Broadcasting Ammonium Sulphate Fines as a Source of Nitrogen

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Abstract
Broadcasting of Ammonium Sulphate fines (21-0-0-24) was compared to Ammonium Nitrate (34.5-0-0) at eight different sites with pH ranging from 6.2 to 8.0 and $CaCO_3$ from 0 to 2.9% over a three-year period. At two sites the products were mixed with 15-20 tonnes ha^{-1} of lime ($CaCO_3$). Yields of barley and hybrid and conventional or open pollinated cultivars of canola were not influenced by the source of fertilizer N.

Introduction

Ammonium sulphate fines (21-0-0-24) are routinely broadcast as a sulphur (S) source, especially for oilseed crops. However, the considerable increase in fertilizer nitrogen (N) price, especially urea (46-0-0) primarily as a result of escalating gas prices, has resulted in broadcast application of the more economically priced, under certain circumstance, fines. However, there are certain conditions that can result in significant N losses as a result of ammonia (NH_3) volatilization (Fenn and Kissel 1973). Ammonia volatilization, independent of the species of ammonium salt (i.e., type of fertilizer) is influenced by a number of factors, such as pH, exchangeable cation, texture, temperature and water content. Thus, the higher the pH, the more predominant K^+ and Na^+ are on the soil colloids (compared to Ca^{2+} and Mg^{2+}), the heavier the texture, the higher the temperature and the drier the soil the higher the volatilization losses (Du Plessis and Kroontje 1964; Chao and Kroontje 1964; Martin and Chapman 1951).

A number of studies have assessed N volatilization losses from various types of N fertilizers (Table 1). In general, losses tend to be considerably lower under acid soil than under alkaline soil conditions and in the former case lower from ammonium nitrate and ammonium sulphate than they are from urea. However, losses from various N sources under alkaline conditions are affected by a number of factors including method of application, environmental conditions (temperature, precipitation or irrigation) and rate of applied N. A number of studies conducted either in the laboratory, the greenhouse or under field conditions on the same soil (a Houston Black clay with pH of 7.6 and $CaCO_3$ content of 25%) have concluded that NH_3 volatilization losses from ammonium sulphate were greater than those from urea and ammonium nitrate (Table 1). The results of these studies were corroborated by the results from studies carried out in the United Kingdom and Turkey with soils containing high lime levels. Fenn and Kissel (1073) proposed a mechanism for the increased NH_3 loss from ammonium sulphate compared to other sources that relates to the formation of $(NH_4)_2CO_3$ and a Ca^{2+} salt from the dissolution of ammonium in a calcareous soil. Subsequent decomposition of the ammonium carbonate thus formed leads to the release of CO_2 at a rate that is greater than that of NH_3 release. This leads to the formation of NH_4OH, which in turn increases soil pH and encourages overall greater NH_3 loss. Manitoba Agriculture, Food and Rural Initiatives (2001) apprised producers of these losses, especially when ammonium sulphate is broadcast applied on soils that contain high free lime. However, no field studies that have quantified this on carbonated Manitoba soils have been carried out.

The objective of this study was to ascertain whether significant losses of N occur from ammonium sulphate fines broadcasted on soils by comparing the performance of this product to that of ammonium nitrate that is commonly accepted as a product that presents less risk of ammonia volatilization.

Table 1. Summary of research carried out to compare ammonia volatilization losses from various N fertilizer sources.

Country	Soil pH (1:1)[a]	$CaCO_3$ (%)	Placement	Rate of N ($kg\ ha^{-1}$)[a]	Losses from: Urea	Ammonium Nitrate	Ammonium sulphate	Others	Reference
Texas, USA	7.6	25	Broadcast	550		18	54	16-68	Fenn and Kissel 1964
Texas, USA	7.6	25	Broadcast	33-280 ($kg\ ha^{-1}$)		3-10	36-45 pelleted 25-55 liquid		Hargrove et al. 1977
India	10.6 (1:2)	3.02	Mixed (laboratory)	60 ($mg\ kg^{-1}$)	61.66[c]	53.91[b]	54.26b 58.33[c]	52.47 & 52.47[b]	Rao and Batra 1983
New Zealand	6.1 (1:2.5)		Broadcast	3 X 30 ($kg\ ha^{-1}$)	11.9	0.8	1.0	5.3	Black et al. 1985
Australia	5.1 (1:5)		Broadcast	0-112	4-50		2-24		Ellington 1986
Turkey	7.52 (1:2 KCl)	10	Mixed (laboratory)	1000 ($mg\ kg^{-1}$)	32.6	3.1	2.3		Bayrakli 1990
United Kingdom	7.4	75	Broadcast (columns)	100 ($kg\ ha^{-1}$)	pH>6.1 23.5-43.1	pH<6.1 1 pH>7.1 17-19	pH<6.1 <4 pH7.1 & $CaCO_3$ 1.8% 31.9 pH 7.4 & $CaCO_3$ 75% 47	<0.5-34.6	Whitehead and Raistrick 1990
India	8.2		Liquid mixed	100-200	18-23		9-11		Patra et al. 1992
Turkey	8.44	20	Broadcast (at tillering)	200 ($kg\ ha^{-1}$)	3.9-12	4.4-6.4	13.6-19.5		Gezgin and Bayrakli 1995
Texas, USA	7.6	25	Broadcast	110-550 ($kg\ ha^{-1}$)		10	10-13.5		Fenn and Escarzaga 1977
Pakistan	7.9		Mixed with gypsum (laboratory)	200 ($mg\ kg^{-1}$)	21	14	16	13	Zia et al. 1999

[a] Unless otherwise indicated.
[b] Treatment at field capacity.
[c] Waterlogged treatment.

Materials and Methods

A field program was established in 2001 to examine whether losses from ammonium sulphate fertilizer (21-0-0-24) were greater than those from ammonium nitrate fertilizer (34.5-0-0), when both of these products were broadcast on soils without incorporation. In 2001, two sites were selected in Alberta, Ellerslie and Aldersyde, with pH values of 6.2 and 7.0. In 2002 three sites were selected, one each in Alberta, Saskatchewan and Manitoba with pH and $CaCO_3$ values of 7.7, 7.0, and 7.9 and 3, 0 and 0 %, respectively, and in 2003 three sites were selected in Manitoba with pH values of 8.0, 7.5 and 7.4 and $CaCO_3$ values of 4.2, 2.9 and 0 %, respectively.

The program contained two types of experiments.
In 2001, a RCB design containing six treatments was implemented at both sites. One rate (60 kg N ha^{-1}) of N either as ammonium sulphate (21-0-0-24) or ammonium nitrate (34.5-0-0) was applied on its own as well as after it was thoroughly mixed with the equivalent of 33.6 tonne lime ($CaCO_3$) ha^{-1} at Ellerslie and 49.3 tonne lime ha^{-1} at Aldersyde and was broadcast on the plots. A control with neither N nor lime and one with lime only were also included. Barley was seeded at both sites (Kasota at Ellerslie and Harrington at Aldersyde) on June 13 and 14, 2001, respectively, with an airseeder with 22.9 cm (9 inch) spacing and equipped with 1.9-cm (3/4 inch) knives at a rate of 399 and 362 seed m^{-2}. Phosphate was seed-placed as monoammonium phosphate (12-51-0) at a rate of 30 kg P_2O_5 ha^{-1} and K was side-banded as potassium sulphate (0-0-51-17) at a rate of 112 kg K_2O ha^{-1}. The plots were harvested on September 20, 2001 using a Wintersteiger Nurserymaster Elite experimental plot combine. The seed weight per plot was measured after being dried by forced air at 60 ^oC to constant weight and was corrected to moisture content of 13.5.

In 2002 and 2003, a split-plot design with two canola cultivars as main plots and a combination of two N sources (21-0-0-24 and 34.5-0-0) and four rates (0, 47, 94 and 141 kg N ha^{-1}) was adopted. The two cultivars in 2002 were 45H21 and 46A65 at Ft. Saskatchewan and Rosebank and SP Admirable and SP Armada at Sylvania and, in 2003, 45H21 and Conquest at all three sites. There was no attempt to balance S out as a result of using ammonium sulphate, thus comparing the two fertilizer N products strictly as N sources. The Ft. Saskatchewan, Sylvania and Rosebank sites were seeded on May 28, May 19 and June 1, 2002, respectively, at rates of 159 and 213 at Ft. Saskatchewan, 202 and 187 at Sylvania 164 and 211 kg seed m^{-2} at Ft. Saskatchewan for the hybrid and conventional canola cultivars, respectively; the corresponding harvest dates were October 7, October 3 and September 21. In 2003, the Petersfield site was seeded on May 6 and the Rosser and Miami sites on May 15 at 162 and 166 seed m^{-2} for the 45H21 and Conquest cultivars, respectively; the corresponding harvest dates were October 7, August 11 and August 18. All Manitoba and the Sylvania site were seeded with a six-row hoe drill at 22.5-cm spacing, whereas the Ft. Saskatchewan site was seeded with an airseeder as indicated above. All plots in 2002 and 2003 were harvested as indicated for the 2001 plots.

All treatments in all three years were replicated six times. The data were analyzed with ANOVA for RCBD in 2001 and a split-plot design in 2002 and 2003.

Results and Discussion

There was no impact of mixing the two N sources with lime ($CaCO_3$) and then broadcasting the mixture on the surface of the soil on the barley yield at both sites in 2001 (Table 2). Both N and lime resulted in a significant yield response, although the response at Aldersyde was considerably smaller as a result of drier conditions. There were no significant interactions between lime, N source or N rate at either of the two sites.

Table 2. The effect of calcium carbonate and nitrogen fertilizer source applied at 60 kg N ha^{-1} on barley yield in 2001.

	Ellerslie		Aldersyde	
Treatment	kg ha^{-1}	bu/acre	kg ha^{-1}	bu/acre
Control	3312	62	1915	36
Control plus $CaCO_3$	3269	61	2101	39
21-0-0-24	4721	88	2100	39
21-0-0-24 plus $CaCO_3$	4366	81	2364	44
34.5-0-0	4766	89	2228	41
34.5-0-0 plus $CaCO_3$	4592	85	2479	46
ANOVA (P) [a]	**	**	NS	NS
LSD	290	5.4	457	9
Contrasts	Significance [a]			
Response to $CaCO_3$ (C)	*		ŧ	
Response to Nitrogen Fertilization (N)	**		*	
Response to Nitrogen Source (S)	NS		NS	
C x N Interaction	NS		NS	
C x S Interaction	NS		NS	

[a] ŧ,*,** Significant at $P \leq 0.10$, 0.05 and 0.01 respectively; NS, not significant.

The source of fertilizer N - ammonium sulphate (21-0-0-24) or ammonium nitrate (34.4-0-0) - had no significant effect on the yield of canola at any of the six sites in 2002 and 2003 (Tables 3 and 5). There was a highly significant ($P<0.01$) response of both hybrid and conventional or open pollinated canola to N application rates. However, seed yield of hybrid canola used in 2003 was significantly higher than that of the open pollinated cultivar (Table 5).

Soil analyses to examine residual soil N levels have been completed for the 2002 trials only (Table 4). There was a significant difference in residual soil N levels in the 0-60 cm (0-24" depth) at the Rosebank site only. Mean residual soil N levels in the 34.5-0-0 treatments were 19 kg ha^{-1} (17 lb/acre) greater than those in the 21-0-0-24 treatment (81 vs. 62 kg ha^{-1} or 73 vs. 56 lb/acre). These are a result of the considerably higher residual N levels at the higher N fertilizer rates of the treatments that received 34.5-0-0 (Table 4). The same magnitude of difference was obtained between residual soil N levels of the hybrid and conventional canola treatments, which resulted in a significant interaction between canola cultivars and fertilizer N rates on residual soil N (Table 4). In any event, higher N residual soil N levels may represent either higher N uptake of N or greater losses of N from the 21-0-0-24 treatments. In spite of excellent soil moisture conditions (soil profile fully charged) and 320 mm (12.6 inches) or precipitation in the months of June to August, late seeding at this site resulted in abortion of canola pods during extremely high temperatures in the month of July, thus making an accurate yield evaluation difficult.

Conclusions

Broadcast without incorporation of ammonium sulphate (21-0-0-24) fines at a number of sites with soil pH values ranging from 6.2 to 8.0 and with lime ($CaCO_3$) content less than 3% resulted in barley and canola yields statistically the same with those obtained by broadcasting equal amounts of N as ammonium nitrate (34.5-0-0).

Table 3. The effect of nitrogen fertilizer source, nitrogen rate and cultivar on canola yield in 2002.

	Ft. Saskatchewan				Sylvania				Rosebank			
	Hybrid		Conventional		Hybrid		Conventional		Hybrid		Conventional	
Nitrogen Rate	AN[a]	AS[b]	AN	AS	AN	AS	AN	AS	AN	AS	AN	AS
(kg ha^{-1})						(kg ha^{-1})						
0	2229		2173		517		523		961		744	
47	2744	2755	2245	2408	890	892	742	681	1091	1267	776	984
94	3197	2783	2537	2637	1261	1296	961	845	1321	1365	1168	1176
141	3097	3041	2716	2654	1110	1415	1161	1058	1221	1227	1063	1124
(lb/acre)						(bu/acre)						
0	39.8		38.8		9.2		9.3		17.2		13.3	
42	49.0	49.2	40.1	43.0	15.9	15.9	13.3	12.2	19.5	22.6	13.9	17.6
84	57.1	49.7	45.3	47.1	22.5	23.1	17.2	15.1	23.6	24.4	20.9	21.0
126	55.3	54.3	48.5	47.4	19.8	25.3	20.7	18.9	21.8	21.9	19.0	20.1

Contrasts	Significance[c]	SE[d]	Significance[c]	SE	Significance[c]	SE
1) Hybrid cultivar vs Open Pollinated cultivar	ŧ	96	NS	82	NS	118
2) Average response to fertilizer	**		**		**	
3) AN vs ASF	NS	109	NS	45	NS	85
4) Linear response to N	**		**		NS	
5) Non-Linear response to N	NS		*		*	
Interaction - 1 & 2	NS	154	*		NS	
Interaction - 1 & 3	NS		**		NS	
Interaction - 1 & 4	NS		NS	64	NS	121
Interaction - 1 & 5	NS		*		NS	
Interactions - 3 & 4 or 3 & 5	NS		NS		NS	
Interaction - 1 & 3 & 4	NS	172	ŧ	101	NS	162
Interaction - 1 & 3 & 5	NS		NS		NS	

[a] AN = Ammonium nitrate. [b] AS = Ammonium sulphate.
[c] ŧ,*,** Significant at P ≤ 0.10, 0.05 and 0.01 respectively; NS, not significant. [d] SE given in kg ha^{-1}.

Table 4. The effect of nitrogen fertilizer source, nitrogen rate and canola cultivar on the post-harvest soil nitrogen level in 2002.

	Ft. Saskatchewan				Sylvania				Rosebank			
	Hybrid		Conventional		Hybrid		Conventional		Hybrid		Conventional	
Nitrogen Rate	AN[a]	AS[b]	AN	AS	AN	AS	AN	AS	AN	AS	AN	AS
(kg N ha^{-1})						(kg ha^{-1})						
0	34		29		41		44		55		65	
47	31	35	38	33	37	34	33	40	67	55	62	50
94	34	33	36	35	38	34	35	35	78	62	68	53
141	42	32	42	31	39	36	38	47	129	93	84	59

	Ft. Saskatchewan		Sylvania		Rosebank	
Contrasts	Significance[c]	SE	Significance[c]	SE	Significance[c]	SE
1) Hybrid cultivar vs Open Pollinated cultivar	NS	1.93	NS	0.67	NS	5.91
2) Average response to fertilizer	NS		NS		NS	
3) AN vs ASF	NS	2.18	NS	2.99	**	6.47
4) Linear response to N	NS		NS		**	
5) Non-Linear response to N	NS		NS		ŧ	
Interaction - 1 & 2	NS		NS		ŧ	
Interaction - 1 & 3	NS		ŧ		NS	
Interaction - 1 & 4	NS	3.08	NS	4.23	*	9.15
Interactions - 1 & 5 or 3 & 4 or 3 & 5	NS		NS		NS	
Interaction - 1 & 3 & 4 or 1 & 3 & 5	NS	3.44	NS	3.98	NS	10.33

[a] AN = Ammonium nitrate. [b] AS = Ammonium sulphate.
[c] ŧ,*,** Significant at P ≤ 0.10, 0.05 and 0.01 respectively; NS, not significant.

Table 5. The effect of nitrogen fertilizer source, nitrogen rate and cultivar on canola yield in 2003.

	Petersfield				Rosser				Miami			
	Hybrid		Open pollinated		Hybrid		Open pollinated		Hybrid		Open pollinated	
Nitrogen Rate	AN[a]	AS[b]	AN	AS	AN	AS	AN	AS	AN	AS	AN	AS
($kg\ ha^{-1}$)					($kg\ ha^{-1}$)							
0	1856		1398		1093		968		1778		1402	
47	2081	2634	1983	1945	1323	1342	1098	1016	2156	2251	1847	1865
94	2774	2437	2412	2309	1376	1463	1198	1150	2587	2352	2074	1988
141	2843	3245	2590	2617	1305	1541	1182	1238	2275	2385	2124	2168
(lb/acre)					(bu/acre)							
0	33.1		25.0		19.5		17.3		31.7		25.0	
42	37.2	47.0	35.4	34.7	23.6	24.0	19.6	18.1	38.5	40.2	33.0	33.3
84	49.5	43.5	43.1	41.2	24.6	26.1	21.4	20.5	46.2	42.0	37.0	35.5
126	50.8	58.0	46.3	46.7	23.3	27.5	21.1	22.1	40.6	42.6	37.9	38.7

	Petersfield		Rosser		Miami	
Contrasts	Significance[c]	SE[d]	Significance[c]	SE	Significance[c]	SE
1) Hybrid cultivar vs Open Pollinated cultivar	*	57	**	18	*	71
2) Average response to fertilizer	**		**		**	
3) AN vs ASF	NS	83	NS	46	NS	95
4) Linear response to N	**		*		*	
5) Non-Linear response to N	NS		NS		NS	
Interaction - 1 & 2	NS		NS		NS	
Interaction - 1 & 3	ŧ		ŧ		NS	
Interaction - 1 & 4	NS	118	NS	64	NS	135
Interaction - 1 & 5	NS		NS		NS	
Interaction - 3 & 4	NS		ŧ		NS	
Interaction - 3 & 5	**		NS		NS	
Interaction - 1 & 3 & 4	NS	123	NS	62	NS	144
Interaction - 1 & 3 & 5	*		NS		NS	

[a] AN = Ammonium nitrate. [b] AS = Ammonium sulphate.
[c] ŧ,*,** Significant at $P \leq 0.10$, 0.05 and 0.01 respectively; NS, not significant.
[d] SE given in $kg\ ha^{-1}$.

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