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# Evaluation of Mbeya based organic fertiliser on maize yield and yield components in Malawi

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## Abstract

*Recent boom in organic business in the name of Mbeya manure fertilizer has taken shape in commercialisation without ATCC approval as several implications were at stake. Laboratory and fields experiments were, therefore, conducted to ascertain the quality of the products with and without modifications. The original products, as proclaimed by suppliers, were evaluated against the control treatment of inorganic fertilizer and the modified products by inclusion of specific microorganisms in solubilisation of fixed nutrients and oxidation of ammonia and nitrite. Field layout followed Completely Randomized Block Design with three replications and 5 treatments viz Modified Funani Mbeya fertilizer, Modified Kambeu Mbeya fertilizer, Original Funani Mbeya fertilizer, Original Kambeu Mbeya fertilizer and the recommended inorganic fertilizer for Maize. Besides assessing the grain yield, biomass and nutrient bioavailability, effect of the organic fertiliser on biostimulation was also studied in the rhizospheric soil. Results showed that that there was no significant differences on grain yield and its components between Mbeya based organic fertilisers and inorganic fertilisers. However, maize yield and some parameters (environmental and nutrient content) was higher in modified organic fertiliser.*

**Keywords:** Funani, Kambeu, Mbeya organic fertilisers, local innovations and Maize.

## Introduction

In spite the effort by the government to increase the use of inorganic fertilizer by smallholder farmers through the introduction of farm input subsidy program (FISP), smallholder farmer's adoption is low despite of economic implication due to prices[1]. The use of commercialised organic fertilizer for maize production is problematic due to inconsistencies in nutrient[2,3]. Knowledge of nutrient values of these organic soil amendments is limited because the nutrients from these sources are gradually released into soils in crop available forms and may be temporally tied up in soil microorganisms or organic matter[4].

Maize production in low to no external input systems (both organic and inorganic) accompanied by degraded soils by smallholder farmers is the major cause of decrease in production[5,6]. There is a need to promote sustainable agriculture which implicates maintenance of soil fertility by combination of inorganic and organic fertilizers. The combination of organic and inorganic fertilizer complement the beneficial effects of organic fertilizer and inorganic fertilizer[7]. Organic fertiliser release nutrients slowly for long period of time in the soil, thus ensuring a long residual effect. Bio-stimulation and inoculation are the main ways of viability of organic fertiliser using PGRM for the biological nitrogen fixation (BNF), phosphate, zinc and potassium solubilisation[8]. In Mbeya based organic fertiliser which is a combination of organic and inorganic fertiliser, macro nutrients are mainly supplied by inorganic fertiliser while organic fertiliser supply micronutrients[9].

The main focus of organic agriculture include; to produce highly nutritious and quality yield; to enhance interaction between PGRM and abiotic factors by mimicking cycles and natural systems; to enhance biological cycles by PGRM through biostimulation or inoculation; to improve and maintain soil fertility; to promote recycling of agricultural waste mimicking natural ways; for bioremediation and promoting diversity in the farms[10–12].

The nutrient release of organic based fertilizers varies based on the microbe used, ingredients and the process[13]. Therefore, predicting nutrient release from organicbased fertilizers is challenging [14], however, organic fertiliser application restores degraded soils[15]. There are a number of composts in Malawi practiced by farmers in Malawi viz. Changu, Windrow, Bokashi, Pit and farm yard manure. In spite of having these various forms of compost being widely promoted farmers have opted for Mbeya organic fertilizer, require certification because of its commercial implication. Farmers like Mbeya based organic fertilisers due to price and environmental implication while increasing maize yield. This research study was done to evaluate the performance of Funani and Kambeu Mbeya based organic fertiliser on improving soil fertility and maize in Malawi.

## Methodology

**Study sites:** The study was conducted at Chitedze Agricultural Research Station, GPS location 13°85'S and 33°38'E at an altitude of 1,146m above sea level representing medium altitude areas. The same study was extended to high potential areas of on-farm conditions in Kasungu, Dowa and Zombaunder both irrigation and rain-fed farming systems. The study was conducted for 2 cropping seasons but during both rain-fed and irrigation seasons in the aforementioned study sites.

**Treatments and study design:** The study had 5 treatments namely; Modified Funani Mbeya fertilizer, Modified Kambeu Mbeya fertilizer, Original Funani Mbeya fertilizer, Original Kambeu Mbeya fertilizer and the recommended inorganic fertilizer for Maize (Control). One maize variety (SC 627) of medium maturity was used in the study. The experiment was conducted in a randomized complete block design (RCBD) with 3 replications. Under on-farm conditions, each farmer hosted the trial as a replicate. All the treatments were subjected to normal management practices for maize production in Malawi under both rain-fed and irrigation conditions. The land used for the trial had no history of inoculation of any microorganisms. Composition of mbeya fertiliser was 10 kg chemical fertiliser (NPK or Urea), 10 kg chicken dropping or pig dung, 10 kg maize bran, 20 kg ash and 8 litres of water while the modified mbeya composed of was 6 kg chemical fertiliser (only Urea), 12 kg chicken dropping or pig dung, 12 kg maize bran, 20 kg ash mixed with charcoal 8 litres water and plant growth regulatory microbes (PGRM).

**Data collection and statistical analysis:** In each field, soil samples were collected and analysed to determine their initial soil fertility in terms of pH, Nitrogen, Phosphorous, Potassium, Calcium, Magnesium, Iron, Manganese, CEC, Organic matter and Total Carbon). Grain and stover yields were measured from each treatment. From the measured yields, the shelling percentage and harvest index were also computed. Maize plant nutrient content was also analysed to compare and contrast the performance of the treatments.

The collected data on yield and yield components was subjected to analysis of variance (ANOVA) using GenStat 18th edition and Minitab statistical software packages. Significant differences were assessed at 5% level and data mean separation was done using Fisher's protected least significant difference (LSD) procedure. After preliminary analysis of data, the presence of non-homogeneity in the data sets among the sites prompted a separate analysis for each site. The analysis was also done separately for irrigation and rain-fed conditions.

## Results and discussion

The results (>90) showed no significant changes in terms of yield between organic fertilizers and recommended fertiliser rates as shown in Figure 1-4. However, the modification of the two had slightly higher yields and grain nutrient content as shown in Figure 1-4, 9 and Table 9 and 3. Higher grain yield may be a result of cob weight shown by seed size (Table 3-6). The results on PGRM shown in Figure-11 and Table-12 expose the danger of inorganic fertiliser on plant growth regulatory microbes. The results gives insight why grain produced using inorganic fertilisers have low nutrient contents compared to those grown organically. This brings to the attention of incorporating PGRM in the soil either by biostimulation or inoculation in organic fertilisers or direct to soil which is in line with other studies and regulations in other countries[16–20].

The result of the trial showed that yield was not significantly affected by location or season but modification of organic fertilisers by inoculation with plant growth regulatory microbes (PGRM) gave higher yields. The greater the number and diversity of PGRM increased plant capability for nutrient uptake due to solubilising nutrients, fixation of nitrogen in mbeya based fertilisers. This observation is consistent with studies documented by Khan *et al.*[21] . Higher grain yield observed in the modified Mbeya based organic fertilisers could be attributed to seed size not cob weight or grain weight or harvest index or shelling percentage. Hussain *et al.*[22] attributed this to accumulation and photosynthesis at grain filling period and its eventual partitioning to the ear. Partitioning of assimilates to the ear suggested that there could be an increased kernel set which was also reported by Barary et al.[23].

**Table-1:** Soil analysis results from the samples taken from the various forms of Mbeya organic fertilizer.

| Lab No. | Reference sample | Ph. | %OC | %OM | %N | P (ug/g) | K (cmol/kg) | Ca (cmol/kg) | Mg (cmol/kg) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Mbeya farmer 1 | 7.81 | 0.87 | 1.49 | 0.07 | 111.13 | 0.04 | 0.08 | 0.00 |
| 2 | Mbeya farmer 1 | 8.2 | 0.81 | 1.39 | 0.07 | 123.5 | 0.01 | 0.09 | 0.01 |
| 3 | Funani Mbeya original | 7.77 | 1.24 | 2.14 | 0.11 | 271.87 | 0.02 | 0.3 | 0.00 |
| 4 | Kambeu Mbeya modified 1 | 8.03 | 1.64 | 2.83 | 0.14 | 282.88 | 0.04 | 0.14 | 0.01 |
| 5 | Funani Mbeya modified 1 | 7.18 | 1.82 | 3.13 | 0.16 | 277.84 | 0.09 | 0.23 | 0.03 |
| 6 | Kambeu Mbeya modified 1 | 7.65 | 2.28 | 3.93 | 0.2 | 274.74 | 0.13 | 0.27 | 0.02 |
| 7 | Funani Mbeya modified 2 | 7.69 | 2.31 | 3.98 | 0.2 | 279.41 | 0.09 | 0.29 | 0.03 |
| 8 | kambeu Mbeya modified 2 | 8.25 | 2.51 | 4.33 | 0.22 | 274.74 | 0.06 | 0.3 | 0.02 |

**Table-2:** Initial soil analysis results from the soil samples taken from the various sites where the study was conducted.

| District | Critical value | Dowa | Dowa | Kasungu | Kasungu | Zomba | Zomba | Lilongwe | Lilongwe |
|---|---|---|---|---|---|---|---|---|---|
| Site | 5.2 | Nachisaka | Nachisaka | Snathe | Snathe | Masaula | Masaula | Chitedze | Chitedze |
| Depth | >0.88 | 0-20cm | 20-40cm | 0-20cm | 20-40cm | 0-20cm | 20-40cm | 0-20cm | 20-40cm |
| pH(water) | 1.5 | 4.98 | 5.31 | 5.77 | 5.04 | 6.6 | 7.14 | 7.55 | 7.28 |
| %OC | >0.1 | 0.8 | 0.89 | 0.45 | 0.36 | 0.09 | 0.8 | 0.53 | 0.86 |
| %OM | 15 | 1.38 | 1.54 | 0.78 | 0.62 | 0.15 | 1.38 | 0.92 | 1.49 |
| %N | 0.2 | 0.07 | 0.08 | 0.04 | 0.03 | 0.01 | 0.07 | 0.05 | 0.07 |
| P(Cmol/kg) | 0.2 | 36.8 | 20.91 | 13.59 | 14.13 | 16.31 | 18.38 | 15.22 | 7.05 |
| K(Cmol/kg) |  | 83 | 1.3 | 0.25 | 0.25 | 0.4 | 0.37 | 0.37 | 0.29 |
| Ca(Cmol/kg) | 0.5 | 1.61 | 1.75 | 0.06 | -0.28 | 0.58 | 0.39 | 0.68 | 0.51 |
| Mg(ug/g) |  | 0.37 | 0.54 | 0.06 | 0.05 | 0.01 | 0.01 | 0.01 | 0.01 |
| Zn(ug/g) |  | 0.03 | 0.03 | 0.06 | 0.03 | 0.03 | 0.03 | 0.06 | 0.03 |
| Mn(ug/g) |  | 56.36 | 56.4 | 0.35 | 0.19 | 1.55 | 0.72 | 0.87 | 0.83 |
| Fe(ug/g) |  | 48.51 | 53.49 | 7.36 | 7.68 | 1.86 | 0.95 | 1.03 | 1.53 |
| Texture |  | SCL | SCL | SCL | SCL | SCL | SCL | SCL | SCL |

The better performance observed in all sites with irrigation than rain fed could be attributed to the stress related issues. The fertility status of sites had no significant in terms of yield as indicated in the tables which could be as a result of cushioning factor of organic carbon which made the organic fertilisers to provide nutrients based on plant nutrient demand. This was equally reported by Phiri et al.[24] where it was observed that combined application of organic and inorganic fertiliser gave the highest performance in maize grown in Malawi. Generally, OC in all sites was low indicating the need to restock and buildup OC as shown in Table-2. Organic carbon is critical for soil health as it regulates biological, chemical and physical parameters[21,25,26]. Buildup of OC in the soil is a gradual process that is contingent on abiotic and biotic soil edaphic factors[27].

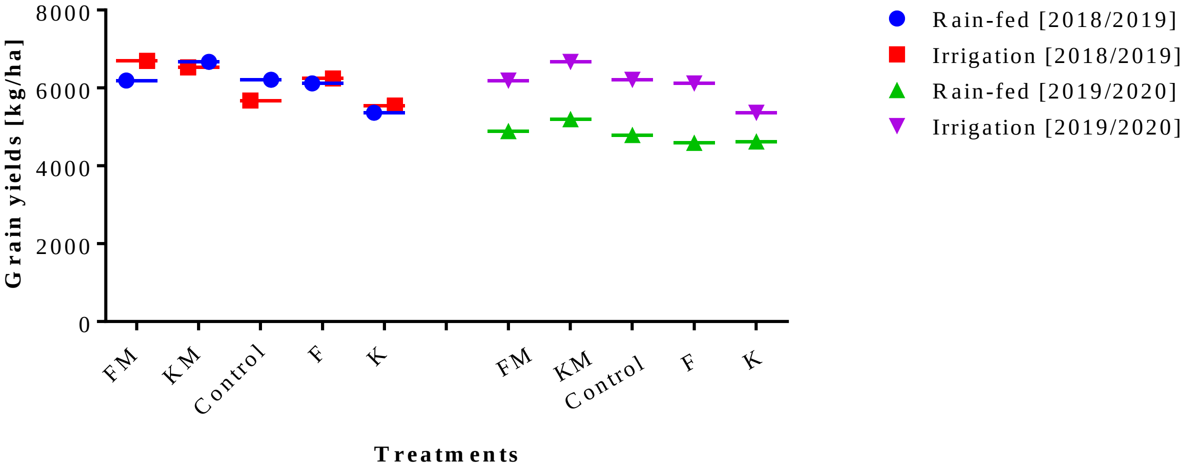
However, significant maize grain yields across districts is a result of native soil nutrient levels[28]. However, no significant differences in maize grain yields were observed between the treatments within the districts because of buffer effect of manure.

Studies have shown that crop nutrient demand and soil nutrient release is achieved through combined application of organic and inorganic fertilizer[24,26].

The results also show that PGPM inoculated in the Mbeya based treatments (modified Funani and Kambeu) had synergistic effect shown by increase in nutrient content and yields. The correlation between rhizosphere and nutrient content is due to the microbial ability to respond chemo tactically[29–31]. The application of phosphate based fertiliser has a negative impact to PGRM due to heavy metal contamination hence no solubilisation and oxidation of native and applied nutrients. These finding are in agreement with the previous reports that maize grain yieldcan increase through inoculation of solubilizing and oxidizing microbes[32,33].

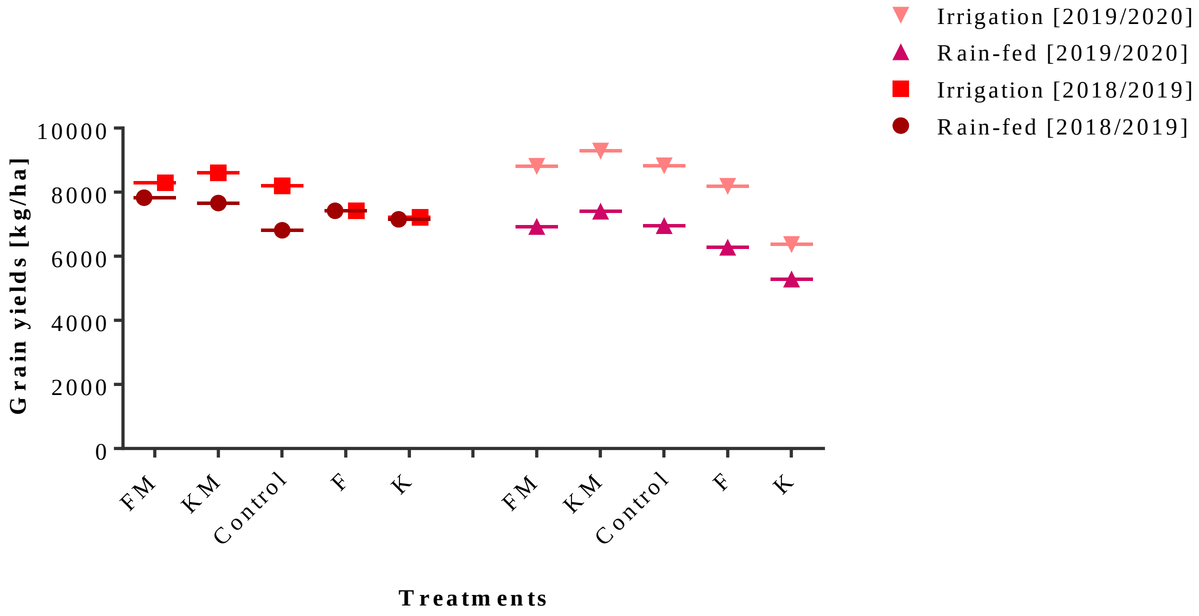
The effect of all treatments, location and season on biomass yield was not significant as shown in figure 5-8.Some researchers found that enhanced N, P, K and Zn released increases grain yield, biomass and 100-seed weight[34].

Grain and biomass (folder) yield increase with the use of organic fertiliser application is of benefit to maize producers[33]. Long term field studies show significant contribution of organic fertiliser for the sustainable soil health and soil fertility[35,36]. Organic fertiliser is responsible for biostimulation and allow their components to interact with each other synergistically, thus, stimulating each other through physically or biologically[37–39].



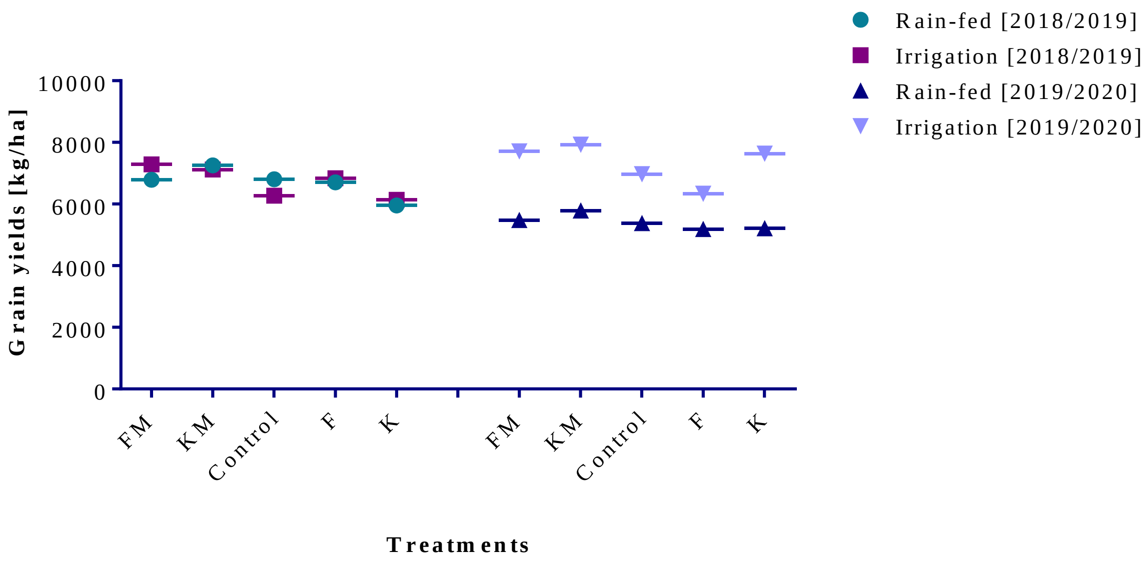
| | 2018-19<br>Rain-fed | 2018-19<br>Irrigation | 2019-20<br>Rain-fed | 2019-20<br>Irrigation |
|---|---|---|---|---|
| Fr(pr) | 0.272 | 0.614 | 0.923 | 0.272 |
| LSD | 1224 | 1985 | 1711 | 1224 |
| CV% | 11 | 17 | 19 | 11 |

**Figure-1:** Effect of different fertiliser treatments on grain yield (kg/ha) at Chitedze research station in Lilongwe during 2018/2019 and 2019/2020 cropping seasons under both irrigation and rain-fed conditions.



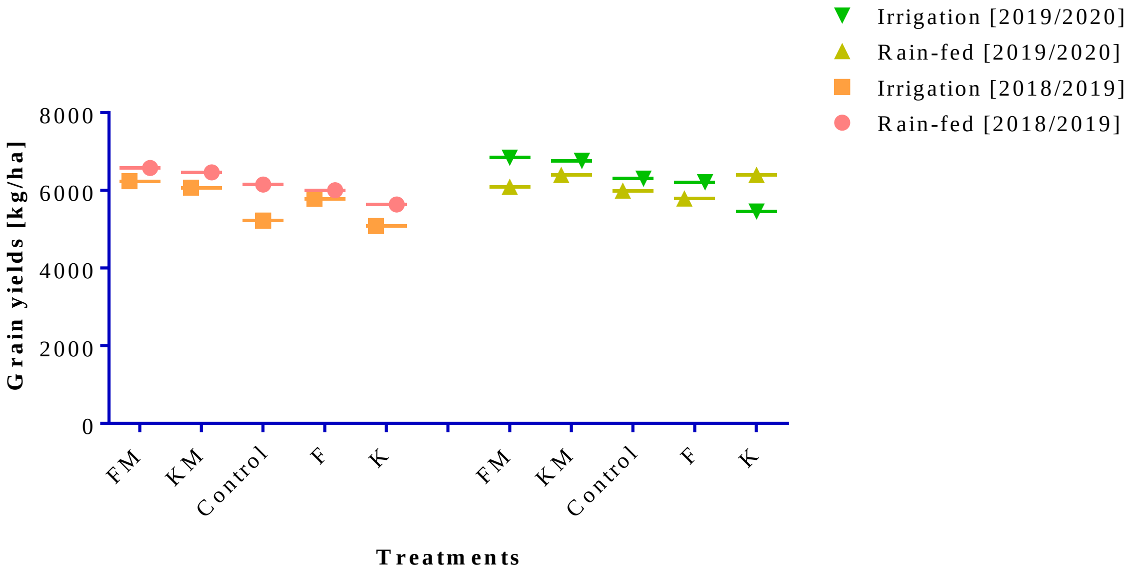
| | 2018-19<br>Rain-fed | 2018-19<br>Irrigation | 2019-20<br>Rain-fed | 2019-20<br>Irrigation |
|---|---|---|---|---|
| Fr(pr) | 0.809 | 0.605 | 0.139 | 0.026 |
| LSD | 2108 | 2303 | 1741 | 1679 |
| CV% | 15 | 15 | 14 | 11 |

**Figure-2:** Effect of different fertiliser treatments on grain yield (kg/ha at Masaula EPA in Zomba during 2018/2019 and 2019/2020 cropping seasons under both irrigation and rain-fed conditions.



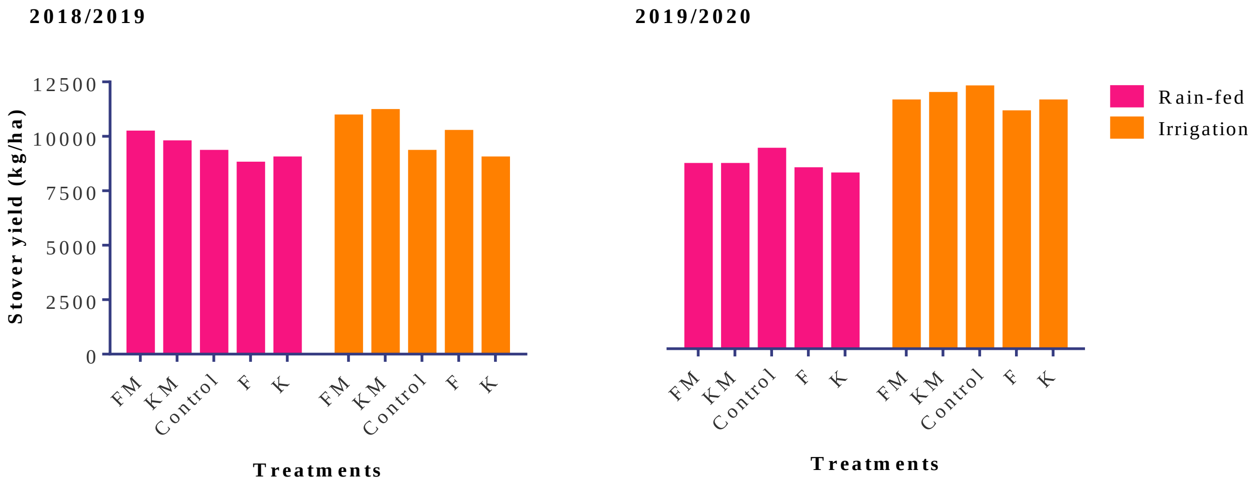
| | 2018-19<br>Rain-fed | 2018-19<br>Irrigation | 2019-20<br>Rain-fed | 2019-20<br>Irrigation |
|---|---|---|---|---|
| Fr(pr) | 0.272 | 0.614 | 0.923 | 0.71 |
| LSD | 1224 | 1785 | 1721 | 2011 |
| CV% | 10 | 16 | 17 | 14 |

**Figure-3:** Effect of different fertiliser treatments on grain yield (kg/ha) at Nachisaka EPA in Dowa during 2018/2019 and 2019/2020 cropping seasons under both irrigation and rain-fed conditions.



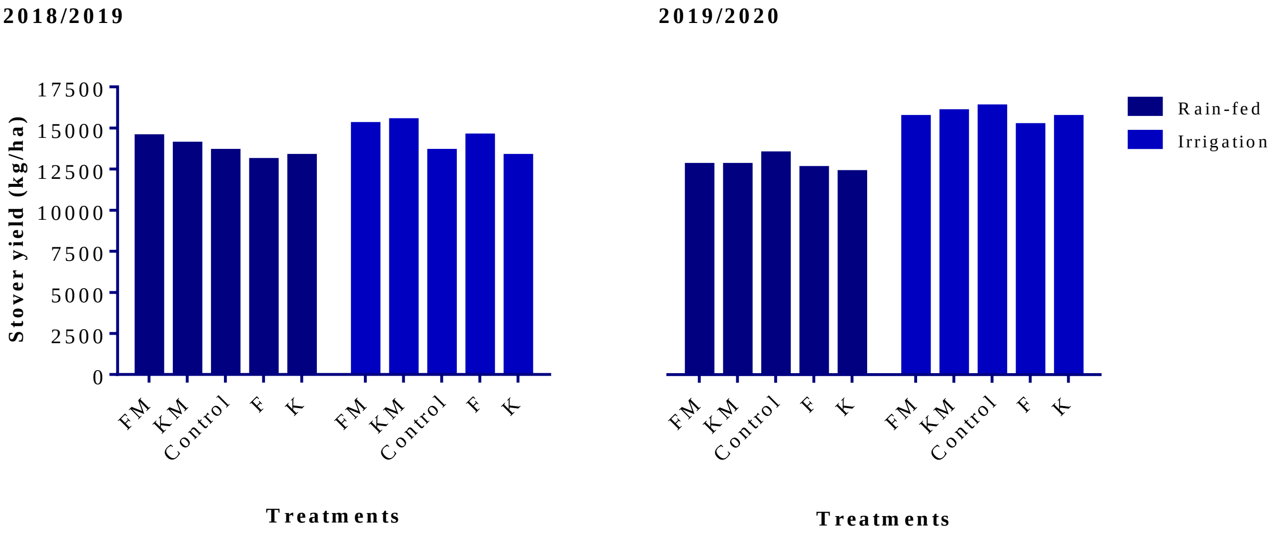
| | 2018-19<br>Rain-fed | 2018-19<br>Irrigation | 2019-20<br>Rain-fed | 2019-20<br>Irrigation |
|---|---|---|---|---|
| Fr(pr) | 0.245 | 0.614 | 0.923 | 0.27 |
| LSD | 907 | 1985 | 1711 | 1436 |
| CV% | 12 | 19 | 15 | 14 |

**Figure-4:** Effect of different fertiliser treatments on grain yield (kg/ha at Santhe EPA in Kasungu during 2018/2019 and 2019/2020 cropping seasons under both irrigation and rain-fed conditions.



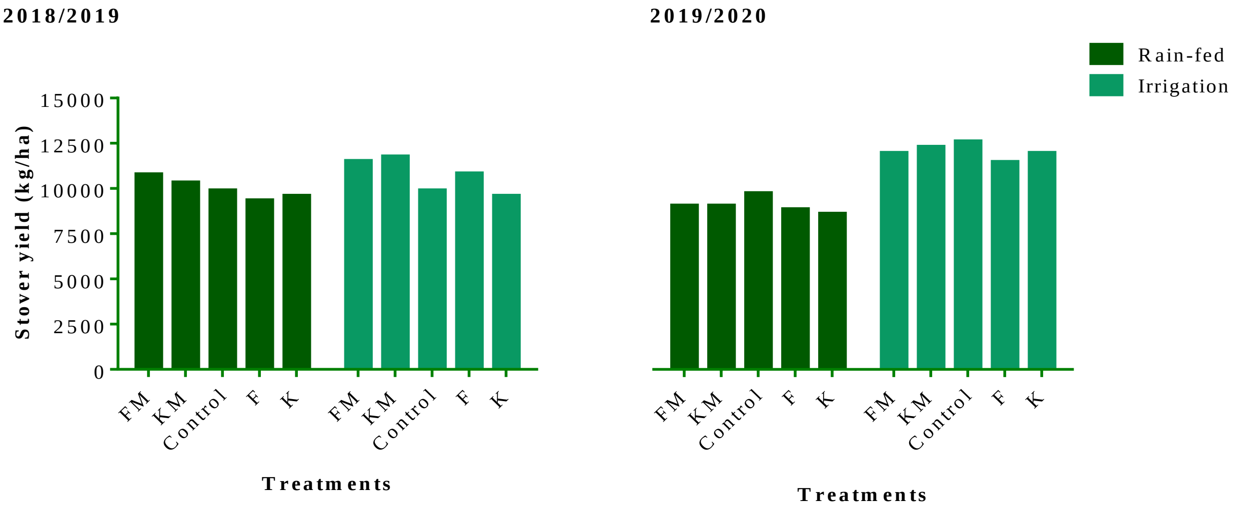
| | 2018-19 | 2018-19 | 2019-20 | 2019-20 |
|---|---|---|---|---|
| | *Rain-fed* | *Irrigation* | *Rain-fed* | *Irrigation* |
| Fr(pr) | 0.89 | 0.148 | 0.947 | 0.945 |
| LSD | 3619 | 2075 | 3323 | 3321 |
| CV% | 21 | 11 | 21 | 15 |

**Figure-5:** Effect of different fertiliser treatments on stover yield (kg/ha) at Chitedze research station during 2018/2019 and 2019/2020 cropping seasons under both irrigation and rain-fed conditions.



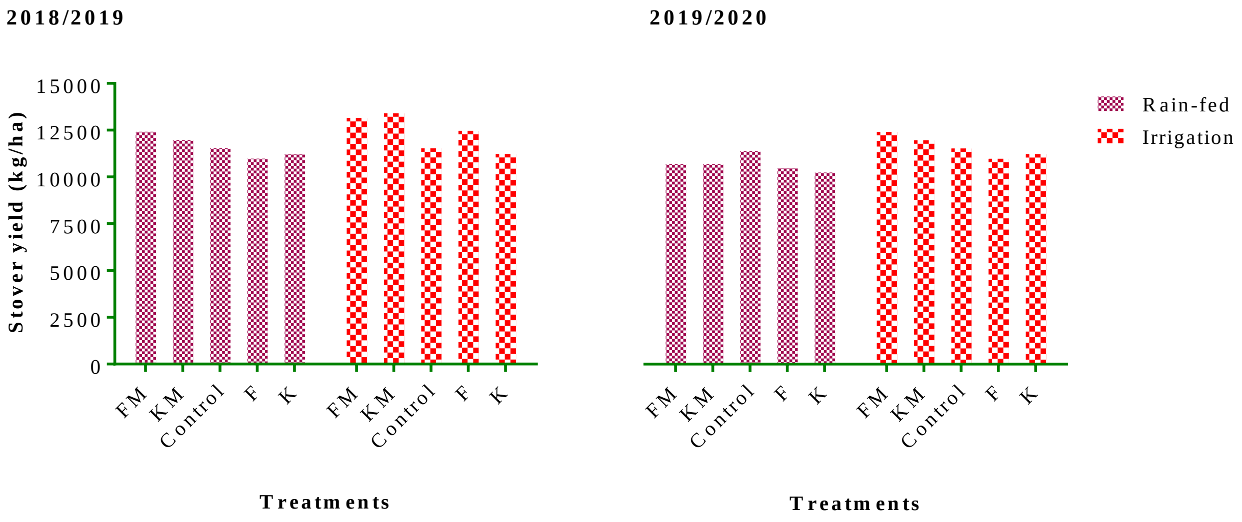
| | 2018-19 | 2018-19 | 2019-20 | 2019-20 |
|---|---|---|---|---|
| | *Rain-fed* | *Irrigation* | *Rain-fed* | *Irrigation* |
| Fr(pr) | 0.890 | 0.148 | 0.947 | 0.945 |
| LSD | 3619 | 2075 | 3323 | 3321 |
| CV% | 14 | 8 | 14 | 11 |

**Figure-6:** Effect of different fertiliser treatments on stover yield (kg/ha) at Masaula EPA in Zomba during 2018/2019 and 2019/2020 cropping seasons under both irrigation and rain-fed conditions.



| | 2018-19 | 2018-19 | 2019-20 | 2019-20 |
|---|---|---|---|---|
| | *Rain-fed* | *Irrigation* | *Rain-fed* | *Irrigation* |
| Fr(pr) | 0.89 | 0.148 | 0.947 | 0.945 |
| LSD | 3619 | 2075 | 3323 | 3321 |
| CV% | 19 | 10 | 20 | 15 |

**Figure-7:** Effect of different fertiliser treatments on stover yield (kg/ha) at Nachisaka EPA in Dowa during 2018/2019 and 2019/2020 cropping seasons under both irrigation and rain-fed conditions.



| | 2018-19 | 2018-19 | 2019-20 | 2019-20 |
|---|---|---|---|---|
| | *Rain-fed* | *Irrigation* | *Rain-fed* | *Irrigation* |
| Fr(pr) | 0.890 | 0.148 | 0.947 | 0.890 |
| LSD | 3619 | 2075 | 3323 | 3619 |
| CV% | 16 | 9 | 16 | 16 |

**Figure-8:** Effect of different fertiliser treatments on stover yield (kg/ha) at Santhe EPA in Kasungu during 2018/2019 and 2019/2020 cropping seasons under both irrigation and rain-fed conditions.

**Table-3:** Effect of different fertiliser treatments on seed size (100 seed weight in grams) at Chitedze research station in Lilongwe during 2018/2019 and 2019/2020 cropping seasons under both irrigation and rain-fed conditions.

| Treatment | Cropping season | | | |
|---|---|---|---|---|
| | 2018-19 Rain-fed | 2018-19 Irrigation | 2019-20 Rain-fed | 2019-20 Irrigation |
| F | 34 | 36 | 35 | 36 |
| K | 35 | 35 | 35 | 36 |
| control | 36 | 36 | 36 | 37 |
| FM | 37 | 38 | 36 | 38 |
| KM | 36 | 37 | 36 | 37 |
| Grand means | 35 | 37 | 36 | 37 |
| Fr(pr) | 0.39 | 0.117 | 0.866 | 0.39 |
| LSD | 2.902 | 2.355 | 2.108 | 2.902 |
| CV% | 4.4 | 3.4 | 3.1 | 4.2 |

**Table-4:** Effect of different fertiliser treatments on seed size (100 seed weight in grams) at Masaula EPA in Zomba during 2018/2019 and 2019/2020 cropping seasons under both irrigation and rain-fed conditions.

| Treatment | Cropping season | | | |
|---|---|---|---|---|
| | 2018-19 Rain-fed | 2018-19 Irrigation | 2019-20 Rain-fed | 2019-20 Irrigation |
| F | 36 | 35 | 35 | 38 |
| K | 37 | 36 | 36 | 39 |
| control | 38 | 37 | 37 | 39 |
| FM | 37 | 38 | 37 | 39 |
| KM | 36 | 37 | 36 | 37 |
| Grand means | 37 | 37 | 36 | 38 |
| Fr(pr) | 0.455 | 0.543 | 0.718 | 0.185 |
| LSD | 2.967 | 4.168 | 3.664 | 1.884 |
| CV% | 4.3 | 6.1 | 5.4 | 2.6 |

**Table-5:** Effect of different fertiliser treatments on seed size (100 seed weight in grams) at Nachisaka EPA in Dowa during 2018/2019 and 2019/2020 cropping seasons under both irrigation and rain-fed conditions.

| Treatment | Cropping season | | | |
|---|---|---|---|---|
| | 2018-19 Rain-fed | 2018-19 Irrigation | 2019-20 Rain-fed | 2019-20 Irrigation |
| F | 35 | 37 | 36 | 36 |
| K | 36 | 36 | 36 | 37 |
| control | 37 | 37 | 37 | 38 |
| FM | 37 | 39 | 37 | 39 |
| KM | 37 | 38 | 37 | 38 |
| Grand means | 36 | 37 | 37 | 38 |
| Fr(pr) | 0.39 | 0.117 | 0.866 | 0.39 |
| LSD | 2.902 | 2.355 | 2.208 | 2.902 |
| CV% | 4.2 | 3.3 | 3.1 | 4.1 |

**Table-6:** Effect of different fertiliser treatments on seed size (100 seed weight in grams) at Santhe EPA in Kasungu during 2018/2019 and 2019/2020 cropping seasons under both irrigation and rain-fed conditions.

| Treatment | Cropping season | | | |
|---|---|---|---|---|
| | 2018-19 Rain-fed | 2018-19 Irrigation | 2019-20 Rain-fed | 2019-20 Irrigation |
| F | 40 | 42 | 40 | 40 |
| K | 41 | 40 | 39 | 41 |
| control | 40 | 38 | 39 | 40 |
| FM | 39 | 40 | 39 | 39 |
| | | | | |
| KM | 37 | 39 | 38 | 37 |
| Grand means | 40 | 40 | 39 | 40 |
| Fr(pr) | 0.005 | 0.555 | 0.789 | 0.005 |
| LSD | 1.523 | 4.323 | 0.277 | 1.523 |
| CV% | 2 | 5.8 | 3.8 | 2 |

**Table-7:** Effect of different fertiliser treatments on shelling % at Chitedze research station in Lilongwe during 2018/2019 and 2019/2020 cropping seasons under both irrigation and rain-fed conditions.

| Treatment | Cropping season | | | |
|---|---|---|---|---|
| | 2018-19 Rain-fed | 2018-19 Irrigation | 2019-20 Rain-fed | 2019-20 Irrigation |
| F | 54 | 69 | 50 | 63 |
| K | 61 | 62 | 50 | 74 |
| control | 59 | 64 | 49 | 67 |
| FM | 57 | 65 | 47 | 47 |
| KM | 51 | 65 | 50 | 61 |
| Grand means | 56 | 65 | 49 | 65 |
| Fr(pr) | 0.827 | 0.903 | 0.999 | 0.873 |
| LSD | 22 | 17 | 29 | 32 |
| CV% | 21 | 14 | 31 | 26 |

**Table-8:** Effect of different fertiliser treatments on shelling % at Masaula EPA in Zomba during 2018/2019 and 2019/2020 cropping seasons under both irrigation and rain-fed conditions.

| Treatment | Cropping season | | | |
|---|---|---|---|---|
| | 2018-19Rain-fed | 2018-19 Irrigation | 2019-20 Rain-fed | 2019-20 Irrigation |
| F | 67 | 84 | 70 | 76 |
| K | 71 | 81 | 71 | 87 |
| control | 66 | 93 | 71 | 87 |
| FM | 61 | 69 | 75 | 65 |
| KM | 68 | 89 | 57 | 55 |
| Grand means | 68 | 84 | 67 | 77 |
| Fr(pr) | 0.998 | 0.916 | 0.812 | 0.195 |
| LSD | 32 | 47 | 31 | 30 |
| CV% | 25 | 30 | 24 | 21 |

**Table-9**: Effect of different fertiliser treatments on shelling % at Nachisaka EPA in Dowa during 2018/2019 and 2019/2020 cropping seasons under both irrigation and rain-fed conditions.

| Treatment | Cropping season | | | |
|---|---|---|---|---|
| | 2018-19 Rain-fed | 2018-19 Irrigation | 2019-20 Rain-fed | 2019-20 Irrigation |
| F | 55 | 69 | 52 | 64 |
| K | 62 | 63 | 52 | 74 |
| control | 61 | 65 | 51 | 68 |
| FM | 58 | 66 | 49 | 62 |
| KM | 53 | 66 | 52 | 62 |
| Grand means | 58 | 66 | 51 | 66 |
| | | | | |
| Fr(pr) | 0.829 | 0.896 | 0.999 | 0.885 |
| LSD | 21 | 16 | 27 | 30 |
| CV% | 19 | 13 | 28 | 24 |

**Table-10:** Effect of different fertiliser treatments on shelling % at Santhe EPA in Kasungu during 2018/2019 and 2019/2020 cropping seasons under both irrigation and rain-fed conditions

| Treatment | Cropping season | | | |
|---|---|---|---|---|
| | 2018-19 Rain-fed | 2018-19 Irrigation | 2019-20 Rain-fed | 2019-20 Irrigation |
| F | 56 | 60 | 58 | 56 |
| K | 58 | 53 | 58 | 58 |
| control | 57 | 54 | 57 | 57 |
| FM | 54 | 56 | 55 | 54 |
| KM | 49 | 54 | 58 | 49 |
| Grand means | 55 | 55 | 57 | 55 |
| Fr(pr) | 0.851 | 0.891 | 0.999 | 0.851 |
| LSD | 21 | 16 | 29 | 21 |
| CV% | 20 | 15 | 27 | 20 |

The results show that nitrogen fixing microbes, nitrifying microbes and potassium solubilising microbes (KSM) availability regulates the competitive interaction of other soil microorganisms and thus the relative increase in grain nutrient content which is in line with other studies[40–42]. This is because nitrogen is an important nutrient in the soil and has implication on nutrient uptake, soil microbial diversity and general soil chemistry [2]. The result predict that usage of low urea in mbeya organic based fertilisers is a result of nitrifying microbes (ammonia and nitrite oxidizing microbes) which improve efficiency of urea[43]. The efficiency is a result of fast and percentage change to nitrate without loss through ammonia or ammonium as gas[2].

Grain nutrient content increase is due to microbial activity through solubilisation, oxidation, sorption, bioremediation and fixation factor [44–48]. Inoculation of PGRM does not only results in increased microbial biomass but has also been linked to changes in microbial community structure and increased functional diversity[45,49–51]. Geisseler and Scow[54] found that microbial diversity, in terms of both species richness and evenness, was affected by application of fertiliser without integration of organic fertilisers. Increased microbial biomass and diversity are beneficial for soil quality because soil microorganisms play a key role in soil nutrient cycling and bioremediation. They accelerate the breakdown of organic substances and mineralize the organic nitrogen (N) and phosphorus (P) into plant available inorganic forms.

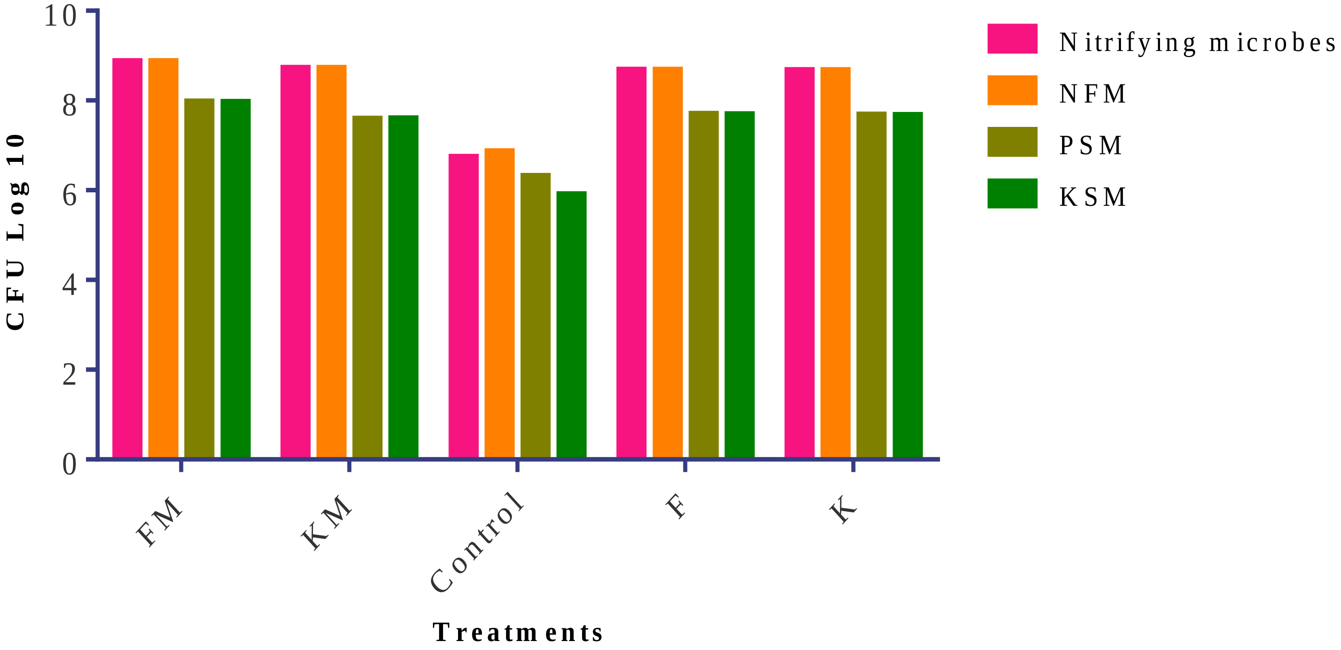


**Table-11:** Mean CFU of PGRM (nitrifying microbes, NFM, PSM) from rhizosphere of different treatments.

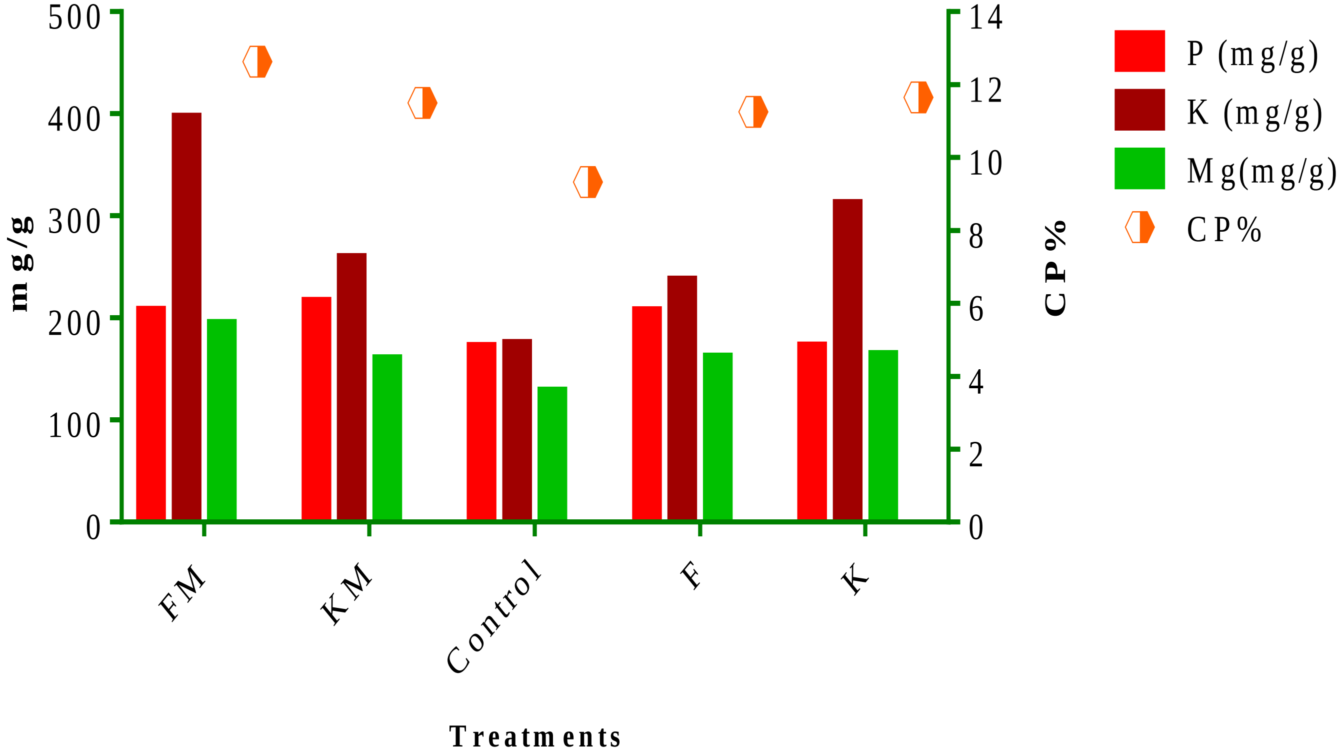


**Figure-9:** Mean grain nutrient content (P, K, Mg and Crude protein) in the fertilizer treatments.

**Table-12:** Correlation between different factors in response to the experiment.

| Microbes | Correlations/p value | Yield per ha | Nitrifying microbes | NFM | PSM | KSM | N % | P % | K % |
|---|---|---|---|---|---|---|---|---|---|
| Nitrifying | Correlations/p value | -0.047 | | 1.000** | .737** | .742** | 0.543** | .661** | .542** |
| | Sig (2-tailed) | 0.777 | | 0 | 0 | 0 | 0 | 0 | 0 |
| NFM | Correlations/p value | -0.047 | 1.000* | 1.000** | .737** | .742** | 0.543** | .661** | .542** |
| | Sig (2-tailed) | 0.777 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| PSM | Correlations/p value | -0.063 | 0.737 | 0.737 | 1 | 999** | 0.374* | 0.286 | .530** |
| | Sig (2-tailed) | 0.702 | 0 | 0 | | 0 | 0.019 | 0.078 | 0.001 |
| KSM | Correlations/p value | -0.051 | 0.742 | 0.742 | .999** | 1 | .380* | 0.302 | .526** |
| | Sig (2-tailed) | 0.76 | 0 | 0 | 0 | | 0.017 | 0.062 | 0.001 |
| | | Mg % | Ca % | Cp % | S % | Zn ppm | Fe ppm | Mn ppm | Cu ppm |
| Nitrifying | Correlations/p value | .787** | 0.085 | .543** | -0.143 | -0.384 | -0.155 | -0.292 | -0.085 |
| | Sig (2-tailed) | 0 | 0.737 | 0 | 0.571 | 0.116 | 0.539 | 0.239 | 0.737 |
| NFM | Correlations/p value | 0.787 | 0.085 | .543** | -0.143 | -0.384 | -0.155 | -0.292 | -0.085 |
| | Sig (2-tailed) | 0 | 0.737 | 0 | 0.571 | 0.116 | 0.539 | 0.239 | 0.737 |
| PSM | Correlations/p value | 0.797 | -0.195 | .374* | -0.036 | -0.428 | 0.048 | -0.41 | 0.24 |
| | Sig (2-tailed) | 0 | 0.437 | 0.019 | 0.886 | 0.076 | 0.85 | 0.091 | 0.337 |
| KSM | Correlations/p value | 0.808 | -0.186 | 0.380 | -0.04 | -0.43 | 0.052 | -0.405 | 0.232 |
| | Sig (2-tailed) | 0 | 0.461 | 0.017 | 0.875 | 0.075 | 0.837 | 0.096 | 0.353 |

## Conclusion

The study has found potentiality of Mbeya based organic fertilisers in maize cropping system in Malawi. In the study, characterization and evaluation of Mbeya based organic fertilisers has hope of biostimulation which help in solubilising fixed minerals using cheap and eco-friendly systems. The outcome of the study is showing positive impact of developing cheap and eco-friendly maize farming systems with high productivity.

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