4R Practices for Efficient Phosphorus Management in Western Kenya

By Samuel Njoroge and Shamie Zingore

On-farm research evaluating 4R Nutrient Stewardship found source, rate, timing, and placement of P fertilizers can be managed to increase productivity, profitability and P use efficiency for smallholder farmers.

IPNI Photo/Sub-Saharan Africa Program

Severe phosphorus deficiency in maize grown in Siaya County, Western Kenya.

Soil P deficiency is widespread under smallholder farming systems in SSA, and has been identified as a major constraint to crop production. This deficiency is particularly acute in the highly weathered and acidic tropical soils in East Africa, including western Kenya. Soil data from 26 nutrient omission trials in western Kenya indicated that 92% of the soils were deficient in P (<20 ppm), highlighting the extent of P deficiency in this region. This widespread P deficiency is mainly due to a combination of low native P and the predominance of acidic, P-fixing soils. This situation is further compounded by the insufficient use of fertilizers, resulting in high nutrient depletion rates and decreasing soil P status. Data from four seasons of fixed-location on-farm nutrient omission trials showed that the percentage of P responsive locations (maize P response >1 t/ha) increased from 35 to 83% over four cropping seasons (**Table 1**), illustrating the high susceptibil-

Abbreviations and notes: P = phosphorus; Ca = calcium; SSA = sub-Saharan Africa; ppm = parts per million.

Table 1. Changes in phosphorus agronomic efficiency (PAE) and grain yield response to P over four seasons in P omission trials* (Western Kenya, 2013-2014; IPNI SSA).

Season	PAE**, kg grain/kg P	P response, t/ha	Sites with >1 t/ha response, %
Long rain season 2013	11	0.46	35
Short rain season 2013	32	1.30	58
Long rain season 2014	50	2.06	78
Short rain season 2014	48	1.96	83

*26 on-farm trials were established in each season
**PAE for each farm calculated as the yield difference (NPK - NK) / 40 kg fertilizer P. Average values for each season were calculated.

ity of P depletion when P application is omitted. A simplified, but effective approach towards the management of available P resources is required in order to sustainably increase crop productivity and attempt to replenish soil P in this region.

The 4R Nutrient Stewardship approach offers a strategy for identifying management practices that can help smallholder farmers in SSA improve P use efficiency (PUE) by optimizing the use of P resources available to them, leading to increased crop productivity and soil P status. Assessment of the various P sources available in the region and the factors that influence their effectiveness and profitability (i.e., rate, timing of application, and placement) offers a good starting point for equipping smallholder farmers and other agricultural stakeholders with the necessary knowledge for addressing P deficiency in crops.

P Sources and Their Relevance in SSA

The main P sources available to smallholder farmers in SSA are mineral P fertilizers such as diammonium phosphate (DAP) and triple superphosphate (TSP), phosphate rock (PR) such as Minjingu phosphate rock (MPR) in Tanzania and Telemsi phosphate rock (TPR) in Mali, and organic sources such as farmyard and cattle manure. However, fertilizer and PR sources are more effective at addressing P deficiency due to their higher P concentrations compared to any organic resources. While mineral fertilizers offer one of the most effective sources of soluble P, limited capacity of farmers to purchase fertilizer is a major hindrance to their increased use. Investments in inland infrastructure and subsidy programs such as those launched by various governments in the region could help in bringing down the costs of mineral fertilizers making them more attractive P sources.

The effectiveness of PR is mainly limited by varying P concentration, reactivity and solubility. As such, only a few PR sources, such as MPR and TPR, have been found to be suitable for direct application due to their relatively high P concentration and reactivity. Assessment of research data indicates that MPR compares favorably with TSP when applied at equal rates (**Figure 1**). Further studies on the economic benefits of MPR

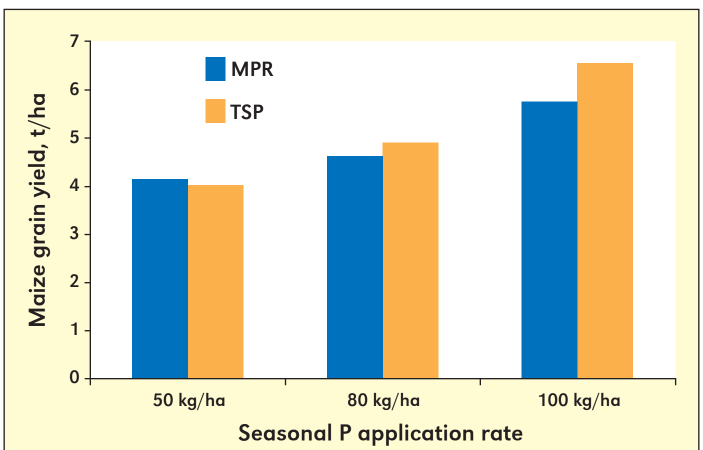

Figure 1. Effects of phosphate rock (PR) and triple superphosphate (TSP) sources applied at equal total P rates on maize grain yield in western Kenya (Jama and Kiwia, 2009).

and TSP have indicated that MPR offers almost similar benefits to those of TSP (Jama and Kiwia, 2009). Given the high vulnerability for price changes in imported fertilizers, and the local availability of MPR, MPR is an attractive source of P given improved inland transportation. However compared to fertilizer P, PR require targeting to soil conditions that can enhance their solubility and ensure improved PUE. For example, MPR can serve as an effective P source in high P-fixing, acidic soils such as those of western Kenya. Acid soils are more conducive to PR dissolution than Ca-rich alkaline soils. Other options that can improve the PUE of PR are grinding to speed dissolution and agronomic effectiveness, and targeting the use of PR to specific crops and regions. For example, some legume crops excrete organic acids from their roots that facilitate P solubilization. Highly reactive PR is better targeted to fast growing crops with rapid P uptake demand; while less reactive PR is better suited to perennial crops, pastures and trees. Consideration of the economics of PR availability and access is a practical concern. For example, where lower grade PR that is easy to mine and modify occurs close to P-deficient soil, it can serve as a suitable source of P due to reduced acquisition costs.

Right P Rate in Smallholder Farming Systems

For crop production to increase sustainably, the right P application rate should aim at not only increasing crop yields, but also maintaining a positive soil P balance to avoid long-term depletion. In western Kenya, Nziguheba et al., 2002 showed that while maize responded to seasonal addition of 10 kg P/ha, the desired positive soil P balances were only achieved at application rates greater than 25 kg P/ha (**Table 2**).

Table 2. Cumulative soil P balances* over five consecutive cropping seasons from the seasonal addition of different rates of P fertilizers to a P-deficient soil in western Kenya (Nziguheba et al. 2002).

Application rate, kg P/ha	Season 1	Season 2	Season 3	Season 4	Season 5
	-------	-------	kg/ha	-------	-------
0	-5	-9	-12	-24	-25
10	4	7	11	2	8
25	17	24	51	53	71
50	41	83	122	146	188
150	137	276	415	536	678

*P applied – P removed in grain + straw.

The right P rate depends on: i) the source of P, ii) the soil P status, iii) the crop (or crops) to be grown, iv) the frequency of application, and v) the P-fixing capacity of a soil. Where P application is from slower P-releasing sources such as PR, higher rates may be required compared to more soluble sources. Soils with low P status will also require higher P rates compared to high P status soils, while single P applications, and applications in high P-fixing soils, will require higher P rates compared to seasonal P applications and application in low P-fixing soils, respectively. With regard to maize, one of the most important cereal crops in the region, data from P rate trials using TSP indicates minimal grain yield increase and income benefit for P rates higher than 40 kg P/ha (**Figure 2**). This is in line with data from a recent review of P studies (80% spot application and 20% broadcast) by Kihara and Njoroge, (2013). They recommended seasonal P application rates between 20 to 38 kg P/ha for high P-fixing soils, such as those in western Kenya, to ensure a marginal rate of return to P application of at least 100%.

Right Time of P Application

For sustainable crop production increases, timing P application is influenced by both the right time to apply P during a single cropping season as well as over several cropping seasons (e.g., seasonal versus annual application for the two crops per year that is common for western Kenya). The right time of P application is influenced by the P source, soil chemical and physical characteristics, and the amount of P to be applied. For soluble P fertilizers and PR of high reactivity, the right time for application is at planting, while less reactive PR should be applied well in advance of planting to allow time for dissolution. Where the P application rate is high, a single application can span a number of seasons, while for lower application rates, seasonal applications are necessary for both soluble fertilizers and PR. However, for high P-fixing soils, seasonal P applications at lower rates are preferable compared to single, high application rates (Buresh et al., 1997).

Right Placement of P

Under the low P input systems characteristic of smallholder farming in SSA, the right placement of applied P can drastically increase PUE, and yields. Spot placement of P fertilizers (which involves the placement of fertilizer in close proximity to seeds in each planting hole) results in higher PUE compared to broadcast application and incorporation. Studies have reported that spot fertilizer placement resulted in higher maize yields than broadcasting and incorporation at P rates less than 50 kg P/ha (van der Eijk et al., 2006). This implies that for the resource-scarce smallholder farmers, spot application of small amounts of P offers the best placement option for improving PUE.

Other Considerations for Improving the PUE

Apart from improving source, rate, time, and place practices in P management, there are other practices that smallholder farmers in SSA can use to improve the PUE of applied P. One of these is ensuring balanced nutrient application, as the response to P in both legume and cereal crops are often limited by multiple nutrient deficiencies. A review of P studies in P-fixing soils in western Kenya by Kihara and Njoroge (2013) reported that the lack of N application together with P decreased phosphorus agronomic efficiency (PAE) from 29 down to 19 kg grain/kg P. Given the low mobility of P in the soil, and the relatively high residual effect compared to other nutrients, smallholder farmers can also benefit from strategic rotation of legumes and cereals. In such a system, P application can be applied once every three seasons, compared to seasonally in continuous cereal cropping, thereby helping farmers save on scarce P resources. BC

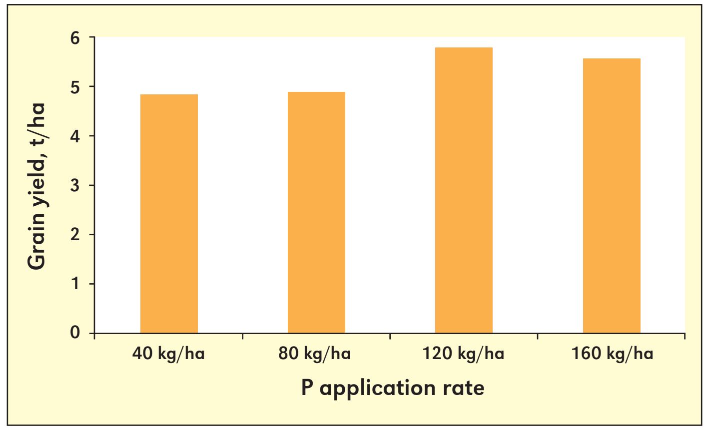

Figure 2. Effects of P applied seasonally as triple superphosphate at varying rates on maize grain yield in western Kenya (Jama and Kiwia, 2009). At all P rates, N and K were also each applied at 100 kg/ha.

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Crop Nutrient Deficiency Photo Contest Entries Due December 9, 2015

This year, the deadline for submitting entries to the annual IPNI contest for photos showing nutrient deficiencies is early December. Remember, our **Feature Crop** category for 2015 is **Root and Tuber Crops** (e.g., Potato, Sweet Potato, Cassava, Carrot, Beets, etc).

Our prizes are as follows:

- US$300 First Prize and US$200 Second Prize for Best Feature Crop Photo.
- US$150 First Prize and US$100 Second Prize within each of the N, P, K and Other Nutrient categories.
- Note that all winners are eligible to receive the most recent copy of our USB Image Collection. For details on the collection please see http://ipni.info/nutrientimage-collection

Entries can only be submitted electronically to the contest website: www.ipni.net/photocontest. Winners will be notified and announced in early 2016. Look for results posted on ipni.net. BC

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Iron deficiency in cassava.