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Full Length Research Paper

Maize yield response to the combined application of Tundulu rock phosphate and Pigeon Pea residues in Kasungu, Central Malawi

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Malawi is endowed with several large deposits of rock phosphate (RP) occurring in the southern part of the country that remain unexploited due to limited knowledge on their agronomic usefulness. A study therefore, was conducted to assess the potential of improving maize yield through use of Tundulu Rock Phosphate (TRP) and pigeon pea residues. Maize yield responses to sole application of either pigeon pea biomass or TRP and the application of these in combination were evaluated. In the study, researcher designed but farmer managed trials involving eight farmers were mounted on farm. Treatments were laid out in a randomized complete block design. The results indicated a non significant maize yield increase from 683 kg ha^{-1} in the control (sole maize) plot to 1,396 kg ha^{-1} (104.4%) in the treatment where TRP was applied. Maize yield was increased significantly ($p<0.05$) from 683 kg ha^{-1} in the control (sole maize) plot to 1,999 kg ha^{-1} (192.7%) in the treatment where pigeon pea biomass was applied in combination with TRP and that maize yield was increased significantly from 683 kg ha^{-1} in the control plot to 1,887 kg ha^{-1} (176.3%), in the treatment where sole pigeon pea biomass only was applied. The result suggests that the combined application of legume biomass and TRP to the soil can improve maize yields to some extent.

Key words: Malawi, maize, rock phosphate, biomass, *Cajanus cajan*.

INTRODUCTION

The soil is Malawi's valuable resource that plays a key role in agriculture. However, most of the soils are highly weathered. Highly weathered soils are low in soil organic matter (SOM), nitrogen (N), phosphorus (P), potassium (K), sulphur (S), zinc (Zn) and copper (Cu) (Bationo et al., 1987). Soils can be classified as dystrophic (highly leached), eutrophic (very little or no leaching) and mesotrophic (intermediate leaching). Over 40% of Malawi soils are Oxisols and Ultisols, which are dominantly acid soils (Saka et al., 2004). Soil fertility depletion in small-holder farms is probably one of the factors responsible for the decline of food production in Malawi (Maida, 2005). Soil fertility depletion is a consequence of continuous growing of crops on the same piece of land and in most cases without rotation or fallowing. N and P are the most important deficient major nutrient elements limiting crop yields in most Malawi soils. Use of chemical fertilizers has been advocated for many years to replenish the depleted soil nutrients. However, the use of such fertilizers is becoming impossible especially for poor smallholder farmers due to increase in prices. Correcting soil nutrient deficiency with large application of inorganic fertilizer during maize cultivation is not profitable due to high costs, difficult logistics of buying mineral fertilizers

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Abbreviations: C:N, Ratio of carbon to nitrogen; **Cu**, copper; **EPA,** extension planning area; **K** potassium; **N,** nitrogen; **OC,** organic carbon; **P,** phosphorus; **RP,** rock phosphate; **S,** sulphur; **SOM,** soil organic matter; TRP, Tundulu rock phosphate; **Zn,** zinc.

and the low market price of maize (Carr, 1997). Recently, the Malawi Government has introduced the targeted fertility subsidy program. This program is tailored to reach out to a segment of resource poor farmers. However, many farmers are not able to access the facility. This is due to the fact that the quantity of the fertilizer purchased by the Government for the program usually is not enough to cover all the resource poor farmers. Such being the case, low-cost input technologies suitable for resource poor smallholder farmers are required to replenish the SOM, N, and P most needed for their crop production. Agroforestry technologies are some of the low-cost input technologies that could be explored.

Cajanus cajan, commonly known as pigeon pea, is a leguminous food crop which also fixes N. Pigeon pea can fix about 70 kg N ha^{-1} per season by symbiosis until the mid-pod-fill stage (Nene, 1987). This is about 88% of the total nitrogen content of the plant at that stage of growth. Under rotation farming, the residual effect of N fixed by pigeon pea in plant tissues on a following cereal crop can be as much as 40 kg N ha^{-1} (Nene, 1987). Studies have shown improved maize yields when pigeon pea leaf biomass is incorporated into the soil with addition of inorganic fertilizer as a supplement. Kumwenda (1998) reported that *Cajanus cajan* biomass, when supplemented with 48 kg N ha^{-1}, increased maize yields from 982 kg ha^{-1} to 1196 kg ha^{-1}; while Makumba and Akinnifesi (2008) reported that sole application of pigeon pea biomass increased maize yields from 0.85 t ha^{-1} to 2.7 t ha^{-1}. Malawi is endowed with several large deposits of rock phosphate (RP) occurring in the southern part of the country (Hoffman, 1991). The major alluvial deposits are at Chingale, Malindi and Bilira in Zomba, Mangochi and Ntcheu districts, respectively. In addition, some deposits of reasonably high grade associated with the carbonate complexes and alkaline rocks are at Tundulu and Kangankunde in Phalombe and Machinga districts respectively (Chisale and Kaphwiyo, 1986). Chingale deposits contain about 8.7 millions tons of RP while Tundulu deposits contain about 2 million tons. The RP is able to supply P to soils. Its dissolution in any particular soil is controlled largely by three soil factors, namely soil pH, concentration of P and concentration of Ca in a soil solution (Chien et al., 1987). The use of RP is limited to acidic soils because it is in such soils that the RP dissolves readily (Singh and Ruhal, 1983) and acid soils are common in Malawi. Such areas have soil pH values that are less than 5.5. With such soil reaction values, Tundulu RP is likely to be an effective source of P and at ameliorating soil acidity, as its dissolution is enhanced. The interactive effect of RP with tree foliage on crop yields has also been investigated by some researchers. Ndung'u et al. (2006) reported that significant maize grain yield increases were obtained in Kenya when Minjingu RP was applied alone or in combination with fallow biomass from *Tephrosia vogelii* and *Crotalaria grahamiana* as compared to treatments with either no external nutrient addition (control) or with fallow biomass.

MATERIALS AND METHODS

Study site

The research was conducted under field conditions in Kasungu District, Mkanakhothi Extension Planning Area (EPA) (12° 35' S, 33° 31' E). Research sites were located in five villages of Kaunda (Kapopo section), Tchezo (Ofesi section), Chisazima (Ofesi section), Ndaya (Simulemba section) and Chaguma (Simulemba section). The site falls within the Kasungu plain and receives an average annual rainfall of 680 mm. The rainy season spans from November to April. During the 2007/2008 growing season, a total of 760 mm was recorded. The dominant soils are Ultisols (Ustults) (MW Lowole, University of Malawi, personal communication). These have low organic matter content, low nitrogen and low to high available phosphorus content. They have poor structure because of the sandy texture of the top soil.

Materials

Ground (<150 µm) Tundulu Rock Phosphate (TRP) was used in the study comprising 29.2% total P_2O_5 (12.8 %P) of which 1.7 and 11.3% is soluble in citric acid and formic acid respectively (Mueller et al., 1993). The P content of TRP was used as a basis for calculating the rate of P applied. The TRP was sourced from OPTICHEM, a fertilizer manufacturing company. Currently, the resource at Tundulu in Phalombe, southern Malawi, is licensed to this company. Maize was the test crop with ZM 621 seed which has a yield potential of 6 - 7 t ha^{-1}). Air dry leaf biomass from pigeon peas was used for treatments where legume leaf biomass was applied. The nitrogen content of this biomass was 3.1% which is slightly higher than that reported by Chirwa et al., 2004, (2.98% N). Other workers have reported 0.16% phosphorus content for *Cajanus cajan* leaves (Niang et al., 2002). The pigeon pea biomass was sourced from Njewa farm in Lilongwe, central Malawi.

Experimental design

In this on-farm study, four treatments were laid in a randomized complete block design with eight farmers serving as replicates. The distances between farmers' fields were significant. In general the soils across all the fields were dominantly sandy loam in texture. The treatments were as follows: 1) Maize that was planted without the application of either mineral or organic fertilizer as the control; 2) Maize to which TRP at the rate of 22.9 kg P ha^{-1} was applied; 3) Maize to which pigeon pea biomass at the rate of 92 kg N ha^{-1} was applied; and 4) Maize to which pigeon pea biomass at the rate of 92 kg N ha^{-1}, TRP at 22.9 kg P ha^{-1} were applied. Each treatment was applied to a 10 x 10 m plot on each farmer's field.

Treatment plot description

Treatments were allocated to 10 x 10 m plots. Ridges were spaced at 75 cm apart. Maize was sown at 25 cm apart, one seed at each planting station. The total plant population was 53,333 maize plants ha^{-1}.

Application of phosphorus and nitrogen organic sources

Tundulu Rock Phosphate (TRP) contains in total 29.2% P_2O_5 (12.8% P) of which 1.7 and 11.3% are soluble in citric acid and formic acid respectively (Mueller et al., 1993). This was used to calculate the quantity of the rock (3.3 g) that was applied per planting station to achieve the rate of 22.9 Kg P ha^{-1}. This was

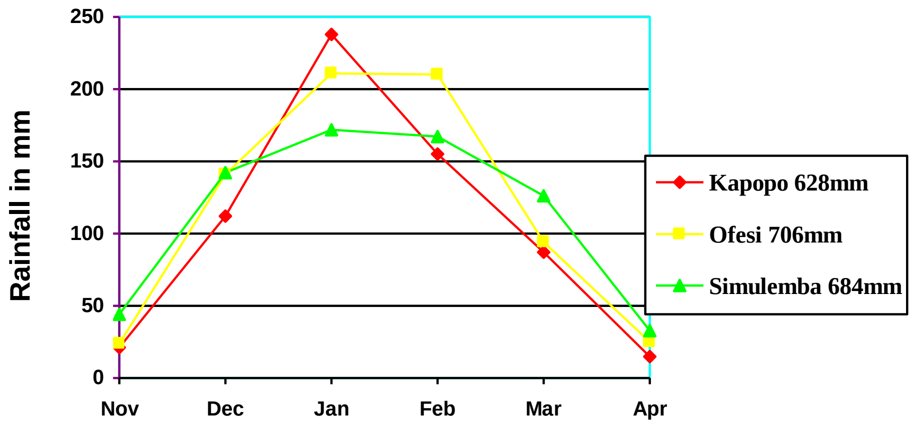

Figure 1. Rainfall distribution in the project area, seven year means (2000/01 to 2007/08).

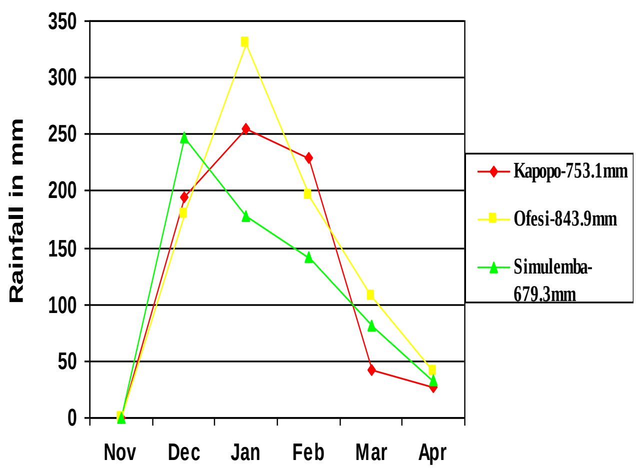

Figure 2. Rainfall distribution in the project area for the 2007/08 season.

applied through dolloping. A sample from the pigeon pea leaf biomass harvested from Njewa farm in Lilongwe was drawn from the air dried leaves for determination of N before delivery to the project area for incorporation into the soil. Laboratory analysis indicated that the leaf biomass contained 3.1% of N. This was used to calculate the amount of leaf (55 g) that was applied per planting station to achieve 92 Kg N ha^{-1} (Okalebo and Lekasi, 1993). The leaf biomass was incorporated into the soil, between planting stations of maize through biomass transfer at the rate of 92 Kg N ha^{-1} either alone or in combination with the TRP at the rate of 22.9 Kg P ha^{-1}. This was done soon after seedling emergence.

DATA COLLECTION AND ANALYSIS

Soil sample collection

Farmers' fields were visited and soil samples collected in all the eight fields. Top (0 -15 cm) and sub (15 - 30 cm) soils were sampled at random before treatment application to plots (Okalebo et al., 2000). Samples (4 borings from each field) were taken. The samples were air dried at Bunda College of Agriculture and then passed through a 2 mm sieve. Soil samples from each field were analyzed. Also, five gram portions taken from each sample were bulked and a composite sample was made representing the eight sites. At the time of harvest, soils were sampled from each plot (3 borings at random per treatment plot). These were thoroughly mixed and a composite sample was taken for each treatment plot.

Plant sample and agronomic data collection

Four whole maize plant samples were randomly collected from within each treatment plot in all farmers fields at tasselling and at maturity stages for plant nutrient analysis. Agronomic data was also collected which include maize grain yield and maize Stover yield.

Rainfall data

Monthly rainfall data for a seven year period for the study area were obtained from the Ministry of Agriculture, Kasungu Rural Development Project. Rainfall data for the year of study were also obtained. Monthly rainfall means were then computed for the period and graphs were plotted (Figure 1). It was observed that the study area receives low amounts of rainfall and that dry spells are a common phenomenon with drought also being a common occurrence in the area.

Rainfall distribution in the project area for the 2007/08 season

The rainfall amount that was received in the area was adequate for crop production, but the distribution over the season was poor. Firstly, planting rains came mid way the month of December 2007. Much of the rainfall recorded was received in the months of December, January and February with little amounts recorded in the month of March and April (Figure 2).

Determination of plant phosphorus and nitrogen in plant tissues

Bulked whole plant samples from each treatment plot for each farmer were separately oven-dried at 70°C to a constant weight. The dried bulked plant materials from each treatment plot for each farmer were separately ground to pass through 1 mm sieve. One

Table 1a. General soil characteristics of farmers' fields under study (bulked).

Parameter	Value (Depth: 0-15 cm	Value (Depth: 15-30 cm)
Clay%	13	13
Silt%	5	8
Sand%	82	79
Texture class	*SL	*SL
pH $_{(H2O)}$	5.4	5.3
N%	0.07	0.07
OC%	0.87	0.81
C/N	12.4	11.6
P-Mehlich 3 (mg kg^{-1})	18.0	9.6

*SL means sandy loam.

gram of each sample plant material was digested using 5 ml of concentrated sulphuric acid and 30% hydrogen peroxide (Thomas et al., 1967). Phosphorus in the digest was determined (Murphy and Riley, 1962). Plant N was determined using colorimetric method as described by Wendt (1996).

Data analysis

Soil analysis was done in order to characterize soil properties and assess changes due to treatments. Soil samples were analyzed for OC, total N, available P, and soil pH (H_2O). Soil analysis for P was done using Mehlich 3 extraction procedures (Mehlich, 1984) while OC and total N were determined using the colorimetric method (Wendt, 1996). All the soil and agronomic data were analyzed using Genstat statistical package and were subjected to analysis of variance at 95% level of confidence.

RESULTS

Soil characterization of the study area

Baseline physical and chemical properties of soil used during the study

Tables 1a and 1b summarize baseline physical and chemical properties of soil used during the study. Laboratory analytical results showed that soil pH ranged from 5.2 to 5.8 for top soils while the range was 5.1 to 5.7 for sub soil; thus the soils are acid to moderately acid. There was high variation in available P across sites (2 to 60 mg P kg^{-1}). It was low both in top soils and subsoil, with mean levels of 18 and 9.6 mg P kg^{-1} respectively. Texture classes were loamy sand, sandy loam to sandy clay loam, with sand loam being the most prevalent texture class across sites. Soils have low levels of OM both in the top soil and subsoil with the mean levels of 1.5 and 1.4% respectively. The C: N ratio for top soil was 9:1. This is close to a C: N ratio range of 10:1 to 12:1 which indicates a stable soil organic matter fraction (Kelly et al., 2005).

Soil chemical properties at harvest

Table 2 shows the status of soil chemical properties at harvest. Soil pH ranged from 5.3 to 5.7 for top soils while the range was 5.1 to 5.6 for sub soil; this range of values was similar to the baseline study values. There was high variation in Mehlich 3 soil available P across treatments. The method used in extracting the P, extracts available P which is that portion of P that is absorbable by crops. Mean values of P across treatments ranged from 3.9 to 9.4 mg P kg^{-1} in the top soil and 3.3 to 8.3 mg P kg^{-1} in subsoil. These mean values of P were below the mean values observed at the onset of the trial. Across treatments, mean total N was low, 0.03 to 0.07% for top soil and 0.03 to 0.05% for sub soil.

Low to medium levels of OC across treatment both in the top soil (0.7 to 1.6%) and subsoil (0.7 to 1.3%) were observed.

CONCENTRATION OF NUTRIENTS IN MAIZE PLANT TISSUES AND STOVER AND MAIZE GRAIN YIELD

Mean nitrogen and phosphorus concentrations in the maize plant at tasselling and harvest

Table 3 shows the mean values of the concentration of tissue N and P at tasselling and harvest in the treatments. The mean concentrations of N in the maize plant at tasselling ranged from 1.8 to 2.9%. The highest concentration of N (2.9%) was for the maize + pigeon pea biomass + TRP treatment. This was within the range of the sufficiency level (2.75 to 3.5%) proposed by Jones, (1974). Tissue N for the other treatments was below the lower sufficiency level of 2.75% proposed by Jones, (1974). This indicated that maize grain yield at harvest for the other treatments might be lower than that for the maize + pigeon pea biomass + TRP treatment.

On the other hand the mean concentrations of N in the maize plant at harvest ranged from 0.47 to 0.62%. The mean N concentration was lower when compared to its concentration at tasselling for all treatments. This was so because some of the N was remobilized to the cobs during grain formation. Mean tissue N was higher in the control compared to other treatments. This was the case because in partitioning less N went to make up grain, leaving a higher proportion in the tissue. This ultimately contributed to the reduced grain yield levels in the control. The mean concentration of P in the maize plant at tasselling was 0.3% in all the treatments. This was within the sufficient range for maize at tasselling (0.25 to 0.40%) proposed by Jones (1974). The mean concentration of P in the maize plant at harvest ranged from 0.13 to 0.14% and these levels were lower when compared with mean tissue P concentration at the tasselling

Table 1b. Site specific soil parameters.

Village	Section	Ph		OC (%)		Mehlich 3 P (mg kg^{-1})		Total N		Texture Classes							
		0 -15 cm	15 -30 cm	0 -15 cm	15 -30 cm	0 -15 cm	15 - 30 cm	0 - 15 cm	15-30 cm	0 – 15 cm				15 – 30 cm			
										%S	%SI	%C	TC	%S	%SI	%C	TC
Kaunda 1	Kapopo	5.5	5.3	0.6	0.6	62	24	0.05	0.05	88	2	10	SL	80	2	18	SL
Kaunda 2	Kapopo	5.8	5.7	0.9	0.6	8	6	0.08	0.07	82	10	8	LS	84	2	14	SL
Tchezo	Ofesi	5.6	5.5	0.8	0.6	30	26	0.08	0.06	78	4	12	SL	78	4	18	SL
Chisazima 1	Ofesi	5.3	5.1	0.8	0.6	2	2	0.06	0.06	88	2	10	SL	86	4	10	SL
Chisazima 2	Ofesi	5.7	5.6	0.5	0.6	4	2	0.04	0.03	84	6	10	SL	82	6	12	SL
Ndaya 1	Simulemba	5.4	5.3	1.5	0.6	11	2	0.1	0.1	76	6	18	SL	72	8	20	SCL
Ndaya 2	Simulemba	5.3	5.1	0.8	0.6	14	3	0.07	0.07	84	2	14	SL	76	6	18	SL
Chaguma	Simulemba	5.2	5.1	1.2	0.6	14	13	0.1	0.1	76	2	22	SCL	74	2	24	SCL
Mean	-	5.4	5.3	1.5	1.4	18	9.6	0.07	0.07	82	4.25	13	SL	79	4.25	16.75	SL
Std. dev	-	0.21	0.24	0.5	0.5	0.36	0.34	0.02	0.02	4.6	2.7	4.5	-	4.7	2.1	4.2	-

Classes: S=Sandy soil; SL=Sandy Loam; SCL=Sandy Clay Loam; SI=Silt; TC=Texture class

stage. This indicates translocation of P to the grain. Although mean tissue P concentration differed between treatments, the differences were not significant ($p<0.05$). This suggests that translocation of P to the grain was similar across the treatments. Means with different super-scripts within the same column are significantly different $p<0.05$; Number of replicates (N) = 8; Mz = Maize, Ppb = Pigeon pea biomass

Nitrogen, phosphorus, grain and stover yields of maize at harvest

Table 4 shows the mean nitrogen, phosphorous, grain and stover yields of maize in the trial at harvest on a hectare basis. In general, the maize grain yield was low to medium across treatments partly because of poor seed viability and vigour of the initial maize seed and poor distribution of of rainfall of rainfall across the season. This required replanting which affected crop management in all treatments on all farmers' fields and subsequent maize yields. However, significant differences ($p<0.05$) were observed in the amount of grain produced under the different treatments.

The maize sole crop without fertilizer or biomass produced the least amount of grain (683 kg ha^{-1}) but this was not significantly different from that produced by the maize + TRP treatment. Significantly higher maize grain yields were recorded in the maize + pigeon pea biomass + TRP and maize + pigeon pea biomass treatments.

Significant differences ($p<0.05$) in stover yield were observed. The mean yield of stover ranged from 1,899 kg ha^{-1} to 3,816 kg ha^{-1}. The highest stover yield was obtained from the maize that was treated with pigeon pea biomass and the rock phosphate while the lowest stover yield was obtained from the sole maize control plot and maize that was treated with TRP. The yield pattern depicted in stover followed the grain yield pattern for all the treatments. Higher stover yields gave higher grain yields. The bigger crop produced more carbohydrates by photosynthesis which was later partitioned into more grain. The mean yields of N at harvest ranged from 9.7 to 18.3 kg N ha^{-1} while mean yields of P ranged from 2.7 to 5.0 kg P ha^{-1}.

DISCUSSION

The effect of pigeon pea leaf biomass and the combination of the leaf biomass with Tundulu rock phosphate on maize grain yield

Positive yield response to pigeon pea leaf biomass application (1,887 kg ha^{-1}), which was-176.3% yield increase above the control (683 kg

Table 2. Status of soil chemical properties at harvest.

Treatments	%N		%OC		P (mg kg^{-1})		pH_{H2O}	
	0 -15 cm	15 -30 cm	0 -15 cm	15 - 30cm	0 -15 cm	15 -30 cm	0 -15 cm	15 -30 cm
Mz only	0.05^{ab}	0.05	1.2^{ab}	1.2	3.9^{b}	3.3^{b}	5.7^{a}	5.6^{a}
Mz + TRP	0.03^{b}	0.03	0.7^{b}	0.76	6.4^{ab}	6.4^{ab}	5.4^{ab}	5.5^{ab}
Mz + TRP + Ppb	0.04^{ab}	0.05	1.2^{ab}	1.2	7.8^{ab}	6.4^{ab}	5.3^{b}	5.3^{bc}
Mz + Ppb	0.03^{b}	0.04	1.2^{ab}	0.7	6.3^{ab}	5.4^{ab}	5.3^{b}	5.1^{c}
LSD (0.05)	0.03	0.03	0.8	0.7	3.8	3.3	0.4	0.3
C.V. (%)	41	42.3	50.00	45.4	53.06	51.06	6.4	5.91

Means with different superscripts within a column are significantly different $p<0.05$; Number of replicates (N) =8

Table 3. Nutrient concentration in the maize plant at tasselling and harvest.

Treatments	Mean nutrient concentration (at tasselling)		Mean nutrient concentration (at harvest)	
	N (%)	P (%)	N (%)	P (%)
Mz only	1.9^{b}	0.3	0.62	0.14
Mz + TRP	1.8^{b}	0.3	0.47	0.13
Mz + Ppb + TRP	2.9^{a}	0.3	0.48	0.13
Mz + Ppb	1.8^{b}	0.3	0.50	0.14
LSD (0.05)	0.8	0.2	0.20	0.03
C.V. (%)	33.3	43.8	33.36	23.26

Means with different superscripts within a column are significantly different $p<0.05$; Number of replicates (N) = 8; Mz =Maize, Ppb = Pigeon pea biomass.

Table 4. Nitrogen, phosphorous, grain and stover yields of maize at harvest.

Treatments	Yields in kg ha^{-1}			
	N	P	Grain	Stover
Mz only	11.8	2.7^{b}	683^{b}	1,899^{bc}
Mz + TRP	9.7	2.7^{b}	1,396^{b}	2,073^{bc}
Mz + Ppb + TRP	18.3	5.0^{a}	1,999^{a}	3,816^{a}
Mz + Ppb	13.4	3.8^{ab}	1,887^{a}	2,687^{abc}
LSD (0.05)	7.8	1.5	796.2	1,260
C.V. (%)	48.54	44.09	44.19	42.00

Means with different superscripts within a column are significantly different $p<0.05$; Number of replicates (N) = 8; Mz = Maize, Ppb = Pigeon pea biomass

ha^{-1}) for maize was observed in the trial (Table 4). Application of 176.3% yield increase above the control (683 kg ha^{-1}) for maize was observed in the trial (Table 4). Application of leaf biomass could have directly improved availability of N to maize. Pigeon pea leaves have a low C:N ratio of 15.1 (Chirwa et al., 2004) and low lignin content. Such being the case, the process of leaf decom-position and subsequent mineralization was quick. This fact has been well documented in literature (Vanlauwe et al., 1996).

Nutrients that were released from the residues therefore subsequent mineralization was quick. This fact has been well documented in literature (Vanlauwe et al., 1996). Nutrients that were released from the residues therefore were available to the crop within the growing season and this generated the observed positive yield responses.

A positive significantly higher maize yield-response, 192.7% above the control (Table 4) was generated through the combination of TRP and pigeon pea leaf biomass (1,999 kg ha^{-1}). Though higher, the yield was not significantly different from that obtained from the sole pigeon pea biomass treated plot which generated 176.3% yield (1,887 kg ha^{-1}) increase above the control (683 kg ha^{-1}). The positive yield response agrees well with the findings of Okalebo and Woomer (1994) that used the groundnut haulms plus Mijingu Phosphate Rock. This treatment gave the highest grain yield of 102% above the control. Singh and Amberger (1990) indicated that RP dissolution is enhanced when combined with organic residues. The decomposing organic matter produces organic acids that can enhance the dissolution of RPs.

Further, microorganisms during decomposition require P nutrition for growth. In the process inorganic P is converted into the organic form of P. Upon death and decomposition of microorganisms, this organic P pool is converted to plant available P. Further calcium chelation by organic functional groups or anions supplied during decomposition can also contribute to RP dissolution (Singh and Amberger, 1990).

However, in this study the level of TRP dissolution apparently might have been minimal. This is evident in the level of soil P at harvest (Table 2), which was similar to the level at baseline soil characterization (Table 1a and b).

Further, the yield obtained from plots where pigeon pea biomass was combined with TRP was not significantly different from that obtained from the sole pigeon pea biomass treated plots, suggesting that dissolution of TRP was not sufficient to supply adequate amount of soil P that could increase yield significantly. In general, large Coefficient of Variation (C.V. (%) values were observed in the yield data obtained in the trial. Such was the case because this was on farm research whereby controlling many factors that affect results is often a challenge.

Conclusion

From the study, it can be concluded that the combined application of pigeon pea biomass and TRP to the soil can to an extent improve maize yields compared to the control. The dissolution of TRP might have been marginally enhanced with the combination of organic residues. The decomposing organic matter produced organic acids that might have enhanced the dissolution of TRP. Further, microorganisms during decomposition required P nutrition for growth. In the process inorganic P was converted into the organic form of P. Upon death and decomposition of microorganisms this organic P pool was also converted to plant available P. Further studies should consider the application of different rates of pigeon pea biomass plus TRP combinations with the aim of determining the best combination that will enhance TRP dissolution. A longer term trial should also be considered that would evaluate residual effects of pigeon pea biomass plus TRP application since the dissolution process may take longer with benefits that show up later.

Further, the application to the soil of legume biomass alone can improve maize yield. Application of leaf biomass improved availability of N to maize. Pigeon pea leaves have a low C:N ratio and low lignin content. Such being the case the process of leaf decomposition and subsequent mineralization was quick. Nutrients that were released from the residues therefore were available to the crop within the growing season and this generated the observed positive yield responses. However a sustained application/incorporation is required to significantly change soil chemical parameters and increase rates and frequencies of application/incorporation of the residues to achieve higher yields. Further studies should also consider investigating on optimal rate of application, time and method of application of the leaf biomass for increased yield. Additionally, modifications in the design should also be considered to reduce variability between treatments and manage better external factors. Aspects that might be considered in the modification of the design may include; selection of participating farmers, site and choice of type and variety of maize seed to be used in the trials. Also, selected farmers should run replicated trials and their fields should be in proximity.

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