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Rock Phosphate Availability and Long-Term Effectiveness

Rock phosphate provides extended release of plant available phosphorus season long and over multiple years according to research.

Dissolution	Soluble phosphate is an indicator of plant available phosphate in the soil (Chien and Hammond, 1978). Dissolution of rock phosphate is dependent on soil proton supply as well as calcium and phosphate concentration gradients in the soil solution. In acidic soil, phosphate may become soluble within the first year of application however in pH neutral soils, 50% dissolution occurred within the first 2 years (Robinson et al., 1994).
Rhizome and Solubility	Various crops are also capable of increasing rock phosphate use efficiency by lowering the pH in the rhizosphere through secretion of organic acids; thus improving the solubilization of phosphorus from rock phosphate e.g. Canola (Bekele et al., 1983).
Solubility by Organic Substances	Humic substances, applied with rock phosphate effectively increased phosphate availability in Nigerian soil by 233 % (Adesanwo et al., 2013). P solubility is enhanced in rock phosphate enriched compost due to the formation of weak carbonic acid during decomposition of organic matter CO_2 (Meena and Biswas, 2013).
Solubility by Sulphur	Numerous studies have shown that the agronomic effectiveness of rock phosphate can be improved when admixing or cogranulating with sulphur (Zapata and Roy, 2004). These early studies found that rock phosphate blended with sulphur at rates between 1:1 and 5:1 were as effective Single Superphosphate (Kittams and Attoe, 1965; Attoe and Olson, 1966; Swaby, 1975)
Residual Effects MICROBIOME	Soil bacterial and fungal species improve soil health and are important for the solubilisation of plant-available phosphate in soil, through various methods. • Phosphate availability from rock phosphate can be increased over years of cultivation due to the action of soil microbiota (Coutinho et al., 1991 and Silva et al., 2017). Soil microbes also produce organic acids, which is involved in P solubilisation (Mendes et al., 2014). Additionally metabolic reactions such as cellular respiration by soil microbes also contribute to P solubilisation (Illmer and Schinner, 1995). Lastly, microbes help supply P by hydrolysis of organic P through the action of phosphatases, especially phytases (Richardson and Simpson, 2011). • Long-term effects of rock phosphate on the maize rhizosphere were studied by Ubiana et al., 2017. They found that phosphate from rock phosphate may favourably alter microbial communities to improve P availability.
Residual Effects SOIL P + CROP DEVELOPMENT	• Residual effects of rock phosphate application on Nigerian soil were evaluated over 2 years after rock phosphate appplication and show continued phosphorus availability in soil and better rice yields compared to control (Adesanwo et al., 2013). • Smalberger et al., 2010 conducted a small pot trial with 2 consecutive cropping seasons and found residual available phosphate in soils at the end of the first canola cropping. Residual agronomic effectiveness was measured on the second wheat cropping and rock phosphate was deemed as effective as Triple SuperPhosphate in Hiwassee soil following an initial canola crop. • Rock phosphate supplied phosphate to crops and improved yields annually in alkaline soil over multiple rotations during an 8 year period in a study by Choudhary et al., 1993.

Residual Effects **SOIL P + CROP DEVELOPMENT (Contd)**	• A wheat then maize rotation in calcareous soil demonstrated the residual effects of rock phosphate during 2 consecutive seasons. Compared to control, water soluble phosphorus concentration in soil was significantly higher from rock phosphate treatments during season 1, post-harvest and throughout season 2 of the study. Uptake of phosphorus was also higher during both seasons. Significantly higher grain and biomass yield were observed after both seasons from rock phosphate compared to a control treatment (Muhammed and Muhammed, 2014). • A 2 year maize study demonstrated the relative agronomic effectiveness of rock phosphate compared to control. Dissolution of rock phosphate was improved during year 2 with significantly higher available P tested as resin-extracatble inorganic P, sodium bicarbonate P and hydrochloric acid extractable P compare to control. Rock phosphate treated maize plots yielded 39.6% and 154% higher in year 1 and 2 respectively. Significant increases in root, shoot and leaf uptake were also observed (Ikerra et al., 2006). • A study observing the residual effects of rock phosphate application versus control (applied in year 1 on wheat) showed 67.5% (significant) better P uptake and yield in year 2 soybean. Significantly higher available P was analyzed in the RP treated soil after year 2 soybean crop harvest with 48.7% (0-15 cm) and 35.9% (15-30 cm) increase from control (Meena and Biswas, 2013). • During year 1 - Rock phosphate, applied at 20 kg P/ha to soil with maize crop increased soil Olsen-P levels from 6.8 mg P/ha to 16.5 mg P/ha (21 days after emergence) then to 23.5 mg P/ha (silking). Soil P levels in the control decreased gradually from 6.8 mg P/ha to 4.7 mg P/ha during this trial-year. A second seeding in these soils yielded soil Olsen-P levels of 19 mg P/ha at seeding, 24.7 mg P/ha (21 DAE) and 26 mg P/ha (silking). Significantly higher dry matter yields (early growth, silking, stover, grain) resulted from RP treatments in both years (Aye et al., 2009). • Rock phosphate can persist in soils for up to 6 seasons according to Ntundu, 1997 and Mkangwa, 2003. Under adequate rainfall conditions in Tanzania, residual effects of rock phosphate are seen during a 2nd season after application in maize and groundnut according to yield data by Mkangwa, 2003. • In most cases conventional fertilisers were better than rock phosphate in the 1st year of application but in subsequent seasons the effectiveness of rock phosphate increases. Generally, from the 3rd year onwards the yields obtained from rock phosphate applications were higher than those obtained from conventional P fertilisers (Semoka and Kalumuna, 1999). • Initial and residual effects of rock phosphate and single super phosphate demonstrated that RP slowly released available P in year 1, however rock phosphate supplied significantly more available phosphate than single super phosphate in year 2 (Akande et al., 1998). • NDung et al., 2006 calculated that a one-time application of 60 kg P ha–1 rock phosphate to maize could earn a return to land of US$1541 in three years without additional fertilizer application. The residual benefits of rock phosphate at modest rates of application (60 kg P ha–1) were found to persist in the soil for three cropping seasons in Kenya. Significant increases in soil extractable bicarbonate P from the residual rock phosphate were noted in the second and third seasons. • Brahima et al., 2011 compared a one time application of rock phosphate to annual triple superphosphate applications on rice production and found that 50 kg P/ha applied annually was equally as effective as a 1 time application of rock phosphate for 3 cropping years.

Environment	The environmental benefits received through the substitution of highly soluble commercial fertilizers with rock phosphate are also important to consider. Commercial phosphate sources are highly soluble leading to surface and ground water contamination through leaching and run-off shortly after application. Rock phosphate is solubilized slowly through soil processes, made available to the crop as required and mitigates loss of phosphate from the field (Chien et al., 2011).

Table 11 Cumulative loss of dissolved reactive and total P in surface runoff from three soils treated with phosphate rock (PR) or triple superphosphate (TSP) (Shigaki et al. 2007)

Soils	P sources		
	Control	North Carolina PR	TSP
Cumulative dissolved reactive P (DRP) loss (kg ha^{-1})			
Alvira	0.28	0.52	32.2
Berks	0.18	0.39	14.5
Watson	0.23	0.43	16.2
Average[a]	0.23^{C}	0.45^{B}	20.9^{A}
Cumulative total P loss (kg ha^{-1})			
Alvira	0.35	0.83	33.2
Berks	0.30	0.68	15.5
Watson	0.31	0.72	19.6
Average[a]	0.32^{C}	0.74^{B}	22.7^{A}

[a] Average DRP and total P loss values in the same row followed by the same letter are not significantly different at $P < 0.05$

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