

Ground basalt and tuff as iron fertilizers for calcareous soils

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Summary Crushed basalt and tuff were found to significantly improve the iron nutrition of peanuts grown in pots of highly calcareous soil. At a rate of $\frac{1}{2}\%$ powdered rock (by weight), chlorophyll contents were double those of plants grown in untreated soil. At rates of 5% by weight, the effect of the rock powders was equal to that of FeEDDHA. The effectiveness of the rock powders was lower in the second crop on the same soils.

Introduction

Chlorosis due to iron deficiencies in agricultural plants is relatively common in calcareous soils, hence the term “lime-induced chlorosis”; in extreme cases, iron deficiencies may lead to complete crop failure³. Treatment of iron deficiency usually entails either soil application of synthetic organic chelates, such as FeEDDHA or FeDTPA, or periodic foliar application of iron salts.

Ground rocks and minerals have been widely used as fertilizers for macronutrients such as calcium (lime, dolomite and gypsum), magnesium (dolomite, kieserite and serpentine), potassium (glauconite, feldspar, basalt and granite), sulfur (gypsum, pyrite and elemental sulfur), and phosphorus (phosphate rock). This communication presents results of experiments conducted to determine if crushed basalt and lapilli tuff (pyroclastic deposits of volcanic ash and larger vesicular fragments), byproducts of local quarrying operations, are useful as fertilizers for iron and remedying lime-induced chlorosis.

Materials and methods

Peanuts (*Arachis hypogaea* L. cv “Shulamit”) were grown in pots containing 500 g of a rendzina soil from Mitzpeh Massua, (light clay, 63% CaCO₃, 34% active lime, pH 7.8, 1.1 ppm DTPA-extractable Fe, and 0.2% dithionite-extractable Fe) in a conventional growth chamber. Basalt and tuff powders, with characteristics as listed in Table 1 and a mineralogy as detailed by Singer⁸, were thoroughly mixed into the soil at rates of 0 to 5% by weight. As an additional check, one treatment received 2 mg iron per kg soil as FeEDDHA added to the irrigation water; this amount was sufficient to completely eliminate chlorosis. At 35 days, plants were harvested and chlorophyll was extracted in 80% acetone and determined spectroscopically. After the first harvest, plant residues were removed and soils were air-dried for 50 days. A second crop of peanuts was grown in the same pots to test residual fertilizing effects and was harvested in the same manner. A fresh FeEDDHA treatment was included in the second crop as an additional check. Each treatment consisted of five pots with two plants in each. Further experimental details are presented elsewhere¹.

Table 1. Characterization of the rock powders

Rock powder	Fe content				Particle size, μm			
	Total,*	Fe(II),	Dithionite- extractable,	DTPA- extractable,	1000- 700	700- 250	250- 100	100- 0
	%	%	%	ppm	%	%	%	%
Basalt	7.99	3.91	0.4	16.1	0	5	31	64
Black tuff	8.26	4.93	0.6	14.9	13	54	32	1
Yellow tuff	7.95	2.14	2.6	32.5	1	22	32	45

* Fe (II) + Fe (III)

Results

The characteristics of the rock powders shown in Table 1 reveal that DTPA-extractable iron in the three rock powders exceeds the critical level (5 ppm) set for soils⁵. All three rock powders contain about 8% Fe by weight, of which 27 to 60% is Fe (II); such high levels of Fe (II) are quite unlike those found in well-aerated soils. All three rock powders comprised particles smaller than 1 mm in diameter. No attempt was made to ascertain the effects of sieving or further grinding on effectiveness as an iron fertilizer.

Among the peanut plants, a wide range of chlorosis was noted visually, ranging from completely dark green leaves with FeEDDHA- and several rock-treated plants to yellow leaves with green areas only along leaf veins in untreated plants. Since chlorophyll contents have been shown to be highly correlated to chlorotic appearance⁷ and since FeEDDHA is the treatment against which all other iron fertilizers are compared^{1,3}, results are presented in Table 2 as chlorophyll content relative to that of the FeEDDHA treatment.

Table 2. Relative chlorophyll contents at first and second harvest. Means followed by the same letter do not differ at the 5% confidence level (Student-Newman-Keuls test). Statistical analysis for each harvest was independent

Control	FeEDDHA		Rock powder				
	Fresh	Residual	Type	Rate			
				$\frac{1}{2}\%$	1%	2%	5%
<i>First harvest</i>							
35 e	(100) a	-	Basalt	69 d	74 cd	90 ab	99 a
			Black tuff	74 cd	80 bcd	92 ab	101 a
			Yellow tuff	75 cd	89 abc	84 bcd	nd.
<i>Second harvest</i>							
33 f	(100) a	90 ab	Basalt	38 f	56 de	75 bc	nd.
			Black tuff	40 ef	50 def	77 bc	nd.
			Yellow tuff	48 ef	57 de	69 cd	nd.

The results show that effective iron fertilizers can triple the chlorophyll content relative to unfertilized plants. Statistical analysis reveals that the various rock powders are indistinguishable one from the other at any given dosage but do possess clearcut iron fertilizing effects. The mean response curve in Fig. 1 for all rock powders shows that $\frac{1}{2}\%$ rock by weight doubled the chlorophyll content and that 5% by weight fully equals the results of FeEDDHA.

In the second harvest, the residual effects of the rock powders may be seen from Table 2 and Fig. 1 to be considerably lessened by air-drying, but they are still significant. The fertilizing effects of the residual FeEDDHA from the first crop are 90% of those of FeEDDHA added to the second crop. The high efficiency of FeEDDHA during the second growth period relates to the experimental system which did not allow leaching from the pots and the high initial dosage equivalent to 100 kg FeEDDHA per hectare.

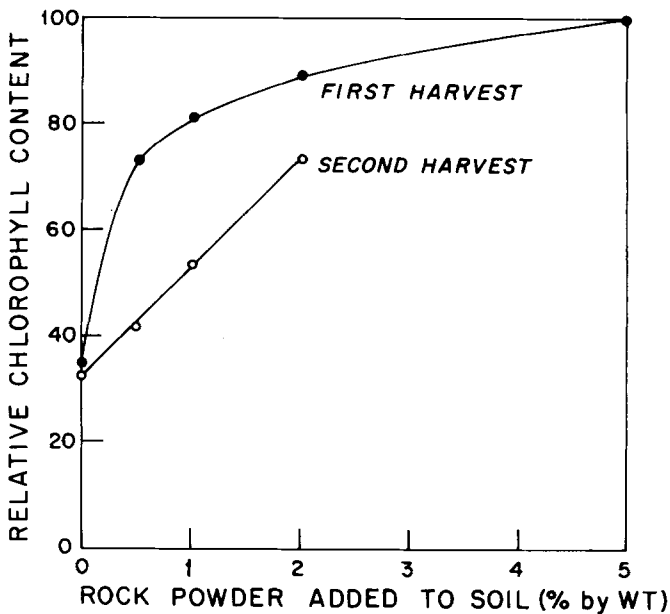


Fig. 1. The mean response curve for all rock powders (FeEDDHA = 100).

Discussion

The soil used in this experiment cannot be properly considered iron deficient since it contains 2000 $\mu\text{g/g}$ iron as free iron oxides and since iron uptake at this stage is of the order of 100 μg per plant. Measured concentrations of Fe^{+3} in soil solutions of neutral and slightly alkaline soils are typically on the order of $10^{-16.4}$ to $10^{-20.5} M$ ^{6,9}. In view of such low concentrations in the bulk solution, plant roots require proximity or contact with iron-bearing minerals in order to mobilize iron. For example, plants have been shown to grow normally in sand culture in the presence of calcium carbonate and magnetite² or ferric oxide⁴, but to have been iron deficient when grown in the effluent of such cultures.

It appears that the rock powders used here supply fresh surfaces of iron-bearing minerals from which plant roots are able to mobilize iron. The minerals exposed by grinding initially include mafic minerals and iron ore minerals, both of which contain Fe (II) and would, but for oxidation in the soil, support much higher levels of soluble iron than the native soil minerals⁵. The decline in the

effectiveness of rock powders would seem to be due to the oxidation and/or coating with carbonates of the mineral surfaces. The readily available iron in the rock powders may also have been exhausted by plant uptake, particularly among the lower application rates.

It should be noted that this specific combination of plant and soil has been chosen so as to cause extremely severe chlorosis under experimental conditions. Lower dosages of powdered tuff and basalt may equal the fertilizing effects of FeEDDHA in other soils where lime-induced chlorosis is less severe. The economics of the use of rock powders probably rests upon their availability as a byproduct rather than as a primary product. Further, crops certified and marketed as organically grown may be fertilized for iron with crushed basalt rock whereas conventional iron chelates are not permitted¹⁰.

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