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Evaluation of Ground Serpentine Rock and Ground Magnesium Limestone as Magnesium Sources for Oil Palm Nursery Seedlings

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Treatment of ground magnesium limestone and ground serpentine by boiling in 5 ml of concentrated nitric (HNO_3) acid and 10 ml of concentrated hydrochloric (HCl) acid for 1, 2, 4, 8 and 16 hours in the laboratory showed mean magnesium oxide (MgO) content of 18.2 and 29.20 per cent, respectively. The experiment for the two sources of magnesium (Mg) was carried out on oil palm nursery seedlings grown in large polybags with coarse river sand as the medium of growth. The rates were 5, 10, 20 and 30 g of MgO, applied in planting holes at the time of transplanting of three-month-old pre-nursery seedlings. Initially, up to four months, the leaf 3 Mg levels were slightly higher in ground serpentine treatment, although the difference in values was statistically not significant when compared to the rest of the treatments. As the age of the seedlings increased, there was a continuous decline in leaf Mg levels for all treatments. At the eighth month, the Mg levels of oil palm leaves grown with ground magnesium limestone were significantly higher than the control treatment with no Mg. The source of Mg had no influence on the vegetative growth of seedlings, as all the treatments including control showed no significant differences for the measured growth parameters. In conclusion, ground serpentinite rock is comparable to ground magnesium limestone as a source of Mg. The rate of 30 g MgO per plant, when placed in the planting hole, is insufficient to meet the oil palm needs after the fourth month of application. Higher rates or different methods of application may be needed and to be studied in subsequent trials.

***Keywords**: Ground serpentine, serpentinite rock, ground magnesium limestone, ultrabasic igneous, ultramafic, oil palm seedlings.*

Serpentinites are derived from ultramafic rocks comprising of ferromagnesian minerals and usually occur in the outcrop of fold orogenic belts and stable interior platforms of every continent. Serpentinisation is a process of circulation of fluids detached from the subducted blocks of hot peridotites, which materialises at tectonic settings or movements in earth's lithosphere. The ultramafic rocks are predominately composed of olivine and pyroxene, of which the pyroxene comprises of ortho and clinopyroxenes, which undergo several stages of complex reactions under varied temperature and pressure resulting in the process of serpentinisation. The hydration reaction of ortho and clinopyroxenes at high temperature of less than 800°C and low pressure of 1 kbar results in amphiboles, a lesser

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component of serpentine mineral, and is composed mainly of tremolite and olivine. The minerals resulting from the direct hydration of olivine at a lower temperature of less than 400°C and at a pressure of 1 kbar are serpentine and brucites. A hydration reaction of both olivine and orthopyroxene at less than 400°C but with increased pressure greater than 15 kbar leads to the formation of serpentine. These are some of the complex and natural hydration/hydrothermal processes and reactions that progressively alter the mineralogy and geochemical compositions of the ultramafic rocks to serpentinite (Iyer, 2007; Tashakor, 2014; Tashakor *et al.*, 2014).

The serpentinite rock contains less than 45 per cent silicon dioxide (SiO_2), but high magnesium (Mg) and iron (Fe) (Proctor & Woodell, 1971). Serpentine soils derived from serpentinite rocks are poor in major nutrients of nitrogen (N), phosphorus (P), potassium (K) and calcium (Ca) required for plants. They contain trace and heavy elements such as manganese (Mn), copper (Cu), cobalt (Co), cadmium (Cd), chromium (Cr) and nickel (Ni) (Tashakor, 2014; Baumeister *et al.*, 2015).

Normally, plants growing on serpentinite bedrock have "serpentine syndrome" which is a stress-related growth adaptation in the presence of trace and heavy metals. This syndrome is characterised by reduced plant stature, reduced growth rate with unusual increased development of roots and higher tolerance to Mg and heavy metal like Ni (Baumeister *et al*., 2015). In Sabah, rocks of serpentinite are found in Segama Valley encompassing Mount Silam and Darvel Bay, and Labuk Highlands spreading to Meliau range, Mount Tavai, Mount Tingka and Bidu Bidu hills (Hutchison, 2005). In Peninsular Malaysia, isolated serpentinite outcrops related to chert, schists, chaotic deposits and conglomeratic diamictite occur along the suture of Bentong-Raub (Hutchison & Tan, 2009). The profiles of soils related to serpentinite like Ambun (Anionic Acrudox), Pinianakan (Typic Acrudox) and Nebuso (Rhodic or Typic Hapludox) for Sabah, and Sungei Mas (Typic Acrudox) for Peninsular Malaysia have been described by Paramananthan (1998; 2000).

Various experiments in pots and field trials have been conducted to evaluate serpentine as an alternative source of Mg fertiliser. Shorrocks (1965) studied ground serpentine and its performance on *Pueraria phaseoloides* in pot culture. Chinttenden *et al.* (1967) studied the effect of ground serpentine on tobacco, white clover and perennial rye grass. Proctor (1971a; 1971b) evaluated the growth of *Avena sativa* (oats) grown on several serpentine soils in England, Scotland and Sweden. Loganathan *et al.* (2005) studied the effect of serpentine as Mg fertiliser on pasture by its uptake on the herbage and its retention in the soil. Ten Berge *et al.* (2012) studied the uptake of Mg with various rates of olivine, a form of serpentine on rye grass. Błońska *et al.* (2016; 2017) showed that the heavy dressing of ground serpentinite containing 30 per cent magnesium oxide (MgO) in combination with other fertilisers like ammonium nitrate, triple super phosphate and potassium sulphate reduced the mortality of young *Picea abies* (spruce) in the forest and maintained the soil enzyme activities. Viana *et al.* (2021) studied the uptake of Mg from serpentine mixed with calcium carbonate limestone on *Zea mays* (corn) and *Phaseolus vulgaris* (common bean). Ottavio *et al.* (2020) in their review paper postulated that serpentinite may be used in agriculture in view of it containing high Mg, Si and trace elements. They also suggested that one of the serpentine minerals *viz.* brucite (containing magnesium hydroxide layer) may help to improve the pH of acidic soils in Brazil.

In Sabah, Labuk district has a high proportion of soils derived from serpentinite that is being cultivated with oil palm. The hard serpentine rocks are quarried and used for the construction of plantation roads and as under pavement for public tar roads. The soils of Pinianakan (Typic Acrudox), Tingkayu (Orthic Hapludolf) and Nebuso (Typic Hapludox) are derived from weathered ultrabasic igneous rock parent materials (Paramananthan, 1998; 2000). The IOI group is cultivating oil palm along the valley of Meliau range. The oil palms are growing and yielding well in soils derived from serpentinite without any Mg fertilisation for the past 18 years and contain very high Mg content in leaf 17 (IOI Group, 2021).

A research was carried out to evaluate if soft serpentinite rock collected at the base of the quarry can be used as a source of magnesium fertiliser. The objective of the first study was to find out the time required to extract the maximum amount of MgO by boiling the serpentinite sample in a mixture of nitric (HNO_3) and hydrochloric (HCl) acids. The objective of the second study was to evaluate the uptake of Mg from the ground serpentinite and to compare it with that of ground magnesium limestone at the second growth stage of oil palm seedlings in large polybags with river sand as the growing medium.

MATERIALS AND METHODS

Laboratory analysis of ground serpentinite and ground magnesium limestone

The serpentinite rock samples were obtained from a quarry site [latitude 5^0 95'14.24"N longitude 117^0 32'89.56"E (WGS94)] located at Nangoh village within the Labuk highland range in between the Bidu Bidu hill and Meliau mountain range in Sabah. Samples were collected from the site, dried, ground to powder and sieved through a standard sieve of 500 µm. The ground magnesium limestone was purchased from a local fertiliser supplier.

The percentage of MgO in both ground serpentinite and ground magnesium limestone samples were analysed with slight alteration to the Malaysian Standard methods MS 417: Part 6: 1994. According to the Malaysian Standard method, the time taken for boiling and stirring a known quantity of sample with a mixture of acids in a conical flask over a hot plate is 5 to 10 minutes. In the present study, the only alteration made was on the boiling time of sample, ranging from 0 to 16 hours. The methodology, reagents used, their concentrations, dilution and equipment for analysis remained the same as MS 417: Part 6: 1994. The present method involved the boiling of the sample in 100 ml deionised water mixed with 5 ml of 16 Molar (M) HNO_3 and 10 ml of 12 M HCl acids for a period of 0, 1, 2, 4, 8 and 16 hours to determine the maximum extractable MgO from samples of ground serpentinite and magnesium limestone.

Experiment on oil palm seedlings at large polybag stage

The experiment was set in a completely randomised block design (CRBD), where the treatments comprised of two types of Mg sources applied at four different rates of 5, 10, 20, and 30 g of MgO equivalent. Each dosage was replicated thrice, with four palms per replicate, thus each treatment comprised of 12 palms. In total, there were 27 treatment plots including the control treatment with no Mg fertilisers. The rates were determined after the laboratory analysis, whereby the ground magnesium limestone contains 18.7 per cent and ground serpentinite contains 29.2 per cent of MgO. The treatment numbers, respective rates of ground serpentinite and ground magnesium limestone fertilisers for each treatment are given in *Table 1*.

The large polybags (size 18 in. x 7.5 in. lay flat) were filled with coarse river sand which had a mean coarse sand content of 96 per cent with coefficient of variation (CV) of 1 per cent between the treatment plots. The mean exchangeable Mg content was low with 0.078 cmol per kilogramme soil and CV between treatments was 10.6 per cent. The polybags were placed at a distance of 0.9 m in a triangle pattern. Thick plastic sheets were placed underneath each polybag to prevent the root growth of the seedlings into the ground and absorbing any form of Mg from there. The centre core of the polybags were augured to the depth of 15 cm. The ground magnesium limestone or ground serpentinite were applied at the base of the planting hole. Three-month-old pre-nursery IOI Deli *Dura* x *Pisifera* seedlings of the same progeny crosses were planted. The fertiliser compound 15:15:15 (without Mg) was applied throughout the course of this experiment and was applied around the seedlings at a radius of 5 cm from the seedling collar. Five grammes of compound fertiliser 15:15:15 were applied weekly to each plant for the first 20 weeks of the trial. Subsequently, a rate of 7.5 g of the fertiliser was applied weekly until the thirty-second week.

Leaf 3 was regularly sampled at bimonthly intervals after planting for a period of eight months and the samples were sent to the laboratory for Mg analysis as per the method of Ng and Lancaster (1970). The leaf samples were cleaned, dried and the ash hydrolysed with a mixture of 12 M HCl and 12 M HNO_3 and analysed on atomic absorption spectrometer AAnalyst 200 at the wavelength of 285.21 nm.

The vegetative growth of the palms were measured at the eighth month of the trial. The groundwater from the tube well which was the water source used to irrigate the nursery seedlings was analysed for Mg content and found to be 3.70 ppm. The two-way analysis of variance (ANOVA) on Mg content in leaf

TABLE 1
TREATMENTS AND QUANTITY OF GROUND SERPENTINITE AND MAGNESIUM LIMESTONE USED FOR THE STUDY

Treatments	*Rates (g) in terms of MgO*	*Total number of palms*	*Quantity (g/palm)*	
			Ground serpentinite (29.2% MgO pH 8.2)	*Ground magnesium limestone (18.7% MgO pH 8.5)*
T0	Control (no MgO)	12	-	-
T1	5	12	17	-
T2	10	12	34	-
T3	20	12	69	-
T4	30	12	103	-
T5	5	12	-	27
T6	10	12	-	54
T7	20	12	-	108
T8	30	12	-	161

and vegetative growth at eighth month were analysed according to the methodology in the Hand Book of Agricultural Statistics (Chandel, 1984).

RESULTS

Laboratory analysis of ground serpentinite and ground magnesium limestone

The pH of ground magnesium limestone and ground serpentinite were 8.5 and 8.2 respectively. The Mg contents of the ground serpentinite and ground magnesium limestone solutions for different times of extraction are shown in *Table 2*.

It was observed that without boiling, but only by stirring of ground magnesium limestone in the mixture of acids for 2 minutes released higher MgO content of 14 per cent, while ground serpentinite released only 3 per cent. This indicates that the MgO released in the acid mixture from ground serpentinite soil is not immediate like ground magnesium limestone. In both ground serpentinite and ground magnesium limestone, the Mg released from the ground rocks stabilised at 12 hours of boiling in acid mixture. The maximum MgO extracted at twelfth hour in ground serpentinite was 33 per cent, while in ground magnesium limestone was 21 per cent. From hours 1 to 16 of boiling, the average MgO content in ground serpentinite was 29.2 per cent, while ground magnesium limestone had 18.7 per cent and this was the basis of determining the quantity of ground magnesium limestone and ground serpentinite for the experiment in nursery seedlings (*Table 1*).

Magnesium concentration in oil palm seedling leaf 3

The Mg contents in leaf 3 analysed at bimonthly intervals are given in *Table 3*.

The Mg concentration of the leaves of ground serpentine and ground magnesium limestone treatments in second and fourth month were generally higher than control treatment. However, the values were not significantly different from the control treatment. The leaf Mg concentration diminished in all treatments after the fourth month. From the eighth month onwards, the plants grown on ground magnesium limestone showed slightly higher Mg content than the rest of the treatments. The treatments with 10 g (T_6) and 20 g (T_7) of MgO were significantly higher ($p \leq 5\%$) than the control in the eighth month. The leaf Mg levels from ground serpentine and ground magnesium limestone

TABLE 2
RESULTS OF MgO % CONTENT AT DIFFERENT HOURS OF BOILING MAGNESIUM SOURCES

Time of boiling (hours)	*Ground magnesium limestone MgO (%) (pH 8.5)*	*Ground serpentinite MgO (%) (pH 8.2)*
1	17	24
2	18	26
4	17	27
8	18	32
12	21	33
16	21	33
Mean (1 to 16 hours)	18.7	29.2

TABLE 3
MAGNESIUM CONCENTRATIONS IN LEAF 3

Treatments and rates of MgO per seedling	*Mg (%)*				
	2 MAT	*4 MAT*	*6 MAT*	*8 MAT*	*10 MAT*
T0 (Control) (0 g)	0.36	0.28	0.26	0.24	0.21
T1 Ground serpentinite (5 g)	0.40	0.32	0.27	0.27	0.24
T2 Ground serpentinite (10 g)	0.43	0.33	0.26	0.25	0.24
T3 Ground serpentinite (20 g)	0.41	0.33	0.28	0.27	0.23
T4 Ground serpentinite (30 g)	0.42	0.34	0.25	0.26	0.23
Mean of ground serpentinite	0.42	0.33	0.27	0.26	0.24
T5 Ground magnesium limestone (5 g)	0.41	0.30	0.25	0.27	0.24
T6 Ground magnesium limestone (10 g)	0.39	0.33	0.26	0.29	0.24
T7 Ground magnesium limestone (20 g)	0.42	0.31	0.28	0.29	0.26
T8 Ground magnesium limestone (30 g)	0.41	0.33	0.26	0.28	0.25
Mean of ground magnesium limestone	0.41	0.32	0.26	0.28	0.25
Experiment general mean	0.41	0.32	0.26	0.27	0.24
Least significance difference ($p \leq 0.05$)	0.07	0.07	0.04	0.04	0.03
Coefficient of variation (CV)%	5.98	7.20	5.00	4.46	3.94

MgO - magnesium oxide, Mg - magnesium, MAT - months after treatment

were not significantly different at eighth month. In the tenth month the Mg level diminished further in all treatments. At the tenth month, ground magnesium limestone at 20 g (T_7) and 30 g (T_8) treatments showed statistically significantly higher leaf Mg contents than the control (T_0). The difference in levels of Mg in leaves of ground serpentine and control treatment was not significant at the end of trial, although the levels were slightly higher in serpentine treatments. The leaf Mg levels between ground magnesium limestone and ground serpentine treatments were also not significantly different in the tenth month.

The vegetative growth of seedlings at the eighth month is shown in *Table 4*.

The seedlings grown in all the treatments did not show significant differences in palm height, girth, rachis length and leaf area at the eighth month after transplantation. There was no significant difference in oil palm growth between Mg fertiliser types and control.

DISCUSSION

The laboratory results showed that the extraction of ground serpentinite stabilised at 12 hours to yield 33 per cent of MgO. The average MgO in ground serpentinite from 1 to 16 hours in the mixture of concentrated 12 M HCl and 16 M HNO_3 was 29.2 per cent. The study conducted by Shorrocks (1965) showed that ground serpentine contained 33.4 per cent MgO. Chinttenden *et al.* (1967) found ground serpentine to contain 35.0 per cent MgO. Proctor and Woodell (1971) analysed the serpentine rock from ultrabasic soils and found it to have 37.36 per cent MgO. Błońska *et al.* (2016) used serpentinite with 30 per cent MgO for their experiment in spruce

TABLE 4
VEGETATIVE MEASUREMENT OF OIL PALM SEEDLINGS AT EIGHTH MONTH

Treatments and rates of MgO per seedling	*Palm height (m)*	*Girth (m)*	*Leaf 3*	
			Rachis length (m)	*Actual leaf area (m^2)*
T0 (Control) (0 g)	1.19	0.064	0.61	0.212
T1 Ground serpentinite (5 g)	1.12	0.067	0.56	0.189
T2 Ground serpentinite (10 g)	1.25	0.066	0.66	0.241
T3 Ground serpentinite (20 g)	1.04	0.058	0.55	0.186
T4 Ground serpentinite (30 g)	1.12	0.060	0.58	0.192
Mean for ground serpentinite treatments	1.13	0.060	0.58	0.202
T5 Ground magnesium limestone (5 g)	1.03	0.058	0.55	0.188
T6 Ground magnesium limestone (10 g)	1.22	0.070	0.66	0.210
T7 Ground magnesium limestone (20 g)	1.13	0.058	0.59	0.208
T8 Ground magnesium limestone (30 g)	1.18	0.074	0.63	0.238
Mean of ground magnesium limestone treatments	1.14	0.065	0.60	0.211
Experiment general mean	1.14	0.064	0.60	0.207
Least significance difference ($p \leq 0.05$)	0.23	0.02	0.11	0.055
Coefficient of variation (CV)%	12.4	4.6	8.3	6.9

forest plants. The total MgO content of 33 per cent taken from the old quarry in between Bidu Bidu hill and Meliau range for this study is found to be similar to the MgO contents of other serpentinites in other parts of the world except for the serpentinite source reported by Proctor and Woodell (1971) which had the highest MgO content.

Shorrocks (1965) concluded that the ground serpentine was not a promising fertiliser source in view of the poor growth of *Pueraria phaseoloides* in pot culture experiments that compared it with kieserite. He experimented with 7 kg of soil in pot experiments with two rates of serpentinite at 3 g and 6 g (20% Mg or 33.4% MgO) of which one experiment at 18 months showed 24 to 65 per cent lower total dry weight than the kieserite treatment. In another experiment, the serpentinite treatment showed 48 to 51 per cent lower total dry weight of *Pueraria phaseoloides* when compared with kieserite of same Mg equivalent rates. Interestingly, in his study the growth of *Pueraria phaseoloides* treated with ground serpentine in one of the experiments was 74 to 308 per cent better, while in the other experiment the growth was 149 to 234 per cent better than control with no Mg treatment. Although the growth of *Pueraria phaseoloides* may not be as good as kieserite treatment, better growth effect was reported by using serpentinite control (with no Mg) in pot culture studies (Shorrocks, 1965). He postulated that heavy dressing serpentine may be required to be effective and to elevate the Mg status in the soil and plants may be able to absorb the Mg nutrient from the residual Mg in the soil.

Chinttenden *et al*. (1967) tried four different types of Mg fertilisers of ground serpentine, dunite, dolomite and talc-magnesite on tobacco, white clover and perennial ryegrass in pot cultures. They found that the Mg content in tobacco leaf was better in serpentine than dunite treatment. The uptake of Mg from talc magnesite and dolomite was lowest in tobacco leaf. In white clover, the Mg uptake was somewhat equal in serpentine, dunite and talc magnesite. However, dolomite responded inferiorly in Mg uptake in dolomite treated in tobacco was the lowest. In perennial ryegrass, all four types of Mg fertiliser performed better than the control treatment without Mg. The authors also found that the response of the Mg fertilisers types also depended on the plant types. The same authors carried out field trials of these four fertilisers in field pastures and found that dunite was the most effective Mg fertiliser, while serpentine and dolomite performed equally well and raised the Mg in pasture herbage. A response to talc magnesite, serpentine and dolomite was obtained by the pasture after one year of application which indicated that more time was needed for the uptake of Mg from these slow released sources.

Proctor (1971a;1971b) investigated the response of oats (*Avena sativa*) in various serpentine soils of England, Scotland and Sweden and one of the soils from Meikle Kilrannoch, Angus showed high toxicity to the plants even with enhanced NPK fertilisation. He found that the presence of high Mg and low Ca in oats was the cause of Mg toxicity, whereby the Mg level was 11 020 ppm and Ca was 1 262 ppm. He ruled out the toxicity of heavy metals as the analyses of nickel in the plant tissue of 10 ppm and chromium of 20 ppm was considered normal. However, toxicity due to other heavy metals in serpentine like Mn, Cu, Co and Cd were not mentioned by Proctor (1971b) and this could be a possible reason for toxicity of oats in serpentine soil.

Loganathan *et al.* (2005) conducted experiments using several sources of Mg fertilisers on pastures at the rate equivalent to 100 kg Mg per hectare for a period of 29 months in immature orthic pumice soil of pH 6.3. The type of Mg fertilisers tried were ground serpentine, acidulated serpentine, E-mag (magnesium oxide) and Epsom salts (magnesium sulphate heptahydrate). In their findings, the dissolution of Mg fertiliser sources in the soil were 15 to 20 per cent for ground serpentine, 50 to 98 per cent for acidulated serpentine, 95 per cent for E-mag and 98 per cent for Epsom salts. Dissolution of fertilisers were positively correlated to the recovery of nutrients on pasture herbage with 4-8 per cent in raw serpentine, 19-22 per cent for acidulated serpentine, 17 per cent for E-mag and 25 per cent for Epsom salt. Total recovery of Mg from applied sources of fertiliser in soil (0-15 cm) and in pasture herbage was 51 per cent for Epsom salt, 53-90 per cent in acidulated serpentine, 91-95 per cent for ground serpentine and 90 per cent for E-mag. The higher recovery of Mg was observed in the soil for less soluble fertiliser sources as compared to highly soluble fertiliser like Epsom salt. It appears that the Mg recovery on plants from raw ground serpentine was very low and slow, which could explain the reason why the uptake of Mg in oil palm seedling was not significant from ground magnesium limestone. There might be a need to re-formulate raw serpentine through an acidulated process to release more MgO to the plants.

Błońska *et al.* (2016; 2017) studied the heavy dressing of ground serpentine at the rate of 2 to 4 tonnes per hectare to reduce mortality in young spruce forest in Poland. The application of serpentine with other nitrogenous, phosphatic and K fertilisers improved the pH of "O" horizon of highly acidic soil of haplic podozol and cambisol and stimulated the dehydrogenase enzyme activities, reduction in molar ratio of exchangeable Ca and Mg ions. Such reduction of Ca/Mg ratio may facilitate the long-term absorption of Mg by roots of the trees. Moreover, the release of Mg was slow in ground serpentine and the Mg content of the needle of spruce pine was not significantly different from the control treatment (no fertilisation) (Błońska *et al.*, 2017).

Pot culture study conducted by Ten Berge *et al.* (2012) for a period of 32 weeks with olivine material, found an increment in dry matter and Mg content of perennial ryegrass (*Lolium perenne*) with the increase in rates of olivine applied. They also observed that the uptake of heavy metal nickel was five times higher at 2 669 ppm in the highest rate of 392 g MgO or 235 g of Mg (equivalent to 1 kg of product) applied to the plants as compared to control with no olivine Mg treatment.

Viana *et al.* (2021) tried serpentine treatments equivalent to 1.2, 2.3 and 3.5 tonnes per hectare mixed with 5 tonnes equivalent per hectare of calcium carbonate limestone. Dolomite (5 tonnes per hectare) was the control treatment and two plant species, *Zea mays* and *Phaseolus vulgaris,* grown on a dystropic red yellow latosol were studied. In another study, the same authors tried serpentine at rates of 0.5, 0.9, 1.4 tonnes per hectare equivalent mixed with 2 tonnes per hectare equivalent of calcium carbonate limestone in a quartzipsamment soil. Here again dolomite was used as control applied at an equivalent of 2 tonnes per hectare. Both experiments were conducted for a period of 40 days. They found that the dry weights of both corn and common bean plants in both soils were not statistically significantly different between dolomite and serpentine treatments, although the former gave slightly better plant weight. The Mg content in the plants were significantly higher in dolomite than serpentine treatments. The reason for low Mg in the plants possibly could be due to the dilution of serpentine with 5 tonnes per hectare of limestone in dystropic red yellow latosol soil and 2 tonnes per hectare in quartzipsamment soil.

Poeloengan (1995) studied the Ni toxicity in oxisols of ultrabasic soil planted with oil palm and found that the soils are rich in Ni, but poor in K, Mg and Ca, although the Mg content in the soil of published data showed Mg of 0.9 cmol per kilogramme at 0-10 cm and 0.37 cmol per kilogramme Mg at 10-44 cm. Moreover, the palms affected with Ni toxicity manifested retarded growth, pale yellow stripes running along the laminae of leaves, knotted and stunted roots and poor fresh fruit bunch (FFB) and fruit formation.

On the contrary, 24-year-old oil palms grown on soils derived from serpentinite parent material like Pinianakan, Nobusu, Tingkayu series in Sabah along the Meliau range have shown mean high yields of 29.25 tonnes FFB per hectare per year for the period of 2018-2020. These palms showed exceptionally high leaf Mg of 0.36 to 0.40 per cent even without the application of any form of additional Mg fertilisers for the past 18 years (IOI Group, 2021).

In the same location, Paramananthan (2000) studied the soil profile of Pinianakan series from this estate and showed the average soil exchangeable Mg content was 1.94 cmol per kilogramme up to a soil depth of 130 cm, while Nobusu, an alluvium soil, had an average exchangeable Mg level of 5.36 cmol per kilogramme for the same soil depth. High exchangeable Mg in the soil is the main reason for high Mg content in oil palm frond 17. In these soils, the Mg fertilisers can be completely avoided throughout the life cycle of the planted palms. The water analysed from hill creeks and streams of such soils showed high Mg content of 29.10 ppm, which is almost eight times more than that of the water used for irrigation in the nursery of the present study at 3.70 ppm. Tashakor *et al.* (2018) had also reported high Mg contents in the tributaries of ultrabasic soils, ranging from 85 to 135 ppm. The water flowing through the weathering rocks of ultrabasic igneous parent material has high Mg content and that could be another reason for high Mg in the oil palm leaf 17.

Overall, the results from this study showed that the ground serpentinite is similar to ground magnesium limestone in effect to Mg uptake and growth of oil palm seedlings. The Mg availability is very low as oil palms subjected to these treatments are similar to the control treatment, that is without Mg application. In this study, the leaf Mg status ranging from 0.23 to 0.26 per cent by applying ground serpentine and ground magnesium limestone on seedlings grown in a sand medium is a sub optimal Mg level for young nursery seedlings. In another study by Amirul *et al.* (2021) using compound 12/12/17/2, where kieserite was the component of Mg source, showed a higher leaf Mg level. Here, the kieserite was applied from compound fertiliser equivalent to 20 g per seedling periodically and the seedlings were grown in Bungor soil medium with a mean exchangeable Mg of 0.43 cmol per kilogramme soil. The oil palm leaf Mg status was 0.33 per cent at 8.5 months after transplantation.

This study shows that ground serpentinite rock is comparable to ground magnesium limestone as a source of Mg. Leaf Mg status declined after the fourth month of application even for the highest rate of 30 g MgO per oil palm seedling. Higher rates of these fertilisers are possibly required in order to sustain the Mg status of the plants after the fourth month. Natural weathering process may allow slow release of Mg from the serpentinite rock to the soil in the field as seen by the high Mg status and performance of oil palms grown on such soils in IOI estates without the use of Mg fertilisers at all. More work is needed to ascertain the uptake in oil palm. Variable responses of serpentinite as Mg fertiliser as compared to ground magnesium limestone on plants have been reported (Chinttenden *et al.*, 1967; Loganathan *et al.*, 2005; Błońska *et al.*, 2016; Błońska *et al.*, 2017; Viana *et al.*, 2021). Most of them agreed that there is accumulation of Mg in soil as the result of serpentinite application to the soils (Loganathan *et al.*, 2005; Błońska *et al.*, 2016; Błońska *et al.*, 2017). For long-term Mg availability from ground serpentinite can be increased with a higher dosage without the involvement of heavy metal toxicity to plants (Ten Berge *et al.*, 2012). As per Shorrocks (1965), for the possibility to increase Mg availability from ground serpentine one should try higher rates of more than 30 g MgO per plant. Perhaps, in a new experiment kieserite could be used as one of the treatments. Instead of applying onto planting hole as the method of application, surface and spilt applications may have to be tried. One important aspect is to look into the possibility of releasing MgO from ground serpentinite through a partial acid treatment and the methods for such an approach needs further investigation.

CONCLUSION

The total MgO content in ground serpentinite was higher than the ground magnesium limestone. Nevertheless, the uptake and leaf Mg status in nursery seedlings does not differ significantly from ground magnesium limestone and ground serpentine. Moreover, leaf Mg levels between the control without Mg and ground serpentine do not differ significantly throughout the experiment. Under natural condition, the mature palms grown in soils derived from serpentinite parent material are generally responding well without any additional Mg fertilisers for several years with respect to leaf Mg status and yield. More studies are needed to understand the use of ground serpentinite material as fertiliser for oil palm.

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