Magnesium Limestone, Kieserite and Ground Serpentine as Magnesium Fertilisers

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An assessment was made of magnesium limestone, kieserite and ground serpentine as magnesium fertilisers, using Pueraria phaseoloides *as the test plant in pot culture.*

At high rates of application, magnesium limestone was as effective in promoting growth as kieserite, but at low rates of application kieserite was more effective. It is considered that the overall value of magnesium limestone should be assessed on the basis not only of its magnesium content but also of its calcium content, for it appeared, from the data on shoot calcium content, that the provision of calcium by the magnesium limestone was an additional benefit. Serpentine compared very unfavourably with kieserite in promoting plant growth and in providing magnesium for plant uptake, and it does not seem to be a promising magnesium fertiliser.

The magnesium status of many Malayan soils is known to be low, magnesium deficiency symptoms being frequently found particularly on mature rubber. The deficiency can adversely affect tree growth and yield and the value of correcting magnesium deficiency in mature trees has been demonstrated by BOLTON AND SHORROCKS (1961) who reported yield increases of 14% following three biennial applications of magnesium limestone at the rate of 3 lb per tree.

There are two magnesium fertilisers in common use on rubber in Malaya, imported kieserite ($MgSO_4.H_2O$) and locally available magnesium limestone ($MgCO_3.CaCO_3$). Kieserite is particularly useful for incorporation in fertiliser mixtures containing ammonium sulphate, for which purpose magnesium limestone is unsuitable because of its lime content. As a straight fertiliser also, kieserite is often preferred to magnesium limestone because it is considered to be quicker acting. Serpentine (a hydrated magnesium silicate of the general formula $Mg_6Si_4O_{11}(OH)_6H_2O$) exists close to the surface in mineable quantities in Malaysia and it was thought that it might provide a suitable magnesium fertiliser when finely ground.

The pot culture investigations reported here were carried out to assess and compare the value of kieserite, magnesium limestone, serpentine, and Epsom Salts ($MgSO_4.7H_2O$) as suppliers of magnesium for plant uptake, using *Pueraria phaseoloides*, the leguminous creeper commonly used as a ground cover, as the test plant.

EXPERIMENTAL METHOD

In all experiments the magnesium fertilisers were mixed with dry soil in pots immediately before the sowing of germinated and inoculated *Pueraria phaseoloides.* The weights of the different fertilisers incorporated into the soil, calculated to provide the same amount of magnesium at any given level, are shown in *Tables 1* and *2.*

In Experiments 1 and 2 kieserite (16.4% Mg), magnesium limestone (14.4% Mg) and Epsom Salts (9.9% Mg) were each applied at three levels together with a control. The magnesium treatments were carried out in triplicate and nine replicates were used for control.

In Experiments 3 and 4 serpentine (containing 20% Mg, and ground to pass through a 0.5 mm sieve) and kieserite were each applied

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TABLE 1. EXPERIMENTS 1 AND 2. WEIGHTS IN GRAMS OF DIFFERENT MAGNESIUM FERTILISERS MIXED WITH 0.6 KG DRY SOIL (EXPERIMENT 1) AND WITH 7 KG DRY SOIL (EXPERIMENT 2)

Fertiliser level	Kieserite		Epsom Salts		Magnesium limestone	
	Expt 1	Expt 2	Expt 1	Expt 2	Expt 1	Expt 2
1	0.105	1.22	0.174	2.03	0.118	1.39
2	0.209	2.44	0.347	4.05	0.236	2.78
3	0.418	4.88	0.694	8.10	0.472	5.56

at two levels together with a control; all treatments were carried out in triplicate.

Small polythene pots holding 0.6 kg soil were used in Experiment 1, whilst for all other experiments clay pots holding 7 kg soil were employed. In Experiments 1, 3 and 4, ten plants were sown in each pot, and in Experiment 2 twenty plants were sown.

TABLE 2. EXPERIMENTS 3 AND 4. WEIGHTS IN GRAMS OF KIESERITE AND SERPENTINE MIXED WITH 7 KG DRY SOIL

Fertiliser level	Kieserite	Serpentine
1	3.65	3.00
2	7.30	6.00

Soils

The soils chosen were ones in which magnesium applications could be expected to improve growth of *P. phaseoloides*. Experiments 1 and 2 were carried out on a Serdang series soil, Experiment 3 on a Sungei Buloh series soil, and Experiment 4 on a Rengam series soil (OWEN, 1951).

In order that growth should not be restricted by nutrient deficiencies other than that of magnesium, a nutrient solution (composition in milligram equivalents per litre: NH_4^+...3, NO_3^-...5, PO_4^{---}...4, K^+...4, Ca^{++}...5, SO_4^{--}...6, Na^+...1.3, and a trace element supplement as prescribed by HEWITT (1952)), was applied daily at the rate of 50 ml per pot for the 0.6 kg pots, and 500 ml per pot for the 7 kg pots.

Sampling for Dry Weight Determination and Analysis

Experiment 1. Plants were harvested after eight weeks' growth and divided into roots, nodules, and laminae plus bines ('shoots').

Experiment 2. Laminae and bines were separately harvested fourteen weeks after germination by cutting bines six inches from ground level. Following shoot regeneration the entire plants were finally harvested twenty-four weeks after germination and were divided into roots, laminae and bines.

Experiments 3 and 4. Shoots (laminae plus bines) were harvested from six plants in each pot five weeks (Experiment 3) and six weeks (Experiment 4) after germination; after eighteen weeks the four remaining plants were harvested in their entirety and separated into laminae, bines and roots.

General. The dry weight of all plant material was determined. Shoot material was analysed for magnesium, potassium, calcium, and manganese and also, in Experiments 1 and 2, for nitrogen and phosphorus. In the present paper consideration is given only to the dry weight and nutrient content data relating to the combined shoot material or the total plant. Similar effects to those described are obtained on consideration of the more detailed data of the individual plant samples referred to above.

RESULTS

Experiments 1 and 2. Comparison of Kieserite, Magnesium Limestone and Epsom Salts

Observations. In Experiment 1, using small pots, marked magnesium deficiency symptoms were observed in the control plants after four weeks' growth: the plants receiving magnesium fertilisers also showed magnesium deficiency symptoms indicating that insufficient magnesium had been applied to maintain satisfactory growth. At the lowest level of magnesium supply the symptoms were more marked in the plants receiving magnesium limestone, whereas at the highest level the symptoms were less marked in the plants receiving magnesium limestone than in those receiving the other fertilisers.

In the large pots (Experiment 2) magnesium deficiency symptoms, recorded after ten weeks' growth, occurred in the control plants and in those receiving the lowest level of magnesium limestone; after fourteen weeks, plants receiving the lowest level of kieserite and Epsom Salts and plants receiving the two lower levels of magnesium limestone also showed symptoms. After harvesting of the entire shoot in Experiment 2, magnesium deficiency symptoms developed on the second crop of leaves formed in all treatments, the symptoms being particularly marked on the plants receiving the lowest level of magnesium limestone.

Dry weight. All magnesium treatments markedly increased growth, as shown in *Table 3*. Increases in the level of kieserite and Epsom Salts application resulted in relatively small increments in growth in Experiment 1 and in the first harvest of Experiment 2, whereas in the second harvest in Experiment 2 growth was markedly better at the higher rates of application, probably owing to the depletion of soil magnesium by the earlier harvested shoot material. There was very little difference between the growth of plants supplied with kieserite and those receiving Epsom Salts, although at the second harvest of Experiment 2 Epsom Salts applied at the highest level gave better growth than did kieserite.

In contrast with the effect of the above two fertilisers, increases in the level of application of magnesium limestone resulted in relatively large increases in growth in both experiments: at the lowest level of magnesium application the plants receiving magnesium limestone were

TABLE 3. EFFECT OF DIFFERENT MAGNESIUM FERTILISERS ON PLANT DRY WEIGHT (GRAMS PER PLANT)

Treatment and level		Experiment 1	Experiment 2	
		Total plant[a]	Shoot[b]	Total plant[c]
Control		0.24	1.06	0.76
Kieserite	1	1.05	4.39	2.22
Kieserite	2	1.34	5.23	5.25
Kieserite	3	1.34	5.47	5.63
Epsom Salts	1	1.07	4.87	2.31
Epsom Salts	2	1.23	5.35	5.12
Epsom Salts	3	1.33	5.54	7.28
Magnesium limestone	1	0.76	3.25	1.55
Magnesium limestone	2	1.09	5.32	3.31
Magnesium limestone	3	1.47	5.71	7.38
s.e. magnesium treatment mean ±		0.051	0.332	0.459
Min. 5% sig. diff.		0.149	0.987	1.365
s.e. diff. control and magnesium treatment mean ±		0.053	0.346	0.465
Min. 5% sig. diff		0.118	0.799	1.074

[a]Harvested after 8 weeks. [b]Harvested after 14 weeks.
[c]Harvested after 24 weeks, following shoot regeneration.

TABLE 4. EFFECT OF DIFFERENT MAGNESIUM FERTILISERS ON THE SHOOT CONTENT OF MAGNESIUM, CALCIUM AND POTASSIUM (MG PER PLANT)

Treatment and level		Magnesium			Calcium			Potassium		
		Experiment 1	Experiment 2 a	Experiment 2 b	Experiment 1	Experiment 2 a	Experiment 2 b	Experiment 1	Experiment 2 a	Experiment 2 b
Control		0.11	0.35	0.05	2.0	6.1	3.9	6.9	34.9	7.2
Kieserite	1	0.40	2.21	0.67	9.0	20.9	9.8	24.9	101.1	36.3
Kieserite	2	0.55	3.99	1.65	10.5	28.9	20.5	23.1	93.6	76.6
Kieserite	3	0.53	5.27	1.97	10.1	27.9	22.0	21.8	100.8	86.0
Epsom Salts	1	0.33	2.19	0.47	8.7	24.2	9.9	23.7	99.4	37.3
Epsom Salts	2	0.41	4.01	1.47	9.7	27.1	20.5	23.4	94.8	81.9
Epsom Salts	3	0.54	5.40	3.15	10.3	26.6	29.5	21.2	86.3	97.5
Magnesium limestone	1	0.23	1.20	0.39	7.9	15.4	8.7	20.2	69.5	26.7
Magnesium limestone	2	0.33	2.20	0.90	10.1	31.6	16.3	25.5	95.1	56.4
Magnesium limestone	3	0.55	3.53	2.81	14.4	40.5	41.4	24.2	85.4	123.7
s.e. magnesium treatment mean ±		0.050	0.343	0.314	0.40	2.24	2.74	0.76	7.14	8.44
Min. 5% sig. diff.		0.146	1.018	0.932	1.15	6.65	8.14	2.22	21.20	25.08
s.e. diff. control and magnesium treatment mean ±		0.051	0.344	0.314	0.42	2.44	2.78	0.88	7.71	8.47
Min. 5% sig. diff.		0.112	0.793	0.742	0.92	5.62	6.58	1.93	17.79	19.54

a Harvested after 14 weeks. b Harvested after 24 weeks, following shoot regeneration.

not as well grown as those receiving kieserite or Epsom Salts, but at the highest level of magnesium application the plants receiving magnesium limestone were better grown than those receiving either kieserite or Epsom Salts.

Nodule weight per plant was increased by all magnesium fertilisers and increased levels of applications caused further increases in nodule weight. The increases in nodule weight appeared to be related to the increases in root weight, and not to any specific effect of the magnesium fertilisers on nodulation, since the nodule weight increased in proportion to the weight of roots.

Shoot magnesium, calcium and potassium content. As expected from the effects on plant dry weight, both kieserite and Epsom Salts markedly increased the shoot magnesium content in both experiments, with relatively little difference between the effects of the two fertilisers at any given level of application (*Table 4*).

Magnesium limestone applied at the two lower levels caused a smaller increase in the shoot magnesium content than did kieserite or Epsom Salts: in contrast there was generally little difference between the effects of magnesium limestone, kieserite and Epsom Salts when applied at the highest level of application. The magnesium concentration of laminae and bines was low in all treatments; the maximum recorded concentration in the laminae was 0.12% Mg, a value which is far lower than that expected in healthy laminae of *P. phaseoloides* (SHORROCKS, 1964).

All three magnesium fertilisers increased the shoot calcium content (*Table 4*), the application of the highest level of magnesium limestone resulting in the greatest content. The calcium concentration in the laminae of plants treated with magnesium fertilisers in Experiment 2 varied from 0.30 to 0.59% Ca, values slightly less than those expected in healthy laminae of *P. phaseoloides* (SHORROCKS, 1964).

The concentration of potassium in laminae and bines was reduced by all magnesium fertilisers and also by increasing levels of application, but in no case did the potassium concentration in the laminae fall below that expected in healthy plants. Despite the reduction in the shoot potassium concentration, it was found that where increasing levels of magnesium treatment caused relatively large increases in shoot dry weight (as was the case in the magnesium limestone treatment) the total shoot potassium content was increased by raising the level of magnesium application; when relatively small increases in the shoot dry weight were caused by increasing the level of magnesium application, a reduction in the shoot potassium content was observed (*Table 4*). In view of the better growth of plants receiving the highest levels of magnesium it does not appear that variation in the potassium uptake or the potassium concentration in laminae was affecting the growth response to the individual magnesium fertilisers.

Shoot manganese and phosphorus concentrations. Application of all magnesium fertilisers, and increase in their level of application, resulted in reductions in the manganese and phosphorus concentrations in the shoots, effects similar to those reported by BOLLE-JONES (1954 and 1957) and BOLTON AND SHORROCKS (1961). There were, however, no indications that the concentrations of either manganese of phosphorus were reduced to a deficiency level; the lowest manganese concentration recorded was 38 p.p.m. and the lowest phosphorus concentration was 0.22% P, both values being higher than those quoted for deficient laminae by SHORROCKS (1964).

Experiments 3 and 4. Comparison of Kieserite and Serpentine

Observations. Plants treated with both levels of serpentine in Experiments 3 and 4 showed magnesium deficiency symptoms, first recorded after eight weeks, whereas those treated with kieserite did not.

Dry weight. Application of kieserite resulted in marked increases in growth, there being little difference between the effects of the two levels of application (*Table 5*). In contrast the application of serpentine caused

TABLE 5. EFFECT OF KIESERITE AND SERPENTINE ON PLANT DRY WEIGHT (GRAMS PER PLANT)

Treatment and level		Experiment 3		Experiment 4	
		Shoot[a]	Total plant[b]	Shoot[c]	Total plant[b]
Control		0.25	7.73	0.66	4.08
Kieserite	1	0.41	39.46	0.60	20.71
Kieserite	2	0.45	40.96	0.53	25.38
Serpentine	1	0.32	13.46	0.66	10.19
Serpentine	2	0.33	31.30	0.61	13.61
s.e. ±		0.045	2.382	0.073	0.705
Min. 5% sig. diff.		0.148	7.507	0.232	2.221

[a]Harvested after 5 weeks. [b]Harvested after 18 weeks. [c]Harvested after 6 weeks.

much smaller increases in growth, and the high level application of serpentine was not as effective as kieserite applied at the low level.

Shoot magnesium, calcium, potassium, and manganese concentrations. The magnesium concentration in shoot material (*Table 6*) was substantially increased by kieserite applications but was only slightly increased by serpentine applications in both experiments. There were no indications, from the results of the harvest after eighteen weeks, that magnesium in the serpentine was becoming more available for plant uptake with time.

As in Experiments 1 and 2, depressive effects of kieserite on the calcium, potassium and manganese concentrations were observed in Experiments 3 and 4. There was however little evidence of any particular effect of serpentine on the calcium, potassium and manganese concentrations, further indicating that the serpentine remained largely inert in the soil.

DISCUSSION

The results clearly indicate that whereas there was little difference between the effect of kieserite and Epsom Salts on plant dry weight at any of the levels of application employed, low levels of magnesium limestone application were not as effective as kieserite or Epsom Salts. However, when high levels of application were employed, magnesium limestone was somewhat more effective in promoting growth than either kieserite or Epsom Salts.

Little difference was observed between the effects of kieserite and Epsom Salts on the shoot magnesium, calcium and potassium content, and magnesium limestone applications were in general not as effective in increasing the shoot magnesium content as were the other two fertilisers. It would appear likely that at the highest levels of application the immediate requirement for magnesium by the plants in all treatments was satisfied, and that the provision of calcium by the magnesium limestone then gave additional benefit.

Unless magnesium limestone is applied at high rates of application it would appear that it is not likely to be as satisfactory a magnesium fertiliser as kieserite; however, in assessing the overall benefit of magnesium limestone its calcium content should also be considered. Thus for soils suspected or known to have a low calcium content magnesium limestone would be preferred to kieserite as a magnesium fertiliser.

Serpentine compared very unfavourably with kieserite in promoting plant growth. Serpentine applications were not as effective as kieserite applications containing only half the quantity of magnesium, and thus does not appear to be a promising magnesium fertiliser. However, as applications of serpentine did promote growth slightly, it is con-

TABLE 6. EFFECT OF KIESERITE AND SERPENTINE ON THE CONCENTRATIONS OF MAGNESIUM, CALCIUM, POTASSIUM AND MANGANESE IN SHOOT, BINES AND LAMINAE

(Results expressed on dry weight basis)

Treatment and level		Experiment 3			Experiment 4		
		Shoot[a]	Laminae[b]	Bines[b]	Shoot[c]	Laminae[b]	Bines[b]
				%Mg			
Control		0.21	0.04	0.02	0.11	0.05	0.03
Kieserite	1	0.63	0.12	0.10	0.45	0.21	0.11
Kieserite	2	0.82	0.16	0.07	0.55	0.24	0.14
Serpentine	1	0.20	0.04	0.02	0.17	0.06	0.05
Serpentine	2	0.31	0.06	0.04	0.20	0.07	0.05
s.e. ±		0.021	0.009	0.017	0.011	0.006	0.008
Min. 5% sig. diff.		0.065	0.028	0.054	0.036	0.019	0.026
				% Ca			
Control		1.01	0.85	1.65	1.00	0.08	1.12
Kieserite	1	0.50	0.66	0.82	0.65	0.45	0.49
Kieserite	2	0.45	0.65	0.81	0.73	0.49	0.57
Serpentine	1	0.92	0.85	1.76	0.96	0.45	0.89
Serpentine	2	1.02	0.81	1.53	0.99	0.46	0.79
s.e. ±		0.036	0.049	0.130	0.049	0.042	0.055
Min. 5% sig. diff.		0.114	0.156	0.409	0.156	0.133	0.173
				% K			
Control		3.08	3.27	2.47	2.85	3.81	3.37
Kieserite	1	2.66	2.92	2.31	2.26	2.92	2.98
Kieserite	2	2.49	2.83	2.44	2.34	2.66	2.66
Serpentine	1	3.02	3.25	2.35	2.56	3.46	3.13
Serpentine	2	3.10	3.29	2.38	2.47	3.28	2.99
s.e. ±		0.224	0.082	0.045	0.084	0.126	0.096
Min. 5% sig. diff.		0.705	0.259	0.141	0.266	0.396	0.301
				p.p.m. Mn			
Control		291	270	279	217	236	484
Kieserite	1	205	158	132	178	157	222
Kieserite	2	198	161	129	218	129	237
Serpentine	1	264	261	237	212	172	484
Serpentine	2	267	213	217	224	163	353
s.e. ±		24.5	17.8	33.6	21.4	7.2	16.5
Min. 5% sig. diff.		77.3	56.1	105.7	67.6	22.3	51.9

[a]Harvested after 5 weeks. [b]Harvested after 18 weeks. [c]Harvested after 6 weeks.

ceivable that provided sufficient of the mineral was incorporated in the soil it could be effective in improving the soil magnesium status over a long period of time. In these experiments the fertiliser materials were mixed with the soil and were not applied to the soil surface, as would be the practice under normal planting conditions. With the field method of fertiliser application it would still be expected that the more soluble magnesium fertiliser, namely kieserite, would be the quicker acting fertiliser. Heavy dressings of serpentine would probably only be effective when the serpentine was intimately mixed with the soil.

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