UNIVERSITI PUTRA MALAYSIA

THE EFFECTS OF DOLOMITIC LIMESTONE AND GYPSUM ON CHEMICAL PROPERTIES OF AN ULTISOL AND OXISOL IN MALAYSIA AND ON THE GROWTH OF CORN (ZEA MAYS L.)

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FPP 1992 1

THE EFFECTS OF DOLOMITIC LIMESTONE AND GYPSUM ON CHEMICAL PROPERTIES OF AN ULTISOL AND OXISOL IN MALAYSIA AND ON THE GROWTH OF CORN (*Zea mays* L.)

by

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Thesis Submitted in Fulfillment of the Requirements
for the Degree of Master in Agricultural Science
in the Faculty of Agriculture,
Universiti Pertanian Malaysia,
Serdang, Selangor Darul Ehsan.

July 1992

ACKNOWLEDGEMENTS

The author would like to express his profound gratitude and appreciation to the following people for their invaluable contributions in the completion of this dissertation:

My chairman, Associate Professor Dr. Shamshuddin Jusop, for his constant encouragement, guidance and valuable comments in completing of the thesis;

To my committee members, Tuan Haji Syed Omar Syed Rastan and Dr. Hamdan Suhaimi, for their understanding and constructive criticism and also for being members of the graduate committee;

Tuan Haji Ahmad and his assistants at MARDI for help in the analysis using Inductively Coupled Plasma Emission Atomic Spectrophotometer;

The members of Soil Mineralogy Analyses Laboratory, Department of Soil Science, UPM, especially Azali, Jamilah, Mas and khuzaimah, who have directly or indirectly contributed to the success of this thesis; and

My wife, my son, and members of my family for their continued encouragement, moral and financial support throughout the study.

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LIST OF ABBREVIATIONS

GML	:	Ground Dolomitie Limestone
CEC	:	Cation Exchange Capacity
ECEC	:	Effective Cation Exchange Capacity
kPa	:	Kilo Pascal
PVC	:	Polyvinylchloride
ICPEAS	:	Inductively Coupled Plasma Emission Atomic Spectrophotometer
CEC_T	:	Total Cation Exchange Capacity*
CEC_B	:	Basic Cation Exchange Capacity*
AEC	:	Anion Exchange Capacity*
μScm^{-1}	:	MicroSiemens per centimeter

* : as defined by Gillman and Sumpter (1986)

Abstract of the thesis submitted to the Senate of Universiti Pertanian Malaysia in fulfilment of the requirement for the degree of Master of Agricultural Science.

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July 1992

Chairman : Associate Prof. Dr. Shamshuddin Jusop

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Ultisols and Oxisols are acidic in nature, with low CEC, low exchangeable bases, and high Al saturation, and are dominated by variable-charged minerals. The soils need to be ameliorated before they can be utilized productively. This study was conducted to determine the reactions taking place in the soils as affected by limestone and gypsum applications and to assess the effects of these changes on the growth of corn.

Based on mineralogy, charge and texture, two soils were selected for investigation in the glasshouse. These soils were Bungor (Ultisol) and Prang series (Oxisol). In experiment 1, the soils were repacked into PVC leaching columns to a depth of 90 cm. Ground magnesium limestone (GML), gypsum and their combinations were incorporated

into the soils at 0-5 cm depth, and were subjected to leaching environments for 6 months. In experiment 2, the soils were mixed with GML, gypsum and their combinations as a precursor to a glasshouse trial to asses the response of corn to the ameliorants. The trial involved equilibrating the ameliorants and basal nutrients for 30 days prior to the corn growth for 40 days.

The results showed that the Ultisols and Oxisols differed in their mineralogy and charge properties. The Ultisols contained mainly kaolinite, while the Oxisols contained kaolinite, gibbsite, and goethite. The chemical properties of these three minerals were affected by the application of limestone and gypsum.

GML application increased soil pH, resulting in an increase in negative charge on clay surfaces. This explain the retention of Ca in the zone of GML incorporation. In the gypsum treated soils, Ca moved deeper into the profile, ameliorating Ca deficiency in the subsoil. The study indicates that GML application in combination with gypsum help alleviate Al toxicity in the top soil and Ca and/or Mg deficiency in the subsoil.

Sulfate from the gypsum was adsorbed on the oxides of Fe and/or Al. The adsorption of SO_4^{2-} resulted in an increase in negative charge and soil pH. This phenomenon was well manifested in the Oxisol due to the presence high amount of oxides. Data from soil solutions and leachates showed that gypsum application resulted in precipitation of alunite and/or jurbanite.

Corn can be grown on Ultisol and Oxisol in Malaysia if the soils are treated by GML in combination with gypsum at a suitable rate. It was found that 2 t GML applied together with 1-2 t gypsum ha^{-1} yielded near maximal top corn weight. At this rate of application, soil solution pH increased from 4.0 to about 5.3, with a consequent reduction in Al and Mn concentrations to about 20 and 6 μM, respectively. It was observed that Al concentration in the soil solution was positively correlated with the amount of Al in the leaf, but negatively correlated with relative top corn weight. Similarly, Ca and Mg in the soil solutions were positively correlated with Ca and Mg in the leaf. It was observed that Mg in the soil solution was positively correlated with relative top corn weight. This study shows that Al, Ca and Mg concentrations, and Ca/Al concentration ratio in the soil solution can be used as indices of soil acidity.

Abstrak tesis yang dikemukakan kepada Senat Universiti Pertanian Malaysia sebagai memenuhi keperluan untuk mendapatkan Ijazah Master Sains Pertanian.

KESAN BATUKAPUR DOLOMIT DAN GIPSUM KE ATAS SIFAT KIMIA TANAH ULTISOL DAN OKSISOL DI MALAYSIA DAN KESANNYA KE ATAS PERTUMBUHAN JAGUNG (Zea mays L.)

Oleh

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Julai 1992

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Ultisol dan Oksisol adalah tanah berasid, mempunyai KPK, bes bertukarganti yang rendah sementara tinggi ketepuan Al dan mengandungi mineral muatan berubah. Tanah-tanah ini perlu diperbaiki sebelum ianya boleh digunakan untuk pertanian. Penyelidikan telah dijalankan untuk menentukan reaksi kimia yang berlaku pada tanah dan seterusnya menilai perkaitannya terhadap pertumbuhan jagung.

Berdasarkan kepada mineralogi, sifat muatan dan tekstur, dua siri tanah telah dipilih untuk penyelidikan di rumah kaca. Tanah tersebut adalah siri Bungor (Ultisol) dan Prang (Oksisol). Di dalam penyelidikan pertama, profil tanah sedalam 90 cm telah dimasukkan ke dalam tiub larutlesap PVC. Batukapur dolomit, gipsum dan kombinasi antara kedua-duanya diberikan pada paras 0-15 cm

dan proses larutlesap dijalankan selama 6 bulan. Pada penyelidikan kedua tanah yang telah dicampurkan dengan GML, gipsum dan kombinasi antara kedua-duanya digunakan di dalam penyelidikan rumah kaca untuk melihat reaksi tanaman jagung terhadap rawatan yang telah diberikan. Baja asas juga diberikan 30 hari terdahulu dan jagung dituai selepas berumur 40 hari.

Hasil analisis menunjukkan Ultisol dan Oksisol adalah berbeza dari segi mineralogi dan sifat muatannya. Tanah Ultisol mengandungi kaolinit manakala Oksisol mengandungi kaolinit, gibsit dan goetit sebagai mineral utama. Sifat kimia ketiga-tiga mineral tersebut dipengaruhi oleh pemberian batukapur dolomit dan gipsum.

GML meningkatkan pH tanah yang mengakibatkan bertambahnya muatan negatif pada permukaan lempung. Ini dapat menerangkan bagaimana Ca tetap kekal di bahagian di mana GML diberikan. Di dalam tanah yang dirawat dengan gipsum, Ca bergerak lebih jauh ke dalam profil tanah, seterusnya dapat memperbaiki kekurangan Ca di profil bawah. Penyelidikan ini menunjukkan GML dan kombinasinya dengan gipsum dapat memperbaiki keracunan Al di lapisan atas serta memperbaiki kekurangan Ca dan/atau Mg di profil bawah.

Sulfat daripada gipsum dijerap oleh oksida Fe dan/atau Al. Jerapan ini mengakibatkan peningkatan muatan negatif dan pH tanah. Fenomena ini terjadi dalam Oksisol kerana kandungan mineral oksida yang tinggi. Data dari larutan tanah dan hasil larutlesap menunjukkan gipsum menyebabkan pemendakan alunit dan/atau jurbanit.

Tanaman jagung dapat tumbuh dengan lebih baik di tanah Ultisol dan Oksisol di Malaysia sekiranya tanah-tanah tersebut terlebih dahulu dirawat dengan GML berserta gipsum dengan kadar dan kombinasi yang sesuai. Kadar 2 t GML berserta 1-2 t gipsum ha^{-1} memberikan hasil jagung yang hampir tertinggi. Pada kadar tersebut, pH larutan tanah meningkat dari 4.0 kepada kira-kira 5.3, manakala kepekatan Al dan Mn turun kepada 20 dan 6 μM. Ternyata bahawa kepekatan Al di dalam larutan tanah mempunyai perkaitan positif dengan jumlah Al di dalam daun, sementara perkaitannya adalah negatif degan berat relatif jagung. Kepekatan Ca dan Mg di dalam larutan tanah juga menunjukkan perkaitan positif dengan jumlah Ca dan Mg di dalam daun. Mg di dalam larutan tanah mempunyai perkaitan positif dengan berat relatif jagung. Kajian ini menjelaskan bahawa Al, Ca dan Mg di dalam larutan tanah, serta nisbah Ca/Al di dalam larutan tanah boleh digunakan untuk menentukan tahap kemasaman tanah.

CHAPTER I

INTRODUCTION

The world is using about 40% of the potential land sources for agricultural purposes (Sanchez and Salinas, 1981). The areas which have high potential for agricultural development are partly located in tropical region where the soils are acidic and have low fertility status. These soils are classified by the United States Soil Taxonomy as Ultisols and Oxisols (Soil Survey Staff, 1975; 1990). Oxisols are soils that have undergone intensive weathering, and have oxic B horizons rich in kaolinite and sesquoxides. They do not have argillic horizons. On the other hand, Ultisols are characterized by the presence of argillic horizons. They are acid soils and have base saturations of less than 35% at a depth of 75 cm.

Ultisols and Oxisols occupy about 72% of the land surface in Malaysia (IBSRAM, 1985). The soils are acidic in nature, with pH values ranging from 4 to 5 (Tessens and Shamshuddin, 1983). The soils are high in Al saturation and base deficient. Their cation exchange capacities vary with the change in pH. The low fertility status is the reason for the soils being not agriculturally very productive, unless they are amended with lime and/or organic matter.

The charges on the surfaces of the oxides and kaolinite in Ultisols and Oxisols are variable in nature. The values change with pH and ionic strength (Uehara and Gillman, 1981). The chemistry of the soils containing these minerals can be manipulated by application of inorganic and organic amendments such as lime, gypsum and palm oil mill effluents.

Lime has been applied frequently in cocoa plantation to reduce soil acidity. As a result, cocoa production has improved. The yield of corn grown on Ultisols is reported to improve as a result of lime application (Shamshuddin et al., 1991). The effects of these amendments on soil chemical properties and yield of crops have been studied, but the mechanism of NO_{3^-}, SO_4^{2-} and Ca^{2+} movements in the soil profiles treated with the amendments has not been clearly explained.

Most of the Ca from lime application does not move beyond the zone of incorporation (Pavan et al., 1984; Gillman et al., 1989), thus the subsoil remain deficient in Ca after lime application. Sumner et al. (1986) suggested that Ca subsoil deficiency could be overcome by surface application of gypsum. Top soil and subsoil calcium deficiency can be alleviated by surface application of lime together with gypsum (Pavan et al., 1984).

The objectives of the study were: (i) to determine the effects of dolomite limestone (GML) and gypsum applications on chemical properties of an Ultisol and Oxisol; (ii) to study the mechanism of cations and anions movement in the soils; and (iii) to determine the effects of limestone, gypsum and their combinations on corn growth.

CHAPTER II

REVIEW OF LITERATURE

Parent Materials

Soil series in Malaysia have been defined at least in part by the rocks from which the soils are derived (Paramananthan, 1987). Beside parent material, geomorphology plays a very important role in soil formation in Peninsular Malaysia (Paramananthan and Zauyah, 1986). Soil chemical properties are also being used to define soil series. The differences in chemical and mineralogical composition of different rock types are often reflected in the resultant soil types. For instance, the rate of weathering of the rock depends on its iron content. Rocks with high iron content weather more readily, resulting in soils which have low silt content and rich in oxides of iron and aluminium.

Granite is the most important rock type in Peninsular Malaysia, occupying large areas in the upland. Other rock types include shale, limestone, sandstone and volcanic tuff. Figure 1 shows rock type distribution in Peninsular Malaysia. These rocks become the major parent materials of the soils in the Peninsula.

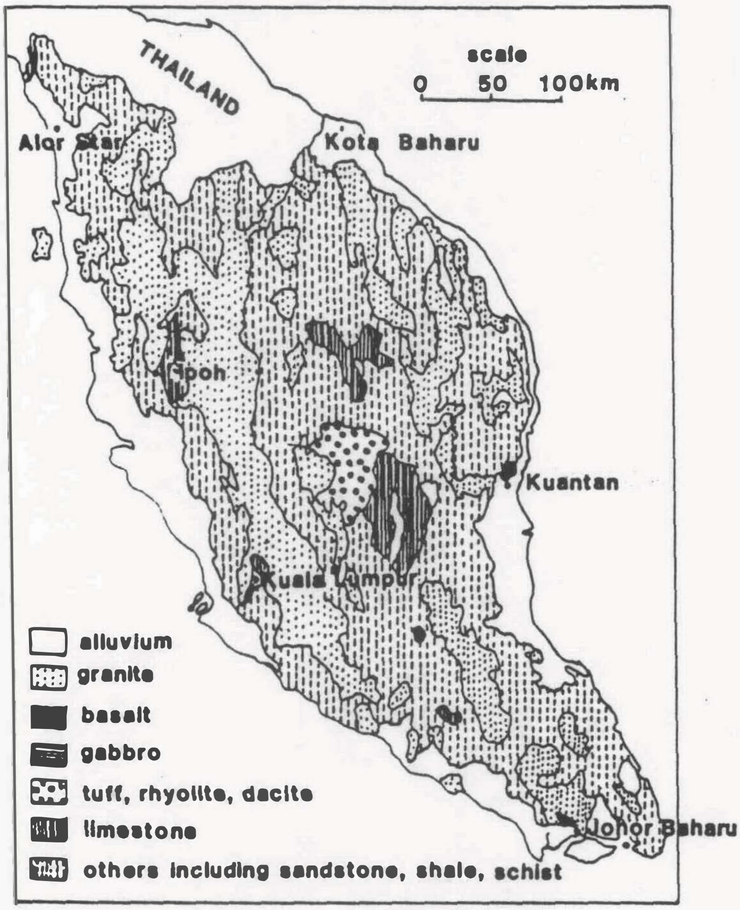

Figure 1

Rock Type Distribution in Peninsular Malaysia (Law, 1968; Staufer, 1973).

Detailed morphological, chemical, mineralogical studies of a wide range of soils have been carried out in an effort to characterize and reclassify the major soils found in Peninsular Malaysia (Paramananthan, 1977; Tessens and Shamshuddin, 1983). The results of these studies have been reported in journals, seminars and monographs. The information gathered from these publications has been used to identify soil series required for this study.

Weathering

Malaysia is located on the Equator. Like many of the tropical countries in Southeast Asia, Malaysia has a warm humid climate, which is classified as subtype Af using Koppen's Classification (Paramananthan and Eswaran, 1983). The mean annual air temperature is 24 ^{o}C, while the mean annual rainfall is 2000 mm. This high temperature and rainfall result in a high degree of rock weathering. The soils that form under these conditions are highly leached and weathered.

The rapid rock weathering in Malaysia results in soils containing kaolinite, iron oxide and aluminium oxide (Tessens and Shamshuddin, 1983; Paramananthan and Eswaran, 1983), which are clay minerals with variable charges. Most of the physico-chemical properties of the soils are influenced by the properties of these minerals. The minerals have low nutrient retention properties, thus, the soils are reduced almost to an inert medium (Eswaran and Sys, 1984).

Mineralogy

As a stated above, weathering under condition of high temperature and rainfall produces the soils containing 1:1 clay minerals and oxides of Al and Fe. The dominance of a mineral type depends largely on the degree of weathering. Less weathered soils (fig. 2) contain large amounts of kaolinite, mica (10 A) and smectite (14.5 A). Smectite was absent in a more highly weathered soil (fig. 3). Gibbsite and kaolinite dominate the clay fraction of a soil in an ultimate stage of weathering (fig. 4). Data in table 1 shows the mineralogy of the soil residual parent materials in Peninsular Malaysia arranged in increasing order of degree of weathering. It can be noticed that Fe oxides increase with degree of weathering. On the other hand, mica content decreases with increase degree of weathering.

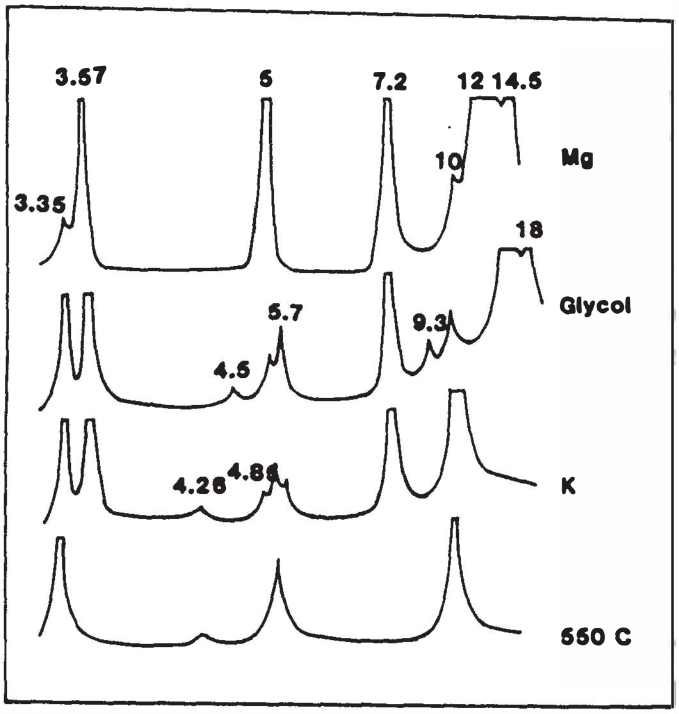

Figure 2

X-ray Diffractograms of the Clay Fraction (B2t) in Kuala Brang Series Soil (Shamshuddin, 1990).