Response of Field Beans *(Phaseolus vulgaris* L.) to Unacidulated Phosphorus Source in an Andosols in Kenya

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ABSTRACT

The agronomic effectiveness of minjingu rock phosphate (MRP) was compared with that of highly soluble phosphate triple superphosphate (TSP), in pot studies with field bean (*P. vulgaris L.*) in a greenhouse at the field station of Faculty of Agriculture, University of Nairobi, Kenya. MRP finely ground with 30 Grade % P and TSP with 99.6 Grade % P fertilizer at rates 0, 30, 45 and 60mg P pot^{-1} were applied on 2kg soil pot^{-1}. The soil used in the study was an acid humic andosol from fields with moribund tea bushes, tea bushes planted in 1958 and 1979 and newly cleared forest in Kagaa, Kenya. Shoot and root dry matter yields, dry seed yield responses and their response estimates were determined and showed positive significance in most cases when TSP fertilizer was applied on the soils except that from moribund tea field. The relative agronomic effectiveness (efficiency) of MRP on biomass and also seed yield of beans was found to be significantly inferior to TSP in most of the soils except that from moribund tea field where both sources were found to be ineffective. This study confirms that inspite of its high reactivity, MRP is still agronomically ineffective as nutrient source of Phosphorous for growing *P. vulgaris* in acid soils.

Key Words*:* Andosol(s), phosphorus, source, yield

1.0 INTRODUCTION

The importance of field beans (*Phaseolus vulgaris L.)* the world over is well established (Henry, 1990). This is attributed to their increased importance in human diet (Henry, 1990; Smart, 1990) which, in Africa is manifested in their high daily consumption as a natural supplement to cereals especially by the rural poor and the role it plays in the farming systems of the region, either in rotation or in mixed or multiple cropping (Al Jibouri and Kassapu, 1987). However, its establishment and growth on acid soils, which cover a large proportion of the tropics is poor (Kirkby, 1987). Aluminium (Al) toxicity and phosphorus deficiencies have been identified as the main factors inhibiting *P. vulgaris* growth in acid soils (C.I.A.T., 1985; 1989).

It is often difficult to distinguish between Al toxicity and phosphorous (P) deficiency in acid soils. Applied phosphate precipitates Al and reduces or eliminates its toxicity (FAO, 1986). In most cases this can be achieved only by the excess application of fertilizer. The high cost of soluble phosphate fertilizer such as single or triple superphosphate puts considerable interest in the utilization of rock phosphate (RP) and other P sources that require fewer inputs in their manufacture (Nnadi and Haque, 1988). Reports from tests carried out on acid tropical soils have confirmed (depending on the inherent reactivity of the rock) the effectiveness of RP for direct application. Crop responses to RP were equal (in some cases even superior) to those obtained through commercial P soluble sources (Mokwunye and Vlek, 1986). However, although RP could contribute positively to improving the growth and nitrogen fixation potential of *P. vulgaris* in acid soils, there is a complete dearth of information on the ability of *P. vulgaris* to utilize P from RP in acid soils of Kenya. This study investigated the response of field beans (*P. vulgaris* L) to a reactive rock phosphate material in an andosol(s) from a high potential agro-ecological zone of Kenya and compared it with that due to soluble phosphorus source.

2.0 MATERIALS AND METHODS

Greenhouse studies were conducted at the field station of Faculty of Agriculture, University of Nairobi in Kenya. Mean day and night temperatures in the greenhouse were 25 and 20°C, respectively. The soil used for the experiments was an acid humic andosol from fields with Moribund tea bushes, tea bushes planted in 1959 and 1979 and a new forest clearing intended for growing tea in Kagaa, Lari Division, Kiambu District, Kenya. Some properties of the soils from the four fields are listed in Table 1 after air drying, grinding, sieving through a 2.00mm sieve and analysing some of the bulk sample taken at depth 0 to 30cm from a profile pit. Two kilograms of each of the air-dried, ground to pass a 2.00 mm sieve soil was then transferred into a round plastic pot of 11.5 cm diameter. The pots were then placed on a table raised 50cm above the ground in a greenhouse.

The phosphate sources used were finely ground Minjingu rock phosphate (MRP) with 30 Grade % P and Triple superphosphate (TSP) fertilizer with 99.6 Grade % P. The phosphate treatments consisted of: 0, (control), 30, 45 and 60mg P pot^{-1} as TSP and MRP fertilizers respectively. The treatments were added to the soils in pots arranged in a completely randomized design in three replicates and then thoroughly mixed. Thereafter, two pregerminated seeds of *P. vulgaris* cv Rosecoco GLP2 which were previously surface sterilized in 5% sodium hypochlorite solution and germinated in sterile petri dishes were planted per pot. Thereafter, the pot was watered regularly with deionized water to field capacity. After seed emergence they were thinned to one plant per pot.

Two experiments were conducted. In the first experiment, the shoots were excised 1 cm above soil surface at 4 week after seed emergence. This was done to determine the effects of the P-source on the growth of *P. vulgaris*.

Table 1: Some physico-chemical characteristics of the four andosols in Kenya

	Particle Analysis			PH (1:2.5)			Tot	Avail	Exchangeable cations*						
Soil	Sand	Silt	Clay	Soil/$H_2$0	Soil/INKC	Org. C	N	P	Ca	Mg	K	Na	Al	CEC	Hp
	%					-----gkg^{-1}-----			CMol (+) Kg-1						
Moribund Tea	5.4	51.7	42.9	4.8	4.15	44.1	0.40	1.23	1.05	0.25	1.84	0.31	4.36	25.40	5.03
1959 planted tea	5.9	60.4	33.1	5.6	4.50	47.8	0.29	0.22	5.30	1.20	2.25	0.25	0.70	27.80	1.44
1979 planted tea	5.7	49.7	44.6	4.7	4.00	44.8	0.40	2.60	0.66	0.44	0.99	0.64	4.50	22.86	5.58
New forest clearing	5.1	56.2	38.6	5.5	4.20	47.5	0.17	0.25	5.06	1.35	2.77	0.25	1.88	25.36	3.27

* - Extract Menlich 1 represent (0.025NH_2So_4 in o.1NHCl)
Org. C. - Organic Carbon
Tot. N - Total Nitrogen
Avail. P - Available phosophorus
CEC - Cation exchange capacity
Hp - Exchangeable acidity

The soils were washed off the roots and both the shoots and roots dried at 70°C in an oven for 48 hours: their dry weights were then recorded. In the second experiment, the plants were allowed to grow to maturity and the dry seed yield per pot was recorded. The shoot and root dry matter weight (DMY) and seed yield per pot were then used to estimate the response of *P. vulgaris* to the P-sources at different rates using a semilog equation 1 (eq.1) response function models.

$$Y = \beta_0 + \delta_i \ln X_i + e_i \quad \ldots\ldots 1$$

where;

i = 1, 2, 3,..................n: n fertilizer sources.

Y = Crop yield in $gPot^{-1}$

X_i = Quantity of TSP or MRP applied using fertilizer technology i in g Pot^{-1}

ß and δ are parameters of the response functions and e is a random error with normal properties.

From the response function (eq.1) an agronomic index of efficiency (AEI) of the following form was obtained:

$$AEI = \frac{\delta_i \ln x_i}{\delta^1_i \ln x_i} = \frac{\delta_I}{\delta^1_i} \quad \ldots\ldots 2$$

Where δ^1_i and δ_i refers to the response estimates of TSP and Minjingu rock phosphate (MRP) respectively.

A statistical test (t-test) on the agronomic index based on the general hypothesis (Table 2):

$$\delta_i - \delta_i^1 = 0 \quad \ldots\ldots 3$$

$$\delta_i - \delta_i^1 \neq 0 \quad \ldots\ldots 4$$

3.0 RESULTS AND DISCUSSION

The shoot and root dry matter yields (DMY's) of *(P)* cv Rosecoco GLP 2 grown on the four soils are shown in Tables 2, 3 and 4 respectively. Significant ($P \leq 0.05$) higher shoot DMY's were noted for the following; TSP and MRP fertilizers when added to soils from fields with moribund tea bushes, tea bushes planted in 1979 and the new forest clearing and on the soil from the field with tea bushes planted in 1959 when TSP fertilizer was added to the soil. Significant ($P \leq 0.01$) positive root DMY responses were also noted when TSP and MRP fertilizers were added to soils from fields with moribund tea bushes and tea bushes planted in 1979. The responses due to the two sources on the soil from the field with tea bushes planted in 1979 where significantly different ($P<0.05$). Higher response was found when MRP fertilizer was added to the soil. The dry seed yield response of field bean to TSP and MRP fertilizer were significant ($P \leq 0.01$) only on soils from field with 1959 and 1979 planted tea bushes and newly cleared forest where significantly ($P \leq 0.05$) higher responses were found due to addition of TSP fertilizer.

The TSP fertilizer was found to be significantly ($P \leq 0.05$) superior to MRP fertilizer in increasing shoot DMY's only on soils from fields with moribund tea bushes and tea bushes planted in 1959 (Table 5). This was true for the root DMY only on the soil from the field with tea bushes planted in 1959 whereas for the seed yield, significant ($P \leq 0.05$) higher agronomic efficiency of TSP over MRP fertilizer was found in most of the soils except that from the field with moribund tea bushes.

The significant response of shoot DMY in most of the soils studied when the P sources were added to the soils could be attributed to the increase in available P in all the soils studied. Phosphorus is one of the essential plant nutrients and its content determine growth in most of acid tropical soils like the soil used in this study. The significantly higher response due to TSP than MRP fertilizer could be attributed to its ability to dissolve and avail P for shoot growth hence higher shoot DMY.

The significant positive response in root DMY's when TSP and MRP fertilizers were added to the soils could also be attributed to the increase in available phosphorus, reduction of aluminium concentration in the soil solution and increase in soil pH particularly for the MRP fertilizer source. High Al content in soil solution is toxic to the growth of most plants. The effects is particularly manifested on the root growth (Haynes, 1984: Alva et al., 1986; Bell and Edwards, 1986; Kim et al., 1985; Konishi, 1990 and Owino-Gerroh and Keter, 1993).

In spite of the significant increase in the dry seed yield of *P. vulgaris* on the soil from Moribund tea field when TSP fertilizer was added, quantitative analyses (Table 5) of the yield response estimates for both TSP and MRP fertilizers showed that the quantities used did not significantly increase the yields. This could be attributed to the inability of the two sources to supply sufficient quantities of phosphorus for both the soil and crop. The soil had high phosphate fixation capacity and also exchangeable Al content. The high exchangeable Al content in the soil could have reacted with the dissolved phosphate ions from the sources to form sparingly soluble phosphate compounds thus reducing the dissolved available phosphorus in the soil solution for plant growth. This is consistent with the observation made by Bationo et al. (1986) where insignificant yield responses were observed when rock phosphate, acid treated phosphate and calcium monophosphate monohydrate were used on maize, millet and groundnuts in West Africa soils containing high P-fixation capacities and exchangeable Al contents.

Table 2: Regression estimates for field bean shoot dry matter yield (DMY) response to phosphorous sources on andosols in Kenya

Variate	Function	Soils			
	$= \beta_0 + \delta_i l_n x_i$	Moribund tea	1959 planted	1979 planted	New forest clearing
Intercept	β_0	0.97^*	1.41	0.92	1.28
TSP	δ_1	0.22^a	0.25^b	0.20^b	0.16^b
MRP	δ_2	0.17^a	0.06^{ns}	0.19^b	0.16^b
R_2		0.98	0.82	0.83	0.71
S_{xy}		0.02	0.07	0.05	0.06
X		1.66	1.93	1.61	1.87
N		7	7	7	7

NB. Mean separation done by t-test. Means with same letter in each column are not significantly different at 5% probability level.

TSP - Triple superphosphate
MRP - Minjingu rock phosphate
* - Extract Menlich 1 represent ($0.025NH_2So_4$ in o.1NHCl)

Table 3: Regression estimates for field bean root dry matter yield (DMY) response to phosphorous sources on andosols in Kenya

Variate	Function	Soils			
	$= \beta_0 + \delta_i l_n x_i$	Moribund Tea	1959 planted	1979 planted	New forest clearing
Intercept	β_0	0.47[a]	0.67[a]	0.25	0.51[a]
TSP	δ^1	0.07[a]	0.03[ns]	0.09[b]	0.40[ns]
MRP	δ_2	0.06[a]	0.02[ns]	0.10[a]	0.08[ns]
R		0.98	0.12	0.90	0.73
S_{xy}		0.01	0.04	0.02	0.02
X		0.67	0.76	0.58	0.72
N		7	7	7	7

N.B. Mean separation done by t-test. Means with the same letter in column are not significantly different at 5% probability level.

ns - Not significant
TSP - Triple superphosphate
MRP - Minjingu rock phosphate

Table 4: Regression estimates for field bean yield response to phosphorous sources on andosols in Kenya

Variate	Function $= \beta_0 + \delta_i l_n x_i$	Soils: Moribund tea	Soils: 1959 planted	Soils: 1979 planted	Soils: New forest clearing
Intercept	β_0	0.75	3.59	0.40	1.13
TSP	δ_1	0.61^{ns}	0.99^{a}	0.89	0.93^{a}
MRP	δ_2	0.23^{ns}	- 0.24	0.27^{ns}	0.05^{ns}
R_2		0.57	0.57	0.94	1.00
S_{xy}		0.30	0.77	0.13	0.03
X		2.23	3.96	2.30	2.53
		7	7	7	7

NB. Mean separation done by t-test. Means with same letter in each column are not significantly different at 5% probability level.

ns - Not significant
TSP - Triple superphosphate
MRP - Minjingu rock phosphate

Table 5: Relative Agronomic Efficiency indices for field beans shoot and root dry matter weight and yield to phosphorous sources on andosol in Kenya

P-source	Relative Agronomic efficiency index (%)			
	Moribund tea	1959 planted tea	1979 planted tea	New forest clearing
	..................Shoot dry matter yield..........			
TSP	100[a]	100[a]	100[a]	100[a]
MRP	27.3[b]	24[b]	95[a]	100[a]
	..................Root dry matter yield..........			
TSP	100[a]	100[a]	100[b]	100[a]
MRP	85.7[b]	66.7[a]	111[a]	20[b]
	..................dry seed yield..........			
TSP	100[a]	100[a]	100[a]	100[a]
MRP	38.7[a]	24.2[b]	31.5[b]	5.4[b]

Means separation done by t-test. Means with the same letter in each row are not significantly different at 5% probability level.

TSP - Triple superphosphate MRP - Minjingu rock phosphate

The significantly higher seed yields and responses of field bean to TSP fertilizer on soils from fields with teas planted in 1959 and 1979 could also be attributed to the ability of the source to avail sufficient quantities of phosphorus to take care of the high P-fixation capacities and exchangeable Al contents in the soils with some remaining for plant growth.

The insignificant field bean yield responses to MPR fertilizer on soils from fields with tea bushes planted in 1959 and 1979 and new forest clearing could be adduced to its inability to supply adequate quantities of phosphate ions for plant growth. MRP is sparingly soluble in soil solution and the little that dissolve normally increases the soil reaction and exchangeable Ca content into the soil solution. These affect its (MRP) further dissolution and therefore, available phosphorus content in the soil for plant growth (Khasawner and Doll, 1978; Hammond et al., 1986). The dissolved Ca from the rock phosphate also react with available phosphate ions in the soil to form sparingly soluble compounds (Lindsay, 1979), thereby reducing even the little phosphate available in the soil solution. This effect was emphatically elucidated on the soil from the field with tea planted in 1959 (Table 5 and Figure 1) where negative yield response was found with the increase in quantities of MRP fertilizer added to the soil. Baanante (1986) reported similar observation with beans in soils of Kabete, Kenya and noted that the probability of loss due to direct application of less soluble phosphorus sources was high compared to the soluble sources. Consistent observation was also made with maize, sorghum, millet and groundnuts on West Africa soils by Batiano et al. (1986).

The significantly higher agronomic efficiency index of TSP over MRP fertilizer for the shoot DMY on the soil from the field with tea planted in 1959 (Table 5) could be attributed to the inability of MRP fertilizer to dissolve and avail adequate quantities of phosphorus for plant growth. This was because the soil had low acidity (higher pH) therefore, MRP fertilizer could not dissolve and avail adequate quantities of phosphate ions for the plant to grow.

The significantly higher agronomic efficiency index of MRP over TSP on root DMY on the soil from the field with tea planted in 1979 (Table 5) could be attributed to the acidifying effect of TSP fertilizer. TSP, a monocalcium phosphate dehydrate on dissolution increased the soil acidity and thus, enabled heavy metals such as Al, Fe and Mn to dissolve in the soil solution. These dissolved heavy metals inhibited the growth of field bean, particularly the root growth (FAO, 1986).

Lack of significant differences in agronomic efficiency indices observed when the two phosphorus sources were applied on the soil from the field with moribund tea on the yield of field bean (Table 5) could be attributed to insufficient P supply. Most of the quantities which dissolved from the two sources on dissolution were fixed or precipitated and therefore, little remained to sustain the crop. In the soils from field with teas planted in 1959 and 1979 and new forest clearing, the quantities of phosphate ions which dissolved from TSP source could sustain crop growth hence higher yields whereas the contribution from MRP fertilizer was insufficient to show up even in statistics. This product was therefore, found to be inferior to TSP for use in growing field bean on the three soils. Chien and Hammond (1977) working with field beans on Andepts from Columbia showed that positive yield responses of RP compared to that of TSP could only be observed from highly reactive phosphate rock source whose relative agronomic efficiency index was 87% to that of TSP. The relative agronomic efficiency indices of MRP in all the soils was very low. Ikerra et al, (1994) although working with maize on an ultisol in Tanzania, also showed that Minjingu rock phosphate was agronomically inferior to TSP fertilizer. For comparable yields in conducive soils environment as outlined by Khasawneh and Doll (1978), he recommended that MRP be applied three times the rate of TSP.

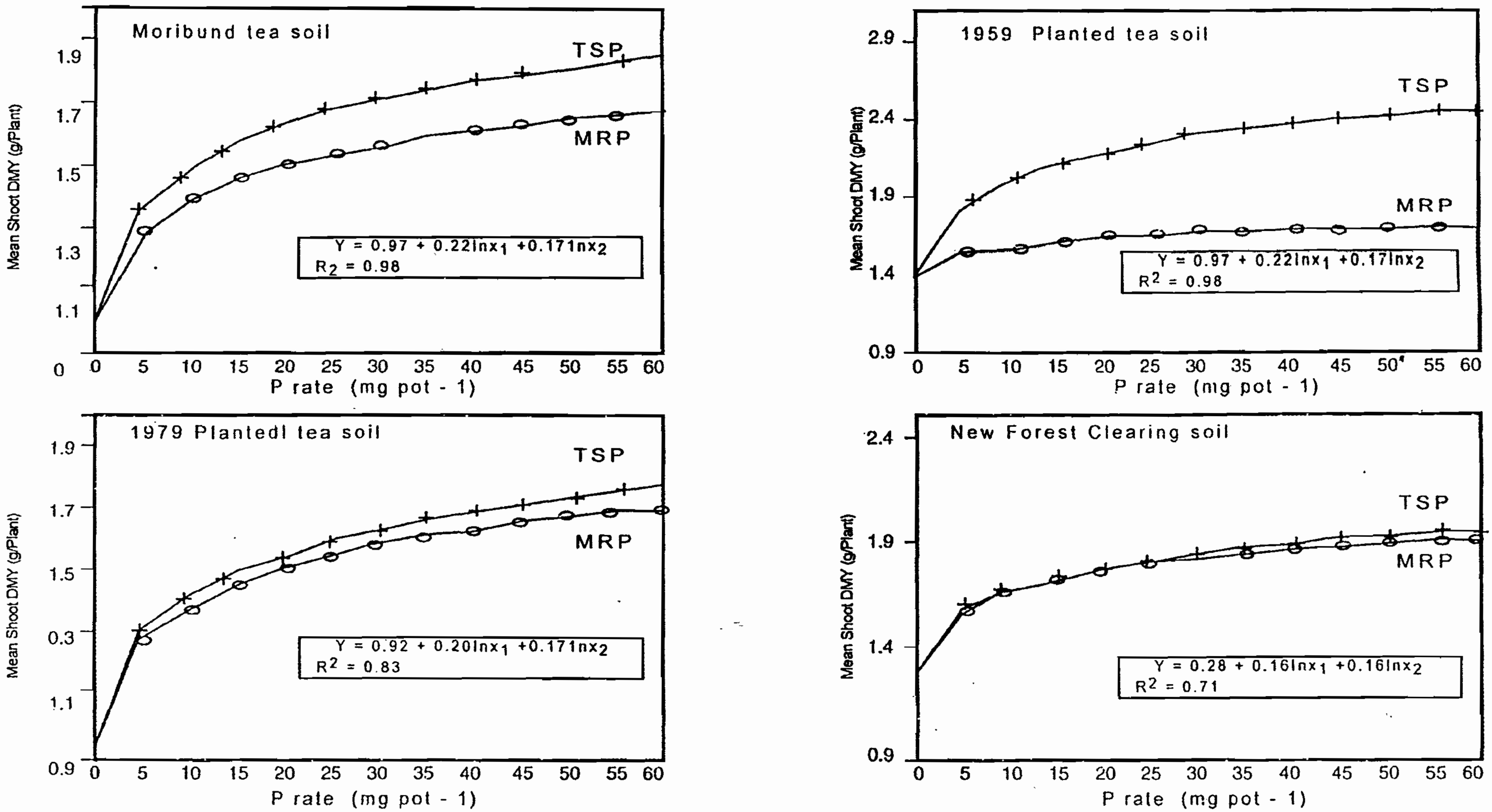

Fig 1. Mean shoot dry matter yield response estimate of P.vulgaris L. to phosphorus sources on the soils studied

4.0 Conclusion

The results of this study show that even in acid andosols, water soluble phosphate source is superior to water insoluble phosphate source as a source of phosphorus for plant growth. TSP is also more agronomically efficient as a source of phosphorus for growing field bean in acid tropical soils.

Acknowledgement

African Academy of Sciences for financial support and Ruphine Opondo for typing the manuscript.

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