Original Research Article

Tanzanian bat guano as alternative source of phosphorus for organic rice production

ABSTRACT

Many tropical and subtropical soils are low in phosphorus. This is partly because of excessive weathering, high P fixation rates and low P level in soil parent materials. Continuous removal of P from soils by crops, coupled with limited application of P fertilizers, is also among the contributing factors for low P in soils. Phosphorus is among the most limiting macronutrient in rice (*Oryza sativa* L.) production. This study was conducted to evaluate the suitability of bat guano collected from Kisarawe (BGK-A and BGK-B) and Sukumawera caves (BGS) in Tanzania. The screen-house experiment at Sokoine University of Agriculture was designed as a 4 × 6 factorial experiment conducted as a randomized complete block design (RCBD). Guano and triple super phosphate (TSP) were used as standard fertilizer at six P application rates. Yield of rice in response to applied TSP was comparable to applied guano but in the order TSP > BGK-A > BGS > BGK-B. All parameters increased with an increase in applied amounts of P from guano and TSP. Besides the study revealed the significant ($P = .05$) interaction between P sources and P rates on plant height (PH), micronutrient concentration and dry matter (DM). The study showed correlation between grain yield (GY) and other crop components of dry matter (DM), number of panicle (NP), Panicle height (PAH), plant height (PH) and number of tillers (NT). A significant and positive correlation was found for the GY-DM ($r = 0.58, P = .05$), GY-PAH ($r = 0.65, P < .001$), and GY-NT ($r = 0.420, P = 0.1$). But strong positive correlation was found between GY-PH ($r = 0.76, P < .001$) and GY-NP ($r = 0.84, P < .001$). It was concluded that studied guanos can be used as an alternative source of P especially for smallholder farmers.

Keywords: Bat guano, Grain yield, Phosphorous, Rice response, Yield components

1. Introduction

Rice (*Oryza sativa* L.) is the second most important food and commercial crop in Tanzania after maize (*Zea mays* L). Fifty percent of Tanzanian farming households depend on rice as staple food, source of employment and income. Tanzania is among the top rice producers in Africa. The country ranks fourth after Nigeria, Egypt and Madagascar [1], producing 3 million tons annually [2]. Total area under rice cultivation in Tanzania is 1,199,875 ha, which represents 31 % of Tanzania's cultivated land [2]. The average rice yield in Tanzania ranges from 1 to 1.5 tons ha^{-1} because of factors, such as declining of soil fertility, drought, insect-pest damage, disease infestations, and poor agronomic practices [3,4]. Soil fertility decline is probably the most limiting factor in rice production. Use of inorganic fertilizers has not been very successful because of various factors, e.g., high and unaffordable prices of fertilizers, non-availability of materials when required and lack of knowledge about appropriate fertilizer application [5,6]. Consequently, most smallholder farmers cultivate their rice fields without or with minimal application of industrial fertilizers. Low rice yields, coupled with population increase, warrants research on the use of less costly alternative fertilizers.

Despite the local availability of bat guano in Tanzania, little information is available on its use as P fertilizer for rice production. Appropriate application rates and timing of guano application for optimum P uptake in rice production are also not known. This study was conducted to investigate the response of rice to bat guano used as an alternative source of phosphorous for rice production.

2. Materials and methods

2.1 Description of the study area

The experiment was conducted in a screen-house at Sokoine University of Agriculture Department of Soil and Geological Sciences. The screen-house is located at Latitude 06°51' S, and Longitude 37°39' E, at an elevation of 550 m above sea level.

2.2 Soil sampling and analysis

A bulk sample of surface soil (0-20 cm depth) was collected from the Soil and Geological Sciences experimental field which is located at Latitude 06°85' S, and Longitude 37°65' E, at an elevation of 550 m above sea level. A random sampling method was used where surface soil samples were collected in two diagonals and thoroughly mixed into a composite sample for pot experiment. Collected soil was air-dried, crushed and sieved through an 8-mm sieve for pot experiment and representative sub-samples were further ground to pass through a 2-mm sieve for physical-chemical characteristics determination. Particle size distribution was determined by the hydrometer method after dissolving soil sample in sodium hexametaphosphate solution [7]. Soil textural class was determined by using USDA textural class triangle [8].

Soil pH was determined using a glass electrode pH meter in 1:2.5 (soil: water suspension) [9]. Electrical conductivity was measured in 1:2.5 (soil: water suspension) by using conductivity meter [9]. Organic carbon was determined via the Walkley and Black method using wet oxidation with potassium dichromate [10]. Total N was determined by the micro-Kjeldahl digestion procedure, followed by distillation [11]. Available P was extracted using the Olsen method [12] and determined by the ascorbic acid colorimetric method [13]. Cation exchange capacity (CEC) was determined by using neutral ammonium-acetate saturation method (NH_4OAc, pH 7), followed by Kjeldahl distillation. Exchangeable K, Ca, Mg and Na were determined from the ammonium-acetate filtrates by Atomic Absorption Spectrophotometer [7]. Laboratory analyses revealed that experimental soil was sandy clay with neutral pH and medium total N and available P (Table 1). The soil had adequate essential micronutrients and exchangeable cations, except Zn which was deficient.

((Table 1))

2.3 Design of the pot experiment

The experiment was carried out as a 4 × 6 factorial experiments using a randomized complete block design (RCBD). The first factor was P sources with four levels, namely, bat guano from Kisarawe cave A (BGK-A), bat guano from Kisarawe cave B (BGK-B), bat guano from Sukumawera cave (BGS) and triple super phosphate (TSP) used as standard fertilizer for comparison. The second factor was six rates of P application: absolute control, 0, 10, 20, 40 and 80 mg P kg^{-1} soil (Table 2). The experiment was replicated three times.

((Table 2))

2.4 Set- up of the pot experiment

A bulk soil previously sieved through 8 mm was used to test rice response to various P sources and rates in the pot experiment. Four kilograms of soil were weighed and placed into each pot previously labeled according to the treatment to be applied. After weighing the soil, the respective amount of each P source required to supply the prescribed P rate was weighed using a chemical balance and thoroughly mixed with the soil on a polyethylene sheet. In order to avoid cross contamination of treatments, different sheets were used to mix soils receiving different P sources and the lowest rate of each P source was mixed first, followed by subsequent higher rates. Nitrogen was uniformly applied in the form of urea ($CO(NH_2)_2$) was uniformly applied at a rate of 400 mg N kg^{-1} in two splits to all pots (except absolute controls) [14, 15, 16] and zinc was applied at a rate of 2.5 mg Zn kg^{-1} soil as zinc sulfate ($ZnSO_4$) [17]. Only N and Zn were applied because of their insufficient amounts in the soil.

After mixing with fertilizers, the soil was re-filled in the pots and equilibrated to about 90% of field capacity by using tap water. After 24 hours of equilibration, eight rice seeds (*Oryza sativa* L.) variety SARO-5 were planted and irrigation was done to maintain soil moisture around field capacity for the first 21 days. On the 21st day after germination, the rice plants were thinned to four plants per pot, and the soil was submerged to mimic the recommended water supply for low-land rice culture. Weeding was done by uprooting all emerging weeds to keep the crop free from weed competition. The second split of N was applied during panicle initiation.

2.5 Physiological data collection

Physiological data for rice response as determined by P sources and rates were collected from initial stages of growth, vegetative, maturity and harvesting. The parameter assessed were plant height measured by using a tape measure, number of tillers, tissue nutrient concentrations, dry matter yield, number of panicles and grain yields. When the crop was at booting stage, one plant was cut close to soil surface from each pot by using sharp scissors for tissue nutrient analysis and the remaining three plants were maintained in each pot to maturity. Above-ground plant parts harvested at booting stage were thoroughly washed using distilled water, oven dried at 55 ^{o}C for 72 hours to constant weight and ground to pass a 0.5 mm sieve. Ground plant materials were digested by dry ashing at 600 ^{o}C in a muffle furnace and allowed to cool. After cooling, the ash sample was diluted in a 6N HCl and the digest was filtered for determination of P, K, Fe, Zn, Cu, and Mn. In the digests, P was determined following a colorimetric procedure [13], K was determined by Flame Emission Spectrophotometer [18], whereas Fe, Zn, Cu and Mn were determined using Atomic Absorption Spectrophotometer [7]. Nitrogen in ground plant samples was determined by Macro-Kjeldahl method [19]. When the remaining plants reached maturity, the average number of panicles per plant was recorded and harvested, and rice grain yield was determined by weighing the grains harvested from each pot.

2.6 Data analysis

Collected data were subjected to analysis of variance using GenStat Discovery edition 14 software [20]. Treatment mean separation was done via Duncan's New Multiple Range Test at the 5% probability level. Correlations between grain yield and other crop components were carried out using Analysis Tool Pak in MS Excel (Microsoft 2010).

3.0 Results

3.1 Effect of P rate on number of tillers and plant height

The effect of P rates on number of tillers and plant height is presented in Table 3 and the ANOVA for plant height and numbers of tillers are presented in Tables 4 and 5, respectively. There was a significant effect of P rates ($P < 0.05$) on number of tillers and plant height at the 28th, 56th and 84th day after sowing for all P sources.

((Table 3))

((Table 4))

((Table 5))

3.2 Interaction effect of P sources × P rates on number of tillers and plant height

There was no significant interaction effect of P sources and P rates on number of tillers for all treatments. However, significant interaction effects of P sources and P rates ($P < 0.05$) were observed on plant height (Table 6). Plant height increased gradually with increase in number of days after sowing. The tallest plants (53, 105, 119.5 cm) were observed in pots receiving 80 mg P kg^{-1} of soil from TSP at 28 days as well as from BGK-A at 56 and 84 days after sowing, respectively. Higher increase in plant height was observed in plants received TSP than those received guano (BGKA) at the 28th day after sowing.

((Table 6))

3.3 Effects of P sources, P rates and their interaction on plant tissue nutrient concentrations

3.3.1 Effects on macronutrients concentration

There was no significance effect of P sources and interaction of P sources × P rates ($P < 0.05$) on macronutrients concentrations in plant tissue (Table 7). Only P rates showed a significant effect on tissue macronutrients concentrations (Tables 8 -10).

((Table 7))

((Table 8))

((Table 9))

((Table 10))

3.3.2 1 Effects on micronutrients concentration

There was significant effect ($P < 0.05$) of all P sources, P rates and P source × P rate interactions on rice plant tissue micronutrients concentrations (Table 11-13).

((Table 11))
((Table 12))

((Table 13)

3.4 Effect of P Sources, P Rates and P Sources × P Rates on Number of Panicles and Panicle height

3.4.1 Number of panicles per plant

P sources and the interaction of P sources × P rates had no significant effect on number of panicles per plant while P rates showed significant ($P < 0.05$) effect on the same parameter (Tables 14 -15).

3.4.2 Panicle height

There was no significant effect of P sources and the interaction of P sources × P rates on panicle height. Nevertheless, P rates significantly ($P < 0.05$) increased panicle height (Table 14 and 16).

((Table 14))

((Table 15))

((Table 16))

3.5 Effect of P sources, P rates and P sources × P rates interaction on dry matter and grain yield

3.5.1 Effect on dry matter yield

P sources showed significant effect ($P < 0.05$) on dry matter yield (Table 17-18) furthermore there was significance effect ($P < 0.05$) of P rates and the interactions of P sources versus P rates on dry matter yield. Significantly higher dry matter yield was recorded in plants receiving TSP while BGK-A and BGS ranked next to TSP with statistically similar dry matter yields. BGK-B resulted into the lowest dry matter yields. The highest dry matter yield was recorded in pots treated with TSP, followed by BGK-A and BGS and lastly BGK-B.

((Table 17))

((Table 18))

3.5.2 Effect on grain yield

The result showed no significant ($P < 0.05$) difference in rice grain yield on account of P sources (Tables 17 and 19).

((Table 19))

3.5.3 Effects of P rates on dry matter and grain yield

Shoot dry matter yield significantly ($P < 0.05$) increased with increasing P application rates (Table 20).

((Table 20))

3.6 Correlation between grain yield and other crop components.

We assessed the association between rice yield and other agronomic traits. We found that associations between grain yield and other crop components were dependent. The grain yield per plant (GY) showed positive and significant relationship with dry matter yield (DM), number of panicles (NP), panicle height (PAH), plant height (PH) and number of tillers (NT) (Table 21). Positive correlation was observed for the GY-DM ($r = 0.41$, $P < 0.1$), GY-PAH ($r = 0.84$, $P < 0.001$), and GY-NT ($r = 0.87$, $P < 0.001$). On the other hand, strong positive correlation was found between GY-PH ($r = 0.91$, $P < 0.001$) and GY-NP ($r = 0.95$, $P < 0.001$).

((Table 21))

4. Discussion

4.1 Pot experiment visual assessment of rice growth

Germination of seeds started seventh day after sowing, and the germination was 100% in all Pots. The deposits of some salts were observed on the surface of soils, which implied that the soil from the experimental site had a saline property. The deficiency of nitrogen started to be observed in absolute control pots during 21st day after sowing by showing yellow coloration of the leaves and in other pots it was observed during 42nd day after sowing where it was controlled by adding a second split of N (200 mg N per pot). Pots with bat guano from Kisarawe cave A (Plate 1) showed darker green colour in leaves than bat guano from Kisarawe cave B (Plate 2), Sukumawera (Plate 3) and TSP fertilizer (Plate 4) during vegetative growth stage. Also, higher number of tillers and height of the leaves were observed plants treated with TSP, BGK-A, BGS and lastly with BGK-B at a rate of 80 mg P kg^{-1}. The first flower was observed in a pot treated with BGK-A at a rate of 80 mg P kg^{-1} on the 81st day. Latest flowering and maturation of rice grain was observed on absolute control treatment.

((Plate 1))

((Plate 2))

((Plate 3))

((Plate 4))

4.2 Grain and yield components responses to soil applied with bat guano

Data presented in Table 3 revealed that the number of tillers increased gradually after thinning up to the maximum tillering stage (around 56 to 84 days after sowing). At this stage, the main culm was difficult to distinguish tillers from the main/original rice plants. Generally, rice plants produce 2 to 5 panicle bearing tillers per plant [21]. The lowest number of tillers per plant (4.92) was recorded in an absolute control because of insufficient nutrients in the soil which limited plant growths.

The highest number of tillers (22.83) was recorded at the 84th day after sowing in treatments receiving P at a rate of 80 mg P kg^{-1} (Table 3) and no additional tillers formed thereafter. The increase in the number of tillers could be attributed to increasing phosphorus application rate to 80 mg P kg soil as reported in other studies [22,23]. Moreover, the highest number of tillers was recorded around 80thdays and no more tillers formed thereafter. This concern could be because of high rate of mineralization at the mid period of the study also at that time all plant parts haste to make sure that grains are formed. In most cases, rice tillering begins around 40 days after sowing and can last up to 120 days [24]. Root elongation is the physiological function of P in soil [25], consequently the availability of P sources in the soil might influence the formation of more roots and increase in number of tillers.

Higher increase in plant height observed in plants which received TSP than those receiving guano (BGK-A, BGK-B and BGS) at the 28th day after sowing (Table 4) could be attributable to faster P release from TSP which is in mineral and soluble form as compared to guano in which most of its P is in organic form and undergoes gradual release [26]. The shortest plants (43.83, 51.67 and 78.1 cm) at 28th, 56th and 84th days respectively were recorded in absolute control implying that a positive increase in plant height was attributed to availability as influenced by P application [27]. Furthermore, in absolute control the deficiency of nutrients could be the source of slow uptake of nutrients which cause stunted growth of rice shoots.

The highest P rates of 80 mg P kg^{-1}soil resulted into the highest number of panicles per plant (Table 7) due to increased supply of P and other nutrient element in rice [28]. Moreover, formation of higher number of panicles could be attributed to the adequacy other factors such as solar radiation, temperature and moisture contents reported to have direct effect on panicles [29] This observation is supported by the lowest number of panicles recorded in absolute control treatments. These results are further supported by findings reported by [30-32],

Moreover, the longest panicle (24.18 cm) was recorded in plants that received the highest P rate (80 mg P kg^{-1} of soil) while the shortest panicle (19.18 cm) was recorded in absolute control indicating positive effect of P application on panicle height. Many studies showed that panicle development is closely associated with preliminary plant growth which produce good vigor of traits such as leaf emergence rate [33-36]. [37,38] also reported that tillering increases the number of panicles in rice. On the other hand; [39] and [40] reported that reducing the number of tillers and panicle height with increasing stem size can increase the potential yield of rice.

In rice grain yield is determined by plant height, growth period, tillering ability, panicle height, grains per panicle, number of panicles per plant or per unit area, filled grains per panicle and 1000-grain-weight [41-43]. In this study it was found that rice grain yield from pots applied these three types of guano was similar to that of TSP (Table 16). This implies that applications of bat guano enhanced grain yield equally to industrial fertilizer (TSP) indicating that guano can serve as an alternative P source in organic rice production where industrial fertilizers are not acceptable. Effectiveness of guano as source of P is supported by the findings reported by [44] in their study of the effect of bat guano on some yield parameters of wheat.

4.3 Dry matter yield and nutrient concentrations of rice treated with bat guano

4.3.1 Dry matter yield

Significantly higher dry matter yield was recorded on plants receiving TSP, followed by BGK-A and BGS which ranked next to TSP with statistically similar dry matter yields and plants treated with BGK-B had significant difference in dry matter yields (Table 16). This implies that bat guano was as effective as TSP when all P sources were applied at the same rates based on total P contents.

The highest dry matter yield was recorded in pots treated with TSP, followed by BGK-A and BGS and lastly BGK-B. This may be because of more P available from TSP, as P is more soluble from TSP than from bat guano. The differences in P availability from the two types of bat guano (BGK-A and BGK-B) may be attributed to both the nature of food eaten by bat, geology of the caves and other environmental conditions can also account for differences of dry matter yields observed from sources of the two bat guanos.

Conversely, the lowest dry matter yield recorded in BGK-B could also triggered by excessively acidic nature of this guano as compared to the other two guano. According to [45], acidic condition has a tendency of impairing absorption of Ca, Mg, and P. It can also increase solubility and toxicity of Al, Mn and Fe hence reduce the availability of P in soil. Also, he reported that the inhibition of phosphorus uptake and absorption by Al has a drastic effect on the growth of plant include dry matter yield, this statement support the proneness of low dry matter yield in treatments treated by BGK-B. Similarly, [46] reported that one of the major consequences of acidification is a decline of basic cations such as Ca^{2+} and Mg^{2+}, leading to potential deficiency of these cations for plant growth. Furthermore, at low pH, the bioavailability of Ca may be restricted because of antagonistic effects of soluble Al. With increasing soil acidification, smaller amounts of Mg^{2+} remain in exchangeable form because of reduction in negative charge. Since Mg^{2+} is a poor competitor with Al^{3+} and Ca^{2+} for the exchange sites hence it accumulates in the solution and become leached.

4.3.2 Nutrient concentrations of rice treated with bat guano

In Table 7 on P rates, only K showed significance effects ($P < 0.05$) in macronutrients analyzed. This could be attributable to high level of K present in soil (Table 1) and that added from guano during the study. [47] reported that guano contains K which can be released on medium to fast rates within the soil. There was no significant difference ($P < 0.05$) of N and P tissue concentrations on P rates since N was applied on the same rate in all treatments except absolute control and P was applied based on total P contained in guano source. NPK tissue concentrations were higher on application rate of 80 mg P kg^{-1} (Table 7). This reveals that the synergistic interaction of plant nutrients influences higher use of nutrients in a plant. [48] reported that higher K level in plant tissue increase N uptake and lower K level decrease the N uptake resulting into low N concentrations in plant tissue. This observation is due to the fact that high level of exchangeable K in soil solution improves N use efficiency of plant. On the other hand, there was no significant difference in P tissue concentrations in all P rates. This could be due to the reason that the level of P availability in the test soil was medium hence the soil was responsive enough to external P sources. Tissue P concentration (0.23 %) determined in the shoots of rice plants treated with external P sources at the rate of 80 mg P kg^{1} was above critical range of 0.16% as reported by [17] indicating that P supply at this rate was adequate for rice plants. Similarly, N and K were above the critical range (1.8 – 2.5%) and 1.6 % respectively [17, 49] henceforth there was no limit of rice response to applied P.

On the other hand, all P sources had significant effect ($P < 0.05$) on plant tissue concentrations of micronutrients (Table 12). This observation could be attributed to the release of micronutrients from the guano as analyzed earlier before sowing.

4.4 Correlation between grain yield and other crop components

This study confirmed positive correlation between rice grain yield and other crop components namely DM, NP, PAH, PH and NT hence these can be successfully used as indicators or determinants of rice grain yield as previously reported by other researchers [50-52]. Results clearly showed positive association between rice grain yield and crop components mentioned on the above statement. It was found that rice grain yield increased with NP, PAH and PH while the increase in DM and NT was associated with low grain yield. This gave an impression that NP as the most important agronomic character in rice was influenced by NT produced [53]. Moreover, NP was higher due to genotype of the rice cultivar SARO 05 (TXD 306) which used as a test crop. As reported by [54] and [55], SARO 05 is a high yielding cultivar that produces large NT, NP and high DM. Moreover, the correlation between PH and GY was strong and positive this is because of positive interaction of the genotype and the environment [56]. This study further showed that PAH was high in rice and was associated with high yield. It observed that large PAH was influenced by many spikelets formed per panicle which were associated with higher grain filling proportion.

5. Conclusions

Rice response to TSP as determined in terms of plant height, number of tillers and panicles per plant, dry matter and grain yields was comparable to that of bat guano from Kisarawe and Sukumawera of Tanzania. Rice yield increased progressively with increasing P levels to the maximum application rate of 80 mg P kg^{-1}. The GY significantly ($P < 0.05$) showed strong relationship with other yield components which were NT, PH, PAH, NP and DM. The results indicate that the three bat guano are as effective as TSP in improving rice yields. Nevertheless, these results are based on screen-house condition (controlled environment), thus need to be further tested under field conditions to evaluate how rice responds to guano.

Field based results will make it possible to generate recommendations on the use of guano as an alternative P source for rice.

Disclosure statement

No potential conflict of interest was reported by the authors.

REFERENCES

1. John, G. (2019, March 21). Nigeria eclipses Egypt as Africa's largest rice producer. *The Exchange.* Accessed 04 June 2020. Available: https://allafrica.com/stories/201903210453.html.
2. FAO 2019. Statistic Division (FAOSTAT). Accessed 25 July 2020. Available: http://www.fao.org/faostat/en/#home.
3. RLDC 2009. Rice sector strategy improving rice profitability through increased productivity and better marketing focusing on Tanzania's Central Corridor. Rural Livelihood Development. 6pp.
4. Lu, Z., Zhu, P., Gurr, G. M., Zheng, X., Chen, G. and Heong, K. L. 2015. Rice pest management by ecological engineering: a pioneering attempt in China. In: Rice Plant hoppers. pp. 161-178.
5. Chianu, J. N., Chianu, J. N., and Mairura, F. 2012. Mineral fertilizers in the farming systems of sub-Saharan Africa. A review. *Agronomy for sustainable development*, *32*(2), 545-566.
6. Middendorf, B.J., Pierzynski, G.M., Z P. Stewart and Vara Prasad, P.V. 2017. Report of the Sub-Saharan Africa Soil Fertility Prioritization: II. Summit Results. Prepared by Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification (SIIL) Kansas State University.
7. Jember, T. S. 2011.Management of Salt Affected Soils, Soil Analysis for Soil Salinity and Soil Fertility Status. Amazon Distribution GmbH, Leipzig. Pp 43-69.

8. FAO 2006.Soil textural classes and field tests for their determination. Accessed 29 July 2018. Available: www.fao.org/ tempref/FI/CDrom/FAO_Training/FAO_Training/.../x6706e06.htm
9. Warncke, D. and Brown, J. R. 1998 pH and Lime Requirement. Recommended Chemical Soil Test Procedures for the North Central Region. North Central Regional Research Publication No. 221, Missouri, Columbia. pp 13-14.
10. Nelson, D. W. and Sommers, L. E. 1996.Total carbon, organic carbon, and organic matter. Methods of Soil Analysis part 3—Chemical Methods 3: 961-1010.
11. Okalebo, J. R., Gathua, K. W. and Woomer, P. L. 2002.Laboratory Methods of Soil Analysis. A Working Manual KARI, Nairobi, Kenya.29-61pp.
12. Olsen, S. R., Cole, C. V., Watanabe, F. S. and Dean, L. A. 1954. Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonates Circular No. 939, United States Department of Agriculture, Washington, DC., USA.pp 1-18.
13. Kuo, S. 1996.Phosphorus. In: Sparks, D. L. (ed) Methods of Soil Analysis. Part 3. Chemical Methods 869–919.
14. Semoka, J. M. R. and Mnguu, Y. O. (2000). Assessment of soil N, P, and K status of selected paddy growing areas of Tanzania. *Tanzania Journal of Agricultural Sciences* 3(1): 1-10.
15. Fageria, N. K., Dos Santos, A. B. and Coelho, A. M. 2011. Growth, yield and yield components of lowland rice as influenced by ammonium sulfate and urea fertilization. *Journal of Plant Nutrition* 34(3): 371-386.
16. Mbaga, H. R. 2015. Response of rice to nitrogen and phosphorus applied to the dominant soil type at the Dakawa irrigation scheme, Morogoro Tanzania. Dissertation for Award Degree of MSc. at Sokoine University of Agriculture. 122pp.

17. Kalala, A. M., Amuri, N. A. and Semoka, J. M. 2017.Optimum Levels of Phosphorus and Potassium for Rice in Lowland Areas of Kilombero District, Tanzania. Agriculture, *Forestry and Fisheries Journal* 6(1): 26-33.
18. Thomas, G. W. 1982.Exchangeable Cations. Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties 2: 159-165.
19. Chapman, H. D. and Pratt, P. F. 1961.Methods of Analysis for Soils, Plants and Waters. University of California, Los Angeles.pp150-179.
20. Buysse, W., Stern, R., and Coe, R.2004. GenStat discovery edition for everyday use. *ICRAF Nairobi, Kenya, 114*.
21. Moldenhauer, K. E. W. C. and Slaton, N. 2001. Rice growth and development. Rice production handbook. Pp 7-14.
22. Cralle, H. T., Fojtasek, T. B., Carson, K. H., Chandler, J. M., Miller, T. D., Senseman, S. A. and Stone, M. J. 2003.Wheat and Italian ryegrass (*Lolium multiflorum*) competition as affected by phosphorus nutrition. *Weed Science* 51(3): 425-429.
23. Fioreze, S. L., Castoldi, G., Pivetta, L. A., Pivetta, L. G., Fernandes, D. M. and Büll, L. T. 2012.Tillering of two wheat genotypes as affected by phosphorus levels. Acta Scientiarum. Agronomy34(3): 331-338.
24. Santos, F., Borém, A., and Caldas, C. (Eds.). (2015). *Sugarcane: agricultural production, bioenergy and ethanol*. Academic Press.
25. Marschner H. *Marschner's mineral nutrition of higher plants*. Academic press. 2011.
26. Nkongolo, M., Lumpungu, K., Kizungu, V., Tshimbombo, J. and Mukendi, K. 2016.Evaluation of the effect of two forms (Dissolved and undissolved) comparative bat guano to Diammonium Phosphate (DAP) on the cultivation of corn (Zea mays L. VarMus) in the humid tropics of the DRC (Region De Gandajika). *European Journal of Biotechnology and Bioscience* 4(3): 1-5.

27. Ojobor, S. A., Ade-Oluwa, O. O. and Adeoye, G. O. 2014.Response of Upland Rice and Soil Chemical Properties to Formulated Organic Manures in Asaba, Delta State, Nigeria. *Journal of Biology, Agriculture and Healthcare*4 (27): 284-290.
28. Yoseftabar, S. 2013.Effect of nitrogen and phosphorus fertilizer on spikelet structure and yield in rice (*Oryza sativa* L). *International Journal of Agriculture and Crop Sciences* 5(11): 1890-1204.
29. Deng, N., Ling, X., Sun, Y., Zhang, C., Fahad, S., Peng, S., and Huang, J. (2015). Influence of temperature and solar radiation on grain yield and quality in irrigated rice system. *European Journal of Agronomy*, *64*, 37-46.
30. Nesgea, S., Gebrekidan, H., Sharma, J. J. and Berhe, T. 2012. Effects of Nitrogen and Phosphorus Fertilizer Application on Yield Attributes, Grain Yield and Quality of Rain Fed Rice (NERICA-3) in Gambella, Southwestern Ethiopia. *East African Journal of Sciences* 6(2): 91-104.
31. Kanfany, G., El-Namaky, R., Ndiaye, K., Traore, K. and Ortiz, R. 2014. Assessment of rice inbred lines and hybrids under low fertilizer levels in Senegal. *Sustainability* 6(3): 1153-1162.
32. Amanullah, H. 2016. Influence of organic and inorganic nitrogen on grain yield and yield components of hybrid rice in Northwestern Pakistan. *Rice Science* 23(6): 326-333.
33. Dong, Y. J., Kamiunten, H., Ogawa, T., Tsuzuki, E., Terao, H. and Lin, D. Z. 2004.Mapping of QTLs for leaf developmental behavior in rice (*Oryza sativa* L.).*Euphytica* 138: 169–175.
34. Streck, N. A., Lago, I., Bosco, L. C., de Paula, G. M., Oliveira, F. B. and Gabriel, L. F. 2009.Relationship between panicle differentiation and main stem leaf number in rice genotypes and red rice biotypes. *Science Agriculture* 66: 195–203.

35. Itoh, Y. and Shimizu, H. 2012.Phyllochron dynamics during the course of late shoot development might be affected by reproductive development in rice (Oryza sativa L.). Development Genes and Evolution 222: 341–350.

36. Rebolledo, M. C., Dingkuhn, M., Courtois, B., Gibon, Y., Clément-Vidal, A., Cruz, D. F and Luquet, D. 2015 Phenotypic and genetic dissection of component traits for early vigour in rice using plant growth modelling, sugar content analyses and association mapping. *Journal of Experimental Botany* 66(18): 5555-5566.

37. Lafarge, T. and Bueno, C. S. 2009. Higher crop performance of rice hybrids than of elite inbreds in the tropics: 2. does sink regulation, rather than sink size, play a major role? *Field Crops Residues* 114: 434–440.

38. Borras-Gelonch, G., Denti, M., Thomas, W. T. and Romagosa, I. 2012.Genetic control of pre-heading phases in the Steptoe× Morex barley population under different conditions of photoperiod and temperature. *Euphytica* 183(3): 303-321.

39. Setter, T. L., Conocono, E. A., Egdane, J. A. and Kropff, M. J. 1995.Possibility of Increasing Yield Potential of Rice by Reducing Panicle Height in the Canopy. I. Effects of Panicles on Light Interception and Canopy Photosynthesis. *Functional Plant Biology 22*(3): 441-451.

40. Dutta, R. K., Mia, M. B., Lahri, B. P. and Salam, M. A. 1997.Assessment of grain yield and quality improvements in rice by modern breeding techniques in Bangladesh and projections of future rice improvements. International Rice Communication Newsletter 46: 63-70.

41. Sakamoto, T., and Matsuoka, M. (2008). Identifying and exploiting grain yield genes in rice. *Current Opinion in Plant Biol.* 11, 209–214.

42. Huang, M., Zou, Y.-B., Jiang, P., Xia, B., Md, I., and Ao, H. J. (2011). Relationship between grain yield and yield components in super hybrid rice. *Agric. Sci. China* 10, 1537–1544.

43. Li, R., Li, M., Ashraf, U., Liu, S., and Zhang, J. (2019). Exploring the relationships between yield and yield-related traits for rice varieties released in China from 1978 to 2017. *Frontiers in Plant Science, 10*, 543.
44. Karagöz, K. and Hanay, A. (2017). Effects of bat guano on some yield parameters of wheat. *Academia Journal of Environmental Science* 5(11): 200-206.
45. Rorison, I. H. 1972. The effect of extreme soil acidity on the nutrient uptake and physiology of plants. University. 226pp.
46. Koo, B. J., Adriano, D. C., Bolan, N. S. and Barton, C. 2005.Plant root exudates. Encyclopedia of Soils in the Environment. Elsevier, Amsterdam.pp421-428.
47. Penhallegon, R. 2003. Nitrogen-phosphorus-potassium values of organic fertilizers. Oregon State University Extension Service. [http://extension.oregonstate.edu/lane/sites/default/files/documents/lc437organicfertilizersvaluesrev.pdf.] Site visited on 1/9/2018.
48. Fageria, V. D. 2001.Nutrient interactions in crop plants. *Journal of Plant Nutrition* 24(8): 1269-1290.
49. Dobermann, A. and Fairhurst, T. H. 2000.Nutrient Disorders and Nutrient Management. Potash and Phosphate Institute, Potash and Phosphate Institute of Canada and International Rice Research Institute: Singapore. Pp 12-39.
50. Ranawake, A. L. and Amarasinghe, U. G. S. 2014. Relationship of yield and yield related traits of some traditional rice cultivars in Sri Lanka as described by correlation analysis. *Journal of Scientific Research and Reports* 3(18): 2395-2403.
51. Parimala, K., Bhadru, D. and Raju, C. S. 2018.Combining ability and heterosis studies for grain yield and its components in hybrid rice (Oryza sativa L.). *Electronic Journal of Plant Breeding* 9(1): 244 – 255.

52. Thippani, S., Eshwari, K. B. and Bhave, M. H. V. 2017.Principal component analysis for yield components in Greengram Accessions (Vignaradiata L.). *International Journal of Pure and Applied Bioscience* 5(4): 246-253.

53. Liu, Y., Xu, J., Ding, Y., Wang, Q., Li, G. and Wang, S. 2011.Auxin inhibits the outgrowth of tiller buds in rice (Oryza sativa L.) by down regulating OsIPT expression and cytokinin biosynthesis in nodes. *Australian Journal Crop Science* 5(2): 169-174.

54. Ndaeyo, N. U., Iboko, K. U., Harry, G. I., and Edem, S. O. 2008. Growth and yield performances of some upland rice (Oryza sativa L) cultivars as influenced by varied rates of PNK (15: 15: 15) fertilizer on an ultisol. *Agro-Science*, *7*(3).

55. URT 2009. National Rice Development Strategy Published by Ministry of Agriculture Food Security and Cooperatives, Dar-es-Salaam, Tanzania. 14pp

56. Tiwari, D. N., Tripathi, S. R., Tripathi, M. P., Khatri, N., and Bastola, B. R. 2019. Genetic variability and correlation coefficients of major traits in early maturing rice under rain fed lowland environments of Nepal. *Advances in Agriculture*, *2019*.

Tables:

Table 1: Physico-chemical properties of the soil used in the experiment

Parameter	**SI-unit**	**Value**	**Rating**	**Reference**
pH (H_2O)		7.2	Normal	Msanya et al. 2001
EC	mS/cm	561	Normal	Msanya et al. 2001
OC	%	11.05	Very High	Landon, 1991
Total nitrogen	%	0.48	Medium	Landon, 1991
Available phosphorus	mg/Kg	6.59	Medium	Landon, 1991
Calcium	cmol (+) Kg^{-1}	7.97	Medium	Msanya et al. 2001
Sodium	cmol (+) Kg^{-1}	3.98	Very High	Msanya et al. 2001
Magnesium	cmol (+) Kg^{-1}	5.12	High	Msanya et al. 2001

Potassium	cmol (+) Kg^{-1}	6.07	Very High	Msanya et al. 2001
Cation Exchange Capacity	cmol (+) Kg^{-1}	20.2	Medium	Msanya et al. 2001
Copper	mg kg^{-1}	3.79	Sufficient	Landon, 1991
Zinc	mg kg^{-1}	1.61	Deficient	Landon, 1991
Iron	mg kg^{-1}	133.98	Sufficient	Landon, 1991
Manganese	mg kg^{-1}	98.80	Sufficient	Landon, 1991
Particle size:				
Sand	%	49.3		
Clay	%	41.1		
Silt	%	9.6		
Textural class	Sandy Clay			FAO, 2006

Table 2: P rates used in pot experiment

P rate (mgP kg^{-1})	**Equivalent rate of each P source applied (mg kg $soil^{-1}$)**			
	BGK-A	**BGK-B**	**BGS**	**TSP**
0^a	0	0	0	0
P_0^b	0	0	0	0
P_{10}	0.47	0.57	1.16	0.2
P_{20}	0.94	1.14	2.32	0.4
P_{40}	1.88	2.28	4.64	0.8
P_{80}	3.76	4.56	9.28	1.6

[a,] Without addition of any external source of nutrients (Absolute control)
[b,] All nutrients were applied to recommended levels except P.

Table 1: Effects of P rates on number of tillers and plant height at various growth stages

Treatment (mg kg^{-1})	Number of tillers			Plant height (cm)		
	28 day	56 days	84 days	28 day	56 days	84 days
AbsC	4.6 ab	4.9 a	4.92 a	44.8 a	54.0 a	78.1 a
P 0	4.2 a	16.1 b	19.6 b	47.0 b	90.3 b	104.2 b
P 10	4.7 b	17.8 bc	21.2 bc	47.1 b	92.1 bc	107.4 c
P 20	4.6 b	17.3 bc	21.0 bc	48.7 bc	94.1 c	110.0 d
P 40	4.8 b	17.8 bc	20.9 bc	48.8 bc	97.5 d	112.2 de
P 80	49 b	18.7 c	22.8 c	50.7 c	98.2 d	112.9 e
Mean	4.6	15.43	18.4	48	87.7	104
CV (%)	10.8	17.6	14.9	5.1	3.8	2.9
LSD (0.05)	0.41	2.23	2.26	2	2.8	2.4

Means in the same column followed by the same letter(s) are not significantly different at 5% level of probability according to Duncan New Multiple Range Test. Means in each column analyzed separately.

Table 4: ANOVA table for plant height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	61.882	30.941	3.51	
Block.*Units* stratum					
P_Source	3	164.20	54.734	6.21	0.001
Rate_mg_kg_1	5	10367.28	2073.456	235.19	<.001
P_Source.Rate_mg_kg_1	15	498.80	33.253	3.77	0.001
Residual	46	405.54	8.816		
Total	71	11497.69			

Table 5: ANOVA table for number of tillers

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	8.361	4.181	0.55	
Block.*Units* stratum					
P_Source	3	17.264	5.755	0.76	0.522
Rate_mg_kg_1	5	2683.236	536.647	71.01	<.001
P_Source.Rate_mg_kg_1	15	94.819	6.321	0.84	0.634
Residual	46	347.639	7.557		
Total	71	3151.319			

Table 6: Effects of interaction between P sources and rates on Plant height

P-Source	Rates (mg kg^{-1})	Plant height (cm)		
		28 days	**56 days**	**84 days**
BGK-A	AbC	45.75 abcd	58.50 b	77.4 a
BGK-A	0	45.83 abcde	91.50 defgh	103.0 bc
BGK-A	10	46.67 abcdef	95.00 ghijk	107.3 cdef
BGK-A	20	49.33 cdefg	97.67 hijkl	111.2 efghi
BGK-A	40	49.33 cdefg	100.50 klm	113.3 ghi
BGK-A	80	51.00 fg	105.00 m	119.5 j
BGK-B	AbC	43.83 a	51.67 a	78.1 a
BGK-B	0	47.17 abcdef	91.33 defgh	104.7 bcd
BGK-B	10	49.00 bcdefg	94.00 efghij	107.3 cdef
BGK-B	20	46.33 abcdef	95.83 ghijk	110.0 defgh
BGK-B	40	47.00 abcdef	99.50 jklm	112.7 fghi
BGK-B	80	51.00 fg	102.67 lm	116.0 ij
BGK-S	AbC	44.33 ab	52.83 ab	77.3 a
BGK-S	0	47.00 abcdef	90.67 defg	104.3 bcd
BGK-S	10	45.33 abcd	92.33 defghi	106.7 cde
BGK-S	20	48.67 abcdefg	94.67 fghijk	109.3 defg
BGK-S	40	48.3 bcdefg	98.33 ijkl	111.0 efghi
BGK-S	80	47.67 abcdef	89.33 defg	100.7 b
TSP	AbC	45.17 abc	52.83 abcd	79.79 a
TSP	0	47.83 abcdef	87.83 de	105.0 bcd
TSP	10	47.33 abcdef	87.00 d	108.3 cdefg
TSP	20	50.50 efg	88.33 bef	109.5 defg

TSP	40	50.17 befg	91.50 defgh	112.0 efghi
TSP	80	53.00 g	95.67 ghijk	115.3 hij
Mean		48	87.69	104
CV %		5.1	3.8	2.9
LSD (0.05)		4	5.5	4.9

Means in the same column followed by the same letter(s) are not significantly different at 5% level of significance according to Duncan New Multiple Range Test. Means in each column analyzed separately.

Table 7: Effects of P- rates on macronutrients tissue concentrations

P-rates	**Macro nutrients (%)**		
(mg kg^{-1})	**N**	**P**	**K**
Absc	0.927 a	0.115 a	22.09 a
P 0	1.761 b	0.120 a	42.22 bc
P 10	1.791 b	0.137 a	42.80 bc
P 20	1.901 b	0.144 a	37.47 b
P 40	1.872 b	0.178 a	41.26 bc
P 80	1.902 b	0.231 a	44.17 c
Mean	**1.71**	**0.15**	**38.33**
CV (%)	**11**	**83.4**	**17.6**
LSD (0.05)	**0.754**	**0.106**	**5.56**

Means in the same column followed by the same letter(s) are not significantly different at 5% level of significance according to Duncan New Multiple Range Test. Means in each column analyzed separately.

Table 8: ANOVA table for P%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.04209	0.02104	1.27	
Block.*Units* stratum					
P_Source	3	0.07321	0.02440	1.47	0.234
Rate_mg_kg_1	5	0.11513	0.02303	1.39	0.245
P_Source.Rate_mg_kg_1	15	0.19773	0.01318	0.80	0.675
Residual	46	0.76157	0.01656		
Total	71	1.18973			

Table 9: ANOVA table for N%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.20833	0.10416	2.95	
Block.*Units* stratum					
P_Source	3	0.24816	0.08272	2.34	0.086
Rate_mg_kg_1	5	8.91303	1.78261	50.45	<.001
P_Source.Rate_mg_kg_1	15	0.93213	0.06214	1.76	0.072
Residual	46	1.62551	0.03534		
Total	71	11.92715			

Table 10: ANOVA table for K%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	613.24	306.62	6.71	
Block.*Units* stratum					
P_Source	3	167.57	55.86	1.22	0.312
Rate_mg_kg_1	5	4104.43	820.89	17.97	<.001
P_Source.Rate_mg_kg_1	15	1053.71	70.25	1.54	0.131
Residual	46	2101.71	45.69		
Total	71	8040.65			

Table 11: Effects of P- sources on micronutrients tissue concentrations

P- sources	**Micro nutrients (mg kg^{-1})**			
	Cu	**Fe**	**Zn**	**Mn**
BGK-A	9.16 a	171.5 a	15.40 b	482.2 b
BGK-B	10.38 ab	189.8 a	8.97 a	362.0 ab
BGS	11.29 bc	155.9 a	9.20 a	362.5 ab
TSP	12.96 c	170.3 a	11.03 ab	298.2 a
Mean	10.9	171.9	11.15	371.48
CV (%)	27.5	31.8	69.9	55
LSD (0.05)	2.02	36.72	5.23	137.15

Means in the same column followed by the same letter (s) are not significantly different at 5% level of significance according to Duncan New Multiple Range Test. Means in each column analyzed separately.

Table 12: ANOVA table for Cu

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	27.728	13.864	1.53	
Block.*Units* stratum					

P_Source	3	138.770	46.257	5.10	0.004
Rate_mg_kg_1	5	36.810	7.362	0.81	0.548
P_Source.Rate_mg_kg_1	15	124.549	8.303	0.91	0.554
Residual	46	417.547	9.077		
Total	71	745.404			

Table 13: ANOVA table for Fe

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	5782.	2891.	0.97	
Block.*Units* stratum					
P_Source	3	10413.	3471.	1.16	0.336
Rate_mg_kg_1	5	26017.	5203.	1.74	0.145
P_Source.Rate_mg_kg_1	15	86859.	5791.	1.93	0.044
Residual	46	137771.	2995.		
Total	71	266842.			

Table 14: Effects of P-rates on number of panicle plant $^{-1}$ and panicle length

Treatment	Number of panicles plant^{-1}	Panicle length (cm)
AbsC	3.00 a	19.18 a
P 0	12.92 b	23.30 b
P 10	13.00 b	23.47 b
P 20	13.75 c	23.58 b
P 40	14.42 c	23.68 b
P 80	15.25 d	24.18 b
Mean	12	22.90
CV (%)	7.5	4.3
LSD (0.05)	0.7	0.80

Means in the same column followed by the same letter(s) are not significantly different at 5% level of significance according to Duncan New Multiple Range Test. Means in each column analyzed separately.

Table15: ANOVA table for number of panicles per plant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	9.5278	4.7639	5.90	
Block.*Units* stratum					
P_Source	3	6.7778	2.2593	2.80	0.050
Rate_mg_kg_1	5	1227.4444	245.4889	304.06	<.001
P_Source.Rate_mg_kg_1	15	16.8889	1.1259	1.39	0.190
Residual	46	37.1389	0.8074		
Total	71	1297.7778			

Table 16: ANOVA table for Panicle height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	4.3047	2.1524	2.26	
Block.*Units* stratum					
P_Source	3	6.4466	2.1489	2.25	0.095
Rate_mg_kg_1	5	204.6782	40.9356	42.93	<.001
P_Source.Rate_mg_kg_1	15	12.0603	0.8040	0.84	0.627
Residual	46	43.8587	0.9534		
Total	71	271.3485			

Table 17: Effects of P- sources on dry matter and grain yield

P-source	Dry matter yield	Grain yield
	g pot $^{-1}$	
BGK-A	31.11 b	92.20 a
BGK-B	28.44 a	90.24 a
BGS	31.11 b	93.93 a
TSP	33.17 c	94.64 a
Mean	31	92.75
CV (%)	6.9	10.4
LSD (0.05)	1.4	6.49

Means in the same column followed by the same letter(s) are not significantly different at 5% level of significance according to Duncan New Multiple Range Test. Means in each column analyzed separately.

Table 18: ANOVA table for Dry matter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	42.194	21.097	4.66	
Block.*Units* stratum					
P_Source	3	202.278	67.426	14.88	<.001
Rate_mg_kg_1	5	344.611	68.922	15.21	<.001
P_Source.Rate_mg_kg_1	15	293.056	19.537	4.31	<.001
Residual	46	208.472	4.532		
Total	71	1090.611			

Table 19: ANOVA table for Grain yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	123.95	61.97	0.66	
Block.*Units* stratum					
P_Source	3	208.59	69.53	0.74	0.531
Rate_mg_kg_1	5	91173.42	18234.68	195.09	<.001
P_Source.Rate_mg_kg_1	15	2813.17	187.54	2.01	0.036
Residual	46	4299.46	93.47		
Total	71	98618.59			

Table 20: Effects of P- rates on shoot dry matter yield and grain yield

Treatment	Shoot dry matter yield	Grain yield
	g pot $^{-1}$	
Absc	27.42 a	13.85 a
P 0	29.00 a	101.94 b
P 10	31.25 bc	105.56 bc
P 20	32.83 cd	106.36 bc

P 40	30.75 b	113.74 cd
P 80	33.92 d	115.06 d
Mean	31	92.75
CV (%)	6.9	10.4
LSD (0.05)	1.7	7.9

Means in the same column followed by the same letter (s) are not significantly different at 5% level of Significance according to Duncan New Multiple Range Test. Means in each column analyzed separately.

Table 21: Simple correlation coefficients for grain yield and yield components

Characters	Grain yield (g)	Dry matter yield (g)	Number of panicles/plant	Panicle height (cm)	Plant height (cm)	Number of tillers
Grain yield (GY)	1					
Dry matter yield (DM)	0.413*	1				
Number of panicles/plant (NP)	0.945***	0.488**	1			
Panicle height (PAH)	0.844***	0.346*	0.809***	1		
Plant height (PH)	0.909***	0.469**	0.910***	0.857***	1	
Number of tillers (NT)	0.869***	0.460**	0.918***	0.788***	0.872***	1

Statistically significant effects are indicated: ***, P < 0.001; **, P < 0.05; *, P < 0.1.

Plates:

Plate1: Rice response to applied guano from Kisarawe cave A (BGK-A) in reproductive stage: from absolute control, 0, 10, 20, 40 and 80 mg/Kg P under screen house condition

Plate2: Rice response to applied guano from Kisarawe cave B (BGK-B) in reproductive stage: from absolute control, 0, 10, 20, 40 and 80 mg/Kg P under screen house condition

Plate3: Rice response to applied guano from Sukumawera cave (BGS) in reproductive stage: from absolute control, 0, 10, 20, 40 and 80 mg/Kg P under screen house condition

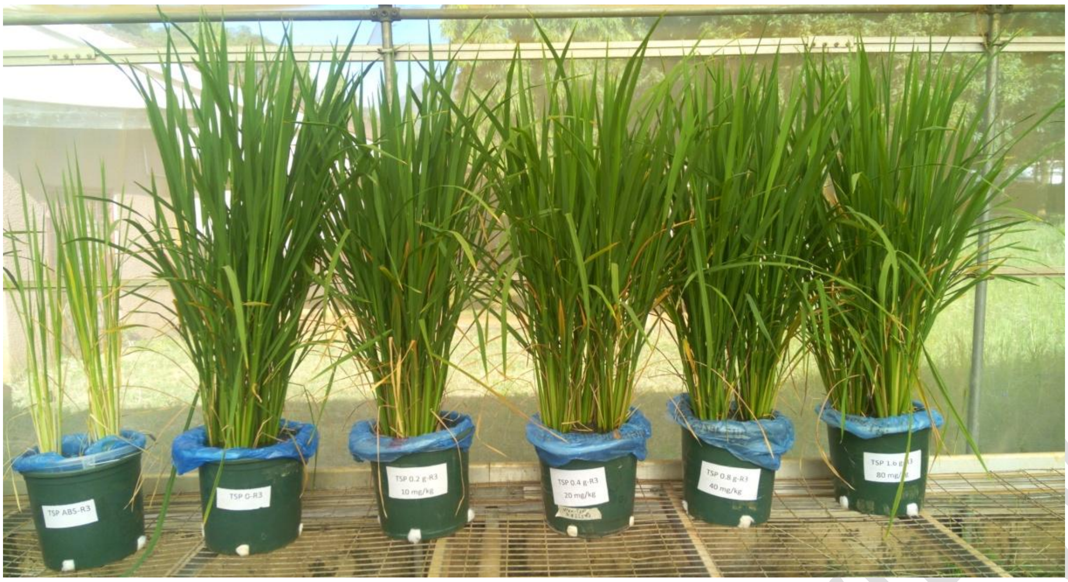

Plate4: Rice response to applied guano from TSP fertilizer in reproductive stage: from absolute control, 0, 10, 20, 40 and 80 mg/Kg P under screen house condition