International Scholars Journals

African Journal of Soil Science ISSN 2375-088X Vol. 7 (10), pp. 001-005, October, 2019. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Incorporating pigeon pea compost with Minjingu fertilizer brands to determine their effects on maize production in Morogoro, Tanzania

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Accepted 14 July, 2019

This study intended to find alternative ways of increasing phosphorus (P) in soils using Minjingu fertilizer brands since maize yield in Tanzania has been retarded by low soil fertility. Maize (*Zea mays* L.) var. TMV-1 was used as a test crop. The treatments used (g per 2.16 m^2 plot) were: absolute control (C), Pigeon pea compost (PP) (100), M-Mazao (MM) (420), Hyper (MH) (160), MM + PP (520) and MH + PP (260). The results showed that Agronomic Efficiency (AE) varied significantly (p <0.001) among treatments. Harvest index (HI) also differed significantly (p ≤0.05). This study revealed that exclusive application of Minjingu Hyper fertilizer to maize proves to be superior to Minjingu Mazao fertilizer by having the highest harvest index (24.7%) with relatively high maize yield (2.94 t ha^{-1}). The former fertilizer brand compares better with the latter, which produced yield of 1.65 t ha-1 and harvest index of 6.94%. Furthermore, upon incorporation of pigeon pea compost, Minjingu Mazao fertilizer recorded the highest yield (3.85 t ha^{-1}). This differed slightly numerically but was statistically similar with yield obtained when compost was incorporated with Minjingu Hyper fertilizer (3.64 t ha^{-1}).

Key words: Compost, maize yield, Minjingu fertilizer brands.

INTRODUCTION

Maize is the most commonly grown crop by smallholder farmers in Tanzania as it is the staple food for most communities. Maize is increasingly becoming an important source of food and raw material in developing countries. Its demand is expected to increase from 282 million tons in 1995 to 504 million tons in 2020 (Ibrikci et al., 2005). According to Rowhani et al. (2011), annual production of maize in Tanzania has increased to 3.0 million tons for the past ten years. However, the slow pace of maize production is related to variation in weather conditions, low soil fertility and use of ungraded seeds. Maize production in Tanzania is high in Iringa, Njombe and Mbeya regions contributing to a quarter of the national maize, producing on average more than 700 000 tons each year. Other regions in the order of maize production include Shinyanga, Rukwa, and Arusha. On the other hand, Coast, Dar es Salaam, Mtwara, and Lindi are the maize deficit regions. Furthermore, Arusha and Shinyanga regions are in the middle and lower ends of production with 1.24 and 1.07 t ha^{-1} of maize, respectively. According to Gehl et al. (2005), the national maize yield average is 1.2 t ha^{-1}, which is far below the potential yield of 4 t ha^{-1}. Among the reported factors to deviated yield potentials is low soil fertility and low or no

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use of fertilizers (Mnkeni et al., 2000; Weil, 2000).

Use of inorganic fertilizers in crop production is inevitable in arable Tanzanian soils and this has resulted in promising yields (Kisetu and Teveli, 2013). However, Tanzania is reported as one of the sub–Saharan Africa (SSA) countries which use the lowest quantities of inorganic inputs. A study by Walter (2007) reported that fertilizers in Tanzania are applied at 8 kg ha^{-1}, whereas, relatively high rates of 52 kg ha^{-1} are used in South Africa and 27 kg ha^{-1} in Zimbabwe and Malawi. Impact of high costs of fertilizers to smallholder farmers in Tanzania could be interrupted by the use of locally available nutrient reserves such as P-deposits. Existing Minjingu fertilizer brands (Mazao and Hyper) are immediately available in the country but require salient application techniques in order to increase nutrient P release. Minjingu Mazao fertilizer fetches agricultural advantage because it is currently being manufactured along with N, S, Zn, Cu, Mn, etc, apart from P (Kisetu and Teveli, 2013). According to Wasonga et al. (2008), high response of maize to P application is attributed to low P levels in soils. However, low responses to P greater than 13 kg ha^{-1} might be hampered by high Al saturation. According to Okalebo et al. (2002), Al levels exceeding 30% in soils lead to toxicity of plants.

Soil P dynamics in soils establish physicochemical (sorption-desorption) and biological (immobilization-mineralization) processes. Large amount of P applied in form of fertilizers (85 – 90%) enters into immobile pools through fixation and precipitation reactions (Brady and Weil, 2008). This indicates that only small amount of P (10 – 15%) is recovered by plants from soils. Khan et al. (2009) reported that highly reactive oxy-hydroxides of Al^{3+} and Fe^{3+} in acid soils and carbonates of Ca^{2+}, Mg^{2+} and Mo^{2+} in calcareous alkaline soils are powerful fixing constituents of P in such soils. Bekele et al. (1983) reported significant effects of leguminous plants in enhancing P release from Ca-phosphates such as those found in phosphate rock (PR). Ae et al. (1990) also indicated the importance of piscidic acid excreted by pigeon pea roots (*Cajanus cajan* L.) in forming complexes with Fe and increase the soil availability of Fe-bound P. If similar technique is employed under highly weathered Tanzanian soils, it would because farmers are in position to gain yield from crops treated with easily available nutrient sources. The objective of this study was to assess the performance of maize variety TMV1 using Minjingu Mazao and Minjingu Hyper fertilizers incorporated with decomposed pigeon pea leaves.

MATERIALS AND METHODS

Description of the study area

This study was conducted at the Sokoine University of Agriculture (SUA) Farm between February and May 2013. The field where this study was carried out is located between latitude 07° 25' south and longitude 38° 04' east and 540 m above mean sea level. The soil is characteristically predominated by kaolinite minerals hence kaolinitic soils. The area receives average annual rainfall between 800 and 950 mm falling between November to January, which is short rainfall and February to May for extensive rainfall (Kisetu et al., 2013).

Layout of the field and experimental design

The study was conducted at SUA Farm and laid down in a randomized complete block design (RCBD) and treated as a factorial experiment. Minjingu fertilizer brands and pigeon pea compost exclusively formed the two factors. The interaction of each fertilizer brand with pigeon pea compost formed the two levels at a time. The experimental plot was 9 m x 6.3 m in size and it had 18 sub-plots each with size of 1.8 m x 1.2 m. Each experimental sub-plot had 10 planting holes and 2 planting rows except the side-plots which had 1 extra guard row. The spacing between sub-plots was 60 cm encompassing the path spacing in either direction, whereas, the spacing between holes and between rows was 30 cm.

Composted pigeon pea leaves were applied at a rate of 4 t ha^{-1} into each experimental sub-plot, except for the absolute control and plots meant for fertilizers only. Each fertilizer was applied at a rate of 80 kg P_2O_5 ha^{-1}. Three maize seeds were sown and thinned to two plants per planting station 14 days after emergence. All treatments were in three replications.

Data collection

Maize yield was determined by harvesting and threshing maize after attaining maximum maturity. Weights of total biomass and grain were measured by a spring balance and yield expressed in t ha^{-1}. Harvest index (HI) was calculated with the proposed method of Fageria et al. (2007) such that:

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Biomass yield (kg ha}^{-1})} \times 100 \qquad (1)$$

In addition, Agronomic Efficiency (AE) of each treatment (g g^{-1} plot) was calculated based on the proposed approach of Roberts (2008) and Nemati and Sharifi (2012), such that:

In addition, Agronomic Efficiency (AE) of each treatment (g g -1 plot) was calculated

$$\text{Agronomic Efficiency (AE)} = \frac{\text{Yield from treatment (g)} - \text{Yield from control (g)}}{\text{Weight of treatment used (g/plot)}} \qquad (2)$$

(2)

The agronomic efficiency (AE) of each treatment was computed on an assumption that P uptake by maize plants from soils is almost uniform in fertilized and unfertilized plots (Brye et al., 2002). This assumption was inevitably pertinent taking into caution that inherent and added P in soil undergoes various hidden complex transformations and root development of maize crops may differ between fertilized and unfertilized plots.

Data analysis

The data collected were subjected to the analysis of variance (ANOVA) using GenStat Software (Wim et al., 2007). Least significance difference (LSD) at 5% allowable error was employed to compare treatments means which differed significantly and then summarized based on the Duncan's Multiple Range Test (DMRT).

RESULTS

Response of maize to application of treatments

Table 1 presents the results of the data generated from the studied maize variety TMV-1 following application of different treatments.

DISCUSSION

Effects of Minjingu fertilizers and pigeon pea compost to Maize yield

Total biomass of maize per plot

The results of the total biomass showed variation with respect to treatments used. The largest total biomass (6 kg per plot) was recorded for the plants that were treated with pigeon pea compost alone. However, the lowest total biomass (2.3 kg per plot) was recorded for the plants treated with Minjingu Hyper alone. The maize plants from absolute control plots showed relatively larger total biomass (5.3 kg per plot) next to pigeon pea alone (6 kg per plot).

Results showed that maize plants treated with Minjingu Mazao fertilizer accumulated relatively larger total biomass (5.2 kg per plot). This was statistically similar with that of maize plants treated with pigeon pea compost and with that of the absolute control (5.3 kg per plot). Furthermore, the results showed that incorporating compost with Minjingu Mazao and Minjingu Hyper gave different total biomasses (4.7 and 4.3 kg per plot, respectively), which were statistically similar. These findings suggest slightly significant ($p \leq 0.05$) differences in maize total biomass as affected by treatments used. The highest total biomass obtained from maize plants which were treated with pigeon pea compost and Minjingu Mazao fertilizer only is in line with the findings of Phiri et al. (2010). The positive increase in the total biomass observed following application of pigeon pea compost and Minjingu Mazao could be attributed to N and S released from the residues and others contained in the fertilizer material. This indicates the significance of N, P and S to the crop throughout its growing period.

According to Chirwa and Mafongoya (2004), pigeon pea leaves have low C:N ratio of 15.1 with very low contents of lignin materials. This property increases their rates of decomposition and release of nutrients. The findings of this study suggest that nutrient content of pigeon pea compost tricked maize plants in accumulating substantial content of dry matter which in turn might have reduced grain yield. This is associated with luxurious consumption of N released by Minjingu Mazao fertilizer and pigeon pea compost. Similar scenario is also envisaged in maize plants that were treated Minjingu fertilizer brands incorporated with pigeon pea compost as compared to maize plants that were not treated with fertilizers.

Agronomic efficiency of treatments used to maize yield

The results showed significant ($p < 0.001$) variation in the agronomic efficiencies (AE) of treatments used in maize yield. The highest AE (4.43 g g^{-1} per plot) was recorded for yield from maize plants that were treated with Minjingu Hyper and this was statistically similar with that of Minjingu Mazao + pigeon pea compost (3.07 g g^{-1} per plot). On the other hand, the lowest AE (0.7 g g^{-1} per plot) was recorded in maize plants that were treated with Minjingu Mazao fertilizer alone. Furthermore, these results showed that the combination of Minjingu Hyper with pigeon pea compost gave AE (1.61 g g^{-1} per plot) which was statistically comparable to that of pigeon pea compost alone (1.56 g g^{-1} per plot). These findings suggest that Minjingu Hyper alone is the best among other treatments used in contributing to relatively high maize AE based on the amount of treatment or fertilizer used. This is related to the ability of P to express its agricultural potential in the studied soil because of inherent low P levels. Kisetu et al. (2013) report low P levels (7.9 mg kg^{-1} soil) in soils of the field where this study was conducted.

Harvest index of maize

According to Nemati and Sharifi (2012), the physiological efficiency and ability of a crop to convert its total dry matter into economic yield signifies its potentials on harvest index (HI) as a yield parameter. The results showed significant ($p < 0.01$) variation of Harvest Index (HI) with respect to treatments used. The highest HI (24.78%) was recorded for the maize plants treated with Minjingu Hyper fertilizer alone. In addition, the

Table 1. Yield components of maize variety TMV-1 as affected by treatments.

Treatments	Total biomass		Yield variables			
	Rate	Per plot	Per plot	AE per plot	Per ha	HI
	(g)	(kg)	(g)	$g\ g^{-1}$	(t)	(%)
Absolute control	0	5.3^{b}	230^{a}	N/A	1.08^{a}	4.3^{a}
Pigeon pea (PP)	100	6.0^{b}	270^{ab}	1.56^{b}	1.28^{a}	4.5^{a}
Minjingu Mazao (MM)	420	5.2^{b}	360^{b}	0.70^{ab}	1.65^{a}	6.9^{a}
Minjingu Hyper (MH)	160	2.3^{a}	570^{c}	4.43^{c}	2.94^{a}	24.8^{c}
MM+PP	520	4.7^{ab}	630^{c}	3.07^{c}	3.85^{b}	13.4^{b}
MH+PP	260	4.3^{ab}	620^{c}	1.61^{b}	3.64^{b}	14.4^{b}
LSD		2.29	130.5	0.94	2.69	12.9
CV (%)		27.1	16	27.2	5.09	33.2
F pr.		*	***	***	**	*

Key: AE = Agronomic efficiency; HI = Harvest index.
Significant levels: *$p \leq 0.05$; **$p < 0.01$; ***$P < 0.001$.
Different letter(s) in each column indicates significant difference at 5% level based on Duncan's all-pair-wise comparison.

combination of Minjingu Mazao and Minjingu Hyper fertilizers with pigeon pea compost gave relatively low HI (13.4 and 14.42%, respectively), but these were still far higher than in the absolute control (4.34%). Furthermore, results from maize plants which were treated with Minjingu Mazao and pigeon pea compost excusive of each other indicated that HI was relatively low (6.94% and 4.5%, respectively) but slightly higher than that of the absolute control. These findings imply that Minjingu Hyper fertilizer is better in terms of HI which signifies the presence of P in it. This shows that P potential recovers higher yields than other treatments for the expense of accumulated total biomass as it is the case in maize plants treated with Minjingu Mazao fertilizer and pigeon pea compost. Similar findings are also reported by Singh and Amberger (1990) that the functional groups or anions present in organic materials have high ability to react with Ca contained in PR by Ca-chelation thereby contributing to RP dissolution and release of P. The findings of this study suggest that the rates of dissolution of Minjingu Hyper and Minjingu Mazao fertilizers used were apparently minimal. However, this could have been ascertained in the levels of P in soils after maize crop harvest, which was beyond the scope of this study.

Yield of maize

Results of maize yield harvested showed significant ($p < 0.01$) variation with respect to the treatments used and the absolute control (1.08 t ha^{-1}). The results showed that the highest yield (3.85 t ha^{-1}) was obtained for the maize plants which were treated with Minjingu Mazao fertilizer + pigeon pea compost. This yield differed slightly with maize yield (3.64 t ha^{-1}) obtained from plants which were treated with Minjingu Hyper fertilizer + pigeon pea compost, but they were statistically similar. On the other hand, the lowest yields of maize were obtained from sole application of each treatment. These were in the order of Minjingu Hyper fertilizer (2.94 t ha^{-1}) > Minjingu Mazao fertilizer (1.65 t ha^{-1}) > pigeon pea compost (1.28 t ha^{-1}), which did not differ statistically from the absolute control. These findings are in agreement with Okalebo and Woomer (1994) who report the highest grain yield of 102% above the absolute control.

The findings of this study indicate that maize yields obtained from plots where pigeon pea compost was combined with Minjingu Mazao and Minjingu Hyper fertilizers were significantly ($p < 0.001$) different from that obtained from sole application of these treatments. These findings suggest that dissolution of Minjingu Mazao and Minjingu Hyper fertilizers as an effect of pigeon pea compost increased maize yield significantly. However, the extent of their dissolution as a result of the effects of incorporated pigeon pea compost is still questionable and yet to be addressed. The existence of high variation among these treatments could be unveiled by large values of Coefficient of Variation (C.V. (%)) (>18%) obtained for some variables in this study. Similar observation is also reported by Phiri et al. (2010).

Conclusion

This study revealed that exclusive application of Minjingu Hyper fertilizer to maize proves to be more superior than Minjingu Mazao fertilizer by having the highest harvest index (24.7%) with relatively high maize yield (2.94 t ha^{-1}). The former fertilizer brand compares better with the latter, which produced yield of 1.65 t ha^{-1} and harvest index of 6.94%. Furthermore, upon incorporation of pigeon pea compost, Minjingu Mazao fertilizer recorded the highest yield (3.85 t ha^{-1}). This differed slightly numerically but was statistically similar with yield obtained when compost was incorporated with Minjingu Hyper fertilizer (3.64 t ha^{-1}).

ACKNOWLDEGMENTS

Authors wish to thank Professor Johnson M.R. Semoka of the Department of Soil Science at the Sokoine University of Agriculture for providing fertilizers used in this study. Special thanks to Debora Daudi Nguvu and Abigael Eliya who cordially assisted the authors in the collection of pigeon pea leaves.

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