Potassium response in some Malawi soils

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ABSTRACT

Potassium (K) response curves were generated for some Malawi soils using four different rates of potassium fertilizer, with grass being used to estimate plant availability. The study was conducted to find the point of maximum response for potassium. The soils were characterized, limed and fertilized with equal amounts of nitrogen. Potassium was applied at four rates: 0.0, 0.1, 0.2 and 0.4 me K/100 cm^3 soil. The K treated soils were put in pots and cropped with grass. The grass was harvested six weeks after planting, dried and weighed. In general, addition of potassium resulted in increased growth of grass in all soils, with some soils showing better response than others. For montmorillonitic soils and soils with mixed mineralogy response was linear up to the highest rate of 0.4 me K/100 cm^3. Apparently the 0.4 me K/100 cm^3 soil was not enough to give maximum yield for these potassium depleted soils. For the kaolinitic soils 0.4 me K/100 cm^3 soil was beyond point of maximum response. The variation of response to added potassium in the different soils calls for soil specific fertilizer additions. Smallholder farmers should move from blanket (crop specific) fertilizer recommendations currently being used to crop and soil specific fertilizer recommendations. Basal fertilizer dressings (starter packs) should always contain potassium. Correlation and calibration studies should be conducted to establish a potassium low optimum level for Malawi soils.

*Keywords***:** potassium (K), kaolinite, Malawi soils, minerals

1. INTRODUCTION

Potassium (K) is required by all plant and animal life. It is the third major plant and crop nutrient after nitrogen and phosphorus. "Potassium is associated with movement of water, nutrients, and carbohydrates in plant tissue. If K is deficient or not supplied in adequate amounts, growth is stunted and yields are reduced.

Various research efforts have shown that potassium stimulates early growth, increases protein production, improves the efficiency of water use, is vital for stand persistence, longevity, and winter hardiness of alfalfa, and improves resistance to diseases and insects" (Rehm and Schmitt, 2002).

Potassium in Soils

Three forms of K (unavailable, slowly available or fixed, readily available or exchangeable) exist in soils. The general relationships of these forms to each other are illustrated in **Figure 1.**
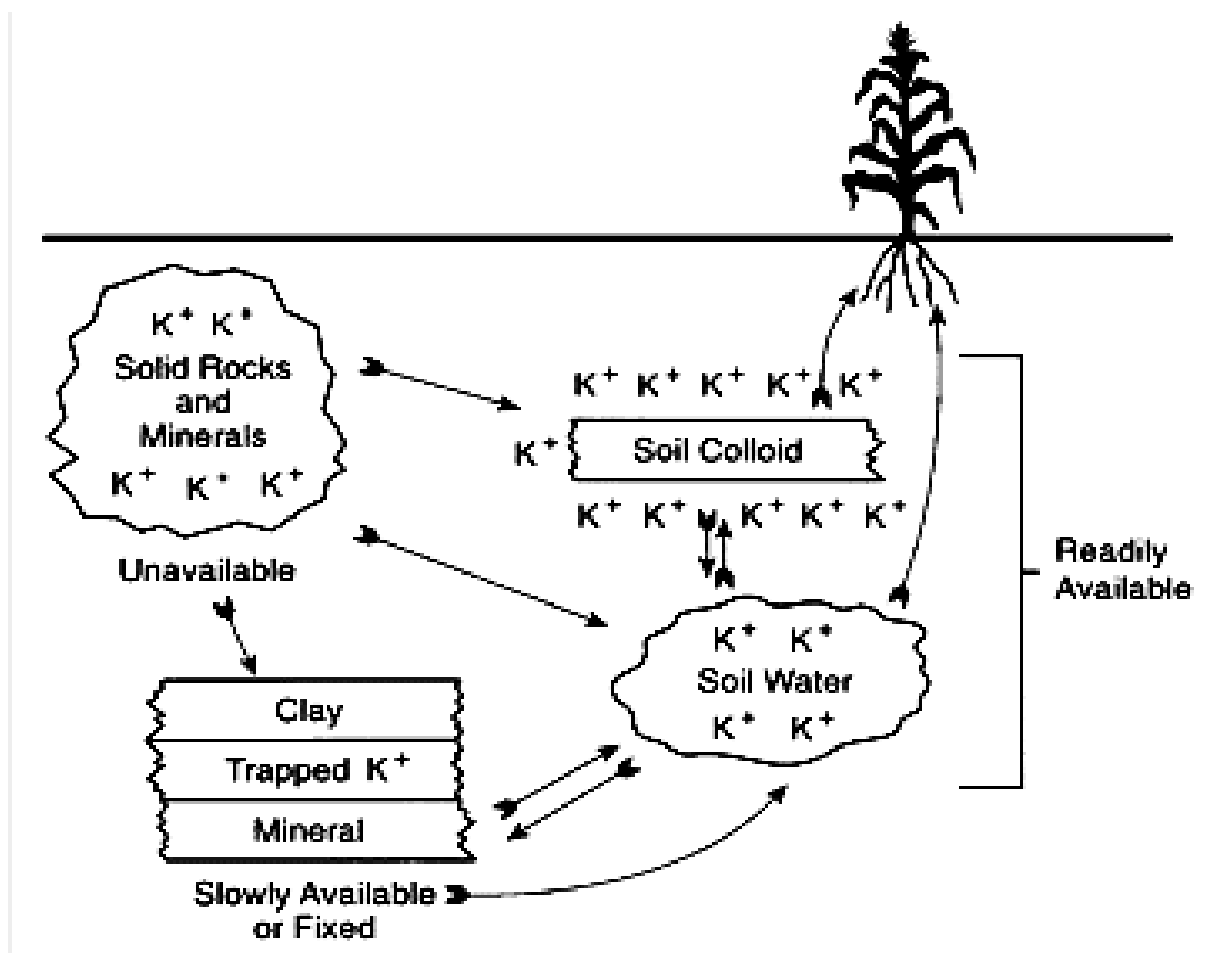
Figure 1. Relationship among unavailable, slowly available, and readily available potassium in the soil-plant system. **Source**: Rehm & Schmitt, 2002.

In Malawi, high acidity and low levels of available nitrogen and phosphorus are usually the most common soil chemical factors that limit crop yields. But soil reserves of potassium have also been insufficient for the needs of crops. Potassium deficiencies have been recognized in many continuously cultivated soils of Malawi (Mueller *et al.* 1993). According to Gwosdz *et al*. (1996) 59,000 km^2 of Malawi's soils are K-deficient, representing more than 60 % of the land area. The current fertilizer recommendation review in Malawi revealed that Malawi soils are also deficient in potassium, sulphur and zinc (Chilimba and Liwimbi, 2008). When soil potassium is low potassium fertilization becomes necessary. The need for potassium fertilizer has also been increased by factors such as introduction of high yielding varieties, increase in cropping intensity and use of land for cash and export crops.

Response to potassium fertilizer was studied for some potassium deficient soils in Malawi with different physical and chemical properties. The soils are shown in Table 1.

Table 1. Description of soils used in the potassium response study.

Place (source)	Description	Symbol	Clay Mineralogy (Source: Nkhoma, 1986)								
			Soil ID	K	Mo	HIV	G1	Go	M1	Q	T
Mphonde	TP, brown Vertisol	MP-ZT	1		*	x					
Nsuwadzi	TP, trt 200, plot5	NSU-200-5T	2	*		v	x				
Nsuwadzi	TP, trt 000, plot6	NSU-000-6T	3	*	v	v	x				
Kasungu	TP, estate 88 Maize field	KA-1T	4	x	x		v			x	
Bvumbwe	TP, coffee field	BV-2T	5	x		v					
Chitedze	SB, Chipinika ss	CTE-1	6	x				x	x		

Key: K = kaolinite; Mo = montmorillonite; HIV = hydroxy interlayered vermiculite;
G1 = gibbsite; Go = goethite; M1 = mica; Q = quartz; T = talc;
* = dominant mineral; x = > 20 % but not dominant; v = less than 5 %;
ID = identity; TP = top soil; trt = treatment; ss = series.

2. MATERIALS AND METHODS

Soils for the potassium response study were amended to ensure that no element other than potassium was limiting. Hence the soils were analysed (using standard methods according to Hunter, 1979) to check the status of nutrients in the soils. Air dried soils were sieved through a 2 mm sieve and tested for pH, extractable (Extr.) acidity, cation exchange capacity (CEC) and exchangeable calcium (Ca), magnesium (Mg), potassium (K), sulphur (S) and micronutrients, manganese (Mn), iron (Fe), copper (Cu) and zinc (Zn). The nutrient levels of the soils are presented in Table 2.

The levels of calcium, magnesium and sulphur in the soils were adequate for crop production based on nutrient indices by Hunter (1980). The extractable acidity was high in all soils with the exception of soil 1.

Lime was added to neutralize the acidity, thereby decreasing the solubility of the micronutrients (Mn, Fe, Cu and Zn) which seem high in Table 2. The high acidity levels were corrected through additions of the required amounts of lime [$Ca(OH)_2$], derived using the procedure by Hunter (1980). $Ca(OH)_2$ was used in this study because it reacts with soil faster than $CaCO_3$.

One kilogramme portions of soil were spread out as a thin layer on plastic paper. $Ca(OH)_2$ powder was sprinkled on the soils and thoroughly mixed with the soils, then the soil – lime mixtures were wetted to field capacity with distilled water and the lime treated soils were left to equilibrate for two weeks in air tight bags.

Table 2. Soil chemical properties: pH, % clay, Extr. acidity, CEC, and exchangeable S, Ca, K, Mg, P, Mn, Fe, Cu and Zn, ***.**

Soil ID	pH	% clay	Extr. acidity	S	Ca	Mg	K	CEC	P	Mn	Fe	Cu	Zn
			Milliequivalents per 100 cubic centimeters (me / 100 cm3) of soil						Microgrammes per 100 cubic centimeters (μg / 100 cm3) of soil				
			Montmorillonitic soil										
1	7.76	76	0.16	> 6	> 5.00	> 1.80	0.015	18.30	27.5	3.1	0.9	3.5	2.2
			Kaolinitic soils										
2	4.32	50	1.77	> 6	2.77	0.36	0.023	3.27	> 40	69.9	90.5	3.3	5.9
3	4.65	50	1.05	> 6	2.78	0.38	0.034	3.30	> 40	40.7	60.2	6.4	7.0
			Soils with mixed Mineralogy										
4	5.03	17	0.56	> 6	> 6.38	> 2.30	0.054	7.10	> 40	42.8	239.6	3.0	8.8
5	4.74	35	0.86	> 6	2.36	0.42	0.056	4.17	> 40	75.3	191.5	46.0	8.3
6	5.37	34	0.66	> 6	3.16	1.14	0.022	7.53	> 40	83.1	83.3	3.9	7.5

*Clay content was determined using the hydrometer method (Day, 1956). Cations were detected using atomic absorption spectrophotometry. Extractable P, K, Cu, Fe, Mo and Zn were extracted using 0.5M $NaHCO_3$ (420 g $NaHCO_3$ + 37.3 g EDTA + 5 g Superfloc + 10 litres distilled water). Ca, Mg and Extractable acidity were extracted using 1 M KCl. Extractable acidity was titrated with 0.01M NaOH to phenolphthalein endpoint. P was detected using colourimetric procedure based on the formation of a phosphomolybdoblue complex. Cation exchange capacity was determined using the barium exchange method (Gillman, 1979).

After two weeks, the plastic bags were opened and the soils allowed to air dry. Each soil was then spread out as a thin layer and nitrogen and phosphorus were added. Phosphorus, as $Mg(H_2PO_4)_2$, was added to soil 1 only since the other soils had adequate phosphorus. Nitrogen was added as ammonium nitrate (NH_4NO_3), 5 cm^3 of 49 g NH_4NO_3 / litre solution per pot for all soils. Potassium was applied at four rates: 0, 0.1, 0.2 and 0.4 me / 100 cm^3. Potassium was added as K_2SO_4 solution. Required aliquots of 0,4 M K_2SO_4 solution plus the 5 cm^3 of nitrogen solution were added to 60 cm^3 of distilled water. A mist bottle was then used to spray the solution onto the soil to ensure uniform mixing of fertilizer with soil.

The soils were cropped in triplicate in three randomized blocks of pots holding 1 kilogramme of air dry soil. Twenty fungicide - treated rye grass seeds were planted per pot. Rye grass was chosen because it has an extensive root system, high affinity for potassium and is capable of extracting potassium from the non-extractable sources (Malavolta, 1985). Germination was 100 % in all the pots.

Distilled water was added to the top of the soils. Enough water was added to bring each soil to field capacity. (Water content at field capacity was estimated for each soil before planting. A mound of soil was made with a depression in the centre. A known mass of water was added to the centre of soil. After two days the dry soil was removed from the mound and the remaining moist soil was weighed.

The field capacity water content was estimated as follows:

$$\frac{wt.\ of\ water\ added\ x\ 100}{wt.\ of\ moist\ soil - wt.\ of\ water\ added}).$$

Three weeks after planting, nitrogen was applied as NH_4NO_3 every week at a rate of 10 millilitres of a 9 g NH_4NO_3 / litre solution per pot. The grass was harvested six weeks after planting by cutting to 2.5 inches above the soil. The grass was air dried and weighed.

3. RESULTS AND DISCUSSION

The results for K response study are presented in Table 3. All the soils showed response to addition of potassium fertilizer. Yield order soil 6>1>4>5>3>2 generally followed the cation exchange capacity (CEC) order soil 1> 6>4>5>3>2. Compared to the control (no potassium added) soil 3 had the greatest percentage increase in yield followed by soil 1, then soil 6. With the highest CEC, Soil 1 would have been expected to have the greatest increase in yield if watering was not a problem. It was very difficult to maintain water at field capacity in soil 1 because of high clay content and montmorillonitic minerals in the soil. For soil 3 and other soils it was very easy to maintain water at field capacity. On the other hand the slightly lower yield for soil 1 could have been due to fixation of some of the added potassium by the montmorillonitic minerals (Sanchez, 1976).

The response to addition of K on all but one soil was linear up to the highest addition rate of 0.4 me. K / l00 cm³soil. The choice of 0.4 me K / 100 cm³ soil was based on Hunter's research work, which suggested a low optimum level of 0.4 me K / l00 cm³ soil (Hunter, l980). [The low optimum level is the level above which yield response does not occur (Hunter, l980)].

The yield data seems to suggest that the rate of 0.4 me. K/100 cm³ soil is not the low optimum level for these potassium depleted soils, particularly the montmorillonitic soils and some soils with clay mixed mineralogy. For the kaolinitic soil (soil 2) 0.4 me.

K / 100 cm³ soil produced less than maximum yield, implying that it is above the low optimum level. Soil 2 has the lowest CEC hence least ability to hold the potassium in the soil. The results show that soils are different and that response to potassium differs from soil to soil. Thus crop specific (or general or blanket) fertilizer recommendations will not work well for all soils. There is need for soil specific fertilizer recommendations. Blanket fertilizer recommendations (starter packs) such as those used by smallholder farmers in Malawi are crop specific and not soil specific.

They are applied without considering inherent soil fertility. For example there is one fertilizer recommendation for a given variety of maize, but there are many different soils with different fertility levels. With blanket fertilizer recommendations farmers may fail to realize optimum yield on some soils (like soil 1 or 6) or add more than necessary fertilizer on other soils (like soil 2) ending up with diminishing returns.

For optimal agricultural production there is need for precise soil fertility information. Smallholder farmers should be encouraged to utilize free Government soil testing services at Chitedze and Bvumbwe agricultural research stations for them to use both soil and crop specific fertilizer recommendations.

4. CONCLUSION

All soils had low potassium and responded to added potassium. The response, however, differed among the soils. The internationally recommended 0.4 me K/100 cm^3 soil was not the low optimum for four of the five soils.

RECOMMENDATIONS

Smallholder farmers should move from blanket (crop specific) fertilizer recommendations currently being used to crop and soil specific fertilizer recommendations. Basal fertilizer dressings should always contain potassium. Correlation and calibration studies should be conducted to develop a low optimum level for potassium for some Malawi soils.

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