AMMONIUM THIOSULPHATE AS AN ENVIRONMENTALLY FRIENDLY TOOL FOR REDUCING INPUTS

END OF PROJECT REPORT

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SUMMARY

The overall objective of the EU funded project was to evaluate the ability of ammonium thiosulphate (ATS) to act as an inhibitor of urease and nitrification processes and as a source of plant nutrient S when added to solid and liquid fertilisers and to slurries.

The project had the following seven partners but mainly Irish work is reported here.

Italy. ERSA-Ente Regionale Promiozone e Sviluppo 'Agricultura.

Italy, ESSECO SPA

France. ENSAIA-INRA-Institute National Polytechique de Lorraine. Agronomie et Environment.

Portugal. Departamento de Ciencias Agrarias, Unversidade Dos Acores

Austria. Joanneum Institut fur Geothermie und Hydrogeologie

Finland. MTT-Agricultural Research Centre.

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Between 1995 and 1997 a number of laboratory and field experiments were carried out in Ireland on various soil types using grass, grass/clover, maize and cereal crops. ATS is a nitrogen/sulphur (N/S) compound and the commercial source is a 60% aqueous solution containing 12% N and 26% S. The compound is widely used as an N/S fertiliser, particularly in the United States. The purpose of this project was to evaluate ATS mixed with urea or slurry, both as a source of plant nutrient S, an inhibitor of N volatilisation and of N leaching, by measuring its effect on crop yields and uptake of N and S.

Addition of ATS to ammonium fertiliser was found to significantly inhibit nitrification under laboratory conditions on 9 different European soils The observed inhibition of nitrification in the laboratory was not found in field trials although soil ammonium-N concentrations in the soil were increased by ATS. Field measurements of ammonia volatilisation from urea and slurry were ambiguous and the variation was high. In general ATS resulted in higher emissions from urea and both higher and lower emissions from slurry at different measurement periods.

The test crops employed to measure the effect of ATS on yield and N efficiency were grass, grass/clover, maize, wheat and barley. When applied to slurry it increased its N efficiency and in general it resulted in higher yields of 1^{st} and 2^{nd} cut silage. The slurry experiments were carried out on a soil that was not deficient in S so the increases obtained could not be attributed to the additional S in the ATS. The urea/ATS experiments however were carried out on S deficient soils and the resulting yield increases may be due, at least in part, to the action of ATS as a plant nutrient. Various components of cereal yield were examined and it was found that the increases obtained were as a result of ATS increasing the number of ears per unit area. The economic and environmental advantages of ATS under Irish conditions are discussed.

These initial experiments have shown the need for further research on (a) applying ATS directly to the soil rather than to the herbage surface, and (b) adding ATS to the slurry in the storage tank simultaneously with slurry excretion.

INTRODUCTION

Consumption of nitrogen (N) fertilisers in Ireland has risen annually from 70,000 tons in 1969 to over 400,000 tons in 1997. Losses from N fertilisers and animal slurries by nitrate leaching, denitrification and ammonia volatilisation have long been a concern to soil scientists. To the farmer such losses are uneconomical and to the environmentalists they are seen as having major impact on atmospheric and water quality (Jarvis et al, 1995). Nitrate levels, in rivers and groundwater, are increasing in certain regions of Ireland (Stapelton, 1996) and there is an increasing likelihood of nitrate vulnerable zones being declared where the use of N fertilisers will be restricted. Emissions of ammonia from cattle feedlots are particularly high and it has been estimated that 75% of the N excreted by animals is lost under current waste management systems, (Power et. al. 1994). Besides the environmental consequences of leaching and volatilisation, large quantities of N are lost which could be used in plant production.

In an effort to reduce N losses from fertilisers and slurry many nitrification and urease inhibitors have been evaluated over the past 25 years. However few of them have been found which meet the criteria of low cost, effectiveness, safety and acceptable environmental impact and currently only one nitrification inhibitor (nitrapyrin) and no urease inhibitor are receiving widespread commercial use in agriculture. Therefore in 1995 an EU project entitled "Ammonium Thiosulphate (ATS) as an Environmentally Friendly Tool for Reducing N Inputs" was initiated in six member states, including Ireland, to examine the possibility of using ATS as a nitrification and urease inhibitor.

ATS is a common nitrogen-sulphur fertiliser and is widely used in liquid fertilisers. The commercial source is a 60% aqueous solution containing 12% N and 26% S derived from the reaction of aqueous ammonia and sulphur dioxide. Laboratory and field trials carried out in the past few years have shown that ATS can inhibit nitrification and urease activity in soils (Goos, 1985, Goos et. al. 1986,Sallade and Sims, 1992, Sullivan and Havlin, 1988). Most researchers examining its effect on nitrification and urease activity have used ATS with urea-ammonium nitrate solutions (UAN, 30%N) or other liquid fertilisers.

In Ireland the situation differs from other European countries, as liquid fertilisers are not commonly used and it has also been shown that S deficiency is widespread (Murphy and Boggan, 1988). S is normally applied to Irish grassland in combination with N fertiliser to give a N/S ratio of approximately 6:1. Because ATS is relatively costly and has a low N/S ratio (1:2) its use as an N: S grassland fertiliser would appear to be limited. However this situation could change rapidly if there was an increase in the use of liquid fertilisers or if it were shown that ATS can significantly improve the efficiency of N in fertilisers or slurry. Since 1994, the Rural Environment Protection Scheme (REPS), which restricts N input on farms, is being implemented in Ireland. For farms within REPS, an improvement in N fertiliser efficiency by using nitrification or urease inhibitors would enable the farmer to increase production while complying with the N restrictions of the scheme

The research project was subdivided amongst the six participating countries into a number of tasks; the results of those tasks assigned to Teagasc are summarised in this report and published in more detail in scientific publications (Murphy et al 1998, Richards and Murphy, 1998).

THE ABILITY OF ATS TO REDUCE N LOSSES FROM FERTILISERS

Inhibition of nitrification in the laboratory

Nine soil samples from the six participating countries were examined to determine the effect of ATS on nitrification of applied ammonium chloride (NH_4Cl) in a laboratory incubation experiment. Addition of ATS to these soils significantly inhibited nitrification ($P<0.01$). The effect of ATS on the nitrification of applied NH_4-N for 4 of the soils is shown diagrammatically in Fig 1. Each soil behaved differently, although similarities can be seen between soils 4 and 6, both of which had rapid nitrification rates. ATS significantly delayed full nitrification of NH_4-N by 10 days in soil 4.

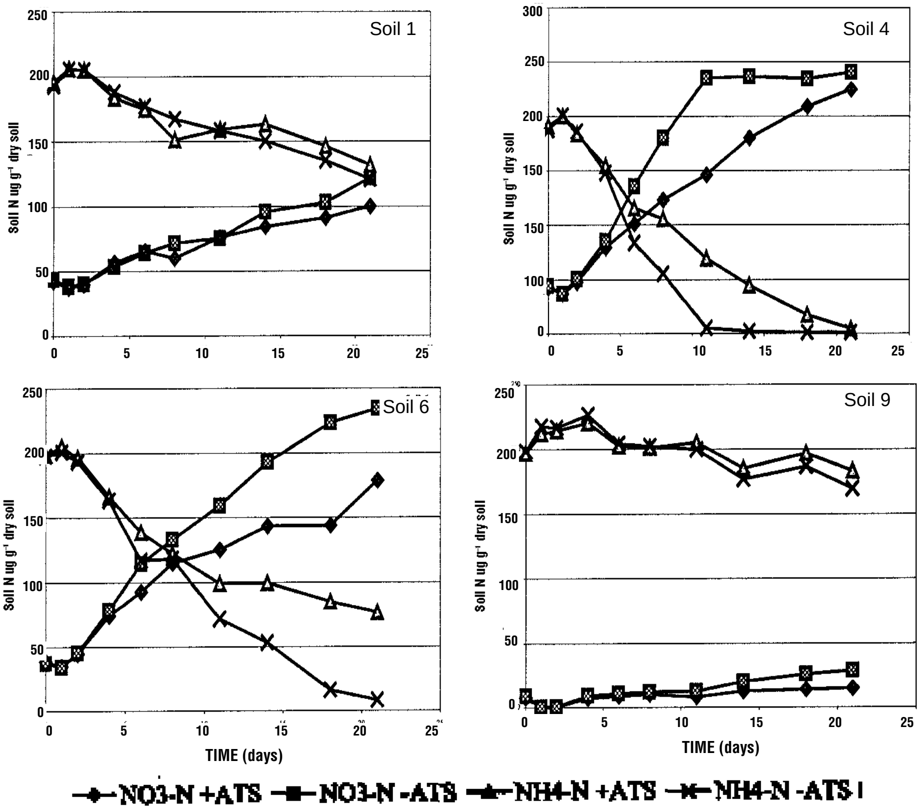

Fig. 1 Nitrification of applied NH_4-N in the following soils : Soil 1 Ireland (Bree), Soil 4 Italy, Soil 6 France, Soil 9 Finland.

The effect of ATS in reducing N volatilisation from slurry or urea on grassland

Ammonia (NH_3) emissions were measured by a dynamic chamber technique developed by the Swedish Institute of Agricultural Engineering (Svensson, 1994). Volatilisation was estimated by means of a stirred dynamic chamber technique in combination with passive diffusion sampling.. NH_3 concentrations within each chamber and the ambient air concentration were measured by absorption on oxalic acid impregnated filter papers. After the application of slurry or urea three measuring chambers were placed on each plot and measurements taken at intervals. There were large variations between the measurements from each plot with a mean coefficient of variation of approximately 40%.

The proportion of NH_4 - N volatilised from slurry and its rate of volatilisation was significantly higher than from urea during the field trials. Their emission patterns were also completely different. Volatilisation from slurry decreased from a maximum emission within the first hour after application and between 75 and 90% of NH_3 was volatilised within the first 24 hours. Volatilisation from urea on the other hand increased with time to a maximum on day 5 or day 6 as shown in Table 1.

Table 1: The effect of ATS on ammonia emissions from urea and slurry under field conditions.

Urea (70 kg/ha N applied)			Slurry (47 kg/ha NH_4N applied)		
Hours after application	g/ha/hr N -ATS	g/ha/hr N +ATS	Hours after application	g/ha/hr -ATS	g/ha/hr +ATS
46	15	63	1	1945	1416
52	34	124	3	1219	1304
67	100	435	5	824	733
74	100	173	17	598	471
80	192	296	23	94	138
109	84	98	28	0	0
127	404	401	100	7	1
152	69	172	124	5	3

The effect of ATS on N volatilisation from urea and slurry was inconclusive. It had no significant effect on N emissions from slurry and the increased emissions recorded from the urea +ATS treatment may have been due to the extra 12 kg/ha N contained in ATS. Further study is needed on methods of applying ATS. It has been shown that ATS is more effective after it has come in contact with the soil but in the urea experiments it was applied by spraying and a large amount of it may have remained on the herbage surface. Applying urea and ATS simultaneously in narrow bands to the soil surface may be more effective. In the case of slurry, it has been shown that ATS can inhibit the formation of ammonia from urea. As this transformation takes place almost immediately after excretion of urine by the animal, the ATS should be added at that time in the storage tank if it is to be effective (Varel, 1997).

Nitrate leaching Field measurements of nitrate leaching did not confirm the laboratory findings that ATS inhibited nitrification as there was no significant difference in nitrate concentration in the top 30 cm of the soil between the urea -ATS and urea +ATS treatments. This may have been due to the fact that the soil from the field experiment had a very low nitrification rate and that urea rather than NH_4Cl was the source of N. However NH_4- N concentrations in the soil were significantly increased in the +ATS treatment as shown in Fig. 2.

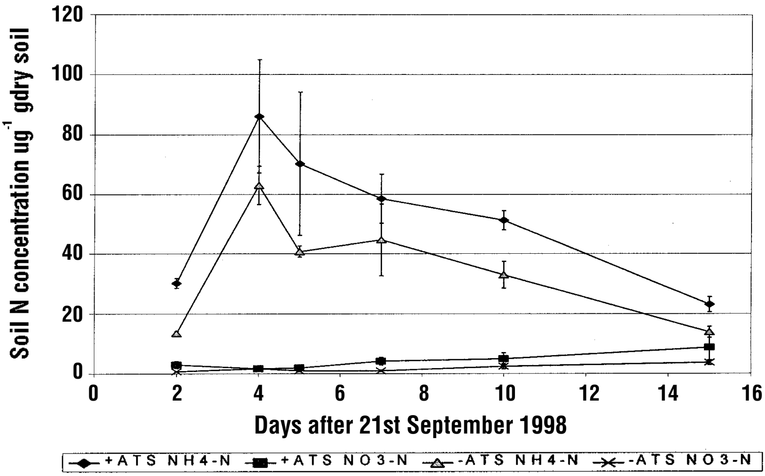

Fig 2 Mean soil inorganic N transformations for urea trial 2.

REDUCING THE OPTIMUM N APPLICATION TO CROPS BY USING ATS

The efficiency of ATS was measured by adding ATS to slurry and urea and applying the mixture to test crops of grass, grass/clover, maize, wheat and barley. The evaluation was determined by its effect on crop yield and N efficiency. The percentage efficiency of the slurry NH4-N fraction compared to calcium ammonium nitrate (CAN) is calculated as follows:

$$\frac{\text{N fertiliser equivalent}}{NH_4 \text{ - N applied in slurry}} \quad \mathbf{x\ 100}$$

The N fertiliser equivalent is obtained from the response curve obtained from the five mineral N treatments. Addition of 100 kg/ha ATS to the slurry resulted in an additional 12 kg/ha N that has been taken into account in the calculations. ATS was applied at 35 kg/ha in 1995 and at 100 kg/ha in 1996 and 1997.

Using ATS with slurry for grass silage

These experiments were carried out on a non- S deficient soil at Johnstown Castle between 1995 and 1997. Cattle slurry at a rate of 33 M^3/ha was applied to 1^{st}. and 2^{nd}. cut silage by the splashplate and bandspread methods. Mean results of 1^{st}. cut silage for the three years are shown in Table 2. Herbage yield and the efficiency of slurry N compared to CAN was significantly higher in the bandspread slurry Addition of ATS significantly increased yield and N efficiency of both bandspread and splashplate slurry.

Table 2: The effect of slurry -/+ ATS on 1^{st}. cut silage yield (t/ha) and N efficiency (%) Mean of three years.

	Splashplate		Bandspread	
	Yield	N efficiency	Yield	N efficiency
-ATS	3.13	12.4	3.70	30.5
+ATS	3.97	39.9	4.21	45.4

Using ATS with slurry for silage maize

Maize experiments were carried out at Bree, Co. Wexford in 1995 and 1996 and at Castlebridge, Co. Wexford in 1997 using the following treatments:

1. Slurry at a rate of 33M^3 was applied by bandspreading on the soil surface where it remained overnight before being ploughed into the soil immediately prior to sowing.
2. ATS was mixed in the tanker and the mixture applied at the same rate and in the same manner as the slurry
3. Mineral N treatments at rates of 0, 50, 100, 150, 200 and 250 kg/ha were used to obtain the necessary N response curve to calculate the N efficiency.

The mean yields for the three years are summarised in Table 3.

Table 3: The effect of slurry -/+ ATS and CAN on maize yields. Mean of three years

Treatment	DM yield t/ha
Slurry -ATS	14.4
Slurry +ATS	15.7
Control (no N)	13.8
CAN (100 kg/ha N)	15.0

Addition of ATS significantly increased yields of silage maize over the three years.. As ATS contains 12% N, an additional an additional 12 kg/ha N was supplied in the +ATS treatment. This extra N may have contributed to increasing yield but data obtained from the N response curves which were carried out each year, showed that the contribution of N from ATS was not significant. Yields from the control and the treatment which received 100 kg/ha N are included in Table 3 to give an indication of the small response obtained to mineral N fertiliser each year.

Using ATS with urea on grass and grass clover

The grass and the grass/clover experiments were carried out on S deficient sites in Cos. Tipperary and Carlow respectively. ATS was applied to both granular urea and an aqueous solution of urea and three or four cuts of herbage were taken annually.

The results which are summarised in Table 4 show the mean annual yields for the two crops. Addition of ATS to either granular or solution urea significantly increased grass yield. The increase was greater in the solution urea treatments where grass dry matter was increased from 8.96 to 11.15 by ATS. There was no significant increase from ATS in the grass/clover crop and in fact yields were reduced when solution urea + ATS was applied. This may have been due to damage in the clover leaves caused by the urea/ATS spray.

Table 4: The effect of granular and solution urea -/+ATS on annual herbage yields (t/ha). Mean of three years

	Granular urea		Urea in aqueous solution	
	grass	grass/clover	grass	grass/clover
Urea -ATS	7.86	6.24	8.96	7.19
Urea +ATS	9.15	7.01	11.15	7.23

Using ATS with urea on wheat and barley

The winter barley (Pastoral) and the spring wheat (Minaret) experiments were carried out on a S deficient site in Co. Carlow

Addition of ATS to urea significantly increased the three year mean yield of barley from 5,26 to 5,80 t/ha. (Table 5). It also increased the wheat yield from 6.84 to 7.17 t/ha but this increase was not significant. The number of ears/unit area was significantly increased by ATS for both crops but the other yield components i.e. grains/ear and 1000 grain weight were not affected. It should be noted that these experiments were carried out on S deficient soils and it has been shown that the addition of S as gypsum (calcium sulphate) produced similar effects on grain yield and ears/unit area. It seems that on these soils, ATS is acting mainly as a source of plant nutrient sulphur.

Table 5: Effect of N (urea) and ATS on yield and components of yield of wheat and barley

Crop	Treatment	Grain yield t/ha	Ears per M^3	Grains per ear	1000grain weight g
wheat	urea -ATS	6.84	710	32.9	32.9
	urea +ATS	7.18	771	36.6	32.1
barley	urea -ATS	5.26	831	16.2	39.4
	urea +ATS	5.80	972	16.3	40.2

USING ATS TO REDUCE THE AMOUNT AND FREQUENCY OF N APPLICATION

This project has shown that the addition of ATS to urea improved its efficiency and increased the amount of dry matter produced from 15.2 to 19.6 kg per kg of N (Table 6). In other words a crop of 5000 kg/ha of dry matter could be produced by applying 255 kg/ha N + ATS, whereas without ATS, 328 kg/ha N was needed i.e. 73 kg/ha less. Economically the saving achieved in N fertiliser would need to be balanced against the cost of ATS but the possibility of reducing N inputs while maintaining crop yields is very environmentally desirable. The ability of ATS to improve the efficiency of urea and slurry would also have obvious advantages for those in the REPS scheme where the use of N is restricted. However the urea/ATS experiments were carried out on S deficient soils and it has been shown that on such soils, gypsum had a similar effect in increasing herbage yields or maintaining them with reduced N inputs.

Table 6. The effect of ATS in reducing N inputs.

N and ATS applied for season kg/ha		1995	1996	1997	Mean
N0	ATS0	3687	3256	2890	3278
N300	ATS0	8348	8909	6287	7848
N300	ATS100	9105	11337	7018	9153

No N treatment produced		3278 kg/ha DM
Extra DM produced by 300 kg/ha N without ATS		4570 = 15.2/kg N
Extra DM produced by N300 +100 ATS treatment		5875 = 19.6/kg N
N needed to produce 5000 kg/ha extra DM	=	5000/15.2 =328 kg
N + ATS needed to produce 5000 kg/ha extra DM	=	5000/19.6 =255 kg

In Ireland slurry is mainly applied by a splashplate method and most of the NH_4-N is lost by volatilisation within hours of application. Addition of ATS to slurry improved its efficiency and resulted in a mean herbage dry matter increase of approximately 800kg for 1st cut silage (Table 6). Assuming that one kg of mineral N produces 15kg of dry matter this represents an extra 53kg of mineral N from the ATS treated slurry. This has obvious economical and environmental advantages.

CONCLUSIONS

- Laboratory incubation experiments showed that ATS delayed nitrification when NH_4 -N was added to nine European soils.

- Field measurements of nitrate leaching on one soil did not confirm the laboratory findings that ATS inhibited nitrification. However the soil NH_4 -N concentrations were significantly higher in the + ATS treatment.

- When ATS was added to slurry, the silage and silage maize yields increased by 9% and the efficiency of the slurry N was improved. These effects were not due to the S content of ATS as there was no response to S on these soils.

- Yield increases were also recorded when ATS was included with granular urea on grass (8%), grass/clover (12%), wheat (5%) and barley crops (10%). However as these experiments were carried out on S deficient soils the effect of ATS was due at least in part to it acting as a source of plant nutrient S.

- From an environmental viewpoint the project has shown that the use of ATS with slurry on non sulphur deficient soils, and with urea on S deficient soils makes it possible to maintain crop yields with reduced N inputs.

- At the present price of N fertilisers the use of ATS to obtain increased yields would not be economic. This could change if there was an increase in the use of liquid fertilisers such as urea ammonium nitrate.

- Further research is needed on methods of applying ATS with both granular fertilisers and slurry, and on the effect of ATS on fertilisers containing NH_4-N rather than urea.

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