



Improving Maize Productivity under Rain-Fed Conditions through the Combined Use of Inorganic and Organic Fertilizer in Malawi

Austin T. Phiri^{1*}, Kate Malola¹, Samuel Mwafurirwa¹ and Pacsu Simwaka¹

¹*Department of Agricultural Research Services, Bvumbwe Agricultural Research Station, Malawi.*

Authors' contributions

The work was conducted in collaboration among all authors. Author ATP designed the study. Authors KM, SM and PS managed the experiments and collected the data. Author ATP performed the statistical analysis and managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/APRJ/2020/v4i230082

Editor(s):

(1) Dr. Langa Tembo, University of Zambia, Zambia.

Reviewers:

(1) Chemutai Roseline, Bukalasa Agricultural College, Uganda.

(2) Yesim Togay, Turkey.

(3) Joseph A. Orluchukwu, University of Port Harcourt, Nigeria.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/56793>

Original Research Article

Received 04 March 2020

Accepted 10 May 2020

Published 25 May 2020

ABSTRACT

Integrated soil fertility management was promoted on-farm during the 2018/2019 cropping season in Thyolo, Phalombe, Mulanje and Zomba districts of southern Malawi, in purposively selected extension planning areas (EPAs). Sixty farmers, fifteen from each district were involved. Trials were established in farmers' fields with smallholder farms as replicates and extension EPAs as blocks. The following were the treatments; Maize + 92 kg N ha⁻¹ + 46 kg of P ha⁻¹; Maize + 3 tons of compost manure ha⁻¹; and Maize + 46 kg N ha⁻¹ + 23 kg P ha⁻¹ + 1.5 tons of compost manure. Grain yield data were collected at harvest. The data were analyzed in Genstat Discovery Edition 4 and were subjected to ANOVA at 95% level of confidence. Means were separated by the least significant difference (LSD_{0.05}). No significant differences (>0.05) in Maize grain yields were observed between the treatment with Maize + 46 kg N ha⁻¹ + 23 kg P ha⁻¹ + 1.5 tons of compost manure and the treatment with Maize + 92 kg N ha⁻¹ + 46 kg of P ha⁻¹ in all the districts. Maize grain yields were significantly lower in plots treated with the full rate of manure (3 tons of compost manure ha⁻¹) in Thyolo, Mulanje and Zomba district. Higher maize grain yields were registered in

*Corresponding author: E-mail: phiriaustin534@gmail.com;

Phalombe (3,867-4,838 kg ha⁻¹), followed by Thyolo (1,764-2,374 kg ha⁻¹) and Zomba (740-1,120 kg ha⁻¹). The trials confirmed that applying a combination of organic and inorganic fertilizer to maize, increase grain yields.

Keywords: Soil fertility; soil organic matter; maize; legumes; climate.

1. INTRODUCTION

Maintenance of soil organic matter (SOM) at levels (0.85-3.4%) [1] that sustain optimal supply of soil nutrients for uptake by crops and enhance efficiency of applied mineral fertilizers is a major challenge for smallholder farming systems of southern Africa in general and Malawi in particular [2]. Many reports have shown that use of inorganic fertilizers alone may lead to deficiency of nutrients not supplied by the chemical fertilizers and may also lead to chemical soil degradation [3], like loss of the soil's natural buffering capacity. Chemical fertilizers are also too costly for farmers to apply the recommended rates. On the other hand, there are demonstrated benefits of the use of organic sources of plant nutrients on soil properties like soil pH, water holding capacity, hydraulic conductivity and infiltration and decreased bulk density [3]. SOM is a key factor in soil aggregation that leads to improved soil porosity hence increasing the infiltration, storage and drainage of water, improving soil aeration, and the ease of penetration of plant roots [4]. However, sole application of organic sources of plant nutrients is constrained by their low contents and availability of the essential nutrients, N in particular, to the current crop [5], imbalanced nutrient contents, unfavorable quality and high labor demands for transporting the bulky organic materials [6].

Many researchers have suggested that the alternative is to use the integrated approach to soil fertility management (ISFM), which among other things involves the combined application of organic and inorganic fertilizers for the improvement of crop yields and maintenance of soil fertility [7]. According to [8] suggested an operational definition of ISFM as 'the set of soil fertility management practices that necessarily include the use of fertilizers, organic inputs, and improved germplasm, combined with knowledge on how to adapt these practices to local conditions, aiming at maximizing agronomic use efficiencies of the applied inputs and improving crop productivity. However, [1] propose to define ISFM as a practice of improving and restoring soil fertility while optimizing yields using a set of soil fertility management practices that

necessarily includes organic and mineral fertilizers, improved germplasm; and using a set of knowledge to adapt them to a given environment, while targeting maximizing production and recovery efficiencies of applied nutrients for sustainable land use intensification. According to [9] half the number of smallholder farmers in SSA may reduce N fertilizer rates if high quality green manure rich in N is used in legume-cereal rotation cropping systems, while [10] was of the idea that comprehension by farmers on the positive effects of OM application on NUE could increase the number of inorganic fertilizer users by reducing the amount of mineral fertilizer that farmers would purchase for application in their fields. The chief consequence of soil degradation has been declining soil fertility and resultant low soil productivity [11]. For instance, the average maize grain yield in Africa is estimated to be at 1.7 tons ha⁻¹ compared with the global average of about 5 tons ha⁻¹ [12]. In Malawi, the national yields of maize have averaged 1.3 t ha⁻¹ during the last 20 years [13] against a yield potential range of 6 to 10 t ha⁻¹ of many maize hybrid varieties currently grown by some progressive Malawian farmers. In the 2005/06 season, the national average maize yield was estimated to be at 1.6 t ha⁻¹. A strong Government-led Farm Input Subsidy Program (FISP) with special emphasis on the use of inorganic fertilizer, increased the national average maize yield to over 2 t ha⁻¹ in the 2006/07 season [14]. The low productivity is attributed largely to low plant nutrient availability and nutrient use efficiency [15].

Prevailing economic conditions in Malawi have limited the use of mineral fertilizers by smallholder farmers, due to their low purchasing power. At the same time, annual estimates indicate an increase in nutrient losses under various farming systems through different pathways [16], for example; through soil erosion, leaching and denitrification. Total national estimates for annual nutrient losses of around 160,000 metric tons, lost mainly through nutrient mining by crops have been reported, with annual estimates of inorganic fertilizer nutrient inputs into the farming systems pegged at 70,000 metric tons thus leaving a net deficit of 90,000 metric tons [16]. About 52.4% of Malawi's 13

million people live below the poverty line, of 1US\$/day [17], yet the delivery price for a metric ton of urea from the ocean ports of East African countries is \$770 [18], translating to \$38.5/50 kg bag. Certainly, this is beyond the smallholder farmers' purchasing power, hence the low use of the mineral fertilizers by the farmers. Conscious of the smallholder farmers' resource limitations, the Government of Malawi (GoM) introduced the targeted fertilizer subsidy program. This program is tailored to reach out to resource poor smallholder farmers with the aim of boosting agricultural production at village and national levels. However, many smallholder farmers are not able to access the facility. This is due to the fact that the quantity of the fertilizers purchased by the Government for the program usually is not enough [19]. Furthermore, on farm maize grain yield response to the application of N from inorganic fertilizers (PFP_N) is low as a result of declining levels of soil organic matter (SOM), deficiencies of macro and micronutrients and reduced soil buffering capacity [10]. According to [20], in Malawi PFP_N is usually below 20 kg maize grain kg^{-1} nitrogen applied. Potentially, combined use of mineral fertilizer and compost manure could help address the situation in Malawi. This could increase fertilizer use efficiency and yields by maize through enhancement of nutrient retention within the crop rooting zone, moisture conservation and hence uptake by crops of the nutrients. Additionally, reduction in amount of the applied mineral fertilizer and the addition of organic materials to the soil will go a long way to mitigate climate change, through reduced emissions of green house gases (GHGs) like nitrous oxide and

carbon dioxide. Furthermore, use of organic materials as fertilizer could potentially lead to enhanced carbon sequestration and storage in the soil.

2. MATERIALS AND METHODS

2.1 Materials

Maize seed (SC 403) yield potential of 5.0-6.0 t ha^{-1} , NPK 23:10:5 + 6s + 1Zn and Urea.

2.2 Laboratory and Data Analysis

Composite samples each weighing 500 g from three random points within farmers's fields were collected before planting and after harvest. Soil samples were taken at a depth of 0-20 cm and 20-40 cm with an auger. Laboratory soil analysis was done in order to characterize the soils. Soil samples were analyzed for OC, total N, available P, and soil pH (H_2O). Soil pH was determined in water using pH meter. Determination of plant available P was done using the Mehlich 3 Extraction Procedures [21] while OC was determined using the colorimetric method [22] and total N was determined by the Kjeldahl method [23]. Soil texture was determined using the hydrometer method. For samples collected after harvest, only OC was analysed to ascertain the effect of manure application on OC content in the soil.

2.3 Rainfall

The districts where the trials were implemented received adequate rainfall (Fig. 1) during the 2018/2019 cropping season with the highest

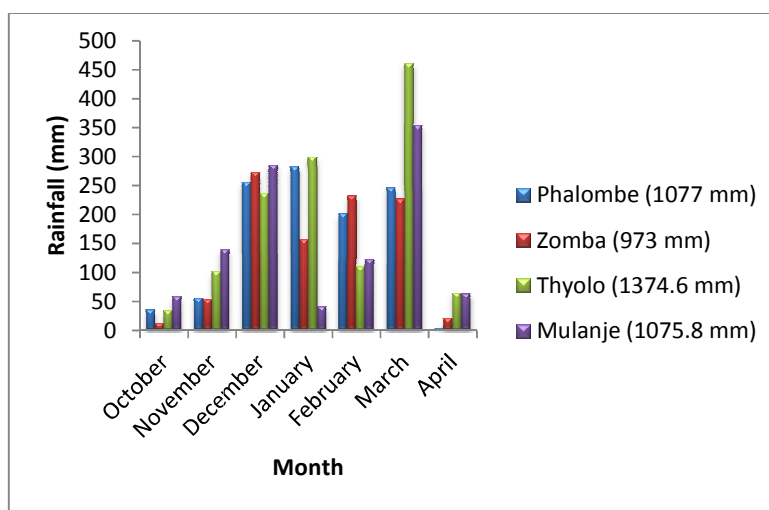


Fig. 1. Rainfall in the four districts during the 2018/2019 cropping season

amount recorded in Thyolo (1,374.6 mm), followed by Phalombe (1,077 mm), Mulanje (1,075.8mm) and Zomba (973 mm).

2.4 Field Trials

The trials were planted on farmers' fields in the 2018/2019 cropping season in Thyolo, Phalombe, Mulanje and Zomba districts of southern Malawi, in purposively selected extension planning areas (EPAs). Sixty farmers, fifteen from each district were involved. Farmer selection was conducted through the district agricultural offices. Maize was planted on ridges spaced at 75 cm apart with planting stations at 25 cm apart. One seed was planted per planting station. The plot size was 10 m x 10 m. The following were the treatments: Maize + 92 kg N ha⁻¹ + 46 kg of P ha⁻¹ (full application rate of inorganic fertilizer, applied at basal and top dress in between planting stations); Maize + 3 tons of compost manure ha⁻¹ (full application rate of compost manure, thus two handfuls of compost manure applied between planting stations); Maize + 46 kg N ha⁻¹ + 23 kg P ha⁻¹ + 1.5 tons of compost manure (half application rate of mineral fertilizer, applied at basal and top dress in between planting stations plus half application rate of compost manure, thus one handfuls of compost manure applied between planting stations). Farmers' fields were treated as replicates and EPAs as blocks. Grain yield data were collected at harvest. Statistical data analysis was done using Genstat Discovery Edition 4. Data were subjected to ANOVA at 95% level of confidence and means were separated by the least significant difference (LSD_{0.05}).

3. RESULTS

3.1 Soil Fertility Status at the Sites

Following the observed soil variability in sampled fields and the number of sampled fields within a

district (n=15 per district), a none tabulated range of soil characteristics after laboratory analysis are presented and were as follows; In Phalombe soil texture is largely sandy loam and clayey in some areas. Soil pH is slightly acid (6.0-6.5) to very slightly alkaline (7.1-7.5), with low (<0.88%) organic carbon (OC) and very low nitrogen (N) content (<0.08%). In Thyolo, soil texture is largely clayey and sandy loam and in some areas. Soil pH is slightly acid (6.0-6.5) with low (<0.88%) OC content and very low N content (<0.08%). In Zomba, soil texture is variable from clay, sandy loam, sandy clay loam and loamy sand. Soil pH is acid (5.1-5.5) to moderately acid (5.6-6.0), while some parts are slightly acid (6.1-6.5) with low (<0.88%) OC content and very low N content (<0.08%). In Mulanje, soil texture is largely clay and sandy loam in some parts. Soil pH is acid (5.1-5.5) to moderately acid (5.6-6.0) with low (<0.88%) to high (0.88-2.35%) OC content and very low N content (<0.08%). The range of values for the status of OC in the fields after harvest indicated low contents with values falling within the range of 0.56% to 0.83% in all the sites.

3.2 Maize Grain Yield

Table 1 below show maize grain yields in Phalombe, Thyolo, Mulanje and Zomba districts in southern Malawi. No significant differences in maize grain yields were observed in plots treated with half the application rate of manure combine with half the application rate of mineral fertilizer and the plots treated with the full application rate of mineral in all the districts. Maize grain yields were significantly lower in plots treated with the full rate of manure in Thyolo, Mulanje and Zomba district. Higher maize grain yields were registered in Phalombe (3,867-4,838 kg ha⁻¹), followed by Thyolo (1,764-2,374 kg ha⁻¹) and Zomba (740-1,120 kg ha⁻¹).

Table 1. Maize grain yield for the 2018/2019 cropping season in the implementing districts

Treatments	Phalombe yield (kg ha ⁻¹)	Thyolo yield (kg ha ⁻¹)	Mulanje yield (kg ha ⁻¹)	Zomba yield (kg ha ⁻¹)
Maize + 92 kg N ha ⁻¹ + 46 kg of P ha ⁻¹	4,622	2,330 ^a	1,180 ^a	838 ^{ab}
Maize + 3 tons of compost manure ha ⁻¹	3,867	1,764 ^b	720 ^b	740 ^b
Maize + 46 kg N ha ⁻¹ + 23 kg P ha ⁻¹ + 1.5 tons of compost manure	4,838	2,374 ^a	1,160 ^a	1,120 ^a
%CV	23.7	18.08	19.32	31.6
LSD _{0.05}	1,534	389.6	287.4	305.0
F pr.	0.357	0.007	0.010	0.046

Means with different super scripts within a column are statistically different $p < 0.05$

4. DISCUSSION

Generally, OC in all sites was low indicating the need to restock and buildup OC. Organic carbon is critical for soil health as it regulates many functions in the soil like, water and nutrient retention and uptake by crops, soil buffer capacity, soil aggregation and aggregate stability, population and activities of microbes and water infiltration rate among other things. After harvest the status of OC remained low despite application of manure to the soil. Buildup of OC in the soil is a gradual process that is contingent on soil factors like texture, pH, tillage practices, temperature, moisture as well as type, quality and quantity of organic residues incorporated to the soil and frequency of incorporation of the organic residues. However, higher maize grain yields were registered in Phalombe (3,867-4,838 kg ha⁻¹), followed by Thyolo (1,764-2,374 kg ha⁻¹) and Zomba (740-1,120 kg ha⁻¹). Potentially soil pH could have contributed to the stated yield trend. Phalombe and Thyolo has more favorable soil pH compared to acid soils of Mulanje and Zomba. Nutrients in the soil are less available under acid than slightly acid conditions. However, no significant differences in maize grain yields were observed between the treatment with half the application rate of manure combine with half the application rate of mineral fertilizer and the treatment with the full application rate of mineral in all the districts, attributable to improved nutrient use efficiency in the treatments with half the application rate of manure combine with half the application rate of mineral fertilizer. Synchrony between N release and crop nutrient demand is attained through combined application of organic fertilizer and factory N and reduces leaching of applied nutrients, leading to improved nutrient use efficiency and grain yields. Additionally applying manure buffer soil pH, improve soil tilth, water infiltration, nutrient and water holding capacities, thus making the soils healthier and more productive, sustainably.

5. CONCLUSION

The work has confirmed that applying a combination of organic and inorganic fertilizer to maize, increases grain yields. However, consistent application of organic matter to the soil by the farmers is required in order to buildup OC, for yields and soil health improvement, sustainably.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Musinguzi P, Tenywa JS, Ebanyat P, Makoo M. Soil organic carbon thresholds and nitrogen management in tropical agroecosystems: Concepts and prospects. *Journal of Sustainable Development*. 2013;6-12.
2. Mapfumo P, Mtambanegwe F, Vanlauwe B. Organic matter quality and management effects on enrichment of soil organic matter fractions in contrasting soils in Zimbabwe. *Plant Soil*. 2007;296:137–150.
3. Mafongoya P, Bationo A, Kihara J, Waswa B. Appropriate technologies to replenish soil fertility in Southern Africa. *Nutrient Cycling in Agroecosystems*. 2006;76:137–151.
4. Verhulst N, Govaerts B, Verachtert E, Castellanos-Navarrete A, Mezzalama M, Wall P, Deckers J, Sayre. Conservation agriculture, improving soil quality for sustainable production systems? In: Lal, R., Stewart, B.A. (Eds.), *Advances in Soil Science: Food Security and Soil Quality*. CRC Press, Boca Raton, FL, USA. 2010;137–208.
5. Nyamangara J, Mtambanengwe F, Musvoto C. Carbon and nitrogen mineralization from selected organic resources available to smallholder farmers for soil fertility improvement in Zimbabwe. *African Journal of Agricultural Research*. 2009;4(9):870-877.
6. Palm C, Myers RJ, Nandwa SM. Combined use of organic and inorganic sources for soil fertility maintenance and replenishment. *SSA Special Publication*. 1997;51:193-218.
7. Bationo A, Vanlauwe B, Kimetu J, Kihara I, Abdoulaye MS, Adamou A, Tabo R, Koala S. Increasing land sustainability and productivity through soil fertility management in the West African Sudano-Sahelian zone. In: *Nutrient and water management practices for increasing crop production in rain-fed Arid/Semi-arid areas*. International Atomic Energy Agency, TECDOC. 2005;1468:53-75.
8. Vanlauwe B, Bationo A, Chianu J, Giller KE, Merckx R, Mokwunye U, Ohiok O, Pypers P, Tabo R, Shepherd KD, Smaling EMA, Woomer PL, Sanginga N. Integrated

- soil fertility management: Operational definition and consequences for implementation and dissemination. *Outlook on Agriculture*. 2010;39:17-24.
9. Abera T, Feyissa D, Yusuf H, Georgis T. Influence of precursor crops on inorganic and organic fertilizers response of maize at Bako, Western Oromiya, Ethiopia. *Pakistan Journal of Biological Sciences*. 2005;8(12):1678-1684.
 10. Kumwenda JDT, Waddington SR, Stephen, R, Snapp SS, Jones RB, Richard B, Blackie MJ. Soil fertility management in the smallholder maize-based cropping systems of Africa a paper for a workshop on. "The emerging maize revolution in Africa: The role of technology, institutions and policy" Michigan State University, USA, 9-12 July. 1995;24.
 11. Amede T. Opportunities and challenges in reversing land degradation: A regional experience. In: Amede, T (Ed), *Natural resource degradation and environmental concerns in the Amhara National Regional State: Impact on food security*. Ethiopian Soils Science Society. 2003;173-183.
 12. Forum for Agricultural Research in Africa (FARA). Change in maize production in Africa: Implications for maize policy development. Ministerial Policy Brief Series. Number 3. 2009;10.
 13. Food and Agriculture Organization (FAO). FAOSTAT database production: Crops; 2008. Available:<http://faostat.fao.org/site/567/default.aspx>
 14. WFP. Country portfolio evaluation of WFP assistance to Malawi, Rome; 2009. Available:<http://documents.wfp.org/stellent/groups/public/documents/newsroom/wfp207899.pdf>
 15. Sakala WD, Kumwenda JDT, Saka AR. The potential of green manures to increase soil fertility and maize yield in Malawi. *Maize Agronomy Research Report*, Chitedze Agricultural Research Station, Lilongwe, Malawi. 2004;14-20.
 16. Kanyama-Phiri GY. Best-bet soil fertility management options: The case of Malawi. *African Crop Science Conference Proceedings*. African Crop Science Society. 2005;7:1039-1048.
 17. GoM. Malawi growth and development strategy from poverty to prosperity. Available:http://siteresources.worldbank.org/MALAIEXTN/resources/MGDS_2006_final.pdf
 18. Conway G, Waage J. Harnessing science for global health. *The Lancet*. UK Collaborative on Development Sciences Publication. 2010;375(9726):1599-1600.
 19. Phiri AT, Njoloma JP, Kanyama-Phiri GY, Snapp S, Lowole MW. Maize yield response to the combined application of Tundulu rock phosphate and pigeon pea residues in Kasungu, Central Malawi. *African Journal of Agricultural Research*. 2010;5(11):1235-1242.
 20. Waddington SR, Sakala W, Mekuria M. Progress in lifting soil fertility in Southern Africa. *Proceedings of the 4th International Crop Science Congress Brisbane, Australia, 26 September – 1 October*. 2004;15.
 21. Mehlich A. Mehlich 3 soil test extractant: A modification of Mehlich 2 extractant. *Community of Soil Science and Plant Analysis*. 1984;15(12):1409-1416.
 22. Schumacher BA. Method for the determination of total organic carbon (TOC) in soils and sediments. *US Environmental Protection Agency Environmental Sciences Division National Exposure Research Laboratory, Las Vegas*. 2002;3-23.
 23. Amin M, Flowers TH. Evaluation of the Kjeldahl digestion method. *Journal of Research (Science)*. 2004;5(2):59-179.

© 2020 Phiri et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
<http://www.sdiarticle4.com/review-history/56793>