Research Application Summary

Characterisation of vermiculites from the Neoproterozoic Mozambique Belt of Tanzania for agricultural applications

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Abstract

The study assessed the mineral phases and properties of five Tanzanian vermiculites in response to the temperature used to expand them with respect to their potential suitability for agricultural applications. One sample from Palabora Mines in South Africa was included for comparison. X-ray diffraction was used to establish their mineralogy. Water release characteristic, cation exchange capacity (CEC) and pH were among the agronomic properties assessed after heating the samples at 15, 200, 400, 600 and 800^{o} C in a muffle furnace. The XRD studies revealed that not all the studied samples were vermiculites; some were hydrobiotites with a wide variety of accessory minerals, which cannot preclude them for agricultural applications. Heating decreased the CEC and exchangeable Mg, Ca and Na while increased exchangeable K particularly in hydrobiotites. Vermiculites had high CEC and thus, they are suitable as a growing medium with ability to retain plant nutrients from leaching. However, heating above 600 ^{o}C should be avoided as it reduced the CEC of vermiculites by more than 80% and made some of the exfoliated products strongly alkaline and, thus, unfavourable for crop production. Although samples from Tanzania expanded on heating, their capacity to retain plant available water was relatively low in comparision to that from Palabora. Disintegration on heating and the presence of a high amount of iron could be among the factors affecting their water release characteristic.

Key words: Hydrobiotite, Mozambique belt, Tanzania, Vermiculite

Résumé

L'étude a évalué les phases minérales et les propriétés de cinq vermiculites tanzaniennes en réponse à la température utilisée pour les développer en fonction de leur aptitude potentielle pour les applications agricoles. Un échantillon de Mines de Palabora en Afrique du Sud a été inclus pour la comparaison. La diffraction des rayons X a été utilisée pour établir leur minéralogie. La caractéristique de libération de l'eau, la capacité d'échange des cations (CEC) et le pH ont été parmi les propriétés agronomiques évaluées après avoir chauffé les échantillons à 15, 200, 400, 600 et 800 o C dans un four à moufle. Les études de diffraction des rayons X ont révélé que les échantillons étudiés n'étaient pas tous des vermiculites; certains étaient des hydrobiotites avec une large variété de minéraux accessoires, qui ne peuvent pas les exclure pour des applications agricoles. Le chauffage a diminué la CCE et le manganèse Mg, le calcium Ca et le sodium Na échangeables tandis il a augmenté le potassium K échangeable en particulier dans les hydrobiotites. Les vermiculites avaient la CEC élevée et, par conséquent, elles peuvent être utilisées comme un milieu de culture avec la capacité de retenir les éléments nutritifs des plantes provenant de la lixiviation. Cependant, le chauffage au-dessus de 600 ° C devrait être évité car il a réduit la CCE des vermiculites de plus de 80% et a fabriqué certains produits exfoliés fortement alcalins et, par conséquent, défavorables à la production agricole. Bien que les échantillons en provenance de Tanzanie ont dilaté par chauffage, leur capacité à retenir l'eau disponible pour les plantes a été relativement faible en comparaison à ceux de Palabora. La désintégration par chauffage et la présence d'une grande quantité de fer pourraient être parmi les facteurs qui affectent leur caractéristique de libération de l'eau.

Mots clés: Hydrobiotite, Chaine du Mozambique, Tanzanie, vermiculite

Background

Tanzania is an agricultural country in which 90% of the rural population gets their earning through subsistent rain-fed agriculture (Mmbaga and Lyamchai, 2001). However, crop productivity is generally low and is compounded, among other factors, by inadequate content and retention of plant nutrients and water (Mwakalila, 2006). The outcome is frequent food shortage and low earnings not only to the farmers but also to the nation. Importation of food from outside the country is sometimes inevitable. Despite having a number of vermiculite deposits (Harris, 1961); no attempt has been made in Tanzania to use them to improve the soil fertility in order to increase crop production as done in other countries (Jayabalakrishnan, 2007). One reason that is hindering the exploitation of the Tanzanian vermiculites for agricultural purposes is the absence of adequate information on their potential suitability.

Literature Summary

Vermiculite has a high cation exchange capacity (CEC) falling between 50 and 150 $cmol_{(+)}/kg$ (Hindman, 2006; Van Straaten, 2002). The high CEC is an indication that vermiculite has a good fertility potential and a positive response to fertiliser application when used as a growing medium (Landon, 1991). It expands when heated and becomes light and porous with a high ability to retain moisture and nutrients as well as to release them gradually to the roots of plants (Potter, 2000). These properties make it a suitable material for use as a soil amendment, an additive to mulch, potting soils, and growing mixes (Potter, 2000). Characterisation of vermiculites prior to their utilisation is essential because literature shows that they occur with a wide range of compositions and variable physical and chemical properties (de la Calle and Suquet, 1988; Van Gosen *et al*., 2005). In addition, they occur with a substantial amount of accessory minerals, some of which could be of health concerns (Whitehouse *et al*., 2008).

Study Description

Six vermiculite samples were used. Five of these were from Tanzania (KL1, KL2, MS, MK1 & MK2) while the sixth was from South Africa (PB), included for comparison. X-ray diffraction was used to identify the mineral phases. Water release characteristic, pH and CEC were determined in response to heating of the samples at 15-800^{o} C.

Research Application

The XRD studies found both vermiculites and hydrobiotites in the samples with a number of accessory minerals which are safe for agricultural applications (Table 1). Samples from

Table 1. Mineral composition (% wgt) in vermiculite samples from Tanzaniaas determined by XRD.

Sample	Vermiculite	Hydrobiotite	Tri-mica	Quartz	Calcite	Rutile	Hematite	Apatite	Amphibole	Pyroxene	Sapphirine	Opal-CT	Total
KL1	81.8			0.3			1.6					16.1	99.7
KL2	100.0												100.0
MS	78.5			0.8							20.5		99.8
MK1	15.2	74.3		6.5	1.2	0.9		2.0					100.0
MK2	60.0	16.3		2.3	1.0	1.7	1.4	2.7	6.7	8.3			100.4
PB	0.9	87.4	10.7		1.0								99.9

Tanzania can retain plant-available water but their ability is less than that from South Africa (marked PB) (Fig.1). Heating of vermiculites decreased the CECs and exchangeable Mg^{2+}, Ca^{2+}, and Na^{+} but increased the availability of exchangeable K^{+} (Table 2). However, heating above 600°C reduced the CEC of vermiculites by more than 80% (Table 2) and made some of the exfoliated products strongly alkaline (Fig. 2) and, thus, unfavourable for crop production.

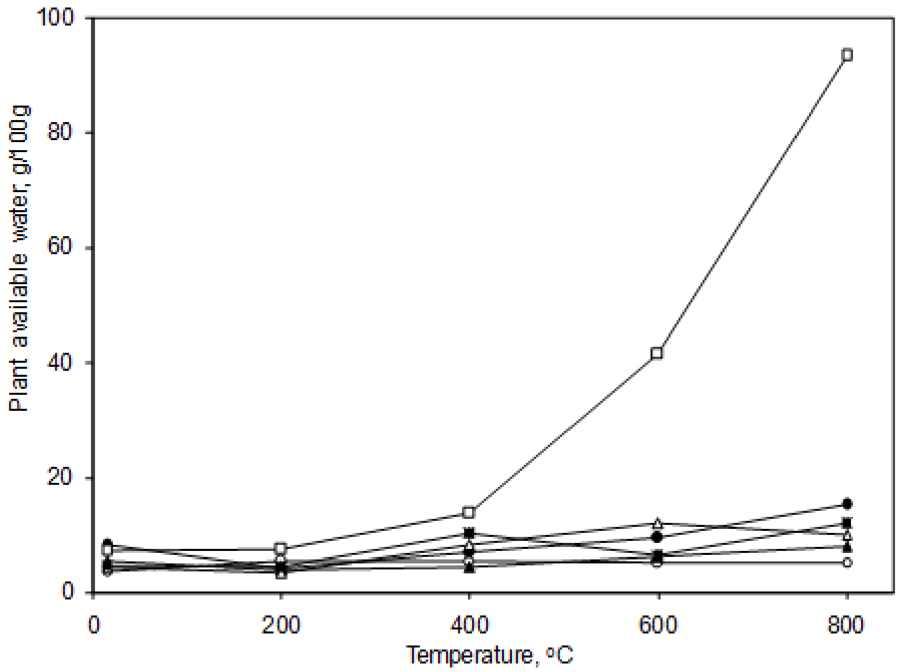

Figure 1. Relationship between temperature and retention of plant available water for the six samples: Open squares refer to sample PB, open triangles sample MK1, shaded circles refer to sample KL1; shaded squares sample MK2, shaded triangles sample MS, and open circles (slightly obscured) sample KL2. Each plotted value represents a mean of three replicates. Error bars omitted for clarity.

Table 2. Overall effect of heating on the CEC and exchangeable cations for vermiculite samples from Tanzania.

Temperature	CEC	Exchangeable cations, $cmol_{(+)}$/kg			
°C	$cmol_{(+)}$/kg	Mg^{2+}	Ca^{2+}	K^{+}	Na^{+}
15	89.7a	58.0b	14.5a	0.19c	1.14b
200	68.1b	61.7a	14.5a	0.20c	1.34a
400	70.5b	51.8c	5.3b	0.20c	1.08b
600	62.6c	27.3d	2.9c	0.51a	0.44c
800	16.7d	4.1e	3.1c	0.45b	0.07d
Standard error	1.7	1.3	0.2	0.01	0.04
CV, %	13.8	13.1	10.8	13.2	23.0

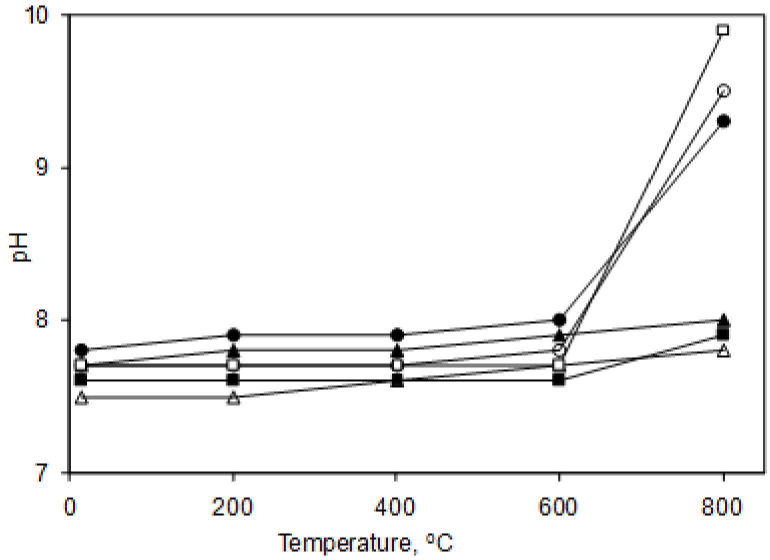

Figure 2. Relationship between temperature and pH for the six samples: Open squares sample PB, open circles sample KL2, shaded circles refer to sample KL1; shaded triangles sample MS; open triangles sample MK1; and shaded squares sample MK2. Each plotted value represents a mean of three replicates. Error bars omitted for clarity.

Acknowledgement

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References

De la Calle, C. and Suquet, H. 1988. Vermiculite. In: Bailey, S.W. (Ed.). *Hydrous Phyllosilicates (Exclusive of Micas): Reviews in Mineralogy*. Mineralogical Society of America. Washington, D.C. pp.455-496.

Harris, J. F. 1961. Summary of the Geology of Tanganyika. Part IV. Economic Geology. Government printer, Dar es Salaam, Tanzania. 141pp.

Hindman, J.R. 2006. Vermiculite. In: Kogel, J.E.,Trivedi, N.C, Barker, M.J. and Krukowski, S. (Eds.). *Industrial Minerals and Rocks, Commodities, Markets and Uses*. 7th edition. Society of Mining, Metallurgy and Exploration. pp. 1015-1026.

Jayabalakrishnan R.M. 2007. Effect of vermiculite as an ameliorant for paper mill effluent irrigated soil and on the productivity of sunflower. *Journal of Agronomy* 6(1):175-178.

Landon, J.R.1991. Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical Publishers, Harlow, England. 474pp.

Mmbaga, T.E. and Lyamchai, C.Y. 2001. Drought management options in maize production in Northern Tanzania. 7th Eastern and Southern Africa Regional Maize Conference, 11-15th February, 2001. pp 281-287.

Mwakalila, S. 2006. Socio-economic impacts of irrigated agriculture in Mbarali District of south-west Tanzania. *Physics and Chemistry of the Earth* 31:876-884.

Potter, M.J. 2000. Vermiculite. In: Minerals Yearbook-2000. U.S. Geological Survey. pp.83.1-83.5.

Van Gosen, B.S., Lowers, H.A.,Bush, A.L., Meeker, G.P., Plumlee, G.S., Brownfield, T. K. and Sutley, S.J. 2005. Reconnaissance study of the geology of U.S. vermiculite deposits – Are asbestos minerals common constituents? Version 2.0, USGS, Bulletin 2192. 8pp.

Van Straaten, P. 2002. Rocks for Crops: Agro-minerals of Sub-Saharan Africa. International Centre for Research in Agroforestry Project. Nairobi, Kenya. 388pp.

Whitehouse, A. C., Black, C.B., Heppe, M.S., Ruckdeschel, J. and Levin, S.M. 2008. Environmental exposure to Libby asbestos and mesotheliomas. *American Journal of Industrial Medicine* 51:877-880.