The effects of application of integrated soil fertility management technologies on yields and economic benefits of maize in Kagera region, Tanzania


Maruku Agricultural Research Institute,
P.O. Box 127, Bukoba, Kagera, Tanzania, marukuardi@yahoo.com

Abstract

The production of maize in many parts of Kagera region is increasing rapidly due to declining production and yields of banana. However, maize yields from farmers’ fields are low. The low maize yield is due to declining soil fertility aggravated by extensive weathering of the soils, low organic matter content in the soils and continuous crop removal of the nutrients from the soils without replenishment, use of poor germplasm and poor agronomic practices by farmers. Demonstration fields were established during 2010-2011 season in Biharamulo, Bukoba and Muleba districts of Kagera region to explore the effect of using ISFM technologies on maize yields and economic benefit. The treatments tested were Urea alone, Urea and Minjinghu granular, Urea and Minjinghu powder, Urea and Minjinghu mazao, Urea and triple superphosphate and the control (no fertilizer). Urea was applied at the rate of 60 kg N ha⁻¹ while TSP and Minjinghu fertilizers were applied at the rate of 20 kg P ha⁻¹. Demonstration fields were laid out using randomized complete block design (RCBD) in three replications. Before planting soil samples were collected and analyzed for texture, total N, available P, organic carbon, pH, and CEC. Agronomic and economic data were collected and analyzed using GENSTAT and excel statistical software respectively. The soils were acidic to moderate acidic, with very low to low organic carbon, low to medium total N, low to medium extractable P, low to medium exchangeable K, low to medium exchangeable Ca, and low to high exchangeable Mg. The results showed significant (P≤0.001) difference in maize yields among the tested treatments but not across the districts. Application of fertilizers increased maize grain and biomass yields from 0.86 to 3.25 t ha⁻¹ and biomass yields from 0.76 to 1.45 t ha⁻¹. Likewise, application of fertilizers gave net profit ranging from 116.7 to 378.7 $ compared to net loss of $ 278 when fertilizers were not applied. The study showed that it was uneconomical to plant maize without application of fertilizers.

Key words: yields, benefits, fertilizers, germplasm

Introduction

Application of fertilizers is of great importance so as to increase maize yield. In order to increase the available P content of soils with low native P fertilizer, materials that contain P should be added to such soils. Sanchez 1976 pointed out that P was known to be the second most limiting nutrient element after nitrogen (N) in crop production in tropical soils, particularly the highly weathered soils. It is, therefore, of greater importance to apply P fertilizer materials, which will ameliorate the problem of insufficient P in such soils. Usually, most P fertilizers applied to agricultural land contain water-soluble components. The common sources of water-soluble phosphate fertilizers applied to field crops are triple super phosphate (TSP), single super phosphate (SSP), and mono or di-ammonium phosphate (MAP or DAP). However, there is little use of inorganic P fertilizers by resource-poor farmers due to high prices of these inputs. The resource poor farmers can benefit by use of less expensive but equally effective alternative P sources such as phosphate rock (PR) (Hammond et al., 1986). Therefore, research has been focused on possible use of agro mineral deposits, namely phosphate rocks, as an alternative to the more expensive water-soluble fertilizers (Khasawneh and Doll, 1978) to improve agricultural production.

Phosphate rocks have received attention as low cost P fertilizers for acid soils (Khasawneh and Doll, 1978; Chien and Menon, 1995). In Tanzania phosphate rocks occur in different locations including Minjinghu in Arusha region, Chali hills in Dodoma region, Sangu-Ikolla, Panda hill, Mbalizi, Njelenje,
Songwe and Nguala in Mbeya region (Patel, 1975; Mchihyo, 1991; Mwambete, 1991) and Bachuba and Ichwandini in Muleba district in Kagera region (Mkamba, 1988). Significant deposits occur at Panda hill, Mbeya (igneous origin) and Minjingu, Arusha (sedimentary origin). Mnkeni et al. (1991) working with four different soils observed varied effects of Minjingu Phosphate Rock (MPR) on maize yields. In their studies, they observed that the rates of 80 kg and 240 kg P/ha significantly increased maize yield on Magadu and Mzumbe soils in Morogoro region, both of which had <6.5 mg P/kg soil and pH value <5.2. Semoka et al. (1992) observed that MPR applied at the rate of 40 mg P/kg soil was as effective as TSP with relative agronomic effective value of 92 % and 111 % in an Ultisols and an Oxisols, respectively.

In Tanzania 80 percent of the population depends on agriculture for their survival. Agriculture is the main source of food which account for about 26 percent of the national GDP and 30 percent of the foreign exchange gain. However, agriculture in the country is dominated by smallholder farmers having average farm sizes of between 0.9 hectares and 3.0 hectares (NBS, 2002). Kagera region is one of the 27 regions in Tanzania found in the Northwest part of the country at latitude 1o-3o S and longitude 30o-32o E. The region supports a population of 2.1 million people, of whom 90 percent live in rural areas (NBS, 2002). The rural economy relies on agriculture and 85% of people are involved in farming. Human population density varies from 250 people km2 in the dry areas to more than 510 people km2 in wetter areas (NBS, 2002). The region is endowed with high rainfall (above 1800 mm) with short and long rain cropping seasons yet it is one of the most food-insecure in the country. The smallholder production system that dominates the region and which is largely banana/coffee-based has low and declining productivity.

Production of maize in many parts of Kagera region is increasing rapidly due to declining production of banana. Fifteen years ago, maize was sparsely planted in the Kibanja (homestead garden where different crops are grown in a mixture), but after realizing that the crop is not suited for shaded conditions, the crop is now planted in Kikamba (open field far from or near to home), the land use type where normally no fertilizers or manure is applied. The average yields of maize is <1.1 t/ha (ARI Maruku, 2011). The major factors contributing to low maize yields in most parts of Kagera region are the low fertility status of the soils, use of local maize seeds and poor agronomic practices such as un-recommended spacing by farmers (Bajukya and Folmer, 1999). Low fertility status of the soil has been attributed to the extensive loss of nutrients through leaching especially in high rainfall zone (above 1800 mm), extensive weathering of the soils, low organic matter content in the soils and continuous crop removal of the nutrients from the soils without replenishment (Bajukya and Folmer, 1999. This suggests the need to apply fertilizers in these soils in order to improve the soil fertility status in the region for increased crop yields. This research study aimed to explore the effect of application integrated soil fertility management technologies (fertilizers, improved germplasm and agronomic practices) on maize yields and economic benefits.

Material and methods

Location of study area

Maize mother demonstration fields were established during 2010-2011 cropping season in three districts of Kagera region namely Biharamulo, Bukoba and Muleba. In Biharamulo district five demonstration fields were established at Mazigera (2.82786oS; 31.45742oE), Kagondo (2.72628oS; 31.49497oE), and (2.73453oS; 31.49109oE), Runazi (3.10336oS; 31.11683oE) and Nyamahanga (2.80190oS; 31.33289oE) villages, in Nyabusozi, Kabindi, Runazi and Nyamahanga wards. In Bukoba district four demonstration fields were established at Izimbya (1.54972oS; 31.44722oE), Missenyi (1.52333oS; 31.57083oE) Kaibanja (1.39917oS; 31.53833oE) and Kasharungu villages in Izimbya, Butelankuzi, Kaibanja and Kasharungu, wards. In Muleba district one demonstration field was established at Kyamunyorwa (2.09408oS; 31.57256oE) village in Kasharunga ward. The number of demonstration fields differs from district to district depending on the potentiality of the crop and availability of land during the respective cropping season.
**Experimental design, treatments and treatment application**

Demonstration establishment sites were selected by extension officers of respective wards/village in collaboration with researchers followed by land prepared by farmers. Demonstration fields were designed and laid out by researchers with the assistance of extension officers using randomized complete block design (RCBD) in three replications. Plot size was 10 m x 10 m and the net plot was 43.2 m². Three seeds of improved maize (Situka variety) were planted in each hole in a flat land at a spacing of 0.9 m x 0.6 m followed by thinning to two seeds per hole after 3-4 weeks of planting. The treatments tested were:

- **Control**
- Urea at the rate of 60 kg N ha⁻¹
- Minjingu granular at the rate of 20 kg P ha⁻¹ + Urea at the rate of 60 kg N ha⁻¹
- Minjingu powder at the rate of 20 kg P ha⁻¹ + Urea at the rate of 60 kg N ha⁻¹
- Minjingu Mazao at the rate of 20 kg P ha⁻¹ + Urea at the rate of 60 kg N ha⁻¹
- TSP at the rate of 20 kg P ha⁻¹ + Urea at the rate of 60 kg N ha⁻¹

**Soil sampling**

Before planting, soil samples were randomly taken using soil auger at a depth of 0-30 cm. At least ten spots sampling was done, mixed thoroughly for composite soil sample, packed in a plastic bags and labelled in the field. The composite soil samples were air-dried, ground and sieved through 2 mm wire-mesh, packed labelled and sent at Ukiriguru Agricultural Research Institute laboratory in Missungwi Mwanza for analysis.

**Fertilizer application**

Phosphorus fertilizers (TSP and Minjingu) were applied at planting. Nitrogen fertilizer (urea) was applied in two splits, half dose (30 kg N/ha) at planting and the second half dose (30 kg N/ha) at active growing (tasselling) stage of maize crop.

**Demonstration fields management, data collection and harvesting**

Demonstration fields were managed by farmers under the supervision of extension officers of the respective wards/villages. However, researchers and district extension officers visited the demonstration fields at least once per month for monitoring, collecting data and technical backstopping whenever required. After crops maturity, harvesting was done from a net plot of 43.2 m². After harvesting, sub samples were taken for oven drying at Maruku station to get sub sample oven dry weights that were used to calculate yield in t/ha. Agronomic data including date of planting, weeding and harvesting, GPS readings and yields were taken during crop management and harvesting period. Harvesting was done after five months. Moreover, economic data including cost of inputs, farm management and prices of produces were collected during the whole period of maize growth.

**Data analysis**

Composite soil samples were analyzed for soil texture, pH, organic carbon, total nitrogen, available phosphorus, and exchangeable cations (calcium, magnesium, potassium and sodium) at Ukiriguru Agricultural Research Institute soil laboratory, in Mwanza region using standard by the National Soil Service, 1990 and Moberg, 2000. The collected agronomic data were processed and entered into GENSTAT statistic program and analysed using ANOVA. The means were compared using LSD at 5%. Economic data were processed and analysed using Excel spreadsheet program. Tables of mean yields and net profit for the treatments are presented in the results and discussion section.
**Results and discussion**

Fertility status of soils in the project area

Some of the chemical and physical characteristics of soils in the project area are presented in table 1. Soil analysis results showed that texture of the soils in the study area ranged from clay, to sandy clay loam. 

Soil pH (in water) range from 4.26 to 6.30, soil organic carbon range from 1.06 to 3.36, total N range from 0.04 to 0.26 %, Bray 1 extractable P range from 12 to 25 mg/kg and exchangeable cations range from 0.01 to 0.92 meq/100g, 0.42 to 5.30 meq/100g and 0.08 to1.85 meq/100 g for K, Ca and Mg, respectively.

**Table 1: Some chemical and physical characteristics of soils in the study area**

<table>
<thead>
<tr>
<th>District</th>
<th>Depth (cm)</th>
<th>Soil texture</th>
<th>Soil pH-H2O (1:2.5)</th>
<th>Soil OC (%)</th>
<th>Total N (%)</th>
<th>Available P –Bray 1 (mg/kg)</th>
<th>Exchangeable cation (meg/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bukoba</td>
<td>0-30</td>
<td>Clay, sandy clay and sandy clay loam</td>
<td>4.26-5.88</td>
<td>1.76-3.36</td>
<td>0.18-0.26</td>
<td>12-15</td>
<td>0.05-0.92 0.54-5.30 0.1-0.94</td>
</tr>
<tr>
<td>B’mulo</td>
<td>0-30</td>
<td>Clay, sandy clay, sandy loam and sandy clay loam</td>
<td>4.67-5.90</td>
<td>1.06-2.0</td>
<td>0.04-0.17</td>
<td>11-13</td>
<td>0.01-0.11 1.05-2.88 0.19-0.44</td>
</tr>
<tr>
<td>Muleba</td>
<td>0-30</td>
<td>Clay, sandy clay, sandy loam and sandy clay loam</td>
<td>4.48-6.30</td>
<td>1.44-3.22</td>
<td>0.13-0.25</td>
<td>12-14</td>
<td>0.05-0.30 0.41-10.51 0.08-1.85</td>
</tr>
</tbody>
</table>

Based on these laboratory soil results it showed that the soils in all sites were acidic to moderate acidic, with very low to low organic carbon, low to medium total N, low to medium extractable P, low to medium exchangeable K, low to medium exchangeable Ca, and low to high exchangeable Mg (Landon 1999). However, soil properties indicated slight differences between districts. These results generally indicated that inherent soil fertility status for soils in all the sites was low. This calls the need for external inputs for fertilizing the soil during crop production. Hence, the use of ISFM technologies is among other solutions to improve the fertility status of the poor soils in the project districts.

Maize grain and biomass yields due to application of nitrogen and phosphorus fertilizers

The mean grain and biomass yields of improved maize varieties planted using different type of fertilizers are presented in the tables 2. The results showed significant (P<0.001) difference in maize grain and biomass yields among the tested treatments fertilizers and districts. Interaction between districts and fertilizer did not show significant (P < 0.0981) difference in grain and biomass yields. Fertilizer application resulted into significant (P < 0.001) increase in grain and biomass yields as compared to control treatment. Application of triple super phosphate (TSP) and Urea gave the highest mean maize grain yield (3.25 t ha-1) followed by Minjingu Mazao and Urea (3.25 t ha-1) and Minjingu Powder and Urea (2.94 t ha-1). No significant (P < 0.0981) difference in maize grain yield was recorded between Minjingu granular + Urea (2.84 t ha-1) and Minjingu Powder + Urea (2.94 t ha-1) indicating that Minjingu powder and Minjingu granular gave equal maize response when applied with N–fertilizer (Urea in this case). Among the fertilizer treatments, the lower maize grain yield was observed from Urea alone (2.28 tha-1). This justified the need to apply both P and N fertilizers during maize production. Moreover, the districts differed significantly (P < 0.001) in maize grain yields. The highest maize yields were recorded in Bukoba district (2.63 t ha-1) and the least (2.12 t ha-1) was recorded in Muleba district. The same trend was observed in maize biomass yields (Table 2). The higher maize grain yields in Bukoba could be attributed to availability of enough soil moisture as compared to the other districts having low rainfall since Bukoba is located in the high rain fall zone with annual
rainfall of >1800 mm based on agro-ecological zones of Kagera region. Application of fertilizers increased maize grain and biomass yields to about 4 and 2 folds, respectively as compared to when fertilizer was not applied.

The results generally, showed that farmers in the study area need to apply the combination of both P and N fertilizers for higher maize yields.
Table 2: Maize grain and biomass yields due to application of nitrogen and phosphorus fertilizer

<table>
<thead>
<tr>
<th>District</th>
<th>Control</th>
<th>Minjingu Granular + Urea</th>
<th>Minjingu Mazao + Urea</th>
<th>Minjingu powder + Urea</th>
<th>TSP + Urea</th>
<th>Urea</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain yield (t ha⁻¹)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biharamulo</td>
<td>0.95</td>
<td>2.80</td>
<td>3.11</td>
<td>2.81</td>
<td>3.31</td>
<td>2.35</td>
<td>2.56</td>
</tr>
<tr>
<td>Bukoba</td>
<td>0.84</td>
<td>2.93</td>
<td>3.30</td>
<td>3.16</td>
<td>3.30</td>
<td>2.56</td>
<td>2.63</td>
</tr>
<tr>
<td>Muleba</td>
<td>0.49</td>
<td>2.53</td>
<td>2.57</td>
<td>2.40</td>
<td>2.67</td>
<td>2.06</td>
<td>2.12</td>
</tr>
<tr>
<td>Mean</td>
<td>0.86</td>
<td>2.84</td>
<td>3.15</td>
<td>2.94</td>
<td>3.25</td>
<td>2.28</td>
<td></td>
</tr>
<tr>
<td>CV (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17.96</td>
</tr>
<tr>
<td>LSD (5%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.49</td>
</tr>
<tr>
<td>Biomass yield (t ha⁻¹)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biharamulo</td>
<td>0.92</td>
<td>150</td>
<td>1.57</td>
<td>1.62</td>
<td>191</td>
<td>1.27</td>
<td>1.46</td>
</tr>
<tr>
<td>Bukoba</td>
<td>0.83</td>
<td>1.02</td>
<td>1.25</td>
<td>1.30</td>
<td>1.11</td>
<td>1.11</td>
<td>1.11</td>
</tr>
<tr>
<td>Muleba</td>
<td>0.71</td>
<td>0.70</td>
<td>0.84</td>
<td>0.88</td>
<td>0.87</td>
<td>0.79</td>
<td>0.79</td>
</tr>
<tr>
<td>Mean</td>
<td>0.86</td>
<td>1.21</td>
<td>1.36</td>
<td>1.41</td>
<td>1.45</td>
<td>1.15</td>
<td></td>
</tr>
<tr>
<td>CV (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>32.02</td>
</tr>
<tr>
<td>LSD (5%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.43</td>
</tr>
</tbody>
</table>

Economic benefits of maize due to the application of nitrogen and phosphorus fertilizers

The economic analysis for the tested treatments is presented in Table 3. The results showed that the control treatment (no fertilizer) gave negative net profit as compared to fertilizer treatments.

Table 3. The economic benefit of maize due to the application of nitrogen and phosphorus fertilizers

<table>
<thead>
<tr>
<th>Item</th>
<th>Control</th>
<th>Minjingu granular + Urea</th>
<th>Minjingu Mazao + Urea</th>
<th>Minjingu powder + Urea</th>
<th>TSP + Urea</th>
<th>Urea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain yield kg ha⁻¹</td>
<td>860</td>
<td>2,840</td>
<td>3,150</td>
<td>2,940</td>
<td>3,250</td>
<td>2,280</td>
</tr>
<tr>
<td>Price: $ Kg⁻¹</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Revenue: $ ha⁻¹</td>
<td>344</td>
<td>1,136</td>
<td>1,260</td>
<td>1,176</td>
<td>1,300</td>
<td>912</td>
</tr>
<tr>
<td>Production cost: $ ha⁻¹</td>
<td>622</td>
<td>925.3</td>
<td>935.3</td>
<td>925.3</td>
<td>921.3</td>
<td>795.3</td>
</tr>
<tr>
<td>Net profit: $ ha⁻¹</td>
<td>-278</td>
<td>210.7</td>
<td>324.7</td>
<td>250.7</td>
<td>378.7</td>
<td>116.7</td>
</tr>
<tr>
<td>Breakeven price: $ Kg⁻¹</td>
<td>0.72</td>
<td>0.33</td>
<td>0.30</td>
<td>0.32</td>
<td>0.29</td>
<td>0.41</td>
</tr>
<tr>
<td>Breakeven yield: Kg ha⁻¹</td>
<td>1.04</td>
<td>1.54</td>
<td>1.56</td>
<td>1.54</td>
<td>1.54</td>
<td>1.57</td>
</tr>
</tbody>
</table>

For the fertilizer treatments, the result showed that combined application of TSP at the rate of 20 kg P ha⁻¹ and Urea at the rate of 60 kg N ha⁻¹ gave the higher net profit ($ 378.67) than Minjingu fertilizers and Urea at the same rates. It also showed combined application of Minjingu Mazao at the rate of 20 kg P ha⁻¹ and Urea at the rate of 60 kg N ha⁻¹ gave higher net benefit ($ 324.67) than Minjingu powder and urea ($ 250.67) and Minjingu granular and Urea ($ 210.67) at the same rates. Among the fertilizer treatments the lowest net profit was recorded from the application of Urea alone at the rate of 60 kg N/ha. These results revealed that farmers in Kagera region who were not apply any type of fertilizer during maize production were losing $ 278 from one hectare regardless using other recommended farm management practices.
Conclusion and recommendations

There was significant difference (P<0.001) in maize yields due to the application of different types of fertilizers among the applied treatments but not across the districts. This meant that the effectiveness of applied fertilizers to the performance of maize was different within the district but equal from one district to another. Thus, the recommendation of a particular type of fertilizer in one district could be applied to another district and bring the same response and all P source fertilizers tested in combination with Urea could be applied during maize production depending on which type is available. However, more benefits can be obtained by farmers when P fertilizer (s) (in this case TSP at the rate of 20 kg P ha\(^{-1}\)) in combination with N fertilizer(s) (in this case Urea at the rate of 60 kg N kg\(^{-1}\)) are to be applied followed by the combination of Minjingu mazao and Urea. Generally, the results showed increased maize grain and biomass yields of about 4 and 2 folds, respectively due to the application of fertilizers as compared to when fertilizers were not applied (control). It also showed that it was uneconomical to cultivate maize without application of fertilizers.

The research suggests more investigation on the rate(s) of fertilizers to be applied for optimum maize yields and economic benefit with in depth economic analysis based on return to labour and investment.

Acknowledgement

We are grateful to Alliance for Green Revolution in Africa (AGRA) for funding this work which enabled the setting of the demonstration fields in the target area. Grateful acknowledgements are also due to CIAT-TSBF for technical backstopping implementation. Thanks are also due to farmers in the target area who hosted and managed the demonstration fields throughout the growing season.

Last but not least sincere gratitude are expressed to the extension officers at district and ward and village level in Bukoba, Muleba and Biharamulo districts who participated fully during the implementation of this work. Their supervision and guidance to farmers from planting to harvesting helped the success of collecting data which enabled the production of this paper.

References


