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Comparisons of kieserite and calcined magnesite for sugar beet grown on sandy soils

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SUMMARY

Twenty-three experiments between 1968 and 1971 compared the effect of magnesium, 50 and 100 kg/ha magnesium as kieserite and 100 and 200 kg/ha magnesium as calcined magnesite, on yield and magnesium uptake by sugar beet. On average, 100 kg/ha magnesium as kieserite increased the mean sugar yield of 7.55 t/ha by 0.17 t/ha whereas 200 kg/ha magnesium as calcined magnesite increased it by only 0.08 t/ha; on fields with less than 15 ppm exchangeable magnesium the magnesium fertilizers increased sugar yield by 0.34 and 0.10 t/ha respectively and there was no response to either fertilizer when the soil contained more than 25 ppm of exchangeable magnesium.

100 kg/ha magnesium as kieserite or calcined magnesite increased magnesium in the dry matter of tops by 0.091 and 0.040% and of roots by 0.013 and 0.004% respectively. Giving 100 kg/ha magnesium as kieserite or calcined magnesite increased uptake of the element in August by 5.1 and 2.6 kg/ha respectively. Differences in soil pH did not influence the uptake of magnesium from kieserite but they greatly affected uptake from calcined magnesite. On the slightly acid soils, the fertilizers were almost equally effective but at pH > 7.6 little magnesium was taken up from calcined magnesite. Glasshouse experiments showed that grinding the calcined magnesite increased the availability of the magnesium.

INTRODUCTION

Previous experiments (Tinker, 1967; Draycott & Durrant, 1969) have shown that spring applications of kieserite ($\text{MgSO}_4 \cdot \text{H}_2\text{O}$) largely prevented magnesium-deficiency symptoms and increased sugar-beet yield where the soils contained small amounts of exchangeable magnesium. During the last 4 years, calcined magnesite (largely MgO) has been imported in increasing quantities from Spain as an alternative magnesium fertilizer for sugar beet and other arable crops. Calcined magnesite has several attractions compared with kieserite, for it is more concentrated (55% Mg compared with 16%), cheaper (magnesium in calcined magnesite is about half the cost of the same weight in kieserite) and magnesite blends easily with other fertilizers.

Most experiments comparing calcined magnesite with other magnesium fertilizers have been on grassland and, unfortunately, few have defined the source of the ore or the calcining conditions. Parr & Allcroft (1957) tested 1255 kg/ha calcined magnesite and found it increased pasture magnesium content and prevented hypomagnesaemia for 6 years. In a later

experiment (Allcroft, 1960), 250–500 kg/ha calcined magnesite was found to be enough to prevent hypomagnesaemia, but in another experiment on a more alkaline soil it gave a much smaller response. McConaghy *et al.* (1963) showed that calcined magnesite slightly increased magnesium in herbage, but was not sufficient to prevent a deficiency of magnesium in blood serum of dairy cows. The efficiency of calcined magnesite was improved by grinding. Hooper (1967) showed that the effect of calcined magnesite on the magnesium content of herbage was linearly related to soil pH – its magnesium was readily available in acid but not in alkaline soils.

In experiments testing response to kieserite and calcined magnesite for wheat and barley, Charlesworth (1967) found that calcined magnesite decreased deficiency symptoms and increased yield of wheat more than kieserite. (Responses were +0.67 and +0.18 t/ha respectively.) Barley with any treatment had no deficiency symptoms although calcined magnesite slightly increased yield.

Our experiments, started in 1968, compared the effect of spring applications of kieserite and calcined

Table 1. *Some properties of kieserite and calcined magnesite used in the experiments*

Origin	Kieserite	Calcined magnesite
	Germany	North-west Spain
Approximate formula of mineral	MgSO ₄ ·H ₂ O	MgCO ₃
Burning temperature	—	850 °C
Formula of product after burning	—	88-90 % MgO
Total Mg (%)	16	55
Water soluble Mg (%) ¹	1.05	0.001
Ammonium nitrate extractable Mg (%) ²	3.4	1.6
Particle size (mm)	% of total weight	
> 6	0	15.5
4-6	0	20.0
2-4	0.5	31.5
1.5-2	2.0	21.0
1-1.5	6.0	7.5
0.5-1	39.0	3.0
< 0.5	52.5	1.5

Notes: 1, 5 g fertilizer shaken for 1 h with 100 ml water. 2, 5 g fertilizer shaken for 1 h with 100 ml *N* ammonium nitrate solution.

magnesite on the composition of sugar beet and on sugar yield and the results are compared with preliminary reports of similar experiments which are in progress elsewhere (Norfolk Agricultural Station (N.A.S.), 1969, 1970; the Agricultural Development and Advisory Service (A.D.A.S.), 1970, and by Fisons Fertilizers Limited, 1971).

EXPERIMENTAL

Magnesium fertilizers. Table 1 lists the two magnesium fertilizers tested. Since the magnesium is three and a half times more concentrated in calcined magnesite than in kieserite, less is needed to apply a given amount of magnesium, so even spreading is more critical. The magnesium in calcined magnesite is less soluble (either in water or ammonium nitrate) and is in larger particles.

Field experiments. Twenty-three experiments between 1968 and 1971 tested the following treatments (per hectare) applied in spring:

No magnesium	
314 kg kieserite	50 kg Mg
628 kg kieserite	100 kg Mg
188 kg calcined magnesite	100 kg Mg
377 kg calcined magnesite	200 kg Mg

All plots received 125 kg/ha nitrogen (as 'Nitro-Chalk'), 28 kg/ha phosphorus (as triple superphosphate), 100 kg/ha potassium (as muriate of potash) and 145 kg/ha sodium (as agricultural salt, crude sodium chloride). Five replicates of the five treatments were arranged in a latin square in 1968 and 1969 and six replicates in randomized blocks in 1970 and 1971. Plot size, method of harvesting and the general procedure was similar to that described by Adams (1961) and Tinker (1965). Members of the Soil Survey of England and Wales described the soil series at each site. Soil samples (0-25 cm) taken in the spring before applying fertilizer were air-dried and shaken with *N* ammonium nitrate solution (1:5 w/v) to extract exchangeable cations. The location, soil series and soil analysis of each field are in Appendix Table 1. Plants were sampled in August from each experiment from treatments receiving no magnesium, 628 kg/ha kieserite and 188 kg/ha calcined magnesite.

Glasshouse experiments. Four soils, described in Appendix Table 2, were cropped five times with sugar beet to deplete exchangeable soil magnesium. The soils were then air-dried, thoroughly mixed and weighed (1800 g soil) into plastic pots and given 0, 9, 18 or 36 mg Mg as kieserite or finely ground calcined magnesite, together with adequate amounts of other nutrients. Dry matter yield and magnesium uptake of whole plants were measured in two successive sugar-beet crops harvested when they had eight leaves.

RESULTS AND DISCUSSION

Field experiments. Table 2 gives the mean sugar yields from the 23 experiments. 100 kg/ha magnesium, as kieserite, increased sugar yield by 0.17 t/ha whereas 200 kg/ha magnesium, as calcined magnesite, increased yield by only 0.08 t/ha. Table 2 also shows that if sites with little exchangeable magnesium (< 15 ppm) are considered separately, differences between the effects of the fertilizers are larger. Kieserite (100 kg/ha Mg) increased yield four times more than the same amount of magnesium as calcined magnesite. When exchangeable soil magnesium was 16 to 25 ppm, yield was increased by kieserite but not by calcined magnesite. On average, no magnesium fertilizer was justified when the soil contained more than 25 ppm exchangeable magnesium. When soils contained less than 25 ppm the sugar yield increase was about 3.3 kg per kg Mg from kieserite but only about 0.1 kg from calcined magnesite.

The effect of magnesium fertilizers on yield is often small and non-significant; however, changes in the magnesium concentration in dry matter indicate the availability of the nutrient in the form tested. Table 3 compares the percentage magnesium in dried tops

Table 2. *The effect of soil magnesium on response of sugar beet to kieserite and calcined magnesite. 23 experiments 1968-71*

Exchangeable Mg in soil (ppm)	No. of sites	Yield without Mg Sugar (t/ha)	Kieserite (kg/ha Mg) applied		Magnesite (kg/ha Mg) applied		s.e.	Response to	
			50	100	100	200		Kieserite	Magnesite
			Response in sugar yield (t/ha)						Sugar (kg) per kg Mg applied
10-15	6	8.04	+0.17	+0.34	+0.08	+0.10	±0.110	+3.4	+0.7
16-25	7	7.86	+0.16	+0.32	-0.15	+0.11	±0.136	+3.2	-0.4
26-50	5	7.08	-0.01	-0.14	+0.07	+0.01	±0.111	-0.8	+0.4
> 51	5	7.00	+0.09	+0.12	-0.04	+0.14	±0.126	+1.5	+0.2
Mean	23	7.55	+0.10	+0.17	-0.03	+0.08	±0.065	+1.9	+0.2

Table 3. *The effect of soil magnesium and soil pH on magnesium (%) in dried tops and roots in August. 23 experiments 1968-71*

Exchangeable Mg in soil (ppm)	Response to 100 kg/ha Mg			Response to 100 kg/ha Mg		
	No Mg	Mg in tops (%)		No Mg	Mg in roots (%)	
		Kieserite	Magnesite		Kieserite	Magnesite
10-15	0.135	+0.082	+0.037	0.080	+0.022	+0.010
16-25	0.195	+0.084	+0.037	0.096	+0.007	+0.004
26-50	0.175	+0.055	+0.015	0.095	+0.012	+0.006
> 51	0.490	+0.150	+0.072	0.141	+0.009	-0.009
Soil pH (in water)						
< 6.5	0.729	+0.145	+0.135	0.149	+0.004	-0.006
6.6-7.0	0.173	+0.100	+0.052	0.083	+0.017	+0.011
7.1-7.5	0.196	+0.068	+0.022	0.100	+0.013	+0.003
> 7.6	0.202	+0.097	+0.011	0.103	+0.012	+0.001
Mean of all experiments	0.239	+0.091	+0.040	0.101	+0.013	+0.004

and roots in August when no magnesium was given and after applications of 100 kg/ha magnesium as kieserite or calcined magnesite. On average, kieserite and calcined magnesite increased magnesium in tops by 0.091% and 0.040% and in roots by 0.013% and 0.004% respectively. On fields with less than 25 ppm exchangeable soil magnesium, kieserite increased magnesium in tops by 0.083% - two and a half times more than calcined magnesite.

Sugar beet is usually grown on neutral or alkaline soils. Table 3 shows that small differences in soil pH did not influence the availability of magnesium from kieserite, but greatly affected availability from calcined magnesite. On the two slightly acid soils, kieserite and calcined magnesite were almost equally effective (increase in magnesium in tops 0.145 and 0.135% respectively). At pH 6.6-7.0 the increase in magnesium concentration from kieserite was twice that from calcined magnesite and at soil pH greater than 7.6 kieserite was nine times as effective.

As kieserite increased both dry-matter yield and magnesium concentration more than calcined magnesite, differences in magnesium uptake were large. Table 4 shows that 100 kg/ha magnesium as kieserite or calcined magnesite increased total uptake (tops and roots) in August by 5.10 and 2.64 kg/ha respectively. The uptake of magnesium from kieserite was not affected by soil pH but increasing soil pH progressively decreased uptake from calcined magnesite. The marked effect of soil pH may explain inconsistencies in response to calcined magnesite in early grassland experiments. However, the present experiments did not test whether the differences in availability of magnesium from kieserite and calcined magnesite were wholly chemical or due in part to the different particle sizes.

Glasshouse experiments. Kieserite and calcined magnesite were compared in alkaline soils but the calcined magnesite was ground to give approximately the same range of particle size as kieserite.

Table 4. *The effect of soil magnesium and soil pH on total magnesium uptake (kg/ha) by sugar beet in August. 23 experiments 1968-71. Kieserite and calcined magnesite supplied 100 kg/ha Mg*

Exchangeable Mg in soil (ppm)	Uptake without Mg fertilizer	Increase in uptake (kg/ha)		Ratio of increases Kieserite/ Magnesite
		From kieserite	From magnesite	
10-15	9.84	+4.87	+2.70	1.80
16-25	12.15	+4.96	+3.64	1.36
26-50	12.31	+3.46	+0.95	3.64
> 51	25.37	+7.24	+2.87	2.52
Soil pH (in water)				
< 6.5	26.39	+6.65	+6.97	0.95
6.6-7.0	12.29	+5.08	+3.78	1.34
7.1-7.5	12.64	+4.99	+2.09	2.39
> 7.6	15.84	+6.99	+0.65	10.75
Mean of all experiments	14.46	+5.10	+2.64	1.93

Table 5. *Comparison of kieserite and calcined magnesite in two glasshouse experiments with sugar beet*

Treatment (mg Mg/pot)	(Mean results from four soils)						
	0	As Kieserite			As Magnesite		
		9	18	36	9	18	36
Mg in whole plants (%)							
First crop	0.087	0.133	0.204	0.264	0.122	0.122	0.184
Second crop	0.152	0.191	0.258	0.369	0.173	0.221	0.287
Mg (mg/pot)							
Uptake by first crop	4.75	7.98	11.46	15.50	4.77	5.76	7.80
Amount from fertilizer	0	3.23	6.71	10.75	0.02	1.01	3.05
Total uptake by first and second crops	7.20	12.87	20.36	25.98	9.39	11.86	16.12
Amount from fertilizer	0	5.67	13.16	18.78	2.19	4.66	8.92
(%)							
Fertilizer efficiency							
First crop	—	36	37	30	0	6	8
First and second crops	—	63	73	52	24	26	25

The first crop grew rapidly and sugar beet in pots given no magnesium or 9 and 18 mg Mg/pot as calcined magnesite often showed magnesium-deficiency symptoms. The second crop grew very slowly during the winter months even with supplementary light, and had no magnesium-deficiency symptoms. Table 5 shows the magnesium treatments increased magnesium in the dry matter of both crops, but, as in the field experiments, the magnesium in kieserite was more available. 36 mg Mg/pot as kieserite or calcined magnesite increased magnesium in dry matter in the first crop by 0.177 and 0.097% and in the second crop by 0.217 and

0.135% respectively. Compared with kieserite, the magnesium in calcined magnesite was more available in pots than in the field, suggesting that grinding increased the availability of magnesium from calcined magnesite.

In the pot experiment about 30% of the magnesium given as kieserite was removed in the first crop whereas only about 5% was used from calcined magnesite (ratio 6:1). The total amount of magnesium removed by the first and second crops was greater from kieserite (63% compared with 25%; ratio 2.5:1), suggesting that the magnesium from calcined magnesite might be useful on some soils as

Table 6. Effect of kieserite and calcined magnesite on yield of sugar in 33 experiments on sugar beet made in 1968-71

No. of experiments	Years	Magnesium fertilizer	Amount tested (kg/ha Mg)								Reference	
			0	37	50	65	80	100	126	200		
23	1968-1971	Kieserite	7.55	—	7.65	—	—	7.72	—	—	—	—
		Calcined magnesite	7.55	—	—	—	—	7.52	—	—	7.63	—
6	1969-1970	Kieserite	4.93	5.48	—	5.72	—	5.69	—	—	—	Fisons (1971)
		Calcined magnesite	4.93	5.27	—	5.32	—	—	—	—	—	—
1	1969	Kieserite	5.38	—	—	6.25	—	—	—	6.83	—	Norfolk Agricultural Station (1970)
		Calcined magnesite	5.38	—	—	6.00	—	—	—	6.15	—	—
1	1970	Kieserite	6.31	6.46	—	6.71	—	—	—	—	—	Norfolk Agricultural Station (1971)
		Calcined magnesite	6.31	6.35	—	6.34	—	—	—	—	—	—
2	1970	Kieserite	6.77	7.35	—	—	7.34	—	—	—	—	Agricultural Development and Advisory Service (1970)
		Calcined magnesite	6.77	6.80	—	—	7.20	—	—	—	—	—

a 'slow acting' fertilizer to maintain the amount of available magnesium in the soil.

CONCLUSIONS

Table 6 compares the sugar yields in our experiments with preliminary results of other similar experiments being made by others. The results of all the experiments are remarkably similar for, on average, weight for weight of magnesium, kieserite increased sugar yield by over twice as much as calcined magnesite.

On deficient soils (0–15 ppm of exchangeable Mg) the response to kieserite was four times as great as to magnesite. However, soil pH greatly influenced the effectiveness of magnesite; on slightly acid soils there was little to choose between the two forms, but sugar beet is mostly grown on neutral or alkaline

soils and, on these, kieserite was far more effective. The pot experiment suggested that grinding calcined magnesite increased the availability of its magnesium. Long-term field experiments are investigating the rate at which calcined magnesite and other fertilizers release magnesium. Preliminary results of other experiments with calcined magnesites suggest that their method of preparation from magnesite (particularly the calcining temperature) and the source of the ore greatly affect the availability of the magnesium they contain (Bennett, 1972).

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APPENDIX

Table 1. *Soils used in the field experiments*

Year	Factory area	Map reference	Soil series	Exchangeable cations in soil			Soil pH (in water)
				K	Na ppm	Mg	
1968	Peterborough	TL 081 998	Sherborne	225	19	57	7.5
	Kidderminster	SO 884 790	Newport	85	7	15	6.8
	Selby	SE 748 280	Naburn	80	17	102	7.7
	York	SE 498 739	Wighill	165	15	40	7.7
1969	Bury St Edmunds	TL 743 708	Worlington	95	4	14	7.9
	Cantley I	TG 303 125	St Albans	112	10	27	7.1
	Cantley II	TG 225 202	Freckenham	145	8	15	6.8
	King's Lynn	TF 977 190	Beccles	230	8	31	7.2
	Ipswich	TM 125 545	Freckenham	108	4	17	7.4
	Selby	SE 735 274	Stockbridge	92	7	76	7.3
	York	SE 702 687	Martock	140	7	26	7.2
	Wissington	TF 665 985	Isleham	80	4	21	7.6
1970	Brigg	SE 923 043	Holme Moor	165	9	16	5.9
	Bury St Edmunds	TM 033 833	Ashley	95	8	30	7.5
	Ipswich	TM 292 701	Ashley	155	18	19	6.8
	Kidderminster	SO 874 798	Newport	150	14	10	6.9
	Newark	SK 615 766	Newport	115	13	100	6.0
	Spalding	TF 113 281	—	315	8	57	7.3
1971	Brigg	TF 088 968	Holme Moor	135	4	14	7.0
	Bury St Edmunds	TL 898 674	Euston	150	4	12	7.6
	Ipswich	TM 144 243	Gresham	125	9	21	7.8
	Newark	SK 828 642	Newport	160	5	25	7.4
	York	SE 839 737	Newport	180	16	25	7.5

Table 2. *Soils used in the glasshouse experiment*

Area	Soil series	Response to Mg fertilizer in field experiments (sugar, t/ha)	Exchangeable Mg in soil		Soil pH (in water)
			Before exhaustive cropping	After five glasshouse crops	
Bury St Edmunds	Worlington	+0.21	13	3	7.9
Herringswell	Freckenham	—	17	3	7.9
Sporle	Worlington	+1.51	19	4	7.8
Broom's Barn	Ashley	+0.63	30	9	7.9