Polyhalite (Polysulphate)® - A Potential slow-release fertilizer for plant nutrition With potassium, Calcium, Magnesium and Sulphur

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Abstract

The potential of polyhalite, a natural mineral consisting of K_2O, SO_4^{-2}, MgO, and CaO at 14%, 48%, 6%, and 17%, respectively, to become a slow-release multi-nutrient fertilizer was the focus of the present study. Fertilizer solubility, and hence the potential long-term availability of its various constituent minerals, was investigated in both a laboratory test and a field experiment.

Introduction

Polysulphate® (PS) fertilizer (Cleveland Potash Ltd. UK) is the trade mark of the natural mineral polyhalite. The mineral is a hydrated sulfate of potassium, calcium and magnesium with the formula: $K_2Ca_2Mg(SO_4)_4 \cdot 2H_2O$ (Tiwari et al., 2015). Polysulphate may serve as an alternative fertilizer that supplies four nutrients and that conceivably may provide a slower release of nutrients since it is less water soluble than more conventional sources (Barbarick, 1991). Practical examinations of Polysulphate in recent years have demonstrated significant advantages for a broad number of crops (PVFCCo, 2016a, b; Satisha and Ganeshamurthy, 2016; Tam et al., 2016; Vale and Sério, 2017; Bernardi et al., 2018; Melgar et al., 2018; Tien et al., 2018; Eryuce et al., 2019). Nevertheless, there were field observations showing that granules remain visible in the field for some time after application and subsequent rain (Pic. 1), raising doubts regarding nutrient availability following application of this fertilizer. The objective of the present study was therefore to characterize solubility under laboratory as well as field conditions, focusing on the different nutrients comprising this fertilizer.

Materials and methods

The work was divided into two stages: a laboratory observation and a field experiment.

Laboratory observation

Amounts of 9, 18 and 27 g of PS were dissolved in beakers containing 1 liter of tap water, and stirred with a magnetic stirrer for 24 hours. Tap water, and not distilled water, was used as the field experiment also used tap water with similar qualities. The concentrations of Ca, Mg and K were measured in the solution.

Field experiment

In a field at the western Negev in Israel (sandy soil), 0.5 x 0.5 m agryl (Non-woven cloth) sheets were placed and fixed to the soil with hooks (Pic. 2). The sheets were covered with a layer (1-2 cm) of dry, sieved soil (<2 mm). A wooden 0.3 x 0.3 m frame was placed at the center of each sheet. Granular PS was broadcasted over the soil, within the outline of the wooden frame, at 9, 18 and 27 g sheet^{-1} (equivalent to 1,000, 2,000 and 3,000 kg ha^{-1}), respectively (Pic. 3). The wooden frame was removed after application. Two soil samples (<2 mm) were taken for analysis, to assess soil Ca, Mg, K and S contribution, without PS application. A pre-installed sprinkler irrigation system applied water every five days at rates of 10 mm h^{-1}, 35 mm per application, including rainfall events. This irrigation scheme was adopted in order to avoid runoff. Rainfall was monitored in a nearby (200 m) standard meteorological station. Weed control was carried out regularly using herbicides. Following about 300 mm of accumulated water application, one set (three PS application levels in four replicates) of agryl sheets were collected. The soil + residual polyhalite from each sheet was dried, weighed and homogenized using a soil grinder. A 25 g sample of soil homogenate was mixed with 500 ml distilled water (soil:water ratio 1:20) and shaken for 24 hours. The suspension was filtered and the concentrations of Ca, Mg, K, and S were determined, followed by calculation of their residual amounts and, subsequently, percentage of the initial application. This procedure was repeated following each interval of 100 mm water application, up to 800 mm (six sampling events). Each treatment had four replicates.

Picture 1: Differences in solubility of PS compared to common soluble fertilizers.

Picture 2: An over-view of the experimental plot during installation of the experiment.

Picture 3: One plot, after application of PS granules.
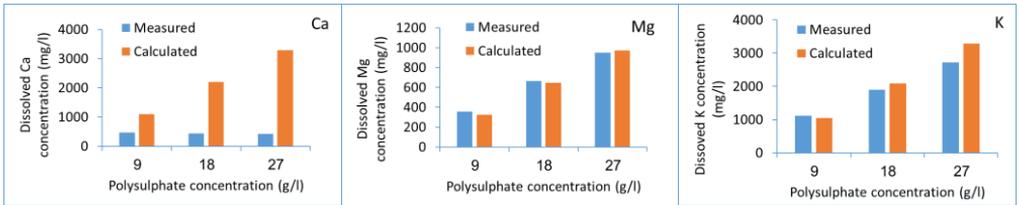
Results and discussion

Figure 1: Actual and theoretically calculated dissolved amounts of Ca, Mg and K in the laboratory observation.

In Fig. 1, the actually dissolved amounts of Ca, Mg and K in the laboratory observation are presented, together with the theoretically calculated dissolved amounts had all PS components dissolved completely. The dissolution of the Mg component of the PS crystal was complete. The dissolution of the K component depended on PS concentration in the solution and its dissolution decreased as PS concentration increased. The Ca component dissolved very little, forming, apparently, a saturated CaSO4 solution, with the Ca concentration remaining constant regardless of the amount of PS applied. This is an indication that there is selective dissolution of the PS crystal, as already proposed by Barbarick (1989) and that not all components are released to the soil solution at the same rate.
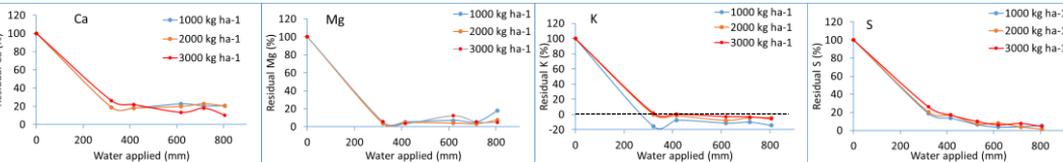

Figure 2: The residual percentage of Ca, Mg, K and S, recovered after increasing amounts of applied water (% of the initial amounts of nutrient applied). The residual percentage of each of the PS constituents, relative to the amount applied and after subtracting the soil's contribution are presented in Fig. 2. The dissolution of the Mg component was almost complete, reaching close to 0% residual Mg after a relatively small amount of applied water (300-400 mm). The traces of Mg observed are probably the result of the release of Mg from soil minerals. The residual S component decreased fast with the first (300 mm) volume of applied water and followed an almost linear pattern, approaching zero at 800 mm. A similar trend was observed also for K. However, residual K concentrations reached below zero after 300-400 mm of applied water, signifying that also K from the adsorbing complex of the soil was released. Residual Ca concentrations decreased very fast with the initial 300 mm of applied water but then maintained a constant value, regardless of the amount of water applied. These results are in agreement with the laboratory results (Fig. 1). A qualitative assessment of the potential interactions between the soil and PS constituents is presented in Table 1.

Table 1: Qualitative demonstration of the potential interactions between the soil and PS constituents.

Source Element	Irrigation water	Soil CaCO₃	Adsorbed	Soluble	PS
Ca	+	+++	+	+	++
Mg	-	+	+	+	+
K	-	-	++	+	++
S	-	-	-	+	+++

Conclusions

the present study demonstrated that polysulphate dissolution in water takes longer and requires larger volumes of water compared to other soluble fertilizers. This advantage reduces possible risks of damage due to over-fertilization and enables the application of PS as a slow-release substance. Nevertheless, the slow-release impact would be largely dependent on interactions with the local soil properties and on soil wetting regimes.