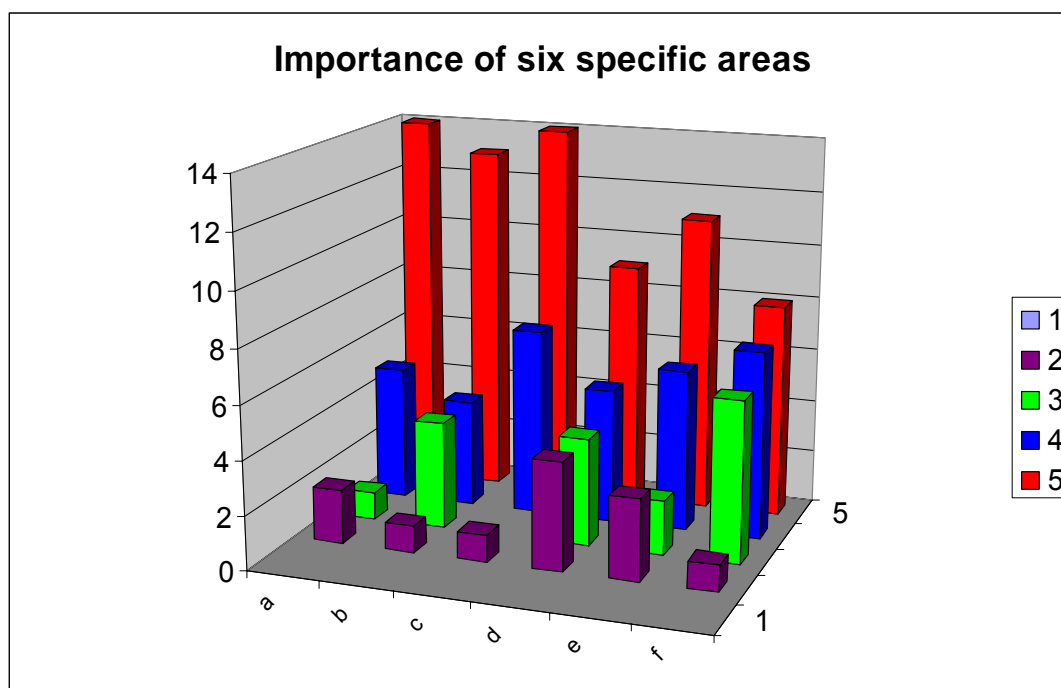
Which of the following schemes would you like the compost to be certified by?

9 farmers voted for the Compost Association, 6 for the Soil Association and 2 for HDRA.

How would you like to receive additional information on Compost in Agriculture?

19 farmers requested a fact sheet, 3 a CD presentation and 3 a meeting or open day on compost in agriculture.

Graph 17 Importance of six specific areas



7.2 Value of compost

Artificial fertilizers are valued £0.34, £0.33 and £0.20 per kilogram for nitrogen, phosphate and potash, respectively (The Farm Management Handbook 2003/04). Magnesium and sulphur also have a value but are often incorporated in fertilizers and liming materials as a consequence of manufacture or source materials. With UK compost containing approximately 8.1 kg total nitrogen, 3.3 kg total phosphate and 6.6 kg total potash per tonne of moist product, the total nutrient content of compost is worth over £5 per tonne but, as much of the nitrogen is in slow release form, is worth £2.50 to the crop after application (£75/ha at 30 t/ha compost application).

Many benefits from organic matter in compost are long term and are found from repeated applications building up soil organic matter and hence fertility. Assigning an economic value to organic matter is currently difficult but with the possible adoption of carbon credit systems within agriculture in the future the importance of this value looks to increase.

Certainly this project has identified a buffering effect of the compost on soil pH levels. Compost can raise soil pH when it is low and stabilize it when it is at or above neutral. This can counteract the effect of inorganic fertilisers, which tend to lower soil pH over time. If the buffering effect of a typical 30t/ha application of compost is equated to that of a 2t /ha application of agricultural lime, this will equate to a saving of in the region of £33/ha (£16.50/t lime delivered and spread excluding VAT).

The work carried out on the soils from the plots where compost was applied has shown that water holding capacity can be improved in light textured soils equivalent to 12.5 mm irrigation water /ha. Irrigation has an annual capital charge of £250 to £500 per hectare and water/labour charges of £1.20 to £1.60 per mm of water applied per hectare (The Farm Management Handbook 2003/04). Water can be saved through improving the retention of rainfall and irrigation within the root zone, and reducing surface runoff by increasing infiltration rates. At an average cost of £72 per hectare per 25 mm application, 30t compost applied per hectare (over time and for a number of irrigated crops to build up soil effects) is worth £2.40 per tonne of compost. If two out of eight 25 mm irrigations could be cut through efficiencies, then £144/ha could be saved giving the compost a value of £4.80 per tonne.

The spreading of compost can be accomplished very effectively with rear discharge muck spreading equipment. A spreader can hold 10 tonnes and take 3 minutes to load and another 3 minutes to spread. Turnaround time depends on the distance from the loading area to the field but can be as short as 10 minutes. However, a typical daily rate of application would be 200 t/day. With labour, the cost of a loader and the tractor plus spreader hire charges, the application cost per tonne of compost works out at £1.85/t, or £55.50/ha based on 30 t/ha applied. This cost is offset by the liming value and the reduced costs for the spreading of artificial fertilizers.

Haulage costs are the principal limiting factor on assigning a delivered and spread cost to compost. Due to the low bulk density of compost generally a lorry load will be equivalent to 16 tonnes. The haulage distance will limit whether the farmer is able to collect and spread compost or whether contractors will need to be employed. Using farm haulage equipment may be cheaper due to fuel price differentials and because existing equipment can be used during quiet times.

However, farm haulage may still cost £4/t depending on distance (£120/ha at 30 t/ha)

Contracting costs need to be assigned according to an individual site. For guidance at an application rate of up to 35t/ha a spreading cost of £3.50/t and haulage of £6.25/t giving an overall cost of £9.75/t (excluding VAT) might be quoted. From our research lower costs of delivery and spreading have been quoted but again this is dependent on proximity of the source of compost to the land to which it will be applied.

Overall, the value of applying good quality compost to farmland is in the long term improvement of soil and land as an asset. The value of the compost as a fertilizer (£75/ha), its liming qualities (£33/ha) and for soil improvement effects giving water savings through reduced irrigations (£144/ha) is partially offset by the cost of haulage (£120/ha) and spreading (£55.50/ha). Depending on the crops being grown, soil type and the circumstances around a given farm, this gives a net value of compost, applied at 30 t/ha, of £2.55/t assuming farm equipment is used for haulage and spreading rather than contractors. Further value may be ascribed to compost from yield improvements according to the crop being grown.

8. DISSEMINATION

Dissemination was carried out by Fieldfare Associates Ltd and Enviros Consulting Ltd.

Fieldfare set up a website for the project. Fieldfare introduced the concept of compost use into their agronomy seminars. These comprised FACTS (Fertiliser Advisory and Certification Training Scheme) courses and one day courses in 'Off Farm Waste Management to Agricultural Land' during the spring period; the target audiences for these events being both advisors and farmers. Further interest was generated during a seminar for MSc students held at Southampton University.

Enviros gave a seminar with FoodFen May 8th 2002 to local farmers and talked on 1st May 2003 at the Soil Association Conference.

Enviros attended the Royal Show with a stand in 2003 where the preliminary results were displayed and the project discussed with a large number of farmers. There was a composting feature at the show and attendance was good. Elliot Morley, the Minister for the Environment, visited the stand and Phil Wallace was able to discuss the project with him.

Enviros also disseminated the project at the Royal Show in 2004 where the composting event was even larger than 2003.

Stand at the Royal Show 2003



Royal Show 2003 with Elliot Morley

Field visits were made with Remade Essex to farmers in 2002 and with McCain and Greenvale agronomists in 2004. Talks to local NFU meetings in Essex were held on 18th February 2004 at Braintree. In September 2003 Phil Wallace attended the British Potato Council Newark Show and discussed the project with farmers.

Phil Wallace also talked at the On-Farm Composting Network Conference on 12th September 2003 at Harper Adams University as well as WRAP's event on the benefits of compost use at Stockbridge Technology Centre on 17th September 2003. He spoke about the project and indicated preliminary results, as well as having a display board.

Phil Wallace attended the Composting Association Conference on 3rd and 4th December 2003 and presented some results and progress of the project. Phil Wallace also presented the project progress at a meeting organised by FoodFen and ADER for farmers on 29th October 2003.

A meeting was held with BPC agronomists on 13th February 2004 with the aim of disseminating information in March through the BPC newsletters, the press, web sites and the FACTS-TIS. A leaflet of information was drawn up by Fieldfare and Enviros and was published on the website www.compost.me.uk, linked to the BPC website. Farmers were made aware of the information through the FACTS-TIS and Composting Association newsletters.

Additional meetings with farmers were held on 10/8/04 with Velcourt, 14/7/04 with Sovereign and through a breakfast meeting held on 27/9/04 organised by FoodEast.

An Applied Research Forum meeting (jointly organized by levy funders BPC, HGCA, MDC, and MLC, BRO, PGRO and HDC) was attended by P Wallace on 7-8/9/04 at Harper Adams. Future research requirements were discussed for recycling organic residues in agricultural land. The summary leaflet was distributed.

Fieldfare and Enviros disseminated the leaflets at the Composting Association Conference on 1st and 2nd December 2004.