Rock dust as agricultural soil amendment: A review

Philipp Swoboda, Karl-Franzens University, Graz, Austria
Institute of Systems Sciences, Innovation and Sustainability Research
Merangasse 18/1A-8010 Graz

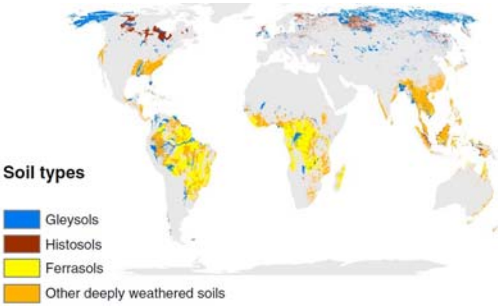
Introduction

The declining quality and quantity of soils is one of the biophysical root causes of falling per-capita food production. Up to 60% of cultivated soils have growth limiting problems with mineral nutrient deficiencies and estimates suggest that 23% of all used land is degraded to some degree.

One way to reverse the declining quality of the soils is to apply finely crushed silicate rocks, as they contain most of the nutrients required for higher plant growth.
The scientific evidence about rock dusts effectiveness is however contradictory (e.g. inconsistent weathering rates).

The limited evidence within literature suggests a wide scope of potential agronomic benefits and a suitability in areas where it would be needed the most, namely in acid, deeply weathered soil environments of the global South (figure 1).

Figure 1: Areas of suitable soil types for silicate rock weathering.
Source: Hartmann *et al*., (2012)



Materials and methods

- Review of 42 peer-reviewed greenhouse/ field studies that used silicate rock dust as agricultural soil amendment

- Studies have been analysed according to a matrix incorporating the most important factors, which enables comparison on a meta-level:

I. Mineral / Rock (granite, feldspar, nepheline …)
II. Crop
III. Soil Type / Properties
IV. Application amount (t/ha)
V. Particle size
VI. Trial Type (pot/field)
VII. Results

- The factors have been evaluated for their relevance in terms of rock dust application and to see if there are correlations between specific factors and outcomes of the trials.

Results

The review of the trials confirmed the contradictions outlined in earlier studies, the majority of trials however resulted in minor to significant agricultural ameliorations. Basalt and volcanic rocks generally performed better than granite or rocks containing primarily feldspar. Rock dust led to significant results when applied to highly weathered soils in tropical environments, as well as in combination with organic materials and microorganisms (**table 1**).

	Mineral/Rock	Crop	Soil	Application amount (t/ha)	Duration	Particle size	Trial type	Results	Reference
a)	Illite & phosphate (– P, K solving bacteria)	Hot pepper (*Capsicum annuum* L.)	Endoaquepts Inceptisols	56 kg ha^{-1} P rock, 395 kg ha^{-1} K rock	2x5months	<1mm	Field	P&K rocks + P&K solubilising bacteria had almost same plant dry matter, yield and mineral uptake as soluble fertilizers	(Supanjani *et al.*, 2006)
b)	K-feldspar (mixed with bacteria SDB and compost)	Tomatoes	Sandy soil	27-45	5 months	125-250μm	Field	Increased yield with compost/SDB (higher than control plot with potash K_2SO_4) 3–4 times cheaper than equivalent potash. K-sp alone insignificant	(Badr, 2006)
c)	Ksp (K-feldspar), PR + organic material	Faba beans	Sandy soil	478 kg/ha	162 days	<2mm	Field	Organic material+Ksp/PR had significant results, increased water use efficiency and 3–4 times cheaper than chemical fertilizer, compost alone significant on NPK values, no single Ksp/PR results	(Hellal *et al.*, 2009)
d)	Feldspar	Sugar beet	Calcareous sandy soil	0, 40, 80 and 120 kg K_2O ha-1	Two seasons	<2mm	Field	Ksp increased several growth characteristics and nutrient uptake, superior results with combined compost use. Reduced environmental burden and 3–4 times cheaper than imported potash	(Hellal *et al.*, 2013)
e)	Glauconitic sandstone	Olive tree	Sand & aquaponics	400g per 2.5L sand, 400g per 10L aquap.	80 days	0.250 mm	Pot	Sandstone outyielded soluble K fertilization on hydroponic cultures. Extractability of K was significantly raised by using acids instead of water. Combination with other fertilizers is proposed	(Karimi *et al.*, 2012)
f)	Mica with K dissolving bacteria	Sudan grass	Alfisol	20,50,100 mg K per kg soil	6 months	<2mm	Pot	Waste mica and KSB improved biomass yield and K uptake. Mica + KSB superior results to mica or KSB alone	(Basak and Biswas, 2009)
g)	Phlogopite	Rice	-	200 kg per ha	-	<149 μm	Pot	Acidulated mica increased yield up to 41% compared to control plot / and with KCl. Acidulated feldspar (+dolomite) not significant. Acidulation highly increased solubility of all rock powders	(Weerasuriya *et al.*, 1993)

Table 1 summarizes the reviewed trials with silicate rocks in combination with organic materials or solubilizing bacteria.

The dissolution of silicate rocks generally improved with finer particle seizes, and agronomic effectiveness culminated with high-energy milling of the rocks. Rock dust reduced NH3 emissions of cattle manure and CO2 emissions of compost respectively. The supply of macro- and micro-nutrients strengthened the plant itself and significantly reduced diseases in trials with tomatoes (**Figure 2** and **3**).

Figure 2:Systemic protection against bacterial wilt in tomato triggered by different treatments. M commercial organic fertilizer, A Rock Dust, M + A commercial organic fertilizer combined with soil amendment, and CK blank control. Source: Li and Dong (2013, p.17)

Figure 3: Differences in apical blossom end rot losses during early (right) and later (left) growing stages. KO = control, EM = rock dust with effective microorganisms.
Source: Ndona (2008, p.48)

Conclusions

The application of rock dust yielded varying results and the presumed contradictions about its effectiveness as a soil ameliorant have been confirmed. The weathering of the rock and thus its effectiveness is dependent on a variety of site specific factors and interactions which are at the present moment not universally understood.

Trials suggest that the efficiency is best in tropical regions with weathered, highly nutrient depleted soils, where conventional fertilizers are rarely affordable and show declining use efficiencies. An overall evaluation of its sustainability is difficult, yet rock dust can be seen as environmentally benign and a shortage of supply is not likely to occur at any realistic rate of application. The conventional economic paradigm is however not in favour of a technique like rock dust.

The review proofed that rock dust is definitely capable to act as a soil ameliorant with a wide range of reported benefits. Cooperation between scientists and farmers as well as expertise in both biology and mineralogy is therefore needed to evaluate the practicality of rock dust and to fully understand weathering mechanisms.

- "Had this (fertilizer) technology been originally developed for the deep leached laterite soils of the tropics instead for the glacial and rock-debris-rich soils of the northern hemisphere our present fertilizers might have been quite different. Perhaps, the concept of petro(rock-)fertilizer would have been well established" (Leonardos *et al.*, 1987, p.362).

Literature cited

Hartmann, J., West, A.J., Renforth, P., Köhler, P., De La Rocha, Christina L., Wolf-Gladrow, D.A., Dürr, H.H. and Scheffran, J. (2013), "Enhanced chemical weathering as a geoengineering strategy to reduce atmospheric carbon dioxide, supply nutrients, and mitigate ocean acidification", *Reviews of Geophysics*, Vol. 51 No. 2, pp. 113–149.

Li, J.-G. and Dong, Y.-H. (2013), "Effect of a rock dust amendment on disease severity of tomato bacterial wilt", *Antonie van Leeuwenhoek*, Vol. 103 No. 1, pp. 11–22.

Ndona, K.R. (2008), "Einfluss von effektiven Mikroorganismen als Pflanzenstärkungsmittel auf Qualitätsparameter von Tomaten im geschützten Anbau.", Dissertation, Universität für Bodenkultur Wien BOKU, 2008.

Leonardos, O.H., Fyfe, W.S. and Kronberg, B.I. (1987), "The use of ground rocks in laterite systems: an improvement to the use of conventional soluble fertilizers?", *Chemical Geology*, No. 60, pp. 361–370.

Universiteit Utrecht
UNIVERSITEIT STELLENBOSCH UNIVERSITY
UNI GRAZ