Comparing N and S sources to improve yield and nutrient efficiency in canola cropping systems in south-eastern Australia.

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ABSTRACT

Canola (*Brassica napus* L.) has a higher sulphur requirement than most cereals and to meet that demand, additional sulphur may be needed in a balanced fertilizer program. A glasshouse experiment was used to evaluate N and S supplied from either urea plus gypsum or ammonium sulphate to canola plants. In this experiment, canola growth to 42 DAS was 27% higher ($p<0.05$) when N and S were supplied as ammonium sulphate compared to urea and gypsum and this response could be a consequence of root zone acidification with the ammonium sulphate increasing total P uptake compared to the urea and gypsum.

In 2009 and 2010, field experiments were established in the Wimmera and Mallee where equivalent N and S rates were supplied from ammonium sulphate (21:0:0:24) or urea and gypsum (alone or in combination) applied at seeding to canola. The field experiments showed that ammonium sulphate produced significantly better canola grain yields than urea and gypsum on two of the four sites evaluated in 2010 and 2011 and increased nutrient use efficiency compared to N and S derived from urea and gypsum.

On certain soil types, these data show that ammonium sulphate increases yield and nutrient recovery for canola when compared to urea and gypsum. On alkaline, poorly buffered soils, the acidification of the root zone may result in improved access to N and S, as well as extra P, although the mechanisms of the improvement are likely mediated through different mechanisms.

Key words: sulphur – nitrogen – nutrient use efficiency – Wimmera – Mallee

INTRODUCTION

It is generally recognised that nitrogen and phosphorus are the two most limiting nutrients for crop production in south-eastern Australia. Phosphorus demand is usually met with at-sowing P sources such as mono-ammonium phosphate or triple superphosphate. A consequence of around 20 years use of these nutrient dense fertilizers is that sulphur input has been reduced to the extent that sulphur deficiency is becoming recognised, particularly with crops such as canola which have a higher S demand than cereals (Hocking *et al*. 1993). It has been recognized that both N and S are important for cereal and oil seed crop nutrition and getting the correct balance of these nutrients is critical in developing a balanced crop nutrition program.

To supply N and S, urea and gypsum (UG) are the usual sources applied in south-eastern Australia, but there is little information on the efficiency of these sources for cereal and oil seed crops with variable soil types and agro-climatic conditions. Furthermore, the physical and chemical constraints of calcarosol and vertosol (Nutall *et al*., 2003) limit the efficient use of urea and gypsum sources. We hypothesise that the use of ammonium sulphate (AS) can increase the N and S use efficiency of crops such as wheat (*Triticum aestivum* L.) and canola (*Brassica napus* L.) in south-eastern Australia compared to the current practice. This paper reports the response to N and S on canola from different fertilizer sources when grown on either a sandy calcarosol or a clay loam vertosol over two years.

MATERIALS AND METHODS

A preliminary glasshouse study was undertaken to test the comparative response of canola to UG and AS. The soil selected was a Mallee calcarosol with 13 mg/kg nitrate N and 3.6 mg/kg KCl40 S. Canola was grown with these fertilizers in a naturally ventilated glasshouse for 42 days. Half the plants per pot were harvested at 28 d after planting and the other half at 42 d after planting. Plants were dried at 75°C and then ground before tissue mineral contents were assessed. Tissue N was assessed using a LeCo CNS analyser while a suite of other minerals including P and S were assessed using ICP-OES. Soil pH was measured after the plants were harvested.

Field sites in the Mallee (Mallee sandy calcarosol – Rynaby 2009, Rynaby 2010) and the Wimmera (Wimmera clay loam vertosol Nurrabiel 2009, Horsham 2010) were selected. All sites were in cereals or pasture the previous year and managed along normal cropping best practice, which includes minimum tillage and stubble retention. The soil types, seasonal rainfall and soil tests (top 10 cm) for each site are shown in Table 1.

Table 1: Physical and chemical characteristics of soil (0-10 cm) in Nurrabiel, Rynaby, Horsham and Rynaby and seasonal rainfall for each site in 2009 and 2010.

Site & year	Soil Type	Ec (dS/m)	Org.C (%)	Av NO_3 mg/kg	KCl40 S mg/kg	Colwell mg/kg	1:5 water	May to November Rainfall (mm)
Nurrabiel (2009)	Clay loam Vertosol	0.15	2.3	18.0	22.0	40	5.8	369
Rynaby (2009)	Sandy loam Calcarosol	0.05	0.36	12	2.5	16	6.4	246
Horsham (2010)	Clay loam Vertosol	0.16	1.10	3.1	1.5	16	8.5	399
Rynaby (2010)	Sandy loam Calcarosol	0.05	0.43	7.2	2.7	23	6.6	400

At each site, canola (Brassica napus L, cv. 44C79) was sown at 4 kg/ha with 15 kg P or 20 kg P in the Mallee and Wimmera respectively, supplied as triple superphosphate (0:18:0:1 N:P:K:S). A range of fertilizer treatments were included as well as another series of experiments on wheat, but this paper reports the results from canola on the comparisons among nil fertilizer, ammonium sulphate (AS) (24:0:0:21), urea (U) (46:0:0:0) alone, gypsum (G) (0:0:0:16) alone and urea and gypsum (UG) together. Four replicates were used and the experiments were designed as randomised complete blocks. The ammonium sulphate and urea fertilizers were banded at sowing to give rates of 25 kg N ha^{-1} and 29 kg S ha^{-1} in the Mallee and 35 kg N ha^{-1} and 40 kg S ha^{-1} (2009) or 40 kg N ha^{-1} and 46 kg S ha^{-1} (2010) in the Wimmera. The gypsum was pre-spread and incorporated by sowing at rates equivalent to the S applied as ammonium sulphate. In 2009, the pH of the soil in the fertilizer band was measured in 5:1 water: soil solution at 90, 120 and 150 days after sowing at each site.

At crop maturity, four meters of drill row was hand harvested to ground level and seed was hand threshed. Representative subsamples of seed and straw were oven dried at 70°C for 72 hrs and ground to fine powder for N and S analysis. The N and S content of straw and grain were analysed by combustion method using CNS auto-analyzer.

In order to compare the treatment effects, all set of data from each site were compared by analysis of variance (ANOVA) using the GLM model in Minitab. Least significant differences (LSD) were calculated where the F test showed significant differences ($p \leq 0.05$) although in some cases, significance was notes at $p<0.10$.

RESULTS AND DISCUSSION

Under glasshouse conditions in a low nutrient status medium and by 42 days after sowing, AS produced significantly more growth than the UG treatment (Table 2). Although nutrient uptake was similar for AS and UG at 28 d, by 42 d N and S uptake was significantly ($p<0.05$) greater for

AS than UG, while P uptake was higher with the AS treatment. Soil pH was measured in these pots at the conclusion of the experiment and AS showed a significant drop, which may help explain the increased P availability.

The effects of these fertilizer treatments on growth, seed yield and nitrogen uptake are summarised in Table 3. Based on the soil test results (Table 1), the Rynaby 2009, Horsham and Rynaby 2010 sites should all have been S responsive (Brennan and Bolland, 2006) and given the above average rainfall in both years, the crops were also likely to respond to added N. Despite these test values, N and S responses were seen not seen at Nurrabiel or Rynaby 2010, while S responses to gypsum alone were noted only at Rynaby 2009. The KCl40-S content at Rynaby 2010 in the 30-60 cm layer was 12 mg/kg, which would have given an adequate S supply later in the season. While topsoil S content indicates potential S responses, Brennan and Bolland (2006) noted that subsoil S can provide an additional S supply even when topsoils levels are low, so that a deep soil test, similar to a deep soil N test to 60 cm, would be a better indicator of potential S responsive paddocks.

Table 2. Shoot growth, N, S and P uptake of canola at 28 and 42 days after planting, and soil pH 42 days after planting.

	Shoot growth (g/pot)		N uptake (mg/pot)		S uptake (mg/pot)		P uptake (mg/pot)		Soil pH (1:5 soil:water)
	28 d	42 d	28 d	42 d	28 d	42 d	28 d	42 d	42 d
Nil	2.89	3.94	29	42	15	19	13	14	6.65
UG	4.60	6.36	101	64	42	30	20	17	6.20
AS	5.13	8.05	91	87	42	36	20	21	5.99
LSD (p=0.05)	*0.72*	*1.52*	*19*	*20*	*9*	*5*	*4*	*4*	*0.31*

At all sites except Rynaby 2010, AS gave the highest grain yields, although AS was significantly (*p<0.05*) better only than UG at Rynaby 2009 site, but the difference at Horsham was significant at *p=0.08* (Table 3). The recovery of N by the crop was greater when AS was used rather than UG at all except the Rynaby 2010 site (Table 4). The better performance of AS compared to UG could be the consequence of several mechanisms, either alone or in combination including co placement of the N and S, poor solubility of the gypsum, root zone acidification or reduced N losses with AS.

Field measurements on alkaline soils have shown that urea is more susceptible to ammonia loss than ammonium sulphate (Sommer and Jensen, 1994; Harrison and Webb, 2001). In fact, urea itself produces high pH (up to 9) upon hydrolysis to form ammonium (Zia *et al*., 1999). In south eastern Australia It has been found that 26 and 12% N lost from urea and AS respectively in vertosol (pH of 7.1-7.7) while in another experiment 13 and 2.8% N loss from urea and ammonium sulphate respectively (Turner *et al*., 2010). Therefore, the losses of N through volatilization could be less with AS.

Gypsum solubility is low and declines with increasing pH, however at these sites and in these years while there was likely to have been adequate water to mobilize all the applied gypsum, the fate of that gypsum when moved into the subsoil is uncertain. Ammonium sulphate reduces soil pH and this may have caused slower nitrification so acting to enhance the efficiency of N when compared to urea (Martikainen, 1985; McInnes and Fillery, 1988; Bolan *et al*., 2003). Because the subsoils of Horsham and Rynaby sites have high pH (8-9), decreasing the pH increases the availability of both nitrate and sulphate (Bolan *et al*., 2003). This hypothesis is supported by measurements of soil pH on the Rynaby 2009 site, which showed that 90 days after sowing soil pH declined from 6.42±0.13 (nil fertilizer) to 5.40±0.13 with AS compared to 5.77±0.15 for UG.

These various mechanisms indicate that a response to AS over UG is likely to be soil and year specific. Further investigation in being undertaken to develop guidelines to identify where AS could be the preferred N and S source for canola.

Table 3. The effect of fertilizer treatments on growth, yield and N uptake of canola at four sites in 2009 and 2010.

Site & Year	Treatment	Dry matter	Grain yield g/m2	Grain N uptake g/m2	Straw N uptake g/m2	Total N uptake g/m2	Total S Uptake g/m2
Nurrabiel 2009	AS	842	224	7.93	3.49	11.42	3.50
	UG	770	202	7.12	3.41	10.53	3.03
	U	648	167	5.95	2.70	8.65	2.88
	G	562	148	4.89	2.16	7.04	2.36
	Nil	690	181	6.12	2.99	9.10	2.96
LSD (p<0.05)		*208*	*58*	*2.12*	*1.30*	*3.36*	*0.83*
Nyrraby 2009	AS	459	155	5.52	1.40	6.91	1.60
	UG	331	108	3.65	0.99	4.63	1.11
	U	nd*	nd	nd	nd	nd	nd
	G	386	125	4.25	1.09	5.34	1.33
	Nil	274	90	3.07	0.81	3.87	0.87
LSD (p<0.05)		*98*	*21*	*0.16*	*0.39*	*2.15*	*0.42*
Horsham 2010	AS	561	203	5.59	1.38	6.97	2.16
	UG	469	167	4.57	1.08	5.65	1.62
	U	451	173	4.91	1.07	5.98	1.64
	G	322	121	3.44	0.83	4.28	1.28
	Nil	326	129	3.82	0.96	4.78	1.23
LSD (p<0.05)		*118*	*48*	*1.29*	*0.49*	*1.83*	*0.49*
Nyrraby 2010	AS	476	193	6.52	1.40	7.93	2.02
	UG	489	193	6.43	1.76	8.20	1.94
	U	602	239	7.99	1.66	9.65	1.90
	G	521	203	6.94	1.81	8.75	2.29
	Nil	452	172	5.71	1.49	7.19	1.68
LSD (p<0.05)		*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

*nd – not determined in this experiment, ns= not significant

At all sites except Nyrraby 2010, AS gave the highest grain yields, although AS was significantly (*p<0.05*) better only than UG at Nyrraby 2009 site. The recovery of N by the crop was greater when AS was used rather than UG at all except the Nyrraby 2010 site (Table 4). The better performance of AS compared to UG could be the consequence of several mechanisms, either alone or in combination including coplacement of the N and S, poor solubility of the gypsum, rootzone acidification or reduced N losses with AS.

Table 4. Fertilizer nitrogen applied and its recovery (FNR) for ammonium sulphate, urea and gypsum and urea alone. FNUE is calculated as the increase in total N uptake over the control divided by the amount of applied N. No statistical comparisons are given as these values are means of the treatments in Table 2.

Site	N applied (kg/ha)	FN recovery (%)		
		AS	UG	U
Nurrabiel 2009	35	66	41	-13
Nyrraby 2009	25	122	30	nd*
Horsham 2010	40	55	22	30
Nyrraby 2010	25	28	38	96

*nd-not determined.

These various mechanisms indicate that a response to AS over UG is likely to be soil and year specific. Further investigation in being undertaken to develop guidelines to identify where AS could be the preferred N and S source for canola.

CONCLUSIONS

On certain soil types, these data show that ammonium sulphate increases yield and nutrient recovery for canola when compared to urea and gypsum. On alkaline, poorly buffered soils, the acidification of the root zone may have result in improved access to N and S, as well as extra P, although the mechanisms of the improvement are likely mediated through different mechanisms.

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