ANAEROBICALLY DIGESTED SOURCE SEPARATED FOOD RESIDUES AS FERTILISER IN CEREAL PRODUCTION

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ABSTRACT

Field trials were carried out during 1999-2003 in southern Sweden in order to evaluate the effect of anaerobically digested, source separated food waste originating from households as fertiliser in cereal production. The aim of the trials was to study the effect of the fertiliser on yield and grain quality in production of spring-sown cereals and to establish nutrient field balances.

The field trials were designed as split plot trials with three replications with seven treatments in 1999, 2000 and 2003, and eight treatments in 2001 and 2002. The digested residues (DR), with a dry matter content of 1-3 %, were compared to mineral fertiliser (all years) and slurry from dairy cattle (2001-2003). Two different spreading strategies were evaluated in 1999 and 2000; spreading at time of sowing as well as spreading when the crop was between 15 and 20 cm high. In 2002 and 2003 a treatment with concentrated DR was included.

Results show that DR is a fertiliser that can replace mineral fertiliser in cereal production. The nutrient balances show higher surpluses of nitrogen for DR and slurry, compared to mineral fertiliser. The nutrient balances also showed small deficits concerning phosphorus when using digested food waste as fertiliser.

INTRODUCTION

A precondition for the recirculating systems of nutrients from household waste is that farmers accept the fertiliser. A basis for this acceptance is knowledge of the properties and agronomic effects of the digested household waste. No such field trials have been reported in international literature. However, similar fertilisers such as digested slurry originating from animal manure or crop residues, as well as untreated slurry have been reported (Örtenblad et al., 1995; Örtenblad et al., 2000; Holm-Nielsen et al., 1997; Rodhe and Salomon, 1992).

A Swedish pre-study with DR spread in barley at sowing and in growing crop gave a yield that was 82% and 52% of the yield achieved with mineral fertiliser (Stintzing et al., 1999). Swedish trials with slurry to spring cereals have shown yields that corresponded to 70 to 120% of the yield after treatment with 100 kg fertiliser-N ha^{-1}, when spread at sowing or when the crop was 15 cm high. Slurry rates were based on total ammoniacal nitrogen [TAN] ha^{-1} (Steineck et al., 1991; Rodhe and Salomon, 1992). Other Swedish trials, where plant residues were digested and used as fertiliser, showed yield increases in spring wheat of 9 and 24 % for the first two years respectively, compared to unfertilised crop (Svensson and Gunnarsson, 2003).

Danish trials with digested slurry spread with different techniques and spreading times showed that injected slurry gave higher yields than broad-cast slurry incorporated after one hour. Yield in treatments with 100 kg digested slurry total-N ha^{-1}, corresponded to yield in treatment with 50-70 kg fertiliser-N ha^{-1}. When 100 kg digested slurry total-N was spread at the end of May it corresponded to 24-48 kg mineral-N ha^{-1} (Örtendal et al., 1995).

DR has a high content of TAN as well as a high pH, which increases the risk of ammonia volatilisation. When spread the DR should be incorporated as soon as possible or injected to reduce the risks for ammonia losses (Rodhe and Salomon, 1992; Örtendal et al., 1995).

MATERIALS AND METHODS

Field trials financed by the Municipality of Jönköping using digested food residues as fertiliser to spring sown oats and barley were carried out during 1999-2003 on a farm near Jönköping in southern Sweden, situated at 230 m above sea level.

The field trials were designed as split plot trials with three repetitions and seven treatments in 1999, 2000 and 2003, and eight treatments in 2001 and 2002. The DR, with a dry matter content of 1-3 %, was compared to mineral fertiliser (all years) and slurry from dairy cattle (2001-2003). Two different spreading strategies were evaluated in 1999 and 2000; spreading at time of sowing as well as spreading when the crop was between 15 and 20 cm high. In 2002 and 2003 a treatment with concentrated DR was included. The field plan is shown in Table 1.

***Table 1**. Field trial treatments with digested residues (DR) in Jönköping, 1999-2003.*

	Treatment	kg tot N ha^{-1}	Year
A-E	Fertiliser in spring (0, 30, 60, 90, 120)	0-120	All years
F	DR (1-3% DM), in spring	90	All years
G (99-00)	Fertiliser in spring, DR in summer	90	1999-2000
G (01-03)	Slurry, spring	90	2001-2003
H (01-02)	DR, (25% DM), spring	90	2001-2002

The DR used in the field trials originated from the region of Stockholm all years except 2002 when the DR were transported from the western part of Sweden. The DR was transported to Jönköping and stored for a few weeks before spreading. The slurry from dairy cattle originated from a farm nearby. Nutrient contents in DR and slurry are shown in Table 2. The percentage of TAN in relation to total-N was 62, 59 and 21 % for DR, slurry and concentrated DR respectively.

***Table 2**. Content of nutrients in fertilisers used in trials, lowest and highest value.*

Fertiliser	DM	Tot-N	NH4-N	P	K
	%	kg per metric ton			
DR (1-3%ts)	0,85-2.4	1.4- 3.4	1-2.5	0.1- 0.4	0.8 -1.6
Slurry	5.5-6.8	2.6-3.7	1.6-2.1	0.15-0.55	2.2-3.6
DR (25%)	28-29	17 - 19	3.9	3.5 - 3.6	1.2 - 1.3

The soil was analysed for phosphorus (P) and potassium (K) according to Egnér *et al.* (1960). Organic matter and pH was also analysed and results are shown in Table 3.

***Table 3**. Soil characteristics at sites used in field trials 1999-2003*

Year	1999	2000	2001	2002	2003
Content of organic matter, %	2.1	2.4	2.2	1.9	2.7
PH	5.7	5.8	6.0	6.1	6.3
P-AL, mg/100 g soil	17.0	21.4	17.4	10.9	23.6
P-HCL, mg/100 g soil	113	127	110	93	153
K-AL, mg/100 g soil	6.5	6.5	5.5	8.5	7.8
K-HCl, mg/100 g soil	70	80	65	100	69

Precipitation and temperature levels are presented in Table 4. The field trials were sown between the end of April to the middle of May, and harvested between the end of August and the end of September depending on the weather conditions of the year.

The slurry and DR were band-spread followed by harrowing as soon as possible after spreading, usually within an hour. For the late application of DR, the fertiliser was band- spread and no harrowing took place. The DR with high DM content was spread by hand. The target fertiliser rate was 90 kg total N ha^{-1}. Between the years there is a variation in the actual amount of N spread per hectare depending on variations in the nutrient content of the manure.

Table 4. *Yearly precipitation and temperature and average reference 1960-1991 at the Flahult station (Alexandersson et al., 2001; SMHI, 2004).*

Year	1960-1991	1999	2000	2001	2002	2003	1960-1991	1999	2000	2001	2002	2003
	Temperature, C ^{o}						Precipitation, mm					
April	3.6	6.2	6.7	4.2	5.6	4.2	49	90.7	75.0	66.9	30.9	88.6
May	9.4	8.8	11.8	10.4	11.4	10.6	52	47.0	41.9	58.2	94.7	73.7
June	13.6	13.8	13.3	12.8	14.7	14.8	63	138.4	78.4	44.8	114.4	70.2
July	14.9	16.9	14.3	17.5	16.8	17.2	86	38.5	83.4	31.1	61.5	184.3
Aug	14	14.4	13.9	15.4	17.6	15.2	78	116.3	59.5	83.7	21.8	51.1
Sept	10.2	13.3	9.1	10.6	11.1	11.5	87	84.1	62.4	96.3	11.8	19.1

To enable a comparison between the fertilisers, a regression line for the mineral fertiliser at different N rates was calculated for the yield each year. The efficiency of nitrogen utilisation was calculated according to apparent nitrogen recovery and apparent nitrogen efficiency. ANRt, Apparent recovery of total-N = ((N removal in amended plot – N removal in unfertilised control plot)/ total N applied)*100 ANEt, Apparent nitrogen efficiency of total-N = ((DM yield in amended plot – DM yield in unfertilised control plot)/ total N applied)*100.

RESULTS

Yields for DR and slurry were compared with a regression curve of increasing levels of mineral fertiliser amended every single year. The comparison was based on the total-N content in DR and slurry. Results are shown in table 5. The efficiency of N in the different treatments are presented as ANRt and ANEt in table 6.

Table 5. *Yield of barley (1999, 2000, 2002) and oats (2001) in treatments with DR compared to mineral fertiliser and slurry.*

Year	DR, spring		DR, spring	DR, summer	Slurry	Conc. DR
	Yield kg ha^{-1}	(kg N ha^{-1})	Yield, % of yield with mineral fertiliser			
1999	5200	(87)	99	95	--	--
2000	4260	(109)	90	81	--	--
2001	3800	(91)	105	--	110	80
2002	2060	(110)	72	--	70	65
2003	3160	(61)	81	--	73	--

Table 6 *Mean ANR and ANE-values for fertiliser, DR and slurry, years 1999-2003 and 2001-2003.*

		Years 1999 -2003	Years 2001 -2003
Mineral fertiliser	ANRt, %	32	30.8
Digested residues	ANRt, %	24.2	23.6
Slurry	ANRt, %	--	15.6
Mineral fertiliser	ANEt, kg DM per kg N	21.9	14.5
Digested residues	ANEt, kg DM per kg N	17.4	11.8
Slurry	ANEt, kg DM per kg N	--	9.0

Field balances showed a small deficit of P in plots treated with DR. P removed with grain harvest resulted in a balance that varied between a deficit of 18 kg P ha^{-1} to a surplus of 2 kg ha^{-1} (mean -6,4 kg ha^{-1}). The K balance showed a deficit of 4 kg ha^{-1} to a surplus of 50 kg ha^{-1} (mean +18 kg K ha^{-1}). For DR with high DM content there was a mean surplus of 11 kg P ha^{-1} and a mean deficit of K of 4 kg ha^{-1}. The field balance for slurry showed a surplus of both P (mean 3 kg ha^{-1}) and K (mean 66 kg ha^{-1}).

CONCLUSIONS AND DISCUSSION

DR is a fertiliser that can replace mineral fertiliser in the production of spring-sown cereals, yielding 72 to 105 % of corresponding yield with mineral fertilisers. The yields with DR are on the same level as for cattle slurry. However, the nutrient recovery and efficiency is better for DR than for cattle slurry. Yield results vary depending on weather conditions during the growing season. Dry and cold weather has a more negative effect on yield in treatments with DR compared with mineral fertiliser.

Another conclusion is that spreading of DR can be extended into the growing season, as long as the crop is supplied with a starter dose at the time of sowing. This is an advantage in case of soil compaction problems.

The information generated in this project can be used as a basis for the farmer in order to determine the value of DR as a fertiliser. Other aspects that need to be taken into consideration if the DR is to be accepted by the farming community are economic and hygienic aspects, as well as logistics and market acceptance, which have not been studied in this project.

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