K from zeolite: glasshouse trial for testing K availability to the plants

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Abstract
MesoLite, a zeolite material manufactured by NanoChem Holdings Pty Ltd is made by caustic reaction of kaolin at temperatures between 80-95°C. This material has a moderate surface area (9~12 m^2/g) and very high cation exchange capacity (500meq/100g). To measure the availability of K in K-MesoLite to plants, wheat was grown with K-MesoLite or a soluble fertiliser (e.g. KCl) in non-leached pots in a glasshouse. The weights and elemental compositions of the plants were compared after four weeks growth.
Plants grown with K-MesoLite were slightly larger than those grown with KCl. The elemental compositions of the plants were similar except for Si, which was significantly higher in the plants grown with K-MesoLite than in those fertilised with KCl. K from K-MesoLite is readily available to plants.

Key Words
Zeolite from alkali modified kaolin, K-fertiliser, glasshouse experiment, wheat.

Introduction
The synthetic zeolite, known by the trade name MesoLite (Mackinnon, 1998) is designed to have a very high cation exchange capacity (CEC) of approximately 500 meq/100g and in particular, a high ammonium (NH_4^+) sorption capacity for removing NH_4^+ from wastewater (Mackinnon *et al*. 2003; Thornton *et al*. 2007a, b) by cation exchange with K^+. In our previous work (Zwingmann *et al*. 2009) we showed that NH_4^+ was gradually released to soil solution from NH_4^+-MesoLite which suggests the potential of this material for use as a slow release fertilizer. We present results from a glasshouse experiment to measure the availability to plants of K^+ in K-MesoLite.

Materials and Methods
Materials
Bassendean sand from Kwinana, 50 km south from Perth (Western Australia) was used for the glasshouse experiments. Bassendean sand (Pleistocene age) is a podsolised beach dune material present over much of the Perth region. The sand consists almost entirely of quartz (Playford and Low 1972). The pH and EC of Bassendean sand was 5.9 and 20 µS/cm (1:5 soil/DI water) respectively. Bassendean sand contained 0.28% of C and 0.05% of N. The K content was below detection limits.

K-MesoLite (with exchangeable K cation) manufactured by NanoChem Holdings Pty Ltd by caustic reaction of kaolin at a temperature between 80° and 95°C (Mackinnon, 1998) was used as the trial fertiliser. The pH and EC of K-MesoLite was 11.3 and 4.23 mS/cm (1:5 solid/DI water) while pH and EC for the soil with K-MesoLite at the highest application rate were 6.3 and 23 µS/cm respectively. Detailed chemical analyses of Bassendean sand and K-MesoLite are shown in Table 1. Detailed properties of K-MesoLite including the high exchange capacity in particular to NH_4^+ are described in Mackinnon *et al.* (1998) and Zwingmann *et al.* (2009).

Glasshouse experiment procedures
Soil was air-dried and sieved to less than 4 mm. Basal nutrients (N as NH_4NO_3 applied every two weeks) 96.37 mg/kg soil, Ca as $CaCl_2$ 40.91 mg/kg soil, Mg (as $MgSO_4$) 3.94 mg/kg soil, Zn (as $ZnSO_4$) 3.25 mg/kg soil, Mn (as $MnSO_4$) 2.04 mg/kg soil, Cu (as $CuSO_4$) 0.51 mg/kg soil, B (as H_3BO_3) 0.12 mg/kg soil Co as $CoSO_4$ $7H_2O$ 0.08 mg/kg soil, Mo as Na_2MoO_4 $2H_2O$ 0.08 mg/kg soil, S (as $MgSO_4$, $ZnSO_4$, $MnSO_4$, $CuSO_4$) 34.20 mg/kg soil, Na (as Na_2MoO_4) 0.04 mg/kg soil, P (as $(NaPO_3)_6$ 20.50 mg/kg soil, Cl^- as $CaCl_2$ 72.44 mg/kg soil and KCl (for control, KCl pots) maximum addition 81 mg/kg soil and K-fertiliser (K-MesoLite and KCl as soluble fertiliser for control treatments) were added to 1.2 kg soil, mixed and placed in 13 cm diameter black plastic non-leached pots. All nutrients were added once before sowing and the same amount

of N also added two weeks after sowing. The application rates of K fertiliser were 0, 2.8, 5.6, 11, 23, 45, 89 mg/kg soil. Treatments were undertaken in triplicate. Pots were watered the day before sowing with deionised water (DI water) at an amount corresponding to field capacity. Ten pre-germinated wheat (*Triticum aestivum L.*) seeds were sown per pot at the 1cm depth and the pots were placed in a glasshouse. The plants were watered every day with DI water to maintain the soils at 95 % of field capacity. The pots were randomized every day. At the two leaf stage, plants were thinned to five seedlings per pot by selecting the five most uniform plants. After three weeks post-emergence, plants were affected by fungus and all the pots were treated with fungicide. At 25 days post-emergence, the plants were cut at 5 mm above the soil and dried at 70 °C for weighing and elemental analysis.

Analytical methods

Elemental analyses were carried out by X-ray fluorescence spectrometry (Philips, PW 1730) on fused bead samples for Bassendean sand and K-MesoLite and on pressed pellets for plant material. Finely ground plant samples of approximately 0.3 g with 0.13 mL PVA solution as binder were mixed thoroughly and pressed on to a boric acid base at 350 bar using a Sietronics Autopress. Some plant samples had extremely low weights and were diluted with cellulose to make 0.3 g before pressing into a disc. C and N concentrations of the dried plant material were measured with a LECO CHN-1000 analyser. Due to the small amounts of plant material, XRF and C/N analysis were carried out on combined plant material from triplicate treatments.

Results

The weight of the plants increased with K fertiliser application rate. The plants grown with K-MesoLite with high application rate reached a higher yield plateau than those supplied with the soluble K fertiliser KCl. (Figure 1).

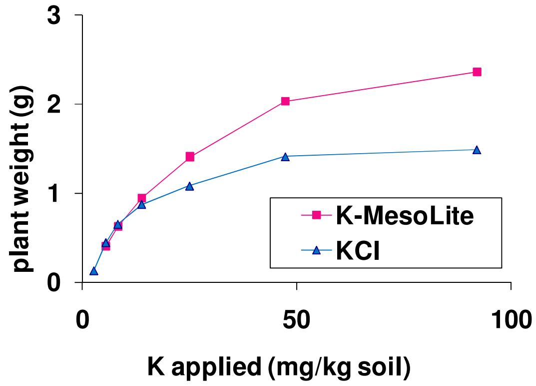

Figure 1. The weight of plants versus the rate of K application.

The concentration of K in the plants increased with K application rate and is similar for KCl and K-MesoLite (Figure 2a). Figure 2b is a plot showing the internal efficiency of K utilisation, i.e. the weight of plant material for the same amount of K in plant for the two fertilisers. The internal efficiency of K for the plants fertilised with K-MesoLite was higher than for plants fertilised with KCl where some factor other than K supply had limited yield.

To identify this limiting factor concentrations of other elements in the plants are plotted against plant weight in Figure 3. The concentrations of N, P, S, Ca, Mg, Zn, and Cl in the plants fertilised with K-MesoLite are identical or similar with those fertilised with KCl. The concentrations of these elements are sufficient for maximum growth (Reuter and Robinson 1997). However Si was much more abundant in plants fertilised with K-MesoLite which evidently acts as a Si fertiliser, which is consistent with its Si rich composition and synthesis procedure that liberates Si from the kaolin structure.

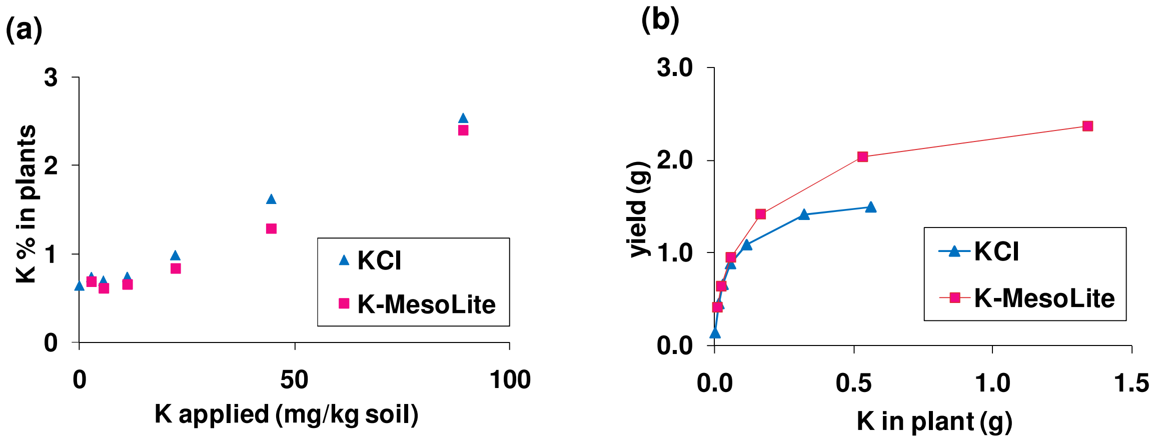

Figure 2. The concentration of K in plants vs. K applied (a) and the internal efficiency of K use, i.e. the weight of the plants (yield) vs. amount of K in plant.

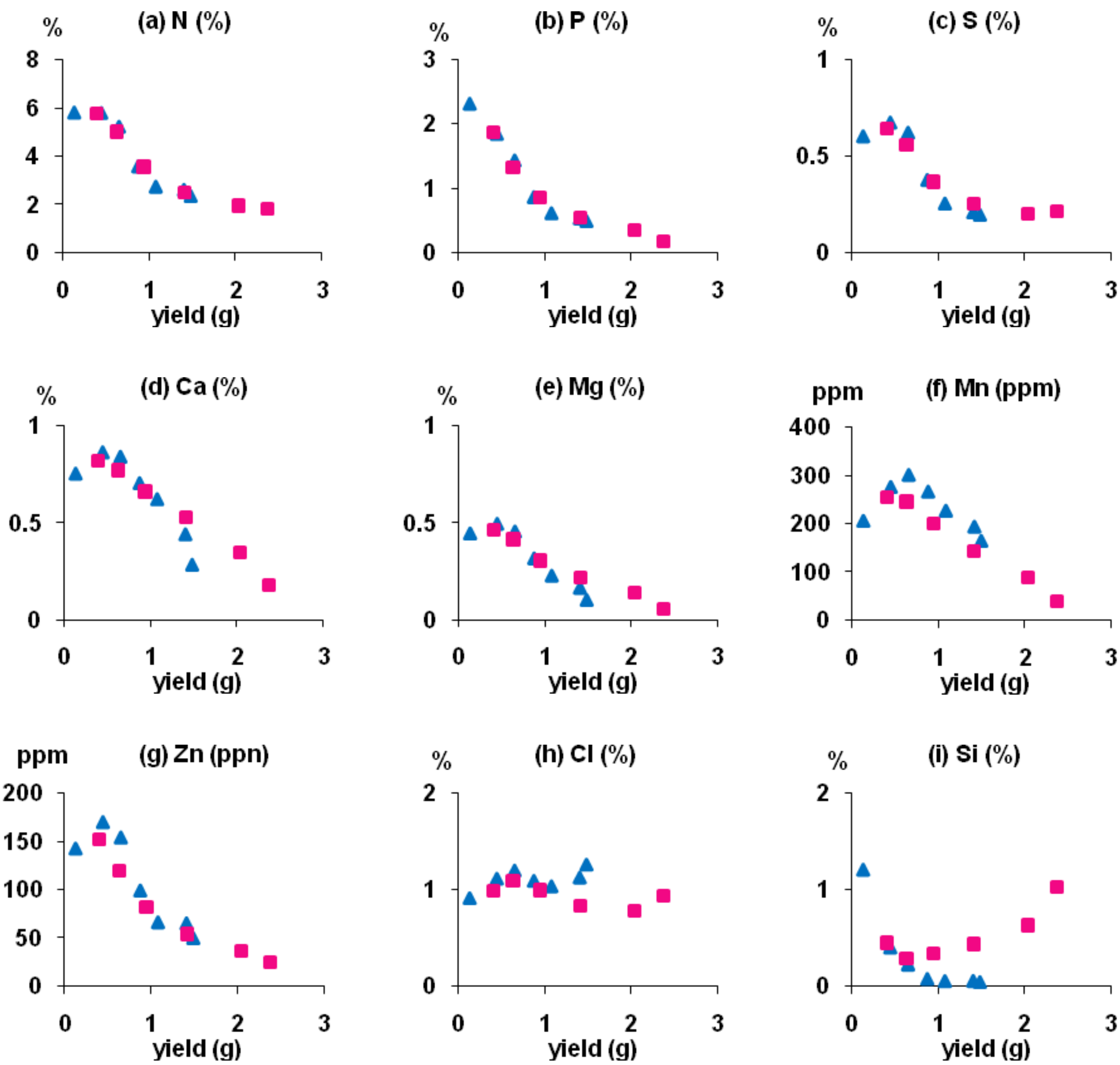

Figure 3. Element concentrations in plants vs. yield. The concentration of Si in plants fertilised with K-MesoLite is much higher than for plants fertilised with KCl.

According to Ma and Yamaji (2008), Si influences plant growth through various mechanisms. In particular Ma *et al.* (2001) showed that Si protects plants from fungal disease thereby increasing yields. In the present experiment all plants were affected by a fungal disease after the third week. Plants fertilised with KCl were more severely affected by the fungal disease than those fertilised with K-MesoLite.

Applied K is taken up by plants or remains in the soil for plants grown under non-leaching conditions. Much K remained in the soil at the end of the experiment (Figure 4a) with slightly more of the applied K from K-MesoLite being used by plants than for KCl at the higher rates of application (Figure 4b).

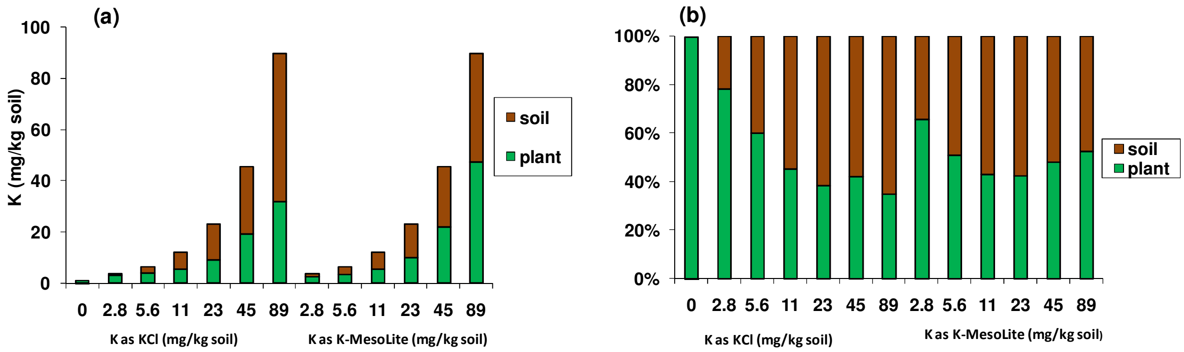

Figure 4. The mass balance for applied K (a) and the percentages of K in plants and soil (b).

Conclusion

This glasshouse experiment showed that K from K-MesoLite was as available for plants as K supplied as KCl. The internal efficiency of K use by plants grown with K-MesoLite was higher than for plants fertilised with KCl. This difference can be related to the higher Si concentrations in plants fertilised with K-MesoLite enabling better resistance to fungal infection.

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